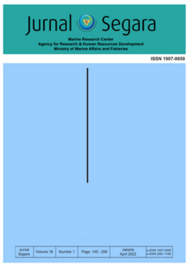

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ECONOMIC BENEFITS OF MARINE PROTECTED AREAS: CASE OF ANAMBAS ISLANDS

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ABSTRACT

This study aims to evaluate the economic benefits derived from conservation areas using the case of National Marine Protected Areas (MPA) in Anambas Islands. The study evaluated the top four reef-associated fish with high economic values, namely grouper, red snapper, threadfin bream, and trevally fish. The employed bioeconomic hybrid model to estimate the Maximum Economic Yield (MEY) for those fish under the sustainable conservation policies. We found positive economic benefits from conservation in Anambas Islands. The MPA has shown both biological and economic benefits, namely the spill over impact and total economic value of harvest at amount of IDR 301,481,685,170/year. We found that the 50% MSY policy on fisheries TAC in MPA site will still sustain the fisheries resource but fishers are less profitable. Some strategies to augment the outcome of Anambas Islands MPA include affirmation policies both from national and local government to increase fishing capacity and skills such as operating larger vessels, eg 10 GT and provide programs and assistance on providing alternative livelihoods for fishermen.

Keywords: Bio Economic, marine conservation, reef fisheries, Anambas Islands-Indonesia, Marine Protected Areas (MPA).

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INTRODUCTION

For multiple centuries, the environment has provided human beings and other many organisms with habitation. However, human beings possess numerous needs and wants, which result in them devising multiple ways to survive and adapt, and some of the strategies are harmful to the environment. The government of Indonesia has just declared its 20 million hectares' achievements on meeting the national target for marine protected areas during Our Ocean Conference in Bali in October 2018. However, the next level is to increase the effectiveness of those Marine Protected Areas (MPAs) to provide benefits for the fisheries sector and the surrounding communities as well as to reach sustainable governance of these MPAs.

Some of the Anambas Islands have been designated as National Marine Protected Area (KKPN), based on Ministerial Decree Number 37 of 2014 with a total area of 1,262,686.2 ha. The Anambas Islands National Marine Protected Area is a marine protected area that is managed based on conservation principles allowing limited fisheries resource utilization based on the zonation. The sustainable capture fisheries zone is a subzone that is regulated in the formation of the Anambas Islands MPA. This subzone is the only area where capture fisheries activities can operate. Based on Ministerial Decree No. 53 of 2014, the total area of the sustainable capture fisheries subzone in the Anambas Islands MPA reaches 1,222,498.99 ha, which is about 96.82% of the total area of the Anambas Islands MPA or about 26% of the total area of Anambas Islands Regency waters, which reaches 4,602,927 ha.

Fishers, in general, feel that MPA establishment in Anambas Islands would harm their economy since they are not able to fish in the no-take zones. The MPA in Anambas Islands itself consists of no-take zones and sustainable fisheries zones. The goal of this paper is to evaluate the impact of Anambas Islands MPA on the biological and economic benefits. The open access of fisheries encourages more people to enter the fisheries business, leading to over exploitation of resources economically (Bene, 2003 in Hidayat,*et al*., 2020). 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). On the biological front, MPAs are known as a management approach to conserve both marine habitat and the fish stock. MPAs set aside certain areas of the ocean usually of high biological importance from exploitative use, such as fishing.

Many bio-economic models find that an MPA does not necessarily improve the economic performance of the fishery. This is partly due to the fact that economic models are only concerned with profits from the fishery in the open areas and disregard non-economic ecological benefits from the closed areas. It can be shown that an MPA can improve economic efficiency under several condition. That the fishery was heavily exploited prior to the establishment of the MPA. The second condition relates to the presence of uncertainty where an MPA acts as a hedge against shock. The third condition is the inclusion of the non-market value of ecological benefits of the MPA (Schnier, 2005b; Armstrong, 2007). A relevant policy question concerning MPAs is whether there is a win-win solution where an MPA can achieve both biological and economic goals as compared to non-MPA regions.

METHODOLOGY

The area of study is the MPA in Anambas Islands. Based on Ministerial Decree Number 53 Year 2014, the MPA has sustainable fishing zone of 1.2 million Ha or 96.8% of the MPA. The no-take zone is only about 4% of the MPA. Evaluated 4 reef-associated fish namely Brown-Marbled Grouper (*Ephinephelus fuscoguttatus*), Trevally (*Caranx sexfasciatus*), Threadfin Bream (*Pristipomoides filamentosus*), and Red Snapper (*Lutjanus bitaeniatus*). Figure 1 shows the locations of the fishing and no-take zones in the conservation area (Figure 1). The fishers are handline fishers operating in the sustainable fishing zones and outside the fishing zones in the Anambas Islands. Time series data on catch, fish price, and catch per unit effort (CPUE) of the handline fishing in the conservation area are gathered from Regional of Fisheries, Agriculture and Food of the Anambas Island Regency.

