Optimization of fisheries surveillance vessel deployment in Indonesia using genetic algorithm (Case study: Fisheries Management Area 711, Republic of Indonesia)

[1,2] Yaser Krisnafi, [2]Budhi Hascaryo Iskandar, [2]Sugeng Hari Wisudo, [2]John Haluan

[1] Department of Fishing Technology, Jakarta Fisheries University, Jakarta, Indonesia; [2] Department of Fishery Resource Utilization, Faculty of Fishery and Marine Science, Bogor Agriculture University, Bogor, Indonesia. Corresponding author: Y. Krisnafi, yaser_bunda@yahoo.com

Abstract. Fisheries surveillance, a top priority for the Ministry of Marine Affairs and Fisheries Republic of Indonesia, with limited amount of fisheries surveillance vessel and budget provided by the State, it is not easy to monitor the Fisheries Management Area Republic of Indonesia 711 (FMA-RI 711) at every time, so a mathematical system is needed to assist the decision-make process. Problems often faced of process decision making in the field of optimization multiple objectives, one of which is on the optimization of assignment fisheries surveillance vessel to each unit work in accordance with the specifications it have. Genetic algorithms (GA) is a searching algorithm based on works through natural and genetic selection mechanism, the basic elements of GA are: reproduction, crossover and mutation. Results from GA are not global optimum but are acceptable optimum. This study one chromosome contains ship type and work unit with objective function maximize coverage area and minimize operational cost. The optimum result Batam work unit only need 3 units of fisheries surveillance vessel with combination of type (D-E-D), has an over coverage area of 3% and a budget efficiency of 49% of provided cost. Pontianak work unit requires 3 units of fisheries surveillance vessel with combination of type (D-E-E), has an over coverage area of 4% and a budget efficiency of 50% of provided cost and Natuna work unit need 5 units of fisheries surveillance vessel with combination of type (E-D-D-D-C), has an over coverage area of 4% and a budget efficiency of 33% of provided cost.
Key Words: decision-make process, objectives, assignment of vessels, MFA-RI 711.

Introduction. Indonesia is the world's largest archipelagic country, with more than seventeen thousand islands. Currently, the country is ranked the second world fisheries production (391.931 tonnes) after China (843.626 tonnes). Fisheries sector contributes 3.25% (US$ 263 million) towards national GDP (FAO 2016; MMAF 2016).

To support the national policy on sustainable fisheries management, the Indonesian Ministry of Marine Affairs and Fisheries (MMAF) has designed 11 Fisheries Management Areas Republic of Indonesia (FMA-RI) covering all marine national waters (Figure 1) (MMAF 2009). To ensure the implementation of monitoring, controlling and surveillance program, Indonesian government is actually deploying 35 fisheries surveillance vessels (Table 1).

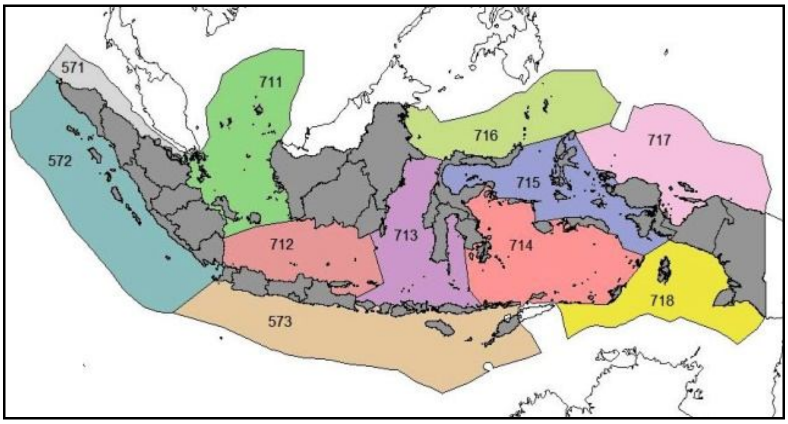

Figure 1. Map of Fisheries Management Area of Republic of Indonesia (FMA-RI).

Table 1

Data of fisheries surveillance vessels

No.	*Name vessel*	*Amount*	*Material*
1	KP Hiu Macan Tutul	2	Steel + Aluminum
2	KP Hiu Macan	4	Steel + Aluminum
3	KP Hiu Macan	2	Fiberglass
4	KP Hiu	5	Aluminum
5	KP Hiu	10	Fiberglass
6	KP Takalamongan	1	Fiberglass
7	KP Padaido	1	Fiberglass
8	KP Todak	2	Fiberglass
9	KP Baracuda	2	Fiberglass
10	KP Paus	1	Steel
11	KP Akar Bahar	1	Fiberglass
12	KP Orca	4	Steel

Since 2000s, Illegal, Unreported and Unregulated (IUU) fishing is considered as the most threats to Indonesian fisheries resources, causing an immense lost about US$ 7 million per year. Most IUU Fishing activities are believed to take place in 3 highest potential fisheries areas namely Arafura Sea, Sulawesi Sea and Natuna Sea (Southern most of South China Sea), the latter is highly prone to illegal fishing (DGMFRS 2015).

Natuna Sea and its adjacent waters belong to FMA-RI 711 covering 266.382 mi^2 and situated at the world's heavily sea traffic surrounded by five countries including Singapore, Malaysia, Philippines, Vietnam and Thailand.

