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Are the economic valuations of marine and coastal ecosystem services supporting policymakers? A systematic review and remaining gaps and challenges

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With the increasing adoption of the ecosystem approach as integral to sustainable development policies, the economic valuation of marine and coastal ecosystem services (ESs) has become relevant for informing decision-making processes. Through an integrated approach encompassing bibliometric, network, and content analyses, this review is aimed at analyzing the evolution trend, the main research clusters, and the research gaps of the scientific literature in the field of economic valuation of marine and coastal ESs. The bibliometric results showed that the research field is experiencing an evolving positive trend and represents a challenging research topic. From the network and overlay visualization of keyword co-occurrences, it emerged that the research clusters comprehensively address the key policy-relevant issues. In the content analysis, an examination of the estimated ESs and the economic valuation methods used by studies with the highest impact on scientific research was conducted. The findings suggest that while studies provide valuable data and insights, their practical applicability in policymaking is limited, due to contextual relevance and bias issues. Overall, the review underscores the need for a paradigm shift to better inform real-world policy decisions, identifying the Marine Spatial Planning (MSP) process as a key framework for bridging these gaps in future research and policy implementation.

KEYWORDS

marine and coastal ecosystems, ecosystem services, economic valuation, decision-making, bibliometric analysis, network analysis

1 Introduction

Marine and coastal ecosystems provide a wide range of services to society that contribute to human well-being, including food provision, natural shoreline protection against storms and floods, water quality maintenance, support for tourism, and preservation of the basic global life support systems (Millennium Ecosystem Assessment [MA], 2005). However, most of them are being degraded faster than other ecosystems due to unsustainable human uses (United Nations Environment Programme [UNEP], 2006), pollution (Halpern et al., 2007) and climate change (Saraswathi et al., 2023; Jha et al., 2023). In response to these challenges, several efforts have been made to streamline policies and improve the comprehensive management of the maritime environment through the adoption of the ecosystem approach (Paramana et al., 2023). Originating from the Convention on Biological Diversity (CBD), the ecosystem approach involves the integrated management of land, water, and living resources by promoting conservation and sustainable use in an equitable way (Secretariat of the Convention on Biological Diversity [CBD], 2004). The strategy embeds ecosystem services (ESs) within a socio-economic framework for inclusive decision-making (Judd and Lonsdale, 2021; Vlachopoulou et al., 2014).

The concept of ESs refers to the benefits people obtain from ecosystems, linking ecosystem functioning to human wellbeing (Millennium Ecosystem Assessment [MA], 2005). It is increasingly employed in environmental policy and management to promote socio-economic development (Hauck et al., 2013), since it provides a valuable framework for identifying trade-offs between natural resource use and conservation (Friedrich et al., 2020).

The first policy initiative concerning marine and coastal ecosystems that mainstreamed the ESs concept was the Marine Strategy Framework Directive (2008/56/EC) in the European Union (Bouwma et al., 2018), followed by the National Ocean Policy in the United States (Sutton-Grier et al., 2014). Recently, the ES concept has emerged as a framework for supporting Maritime Spatial Planning (MSP) (Galparsoro et al., 2021) (EU Directive 2014/89/EC). MSP is a comprehensive process that aims to align with environmental and sector-specific policies (Schernewski and Robbe, 2023), through an integrated planning framework to balance ecological, economic, and social objectives (Ehler and Douvere, 2009). Integrating ESs into MSP provides a useful tool to support strategic environmental assessments, promoting the development of new maritime activities in accordance with the Blue Growth strategy and supporting the creation of Marine Protected Areas (Galparsoro et al., 2021; Longato et al., 2021).

A key step in making the integration of ESs operational for management and decision-making involves quantifying them in monetary terms (Boerema et al., 2017; Laurans et al., 2013). By employing different economic valuation methods, categorized into market-based, revealed preference, and stated preference categories, both the use and non-use values that define the Total Economic Value (TEV) of a given habitat or ecosystem can be estimated. Valuation serves as a standard unit of measurement for the worth of ecosystem goods and services to aid in understanding the consequences of modifying habitats, whether through natural processes or human intervention (Hindsley and Yoskowitz, 2020).

Previous studies have identified several gaps in the valuation of marine and coastal ESs. Liquete et al. (2013) reported that estimations were usually carried out in only a few habitats or environments (i.e., mangroves and coastal wetlands), leaving many others unassessed. Additionally, Martin et al. (2016) highlighted a poor understanding of socio-ecological relationships, including the different meanings and values people assign to habitats and ecosystems and how these relate to ecological and biophysical conditions. Rodrigues et al. (2017) stressed the need to prioritize integrated marine and coastal ESs assessments by actively engaging stakeholders to identify relevant ESs, recognize their plural sociocultural, ecological, and economic values, and address conflicts and trade-offs in decision-making. Galparsoro et al. (2021) highlighted that data availability stood out as the main challenge for mapping coastal and marine ESs due to a lack of biophysical, quantitative, and geo-referenced data on ecosystem functioning. Carrasco de la Cruz (2021) underscored the deficiency in the advancement of tools and methods for improved valuation of marine and coastal ESs, which implies that the ES concept continues to be primarily advanced through research on terrestrial ecosystems. Addressing the existing gaps in the valuation of marine and coastal ESs remains a pressing challenge from a policy perspective, requiring efforts to improve data availability, socio-ecological understanding, and methodological advancements.

This review attempts to analyze the evolution of research in the field of economic valuation of marine and coastal ESs from a policy perspective. The main objective is to track how research is responding to the growing demand for studies that provide economic values to support ecosystem-based policies, thereby guiding future research and developments. To achieve this goal, a systematic review encompassing bibliometric, network, and content analyses was conducted. This approach enables us to analyze the distribution characteristics in the research field from three main perspectives:

- Bibliometric analysis, by focusing on the quantitative characteristics of the literature, including publication trends, key authors, and influential journals;
- Network analysis, by examining the key research clusters;
- Content analysis, by examining the studies with the highest scientific impact.

By addressing these objectives, this review provides a comprehensive overview of the state of the art in the economic valuation of marine and coastal ESs, identifies emerging trends, challenges and key research gaps.

2 Methodology

2.1 Data collection

Document extraction was performed using Scopus and Web of Science (WoS) databases, which are the widest repositories of peer-reviewed scientific literature. To achieve the objectives of this paper, the query was developed considering specific Terms (T) and Combination (C) employed in the search protocol within the title, abstract, and index keywords of the documents. In particular, two groups of terms were selected based on a literature analysis. Group A included the terms related to marine and coastal ESs and their synonyms, while Group B included the terms related to the main economic valuation methods of ESs (United Nations, 2021; UNEP-WCMC, 2011; DEFRA, 2007). Table 1 shows the twenty-five terms connected by the Boolean operators (AND/OR) used to identify the most relevant documents in the analyzed research field. The symbol "*" indicates words with the same root but with different endings.

Documents were filtered by document type, language, and research area. Journal articles in English were extracted to ensure that the studies met methodological rigor and adherence to established peer-review standards, while also enabling subsequent analyses based on bibliometric indicators. The extraction generated an output of 703 and 775 documents from Scopus and WoS, respectively. Following the screening process based on the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) approach illustrated in Figure 1, a total of 194 documents were excluded from the Scopus results, and 250 documents were excluded from the WoS results. Consequently, 509 documents from Scopus and 525 documents from WoS were deemed eligible for the analysis. In order to ensure the reliability of the analyses, the 313 documents included in both databases were considered only once. Finally, citation information (i.e., authors, document title affiliations, and publication year), abstracts, and index keywords were exported for a sample of 721 eligible documents, which were included in the sample for bibliometric and network analyses. For the content analysis, a distinct selection was conducted, considering documents published in the top-5 journals based on Impact Factor (IF) at the time of the document extraction (190).

