Forecasting potential fishing areas in fisheries management area 718 (FMA-718) in Indonesia using GIS and Monte Carlo Simulation

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Abstract. Fisheries Management Area - State of the Republic of Indonesia 718 or abbreviated FMA-RoI 718 has a very large fishery potential, namely 13% of the national fishery potential. The most dominant fisheries potential in Fisheries Management Area 718 (FMA 718) are squid, tuna, mackerel and shrimp. Problems of the local fishermen on FMA-RoI 718 are the lack of the information related to the Fish Catching Potential Zone (FCPZ) and fish movement predictions on FMA 718, resulting in reduced efficiency and productivity of fishing. This research has succeeded in combining the Monte Carlo method and the Geographic Information System (GIS), the Monte Carlo simulation is used to predict the potential and movement of squid, tuna, mackerel and shrimp, GIS is used to present the forecasting results into a potential fishing zone map in FMA-RoI 718. Data used to predict fish position data and fish potential in FMA-RoI 718 in 2013-2016 owned by TNI-AL. The prediction of potential squid is at position 9° 40" 20" S 138° 57" 33" E which is equal with 34%, the potential of mackerel is most likely to be at position 6° 51" 9" S 134° 6" 10" E which is 40%, the potential of tuna fish is most likely to be at position 5° 48" 0" S 133° 51" 53" E which is equal with 94%, the potential of shrimp is most probably at position 8° 0" 10" S 138° 15" 24" E which is equal with 38%. The results of this study can be used by local fishermen in FMA-RoI 718 to improve the efficiency and productivity of fish catches.
Key Words: FMA-RoI 718, remote sensing, spatial information, catch composition, prediction.

Introduction. Fisheries Management Area - State of the Republic of Indonesia 718 (FMA-RoI 718) covers the waters of the Aru Sea, Arafuru Sea and Timor Sea. The eastern part is one of the most productive commercial shrimp and fish catching areas in Indonesia. Shrimp commodities and other types of commercial fish have made FMA-RoI 718 a magnet for the development of fishing efforts since the last 4 decades. Estimation of the potential of fish resources in FMA-RoI 718 reaches 13% of the potential of national marine fish resources.

Based on the Decree of the Ministry of Marine and Fisheries and Affairs No. 45/2011 concerning the estimation of the potential of fish resources in the Republic of Indonesia Fisheries Management Area, the estimated potential of fish resources in FMA-RoI 718 is displayed in Table 1.

In Table 1, it can be seen that five fish resource groups dominate the waters of FMA-718: small pelagic fish of ±468,700 tons/year, commercial fish of ±284,700 tons/year, large pelagic fish of ±50,900 tons/year, shrimp penaeid of ±44,700 tons/year and squid of ±3,400 tons/year. The total potential of these five fish resource groups reaches 99% of the potential of all aquatic biota in FMA-RoI 718 (Decree of the Ministry of Marine and Fisheries and Affairs No. 45/2011).

Table 1

Estimation of potential fish resources in FMA 718

No	*Fish resource group*	*Potential (thousand tons/year)*
1	Big pelagic fish	50.9
2	Small pelagic fish	468.7
3	Demersal fish	284.7
4	Penaeid shrimp	44.7
5	Reef fish consumption	3.1
6	Lobster	0.1
7	Squid	3.4
	Total	855.6

Source: Decree of the Ministry of Marine and Fisheries and Affairs No. 45/2011.

The problems with the local fishermen on FMA-RoI 718 are due to the lack of information related to the Fish Catching Potential Zone (FCPZ) and fish movement predictions on FMA-RoI 718, which resulting in reduced efficiency and productivity of fishing. This study aims to make a map of the potential fishing zone (FCPZ) and the prediction of fish movement on FMA-RoI 718 based on the season in one year. This research will be useful for fishermen, fisheries companies and the government to obtain information on fisheries potential in FMA-RoI 718 and predict the movement of fish and the number of catches in one catchment period.

To solve this problem the method that will be developed in this research is a combination of the Geographic Information System (GIS) and Monte Carlo simulation. GIS is an information system that can combine graphic data (spatial) with text data (attributes) objects that are geographically connected on earth (georeference) (Syawaludin Alisyahbana Harahap 2012; Rosana et al 2014 a,b). The spatial data structure is divided into two, namely the raster data model and vector data model. Raster data is data that is stored in the form of a rectangular (grid)/cell box so that a regular space is formed. Vector data is data recorded in the form of point coordinates that display, place and store spatial data using points, lines or areas (polygons). Monte Carlo simulation is a method to repeatedly evaluate a deterministic model using a set of random numbers as input. This simulation involves using random numbers to model the system, where time does not play a substantive role (static models) (Chen 1982; Estember & Maraña 2016; Reddy & Clinton 2016; Trimono et al 2017; Mirhosseini et al 2017). The map analysis is divided into four seasons, namely: Western Monsoon (MB), Transition Season 1 (P1), Eastern Monsoon (MT) and Transition Season 2 (P2). Monte Carlo simulations are used to predict fish movements in FMA-RoI 718 and predict the amount of fish catch in one period.

The research was carried out at FMA-RoI 718 which included the waters of the Aru Bay, Arafura Sea and the East Timor Sea. The type of data used in this study is primary and secondary data. Primary data is obtained by direct interviews with fishermen and government. Secondary data used are: (1) Hidros Sea Map, (2) Ocean Forecast System (OFS) Map, (3) PPDPI for MPA fishing areas as shown in Figure 1.

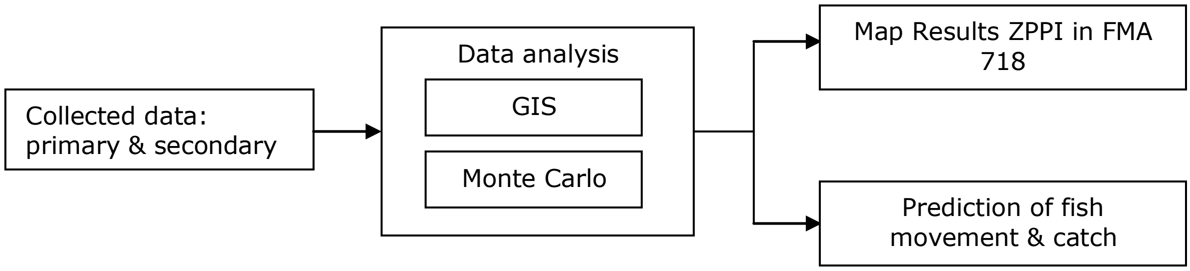

Figure 1. Block research diagram.

Figure 1 explains the stages of the research process, the first is the process of collecting primary and secondary data (fish potential data on FMA-RoI 718, fish catch data by type, flow data, wind data and forecast map data for fishing grounds). The second is to perform data analysis by creating a Geographic Information System (GIS) about the Potential Fishing Zone (FCPZ) based on 4 seasons. Third is to predict the movement of fish based on the season and the prediction of the number of catches. The final result of this study is the prediction of the movement of fish based on the season and the prediction of potential catch results as well as the FCPZ map on FMA-RoI 718 based on the season.

FMA-RoI 718. Based on the Regulation of the Ministry of Marine and Fisheries and Affairs No. 18/2014 concerning the Fisheries Management Areas of the Republic of Indonesia, FMA-RoI 718 covers the Aru Sea region, Arafuru Sea and the East Timor Sea (Regulation of the Ministry of Marine and Fisheries and Affairs No. 18/2014). The region is geographically bordered by the mainland of Papua and the Banda Sea to the north, and is directly bordered by three countries, namely Australia in the south, East Timor in the west, and Papua New Guinea in the east (Figure 2).

