A Systematic approach to world regional marine resources development models through case studies

Yawen Kong¹, Chunyu Liu², Shuguang Liu¹,³,⁴ and Lei Song¹

¹School of Economics, Ocean University of China, Qingdao 266100, China; ²Graduate School of Arts and Sciences, Columbia University, New York 10027, USA; ³KRI Institute of Marine Development, Qingdao 266100, China
⁴Corresponding author’s e-mail: 2000046@ouc.edu.cn

Abstract. The marine resources are regarded as the major components of global marine ecosystem within the sphere the earth surface. While the sustainability of regional marine resources is essential for worldwide human-nature co-existence and coordinated development in the long run. Highlighted by principles of modern regional economics, the paper manages to conduct systematic assessment of 12 worldwide cases in 4 categories of coastal zones, islands, offshore waters, as well as high seas & international seabed. Five aspects of indicators are determined in terms of innovation, coordination, adaptation, openness, and sharing during the research. Among the findings of the initial approaches, the coastal zone, high seas & international seabed cases show higher indicator performances than those of near seas and islands, and conservation oriented cases are better in scoring results than those of resource exploitation cases.

1. Introduction

Marine resource and environment system, the main part of surface earth system, is a vital material basis for the development and progress of human society [1]. Sustainable exploitation and utilization of marine resources have become the basic premise for the sustainable development of mankind [2]. The "global commons" nature of marine resources has made them the focus of global economic attention [3]. It is necessary to draw on and evaluate regional marine resource development mode. The development of human civilization is accompanied by the change and transformation of the exploitation of regional marine resources. The Ancient Greek Xenophon discussed the strategic role of the acquisition of marine resources for national economic development [4]. In the Middle Ages, Venice and Genoa broke through “the Braudel Bell Jar” and created the thriving history of a country using Mediterranean Sea resources [5], and “the Hanseatic League” extended the European model of the overall development of land and sea [6]. In modern times, Columbus started the trans-Atlantic Ocean and even the global marine resources development boom [7]. In the 17th century, the East India Company established by Dutch was an early example of the modern capitalism commercially expands the space of marine resources [8]. In the 18th century, Britain achieved the synchronization of the internationalization development of industry and the construction of colonial trade network, and became an important member of the development both in deep and far sea resources [9]. With the profound global division of labor and global environmental change in the 21st Century, the exploitation and protection of marine resources become an important topic of sustainable development, and the research on sustainability of marine resources and environmental protection has been integrated into the mainstream research category of economics [10,11]. The research progress of regional marine resource development is in the stage of conceptual
discussion and case analysis, resulting in the lack of systematic analysis and evaluation on global classic regional marine resource development model. The purpose of the paper is to categorize the characteristics of world typical regional marine resource cases through applying methodologies of regional sustainable economics, and summarize the world regional marine resources development models through case studies. Hopefully this research could lay foundations for further approaches in regional marine resources development studies.

2. Theory and methods

2.1. Theory discussion
The regional marine resource system is an intrinsic part of the earth surface sphere, and has basic characteristics of open complex system. The space-time integrating attribute of marine resource system provides the possibility for systematically studying the marine resource development mode [12]. The land-based living characteristic of human beings objectively cause the difference between human-sea and man-land spatial relationship, enlarging the complex spatial relationship between marine resource object and marine resource exploitation subject [13]. It is a challenge for traditional analysis paradigm of regional economics, which takes land economic activities as the premise of analysis [14]. Therefore, we integrate analysis paradigm of system science into classic analysis of regional economics, and construct an analytical framework of the coupling between regional marine natural resource system and socio-economic development activity system. We regard issues of regional marine resource development as sustainable development issues of regional marine resources and marine economy complex system, and then apply the analytical paradigm of modern regional sustainable development system to study them [15].

Based on existing research results [16], we combine the five state parameters of "innovation, coordination, adaptation, openness, and sharing" with the sustainable development system evaluation method, integrate basic concepts of marine resources development and protection, and try to construct a corresponding evaluation paradigm and index system that is suitable for regional marine resources development system around the world.

2.2. Research methods

2.2.1. Construction of evaluation model. Based on the above-mentioned general theoretical discussion, we formulate an evaluation and analysis program suitable for regional marine resources development: (1) regard the development and utilization of specific regional marine resources as a sea area resource economic system. According to the spatial relationship between human and sea, the development and utilization of specific regional marine resources can be divided into four types: coastal resources development, islands and surrounding waters resources development, offshore waters resources development, as well as high seas & international seabed area resources development; (2) define the spatial boundary of the sea area resource economic system is the location and scope of the selected cases; (3) determine the system parameters that are suitable for the high-quality development of marine resources as evaluation indicators; (4) construct the equation between the development situation / state parameters of regional marine resources and its main indicators, prepare for experts scoring of through providing them with case descriptions, and (5) evaluate regional marine resource development state and models based on scoring results.