2.2 Bibliometric, network and content analyses

The 721 eligible articles were elaborated to compute the bibliometric and network analyses. Bibliometrics involves employing statistical analysis to quantitatively assess academic literature and innovative perspectives on evaluating research trends (Ellegaard and Wallin, 2015). The key information derived from the bibliographic data frame encompassed annual scientific output, the average number of citations per document, the most prolific authors, the prominent journals, and the annual percentage growth rate (Aria and Cuccurullo, 2017). Based on such data, statistical analysis can aid in understanding the basing information and the development status of the literature (Liu et al., 2019). To generate a bibliographic data frame, the original dataset was converted from.csv to.bib format and uploaded into R software. Subsequently, the Bibliometrix tool was run to conduct the bibliometric analyses. The same dataset of 721 documents was employed and processed using VOSviewer software version 1.6.19 to perform network analysis. This software facilitates the computation of co-occurrences among index keywords using the full counting method and assigns equal weight to

TABLE 1 Research protocol for the review.

Terms	Group A	T1: marine	T2: coastal	T3: “ecosystem service*”	T4: “environmental service*”	T5: “ecological service*”
	Group B	T6: “revealed preference”	T7: “stated preference”	T8: “direct market”	T9: “market-based”	T10: “market price”
		T11: “market prox*”	T12: “production function”	T13: “hedonic pric*”	T14: “avoided cost”	T15: “replacement cost*”
		T16: “substitute cost*”	T17: “damage cost*”	T18: “benefit transfer”	T19: “contingent *valu*”	T20: “choice experiment”
		T21: “choice model”	T22: “travel cost”	T23: “economic *valu*”	T24: “monetary *valu*”	T25: “total economic value”
Combination		C: ((T1 OR T2) AND T3) OR ((T1 OR T2) AND T4) OR ((T1 OR T2) AND T5) AND (T6 OR T7 OR T8 OR T9 OR T10 OR T11 OR T12 OR T13 OR T14 OR T15 OR T16 OR T17 OR T18 OR T19 OR T20 OR T21 OR T22 OR T23 OR T24 OR T25)				
Publication type		Journal articles in English				
Databases		Scopus; Web of Sciences				
Subject areas		Scopus	Environmental Science; Agricultural and Biological Sciences; Business, Management and Accounting, Economics; Econometrics and Finance			
		WoS	Environmental Sciences Ecology; Business economics; Agriculture			
Period		Earliest published document (1 January 1998) – 1 December 2023				

each co-occurrence (Agnusdei and Del Prete, 2022). Since index keywords are single or multiple terms that summarize document content, keyword co-occurrence analysis was carried out to identify the most prevalent features and issues within the research field under investigation (Agnusdei et al., 2021). Out of the 2,953 index keywords, those with a minimum of 10 occurrences were selected, and off-topic keywords were discarded. As a result, 91 index keywords were deemed relevant for inclusion in the network visualization. In the network visualization, the circle sizes reflect keyword weights, and lines represent keyword relations, with ticker lines indicating more robust links between words and different colors representing distinct research clusters to which the index keywords belong (Van Eck and Waltman, 2010). The overlay visualization provides a temporal perspective for the interpretation of the co-occurrence network map of index keywords by presenting network elements with different colors depending on their average publication year (Picone et al., 2021).

In order to perform the content analysis among the included documents, only the top-5 journals in term of IF were considered: (i) Science of the Total Environment, (ii) Journal of Environmental Management, (iii) Ecosystem Services, (iv) Ecological Economics, and (v) Marine Policy. A total of 190 documents were screened, and the study objectives, study areas, estimated ESs and valuation methods used were analyzed. The ESs estimated by each study were identified and classified according to Millennium Ecosystem Assessment [MA], 2005, into three classes, excluding supporting services: (i) provisioning services, (ii) regulating services; (iii) cultural services. Furthermore, the methods employed for determining the economic values of ESs were categorized according to TEEB (2010) as follows:

- *Market-based*, which includes market price, avoided cost, production function, and replacement cost;
- *Revealed preference*, which encompasses travel cost and hedonic price;
- *Stated preference*, comprising contingent valuation and choice experiment;
- *Benefit transfer*, which involves valuations that apply economic values from another context.

Table 2 presents a brief description of each method, together with the corresponding ESs class(es) for their application.

3 Results and discussion

3.1 Bibliometric analysis

Table 3 presents the key findings of the bibliometric analysis, while Figure 2 shows the annual scientific production from the year of the earliest document published (1998) to 2023. A total of 721 documents were written by 2,680 authors and published in 209 different journals. The documents had a median of 13 citations, with an average citation of 32.98 per document. While the median represents the typical citation distribution, the average citation count is influenced by extreme values (i.e., minimum and maximum number of citations), suggesting that a small number of highly cited documents drive the average citation count upwards. The annual percentage growth rate of the number of published documents is on average 35.15%.

Figure 2 shows the comparison between the number of documents included in the bibliometric analysis by year, based on the criteria of language, document type, and subject areas, as outlined in Tab. 1, with the overall number of documents using the same criteria but covering all subject areas. The number of articles per year related to the considered subject areas closely reflects the overall trend of documents. This indicates that the subject areas considered in the analyses constitute a representative sample of the scientific production in the research field during the period under consideration.

Considering the publication trend, the results suggest a relatively low number of papers published before 2009, followed by a significant increase starting in 2010. This growth is linked to the publication of relevant reports and research initiatives, including the MA, TEEB, and CICES (McDonough et al., 2017) and the growing integration of the ES concept across a wide range of policies (Tinch et al., 2019; Sutton-Grier et al., 2014).

Table 4 shows the top ten leading journals as well as key indicators about their quality, i.e., IF used by WoS, CiteScore used by Scopus, and Best Rank. IF, provided by WoS, is computed by dividing the number of times cited in a year (referring to documents published in the previous two years) by the number of articles published by that journal in the same interval; CiteScore, used by Scopus, is calculated by dividing the number of citations received in a specific year by the number of documents published in the preceding three years (Roldan-Valadez et al., 2019). The Best Rank, derived from Scimago Journal Rank (SJR), attempts to measure a journal's reputation within the community by examining the sources of its citations (Jones et al., 2011). Along with the number of publications, *Ecosystem Services* (71) was the most popular journal in the analyzed field, followed by *Ecological Economics* (62), *Marine Policy* (39) and *Ocean & Coastal Management* (32). In terms of the number of citations obtained by each journal, *Ecological Economics* leads the ranking with 6,011 total citations. According to SJR, each of the ten top-leading journals is in the first quartile (Q1). *Science of the Total Environment* stands out as the top-ranking journal when considering both CiteScore and IF. Journal rankings can vary significantly depending on the criteria used, particularly when comparing metrics related to the analyzed research strand (i.e., number of documents and citations) with broader indicators of overall journal impact (i.e., CiteScore and Impact Factor). This underscores the importance of using multiple metrics to evaluate a journal's overall contribution to scientific research comprehensively. Considering all parameters, including published documents, citations, CiteScore, Best Rank, and Impact Factor, documents published in *Ecosystem Services* and *Ecological Economics* have a more significant impact on scientific research.

