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Review

Coastal Cultural Ecosystem Services: A Bridge between the Natural Ecosystem and Social Ecosystem for Sustainable Development

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Abstract: Cultural Ecosystem Services (CESs), as non-material benefits and well-being provided by ecosystems to humans, possess the ability to bridge nature and human society and interpret their complex interrelationships. Coastal areas are regions with concentrated human activities, where coastal zones are often subject to human development, pollution, and degradation. Compared to other ecosystems, coastal ecosystems face greater pressures and threats, and the cultural services they provide are more vulnerable. Research on coastal ecosystem cultural services needs to consider ecosystem vulnerability and find ways to protect and restore ecosystem functions. Therefore, this paper explores the intrinsic logical system and feasibility of guiding natural resource management and enhancing human well-being through coastal CESs, discussing related research data acquisition, method analysis, and perceptual application. Based on this, this paper analyzes the development trends of coastal CESs in natural resource management and enhancing human well-being from aspects such as biodiversity, human–nature interaction processes, cultural heritage conservation, local economic development, and community management. Finally, it proposes advancing the in-depth research of coastal CESs from the perspectives of integrating multi-source data, interdisciplinary development, and incorporating CESs into policy making, providing theoretical support for the systematic study of rational resource utilization and sustainable ecosystem development.

Keywords: coastal CESs; natural resource management; human well-being; policy making

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1. Introduction

With the rapid development of the socio-economy, the theory of sustainable development can guide humanity to actively explore solutions to development issues in environmental, economic, and social domains, collectively addressing new global challenges [1–3]. As human activities continue to intensify, issues such as overexploitation of resources, environmental pollution, climate change, and loss of biodiversity have emerged globally, subjecting the atmosphere, water bodies, and land to sustained pressure, gradually expanding the negative impacts on the resilience and sustainability of ecosystems [4]. In recent years, as a bridge and link connecting natural processes with human activities, research on ecosystem services (ESs) has become a frontier and hotspot in international geography, ecology, and related disciplines. ESs, as vehicles for resource allocation and benefit coordination, can be divided into four major categories: provisioning services, regulating services, cultural services, and supporting services, linking ecosystems with human well-being and

serving as important tools for achieving land space optimization and guiding planning decisions in line with the concept of ecological civilization [1,5–7]. Among them, cultural ecosystem services (CESs), due to their intangible, subjective, and non-economic characteristics, have been controversial in their development. However, as the basic social and cultural benefits provided by ecosystems to humanity, they embody the profound interrelationships between human spatial perceptions and cultural practices reflected in outdoor recreation, scientific exploration, artistic creation, and other production and consumption activities [8,9]. Effective protection and management of CESs are of significant theoretical and practical importance for achieving rational resource utilization, cultural inheritance and innovation, safeguarding the sustainable development of ecosystems, and building a harmonious coexistence between humans and nature.

Coastal areas constitute one of the most important geographical structures and functional systems on Earth. From an ecological perspective, coastal areas are among the most biodiverse ecosystems on the planet, including important ecosystems such as coastal wetlands, coral reefs, and marine grass beds, which provide habitats and breeding grounds for many species and play a crucial role in maintaining global marine ecological balance and biodiversity [10,11]. From an economic standpoint, coastal areas are often key nodes for international trade, port transportation, and fisheries activities, providing abundant fishery resources and serving as important bases for multiple industries such as tourism and shipping. From a social perspective, coastal areas are typically densely populated regions, home to numerous cities and communities with rich historical and cultural traditions. Social activities, cultural heritage, and community life in coastal areas often present distinctive characteristics compared to inland regions. However, coastal areas also face a series of challenges including environmental pollution, sea level rise caused by climate change, natural disasters, and coastal erosion. These challenges not only affect sustainable development at the local level but also pose threats to the global environment and development [12,13]. Therefore, there is a need to enhance attention to the ecological, economic, and social development of coastal areas, seeking ways to safeguard coastal CESs from the perspective of community governance, protect their unique ecosystems and social cultures, foster public sentiments towards environmental friendliness, and thereby increase understanding of coastal ecosystems. Such efforts play a crucial role in human health and well-being.

Research on CESs covers a range of disciplines including geography, ecology, economics, and psychology. It not only focuses on natural aspects such as biodiversity, soil quality, and water resources but also emphasizes the integration of human society with nature. Centered around the framework of "perception-attitude, values-worldview", CESs research seeks to understand the perceptual differences and behavioral preferences of different actors in the interaction with natural ecosystems, thereby providing theoretical support and guidance for optimizing land space [14–17]. Currently, research on ecosystem services in coastal areas mainly focuses on provisioning, regulating, and supporting services, with relatively limited attention to cultural services. This comprehensive research contributes to the establishment of more comprehensive sustainable development strategies and promotes the coordinated development of society in economic, cultural, and ecological aspects. By deeply understanding the role of CESs in sustainable development, it is possible to provide a scientific basis for ecological protection, cultural inheritance, social stability, and other aspects, thereby offering scientific support for the sustainable development of human society. In this context, research on coastal CESs not only helps scientists explore the relationship between ecosystems and culture but also provides important policy recommendations for decision makers.

Increasing attention has been paid to the development and application of CESs. As a special zone of sea–land interaction, coastal areas are characterized by rich natural resources, fragile ecological environment, and frequent human activities. Coastal CESs not only reflect the natural ecological characteristics of specific geographical environments, such as coastlines, wetlands, and coral reefs, but are also closely related to the lifestyles,

cultural traditions, and economic activities of local communities. Additionally, factors such as the level of economic development, population density, urban planning, and policy orientation in coastal areas significantly influence the quality and sustainability of CESs. It is very important and necessary to evaluate coastal CESs on unique coastal ecosystems and coastal communities. However, much of the current research focuses on the quantification of assessments of coastal CESs, and there is a relative lack of in-depth exploration and systematic review of coastal CESs. This has led to an unclear understanding of the research focus and trend of coastal CESs. In order to better utilize and expand the application scenarios of coastal CESs, there is an urgent need for more comprehensive and in-depth research on them to reveal the diversity, complexity and potential value of coastal CESs. Therefore, based on the published coastal CESs literature in the WOS core collection and Scopus database, this study uses knowledge mapping tools, such as VOS viewer 1.6.20, to quantify and visualize the analysis, to systematically analyze and summarize the coastal CESs research, and to put forward the future research outlook accordingly. This study aims to provide useful explorations for coastal CESs to promote the positive interactions between natural ecosystems and social ecosystems.

2. The Interactive Relationship among Coastal CESs, Natural Resource Management, and Human Well-Being

In coastal areas, a close interactive relationship exists between coastal CESs, natural resource management, and human well-being (Figure 1). Coastal ecosystems provide rich CESs such as landscape aesthetics, biodiversity conservation, and cultural heritage, which directly impact human spiritual, cultural, and economic life [18,19].

