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Theory and Practice in Convergence of Revisions of Marine Functional Zoning at Provincial and Municipal Levels: A Case Study of Revision of Putian Marine Functional Zoning in China

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Abstract

Marine spatial planning (MSP) promotes the realization of marine ecosystem-based ocean management by regulating the spatial and temporal distribution of human activities in the oceans and coastal areas. Marine functional zoning (MFZ), as an implementation form of marine spatial planning in China, is one of the three major systems defined in the Law of the People's Republic of China on the Administration of Sea Areas. Due to most of the advanced maritime countries in the world adopts “bottom-up management”. The upper level of these countries only plays a strategic and policy guide to the lower level, there was no outstanding the contradiction between the upper and lower levels. However, China adopts an “up-bottom management”, and the upper level has clear constraints and restrictions on the lower level. As a result, there are problems in the process of compiling the marine functional zones in different levels, such as inflexible boundary convergence, single spatial function planning, and unreasonable allocation of control indicators. Therefore, in the process of formulating and implementing MFZ, how to make a good convergence between provincial and municipal levels of MFZ, which had become a pressing problem. This paper studies and discusses the three aspects of the convergence of control boundaries, compatibility of different functions, and the allocation of control indicators in the marine functional zones. It proposed a solution for the convergence between provincial and municipal levels of MFZ, and applied it to the revision and practice of MFZ in Putian, China. The results shown that the research program for the convergence of control boundaries, compatibility of dominant and auxiliary functions in marine functional zones and the allocation of control indicators

of provincial and municipal levels in the marine functional zones could realize the effective and reasonable convergence between provincial and municipal levels of MFZ revision. The research results would provide a reference for the revision of provincial and municipal levels of MFZ in other regions of China and the convergence of different levels of MSP in other countries.

Keywords: Marine functional zoning; Establishment convergence; Control boundaries; Dominant function; Control indicators

1. Introduction

Development activities of global maritime are putting increasing pressure on the oceans, including oil-gas resources, wind energy, fisheries, mineral resources and shipping industry. There are two major conflicts between such activities: one is the conflict between the utilization of marine resources and the environmental capacity, which results is a huge and basically irreversible loss of marine and coastal biodiversity; the other is the conflict between various uses of marine resources, such as fisheries industry and wind farms, which is caused by the limited space and quantity of resources [1, 2]. Marine spatial planning (MSP) is a powerful way to resolve these two major conflicts. It promotes the realization of marine ecosystem-based ocean management by regulating the spatial and temporal distribution of human activities in the oceans and coastal areas [3-6]. The ocean management of advanced ocean countries in the world usually adopted "bottom-up management", which would delegate most decision-making power to the middle and lower levels. The highest level was only responsible for the long-term strategy of the organization and major events related to the long-term interests of the organization [7-10]. For example, the marine spatial planning in the United States was divided into three levels: federal, regional, and state. The social-cultural, political, and administrative boundaries were considered according to the boundaries of natural ecosystems to determine the extent of space in different sea areas [11]. Regional management was the management mode of its marine spatial planning, each region had its own independent planning agency for formulated marine spatial planning within the region. In the case of regional overlap, the two regions exchanged representatives to jointly negotiate the completion of the planning [12].

China's ocean management adopts "up-bottom management". Most of the decision-making power was at the highest level of the organization, they were responsible for allocating resources, and when there was a contradiction between the departments, it was mainly coordinated by them. Marine functional zoning (MFZ) system implemented since 2002, it was one of the important control measures for China's current implementation of integrated marine space management plan. It was the basis for guiding marine development, protection and management, and aims to rationally use marine resources, increased development and utilization efficiency, improved quality of the marine environment, maintained marine ecosystem health and promoted the sustainable development of marine resources [13]. The three-levels were adopted by the current MFZ, comprehensively covering all sea areas in China, and also incorporating local marine development and utilization activities into the overall strategic layout of China's marine development and protection [14]. Based on the requirements for ecosystem protection, strengthening the top-down control of the sea area and ensuring the smooth progress of various indicators, targets and measures. The specific partitioning scheme was as follows: (1) First-level: According to the physical geographical regionalization, the China's sea area was divided into five marine functional zones: the Bohai Sea, the Yellow Sea, the East China Sea, the South China Sea and the waters east of Taiwan. The First-level zoning determined the overall management requirements of the sea area [15]. (2) Second-level: According to the characteristics of mesoscale sea area differentiation and the geographical division of the rational development of marine economy in different provinces, the provincial MFZ of the coastal areas was formulated, and the sea area was divided into several concrete marine functional type areas. (3) Third-level: According to the spatial layout of the provincial level marine development and the different characteristics of natural resources and environment in the sea area of each city. Each coastal city had formulated municipal-level of MFZ within the scope of provincial-level of MFZ. Provinces and municipal levels of MFZ divided each sea area into into 8 first-class and 22 second-class marine basic functional zones (Table 1) [16].