The economic survey was conducted from May to July of 2019, covering the sub-districts of Siantan, East Siantan, and dan Jemaja. Respondents were fishers from the villages of Tarempa, Batu Belah, Nyamuk, and

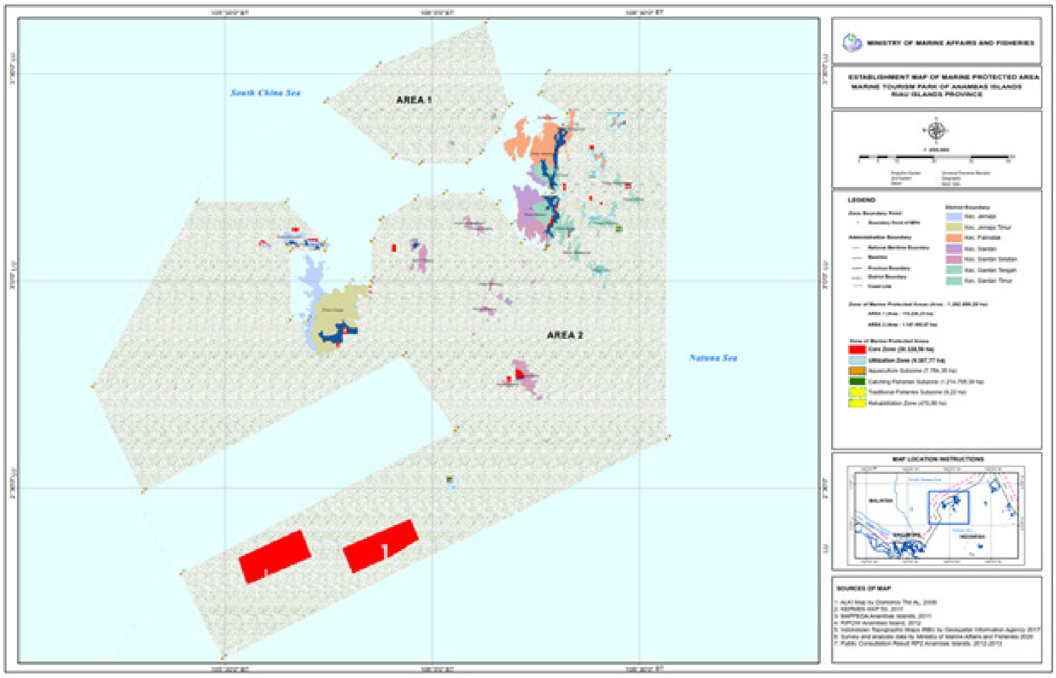

Figure 1. Location of zones within Marine Protected Areas in Anambas Islands.

dan Letung.

Model Walter - Hilborn (1976) is used to estimate the catchability (q) coefficient needed for further Hybrid-Model using the catch time series data, as follows:

$$\frac{U_{t+1}}{U_t} - 1 = r - \frac{r}{Kq} U_t - qE_t \qquad \text{.............................. 1)}$$

Equation (1) is a Linear Regression between $\frac{CPUE_{t+1}}{CPUE_t} - 1$ as Y and $CPUE_t$ as X1 dan E_t as X2 (Pasisingi, 2011), or can be written as:

Y = a – bX1 – CX2 .... 2)

in which a = r , b = r/kq, c = q

where,

Ut+1 : CPUE year t+1 (ton per unit)
Ut : CPUE year ke t (ton per unit)
Et : Effort in Year t (unit)
r : Growth Rate
K : Carrying Capacity
q : Catchability Coefficient (per unit)

Surplus Production Hybrid Model in Conservation Areas

We follow Haryani & Fauzi (2010) on the Surplus Production Hybrid Model for Conservation Areas. The idea is that the spillover biomass will stay in the no-take zones and will be redistributed to the sustainable fishing zones. Spillover biomass equals spillover coefficient (ε) multiplied by biomass (X). The spillover coefficients were estimated from the biological parameters derived from weight and length of fish caught.

Surplus Production Model by MMAF, which is a modification of Schaefer's and developed by Haryani & Fauzi (2010), is the spillover biomass production, which equals spillover coefficient (ε) multiplied by biomass (X). GWA Surplus Production Model defines effort to biomass as the result of the surplus of population growth rate (εX) because the effort is still below the maximum catch yield. Therefore, the analyzed catch data (C) and effort (E) are total biomass with spillover εX because the effort is below the maximum catch yield which complies with sustainable fishing regulation within the MPA after its designation.

Production Surplus Hybrid Model substitutes spillover coefficient (ε) from the analysis of growth, mortality, and exploitation rate. Some of the parameters were derived from the fish length. Then the spillover coefficient (ε) was inserted into Walter-Hilborn Production Surplus Model to find substituted parameter a and b (hybrid). The hybrid parameters were then used in Schaefer Production Surplus Model chart to view the comparison between the optimum biomass with fisheries management in place and that without fisheries management. The difference between those two conditions was interpreted as the estimate of spillover fish biomass.

Production Surplus Hybrid Model used catch and effort data from 2015 to 2018 (after the designation of

Anambas Islands MPA). After the designation, fish biomass production was still at the maximum point thus, if the utilization was below the Maximum Sustainable Yield (MSY), then there was unutilized biomass. To detect whether the biomass production surplus was utilized maximally according to MSY, Exploitation Rate (E) in Analytical Model analysis needed to be determined/examined. If the Exploitation Rate (E) is below 0.5, it was assumed that the current catch still has unutilized surplus biomass. On the other hand, if the Exploitation Rate (E) is above 0.5, it was assumed that the current catch has passed its maximum sustainable potential. Therefore, the maximum potential from the estimation of hybrid model lower than the initial estimation.