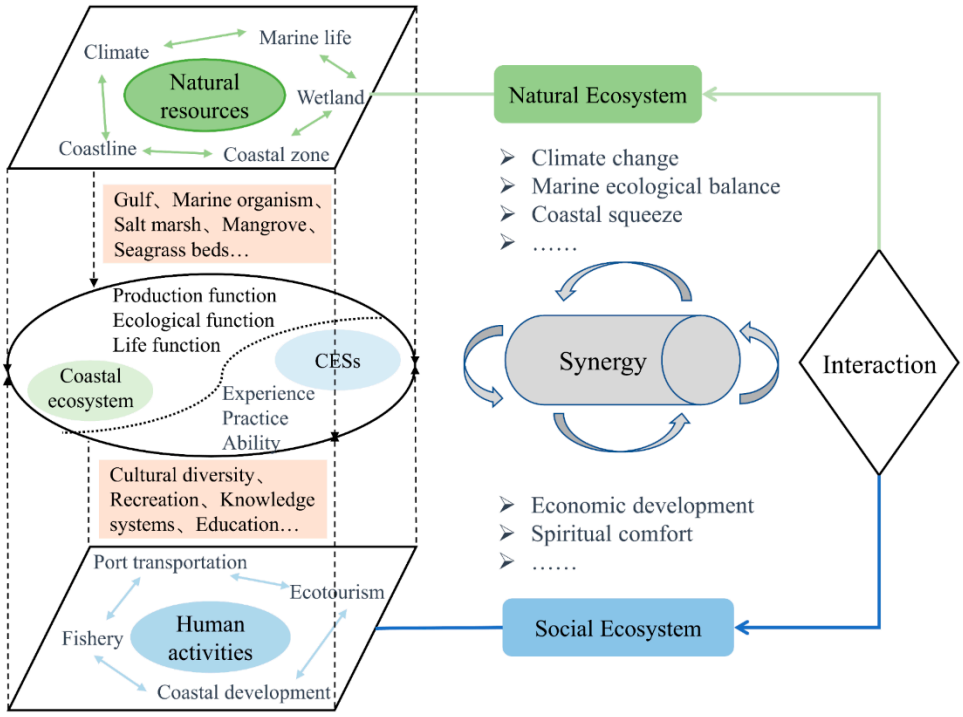


Figure 1. Interaction between natural resources, human activities, and CESs in coastal areas.

Firstly, coastal CESs are a crucial component of natural resource management. Coastal ecosystems, such as salt marshes, mangroves, and seagrass beds, provide rich biodiversity and ecological functions. The goal of natural resource management is to ensure the health and sustainability of these ecosystems, thereby ensuring their continued provision of coastal CESs. For example, by protecting and restoring coastal wetlands, their ecological functions can be enhanced, which in turn supports cultural diversity and recreational activities.

Secondly, coastal CESs have a direct impact on human well-being. They enhance people's mental comfort and social cohesion by providing opportunities for recreation and leisure. Coastal CESs are also closely related to education and cultural experiences; through participation in ecotourism and environmental education activities, individuals can relax, gain knowledge and skills, and improve their awareness and practical abilities regarding environmental issues.

Additionally, coastal CESs are closely connected with economic activities, particularly in the fields of ecotourism and fisheries. These activities not only provide economic income to local communities but also promote the sustainable development of socio-ecological systems. However, human activities, such as coastal development and port transportation, can place stress on coastal ecosystems, leading to what is termed "Coastal squeeze". This necessitates effective natural resource management to balance economic development with ecological protection.

In summary, the interdependence and influence between coastal CESs, natural resource management, and human well-being form a mutually reinforcing system. Effective natural resource management is fundamental to ensuring the sustained provision of coastal CESs, which in turn directly contributes to enhancing human well-being. Concurrently, the improvement in human well-being supports the rational use and protection of natural resources. This synergy underscores the importance of achieving sustainable development in coastal regions.

3. Materials and Methods

3.1. Database Search

This study conducted a search on the Web of Science Core Collection database and Scopus on 5 June 2024. The search covered all years from 2009 to 2024. In order to understand the amount of ongoing research, different terms and combinations have been used, as shown in Table 1. To focus on research related to coastal CESs, proceeding papers, book chapters, letters, and other document types were excluded. Only articles and reviews were selected, and duplicate data were removed. Ultimately, 150 documents were chosen for analysis.

Table 1. Searched terms and results from queries to WOS core collection and SCOPUS.

Searched Terms	Occurrences	
	WOS Core Collection	Scopus
"cultural ecosystem services" AND "coastal"	62	83
"culture ecosystem services" AND "coastal"	3	2
"cultural ecosystem services" AND "ocean"	7	16
"cultural ecosystem services" AND "sea"	19	31
"cultural ecosystem services" AND "marine"	35	48
"cultural ecosystem services" AND "fish"	21	16
"cultural ecosystem services" AND "mangrove"	7	16
"cultural ecosystem services" AND "bay"	7	14
"cultural ecosystem services" AND "shellfish"	3	4
Total	164	230

3.2. Literature Classification

For the identified coastal CESs literature, this study classified, summarized, and concluded the selected literature from the following aspects: (1) geographic distribution; (2) types of coastal ecosystems; (3) subcategories of CESs; (4) research methods for coastal CESs; and (5) scientific issues concerned by coastal CESs research.

3.2.1. Geographic Distribution

In this study, we conducted an in-depth reading of each piece of literature and paid particular attention to the geographic location of the study. During the reading process, we

meticulously scrutinized the specific regions covered by each empirical study and made exhaustive records of the countries in which these regions are located. These records not only provided us with the geographic context of each study, but also served as the basis for further analysis of the relationships between different countries and coastal ecosystem types. By gaining insight into these geographic locations, we were able to more accurately explore and understand the diversity of coastal ecosystems and their interactions with human activities.

3.2.2. Identification of Coastal Ecosystem Types

The diversity of ecosystems determines that the CESs they provide also vary. Different researchers will focus on CESs in different ecosystem types, depending on the characteristics of the study area, research interests, and goals. In this study, we synthesized the coastal ecosystem types involved in the study of coastal CESs with reference to the usual classification of coastal ecosystem types [20]. We propose that coastal ecosystem types should include the following ten types: marine organism, estuary, salt marsh, dune, mangroves, lagoon, seagrass beds, estuaries, coral reef, and gulf (represents the shoreline area near the gulf). These types not only cover the natural ecological characteristics of coastal areas, but also reflect their important role in providing various types of ecosystem services. Through this categorization, this study aims to more systematically analyze and understand the contribution of different coastal ecosystems in maintaining ecological balance and supporting human well-being.

3.2.3. Identification of Subcategories of Coastal CESs

The current international classification and definition of CESs is mainly provided by Millennium Ecosystem Assessment (MA), The Economics of Ecosystems and Biodiversity (TEEB), Common International Classification of Ecosystem Services (CICES), Intergovernmental Science-Policy Platform for Biodiversity and Ecosystem Services (IPBES), UK National Ecosystem Assessment (UK NEA), which includes types such as aesthetic value and recreational value. In order to ensure consistency in the understanding of CESs, this paper selects the definitions and categories proposed by the MA reports, which are referenced and emphasized in a number of studies (plus references). These categories were identified as Recreation, Aesthetic, Sense of place, Spiritual and religious, Education, Social relations, Cultural heritage, Cultural diversity, Knowledge system, Inspiration.

3.2.4. Identification of Methods Used in Coastal CESs Research

Based on a systematic review of the literature on coastal CESs, we summarized and concluded the data types and research methods in detail. We took detailed notes on the types of data used by researchers when reading the literature and initially categorized them into three main groups: natural environment data, social data, and perceptual data. For each type of data, we not only recorded its main characteristics, but also looked in detail at the sources, collection, and analysis processes used to obtain these data. In terms of research methodology, we classified the methods into two categories, statistical analysis and spatial visualization analysis, based on the research process and technical support. In addition, the literature systematic review was an iterative process that adjusted the selection of data types and research methods based on new findings and feedback to ensure that systematic generalizations and summaries were obtained.

3.2.5. Identification of Scientific Issues Concerned by Coastal CESs Research

When conducting a systematic review of the literature on coastal CESs, we first familiarized ourselves with the current state and trends in the research field through a literature preview, which in turn identifies key themes. Next, we defined the purpose of this study, around which we formed specific scientific questions designed to guide the review process and ensure research direction. We then refined these questions to ensure that they were both relevant and actionable. Finally, we documented the questions and

updated them with new findings and understandings throughout the review process to ensure the currency and depth of the research.

3.3. Bibliometric Analysis Methods

Visual mapping software usually has powerful data mining and analysis functions, which can perform operations such as keyword extraction and topic clustering, reveal the interrelationships and citation networks among the literature through the layout of nodes and links, sort out the overall structure and development of the research field, and understand the core topics and development trends of the research field in a more in-depth manner. Providing researchers with tools for quantitative literature trend analysis, in-depth knowledge structure visualization, and interdisciplinary correlation exploration can effectively meet diverse research needs. Therefore, we utilized the keyword clustering and emergence functions of VOS viewer 1.6.20 software to explore the research and hot frontiers of coastal CESs in recent years.

