Research Article

Research Status, Hotspots, and Evolution Trend of Decision-Making in Marine Management Using VOSviewer and CiteSpace

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Clarifying the research status, hotspots, and evolution trend of the field of research on decision-making in marine management has certain reference significance for the scholars and decision makers in the field of decision-making in marine management at the theoretical and practical levels. In view of this, this study used 443 pieces of literature retrieved from the Web of Science from 2002 to 2021 as the data source. It adopted the methods of statistical analysis and bibliometric analysis to conduct knowledge mapping visualization analysis in the field of research on decision-making in marine management. The results show that ① there is a high correlation between the level of economic development among countries/regions and the number of publications, and the geographical distribution is closely related to the intensity of research cooperation; ② the research organizations show the characteristics of diversified distribution. Moreover, although there is no noticeable difference in scientific research output among research organizations, influential research organizations such as NOAA, The Nature Conservancy, and so forth have emerged; ③ the author groups as a whole do not show a high cooperation intensity, but there are also scholars with high cooperation intensity within the internal group and other research groups; ④ the research hotspots distribution in the field of decision-making in marine management is relatively extensive and belongs to a multidimensional and multiperspective systematic research. Furthermore, the research focuses on subdivision research hotspots mainly involving ecosystem services, knowledge exchange, decision analysis, multicriteria decision, decision support, fisheries management, specific mathematical models and theories, etc; ⑤ from the perspective of the evolution trend, it can also be found that different clusters show the evolution trend of overlapping common features and individual features.

1. Introduction

Currently, the marine is considered a huge complex and a large-scale system, and it has become an indispensable part of global processes [1]. Under the background of the growing global population and increasing demand for resources, the marine has become a key concern of international exploration and development [2]. Humans are affecting the marine environment through coastal development, unsustainable fishing, pollution, etc., which have led to crises such as invasive species, habitat loss, climate change, and so forth [3]. With the emergence of new industries and increasing population, the utilization of resources and space in coastal and offshore areas may further aggravate the environmental pressure [3]. Therefore, many researchers and institutions have been committed to studying marine management methods that can eliminate the increasing environmental pressure [4]. Over the years, humanity has been widely aware of the importance of a more effective management on the impact of human activities in marine space, and it is now included in the United Nations Sustainable Development Goals [5]. During the United Nations Conference on Environment and Development, Chapter 17 of Agenda 21 explicitly referred that oceans, coasts, and marine resources
need to be properly managed for the future [6]. Moreover, research on marine management has shown a multiple growth trend over the past half-century, and different academic disciplines have played an important role in advancing marine management [7]. It can be seen that marine management is a hot topic in environmental policy, which has attracted the attention of international and national governance institutions, non-governmental organizations, global media, and the wider public [7].

Decision theory, which examines the reasoning underlying the choices of decision-makers or experts, is employed to make an optimal selection from a finite number of alternatives [8]. The emergence of many decision-making methods, such as the Bayesian best-worst method [9], the T-SSGDM method [10], and the hierarchical DEMATEL method [11], etc., further promote and deepen the research of decision-making theory. Meanwhile, decision-making is also an important way of marine management, and effective decision-making plays an important role in the formulation and implementation of marine management plans. In recent years, scholars have focused on decision-making related to oil spill responses [12, 13], coastal management [14, 15], marine protected areas [16, 17], and other aspects that have been carried out in a series of studies, so decision-making in marine management has become one of the research hotspots in the field of marine management. However, the research on decision-making in marine management involves more research results, such as decision-making models and methods, while the research results that systematically comprehensively analyze the literature are relatively few. Furthermore, related research on the systematic review of decision-making in marine management, including decision-making research related to fisheries [18, 19], marine resources [20, 21], etc., which undoubtedly has an important supporting role for decision-making in marine management research. However, the related research on a systematic review of decision-making in marine management by scholars usually focus on a specific field of marine management, while the research results that systematically analyze the literature from the comprehensive perspective of marine management are rare. Moreover, the literature analysis is conducted in the way of summary and induction in a large number of pieces of literature, which is inevitably subjective and debatable. Therefore, it is necessary to systematically analyze the field of decision-making in marine management in the way of scientific measurement.

Bibliometric analysis is a quantitative method, which is mainly used to review and analyze published studies, and it helps scholars to assess academic research in key fields [22]. In bibliometric analysis, knowledge mapping is visualized through data mining, information analysis, scientific measurement, and graph drawing, so as to realize the visualization of knowledge in a certain discipline [23]. Pajek, UCINET, CiteSpace, VOSviewer, and other tools can be used to visualize knowledge mapping [24]. Among them, CiteSpace is a particularly popular knowledge mapping tool, which combines co-citation analysis, collaborative network, and evolutionary trend detection, and can be used to identify research fields and future trends in literature [25]. Moreover, the visualization tool VOSviewer exploited by Eck and Waltman is also extensively applied [26], which can characterize the relationship between the structure, evolution, and collaboration of knowledge domains in the way of drawing scientific knowledge mapping [27].

In view of this, this study combined CiteSpace and VOSviewer software in the way of knowledge mapping visualization to conduct a bibliometric analysis on 443 pieces of literature of research on decision-making in marine management from 2002 to 2021. This study aims to systematically sort out the research status, hotspots, and evolution trends on decision-making in marine management by means of scientific measurement and reveal the research development situation in the field of decision-making in marine management, so as to provide a theoretical and practical reference for this research field. Specifically, on the one hand, this study can provide certain knowledge-based information for follow-up researchers to comprehensively and systematically understand the field of decision-making in marine management, so as to further improve and deepen the theoretical results of the field. On the other hand, this study can provide decision-making aid and reference for decision-makers related to marine management to a certain extent. In summary, this study mainly addresses the following issues:

Q1: What are the trends in the publications of decision-making in marine management research?
Q2: Which countries/regions have the most publications in the field of decision-making in marine management research? What is the level of cooperation between countries/regions? Which research organizations have significant influence in the field of decision-making in marine management research? Which authors are the most prolific in the field of decision-making in marine management, and what is the level of cooperation among authors?
Q3: What are the characteristics of the distribution of research fields on decision-making in marine management?
Q4: What are the research hotspots in the field of decision-making in marine management?
Q5: What are the evolving trends in the field of decision-making in marine management?

The organizational structure of the remaining sections of this study as follows: In Section 2, we describe the methods and data sources used in this study; in Section 3, we analyze the research status of decision-making in marine management from three aspects: publications trends, research activities, and research fields. Meanwhile, the hotspots and evolution trend of research on decision-making in marine management are revealed; in Section 4, we illustrate the main conclusions of this study.

