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Reference:
Van Schoubroeck Sophie, Anougmar Soukaina, Finizola e Silva Maira, Ala-Harja Venla, Statzu Vania, Everaert Gert, Watt Lois, Barboza Francisco R., Compernolle Tine.- Valuation of ecosystem services in marine protected areas : a comprehensive review of methods and needed developments
Ecosystem services - ISSN 2212-0416 - Amsterdam, Elsevier, 70(2024), 101678
Full text (Publisher's DOI): https://doi.org/10.1016/J.ECOSER.2024.101678
To cite this reference: https://hdl.handle.net/10067/2103430151162165141

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Valuation of Ecosystem Services in Marine Protected Areas: A comprehensive review of methods and needed developments

Sophie Van Schoubroeck[a*], Soukaina Anougmar[a], Maira Finizola e Silva[a], Venla Ala-Harja[b], Vania Statzu[c], Gert Everaert[d], Lois Watt[b], Francisco R. Barboza[e], and Tine Compernolle[af]

[*]Corresponding author, sophie.vanschoubroeck@uantwerpen.be
[a]University of Antwerp, Department of Engineering Management, Prinsstraat 13, 2000 Antwerp, Belgium
[b]Baltic Marine Environment Protection Commission, (Helsinki Commission - HELCOM), Katajanokanlaituri 6B, 00160 Helsinki, Finland
[c]Mediterranean Sea and Coast Foundation (MEDSEA), via Piemonte 33, 09127, Cagliari, Italy
[d]Flanders Marine Institute, Jacobsenstraat 1, 8400 Ostend, Belgium
[e]Estonian Marine Institute, University of Tartu, Mäealuse 14, 12618, Tallinn, Estonia
[f]Geological Survey of Belgium, Royal Belgian Institute of Natural Sciences, Jennerstraat 13, 1000 Brussels, Belgium

Abstract

Effectively managing Marine Protected Areas (MPAs) requires recognising and understanding the fundamental services offered by marine ecosystems and the socio-economic consequences that their changes will have. A systematic literature review was performed to generate a first in-detail screening and assessment of monetary and non-monetary methods for the valuation of ecosystem services (ES) and their application in MPAs and MPA networks. A total of 100 peer-reviewed papers on ES valuation within MPAs and MPA networks were identified and analysed. Valuation methods can be classified into nine monetary and seven non-monetary methodologies. There is a predominant use of monetary valuation methodologies, especially stated preference methods. However, combining monetary with non-monetary valuation approaches can provide deeper insights into the underlying reasons for assigning values to ES and offer enhanced opportunities to capture the value of services that may be challenging to express solely in monetary terms. Besides, the review underscores the gaps in assessment methodologies, particularly in addressing supporting and regulating ES, as well as non-use and option values related to MPAs, underscoring the need for innovative approaches to overcome challenges in capturing these essential components of marine ecosystems.

Keywords

Ecosystem services, Marine Protected Area, MPA, monetary valuation, non-monetary valuation

1. Introduction

Marine Protected Areas (MPAs) are designated areas legally protected and managed for the conservation and sustainable use of marine ecosystems and biodiversity. The protected areas can vary in size and management objectives. They can be classified based on their level of protection into distinct types ranging from multiple-use areas to fully protected and reinforced closure zones. The benefits of MPAs include safeguarding marine biodiversity and supporting ecosystem services (ES), enhancing resilience to climatic impacts, and combating marine pollution (Angulo-Valdés and Hatcher, 2010; Micheli et al., 2012). These area-based conservation measures are established through various mechanisms, including legislation, international agreements, and community-based management. The effectiveness of MPAs depends on several factors, including their size, location, level of protection, and management regime, as well as their level of community participation and support (Bennett, 2016; Claudet et al., 2008; Guidetti et al., 2008). A report by the NGO Oceana found that more than half of the MPAs within Europe had no management plan and, thus, have the potential to increase their effectiveness (Perry et al., 2020).

To effectively manage an MPA, it is crucial to identify and understand the sociologic, ecologic, and economic benefits that marine ecosystems provide. The direct and indirect benefits people obtain from nature are referred to as ecosystem services (ES) (Pascual et al., 2022). The ES can generally be categorised into four types: provisioning (e.g., food), cultural (e.g., tourism), regulating (e.g., flood protection), and supporting services (e.g., habitat provision) (M.E.A., 2005). The ES concept provides a formal framework for analysing and quantifying nature's contributions to human well-being. Valuing and monitoring the state of ES is essential for assessing the socio-economic consequences of service degradation and informing sustainable management practices, thereby contributing to the preservation of marine environments for future generations.

An ES valuation can be defined as the process of expressing a value for an action or object, and the benefits it offers (Farber et al., 2002). Angulo-Valdés and Hatcher (2010) defined 99 benefits provided by MPAs. A wide range of methods and techniques are available to value these benefits. Proper valuation can enhance marine and environmental management by accounting for ecosystem services that might otherwise go unrecognised, mainly when these services are not traded in markets (Daily, 1997; Hattam et al., 2015). However, the concept of ES and their valuation does not come without its critics. Most arguments state that the anthropocentric perspective of the concept overlooks the intrinsic value of nature (Schröter et al., 2014).

ES valuation can be approached either through the ES framework, which classifies services based on their types, or the Total Economic Value (TEV) framework, which considers the various values people derive from these services (de Groot et al., 2002; M.E.A., 2005; Plottu and Plottu, 2007). Both frameworks, commonly used in environmental economics, can be employed complementarily to achieve a more comprehensive assessment of ES. Despite TEV and the ES framework sharing common goals, they exhibit distinctions in their scope, methodologies, and objectives. The TEV provides a broader economic perspective by incorporating both market and non-market values and utilises a variety of methods, such as stated and revealed preference techniques, to assess the different values derived from ES. On the other hand, the ES framework is based on a detailed understanding of the specific services ecosystems provide, often employing mapping, modelling, and quantitative methods in the process. For both frameworks, the choice of adequate methods or techniques depends on the context and objectives of the study. In general, these valuation methods can either be monetary or non-monetary. In the context of MPAs, the significance of integrating multiple valuation frameworks becomes evident. For example, De Valck et al. (2023) highlight this in their study on managing the Australian Great Barrier Reef. They emphasise the importance of using different valuation frameworks, including the ES and TEV frameworks, to capture the full range of ecosystem services and benefits (De Valck et al., 2023). Their research illustrates how employing both frameworks leads to a more comprehensive and sustainable management of ecosystem services in MPAs.

Monetary ES valuation can be used for all types of ES (i.e., provisioning, regulating, cultural, and supporting) and can estimate (direct and indirect) use values, non-use values, and option values. Use values can be associated with the use of the ES (such as fishery and mining), while non-use values can be associated with long-term sustainability and the preservation of intrinsic values of ecosystems (Failler et al., 2019). The latter can refer to the existence value, i.e., the satisfaction an individual gets from knowing an environmental asset will be preserved (independently of any use), or the bequest value, i.e., the satisfaction that individuals derive from knowing that a resource will be preserved for use by successive generations. The notion of the option value, introduced by Weisbrod (1964), is defined as the price that individuals are willing to pay to conserve an element because of its possible use in the future. This value displays the characteristics of a risk aversion premium. It refers to all use values (direct and indirect) that can be realised in the future.

The benefit of monetary valuation is that it expresses everything in a common metric, facilitating a better understanding of trade-offs and ensuring that ecosystem services are considered in decision-making and investment processes (Qu et al., 2021). However, the difficulty of monetary valuation increases when the value is less tangible to individuals, meaning that the non-use value is more difficult to measure than the use value. Valuing an ecosystem service, especially when involving target populations, requires participants to fully understand the service and its benefits. However, some services rely on complex biophysical mechanisms, primarily regulating and supporting services, which can make their valuation more challenging (Small et al., 2017). In addition, double counting may occur because supporting services often underpin the other three types of services (Fu et al., 2011).

