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REVIEW VALUATION METHOD FOR MARINE ECOSYSTEM SERVICE

Wan Nur Ayuni Wan Ab Rashid[1*] and Junainah Mohamad[2]
[1]College of Built Environment, Universiti Teknologi Mara Shah Alam, Malaysia
[2]Department of Built Environment Studies and Technology, College of Built Environment, Universiti Teknologi Mara Perak Branch, Seri Iskandar Campus, Malaysia

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*Corresponding author's email: ayunirashid7@gmail.com
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Abstract — Increased human pressure on marine ecosystems in the coming decades is expected, leading to a decline in ecological functioning and loss of marine biodiversity. Restoration efforts are crucial to address habitat deterioration and support conservation measures. Ecosystem service valuation measures the flows of products and services from natural capital assets under the presumption that decision-makers and stakeholders can control them. By doing that, ecosystem service valuation guarantees that ecosystems' worth and the services they offer are more fully acknowledged during the policy-making process. Ecosystem service value, for instance, might assist decision-makers in comparing various management approaches. Estimating the cost for insurance policy setting and evaluating the cost of preventing climate disasters could also be made possible via valuation. Formulating a strong valuation approach that fits the local environment and can effectively communicate pertinent information to decision-makers is one of the main recommendations for valuation practitioners. A detailed assessment of the literature has been conducted to provide a comprehensive overview of the body of knowledge addressing the valuation of marine ecosystem services. Based on previous research on present and upcoming practices as well as concerns related to coastal and marine ecosystem service values, a strengths, weaknesses, opportunities, and threats analysis could be conducted. Alternative methods acknowledged for ecosystem valuation are aimed at facilitating a more thorough identification and elicitation of various ecosystem values.

Keywords: ecosystem service, ecosystem valuation, marine, SWOT

1.0 INTRODUCTION

It is anticipated that in the upcoming decades, a significant increase is expected in both direct and indirect human pressures on marine ecosystems, with detrimental effects on ecological functioning and marine biodiversity. The need for restoration efforts in marine stewardship to address ongoing habitat deterioration and support conservation measures is becoming more widely acknowledged [1]. The ecological results of restoration determine its success. However, given the limited resources available, policymakers also need to consider the size of the socioeconomic benefits. Ecosystem Service (ES) valuation measures the flows of products and services from natural capital assets under the presumption that decision-makers and stakeholders can control them. By doing so, valuing seeks to ensure that ecosystems' worth and the services they offer are more fully acknowledged during the policy-making process. For example, ES value could help decision-makers compare different management strategies. Valuation has also made it feasible to estimate costs for insurance policy-making and assess the cost of averting climate calamities. There are a number of ES valuation recommendations available to guarantee that decision-making supports accurately considering the genuine value of ES rendered.

Valuation studies are crucial in highlighting the importance of marine ES and supporting cost-benefit analyses. Nevertheless, practitioners may not fully understand policymaking, the political environment, rights issues, and stakeholder demands, potentially hindering the efficient use of ecosystem valuation outcomes. External variables like local political climate, governance, and economic dependency on ES are beyond their control despite their potential assistance. Effective coastal management has disadvantages such as lack of integration, authoritative agencies, and inadequate institutional capacity [2]. Neoclassical economics and monetary valuation have dominated the environmental valuation literature, leading to requests for a more accurate representation of various values. Analysing relative or marginal changes in value is more instructive than evaluating ecosystems' absolute or total value [3].

Evaluation of marine services also examines other aspects like renewable energy, coastal protection, and waste assimilation capacity. An Economic Valuation (EV) can lead to fair allocations, but conflicts arise in coastal defence and renewable energy [4]. Integrating utilitarian resource allocation with legislation and communal values is necessary to improve sustainability. Recent changes include choice experiments and considered preference procedures.

This paper examines marine ES valuation methods. The objective is to ascertain the environmental valuation's trend, success, and significance in explaining market issues. The Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis makes it possible to recognise the issues and benefits of using an approach to comprehend the valuation of marine ES. Examining an approach's strengths, weaknesses, and issues reveals its primary strength in its ability to offer an unbiased explanation for concerns and establishes connections with other technological advancements that help address environmental issues. Although Malaysia's experience in this area is relatively recent, it has substantially contributed to the use of models in real estate research.