2. Methods and Data Resources

The main research methods adopted in this study include the statistical analysis method and bibliometric visualization method. To be specific, the statistical analysis method was...
used to conduct statistics and analysis on the number of publications of decision-making in marine management (including the annual development trend of the number of publications, number of countries/regions publications, number of research institutions publications), discipline distribution, important documents, etc. The analysis method of bibliometric visualization is mainly supported by VOSviewer and CiteSpace software. On the one hand, VOSviewer was used to visually analyze the national cooperation, research institution cooperation density, and author cooperation of research on decision-making in marine management; on the other hand, CiteSpace was used to visually analyze the keyword co-occurrence, keyword cluster, and keyword timeline of research on decision-making in marine management.

The research data in this study was retrieved from the core collection of Web of Science, and the original data of research on decision-making in marine management was obtained through advanced retrieval. To be specific, the retrieval formula was set as (TS = (marine management or Marine Management or Ocean Governance or Marine Administration) and AK = (decision making or decision-making or decision or make policy or make a strategic decision) AND LA = (English)), the citation index was selected as "All" and the publication date was selected from January 1, 2002 to December 31, 2021. A total of 443 pieces of literature were retrieved through the above retrieval methods, so the retrieved literature was used as the data source of this study.

### 3. Results and Discussion

#### 3.1. Publications Trend Analysis

Changes in the number of publications can be used to analyze the state of development, knowledge accumulation, and maturity of a study [28]. In view of this, according to the retrieval results of Web of Science, this study conducted a statistical analysis on the trend of the number of publications of research on decision-making in marine management. The statistical results are shown in Figure 1.

Figure 1 shows the annual change trend of the number of publications of research on decision-making in marine management in the past 20 years. Based on the overall perspective, it can be seen that the number of publications by research on decision-making in marine management is in a steady development trend of fluctuating and rising during the research period. From the microperspective, it can be seen that the number of publications of research on decision-making in marine management can be divided into two phases: phase one (2002–2010), where, the number of research publications is relatively small and the annual number of publications is less than 20. Therefore, this phase belongs to the slow development phase of research on decision-making in marine management; and phase two (2011–2021), where the number of research publications in this phase shows an obvious growth trend as a whole, which indicates that research on decision-making in marine management has entered a phase of steady development. Among them, the number of research publications in 2011 exceeds 20 for the first time, and the number of research publications from 2012 to 2021 is in a period of rising fluctuations. Especially from 2020 to 2021, the number of publications each year exceeds 50, and the number of publications increases significantly compared with the previous years, which indicates that research on decision-making in marine management has attracted more and more scholars’ attention and recognition.

#### 3.2. Research Actives Analysis

This study used VOSviewer software to analyze decision-making in marine management research activities from three dimensions: country/region, organizations, and authors, thereby exploring the number of documents and cooperation of countries/regions, the number of documents and influence of organizations, and the cooperation of authors and so forth in this field.

##### 3.2.1. Analysis of Country/Region

The number of national/regional publications can measure the contribution of the country/region in the research field [29]. In view of this, the VOSviewer software was used to calculate the number of national/regional documents in the field of research on decision-making in marine management, and the Top 10 countries in terms of the amounts of documents were selected for statistical analysis; the results are shown in Table 1.

As can be seen from Table 1, the top 10 countries in the number of publications of research on decision-making in marine management have 20 or more studies, and these countries play an important role in steadily promoting the development of research on decision-making in marine management. Among them, the United States has the largest number of publications in the field of research on decision-making in marine management. Compared with other countries, the number of publications in the United States is significantly more and almost twice that of the United Kingdom. It can be seen that the United States occupies a relatively dominant position in the field of research on decision-making in marine management. Further analysis shows that developed countries account for 90% of the top 10 published countries in the field of research on decision-making in marine management. Moreover, China, the world’s second-largest economy [30], indicates that research output in the field of decision-making in marine management has entered a phase of steady development. Among them, the number of research publications in 2011 exceeds 20 for the first time, and the number of research publications from 2012 to 2021 is in a period of rising fluctuations. Especially from 2020 to 2021, the number of publications each year exceeds 50, and the number of publications increases significantly compared with the previous years, which indicates that research on decision-making in marine management has attracted more and more scholars’ attention and recognition.
Table 1: Top 10 countries in terms of the number of documents.

| No. | Country         | Documents |
|-----|----------------|-----------|
| 1   | USA            | 142       |
| 2   | Australia      | 73        |
| 3   | England        | 55        |
| 4   | Canada         | 49        |
| 5   | Germany        | 30        |
| 6   | France         | 29        |
| 7   | Italy          | 28        |
| 8   | Spain          | 27        |
| 9   | Peoples R China| 27        |
| 10  | Denmark        | 20        |

Management is highly correlated with the factors of economic development level.

In addition, national/regional cooperation is also an important aspect of the research power analysis, so the VOSviewer software was used to further generate the visual knowledge mapping of the national/regional network in the research of decision-making in marine management, as shown in Figure 2.

Figure 2 has a total of 29 network nodes, 166 links, and 6 clusters. Among them, the network nodes correspond to the country names, the size of nodes has a positive correlation with the number of documents, and the link indicates the cooperative relationship between countries/regions. In addition, the cluster can represent the closeness of cooperation between countries/regions, and the same cluster shows nodes and links of the same color in the network. It can be seen from Figure 2 that the United States, Australia, the United Kingdom, Canada, etc., have large nodes in the network, which is highly consistent with the statistical data of the number of documents in Table 1. Moreover, it can be seen from the network links that there are many links between network nodes in Figure 2, which indicates that the feature of international cooperation in the research on decision-making in marine management is more prominent. Further analysis also shows that the clusters with close geographical locations between countries/regions account for a large proportion in the same cluster, such as the red region in Figure 2, and most of the countries are distributed in Western Europe, such as the green region in Figure 2. The country distribution also shows close geographical characteristics and so forth. Therefore, it can be concluded that the feature of regional cooperation in research on decision-making in marine management is more apparent, and the geographical distribution has a close relationship with the research cooperation among countries/regions in decision-making in marine management.

3.2.2. Analysis of Organizations. The publication pattern of a certain field can be presented by statistical analysis of the number of publications by research institutions (or universities) and by analyzing the research results of key research institutions (universities) in a certain field, we can rapidly discover the research trends [31]. In view of this, the VOSviewer software was used to calculate the amount of documents issued by organizations of research on decision-making in marine management. The Top 10 organizations in terms of amount of documents are shown in Table 2.