The first classification	**The second classification**
1 Agriculture and fishery zone	1.1 Agricultural reclamation zone
	1.2 Aquaculture zone
	1.3 Proliferation zone
	1.4 Fishing zone
	1.5 Aquatic germplasm resources protected zone
	1.6 Fishery Infrastructure zone
2 Port Zone	2.1 Port Zone
	2.2 Channel zone
	2.3 Anchor zone
3 Industrial and urban zone	3.1 Industrial sea zone
	3.2 urban zone
4 Mineral and Energy Zone	4.1 Oil and Gas Zone
	4.2 Solid mineral zone
	4.3 Salt zone
	4.4 Renewable energy zone
5 Tourism and Entertainment Zone	5.1 Tourist Scenic zone
	5.2 Recreation zone
6 Marine Protected Zone	6.1 Marine Nature Protected Zone
	6.2 Marine Special Protected Zone
7 Special use zone	7.1 Military zone
	7.2 Other special use zone
8 Reserved zone	8.1 Reserved zone

Table 1: The current classification of marine basic functional zone.

China's MFZ system had advantages over marine space planning in other countries in the world, for example, high legal status and wide implementation level [17]; However, China adopted "up-bottom management", it required each level to undertake the upper-level of control boundaries, leading functions and control indicators. This leaded to the following problems in the process of formulation and implementation of MFZ [18]: (1) Applicability: As a meso-type provincial-level of MFZ, the boundary was only an approximate position indication, not a precise boundary determined by scientific investigation and argument; However, when it came to the construction of sea for project, it needed to make clear the boundary line through the specific investigation of marine geology, tidal current and wave, so there was often a phenomenon that the boundary of sea for actual project did not conform to the boundary of functional area. The boundary of the marine functional zone that has been demarcated in the implementation of sea area management had a rigid control significance for the project sea, resulting in low adaptability of MFZ. (2) Scientificity: The definition of a certain sea area as a certain functional area type in MFZ often meant exclusivity for other uses when the functional zoning is implemented, which hindered the ocean had a multi-functionality. (3) Rationality: China's MFZ system required that each level must undertake the upper-level of management and control indicators, so that how to assign indicators of various functional types under total area control of reclamation and fisheries became a difficult point. So the convergence between the upper and lower levels appeared particularly important.

The Chinese government launched the third round of revision of MFZ in 2012 [19]. Facing the situation of increasingly fine-grained management of sea areas, the preparation and implementation of municipal level of MFZ had become an indispensable key link in China's MSP. The current sea area management policy of the Chinese government required that the municipal-level of MFZ should maintain the "three consistent principles" of "consistent boundaries of the functional areas", "consistent management requirements of functional areas" and "consistent target indicators" with the provincial-level of MFZ [20, 21]. It is also necessary to meet the actual situation of local sea use, and ensured the development needs of coastal cities, adapted to local conditions, and scientifically innovated. Therefore, in the actual preparation and implementation process, establishing the convergence between provincial and municipal level became a key and difficult point. Due to most of the advanced maritime countries in the world adopt a "bottom-up management". The upper level of these countries only plays a strategic and policy guide to the lower level, there was no outstanding the contradiction between the upper and lower levels. Therefore, there were few theoretical studies on the convergence between upper and lower levels of marine spatial planning or MFZ in the world. There was currently no ready-made experience for reference in the convergence between upper and lower levels of China's MFZ.

In view of the above problems, the research method was based on the indicator method, combined with superposition method, comprehensive method and stakeholder investigation method. This study explored the three aspects of the processing of provincial and municipal level functional zone boundary boundaries, the compatibility of marine leading functions and auxiliary functions, the total allocation of management and control indicators. First of all, breaking through the rigid boundary requirements at the provincial level, improving the applicability of municipal-level of MFZ, and solving the problems of difficult implementation of marine spatial planning in the past (Planning without implementation). What's more, the study of ocean dominant function and auxiliary functions avoided the singularity of using the sea and improved the spatial utilization rate of the sea area. Finally, the method of mathematical model such as a production function method, moving average method, exponential smoothing method, trend line prediction method was adopted. This study calculated the total allocation of the control indicators of reclamation and fisheries areas at the municipal level, met the requirements of fine-grained management of sea areas, and provide a more effective and effective basis for the implementation of MFZ. The above research results were applied to the revision of the new round of MFZ in Putian, Fujian Province, China. The results shown that the research program for the control boundary, leading function and control indicators of provincial and municipal level marine functional zones could realize the effective and reasonable convergence between provincial and municipal levels of MFZ revision.