The boat of patrol is a major component in maintaining the surveillance of sea. Without a patrol boat and relying solely on surveillance of air monitoring the waters of operation area, the impact is less effective. The presence of patrol boats is a major one as it will show the state law's sovereignty and control capability in the region (Munaf 2013). MMAF is currently employing 18 fisheries surveillance vessels for the western and 17 vessels for eastern regions. Regarding the complexity of the Indonesian waters (shallow, deep and open sea), government should allocate five different types of vessel (length, speed and endurance). However, no vessel is dedicated to each FMA.

Based on (Table 1), the government in this case is the Directorate General of Marine and Fisheries Resources Surveillance (DGMFRS) is required to be able to face challenges such as: optimizing vessel operating coverage area, minimizing operational costs, appropriateness of assignment, arranging vessel scheduling for each operation area (Al-Hamad et al 2012; Hozairi et al 2014). Scheduling is one of major matters of concern and research, as to allocate maximum resources efficiently is a rigid task to perform. Time table scheduling (TTS) is a category of scheduling in which the mission is to generate a formatted schedule for particular organization (Kanavade et al 2016).

Therefore, the problem of securing FMA 711 is not only in the form of single objective problem but also multi-objective problem.

The genetic algorithm (GA) is a search algorithm based on the mechanisms of natural selection and genetics. The genetic algorithm is one of most appropriate algorithms used for solving complex and difficult problem solving using conventional methods (Artana et al 2012; Santoso et al 2014). The nature of genetic algorithm is look for possible candidate solutions to find an optimal solution for problem solving. The solution sought in the genetic algorithm is the point (one or anymore) among the feasible solutions in the search space. GA is widely used of combination problem solving such as Travelling Salesman Problem (TSP), Vehicle Routing Problem (VRP), crew scheduling for airlines and control issues (Asim et al 2014; Chand & Mohanty 2013; Kornilakis & Stamatopoulos 2002). With certain procedures such as mutation, selection and crossover finally got the final solution of optimization problem faced. GA includes important findings in the field of optimization where an algorithm is created by mimicking the mechanism of evolution in the development of living organisms.

To analyze the needs of the number of vessel related to coverage area and operation cost, this study formulates a comprehensive optimization of fisheries surveillance vessel deployment based on GA.

Material and Method. The research was conducted in FMA-RI 711 at 11 stations/work unit of fisheries surveillance residing in the area. This research took place from March to November 2016. The data used are primary data and secondary data. Primary data in this research is survey result and interview with head station/work unit residing in FMA-RI 711. Secondary data come from report notes, scientific journals, books and information obtained from DGMFRS. The present study using multi-objective optimization and genetic algorithm as a method to solve the problem in finding the optimal combination of fisheries surveillance vessel to be assigned for each work unit in FMA-RI 711.

Multi-objective optimization. Multi-objective optimization is an optimization problem with multiple objective functions, among these objectives functions so highly likely to conflict. The goal of completion and regulation of multi-objective optimization is to find a solution for each optimized objectives and quantify how superior the solution is when compared to other solutions (Hicham et al 2015).

Mathematically, multi-objective optimization problems can be written as a way to find vectors $X = [x_1, x_2, \ldots, x_k]^T$ that will satisfy the following inequalities:

$$g_i(x) \geq 0,\ i = 1,2,3,\ldots\ldots m \qquad \ldots\ldots (1)$$

with constraints I an equation:

$$h_i(x) = 0,\ i = 1,2,3\ldots\ldots I \qquad \ldots\ldots (2)$$

and optimizing the following objective function vector:

$$F[x] = [f_1(x),\ f_2(x), \ldots\ldots f_N(x)]^T \qquad \ldots\ldots (3)$$

Genetic algorithms (GA). Genetic algorithm is an algorithm for searching based on workings through the mechanism of natural selection and genetics. The goal is to define the structures called high-quality individuals within a domain called population to find solutions for a problem. John Holland developed a genetic algorithm through an iterative procedure to regulate an individual population that was a candidate solution (Bajpai & Kumar 2010).

Genetic algorithms are different from conventional search algorithms because they start with an initial set of so-called populations. Each individual in the population is called a chromosome, within a chromosome there are some genes and each gene have a value called a allele. With the theory of evolution and genetic theory, in the application of genetic algorithm will involved several operators, like:

a. Evolution operator that involves the selection process in it;

b. Genetic operators involving crossover operators and mutation.

If check the optimization result, we need the fitness function, which indicates the description of encoded result (solution). During the run, the parent must be used for reproduction, cross-over and mutation to create offspring.

Some things to do in the genetic algorithm are:

a. Defines the individual, where the individual states one possible solution of issues raised. In detail the definitions of chromosomes, individuals, genes and alleles can be seen in (Table 2).

Table 2

Genetic algorithm components

Component	*Definition*	*Information*
Population	A-B-C-D-E C-D-E-A-B C-C-E-E-B	Collection of vessel types
Individual	A-B-C-D-E	1 Combination of vessel types
Genes	A	1 Vessel type
Allele	37.454 mi^2 IDR 1.549.454.136	Value of coverage area of vessel type A Value of operational cost of vessel type A

b. Defining the value of fitness, which is a measure of whether or not an individual has a good solution.

$$Ca_{total} = \sum_{i=1}^{n} Ca_i \quad \text{........ (4)}$$

$$Oc_{total} = \sum_{i=1}^{n} Oc_i \quad \text{........ (5)}$$

Where:

i = Amount of type vessel
n = Amount vessel
Ca = Coverage area
Oc = Operational cost

After this to find a fitness *Coverage area* (Ca) and *Operational cost* (Oc). Further for fitness value on each Coverage area (Ca) and Operational cost (Oc).