As can be seen from Table 2, the distribution of publications among research organizations is relatively balanced, which indicates that there is no apparent difference in scientific research output capacity among research organizations in the field of research on decision-making in marine management. Moreover, these research organizations have made significant contributions to develop research on decision-making in marine management through active exploration of research in this field. From the nature of research organizations, it can be seen that research organizations include not only universities and research institutions but also international government organizations and national government departments, etc., which indicate that the distribution of organizations for research on decision-making in marine management has the property of diversification.

To further explore the influence of the organization for research on decision-making in marine management, the VOSviewer software was used to explore the project density of research organizations. The visual knowledge mapping generated by running the software is shown in Figure 3.

Figure 3 shows the distribution of project density of the organization for research on decision-making in marine management. It can be seen from Figure 3 that the network nodes are distributed in different color areas. The more the network nodes tend to the red area, the more important they are in the network nodes. On the contrary, the more the nodes tend to the yellow area, the less obvious their importance is. It can be seen that NOAA, The Nature Conservancy, University of Oxford, University of Tasmania, University of Western Australia, and other research organizations tend to the red area in Figure 3, which represents their importance in the field of research on decision-making in marine management. Therefore, it can also be reflected that these research organizations have significant academic influence in the field of research on decision-making in marine management.

3.2.3. Analysis of Authors. Author cooperation networks can reflect the cooperation density and cooperative relationship among authors [32]. In view of this, this study analyzed the authors’ cooperation in research on decision-making in marine management and used VOSviewer software to generate the author’s network visual knowledge mapping, as shown in Figure 4.

In Figure 4, there are 24 network nodes and 44 links. Among them, the network node corresponds to the author’s name, and the size of nodes has a positive correlation with the number of authors’ publications. The link represents the cooperative relationship among authors, and the number of links has a positive correlation with the density of authors’ cooperation. In addition, different colors of node labels represent different research collaboration groups. It can be seen from Figure 4 that six main research cooperation groups have emerged in research on decision-making in marine management, and there are certain differences in the
Figure 2: Country/region network visualization.

Table 2: Top 10 organizations in terms of the number of documents.

| No. | Organization                          | Documents |
|-----|---------------------------------------|-----------|
| 1   | NOAA                                  | 16        |
| 2   | The University of Queensland          | 14        |
| 3   | University of Tasmania                | 14        |
| 4   | Jams Cook University                  | 12        |
| 5   | The nature Conservancy                | 12        |
| 6   | IFREMER                                | 11        |
| 7   | University of Western Australia       | 10        |
| 8   | The University of Cape Town           | 10        |
| 9   | Fisheries and oceans Canada           | 9         |
| 10  | University of Oxford                  | 8         |
amount of publications and cooperation intensity among different research cooperation groups. Based on the integral perspective, it can be seen that the number of links between different research cooperation groups is relatively small, which indicates that the author groups of research on decision-making in marine management do not show a high cooperation intensity on the whole. From a local perspective, it can be seen in Figure 4 that there are also authors who have strong cooperation within the internal group and other research groups, such as the scholar Possingham, Hugh P., and the scholar has the highest number of publications in the field of decision-making in marine management. Meanwhile, the scholar not only has a relatively close cooperative relationship with the authors within their research group but also has a research cooperation relationship with other research cooperation groups (e.g., the yellow area and the green area in Figure 4). Therefore, it can be considered that the scholar has strong research abilities and academic influence in the field of research on decision-making in marine management.

3.3. Research Field Analysis. Exploring the distribution of research fields is an effective way to analyze the discipline attribute of research on decision-making in marine management. In view of this, this study showed the top 10 research fields according to Web of Science category statistics based on the literature retrieval results of research on decision-making in marine management. The results are shown in Figure 5.

It can be seen from Figure 5 that research on decision-making in marine management mainly covers the research fields of Environmental Sciences, Environmental Studies, Ecology, etc. Among them, most research results are related to environmental topics in research on decision-making in marine management. Meanwhile, the distribution of research results in related research fields involving ecology, ocean, and other themes is also more, which indicates that research on decision-making in marine management is diversified and extended, and shows the characteristics of interdisciplinary. In addition, further analysis shows that research on decision-making in marine management includes both the research in the fields of Natural Sciences (e.g., Environmental Sciences, Ecology, Oceanography, etc.) and the research in the fields of Humanities and Social Sciences (e.g., International Relations). It also includes the research in the interdisciplinary fields of Natural Sciences and Humanities and Social Sciences (e.g., Operations Research Management Science), which also further confirms that research on decision-making in marine management has the characteristics of interdisciplinary.

3.4. Research Hotspot Analysis. To further reveal the research hotspots and evolution trends of decision-making in marine management, CiteSpace software was used in this study for keyword co-occurrence, cluster analysis, and timeline visualization analysis.

3.4.1. Keyword Co-Occurrence Analysis. Keywords in the literature reveal the relationship between the research objects and the main content of the research [33]. Meanwhile, researchers can extract valuable information from keywords in the literature, e.g., goals, methods, and viewpoints [34]. Moreover, co-occurrence analysis can quantitatively analyze information media and it also enables knowledge service and mining [35]. In view of this, CiteSpace was used to analyze
the co-occurrence of keywords in research of decision-making in marine management, thereby generating the visual knowledge mapping of co-occurrence of keywords, as shown in Figure 6.

In Figure 6, there are 337 network nodes and 1156 links, and the network density is 0.0204. Among them, the size of nodes has a positive correlation with the frequency of keywords, the thickness of the link between nodes indicates the degree of co-occurrence of keywords, and the value of network density can reflect the degree of connection between keywords from the integral perspective. It can be seen from the network nodes in Figure 6 that the largest keyword node of research on decision-making in marine management is “management,” and the keyword nodes such as “conservation,” “decision making,” “decision support,” “impact,” “model,” etc. are also relatively large. Due to the high frequency of occurrence, these keywords can reflect research hotspots of decision-making in marine management to a large extent, thus becoming an important node in the visual co-occurrence network of research on decision-making in marine management. According to the link between the nodes in Figure 6, the line between keywords with large nodes in the visual knowledge mapping is relatively thick, such as between the nodes “conservation” and “biodiversity,” “system.” The co-occurrence and close connection between these keywords can reflect the relatively concentrated research content of decision-making in marine management to a certain extent. In addition, based on the perspective of network density analysis, it can be seen from the overall layout of the keyword co-occurrence network in Figure 6 that the internal structure of the visual knowledge mapping is relatively close, but its external structure has relatively many branches and there exist some scattered keyword nodes. To a certain extent, it can reflect that the main content of research on decision-making in marine management is relatively concentrated, and there are many research branches.