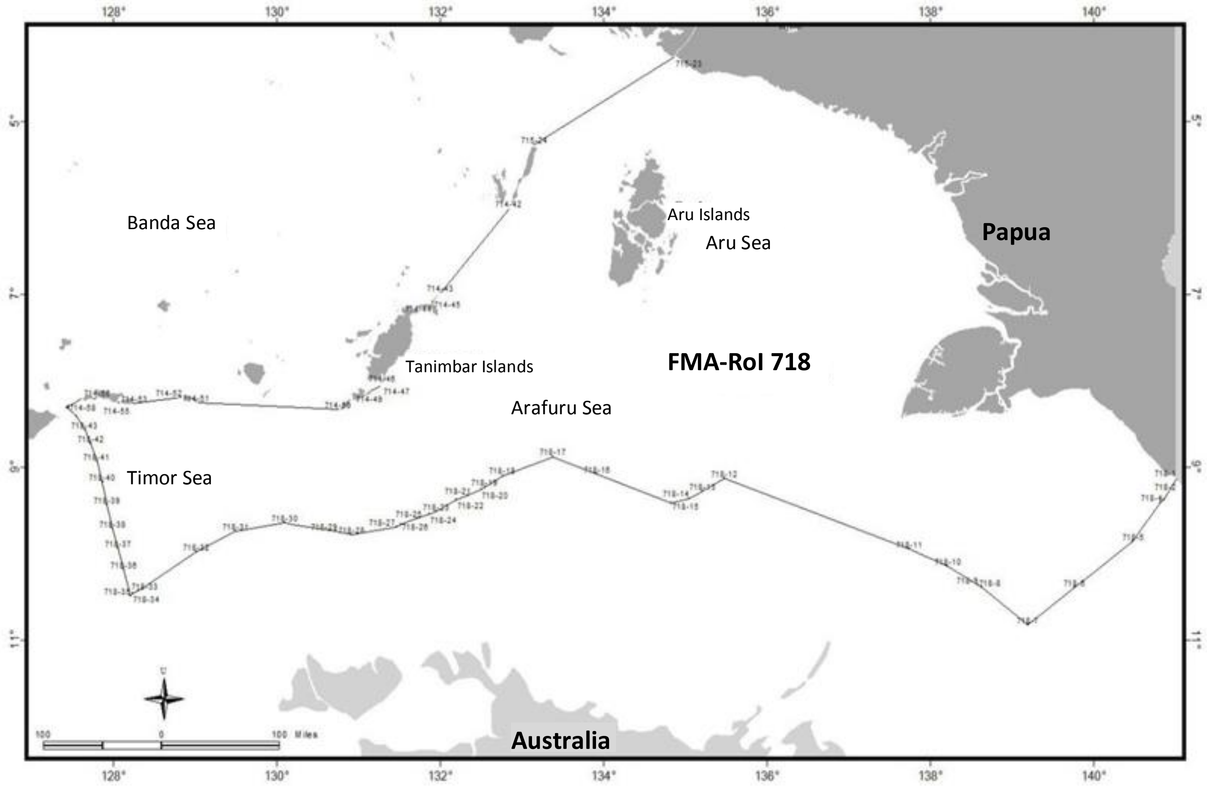

Figure 2. Areas of Aru Marine Fisheries Management, Arafuru Sea and East Timor Sea (FMA-RoI 718).

Administratively, the Regional Government that has the authority and responsibility for managing fish resources in FMA-RoI 718 consists of three Provincial Governments, namely Papua, West Papua and Maluku, and eight regency/city governments, including Maluku Regency West Southeast, Southeast Maluku Regency, Southwest Maluku Regency, Merauke Regency, Mappi Regency, Asmat Regency, Mimika Regency and Aru Kepulauan Regency (Regulation of the Ministry of Marine and Fisheries and Affairs No. 18/2014).

Fisheries Management Area of the Republic of Indonesia has a very large fishery resource potential so studies and analyzes need to be conducted (Krisnafi et al 2017; Hozairi & Krisnafi 2018). Based on the status of the utilization of fish resources in FMA-RoI, including in FMA-RoI 718 still refers to the Decree of the Ministry of Marine Fisheries and Affairs No. 45/2011 concerning Estimation of the Potential of Fish Resources in the Republic of Indonesia Fisheries Management Area (Regulation of the Ministry of Marine and Fisheries and Affairs No. 18/2014), as shown in Table 2.

Table 2

Status of fish resource utilization on FMA 718

No	*Fish resource group*	*Status*	*Explanation*
1	SHRIMP	F	Fully-exploited
2	DEMERSAL	O	Over-exploited
	Mackerel Fish	O	Over-exploited
	Threadfin Bream	O	Over-exploited
	Sulphur Goatfish	O	Over-exploited
	Purplespot Bigeye	O	Over-exploited
	Greater Lizardfish	O	Over-exploited
	Largefin Croaker	O	Over-exploited
	Red Snapper	O	Over-exploited
	Sole	F	Fully-exploited
3	SMALL PELAGIC	M	Moderate-exploited

In Table 2 it can be seen that the level of utilization of fish resources in FMA-RoI 718 is mostly in over-exploited status, except fully-exploited and small (moderate-exploited) pelagic fish. For demersal fish as a management target that has been over-exploited requires a reduction in fishing activities in order to restore the sustainability of fish resources and the environment. Whereas for small pelagic fish the level of utilization can still be increased, but with regard to the sustainability of fish resources and the environment. In contrast to shrimp, arrangements are needed in order to maintain utilization.

Monte Carlo simulation. Monte Carlo simulation is also known as the Sampling Simulation or Monte Carlo Sampling Technique. This simulation illustrates the possibility of using sample data in the Monte Carlo method which distribution can also be known or estimated (Estember & Maraña 2016; Trimono et al 2017). This simulation uses existing data (historical data) that is actually used for other purposes. In other words, if you want a simulation model that includes random and sampling with a probability distribution that can be known and determined, then this simulation method can be used. Monte Carlo simulation is a numerical computation method that involves taking experimental samples with random numbers. This method is quite easy to apply with a computer. This method is described as a statistical experimental method, because in its implementation involves elements of statistical calculations, such as the form of distribution, probability, variance, and standard deviation.

Monte Carlo simulations are often used to make decision analysis in situations involving risks that involve several parameters for simultaneous consideration (Han 2018; Wang et al 2018). This method can be used widely because it is based on a simulation process with a random selection of possibilities. Thus the number of iterations performed is very determining the level of accuracy of the answers obtained. This method is often referred to as the method of stastical trials. This method assumes the pattern of occurrence of the calculation variables in two distribution models, namely normal distribution and uniform distribution. This assumption can weaken a case that has a distribution pattern outside of these two assumptions. However, by doing statistical manipulation, by transforming raw data on variables to be changed so that they meet the two assumptions of distribution in a simple way.

Thus the decision maker must pay attention before using this method, namely to test the distribution of the calculation variables that will be used to meet the required distribution assumptions and then perform calculations based on the existing procedures. This method is based on simple calculations and can be adapted to a computer. The stages of the Monte Carlo simulation model process can be seen in Figure 3.

Based on Figure 3, the stages of the Monte Carlo simulation process can be explained as follows:

1. Formulation of the problem, in this stage the problem will be discussed and determined the boundaries of the problem.

2. Making a Monte Carlo simulation model, in this stage we create a model and determine the model parameters, variables, relationships between parts of the model.
3. Making distributions for variables, in this stage we determine the probability distribution for the main variables.
4. Change the probability distribution to be a cumulative probability. After determining the next probability distribution is to convert it to a cumulative probability distribution.
5. Simulate the model. Perform simulations and analyzes for a large number of observations. The number of replications that correspond in the same way to the exact number of samples in the actual experiment.
6. Evaluate the model strategy. At this stage we evaluate the model whether it resembles a real system.
7. Check whether there is a need to repair the model.
8. Decision. Decisions are taken if the model is in accordance with the real system.

Monte Carlo simulation is an attempt to predict the future many times. At the end of the simulation, thousands or millions of "random experiments" produce a distribution of results that can be analyzed. In the Geometric Brown Motion (GBM) model uses Markov calculation technical processes. This means that the position of the fish and the amount of potential fish follow a random and consistent path, a form of the hypothesis of the prediction of fishing zones in FMA-RoI 718. Information on the position of fish and the amount of potential fish have been included in "independent conditional" from the past, the movement of fish position and number of fish potential.