Critics argue that assigning a monetary value to nature is ethically questionable, as it reduces the complexity of natural benefits to mere monetary terms, thereby neglecting certain aspects that are difficult to quantify in financial metrics (Angulo-Valdés and Hatcher, 2010). Non-monetary ES valuation goes beyond traditional economic methods and seeks to capture the full range of benefits associated with ecosystems, including those that are difficult or impossible to quantify in monetary terms. A non-monetary valuation can be both quantitative (e.g., number of species saved, or number of homes affected) or qualitative (e.g., scale-based such as ‘poor’, ‘good’, or ‘excellent’) (Martin and Mazzotta, 2018). It often includes participatory approaches, involving stakeholders in the valuation process to capture their perceptions, attitudes, and values towards the ecosystems and the services they provide (Cheng et al., 2019). The perspectives of stakeholders cannot be ignored in valuation processes as ES are intimately tied to the well-being and livelihoods of people and communities affected (Burdon et al., 2019). Different stakeholders have different interests, values, and knowledge related to ES, and their involvement in the valuation process ensures that these diverse perspectives are considered and integrated into decision-making (Baker et al., 2021; Belgrano et al., 2018). Additionally, involving stakeholders builds trust, promotes transparency, and can lead to more socially and environmentally just outcomes. Overall, the non-monetary valuation of ES provides a more comprehensive understanding of ecosystems and can inform policy and decision-making processes on the value of ES that are difficult to monetise (Cheng et al., 2019). However, decision-makers can overlook non-monetary values because they lack a common economic unit. It is more difficult to compare the values of different types of ES when they are expressed in various quantitative and qualitative units.

Previous (review) studies predominantly concentrated on country-specific valuations or certain types of valuations, particularly those related to monetary considerations (Norton et al., 2018; Qu et al., 2021; UNEP, 2014). However, there is currently no comprehensive review of all existing methods for the valuation of different types of ES and how they are employed and combined to inform the design and management of MPAs. In response to this research gap, the present study conducts a systematic review of ES valuation methods and their applications in MPA and MPA networks. The primary aim of this review is to provide a detailed account of the valuation methods most commonly employed, to highlight emerging methodologies, and to identify areas that remain largely unexplored. Specifically, we seek to (1) examine the diversity of valuation techniques used to assess different types of ES in MPAs, (2) analyse which type of values are emphasized, and (3) uncover gaps in current valuation approaches. Through this nuanced analysis, we offer valuable insights to valuation practitioners, both within academia and more practical fields, into the strengths and limitations of various approaches guiding upcoming initiatives in the valuation of ES in the specific context of MPAs and MPA networks.

2. Method

We performed a systematic literature review to advance the scientific understanding of how monetary and non-monetary valuations are being performed within MPAs and MPA networks. This systematic literature review was guided by the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) Statement standards (Page et al., 2021). A literature search of English-language documents was done on the Web of Science up to and including 2023, with the following keywords: “marine protected area*” or “marine reserve*” or “marine park*” and “ecosystem service* valuation” or “cultural ecosystem service* assessment” or “provisioning ecosystem service* assessment" or "regulating ecosystem service* assessment" [1]. Only peer-reviewed papers have been considered to guarantee the quality of the publications. No date restrictions were applied in the selection of studies for this review. Initially, the search resulted in 307 papers (excluding duplicates). A full-text screening was performed for all 307 papers. Studies were retained if they (1) performed or summarised ES valuation methods and (2) particularly focused on MPAs or MPA networks. After the first screening, a total of 100 papers were included in the final review database. The final list of included papers can be found in Supplementary Materials A1.

For each article included in the final review database, the following data was retrieved: (1) Author names, journal, publication year, the aim of the study and reason for valuation, and main results; (2) Whether the article provides a general overview of ES valuation methods for MPAs and MPA networks or is an application of these methods to a specific MPA or MPA network; (3) Whether the application has been performed inside or outside Europe; (4) The valuation method(s); (5) Whether this method is monetary, non-monetary, or mixed; (6) The type of value assessed, i.e., use, non-use, and option values; and (7) The type of service assessed. The ES were classified according to the Common International Classification of Ecosystem Services (CICES) in (1) provisioning, (2) cultural, and (3) regulating and maintenance. Here, the 'supporting' services are considered part of the underlying structures, processes, and functions that characterise ecosystems (Haines-Young and Potschin, 2018). However, given the strong focus in the literature on supporting services, we included "supporting" as a fourth category when evaluating the types of services. All the information was systematically collected from the included papers, compiling the data into a comprehensive database (Supplementary Materials B). The results section compiles an overview of all ES valuation methods, and with every method explained, examples are provided within the context of an MPA to clearly illustrate how given methods can be useful in the marine realm. This approach not only enhances the comprehensibility of the methods but also demonstrates their practical applicability. The prevalence of different valuation methods and (types of) values were examined, and the most utilised methods and values were highlighted, as well as those that received less attention.

3. Results

3.1 General

The 100 included papers were published between 2003 and 2023. The most frequently used scientific journals were 'Ecosystem Services' (n=16), 'Ocean and Coastal Management' (n=15), and 'Marine Policy' (n=12). Of the 100 papers, nine focused on general techniques and methods for ES valuation in MPAs and 91 showcased actual applications. The application papers mainly focused on monetary valuation (n=47), some on non-monetary valuation (n=25), and others mixed both monetary and non-monetary valuations (n=19). There is a balanced spread between application papers focusing on European (n=44) and non-European (n=44) case studies. Three studies

[1] The asterisk (*) represents any group of characters, including no character for searching in the Web of Science (https://webofscience.help.clarivate.com/en-us/Content/search-rules.htm). In this case, the asterisk was used to include both the plural and singular forms in searching.

considered both European and non-European areas (Figure 1). Most application papers provide cases in the United Kingdom (n=24). This observation prompts consideration of potential language bias, which may contribute to the prevalence of publications from English-speaking countries. Fourteen (n=14) of the application papers specifically focus on MPA networks.

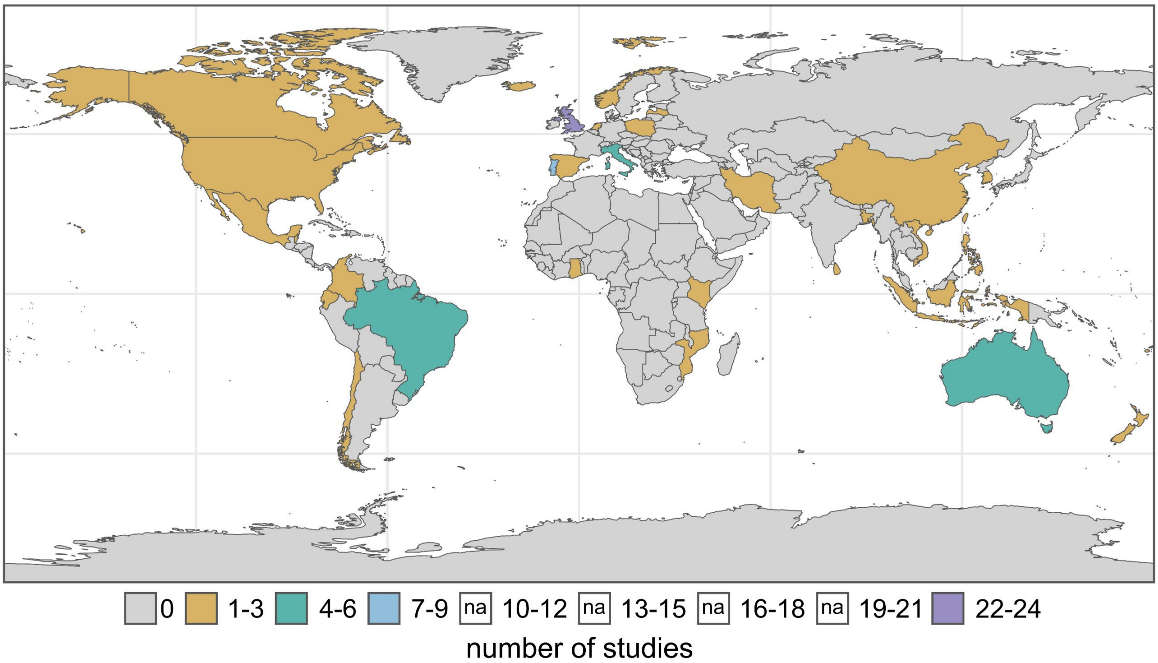

Figure 1. Global distribution of published research, based on study locations, applying valuation methods in the context of Marine Protected Areas (MPAs) and MPA networks.