Frequency analysis of keywords focuses on mining hot topics related to a specific research field and clarifying its development trend [36]. Therefore, to further explore the research hotspots information in the field of decision-making in marine management, combined with the operation results of CiteSpace software, the related data of the top 15 keywords with the frequency of occurrence were counted. The results are shown in Table 3.

According to the frequency analysis in Table 3, the keyword “management” appears most frequently, 119 times. Combined with the analysis from the perspective of retrieval strategy, the keyword “decision making” also has a high frequency of occurrence, which is consistent with the retrieval strategy of this study. However, the keywords with the highest frequency and relatively high frequency, such as “management,” “fishery,” “marine protected area,” etc., are not “Marine management” or “Ocean management,” etc. Furthermore, this also proves the effectiveness of marine management retrieval with the subject as the entry point. In addition, it can be seen from the frequency distribution of keywords in Table 3 that the frequency distribution of other keywords except “management” is relatively uniform, which indicates to some extent that there are many segmentations in research on decision-making in marine management.

Centrality is the key element to measure the importance of network nodes. The value of centrality is a positive correlation with the importance of nodes in the network [37]. Meanwhile, keywords with a centrality value >0.1 represent hot topics in the research field [38]. Combined with the analysis of keywords centrality, it can be seen that the keywords centralities >0.1 in Table 3 are “decision
support,” “model,” and “decision support system,” which show the importance and popularity of these keywords in the research of decision making in marine management. Especially when it comes to decision support, the keyword “decision support tool” also appears in Table 3 with relatively high frequency and centrality. It can be seen that the relevant research of decision support systems or tools is an important hotspot of research on decision-making in marine management.

Focusing on the perspective of the year when keywords appeared, it should be noted that the label “Year” in Table 3 represents the year in which keywords first appeared. According to the statistics of keywords corresponding to the first occurrence year, the high-frequency keywords of research on decision-making in marine management mainly concentrated in 2002–2012. Among them, there are many high-frequency keywords that appeared between 2002 and 2006, especially “framework,” “system,” “model,” and other keywords focusing on the type of basic research, which lays an important theoretical and technical support for the field of research on decision-making in marine management. There are relatively few high-frequency keywords from 2007 to 2012, and the characteristics of keywords in this phase are strongly correlated with applied research on decision-making in marine management.

In summary, research on decision-making in marine management covers a relatively wide range of research hotspots. It involves both theories and methods in technologies of research on decision-making in marine management, such as the information represented by high-frequency keywords “framework,” “model,” “system,” “decision support system,” “decision support tool,” etc., as well as goals of decision-making in marine management, such as the information represented by keywords “conservation,” “biodiversity,” and so forth. It also involves important factors considered in decision-making in marine management, such as the information represented by keywords “climate change,” “ecosystem service,” etc. Meanwhile, the
application of decision-making in marine management is also one of the research hotspots, for example, the information revealed by high-frequency keywords such as “fishery,” “marine protected area,” and so forth. Therefore, research on decision-making in marine management is a multidimensional and multiperspective systematic research.

3.4.2. **Keyword Cluster Analysis.** Cluster analysis is a method to summarize similar research subjects, so as to obtain representative clusters in related research fields [39]. In the process of scientometrics, cluster analysis can be used to analyze the overall status of the research field from different angles [40]. In view of this, to further explore the main direction of research hotspots on decision-making in marine management, CiteSpace was used to conduct a cluster analysis of the research. Meanwhile, to clarify the main line of research on decision-making in marine management, the top 10 clusters with the largest cluster size were selected for co-occurrence analysis, and the generated keyword cluster visual knowledge mapping is shown in Figure 7.

Figure 7 shows “ecosystem services,” “knowledge exchange,” “multicriteria decision analysis,” “decision analysis,” “decision support system,” and other 10 cluster labels. Meanwhile, the analysis of whether the clustering results are reasonable and effective mainly involves “Modularity Q” and Silhouette indicators. Among them, the modularity value (Q) ranges from 0 to 1, and the closer the value is to 1, the closer the relationship between clusters is [41]. In general, when modularity value (Q) > 0.3, it indicates that the clustering structure is significant [42]. Silhouette value (S) ranges from 0 to 1, and it can be used to evaluate the internal homogeneity of a cluster or to analyze the similarity between a research subject and its cluster by comparing it with other clusters [43]. Moreover, the silhouette value (S) > 0.7 indicates that the clustering is convincing [44]. Combined with the clustering results of the CiteSpace operation, the clustering results of this study show that the Modularity Q value and the Silhouette value are 0.565 and 0.7903, respectively. Therefore, this indicates that the clustering structure is significant and the clustering results are convincing.

To further explore the clustering situation of research on decision-making in marine management, this study made statistics on the cluster data calculated by CiteSpace software, and the results are shown in Table 4.