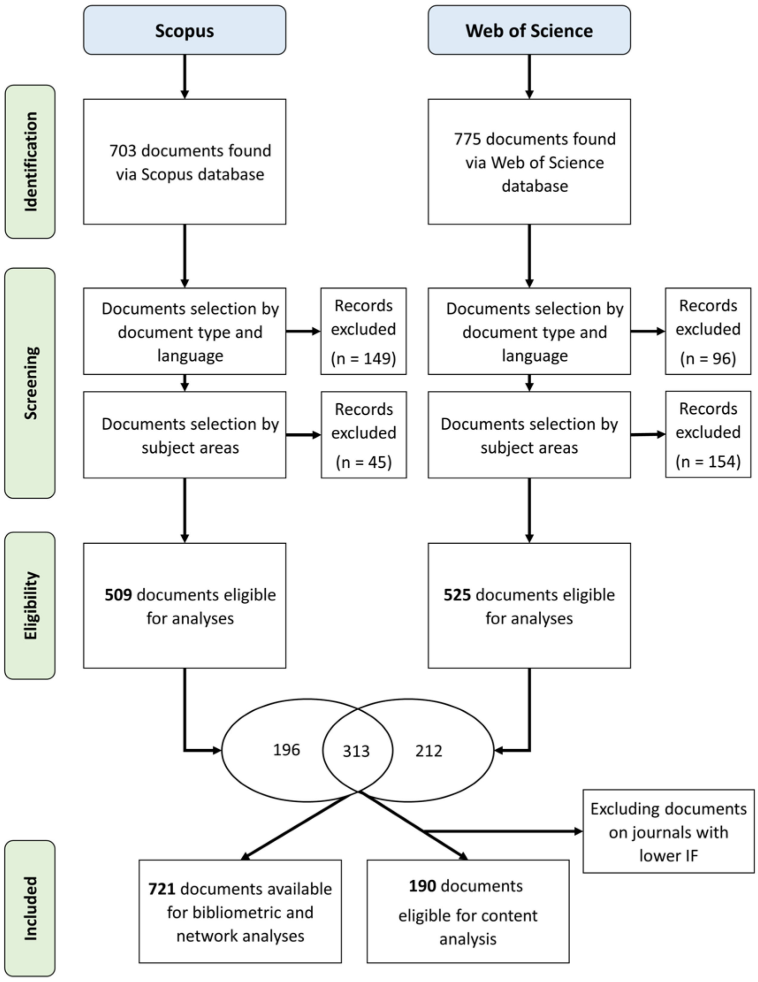

FIGURE 1
Documents selection scheme based on the PRISMA approach.

TABLE 2 Overview of the economic valuation methods of ESs. Adapted from United Nations (2021).

Category	Methods	Definitions	ESs valued
Market-based	Market price	Estimates the value of ESs that are traded in regular markets.	Provisioning
	Avoided cost	Estimates the value of ESs by considering the costs of damages that would result from their absence.	Regulating
	Production function	Considers ESs as an input in the production function of a marketed ESs.	Regulating
	Replacement cost	Estimates the cost of replacing ESs with alternatives that provide the same benefits, i.e., man-made alternatives.	Regulating
Revealed preference	Travel cost	Estimates the value of recreational areas by modeling a demand function.	Cultural
	Hedonic price	Estimates the differential premium on properties values that arises from the effect of an ecosystem characteristic (e.g., clean air, local parks).	Regulating, Cultural
Stated Preference	Contingent valuation	Survey-based method, in which respondents are asked about their willingness to pay (or willingness to accept) for a hypothetical change in the level of provision of the ESs	All classes
	Choice experiment	Survey-based method in which respondents are presented with a set of attributes related to ESs with characteristics that vary based on levels of provision, quality, and cost.	All classes

TABLE 3 Key bibliometric analysis information.

Indicators	
Documents	721
Sources (Journals)	209
Index Keywords	2,953
Authors' keywords	1,945
Years	26
Median citation	13
Average citation per document	32.98
Authors	2,680
Documents per Authors	0.269
Average annual percentual growth rate	35.15%

Table 5 presents the top five authors in terms of the number of published works as well as in terms of productivity and influence as determined by WoS and Scopus h-indexes[1]. There are two ex aequos in first and second places. The most prolific authors are *Andrea Ghermandi*, affiliated with the University of Haifa, and *Jasper O. Kenter*, affiliated with the University of York, both with a total of 14 documents. Following closely with 12 documents each, *Robert Costanza*, affiliated with University College London, shares the second spot with *Stephen Hynes*, affiliated with the University of Galway. Notably, *Costanza, R.*, reports the highest Scopus and WoS h-indexes, while *Kerry R. Turner*, affiliated with the University of East Gallia, reports the second-highest Scopus and WoS h-indexes.

The authors contributed to advancing the field by integrating interdisciplinary approaches, methodological innovations, and practical applications in ESs valuation to inform policy and management in marine and coastal ecosystems. Costanza laid the foundation for interdisciplinary approaches by emphasizing the need for integrated frameworks (Liu et al., 2010) and addressing the challenges of estimating non-market services, including oxygen production (Chen et al., 2022). His work bridged theoretical and applied research, exemplified by the valuation of ESs provided by mangrove storm protection (Hernández-Blanco et al., 2022) and the assessment of salt marsh responses to sea-level rise (Feagin et al., 2010). Moreover (Sutton and Costanza, 2002), Costanza applied innovative methodologies, such as nighttime satellite imagery, to enhance global ESs valuation (Sutton and Costanza, 2002). Turner expanded upon these foundations by merging theoretical principles with practical applications to inform policy and management, particularly in coastal zone contexts. His integration of ecosystem valuation and decision-support frameworks (Morse-Jones et al., 2011; Turner et al., 2010) underpinned studies on carbon sequestration in blue carbon ecosystems (Luisetti et al., 2013; 2019) and the economic benefits of ecological restoration (Pouso et al., 2018). Turner also addressed the impacts of environmental degradation, such as eutrophication in the Gulf of Mexico (Rabotyagov et al., 2014), and examined sustainable tourism in small island states (Grilli et al., 2021). Building on this practical orientation, Ghermandi focused on regulating services, including carbon sequestration (Canu et al., 2015) and shoreline protection (Rao et al., 2015), as well as cultural services related to recreation and heritage (Ghermandi and Nunes, 2013). His research spanned diverse ecosystems, including tropical wetlands and coral reefs, employing advanced GIS techniques for mapping and valuing ESs (Ghermandi et al., 2018). Hynes furthered these perspectives by focusing on marine and deep-sea ecosystems, using choice experiments and contingent valuation methods to assess public willingness to pay for conservation (Ankamah-Yeboah et al., 2022). His use of spatial value transfer methods informed marine policies, including the EU Marine Strategy Framework Directive (Norton and Hynes, 2018). Additionally, Hynes estimated the economic values of marine recreational services and developed international benefit transfer methods to account for cultural differences in valuation (Hynes et al., 2013). Finally, Kenter developed deliberative, participatory, and spatially explicit valuation methods (Kenter et al., 2016), highlighting subjective and shared cultural values, such as identity and sense of place (Ainsworth et al., 2019).

1 The h-index is a citation-based performance metric that measures both the productivity and citation impact of an author's documents. It is defined as the highest number h such that the author has h or more documents with at least h citations each.

3.2 Network analysis

The analysis included 91 index keywords with a minimum occurrence of 10, excluding those that did not adequately represent the research field (i.e., journal, article, animal, human). The index keywords were counted in order to calculate their frequency and draw up a ranking.