3.2 Objectives of ES valuation

ES valuation can be used for distinct purposes and for a diverse range of motivations. Two primary justifications for the valuation of ES were found in the literature investigated. The first pertains to its use for decision-making processes, while the second focuses on enhancing effective communication. First, to improve decision-making, ES valuation collects pertinent information for various aspects such as the current state of the ecosystem, spatial planning (Gomes et al., 2018), coastal development, and conservation management (Burdon et al., 2019). This can provide decision-makers with relevant data for better budget allocation (Failler et al., 2019), advising on trade-offs (Outeiro et al., 2019), and formulating strategies to facilitate restoration or prevent degradation (e.g., by implementing park fees (Robles-Zavala and Chang Reynoso, 2018)). Second, enhancing communication, particularly concerning the value of ecological ecosystems, is imperative for garnering increased support from stakeholders for marine projects, as well as novel policies and strategies (Vassallo et al., 2017). Furthermore, the valuation of ES can serve as a communication tool for resolving conflicts that may arise within these contexts (Lopes and Villasante, 2018). While there are two primary justifications for the valuation of ES found in the literature investigated—decision-making and communication—these motivations are not mutually exclusive. Effective communication can play a crucial role in supporting and improving decision-making.

ES valuation can be conducted both ex-ante (Jobstvogt et al., 2014; Lan et al., 2021) and ex-post (Failler et al., 2019; Johnson et al., 2019), providing insights before and after the implementation of an MPA or MPA network. Ex-ante valuations enable decision-makers to assess the potential benefits and costs of establishing an MPA or connecting MPAs into a network, aiding in the design and planning stages. Ex-post valuations allow for the evaluation of the actual impacts and effectiveness of an established MPA, informing adaptive management strategies and policy adjustments. However, both ex-ante and ex-post assessments have their respective challenges. These challenges are linked to (1) the inaccuracy of quantifying values for ES due to difficulties in measurement and calculations, (2) the broad range of methodologies and assumptions within valuation assessments, which might hinder comparability between studies, and (3) the complex nature of integrating preferences and needs of different stakeholders.

3.3 Monetary valuation

Markets usually fail to capture the actual value of ES (Costanza and Liu, 2014). In this case, monetary valuation can provide a monetary measurement for ES. Such valuation exercises enable and ease the inclusion of the benefits of biodiversity into decision-making processes, weighing them against the costs of conservation (Rands et al., 2010). The monetary valuation of ES can, thus, be used to advocate the protection of MPAs for policymakers. The monetary valuation of services can also justify investments in ecosystem management, which can help avoid future restoration costs and enable comparisons of economic welfare between decisions and policies related to MPAs (Balmford et al., 2002).

Most papers analysed in this review (66 out of 91 application papers, including mixed approaches) rely on monetary approaches, with a clear preference for stated preference methodologies, such as contingent valuation and discrete choice experiments. Depending on the goal of the study and the ecosystem service under evaluation, a different monetary approach or combination of approaches can be used. Based on the information retrieved within this review study, an overview of nine method categories is provided for a monetary valuation of ES currently used for their assessment in MPAs and MPA networks (Figure 2).

3.3.1 Stated and revealed preference methods

The stated preference methodology elicits people's preferences for hypothetical goods or services, using interviews, surveys, or other data collection techniques. Two common types of stated preference methods are used to value ES: (1) contingent valuation and (2) choice modelling (Pearce and Ozdemiroglu, 2002). Contingent valuation asks individuals directly about their willingness to pay (or accept) (WTP or WTA) for a good or service (Mitchell and Carson, 1989). In choice modelling, the WTP or WTA is estimated more indirectly; respondents are presented with multiple alternative descriptions, differentiated by attributes and their levels, of a service, and are asked to rank them, rate them (contingent ranking, contingent rating, and paired comparison), or choose their most preferred one (discrete choice experiment, DCE) (Hanley et al., 2001; Louviere and Hensher, 1982). Most of the papers found in this review (51 out of 91 application papers) applied a contingent valuation and/or a DCE. The WTP for marine conservation in general (Wang et al., 2022), or applied to some more specific ecosystem features (e.g., conserving a shark population), were calculated, for example, to justify a tax increase or the implementation of an entrance fee for marine reserves (examples are: Brouwer et al., 2016; Castaño-Isaza et al., 2015; Daly et al., 2015; Ison et al., 2021; Malinauskaite et al., 2020; Yu et al., 2018).

The revealed preference methodology assesses people's preferences for a good or service by observing their actual behaviour, for example, by monitoring which goods people buy or which places they visit. The travel cost method (applied by 8 out of 91 application papers) and hedonic pricing method (applied by 4 out of 91 application papers) are two revealed preference methods, both using regression analysis for their calculations. The travel cost method (TCM), first suggested by Hotelling (1949), is often used to estimate the recreational value of marine and coastal areas. The method assumes that the travel cost is the implicit price visitors pay for their trip to access (recreational) sites (e.g., a beach) or to be able to take part in an activity (Zhang et al., 2015). An example is provided by Trujillo et al. (2017), who estimated the financial benefits of scuba diving services in the coral reefs of Rosario and San Bernardo National Park in Colombia (Trujillo et al., 2017). Hedonic pricing analyses the relationship between the price of a good or service and the characteristics that determine its value (e.g., the market price of a house) (Angulo-Valdés and Hatcher, 2010). For example, the assessment of cultural ES can be done by studying how the proximity of aquaculture and scenic areas influence housing prices (Spanou et al., 2020). The same was done by Banarsyadhimi et al. (2022), who applied a hedonic model to monetise the cultural ES at the Gili Matra Islands. They discovered that housing prices were higher near the coastline (with sunset views) and beach spots, although this varied between different islands (Banarsyadhimi et al., 2022).

3.3.2 Input valuation methods

Input valuation methods assess how changes in the environment impact biological resources or ecological services and, thereby, economic activities. Thus, biological resources or ecosystem services (e.g., fisheries) are treated as an "input" to the outputs of production (e.g., marketed fish catch). Input valuation methods (applied by 17 out of 91 application papers) can be cost-based, production function-based, or market-based (UNEP, 2014).

The cost-based method is a type of input valuation method that analyses the value of the inputs that are necessary to produce the non-market good or service. For this, one could rely on the replacement cost or the damage cost method. The replacement cost method (applied by 4 out of 91 application papers) can, for example, be used to value storm prevention and flood mitigation services by estimating the costs of replacing coastal habitats by constructing physical barriers to perform these services (Barbier, 2016; Gravestock and Sheppard, 2015). Another example is provided by Watson et al. (2020), who valued natural N and P removal rates for maintaining good water quality by using the cost difference associated with human-generated alternatives (Watson et al., 2020). However, economists caution against using the replacement cost approach to estimate the value of ES like storm protection or bioremediation. This is because it involves estimating benefits based on costs, and human-built solutions are often not the most cost-effective means of providing a service (Barbier, 2016). An alternative to the replacement cost method is the damage cost method (applied by 3 out of 91 application papers). Barbier (2016) used the expected damage function approach to estimate coastal protection provided by mangroves. A non-market ecosystem service, such as the protection of a property or a human life, is valued by using the environment as an input to a benefit. However, this method has limitations as well, especially regarding risk-averse households, and may not accurately represent their willingness to pay to avoid risks. If households are highly risk-averse, the option price for reducing the risk might exceed the expected damages (Freeman, 2003).

