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Research on integrated coastal zone management from past to the future: a bibliometric analysis

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Integrated coastal zone management (ICZM) has been regarded as an effective tool for achieving sustainable development of coastal ecosystems and reducing potential human health risks, but questions remain regarding its research status and future directions. Therefore, a bibliometric analysis was conducted using screened 6151 publications collected from Web of Science Core Collection databases. An exponential increase trend of publications revealed the continuous and strong research interests for ICZM worldwide. The most high-yield country, institution, category, and journal were USA, NOAA, Environmental Sciences, and Ocean & Coastal Management, respectively. Regarding the number of publications, academic influence, and international collaboration, the developed countries occupied the predominant positions. Co-word analysis reveals eight important topics: challenge, service, management and planning, method and technology, development, process, area, and system. Relevant future directions of the ICZM field were proposed based on the Sustainable Development Goals of the United Nations. This review addresses the question of what focal topics in the ICZM field and what should be focused on in future works by objective and quantitative methods. Our results provide valuable insights into the evolution of the ICZM field and the sustainable development of the coastal areas.

KEYWORDS

coastal management, sustainable development, content analysis, international collaboration, future direction

1 Introduction

The coastal zone has been thought to play a crucial role in delivering ecosystem services and sustaining livelihoods (Costanza et al., 1997; Islam et al., 2014; Neumann et al., 2015; Fuentes et al., 2018). Humans depend on coastal ecosystems for a wide range of basic services, such as carbon sequestration, food supply, and leisure entertainment (Barbier et al., 2011). Meanwhile, coastal fisheries and aquaculture support the livelihoods of a

number of community residents (Slater et al., 2013; Andrews et al., 2021). However, anthropological activities and climate change exert dual pressures on the sustainable development of the coastal zone, and that led to the degradation of ecological quality and the increase of potential human health risks (Storelli, 2008; Judd et al., 2015; Borja et al., 2020; Caviedes et al., 2020; O'Mahony et al., 2020). The urgent need for an integrated and strategic approach to improving environmental quality and human well-being of coastal areas facilitated the generation of integrated coastal zone management (ICZM) (Ballinger et al., 2010). ICZM is a continuous decision-making process for the sustainable use, development, and conservation of coastal environments and their resources (Tiller et al., 2012). ICZM has been widely recognized as an essential paradigm for the sustainable coastal zone and the most appropriate process for dealing with long-term challenges (Koutrakis et al., 2011), such as sea level rise, coastal erosion, land use change, and environmental pollution (Deboudt et al., 2008; Pinto and Martins, 2013; Gari et al., 2014; Allenbach et al., 2015; Albotoush and Shau-Hwai, 2019; Khelil et al., 2019; Papatheochari and Coccossis, 2019). To date, ICZM has been implemented in a large number of coastal countries, such as China, the USA, Australia, and Spain, and certain achievements have been made (Chen et al., 2009; Wheeler and Peterson, 2010; Bell et al., 2013; Botero et al., 2013). For instance, Spain has gained achievements in the stakeholder engagement of ICZM (Bell et al., 2013), and regional economic development in China was improved through ICZM implementation (Qing et al., 2022). A systematic understanding of ICZM is imperative for reasonable protection and orderly utilization of coastal zones, but questions remain regarding what are focal topics in the ICZM field and what should be focused on in future works from an objective perspective.

Bibliometric analysis, first introduced by Pritchard (1969), is an effective tool for assessing current status or gaps by capturing the characteristics of documents (Karimi and Khalilpour, 2015). The primary goal of bibliometrics is to quantify the external characteristics of the literature and references (Chiu and Ho, 2005; Zhou et al., 2007). Generally speaking, there are two types of bibliometrics. One type is based on activity level and offers information on the impact of research, including categories and nations with high productivity rates. The other type uses network analysis to follow connections and interconnections between various nations and keywords (de Battisti and Salini, 2013). The advantage of bibliometric analysis is that it objectively reflects the characteristics of the literature through quantitative methods. Bibliometrics is usually combined with social network analysis (SNA) and content analysis to explore the scientific collaboration patterns and research hotspots (Gallardo-Gallardo et al., 2015; Huang et al., 2019) and have been widely used in the field of environmental science, ecology, and management (Feng et al., 2017; Zhang et al., 2017; Webber and Vander Wal, 2019). With the help of these quantity methods, research on certain topics or fields from the past to the future could be clearly summarized (Mao et al., 2018). Moreover, the bibliometrics, combined with SNA and content analysis, could be potentially extended to the ICZM topic.

In this study, 6151 publications on ICZM from Web of Science Core Collection databases (WoSCC) were evaluated quantitatively using bibliometrics, SNA, and content analysis. Specifically, the review of ICZM was conducted from the perspectives of spatio-temporal distribution of publications, high-productive characteristics, international collaboration patterns, hotspots, and future directions. This research provides a comprehensive understanding of ICZM-related research by objective and quantity methods, and clear knowledge gaps in further research should be focused under the UN-SDGs framework. The findings of this paper provide directions and advice for researchers, stakeholders, and policymakers.

2 Data sources and methods

2.1 Data sources

Raw data used in this study was obtained from WoSCC on July 10th, 2021, with the keywords = integrated AND (coast* OR coastal zone*) AND (manage* OR govern*). Various items, including author information, journals and categories, and keywords, were extracted to clarify the external literature characteristics and potential future directions in the field of ICZM. A total of 6247 publications met the selection criteria. Thereafter, 6151 papers with the type of articles, reviews, and proceedings papers were screened for bibliometric analysis by artificial interpretation. In terms of geographic distribution, publications from England, Northern Ireland, Scotland, and Wales were contained in the UK heading. Papers from Hong Kong, Macao, and Taiwan were included under the China heading. The research framework of this study is shown in Figure 1.