Parameter r, k, and q of the Walter-Hilborn Model and spillover coefficient parameter of the Analytical Model were substituted into parameter a and b in Schaefer Model to generate parabolic curve, maximum effort, and biomass from maximum catch. Schaefer Model charts with spillover coefficient (potential) and without spillover coefficient (factual) were shown in the parabolic curve.

Bio-Economic Hybrid Model in Marine Protected Areas

Bio-Economic Hybrid Model used Production Surplus Hybrid Model and adopted Gordon-Schaefer Bio-Economic Model. The difference that parameter a and b in Production Surplus Model were substituted (hybrid). The calculation of Total Revenue (TR) in this model was by inserting price variable, while Total Cost (TC) was derived from the cost variable.

The annual average price of grouper was calculated to determine Total Revenue (TR). Meanwhile, annual Total Cost (TC) was obtained through multiplying total cost for one trip with total number of trips annually and divided by total handline catch of coral reef fish in Anambas Islands MPA. Then, optimum effort (E MEY) and optimum biomass at maximum economic yield (MEY) were obtained. Gordon-Schaefer Bio-economic Model charts with and without spillover coefficient were shown in the parabolic curve.

RESULTS AND DISCUSSION

Production Surplus Model (PSM)

The catch graphs (Figure 2) show a consistently increasing trend from 2010-2018 for those 4 fish. However, the effort graphs (units of boats) show a declining trend from 2010-2015 and an increasing one from 2015-2018. The conservation area was endorsed in October of 2014. Therefore, we can infer from these graphs in Figure 2 that the catches increased after the endorsement, and the fishing effort was high before the conservation area was established and slowly decreased afterwards.

Figure 1. Annual total catch for 4 (four) coral reef fish groups with total operating vessels in Anambas Islands MPA. (Source: processed primary data, 2019).

Figure 2 shows the improvement (recovery) of fish stock, reaching its maximum carrying capacity. Besides, it is assumed that by implementing environmentally friendly fishing practice and limiting utilization to 50% of the MSY in MPA, there was a surplus of stock (uncaught) in MPA, which potentially Coral Groupers could be spilled over to the area outside the MPA.

Figure 3 shows the Estimation of optimum MSY in Anambas Islands MPA using Schaefer Model. According to the Schaefer Model, the potential maximum fishing effort to utilize coral groupers was 1,765 unit per year, with maximum biomass of caught groupers being 1,557.26 tons per year, the potential maximum fishing effort to utilize red snappers being 1,616 units per year, with maximum biomass of caught red snappers being 1,044.91 tons per year, the potential maximum fishing effort to utilize threadfin breams being 2,143 units per year, with maximum biomass of caught threadfin breams being 1,377.09 tons per year, and the potential maximum fishing effort to utilize trevallies being 1,803 units per year, with maximum biomass of caught trevallies being 2,601.37 tons per year.

Walter-Hilborn Model

The most statistically model was Walter-Hilborn's. The data used in this model was secondary data of annual catch and fishing effort in 2015-2018 (after the designation of Anambas Islands MPA). The Regression Parameter Estimates from the model for coral groupers were a= 26.1974, b1= 13.5050, and b2 = 0.0072. The biological parameter estimates obtained from natural growth rate, were r= 26.1974, K=269.092, and q= 0.0072. Therefore the estimated actual MSY was 1,675.45 tons/year and the actual fishing effort was 1,772 units/year, for red snappers were a= 14.7293, b1 = 13.3149, b2 = 0.0040 with biological parameter estimates r= 14.7293, K = 278.3930, and q = 0.0040. Therefore, the estimated actual MSY was 996.05 tons/year, and the actual fishing effort was 1.827 units/year. For threadfin breams, a= 5.8719, b1= 4.8817, and b2 = 0.0013, with biological parameter estimates r= 5.8719, K = 905.7768, and q = 0.0013. Therefore, the estimated actual MSY was 1,817.86 tons/year, and the actual fishing effort was 2.585 units/year. For trevallies, a= 5.8719, b1= 4.8817, and b2 = 0.0013, with biological parameter estimates r= 5.8719, K = 905.7768, and q = 0.0013. Therefore, the estimated actual MSY was 1,817.86 tons/year and actual fiishing effort was 2.585 units/year.

Schaefer Model

The optimum MSY in Anambas Islands MPA was estimated using Schaefer Model. The data used were

