Research on Optimal Allocation of Sea Area Utilization Based on Genetic Algorithm: A Case Study of Dengsha Estuary Sea Area

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Abstract. Optimal allocation of sea area utilization is a necessary method to coordinate the conflicts between different departments and realize the dual goals of development and ecological protection. This paper presents an optimal allocation method of sea area utilization based on genetic algorithm. Taking the estuarine sea area of Dengsha Estuary Sea Area as an example, the empirical study was conducted. The results show that the sea area utilization optimization allocation method based on genetic algorithm can produce the optimization result scheme with higher comprehensive benefit and lower ecological loss based on the initial scheme. Under the guidance of constraint conditions, the problem of conflicts between different departments can be solved by optimizing the spatial distribution and the demand of each department can be fully met. Different spatial distribution optimization alternatives can be produced under the same sea area utilization structure.

Keywords: Allocation of Sea Area Utilization, Marine spatial planning, marine zoning.

1. Introduction
Optimizing the allocation of sea area space resources is a necessary method to coordinate the conflicts among departments and achieve the dual goals of development and ecological protection. The optimal allocation of sea area utilization is a multi-objective space optimization issue, and solves problems of quantity allocation and spatial distribution of sea area utilization. At present, on the basis of suitability evaluation, marine zoning and planning research adopts the superposition analysis method based on GIS to solve the spatial distribution problem of sea area utilization among departments [1-3]. The superposition method has a heavy workload, is susceptible to human factors, generates new optimization schemes inefficiently to changing requirements, and is difficult to solve the multi-objective conflict problems. The optimal allocation of sea area utilization can learn from the research method of optimal allocation of land use. The spatial resource optimal allocation method based on intelligent optimization algorithm has been applied in the field of optimal allocation of land use and has achieved many research results [4]. Combined with GIS, simulated annealing algorithm, genetic algorithm, particle swarm optimization algorithm [5, 6], ant colony algorithm are widely used in the study of optimal allocation of land use. In recent years, the combination of multi-agent model and optimization algorithm, and the combination of multi-objective decision model and CLUE-S model have become the research hotspots of optimal allocation of land use. [7-9]

This paper presents an optimal allocation method of sea area utilization based on genetic algorithm. Taking the estuarine sea area of Dengsha Estuary Sea Area as an example, the empirical study was conducted.
2. Overview of the Study Area

Dengsha Estuary Sea Area is located in the east of Jinzhou District, Dalian, Liaoning Province, bounded at 39°09′N ~ 39°29′N, 121°54′E ~ 122°06′E, with a total length of 25.7km and a basin area of 229km². The banks on both sides of the Dengsha Estuary Sea Area Estuary are zigzag and S-shaped, and the formed area outside the estuary is about 3.5km². The sea water quality is good, and the water depth is 0-5m. The marine functional zoning in Liaoning province is the industrial and urban construction area on both sides of the estuary, the central part of the estuary is the reserved area, and the northern sea area outside the estuary is the port shipping area.

3. Method

The solution process of sea area utilization optimization scheme starts by initializing the population and then enters into the iterative process of continuous evaluation and evolution in genetic algorithm. The genetic algorithm process is programmed in C#. The evaluation model detail refers to previous study [10].

The basic geographical data of the sea area is from the Survey Report on the Basic State of Marine Resources and Environment in Liaoning Province. Vector data files are established digitally through ArcGIS. The research scope is based on the analysis results of the 5km buffer zone in the Dengsha Estuary. Data on the economic benefits of sea area utilization were collected from the 2015 China Marine Statistical Yearbook and The State Administration of The Use of Sea Area Bulletin. The economic benefits of various sea areas are adopted the national average value.

4. Results Analysis

4.1. Initial Population Analysis

Based on the current situation of sea area utilization, the sea use demand of each department under the scenario of the overall sea area development utilization rate increasing by 10% is simulated. Three types of development and utilization schemes for industrial and mining seas (T2), fishery seas (T3) and tourism seas (T5) were simulated respectively. And for each sea area utilization type, five schemes were generated by random distribution. The initial population was constructed based on the current situation of sea area utilization and the sea use demand schemes of various departments. The initial population evaluation results are shown in Table 1.