Based on the analysis above, the evaluation model of marine resources development state is:

\[ Y = F(X) \]  

\[ X = \{X_1, X_2, X_3, X_4, X_5\} \]  

Here \( Y \) is the marine resources development state. \( X \) represents characteristic factor indexes that affect the development state of regional marine resources, including innovation index of marine resources development (\( X_1 \)), coordination index of marine resources development (\( X_2 \)), adaptation
index of marine resources development ($X_1$), openness index of marine resources development ($X_2$),
and sharing index of marine resources development ($X_3$). Assuming $X > 0$, the increase in any
dimension of characteristic factors will promote the increase of $Y$, and this positive effect satisfies the
marginal diminishing utility.

2.2.2. Evaluation index system. With reference to the construction specifications of the general
evaluation model index system for regional economic development, taking into account the complexity
of regional marine resources, and taking into account the data availability as well as resolution accuracy
of the selected regional sea area, we establish the evaluation index system for regional marine resource
development state ($Y$). The index system structure is divided into three levels. The first-grade indexes
include the degree of innovation in marine resource development, coordination, adaptability, openness,
and sharing (Table 1).

Table 1. The evaluation index system for regional marine resources development state.

| First-Grade Indexes | Second-Grade Indexes | Third-Grade Indexes | Indexes for scoring |
|---------------------|----------------------|---------------------|---------------------|
| Innovation ($X_1$)  | Innovation of development elements | Quality of resource endowment | Area and depth of the sea |
|                     |                      | Capabilities of technology research | Sea water quality standard |
|                     |                      | Capabilities of financial integration | Quality and abundance of marine resources |
|                     |                      | Strength of human capital | Average straight-line distance between the sea and the world's three major economic centers |
|                     | Innovation of development organizations | Innovation ability of leading enterprise | National Marine Science and Technology Innovation Index |
|                     |                      | Innovation capability of industrial cluster | Number of global financial centers |
| Coordinati-         | Construction of collaborative organization | Soundness of organizations | Score of global financial centers index |
| on ($X_2$)          |                      | Linkage mechanism of inter-organization | National average human capital index |
|                     | Level of collaborative activities | Efficiency of collaborative operation | Global influence of leading companies (institutions) |
|                     |                      | Degree of Collaborative Stability | Comprehensive strength of the state in the development (protection) of marine resources |
| Adaptation ($X_3$)  | Degree of environmental adaptation for development | Awareness of environmental changes | Number and influence of organizations, institutions and committees for the conservation of the marine habitats |
|                     |                      | | Meetings between maritime management and protection authorities |
|                     |                      | | Frequency of meetings |
|                     |                      | | Collaboration time between organizations |
|                     |                      | | Authority of the conventions and regulations between collaborative organizations |
|                     |                      | | Number of organizations responsible for exploration and inspection of the sea area |
|                     |                      | | Number of literatures for exploration and inspection of the sea area |
|                     |                      | | Response time of developers to environmental changes |
### 3. Analysis of global classic cases of regional marine resources development

3.1. Selected cases

According to the spatial classification of global regional marine resources development, we select four spatial types: coastal zones, islands and surrounding waters, offshore waters, and high seas & international sea-beds. Based on the principles of significant global impact, balance of spatial classification and development methods, and random distribution of sea areas, 12 regional marine resources development cases were initially selected for analysis and evaluation (Figure 1).

| Similarly | Ability to cope with environmental change | Emergency preparedness of developers to environmental changes |
|-----------|------------------------------------------|----------------------------------------------------------|
|          | Renewal capacity of renewable resources   | Degree of reasonable utilization for renewable resources |
|          | Protection capability of non-renewable resource | Degree of protection for renewable resources |
|          | Cross-border flow of natural elements | Number of marine protected areas |
|          | Cross-border flow of economic elements | Operational effects of marine protected areas |
|          | Openness of industrial division of labor | Maturity of resource development technology |
|          | Openness of institutional cooperation | Natural attributes of ocean energy resources flow |
|          | Participation in the development process | Natural attributes of marine life migration |
|          | Distribution of development results | Degree of funds, technology and talents flow |
|          | Knowledge of the development process | The degree of internationalization of the enterprise |
|          | Degree of overflow of development results | The degree of internationalization of organizations |
|          | Sharing of direct stakeholders | Number of countries participating in the organization |
|          | Sharing of indirect stakeholders | Integrity of the subject's participation in the development or protection process |
|          | | Fairness of results allocation in the development or protection process |
|          | | Number of media reports |
|          | | Degree of knowledge of experts on the cases |
|          | | Availability of marine resource development reports |
|          | | Number of marine resource development reports |
3.2. Costal zones

