Economic impact of moratorium of foreign fishing vessel policy in Arafura Sea, Indonesia

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Abstract. Demersal fisheries provide significant economical commodities in the Arafura Sea. These areas have been illegally exploited and this has harmed the ecosystem as well has influence on the social, economic, defense, and security aspects. In 2014, the ministry of marine and fisheries released the moratorium policy no. 56 that limits fishing vessels manufactured in a foreign country. This study aims to determine the impact of foreign fishing vessels moratorium on fish stock, volume of fish production and fishing rent received by fishermen in WPP 718. The method used in the study is dynamic system modeling which is validated using Mean Absolute Percentage Error (MAPE). The stock variables used are fish biomass, number of vessels, fish price, and the rent of fisheries. Each stock variable is influenced by the flow variable. Validation test showed that MAPE accounted for 15.73% using production data and 11.60% using the number of vessels. Results showed that the reduction of 614 trawl vessels also reduced the operating vessels by 22.75%, production went down by 18.41% in the start of the period but increased by 8.84% in the end. Rent increased by 34.09% as well as biomass by 31.57%. This increase is caused by the reduced cost which was bigger than the reduced income calculated from multiplying production and selling price. The lower the production rate is, the higher the selling price of fish.
Key Words: demersal fishery, limited entry, dynamic system, fish biomass, fisheries rent.

Introduction. The fishery is a system combining humans and environment. Dynamic system modeling can expand our understanding of the system and support policy-makers. Dynamic modeling can be used to evaluate the impacts of the decisions made towards a variety of aspects within the system such as fish stock, labor management, and benefits for the fishery. Several researchers have used dynamic modeling in fishery industries namely Dudley (2008), Haldorsen (2017), and Sigurdardottir et al (2016). The effects of fishery management can be viewed from biological, economical, and social aspects (Sigurdardottir et al 2016).

Demersal fisheries in Indonesia is one the important exporters and economically contributed to investment in the fisheries sector with incremental capital-output ratio (ICOR) of 3.25 (Kusumastanto 2006). Industrial fishing, particularly of shrimp, has been conducted since 1980 by an Indonesian and Japanese corporation located in Sorong and Ambon (Suman & Satria 2014). The most common fishing gear in the Arafura Sea is trawl, particularly targeting shrimp. Apart from shrimp, however, this fishing gear captures demersal fish far more than shrimp. Suman & Satria (2014) stated that natural resources of shrimp have been highly- and overly-exploited. In the long term, this exploitation may lead to deterioration of natural resources as well as can cause extinction of some species. Regulation No. 31/2004, which was revised to No. 45/2009, was aimed to manage and achieve optimum practice while preserving fisheries resources. In 2014, the Ministry of Marine Affairs and Fishery released the regulation no. 56/2014, limiting permission for fishing vessels which are made in foreign countries. These vessels have been banned to operate in Indonesia's fishing areas until further notice. 614 trawl vessels have ceased to operate in the Arafura Sea.

The regulation of limited entry for foreign fishing vessels is a form of government intervention in managing fishery resources that have an impact on investment. Therefore the management of fishery resource policy will give an impact to fisheries sector economic growth. The management of fishery resources can be improved in three ways (Haynes et al 1986), firstly, efficiently managing fish stock for long-term fishing to increase output, secondly, reducing competition between fishermen to reduce the cost per fishing unit, and thirdly, increasing profit for the unit's output. The regulation of limited entry can increase rent and fish supply (Anderson 1985; Campbell & Lindner 1990; Asano et al 2016).

The present research aims to determine the impact of foreign fishing vessels moratorium on fish stock, on fish production volume and on fishing rent received by fishermen in Fisheries Management Area 718 (WPP 718).

Material and Method

Description of the study sites. This study was conducted at Arafura Sea. The area studied includes the WPP 718 (Aru sea, Arafuru/Arafura sea, Eastern Timor sea). Technically, it also includes the province of Papua, West Papua, and some parts of Maluku (Figure 1) (Mulyana 2012). This area was chosen as most of the fishing vessels affected by the moratorium policy conduct fishing here. This area also has one of the highest potentials as fishery resources among the 11 fishing areas in Indonesia.