The comprehensive benefits of the industrial and mining sea use growth scheme increased by 33.11% on average, and the ecological loss increased by 25.82% on average. From the average level, the new industrial and mining sea use scheme can enhance the comprehensive benefits of sea area utilization. However, the ecological loss of different schemes can differ by 15%. Compared with the 10% increase in comprehensive benefits, the ecological loss increased even more. Therefore, if the impact of sea area utilization layout is ignored, new development and utilization will bring more ecological loss.
### Table 1. Initial population evaluation results.

| Scheme | Comprehensive benefit | Ecological value after development | Economic benefit | Ecological loss | Ecological value with non-development |
|--------|-----------------------|-----------------------------------|-----------------|----------------|---------------------------------------|
| Current | -2.12                 | 6.35                              | 9.23            | 11.35          | 17.70                                 |
| T21    | -1.43                 | 7.89                              | 12.83           | 14.26          | 22.15                                 |
| T22    | -0.99                 | 7.69                              | 12.88           | 13.87          | 21.56                                 |
| T23    | -2.03                 | 8.28                              | 12.92           | 14.95          | 23.23                                 |
| T24    | -0.70                 | 7.51                              | 12.85           | 13.55          | 21.06                                 |
| T25    | -1.93                 | 8.18                              | 12.87           | 14.80          | 22.98                                 |
| T31    | -2.02                 | 6.36                              | 9.31            | 11.33          | 17.69                                 |
| T32    | -2.04                 | 6.44                              | 9.40            | 11.44          | 17.88                                 |
| T33    | -1.97                 | 6.21                              | 9.06            | 11.03          | 17.24                                 |
| T34    | -2.02                 | 6.41                              | 9.40            | 11.42          | 17.83                                 |
| T35    | -2.04                 | 6.40                              | 9.37            | 11.41          | 17.81                                 |
| T51    | 29.64                 | 90.22                             | 67.20           | 37.56          | 127.78                                |
| T52    | 32.66                 | 80.67                             | 66.81           | 34.15          | 114.82                                |
| T53    | 31.64                 | 76.06                             | 66.22           | 34.59          | 110.64                                |
| T54    | 35.08                 | 73.15                             | 67.38           | 32.30          | 105.46                                |
| T55    | 36.12                 | 69.99                             | 67.69           | 31.56          | 101.56                                |

The comprehensive benefits of the fishery sea use growth scheme increased by 4.88% on average, and the ecological loss decreased by 0.24% on average. The growth rate of the comprehensive benefits of the new fishery sea use is lower than that of the industrial and mining sea use, but the ecological loss may be reduced. The main reason for the reduction of ecological loss is that the new fishery occupies a small part of the industrial and mining sea use, and the reduction of the scale of industrial and mining sea use reduces the ecological loss of the fishery scheme. The average comprehensive benefits of the fishery sea use growth scheme are far lower than that of the industrial and mining sea use scheme. The higher comprehensive benefits of the industrial and mining sea use scheme bring higher ecological loss; even the ecological loss of the fishery sea use scheme is small, its comprehensive benefit level is low. A dilemma will appear when choosing from these schemes.

The comprehensive benefits of the tourism sea use growth scheme increased by 1658.09% on average, and the ecological losses increased by 199.74% on average. As a new sea area utilization type, under the same scale, the new tourism sea use produced greater ecological loss. The main reason is that the tourism sea use generates higher economic benefit per unit area which further improves the sea area ecological value, even if the ecological damage generated by its development and utilization is lower than the industrial and mining sea use, it causes higher ecological value loss. The new tourism sea use has achieved a significant improvement in the level of comprehensive benefits, and the average level of comprehensive benefits is much higher than that of the schemes for industrial and mining sea use and the fishery sea use. Moreover, the overall comprehensive benefits of the sea area utilization in the research scope are greater than the ecological losses. The tourism sea use growth scheme is not a one-size-fits-all solution. The growth sea use demand of other departments are not met and even occupied, which lead to more sea use conflicts among different departments.

With the increase of the scale of sea use demands, the conflicts between various sea use demands increase. There are 247 sea area units in sea use conflict in the industrial and mining and fishery sea use schemes; and the tourism sea use scheme will lead to a further increase, as 303 additional sea area units were in conflict after the new tourism sea use scheme. The number of sea area units in conflict has accounted for 52% of the total development and utilization units. The sea area utilization schemes planned by different departments will occupy the sea use demand of each other, which also leads to the failure of the realization of the comprehensive benefits maximization of the regional sea area utilization. In the industrial and mining sea use scheme, the number of fishery sea use has been reduced by an average of 45 units; in the fishery scheme, industrial and mining sea use has been reduced by 3 units; in the tourism scheme, the number of industrial and mining sea use has been reduced by 38 units and the number of fishery sea use has been reduced by 20 units. Sea use conflicts...
among various utilization types need to be coordinated.

