# Optimization of Determination of the Number of Fisheries Supervisory Vessels in the Fisheries Management Area -713 Using Genetic Algorithm

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# Optimization of Determination of the Number of Fisheries Supervisory Vessels in the Fisheries Management Area -713 Using Genetic Algorithms

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***Abstract*— The Indonesian Fisheries Management Area (FMA) consists of eleven regions, one of which is FMA-713. FMA-713 includes Makassar Strait Waters, Bone Bay, Flores Sea and Bali Sea with an area of 203,920 Mil$^2$. Problems that often occur in FMA-713 include high illegal fishing, overfishing, fishing with bombs. The influencing factor is the lack of Fishery Surveillance Vessel owned by the Ministry of Maritime Affairs and Fisheries which are assigned to FMA-713. The purpose of this research is to choose the optimal number of fishery surveillance vessel to operate in FMA-713. To solve this problem, the method used is the Genetic Algorithm method. Genetic Algorithm is the most widely used optimization method to solve multi-objective problems. The results of the optimization recommend the number of ships operating in FMA-713 are six ships of type A-B-B-B-C-C with an achievement area coverage of 209,342 Mil$^2$ and operational costs of IDR. 1,621,184,100. The findings in this study can be used as a consideration by the Government to determine policies to improve Indonesia's marine security.**

***Keywords—FMA-713, optimization, genetic algorithms***

## I. INTRODUCTION

Indonesia is a maritime country, where its territory is mostly sea. The sea is one of the resources of life that has a large enough potential to meet the needs of human life. Technological advances owned by humans cause the sea, not as a natural secret that is not solved but has become a natural resource that contains economic, political, and strategic values so that it is contested by many countries in the world to become the foundation of the second natural resource after the mainland. Therefore, there is a need for sea supervision and good management to protect the natural resources in the sea [1], [2].

Supervision of the area of fisheries management is a duty mandated by law to the Ministry of Maritime Affairs and Fisheries. The purpose of supervision is to ensure the implementation of sustainable fisheries management through optimal and responsible utilization in order to achieve the objectives of fisheries management, namely: welfare for fishermen and increasing foreign exchange derived from the fisheries sector. Fisheries Supervisor is an activity to prevent deviant or repressive actions in violation of laws and regulations in the field of fisheries [3], [4].

Supervision and law enforcement in the field of fisheries is one of the main tasks and functions of the Supervisory Ship Directorate which is implemented through a supervisory ship to conduct surveillance operations on marine and fisheries resources. Fisheries Oversight is an activity that aims to ensure an orderly implementation of the provisions of the laws and regulations in the field of fisheries. The Republic of Indonesia Fisheries Management Area (FMA-RI), Nusantara waters are divided into 11 fisheries management areas. The fisheries management area is a management area for capture fisheries, aquaculture, conservation and for research and development activities [2], [5].

The fishery surveillance vessel operated were ± 24 units and the surveillance speedboats were less than ± 50 units. The entire fleet of fishery surveillance vessel were deployed to oversee 11 State Fisheries Processing Areas of the Republic of Indonesia with an area of 2,627,456 Nautical square miles (Nmil2). The fisheries areas include FMA-571 to FMA-573 and from FMA-711 to FMA-718. The naming is based on the division of the FAO (Food and Agriculture Organization) fisheries statistics, because Indonesian waters are in two areas, namely area 57 of the eastern Indian Ocean region and area 71 of the Western Central Pacific [5]. Eleven FMA-RI regions consist of: FMA 571, FMA 572, FMA 573, and FMA 711, FMA 712, FMA 713, FMA 714, FMA 715, FMA 716, FMA 717 and FMA 718 [6], in detail the position of each FMA can be seen in Figure 1.