The production function method is another type of input valuation, closely linked with the cost-based ones, which analyses the relationships between the inputs used to produce a good or service and its output. For example, in the case of commercial fisheries, the value of the fishery as an ecosystem service can be estimated through changes in production and its impact on welfare (Pascal et al., 2018). There are two approaches to this estimation: static and dynamic (Barbier, 2000). In static approaches, the estimation is calculated through changes in producer and consumer surplus measures, which are affected by environmental changes. For example, in the case of fisheries, declining fish stocks diminish both producers' and consumers' welfare. In dynamic approaches, change is considered to have an intemporal, "bioeconomic" effect. In the case of fisheries, this would mean that changes in the environment could be modelled as part of the fish stock's growth function, which again impacts social welfare. Cost-based methods and production function methods usually depend on biophysical and ecological modelling expertise, as well as data concerning production and markets.

Market-based methods (applied by 17 out of 91 application papers) follow the principle of shadow pricing. Market prices of related goods and services are used as a proxy for the value of the non-market good or service. For example, it is assumed that the market price of fish reflects the value people place on the fish and the ecosystem supporting the fishery. Sagoe et al. (2021) estimated the values for finfish and shellfish harvested annually as a proxy to express the income that would have been lost in the absence of nursery services provided by the marine habitats in Ghana (Sagoe et al., 2021). In addition, carbon market prices can be used to value carbon sequestration (Watson et al., 2020). Sagoe et al. (2021) value carbon storage and cycling by connecting carbon storage models with the unit price of carbon (EU ETS).

3.3.3 Benefit transfer method

The benefit transfer (BT) method is an indirect economic procedure that uses existing valuations of similar ecosystems and their services in other locations to estimate the values within a new study area (often referred to as 'the policy site') (Johnston and Rosenberger, 2009). This is especially the case for economic values. The benefit-transfer method is based on extrapolating values from one context to another, highlighting the importance of matching the two to obtain reliable results. (Barbier, 2016). Benefit transfer was used in 8 out of 91 application papers within this review. For example, Hussain et al. (2010) estimated the benefits of a proposed network of marine conservation zones in the UK (Hussain et al., 2010). However, the authors question the use of benefit transfer to accurately assess ES and create policy evidence because of the lack of primary data and the fact that benefits in other studies are often reported in aggregated terms. Hicks et al. (2009) assessed ES related to waste regulation, coastal protection, habitat, and biological control on the Kenyan coast using past studies and corrected for inflation (Hicks et al., 2009).

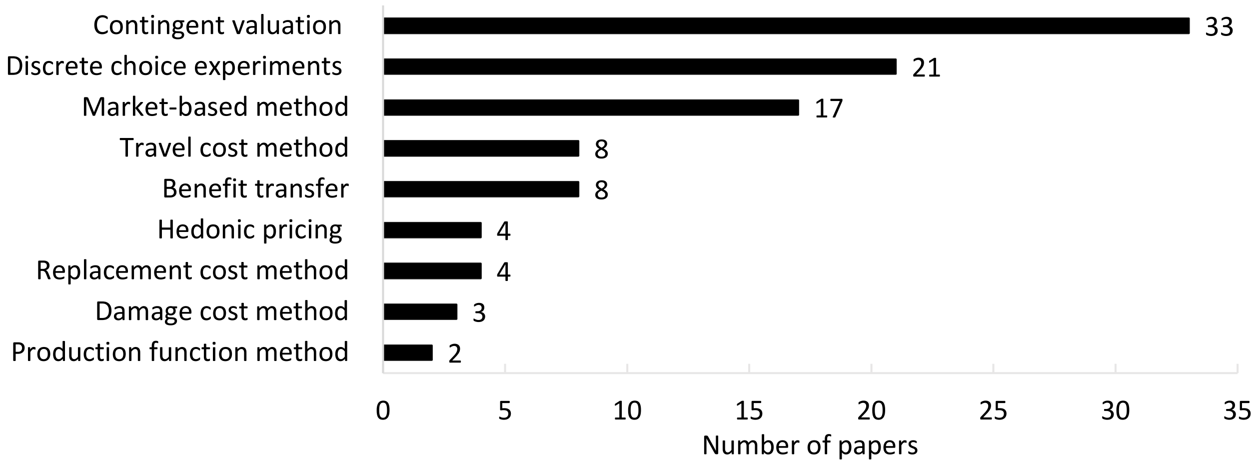

Figure 2. Number of application papers that applied monetary valuation methods. Note: Some papers applied multiple methods. More details regarding the application of specific methods in each study (per study ID) can be found in Supplementary Materials A2.

3.4 Non-monetary valuation

Unlike monetary values, which can be easily integrated into economic frameworks, non-monetary values often encompass both tangible ecological and intangible cultural aspects that are complex to measure and difficult to compare across different contexts. Monetary values provide a more straightforward and recognisable basis for justifying conservation efforts, as they can be directly compared to costs and benefits (Rees et al., 2010). As a result, compared to monetary valuation, the application of non-monetary approaches for ES valuation remains more limited within the literature despite their potential to capture a broader range of values, avoid many assumptions on economic values, and inform holistic management strategies. Most non-monetary applications either focus on biophysical modelling or use surveys and interviews with mapping, Likert scales, and open-ended questions to value ES. This review found 44 application papers applying non-monetary valuation (including mixed approaches). We outline seven possible non-monetary method categories for ES valuation for MPA and MPA networks (Figure 3).

3.4.1 Biophysical modelling and mapping

Instead of valuing ecosystems from a socioeconomic point of view, based on market prices and human preferences, one can also follow a biophysical perspective (Franzese et al., 2017). This approach allows for an intrinsic valuation of natural capital, going beyond sole anthropocentric values.

Biophysical modelling and mapping (applied by 14 out of 91 application papers) can include observations, monitoring, surveys, and interviews to gather data. Biophysical modelling makes use of various methods such as carbon or water (quality) footprint models (Nahuelhual et al., 2020) and emergy (the amount of energy consumed to make a product or service) accounting. Mapping software is often used to spatially link biological data to existing and proposed conservation areas (i.e., creating biological valuation maps) (Gomes et al., 2018). The Marine Biological Valuation (MBV) protocol has been used to assess the biological value of MPAs (Derous et al., 2007; Gomes et al., 2018). The value of an area is assessed for different indicators in terms of its resilience and stability of species and species assemblages (Węsławski et al., 2009).

The (carbon) footprint analysis can be performed through a life cycle assessment (LCA) approach. This allows practitioners to calculate CO_2 equivalent emissions using software such as Open LCA or SimaPro and databases such as Ecoinvent. Methods such as Social Cost of Carbon (SCC) or Abatement Cost (AC) can be used to quantify emissions in monetary values (Dauwe et al., 2023; Tyllianakis et al., 2020; Visintin et al., 2022). The SCC is the marginal cost of damage caused by carbon emissions or the marginal benefit resulting from reduced greenhouse gas emissions (Pearce and Pretty, 1993). Abatement costs reflect the cost of policies required to mitigate the damages from the emission of an extra ton of CO_2 (Tyllianakis et al., 2020). Applications of this method were found in Tyllianakis et al. (2020) and Visintin et al. (2022), which valued carbon sequestration and storage for an area including multiple MPAs in the UK and one in Italy, respectively.

Emergy accounting, another technique for environmental accounting, has been applied by, for example, Vassallo et al. (2017), where the accounting procedure relies on trophodynamic analysis to value natural capital in MPAs. Emergy accounting provides a value of natural and human-made capital by assessing the cost of production in terms of biophysical flows used to support its generation (Franzese et al., 2017). Economic valuation can be added based on economic approaches such as benefit transfer (Vassallo et al., 2013). Vassallo et al. (2013) did this to value the ES provided by a seagrass ecosystem in Italy.