2. Methods and Theoretical research

2.1 Research methods

The research method was based on the indicator method, combined with the application of superposition method, comprehensive method and stakeholder investigation method.

2.1.1 Indicator method [22]: The specific indicators were: the indicator system specified in the "City Level Guide". In addition, combined with the characteristics of local oceans, the intrinsic attributes in the zoning such as natural conditions, location conditions, environmental conditions, resource conditions, social conditions, and social needs of specific regions meet indicator system that the requirements of national laws and regulations as well as industry standards and norms.

2.1.2 Superposition method [23]: The collected Various types of data were compiled into maps and superimposed with the collected maps (under the same scale), and analyzed and compared according to the principle of functional zoning. And which retained reasonable functionality, discarded unreasonable features, identified dominant features, and proposed compatible features.

2.1.3 Comprehensive method: Compared the natural and social attributes of different sea areas and made a comprehensive trade-off. On the basis of using the index method to determine the applicability of each region to various functions, it could only solve what the region can do, but what should be done and what function was the dominant function, then comprehensive factors needed to be considered. Therefore, the function should be delineated by natural attributes, and the six principles of MFZ should be followed according to social attributes. Which analyzed, compared and judged, and determined the function of the comprehensive economic benefit of the region and the function of the take-off action as the leading function, and removed the function that cannot be compatible with it and discharged the functional sequence.

2.1.4 Stakeholder investigation method [24]: The concept of marine spatial planning argued that stakeholder participation in the marine spatial planning process should be early, regular, and long-term sustainable [25]. Therefore, it is necessary to conducted opinions collection for stakeholders in the practice of the convergence between provincial and municipal levels of MFZ. The communication and coordination of stakeholders mainly included: firstly, propaganda and explanation of laws and regulations; secondly, interaction and influence of functional intervals; thirdly, contribution level of industrial benefits; fourthly, environmental carrying capacity. In addition, the relationship between development-utilization and governance protection issues, recent and long-term benefits, interests between different regions and different industries needed to be explained.

2.2. Theoretical research

2.2.1 Research on the boundary convergence between provincial and municipal levels functional zones: The boundary of functional zoning at provincial levels was only an approximate position indication, not very precise; However, when it came to the construction of sea for project, It is necessary to carried out investigations on marine geology, tidal wave, scouring and silting change, ocean water quality and ecology, in order to determined the feasibility and suitability of the boundary of project sea use, so there was often a phenomenon that the boundary of sea for actual project did not conform to the boundary of functional area. However, the "City-level Guide" required that the boundary of the first-class marine basic functional zone in the municipal and county level of MFZ must be completely consistent with the scope of the first-class marine basic functional zone in the provincial level. The division of the second-class marine functional zones of the second class must be strictly controlled within the scope of the first-class marine functional zones [11]. This regulation had rigid control requirements for the boundary line of the MFZ, resulting in low adaptability of MFZ. Therefore, this study proposed to change the mechanization of the determination of the suitability of MFZ, and the sea area uses argumentation procedure and the impact analysis content to formulated flexible compatibility standards. In order to avoid the normalization of the breakthrough boundary, the use of the sea part of the breakthrough boundary was recommended usage the classified sea area royalty charging standards shall.

2.2.2 Research on compatibility of dominant and auxiliary functions in marine functional zones: Most of the MFZ focused on determining the functional area and its dominant function. The definition of a certain sea area as a certain functional area type in MFZ often meant exclusivity for other uses when the functional zoning is implemented. The management requirements for MFZ are mostly emphasizing gave priority to one function, Its binding effectiveness was manifested in the use of sea area management. The "whether the type of sea is consistent with the type of functional area" was simple and mechanical judgment. Which hindered the ocean had a multi-functionality, and made the use of compatible sea areas ostracized.

(1) Marine protected areas were smaller range of choices marine functional zones, and their functional positioning must be prioritized in the preparation of the zoning. However, the sea area of some marine protected areas was too large, resulting in the failure to obtain reasonable arrangements for other functional

areas [26]. For example, the Dongshan Coral Reef Marine Provincial-levels Nature Reserve in Fujian Province had a large core area and ambiguity of scope definition, which made site selection of sewage pipes in nearby towns subject to the protection zone. Luo Meixue suggested that the management department made reasonable adjustments to the core area of the protected area and then coordinated the contradiction between the two functions [15].

(2) The agricultural and fishery areas were more compatible functions into first-class marine functional zones. If they continued to be subdivided into single-purpose breeding, breeding, aquatic germplasm protection and fishery infrastructure construction, they would be lost flexibility and compatibility with the maritime use.