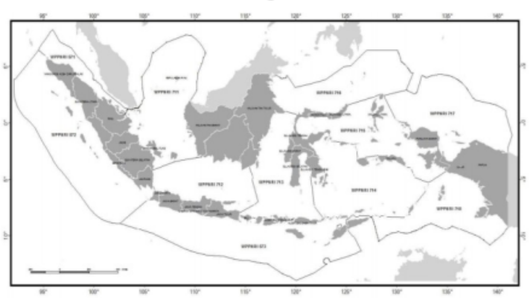

Fig 1. The territory of the Republic of Indonesia Fisheries Management

Illegal fishing and Logging, Piracy, Smuggling, Terrorism at Sea, Illegal Crossing, Claim of Area are problems that occur because of weak sea security surveillance. Due to the lack of a fleet of ships deployed to the Fisheries Management area of the Republic of Indonesia and the limited state budget, making it easier for violations to occur at FMA-RI [1].

While the problems that occur in areas that are not directly adjacent to neighboring areas such as FMA-713 which includes: Makassar Strait, Bone Bay, Flores Sea, and Bali Sea. Problems that occur in FMA-713 include: illegal fishing is still high, overfishing, fishing with fish bombing. This problem occurs because the certification of ship crews is still low, namely the number of ships with sizes >30 GT totaling 1046 units [5]. To overcome these problems optimal supervision is needed so that violations do not occur again.

In this study, the authors simulate the determination of the optimal number of surveillance vessels in FMA-713 using Genetic Algorithm. The Genetic Algorithm method as a branch of the Evolution Algorithm is an adaptive method commonly used to solve a value search in an optimization problem. This algorithm is based on genetic processes that exist in living things, namely the development of generations in a natural population, gradually following the principle of natural selection or "who is strong, he survives". By imitating this theory of evolution, the Genetic Algorithm can be used to find solutions to problems in the real world. The advantage of genetic algorithms compared to other algorithms is that they have a large choice of solutions and work more closely to find solutions to their solutions.

## II. Material and Methods

### A. Research Stages

Research activities are a process of gaining or obtaining knowledge or solving problems faced, which are carried out scientifically, systematically and logically. In this study the stages of the study are used as follows:

First, the identification of the problem, at this stage the researcher conducted a literature review on the condition of FMA-713, conducted interviews with several stakeholders about the condition of fishing results in FMA-713. An important finding of the problem at FMA-713 is the large number of fishing vessels that carry out the fishing theft process.

Second, the data collection process, namely the type and type of vessels used by the Ministry of Maritime Affairs and Fisheries, recognizes operational costs determined by the government to carry out surveillance of fisheries management areas, identify potential natural resources that exist and identify border areas in FMA-713.

Third, the process of data analysis, which involves calculating the coverage area of a fishery control vessel, calculating operational cost requirements, defining individuals and determining the value of fitness.

Fourth, the optimization process, which is to determine the optimal combination of fishery surveillance vessel , determine the operational costs of the optimal control ship, graph fitness values and determine the best solution.

Fifth, Analysis of the results, namely analyzing the solutions provided by GA with the aim of choosing the best solution. In detail, the stages of the study can be seen in Figure 1.

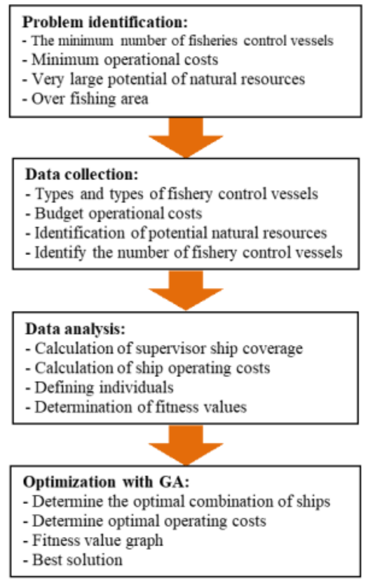


Fig 2. Research stages

### B. Calculation of Fisheries Management Area-713

To find out the area of FMA - 713 as shown in Figure 1, the research team did the digitization on the FMA - 713 map using Arc GIS software so that the area was 203,920 square miles.

