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Strengthened multi-stakeholder linkages in valuation studies is critical for improved decision making outcomes for valuable mangroves – The Malaysian case study

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Mangrove forests in Southeast Asia are continuously declining as a result of unsustainable practices, partly due to limited recognition of the value of mangrove services in land use decision making. Valuation practitioners have assumed that monetary valuation should inform local and national decision makers to ensure sustainable management of mangrove resources. For ecosystem service valuation to be of use to decision makers, best practices should be adhered to such as having straightforward policy questions and strong stakeholder engagement from the onset of valuation studies, suitable choice of valuation methodologies, and the ability to effectively demonstrate causal links between drivers of ecosystem health, change, and resource users. This study, focusing on the Malaysian case study, assessed the effectiveness and challenges of local ecosystem service valuation studies in informing mangrove management decisions against a set of global best practices. A systematic review approach was undertaken to identify relevant Malaysian mangrove ecosystem service valuation studies. Of 184 studies identified, only 17 provided monetary values for mangrove ecosystem services. These studies valued nine different mangrove ecosystem services, with the cultural ecosystem services of tourism being the most frequently valued. Most of the valuation studies were designed to raise awareness of the value of ecosystems (64.7%). Other intended uses included determining appropriate charging rates for mangrove uses (17.6%), comparing the costs and benefits of different environmental uses (11.8%), and providing a justification and support for certain decision making (5.9%). Overall, mangrove valuation studies in Malaysia were characterized by weak multi-stakeholder engagement, non-

standardized valuation units across the whole country, limited dissemination of the valuation outcome, and cursory references to the potential use of mangrove ecosystem services. Most of the studies did not exert apparent influence on mangrove management. Future valuation studies in Malaysia and the Southeast Asian region should aim to build more robust engagement between valuation practitioners and key stakeholder groups, especially decision makers, at all stages of the study process and incorporate a clear dissemination strategy for sharing results.

KEYWORDS

ecosystem service assessment, policy making, southeast Asia, natural resources, decision making, result dissemination

1 Introduction

Worldwide, mangrove ecosystems are in decline due largely to unsustainable anthropogenic activities and the effects of climate change (Gilman et al., 2008; Friess et al., 2019). One of the factors contributing to the continual loss of mangrove ecosystems is the limited understanding of the value of mangrove ecosystem services, and their consequent omission in public decision and policy making (Brander et al., 2012). This is despite mangroves being widely recognized as a vital nature-based solution to mitigate climate change impacts, particularly for their ability to sequester and store blue carbon (McLeod and Salm, 2006; Zeng et al., 2021). Decision-makers worldwide have thus been urged to increase efforts to conserve remaining mangrove forests and rehabilitate degraded ones (Duarte et al., 2020; Ellison et al., 2020).

Ecosystem services are the direct and indirect contributions of ecosystems to human well-being (TEEB, 2010). Notable ecosystem services from mangroves include provisioning services such as timber extraction and coastal fishery production; regulatory services such as storm surge and erosion protection, and climate regulation; supporting services such as carbon sequestration and primary production; and cultural services such as recreation, and knowledge-based activities. The practice of ecosystem service valuation quantifies the flows of goods and services from natural capital assets (including mangroves) and assumes that they are manageable by stakeholders and decision makers (Daily et al., 2009; Tisdell and Xue, 2013). In doing so, valuation aims to ensure that the value of ecosystems and the services they provide is better recognised in policy decision-making processes (Daily et al., 2009; Pendleton et al., 2015). For example, valuation of ecosystem services can support decision-makers to make comparisons between alternative management regimes (van Oudenhoven et al., 2015). Valuation has also enabled cost estimation for the purposes of setting insurance policies and assessing the cost of climate disaster prevention (Bayraktarov et al., 2016; Beck et al., 2020). In the context of mangroves, ecosystem service valuation studies appear to have gained higher traction in recent years to support decision making (Barbier et al., 2011; Mukherjee et al., 2014; Himes-Cornell et al., 2018a).

Common methods used for natural resource valuation can be categorized into two broad groups: revealed preference methods (such as market price, travel cost and production function) and stated preference methods (such as contingent valuation and conjoint analysis). The former rely on individual preferences for services with definite market value, whereas the latter survey individuals' stated preferences in value for a given change in a natural resource or services (DEFRA, 2007). In the context of mangroves, the benefit transfer method appears to be one of the most commonly used valuation methods (Himes-Cornell et al., 2018b). Benefit transfer allows researchers to transfer ecosystem service values calculated in previous studies for ecosystems similar to the one(s) they are studying. The method may circumvent the need for costly and time-intensive field valuation studies (TEEB, 2010). However, benefit transfer has a number of shortcomings. For example, values may be inflated as they are estimated from global values, such as those from Costanza et al. (2014), who originally created values by statistically extrapolating value estimates to entire biomes (Pendleton et al., 2015). Moreover, benefit transfer values can be laden with inaccuracies due to the use of values for one site that were originally calculated for another biophysically, ecologically and socioeconomically distinct location (Emerton, 2014; Himes-Cowell et al., 2018b). Valuation studies that rely heavily on benefit transfer data (secondary data) also suffer from insufficient primary studies or meta-analyses that include comprehensive socio-economic information (Himes-Cornell et al., 2018b), which could be vital to decision making.