(3) Some sea areas in the MFZ that were look-ahead plan and would not achieve the specified function types in the near future, and could be set compatibility function. For example, the Minzao industry and the urban sea area in the open seas of Fuding, Fujian Province, were located in remote areas, and the traffic conditions were extremely inconvenient. At present, there was no suitable developable project, but there was currently a breeding phenomenon in the area, so it could be used in the recent sea area use setting breeding as compatible function.

Therefore, in the revision of municipal level of MFZ, in addition to emphasizing the dominant function, the study proposed to increase the formulation of compatible functions. Including permissible marine uses when not use, and compatible use of sea area allowed when using dominant function, in order to achieve more comprehensive and rational use of the sea area.

2.2.3 Research on total allocation of control indicators: MFZ as an important basic system for sea area management, which its core content is the control system. The control system is the most important factor to ensure the realization of MFZ objectives and affect its role. It is mainly composed of text, map control, index control, and whole process control of sea area use [27, 28]. Among them, the index control as a quantifiable evaluation control value, which plays an important role in controlling the scale and intensity of sea area use, adjusting the proportion of sea area use structure and the composition of the sea area development and utilization mode. It is beneficial for guiding the actual operation of zoning management. In the index control, the indicators such as the reclamation area, the sea area for fishery industry, the area of the reserved area, the area of the marine protection area, and the natural shoreline retention rate were mainly controlled. The development and utilization of the ocean was not evenly distributed in space. The cities had different development priorities, development conditions and location conditions. Therefore, it was impossible to decompose the simple machinery of each index into each city on average. How to differentiate and rationally allocate the control ratio determined by provincial zoning, there was a large coordination difficulty. First of all, each city had different levels of supply and demand contradiction between land resources. The “environmental reclamation area” belonged to the competing area among the various control indicators. What’s more, the development time and the leading industries of each city was different, and the distribution of the fishery aquaculture area. It needed to be allocated according to the status quo and resources of fishery seas use in various cities. Finally, due to the sensitivity and particularity of marine protected areas, strict protection systems were imposed on them, thus to limit their development and utilization. However, the addition of marine protected areas has encountered great obstacles in the process of revision of municipal marine functional zones. In summary, the municipal level was difficult to determine the specific standards of control indicators such as protected areas at the municipal level.

In view of this kind of situation, this study proposed to adopt a mathematical model for the control indicators for reclamation, fishery and aquaculture seas and other types of use in actual sea areas. The mathematical models adopted include production function method, moving average method, exponential smoothing method, trend line prediction method, and so on. According to the type of sea area used in the historical period and the future major sea use planning statistics, and analyzing the development trend and establishing prediction and simulation. To meet the target control value to be satisfied after the zoning period was reached, and then divided the control index.

3. A Case Study of Revision of Putian MFZ

3.1 Overview of the study area

This article selects Putian city as the study area, which is located in the middle of the coastal area of Fujian Province whose latitude is between 24°55 '~ 25°45' and longitude is between 118°41' ~ 120°05'. It is adjacent to the east of the Taiwan Strait and the north of Fuzhou, the south of Quanzhou border. It has 11 residential islands and 146 uninhabited islands and 461 reefs. Its island coastline has a total length of about 107 km. Putian city has three major bays: Xinghua Bay (South Bank), Meizhou Bay (North Shore) and Ping Bay. Putian city has a long history and it has now formed a more complete marine economic system includes marine fisheries, port shipping industry, coastal tourism industry and so on.

But its development is also facing challenges. First, the overall level of marine industry is not high. Marine fisheries, aquatic products and processing industry sea salt and other traditional industries still account for an important position; coastal industry is still in its infancy. Second, the port infrastructure can not meet the demand. Port function is single and the overall capacity of collection and distribution needs to be improved. Third, the support role of science and technology is not strong. The development of marine science and technology is weak. Fourth, the carrying capacity of resources and environment is limited. Industry, ship, sewage and high-density farming pollute the marine environment. Fourth, the carrying capacity of resources and environment is limited. Industry, ship, sewage and high-density farming pollute the marine environment. Fifth, the marine management system remains to be straightened out. Development management and control of pollution need to be further strengthened.

3.2 The practice of boundary convergence between provincial and municipal MFZ

In the investigation and surveying on the current situation of sea area use aimed to the revision of Putian municipal MFZ, the marine functional zone boundary of Fujian provincial MFZ had been broken through by the present situation of sea area use or need to be surpassed by the demand of sea area use. According to the conditions of sea resources and the present situation of sea area use, combing with the revised guidelines of provincial and municipal MFZ, some municipal-level marine functional areas need to be adjusted and added appropriately, which involves the sea area use of key provincial projects and industry, important ports, key transportation infrastructure projects and town construction. Specifically, it should be treated as follows:

3.2.1 Large-scale breakthrough at provincial-level division of the first class boundary: Marine functional areas need to be adjusted following the principles of intensive and economical sea area use, if they will be occupied by key provincial projects in large scale. One of the examples is the new Cheng-feng Industrial and Urban Zone. According to "Putian second five plan", the region will become the new gathering area of Putian port industry in the future. Furthermore, the comprehensive status of the sea should be considered fully from the two aspects of the region's natural and social attributes and other factors such as industrial park location and the rationality of sea area use, so that the new Cheng Feng Industrial and Urban Zone came from the Xinghua Bay Reserve Zone had been added into the Putian municipal MFZ (Figure 1).