2.2 Methods

After searching and selecting for publications, bibliometric analysis based on the 6151 documents was conducted from the perspectives of descriptive analysis, international collaboration patterns, and keyword analysis. Some software, including BibExcel (version 2014-03-25), Gephi (version 0.9.2), R (version

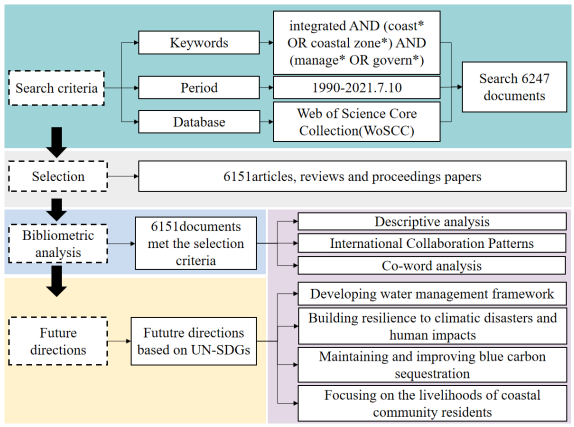

FIGURE 1
Research framework of this study.

4.2.2), Microsoft Excel (version 16.65), and Origin (version 2021), was employed in data processing and visualization. BibExcel was used to extract basic information and analyze the spatio-temporal distribution of publications, journals, categories, and keywords (Rashidi et al., 2020). Gephi was utilized to form social network maps for visualizing the countries' relationships and keywords (Bastian et al., 2009). Gephi was also applied in the community detection of international cooperation patterns based on degree. Degree is an important indicator to measure the importance of a node in the social network, which can be explained as the number of the links connected with the node. The larger the degree value, the higher the importance of the node in the network (Gonzalez et al., 2021). R was applied to depict the connection intensity between countries worldwide (R Core Team, 2022). Data processing and analysis were carried out in Microsoft Excel, and relevant graphics were created by Origin software. Co-word analysis is a technology that counts and analyses the co-occurrence relationship of keywords in publications on a given subject (Ding et al., 2001). SNA is a broad quantity strategy for investigating the network structure, which consists of individuals and ties (Otte and Rousseau, 2002). Co-word analysis in SNA combined with content analysis revealing the cooperative relationships among different entities and the intensity of their cooperation (Chen and Chang, 2015; Zhang et al., 2017) were conducted using BibExcel (version 2014-03-25) and Gephi (version 0.9.2). The occurrence frequency of keywords of selected papers was indicated by the size of the node, and the co-occurrence frequency of keywords was indicated by the thickness of the connection. SNA indicates importance with the thickness of the lines and the size of a node. The nodes indicate the frequency number, and the lines between the nodes indicate relationships. The stronger the relationship, the thicker the line is. The content analysis could quantitatively summarize the contents of the literature (Coulter et al., 1998), which was applied to indicate the research trend on ICZM in this study. Co-word analysis was conducted to identify focal themes in this paper. Future directions on ICZM were implicated using the United Nations Sustainable Development Goals (UN-SDGs) framework (Orhan and Guajardo, 2021). To measure the academic influence of journals and authorship, the two most used indicators, impact factor (IF) and h-index, were selected in this paper (Hirsch, 2005; Du et al., 2015; Mao et al., 2015).

3 Results and discussion

3.1 Descriptive analysis of ICZM

3.1.1 Publication type and quantity analysis

In terms of literature categories, raw 6247 publications can be categorized into 13 document types. As illustrated in Figure 2A, "Article" was the most prevalent type, accounting for 74% of the total publications, followed by "Proceedings Paper" (19%), "Review" (4.9%), and others (e.g., "Editorial Material" and "Book Chapter"). Here, "Article," "Proceedings Paper," and "Review" included a total of 6151 papers (98.46% of the raw publications) and could greatly reflect the development trends and evolution in ICZM research. Therefore, these three types of papers were focused in the following analysis and evaluation.

An increasingly exponential trend existed for ICZM-related publications (Figure 2B). Based on a polynomial model, the number of articles has increased significantly along the year-by-year gradient (R^2>0.97, P<0.05), revealing that the topic has gained widespread attention in the recent several years. On the basis of the number of publications and key events (e.g., the establishment of Partnerships in Environmental Management for the Seas of East Asia), the evolution of papers in the ICZM field was divided into four stages and included the embryonic period (1990-1998), the preliminary development period (1999-2007), the stable development period (2008-2016), and the rapid development period (2017-2021). Before 1998, ICZM-related research was in its infancy, and no more than 50 papers were published per year during this period. A slight increase was observed between 1999 and 2007. Subsequently, ICZM-related studies gradually increased from 2008 to 2016, and the wide attention gained in the ICZM field mainly because the challenges in coastal areas increasingly diversified (Sonak et al., 2008; Hansen and Fuglsang, 2014). After 2016, ICZM-related research showed an explosive growth trend, mainly due to the gradually increasing attention to anthropogenic pressures and climate change in the coastal zone (Bruno et al., 2020; Cantasano et al., 2021).

3.1.2 National and institutional contribution analysis

Scientific researches from different countries in the field of ICZM were analyzed based on the extracted information from the addresses of authors. As shown in Figure 3A, an obvious imbalance in geographical distribution was found in terms of the number of published articles, which might be caused by the discrepancy in research and development expenditure (Callaghan, 2021). In addition, most countries involved in the ICZM research field were coastal countries, which may reflect the urgent need for ICZM in coastal countries (Shipman and Stojanovic, 2007).