1.1. Ecosystem Service

ES is described as the direct and indirect benefits obtained from ecosystems that contribute to human well-being [1]. The definition of ES is "the circumstances and mechanisms by which natural ecosystems, and the species that comprise them, sustain and fulfil human life" [5]. Marine ecosystems offer a multitude of products and services, including commodities exchanged in official marketplaces, such as food and materials, as well as non-market commodities and services, like opportunities for recreation, waste management, climate regulation, and coastal preservation [6]. Furthermore, because of the numerous ES that coastal habitats provide for humans, they are highly productive, ecologically significant on a global scale, rich in biodiversity, and highly valued. Food, fuel, wood, energy resources, and natural products are examples of provisioning services.

ES provides regulating & maintenance services, including controlling nutrients, stabilising shorelines, sequestering carbon dioxide, cleaning contaminated waters, and disposing of waste. ES also provides cultural services, including tourism, recreation, spiritual experiences, aesthetics, and the dissemination of traditional and religious knowledge. ES supports services like nutrient cycling and soil formation [7]. Coastal ecosystems include more ecosystems providing services that people are more familiar with, compared to marine ecosystems, some of which provide services that are very unfamiliar to individuals (e.g., deep sea) [8].

Eight (8) main ecosystem types have been taken into consideration in order to categorise the publications, as indicated [8] in Table 1. The table also shows the particular ecosystems within each ecosystem type whose services are valued and the management domains to which the articles within each category may contribute. The types of marine ecosystems are not mutually exclusive, as shall be seen.

Table 1 Ecosystem types and management areas

Broad Ecosystem	Type	Specific Ecosystem	Management Area
Coastal Ecosystem	Wetlands	Wetlands, mangroves, marshes and swamps	Wetland management
	Beaches	Beaches	Beach management
	Coastal Area	Coastal protected natural area, capes, peninsulas and barrier islands	Coastal area management
	Inlands and Transitional Waters	Rivers, streams, canals, lakes, reservoirs, deltas, estuaries, and catchments	River basin management
Marine Ecosystem	Coastal Waters	Bays, gulfs, sounds, fiords, inland seas and sea waters near the coast	Coastal water management
	Coral Reefs	Coastal coral reefs	Coral reef management
	Deep Sea	Deep sea, open ocean (including cold-water corals)	Deep-sea waters protection
	Marine Protected Area	Marine conservations zones, marine parks, marine reserves, marine sanctuaries and marine critical habitat units	MPA policy design

Using a combination of the CICES 5.1 and TEEB ES classifications, with division, groups, and class merged for convenience, pertinent marine ES are chosen and specified [9], as listed in Table 2.

Table 2 Classification of ecosystem services

Provisioning Services	**Regulating Services**	**Cultural Services**
Products obtained from ecosystems, e.g., ● Food ● Fresh water ● Fuel wood ● Fiber ● Biochemicals ● Genetic resources	Benefits obtained from the regulation of ecosystem processes, such as: ● Climate regulation ● Disease regulation ● Water regulation ● Water purification ● Pollination	Non-material benefits obtained from ecosystems, e.g., ● Spiritual and religious ● Recreation and ecotourism aesthetic ● Inspirational ● Educational ● Sense of place ● Cultural heritage
Supporting Services Services necessary for the production of all other ecosystem services, etc.		
● Soil formation	● Nutrient cycling	● Primary production

1.1.1. Ecosystem Service Value

Many advantages, including the use and non-use values like existence and bequest values, can be clearly categorised as ES. Table 3 indicates the classification of the main coastal and marine ES modified from [10].

Table 3 Values provided by coastal and marine ecosystem services

Use Values		**Non-Use Values**
Direct Values	Indirect Value	Existence and Bequest Values
Food, fiber and raw materials provision	Flood control	Cultural heritage and spiritual benefits
Transport	Storm protection, wave attenuation	Resources for future generations
Water supply	CC impacts mitigation.	Biodiversity
Recreation and tourism	Contaminant storage, detoxification	
Wild resources	Shoreline stabilization/erosion control	
Genetic materials	Nursery and habitat for fishes and other marine species	
Educational opportunity	Nutrient retention and cycling	
Aesthetic	Regulation water flow, water filtration	
Art	Sources of food for sea organism	
	Climate regulation, primary productivity as oxygen production and CO_2 absorption, carbon sequestration, etc.	