Figure 1: Adjustments comparison(left: provincial zoning, right:municipal zoning).

Another example is the new Nanri Island Tourism and Entertainment Zone. Nanri Island Tourism and Recreation Zone came from Nanri Island Agricultural and Fishery Zone had been adjusted into the Putian municipal MFZ, which is conducive to the development of high-end marine tourism and the full use of Nanri Island's location advantages and excellent port resources (Figure 2).

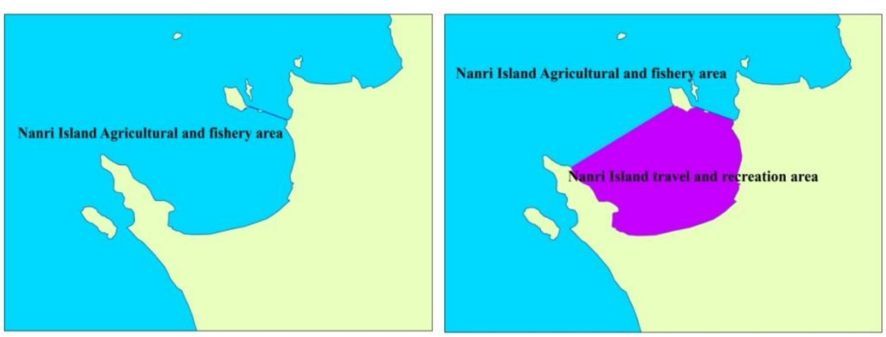

Figure 2: Adjustments comparison(left: provincial zoning, right:municipal zoning.

3.2.2 Small-scale breakthrough at provincial-level division of the first class boundary: In principle, if the boundary of provincial marine functional zone needs to be broken through in a small scale, it can only be applied to the construction of new coastal countryside, road construction, sewage treatment projects, fishing harbor shelter and other projects involving public needs, livelihood projects, disaster prevention and mitigation, and the breakthrough area should be less than 5 hectares.

3.2.3 Setting up of special utilization zone: Provincial Technical Requirements for the Establishment of Marine Function Zoning stipulates that special utilization zones such as sewage outlets, bridges, tunnels, submarine pipelines and pipelines are not set up in provincial marine function zoning. However, the above-mentioned special utilization zones will be set up in municipal level of MFZ, due to the need of increasingly fine-grained management of sea areas.

3.3 The handling of compatibility of dominant and auxiliary functions in marine functional zones

3.3.1 Compatibility between industrial and urban zone and other sea area use: It is required to ensure that the sea area used for industrial and urban construction for which without special requirements, and compatible with Sea-using activities that do not damage the functions of industry and urban construction. When factual reclamation exists, it is required to be compatible with the current types of sea area use in the absence of industrial construction and to coordinate the development and utilization sequence. For example, the cultivated land area already existing in the new Cheng-feng Industrial and Urban Zone will become a new agglomeration area of coastal port industry in Putian City in the future. Therefore, part of the Xinghua Bay Reserve Zone in the provincial functional zoning had been adjusted to Chengfeng Industrial and Urban Zone, which need to compatible with existing agricultural cultivated land.

3.3.2 Compatibility between agricultural and fishery zone and other zones: According to the natural and social attributes of different agricultural and fishery zones, combined with the current situation of sea area use and the development direction in the future, agricultural and fishery areas can be compatible with some functional zones involves coastal tourism, recreational fishery, Traffic Pier to connect Land and Island, shelter dock, new energy, marine pasture and marine protected areas. For example, Nanri Island Agricultural and Fishery Zone are required to ensure unclosed fishery farming, and compatible with shelter areas, new energy industry areas and coastal tourism areas. Which should be pointed out is that the reclamation area existed in the south of Nanri Island can be compatible with marine pasture infrastructure construction areas.

3.3.3 Compatibility between tourism and entertainment zone and other zones: Tourism and Entertainment Zone can be compatible with other functional zones which do not interfere with its own functions, includes shelter, anchorage and new energy. For example, the requirements of Nanri Island Tourism and Entertainment Zone is to plan and construct tourism infrastructure, which is compatible with shelter anchorage before construction.