Figure 3B and Table S1 show the basic information of the top 20 most active countries. The most productive country was the USA, with the publication number of 1523 and a proportion of 24.76%, followed by the UK (684, 11.12%) and Australia (601, 9.77%). Meanwhile, the same trend of h-index was also found for these three countries. As a developing country, China ranked fourth in the number of publications (505) and tenth in the h-index (40). An apparent increase in publications over time by China (Figure S1) may be due to the increasing budget of the National Foundation of China since 2000 (Yang, 2016a; Yang, 2016b). Other developing countries, such as Brazil and India, also perform well in paper publishment. Generally, developed countries were found to be characterized by more publication papers and higher h-index (Figure S2). These results indicated that developed and developing countries have different contributions to the ICZM field, and developed countries have dominated the mainstreams in this field with great global influence.

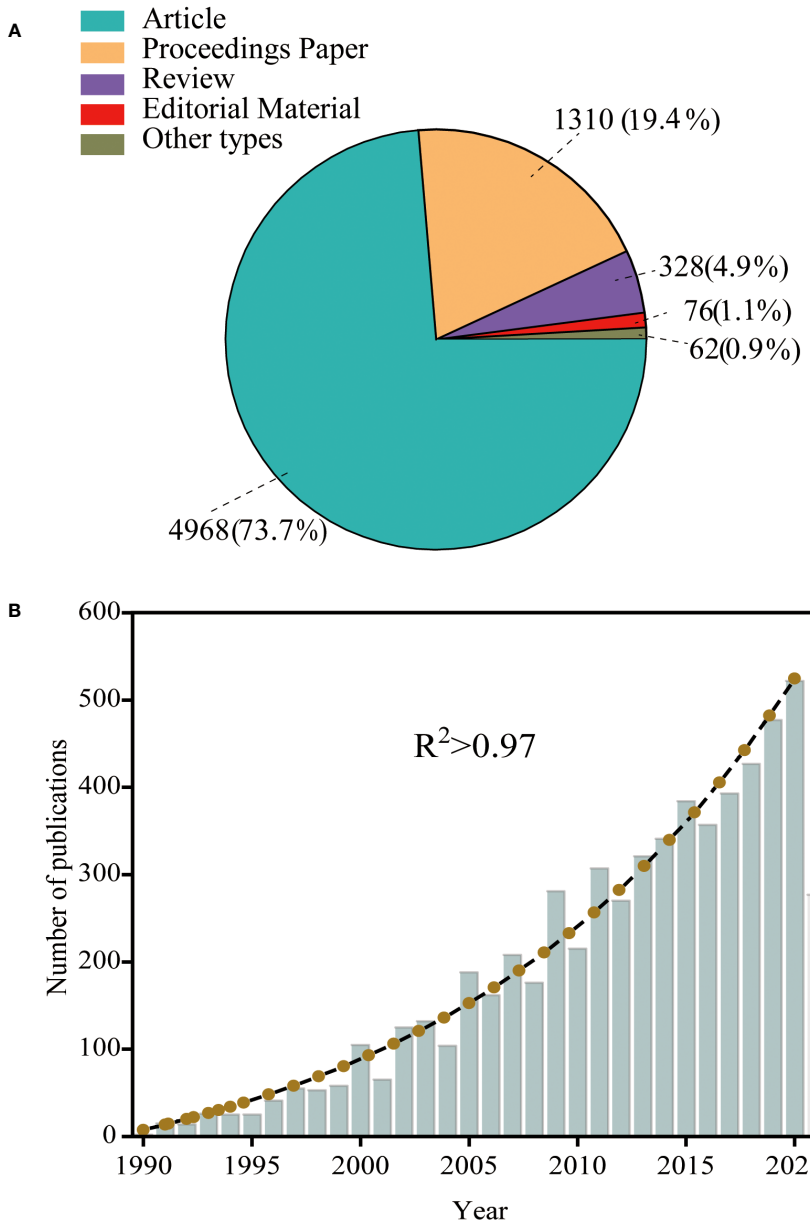

FIGURE 2
Published pattern of the ICZM field. **(A)** Publication type percentage for ICZM research. **(B)** Distribution of publication quantity for ICZM per year.

The contributions of various institutions to the ICZM field are summarized in Figure 4 and Table S2. The National Oceanic and Atmospheric Administration (NOAA) was characterized by the most publications of 161 and the highest h-index of 35. The Chinese Academy of Sciences (Chinese Acad Sci) ranked second in terms of the publication number (101) and ranked sixth in terms of h-index (23). National financial support may be an important driver for the excellent scientific outputs of NOAA and Chinese Acad Sci (Suttmeier et al., 2006; Gall et al., 2013). Among the top 20 most productive institutions, twelve belong to the USA and Australia, which indicated that the USA and Australia have formed strong institutional groups in the field of ICZM. Compared to the data about country contributions to the ICZM field (Figure 3B), the UK, Canada, Spain, and the Netherlands were among the 20 most productive countries but were not home to any of the top 20 most productive institutions (Table S2). This phenomenon may suggest that the scientific capabilities are not only impacted by research institutions but also depend on other factors, such as funding agencies and big names (Leberman et al., 2016; Zhang et al., 2017).