Table 4 includes indicators such as “Cluster-ID,” “Size,” “Silhouette,” “Mean (Year),” “Label,” etc. Among them, cluster-ID is inversely proportional to size, that is to say, the larger the cluster size is, the smaller the cluster-ID is. Silhouette indicators indicate that the clustering values in Table 4 are generally high, and most of the cluster values are greater than or equal to 0.8. Meanwhile, when the scales between the compared clusters are similar, the larger the Silhouette value (S), the higher is the consistency among the cluster members [45]. Therefore, this indicates that the keywords included in most of the clusters involved in Table 4 have high consistency, which further confirms the reasonable validity of the clustering results in this study. In addition, it can be seen from the “Mean (Year)” index that the average years of cluster labels are concentrated from 2009 to 2013, and especially after 2010, more cluster labels appeared. Combined with the above analysis, it can be seen that there is a large number of high-frequency keywords in research on decision-making in marine management from 2002 to 2006, which is quite different from the corresponding time of cluster labels. The reason is that the cluster labels correspond to the average year, while the high-frequency keywords correspond to the year when they first appeared, so the corresponding year between the two is not contradictory. In summary, it can be considered that the research results from 2002 to 2006 play an important role in promoting research on decision-making in marine management. Meanwhile, after years of development, the research on decision-making in marine management has gradually focused its research direction in the middle phase of the research (around 2011), thus some relatively large research clusters are presented. To deeply analyze research hotspots of decision-making in marine management, the cluster was combined and analyzed by studying the relevant literature. To be specific, it can be seen from Table 4 that the research of ecosystem services(#0) involved in decision-making in marine management has the largest cluster scale compared to the other 9 clusters, so it can be considered that the research of ecosystem services is an important aspect of research on decision-making in marine management. For example, some scholars explored the application or effect of ecosystem service value or economic value assessment in decision-making in marine management [46, 47], some scholars also studied the application of ecosystem services or ecosystem service knowledge in decision-making in marine management [48, 49], etc., and all these research results involved the application of ecosystem services-related research in decision-making in marine management. Therefore, it can be considered that the related research of ecosystem services in the application of decision-making in marine management is one of the hotspots of research on decision-making in marine management. Moreover, knowledge exchange is also a key factor in research on decision-making in marine management. The decision-making in marine management involves the research of knowledge exchange, and its research content is
relatively concentrated. Among them, the related research on overcoming the barriers of knowledge exchange between scientists and policymakers is one of the key points of research on decision-making in marine management, as shown in the literature [21, 50, 51]. Therefore, it can be considered that knowledge exchange is an effective way to assist and enhance the effectiveness of decision-making in marine management. In addition, decision analysis (#2) is an important way and cornerstone of research on decision-making in marine management, which takes decision analysis as the main line to explore the specific decision of marine management. Decision analysis methods involved in research on decision-making in marine management include multicriteria decision analysis (#2), structured decision analysis [52], etc. Among them, there are many research results about the multicriteria decision analysis. The multicriteria decision research (#2 multicriteria decision analysis, #8 multi-criteria decision models) of decision-making in marine management mainly involves the related research on the analysis of the multicriteria decision and the multicriteria model. Among them, the research on multicriteria decision analysis includes the application of multicriteria decision analysis in the evaluation of remediation technologies for contaminated marine sediments [53], harmful algal bloom management [54], zoning of Hangzhou Bay ecological red line [55], etc. Moreover, the research on the multicriteria decision model is also an important aspect of research on the multicriteria decision. For example, some scholars studied the multicriteria decision model of Management of Tropical Coastal Fisheries [56], and some scholars explored planning in fisheries-related systems as multicriteria models for decision support [57]. The research on decision support (#4 decision support system, #7 decision support) of decision-making in marine management mainly includes the related research of decision support tools and decision support systems of decision-making in marine management. Among them, regarding research on decision support tools of decision-making in marine management, scholars explored the development or design of decision support tools [58–60], the utility of a decision-support tool [61], performance, and end-user preferences [62], etc. Moreover, the research on decision support systems for marine management involves more research results on the development or design of decision support systems through the development or design of decision support systems, which are primarily used in automatically determining the route priority of vessels entering/exiting the ports [63], integrated coastal-zone management for sustainable tourism.
[64], marine spatial planning [65], marine space resource utilization [66], the management of contamination in marine coastal ecosystems [67], monitoring marine management areas [68], etc. In terms of specific application fields of decision-making in marine management, according to the cluster labels in Table 4, fisheries management (#5) is an important aspect of the practice of decision-making in marine management. Therefore, it can also be considered that there is much research funding on the application of methods, models, etc., of decision-making in marine management in the field of fisheries management. In addition, combined with the clustering labels in Table 4, it can be seen that the research involves specific mathematical models and theories, which are also one of the research hotspots of decision-making in marine management, e.g., Bayesian belief network (#6) and machine learning (#9). The application of these methods and technologies in the field of decision-making in marine management provides important support for further deepening research on decision-making in marine management.

3.4.3. Research Evolution Trend Analysis. The timeline view covers a series of keyword clustering, which is used to explore the evolution trend of clustering in a certain period and the time when landmark literature appears in the overall clustering process [69]. In view of this, based on the previous keyword cluster analysis, this study adopted CiteSpace software to analyze the evolution trend of research on decision-making in marine management and generated a timeline view of keywords, as shown in Figure 8.

The information on cluster labels, keyword nodes, links, years, etc., is contained in Figure 8. Among them, each cluster axis shows the keyword node that appeared for the first time in the cluster, the link between nodes represents the co-occurrence relationship between keywords, and the year corresponds to the time when the keyword first appeared.

According to the year when keywords first appeared, among the 10 clusters shown in Figure 8, high-frequency keywords that appeared earlier for the first time include decision analysis (#3), decision support system (#4), decision support system (#7), etc. For example, the keyword management appeared in the decision analysis (#3) cluster in 2002, and the keyword framework appeared in the decision support system (#4) cluster in 2002. Further analysis shows that there is a line relationship between these keywords and some subsequent keyword nodes on the cluster axis. In other words, some scholars also take these keywords to conduct research as the main line in the subsequent research process. Meanwhile, some high-frequency keyword nodes also emerge on the clustering axis, such as the keywords decision support tool, marine protected area, and others in the cluster of the ecosystem services (#0), the keywords such as conservation, climate change, etc. appeared in the cluster of the multicriteria decision analysis (#2), and the keywords such as management, uncertainty, etc. appear in the cluster of decision analysis (#3). These important keyword nodes lay an important foundation for expanding the research hotspots’ direction of their clusters.

According to the time distribution of clustering keyword nodes in Figure 8, more high-frequency keywords emerges in the cluster (#0 ecosystem services) from 2010 to 2012, e.g., ecosystem-based management, marine protected area, ecosystem services, which indicates that the related research on ecosystem services begin to attract the attention of scholars during this period. In 2016, the high-frequency keyword marine appeared. After 2016, the high-frequency keywords decreased, but the number of keyword nodes was still more, and there were many links with nodes of an earlier time on the cluster axis, which indicated that decision-making in marine management involved related research of ecosystem services gradually expands from concentrated research direction to subdivision fields with the evolution of time. Moreover, there are also #2 multicriteria decision analysis, #3 decision analysis, and #5 fisheries management with similar evolution rules. Among them, the evolution characteristics of cluster #2 and cluster #3 are the most obvious. For example, in cluster #2 high-frequency keywords appears in 2005 and 2008, and in cluster #3 also high-frequency keywords appeared in 2002 and 2008, which indicates that the research subjects are concentrated during this period. However, the high-frequency keyword nodes decreased while the number of relatively small nodes increases over time, which further confirms the evolution rule of research subjects extending to the subdivision fields. In comparison, some clusters show different evolutionary rules, e.g., clusters #6 Bayesian belief network, #7 decision support, #8 multicriteria decision models, and these shows large keyword nodes at a certain time point during the research period, which indicates that the research has been paid attention to and focused during this period. However, the number of keyword nodes decreased significantly after showing the high-frequency keyword node, and there were relatively few links between keyword nodes and previous keywords, which indicates that the research on these clusters involved in decision-making in marine management becomes more popular and focused at a certain time point. However, with the evolution of time, scholars pay less attention to these clusters. Moreover, further analysis shows that the number of keyword nodes in the clustering axis of #1 knowledge exchange, #6 Bayesian belief network, and #8 multicriteria decision models are very small from the evolution trend of research on decision-making in marine management in the past three years (2019-2021). Meanwhile, there is almost no link with the previous keyword nodes, which indicates that the research related to these clusters of decision-making in marine management is less concerned. On the contrary, the more popular clusters in research on decision-making in marine management in recent three years include #0 ecosystem services, #2 multicriteria decision analysis, #3 decision analysis, #4 decision support system, #5 fisheries management, and #9 machine learning. Especially for clustering #3 decision analysis and #9 machine learning, there are more obvious keyword nodes on the cluster axis, such as keyword node emission, risk analysis, optimum inspection, etc. These nodes on the cluster axis are relatively concerned, and the related researches related to these keywords are likely to be the continuous research hotspot of
research on decision-making in marine management in the future. In addition, there are some iconic keywords in the cluster, such as the keyword node marine protected area on the clustering axis of the cluster (#0 ecosystem services). It has many links with the front and back nodes, which indicates that the keyword plays a role of bond and bridge in the research of ecosystem services on decision-making in marine management. For example, the keyword node framework on the clustering axis of the cluster (#4 decision support system) appears in the early research phase of the cluster, which plays an important role in supporting the research and development of decision support systems for decision-making in marine management.