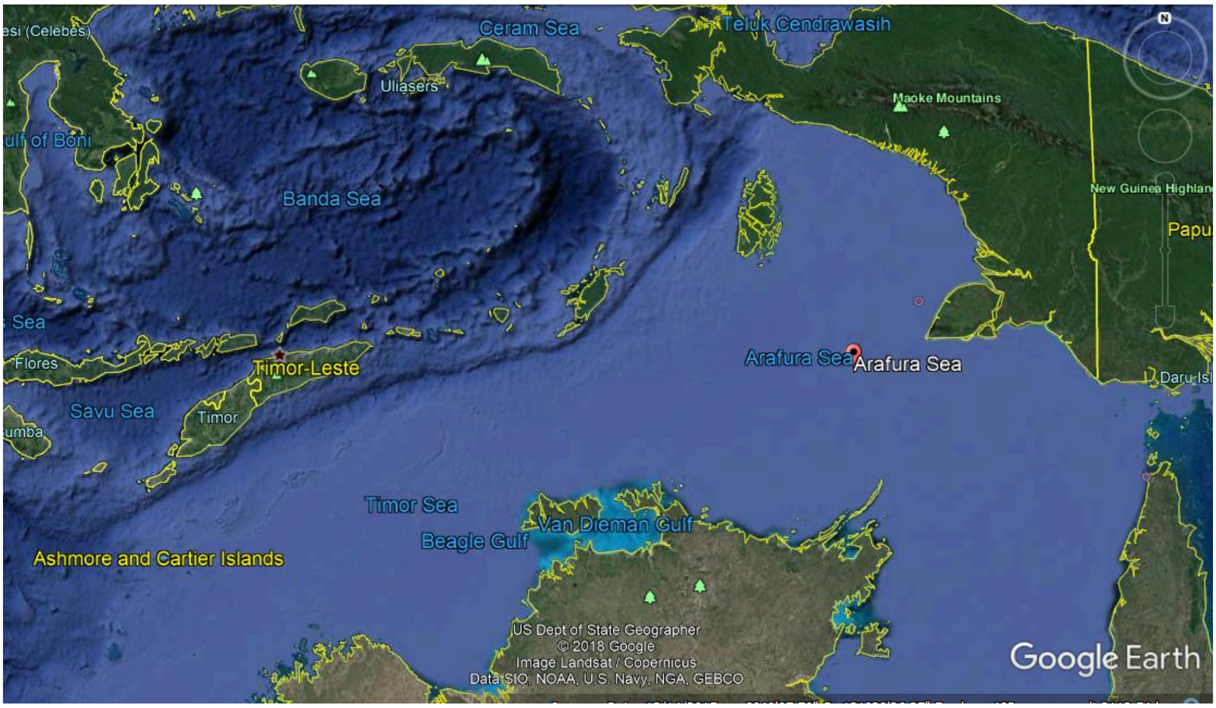

Figure 1. Map of research area.

Data. The data used in this research is secondary data, which was taken from the Statistic book of marine and fishery, Badan Pusat Statistik (Central Department of Statistics), research reports, published journals, and other reliable sources. Secondary data of fish production and fishing gear is from the period of 2011-2014. Fish price and consumer price index is taken from the year 2001 to 2014 with the base year of 2007=100. Data regarding regulations for fishing vessels in WPP 718 was taken from 2011-2017. Data of operational cost using rawai tools as well as the number of crew was taken from earlier researches (Kisworo et al 2013). Biological parameters such as r, q and K refer to bioeconomic analysis (Sari et al 2018). While regression coefficients such as α and μ were obtained from regression analysis (Sari et al 2018). Summary of data values and variables used in this study are presented in Table 1.

Table 1

Value and sources of parameters from abovementioned equations taken from several sources

Parameter	*Value*	*Source*
Intrinsic growth rate (r)	1.59	Sari et al (2018)
Carrying capacity (K)	477,027	Sari et al (2018)
Catchability coefficient (q)	0.000116	Sari et al (2018)
Fishing effort (E)	2,516	KKP (2016, 2017)
Regression intercept (μ)	5.7811	Sari et al (2018)
Regression coefficient (a)	0.7514	Sari et al (2018)
Price (p)	32.06	BPS (2015)
Cost of fishing (c)	868.56	Kisworo et al (2013)

Method of data analysis. Dynamic system was used to model a highly abstract system as well as to holistically model the system of fishery (Dudley 2008). Dynamic system involves causal relationships between the key aspects of the system being investigated. The analysis output is reveled in a form of a visual causal diagram representing the interconnection between variables in the system. Causal diagram is a group of nodes connected with a feedback loop made with a specific kind of relationship (Sterman 2000).