3.2.1. Marine resources development in the Wadden Sea. The Wadden Sea is a marginal sea in North Sea jointly managed by the Netherlands, Germany and Denmark. Its vast intertidal zone is a habitat for more than 10,000 species. Facing conflicts of ecological and economic interests, such as overfishing led to a large reduction of the blue mussel bed in the intertidal zone, three countries established the Trilateral Wadden Sea Cooperation in 1978 [17], which helped improve ecological and economic sustainability by coordinating local residents’ scallop farming, underwater natural gas extraction, and coastal tourism activities [18]. The adopted Wadden Sea Plan carries out protective management, banning wild mussels fishing, limiting mussel farming area and the number of fishing licenses, monitoring the reproduction of migratory bird populations, and controlling natural gas extraction capacity [19]. The practice of the protection plan made the sea area as a World Heritage Site by UNESCO in the early 21st century.

3.2.2. Marine resources development in the Irish Sea. The Irish Sea is located between the island of Ireland and the island of Great Britain on the edge of the Northeast Atlantic Ocean, jointly managed by Ireland and the United Kingdom. The annual economic value of the Irish Sea fishery and aquatic products is about 6 billion euros [20], but overfishing has caused the stock of marine resources facing a crisis of collapse. The European Commission formulated the Irish Sea Cod Recovery Plan in 2000, taking measures such as reducing quotas, banning trawl nets, and closing spawning areas, but the high fishing mortality rate made the plan little effect [19]. Then the Joint Nature Conservation Council (JNCC) formulated a marine spatial planning framework for the Irish Sea with fishermen and other stakeholders. However, there are still problems such as fishing in closed time, difficulty in controlling the scale of fishing, and unfair quota transfers [21].

3.2.3. NEPTUNE project on the Pacific Coast of North America. The North-East Pacific Undersea Networked Experiments (NEPTUNE) project is located in the Juan de Fuca plate on the seabed of the Pacific Ocean off the coast of North America. Canada and the USA jointly invested 300 million US dollars for the project. The NEPTUNE-Canada project operated by Ocean Networks Canada (ONC) was put into operation in 2009. It is the first regional underwater ocean observatory project directly connected to the Internet and provides access for laboratories and universities around the world [22]. The project monitors the marine crustal structure and dynamics, assesses the state of marine biodiversity and fishery activities, etc. [23], and serves the maintenance of national marine sovereignty, marine traffic...
dispatch, and marine big data services [24]. The project is a milestone in marine science and provides valuable experience for building submarine monitoring systems in the world.

3.3. Islands and surrounding waters

3.3.1. Establishment of Papahānaumokuākea Marine National Monument. Papahānaumokuākea Marine National Monument (PMNM) is located in the northwestern part of the Hawaiian Islands, covering an area of 362,000 square kilometers. Approved as a UNESCO World Heritage of Nature and Culture [25], the Monument is jointly managed by the U.S. Fish and Wildlife Service (FWS), National Oceanic and Atmospheric Administration (NOAA), and the local government [26]. PMNM protects the natural marine resources, local cultural resources and the heritage of maritime activities [27]. Because the rising sea level and temperature has caused coastline erosion, inundation of islands and reefs, degradation of coral reef ecosystems, and surrounding fishing has interfered with bird foraging and migration, the expansion protected area was established in 2016. But it has an adverse impact on longline fishing operations in local traditional fishing grounds [28].

3.3.2. Mineral resources development of Bismarck Sea in Papua New Guinea. The Bismarck Sea is located in the southwestern Pacific Ocean, covering the waters north of Papua New Guinea, and south of the Bismarck Islands and Admiralty Islands, a typical accumulation area of hydrothermal sulfide in the global seafloor. Nautilus Minerals Ltd. of Canada obtained a mining license issued by Papua New Guinea in 2011. The operation area is located in the Manus Basin, and aims to extract 120,000 tons of copper, a small amount of gold, and other minerals [29]. Nautilus emphasizes that mining activities are far away from the public, the mining operations are short and limited in scope, and has passed expert environmental assessment and other permits [30]. However, in view of multiple conflicts with local communities in the actual trial mining process, the company began to abandon this controversial development plan [31].