$$Fitness \rightarrow f(Ca) = \frac{Ca_{Total}}{266.392} \ldots Max \quad \text{........ (6)}$$

$$Fitness \rightarrow f(Oc) = \frac{19.355.851.667}{Oc_{Total}} \ldots Min \quad \text{........ (7)}$$

Objective function / Fitness:

$$F_{total} = F_{ca} + F_{oc} \Rightarrow F_{total} = F_{max(ca)} + F_{min(oc)} \quad \text{........ (8)}$$

Constraint:
$1 \leq F_{total} \leq 1.2$

Where:
$F_{(Ca)}$ = Fitness Coverage Area
$F_{(Oc)}$ = Fitness Operational Cost
$F_{(total)}$ = Fitness Total
$F_{Max\ (Ca)}$ = Fitness Maksimum Coverage Area
$F_{Min(Oc)}$ = Fitness Minimum Operational Cost

c. Determine the initial population generation process. This is usually complete by using random generation such as by the random.
The essence of workings of random is to involved random numbers for the value of each gene according to the representation of chromosome used.

$$IPOP = round\ \{random\ (N_{ipop}, N_{bits})\}$$

Explanation:
IPOP is a gene that will contain the rounding of random number generated by N_{IPOP} (population number) x N_{bits} (number of genes in a single chromosome).

d. Determine which selection process to use.
Selection is used select which individuals to be selected for cross breeding and mutation. Selection is used to get the best individual candidates, assuming a good parent will produce good offspring as well. The higher fitness value of an individual is more it is to be selected.
The selection process used in this system:
- Roulette wheel, to select individuals based on the influence their fitness values. Individuals with high fitness means good individuals will be more easily elected.
- Rank - this process is used to ensure the absence of super-individuals that will damage the evolutionary process so that it is trapped in local-optima.
- Elitism - this process is used to ensure that the fitness of a generation is always better or at least equal to the fitness of previous generation by replacing the weakest individual with the strongest.

e. Determine the cross-over process and the gene mutation to be used.
Cross-over is a very important component in genetic algorithms because a chromosome leads a good solution can be obtained from the cross-linking of two chromosomes. The cross-over method in this study used cross-over random-swap, by swapping each gene from each pair of parent then checked again when there is a twin genes then repaired.

Results. Based on data from the MMAF from 2005-2015 succeeded in arresting 1.494 cases of fish theft with details of 657 are Indonesian flagged fishing vessels and 837 foreign flag fishing vessels. Figure 2 shows that since 2005-2008 there has been increase in the amount of violations in FMA-RI successfully captured of fishing surveillance vessels of Ministry of Fisheries and Marine Affairs, both Indonesian fishing vessels (IFV) and foreign fishing vessels (FFV). While during 2009-2013 there was a decrease in violations that were successfully captured by fisheries surveillance vessel of MMFA (DGMFRS 2013).

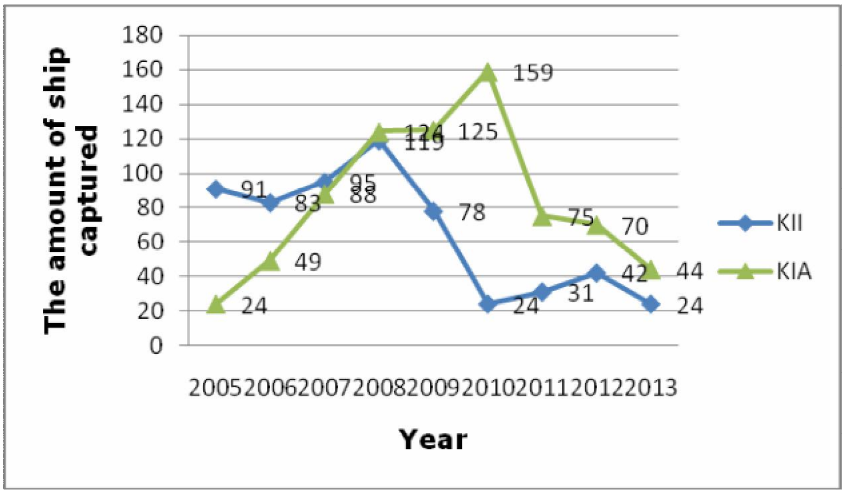

Figure 2. Amount of violations in FMA-RI successfully arrested during the year 2005-2013.

Based on the measurement of the area of MFA-RI 711 using quantum geographic information system (QGIS) software is 266,382 mi^2 and data from the DGMFRS budget provided by the Government of USD 1,455,692.23 for surveillance operations at MFA-RI-711 per year with an area of surveillance of 266,382 mi^2. MFA-RI 711 has 11 work unit scattered in several regions with different regional conditions and different support facilities, the names of each work unit in MFA-RI 711 can be seen in (Table 3 and Figure 3).

Table 3

Name of the work units in MFA-RI 711

Code	*Work unit*
A1	Pontianak
A2	Pemangkat
A3	Teluk Batang
A4	Sungai Liat
A5	Tanjung Balai Karimun
A6	Moro
A7	Batam
A8	Tarempa
A9	Natuna
A10	Pulau Kijang
A11	Tanjung Pinang

Indonesian government has some types of fisheries surveillance vessel with different specifications, but until now existence of surveillance model in MFA-RI 711 is not optimal, it is proved that illegal fishing often occurs in some work unit with abundant natural fisheries resources such as Natuna and Tarempa. Type and specification of fisheries surveillance vessel owned by MMFA can be seen in Table 4.