A feedback loop is a closed sequence of causes and results or a closed end of an action and information (Richardson & Pugh 1981). Every connection is marked (with + or -) and indicated a change in a node which creates a change in the same or different direction. A positive feedback loop strengthens the change and leads to exponential growth. A negative loop or balancing loop indicates that if a variable is above the targeted loop structure, it will cause devaluation. Whereas it will increase the value if the variable is placed under the target (Kirkwood 1998). This method can be applied in a small, or big, scale. One of the benefits of a causal diagram is its simplicity – it is easy to understand and communicate.

After the causal diagram is attained, stock-and-flow model is digitally simulated to further understand long-term behaviors of the study from time to time. Understanding and managing the stock and flow involves investigating supplies that are accumulated or wasted as well as the flow which manages the stock changes. This is a fundamental process in a natural and social system. All problems concerning stock and flow are basically similar where stock accumulate the inflow and reduce the outflow (Sterman 2000). There are plenty of real-life situations that can be simulated in a stock-and-flow process. Dynamic system is used due to the multiple interconnections between variables, non-linear dynamics, and feedback. The complexity of the system resulted in a deeper understanding of the system behaviors needed for the computerized simulation. The simulation tool used in the study was Vensim PLE 6.0 version.

This research used state/stock variables which are fish biomass, fishing vessels, rent from fishery, and price of fish. Each stock variable is accompanied by a flow variable and is separated between inflow and outflow. Fish biomass is accompanied by an inflow variable of fish growth and an outflow variable of fish death rate and fish production from the supply. Fishing effort is accompanied by an inflow variable of trawl vessels and bottom longline vessels and an outflow variable of vessels conducting fishing in the area. Benefit variable if accompanied by an inflow variable of fish captures and an outflow variable of the cost in fishing efforts. Price variable is accompanied by a flow variable of price coefficient which balances request and demands. All the in- and outflows are influenced by auxiliary variables and may directly be influenced by stock variable. Figure 2 presents a complete dynamic system model for this research.

The effects of foreign vessel moratorium are seen by connecting this variable to outflow vessel variable. Simulation is done with the assumption of 0 in the moratorium variable, whereas after the moratorium policy, it becomes 614. Baseline condition is assumed with and without Illegal, Unreported and Unregulated (IUU) fishing, which is 50% of the total number of vessels without fishing permits. The variable of moratorium policy indicates a positive relationship with outflow vessel variable. The higher the value of the policy, the higher the number of outflow vessels, and vice versa. The period of analysis is 40 years, which is until 2050.