3.3.4 Compatibility between mineral and energy zone and other zones: Mineral and Energy Zone can be compatible with fishery seas. For example, Jiangdi Mineral and Energy Zone are required to ensure the sea demand for expansion of salt farms, and compatible with fishery seas. At the same time, fishery production activities must ensure the safety of salt mining and production.

3.3.5 Compatibility between port zone and other zones: Port Zone can be compatible with coastal industrial areas. When factual reclamation exists, Port Zone can be compatible with current types of sea area use before the implementation of port construction. One of the examples is Panyu Port Zone, which is similar to Shimenao Port Zone and Putou Port Zone.

3.3.6 Compatibility between reserved zone, Marine Protected Zone and other zones: Reserved Zone can be compatible with the Transportation and fishing areas. For example, Xinghua Bay Reserved Zone is required to ensure the natural breeding space of fishery resources, and compatible with traffic, fishing port construction and other basic infrastructure construction about people's livelihood. Marine Protected Zone can be compatible with the tourism and entertainment areas, fishery infrastructure areas, submarine pipeline areas and transportation areas. One of the examples is Meizhou Island Marine Protected Zone.

3.4 The handling of total allocation of control indicators

The date of reclamation area, fishery area, reserved area, marine protected area and natural coastline retention rate need to be strictly restricted in the MFZ [29]. According to the "Division of Marine Functions in Fujian Province (2011-2020)", through its implementation, the province's scale of reclamation will be controlled within 33350 hm^2 by 2020 while the mariculture area will not be less than 15.3 million hm^2 and the area of marine protected area is not less than 11.9% of the total zoning area and the reserved area is not less than 10% of the all [30]. So the municipal of MFZ should be adjusted under the prediction and assessment of the various functional areas. The reclamation area and fishery farming area need to be accounted when Putian municipal MFZ is formulated.

3.4.1 The convergence of reclamation control index: The reclamation potential assessment method and proportional growth method are used to forecast reclamation demand in Putian City. Table 2 shows the main types of reclamation projects and areas in Putian City in the past ten years. It can be seen that the reclamation area of Putian City has increased year by year, and the added value reached its peak in 2010 with increasing by 55%.

Year	**Industrial use sea**		**Transport by sea**		**The increasing size of reclamation area every year (hm^2)**	**The total reclamation area (hm^2)**
	Number	Area (hm^2)	Number	Area (hm^2)		
2005	1	47.93	0	0.00	47.93	223.67
2006	2	80.47	0	0.00	80.47	304.14
2007	0	0.00	5	98.72	98.72	402.86

2008	2	88.62	1	37.32	125.94	528.80
2009	4	74.66	4	140.01	214.67	743.47
2010	11	319.61	4	100.90	420.51	1163.98
2011	5	88.86	5	87.85	176.72	1340.69
2012	4	136.09	1	44.00	180.09	1520.78
2013	5	180.65	1	1.51	182.16	1702.94
2014	8	185.94	0	0.00	185.94	1888.88

Table 2: Reclamation area in Putian from 2005 to 2014.

3.4.1.1 Reclamation potential assessment method:

(1) The Assessment of reclamation intensity

The reclamation intensity refers to the reclamation area (hm^2) carried by the unit shoreline length (km). The length of the coastline in Putian is 336 km. Through calculating the reclamation intensity from 2005 to 2014, The results are shown in Figure 3. From Figure 3 and Table 2, it can be seen that the reclamation area of Putian is 1888.88 hm^2 at the end of 2014 and its reclamation intensity is R=5.62.

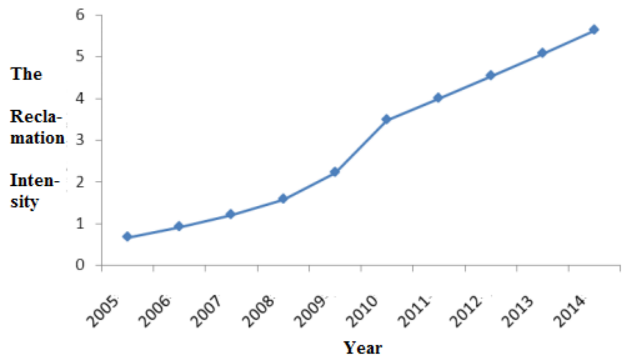

Figure 3: Reclamation intensity from 2005 to 2014.

(2) The potentiality of reclamation

According to the reclamation intensity scale (Table 3), it can be seen that the reclamation intensity of Putian City is grade I so the reclamation pressure is slight and the development potential is large. This paper regards Grade III of the reclamation intensity (50 hm^2 per kilometer of coastline) as the critical level of environmental health of coastal resources. It is considered that when the reclamation intensity is lower than Grade III, the reclamation pressure is affordable. The reclamation potential is calculated as:

$$P=S_{III}-S$$

Where P: the potential reclamation; S_{III}: the largest affordable reclamation capacity of the third level strength; S: the current volume of reclamation.