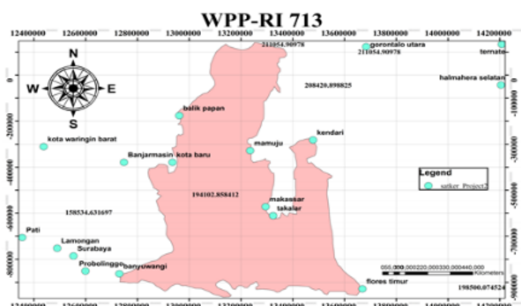


Fig 3. Fisheries Management Area -713

Figure 3, obtained after digitizing using ArcGis to obtain the FMA-713 area that will be used to calculate the overall fitness value.

### C. Fishery Surveillance Vessel

Fishery Surveillance Vessel is a ship used to protect marine and fisheries resources. Fishery Surveillance Vessel is a law enforcer at sea in the field of fisheries. In conducting supervision in coordination with the Navy, the national Police and Marine Security Agency. The Fishery Supervisory Ship is within the scope of the Directorate General of PSDKP under the auspices of the Ministry of Maritime Affairs and Fisheries. In carrying out their duties, the Fishery Supervisory Vessel can stop, inspect, carry, and detain vessels suspected of violating them to the nearest port for further processing. In addition, based on Law No. 31 of 2004 concerning Fisheries, as amended by Law No. 45 of 2009, in certain cases the Fishing Supervisory Ship, in this case, the fishery inspector or the Fisheries Civil Servant Investigator, can also take special action in the form of sinking [5], [7], [8].

According to the legislation, Fishery Supervisory Vessels are government vessels that are given a certain mark to carry out supervision and law enforcement in the field of fisheries within the territory of the Republic of Indonesia fisheries management. In conducting surveillance of fishing vessels carried out in the Indonesian Fisheries Management Area (FMA), a fishing port or a non-fishing port, a public port designated as a port base, a fish landing base, and a center for fishing activities. Even though there were from 2003, the development of fishery surveillance vessel in Indonesia was still felt to be lacking due to the vast territory of the Republic of Indonesia fisheries management [9], [10]. At present Indonesia has 35 Fisheries Supervisory Boats which are scattered in various regions as shown in Table 1.

TABLE I. DATA OF FISHERY SURVEILLANCE VESSEL

| No | Ship type | Amount | Size (m) |
|---|---|---|---|
| 1 | KP Hiu Macan Tutul | 2 | 42 |
| 2 | KP Hiu Macan | 6 | 36 |
| 3 | KP Hiu | 15 | 27 |
| 4 | KP Takalongan | 1 | 21 |
| 5 | KP Padaido | 1 | 21 |
| 6 | KP Todak | 2 | 17 |
| 7 | KP Baracuda | 2 | 17 |
| 8 | KP Paus | 1 | 36 |
| 9 | KP Akar Bahar | 1 | 15 |
| 10 | KP Orca | 4 | 60 |

Based on Table 1, it can be seen that the Ministry of Maritime Affairs and Fisheries (MMAF) has five types of ships that are ready to operate in each region with different specifications, so it needs analysis to calculate each vessel's coverage area so that it can determine the need for number and type surveillance ship on FMA-713.

### D. Multi-objective optimization

Optimization is an activity to get the best results under a given state, or optimization can be interpreted as an activity to get the minimum value of a function because to get the maximum value of a function can be done by finding the minimum of the same negative function [11], [12].

An optimization problem that is mathematically modeled generally consists of objective functions and constraints. The objective function represents the goal that you want to optimize. Because the number of objective functions is more than one, the optimum solution of the multi-criteria optimization problem is also more than one, all of which fit into a set called the Pareto frontier. This is in line with the principle that there is no single solution that can provide more optimal results from one of the existing objective functions without compromising other objective functions [13], [14].