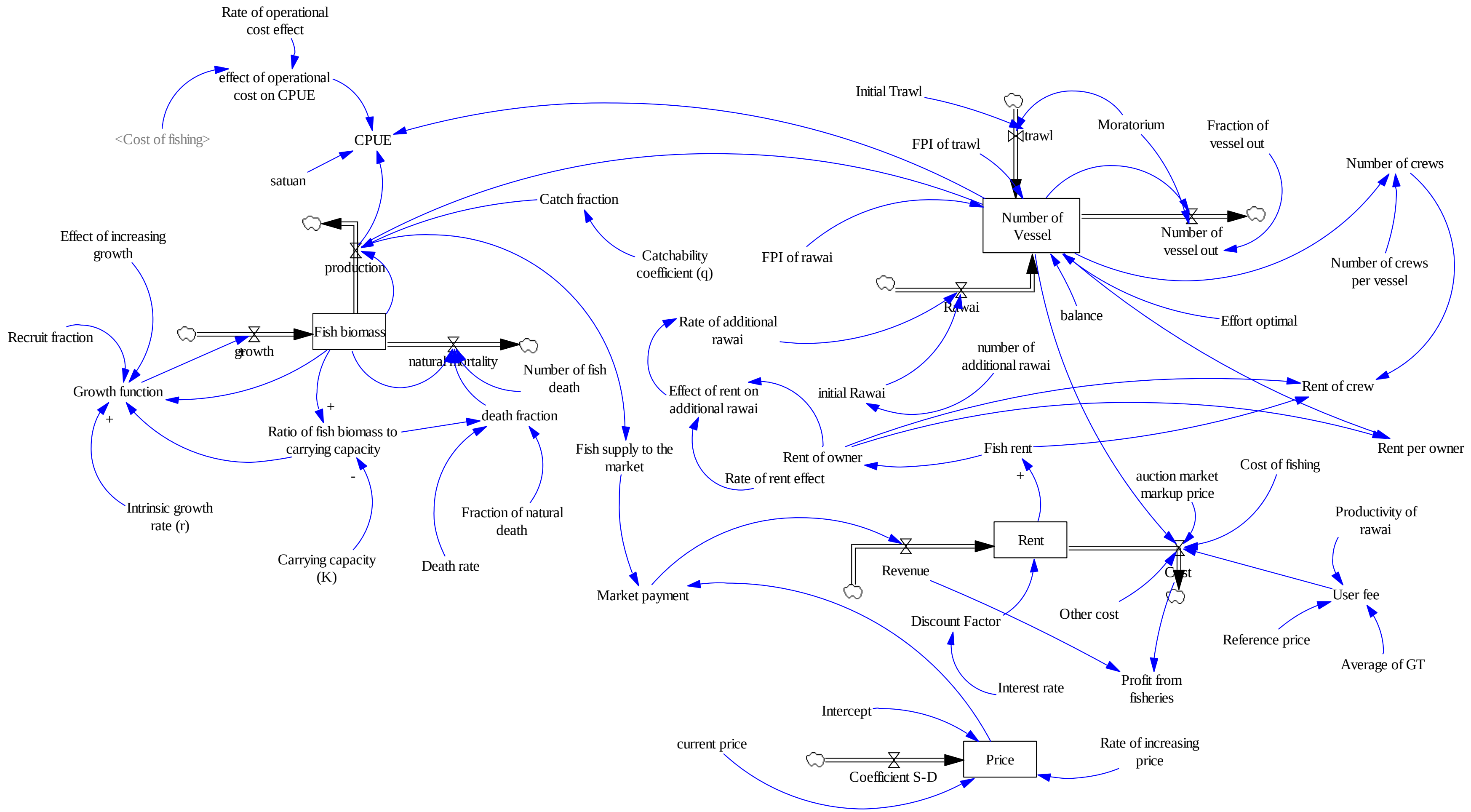

Figure 2. Stock—flow model of demersal fishery system in Arafura Sea.

To determine the reliability and suitability of the model output with the actual conditions, verification and validation tests were carried out. Dynamic system model validation in this study uses several validation procedures such as parameter verification tests, statistical tests and expert opinions. The statistical test used in the study was Mean Absolute Percentage Error (MAPE).

Equations used in the research are growth function, catch/harvest function, price function, revenue and benefit. Growth function of fish is based on logistic growth model

$$F(X) = rX(1 - \frac{X}{K}) \quad (1)$$

Catch function is based on generalized Schaefer function

$$H = qEX \quad (2)$$

Price function, current price is influenced by previously set price

$$p_t = \mu + a.p_{t-1} + \varepsilon_t \quad (3)$$

Revenue is the result of total harvest multiplied with price

$$TR = p.H \quad (4)$$

Total cost is the result of cost per unit effort multiplied with amount of effort

$$TC = c.E \quad (5)$$

Benefit/rent is the result of total revenue subtracted by total cost

$$\pi = TR - TC \quad (6)$$

$F(X)$	:	Natural growth function
X	:	Biomass
r	:	Intrinsic growth rate
K	:	Carrying capacity
H	:	Harvest function
q	:	Catchability coefficient
E	:	Effort
p_t/p	:	Price at t period
p_{t-1}	:	Price at t-1 period
TR	:	Total revenue
TC	:	Total cost
c	:	Cost per unit effort
π	:	Rent

Results

Verification and validation. Verification and validation are crucial in a model to measure its efficiency and accuracy. This is done by looking at the similarity of the results produced by the model and the actual data. Vensim has its own debugging system which helps to verify the model so that it can be run. Validation is a detrimental process to see whether the simulation model is an accurate representation of the system according to the purpose of the model in the research. A valid model can be used to make decisions based on the model behaviors.

Statistical validation in this research is using MAPE. MAPE calculation is conducted on production and fishing vessels which contains available actual data to be compared with the output model. Data used to compare is taken from 2011, which as an initial value of the variable using information in 2011. Comparison of data is done between year 2011 until 2014. The value of MAPE using production in 2011-2014 is 15.73%. This shows that the error rate of the dynamic system model is 15.73%, which means the model can present the actual phenomenon at 84.27% (Table 2).