There are both useful and non-useful aspects to biological variety for humans. The direct use of resources that may be exchanged for money, including food and raw materials, gives them use value. On the other hand, non-use value describes the benefits and features of nature, like enjoyment, fishing, and clean water. Thus, biodiversity services constitute a class of public goods not amenable to economic assessment. Alternatively, non-market estimation techniques can be used to determine its value. These stated and revealed preferences come in two varieties [13, 14, 15]. The hedonic pricing approach and the Travel Cost Method (TCM) are examples of revealed preference methodologies. These assess public goods' worth using actual market observation, while stated preference techniques employ a hypothetical market to determine respondents' Willingness to Pay (WTP) [16, 17]. Because of their approaches and characteristics, revealed preferences are often used to estimate use value, whereas stated preferences are considered for Total Economic Value (TEV) [18]. For instance, raising public knowledge of the

value of ecosystems was the primary objective of 64.7% of valuation studies. Additional planned uses included figuring out how much to charge for mangrove usage (17.6%), weighing the advantages and disadvantages of various environmental uses (11.8%), and offering rationale and assistance for specific decisions (5.9%) [18].

The TEV framework in Figure 1 captures the full range of benefits from marine ecosystems, such as coral reefs, by categorising their value into use and non-use benefits. Use values include direct benefits like fishing and tourism, as well as indirect benefits such as ecosystem support and coastal protection. Option values reflect potential future benefits, while non-use values encompass the intrinsic worth people place on the ecosystem's existence and its preservation for future generations. This comprehensive approach helps justify marine ecosystem conservation and sustainable management efforts [9, 26, 36].

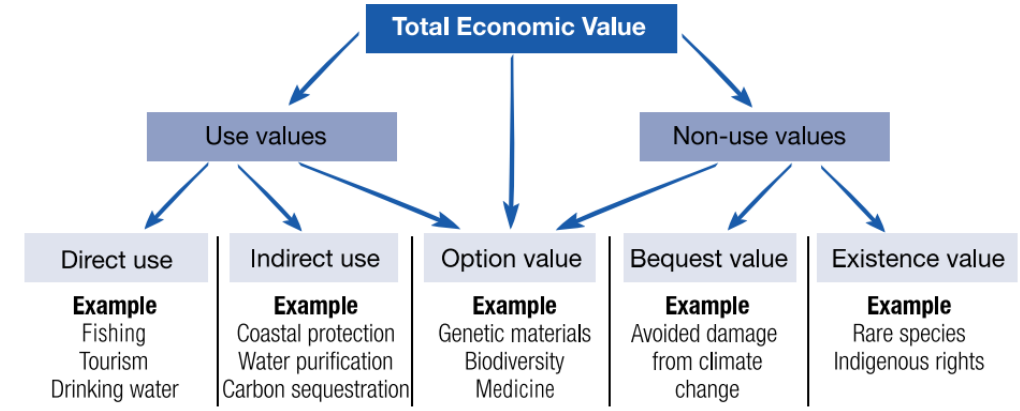

Figure 1 Values provided by coastal and marine ecosystem services

2.0 MATERIALS AND METHODS

Several studies were examined that provided global or regional indices of ecological values. Studies that repeated, evaluated, or aggregated value estimates from previous research were frequently eliminated, with the exception of meta-analyses and applications of value (benefits) transfer. The grey literature contains about 70% of the reviewed studies. Approximately 50% of this body of work employs some form of non-market valuation, while 40% only uses market-based approaches. The peer-reviewed literature shows a comparable distribution of market and non-market approaches, with value estimates from non-market valuation methodologies utilised in around half of the studies analysed, as shown in Figure 2.