3.4.2 Participatory techniques

Participatory techniques are often used for non-monetary ES valuation as they allow for the engagement of a broad range of stakeholders in the decision-making process. It is essential to recognise that different stakeholders have different values, needs, and expectations when it comes to the use and management of natural resources. Using participatory techniques, following a bottom-up approach, ES valuation can reflect the priorities and perspectives of First Nations peoples and other indigenous groups, local communities, tourists, and other stakeholders. Furthermore, participatory approaches can help to build trust and social capital among stakeholders, leading to more effective and collaborative management of MPAs.

Quantitative information on the values of ES can be gathered by assessments, usually through surveys, using rating and ranking questions (applied by 14 out of 91 papers), while qualitative information is collected by open questions, in surveys, interviews, focus group discussions, and using storytelling (comprehensively applied by 7 out of 91 papers). For example, Slater et al. (2020) used a set of linked participatory workshops for cross-sector stakeholder involvement to aid decision-making for a licensing decision for offshore wind farms in the North Sea (UK) (Slater et al., 2020). The workshops resulted in spatial data, a list of benefits and ES, and a conceptual map exploring linkages and trade-offs between existing and new marine activities and ES. In addition, surveys have been widely applied to assess well-being resulting from ES. An example was developed by Kenter et al. (2016), who provided a set of 15 non-monetary indicators which reflect well-being (e.g., rating the statement 'I have felt touched by the beauty of these sites') (Kenter et al., 2016). These have been further applied by Spanou et al. (2020) to value cultural ES on the West Coast of Scotland.

Specific methodologies have been developed for participatory research using the techniques explained in the previous section (workshops, interviews, and surveys). One example is the Community Voice Method, which was applied by Ainsworth et al. (2019) to involve marine stakeholders in the UK to improve the valuation of coastal and marine cultural ES(Ainsworth et al., 2019). The Community Voice Method (http://communityvoicemethod.org/) is a technique using interviews that shows great promise in gathering and conveying diverse stakeholder perspectives in a democratic, cohesive, and non-confrontational manner (Cumming and Norwood, 2012). This method identifies shared values and subjective experiences, establishes management options and criteria, and develops value indicators for different environmental benefits and policy options through workshops.

Participatory mapping encompasses another group of methods that deal with participatory processes to map socio-economic conditions (and their relations), hotspots, social perceptions, values and priorities, mainly focusing on the valuation of cultural ES (Nahuelhual et al., 2020). In this review, 16 out of 91 papers apply these mapping exercises. Social (or cultural) mapping pertains to the process of identifying and delineating specific geographical areas that hold value and cultural significance. Data can be collected by asking respondents to map values to certain locations, inquiring them about the number and frequency of visits, or using databases with the number of visitors or photos taken in specific locations. For example, Johnson et al. (2019) applied the PPGIS (Public Participation Geographic Information Systems) approach to compare how social values relate to landscape metrics. Rees et al. (2010) employed a simple method for identifying recreational hotspots by asking respondents to indicate the frequency of their visits to specific sites on a scale of 1 to 5. This approach offers a simple and practical way to identify areas with high levels of recreational activity (Rees et al., 2010). Cunha et al. (2018) used the InVEST® (Integrated Valuation of Ecosystem Services and Tradeoffs) model to calculate the number of photos in Flickr in a Portuguese MPA as a proxy for the number of visitors (Cunha et al., 2018).

A final example of a participatory method is the Q methodology, which is applied to one MPA in our literature review by Pike et al. (2015). The Q methodology uses a series of interviews to derive 'factors' of value for its stakeholders, allowing the incorporation of minority viewpoints. The Q method can map the views of stakeholders and is especially applicable to examining cultural ES that are more difficult to measure (Pike et al., 2015). It can help decision-makers understand where and how stakeholders within MPAs 'place value' on cultural ES.

3.4.3 Multi-criteria decision analysis

The multi-criteria decision analysis (MCDA) is a method of 'aggregation' and is applied in 5 out 91 papers in this review. Different MCDA techniques exist such as global and local multi-attribute scaling, the analytical hierarchy process, and compromise programming (Martin and Mazzotta, 2018). The MCDA is a non-monetary method in itself but can be used to combine monetary and non-monetary ES values. The MCDA can be organised in a participatory way, engaging stakeholders in decision-making by identifying and prioritising relevant criteria. For example, Lopes and Videira (2019) developed PArticulatES, a three-stage framework for participatory MCDA that was successfully piloted in the Arrábida Natural Park in Portugal to value ES. The framework provides a coherent platform for engaging stakeholders in scoping, assessment, and decision support to make informed decisions about ecosystem management and protection (Lopes and Videira, 2019).

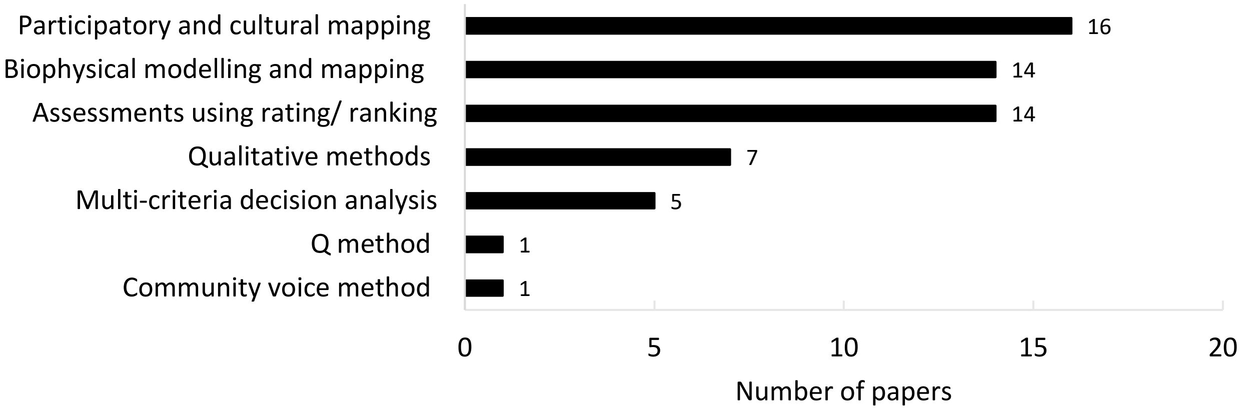

Figure 3. Number of application papers that applied non-monetary valuation methods. Note: Some papers applied multiple methods. More details regarding the application of specific methods in each study (per study ID) can be found in Supplementary Materials A2.

3.5 Mixed methods

Nineteen application papers use a mixed approach, combining monetary with non-monetary approaches. Kenter et al. (2016) emphasise that non-monetary valuation is often valuable in understanding the meaning associated with monetary values. For example, Spanou et al. (2020) developed a valuation approach that included non-monetary valuation through an eudaemonic well-being questionnaire and monetary valuation through hedonic pricing. Chen et al. (2018) combined data from interviews and questionnaires with a contingent valuation approach to evaluate public perceptions and WTP for ES in Taiwanese fishery resource conservation zones (Chen et al., 2018). The Total Social Value (TSV) concept, instead of the TEV, can be followed to include ecological value, economic value, and socio-cultural value, which should be measured by both monetary and non-monetary approaches. An integration of both natural and social sciences, together with stakeholder analysis and engagement, is important for a more comprehensive valuation of ES.

3.6. The Total Economic Value and Ecosystem Services

The reviewed studies were analysed using the TEV and ES approaches. In this section, the types of values and ES targeted in the studies were identified (Figures 4 and 5). In most of the reviewed papers, the specific components of the values assessed are not explicitly stated. Therefore, based on their expertise, the authors of this paper categorised the different ES into the values of the TEV. This categorisation was derived from the authors' interpretation of the texts, using the definitions of TEV to infer and classify the components accordingly.