In summary, different clusters of research on decision-making in marine management show different evolution rules, but some clusters also show similar evolution characteristics. Meanwhile, the keyword nodes that have attracted more attention appear on the cluster axis and the iconic keyword nodes of some clusters in the recent three years, which may be important keywords worth paying attention to the future research on decision-making in marine management.

4. Conclusion

This study explored the research status, hotspots, and evolution trend of decision-making in marine management research from the perspective of the trend of publications, research actives, and research fields; took keyword co-occurrence and cluster analysis as the mainline to reveal the research hotspots of decision-making in marine management; based on keyword clustering analysis, the timeline of keywords is analyzed to clarify the evolution trend of decision-making in marine management research. The main conclusions of this study are as follows:

(1) During the research period, the number of publications of research on decision-making in marine management is in a steady development trend of fluctuating and rising, which can be divided into two phases of slow development (2002–2010) and relatively obvious growth (2011–2021).

(2) The United States, Australia, the United Kingdom, etc., have published a large number of publications in the field of decision-making in marine management. Among them, the United States occupies a relatively dominant position in this field. Moreover, the research on decision-making in marine management shows relatively obvious regional cooperation characteristics among countries/regions. Based on the perspective of research organizations, NOAA, The Nature Conservancy, University of Oxford, University of Tasmania, University of Western Australia, etc., have important academic influence in the field of research on decision-making in marine management. Meanwhile, it can be seen from the number of authors’ publications that the scholar Possingham, hugh p. has the highest number of publications in the field of decision-making in marine management. Furthermore, it can be also seen from the authors’ cooperation that the authors do not show a high cooperation intensity on the whole.

(3) Research on decision-making in marine management focuses on Environmental Sciences, Environmental Studies, Ecology, Marine Freshwater Biology, Oceanography, and other research fields. Among
them, most research results are related to environmental topics. Therefore, research on decision-making in marine management has the characteristics of interdisciplinary.

(4) The research hotspots of decision-making in marine management include the theories and methods technologies of decision-making in marine management, the goals of decision-making in marine management, the important factors considered in decision-making in marine management, the application of decision-making in marine management, etc. Focusing on specific research hotspots, it mainly covers ecosystem services, knowledge exchange, multicriteria decision analysis, decision analysis, decision support system, fisheries management, Bayesian belief network, decision support, multicriteria decision models, machine learning, and other 10 clusters.

(5) There are different evolution trends among different clusters in the time axis of decision-making in marine management, but some clusters also show certain similar rules in the evolution trend. Moreover, the keywords include emission, risk analysis, optimum inspection, marine protected area, framework, etc., which may be the keywords worth paying attention to further deepen research on decision-making in marine management in the future.

Data Availability
The collected data to support the findings of this study are available from the corresponding author upon reasonable request, and the data come from Web of Science.

Conflicts of Interest
The authors declare that they have no conflicts of interest.

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References
[1] J. L. Bailey, “Rethinking the oceans and their management,” Journal of Environmental Studies and Sciences, vol. 8, no. 2, pp. 189–194, 2018.
[2] L. Schøning, “More or less integrated ocean management: multiple integrated approaches and two norms,” Ocean Development & International Law, vol. 51, no. 2, pp. 95–115, 2019.
[3] M. Voyer, C. Moyle, and C. Kuster, “Achieving comprehensive integrated ocean management requires normative, applied, and empirical integration,” One Earth, vol. 4, no. 7, pp. 1016–1025, 2021.
[4] R. Lewison, A. J. Hobday, and S. Maxwell, “Dynamic ocean management: identifying the critical ingredients of dynamic approaches to ocean resource management,” BioScience, vol. 65, no. 5, pp. 486–498, 2015.
[5] J. G. Winther, M. Dai, and T. Rist, “Integrated ocean management for a sustainable ocean economy,” Nature ecology & evolution, vol. 4, no. 11, pp. 1451–1458, 2020.
[6] D. Karnauskaitė, G. Schernewski, J. G. Stottrup, and M. Kataržyte, “Indicator-based sustainability assessment tool to support coastal and marine management,” Sustainability, vol. 11, no. 11, Article ID 3175, 2019.
[7] E. Cardwell and T. F. Thornton, “The fisherly imagination: the promise of geographical approaches to marine management,” Geoforum, vol. 64, pp. 157–167, 2015.
[8] Y. Du and J. Zhong, “Generalized combination rule for evidential reasoning approach and Dempster–Shafer theory of evidence,” Information Sciences, vol. 547, pp. 1201–1232, 2021.
[9] M. Mohammadi and J. Rezaei, “Bayesian best-worst method: a probabilistic group decision making model,” Omega, vol. 96, Article ID 102075, 2020.
[10] C. Zhang, W. Su, S. Zeng, T. Balezentis, and E. Viedma, “A two-stage subgroup decision-making method for processing large-scale information,” Expert Systems with Applications, vol. 171, Article ID 114586, 2021.
[11] Y. Du and X. Li, “Hierarchical DEMATEL method for complex systems,” Expert Systems with Applications, vol. 167, Article ID 113871, 2021.
[12] B. Wu, J. Zhang, T. Yip, and C. G. Soares, “A quantitative decision-making model for emergency response to oil spill from ships,” Maritime Policy & Management, vol. 48, no. 3, pp. 299–315, 2021.
[13] X. Ye, B. Chen, P. Li, L. Jing, and G. Zeng, “A simulation-based multi-agent particle swarm optimization approach for supporting dynamic decision making in marine oil spill responses,” Ocean & Coastal Management, vol. 172, pp. 128–136, 2019.
[14] L. Brabo, R. Andrades, and S. Franceschini, “Disentangling beach litter pollution patterns to provide better guidelines for decision-making in coastal management,” Marine Pollution Bulletin, vol. 174, Article ID 113310, 2022.
[15] G. J. Syme, P. Dzidic, and J. M. Dambacher, “Enhancing science in coastal management through understanding its role in the decision making network,” Ocean & Coastal Management, vol. 69, pp. 92–101, 2012.
[16] J. E. Avelino, J. Sasaki, and M. Esteban, “Sustainability evaluation of marine protected areas index (SEMPAI): a multi-criteria decision-making method to determine the effectiveness of the El nido-taytay managed resource protected area,” Ocean & Coastal Management, vol. 181, Article ID 104891, 2019.
[17] L. Havard, L. Brigand, and M. Carino, “Stakeholder participation in decision-making processes for marine and coastal protected areas: case studies of the south-western Gulf of California, Mexico,” Ocean & Coastal Management, vol. 116, pp. 116–131, 2015.
[18] J. F. Pontón-Cevallos, S. Bruneel, J. R. Marin Jarrín, J. Ramírez-González, J. R. Bermúdez-Monsalve, and P. L. M. Goethals, “Vulnerability and decision-making in multispecies fisheries: a risk assessment of bacalao (mycteropectra olfax) and related species in the galapagos’ handline fishery,” Sustainability, vol. 12, no. 17, Article ID 6931, 2020.
[19] B. Pentz and N. Klenk, “The ‘responsiveness gap’ in RMFOs: the critical role of decision-making policies in the fisheries management response to climate change,” Ocean & Coastal Management, vol. 145, pp. 44–51, 2017.
[20] L. Dutra, O. Thébaud, F. Boschetti, A. D. M. Smith, and C. M. Dickmont, "Key issues and drivers affecting coastal and marine resource decisions: participatory management strategy evaluation to support adaptive management," Ocean & Coastal Management, vol. 116, pp. 382–395, 2015.