3.3.3. Marine resources development of the Indonesian Archipelago. The Indonesian archipelago is located between the Indian Ocean and the Pacific Ocean. It has about one-fifth of the coral reef resources on the earth. Indonesia has approximately 82 billion dollars fishery resources per year [32]. As the main producer of tuna in Asia, destructive fishing methods such as explosives and cyanide has caused the depletion of fishery resources and damage to the coral reef system [33]. The Asian Development Bank and the World Bank provided funds to carry out Coral Reef Restoration and Management Plan (COREMAP) issued by Indonesian Ministry of Ocean Affairs and Fisheries [34], but it didn’t work well. Subsequently, Indonesia promoted a community-participated marine protected area project. It is helpful for conserving island and reef ecosystems, reducing poverty, as well as raising awareness on ecological and economic sustainability [35].

3.4. Offshore waters

3.4.1. Oil and gas resources development of offshore waters in the Gulf of Mexico Basin. The Gulf of Mexico Basin is the third largest petroliferous basin in the world. The United States, Cuba, and Mexico develop its oil through independent or international cooperation. In 2010, the British operating platform near the US shoreline exploded and sank, resulting in oil spill. This serious accident caused more than 10 billion dollars loss to neighboring coastal commercial and aquaculture industries [36]. BP reached a settlement agreement with US federal and local authorities for 18.7 billion dollars and the cost of cleanup, environmental compensation, economic losses, and fines amounted to 54 billion dollars. The incident exposed the lack of logistical, technical, and financial response capabilities, highlighted the importance of deep-sea environmental baseline awareness [37], promoted the establishment of a deep-sea oil spill regional impact assessment system [38], and reflected on the importance of the environmental safety for both international cooperative offshore oil enterprises and the host country [35].
3.4.2. Bluefin tuna culture in the offshore waters of Northwest Australia. The southern waters of Australia and New Zealand are the main living place of southern bluefin tuna with highly migratory characteristics [39]. The declining tuna fishing quota prompted Australia, New Zealand, and Japan to sign the "Convention for the Conservation of Southern Bluefin". Then they established the Commission for the Conservation of Southern Bluefin Tuna (CCSBT), a regional marine fishery management organization of the FAO [40]. To improve the scale and quality of migratory tuna catches, Australia carries out pasture farming of bluefin tuna before harvest in Port Lincoln, which has become an international model for the staged industrial aquaculture and research of deep-sea fish [41]. The marine ranching is facing the dual challenges of international supply and demand with increasing tuna breeding bases. The government has maintained its international leading position by improving the management of the marine ranching [42].

3.4.3. Energy development of British Celtic Offshore Waters. The Celtic Sea is located on the southwest side of Ireland and the United Kingdom. It has huge wind energy, ocean current energy and wave energy brought by sea breeze [43]. The government encourages billion-pound private investors, entrepreneurs, academic institutes, and the public to join in resources development. Especially on the coast of Wales near the Celtic Sea, the government focuses on the development of marine energy industrial clusters, promotes the increase and global expansion of the relevant marine energy value chain [44], promotes the land-sea coordination of marine energy development in the UK through the integration of offshore energy development and terrestrial energy grids [45].

3.5. High seas and international seabed areas

3.5.1. Submarine resources development in C-C Zone. The Clarion-Clipperton Fracture Zone is located in the international seabed area of the Northeast Pacific Ocean. Rich in polymetallic nodules dominated by nickel, manganese, and cobalt, the C-C zone is managed by the International Seabed Authority (ISA) in accordance with the United Nations Convention on the Law of the Sea [46]. The ISA has successively promulgated seabed area development regulations and contract terms since 2016, but not yet effective [47]. By the end of 2018, the ISA had signed 16 contracts for the exploration of polymetallic nodules with contractors from multiple countries and international organizations. However, the huge sunk cost of seabed resource development and coupled with opportunity costs such as damage to the deep sea and seabed ecosystems will make the compensation and restoration technologies very expensive [48]. The social and economic feasibility of seabed mining needs to be reassessed [49].