As shown by the top ten ranking of the most relevant index keywords (Table 6), "Ecosystem services" stood out as the leading keyword with a total of occurrences equal to 278, indicating that the concept is considered a stand-alone field of investigation in the scientific literature. The "contingent valuation" keyword (82 occurrences) ranked high, demonstrating that this method was widely employed to place an economic value on ESs for which a traditional market doesn't exist by estimating both use and non-use values (Tonin, 2018; Ferreira et al., 2017). The high occurrences of the keyword "biodiversity" (77 occurrences) indicate that, from an economic perspective, biodiversity is regarded as an integral component of natural capital, whose changes affect ecosystem functioning and its capacity to support ESs (Daam et al., 2019). Since the flow of ESs represents the interest society receives from natural capital, society needs to choose a level of biodiversity that ensures future ESs flows in order to secure long-term environmental quality and human well-being (Costanza and Daly, 1992). Within the top-ranking, keywords referring to "coastal zone" and "coastal zone management" underline that the economic valuation of marine and coastal ESs is an integral component of the socio-economic methods and tools employed in various stages of coastal zone management (Marre et al., 2016; Le Gentil and Mongruel, 2015). Valuations address the need for a better comprehension of the link between habitat condition and ESs

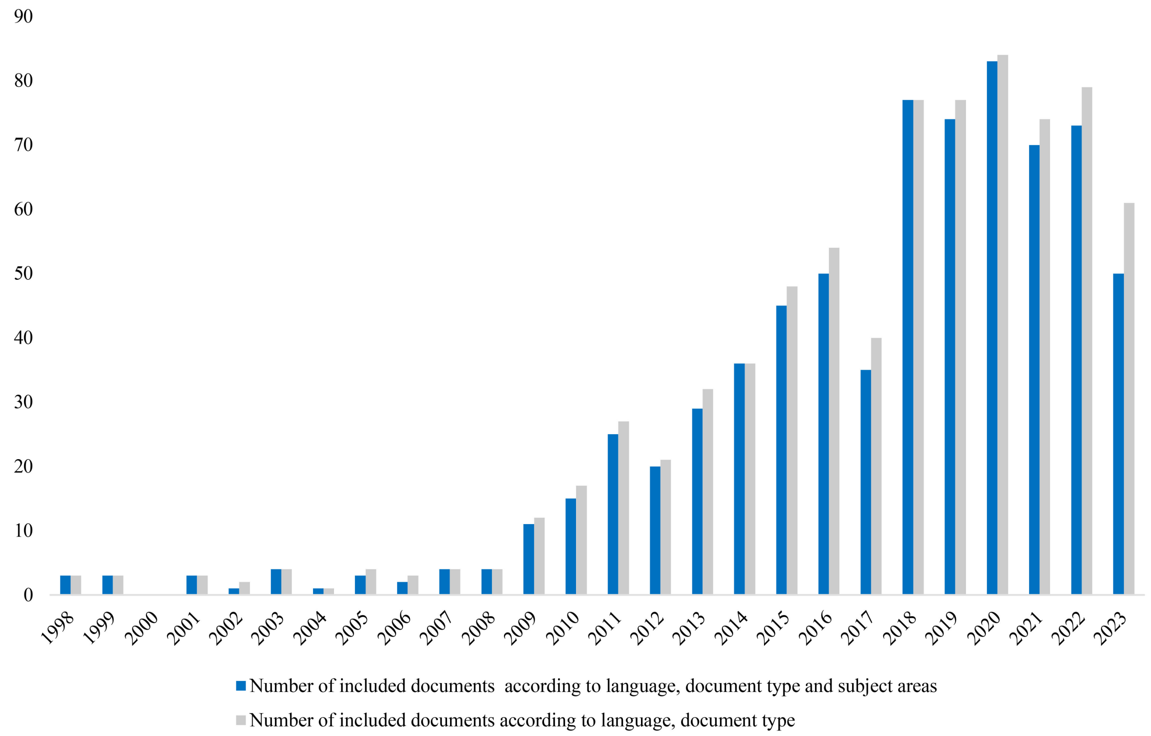

FIGURE 2
Documents by year.

provision, using comparable indicators in order to make more informed management decisions (Watson et al., 2022). In particular, ESs estimates are directly applicable to inform a wide array of coastal management questions related to coral reefs and mangroves management (Fezzi et al., 2023; Gagarin et al., 2022; Marlianingrum et al., 2021), land-use change (Abd El-Hamid et al., 2022), sea level rise (Hindsley and Yoskowitz, 2020), and recreational activities (Huang et al., 2020; Clara et al., 2018). Moreover, when examining the broader implications of ESs, the keyword "environmental protection" has arisen as one of the ten most frequently used keywords, since the concept of ES represents a practical approach to environmental protection for integrating both biophysical and socio-economic factors (Daily, 2000). Figure 3 displays the network visualization and clustering of keyword co-occurrences between 1998 and 2023. Four clusters of connected topics characterize the research field (Appendix A): Environmental

TABLE 4 Top 10 leading journals based on the number of published documents and citations.

Journals	Publisher	No. documents	Earliest document published	Citations	CiteScore	Impact factor	Best rank
Ecosystem Services	Elsevier	71 (1)	2012	3,020 (2)	12.5 (3)	7.6 (3)	Q1
Ecological Economics	Elsevier	62 (2)	1999	6,011 (1)	11.0 (4)	7.0 (4)	Q1
Marine Policy	Elsevier	39 (3)	2009	810 (5)	7.0 (8)	4.3 (8)	Q1
Ocean & Coastal Management	Elsevier	32 (4)	2009	1,029 (3)	7.7 (7)	4.6 (7)	Q1
Journal of Environmental Management	Elsevier	24 (5)	2012	866 (4)	13.4 (2)	8.7 (2)	Q1
Frontiers in Marine Science	Frontiers Media S.A.	21 (6)	2016	311 (8)	5.2 (10)	3.7 (10)	Q1
Ecological Indicators	Elsevier	20 (7)	2007	632 (6)	10.3 (5)	6.9 (5)	Q1
Sustainability	MDPI AG	19 (8)	2010	157 (10)	5.8 (9)	3.9 (9)	Q1
Marine Pollution Bulletin	Elsevier	14 (9)	2010	489 (7)	10.1 (6)	5.8 (6)	Q1
Science of the Total Environment	Elsevier	13 (10)	2014	254 (9)	16.8 (1)	9.8 (1)	Q1

Ranking in parentheses ().

TABLE 5 Top 5 most productive authors within the analyzed research field.

Authors	Affiliation	Documents	Earliest document published	h-index (Scopus)	h-index (WoS)
Ghermandi, A.	University of Haifa (Israel)	14	2011	29	26
Kenter, J. O.	University of York (United Kingdom)	14	2014	27	27
Costanza, R.	University College London (United Kingdom)	12	1999	89	81
Hynes, S.	University of Galway (Ireland)	12	2013	29	27
Turner, R. K.	University of East Anglia (United Kingdom)	11	2003	48	44

policy and management (red cluster) consisting of 27 items, Climate impact and resilience (blue cluster) including 21 items, Socio-economic implications (green cluster) including 24 items, and Public preference for ecosystem management (yellow cluster) consisting of 19 items.

The red cluster, named "Environmental policy and management", includes studies connected to environmental objectives that are relevant for policy discussions on the marine bioeconomy, relating to climate, chemicals, and land use (Hasselström and Gröndahl, 2021). Notably, within this cluster, the keywords "environmental protection" and "conservation of natural resources" emerge as the core content, along with "carbon sequestration" and "eutrophication". The primary research objectives of this cluster are to quantify the economic value of nutrients and carbon sequestered and stored in benthic habitats due to increasing policy ambitions to achieve net zero release of these compounds into the marine environment (Watson et al., 2022). In particular, the emerging keyword "shellfish" highlights that studies in this cluster quantified the ES provided by shellfish for their ecological role in the reduction of eutrophication (Cubillo et al., 2023; Dvarskas et al., 2020; Bricker et al., 2018). Furthermore, the keywords "fishery" and "fishery management" refer to studies that outline policy options (e.g., command and control schemes, payments for environmental services, and marine protected areas) aimed at increasing social welfare through multifunctionality in

TABLE 6 Top 10 ranking of index keywords.