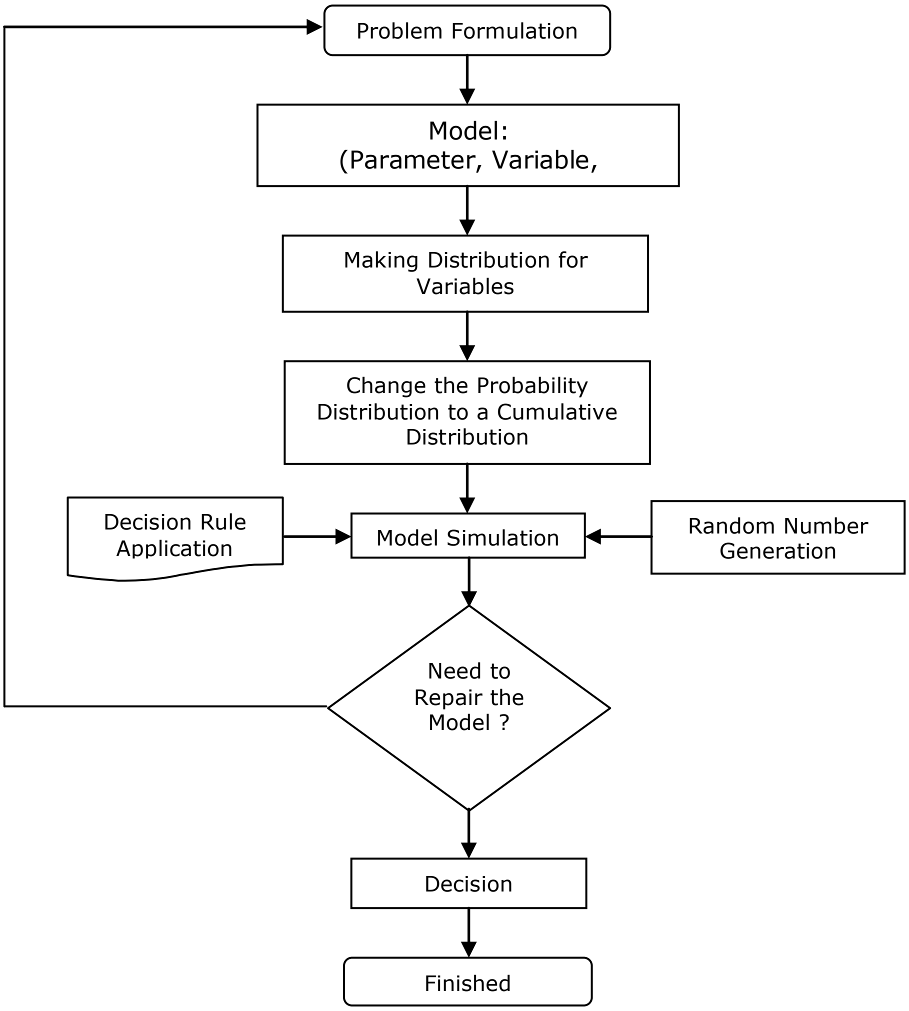

Figure 3. Stages of completion of the Monte Carlo simulation model.

Using a discrete time assumption, the proportion of fish position and the potential amount of fish can be represented by the following equation:

$$\frac{\Delta S}{S} = \mu\Delta t + \sigma\varepsilon\sqrt{\Delta t} \quad (1)$$

So that changes in stock prices are obtained as follows:

$$\Delta S = \mu S\Delta t + \sigma S\varepsilon\sqrt{\Delta t} \quad (2)$$

Wherein:

S = Fish position & Fish catch potential

ε = Random numbers generated from normal default

Δt = Step time review

Based on the research stages that have been designed, then compile an algorithm of Monte Carlo simulations in estimating the movement of fish position and the potential yields of the catches (squid, mackerel, tuna and shrimp) as follows:

1. Calculate Expected Return ($\boldsymbol{\mu}$) and volatility ($\boldsymbol{\sigma}$)

   Input:
   - Historical data on fish position and catch potential (P)
   - Time step (Δt) = 1/T

   Output:
   - Expectation Value (μ)
   - Volatility Value (σ)

   Process:
   - Define the formulation of fish position in time t every day:

     $$\mu_i = \ln\frac{S_{i+1}}{S_i}; i = 1,2,\dots,n \quad (3)$$

     Wherein:

     μ_i = Position of fish results at time

     $\frac{S_{i+1}}{S_i}$ = Movement ratio of fish at time i + l to time (i) without dividends.

     i = daily time
   - Determining the mean ui that is $\bar{u} = mean\ (ui)$ in this case equals the value $E\ (R)$
   - Determine the standard deviation of ui that is $s = std\ (ui)$
   - Or manually formulated with:

     $$s = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(u_i - \bar{u})^2} \quad (4)$$

   - Determine volatility σ that is by formula $\sigma = \frac{s}{\sqrt{\Delta t}}$
   - Determining Expectation Value with $\frac{\bar{u}}{\Delta t} + \frac{\sigma^2}{2}$

1. Perform a Monte Carlo simulation to predict the position of fish (squid, mackerel, tuna and shrimp) with 100 iterations.

   After obtaining the value of Expected Return (μ) and volatility (σ) from the Pos-Geo data. Furthermore, it determines changes in fish movements and fish catches in each zone in each period.

   Input :
   - Expectation Value (μ) = 0.01
   - Volatility Value (σ) = 0,01
   - Longitude (S_1) = 5° 25" 25" South Latitude

- Longitude Value (S_2) = 136° 55" 25" East Longitude
- Catch value potential (S_3) = 5 tons
- Step time (Δt) = 1/100

Output:
- Change in fish position (ΔP_0)formulated by: $\Delta P^k = \mu P^k \Delta t + \sigma P^k \varepsilon^k \sqrt{\Delta t}$
- Fish position every period $S^{k+1} = S^k + \Delta S^k$

Process:
- Generates normal random numbers randn (100.1) as many times as the experiment ε^k; k = 1,2,...,100
- Calculate the movement of fish positions that have been formulated with

$$\Delta P^k = \mu P^k \Delta t + \sigma P^k \varepsilon^k \sqrt{\Delta t}$$

- Perform the calculation of the new fish movement (k+1) based on the previous position S^k plus changes in the position of the fish ΔS^k obtained, formulated with $S^{k+1} = S^k + \Delta S^k$
- Analyze the movement of fish position and predict the potential of fish catches.

Geographic Information Systems (GIS). Geographical Information System (GIS) is a computer-based spatial information system that has a basic function to store, manipulate, and present all forms of spatial information (Rosana et al 2014 a,b). GIS is also an information management tool that occurs on earth and spatial references. GIS is not just a computer system for map making, but also an analytical tool. The advantage of the analysis tool is that it provides the possibility to identify spatial relationships between feature geographic data in the form of maps. In compiling a GIS there are several stages, namely: entering data, data management, data manipulation and analysis, data output, and data usage.

Fisheries management area 718 is divided into 3 territorial waters, namely, Aru Sea Waters (132.5° - 138.4° East and 4.6° - 7.5° South), Arafura Sea (127.7° - 131.5° East and 8.5° - 10.2° South) and Timor Sea eastern part (127.7° - 135.5° East and 8.5° - 10.2° South). Oceanographic data of FMA 718 from Hidros No.151 Papua map and 66 geographic reference points from Permen KP No.18/PERMEN-KP/2014 and represented in FMA 718 application, in the form of thematic maps in Figure 4.

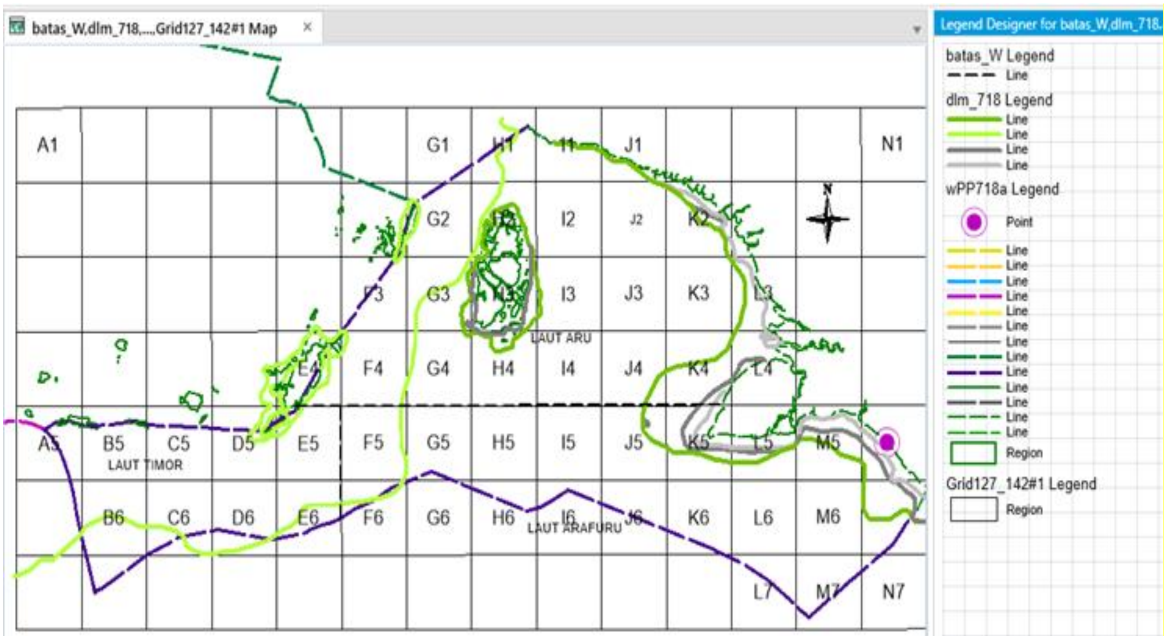

Figure 4. Thematic map of the application of FMA-RoI 718.