To date, a number of ecosystem service valuation guidelines are available that are intended to ensure that the true value of ecosystems services provided are properly taken into account in supporting decision making (e.g. DEFRA, 2007; Stelk and Christie, 2014; Schuster and Doerr, 2015). Several enabling

conditions and lessons learnt for ecosystem service valuations have been identified to ensure such studies are effective or appropriate to the relevant decision makers (Laurans et al., 2013; Waite et al., 2015; Torres and Hanley, 2017). One key recommendation for valuation practitioners is to craft a sound valuation methodology that is suitable to the local context and can effectively convey relevant information to decision makers. Having clear policy questions from the onset of valuation studies will improve relevance of results or recommendations and facilitate their use (McVittie and Moran, 2010; Waite et al., 2015). Policy questions can address, for example, the ecosystem services at stake, the policy options for these services, or the effects of policy change on them (Schuster and Doerr, 2015; Waite et al., 2015). Strong stakeholder engagement and local partnerships (Torres and Hanley, 2017), and clear presentation of methods and limitations (Lange and Jiddawi, 2009; Himes-Cornell et al., 2018a) are important characteristics for increased uptake of ecosystem service valuation studies. This highlights the importance of transdisciplinary cooperation, and the need to combine knowledge and data from different sources and multiple stakeholders, such as from economists, political, communication and natural scientists.

Valuation practitioners may have limited understanding of the circumstances and realities of policy making, the political climate, concerns around rights and the needs of stakeholders and thus unintentionally create barriers to effective use of ecosystem valuation outputs (Kenter et al., 2015; Torres and Hanley, 2017). Many types of information are required to support land-use decision making such as budgets, details of social, political and equity concerns, and understanding of how decisions result in benefits to the beneficiaries and wider stakeholders, often in a constrained time period (Rogers et al., 2015). Decision makers have often lamented that results from valuation studies are not sufficiently relevant to inform socially optimal decisions (Vatn and Bromley, 1994; Torres and Hanley, 2017). The lack of uptake of valuation outputs can be further exacerbated by decision makers' lack of familiarity in the language and axioms of ecosystem service valuation (Laurans et al., 2013). Incorporating causal chains in an ecosystem service assessment has been advocated as a means to help decision makers by expanding the focus beyond ecological outcomes to social outcomes caused by the ecological changes (Wainger and Mazzotta, 2011; Olander et al., 2015).

While a number of enabling conditions can be facilitated by valuation practitioners, there are external conditions that are beyond their control, such as the local political climate, governance, and economic dependence on the ecosystem services (Waite et al., 2015). Good governance within and among governments and other stakeholder organizations is needed to facilitate the use of scientific information in decision making (Nursey-Bray et al., 2014). The existence of legal authorities that develop conservation-oriented policy and legislation can further levy the incentive to use valuation results in the form of establishing protected areas or charging entrance fees (Waite et al., 2015). For example, as a result of a valuation study in close consultation with local communities, the federal government of Mexico had created marine protected areas near Cancun and approved the setting up of marine park entry fees to finance park infrastructure, staff, and environmental education campaigns (Rivera-Planter and Muñoz-Piña, 2005). On the other hand, in instances where government capacity is limited, valuation studies can help support the development of a legal framework or encourage natural resources protection enforcement capacity (see UNDP Equator Initiative Case Study Series - Community Mangrove Forest Conservation of Baan Bang La, Thailand, and Mikoko Pamoja, Kenya). By engaging closely with policy makers, valuation experts can ensure that their studies are tailored to decision-making needs with applied uses. Valuation studies are also more likely to be in demand and inform decision-making when there is high dependency or threat-driven urgency on the natural resources of concern. Therefore, capitalization of the opportunities from these external enabling conditions is critical to maximize the impact of valuation studies in informing decision makers (Waite et al., 2015), especially for countries like Malaysia with has traditionally prioritised economic development over conserving natural resources (Mokthsim and Osman Salleh, 2014).

Malaysia has the third highest mangrove extent globally (Hamilton and Casey, 2016) but experienced a mangrove area decline rate of approximately 793 ha per year (0.13%) between 1990 and 2017 (Omar et al., 2019). Much of the forest clearing was for urban development (e.g., infrastructure, housing) and economic development activities (e.g., commercial-scale agriculture and aquaculture). (Pourebrahim et al., 2011; Shahbudin et al., 2012). These destructive activities were also linked to exacerbation of coastal erosion and hardship faced by coastal poor (Hattam et al., 2020; Ruslan et al., 2022). While inevitable, the extent of mangrove destruction is arguably preventable to some extent. In a case study of the highly urbanized mangroves of Klang Islands, Peninsula Malaysia, Hattam et al. (2020) identified that private sector stakeholders have a low interest in, but high influence on local mangrove forests. Hattam et al. (2020) further noted that education and awareness raising of the importance of mangroves will be important for helping decision makers to reduce destructive activities. This suggests a role for valuation studies that can clearly articulate the importance of mangrove services and support cost benefit analyses. To date, there are considerable scientific studies examining the important services provided by Malaysian mangroves, such as their role in supporting complex food chains (Chong, 2005; Chew et al., 2012; Muhammad-Nor et al., 2019; Then and Chong, 2022), and the provision of nursery and habitat for fish, shrimps and birds species (Sasekumar and Chong, 1991; Norhayati et al., 2009; Chong et al., 2012). There is also a growing number of valuation studies that assess the ecosystem service values of Malaysian mangroves (e.g., Bann, 1999; Kaffashi et al., 2015; Hong et al., 2017; Hasan-Basri et al.,

2020). However, based on available literature, there is no systematic compilation and assessment of these studies in terms of knowledge gaps and impact on decision making that would be important to help direct the future of ecosystem service valuation studies.