4. Results

4.1. Results of the Bibliometric Analysis

From the trend of annual publications in coastal CESs research (Figure 2), it can be observed that literature related to coastal CESs first appeared in 2009. Over the following decade, scholars' attention to this field has continuously increased, especially after 2018, when the number of related research documents rapidly increased and continued to grow. In 2015, the United Nations adopted the "2030 Agenda for Sustainable Development", which includes 17 Sustainable Development Goals (SDGs), emphasizing ecosystem conservation, cultural heritage protection, and other aspects. Meanwhile, academia's understanding of CESs has gradually deepened, shifting from a simple focus on resource utilization to a comprehensive perspective that considers ecology, culture, society, and economy. This shift helps strengthen the connection between CESs and coastal area policy formulation. At present, researchers from 32 countries and regions, including the UK, the US, China, and Spain, have carried out special studies on coastal economic benefits. Among them, the UK and the US have the highest number of publications, with 17 and 11 papers, respectively. In terms of research subjects, the diversification of spatial dimensions and value types further reflects the complexity of the relationship between humans and nature in coastal areas.

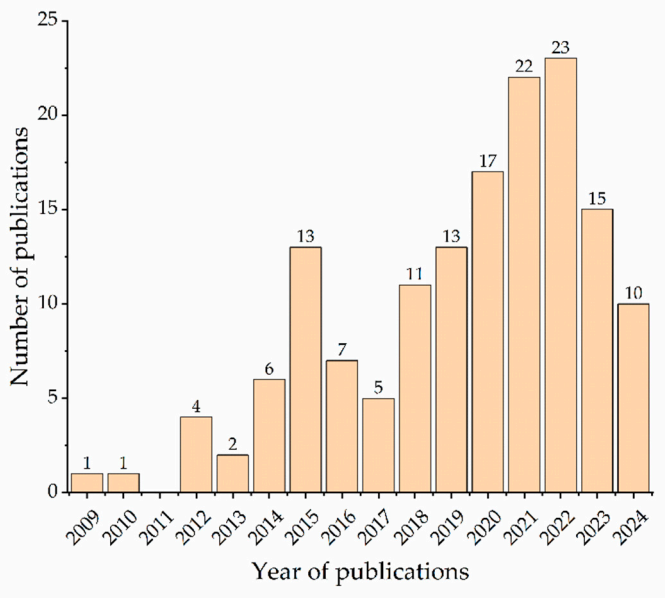


Figure 2. Number of publications per year that addressed coastal CESs.

To better understand the research hotspots in different countries and regions and people's perceptual preferences for different coastal ecosystems, this study further analyzes the relationship between the country of the study area and types of coastal ecosystems, the connection between different types of coastal ecosystems and CESs subtypes (Figure 3). In terms of the location of the study area, the UK, US, Spain, Australia, and China have the highest number of studies of relevant coastal CESs. This is due to the fact that these countries have extensive and diverse coastal ecosystems. The abundance of resources provides a large number of objects and opportunities for research. At the same time, the economies of these countries are highly dependent on coastal resources, especially in fisheries, tourism, port trade, and coastal urban development, all of which have contributed to the increased demand for research on coastal ecosystems and their CESs. Coastal ecosystems refer to natural systems in the ocean composed of biological communities and their interactions with the environment. They mainly include ten typical ecosystem types such as marine organism, estuary, salt marsh, dune, mangroves, lagoon, seagrass beds, estuaries, coral reef and gulf (represents the shoreline area near the gulf). These ecosystems possess natural ecological values and serve various social functions. Currently, CESs research is primarily focused on these types of ecosystems. In terms of individual coastal ecosystem types, the marine organism receives the highest level of attention. This is because the richness of the marine organism plays a crucial role in maintaining ecosystem balance and constitutes a significant component of coastal CESs. Additionally, the marine organism holds special symbolic and cultural value in many societies, closely intertwined with local traditions, religions, and arts. Additionally, gulf, mangroves, salt marshes, and estuary receive considerable attention from researchers. This is because they have significant impacts on local communities' livelihoods, culture, and socio-economic development. They also face threats such as land development, pollution, and sea-level rise. Conducting CESs research on these ecosystems helps understand their vulnerabilities and challenges, aiding in the formulation of appropriate conservation and management strategies.

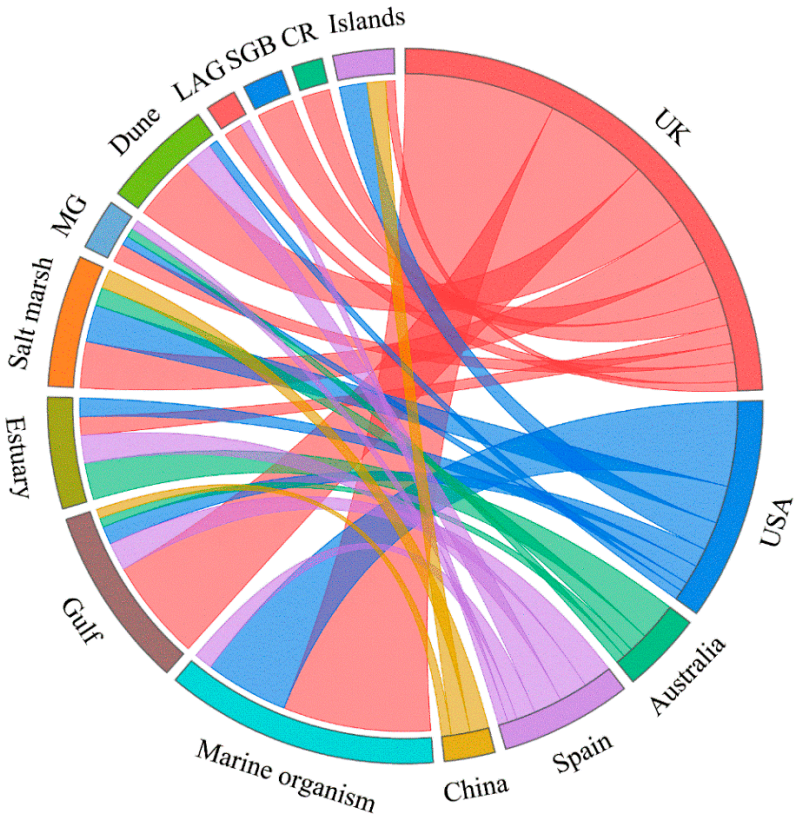


Figure 3. Study of the relationship between countries and coastal ecosystem types. Notes: MG for mangrove; LAG for Lagoon; SGB for Seagrass beds; CR for Coral reef.

From the correspondence between different types of coastal ecosystems and CESs subclasses (Figure 4), it can be observed that the differences in structure and function of different coastal ecosystem types, environmental pressures, ecological vulnerabilities, as well as the needs and cultural traditions of coastal communities, can all influence the CESs provided by coastal ecosystem types. In terms of individual coastal ecosystem types, there is a higher number of studies related to marine organisms and the gulf. This is because marine organisms provide services to humans, including food resources and marine tourism. Additionally, the gulf faces various threats from human activities such as overfishing, pollution, and climate change. Understanding the impacts of these threats on marine organisms and ecosystems, as well as how to effectively protect these biological resources through public participation, is one of the current research directions. In terms of CESs subclasses, there is a higher number of studies related to recreation and cultural heritage. This is because governments and stakeholders need to consider how to balance the development of recreational activities with the need for ecosystem protection, as well as how to effectively protect and manage cultural heritage. Moreover, recreational services and cultural heritage often attract broader public participation, promoting public awareness and protection of ecosystems and cultural heritage.