3.5.2. Establishment of the Ross Sea Marine Reserve. The Ross Sea belongs to the deep bay on the edge of Antarctica. Marine plankton promotes the formation of characteristic marine animal ecological communities of Ross Sea. The Ross Sea is managed by Commission for the Conservation of Antarctic Marine (CCAMLR). Due to the special state of the biological diversity and climate regulation function, coupled with the huge pressure of commercial fishing [50], CCAMLR established the world’s first large-scale marine protected area on the high seas in 2016, becoming an important supporting case of the United Nations for the negotiation of Biological Diversity of Areas Beyond National Jurisdiction (BBNJ) [51]. The establishment, management, and operation of the protected area embodies the determination and actions of the world’s ocean powers to work together for global ocean governance [52].

3.5.3. Conservation and development of Sargasso Sea. The Sargasso Sea is located in the center of the subtropical circulation of the North Atlantic Ocean. The floating “forest” of Sargasso provides food and shelters for the newly hatched red sea turtles in the Atlantic Ocean. It is an endangered European eel and American eel co-laying area [53]. In 2010, the Sargasso Sea Alliance was initiated by the Bermuda government, non-governmental organizations, scientists, and private donors to provide a model for the conservation of high seas [54]. In 2014, the Sargasso Sea Committee was further established in accordance with the Hamilton Declaration, and successively coordinated the management of the sea
area with the International Commission for the Conservation of Atlantic Tunas, the Northwest Atlantic Fisheries Organization, the International Maritime Organization, the International Seabed Authority, etc [55]. The Sargasso Sea Alliance became an observer organization of the United Nations in 2016.

4. Empirical results

4.1. Evaluation process and results
We make a questionnaire with 12 cases descriptions and relevant quantitative background data, and invite 35 experts in the fields of marine resources and regional economics to score online independently. By summarizing the scoring data and the feedback of experts, we obtain the preliminary results of regional marine resources development state (Table 2).

| Marine spatial types | Cases (Exp -Exploration / Con -Conservation) | Score | Total score |
|----------------------|--------------------------------------------|-------|-------------|
|                      |                                            | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ |
| (A) Coastal zones    | (A1) Marine resources development in Wadden Sea (Con) | 3.44  | 4.52  | 4.05  | 4.05  | 3.89  | 19.95 |
|                      | (A2) Marine resources development in Irish Sea (Exp) | 3.24  | 2.58  | 2.72  | 3.19  | 3.33  | 15.06 |
|                      | (A3) NEPTUNE Project on the Pacific Coast of North America (Con) | 4.76  | 3.98  | 3.92  | 4.15  | 3.87  | 20.76 |
|                      | (B) Islands and surrounding waters           |       |       |       |       |       |       |
|                      | (B1) Establishment of Papahānaumokuākea Marine National Monument (Con) | 2.94  | 3.99  | 3.64  | 3.87  | 2.74  | 17.18 |
|                      | (B2) Mineral resources development of Bismarck Sea in Papua New Guinea (Exp) | 3.00  | 1.98  | 2.42  | 2.99  | 2.44  | 13.83 |
|                      | (B3) Marine resources development of the Indonesian archipelago (Exp) | 2.62  | 3.04  | 2.54  | 3.01  | 3.25  | 14.46 |
|                      | (C) Offshore waters                          |       |       |       |       |       |       |
|                      | (C1) Oil and Gas Resources Development of Offshore Waters in the Gulf of Mexico Basin (Exp) | 2.71  | 2.70  | 1.48  | 3.40  | 3.11  | 13.40 |
|                      | (C2) Bluefin tuna culture in the offshore waters of Northwest Australia (Exp) | 3.83  | 3.27  | 3.03  | 3.29  | 3.90  | 17.32 |
|                      | (C3) Energy development of British Celtic offshore (Exp) | 4.21  | 3.28  | 3.26  | 4.25  | 4.11  | 19.11 |
|                      | (D) High seas and international seabed areas |       |       |       |       |       |       |
|                      | (D1) Submarine resources development in C-C area (Exp) | 3.66  | 2.95  | 2.64  | 3.94  | 3.46  | 16.65 |
|                      | (D2) Establishment of the Ross Sea Marine Reserve (Con) | 3.11  | 2.68  | 3.54  | 3.97  | 4.05  | 17.35 |
|                      | (D3) Conservation and development of Sargasso Sea (Con) | 2.39  | 2.46  | 2.80  | 3.47  | 4.12  | 15.24 |