The results of the attributes of the thematic map consist of several criteria, namely the depth of the waters, the width of the waters, the geographic position (latitude and longitude), the contour of the waters and the depth record of the waters.

Results. This study began by analyzing DISHIDROS Cartographic Map data, Flow Map (BMKG), Fishing Potential Area Map (MMA), fishing operations (Indonesian Navy - KRI). The following is presented the results of a map analysis of fishing zones based on the western monsoon, eastern monsoon, transition season-1 and transition season-2.

Geographic Information System results. During the western monsoon of 2016, there were 183 fishing grounds. The spread of fishing areas is only found in the Aru Sea and Arafura Sea. The Aru Sea Region is the most fishing area, which is 118 points. While the Arafura Sea only has 65 fishing grounds. The results of recording the western monsoon map during 2013-2016. The fishing area of the Aru Sea waters lies in the zone (I1, H2, I2, J2, F3, J3, H4, I4). The Arafura Sea is located in the fishing area in the zone (I5, J5, N5, M6, N6, M7). In Figure 5 is presented a map of the western monsoon flow in FMA-RoI 718.

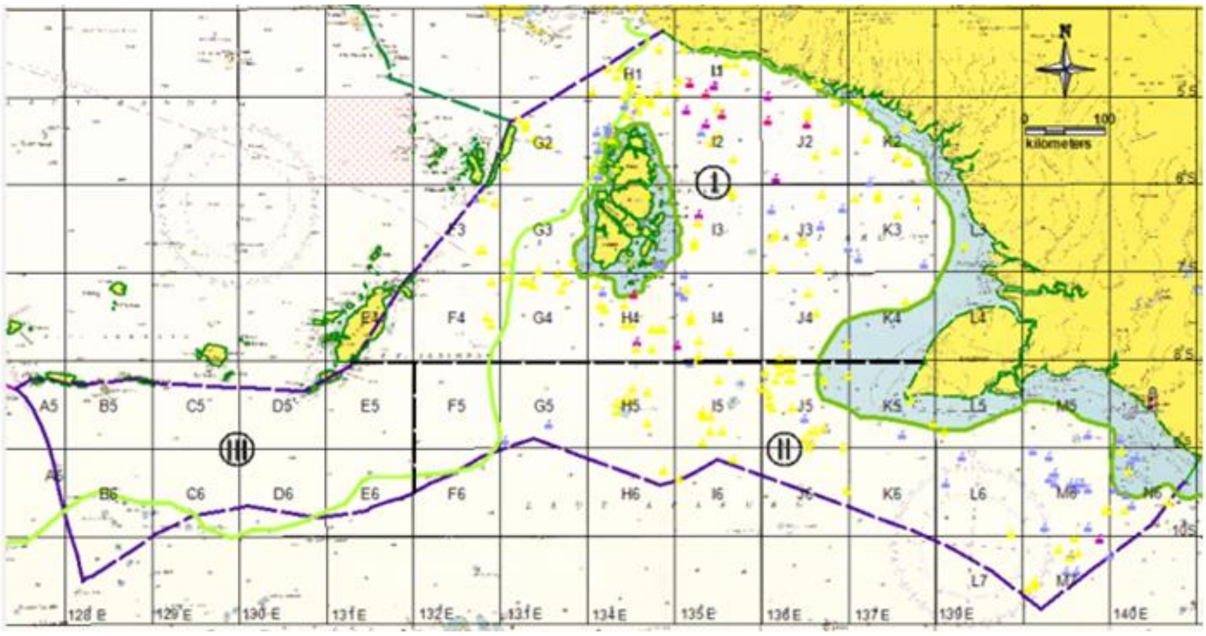

Figure 5. Distribution of fishing zones during the Western Monsoon (December, January, February).

In 2016 in the Transition Season 1 there were 153 fishing grounds. Overall spread evenly in the Aru Sea and Arafura Sea. The Aru Sea has the most fishing locations, namely, 93 points. While the Arafura Sea only has 60 fishing grounds. Between 2013 and 2016 the recording of maps in the Pancaroba-1 season, fishing areas in the Aru Sea waters were located in zones (G2, H2, I2, J2, K2, I3, K3, L3, I4). A good Arafura Sea fishing area is in the zone (I5, J5, J6, K6, L6, M6). In Figure 6 a map of the Pancaroba season flows is presented on FMA-RoI 718.

In 2016 during the eastern monsoon, there were 57 fishing grounds. The location of the arrests is evenly distributed in FMA-RoI 718. Laut Aru fishing areas contribute many fishing locations, namely 44 points. Then followed by the Arafura Sea, there are 8 fishing grounds. But on the Timor Sea there are only 5 fishing grounds. Fishing areas throughout 2013-2016 in the Aru Sea lie in zones (H1, I1, G2, I2, J2, G3, I3, G4, H4, I4, J4). A good Arafuru Sea fishing area is in the H5 zone. In the Timor Sea, a good fishing area is in the zone (B6, C6, D6). In Figure 7 is presented a map of the eastern monsoon flow in FMA-RoI 718.

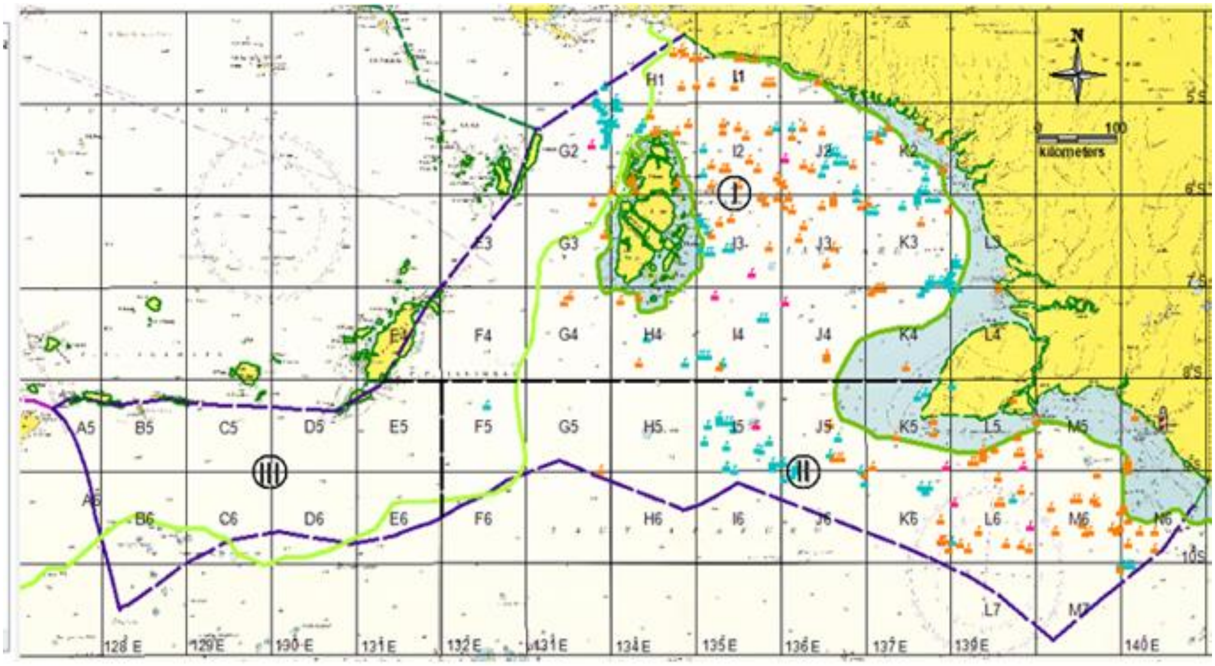

Figure 6. Distribution of fishing zones in the Transition Season 1 (March, April, May).