Therefore, this study aimed to (1) synthesize and compare valuation estimates of existing mangrove ecosystem services in Malaysia, (2) assess the effectiveness of mangrove ecosystem service valuation studies against a set of best practices, and (3) identify the gaps in developing functional and impactful valuation studies. To achieve these objectives, existing Malaysian mangrove ecosystem service valuation studies were collated and reviewed using a systematic literature review approach. Each study was then assessed against advocated criteria from global best practices and lessons learnt from other ecosystem service valuation studies for their effectiveness in informing decision making. This study does not critique the technical aspects of each method, but rather focuses on how they are applied, especially in relation to decision-making and stakeholder engagement. The challenges and opportunities of applying these best practices in Malaysia were discussed, with the overarching goal to advance and integrate ecosystem service valuation studies for improved mangrove decision making.

2 Methodology

2.1 Criteria of best practices of ecosystem service valuation and conditions to support its use in decision making

The first step was to identify and collate the criteria for best practices in conducting an effective ecosystem service valuation to inform policy and decision makers. We reviewed the following documents: de Groot et al. (2006); DEFRA (2007); Stelk and Christie (2014); Olander et al. (2015) and Schuster and Doerr (2015), which were selected for their applied nature, coverage of a range of valuation methods and specific detail relevant to wetland and coastal environments. Recommended best practices were collated to create a summary of best practices in valuing ecosystem services. Based on this review, five best practice criteria for implementing ecosystem service valuation studies were identified, which would serve as benchmarks to assess the effectiveness of ecosystem service valuation studies in Malaysia:

a. Clear project goal(s) and policy question(s). Identifying clear policy questions from the beginning will allow the researchers to determine the appropriate level of stakeholder engagement, appropriate valuation method and data needed (de Groot et al., 2006; Stelk and Christie, 2014; Schuster and Doerr, 2015). The policy question may be linked to the impacts of particular activities, the claims of specific stakeholders or a possible change in collective rules. For example, an ecosystem service valuation study by Cooper et al. (2009) raised awareness of the contribution of coral reefs and mangroves to the GDP of Belize, which then led the local government to enact new policies on fisheries, shipping and offshore oil drilling regulations. The use of ecosystem service valuation can be broadly categorised into three types: informative, decisive and technical (Laurans et al., 2013):

(1) Informative use: studies provide broad-based information that may indirectly influence decision making, for example *via* knowledge improvement and awareness-raising on importance of accounting for ecosystem services, providing justification and support; or merely introducing 'accounting indicators' for stakeholders or decision makers with which they may not be familiar. Green accounting indicators in the form of natural capital and environmental cost are vital information to assist in the management of environmental and operational costs of natural resources (Muralikrishna and Manickam, 2017);

(2) Decisive use: studies are designed to inform a specific decision, identifying impacts of specific scenarios that are economically relevant, physically quantifying impacts as benefits or costs, and then calculating a summary monetary valuation. A study of this type may project future effects of management interventions, comparison of management options, and facilitate trade-offs. In particular, environmental impact assessment value the likely ecological cost of a proposed project or development (MacKinnon et al., 2018);

(3) Technical use: this involves cases where ecosystem service valuation is applied after choosing a policy or project to adjust the economic instrument that will implement the decision. For instance, a study was established to calculate damage compensation after environmental degradation or price setting on certain ecosystem services.

b. Strong engagement with all relevant stakeholders/ decision makers. Identification of important stakeholders groups that will be affected by any changes in management as a result of the ecosystem service valuation study is critical (DEFRA, 2007; Olander et al., 2015). These include decision makers (e.g., landowners, local government, and policymakers) and beneficiaries and detrimentally-impacted end users (e.g., local and

adjacent residents, business owners using the lands, visitors) and ecosystem advocates (e.g. environmental NGOs and other civil society groups). Following identification, strong stakeholder engagement throughout the valuation process is required to produce an appropriate study design, enable effective data collection, determine legitimacy and credibility of results, and to support capacity building (Brown et al., 2001; de Groot et al., 2006). A strong stakeholder engagement is typically indicated by extensive use of stakeholder analysis tools, involving wider group of stakeholders or by subjecting the process of public reviews (Waite et al., 2015; Raum, 2018; Hattam et al., 2020).

c. **Clear causal link(s) between ecosystem services and socio-economic variables.** Identifying and connecting the causal links between drivers of ecosystem change, ecosystem health, ecosystem services, and resource users is essential for stakeholders and decision makers (Olander et al., 2015). A detailed description or illustration of a causal chain and relationships can help garner support of stakeholder groups towards suggestions made by valuation practitioners. Demonstrating a causal link in ecosystem service valuation can sometimes help identify potential equity issues and other often overlooked factors. For example, several connections between cultural ecosystem services (such as urban green spaces) and social determinants of health (such as economic stability and social capital) were demonstrated by Zelenski et al. (2015) and Jennings et al. (2016).

d. **Relevant choice of valuation methodology, indicators, metrics and measurements.** Various valuation methodologies and measurements can be used to value ecosystem services, such as revealed preference (market price, travel cost), stated preference (contingent valuation, choice experiments) and benefit transfer. Each method is appropriate to specific types of ecosystem services and policy questions. For example, market prices can be used for ecosystem services that are traded through markets (e.g. for provisioning services), stated preference methods are particularly useful for capturing non-market values (e.g. for regulating and cultural services), while benefit transfer is useful in data poor situations and can draw on studies from other locations relevant to all ecosystem services (see National Research Council (2005) and Barbier (2007) for details of these methods). It is important to note that valuation methodologies are not necessarily mutually exclusive and more than one method can be applicable for a given policy question. For example, a combination of survey data from actual recreational usage patterns of a site (i.e., through revealed preferences) and from anticipated changes to those patterns under hypothetical increases in trip costs (i.e., through stated preferences) could reduce hypothetical bias, and provide more accurate valuation estimates (Haipeng and Xuxuan, 2012; de Corte et al., 2021). Valuation practitioners should choose appropriate strategies that best answer the policy question and provide tailored results that are appropriate to relevant stakeholders.

e. **Effective dissemination and communication of results with stakeholders/decision makers.** Following valuation studies, strategic dissemination of results and policy recommendations are crucial to ensure that the decision makers and stakeholders are well informed for decision making (de Groot et al., 2006; Olander et al., 2015; Waite et al., 2015). A well-developed communication and outreach strategy, drawing on diverse media platforms such as traditional and social media, can help with both widespread and targeted communication of results. Bundling the valuation results according to the interests of target stakeholders can increase the likelihood that the valuation results being used and relevant locally. In addition, standardisation in reporting valuation outcomes can increase the credibility and comparability of studies (Boyd and Banzhaf, 2007; de Groot et al., 2012; Seppelt et al., 2012).