[21] C. Cvitanovic, A. J. Hobday, and L. Kerkhoff, "Improving knowledge exchange among scientists and decision-makers to facilitate the adaptive governance of marine resources: a review of knowledge and research needs," Ocean & Coastal Management, vol. 112, pp. 25–35, 2015.

[22] X. Ding and Z. Yang, "Knowledge mapping of platform research: a visual analysis using VOSviewer and CiteSpace," Electronic Commerce Research, 2020.

[23] X. Zou, W. Yue, and H. L. Vu, "Visualization and analysis of mapping knowledge domain of road safety studies," Accident Analysis & Prevention, vol. 118, pp. 131–145, 2018.

[24] C. Liang, A. Luo, and Z. Zhong, "Knowledge mapping of medication literacy study: a visualized analysis using CiteSpace," SAGE open medicine, vol. 6, 2018.

[25] C. Zhang, S. Wang, S. Sun, and Y. Wei, "Knowledge mapping of tourism demand forecasting research," Tourism Management Perspectives, vol. 35, Article ID 100715, 2020.

[26] X. Guo, X. Li, and Y. Guo, "Mapping knowledge domain analysis in smart education research," Sustainability, vol. 13, no. 23, Article ID 13234, 2021.

[27] T. Li, L. Cai, and Z. Xu, "Quantitative analysis of the research trends and areas in grassland remote sensing: a scientometrics analysis of web of science from 1980 to 2020," Remote Sensing, vol. 13, no. 7, Article ID 1279, 2021.

[28] H. Liu, R. Hong, C. Xiang, C. Lv, and H. Li, "Visualization and analysis of mapping knowledge domains for spontaneous combustion studies," Fuel, vol. 262, Article ID 116598, 2020.

[29] Z. Wang, D. Ma, and R. Pang, "Research progress and development trend of social media big data (smbd): knowledge mapping analysis based on CiteSpace," ISPRS International Journal of Geo-Information, vol. 9, no. 11, Article ID 632, 2020.

[30] S. Naseer, H. Song, M. S. Aslam, and D. A. Arsalan Tanveer, "Assessment of green economic efficiency in China using analytical hierarchical process (AHP)," Soft Computing, vol. 26, pp. 2489–2499, 2022.

[31] S. Yu, B. Cai, C. Xie, Y. Man, and J. Fu, "Bibliometric review of biodiversity offsetting during 1992–2019," Chinese Geographical Science, vol. 32, no. 2, pp. 189–203, 2022.

[32] W. Zhou, Q. Chen, and S. Meng, "Knowledge mapping of credit risk research: scientometrics analysis using CiteSpace," Economic research-Ekonomska istraživanja, vol. 32, no. 1, pp. 3451–3478, 2019.

[33] K. Xie, B. Liang, M. A. Dulebenets, and Y. Mei, "The impact of risk perception on social distancing during the COVID-19 pandemic in China," International Journal of Environmental Research and Public Health, vol. 17, no. 17, Article ID 6256, 2020.

[34] S. Qi, F. Hua, Z. Zhou, and D. T. L. Shek, "Trends of positive youth development publications (1995–2020): a scientometric review," Applied Research in Quality of Life, vol. 17, pp. 421–446, 2020.

[35] X. Wang, Z. Xu, S. Su, and W. Zhou, "A comprehensive bibliometric analysis of uncertain group decision making from 1980 to 2019," Information Sciences, vol. 547, pp. 328–353, 2021.

[36] L. Huang, M. Zhou, J. Lv, and K. Chen, "Trends in global research in forest carbon sequestration: a bibliometric analysis," Journal of Cleaner Production, vol. 252, Article ID 119908, 2020.

[37] Z. Tao, S. Zhou, and R. Yao, "COVID-19 will stimulate a new coronavirus research breakthrough: a 20-year bibliometric analysis," Annals of Translational Medicine, vol. 8, no. 8, Article ID 528, 2020.

[38] Y. Li, R. Fang, Z. Liu et al., "The association between toxic pesticide environmental exposure and Alzheimer’s disease: a scientometric and visualization analysis," Chemosphere, vol. 263, Article ID 128238, 2021.

[39] B. Wang, Q. Zhang, and F. Cui, "Scientific research on ecosystem services and human well-being: a bibliometric analysis," Ecological Indicators, vol. 125, Article ID 107449, 2021.

[40] Y. Guo, Z. Huang, and J. Guo, "A bibliometric analysis and visualization of blockchain," Future Generation Computer Systems, vol. 116, pp. 316–332, 2021.