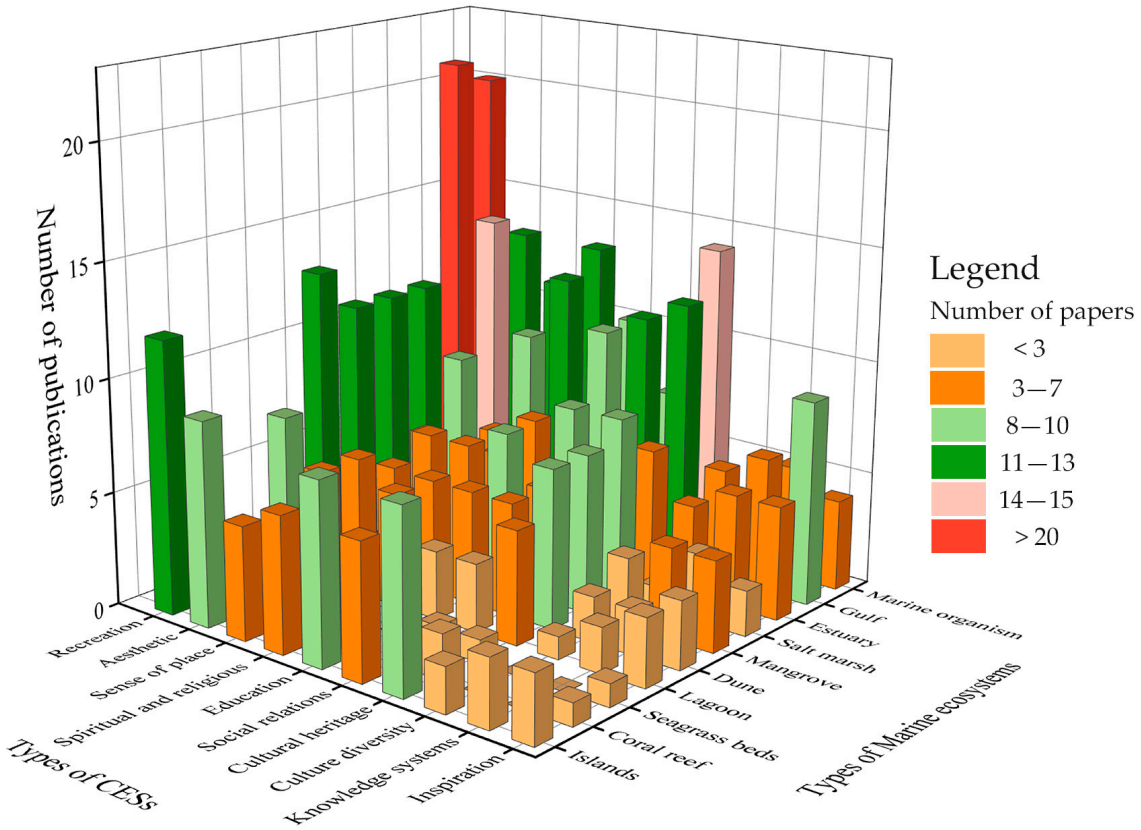


Figure 4. Correspondence between coastal ecosystem types and CESs subcategories in the publications.

In a particular field, research hotspots and the evolutionary context can be explored through keyword mining. With the support of VOS viewer 1.6.20 software, keywords with a co-occurrence frequency exceeding two were subjected to co-occurrence visualization processing (Figure 5). From the figure, it is evident that by excluding terms related to literature search queries such as "cultural ecosystem services", "ecosystem services", and "coastal", keywords like "management" (27), "values" (25), "conservation" (22), and "framework" (19) emerge as hotspots in the field. Additionally, a multi-center research structure has formed, with the search terms as the central point and research hotspots as secondary centers. This structure is further elaborated upon through various entry points such as

"benefits" (14), "biodiversity" (12), "social media" (10), "landscape" (6), and "health" (5). In addition to the aforementioned keywords, environmental ethics is also particularly important in the study of coastal ecosystem cultural services. It establishes the value of nature, emphasizes human responsibility towards the environment, advocates for respect for biodiversity and cultural heritage, supports sustainable development, and encourages proactive efforts to protect these cultural services. Research on CESs operates at spatial and local scales, exploring effective pathways for local resource management by analyzing the perceptual preferences and behavioral patterns of different societal actors in various social contexts. As an interdisciplinary research direction, coastal CESs research utilizes theories from disciplines such as geography, ecology, economics, and sociology to address issues across different domains. It provides theoretical support and methodological guidance for sustainable ecosystem management, coastal land use planning, and the high-quality development and spatial layout of related industries.

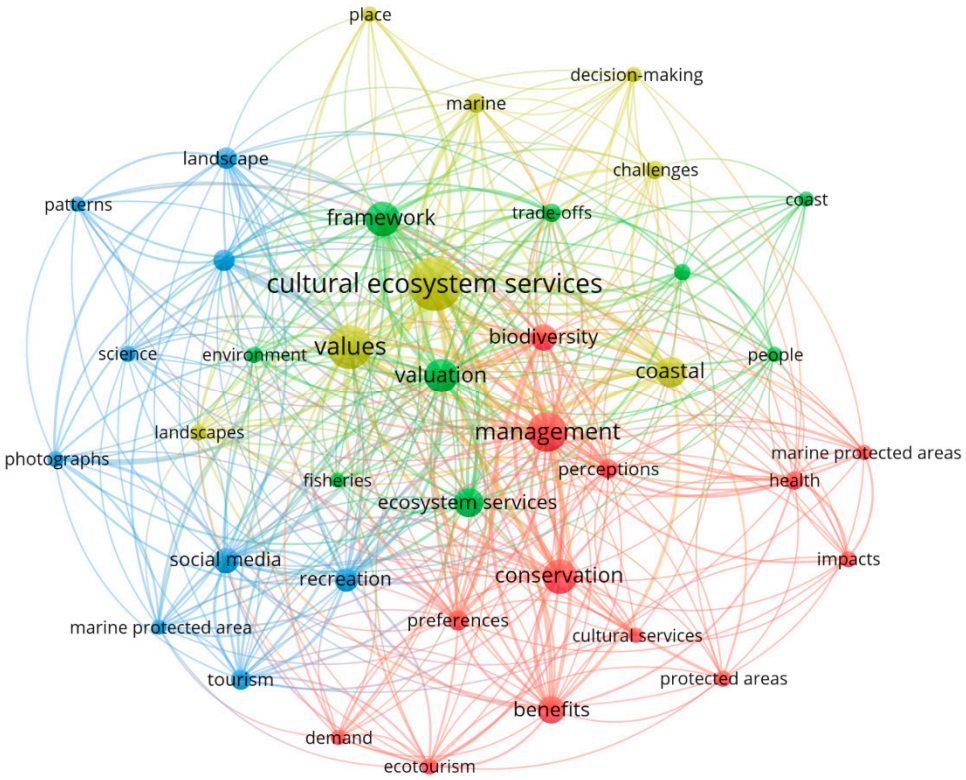


Figure 5. Keywords co-occurrence mapping for coastal CESs research.

The distribution of journals can visualize the distribution of mainstream journals in coastal CESs research, and the distribution of co-cited journals can characterize their influence and relevance to the academic research in this field. From the Figure 6a knowledge graph of coupled distribution of articles, it can be seen that the journals with high volume of publications are *Ecosystem Services*, *Marine Policy*, *Ocean & Coastal Management*, *Ecological Indicators*, *Ecological Economics*, and the fields of the journals are mainly environmental sciences, ecology, and oceanography. As can be seen from the timeline in Figure 6a, the above journals with a high volume of publications focusing on the development of coastal CESs are mainly concentrated in the period of 2018–2021. *Journal of Environmental Management*, *Land*, *Ecosystems and People*'s focus on coastal CESs research has intensified in recent years. As can be seen from the distribution of journal co-citations shown in Figure 6b, the 155 sample documents with a total citation frequency of 200 or more are *Bioscience* (1486), *Ecosystem Services* (672), *Ecological Indicators* (432), *Ecological Complexity* (330), and *Landscape Ecology* (319). Overall, environmental sciences, ecology, and landscape journals continued to pay more attention to coastal CESs research, while oceanography journals

paid less attention, suggesting that environmental, ecological, and landscape journals play an important role in supporting and leading coastal CESs research.