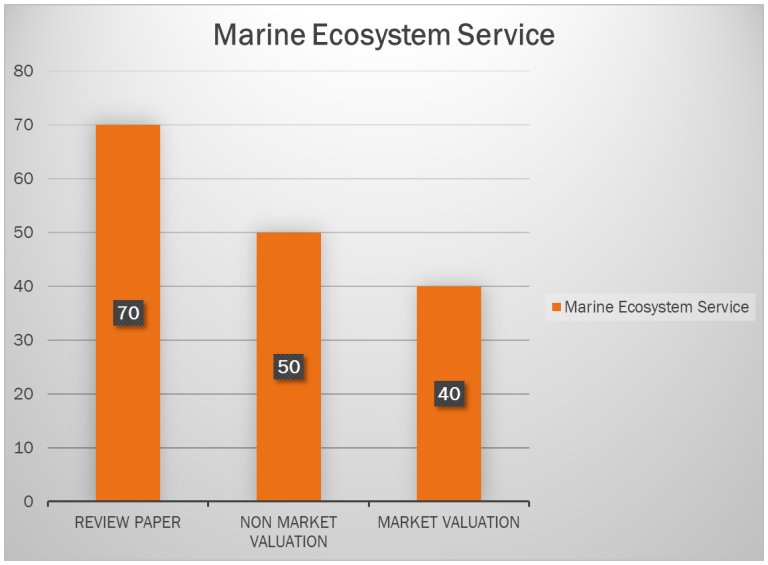

Figure 2 Analysed marine ecosystem services' economic valuations

This study aimed to enumerate the advantages and disadvantages of research on marine EVs. Utilising terms such as "ecosystem services", "fish", "fisheries", "marine protected area(s)", "marine resource(s)", "reef(s)", and "tourism", along with terms indicating economic measures like "benefit(s)", "approaches", "value", "valuation", "willingness to pay", and "methods" in the area, computerised searches turned up pertinent literature. We looked over the reference sections for suggestions for more study. The "cited by" and "related articles" functions of Google Scholar were also utilised, in addition to online valuation databases provided by organisations such as the Environmental Valuation Reference Inventory, the National Ocean Economics Programme, and the Marine Ecosystem Partnership.

The search included publications that were available up until 2018. Approximately 169 of the 441 papers reviewed in the grey and peer-reviewed literature had formal value estimates. The number of original studies that give economic value to marine ecosystem products and services in Malaysia is overestimated by this statistic because many of the studies published in the grey literature later appeared in peer-reviewed journals. Since several studies employ different valuation techniques and provide value estimates for diverse ecosystems, there are considerably more unique value estimates for ecosystem products and services in Malaysia than there are for only 200. Information about the approaches' strengths and weaknesses was compiled from these studies.

3.0 RESULTS AND DISCUSSION

3.1. Marine Ecosystem Service Valuation

3.1.1. Definition Approach

Globally, diverse techniques are used to assess and value marine ES, capturing the range of benefits these ecosystems provide. These are summarised in Table 4 till Table 7.

Table 4 Definition approach

Approach	Definition approach	Author
Market-based valuation	Assess the direct economic benefits such as fisheries revenue or tourism income	[19], [20]
Non-market-based valuation	Estimate the value of non-market marine ES	[21]

Table 5 Marine ecosystem approach

Techniques	Definition	SWOT	Category	Authors
Contingent Valuation	Conduct surveys to understand people's Willingness to Pay (WTP) to preserve marine ES.	Strength	Valuation of Non-Market Goods Public Preferences Flexibility Policy Support	[22], [23], [24], [25], [26], [27], [28], [29], [30], [31]
		Weakness	Subjectivity and Bias Protest Bids Scope Effects Temporal Issues Cultural Differences Difficulty in Valuing Intangible Benefits	

Table 5 Marine ecosystem approach (cont')

Techniques	Definition	SWOT	Category	Authors
Travel Cost Method	Estimate the economic value of recreational activities by analysing travel costs, such as transportation and accommodation expenses.	Strength	TCM is based on real visiting behaviour	[32], [33], [34], [35], [36], [37], [38], [39]
			Site-specific Valuation	
			Incorporation of Substitution Effects	
			Direct Measurement of Use Value	
			Consideration of Access Costs	
			Limited to User Values	
		Weakness	Limited to User Values	
			Assumption of Homogeneous Preferences	
			Data Collection Challenges	
			Temporal Changes	
			Difficulty in Valuing Intangible Benefits	
Hedonic Pricing	Assess property values in proximity to the marine ES to determine the impact of its ES on property prices.		Market-Based Values	[10], [40], [41], [42], [43], [44], 45]
		Strength	Implicit Valuation	
			Consideration of Multiple Attributes	
			Reflects Trade-offs	
			Useful for Urban Planning	
		Weakness	Assumption of Homogeneous Preferences	
			Endogeneity Issues	
			Market Imperfections	
			Dynamic Changes	
			Limited to Market Goods	
			Data Requirements	
Replacement Cost Method	Calculate the cost of human-made alternatives to services like water purification or erosion control.	Strength	Objective Measurement	[46], [47], [48], [49], [50], [51], [52], [53], [54]
			Useful for Restoration Planning	
			Focus on Ecosystem Functions	
			Long-Term Perspective	
		Weakness	Data Limitations	
			Difficulty in Valuing Non-Market Services	
			Assumption of Feasibility	
			Limited Consideration of Non-Use Values	
			Discounting Future Values	
			Simplification of Ecological Processes	