Table 2

MAPE values using production data

Year	*Actual value*	*Output model*	*Difference*	*Error percentage*
2011	119.383	119.672	289	0.24
2012	106.164	124.067	17.903	16.86
2013	104.616	128.862	24.246	23.18
2014	172.967	133.793	-39.173	22.65
		MAPE		15.73

Source: Data analysis (2018).

Validation measurement was also conducted on fishing vessel to attain the MAPE values. Using actual data of 2011 until 2014, MAPE value was 11.60%. This value shows error rate of the dynamic system model at 11.60% (Table 3). This indicates that the dynamic system model is considered good as the validation value is more than 80% with the absolute error rate less than 20%.

Table 3

MAPE value using number of vessels

Year	*Actual value*	*Output model*	*Difference*	*Error percentage*
2011	2.269	1.963	-306	13.49
2012	2.356	2.055	-301	12.77
2013	2.437	2.166	-271	11.12
2014	2.516	2.289	-227	9.02
		MAPE		11.60

Source: Data analysis (2018).

The impact of moratorium policy on fish biomass. The results of bioeconomic analysis and other analysis incorporated to dynamic analysis. Fish stock dynamics is influenced by fish growth, mortality, and captures. Fish growth positively influences fish biomass (refer to equation 1), whereas mortality and captures have a negative effect. Fish biomass will increase if growth is higher than mortality and fishing activities, and vice versa. Fish growth is influenced by existing biomass, intrinsic growth and environmental resources.

Environmental resources data was taken from bioeconomic analysis on MEY conditions which was at 477,027 tons. Intrinsic growth rate of 1.59% was also taken from a bioeconomic analysis. The ratio of biomass to carrying capacity show the amount of biomass compared to natural potentials/resources. The biomass to carrying capacity ratio of 0.45 was taken from output model and shows that the number of fish stock in the area is 45% from the available natural potentials. Death rate of fish is influenced by the aspects of mortality, biomass ration, and the amount of biomass in the previous year. Natural death is assumed to be small, which is 0.5%, based on the assumption that demersal fish in Arafura Sea is already captured before death. Biomass ratio influences the death rate as fish biomass will experience natural deterioration as it becomes higher than natural potentials. Results show that fish biomass will experience a significant increase at the start of the period as vessels are decreasing resulting in lower production. However, as time goes by, fish biomass will continue to decrease with the addition of vessels until it reaches a balance. The comparison of improvement due to moratorium policy in baseline condition with and without IUU fishing can be seen in Figure 3.

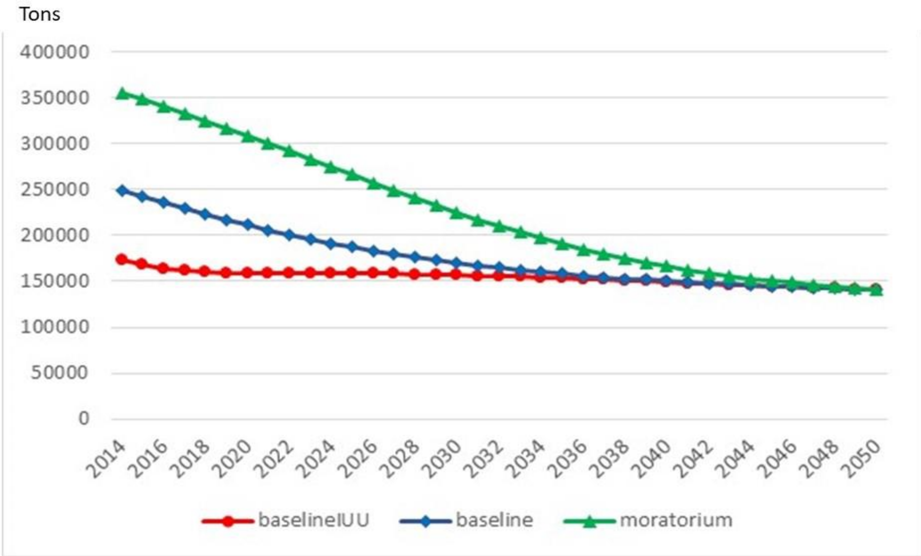

Figure 3. Fish biomass of demersal fisheries in Arafura Sea.