Keyword	Occurrences/Frequency
Ecosystem services	278
Ecosystems	116
Valuation	103
Contingent valuation	82
Biodiversity	77
Environmental economics	73
Coastal zone	69
Marine ecosystem	66
Coastal zone management	65
Environmental protection	63

fisheries (Mulazzani et al., 2019) and reducing fisheries' impacts on marine megafauna (Booth et al., 2023), hence highlighting the positive externalities that sustainable fisheries can bring to coastal communities (Ceccacci et al., 2022).

The blue cluster, named "Climate impact and resilience", refers to studies focused on the consequences of climate change (i.e., the associated costs that negatively impact human well-being) and proposed nature-based solutions to mitigate the potential adverse impacts on ESs provision (Shayka et al., 2023; Trégarot et al., 2021; Mehvar et al., 2019). Within this cluster, keywords such as "Anthozoa", "Rhizophoraceae", "saltmarsh" are included due to their contribution to climate resilience (Fezzi et al., 2023; Fant et al., 2022; Jerath et al., 2016). The keywords "sea level" and "sea level change" emerge, highlighting the pressing issue of sea level rise, which poses a threat to coastal ecosystems worldwide and increases the vulnerability of coastal communities and habitats (Fernández-Díaz et al., 2022; Mazzocco et al., 2022).

The green cluster, named "Socio-economic implications", includes keywords related to documents in which ESs are investigated from an integrated perspective, comparing human activity's reliance and consequences on ESs across multiple sectors (Bryhn et al., 2020; Brown et al., 2018). Since the economic valuation of ESs reshapes the relationship between the socio-economic realm and the environment, economic decisions incorporating ecological concerns are expected to be more environmentally sustainable while offering opportunities for investment and innovation (Lebreton et al., 2019). The keyword "ecosystem service" is included in this cluster as it is an approach used to strengthen the relationship between research and policy in order to improve the interaction of humans and the environment in coastal and marine systems. The keywords "protected areas" in this cluster suggest that establishing protected areas stands out as one of the most effective strategies for protecting biodiversity, securing ESs (Visintin et al., 2022), and restoring ecosystems from the impacts of human activities (Pakalniete et al., 2021).

The yellow cluster, named "Public preference for ecosystem management", includes studies dealing with public preferences for biodiversity and habitat conservation and restoration (Tyllianakis, 2022; Arboleya et al., 2021). The keywords "choice experiment" and "contingent valuation" reveal the most commonly employed methods for eliciting the respondents' willingness to pay in this cluster. Furthermore, as demonstrated by the presence of the keyword "aquaculture", studies in this cluster elicited public

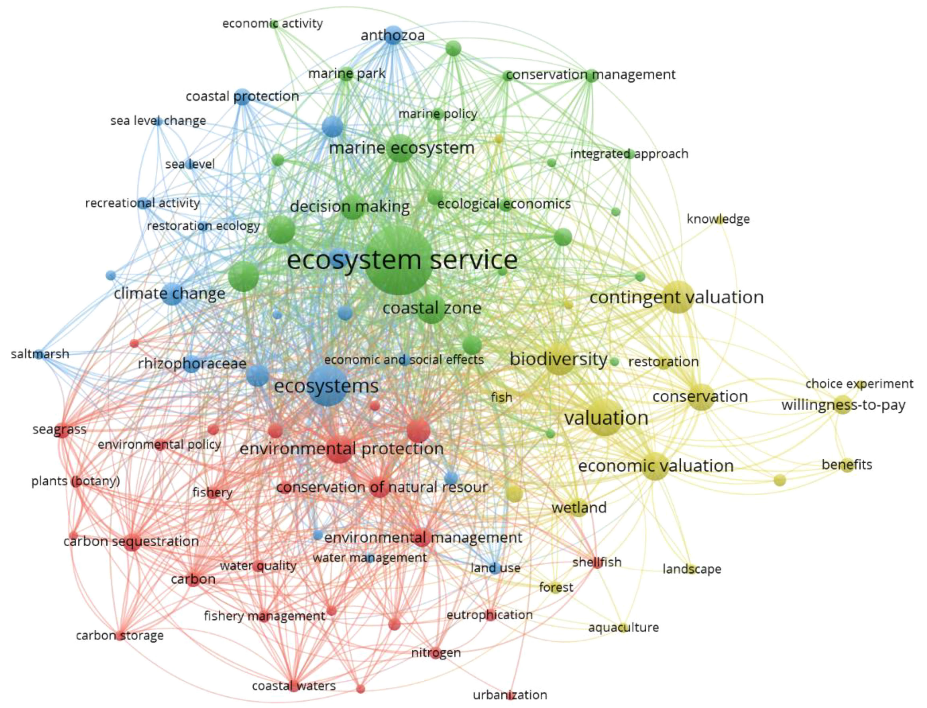

FIGURE 3
Network visualization of keyword co-occurrence analysis.

willingness to pay to mitigate environmental impacts towards sustainable aquaculture (Xuan and Sandorf, 2020), since its expansion is among the analyzed factors influencing habitat loss and degradation (Sinclair et al., 2021).

The overlay visualization of the keyword co-occurrence analysis (Figure 4) allows tracking the temporal trend of the analyzed research field. Until 2018, the research focus was primarily directed towards topics related to coastal protection (Ferreira

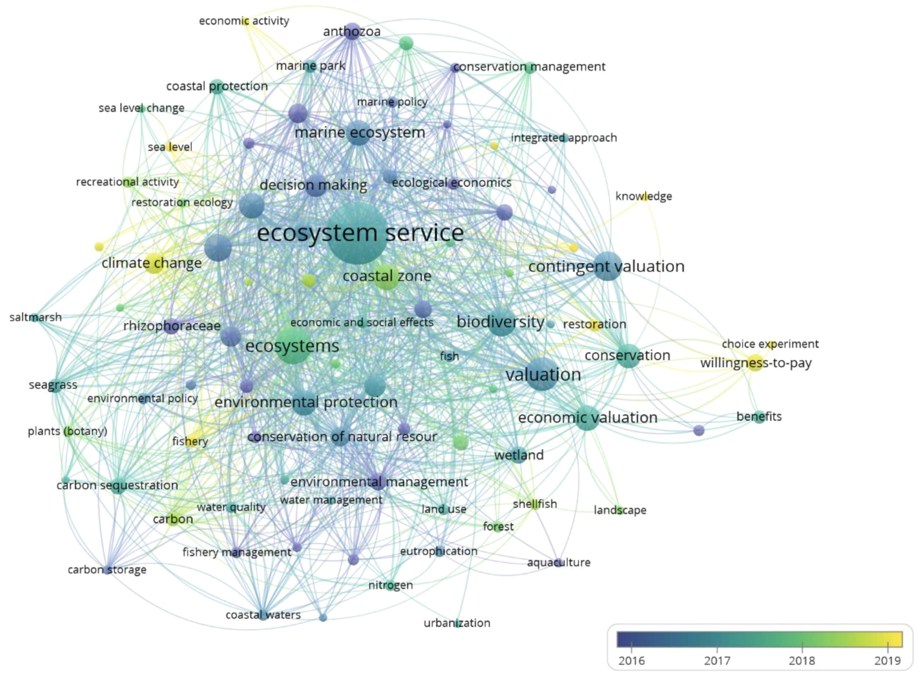

FIGURE 4
Overlay visualization of keyword co-occurrence analysis.

et al., 2017), wetland ecosystems (Sun et al., 2018), and carbon sequestration (Luisetti et al., 2014). Starting in 2019, the research increasingly focused on addressing crucial climate change-related concerns. Researchers delved into topics related to climate change impacts and adaptation strategies, with a particular emphasis on sea-level rise. In this context, research expanded to include practical applications to inform management decisions. Hagedoorn et al. (2021) examined the valuation of ESs in coastal management, comparing nature-based solutions (e.g., beach nourishment) with engineered ones (e.g., groynes). The work by Hindsley and Yoskowitz (2020) further explored public willingness to conserve coastal habitats threatened by sea-level rise, revealing a gap in public understanding of habitat migration and adaptation.