4.2. Results analysis
As shown in Figure 2a and 2b, scores of the four spatial types cases in (A) coastal zones, (B) islands and surrounding waters, (C) offshore waters, (D) high seas and international seabed areas are respectively summed and averaged, and scores of the two utilization types cases in exploitation (Exp) and conservation (Cons, Con) are summed and averaged.
The structural characteristics of the spatial type factors. The evaluation results of the marine resources development state in the four marine spatial types have certain differences (Figure 2b). The score of it from high to low are coastal zones (A), offshore waters (C), high seas and international seabed areas (D), and islands and surrounding waters (B). First, the score of coastal zone cases is overall balanced and outstanding, which means that humans have a deep foundation, sufficient cognition, and strong ability for the development and governance of the coastal zones. Secondly, the high scores of marine resources development state in the high seas and the international seabed area are due to the high degree of openness and continuous sharing. It shows the high openness of the high seas and the international seabed area resource endowment, and reflects people's "collective action" efforts to avoid the "tragedy of the commons". Thirdly, the resource-exhausted mining in offshore waters and the environmental pollution tragedies reflected in case studies objectively show the excess production capacity in offshore development process and the lack of environmental response capabilities. Fourthly, the performance of islands and surrounding waters is limited and fragile toward economic development and technical support, unequal resource development benefit sharing mechanism, etc., making it difficult to extract or maintain island resources.

The structural characteristics of the utilization type factor. The types of development and utilization activities also have differences both in overall resource development state and structural factor performance (Figure 2c). First, the overall index scores of conservation-type cases are higher than those of resource mining cases, indicating that resource development is relatively easy, but it is more likely to cause variation or destruction of the resource system. Resource conservation requires effective interaction in all aspects such as innovation, coordination, adaptation, openness, and sharing; Secondly, both types show a high level of openness and sharing, reflecting the high openness and sharing characteristics of marine resources as common pool resources. The cross-border mobility of marine resources also endows the development process with relatively high openness characteristics. Stakeholders share the distribution of the results of marine resource development and conservation; Thirdly, the two utilization types of innovation capabilities are relatively insufficient, indicating that in the process of marine resources utilization, whether it is exploration or conservation, further technology research and development and increased capital investment are required. Fourthly, the score of adaptability indicator for two utilization types are at a low level among the five factors, indicating that all types of marine resources development needs to deal with the complex and huge risk of the natural environment system and its changes.

5. Conclusion

Based on the description and quantitative evaluation of classic cases of global regional marine resource development, preliminary research has drawn the following conclusions:
(1) Regional marine resources development activities bear basic features of a regional resource economic system. But if compared with the general terrestrial resource economic system, the marine resource development is more difficult in coordinating development subject and the development target. The large scale variability of the environment, highly dynamics of marine resources, widely opening boundaries, and discrete roles of stakeholders, make the evaluation of the marine resource development more sophisticated than general regional resource development systems.

(2) From the perspective of human-ocean spatial relationship, the order of marine resource development state in coastal zones, islands and surrounding waters, offshore waters, high seas as well as international seabed areas is in line with the research results of relevant authoritative documents, and also in line with the common-sense judgments of the regional economics professionals, laying the foundation for further relevant evaluation research.

(3) The complex system characteristics of the regional marine resource system challenge the basic development model of the resource system, based on the relatively fixed and closed land area. This research needs to be improved and upgraded in at least the following aspects: (a) a standardized and refined indexes system suitable for regional marine resources development; (b) expansion in scales and categories of cases, i.e. traditional marine resources development and new marine resources development, single marine resources development and integrated marine resources development, etc.

Acknowledgement
Foundation item: Study on the impact of sea level rise on the development of key coastal areas in China (No. 15ZDB170). The author would like to thank Wang Fang of China Ocean Mineral Resources R & D Association and Chen Jiliang of the Greenovation Hub for their guidance and evaluation. Thanks for their help in the writing of this article. We take sole responsibility for our views.