2.2 Literature review and assessment of Malaysia ecosystem service valuation studies

Existing Malaysian mangrove ecosystem service valuation studies were identified and collated for systematic review following the Preferred Reporting Items for Systematic Reviews and Meta-Analysed (PRISMA) method. Relevant articles were identified from the Web of Science (WOS) and SCOPUS databases using the following search criteria: (1) (mangrove∗) AND ("ecosystem∗ servic∗") AND (valu∗) AND (Malaysia); (2) (mangrove∗) AND (economic) AND (valu∗) AND (Malaysia); and (3) (mangrove*) AND ("benefit transfer" OR "avoided cost" OR "conversion cost" OR "damage cost" OR "mitigation cost" OR "opportunity cost" OR "replacement cost" OR "restoration cost" OR "bio-economic modelling" OR "factor income" OR "production function" OR "consumer surplus" OR "hedonic pricing" OR "market price" OR "net price method" OR "public investments" OR "substitute goods" OR "travel cost method" OR "choice modelling" OR "contingent ranking" OR "contingent valuation" OR "participatory valuation") AND (Malaysia). After removing

duplicates, a total of 184 articles were identified. Reports were then screened and filtered, retaining only articles documenting a monetary value for mangrove ecosystem services. Publications that value mangrove ecosystem services for an undefined geographical location or did not clearly document the valuation methodology were excluded. In addition, grey literature documenting mangrove ecosystem service valuation studies in the form of reports, articles and dissertations were obtained from local libraries and relevant government ministries' archives. This whole exercise resulted in a total of 17 publications for the following data extraction and assessment.

All 17 publications were reviewed and qualitative and quantitative data relevant for comparison across studies were extracted. For each publication the publication year, type of publication, geographic location of the study, valuation methodology, estimated mangrove ecosystem service values and units were extracted and tabulated. Ecosystem service values were organised into categories based on the classification scheme by TEEB (2010). Based on the procedure described in the TEEB database (TEEB, 2010), all values were standardised into USD value on the nasis of Purchasing Power Parity in year 2007 that allowed for direct comparisons between collated studies and global estimates from de Groot et al. (2012); Costanza et al. (2014) and Himes-Cornell et al. (2018b). Where similar units were used, values were pooled to obtain an average. Subsequently, all studies were further assessed against the best practice criteria for ecosystem service valuation.

The studies were scrutinised for basic information including the role of valuation practitioners, the primary use of ecosystem service valuation, main policy question, type of stakeholders engaged and stakeholder engagement, ecosystem service valuation methodology and result dissemination strategy employed. We adopted the typology of stakeholders according to Raum (2018), where (i) producers were defined as those stakeholders who produce goods or services through particular ecosystem services; (ii) users are the stakeholders who passively use or benefit from the use of particular ecosystem services; (iii) regulators are those stakeholders with the ability to set either formal or informal rules to govern the actions of other stakeholders about ecosystem services; (iv) researchers were defined as any stakeholder which engages in scientific research and understanding, including modelling, but excluding monitoring and observing; and (v) monitors are the stakeholders who engage in scientific monitoring and observing of particular ecosystem services, and inform other stakeholders. The whole text was then examined for explicit mentions of links between stakeholders and ecosystem services. For research outcomes and dissemination, texts were examined for description of dissemination, communication or outreach activities. Peer-reviewed studies were also scrutinised in terms of the journal impact factors and the number of citations. For valuation studies that aimed to 'determine appropriate charging rates for environmental use' in conservation areas (e.g., visitor entry fees), changes in visitor entry fees post valuation studies were examined *via* internet search and personal communications from residents.

3 Results

3.1 Overview of ecosystem service valuation studies

A total of 184 publications were screened and 17 publications and reports were identified for inclusion in this study. These studies reported values of ecosystem services produced by mangrove forests (see Supp. Appendix 1 for complete list of publications). Tables 1, 2 summarise these 17 publications which covered 10 of the 13 states of Malaysia (Figure 1). Perak state has the greatest number of mangrove ecosystem service valuation studies (4), with all studies focused on the Matang Mangrove Forest Reserve. No documented mangrove ecosystem service valuations were found for the states of Pahang, Negeri Sembilan and Malacca despite the known presence of mangroves in these states. Among the analysed valuation studies, five estimated the value of mangroves as a whole without indicating specific types of ecosystem services. The remainder valued nine specified types of ecosystem services, with tourism (including recreational) services being captured most frequently (10 studies), followed by carbon sequestration services (7), fisheries production services (4), coastal protection services, including storm surge protection (3), and other services including timber production, non-timber forest production, aquaculture production, riverine production and water quality improvements services. Only three studies were conducted before the year 2000, i.e., in years 1992, 1994 and 1999, two studies in the subsequent decade (i.e., in 2009), and the remaining 12 studies conducted between 2011 to 2020.