The challenges in fishery management, driven by climate change and overfishing, became a prominent area of investigation, focusing on sustainable practices and their implications for marine ecosystems Mulazzani et al. (2019) proposed a theoretical framework that incorporates the concept of multifunctionality into fisheries management, highlighting its potential to address key challenges, including resource depletion and ecosystem degradation. Recognizing fisheries as providers of ESs allows for the development of policies that connect subsidies to sustainable practices. This approach emphasizes management actions (e.g., gear change), as practical and measurable steps to align fisheries with ecological and social sustainability goals. In this regard, Booth et al. (2023) further emphasized the need for payments for ESs as a solution to reduce fisheries' impacts on marine ecosystems, designing locally-appropriate investment-ready schemes, that could support the provision of goods and benefits, such as net positive outcomes for marine biodiversity and a sustainable and equitable blue economy. Moreover, Trégarot et al. (2020) highlighted the crucial role of fishers in shaping management strategies by incorporating their empirical knowledge, perspectives on fishing regulations, and views on alternative measures. They proposed a model for multispecies management that accounts for the trophic interactions of humans, birds, and marine mammals.

Restoration efforts gained attention, with researchers exploring strategies to rehabilitate ecosystems that had been degraded. For instance, O'Connor et al. (2020) examined the value of restoring the Dohrn Canyon to the Italian general public, using stated preference method. Similarly, Hynes et al. (2021) explored the ecosystem service benefits of kelp forest restoration in Norway, employing a choice experiment to assess public preferences and the economic value of restoring these critical marine habitats.

Furthermore, recreational activities associated with coastal and marine areas, along with the willingness to pay for landscape preferences, have also gained increasing attention. De Nocker et al. (2022) estimated the recreational value of Natura 2000 in Belgium, highlighting the importance of ESs in the total economic value of land uses and landscapes. Cook et al. (2020) elicited the willingness to pay for estimating the recreational value of commercial whale watching. Advances in valuation of recreational values were posed by research. Xu and He (2022) estimated the integrated recreational value of a coastal wetland park using choice experiment and travel cost in order to provide a more comprehensive model for estimating the overall recreational value. Oleson et al. (2020) used a choice experiment and Bayesian belief network (BBN) to assess how land and marine management actions affect snorkelers' experiences. In the proposed method, the BBN combined snorkeler preferences with expert insights on ecological dynamics, simulating the attractiveness of sites for recreation. The choice experiment identified snorkelers' preferred site attributes, which helped calibrate the BBN to connect these preferences to management actions affecting coral reefs. The model then produced maps of snorkeling quality under various management scenarios.

3.3 Content analysis

Among the 190 articles included for the content analysis, methodological and conceptual framework articles that did not include the economic valuation of individual marine and coastal ESs (n=87) were eliminated. The sample of 103 studies provided 335 valuations, with 49% relating to regulating services, 31% to cultural services, and 20% to provisioning services. Figure 5 shows the distribution of countries associated with the study areas in the content analysis. The sample included studies from 32 countries, with United Kingdom (20%), the United States (17%), and Italy (8%) making the largest contributions. Spain, China, and Australia each contribute 6%, while Japan, Norway, France, and Portugal each account for 2-3% of the studies. The Others category, which represents 27%, aggregates countries that contributed only a single study area.

Table 7 presents the frequencies of each ESs estimated by the studies included in the content analysis, categorized based on their objectives of the study. The categorization was designed to highlight their main research goals, ensuring alignment with established frameworks. Specifically, the categories related to marine and coastal ecosystems were aligned with the European Nature Information System (EUNIS) classification.

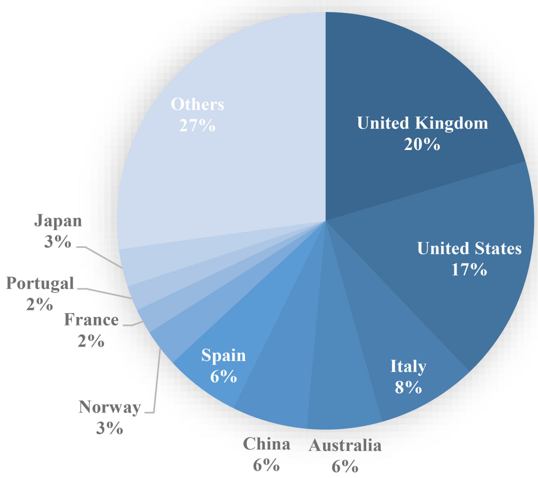

FIGURE 5
Distribution of countries associated with the study areas in the content analysis.

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TABLE 7 Distribution of the ecosystem services estimated by studies included in the content analysis by their study objectives.

	Food provision	Feed provision	Raw materials	Medicine	Water provision	Carbon sequestration	Nutrient removal	Shoreline protection, storm buffering, and erosion control	Life cycle maintenance	Water quality	Recreational	Wildlife and scenic viewing opportunities	Cultural heritage	Sense of place/ identity	Educational opportunities	Existence value
Coastal ecosystems	11		5	1		12	3	17	16	6	15		5	1	3	
Protected areas	7		1		1	7	3	8	5	1	9	2	9	1	7	2
Wetlands	4				3	9	4	5	4	3	4	3	2		2	
Marine ecosystems	11	2	8	2	1	7	3	5	13	1	14		1	1	3	3
Pressures	7		2			4	5	8	12	2	6	1	7	1	1	
Living species														1		2

The color shading reflects the frequencies of the data, with darker shades representing higher frequencies and lighter shades representing lower frequencies.

The coastal habitats category includes studies focused on ecosystems relating to mangroves, grasslands, shrublands, saltmarshes, seagrasses, dunes, and beaches. The marine habitats category encompasses studies related to seagrass meadows, Posidonia oceanica, seabed habitats, coral reefs, coralligenous, native oyster reefs, kelp forests, and marine biodiversity. The protected areas category includes studies valuating ESs within natural reserves, Marine Protected Areas, Natura 2000 sites, and national parks. A distinct category for wetlands was included to address the substantial body of research focusing on the ESs provided by estuaries, floodplains, and wet detention ponds. The classification also incorporates a pressures-based category, which includes studies assessing the value of ESs in the context of both anthropogenic and natural factors that influence their provision. The studies in this category focus on issues such as policy implementation, climate change impacts, plastic pollution, coastal defense strategies, biodiversity enhancement measures, drinking water safeguard zones, land reclamation projects, eutrophication, and marine litter impacts. Lastly, the living species category includes studies focused on engendered species, including sharks, monk seals, and sea turtles.

Coastal ecosystems account for the highest number of estimations (95) with the most frequently ESs associated with shoreline protection, storm buffering, and erosion control (17 estimations) and life cycle maintenance (16 estimations). Protected areas (63 estimations) show a notable emphasis on recreational (9 estimations), cultural heritage (9 estimations), and carbon sequestration (7 estimations). Wetlands (43 estimations) primarily highlight carbon sequestration (9 estimations), underlying the critical role of wetland ecosystems in mitigating climate change. Marine ecosystems (75 estimations) exhibit strong emphasis on food provision (14 estimations), recreational (14 estimations) and life cycle maintenance (13 estimations). Pressures (56 estimations) focus heavily on life cycle maintenance (12 estimations), food provision (7 estimations), erosion control (8 estimations) and cultural heritage (7 estimations), illustrating the need to understand how human activities and natural forces impact ESs.