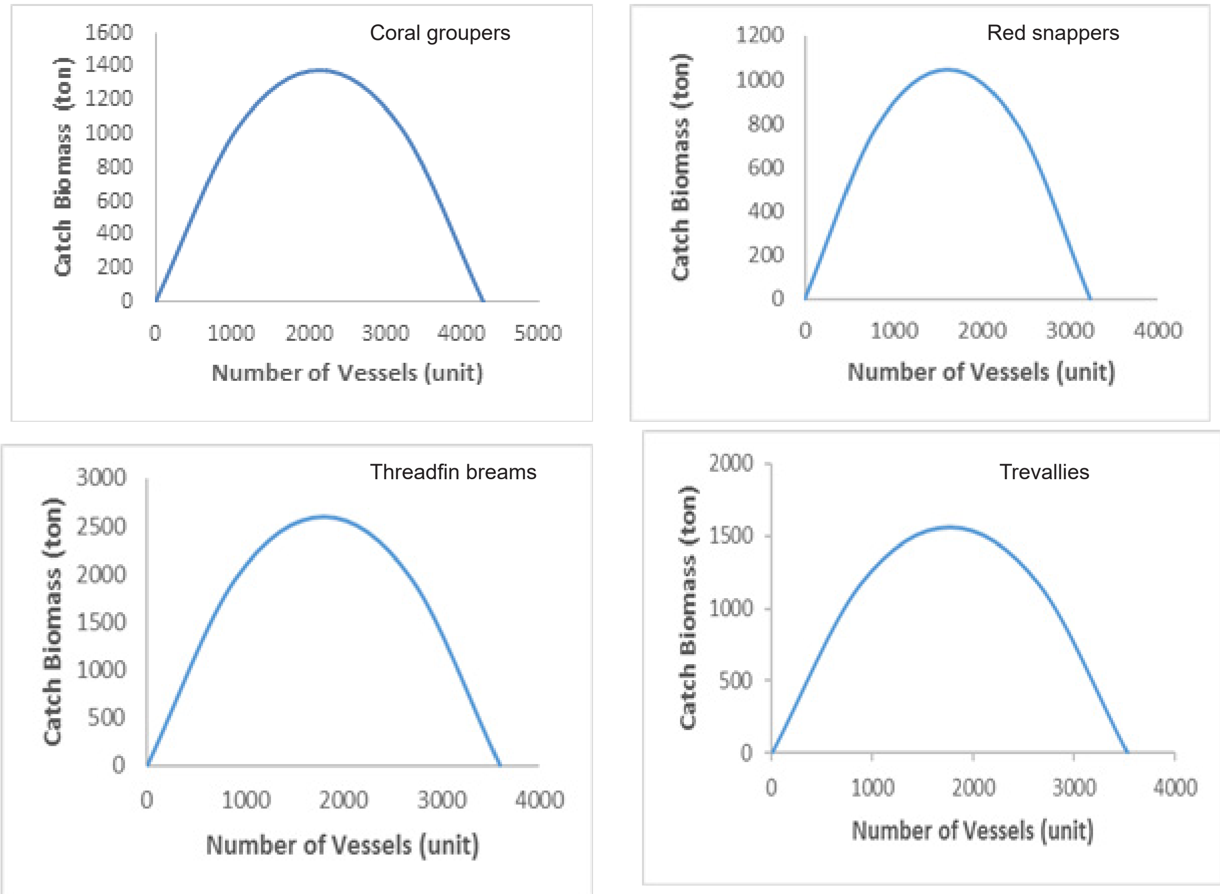

Figure 3. Estimation of optimum MSY in Anambas Islands MPA using Schaefer Model. (Source: processed secondary data, 2019).

catch and fishing effort data in 2015-2018 (after the designation of Anambas Islands MPA). Annual catch per unit effort (CPUE) was calculated from the data. According to the model, the relation between CPUE (c/f) and total effort followed the regression equation: Y = A – bX, where: Y = C/f, and X = f. Based on Schaefer model: c/f =a – bf -> C = af - bf2. At maximum effort point (Fmax), catch was zero. C = af – bf 2 = 0; thus, at that point a = bf; or f = a/b. At MSY, the effort level (Fopt) was half the maximum effort (1/2 . a/b = a/2b).

Figure 4 shows The estimation of MSY hybrid to actual MSY of four coral reef fish groups in Anambas Islands MPA. The improvement (recovery) of fish stock, reaching its maximum carrying capacity. Besides, it is assumed that Maximum fishing effort (hybrid) for coral groupers was 1,817 units and the maximum catch biomass (hybrid) was 1,762.38 tons/year. Maximum fishing effort (hybrid) for red snappers was 1,827 units and the maximum catch biomass (hybrid) was 1,025.13 tons/year. Maximum fishing effort (hybrid) for threadfin breams was 2,211 units and the maximum catch biomass (hybrid) was 1,329.67 tons/year. Maximum fishing effort (hybrid) for trevallies was 1,632 units and the maximum catch biomass (hybrid) was 3,867.73 tons/year.

MPA in Fisheries Management Area (FMA) gives direct and indirect benefits to the sustainability of fish stock. MPA secures the fisheries resource sustainability and important ecosystem for fish stock regeneration/recruitment in FMA because MPA protects the ecosystem from destructive fishing. Additionally, utilization within the MPA is more environmentally friendly, both from the aspects of the limitation of vessels and gears, as well as the limitation of fishing units far under the maximum fishing effort. Therefore, fish stock does not go through depletion or overfishing. Moreover, with maximum utilization level only 50% of the Total Allowable Catch (TAC), there will be spillover to the outside of MPA.