The optimization of multi-objective functions received significant attention from researchers. [15]completed multi-objective optimization using Particle Swarm Optimization (PSO). The experimental results show that PSO can find several optimal Pareto solutions efficiently. [16] used Ant Colony Optimization (ACO) to complete multi-objective optimization in the determination of the project portfolio. They show that ACO is efficient enough to handle interactions between complex projects. [16] proposed Simulated Annealing (SA) which was also quite successful in solving various optimization problems in multi-objective functions. [17], [18], [19] proposed Genetic Algorithms (GA) to resolve the assignment and placement of Indonesian Navy ships.

### E. Genetic Algorithm

A genetic algorithm is a search algorithm based on the way it works through natural and genetic selection mechanisms. The aim is to determine structures called high-quality individuals in a domain called population to get solutions to problems. John Holland developed genetic algorithms through iterative procedures to regulate the population of individuals who are potential solutions [11], [12], [14].

Genetic algorithms are different from conventional search algorithms because they begin with an initial set called populations. Each individual in the population is called a chromosome, inside the chromosome, there are several genes and each gene has a value called an allele. With the theory of evolution and genetic theory, the application of Genetic Algorithms will involve several operators [11], [20], [21], namely:

a. The Evolution operator involves the selection process in it.
b. Genetic Operators that involve cross-shifting and mutation operators.

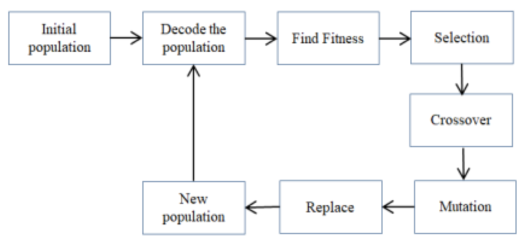


Fig 4. Genetic Algorithm Block Diagram

To check the results of optimization, we need a fitness function, which signifies a picture of the results of the solution that has been coded. During the walk, the parent must be used for reproduction, crossing, and mutation to create offspring [22].

## III. RESULTS AND DISCUSSION

This study aims to find the optimal combination of Fisheries Supervisory Vessels to be assigned to each work unit in the Fisheries Management Area-713 (FMA-713). The Ministry of Fisheries and Maritime Affairs has a budget prepared by the Government of IDR. 1.750.000.000,- Billion for surveillance operations in FMA-713 with a total area that must be secured is 203,920 Mil$^2$.

### A. Defining Problems

*1) Define the individual,* where the individual states one possible solution to the problem raised. In detail the definitions of chromosomes, individuals, genes, and alleles can be seen in Table 2.

TABLE II. COMPONENTS OF GENETIC ALGORITHMS

| Component | Definition | Information |
|---|---|---|
| Population | A-B-C-D-E<br>C-D-A-B-E<br>C-C-B-A-D | Collection of Types of surveillance vessels |
| Individu | A-B-C-D-E | a combination of surveillance vessels |
| Gen | A | one type of surveillance ship |
| Allele | 37.454 Mil$^2$ | Coverage area value of type A surveillance ship |
| | Rp. 666.859.900 | Value of operational costs of type A supervisory vessels |

*2) Define the value of fitness,* where the value of fitness is a measure of whether an individual or a solution is obtained.

$$Ca_{totol} = \sum_{i=1}^{n} Ca_i \quad (1)$$

$$Oc_{total} = \sum_{i=1}^{n} Oc_i \quad (2)$$

Information:
i = Number of ship types
n = Number of ships
$C_a$ = Coverage Area
$O_c$ = Operational Cost

Next, determine the fitness value in each Coverage Area ($C_a$) and Operational Cost ($O_c$).

$$f_{(Ca)} = \frac{Ca_{total}}{\sum_{i=1}^{n} L\arg e_{FMA-713}} \quad (3)$$

$$f_{(Co)} = \frac{Budget}{Oc_{Fisheries\ Supervisory\ Vessels}} \quad (4)$$

$$f_{total} = f_{Ca} + f_{Oc}$$
$$f_{total} = f_{\max(Ca)} + f_{\min(Oc)} \quad (5)$$