The studies included in this review can be categorised based on the types of values they evaluate (Figure 4):

1. Studies focusing only on "use values": most reviewed studies focus on use values (n=43), examining the direct and indirect benefits people derive from MPAs and MPA networks. These benefits include:
    - Recreational benefits: activities such as snorkelling and diving (e.g., Banarsyadhimi et al., 2022; Casey and Schuhmann, 2019; Christie et al., 2015; Daly et al., 2015; Rees et al., 2010).
    - Economic benefits: activities such as fishing (e.g., Christie et al., 2015; Failler et al., 2019; Galparsoro and Borja, 2021; Tyllianakis, 2022).

    These studies highlight the economic importance of MPAs and MPA networks and contribute to a tangible understanding of the economic significance of these protected areas.
2. Studies focusing on both "use and non-use values": this category is the second most important in this review (n=23). Studies in this category provide a more holistic understanding of the economic and intrinsic values associated with MPAs. They may explore:
    - Use and bequest values (e.g., Ison et al., 2021; van Riper et al., 2012).
    - Use, existence, and altruist values (e.g., Johnson et al., 2019).
3. Studies focusing on non-use values: in this category, studies focus on the value associated with the non-use benefits that people derive from MPAs. For example, studies on payments to protect endangered sharks illustrate the intrinsic value people place on these marine resources (e.g., Booth et al., 2022; Lopes and Villasante, 2018).
4. Studies focusing on the combination of the option value and non-use values: research in this category combines non-use values with the option value, emphasising the importance of having the possibility to use or benefit from the resource in the future and adding a temporal dimension to the valuation.
5. Studies assessing the Total Economic Value: studies provide a comprehensive economic assessment of MPAs by including use, non-use, and option values. This captures the full range of economic contributions and intrinsic values.
6. Studies with unclear assessed values: a considerable number (n=12) of the reviewed studies address values in a more general manner, making them difficult to categorise into distinct value types.

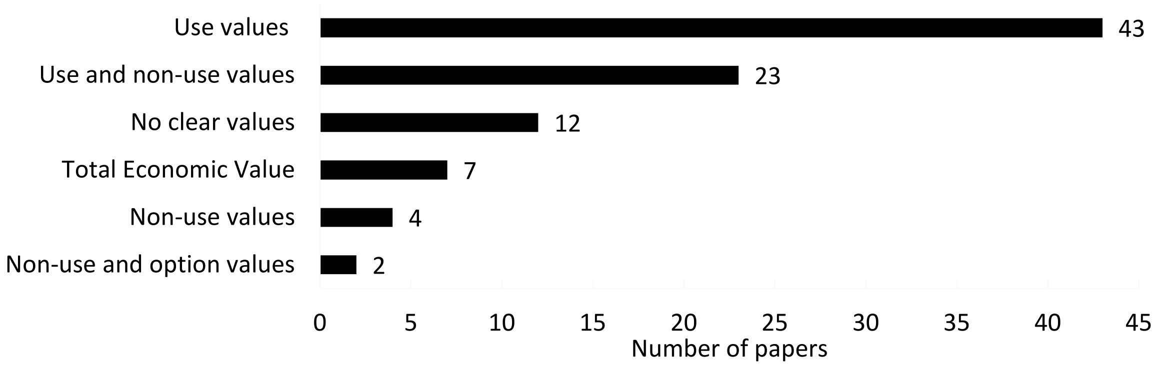

Figure 4. Types of values assessed in the application papers (n=91). More details regarding the types of values assessed in each study (per study ID) can be found in Supplementary Materials A3.

Following the ES approach (Figure 5), the predominant focus of the included papers is on cultural ES, with 23 out of 91 application papers exclusively dedicated to this category and 43 out of 91 applications exploring cultural ES in conjunction with other ES. Cultural ES often translate to use values, such as marine leisure and recreation (sub-aqua diving, sea angling, and wildlife watching) or existence values, such as protecting marine species. Bequest values can also be linked to cultural ES through the willingness to protect a spiritual area or species for future generations.

Provisioning services are the second most examined ES (n=45), with a major focus on the value derived from fishing in MPAs. In the papers, these ES are only translated to use values. Option values can also be linked to provisioning ES, for instance, when considering the option to use fish in the future. Some papers are broadly focused on the general conservation of MPAs, without specifying the ES (n=11) (e.g., Ferreira et al., 2017; HANG et al., 2023; Kim et al., 2021; Kim and Yoo, 2020). Regulating and supporting services are underrepresented in this review, highlighting the need for more research.

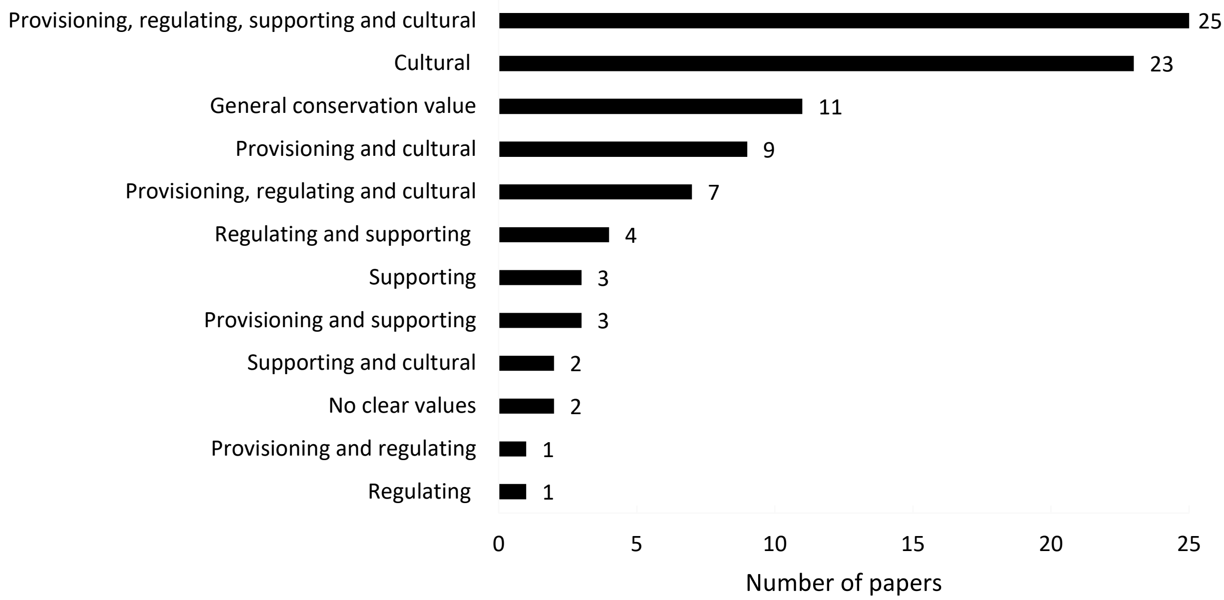

Figure 5: Types of services assessed in the application papers (n=91). More details regarding the types of services assessed in each study (per study ID) can be found in Supplementary Materials A3.

4. Discussion

The papers in this review provide a valuable overview of scientific valuation methods, but there is often a lack of connection to their practical application. While these methodologies offer insights, the focus should also be on the tools necessary for real-world implementation. As highlighted in the results section, there is a strong emphasis on monetary methods. However, the importance of non-monetary methods, particularly those that involve participatory approaches and ecological modelling, is also crucial to capturing deeper underlying processes and enabling a more accurate and comprehensive valuation. In the following three subsections, economic, social, and ecological tools that can be used to facilitate valuation for practitioners are described. Examples drawn from the reviewed papers are presented in this study, supplemented by broader instances to elucidate the tools and potential applications further.