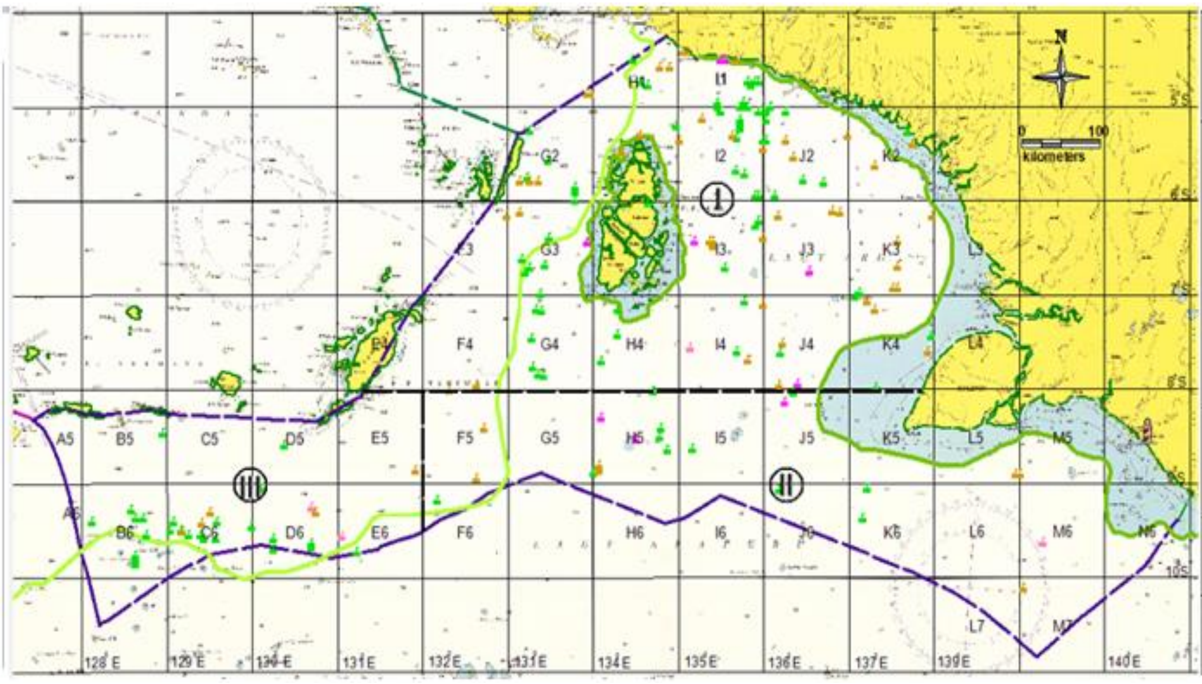

Figure 7. Distribution of fishing zones during the Eestern Monsoon (June, July, August).

Mapping of fishing season 2 in 2016 there were 38 fishing grounds. Fishing locations are spread throughout the Fisheries Management Area (FMA) 718. Aru Sea contains 18 fishing grounds. The Arafura Sea is also like the Aru Sea, where there are 18 fishing grounds. While the Timor Sea only has 2 fishing grounds. In transition season 2, fishing areas in the Aru Sea are located in zones (G2, J2, G3, H4, I4) and are best in the zone (G3). The fishing area in the Arafuru Sea is located in zone (H5). The fishing area in the Timor Sea is located in zone (B6). In Figure 8 a map of the Transition Season 2 flow is presented in FMA-RoI 718.

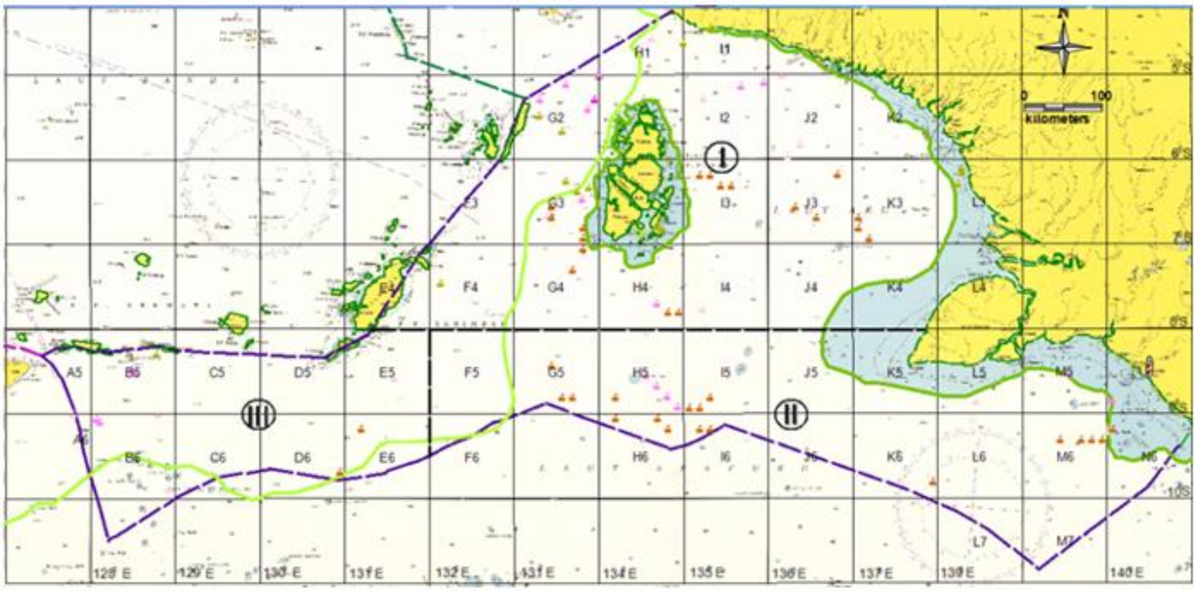

Figure 8. Distribution of fishing zones in the Transition Season 2 (September, October, November).

Monte Carlo results. The data used in this Monte Carlo simulation is the data of Geographic Position and data on the number of catches (squid, mackerel, tuna and shrimp) in each zone in FMA-RoI 718. The following are the results of the Monte Carlo simulation to predict fish position and prediction of potential fish catch.

Squid position simulation results. Before performing a simulation, the first stage must determine the Expected Return (μ) and volatility (σ) values from the Pos-Geo data. Furthermore, it determines changes in fish movements based on the position of the previous squid fish in FMA-RoI 718 by setting the position of South Latitude (S) and East Longitude (E) (Table 3).

Input:

Table 3

Parameters of Monte Carlo simulation

Variable	*Model parameters*		
	μ	*σ*	*N*
S	0.01	0.1	100
E	0.01	0.1	100
Potency	0.01	0.1	100

Based on the post-geo squid data in Table 4 especially in lines 3, 8, 14, 19 and 22, the data should be read as follows:

- Line 3 = 5^{0} 35$''$ 15$''$ S 133^{0} 45$''$ 15$''$ E; Catch Potential Results = 13 Tons
- Line 8 = 6^{0} 35$''$ 15$''$ S 134^{0} 45$''$ 15$''$ E; Catch Potential Results = 52 Tons
- Line 14 = 7^{0} 45$''$ 20$''$ S 138^{0} 55$''$ 20$''$ E; Catch Potential Results = 96 Tons
- Line 19 = 8^{0} 45$''$ 20$''$ S 139^{0} 55$''$ 20$''$ E; Catch Potential Results = 120 Tons
- Line 22 = 9^{0} 15$''$ 10$''$ S 140^{0} 35$''$ 10$''$ E; Catch Potential Results = 122 Tons

Geo-Post Data Squid:

Table 4

Geo-Post squid data in FMA 718

No	*South latitude value (S)*			*East longitude value (E)*			*Squid*
	Degree	*Minute*	*Second*	*Degree*	*Minute*	*Second*	*Tons*
1	5	5	5	133	5	5	4
2	5	15	10	133	15	10	12
3	5	35	15	133	35	15	13
4	5	45	20	133	45	20	14
5	5	55	25	133	55	25	15
6	6	5	5	134	5	5	29
7	6	15	10	134	15	10	35
8	6	35	15	134	35	15	52
9	6	45	20	134	45	20	115
10	6	55	25	134	55	25	120
11	7	5	5	138	5	5	65
12	7	15	10	138	15	10	75
13	7	35	15	138	35	15	86
14	7	45	20	138	45	20	96
15	7	55	25	138	55	25	138
16	8	5	5	139	5	5	38
17	8	15	10	139	15	10	55
18	8	35	15	139	35	15	87
19	8	45	20	139	45	20	120
20	8	55	25	139	55	25	140
21	9	5	5	140	5	5	58
22	9	15	10	140	15	10	122
23	9	35	15	140	35	15	138
24	9	45	20	140	45	20	148
25	9	55	25	140	55	25	171

Source: Indonesian Navy 2016.

With the Monte Carlo simulation, each processed data will be randomized 100 times per period. The results of the Monte Carlo simulation recapitulation can be seen in Table 5.