Based on the research (Krisnafi 2017) the priority of work unit for improvement of fisheries surveillance in MFA-RI 711 using TOPSIS method obtained 3 main work units, like: Pontianak, Natuna and Batam. The results of this study serve as the basis for determining the assignment of an optimal fisheries surveillance vessel in MFA-RI 711 based coverage area and operational cost.

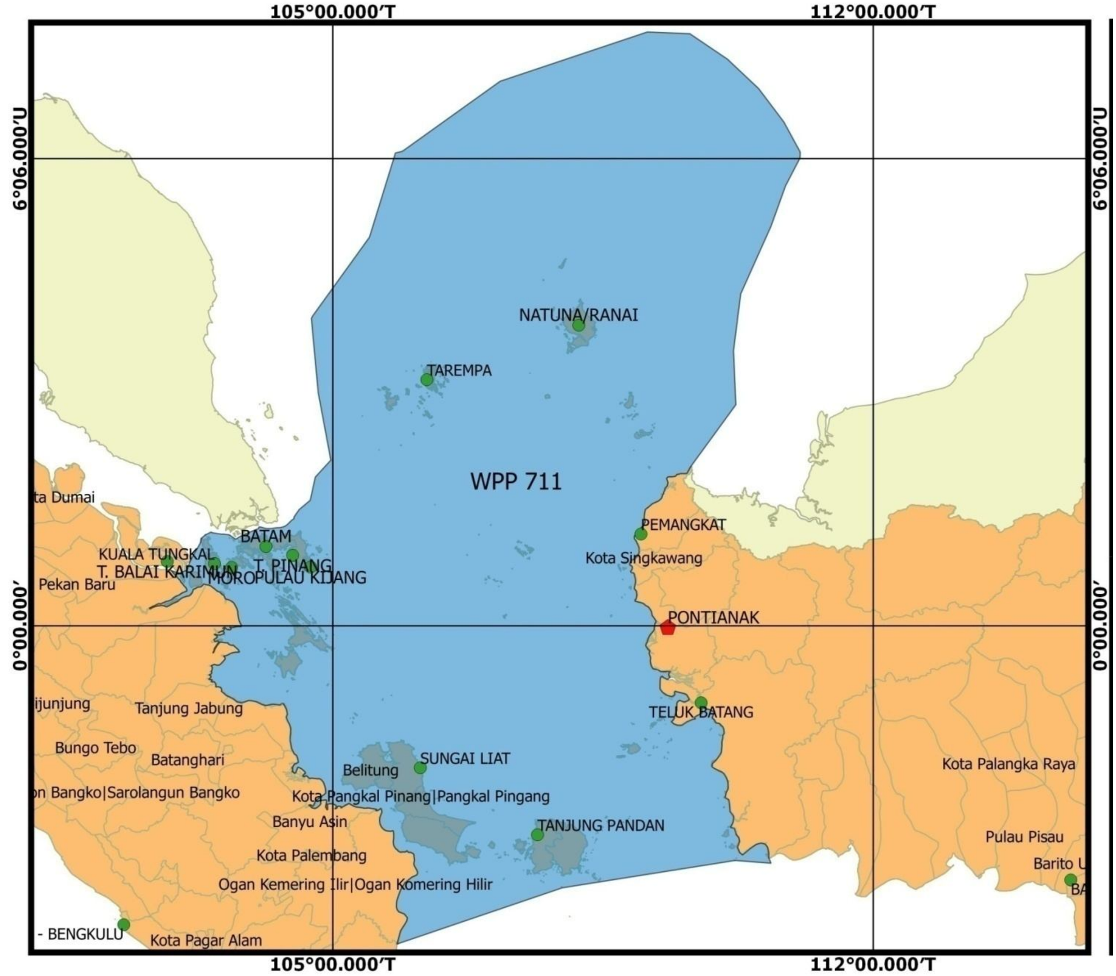

Figure 3. Map of work units in MFA-RI 711.

Table 4

Specification of fisheries surveillance vessel

No	*Vessel type*	*Amount*	*Length of vessel (m)*	*Speed (knot)*	*Endurance (day)*	*Radar (NM)*	*Vessel placement*	
							Westren region	*Eastern region*
1	A	4	60	25	8	64	2	2
2	B	2	42	18	4	96	1	1
3	C	7	36	24	3	48	4	3
4	D	17	23	28	3	48	8	9
5	E	5	18	15	3	48	3	2

Simulation and comparison results. The parameters used for the simulation in the present study are as follows:

Population size *(Pop_size)* = 100
Crossover opportunities (P_c) = 80%
Mutation opportunities (P_m) = 5%

The above displayed parameter refers the area in 3 work units and the costs provided by the government as on (Table 5).

Table 5

Area of surveillance and budget

Work unit	*Area of surveillance* (mi^2)	*Budget (USD)*
Pontianak	62.486	341,466.90
Batam	75.767	414,041.69
Natuna	128.129	700,183.62

Based on the parameters set for the simulation and constraints that have been established, the simulation results obtained in 3 main work units with the combination of fisheries surveillance vessel are as presented in Figure 4.