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

Economic benefit of Anambas Islands MPA was calculated from economic value and maximum profit obtained from sustainable biomass catch (MEY) in

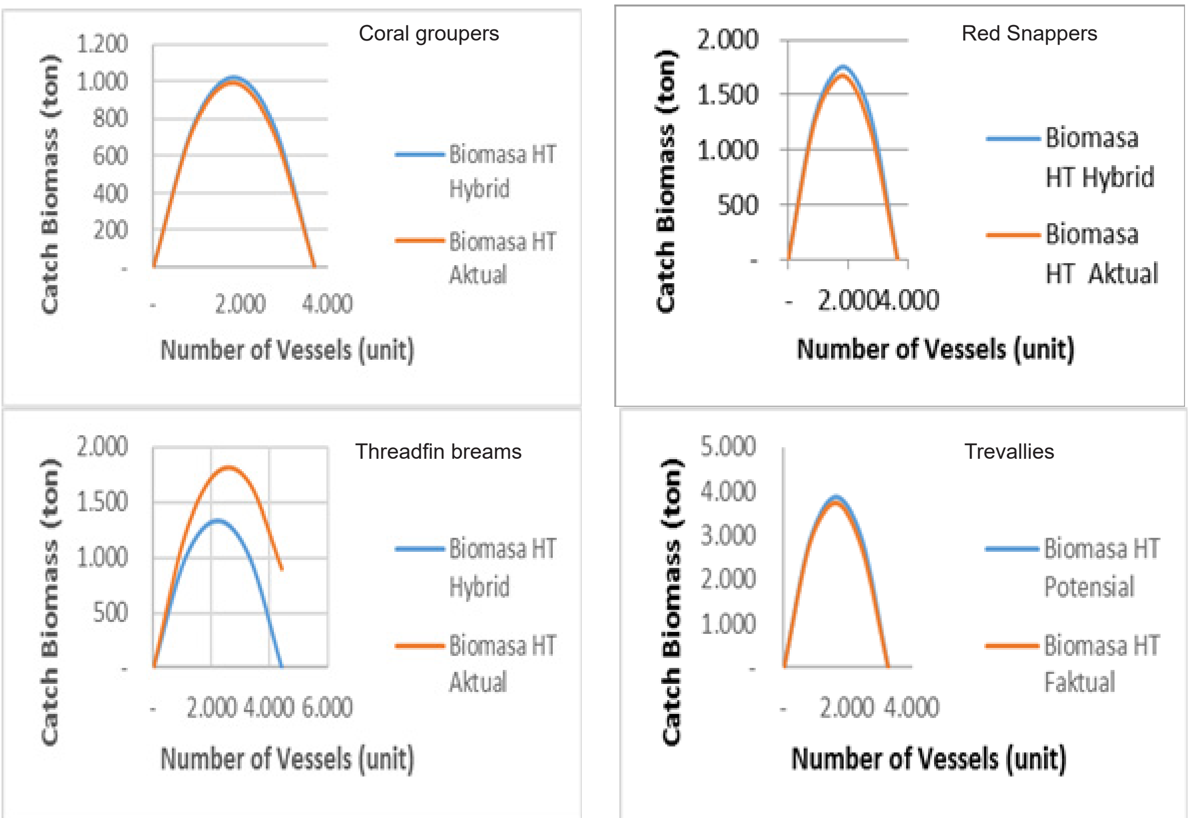

Figure 4. Estimation of optimum MSY in Anambas Islands MPA using Schaefer Model. (Source: processed secondary data, 2019).

the area and reserved potential profit which could be spillover to the outside (Table 1).

The economic value of the four coral reef fish groups in this study was IDR 301,481,685,170 per year, with IDR 38,247,299,860 per year for coral groupers; IDR 50,110,736,110 per year for red snappers; IDR 35,712,250,200 per year for threadfin breams; and IDR 177,411,399,000 per year for trevallies. Economic value was calculated from maximum sustainable biomass at MEY for each fish group multiplied by price per kg.

Meanwhile, the maximum profit for four fish groups in this study was IDR 296,793,855,170 per year with IDR 38,247,299,860 per year for coral groupers; IDR 48,956,576,110 per year for red snappers; IDR 34,331,290,200 per year for threadfin breams; and IDR 176,386,389,000 per year for trevallies. Profit was calculated from total cost (TC) subtracted from total revenue (TR). TR was obtained through multiplying total biomass of each fish group by price. TC was obtained through multiplying total fishing effort per year (vessel unit) by average trip cost per year for each fish group. A similar condition also occurs to density composition from three functional groups of reef fish that showed an improvement. There was also significant variation in periods of change in fish diversity and density among herbivore groups.

According to Christie *et al* (2002), overfishing in MPA areas may occur depending on MPA management. This found that the good management of MPAs can improve the reef fish communities and produces higher economic value than without MPAs (Mosquera *et al*. 2000; Halpern and Warner 2002; Paddack *et al*. 2009; Muallil *et al*. 2015).

Social Benefit of Coral Reef Fish in Anambas Islands MPA

The social benefit from coral reef fish biomass productivity in Anambas Islands MPA was obtained from total fishing effort, which was the number of handline fishing vessels. The number of vessels was then converted into number of fishermen in coral reef fisheries. In other words, MPA provided livelihood for the local community that utilized coral reef fish resources there. According to the survey done to handline fishermen in the MPA, the average number of handline fishermen (captain and crew) on each vessel was 1.96 persons.

The social benefits that can be obtained from the biomass productivity of reef fish resources produced by the Anambas Islands KKPN can be used with an approach to the number of fishing efforts in terms of the number of fishing boats. The number of fishing boats is then converted into the number of fishermen who have a livelihood catching reef fish. In other words, marine conservation areas that provide employment opportunities for people who utilize reef fish resources within the area.