[41] G. Tanrıverdi, M. Bakır, and R. Merkert, "What can we learn from the IATM literature for the future of aviation post Covid-19? A bibliometric and visualization analysis," Journal of Air Transport Management, vol. 89, Article ID 101916, 2020.

[42] L. Huang, G. Xu, and J. He, "Bibliometric analysis of functional magnetic resonance imaging studies on acupuncture analgesia over the past 20 years," Journal of Pain Research, vol. 14, pp. 3773–3789, 2021.

[43] N. Ye, T. B. Kueh, L. Hou, Y. Liu, and H. Yu, "A bibliometric analysis of corporate social responsibility in sustainable development," Journal of Cleaner Production, vol. 272, Article ID 122679, 2020.

[44] M. Ren, X. Yu, A. S. Mumjumdar, A. E.-G. A. Yagoub, L. Chen, and C. Zhou, "Visualizing the knowledge domain of pulsed light technology in the food field: a scientometrics review," Innovative Food Science & Emerging Technologies, vol. 74, Article ID 102823, 2021.

[45] N. R. Zuanazzi, N. C. Ghisi, and E. C. Oliveira, "Analysis of global trends and gaps for studies about 2, 4-D herbicide toxicity: a scientometric review," Chemosphere, vol. 241, Article ID 125016, 2020.

[46] J. B. Marre, O. Thébaud, S. Pascoe, S. Jennings, J. Bonceur, and L. Coglan, "Is economic valuation of ecosystem services useful to decision-makers? Lessons learned from Australian coastal and marine management," Journal of Environmental Management, vol. 178, pp. 52–62, 2016.

[47] J. B. Marre, O. Thébaud, S. Pascoe, S. Jennings, J. Bonceur, and L. Coglan, "The use of ecosystem services valuation in Australian coastal zone management," Marine Policy, vol. 56, pp. 117–124, 2015.

[48] L. L. Bremer, J. M. S. Delevaux, J. K. Leary, L. J. Cox, and K. L. L. Oleson, "Opportunities and strategies to incorporate ecosystem services knowledge and decision support tools into planning and decision making in Hawai ‘I,‘" Environmental Management, vol. 55, no. 4, pp. 884–899, 2015.

[49] E. McKenzie, S. Posner, P. Tillmann, J. R. Bernhardt, K. Howard, and A. Rosenthal, "Understanding the use of ecosystem services knowledge and decision support tools into planning and decision making in Hawai ‘I,‘" Environmental Management, vol. 116, pp. 316–332, 2021.

[50] C. Cvitanovic, N. A. Marshall, S. K. Wilson, K. Dobbs, and A. J. Hobday, "Perceptions of Australian marine protected area managers regarding the role, importance, and achievability of adaptation for managing the risks of climate change," Ecology and Society, vol. 19, no. 4, Article ID 33, 2014.
C. Cvitanovic, A. J. Hobday, L. van Kerkhoff, and N. A. Marshall, "Overcoming barriers to knowledge exchange for adaptive resource management; the perspectives of Australian marine scientists," *Marine Policy*, vol. 52, pp. 38–44, 2015.

W. S. Patrick and K. D. Randall, "Using a five-factored structured decision analysis to evaluate the extinction risk of Atlantic sturgeon (Acipenser oxyrinchus oxyrinchus)," *Biological Conservation*, vol. 141, no. 11, pp. 2906–2911, 2008.

C. Labianca, S. D. Gisi, F. Todaro, and M. Notarnicola, "Evaluation OF remediation technologies for contaminated marine sediments through multi criteria decision analysis," *Environmental Engineering & Management Journal (EEMJ)*, vol. 19, no. 10, pp. 1891–1903, 2020.

C. Pang, A. Radomyski, V. Subramanian, M. Nadimi-Goki, A. Marcomini, and I. Linkov, "Multi-criteria decision analysis applied to harmful algal bloom management: a case study," *Integrated Environmental Assessment and Management*, vol. 13, no. 4, pp. 631–639, 2017.

C. Wang and P. Delu, "Zoning of Hangzhou Bay ecological red line using GIS-based multi-criteria decision analysis," *Ocean & Coastal Management*, vol. 139, pp. 42–50, 2017.

M. N. Andalecio, "Multi-criteria decision models for management of tropical coastal fisheries," *Sustainable Agriculture*, vol. 2, pp. 251–280, 2011.

D. E. Lane, "Planning in Fisheries related Systems: multi-criteria models for decision support," *Handbook on Operations Research in Natural Resources*, vol. 99, pp. 237–271, 2007.

J. N. Bradie and S. A. Bailey, "A decision support tool to prioritize ballast water compliance monitoring by ranking risk of non-indigenous species establishment," *Journal of Applied Ecology*, vol. 58, no. 3, pp. 587–595, 2021.

S. J. Pittman, M. Poti, C. F. G. Jeffrey, L. M. Kracker, and A. Mabrouk, "Decision support framework for the prioritization of coral reefs in the US Virgin Islands," *Ecological Informatics*, vol. 47, pp. 26–34, 2018.

S. Dedman, R. Officer, D. Brophy, M. Clarke, and D. G. Reid, "Towards a flexible decision support tool for MSY-based marine protected area design for skates and rays," *ICES Journal of Marine Science*, vol. 74, no. 2, pp. 576–587, 2017.

A. A. Rowden, F. Stephenson, M. R. Clark et al., "Examining the utility of a decision-support tool to develop spatial management options for the protection of vulnerable marine ecosystems on the high seas around New Zealand," *Ocean & Coastal Management*, vol. 170, pp. 1–16, 2019.

H. Nygård, F. M. van Beest, L. Bergqvist et al., "Decision-support tools used in the Baltic Sea area: performance and end-user preferences," *Environmental Management*, vol. 66, no. 6, pp. 1024–1038, 2020.

S. Kao, C. K. Hsueh, C. Chou, and T. Yuan, "A decision-making support system for automatically determining the route priority of vessels entering/exitng the ports," *Transportation Journal*, vol. 59, no. 4, pp. 335–368, 2020.

W. Tan, C. Yang, P. A. Château, M. T. Lee, and Y. Chang, "Integrated coastal-zone management for sustainable tourism using a decision support system based on system dynamics: a case study of Cijin, Kaohsiung, Taiwan," *Ocean & Coastal Management*, vol. 153, pp. 131–139, 2018.

D. Sutrisno, S. N. Gill, and S. Suseno, "The development of spatial decision support system tool for marine spatial planning," *International Journal of Digital Earth*, vol. 11, no. 9, pp. 863–879, 2018.