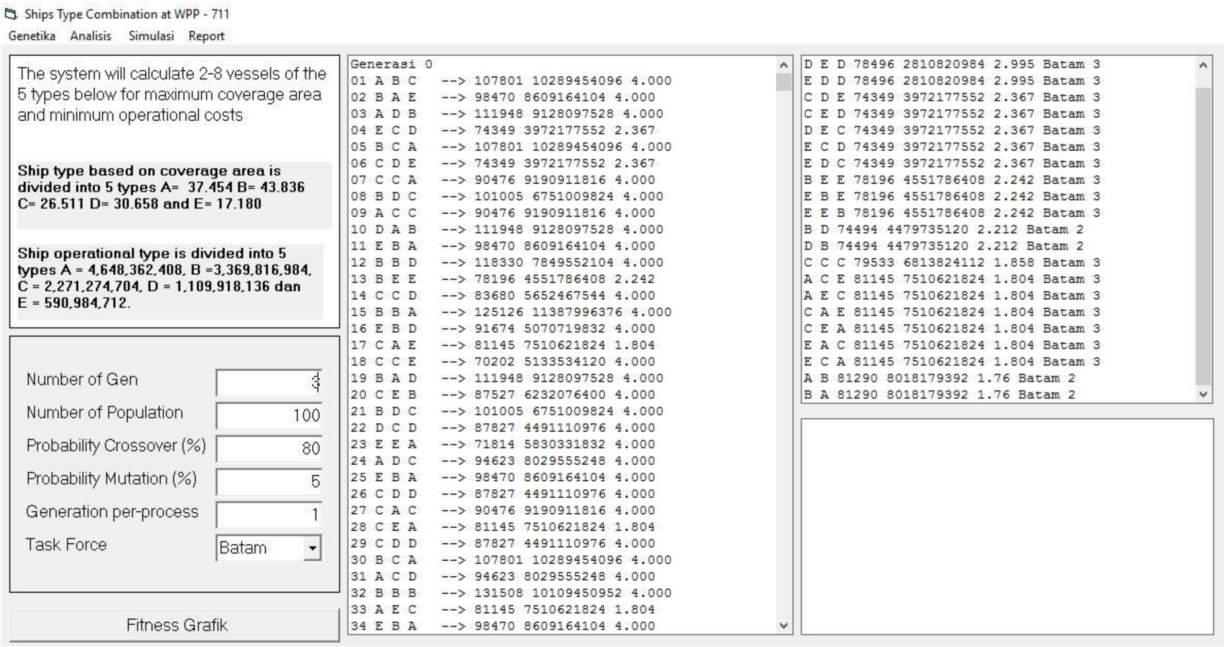

Figure 4. The results of optimization simulation of assignment of fisheries surveillance vessel in the Batam work unit.

The result of optimizing the assignment of fisheries surveillance vessel in work unit Batam, it has being 3 best combination vessel solution to conduct fisheries surveillance in Batam work unit area. Results of optimization analysis of coverage area and efficiency of budget are usage in unit work Batam as follows (Figure 4 and Table 6):

- First solution is a combination of vessels type D-E-C, has an over coverage area of 3% and a budget efficiency of 28% of provided cost.
- Second solution is a combination of vessels type D-E-D, has an over coverage area of 3% and a budget efficiency of 49% of provided cost.
- Third solution is a combination of vessels type E-B-E, has an over coverage area of 7% and a budget efficiency of 17% of provided cost.

Table 6

Results of optimization assignment of fisheries surveillance vessel work unit of Batam

Work unit	*Vessel amount*	*Vessel type combination*	*Coverage area* (mi^2)	*Over coverage* (mi^2)	*Operational cost (IDR)*	*Remaining cost (IDR)*	*Efficiency Ca*	*Efficiency Co*
Batam	3	D-E-C	78.196	2.429	298,734.87	115,306.81	3%	28%
		D-E-D	78.196	2.429	211,392.93	202,648.76	3%	49%
		E-B-E	81.145	5.378	342,325.42	717,16.27	7%	17%

Based on the result of optimizing the assignment of fisheries surveillance vessel in work unit Pontianak, It has being 3 best combination vessel solutions to conduct fisheries surveillance at Pontianak work unit area. Results of optimization analysis of coverage area and efficiency of budget are being used in unit work Pontianak as follows (Figure 5 and Table 7):

- First solution is a combination of vessels type E-E-D, has an over coverage area of 4% and a budget efficiency of 50% of provided cost.
- Second solution is a combination of vessels type E-D-E, has an over coverage area of 4% and a budget efficiency of 50% of provided cost.
- Third solution is a combination of vessels type D-E-E, has an over coverage area of 4% and a budget efficiency of 50% of provided cost.