A notable gap in the cultural services estimations within the sample is the limited estimation of non-use values. While significant attention is given to recreational services, broader non-use benefits, such as the intrinsic value of biodiversity conservation (i.e., existence) and the bequest value, remain underexplored. For policymaking purposes, assessing non-use values is essential for providing comprehensive assessments of the TEV of natural resources or ecosystems (Pacifico et al., 2024). Furthermore, the findings reveal that living species are among the least studied categories, highlighting a significant research gap. Addressing this gap through focused evaluation could offer valuable insights into their intrinsic value, their role in cultural identity, and their critical implications for developing and guiding effective biodiversity conservation strategies

Although the estimated ESs in the sample address the main ESs primarily mentioned by ecosystem-based policies (Bouwma et al., 2018), the results show that the peer-reviewed scientific literature mainly focuses on economic valuation, often suggesting its potential use for decision-making. However, studies rarely clarify how this information should be applied, fail to contextualize its use, and provide few concrete examples or analyses. This finding is consistent with Laurans et al. (2013), who also noted the limited discussion on integrating results into policy decisions and decision-making processes.

When considering the specific methods employed for estimating the economic value of the ESs in the sample, benefit transfer emerged as the most used, accounting for 38% with 126 estimated ESs. Choice experiments followed at 28% (94 ESs), contingent valuation at 13% (43 ESs), and market price at 10% (34 ESs). Figure 6 shows the distribution of valuation methods categorized according to TEEB (2010) for each class of ESs, based on their relative frequencies of application.

The main methods employed for valuing the three classes of ESs were benefit transfer and stated preference. Specifically, benefit transfer was used to estimate provisioning and regulating services at 41% and 37%, respectively. Stated preference were extensively used for valuing cultural services (55%), as well as regulating and provisioning services, representing 36% and 32%, respectively. Market-based were employed for estimating provisioning and regulating services, both at 27%. Finally, from the analysis emerged a limited use of revealed preference (9%), which involves data-intensive valuation approaches. The reliance on observing actual consumer behavior in real-world settings makes revealed preference necessitate detailed information for effective implementation (Carson and Czajkowski, 2014). Overall, the findings indicate that the studies in the sample tend to rely on survey-based methods or benefit transfer instead of carrying out primary valuations using cost-based approaches or data from real market transactions. Cost-based approaches involve computing the avoided costs or replacement costs for non-marketed ESs (e.g., erosion protection, nutrient removal). Using data from real market transactions entails leveraging prices or proxies to value ESs traded in regular markets (e.g., food, raw materials). Similarly, cultural services can be estimated considering the observed behavior of individuals. In this way, the travel cost method involves modeling a demand function for recreation, taking into account both market costs (e.g., fuel) and non-market costs (e.g., time usage) as well as participation rates (Chiputwa et al., 2020). Alternatively, to value cultural services provided by certain ecosystem characteristics (e.g., amenities), the hedonic price method can be employed to assess the differential premium on property values.

As outlined in Figure 6, provisioning and regulating services in the sample were widely estimated using benefit transfer and stated preference. The broad adoption of the above-mentioned categories of methods is driven by their cost-effectiveness and efficiency. Additionally, the use of stated preference aligns with the increasing trend in the literature for estimating ESs based on public preferences (Hanley and Czajkowski, 2019; Liekens et al., 2013). Economic valuations using benefit transfer can be computed using unit value transfer and benefit function transfers. Unit value transfer involves directly transferring a single numerical value from previous studies, whereas benefit function transfer utilizes an estimated parametric function from original studies (Grammatikopoulou and Vačkářová, 2021). The analyzed sample of studies predominantly employed benefit transfer through unit value transfer, which presents several challenges, including spatial aspects of valuation (Lopez-Rivas and Cardenas, 2024; Koundouri et al., 2023). Without considering the linkage between certain ecological conditions and benefits to people, benefit transfer could lead to overestimations and may have limited accuracy or relevance to decision-making (Mandle et al., 2021). Therefore, it is essential to consider potential biases in economic valuations carried out using

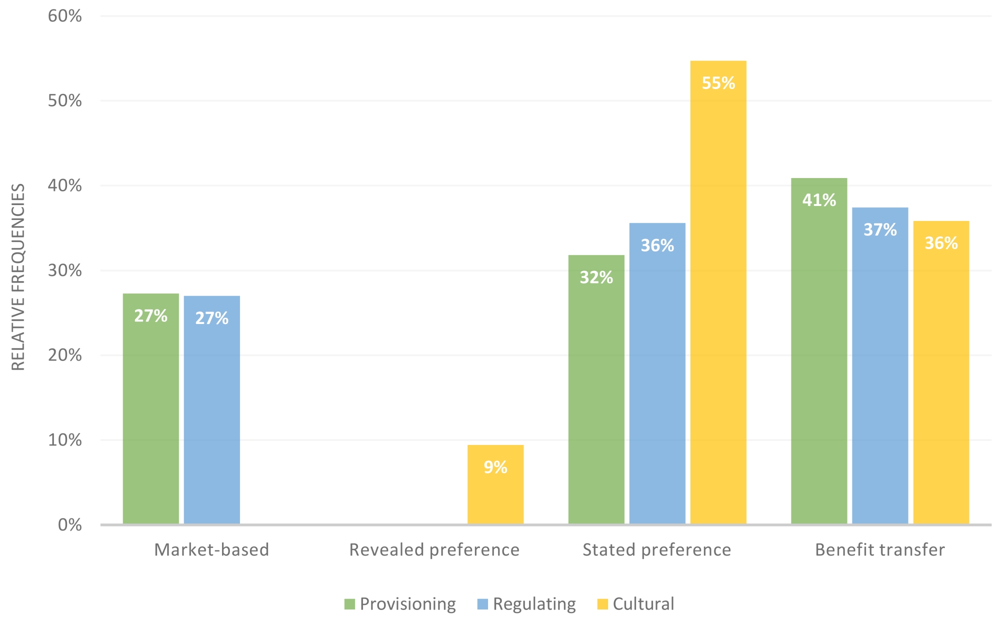

FIGURE 6
Methods used for economic valuations of the analyzed ESs.

benefit transfer, as they may not provide contextually relevant estimates for policymaking purposes, given the gaps between academic theory and practical application (Johnston and Rosenberger, 2010). However, benefit transfer emerges as appropriate when primary valuations are not feasible and when high levels of precision are not required (Johnston and Wainger, 2015).

Further limitations in the economic valuation of ESs could emerge when estimating provisioning and regulating services using stated preference. Specifically, limitations could arise from misspecification problems and the complexity of ecological interactions, which are often beyond human perception, leading to overestimations or underestimations (Barkmann et al., 2008; Nunes and van den Bergh, 2001).

To enhance the reliability of economic estimates for provisioning and regulating services, market-based approaches have the potential to reduce valuation biases, as various corrections can be implemented throughout the estimation procedures. The latter include adjusting the market value to obtain the contribution of the ecosystem to provisioning services (United Nations, 2021) and identifying least-cost alternatives for valuing regulating services through their replacement (Shabman and Batie, 1978). Moreover, market-based methods reduce reliance on survey-based methods, which may introduce biases due to respondents' subjective interpretations or social desirability bias. However, data availability and market distortions may constrain the use of market-based (Morando-Figueroa et al., 2023; UNEP-WCMC, 2011).