Figure 5 shows the Number of fishing effort and fishermen in coral reef fisheries per year. The number of handline fishermen in Anambas Islands MPA was counted based on two criteria : fishermen with catch amount at 50% of the maximum sustainable biomass (TAC50%) and fishermen with catch amount at maximum economic yield (TAC MEY). The number of fishermen in coral reef fisheries was 1,019 and 3,646 persons, for TAC50% and TAC MEY, respectively. If the TAC is still 50% of maximum sustainable potential (TAC50%), the current number of fishermen must be cut down to 1,019. However, the potential number of fishermen that can catch outside the MPA was 2,627. In other words, although the number of fishermen in coral reef fisheries was cut down after the implementation of Marine and Fisheries Ministerial Decree No.47/2016, fishermen outside the MPA increased.

This study analyzed growth, mortality, and exploitation rate of four coral reef fish groups regularly caught by handline fishermen in Anambas Islands MPA. The groups were coral groupers, red snappers, threadfin breams, and trevallies. The analysis resulted in coral groupers, red snappers, and trevallies having exploitation rate lower than 0.5 or lower than maximum catch biomass. On the other side, the exploitation rate of threadfin breams went past the maximum point. According to the Management and Zonation Plan

Table 1. Hybrid MSY, MEY, Economic Value, Profit, Ideal Economic Value, and Potential Economic Value

Fish Group	Hybrid MSY (ton/year)	MEY (ton/year)	Economic Value	Profit	Ideal Economic Value	Potential Economic Value
Coral grouper	1,762.38	1,761.98	38,247,299.86	37,119,599.86	19,123,649.93	19,123,649.93
Red snapper	1,025.13	1,024.99	50,110,736.11	48,956,576.11	25,055,368.06	25,055,368.06
Threadfin bream	1,329.67	1,329.57	35,712,250.20	34,331,290.20	17,856,125.10	17,856,125.10
Trevally	3,867.73	3,867.70	177,411,399.00	176,386,389.00	88,705,699.50	88,705,699.50

Source: processed primary data, 2019

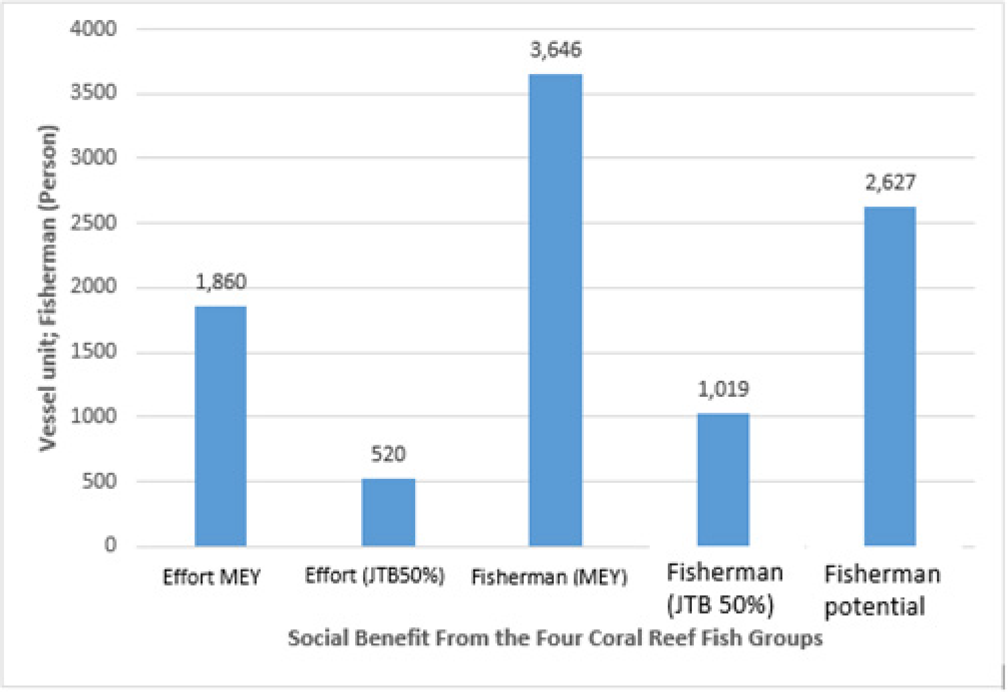

Figure 5. Number of fishing effort and fishermen in coral reef fisheries per year.

Document of Anambas Islands MPA, the total coral reef coverage is 3,705.84 ha or 37.0584 km^2. Using MSY approach, coral reef fish productivity per unit coral reef coverage was calculated from annual MSY divided by total coral reef coverage.

Coral reef ecosystem productivity in Anambas Islands MPA for the four fish groups was 215.47 tons per km^2 per year, with coral groupers consisting of 47.56 tons per km2 per year, red snappers, 27.66 tons per km2 per year, threadfin breams, 35.88 tons per km2 per year, and trevallies, 104.37 tons per km^2 per year.

Muchtar *et al*. (2014) discovered that coral reef fish production from coral reef ecosystem was 1.16 tons per km^2 per year. Dahuri (2003) reported that coral reef MSY in Indonesia was 29.05 tons per km^2 per year. Study conducted by National Marine Protected Area Agency (Loka KKPN) Pekanbaru (2018) stated that coral reef fish production in Anambas Islands MPA was 52.31 tonne per km2 per year. These differences occurred presumably because of the differences in calculation methods, study location, and habitat condition in each ecosystem.