The impact of moratorium policy on production. Fish production is influenced by existing biomass, fishing vessels and catchability coefficient of the vessels (equation 2). This coefficient is constant and does not experience changes resulted by additional effort. With the foreign vessel moratorium policy, there are fewer vessels in the Arafura Sea, while the amount of biomass continues to increase as less fish is captured, leading to lower production values. In the start of the period, the simulation of baseline production is higher than production in moratorium, but at the end of the period, production values in moratorium continue to increase. This is resulted from increasing number of vessels until the end of the period as there is ongoing rent by owners. Decreasing production from baseline to moratorium shows lowering score but in the end of the period it shows an increase of the production values in moratorium which is higher than baseline production Figure 4.

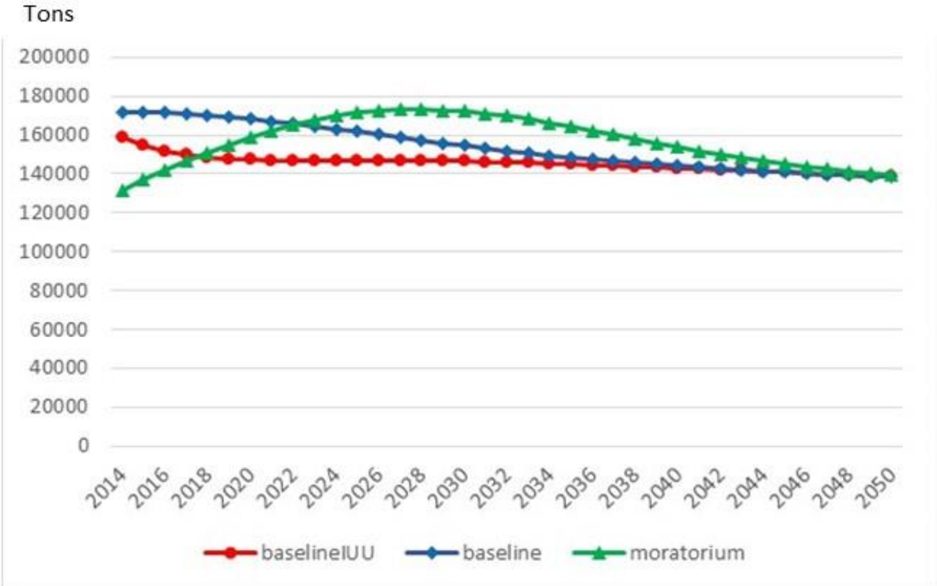

Figure 4. Production of demersal fisheries in Arafura Sea.

Production in 2014 was 168.027 tons according to predicting model. The following year, it increased by 137.667 tons in the end of the simulated period. This increase was influenced by the higher number of vessels. The number of vessels is a stock variable.

The number of fishing vessels operated was a summation of the bottom longline and trawl vessels which capture demersal fish in Arafura Sea. Each fishing tool is multiplied by fishing power index and results in the number of fishing tools that are supposed to be operated with bottom longline - a standard procedure. The initial value of bottom longline tools is the number of bottom longline tools operated in WPP 718 based on statistics. bottom longline is a tool permitted and recommended in WPP 718 which means that there is a possibility of additional bottom longline tools operated by local fishermen. This additional figure is included in the model as bottom longline additional rate, which is 5%. This additional number is a result of several benefits for current fishermen which encourage the increase of bottom longline vessels. In the trawl inflow, there are no additional vessels as there are vessels banned from operating in Indonesian waters. Feedback from the benefit is seen towards the number of fishing effort. The benefit is also influenced by the total income subtracted by the total cost depending on the number of vessels.

It is assumed that the number of vessels does not decrease since there is still profit in the fishing industry. Flow variable of vessel reductions indicates the number of fishing vessels operated in the Arafura Sea as well as the reduction of vessels due to foreign vessel moratorium policy in Indonesia. Without the moratorium policy or simulation in baseline conditions, the number of vessels will be the same as the amount of fishing vessel.

The number of fishing vessels operated is decreased by 614, due to the foreign fishing vessel moratorium in WPP 718. The types of vessels that are affected by the policy are considered highly productive compared to fishing vessels that are not affected, which overall lower the number of vessels. The decline of vessels in baseline condition and during policy (moratorium) shows further decreasing trend. The decrease of 614 units of trawl vessels in Arafura Sea causes the decrease in fishing vessels by 22.75% per year if compared with baseline without IUU fishing, it decreased by 27.41% if compared with baseline with IUU fishing Figure 5.