3.1.3 Category and journal analysis

There were 152 categories included in the ICZM field, and the top 10 most productive categories are shown in Table S3. Environmental Sciences ranked first with 2294 publications and accounted for 37.29% of the total documents, followed by Water Resource (1478, 24.03%), Oceanography (1225, 19.92%), Marine & Freshwater Biology (893,14.52%), and Geosciences & Multidisciplinary

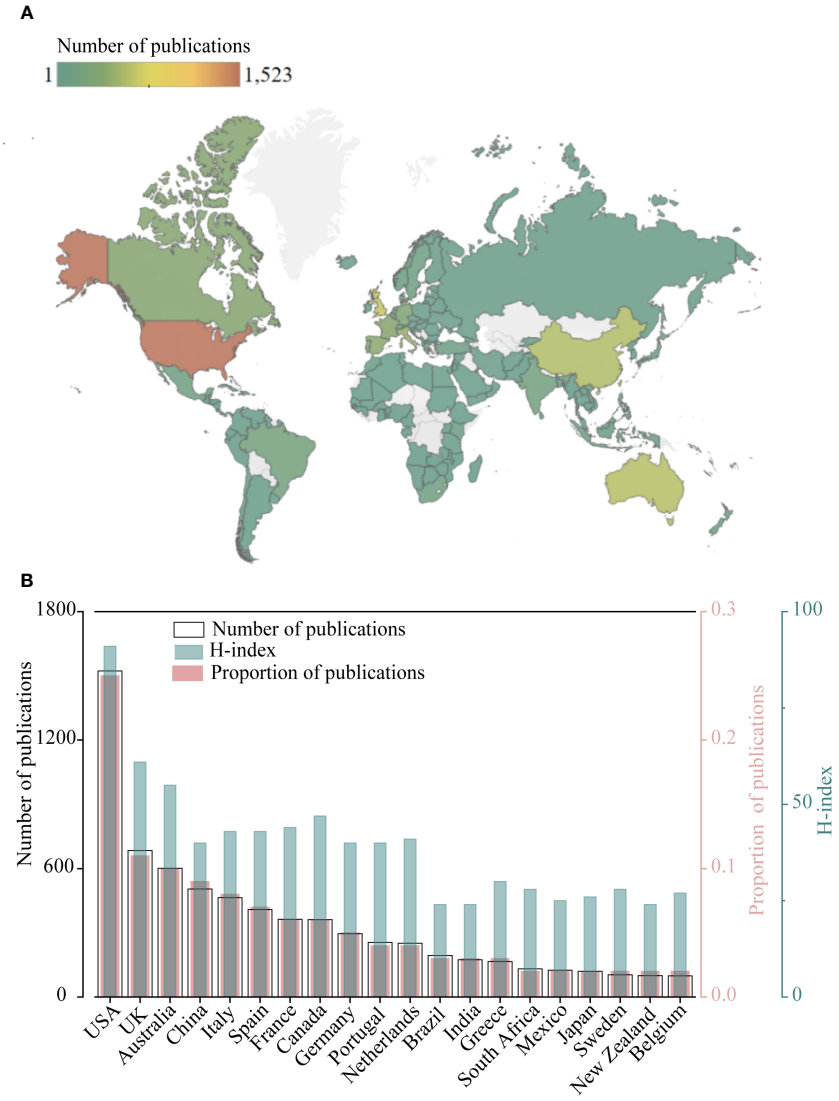

FIGURE 3
Geographical distribution of publications on ICZM. **(A)** Global distribution of publications on ICZM. The color of different countries presents the number of publications. The closer the color is to red, the more papers have been published. **(B)** The basic information of the top 20 most productive countries.

(761,12.37%). There existed 73.66% of the total publications belonging to at least two categories, revealing a clear cross-fertilization trend in the disciplines of ICZM-related research (Table S4), which was consistent with some studies focusing on the multidisciplinary knowledge in ICZM practice (Carlberg, 2005; Balaguer et al., 2008; Garcia-Ayllon, 2018). According to the publications distributed in different journals, Ocean & Coastal Management was the most productive journal with the publication of 622 and a proportion of 10.11%, followed by Journal of Coastal Research (230, 3.74%) and Marine Policy (182, 2.96%) (Table S5). On the basis of the IF for various journals, Science of the Total Environment has the highest IF of 10.754, followed by the Journal of Environmental Management (8.91) and Marine Pollution Bulletin (7.001). As an essential carrier of scientific research output, journals play an important role in disseminating of academic achievements (Ronda-Pupo and Guerras-Martin, 2010). The willingness of more influential journals to publish in the ICZM field should be greatly increased in the future.

3.2 International collaboration patterns

International collaboration has been widely regarded as an important factor influencing research outputs (Orwat et al., 2015; Zanotto et al., 2017). In this study, international collaboration among the various countries with at least five papers in the ICZM field was analyzed by SNA and visualized in Figure 5. A stable quadrilateral collaboration relationship has been formed among the USA, China, European countries, and Australia (Figure 5A). To clarify the crucial countries in the international collaboration network on ICZM, a cooperative network map based on degree was drawn by Gephi software (Figure 5B). The USA ranked first

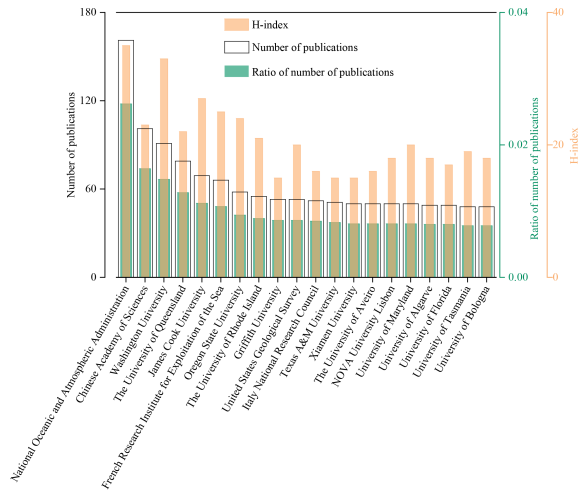

FIGURE 4
Basic information of the top 20 most productive institutions on ICZM.

with a degree of 83 (Table S6), which dominated the center and leader of the network and was closely linked to China and European countries such as the UK, France, and Australia (Figure 5B). This is relatively consistent with the entire Nature Index (Nature, 2022). And India and China had relatively lower degree values of 36 and 31, respectively. According to the distribution of the degree (Figure S3), international collaboration on ICZM is asymmetrical, and the collaboration network remains structured around a few dominated countries, similar to most international scientific collaboration patterns (Chinchilla-Rodriguez et al., 2019). In sum, a broader pattern of international cooperation in the ICZM field should be established in the future.