Table 5 Marine ecosystem approach (cont')

Techniques	Definition	SWOT	Category	Authors
Ecological Valuation	Ecological valuation focuses on the intrinsic value of the ES itself. Use scientific research and models to estimate the ecological importance of the marine ES, such as its role in maintaining biodiversity, carbon sequestration, and habitat provision.	Strength	Holistic Perspective Inclusion of Intrinsic Values Long-Term Sustainability	[55], [56], [57], [58], [59], [60], [61], [62], [63]
		Weakness	Subjectivity in Valuation Challenges in Monetisation Difficulty in Comparisons Temporal Dynamics Limited Public Awareness	
Cultural Valuation	Recognise the cultural significance of the marine ES by conducting surveys, interviews, or community consultations to assess the value people attach to the park for recreation, cultural identity, and spiritual well-being.	Strength	Recognition of Non-Market Values Community Engagement Preservation of Cultural Heritage	[64], [65], [66], [67], [68], [69], [70], [71], [72]
		Weakness	Subjectivity and Context-Dependence Difficulty in Monetisation Interconnectedness with Other Values Representation Challenges Temporal Dynamics Limited Generalisability Potential for Conflicts	
Combine Values	Integrate values from different approaches (market, non-market, ecological, and cultural) to provide a comprehensive picture of the marine ES's economic and ecological importance.	Strength	Comprehensive Assessment Improved Robustness Accounting for Diverse Stakeholder Perspectives Addressing Uncertainties Enhanced Policy Relevance Increased Stakeholder Engagement	[5], [13], [51], [67], [73], 74]
		Weakness	Complexity Data Requirements Potential for Conflicting Results Difficulty in Communicating Results Subjectivity in Integration Time Sensitivity Resource Intensity	

Table 6: Previous marine ecosystem service approach

Country	Approach to Marine Valuation	Methods Used	Key Considerations
United States	Economic and ecological valuation	Market-based approaches, contingent valuation, ecosystem services assessment	Balancing conservation goals with recreational and economic uses, estimating non-market values
Australia	Economic valuation and cost-benefit analysis	Market prices, travel cost method, willingness-to-pay surveys	Incorporating diverse values, assessing impacts on local communities and Indigenous rights
United Kingdom	Economic valuation and natural capital assessment	Market prices, hedonic pricing, choice experiments	Accounting for intangible benefits, engaging stakeholders, considering long-term sustainability
New Zealand	Total economic value assessment	Market prices, travel cost method, contingent valuation	Addressing trade-offs between conservation and resource use, recognising cultural and spiritual values
Costa Rica	Payment for Ecosystem Services (PES) and community involvement	PES schemes, participatory approaches	Involving local communities, integrating traditional knowledge, ensuring equitable distribution of benefits
Philippines	Economic valuation and community-based approaches	Market prices, choice experiments, participatory methods	Incorporating local knowledge and values, addressing poverty and resource management challenges
Seychelles	Marine spatial planning and ecosystem-based management	Zoning, carrying capacity assessment	Balancing tourism and conservation, maintaining biodiversity, responding to climate change
Thailand	Ecosystem services assessment and tourism management	Ecosystem services valuation, tourism impact assessment	Managing tourism pressures, protecting fragile ecosystems, enhancing local livelihoods
Indonesia	Integrated coastal management and community empowerment	Community-based management, spatial planning	Balancing resource use and conservation, involving local communities, and addressing overfishing

Table 7 Applied technique of marine ecosystem service

Country	Valuation Methods	Purpose of Valuation	Key Considerations
United States	Contingent Valuation, Travel Cost	Economic Impact Assessment,	Recreation values, ecosystem services, biodiversity
	Hedonic Pricing, Market Valuation	Conservation Planning	
Australia	Market Valuation, Hedonic Pricing,	Conservation, Economic Impact	Ecosystem services, tourism, fisheries, cultural values
	Contingent Valuation	Assessment	
European Union	Ecosystem Services Assessment	Conservation Planning,	Biodiversity, sustainable resource use
	(e.g., Costanza's approach)	Policy Development	
Canada	Travel Cost Method, Contingent	Conservation, Policy Development	Recreation values, ecosystem services
	Valuation		
New Zealand	Market Valuation, Ecosystem	Conservation and policy development	Biodiversity, recreation, cultural significance
	Services Valuation		
United Kingdom	Ecosystem Services Valuation	Conservation planning and policy	Biodiversity, sustainable resource use
	(e.g., NEA)	Development	