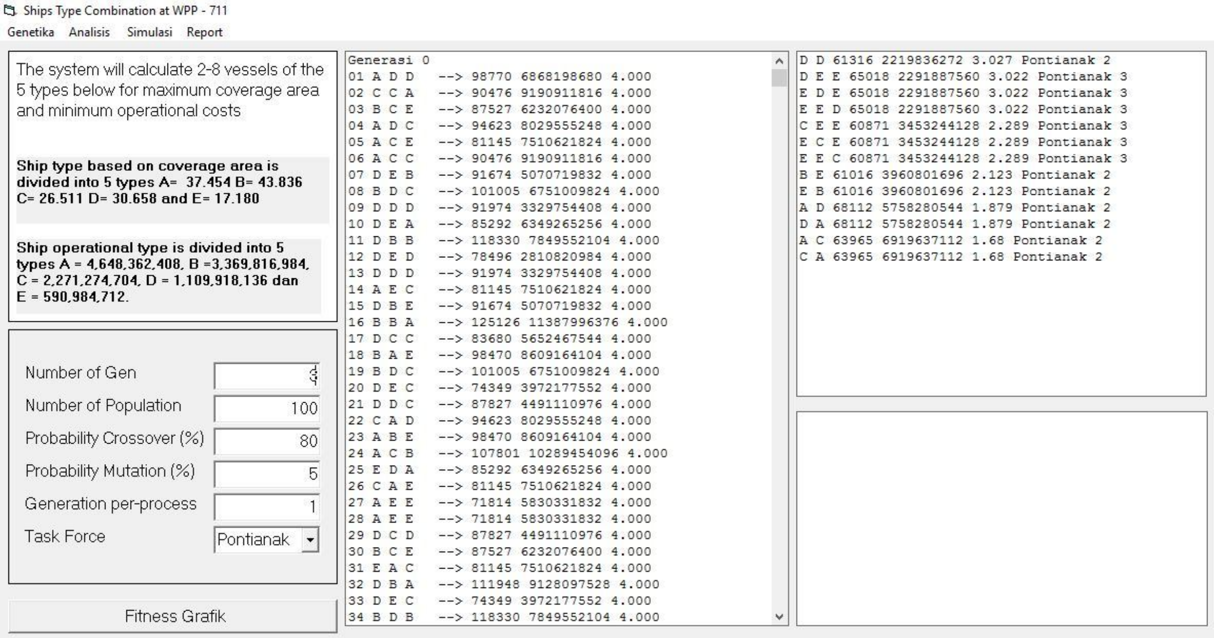

Figure 5. The results of optimization simulation of assignment of fisheries surveillance vessel in the Pontianak work unit.

Table 7

Results of optimization assignment of fisheries surveillance vessel in work unit of Pontianak

Work unit	*Vessel amount*	*Vessel type combination*	*Coverage area (mi^2)*	*Over coverage (mi^2)*	*Operational cost (IDR)*	*Remaining cost (IDR)*	*Efficiency Ca*	*Efficiency Co*
Pontianak	3	E-E-D	65.018	2.532	172,365.59	169,101.31	4%	50%
		E-D-E	65.018	2.532	172,365.59	169,101.31	4%	50%
		D-E-E	65.018	2.532	172,365.59	169,101.31	4%	50%

The result of optimizing the assignment of fisheries surveillance vessel in work unit Natuna, it has 6 best combination vessel solution to conduct fisheries surveillance in Natuna work unit area. Results of optimization analysis of coverage area and efficiency of budget are usage in unit work Natuna as follows (Figure 6 and Table 8):

- First solution is a combination of vessels type A-E-E-D-D, has an over coverage area of 4% and a budget efficiency of 14% of provided cost.
- Second solution is a combination of vessels type E-E-C-D-B, has an over coverage area of 6% and a budget efficiency of 15% of provided cost.
- Third solution is a combination of vessels type E-D-D-D-C, has an over coverage area of 6% and a budget efficiency of 33% of provided cost.

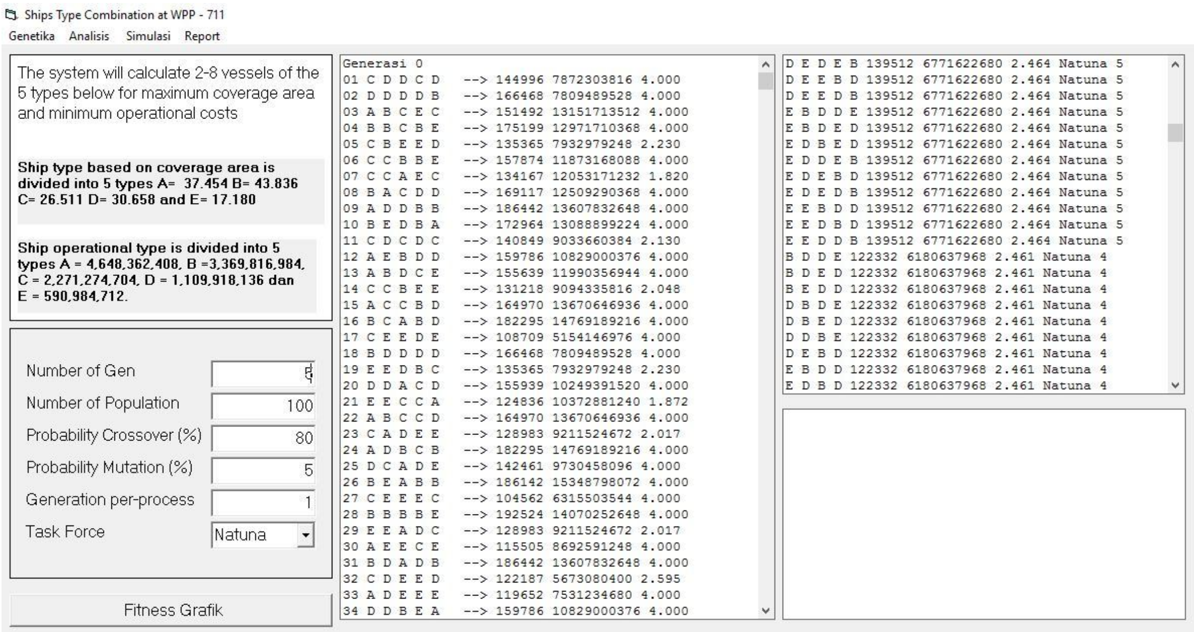

Figure 6. The results of optimization simulation of assignment of fisheries surveillance vessel in the Natuna work unit.