Market price was the predominant valuation methodology (16 estimates) used for direct use services such as fisheries, non-timber forest production and carbon sequestration (Figure 2). The second most dominant valuation methodology was contingent valuation (12 estimates), mainly to estimate tourism and recreational cultural services (6 estimates), and one each for fisheries productions and coastal protection service. Four studies estimated the total value of mangroves using contingent valuation without specifying the types of ecosystem services (willingness to pay for mangrove preservation). The travel cost and replacement cost methods were less commonly used. The former was used for three tourism cultural services and the latter for two coastal protection regulating services. Only one study used the benefit transfer to estimate the value of water quality improvement. Value for water quality treatment in this study was estimated based on a meta-analysis of global mangrove ecosystem services' economic value by Salem and Mercer (2012).

Due to the high variety of measurement units and valuation methodologies, the value estimates for each state and type of service are not directly comparable. Following standardization of estimated valuation to 2007 USD rates to maintain parity, the mean value of local mangrove services valuation was compared against collated global estimates of mangrove ecosystem services value (Table 3). Estimates of food (fisheries production and aquaculture), water and erosion prevention services in Malaysian mangroves appeared to be higher than synthesis from global

TABLE 1 Summary of mangrove ecosystem service valuation in Malaysia.

Components	Valuation methods	Estimated value (USD)	Units	Location	State	Study period	References
TEV Preservation value	CV	44,408	Hectare^{-1} year^{-1}	Kuala Selangor Mangrove Forest	Selangor	1994	Leong et al., 2005
Mangrove value	CV	3	per year	Kuching Delta Mangrove Forest	Sarawak	2012	Shuib et al., 2012
Mangrove value	ES	307	Hectare^{-1}	Sungai Merbok Forest Reserve	Kedah	2013	Khuzaimah et al., 2013
Mangrove value	CV	3	per year	Matang Mangrove Forest Reserve	Perak	2017	Ramli et al., 2017
Mangrove value	CV	3,252	Hectare^{-1}	Kampung Sungai Melayu	Johor	2018	Sunoto et al., 2020
Mangrove value	CV	18,587	Hectare^{-1} year^{-1}	Kuala Perlis Mangrove	Perlis	2020	Hasan-Basri et al., 2020
Aquaculture production	MP	10,479	Hectare^{-1} year^{-1}	Kuala Selangor Mangrove Forest	Selangor	1994	Leong et al., 2005
Fisheries production	MP	72,396,170	Hectare^{-1}	Sarawak Mangrove Forest Reserve	Sarawak	1992	Bennet and Reynolds, 1993
Fisheries production	MP	6,605	Hectare^{-1} year^{-1}	Kuala Selangor Mangrove Forest	Selangor	1994	Leong et al., 2005
Fisheries production	CV	835	Hectare^{-1} year^{-1}	Benut	Johor	1999	Bann, 1999
Fisheries production	MP	18,292	Hectare^{-1} year^{-1}	Teluk Air Tawar-Kuala Muda coast	Penang	2016	Foong et al., 2016
Fisheries production	MP	413	year^{-1}	Kudat	Sabah	2016	Mojiol et al., 2016
Non-timber forest product	MP	135	Hectare^{-1} year^{-1}	Kuala Selangor Mangrove Forest	Selangor	1994	Leong et al., 2005
Timber production	MP	422,770	Hectare^{-1}	Sarawak Mangrove Forest Reserve	Sarawak	1992	Bennet and Reynolds, 1993
Timber production	MP	98	Hectare^{-1}	Matang Mangrove Forest Reserve	Perak	2015	Aziz et al., 2015
Carbon sequestration	MP	197	Hectare^{-1}	Matang Mangrove Forest Reserve	Perak	2015	Aziz et al., 2015
Carbon sequestration	MP	105,525	Hectare^{-1}	Teluk Air Tawar-Kuala Muda coast	Penang	2016	Foong et al., 2016
Carbon sequestration	MP	5,191[a]	Hectare^{-1}	Kuala Selangor Nature Park	Selangor	2017	Hong et al., 2017
Carbon sequestration	MP	3,211[a]	Hectare^{-1}	Sungai Haji Dorani	Selangor	2017	Hong et al., 2017
Carbon sequestration	MP	16,593[b]	Hectare^{-1}	Kuala Selangor Nature Park	Selangor	2017	Hong et al., 2017
Carbon sequestration	MP	10,263[b]	Hectare^{-1}	Sungai Haji Dorani	Selangor	2017	Hong et al., 2017
Coastal protection	RC	16,630	Hectare^{-1} year^{-1}	Kuala Selangor Mangrove Forest	Selangor	1994	Leong et al., 2005
Coastal protection	CV	1,342	Hectare^{-1} year^{-1}	Benut	Johor	1999	Bann, 1999
Coastal protection	RC	3,004	Hectare^{-1} year^{-1}	Teluk Air Tawar-Kuala Muda coast	Penang	2016	Foong et al., 2016
Riverine production	MP	46	Hectare^{-1} year^{-1}	Kuala Selangor Mangrove Forest	Selangor	1994	Leong et al., 2005
Water quality improvement	BT	4,577	Hectare^{-1} year^{-1}	Teluk Air Tawar-Kuala Muda coast	Penang	2016	Foong et al., 2016
Tourism	MP	12,935,237	Hectare^{-1}	Sarawak Mangrove Forest Reserve	Sarawak	1992	Bennet and Reynolds, 1993
Tourism	TC	1,211	Hectare^{-1} year^{-1}	Kuala Selangor Mangrove Forest	Selangor	1994	Leong et al., 2005
Tourism	CV	5	Hectare^{-1} year^{-1}	Benut	Johor	1999	Bann, 1999