Therefore, based on the reclamation of the potential assessment model, the reclamation potential in Putian is:

$P=50\ hm^2 \cdot km^{-1} \times 336\ km-1888.88\ hm^2=14911.12\ hm^2$.

$R/(hm^2 \cdot km^{-1})$	Grade of Strength	The significance of index system
$0 \le R \le 10$	I	Slight Reclamation pressure and great potential for development
$10 \le R <20$	II	Low Reclamation pressure and certain potential for development
$20 \le R <50$	III	Certain Reclamation pressure and influence for further development
$50 \le R \le 100$	IV	Strong reclamation pressure and Sea reclamation should be focused on saving and intensive use
$R \ge 100$	V	Very strong reclamation pressure, and it should not be allowed to have new reclamation projects and if necessary should fill the existing reclamation area first.

Table 3: Reclamation intensity level.

(3) Establishment of regression equation

According to the historical data of the region for linear regression analysis (Figure 4 and Table 4), X_{2005} is set to one and the time series was regarded as an independent variable to calculate the trend line equation:

$Y=1.843+137.711X+5.786X^2$

Where Y: The estimation value of reclamation area; X: The change of time.

The total potential reclamation P is affordable for 29 years. The estimation of reclamation area will reach 3686.435 hm^2 in 2020.

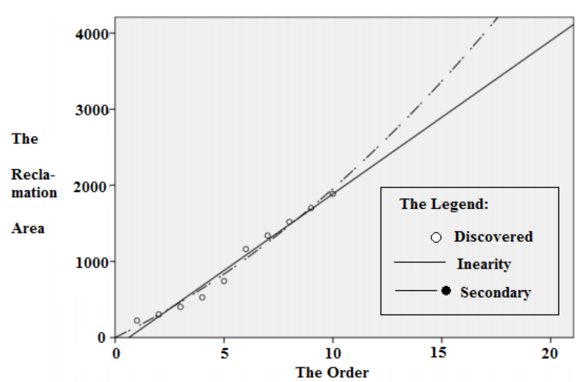

Figure 4: Reclamation areas regression curve.

Equation	Model summary					Estimation of parameter		
	R	F	df1	df2	Sig.	Constant	b1	b2
Linear	.976	328.394	1	8	0.000	-125.455	201.359	-

Secondary	.981	184.445	2	7	0.000	1.843	137.711	5.786

Table 4: Model summary and parameter estimates.

3.4.1.2 Proportional growth method: According to "Measures for the Management of Reclamation plans" in December 2011, the amount of reclamation should not exceed 15% of the annual average size of the last three years of land reclamation. The added value of reclamation area is estimated by the reclamation confirmation project approved by Putian City in 2012-2014, and the approved reclamation area was 180.09 hm^2 in 2012 while 182.16 hm^2 in 2013 and 185.94 hm^2 in 2014, so the average value is 182.73 hm^2. The approved reclamation area increased by 15% annually, the estimated reclamation area for 2015-2020 is calculated and shown in Figure 5. It can be seen that that the total area of reclamation by 2020 will increase by 1839.49 hm^2 and the total reclamation area in Putian will be 3728.37 hm^2.

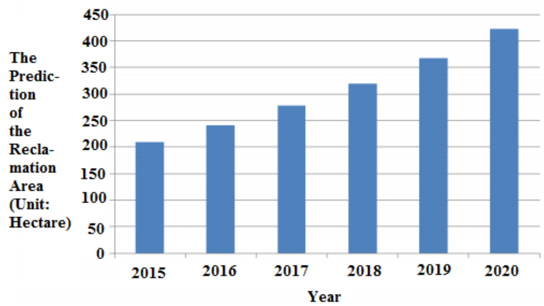

Figure 5: Reclamation areas prediction from 2015 to 2020.

3.4.1.3 The total control target by 2020: Both of the two forecasting results mentioned above are similar between 3600 and 3800 hm^2. Putian city approved two regional spatial planning (1) "Sea planning of Hanjiang port industrial park area construction": planning on reclamation area of 1317.72 hm^2 for 2013-2017; (2) "Shimen Island regional construction sea planning": a planning reclamation area of 994 hm^2 for 2012-2016. According to the total size of the reclamation indexes of the MFZ in Fujian Province, the average area of 6 coastal cities is 5558 hm^2, which is higher than the predicted control value. To sum up in line with the qualitative analysis of the combination of natural and social demand supplemented by the principle of the 2015-2020 period, the total increase in reclamation shall not exceed 4111 hm^2.