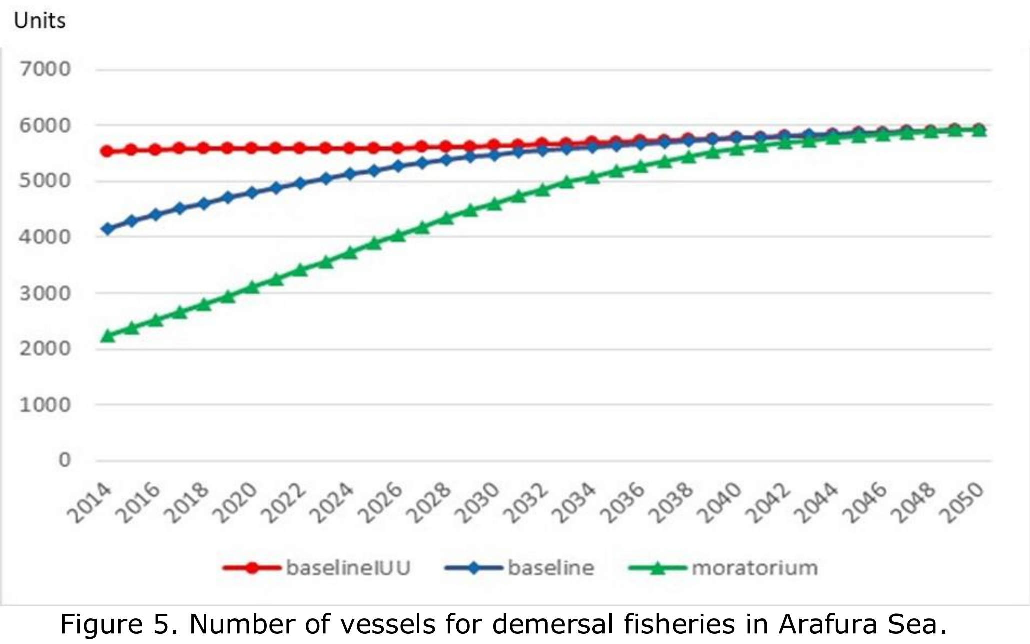

Figure 5. Number of vessels for demersal fisheries in Arafura Sea.

The number of crew is an average of crew members in one fishing unit using bottom longline vessel. The average crew member consists of 17 individuals. The owners of the vessels are assumed to be the same with the number of vessels - every fishing vessel operating in WPP 718 is owned by 1 person. Therefore, the number of owners of vessels is the same as the number of bottom longline vessels operating in WPP 718.

The impact of moratorium policy on rent. Revenue from fishing is calculated from multiplying marketed fish and price (equation 3). The quantity of fish marketed is assumed to be the same as the amount of fish landed. Price is a stock variable which is influenced by a balancing coefficient between supply and demand (Sigudardottir et al 2013). In price formulation, future prices are influenced by current prices. In this research, the price is not affecting the fishing results of each vessel as most captured fish in the Arafura Sea are sent to other regions and even marketed abroad (shrimp). With the integrated marine and fisheries center (SKTP) program, most production at SKTP is managed by two Indonesian public fisheries companies who have been assigned to market the fishing production. Price is not assumed to be fluctuating. The graphs for price in baseline condition and moratorium have parallel lines.

Using prediction of ordinary least square (OLS), we can predict the interception and the coefficient of the relation between price at t period with price at t-1 period. Price at t-1 period is an independent variable whereas price at t period is a dependent variable. Price used to predict the intercept and coefficient is the real price in 2001 until 2014. Prediction by OLS reveals value of determination coefficient at 71.49%. Intercept at 5.78%, and regression coefficient of 0.75138. Value of t test for regression coefficient is significant at an alpha value of 0.01. In this research, it is assumed that price increases 8% every year.

Total cost of fishery in the Arafura Sea is a summation of all the costs including operational cost per vessel, administrative costs, and other costs multiplied by the number of operating vessels (equation 4). Operational cost of bottom longline vessels in this model is using the operational cost which used bottom longline tools conducted by Kisworo et al (2013). Operational cost includes total cost of fishing in one-year period. Administrative costs paid by every vessel are based on calculation of fisheries fees managed in the government regulation (Peraturan Pemerintah) No. 19/2006. A medium-sized vessel with 60-100 GT will pay fisheries fees with the following calculation:

Fisheries fees = 2.5% x vessel productivity x reference fish price

Reference fish price used in the research is the average price of demersal fish stated in regulation of the Ministry of Trade No. 13/M-DAG/PER/5/2011, which is about 748.57 USD/ton. The average size of bottom longline vessels is 75 GT per unit. Therefore, the amount of fisheries fees is 1,402.86 USD/year. Other costs include in the research is miscellaneous fees of 714.28 USD/year. Total sum is then multiplied with the number of vessels to get the overall cost in the fishery industry.