4.1. From economic valuation towards decision support

The economic valuation of ES is beginning to be recognised as an important management tool for protected areas, including marine ones (see Pakalniete et al. 2021, among others). Economic tools for MPA management, in general, provide a means to improve the cost-efficiency of conservation (Albers and Ashworth, 2022) and offer support for measuring outcomes of different options and processes. They can also help to mediate discussions with different stakeholders and competing interests of conservation and other societal interests (Geange et al., 2017).

Economic tools that can be used for MPA governance can combine various methods and data sources. Some tools use results of economic valuations from peer-reviewed literature and map ES related values through Geographical Information System (GIS). For example, InVEST® is a set of open-source software models that provides maps where biophysical and economic results are spatially located (Natural Capital Project, 2024). The InVEST® maps show how changes in ecosystem functions affect ES, both physically and economically, by using a production function. Monetary values are represented in maps. However, for some ES, the tool does not provide a monetary value but a qualitative estimation, e.g., a ranking of coastal ecosystems, indicating the most and the least vulnerable. Examples of papers in this review study that apply InVEST® are Cunha et al. (2018) and Outeiro et al. (2019). A similar approach is adopted in many other tools that provide information on opportunity costs and trade-offs of different outcomes (Qu et al., 2021), including e.g., CO$TING NATURE (https://www.policysupport.org/costingnature), ARIES (Villa et al., 2014), SolVES (Johnson et al., 2019; Sherrouse et al., 2022; van Riper et al., 2012), TESSA (Peh et al., 2022), and MIMES (Boumans et al., 2015).

Valuation data regarding MPAs are not always available or cannot be (easily) provided. In those cases, economic insights can be obtained in an indirect manner, adopting a different typology of tools that are primarily used for other purposes. So-called decision-support tools (DST) help to allocate sea space by combining information on various ecosystem indicators and human-induced pressures and activities. Data used in these tools may not include results from ES valuations, but more likely information on biodiversity features and economic activities. Using these kinds of tools enhances conservation outcomes by selecting the most important biodiversity feature while minimising the socio-economic cost (Rodríguez-Basalo et al., 2019). Examples of DSTs include Marxan (Rodríguez-Basalo et al., 2019), PlanWise4Blue (Kotta et al., 2020; Vaher et al., 2022), FishRent (Rybicki et al., 2021), MAREA (Villaseñor-Derbez et al., 2018), Atlantis (Audzijonyte et al., 2019), and IMPASEA (Rodríguez-Rodríguez et al., 2015). Also, conservation planning software tools alone, such as Zonation, which are not primarily regarded as economic tools, may offer economic benefits (direct and indirect) by maximising the representation of desired biodiversity features in a particular area (Geange et al., 2017) and potentially limiting the area enclosed in an MPA and taken away from other uses. In addition, there are different MPA management effectiveness assessment tools such as SEMPAI, which use multiple data gathering methods (photos, surveys, and key informant interviews) and indicators (e.g., numbers related to MPA management, local economies, ecological aspects, or stakeholders attitudes) (Avelino et al., 2019), RAPPAM (questionnaire) (Araújo and Bernard, 2016), and MOSE (calculating scores using various biodiversity, local economy, and management features) (Picone et al., 2020).

In other cases, valuation of ES can be part of approaches where different stakeholders meet to discuss (economic) importance of certain areas and different use scenarios of them. Participatory tools, such as Seasketch (Burnett, 2020), AquaSpace tool (Gimpel et al., 2018), SEANERGY and Baltic Explorer (Bonnevie et al., 2023), and the MSP Challenge approach (Abspoel et al., 2021), can be used in collaboration with stakeholders to facilitate discussions and to bring out stakeholder views when mapping different options. The participatory approach is also used by some of the tools mentioned earlier, such as TESSA, as it allows for considering the common and collective aspects of ecosystem services (also in an economic way) but also addresses the lack of economic data and the impossibility of estimating them in some contexts.

4.2. A participatory approach for acknowledging social and cultural values

In comparison to the extensive research and availability of tools focused on tangible ES, such as provisioning services, there is a notable gap in the provision of accessible and user-friendly tools for understanding and incorporating intangible values associated with ES. Intangible values, including altruism, bequest, existence, and option values, represent nuanced aspects of human-nature interactions that are often overlooked in traditional ES assessments. These intangible values can be understood as one form of social and cultural aspects, and they highly impact the perceived benefits from ES. Understanding and incorporating these intangible values into ecosystem service assessments are essential for accurately capturing the full spectrum of benefits derived from ecosystems.

In this subsection, the term 'tool' is treated more broadly to complement the methods discussed in this review study. Despite there being a rich amount of academic research developed to better understand how social aspects and culture affect (and are affected by) the environment, a gap in ES persists in relation to these intangible socio-cultural values. However, there are valuation methods, which can be translated into tools, that attempt to evaluate and consider these aspects both qualitatively.

One feature that is strongly linked to this notion of social and cultural aspects is the inclusion and presence of I/TEK (Indigenous and traditional ecological knowledge) frameworks. When considering the concept of ES and the valuation of such services, an emphasis is placed upon the services which humanity receives from the natural environment. Yet, there is an ethical critique to this due to the concept's inherent 'commodification' of nature as well as its attempt to place anthropogenic, oftentimes monetary values on core ecosystem functions. Whilst this argument is often made in relation to earth system processes, the same can be extended to categorised cultural ES. Conflicts, ontologically, in the application of this concept also extend to participants: in many cultural contexts, the premise of a nature/culture binary does not exist, or it may exist in vastly different forms. As such, awareness of local concepts, ontologies, and religions is crucial in the sense that they cannot, necessarily, be effectively reflected in subsequent designations of cultural ES. This awareness can be noted in cases when I/TEK frameworks have been applied: for example, in Australia, IPAs (Indigenous Protected Areas) have been established to incorporate Aboriginal values and non-Western ontological knowledge to marine protection, and such cases reveal core linkages between socio-cultural values as well as the management of protected areas (Gould et al., 2021).

More broadly speaking, the argument for the inclusion of a more pluralistic and diverse understanding of the notion of value has been discussed in depth by IPBES in recent years (2022). Diaz et al. (2018) provoked the discussion with the proposal of a new concept to potentially replace ES called Natures Contributions to People (Díaz et al., 2018), which attempts to truly emphasise the core role that culture plays within relationships between people and nature. For a summary of the debate and evaluation of claims between ES and NCP, see Kadykalo et al., 2019. In continuing this discussion, in 2022, IPBES published a guidance document whereby a value typology was outlined (IPBES, 2022). Within this typology, several core worldviews formed the basis for how values should be classified. From these worldviews, the link to so-called specific values could be made (i.e., instrumental, intrinsic, or relational) to which indicators for the valuation of these different values can be identified (IPBES, 2022a: XXIII). With this, IPBES (2022) wish to broaden the perspective and use of the term value to better reflect the plural meanings that persist globally, arguing that policymakers have tended to perceive value from a narrow perspective and have not adopted the true diversity of nature's various values to people). By doing so, decision-makers have largely ignored the power disparities which persist when prioritising certain values over others (IPBES, 2022: 18).

As IPBES (2022) outline, there are plentiful methodologies from a variety of disciplines whereby social and cultural aspects are valued. For example, participatory mapping techniques incorporate socio-cultural perspectives, and similar qualitative approaches can acknowledge how complex social aspects affect the perception of value of ES within stakeholder groups (Pearson et al., 2019). In the above section on participatory approaches, several reviewed papers were discussed that utilised social and cultural mapping (Johnson et al., 2019; Nahuelhual et al., 2020; Rees et al., 2010), which can be used to map the diversity of perceptions and values tied to specific places. The methods applied within these participatory approaches can differ, with some utilising quantitative data through survey responses, whereas others opt to delve deeper into stakeholder involvement on a local scale through ethnographic methodologies (Gajardo et al., 2023). Additional links can be drawn between the phototalk/photovoice participatory approach adopted by Mohd Noor et al. (2023) and Cosgriff (2023) and the community voice method discussed above (Ainsworth et al., 2019; Cosgriff, 2023; Mohd Noor et al., 2023). However, in the former approach, participants use visual representations to aid their perspective on a given set of issues, prompts, or questions. In these two cases, visual images were used to elicit rich responses on the emotional attachment of youths to coastal environments, which, like with the community voice method, offers a democratic and inclusive path to the identification of diverse well-being values tied to marine environments.