References
[1] Steffen W, Richardson K, Rockström J, Schellnhuber H J, Dube O P, Dutreuil S, Lenton T M and Lubchenco J 2020 The emergence and evolution of Earth System Science. Nat Rev Earth Environ 54–63
[2] Neumann B and Unger S 2019 From voluntary commitments to ocean sustainability. Science 363 35-36
[3] Han X C and Wang Y W 2014 Global commons: Ideological origin, conceptual pedigree and academic reflection. Social Sciences in China 188-205
[4] Xenophon 1981 Economics Revenue of Athens translated by Zhang B J and Lu D N Commercial Press 66-67.
[5] Kirk T A 2005 Genoa and the Sea: Policy and Power in an Early Modern Maritime Republic Johns Hopkins University Press
[6] Beerbühl M S 2012 Networks of the Hanseatic League Institute of European History, retrieved
[7] Crosby A W 1987 The Columbian Voyages: the Columbian Exchange and their Historians American Historical Association
[8] Ames G J 2008 The Globe Encompassed: The Age of European Discovery 1500-1700 Upper Saddle River: Pearson Prentice Hall
[9] Smith S 1998 British Imperialism 1750–1970 Cambridge University Press
[10] Romer P M 1989 What Determines the Rate of Growth and Technological Change World Bank Publications
[11] Ostrom E 2009 A general framework for analyzing sustainability of social-ecological systems Science 325 419-422
[12] Tafon R V 2018 Taking power to sea: Towards a post-structuralist discourse theoretical critique of marine spatial planning Environment and Planning C-Politics and Space 36 258-273
[13] Shafer, C S, Inglis G J and Martin V 2010 Examining Residents' Proximity, Recreational Use, and Perceptions Regarding Proposed Aquaculture Development Coastal Management 38 559-574
[14] Hadjimichaelis C and Hudson R 2014 Contemporary Crisis Across Europe and the Crisis of Regional Development Theories Regional Studies 48 208-218
[15] Ferrol-Schulte D, Wolff M and Ferse S 2013 Sustainable livelihoods approach in tropical coastal and marine social-ecological systems: a review Marine Policy 42 253-258
[16] Liu S G, Xu Y J and Wang J Y 2020 An Approach to the Relationship between the River Basin Economic System Opening-up and Sustainable Development: International Experiences and Its Instruction to Yellow River Basin High-quality Development Resources Science 042 433-445
[17] Slob A F L, Geerdink T R A, Rockmann C and Voege S 2016 Governance of the Wadden Sea Marine Policy 325-333
[18] Egberts L and Hundstad D 2019 Coastal heritage in touristic regional identity narratives: a comparison between the Norwegian region Sørlandet and the Dutch Wadden Sea area International Journal of Heritage Studies 1-15
[19] Swart J A A and Windt H J V D 2012 Knocking on Doors: Boundary Objects in Ecological Conservation and Restoration Sustainability Science: the Emerging Paradigm and the Urban Environment Springer
[20] Vincent M A et al 2004 Marine nature conservation and sustainable development – the Irish Sea Pilot. Peterborough: Report to DEFRA by the Joint Nature Conservation Committee
[21] Yates K L 2014 View from the wheelhouse: Perceptions on marine management from the fishing community and suggestions for improvement Marine Policy 48 39-50
[22] Danovaro R, Aguzzi J and Fanelli E, et al 2017 An ecosystem-based deep-ocean strategy Science 355 452-454
[23] Thomson R, Fine I and Rabinovich A et al 2011 Observation of the 2009 Samoa tsunami by the NEPTUNE Canada cabled observatory: Test data for an operational regional tsunami forecast model Geophysical Research Letters 38 1-5
[24] Barnes C R, Best M M R and Johnson F R et al 2013 Challenges benefits and opportunities in installing and operating cabled ocean observatories: perspectives from NEPTUNE Canada IEEE Journal of Oceanic Engineering 38 144-157
[25] Pala C 2009 Scientists laud Bush’s Blue Legacy but want more Science 5911 192-193
[26] Sekoe K A, Halpern B S and Toonen R J 2008 Aquatic conservation: marine and fresh water ecosystems Aquatic Conserve: Marine Freshwater Ecosystem 18 1149–1165
[27] Gleason K 2014 A monumental distance: education and outreach from the most remote archipelago on earth In: D.A. Scott-Ireton (ed.) New York: Between the Devil and the Deep: Meeting Challenges in the Public Interpretation of Maritime Cultural Heritage Springer Science & Business Media
[28] Chan H L 2020 Economic impacts of Papahanaumokuakea Marine National Monument expansion on the Hawaii longline fishery Marine Policy 115 103869
[29] Lee C and Dover V 2011 Mining seafloor massive sulphides and biodiversity: what is at risk ICES Journal of Marine Science 68 341–348
[30] Childs J 2019 Greening the blue? Corporate strategies for legitimising deep sea mining Political Geography 74 1-12
[31] Childs J 2020 Performing ‘blue degrowth’: critiquing seabed mining in Papua New Guinea through creative practice Sustainability Science 15 117–129
[32] Dutton I M and Resosudarmo B P 2005 If only fish could vote: the enduring challenges of coastal and marine resources management in post-reformasi Indonesia politics & economics of Indonesia’s natural resources 162-178
[33] Gurney G G, Cinner J and Ban N C et al 2014 Poverty and protected areas: An evaluation of a marine integrated conservation and development project in Indonesia Global Environmental Change 26 98-107
[34] Sumaila U R, Cisneros-Montemayor A M and Dyck A et al 2012 Impact of the Deepwater Horizon well blowout on the economics of US Gulf fisheries J. Fish Aquat Sci 69 499–510
[35] Oudhuis M and Tengblad S 2018 *BP and Deepwater Horizon: a catastrophe from a resilience perspective*. In Tengblad S Oudhuis M. (eds.) The Resilience Framework Work Organization and Employment Springer Nature Singapore Pte Ltd