Based on the results of the Monte Carlo simulation in Figure 9 and Table 5, the predicted potential and squid position can be detailed as follows:

- Squid position prediction at 5^0 59˝ 46˝ S 134^0 3˝ 24˝ E has a potential of 3% or equivalent to 14 tons.
- Squid position prediction at 6^0 58˝ 23˝ S 135^0 20˝ 10˝ E has a potential of 13% or equivalent to 53 tons.
- Squid position prediction at 8^0 25˝ 28˝ S 139^0 9˝ 51˝ E has a potential of 22% or equivalent to 96 tons.
- Squid position prediction at 9^0 40˝ 20˝ S 138^0 57˝ 33˝ E has a potential of 28% or equivalent to 121 tons.
- Squid position prediction at 9^0 18˝ 58˝ S 141^0 0˝ 46˝ E has a potential of 34% or equivalent to 123 tons.

This means that the prediction of position and potential of squid in FMA-718 is mostly at position 9^0 40˝ 20˝ S 138^0 57˝ 33˝ E with squid potential of 121 tons and position 9^0 18˝ 58˝ S 141^0 0˝ 46˝ E with potential squid of 123 tons.

Table 5

The simulation results of Monte Carlo position of squid fish in FMA 718

No	*Results of S forecasting*			*Results*	*Results of E forecasting*			*Results*	*Results*
	Degree	*Minute*	*Second*	*S*	*Degree*	*Minute*	*Second*	*E*	*Tons*
1	5	35	0	5.35	133	45	32	133	5
2	5	38	56	5.38	134	4	23	134	12
3	5	59	46	5.59	134	3	24	134	14
4	6	12	46	6.12	133	43	17	133	15
5	6	4	42	6.40	134	3	38	134	15
6	6	43	2	6.43	134	40	53	134	29
7	7	20	14	7.20	134	44	25	134	35
8	6	58	23	6.58	135	20	10	135	53
9	7	1	26	7.10	134	45	40	134	116
10	7	28	26	7.28	135	25	40	135	121
11	8	4	41	8.40	138	45	52	138	65
12	7	31	32	7.31	138	47	59	138	76
13	7	55	15	7.55	138	15	59	138	86
14	8	25	28	8.25	139	9	51	139	96
15	8	58	9	8.58	139	43	53	139	138
16	8	26	15	8.26	140	17	56	140	39
17	8	53	16	8.53	140	16	6	140	56
18	8	45	21	8.45	140	23	9	140	87
19	9	40	20	8.40	138	57	33	138	121
20	9	47	24	8.47	140	12	38	140	140
21	10	25	51	10.25	141	27	38	141	58
22	9	18	58	9.18	141	0	46	141	123
23	10	6	15	10.60	141	40	2	141	138
24	10	13	42	10.13	141	11	10	141	148
25	9	31	3	9.31	141	42	48	141	170

Source: Monte Carlo simulation.

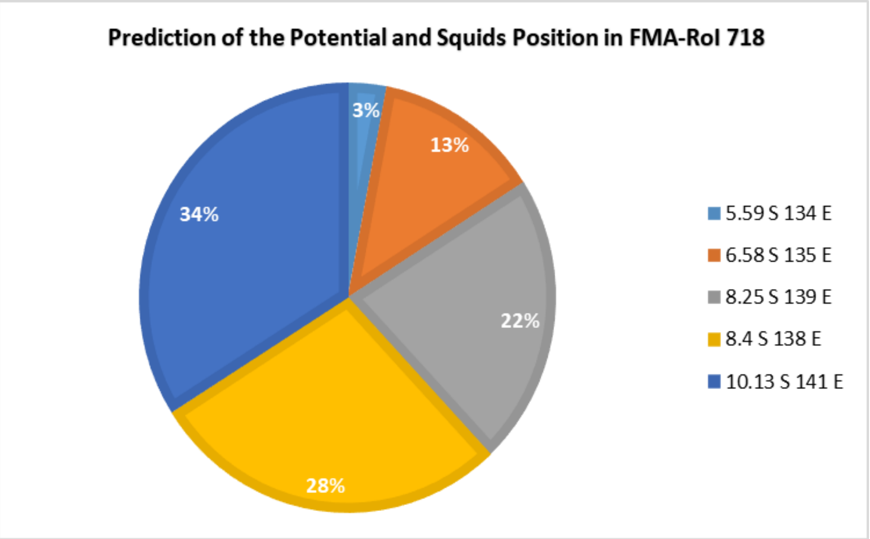

Figure 9. Squid fish potential forecasting in each FMA 718 zone.

Simulation results of mackerel fish position. To obtain simulation results of predictions of dead fish potential and prediction of dead fish position in each zone, the steps carried out are the same as the steps in Table 3, namely determining the Expected Return (μ) and volatility (σ) values of Pos-Geo data. The parameter values used are the same as Table 3.

Based on the pos-geo data of mackerel fish in Table 6 especially in lines 3, 8, 14 and 19, the data should be read as follows:

- Line 3 = 5^0 35″ 15″ S 133^0 45″ 15″ E; Catch Potential Results = 15 Tons
- Line 8 = 6^0 35″ 15″ S 133^0 35″ 15″ E; Catch Potential Results = 22 Tons
- Line 14 = 7^0 45″ 20″ S 134^0 45″ 20″ E; Catch Potential Results = 10 Tons
- Line 19 = 8^0 45″ 20″ S 130^0 45″ 20″ E; Catch Potential Results = 5 Tons

Post-Geo Fish Mackerel Data:

Table 6

Post-Geo mackerel data in FMA-718

No	*South latitude value (S)*			*East longitude value (E)*			*Mackerel*
	Degree	*Minute*	*Second*	*Degree*	*Minute*	*Second*	*Tons*
1	5	5	5	136	5	5	12
2	5	15	10	136	15	10	14
3	5	35	15	136	35	15	15
4	5	45	20	136	45	20	16
5	5	55	25	136	55	25	17
6	6	5	5	133	5	5	19
7	6	15	10	133	15	10	20
8	6	35	15	133	35	15	22
9	6	45	20	133	45	20	24
10	6	55	25	133	55	25	25
11	7	5	5	134	5	5	6
12	7	15	10	134	15	10	7
13	7	35	15	134	35	15	9
14	7	45	20	134	45	20	10
15	7	55	25	134	55	25	12
16	9	5	5	130	5	5	3
17	9	15	10	130	15	10	3
18	9	35	15	130	35	15	5
19	9	45	20	130	45	20	5
20	9	55	25	130	55	25	7

Source: Indonesian Navy 2016.

By means of Monte Carlo simulation, each processed data will be randomized 100 times per period. The results of the simulation recapitulation of Monte Carlo mackerel can be seen in Table 7.

Based on the results of the Monte Carlo simulation in Figure 10 and Table 7, the prediction of the potential and position of mackerel fish can be detailed as follows:

- Prediction of the position of mackerel at 5^0 48″ 0″ S 136^0 51″ 53″ E has the potential of 26% or the equivalent of 16 tons.
- Prediction of the position of mackerel at 6^0 51″ 9″ S 134^0 6″ 10″ E has the potential of 40% or the equivalent of 24 tons.
- Prediction of the position of mackerel at 7^0 37″ 8″ S 135^0 15″ 42″ E has the potential of 21% or the equivalent of 13 tons.
- Prediction of the position of mackerel at 9^0 57″ 43″ SL 131^0 51″ 58″ E has the potential of 13% or the equivalent of 8 tons.

This means that the prediction of the position and potential of mackerel fish in FMA-718 is mostly at position 6^0 51″ 9″ S 134^0 6″ 10″ E with the potential of mackerel fish at 24 tons and position 5^0 48″ 0″ S 136^0 51″ 53″ E with the potential of mackerel fish of 16 tons.

Table 7

The simulation results of Monte Carlo position of mackerels in FMA 718

No	*Results of S forecasting*			*Results*	*Results of E forecasting*			*Results*	*Results*
	Degree	*Minute*	*Second*	*S*	*Degree*	*Minute*	*Second*	*E*	*Tons*
1	6	0	36	6	137	26	8	137.26	13
2	5	20	39	5.2	136	37	42	136.37	14
3	5	48	0	5.48	136	51	53	136.51	16
4	5	53	59	5.53	137	2	13	137.20	18
5	5	42	18	5.42	137	21	30	137.21	20
6	6	41	38	6.41	133	59	44	133.59	21
7	6	27	25	6.27	133	30	52	133.30	22
8	6	51	9	6.51	134	6	10	134.60	24
9	7	13	42	7.13	133	59	46	133.59	25
10	6	40	26	6.40	134	12	13	134.12	6
11	7	49	5	7.49	133	59	38	133.59	7
12	7	52	53	7.52	133	55	24	133.55	10
13	7	43	52	7.43	134	52	34	134.52	11
14	7	37	8	7.37	135	15	42	135.15	13
15	7	28	4	7.28	135	30	6	135.30	4
16	9	58	39	9.58	130	37	28	130.37	3
17	9	36	36	9.36	130	7	5	130.70	5
18	9	33	42	9.33	130	53	22	130.53	6
19	9	57	43	9.57	131	51	58	131.51	8
20	9	59	8	9.59	131	30	44	131.30	8

Source: Monte Carlo Simulation.