Information:
F $_{(Ca)}$ = Fitness Coverage Area
F $_{(Oc)}$ = Fitness Operational Cost
F $_{(total)}$ = Total fitness
F Max$_{(Ca)}$ = Maximum Fitness Coverage Area
F Min$_{(Oc)}$ = Fitness Minimum Operational Cost

*3) Determine the initial population generation process.* This is usually done by using a random generator such as a random walk.

The essence of how random-walks work is to involve random numbers for the value of each gene according to the chromosome representation used.

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

Information:
IPOP is the initialization of the population which will contain rounding of random numbers generated as many as $N_{IPOP}$ (population) x Nbits (number of genes in one chromosome).

*4) Determine the selection process.* Selection is used to select which individuals will be selected for the process of interbreeding and mutation.

Selection is used to get the best individual candidates, assuming a good parent will produce good offspring as well. The higher the fitness value of an individual, the more likely it is to be selected. The selection process used in the system of assignment and placement of fishery surveillance vessel is:

- Roulette Wheel, to choose individuals based on the influence of their fitness value. Individuals with high fitness mean good individuals will be more easily chosen.
- Rank, this process is used to guarantee the emergence of super-individuals that will damage the evolutionary process so that they are trapped in the optimal local.
- Elitism, this process is used to ensure the fitness of a generation is always better or at least the same as the previous generation's fitness by replacing the ugliest individual with the best individual in the previous generation.

*5) Determine the crossover process and gene mutation that will be used.* Crossover is a very important component in genetic algorithms because a chromosome that leads to a good solution can be obtained from the cross-movement of two chromosomes. The cross-over method in this study uses a random-swap crossover, by exchanging each gene for each pair of parent which is then checked again if there are twin genes then it is repaired.

*B. Fitness Value Calculation*

In this study, two objective or fitness functions are used to determine the minimum function and the maximum function. For Fitness Function (1) maximizing coverage area, (2) minimizing operational costs. To calculate the Fitness Function (1), the coverage area of a fishery control vessel during sailing is described and formulated as Figure 5.

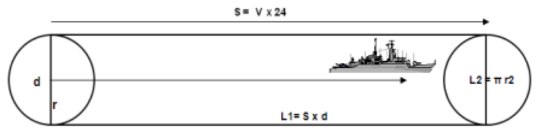


Fig 5. Coverage area of the fishery control vessel [17]

**Information:**
S = Traveling distance per day = Speed x 24 hours = V x 24 (mil)
L1 = Rectangular area = S x d (mil$^2$)
L2 = Area of circle = π r2 (mil$^2$)
d = Radar range (mil)

The range of coverage of fishery surveillance vessels is a rectangular area (L1) plus the area of the circle (L2).

Coverage Area = ( L1+L2 ) x Radar detection probability
= ( L1+L2 ) x 0.9 (mil$^2$)

Traveling distance max = Traveling distance per day * Endurance

RE = S x E (mil)

Endurance is the long endurance of sailing vessels (days) without repackaging.

For the fitness function two is to minimize the operational costs of the supervisory vessels, namely:

*a. Liquid logistics usage fee*

- Fuel costs = Fuel usage per day * Fuel prices
- Freshwater costs = Freshwater Costs per day * Freshwater cost
- Lubricating Oil = Use of lubricating oil per day * Lubricating oil cost

*b. Personnel logistics usage fee*

- Screen Allowances (IDR. 5,000 / hr / personnel)
- Operating Meal Costs (IDR. 15,000 / hr / personnel)
- Leadership Allowance (IDR. 220,000 / E)