(Continued)

TABLE 1 Continued

Components	Valuation methods	Estimated value (USD)	Units	Location	State	Study period	References
Tourism	CV	10	Visitor^{-1} year^{-1}	Matang Mangrove Forest Reserve	Perak	2009	Ahmad, 2009
Tourism	CV	2	Visitor^{-1} year^{-1}	Pulau Redang Marine Park (PRMP)	Terengganu	2009	Yakob et al., 2009
Tourism	CV	2	Visitor^{-1} year^{-1}	Pulau Payar Marine Park (PPMP)	Kedah	2009	Yakob et al., 2009
Tourism	CV	419	Hectare^{-1} year^{-1}	Penang National Park	Penang	2012	Kaffashi et al., 2015
Tourism	TC	34	Hectare^{-1}	Matang Mangrove Forest Reserve	Perak	2015	Razak et al., 2018
Tourism	CV	3,706	Hectare^{-1} year^{-1}	Teluk Air Tawar-Kuala Muda coast	Penang	2016	Foong et al., 2016
Tourism	TC	6,543	Hectare^{-1}	Kilim Karst Geoforest Park	Kedah	2019	Matthew et al., 2019

All values were standardized to year 2007 estimates. ES, Ecosystem service valuation method (remote sensing); CV, Contingent valuation; MP, Market price; BFT, Benefit function transfer; TC, Travel cost; TEV, Total Economic Value.
Estimated value of carbon reported by Hong et al., 2017 are in terms of voluntary market price (a) and from regulated market European Union Emissions Trading System (b).

TABLE 2 Mangrove extent (ha) for each state in Malaysia (2017), and their corresponding number of ecosystem service valuation (ESV) studies up to 2020.

State	Total mangrove area 2017 (ha)	Total number of ESV studies
Perlis	49	1
Kedah	7,725	3*
Penang	1,967	2
Perak	44,990	4
Selangor	20,853	2
Negeri Sembilan	1,557	0
Melaka	1,241	0
Johor	26,818	2
Pahang	3,759	0
Terengganu	1,571	1*
Kelantan	422	0
Peninsular Malaysia	110,952	14*
Sabah	378,195	1
Sarawak	139,890	2
Grand total	629,037	17*

Mangrove area data were collated from Omar et al. (2019). *Valuation study by Yakob et al., (2009) covered two Malaysian states (Kedah and Terengganu).

estimates. Meanwhile, the recreation and tourism ecosystem services in Malaysian mangroves were valued lower compared to global estimates.

3.2 Assessment of studies against criteria of best practices

3.2.1 Ecosystem service valuation study background

Out of the 17 ecosystem service valuation studies, the majority of the identified valuation practitioners were from academic and scientific institutions (82.4%). Only two studies were undertaken by government agencies (state forestry departments) and one by a non-government organization (Table 4). Although there were apparent collaborations between local universities (with inclusion of foreign universities in a few studies) in conducting the valuation, there were no apparent or strong collaborations between the universities and government agencies, who are often the main decision makers in Malaysia in terms of mangrove management. The lack of cross-agency collaborations was also seen for the three studies conducted by government agencies and non-government agencies, who appeared to carry out the valuation independently.

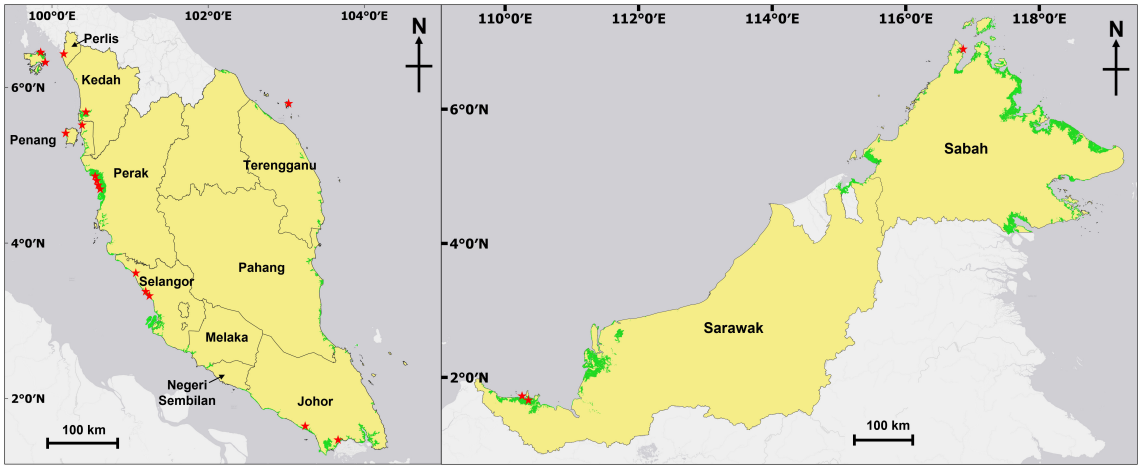

FIGURE 1
Map of Malaysia. Red stars indicate valuation study sites of collated mangrove ecosystem service valuation studies in Malaysia. Green patches overlaying the map indicate mangrove forest coverage (dataset from Bunting et al., 2018).