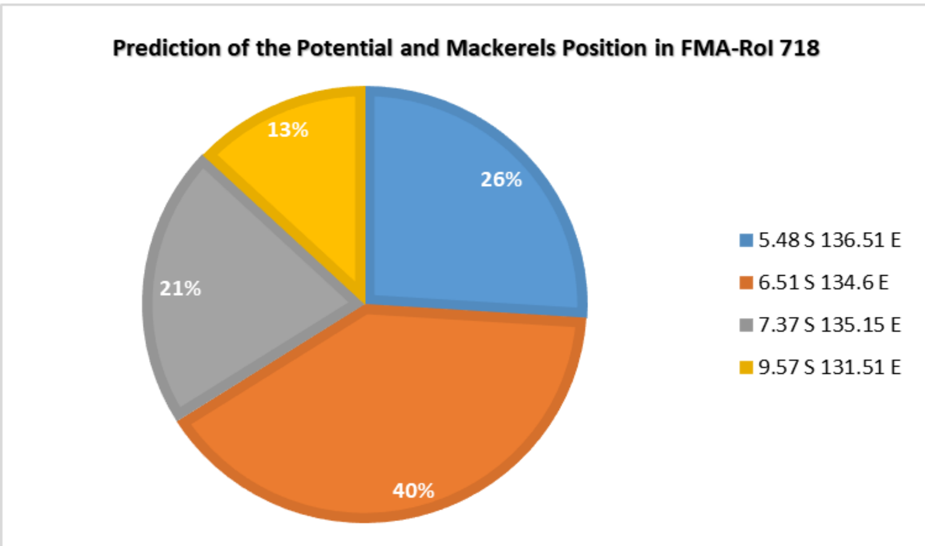

Figure 10. Mackerel potential forecasting in each FMA-718 zone.

Tuna fish position simulation results: To obtain the simulation results of prediction of tuna fish position and prediction of tuna fish potential in each zone, the steps taken are the same as the steps in Table 3, namely determining the Expected Return (μ) and volatility (σ) values of Pos-Geo data. The parameter values used are the same as presented in Table 3.

Based on the tuna pos-geo data in Table 8 especially in lines 3, 8, 14 and 19, the data should be read as follows:

- Line 3 = 5^{0} 35˝ 15˝ S 133^{0} 35˝ 15˝ E; Catch Potential Results = 160 Tons
- Line 8 = 6^{0} 35˝ 15˝ S 132^{0} 35˝ 15˝ E; Catch Potential Results = 0.4 Tons
- Line 14 = 7^{0} 45˝ 20˝ S 134^{0} 45˝ 20˝ E; Catch Potential Results = 5 Tons
- Line 19 = 9^{0} 45˝ 20˝ S 130^{0} 45˝ 20˝ E; Catch Potential Results = 3 Tons

Tuna Geo-Pos Data:

Table 8

Tuna Geo-Pos data in FMA-718

No	*South latitude value (S)*			*East longitude value (E)*			*Tuna*
	Degree	*Minute*	*Degree*	*Minute*	*Degree*	*Minute*	*Tons*
1	5	5	5	133	5	5	160
2	5	15	10	133	15	10	160
3	5	35	15	133	35	15	160
4	5	45	20	133	45	20	160
5	5	55	25	133	55	25	160
6	6	5	5	132	5	5	0.4
7	6	15	10	132	15	10	0.4
8	6	35	15	132	35	15	0.4
9	6	45	20	132	45	20	0.4
10	6	55	25	132	55	25	0.4
11	7	5	5	134	5	5	5
12	7	15	10	134	15	10	5
13	7	35	15	134	35	15	5
14	7	45	20	134	45	20	5
15	7	55	25	134	55	25	5
16	9	5	5	130	5	5	3
17	9	15	10	130	15	10	3
18	9	35	15	130	35	15	3
19	9	45	20	130	45	20	3
20	9	55	25	130	55	25	3

By means of Monte Carlo simulation, each processed data will be randomized 100 times per period. The recapitulation results of the Monte Carlo simulation of the tuna fish can be seen in Table 9.

Table 9

The Monte Carlo simulation results of tuna fish position in FMA-718

No	*Results of S forecasting*			*Results*	*Results of E forecasting*			*Results*	*Results*
	Degree	*Minute*	*Second*	*S*	*Degree*	*Minute*	*Second*	*E*	*Tons*
1	5	0	36	6	133	26	8	133.26	162
2	5	20	39	5.2	133	37	42	133.37	161
3	5	48	0	5.48	133	51	53	133.51	161
4	5	53	59	5.53	133	2	13	133.20	161
5	5	49	40	5.49	134	9	16	134.90	161
6	6	41	38	6.41	132	59	44	133.59	1
7	6	27	25	6.27	132	30	52	133.30	1
8	6	51	9	6.51	132	6	10	134.60	1
9	7	13	42	7.13	132	59	46	133.59	1
10	6	40	26	6.40	132	12	13	134.12	1
11	7	49	5	7.49	133	59	38	133.59	5
12	7	52	53	7.52	133	55	24	133.55	5
13	7	43	52	7.43	134	52	34	134.52	6
14	7	37	8	7.37	135	15	42	135.15	6
15	7	28	4	7.28	135	30	6	135.30	6
16	8	58	39	9.58	130	37	28	130.37	3
17	8	36	36	9.36	130	7	5	130.70	3
18	8	33	42	9.33	130	53	22	130.53	4
19	8	57	43	9.57	131	51	58	131.51	4
20	8	59	8	9.59	131	30	44	131.30	3

Source: Monte Carlo Simulation.

Based on the results of the Monte Carlo simulation in Figure 11 and Table 9, the prediction of the potential and position of tuna fish can be detailed as follows:

- Prediction of the position of tuna fish at 5^0 48˝ 0˝ S 136^0 51˝ 53˝ E has the potential of 94% or the equivalent of 161 tons.
- Prediction of the position of tuna fish at 6^0 51˝ 9˝ S 132^0 6˝ 10˝ E has the potential of 1% or the equivalent of 1 tons.
- Prediction of the position of tuna fish at 7^0 37˝ 8˝ S 135^0 15˝ 42˝ E has the potential of 3% or the equivalent of 6 tons.
- Prediction of the position of tuna fish at 8^0 57˝ 43˝ S 131^0 51˝ 58˝ E has the potential of 2% or the equivalent of 4 tons.

This means that the prediction of the position and potential of tuna fish in FMA-718 is mostly at position 5^0 48˝ 0˝ S 133^0 51˝ 53˝ E with the potential of tuna fish at 161 tons and position 7^0 37˝ 8˝ S 135^0 15˝ 42˝ E with the potential of tuna fish of 6 tons.

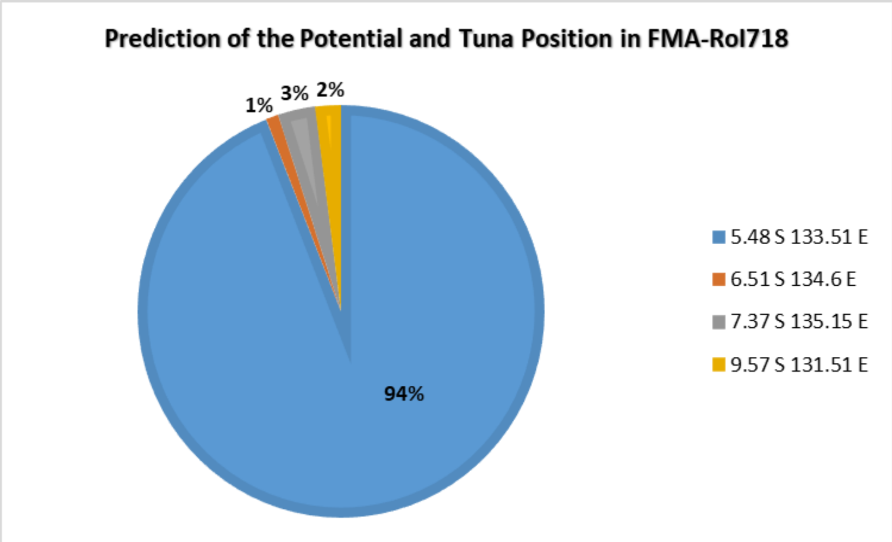

Figure 11. Tuna fish potential forecasting in each FMA-718 zone.