Coral reef has numerous benefits, directly and indirectly. Direct benefits, for instance, are providing fisheries resources as food and livelihood sources (Muchtar *et al*., 2014). Kunarso (2008) stated that coral reef is high in fisheries resources. Out of 132 commercially important fish species in Indonesia, 32 live in coral reef and some are commodities for export. Healthy coral reef can produce 3 to 10 tons fish per km^2.

Economic benefit of Anambas Islands MPA was calculated from economic value and maximum profit obtained from sustainable biomass catch (MEY) in the area and reserved potential profit which could be spillover to the outside. The economic benefit value was IDR 81,353,130 per hectare per year with total coral reef coverage of 3,705.84 Ha. As a comparison, Muchtar *et al*. (2014) found that the economic benefit value for coral reef coverage of 25.24 Ha was IDR 31,859,359 per hectare per year. The differences were presumably because of the fish price difference in each location and the difference in the year of the study, which affected the fish price.

The economic value of the four coral reef fish groups in this study was IDR 301,481,685,170 per year, with IDR 38,247,299,860 per year for coral groupers, IDR 50,110,736,110 per year for red snappers, IDR 35,712,250,200 per year for threadfin breams, and IDR 177,411,399,000 per year for trevallies. Economic value was calculated from maximum sustainable biomass at MEY for each fish group, multiplied by price per kg.

Meanwhile, the maximum profit for four fish groups in this study was IDR 296,793,855,170 per year, with IDR 38,247,299,860 per year for coral groupers, IDR 48,956,576,110 per year for red snappers, IDR 34,331,290,200 per year for threadfin breams, and IDR 176,386,389,000 per year for trevallies. Profit was

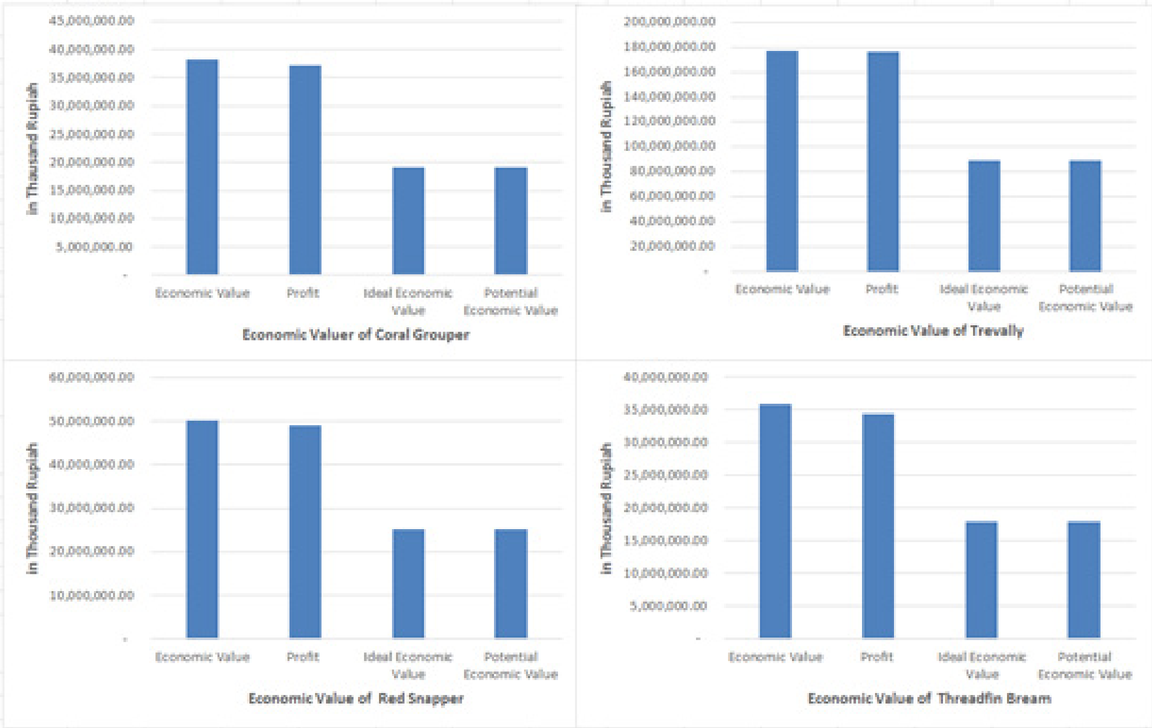

Figure 6. Economic Value of some coral reef Fish groups in Anambas Island MPA.

calculated from total cost (TC) subtracted from total revenue (TR). TR was obtained through multiplying total biomass of each fish group by price. TC was obtained through multiplying total fishing effort per year (vessel unit) by average trip cost per year for each fish group.

On the other side, Haryani *et al*. (2009) found that Raja Ampat with sole-owner management had the highest profit (MEY) as compared to the open access management and MSY, which was IDR 43,040,425 per week. At this production level, the fishing effort was efficient; thus, they had better catch quality, followed by maximum profit.