[36] Court C, Hodges A W and Coffey K et al 2020 Effects of the Deepwater Horizon Oil Spill on Human Communities: Catch and Economic Impacts. In S. A. Murawski et al. (eds.). Deep Oil Spills. Springer Nature Switzerland AG

[37] Joye B 2015 Deepwater Horizon 5 years on Samantha Science 349 592-593

[38] MacKenzie C A, Baroud H and Barker K 2016 Static and dynamic resource allocation models for recovery of interdependent systems: application to the Deepwater Horizon oil spill *Ann Oper Res* 236 103–129

[39] Tomczak M and Godfrey J 2003 Regional Oceanography: An introduction(2nd Edition). Daya Publishing House

[40] Polacheck T 2012 Assessment of IUU fishing for Southern Bluefin Tuna *Marine Policy* 36 1150–1165

[41] Ellis D, Kiessling I and Benetti D D et al 2016 Ranching of Southern Bluefin Tuna in Australia Chapter-9: Advances in Tuna Aquaculture, Elsevier

[42] Mobsby D, Steven A H and Curtotti R 2020 Australian fisheries and aquaculture outlook 2020 Research by the Australian Bureau of Agricultural and Resource Economics and Sciences

[43] Davies A M and Xing J 2003 The Influence of wind direction upon flow along the west coast of Britain and in the north channel of the Irish Sea *Journal of Physical Oceanography* 33 57-74

[44] Renewable UK 2019 Export Nation: A Year in UK Wind, Wave and Tidal Exports EMEC online report

[45] Higgins P and Foley A M 2015 *Chapter 73: Power system performance of offshore wind in the UK in 2030* In A. Sayigh (ed.) Renewable Energy in the Service of Mankind Vol I. Switzerland: Springer International Publishing

[46] Nijen K, Steven Van Passel S V and Squires D 2018 A stochastic techno-economic assessment of seabed mining of polymetallic nodules in the Clarion Clipperton Fracture Zone *Marine Policy* 95 133-141

[47] Markus T and Singh P 2016 Promoting Consistency in the Deep Seabed: Addressing Regulatory Dimensions in Designing the International Seabed Authority’s Exploitation Code *RECIEL* 25

[48] Boetius A and Haackel M 2018 Mind the seafloor *Science* 359 34-36

[49] Feichtner I 2020 Contractor liability for environmental damage resulting from deep seabed mining activities in the area *Marine Policy* 114 103502

[50] Sykora-Bodie S T, Morrison T H, Sykora S T and Bodie Morrison T H 2019 Drivers of consensus - based decision - making in international environmental regimes: Lessons from the Southern Ocean *Aquatic Conserv: Mar Freshw Ecosyst* 29 2147-2161

[51] Dunn A, Vacchi M and Watters G 2017 The Ross Sea region Marine Protected Area Research and Monitoring Plan SC-CAMLR-XXXVI / 20 Commission for the Conservation of Antarctic Marine Living Resources

[52] CCAMLR 2015 A proposal for the establishment of a Ross Sea Region Marine Protected Area Delegations of New Zealand and the USA CCAMLR-XXXV/29 Rev

[53] Als T D, Hansen M M and MAES G E et al 2011 All roads lead to home: panmixia of European eel in the Sargasso *Sea Molecular Ecology* 20 1333-1346

[54] Laffoley Dd’ A, Roe, H S J and Angel M Vet al 2011 The protection and management of the Sargasso Sea: The golden floating rainforest of the Atlantic Ocean Summary Science and Supporting Evidence Case Sargasso Sea Alliance 44

[55] Gjerde K, Reeve L L N and Harden-Davies H et al 2016 Protecting Earth's last conservation frontier: scientific, management and legal priorities for MPAs beyond national boundaries' *Aquatic Conservation: Marine and Freshwater Ecosystems* 26 45-60