A community detection analysis of countries, based on a community modularity algorithm in SNA using Gephi software (Blondel et al., 2008), was shown in Figure 6. Four communities were identified. Community 1, community 2, community 3, and community 4 covered 41.84%, 26.53%, 23.47%, and 8.16% of the number of countries, respectively. Community 1 included various countries from continents, including America, Oceania, Asia, and Europe. Some Mediterranean countries, including Tunisia, Malta, and Cyprus, were involved in community 2. European countries, such as the UK, Poland, and Denmark, are divided into community 3. African countries, including South Africa, Kenya and, Tanzania, belonged to community 4. Countries in close geographical proximity were divided into the same community, such as community 2, community 3, and community 4, revealing the importance of geographical distance in promoting academic collaboration (Acosta et al., 2011). Meanwhile, International collaboration may be affected by economic and cultural factors (Hou et al., 2021).

3.3 Co-word analysis

Based on SNA and content analysis, co-word analysis across the whole period is illustrated in Figure 7. According to the specialized knowledge, eight groups were classified, namely 'challenge,' 'management and planning,' 'system,' 'method and technology,' 'process,' 'service,' 'development,' and 'area.' Co-word analysis also can perform well in displaying the time attribute of keywords (Mao et al., 2015). Therefore, this paper divided the keywords into the four stages mentioned earlier, aiming to clarify the dynamic changing process of themes in the field of ICZM (Figures S4-S7).

3.3.1 Challenges

As illustrated in Figure 7, it could be found that 'Challenges' was the most frequently concerned group with the largest number of keywords. There was an increasingly diversified trend of challenges in the coastal areas (Figures S2-S5). Climate change has become the most striking challenge in the background of the 'Paris Climate Agreement' and 'Kyoto Protocol' to confront the impact and economic loss caused by the climate problem (Santilli et al., 2005; Rogelj et al., 2016). Meanwhile, some secondary disasters of climate change, including flood risk, coastal erosion, and sea level rise, have also been an incremental concern to policymakers and the public (Satta et al., 2016; Warnken and Mosadeghi, 2018). The adaptation and prevention of climate change in the future have drawn significant attention from academia and governments worldwide (Milinski et al., 2008; Helm et al., 2018). Water quality is another ongoing and wide-concerned challenge (Figure 7) as the consequence of excessive exploitation activities, including fishery and aquaculture (Yu et al., 2020). Notably, eutrophication, which is a phenomenon caused by the nutrient enrichment of coastal water, could lead to a series of adverse ecological effects on coastal phytoplankton production and contaminant cycling (Gunnarsson et al., 2000; Lee et al., 2019; Maure et al., 2021). Other challenges on land use change (Mendoza-Gonzalez et al., 2012), fishery (Islam et al., 2014), and biodiversity (Bulleri et al., 2018) were also included in the group 'challenge.' A set of strategies on these challenges based on ICZM were put forward, including defining the management boundary, the monitoring system, and the risk assessment model of anthropical activities (Chen et al., 2009). The past knowledge indicated that ICZM has been revealed to be a widely accepted approach to meet these challenges (Clark, 1997; Portman et al., 2012; de Andres et al., 2023).

3.3.2 Social-ecological system

The social-ecological system has been regarded as the ecosystem inextricably linked to human systems (Martín-López et al., 2017; Dada et al., 2021). As the three typical social-ecological systems identified in this study, estuary, mangrove, and coral reef have been found to confront the dilemma of loss and degradation worldwide (Cinner et al., 2012; Sousa and Alves, 2020; Scemama et al., 2022). For example, 20%-35% of global mangrove extent has lost over the last fifty years (Polidoro et al., 2010), and global coverage of coral reefs has declined by half since the 1950s (Eddy et al., 2021). Concerning the management of social-ecological systems, there still exist some challenges in light of climate-related disasters and human activities, including urban sprawl and industrialization (Wang et al., 2012; Hodgson et al., 2019). The trends and stresses faced by social-ecological systems unfolded the necessity of ICZM