Table 8

Results of optimization assignment of fisheries surveillance vessel in work unit of Natuna

Work unit	*Vessel amount*	*Vessel type combination*	*Coverage area (mi^2)*	*Over coverage (mi^2)*	*Operational cost (IDR)*	*Remaining cost (IDR)*	*Efficiency Ca*	*Efficiency Co*
		A-E-E-D-D	133.130	5.001	605,427.61	94,756.00	4%	14%
Natuna	5	E-E-C-D-B	135.365	7.236	596,614.21	103,569.41	6%	15%
		E-D-D-D-C	135.665	7.536	465,681.72	234,501.90	6%	33%

The results of optimization analysis of coverage area and efficiency presented in Tables 6, 7, and 8, are concluding the following results:

- Batam 3 vessels
- Pontianak 3 vessels
- Natuna 5 vessels.

Based on the analysis of efficiency of coverage area in each work unit obtained various results for the 3rd unit of the combination rock work unit has good efficiency value that is 7% ~ 5.378 mi^2, for Pontianak has the same efficiency value that is 4% ~ 2.532 mi^2 and for Natuna region has the highest efficiency value is the combination of the 1st and 2nd that is 6% ~ 7.536 mi^2 (Table 9 and Figure 7).

Table 9

Comparison of efficiency over coverage area

Result	*Batam*	*Pontianak*	*Natuna*
Combination - 1	3%	4%	4%
Combination - 2	3%	4%	6%
Combination - 3	7%	4%	6%

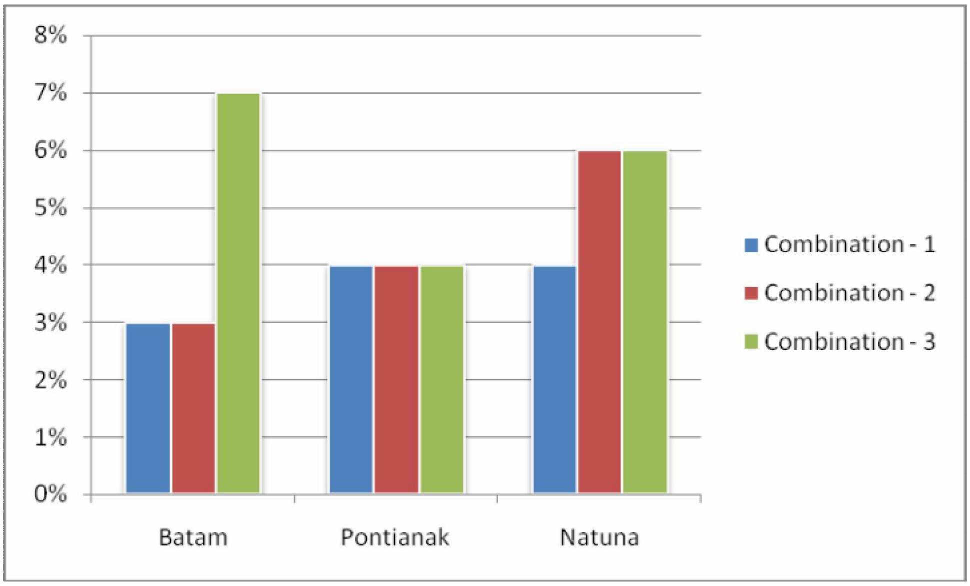

Figure 7. Coverage area efficiency value in each work unit.

Based on the result of operational cost efficiency analysis in each work unit, the result of the various results for the 2nd combination work unit has a good efficiency value of 49% ~ USD. 202,648.76, for Pontianak has the same efficiency value that is 50% ~ USD. 169,101.31 and for Natuna region has the highest efficiency value is the 3rd combination that is 33% ~ USD. 234,501.90 (Figure 8 and Table 10).

Table 10

Comparison of operational cost efficiency

Result	*Batam*	*Pontianak*	*Natuna*
Combination - 1	28%	50%	14%
Combination - 2	49%	50%	15%
Combination - 3	17%	50%	33%

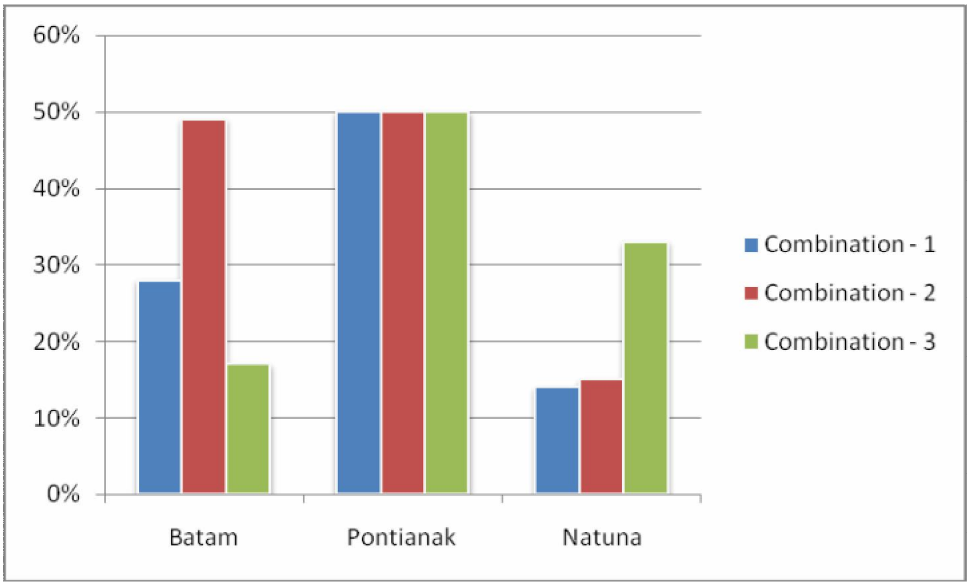

Figure 8. Operational cost value efficiency in each work unit.