Simulation results of the potential and shrimp position. To obtain the simulation results of prediction of shrimp potential and shrimp position in each zone, the steps carried out are the same as the steps in Table 3, namely determining the Expected Return (μ) and volatility (σ) values from the Geo-Pos data. The parameter values used are the same as shown in Table 3.

Based on the tuna pos-geo data in Table 10 especially in lines 3, 8, 14 and 19, and 24 the data should be read as follows:

- Line 3 = 4^0 35˝ 15˝ S 136^0 35˝ 15˝ E; Catch Potential Results = 3 Tons
- Line 8 = 5^0 35˝ 15˝ S 135^0 35˝ 15˝ E; Catch Potential Results = 3 Tons
- Line 14 = 6^0 45˝ 20˝ S 135^0 45˝ 20˝ E; Catch Potential Results = 9 Tons
- Line 19 = 7^0 45˝ 20˝ S 138^0 45˝ 20˝ E; Catch Potential Results = 12 Tons
- Line 24 = 8^0 45˝ 20˝ S 139^0 45˝ 20˝ E; Catch Potential Results = 4 Tons

By means of Monte Carlo simulation, each processed data will be randomized 100 times per period. The results of the simulation recapitulation of monte carlo shrimp can be seen in Table 11.

Shrimp Pos-Geo Data:

Table 10

Shrimp Geo-Pos data in FMA-718

No	*South Latitude Value (S)*			*East Longitude Value (E)*			*Shrimp*
	Degree	*Minute*	*Second*	*Degree*	*Minute*	*Second*	*Tons*
1	4	5	5	136	5	5	2
2	4	15	10	136	15	10	3
3	4	35	15	136	35	15	3
4	4	45	20	136	45	20	3
5	4	55	25	136	55	25	4
6	5	5	5	135	5	5	1
7	5	15	10	135	15	10	3
8	5	35	15	135	35	15	3
9	5	45	20	135	45	20	5
10	5	55	25	135	55	25	5
11	6	5	5	135	5	5	5
12	6	15	10	135	15	10	7
13	6	35	15	135	35	15	8
14	6	45	20	135	45	20	9
15	6	55	25	135	55	25	10
16	7	5	5	138	5	5	7
17	7	15	10	138	15	10	9
18	7	35	15	138	35	15	10
19	7	45	20	138	45	20	12
20	7	55	25	138	55	25	14
21	8	5	5	139	5	5	2
22	8	15	10	139	15	10	3
23	8	35	15	139	35	15	3
24	8	45	20	139	45	20	4
25	8	55	25	139	55	25	5

Source: Indonesian Navy 2016.

Table 11

The Monte Carlo simulation results concerning shrimps position in FMA-718

No	*Results of S forecasting*			*Result*	*Results of E forecasting*			*Result*	*Result*
	Degree	*Minute*	*Second*	*S*	*Degree*	*Minute*	*Second*	*E*	*Tons*
1	4	28	57	4.28	136	53	29	136.53	3
2	4	40	51	4.40	136	28	13	136.28	4
3	5	5	11	5.50	136	47	19	136.47	5
4	5	3	51	5.30	137	22	25	137.22	5
5	5	17	41	5.17	137	14	29	137.14	7
6	5	34	6	5.34	136	3	34	136.30	2
7	5	41	27	5.41	135	36	51	135.36	4
8	5	54	18	5.54	135	43	1	135.43	3
9	6	5	39	6.50	136	9	19	136.90	6
10	5	49	24	5.49	136	23	30	136.23	6
11	6	19	21	6.19	136	18	53	136.18	6
12	6	56	55	6.59	135	42	44	135.42	7
13	6	53	28	6.53	135	59	37	135.59	9
14	6	50	4	6.50	136	15	24	136.15	9
15	6	47	2	6.47	135	55	59	135.55	11
16	7	23	58	7.23	138	42	28	138.42	8
17	7	30	51	7.30	138	53	21	138.53	9
18	7	43	49	7.43	138	44	4	138.44	11
19	8	0	10	8.00	138	15	44	138.15	13
20	7	58	11	7.58	138	35	45	138.35	15
21	8	31	51	8.31	139	57	11	139.57	2
22	9	24	5	9.24	139	22	27	139.22	4
23	9	11	22	9.11	140	0	7	140.00	4
24	8	53	24	8.53	140	23	36	140.23	4
25	8	33	36	8.33	140	37	34	140.37	6

Source: Monte Carlo simulation.

Based on the results of the monte carlo simulation in Figure 12 and Table 11, the prediction of the potential and position of the shrimp can be detailed as follows:

- Prediction of the position of shrimp at 5^0 5˝ 11˝ S 136^0 47˝ 19˝ E has the potential of 15% or the equivalent of 5 tons.
- Prediction of the position of shrimp at 5^0 54˝ 18˝ S 135^0 43˝ 1˝ E has the potential of 9% or the equivalent of 3 tons.
- Prediction of the position of shrimp at 6^0 50˝ 4˝ S 136^0 15˝ 24˝ E has the potential of 26% or the equivalent of 9 tons.
- Prediction of the position of shrimp at 8^0 0˝ 10˝ S 138^0 15˝ 24˝ E has the potential of 38% or the equivalent of 13 tons.
- Prediction of the position of shrimp at 8^0 53˝ 24˝ S 140^0 23˝ 36˝ E has the potential of 12% or the equivalent of 4 tons.

This means that the prediction of the position and potential of shrimp in FMA-718 is mostly at position 8^0 0˝ 10˝ S 138^0 15˝ 24˝ E with the potential of tuna fish at 13 tons and position 6^0 50˝ 4˝ S 136^0 15˝ 24˝ E with the potential of tuna fish of 9 tons.

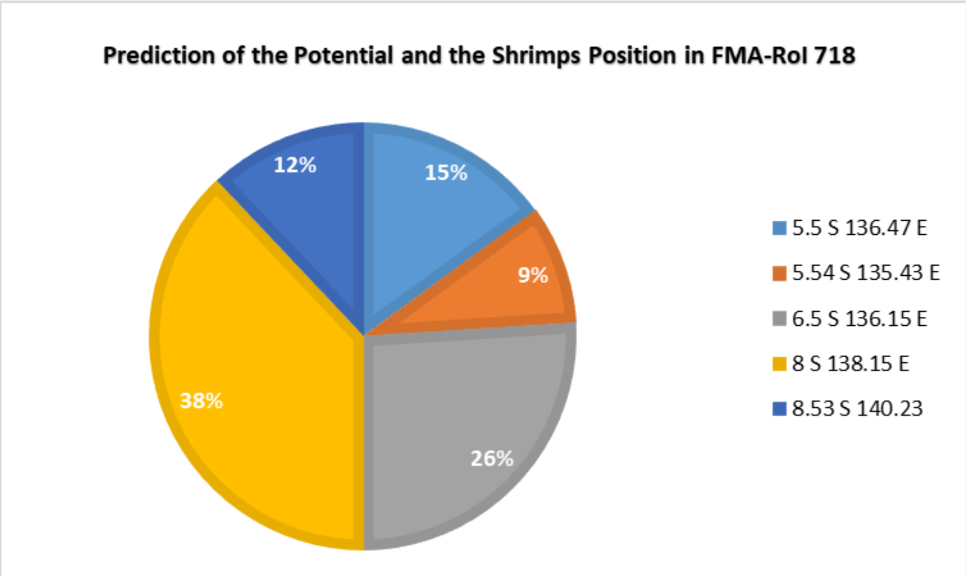

Figure 12. Shrimp potential forecasting in each FMA-718 zone.

Conclusions. This research has succeeded in combining the Monte Carlo method and the Geographic Information System. Monte Carlo methodis used to predict the potential and movement of squid, tuna, mackerel and shrimp, while GIS is used to present the results of forecasting into a potential fishing zone map on FMA-RoI 718. The data used to predict the fish position data and fish potential in FMA-RoI 718 in 2013-2016 owned by the Indonesian Navy. Results showed the highest squid potential prediction at 9° 40" 20" S 138° 57" 33" E which is 34%, the highest potential fish is located at position 6° 51" 9" S 134° 6" 10" E which is 40%, the highest potential of tuna fish is at position 5° 48" 0" S 133° 51" 53" E that is equal to 94%, the highest shrimp potential is at position 8° 0" 10" S 138° 15" 24" E that is equal to 38%.

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