Whilst these are not tools understood in a technical sense, they are approaches which can be employed to better get to grips with the diversity of experience and perceptions of the value of certain intangible cultural ES in specific geo-cultural contexts. For example, the evaluation of sense of place within fishing communities (Baker et al., 2021; Dias et al., 2022; Pearson et al., 2019; Plaan, 2018; Urquhart and Acott, 2014) conveys how this kind of approach extends to various marine contexts across the globe. In utilising broader approaches to study cultural ES, these intersections can be made much clearer than they otherwise would be from a purely monetary approach to valuation. Changes to socio-cultural values can have direct impacts on the perceived importance of ES. These differences can sometimes be attributed to societal shifts and changing relational practices within communities (Ignatius et al., 2019; Malinauskaite et al., 2021).

There are some more technical tools that can be applied to evaluate these intangible ES. Whilst not MPA-specific, the PEAQS scale utilises both qualitative and quantitative approaches in a marine context. Here, the focus was on the aesthetic qualities of blue/green spaces, with aesthetics being one of the least studied aspects of cultural ES. This is an example of a proactive approach using mixed methods to analyse on a broader scale how particular aesthetic values vary between types of blue/green space (Subiza-Pérez et al., 2019). However, whilst multiple interdisciplinary approaches and methodological frameworks are being developed to better evaluate the complexity of various socio-cultural elements relating to humanity's relationship with natural environments, there are core difficulties relating to problems with quantification as well as the depth of effort needed to implement effective qualitative methods.

4.3. Importance of ecological modelling for valuation

As highlighted in section 3.4.1, biophysical modelling and the mapping of marine ecosystems' structural and functional dimensions, and the services they provide, have started to be incorporated into valuation processes (e.g., Gomes et al., 2018). This approach moves beyond the traditional focus on socio-economic factors and challenges the dominant anthropocentric perspective. However, ecologically informed valuations in the marine realm are still in their early stages. When ecological data is incorporated, it typically relies on spatial representations of ecosystems' structural components (particularly the distribution of key species, such as habitat-formers) and expert-based assessments of their contributions to specific ES (Inácio et al., 2020). The popularity of these methods among policymakers and practitioners can be attributed to their low data requirements, ease of implementation, and the simplicity of the outputs they generate. Nevertheless, the biased perception of experts about how ecosystem components influence processes and services, combined with the qualitative nature of these outputs, undermines the reliability of these approaches and often leads to suboptimal decision-making and valuation processes.

In ecology, the mechanistic and quantitative understanding of how transformations suffered by marine ecosystems affect the provision of services has substantially increased in the last decades (Kotta et al., 2020). Most of this knowledge has been exclusively published in highly technical documents, preventing its direct use by policymakers, managers, and experts from other disciplines, including the economy. In this context, models, algorithms, and, more generally, DSTs that can integrate the best available scientific evidence and produce accurate quantitative but easy-to-understand outputs are needed to bridge the gap between environmental sciences, policy and other disciplines. To date, many DSTs (see some examples in section 4.1) have been designed to support policymakers and practitioners accessing, analysing, and implementing available technical evidence (Kotta et al., 2020; Menegon et al., 2018). However, most of these DSTs remain unknown or underused. The creation of these tools is generally the result of academic exercises that rarely involve stakeholders in the design and creation process. Thus, an improved generation of DSTs derived from co-design and co-creation processes explicitly looking at the needs and interests of stakeholders is urgently needed to support the generation of meaningful valuation and decision-making processes.

Beyond the general advances in our understanding of how marine ecosystems function and respond to anthropogenic pressures, there is still a gap in interdisciplinary research connecting physical-chemical, biological, and socio-economic aspects (European Marine Board, 2019; Preiser et al., 2018). Most available marine ecosystem models focus on specific dimensions, limiting their ability to study complex interactions. A detailed understanding of ecosystems' functioning must be accompanied by a profound understanding of ES demands and trade-offs, the stakeholders who rely on and benefit from them, and the feed-backs between ecological and socio-economic subsystems (Drechsler, 2020). Such integration of knowledge from various disciplines into dynamic models is crucial to understanding and predicting how changes in one part of the ecosystem impact others. Although progress has been made, there is still a significant lack of model linkages and proper integration of the diverse features, processes, and interactions that shape marine ecosystems (Drechsler, 2020; Wörsdörfer, 2019).

More integrated, multidisciplinary valuation studies can help to support marine management decisions and conservation policies by: (1) enabling analysis of the trade-offs between competing interests for natural resources; (2) supporting the establishment of compensatory schemes (e.g., in the aftermath of an oil spill); (3) calculation of payments for environmental services and rates for the use of an ecosystem such as user fees for MPAs by assessing the costs of ecosystem degradation (Lopes and Villasante, 2018); and (4) by allowing a complete cost-benefit analysis of marine policies and projects. As Europe's long-term Blue Growth Strategy progresses, the need to apply effective marine ecosystem valuation tools is expected to further intensify (Austen et al., 2019).

5. Conclusion

This review provides a comprehensive summary of the scientific literature on ES' monetary, non-monetary, and mixed valuation methodologies, specifically applied to MPAs and MPA networks. Additionally, it provides an overview of the types of services and values currently addressed in scientific literature and discusses valuation tools that can serve as a guide for practitioners, both within and outside of academia, who are dealing with marine ecosystem protection.

The findings of this review highlight the prevalent use of monetary approaches in ES valuation for MPAs and MPA networks. Stated preference methodologies, such as contingent valuation and discrete choice experiments, are particularly favoured among the analysed studies. Non-monetary approaches are deemed to be especially useful in assessing cultural ES, having the potential to capture a broader range of values. A combination of both monetary and non-monetary, integrating biophysical modelling, social assessments, and monetary quantifications can enable a balanced consideration of environmental, social, and economic facets in alignment with stakeholders' support. Despite the limited number of mixed studies found in this literature review, the significant benefits they offer in quantifying and interpreting ecosystem services in MPAs and MPA networks underscore the need for future research to explore the integration of monetary and non-monetary valuations, ensuring both perspectives are adequately represented.

Most of the papers reviewed place significant emphasis on assessing the use values of MPAs. To broaden the scope and enhance the comprehensiveness of evaluations, more attention should be directed towards non-use values, specifically bequest and altruistic values, as well as the option value, though they might be more challenging to assess compared to use values. These non-use values encompass the appreciation of marine environments as a legacy for future generations and the intrinsic value they hold beyond immediate enjoyment. Incorporating a participatory valuation approach is crucial for capturing these values, ensuring that broader societal and ethical considerations are included in the valuation process.

While the cultural and provisioning ES are duly recognised in the reviewed papers, highlighting the importance of human connections with marine environments, there is a need for a more comprehensive examination that includes the value of supporting and regulating services. These services play a crucial role in maintaining ecological balance and supporting the sustainability of marine ecosystems. However, assessing these aspects might be challenging, particularly when relying on stated and revealed preference methods, the primary approaches found in the reviewed application papers. These methods require an in-depth understanding of the assessed ecosystem service, both from ecological modelling and from the target population, which is often lacking for regulating and supporting services.

6. Acknowledgements

This project has received funding from the European Union's Horizon Europe research and innovation programme under Grant Agreement no 101094014. Tine Compernolle thanks the Belgian Science Policy Office for funding the FED-tWIN profile Prf-2019 (R)-014_Geological Economics.

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