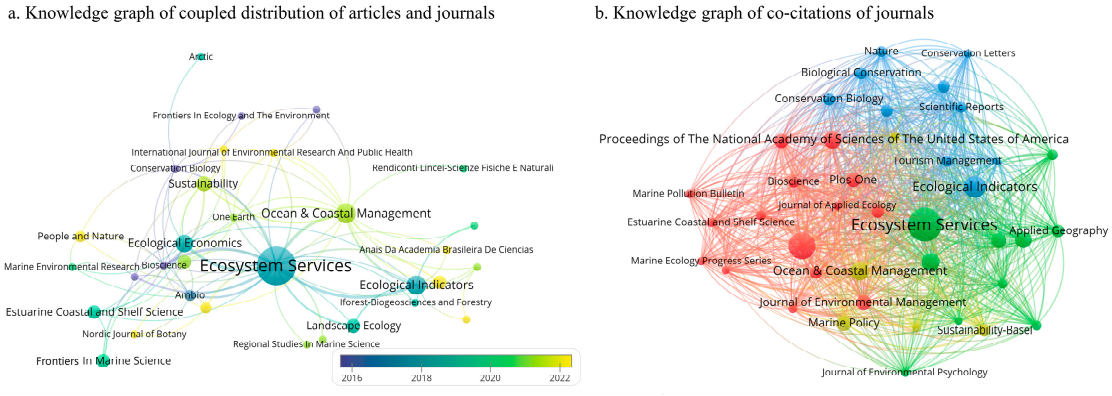


Figure 6. Knowledge map of the distribution of journals carrying articles on coastal CESs research.

4.2. Research Methods for Coastal CESs

Compared to the other three categories of services in coastal ecosystems (supporting, provisioning, and regulating services), research on CESs started relatively late for two main reasons. Firstly, cultural services possess intangible and subjective characteristics, with complex content and thus presenting greater research challenges. Secondly, attention to non-material dimensions of development often builds on material dimensions development, with resulting CESs research having a certain degree of delay. As of now, in terms of data acquisition, coastal CESs have established methods such as remote sensing monitoring, collection of local statistical data, and survey questionnaires to obtain the necessary data on the natural environment, social development, and public perception. Regarding data analysis, approaches predominantly focus on text analysis and spatial visualization, supporting more in-depth practical research in areas such as community-based sustainable management, climate change, and marine protected areas.

4.2.1. Data Acquisition for Coastal CESs

Coastal CESs research typically requires multi-source data including environmental, social, and perceptual data. Environmental data at various scales are mainly obtained through field sampling and remote sensing monitoring methods [21,22]. The identification of CESs hotspots and cold spots, as well as the matching of supply–demand patterns based on environmental data, are equally crucial for landscape sustainable management and biodiversity conservation. Pouso et al. (2018) conducted questionnaire surveys on beach users' behaviors and perceptions, comparing them with environmental time series data (microbial concentrations and water transparency) [23]. The results underscored the significance of water sanitation actions in restoring degraded coastal environments and maintaining ecosystem services. Additionally, remote sensing imagery monitoring of land surface forms and land use types at different historical stages serves as vital reference material for CESs temporal scale analysis. By delineating the timeline of events influencing tidal and freshwater flows in the Tamar River estuary since 1806, Davis and Kidd emphasized the importance of identifying pressure sources [24]. They regarded this as foundational in balancing the potential for reducing various ecosystem services under environmental restoration, particularly between provisioning and cultural ecosystem services.

In terms of social data acquisition, local statistical data serve as the primary source. Uddin et al. utilized tourism revenue data collected by the Forest Department to assess the cultural services provided by the Sundarbans Reserve Forest to the local population. They argued for a comprehensive economic assessment of the total stock and potential of all ecosystem services, and the determination of sustainable yield limits for services under different socio-economic and climate change scenarios to enhance the forest's sustainable management [25]. Apart from local statistical data, geolocated data, which record human

activities associated with geographic entities and their interrelationships with geographic locations, offer new data sources for studying human–nature interactions and regional development. Their application in coastal CESs research is increasingly widespread [26]. Martinez Pastur et al. employed geotagged digital images posted by residents and tourists on the Panoramio web platform to identify hotspots of four cultural ecosystem services. They correlated these hotspots with social and biophysical landscape features, demonstrating the utility of this method for assessing CESs at the regional scale, particularly in areas with low data availability and on-site accessibility [27].

In terms of perception data acquisition, early CESs research often relied on a combination of survey questionnaires as the primary method and semi-structured interviews as a supplementary method to collect perceptions and behavioral preferences of different stakeholders regarding environmental spaces [28]. Urquhart and Acott, through semi-structured interviews with stakeholders in fishing communities, explored the contribution of local perceptions to understanding the relationship between fisheries and coastal CESs. They argued that while ensuring the sustainability of fish resources, the contribution of fisheries to the social and cultural well-being of coastal communities should not be overlooked [29]. To adapt to emerging trends, the application of social media big data in CESs research has become increasingly popular. Moreover, the application of multi-source social media data has successfully overcome the limitations of geographical administrative boundaries, supporting researchers in conducting large-scale assessments of CESs when field surveys are not feasible [30]. To understand the visitation patterns and benefits of different types of natural and cultural heritage tourists, Ghermandi et al. combined social media photos with high-resolution land cover maps to identify different cultural services and their associations with specific ecosystem and land cover types. The results can provide valuable information for decision makers to improve tourism management and conservation strategies [31].

4.2.2. Methodology for Analyzing Coastal CESs

Evaluation of coastal CESs primarily focuses on non-material values that are difficult to quantify, such as spiritual, religious, and local perceptions. The data composition typically includes various types such as textual data, point data, and spatial data. Therefore, analysis of the results often involves statistical analysis and spatial visualization analysis to meet the subsequent applications in natural resource management and enhancement of human well-being.

Coastal CESs research typically involves a large amount of survey questionnaire data, interview data, etc. Statistical analysis can help researchers extract useful information from these data and reveal hidden patterns and trends in the research. Firstly, based on the collection of relevant data such as tourism revenue and cultural heritage, statistical analysis can better understand their contributions to communities and economies. De la Lama et al. identified and described the historical cultural benefits of small-scale fisheries in Peru and their transformative role in early social development, emphasizing the contribution and historical significance of small-scale fisheries to society [32]. Secondly, in coastal CESs research, researchers often find it difficult to conduct comprehensive surveys of entire populations or ecosystems. Therefore, they often need to use statistical analysis for inference and generalization, such as understanding community residents' and stakeholders' perceptions, attitudes, and involvement in coastal CESs, analyzing tourists' behavior patterns and preferences in ecosystems, and determining their needs, concerns, and willingness to participate, thus promoting community involvement and co-management, guiding the planning and management of ecotourism. Based on stakeholder mapping, semi-structured interviews, observation, and surveys of socio-cultural preferences, Malinauskaite et al used grounded theory induction to qualitatively analyze data, examining the CESs derived from whales by people residing in Skjálfandi Bay, North Iceland, and its surroundings, to incorporate CESs related to whale resources into marine resource management in Iceland [33]. Finally, statistical analysis can also assess the impact of human behavioral preferences on ecosystems, including their effects on biodiversity, ecosystem functions, and ecosystem

health, thereby guiding ecosystem conservation and sustainable management. Based on identifying trends in the consumption and collection of wild plants, Reyes-García et al. analyzed the correlation between CESs and this trend, finding that CESs are an important factor in explaining different development trends among different plant species [34].