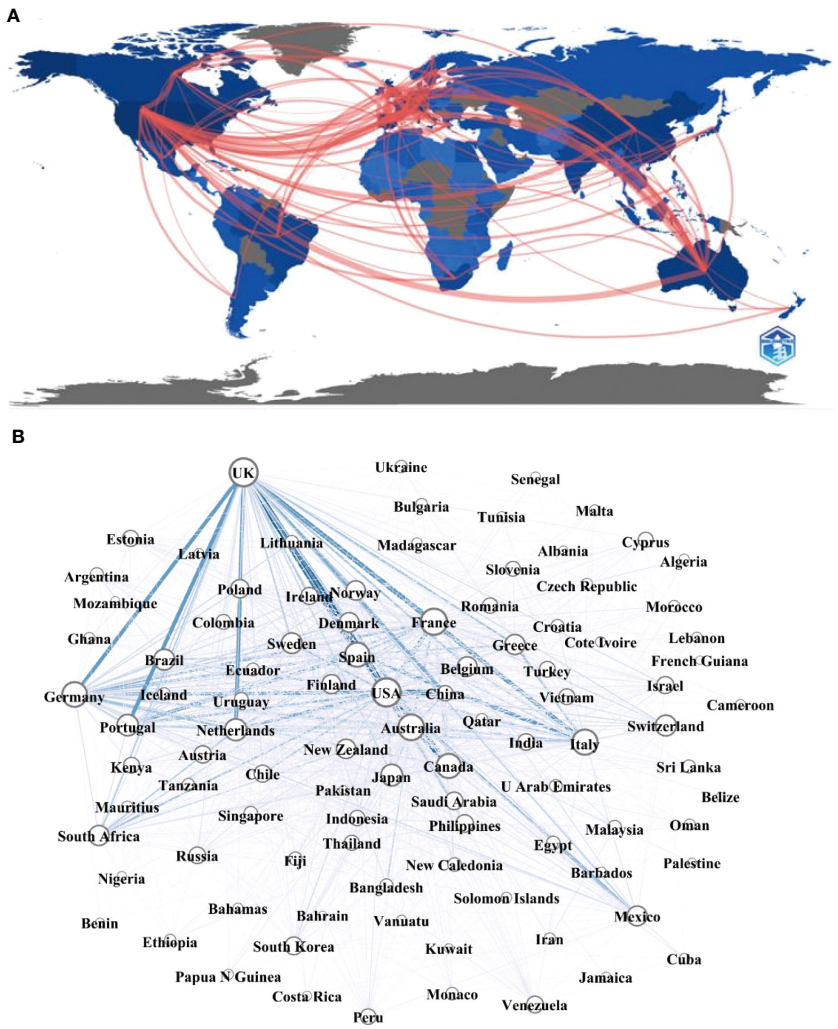

FIGURE 5
Scientific collaboration in the field of ICZM worldwide. **(A)** The academic collaboration network visualized by R software. The width of the line presents the intensity of cooperation between countries. **(B)** The academic network map drawn by Gephi software based on degree. Each node represents a country. The size of nodes depend on the degree of countries. The higher the value of degree, the larger the node.

(Roy et al., 2018), and managing social-ecological systems should be considered a crucial section for ICZM.

3.3.3 Service

The ecosystem service was the only topic included in the group 'service' (Figure 7), which was regarded as the ability of ecosystems to provide services to human society (Costanza et al., 1997). In recent years, ecosystem service mapping has become an increasingly useful tool for providing information to management practice (Malinga et al., 2015). Meanwhile, ecosystem service value was applied in identifying good ICZM projects and establishing the welfare benefits of ICZM (Williams et al., 2006; Ghermandi, 2015). The emergence and development of ecosystem service in ICZM-related studies implied that the relationship between coastal ecosystems and human well-being has been emphatically considered in ICZM (Granek et al., 2010; Schernewski et al., 2018; Hietala et al., 2021). To coordinate the relationship between human welfare and natural resources in the coastal zone, it is necessary to incorporate ecosystem service into the decision-making process of ICZM (Schernewski et al., 2018; Hietala et al., 2021).

3.3.4 Method and technology

The keywords 'remote sensing,' 'geographical information system,' 'model,' and 'indicator' were revealed to be involved in the group 'Method and technology' (Figure 7). Some methods and technologies played vital roles in providing basic information to make decisions. For instance, remote sensing (RS) and geographical information systems (GIS) have been widely applied to monitor coastal environment change, such as ocean color (Kratzer et al., 2013) and shoreline (Maras et al., 2016). To improve the ability to acquire high-resolution data and high-precision classification, RS and GIS have been evolved in combination with some emerging technologies and methods, such as intelligent remote sensing satellite system (Zhang et al.,

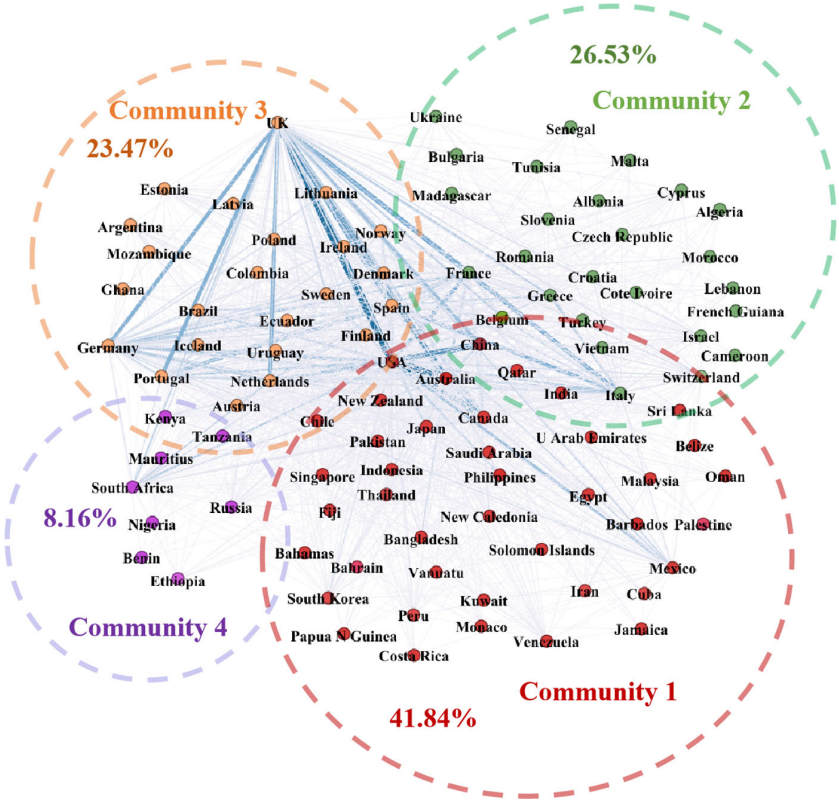

FIGURE 6
Community detection analysis by Gephi software at the country level.