When analyzing the categories of methods used to value cultural services, stated preference emerged as the most employed (55%), followed by benefit transfer (36%), and revealed preference (9%). Valuing cultural services using stated preference involves eliciting individuals' willingness to pay through survey instruments or other means of hypothetical scenarios and choices (Takatsuka et al., 2009). Stated preference provide greater flexibility in capturing context-specific cultural values and preferences. Furthermore, stated preferences are the only method that can be used to value non-use ESs, enabling comprehensive valuations, especially when non-use values represent a substantial component of the total value provided by a resource. However, a major limitation of stated preference methods is the potential for hypothetical bias, as biases are influenced by respondent characteristics, survey design, and framing effects that may affect the reliability and validity of the data. To address issue, contemporary best-practice recommendations for stated preference applications intended to inform decision-making for estimating both use and non-use values have been proposed (Johnston et al., 2017). Moreover, the transferability of cultural services estimated using stated preference between different contexts poses a significant challenge in benefit transfer exercises due to variations in preferences across populations, locations, and time periods (Hynes et al., 2013). Overlooking the distinctive cultural attributes of local communities, primarily relying on existing valuation data from other sites, affects the context-specific values and preferences associated with cultural services, resulting in misrepresentation in decision-making processes.

4 Conclusions

The ES concept bridges ecological and socioeconomic perspectives by linking ecosystems with human well-being. Although environmental policies are often seen as conflicting with economic interests, efforts to mainstream ESs challenge traditional divisions between environmental and economic sectors (Bouwma et al., 2018). This review examined the field of economic valuation for marine and coastal ESs, demonstrating that it has developed alongside the integration of ES concepts into policy. Specifically, research and ecosystem-based policies have co-evolved, with academic inquiry continuously refining policy frameworks.

Through the network and overlay visualizations of keyword co-occurrence, four distinct research clusters were identified, showing how the objectives of valuation studies align with key policy goals. The increasing focus on climate change impacts, adaptation strategies, and sea-level rise aligns with the Paris Agreement and the EU Climate Adaptation Strategy (COM/2021/82). Sustainable fisheries management has gained prominence, with studies providing valuations to support integrated assessments aimed at enhancing the positive externalities that sustainable fisheries can offer to coastal communities. Restoration efforts have also grown more significant, with studies highlighting the ESs of restoration measures in line with the EU Biodiversity Strategy for 2030 (COM/2020/380), the EU Nature Restoration Law, and global commitments under the Convention on Biological Diversity (CBD).

Since the economic valuation of ESs is recognized as a key step in making their integration operational for management and decision-making (Boerema et al., 2017; Laurans et al., 2013), this review analyzed the highest-impact valuation studies to assess how they are designed and how they can be integrated into policymaking. The content analysis revealed that the ESs estimated in these studies align with the main ESs mentioned by ecosystem-based policies (Bouwma et al., 2018). Regarding the valuation methods employed, the findings indicated that stated preference and benefit transfer are the most commonly used approaches for estimating the economic values of ESs in the analyzed studies. Benefit transfer, driven by cost-effectiveness, may produce estimates that lack the contextual relevance needed for decision-making. Stated preference methods, widely used to value various classes of ESs, are susceptible to biases due to misspecification issues and the complexity of ecological interactions. As a result, the estimated economic values of ESs may lack the contextual relevance required for effective policymaking, highlighting the need to apply best-practice recommendations (Johnston et al., 2017).

Overall, the results indicate coherence between the objectives of the valuation studies, the services they assess, and the policies targeting them. However, a significant gap persists in the practical application of economic valuation of ESs for real-world policy integration. This gap stems from a focus on theoretical frameworks and standardized methodologies, which often lack the contextual relevance required for policy design.

The MSP offers a promising approach to address this gap. As a comprehensive, integrated process for managing marine spaces, MSP offers a framework for considering ESs in a spatially explicit way. Beyond being a policy, MSP is a multi-stage, iterative approach that facilitates the integration of economic during the planning process. Specifically, within the ten-step approach to marine spatial planning proposed by Ehler and Douvere (2009), the economic valuation of ESs could be strategically incorporated at different stages, including the development of payment for ecosystem services (PES) schemes that can be framed as innovative financing options (Ansong et al., 2017) and highlighting incompatible marine and coastal uses (Pacifico et al., 2024; Borger et al., 2014). For instance, the economic valuation of ESs can be integrated with scenario development and assessment, ensuring that the valuation process evolves in parallel with the policy design. This approach helps inform and guide planning decisions, focusing on real-world scenarios and assessing how different management options contribute to the provision of ESs. Future research should focus on bridging the gap between theoretical advances in ESs valuation and their practical application in policy contexts. Research should explore how the integration of economic valuations into policy frameworks can enhance real-world decision-making processes, ensuring that economic considerations support effective and sustainable management of marine and coastal resources.

4.1 Study limitations

This review has limitations related to the search protocol, databases used, and the screening process. Firstly, the search protocol may have limited the inclusion of relevant studies, as it relied on specific terms, potentially excluding studies that addressed ecosystem services and methods but did not explicitly use those terms. To mitigate this limitation, the search protocol was refined to include terms related to the study's objectives and their synonyms. Secondly, the study was restricted to peer-reviewed literature indexed in two of the most widely used scientific repositories: Scopus and WoS. While these databases are comprehensive, they may not cover all relevant studies in the field. Grey literature was excluded due to challenges related to searching, replicating, and conducting bibliometric analyses, as well as the need to uphold methodological rigor and adherence to established peer-review standards. The use of both Scopus and WoS allowed for the inclusion of a broader range of relevant studies in the research field.

Author contributions

AP: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Software, Visualization, Writing – original draft, Writing – review & editing. LM: Conceptualization, Methodology, Supervision, Validation, Visualization, Writing – review & editing. GM: Conceptualization, Methodology, Supervision, Validation, Writing – review & editing.

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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 a potential conflict of interest.

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The author(s) declare that no Generative AI was used in the creation of this manuscript.

Publisher's note

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Appendix A. Network analysis results

TABLE 1A Detailed visualization of index keywords by clusters.

Environmental policy and management (red cluster)	Climate impact and resilience (blue cluster)	Socio-economic implications (green cluster)	Public preference for ecosystem management (yellow cluster)
Biomass	Anthozoa	Anthropogenic effect	Aquaculture
Carbon	Climate change	Coastal zone	Benefits
Carbon sequestration	Coastal protection	Coastal zone management	Biodiversity
Carbon storage	Coastal wetland	Conservation management	Choice experiment
Coastal waters	Coral reef	Decision making	Coastal management
Conservation of natural resources	Economic analysis	Ecological economics	Conservation
cost-benefit analysis	Economic and social effects	Economic activity	Contingent valuation
Environmental management	Economic impact	Economic development	Economic valuation
Environmental monitoring	Ecosystems	Ecosystem management	Economic value
Environmental planning	Environmental impact	Ecosystem services	Fish
Environmental policy	Forestry	Ecotourism	Forest
Environmental protection	Land use	Environmental economics	Knowledge
Estuaries	Mangrove	Environmental values	Landscape
Eutrophication	Nature conservation	Human activity	Resource valuation
Fishery	Recreational activity	Integrated approach	Restoration
Fishery management	Restoration ecology	Land use change	Sustainability
Habitat	Rhizophoraceae	Marine ecosystem	Valuation
Marine environment	Saltmarsh	Marine park	Wetland
Natural capital	Sea level	Marine policy	Willingness-to-pay
Nitrogen	Sea level change	Preference behavior	
Plants	Water management	Protected area	
Policymaking		Stakeholder	
Posidonia oceanica		Sustainable development	
Seagrass		Tourism	
Shellfish			
Urbanization			
Water quality			