The moratorium policy causes a slight decrease in income in the beginning of the period but then shows a stronger effect in the end of the simulation period. Cost is affected by operational cost and other costs in the industry multiplied by number of vessels. The graphs of cost show a similar pattern to that of the fishing effort (Figure 3). With the foreign vessel moratorium, the number fishing vessels decline and cost is also reduced by 22.75%. Other variables affecting cost are constant and do not experiences any changes as the number of vessels decrease.

Rent is a stock variable affected by inflow variable of income subtracted with cost and multiplied with discount factor. Rent in fishing is influenced by revenue subtracted with cost (equation 5) (Arnason 2006). To find the change of rent between periods, we need to multiply current rent with discount rate using an interest rate of 10%. The value of rent shows a similar value in baseline condition and moratorium in the beginning of the period but rent increases by 34.09% as the moratorium policy was applied Figure 6.

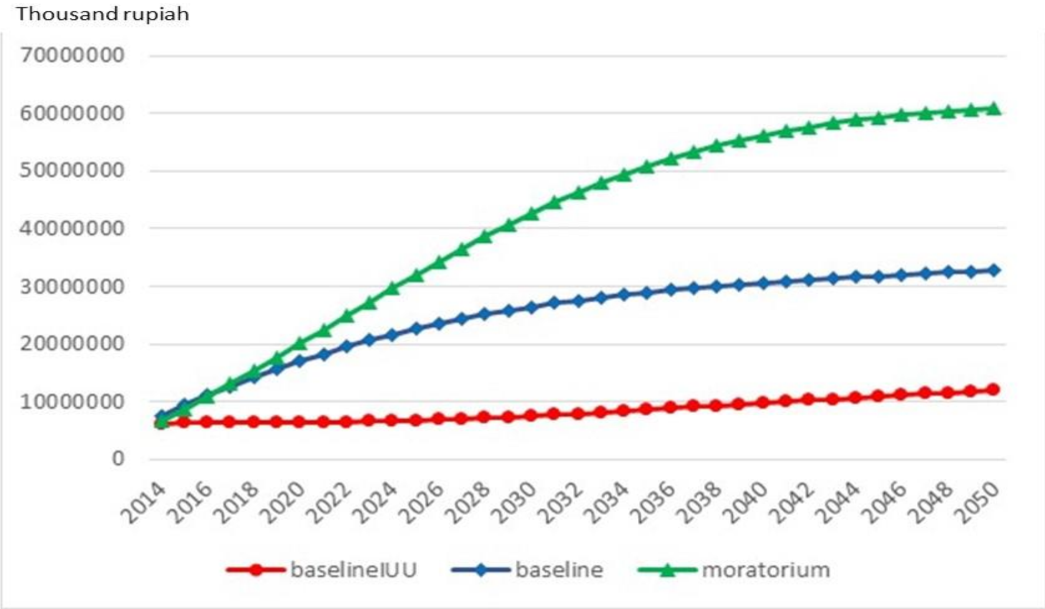

Figure 6. Rent of demersal fisheries in Arafura Sea.

The increase of rent is possible as price rises, which causes increase of income. However, cost, which is a subtracting factor of rent, decreases. Therefore, it can be concluded that rent of demersal fishing increases due to the foreign vessel moratorium policy in the Arafura Sea. The amount of rent attained by the vessel owner and crew show the level of prosperity of people in the fishing industry. In this research, the portion of rent received by owners are assumed to be 40% of the total rent and the rest is given to the crew in the form of dividends, salary, bonus, consumption money, and other beneficial means. Crews are not differentiated between tasks and functions in fishing efforts.

Conclusions. The moratorium policy which regulates fishing vessels and reduces trawl vessels with 614 units in WPP 718 is potentially improving biomass by 31.57%. However, fishing efforts experience a decrease by 22.75% per year. The same is the situation in the case for production rate, which decrease by an average of 18.41% per year. Although there is less production, fishing rent increases by 34.09% as the moratorium policy was applied. The policy has preserved fisheries resources but, it has not provided maximum rent for the community. Therefore another policy is needed to utilize fisheries resources optimally and sustainably.

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