The economic value of coral groupers was IDR 38,247,299,860 per year with profit IDR 37,119,599,860 per year. The ideal economic value at 50% MEY was IDR 19,123,649,930 per year. If the implemented MSY is 50% of MEY, there will be potential economic value as much as IDR 19,123,649,930 per year for uncaught fish.

The economic value of red snappers was IDR 50,110,736,110 per year with profit IDR 48,956,576,110 per year. The ideal economic value at 50% MEY was IDR 25,055,368,060 per year. If the implemented MSY is 50% of MEY, there will be potential economic value as much as IDR 25,055,368,060 per year for uncaught fish.

The economic value of threadfin breams was IDR 35,712,250,200 per year with profit IDR 34,331,290,200 per year. The ideal economic value at 50% MEY was IDR 17,856,125,100 per year. If the implemented MSY is 50% of MEY, there will be potential economic value as much as IDR 17,856,125,100 per year for uncaught fish.

The economic value of trevallies was IDR 177,411,399,000 per year with profit IDR 176,386,389,000 per year. The ideal economic value at 50% MEY was IDR 88,705,699,500 per year. If the implemented MSY is 50% of MEY, there will be potential economic value as much as IDR 88,705,699,500 per year for uncaught fish.

The social benefit from coral reef fish biomass productivity in Anambas Islands MPA was obtained from total fishing effort, which was the number of handline fishing vessels. The number of vessels were then converted into the number of fishermen in coral reef fisheries. In other words, MPA provided livelihood for the local community that utilized coral reef fish resources there.

The number of handline fishermen in Anambas Islands MPA was counted based on two criteria: fishermen with catch amount at 50% of the maximum sustainable biomass (TAC 50%) and fishermen with catch amount at maximum economic yield (TAC MEY). The number of fishermen in coral reef fisheries was 1,019 and 3,646 persons, for TAC 50% and TAC MEY, respectively. If the TAC is still 50% of maximum sustainable potential (TAC 50%), the current number of fishermen must be cut down to 1,019. However, the potential number of fishermen that can catch outside the MPA was 2,627. In other words, although the number of fishermen in coral reef fisheries was cut down after the implementation of Marine and Fisheries Ministerial Decree No.47/2016, fishermen outside the MPA increased.

Capture fisheries shall be optimally managed to prevent ecosystem damage and therefore, encourages a more selective fishing method. To be selective, fisheries management shall use one or more of 6S's of selective strategy, which are Species, Stock, Size, Sex, Season, and Space. However, Zhou *et al*. (2010) argued that selecting 6S's would add more damage to the ecosystem and would negatively affect the production capacity in sustaining the catch.

Hutubessy *et al*. (2016) stated that the bigger the target fish is, the more we harm the fish population by only leaving small fish in the water, Decreased production capacity is one of indications of overfishing. Overfishing on vertebrates and large fish is known to have negative impact on the environment and socioeconomics by damaging the biodiversity and modification of the ecosystem (Worm *et al*., 2010). Mortality rate of caught fish shall be lower than the productivity to ensure the capture is ecologically sustainable (Hutubessy *et al*., 2016). Coral reef fisheries are complex systems. This is due primarily to the multi-species, multi-gear and high labor mobility that often occurs within the fisheries sector. Since many small-scale fisheries operate in remote areas and/ or in developing coastal states, the quality and quantity of data necessary to undertake basic fisheries management, including robust stock assessments, are often lacking Fisheries management must avoid adverse impacts on the ecosystem. Doing so can be challenging in highly complex systems, particularly if the target species serves an important ecosystem function. Loneragan.et.al. (2021). Stated that when insufficient data are available to estimate the current stock status of a fishery, it is called a data-limited fishery. therefore application of alternative stock assessment using data-limited fishery to develop Management Strategy Evaluation and developing Harvest Strategy in the MPA, would be promising in the future MPA management.

Information on the biological aspect of the stocks, their current status, the fishery and its current and potential management can be used to conduct a quantitative risk assessment to evaluate the probability of overexploitation. In addition, the information is used to evaluate a range of potential management options to determine which approaches are most likely to meet the management objectives.

CONCLUSION

The MPA has shown both biological and economic benefits, namely the spill over impact and total economic value of harvest at amount of IDR 301,481,685,170/ year. Biological benefits of the maximum availability of reef fish resources can be utilized as much as 7984.91 tons / year at its maximum sustainable yield point. Therefore, the TAC for fisheries at the MPA is set at 50% of the MSY, the TAC can be utilized is 3992.46 tons / year of fishes. The 50% MSY policy on fisheries TAC in MPA site will still sustain the fisheries resource. However, fishermen are far from getting their maximum profit. Therefore the FAO recommendation of having the TAC at 80% of MSY can be considered as a reference in the MPA site. That policy will also need the government to provide programs and assistance on creating alternative livelihoods for fishermen. Based on our finding, the fishing effort in Anambas Islands MPA at amount 2910 boats are over capacity. Therefore, the efforts shall be reduced to 1860 units to provide maximum sustainable profit at MSY points. Furthermore, the allowed boats will only be 520 units if the Anambas Island MPA implement the TAC at amount of 50% MSY. One of the strategy could be done through encouraging the fishing boats to go fish further outside the Anambas MPA. This needs affirmation policies both from national and local government to increase fishing capacity and skills such as operating larger vessels, eg 10 GT.

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