2022), random forest (Belgiu and Dragut, 2016) and support vector machine (Pradhan, 2013). Meanwhile, some models and indicators, such as the driving-pressure-state-impact-response model (Bruno et al., 2020) and the deterministic hydrodynamic model (Kankara et al., 2007), were involved in informing the design (Arkema et al., 2014), decision-making of ICZM (Chang et al., 2008; Lozoya et al., 2011; Gvilava et al., 2015), and progress-tracking of ICZM (Pickaver et al., 2004).

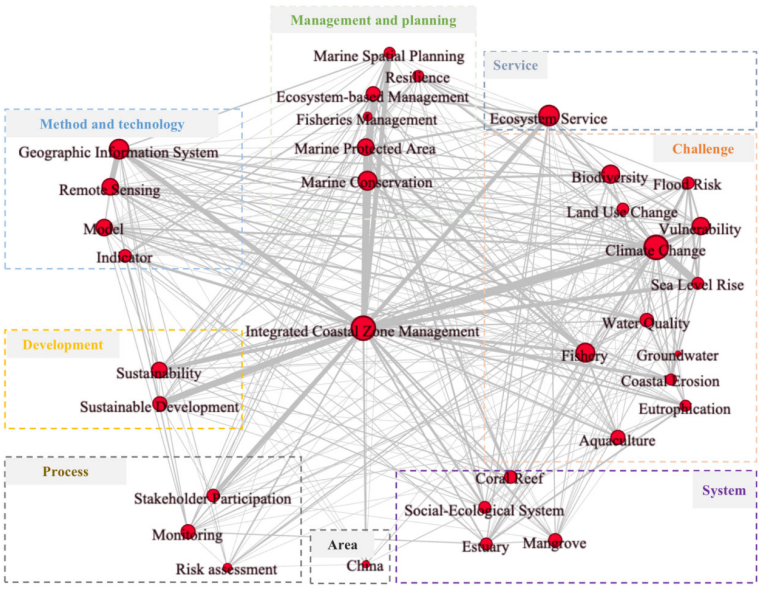

FIGURE 7
SNA of keywords on ICZM across the whole period.

3.3.5 Other topics

Other hot topics, including management and planning, process, area, and development, were also discovered to be involved in the field of ICZM (Figure 7). To address the diversified challenges in coastal areas, ICZM has integrated some management and planning approaches, including marine spatial planning and ecosystem-based management, to reach sustainability and resilience objectives (Granek et al., 2010; Dominguez-Tejo et al., 2016). With respect to the process, there is a growing realization that monitoring, risk assessment, and stakeholder participation are crucial sectors and have crucial roles to play in the delivery and development of policies and practices of ICZM (Jones-Walters and Cil, 2011; Kratzer et al., 2013; Bruno et al., 2020), and stakeholder participation is the core to successful ICZM (Areizaga et al., 2012; Thompson-Saud and Wenger, 2022). There existed regional discrepancies for the ICZM implementation (Figure 7). China is intensely concerned about this field, as revealed by the highest frequency in the co-word network. As one of the earliest countries to implement ICZM, China has achieved remarkable results in some cities, such as Xiamen (Qing et al., 2022). In addition, globally, sustainable development is the long-term goal of ICZM (Uehara et al., 2016). To achieve this ambitious goal, ICZM has been chosen as an effective tool in the context of the UN-SDGs framework, which was a series of sustainable development targets set by the United Nations (Kandrot et al., 2021).

3.4 Future research directions

The United Nations (UN) Sustainable Development Summit adopted 17 Sustainable Development Goals (SDGs) in September 2015, aiming to plan a sustainable path worldwide through an integrated approach that addresses the three dimensions of social, economic, and environmental development (Matlin et al., 2015). A sound ICZM must meet the principles of sustainable development (Barker, 2006). Therefore, some future directions were proposed based on the UN-SDGs framework. The role of ICZM in achieving the UN-SDGs for the coastal regions has been recognized (Kandrot et al., 2021). Moreover, ICZM should continue to be guided by the achievement of the UN-SDGs in the future. Based on the characteristics of the coastal zone, UN-SDGs related to ICZM, consisting of SDG 6, SDG11, SDG13, and SDG14, were screened (Figure 8).

Clean water and sanitation is the theme of SDG6 (Figure 8) and is also one of the most essential pursuits of ICZM (Thompson-Saud and Wenger, 2022). Water quality was a severe problem in the coastal zone in the past, identified by the studies on ICZM (Figure 8). Although ICZM has been regarded as the effective approach to coastal water management, more efforts should be made to strengthen water quality monitoring (Kim et al., 2014), controlling land-sourced pollutant emissions (Thompson-Saud and Wenger, 2022), and developing water management framework (Pavlidou et al., 2015) in ICZM.