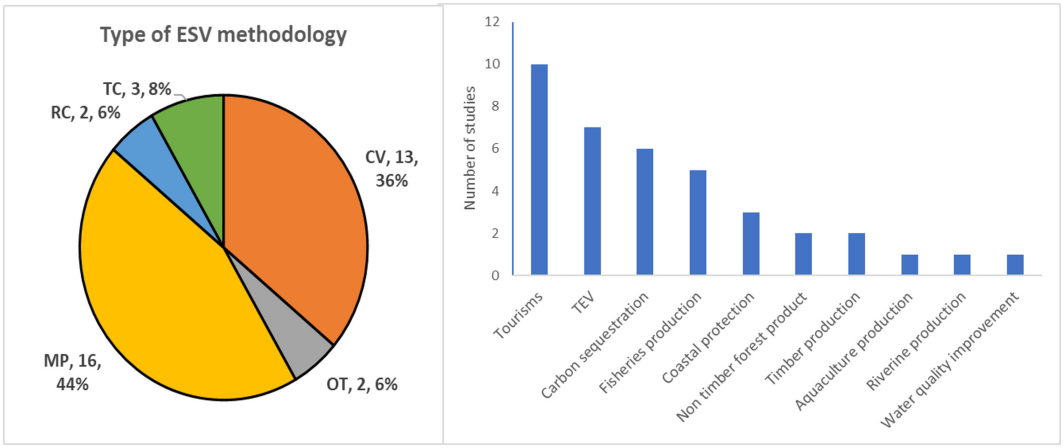

FIGURE 2
Summary of ecosystem service valuation (ESV) methodologies and ecosystem services that had been valued in Malaysia. CV, contingent valuation; MP, market price; BT, benefit transfer; RC, replacement cost; TC, travel cost; OT, others including the benefit transfer and ecosystem service valuation method (remote sensing).

3.2.2 Identification of a clear project goal, policy question, boundaries and scope

Of the 17 ecosystem service valuation studies assessed, only two types of valuation uses were identified (Table 4). Twelve of these studies were classified as ecosystem service valuation for informative use, while the remainder were for decisive uses. All but one of the informative use valuation studies were conducted with the main purpose to raise awareness of the value of mangroves, the exception was a study that aimed to provide justification for and support to certain decision making. For the decisive use valuation studies, two were conducted to help determine charging rates for environmental use, while the other three aimed to inform decision making by comparing costs and benefits of different uses of the environment and assessing trade-offs.

Among the 11 valuation studies designed for informative use, i.e., to raise awareness of the value of mangrove ecosystem services, eight of them addressed specific types of mangrove ecosystem services to their respective stakeholders. Specifically, these studies related the ecosystem services to the end-users and decision makers surrounding the mangrove forest. For instance, Bennet and Reynolds (1993) noted that local residents depended

TABLE 3 Comparisons of the mean estimated value of ecosystem services in Malaysia with global data.

Reference study(s)	de Groot et al. (2012); Costanza et al. (2014)	Himes-Cowell et al. (2018b)	Synthesis from this study
Reference ecosystem(s)	Coastal wetlands (tidal marsh, mangroves, and saltwater wetlands)	Mangroves	Mangroves
Ecosystem services category	Mean value across studies	Mean value across studies	Mean value across studies (number of studies; min-max value)
Food	1,111	8,319	9,053 (3; 835 – 18,292)
Water	1,217	799	2,312 (2; 46 – 4,577)
Climate regulation	65	34,756	23,497 (6; 197 – 105,525)
Erosion prevention	3,929	930	6,992 (3; 1,342 – 16,630)
Recreation and tourism	2,193	3,526	1,335 (4; 5 – 3,706)

To maintain parity with other studies, all values were standardized to 2007 and USD per hectare per year.

heavily on the mangrove resources (fisheries and timber production) and the gain and loss of tourism services from losing the mangrove forest to oil palm plantations and aquaculture practitioners instead of conserving the forest. Hong et al. (2017) noted that the amount of carbon stocks able to be sequestered by the mangrove and the potential revenue in carbon stock trading using the market price for the mangrove manager. On the other hand, three studies valued the total economic value of mangroves conservation, but without clearly specifying the types of ecosystem services (Shuib et al., 2012; Hasan-Basri et al., 2020; Sunoto et al., 2020); these studies did however given information on the role and usage of mangrove users by percentage. For example, in the Kuala Perlis mangrove forest (Hasan-Basri et al., 2020), a majority of the users of mangroves were fishermen (82%) and fish-cage workers (13%). Meanwhile, Sunoto et al. (2020) noted that 67.6% of the villagers (from Kampung Sungai Melayu) were dependent on local mangrove resources (fisheries activities) for their livelihood.

Bann (1999) is the only study designed to provide justification and support to specific decision making. It aimed to inform the Johor State Forestry Department on whether to change the status of Benut mangrove forest from state land into a permanent reserve forest. This study employed contingent valuation to estimate the demand for public services, and the economic value of environmental change.

Three decisive use valuation studies were conducted to determine appropriate charging rates for access to local mangrove forests (Yakob et al., 2009; Kaffashi et al., 2015; Ramli et al., 2017). These studies focused on the cultural ecosystem services: tourism and recreational services using the contingent valuation approach, and the end-user willingness to pay (local residents and tourists) for mangrove preservation as ecosystem service value indicators. For all studies, the visitors to the mangrove forest or park were notably able to appreciate the existence of the mangrove. Meanwhile, the local mangrove managers indicated they were able to accrue funds from increased entrance fees that could be used to support better management.

Two valuation studies performed cost-benefit analyses of different uses of mangrove forest (Aziz et al., 2015; Foong et al., 2016). These studies covered at least two types of mangrove ecosystem services for valuation. Foong et al. (2016) estimated the value of multiple mangrove ecosystem services as beneficial to both the end-users (local residents and fishermen) and decision makers (mangrove managers) under different mangrove management regimes (intact mangrove forest vs. extensive aquaculture farm) *via* benefit transfer (Table 1). Aziz et al. (2015) examined the cost-benefit of different management scenarios of mangrove timber to the mangrove manager. The economic value of timber production and carbon stocks became the indicators and valuation units for the mangrove managers.