Through spatial visualization analysis, researchers can display the spatial distribution of ecosystems, the supply and demand of coastal CESs, and related data on maps, helping to reveal the spatial correlations between landscapes, human activities, and coastal CESs. This provides intuitive spatial information support for decision making. By conducting spatial visualization analysis of factors such as ecosystem characteristics, distribution of cultural landmarks, and population density in different regions, researchers can understand the spatial distribution characteristics of coastal CESs and identify important ecological landscapes and cultural landmarks to explore the spatial correlations between human activities and ecosystems. Zhao et al. used a combination of social media data and the SolVES model to simulate the spatial distribution patterns of tidal wetland CESs from different stakeholders' perspectives, thus reconciling the contradiction between agricultural infrastructure construction and coastal wetland ecosystem management, and providing planning recommendations for the sustainable development of coastal wetland agriculture [35]. Additionally, by mapping the spatial relationships between the supply and demand of coastal CESs in different regions, the spatial accessibility and sustainability of coastal CESs can be clarified, helping policymakers and planners assess whether the supply of coastal CESs in different areas meets demand and identify areas with supply–demand imbalances, providing scientific evidence for ecosystem protection and optimizing user experience. Santana-Santana et al. analyzed and discussed the preference statistical relationships between two user types: those with disabilities and those without disabilities. They also studied whether environmental management and land use in the study area met users' expectations, providing a reference for optimizing user experience [36].

4.3. Trends in Research on Coastal CESs

The trend of coastal CESs research can be determined based on the intensity and timing of keyword emergence in the keyword burst diagram generated by VOSviewer 1.6.20 software (Figure 7). It can be observed that keywords focusing on natural resource management, such as marine spatial planning, biodiversity, and environment management, mostly appeared during the initial stage of coastal CESs research. As the research progresses, the frequency of keywords such as decision making, tourism, health, and perceptions increases, indicating that researchers are no longer solely focused on natural resource management and ecosystem protection, but are also paying attention to the dynamic process of CESs from perception to application. This highlights the greater role played by coastal CESs research in improving human–environment relationships and enhancing human well-being [37–40].

Research on coastal CESs is advancing towards a new interdisciplinary and integrative era. With the integration of modern technologies such as social media and big data, researchers can more accurately capture public perceptions and attitudes towards coastal ecosystems. This, in turn, provides scientific evidence for fields closely related to ecosystems, such as tourism and health, while also assessing the impact of human behavior on ecosystems and formulating effective environmental education and conservation strategies. Additionally, the quantitative assessment of coastal CESs, adaptive management in response to climate change, the provision of scientific foundations for policy and governance, as well as the enhancement of community engagement and local management, are all critical directions in the development of coastal CESs research. These efforts aim to achieve long-term ecosystem sustainability and the maximization of human well-being.

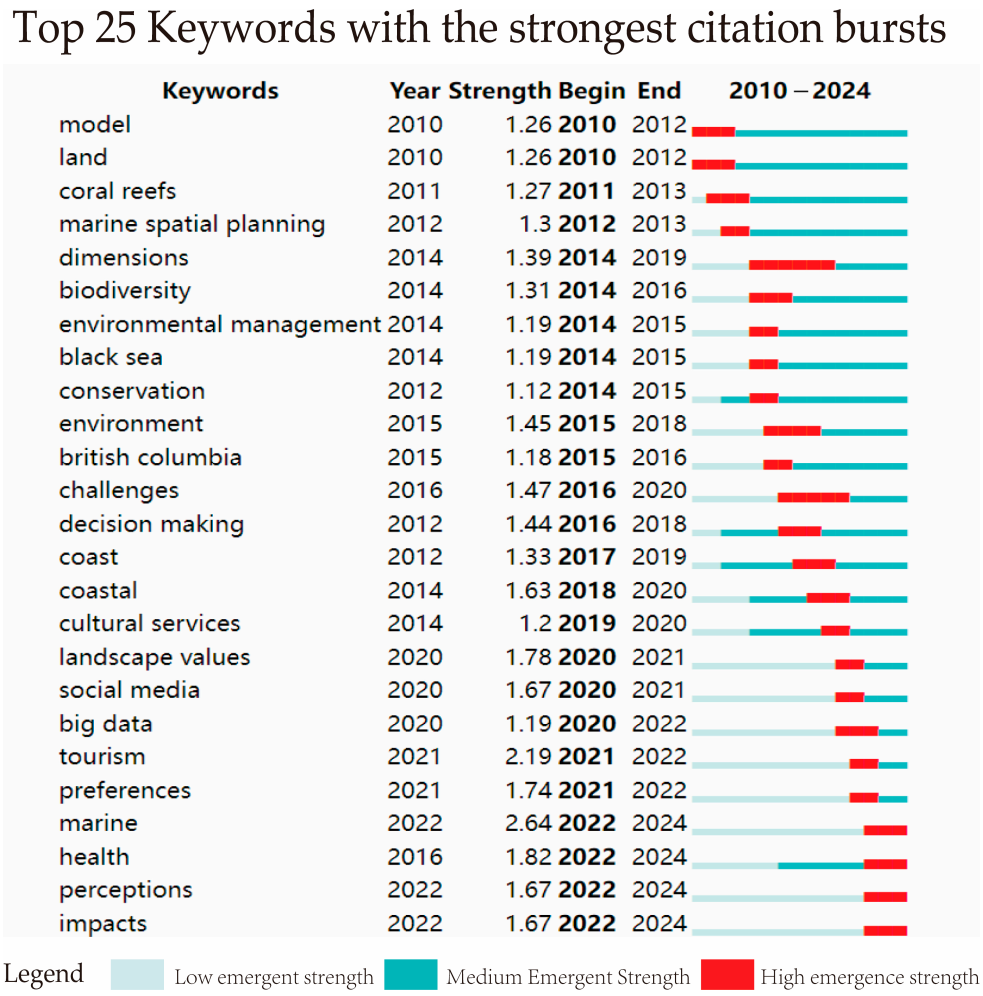


Figure 7. Coastal CESs study high mutability keywords.

4.3.1. Coastal CESs and Natural Resource Management

Coastal areas harbor rich biodiversity and essential ecological functions, including marine fisheries resources, coastal wetlands, and coral reefs. Effective natural resource management can ensure the sustainable utilization of these resources, preventing overfishing and development, thereby protecting the health and ecological balance of marine ecosystems.

Due to the vast array of services and resources provided by the ocean, it is evident that marine biodiversity is crucial for both human and planetary health [41,42]. Through cultural activities, ecotourism, the preservation and promotion of local marine culture, and the traditions of fishermen, people can gain deeper insights into the diversity and fragility of coastal ecosystems. This promotes respect and reliance on the natural environment, reducing overexploitation and damage to natural resources, and enhances awareness and actions towards biodiversity conservation [43–45]. Furthermore, the establishment of marine protected areas, ecological reserves, and similar regions to protect the integrity and stability of rare species and critical ecosystems can effectively maintain the biodiversity of coastal ecosystems [46,47]. Kochalski et al. (2022) surveyed in France, Germany, Sweden, and Norway to clarify the public's perceptions of CESs provided by threatened species such as Salmon salar. The results indicate that improving ecological conditions and raising public awareness can promote the development of perceptible ecosystem services and the value of a species in the public eye [48]. Coastal CESs positively impact biodiversity conservation by increasing awareness and appreciation of biodiversity, fostering harmonious relationships between humans and nature, providing protective measures, and promoting community

participation and cooperation. This contributes to achieving the sustainable development and protection of coastal ecosystems.