Key EV methods include contingent valuation, travel cost, and hedonic pricing, which estimate the monetary value of these services. Applying these techniques helps increase awareness of the value of marine ecosystems, supports informed policy-making, and promotes sustainable management practices. By integrating economic, ecological, and social perspectives, stakeholders are better equipped to address marine environmental challenges and ensure sustainability. Figure 3 illustrates the world map approach of marine valuation.

Malaysia offers a strong basis for the valuation of marine ecosystems due to its abundant natural resources and the growing interest in ecosystem services around the world [84, 75]. SWOT analysis for Malaysia is presented in Table 8. Nevertheless, there is a dearth of technological capability and integration into national policies, and the studies that are now available are dispersed [7]. However, there are also opportunities through emerging technology like remote sensing, regulatory tools like PES and EIAs, and regional cooperation [78, 80, 83]. There are risks due to rapid development, a lack of institutional support, and an excessive dependence on economic valuation techniques. In order to solve these problems, inclusive, comprehensive valuation techniques that take into account cultural, ecological, and economic aspects are needed.

Figure 3 World map approach of marine valuation

Table 8 SWOT Analysis of Marine Ecosystem Service Valuation in Malaysia

Strengths	Weaknesses
• Rich marine biodiversity and ecosystem diversity [84] • Alignment with global ES and sustainability frameworks [75] • Existing baseline studies in coastal regions [77]	• Fragmented data and lack of integration with national policies [4] • Limited technical capacity and valuation tools at local level [76] • Weak community involvement and low recognition of non-economic values [78]
Opportunities	**Threats**
• Potential for regional cooperation within ASEAN [7] • Integration with policy tools (e.g., EIAs, PES, climate financing) [81] • Advancements in remote sensing, GIS, and AI for ecosystem mapping [82]	• Rapid coastal development and resource overexploitation [83] • Political resistance and weak institutional support [79] • Overdependence on monetary valuation, risking neglect of cultural aspects [80]

4.0 CONCLUSION

This study highlights the increasing importance of valuing marine ecosystem services in response to growing human pressure on ocean resources. Without effective action, marine ecosystems face significant risks, including biodiversity loss, habitat degradation, and declining ecological function. Valuation plays a critical role by making the benefits of these ecosystems more visible and measurable for policymakers and stakeholders. It is not only a scientific exercise but also a practical tool for supporting better decision-making and the development of sustainable policies.

In Malaysia, however, the economic value of marine ecosystem services remains poorly defined. Current valuation efforts are fragmented and insufficiently connected to national policies. This is particularly concerning given the ecological and social importance of Malaysia's coastal and marine areas, which often lack adequate legal protection. Effective ecosystem valuation can help address shared sustainability challenges, especially in regions where marine issues cross political borders. This underlines the importance of regional cooperation and policy alignment.

Despite its potential, the use of economic valuation faces several challenges. Significant knowledge gaps remain, especially regarding deep-sea ecosystems and the untapped potential of genetic and chemical marine resources. While economic valuation can inform better decisions by clarifying costs, benefits, and trade-offs, overemphasis on financial metrics risks ignoring equity, cultural significance, and social values important to local communities. Nonetheless, EV can still support environmental managers in assessing the impacts of marine policies and comparing management strategies.

To maximise impact, valuation methods should be tailored to local environmental and socioeconomic contexts. Policymakers should focus on key value priorities and support regional initiatives. Integrating SWOT analysis into valuation practices offers a structured approach for identifying strengths, weaknesses, opportunities, and threats. This supports the development of transferable models, progress tracking, and the generation of reliable and comparable results.

Alternative valuation techniques can improve livelihoods and resilience to environmental change by capturing a wider range of values, including social and cultural measurements, particularly in lower-income areas. By classifying the existing field of knowledge and identifying gaps, this assessment establishes the groundwork for future valuation work in Malaysia. According to theory, it advances the study of ecosystem service valuation. It promotes more inclusive, flexible, and integrated approaches to climate adaptation and marine policy planning from a political and practical perspective.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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