4.2. Optimal Allocation Results Analysis

In order to make the crossover operator be able to calculate the ecological value of various sea area utilization types under the unexploited situation, the undeveloped scheme was added to the initial population. The crossover rate and mutation rate of parameters of the optimal allocation model were set as 0.8, 0.4, and the number of iterations was 100. The optimal allocation model was run 10 times to obtain 10 optimal results schemes with the highest comprehensive benefit (Table 2).

| Scheme | Comprehensive benefit | Ecological value after development | Economic benefits | Ecological loss | Ecological value with non-development |
|--------|-----------------------|------------------------------------|-------------------|---------------|-------------------------------------|
| g1     | 46.24                 | 60.04                              | 72.58             | 86.38         | 26.34                               |
| g2     | 50.65                 | 46.04                              | 72.58             | 67.98         | 21.94                               |
| g3     | 45.57                 | 61.94                              | 72.58             | 88.96         | 27.01                               |
| g4     | 45.22                 | 64.41                              | 72.58             | 91.78         | 27.37                               |
| g5     | 47.26                 | 57.51                              | 72.58             | 82.83         | 25.32                               |
| g6     | 38.95                 | 82.74                              | 72.58             | 116.37        | 33.64                               |
| g7     | 50.09                 | 48.72                              | 72.58             | 71.21         | 22.49                               |
| g8     | 50.88                 | 47.20                              | 72.58             | 68.91         | 21.71                               |
| g9     | 45.48                 | 62.81                              | 72.58             | 89.91         | 27.10                               |
| g10    | 50.29                 | 49.27                              | 72.58             | 71.56         | 22.29                               |

Compared with the initial population scheme, the optimized scheme has higher comprehensive benefit and lower ecological loss. The results showed that the comprehensive benefits of all the optimal schemes were positive, among which the scheme with the minimum comprehensive benefits increased by 7.81%, the scheme with the maximum increased by 40.84%, and the average increase was 30.28%, compared with the initial population with maximum comprehensive benefits. The maximum value of ecological loss in the optimal scheme was lower than the average value of tourism schemes in the initial population, and the average value of ecological loss in the optimal scheme was 19.14% lower than the average value of tourism schemes.

The optimal scheme coordinated the sea use conflict, and the development and utilization scale of each sea utilization type in each scheme reached the growth of sea use demand of each department. First, crossover operator eliminates the unreasonable development and utilization requirements. In the initial population, if the comprehensive benefit of sea area unit development and utilization is less than the ecological value of the development and utilization, the sea use unit will be assigned the value of non-development after the crossing. The optimal schemes eliminated the industrial and mining sea use near the ecological core area. Second, the mutation operator will randomly compete the layout of various sea use demands under the guidance of conditional constraints. Industrial and mining sea use are redistributed in the sea areas far away from the ecological core area. Due to higher comprehensive benefits, industrial and mining sea use may occupy the initial position of fishery, and the occupied fishery sea use demands will be redistributed under the action of mutation operator in the next iteration.

The optimal results show that each optimal scheme has the same sea area utilization structure, and the difference in spatial distribution results in different comprehensive benefits and ecological losses. Typical schemes in the optimal results are Scheme 2, Scheme 6, and Scheme 8. For Scheme 6, the layout of tourism sea use is closer to the ecological core area, with the greatest ecological loss, it still develops the ecological value of sea area fully under the effective utilization, and has the highest ecological benefit after development and utilization. Scheme 8 has the largest comprehensive benefit and the smallest ecological loss. The comprehensive benefits and ecological losses of Scheme 2 and Scheme 8 are nearly the same. But the cost of non-development of Scheme 2 is lower, and its unit ecological cost yields higher comprehensive benefits. Each optimal scheme realizes the effective utilization of sea are space resources, and the specific scheme can be chosen by the sea area management agency.
5. Conclusion
This paper proposes an optimal allocation method of sea area utilization based on the genetic algorithm. The empirical results of Dengsha Estuary Sea Area show that this optimal allocation method of sea area utilization based on the genetic algorithm can produce the optimal scheme with higher comprehensive benefits and lower ecological losses on the basis of initial scheme. Under the guidance of constraint conditions, the sea use conflict among different departments can be solved by optimizing the layout to fully meet the sea use demand of each department. Under the same sea area utilization structure, optimization alternatives with different spatial layout can be generated to provide more options for sea area management requirements.

The process of optimal allocation of sea area utilization pays more attention to coordinate the relationship between development and ecological protection, which has the following two important features compared with the existing land use optimization method. First, by introducing the unexploited scheme into the initial population and adopting the high crossover rate, it eliminates the utilization types with large ecological loss and unreasonable layout in the initial schemes through crossover operator. Second, the constraint conditions guide the mutation operator to rearrange the unmet development and utilization requirements. The mutation operator can adjust the scale of sea use projects according to the development and utilization requirements and management requirements, so as to realize the intensive sea use.

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