*c. Vessels maintenance costs during operation*

- Type A = (IDR. 1.500.000/hr E)
- Type B = (IDR. 1.500.000/hr E)
- Type C = (IDR. 1.200.000/hr E)
- Type D = (IDR. 1.000.000/hr E)
- Type E = (IDR. 800.000/hr E)

d. *Total operating costs* = Liquid logistics costs + Personnel logistics + Vessels maintenance = IDR. / day of operation

## *C. Optimization Results*

The parameters used in this research simulation are as follows:

- Number of Genes = 5
- Population size ($P_{size}$) = 100
- Probability of crossover ($P_c$) = 0.8
- Probability of Mutation ($P_m$) = 0.05

The above parameters will refer to the area of FMA-713 and costs prepared by the Government ± IDR. 1.75 billion. Based on the parameters and constraints that have been set, the simulation results are obtained with a combination of control vessels in FMA-713.

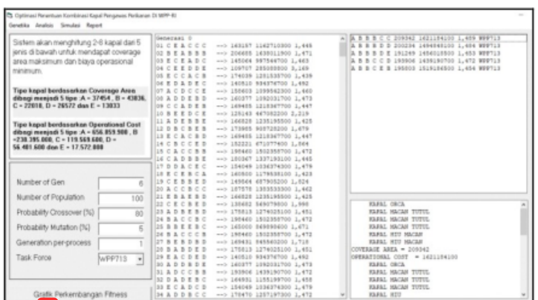

Fig 6. The results of the optimization of the number of fishery surveillance vessel in FMA-713

Based on Figure 6, the optimization process with genetic algorithms will be generated with six genes, one hundred iterations, 0.8 crossover probabilities, and 0.005 mutation probabilities. Based on the initialization of the genetic algorithm components as in Table 2, an initial population of 100 candidate solutions is obtained.

Based on the optimization results of the combination of fishery surveillance vessel in FMA-713 as shown in Table 3, it means that the first solution candidate recommends a type of ship [A-B-B-B-C-C] with coverage area = 209,342 Mil2, and operational costs = IDR. 1,621,184,100. The second perspective solution recommends the type of ship [A-B-B-B-E-B] with coverage area = 206,685 Mil$^2$ and operational costs = IDR. 1,638,011,900. Based on the fitness value that has been set, the best solution among 100 candidate solutions is obtained by the calculation of Genetic Algorithm, which is a combination of 6 types of ships to conduct surveillance in FMA - 713 as shown in Table 3.

TABLE III. RESULTS OF GENETIC ALGORITHM OPTIMIZATION AT FMA-713

| No | Ship Combination | Coverage Area | Operasional Cost | Fitness |
|---|---|---|---|---|
| 1 | A-B-B-D-D-D | 184.798 | 1.312.854.700 | 1.478 |
| 2 | A-B-D-B-D-E | 180.367 | 1.337.193.100 | 1.445 |
| 3 | A-B-C-C-E-E | 160.500 | 1.179.538.100 | 1.423 |
| 4 | A-B-D-B-B-C | 204.788 | 1.558.016.100 | 1.486 |
| 5 | A-B-D-D-D-D | 169.362 | 1.130.861.300 | 1.494 |
| 6 | A-B-B-B-B-E | 206.685 | 1.638.011.900 | 1.471 |
| 7 | A-B-B-B-C-C | 209.342 | 1.621.184.100 | 1.489 |
| 8 | A-B-B-C-B-C | 209.342 | 1.621.184.100 | 1.489 |
| 9 | A-B-B-C-B-D | 204.788 | 1.558.016.100 | 1.486 |
| 10 | A-B-B-D-E-D | 175.813 | 1.274.025.100 | 1.451 |
| 11 | A-B-B-B-C-C | 209.342 | 1.621.184.100 | 1.489 |
| 12 | A-B-B-D-D-D | 184.798 | 1.312.854.700 | 1.478 |
| 13 | A-B-B-B-E-B | 206.685 | 1.638.011.900 | 1.486 |
| 14 | A-B-B-C-B-D | 204.788 | 1.558.016.100 | 1.486 |
| 15 | A-B-B-C-C-B | 209.342 | 1.621.184.100 | 1.489 |
| 16 | A-B-B-B-C-C | 209.342 | 1.621.184.100 | 1.489 |
| 17 | A-B-B-B-D-D | 200.234 | 1.494.848.100 | 1.484 |
| 18 | A-B-B-B-D-E | 191.249 | 1.456.018.500 | 1.453 |
| 19 | A-B-B-C-C-D | 193.906 | 1.439.190.700 | 1.472 |
| 20 | A-B-B-C-E-B | 195.803 | 1.519.186.500 | 1.454 |