3.4.2 The convergence of control indexes in marine aquaculture area: It is necessary to stabilize the marine aquaculture area and ensure the supply of marine aquatic products under the condition of limited marine resources. Therefore, it needs to provide a reasonable keeping objectives in fishery farming area of MFZ. According to the historical area data of fishery farming in Putian city in the last ten years (Table 5), it can be seen that the yield and area of fishery farming are increasing year by year but the unit yield is basically maintained at a stable level. The regression function model was established based on the statistical data of fishery farming area from 2003 to 2013. As can be seen from Figure 6 and Table 6, R2=0.877 and F=64.316, which show that the fitting degree between the predicted curve and the actual value is good. Therefore, according to the regression analysis, the regression equation is calculated as follows:

$Y=403X+16241.182$

Where Y: the predicted value of fishery farming area; X: the change of time.

X_{2003} is set to one, and standard error S=527.036. According to the above results, the area of fishery farming in 2020 (X=18) is estimated to be 23495.182 hm^2. According to the total control data of the fishery farming area in Fujian Province MFZ, the average distribution area of 5 coastal cities is 3.05 hm^2, which is higher than the prediction control value [31]. And because the marine fishery is an important part of the marine economy in Putian, the target area of fishery farming should be reserved sufficiently for the development of fishery in the future. Therefore, the area of the fishery farming functional zone is approximately 24000 hm^2.

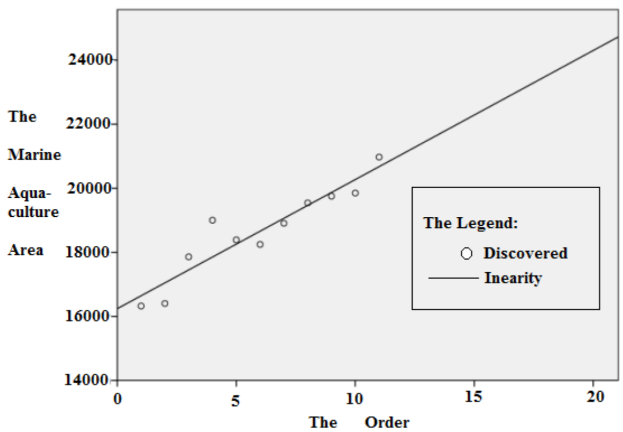

Figure 6: Marine aquaculture area prediction curve.

Year	Fishery Farming Production (t)	Fishery Farming production area (hm^2)	Output per unit (t/hm^2)
2003	479306	16324	29.3620
2004	489201	16404	29.8221
2005	513561	17858	28.7580
2006	533901	19002	28.0971
2007	551822	18387	30.0115
2008	529347	18246	29.0117
2009	551802	18907	29.1851
2010	567950	19544	29.0601
2011	569141	19754	28.8114
2012	587649	19851	29.6030
2013	627700	20974	29.9275

Table 5: Fishery Farming production and area statistics in Putian from 2005 to 2013.

Equation	Model summary					Estimation of parameter	
	R	F	df1	df2	Sig.	Constant	b1
Linear	0.877	64.316	1	9	0.000	16241.182	403.000

Table 6: Model summary and parameter estimates.

4. Conclusion

There are three common problems which include the convergence of control boundaries, compatibility of different functions, and the allocation of control indicators in convergence of revisions of MFZ at provincial and municipal Levels, in China. In order to solve these problems, research methods such as index method, superposition method, synthesis method and stakeholder survey method are applied and three suggestions are put forward. (1) According to the conditions of sea resources and the present situation of sea area use, combing with the revised guidelines of provincial and municipal MFZ, some municipal-level marine functional areas need to be adjusted and added appropriately, which involves the sea area use of key provincial projects and industry, important ports, key transportation infrastructure projects and town construction. Furthermore, the judgment of the conformity between sea area use activities and marine functional zoning can be considered flexibly. (2) On the premise of determining the dominant function of each functional area, compatibility function is taken into account in the management requirements of MFZ. It includes the permitted types of sea area use when the dominant function is not used, and the compatible types of sea area use when the dominant function is used, so as to realize the rational development and protection of sea area resources and achieve the goal of sustainable development. (3) In order to meet the requirements of fine management of sea area use, and to provide an executable basis for the implementation of MFZ, mathematical model methods had been applied to calculate and distribute the areas of reclamation, fishery farming at the municipal level.

The results mentioned above have been applied to the revision and practice of MFZ in Putian, China. The results shown that the research program for the convergence of control boundaries, compatibility of dominant and auxiliary functions in marine functional areas and the allocation of control indicators of provincial and municipal levels in the marine functional zones could realize the effective and reasonable convergence between provincial and municipal levels of MFZ revision. The research results would provide a reference for the revision of provincial and municipal levels of MFZ in other regions of China and the convergence of different levels of MSP in other countries.

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