Furthermore, coastal CESs play a significant role in the interaction between humans and the natural environment, carrying people's cognition, emotions, and values towards the natural environment, thereby playing an important guiding and supportive role in natural resource management [49,50]. Coastal CESs are not only reflected in the aesthetic enjoyment of natural landscapes but also encompass the protection and transmission of traditional fisheries, marine lifestyles, and local cultural heritage [51]. Through shaping people's attitudes and behaviors toward the natural environment, coastal CESs influence the development, utilization, and protection of natural resources [52]. At the same time, the research framework of CESs helps enhance respect and attention towards natural resources, promotes community participation in natural resource management, and drives the formulation and implementation of relevant policies [53–55]. Gajardo et al. quantified the CESs provided by Taytay Bay, identifying human activities that threaten CESs. The results indicate that CESs contribute to promoting human well-being at the community level, and integrating cultural and non-monetary environmental values into ecosystem assessments and on-site policy-making is crucial [56]. Therefore, coastal CESs complement natural resource management, and understanding coastal CESs can enhance the sustainability of natural resource management.

4.3.2. Coastal CESs and Human Well-Being

The unique natural landscapes and biodiversity of coastal areas can provide coastal CESs to meet the growing spiritual needs of humanity. The lifestyles of coastal residents, fisheries culture, and cultural heritage of coastal communities also serve similar functions. The well-being of contemporary and future human societies depends on whether there are ecologically sustainable and socially just ways of life worldwide, which in turn directly impact the functionality, services, and landscape patterns of ecosystems.

The natural environment and cultural landscapes of coastal areas are often closely intertwined, forming unique cultural landscapes and traditional ways of life. These cultural heritages carry rich history, traditions, and cultural memories, representing valuable assets of local communities [57]. By exploring and preserving local cultural heritage, and promoting the development and production of cultural products and traditional craftsmanship, we can not only meet market demands but also enhance the added value of local fishery products. Additionally, by engaging in activities such as ecotourism, marine cultural events, and traditional fishing experiences, people gain a deeper understanding and appreciation of local cultural traditions, which can strengthen awareness and protection of cultural heritage [58,59]. Cabana et al. used the coastal site of Dublin Bay as an example, and proposed a comprehensive evaluation and communication strategy for CESs, integrating research from humanities, social sciences, and environmental sciences. The study suggests that different values and services depend on specific coastal habitats, and integrating CESs into cultural heritage conservation frameworks can enhance contributions from multiple stakeholders and the public [60]. By exploring how coastal ecosystems meet human spiritual needs through CESs, promoting awareness, inheritance, and protection of cultural heritage, CESs contribute significantly to the conservation of cultural heritage in coastal areas.

The natural landscapes and ecological environments of coastal areas are often essential factors attracting tourists [47]. By offering a diverse range of coastal leisure activities such as beach vacations, marine cultural experiences, and traditional fishing tours, coastal areas can attract a large number of tourists, thereby driving the development of the tourism industry. This not only generates tourism revenue for the local community but also stimulates the prosperity of related industries such as catering, accommodation, and fishery product sales, promoting industry upgrading and brand building [61,62]. Through cultural activities, cultural tourism projects, and the provision of employment and entrepreneurship platforms, residents' entrepreneurial and innovative awareness is stimulated, contributing to talent

mobility and optimizing resource allocation, thus making a significant contribution to the diversification of the local economy. Ondiek et al. assessed the CESs provided by natural wetlands and rice fields in Kenya, and the results showed that although rice fields could provide higher economic value, natural wetlands contributed more to meeting residents' spiritual needs. Ensuring the sustainable use of both ecological types is equally important for maintaining residents' livelihoods [63]. Coastal CESs, through promoting tourism development, fostering the growth of the cultural and creative industries, and encouraging community employment and entrepreneurship, provide vital support for the growth and diversification of the local economy, thereby enhancing the competitiveness and sustainability of regional economic development.

Understanding CESs also contributes to enhancing community cohesion and social stability, fostering communication and cooperation among community members, strengthening the inheritance and development of social culture, enhancing community cohesion and identity, and promoting harmonious development within the community [64–66]. At the same time, understanding CESs can inspire community members to pay attention to and participate in environmental protection and ecological civilization construction. By organizing activities such as ecotourism, marine cultural experiences, and environmental volunteer work, community members gain a better understanding and respect for the local ecological environment, enhance their sense of responsibility and awareness of environmental protection, and promote the implementation of community environmental management and ecological protection efforts. Treviño used a local perspective to identify the CESs provided by mangroves to clarify how they support local well-being. The results indicate that users of mangroves attribute profound cultural importance and personal attachment to the mangrove ecosystem [67]. Therefore, coastal CESs, through pathways such as enhancing spiritual enjoyment, promoting economic development, and strengthening social cohesion, play an undeniable positive role in enhancing human well-being.

5. Discussions

5.1. Applications and Challenges of Multi-Source Data in the Study of Coastal CESs

The coordinated integration of "natural ecosystem-socio-economic-public perception" data is the key to conducting coastal CESs research. Among them, public perception data play a vital role, directly reflecting the public's cognition, attitude, and demand for coastal ecosystem cultural services. These data can help researchers understand the public's views on ecosystem protection, utilization, and development, thereby providing a basis for policy making and resource management.

In the research of coastal CESs, the collection and analysis of perceptual data are crucial for understanding human cognition and attitudes toward CESs. Traditionally, perceptual data are primarily obtained through questionnaires or semi-structured interviews. In these cases, researchers can tailor questions according to their research objectives to deeply explore respondents' views and perceptions of coastal ecosystem cultural services. This approach helps clarify public perceptions of CESs categories [68], CESs responses to environmental changes [69], and the threats faced by CESs supply [70]. However, traditional data collection methods also have certain limitations. Field surveys often require high costs and are limited in terms of the selected research areas, which may affect the generalizability and representativeness of the research results.

With the rapid development of information technology, social media data have provided new perspectives and data support for coastal CESs research. Social media platforms such as Flickr and Instagram, due to their real-time nature, large data volume, and rich content interpretation potential, have gradually become favored data sources for scholars. These data can reflect the public's immediate reactions and attitudes toward coastal CESs [55], reveal cognitive differences and value perceptions among different social groups [31], and quickly identify the impact of environmental disasters on CESs at large spatial scales [71]. However, there are limitations in terms of data noise and user bias. As Cao et al. noted, sentiments related to coastal CESs vary based on social media characteris-

tics [62]. Additionally, social media data involve user privacy, and researchers must follow relevant data protection laws and regulations, such as the EU's General Data Protection Regulation (GDPR) or privacy protection laws in other regions, to ensure the legality of data collection and processing.

While social media provides a rich foundation for coastal CESs research, the diversity and vast volume of data also present challenges for data collection and processing. In current research, geotagged photos are widely used and are often manually inspected and classified according to their content to correspond to CESs categories. This manual classification can lead to subjectivity and inconsistency in the results. Identifying CESs through photos can only consider CESs categories that reflect direct, in-site, and outdoor interactions depending on actual presence in the environmental setting [31]. In the context of the explosive growth of social media data, applying machine learning for intelligent classification of photo content can not only reduce subjective bias in the classification process and ensure the objectivity and consistency of the results but also significantly improve data processing efficiency, providing a new solution for coastal CESs data analysis.

In terms of data integration, coastal CESs research needs to involve various types of data, including ecological environment, socio-economic, cultural heritage, and others, typically sourced from different domains and origins, including government agencies, research institutions, community organizations, etc. The quality and reliability of data directly influence the accuracy and credibility of research results. Issues such as low data quality, unclear data sources, and missing data may lead to biases in analysis results. Therefore, ensuring data consistency and reliability is a challenge. In summary, coastal CESs research, leveraging digital technology and data analysis tools, can enhance the quality and benefits of coastal CESs, promoting sustainable development and ecological protection of communities.