After the application of genetic algorithms recommends several candidates for the best solution, the next step is to analyze the results of the efficiency of fitness value achievements, namely how to increase the achievement of the coverage area and minimize the operational costs of securing FMA-713. The achievement analysis uses the determined constraint value, which is the Area of FMA-713 is 203,920 Mil$^2$ and the security operational budget prepared by the government is IDR. 1.75 billion.

The results of the analysis of the achievement of the coverage area and the use of FMA-713 security operational costs can be seen in Table 4. Based on Table 4, the achievement of the coverage area and the need for security operational costs, the genetic algorithm recommends candidate solutions number 7 and 8, with the coverage area coverage of 209,342 Mil$^2$ assuming that it has been able to exceed the area of FMA-713 with an excess percentage gain of ± 3% or equivalent to 5,422 Mil$^2$. As for the operational costs of safeguarding FMA-713 needs IDR. 1,621,184,100, so that it can save costs by IDR. 128,815,100 or about ± 7% of the total costs prepared by the Government.

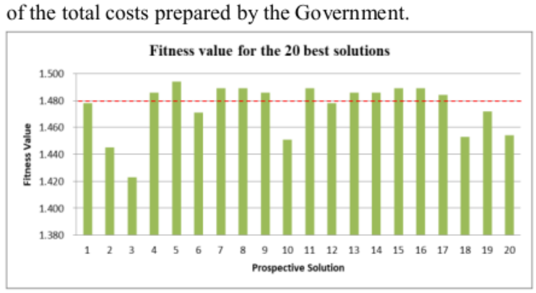


Fig 6. Fitness performance graphs for the 20 best solutions

The recommended optimal combination of ships to secure FMA-713 is one type-A surveillance ship, three type

B vessels, two type C. surveillance vessels. The reason for this combination of ships was taken is to increase the achievement of the area's security area coverage and could save security budget. The reason other solutions are not recommended is because of the achievement of small coverage areas and high ship operating costs.

Based on Figure 6, it can be described as the achievement value of fitness in each prospective solution. In the genetic algorithm, the evaluation of fitness value is obtained by examining each gene in each parent chromosome with penalty criteria as a function of eligibility. The genetic algorithm will stop if no crashes are found or the maximum number of generations has been reached, based on the results of the simulation each time the iteration will display five candidates for the best solution from initialization. From the results of the analysis it was found that the performance of the genetic algorithm was very good for solving the optimization problem in determining the number of fishery surveillance vessel in FMA-713.

## IV. Conclusion

The results of this study indicate that by using the Genetic Algorithm the optimization problem of fishery supervisory vessel needs is easily solved, namely increasing the coverage area and minimizing operational costs. One of the findings in this study is the most optimal combination of ships to secure FMA-713 is a type A ship is one unit, type B ships are three units, type C ships are two units. This research contributes to increase the coverage area of ± 3% or equivalent to 5,422 $Mil^2$ and operational cost efficiency by ± 7% or equivalent to IDR. 128,815,900. This research can be used as a supporter of the decision to adopt a policy to improve Indonesia's marine security.

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# Optimization of Determination of the Number of Fisheries Supervisory Vessels in the Fisheries Management Area -713 Using Genetic Algorithm

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