The topic of SDG 11 is sustainable cities and communities (Figure 8). The coastal zone is home to about 60% of the population and two-thirds of medium-sized cities (Yuan et al., 2017). However, the sustainable development of coastal cities has been threatened by disasters, such as flooding, coastal erosion, and sea level rise (Allenbach et al., 2015; Neumann et al., 2015; Cantasano et al., 2021), which were also the research focuses in the field of ICZM (Figure 7). Therefore, building resilience to climatic disasters and

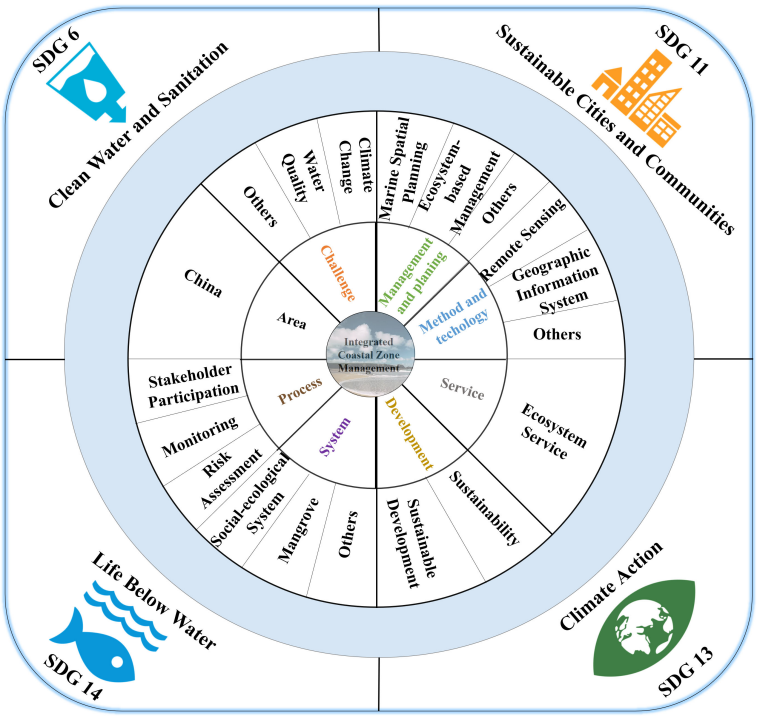

FIGURE 8
Thematic distribution in the field of ICZM based on UN-SDGs framework.

human impacts in coastal cities and communities is urgently needed (Smith et al., 2011; Torabi et al., 2018; He and Silliman, 2019).

Climate change was involved in the topic of SDG 13 (Figure 8). Climate change is one of the only two challenges on ICZM from 1990 to July 10, 2021 (Figures S2-S5). Climate change has been widely regarded as the major inducement for sea level rise and increasing flooding risk in the coastal zone. Coastal vegetated ecosystems are the key carbon sinks, namely blue carbon sinks, which have been demonstrated to be the natural-based solution to mitigate climate change (Jiang et al., 2022). Thus, management practices to best maintain and improve blue carbon sequestration should become an important direction for future works.

SDG 14, namely the life below water, has been regarded to be the most relevant target for the ocean (Ntona and Morgera, 2018). Life below water closely connects with fishery and aquaculture, which are the primary activities for coastal community residents to maintain livelihoods (Slater et al., 2013; Islam et al., 2014). However, the increasing coastal pollution has severely impacted sustainable fishery and aquaculture (Islam and Tanaka, 2004; Thongsamer et al., 2021). Similar to SDG 6, improving water quality should be considered to achieve SDG 14. Meanwhile, the livelihoods of coastal community residents should become a work focus.

Besides, developing relevant tools and methods (section 3.3.4) was imperative for the acquisition and accuracy of basic data to better achieve a sustainable ICZM. According to the analysis above, future research directions on ICZM can be summarized as follows: (1) Coordinating different types of conflicts and achieving integrated benefits; (2) Strengthening the link between coastal ecosystems and human well-being; (3) Enhancing the development of tools and methods to support decision making.

4 Conclusion

The research situation, hot topics, and future directions of ICZM research were analyzed through a bibliometric method combined with content analysis and SNA. The results indicated that the number of published articles per year has increased exponentially from 2 articles in 1990 to 520 in 2020. USA, NOAA, Environmental Sciences, and Ocean & Coastal Management were the most productive country, institution, category, and journal, respectively. Regarding publication number, academic influence, and international collaboration, developed and developing countries have discrepant contributions to the ICZM field, and developed countries tend to be predominant. Among the eight groups identified by the co-word analysis, the most frequently concerned group was 'challenge.' Diversified challenges, such as climate change, water quality, fishery, and biodiversity, pose difficulties for achieving sustainable ICZM and put forward advanced requirements on decision-support technologies and methods, such as RS and GIS. Social-ecological systems, including estuaries, mangroves, and coral reefs, and their services began to be a concern. Based on the characteristics of the coastal zone, four UN-SDGs related to ICZM, consisting of 'clean water and sanitation', 'sustainable cities and communities', climate action', and 'life below water', were identified. And corresponding future directions were suggested to achieve multiple benefits and included: (1) Further studies should strengthen water quality monitoring, control land-sourced pollution, and develop a water management framework; (2) More attention should be paid to building resilience to climatic disasters and human impacts in coastal cities and communities; (3) Improving livelihoods of coastal residents should be prioritized in the ICZM field; (4) Future studies correspondingly need to focus on and deploy relevant tools and methods to obtain high-accuracy data. The most notable strength of this study is that it reveals hot topics in the field of ICZM and provides directions for future research, promoting UN-SDG achievements. However, there are some limitations in this paper. Owing to the difficulty of data acquisition, unpublished documents, which might also contain important information, weren't involved in the raw data of this study. In addition, some topic models, such as latent Dirichlet allocation and latent semantic analysis, could be employed in further study to enhance the efficiency and accuracy of focal topic detection. Our results provide a valuable reference to identify the potential obstacles and opportunities for researchers working on ICZM and related topics.

Data availability statement

The data analyzed in this study is subject to the following licenses/restrictions: data will be obtained by request. Requests to access these datasets should be directed to jianglu@stu.ouc.edu.cn.

Author contributions

LJ participated in conception of research ideas and wrote the sections of the manuscript. TY and XW conducted the bibliometric analysis. JY, JL, and KZ reviewed the literature. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fmars.2023.1201811/full#supplementary-material

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