Conclusions. After going through several stages and testing of optimization results of fisheries surveillance vessel placement in MFA-RI 711 is being the following conclusion is:

- The combination of fisheries surveillance vessel selected in the Batam work unit area are: D-E-D with over coverage area 3% ~ 2.429 mi^2 and can save operational cost by 49% ~ USD 202,648.76 of total cost and optimization results do not recommend vessel type A.
- The combination of fisheries surveillance vessel in the work area of Pontianak is: D-E-E with over coverage area 4% ~ 2.532 mi^2 and can save operational cost by 50% ~ USD 169,101.31 from the total cost as well as from the optimization results does not recommend vessels types A, B and C.
- The combination of fisheries surveillance vessel selected in the Natuna working area is: E-D-D-D-C with over coverage area 4% ~ 5.001 mi^2 and able to save operational cost by 33% ~ USD 234,501.90 of total cost and optimization result recommend all type of vessels.
- Genetic Algorithms has been able to present some of the optimal candidate solutions for the assignment of fisheries surveillance vessels of some unit works in MFA-RI 711.
- The results of this optimization can be used as a reference for decision support in the Ministry of Maritime Affairs and Fisheries Republic of Indonesia.

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References

Al-Hamad K., Al-Ibrahim M., Al-Enezy E., 2012 A genetic algorithm for ship routing and sceduling problem with time window. American Journal of Operations Research 2:417-429.

Artana K. B., Masroeri, A. A., Irawan M. I., 2012 Development of genetic algorithm for optimization of fleet placement of TNI - AL ships in eastern Indonesia. National Seminar on Theory and Applications, pp. 1-8.

Asim M., Gopalia R., Swar S., 2014 Traveling salesman problem using genetic algorithm. International Journal of Latest Trends in Engineering and Technology 3(3):183-190.

Bajpai P., Kumar M., 2010 Genetic algoritm - an approach to solve global optimization problems. Indian Journal of Computer Science and Engineering 1(3):199-206.

Chand P., Mohanty J. R., 2013 A multi-objective vehicle routing problem using dominant rank method. IJCA Proceedings on International Conference in Distributed Computing and Internet Technology ICDCIT, pp. 29-34.

Hicham E. H., Said B., Jamal B., 2015 Multi-objective optimization using genetic algorithms in MOTSP (CO^2 Emissions). International Journal of Artificial Intelligence and Application (IJAIA) 6(5):35-50.

Hozairi, Artana K. B., Masroeiri A. A., 2014 Implementation of nondominated sorting genetic algorithm – II (NSGA-II) for multiobjective optimization problems on distribution of indonesian navy warship. Journal of Theoretical and Applied Information Technology 64(1):274–281.

Kanavade A. T., Kshirsagar A. D., Kokane S. N., Kulkarni M. S., 2016 Time table scheduling using genetic algorithm. International Journal of Advance Research and Innovative Ideas in Education 2(3):122-128.

Kornilakis H., Stamatopoulus P., 2002 Crew pairing optimization with genetic algoritms. Viahavas I. P., Spyropoulus C. D. (eds), LNAI 2308:109-120.

Munaf D. R., 2013 Study analysis of typical marine security infrastructure at the center and in the region. Journal of Sociotechnology 28:320-339.

Santoso P., Artana K. B., Masroeri A. A., Irawan M. I., Dinariana A. A. B., 2014 The implementation of binary genetic algorithm (BGA) for optimizing the task of Indonesian navy ship patrols related to the security of Indonesia seas. Journal of Theoretical and Applied Information Technology 67(1):247–253.

Krisnafi Y., 2017 Determination of work area priority for improvement of fisheries surveillance in MFA-RI 711. Accepted for publcation in Journal of Marine Fisheries.

***DGMFRS [Directorate General of Management Resources Fisheries Surveillance], 2013 Fisheries Resources Data and Information on Fishery Resources. Jakarta (ID): DGFRMS Press.
***DGMFRS [Directorate General of Management Resources Fisheries Surveillance], 2015 Destructive Fishing. Jakarta (ID): DGFRMS Press.
***FAO [Food and Agriculture Union]., 2016 The State Of World Fisheries And Aquaculture.
***MMAF Republic of Indonesia [Ministry of Marine Affairs and Fisheries], 2009 Ministerial regulation about Fisheries Management Area Republic of Indonesia.
***MMAF Republic of Indonesia [Ministry of Marine Affairs and Fisheries], 2016 Data Center, Statistics, and Information.

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Authors:
Yaser Krisnafi, Jakarta Fisheries University, Department Fishing Technology, Faculty Fishing Technology, Indonesia, Jakarta 14440; Bogor Agriculture University, Department of Fishery Resource Utilization, Faculty of Fishery and Marine Science, Indonesia, Darmaga – Bogor 16680, e-mail: yaser_bunda@yahoo.com
Budhi Hascaryo Iskandar, Bogor Agriculture University, Department of Fishery Resource Utilization, Faculty of Fishery and Marine Science, Indonesia, Darmaga – Bogor 16680, e-mail: bhascaryo.iskandar@gmail.com
Sugeng Hari Wisudo, Bogor Agriculture University, Department of Fishery Resource Utilization, Faculty of Fishery and Marine Science, Indonesia, Darmaga – Bogor 16680, e-mail: wisudo1966@gmail.com
John Haluan, Bogor Agriculture University, Department of Fishery Resource Utilization, Faculty of Fishery and Marine Science, Indonesia, Darmaga – Bogor 16680, e-mail: jhaluan@yahoo.com

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