5.2. Promoting Interdisciplinary Integration to Enhance a Comprehensive Understanding of Coastal CESs

The complexity and diversity of coastal CESs necessitate the comprehensive consideration of ecological, economic, and social factors to fully understand their essence and value. Such integrated analysis requires the establishment of effective communication and collaboration mechanisms between ecology, culture, sociology, and economics to advance in-depth research on coastal CESs. Coastal areas face unique natural disaster risks such as sea-level rise and coastal squeeze due to their specific geographic location and environmental conditions, which are exacerbated by climate change. Ecology provides an in-depth understanding and analysis of coastal ecosystems, including knowledge of marine biodiversity and ecosystem functions. Researchers in this field explore changes in coastal CESs against the backdrop of sea-level rise and climate change [22,71], as well as the contributions of typical ecosystems and marine organisms to local coastal CESs [41,63,72,73]. Cultural studies focus on aspects such as maritime culture, traditional customs, and cultural heritage, using CESs as tools to deepen the understanding of marine cultural heritage and emphasizing the impact of cultural differences on CESs [58,74,75]. Sociology examines social factors such as community organization, social relationships, and cultural identity, delving into changes in human emotions, which helps to highlight the importance of fisheries in the social and cultural well-being of coastal communities [29]. Economics addresses issues related to the value of CESs, ecotourism, and industrial development, typically exploring the impact of economic activities such as tourism and aquaculture on CESs and seeking to optimize resource allocation to meet the needs of human society [76].

The composition and functions of coastal CESs are highly complex, involving multiple dimensions such as biodiversity, geographical distribution, and human activities. Coastal regions often face the trade-off between ecological protection and economic development. Coastal area management policies need to comprehensively consider various factors such as ecological protection, economic development, and social well-being. Only by conducting research on coastal CESs from a multidisciplinary perspective can we provide a scientific

basis for policy formulation and ensure the comprehensiveness and effectiveness of policy implementation. For instance, ecology provides a fundamental understanding of ecosystem structures and functions, while cultural studies reveal how human values and traditional customs influence ecosystem services. Sociology analyzes how social structures and behavioral patterns are interconnected with CESs, and economics assesses the economic value of CESs and their contributions to human well-being. The interaction of these disciplines enriches the multidimensional understanding of CESs. Through interdisciplinary integration, knowledge and methodologies from different academic fields can be organically combined, expanding the application scenarios of coastal CESs and providing theoretical support and practical guidance for achieving the dual objectives of marine environmental protection and social development.

5.3. Integrating Public Perception and Coastal CESs into Sustainable Policymaking

Incorporating public perception into the policymaking process is crucial for ensuring that policies are inclusive, effective, and sustainable. Public perception offers a diverse range of perspectives that can reflect the needs and expectations of different groups. This process helps to raise public awareness of environmental issues, thereby encouraging various sectors of society to participate in the maintenance of biodiversity and ecological balance. This two-way interactive policymaking model is an important pathway to building a sustainable society. Coastal CESs, as intangible benefits arising from the interaction between humans and natural ecosystems, can play an effective role in public perception and policymaking.

Coastal CESs have a significant guiding role in enhancing human well-being and promoting the development of coastal communities. By assessing the contributions of coastal CESs to residents' well-being, policymakers can find a balance between development and conservation in coastal areas, especially in communities that are dependent on natural resources. As Elwell et al. (2020) suggested, for communities more reliant on natural resources, small-scale tourism and conservation interventions may be reconsidered as potential means to increase well-being [77]. Similarly, Ghermandi et al. (2020) consider ecotourism a priority [31]. Although the development of ecotourism can balance the ecological and socio-economic benefits of coastal areas to some extent, Malinauskaite et al. (2021) revealed some coastal CESs management challenges originating from intensified tourism [33]. Ecotourism should be developed in such a way as to ensure that local natural resources are not destroyed. Whether a region prioritizes environmental protection or economic development will influence the strategies for the conservation and utilization of coastal CESs. Boeri et al. points out that a multi-dimensional conceptualization of biodiversity needs to be considered when planning and funding conservation actions [45]. And Ruiz-Frau et al. mentioned that the integration of spatially explicit socioeconomic data for various uses of marine biodiversity contributes to the development of comprehensive marine spatial plans [73].

Encouraging stakeholder participation is crucial for maintaining coastal CESs, which are fundamental to fairness, health, and well-being. Identifying and measuring intangible values can be successful only when those with stakes in the decision-making context participate as collaborators throughout [78]. Stakeholder participation can collect diverse perspectives and information, helping to create an inclusive decision-making environment. For example, Tajima et al. investigated the differences in the perception of CESs between residents and tourists, suggesting that the interests of stakeholders might conflict during marine development [28]. Santana-Santana et al. (2022) explored the impact of disabilities on the perception of CESs, finding that disability itself is not a statistically significant conditional factor, but the specific type of disability is [36]. Unlike these findings, which showed differences in the perception of coastal CESs among various stakeholders, Barrena et al. (2013) indicated that coastal CESs can be equally important for both local and distant populations [51].

Coastal CESs not only contribute to the development of local communities but also promote public awareness, ecological restoration, and biodiversity maintenance. Many authors have used coastal CESs as a research perspective to explore topics such as the views of mangrove users [67], the impact of human factors on CESs [79], and the shared benefits of human and coastal restoration projects [80,81]. These research findings can provide valuable information for local marine resource management. Additionally, clarifying public preferences and environmental education can promote ecological protection and restoration efforts to a certain extent, which is beneficial for maintaining biodiversity and ecological balance [45,82]. Furthermore, Quevedo et al. (2024) suggest that there is an opportunity for CESs to be integrated into restoration and climate mitigation strategies. Such research can help develop management strategies that are environmentally and socially just and promote environmental decision making [83].

6. Conclusions

This paper adopts a systematic approach to provide a new perspective for understanding the complexity and dynamics of coastal ecosystems. Through this research, we gain a more comprehensive understanding of the multifaceted value of coastal CESs in maintaining ecological balance, supporting human well-being, and promoting economic activities. Specifically, starting from the interaction between coastal CESs and natural resource management and human well-being, this paper systematically reviews published literature in terms of publication quantity, research content, research methods, and research trends. The results of this study show the following:

(1) Coastal CESs began to be studied by scholars in 2009, and the number of publications was in a fluctuating state in the early period, and has steadily increased since 2018. Among the corresponding coastal ecosystem types, marine organism has received the most attention from researchers. Among the corresponding subcategories of CESs, recreation received the most attention, and correspondingly, culture diversity received the least attention. Management and values were the most frequent keywords, and the largest number of related studies were published in *Ecosystem Services*.

(2) Multi-source data for coastal CESs typically include natural environmental data obtained from field sampling, social data obtained from local statistics, and perceptual data obtained from questionnaires or social media big data. The analysis method also gradually shifted from early statistical analysis to spatial visualization analysis. In terms of coastal CESs research trends, researchers' attention has gradually shifted from natural resource management itself to the dynamic process of CESs from perception to application.

(3) Effective coastal CESs management requires integrating ecological, socio-economic, and public perception data through interdisciplinary collaboration. Addressing challenges in data collection, including cost, representativeness, and social media's biases and privacy issues, is vital. Stakeholder engagement ensures inclusive policy making that balances ecological protection with socio-economic well-being.

In order to include more literature on relevant topics, we conducted an extensive literature search from the WOS Core Collection Database and Scopus Database, which are currently recognized databases in the academic community, and used as many subject word combinations as possible to locate relevant studies. Building on this foundation, the visualization of knowledge maps provided by VOS viewer 1.6.20 software is utilized to assist in identifying research hotspots. However, this has certain limitations. This search method may not cover all studies that are substantially related to coastal CESs. In particular, those works that do not directly use the term "CESs" but whose research content is substantially related to CESs may not be included in this review. Additionally, VOS viewer 1.6.20 may present potential biases and interpretive limitations when handling large datasets. Therefore, in future studies, in addition to major academic databases, professional databases and gray literature should also be considered to capture a wider range of research results. At the same time, more attention should be paid to the expansion and refinement

of the CES conceptual framework to better identify and integrate those studies that are not directly labeled but are substantially related. In terms of research methodology, it is essential to explore and integrate various comprehensive approaches to enhance the depth and breadth of the review, ensuring that the analysis results are both comprehensive and multidimensional.

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