Most of the studies (64.7%) were able to illustrate a direct causal link between mangrove ecosystem services, stakeholders and valuation outcomes. For example, links were demonstrated between local mangrove forests and economic importance from tourism (Yakob et al., 2009; Kaffashi et al., 2015; Ramli et al., 2017; Matthew et al., 2019), and between various mangrove resources with the livelihoods of local residents (Ahmad, 2009; Shuib et al., 2012; Mojiol et al., 2016; Sunoto et al., 2020). Foong et al. (2016) provided detailed causal linkages between mangroves and adjacent mudflat ecosystem services to the residents and fishers living close to the mangrove and made a connection to the aquaculture project as well as a cost-benefit comparison between different management scenarios for all involved stakeholders. Aziz et al. (2015) created a link between mangrove conservation with timber extraction and the carbon market. The multiple levels of jurisdiction, stakeholders, opportunity cost and assumption were clearly defined in this study.

3.2.3 Identification and strong engagement with stakeholders/decision makers

In terms of identification of and engagement with relevant stakeholders over the course of the ecosystem service valuation process, the 17 studies collectively identified seven groups of stakeholders (Table 4). These include the residents adjacent to

TABLE 4 Summary of Malaysia ecosystem service valuation (ESV) assessment based on best practices criteria.

Criteria	Number of studies	Percentage
ESV study background		
ESV study practitioner role:		
Universities	14	82
Government agencies	2	12
NGO	1	6
Identification of a clear project goal, policy question, boundaries and scope		
Type of ESV uses		
Informatic use	12	71
Decisive use	5	29
Technical use	0	0
Objective and policy question of ESV		
Raise awareness of the value of ecosystems	11	65
Provide justification and support to certain decision making	1	6
Determine appropriate charging rates for environmental use	3	18
Compare costs and benefits of different uses of the environment and assess trade-offs	2	12
Identification and strong engagement with stakeholders/decision makers		
Identified major stakeholder groups (with types in bracket)		
Residents adjacent to mangrove (users)	12	71
Fishermen (producers, users)	9	53
Tourists (users)	9	53
Aquaculturists (producers, users)	3	18
Plantation manager (producers, regulators)	1	6
Local forestry department (regulators)	8	47
Mangrove manager (regulators)	9	53
Stakeholders' engagement		
Yes	12	71
No	5	12
Type of direct stakeholders' engagement		
Engagement during design stage	8	47
Engagement during implementation and analysis stage	13	76
Engagement after valuation study	2	12
Effective results dissemination and communication with stakeholders/decision makers		
Publication in the scientific journal	13	77
Malaysian journal	4	24
International journal	9	53
Publication in the grey literature (book/technical report/case studies)	4	24

the mangrove forest (70.6%), fishermen (52.9%) and tourists (52.9%) as 'users' stakeholders, and the aquaculturists (17.6%), plantation managers (5.9%), local forestry department (47.1%) and mangrove managers (52.9%) as stakeholders having stronger control over the governance of mangrove forest (producers and regulators). The majority of the studies indicated engagement with stakeholders (n = 15; 88.2%) while the rest did not. Among the 15 studies that included stakeholder engagement, 47.1% of the studies had engaged stakeholders during the design stage of valuation, 76.5% had direct stakeholder engagement in implementation and analysis stages, and only two studies (11.8%) indicated stakeholder engagement beyond the completion of the valuation studies. Engagement with stakeholders during the design stage of valuation studies was mainly with the local forestry department in the form of acknowledgement and endorsement of the projects, while only one valuation study engaged with local residents' representatives. Meanwhile, 12 valuation studies only engaged with stakeholders as the target audience for their contingent valuation and travel cost valuation studies (i.e., through questionnaire completion and interview as part of data analysis). The remaining two studies showed some degree of wider stakeholder engagement: Bann (1999) is a study conducted by the state forestry department suggesting

communication between the study team and the wider organisation; whereas Foong et al. (2016) indicated exchange with the Forestry Research Institute of Malaysia, the Forestry Department and several local Non-Government Organizations.

3.2.4 Effective results dissemination and communication with stakeholders/ decision makers

For dissemination of valuation results to relevant stakeholders, the majority of the valuation studies were published in scientific journals (76.5%). Eight of the studies were published in international journals such as Forests (Impact factor, IF = 2.634), Ecological Economics (IF = 5.389), and Journal of Tropical Forest Science (IF = 0.770). The other five studies were published in Malaysian-based peer-reviewed journals, namely Journal of Tropical Resources and Sustainable Sciences, the Malaysian Journal of Economics, Planning Malaysia: Journal of the Malaysian Institute of Planners and The Malaysian Forester. In terms of citations recorded by ResearchGate, the number of citations for each study at the time of writing ranged from 2 – 144. Only one valuation study did not have information in numbers of citations. For the grey literature, two studies were published as technical reports for the purpose of informing specific stakeholders on mangrove management, and two studies in the form of book chapter and conference publication. Meanwhile, no studies have indicated or described valuation output dissemination in their texts.

3.3 Synthesis of Malaysian mangrove ecosystem service valuation studies

Drawing on the studies reviewed, key shortcomings in mangrove ecosystem service valuation in Malaysia are identified as follows:

a. The valuation units are not standardised across the whole country, even for the same services. There are variations among the valuation units used by different Malaysian valuation practitioners to value mangrove ecosystem services. This was exhibited particularly in the valuation of tourism cultural ecosystem services by several ecosystem service valuation studies (Table 1). Valuation units include value per hectare per year, value per visitor per year and value per hectare, all derived through the contingent valuation method. These values are not interchangeable, rendering comparative assessment impossible.

b. The majority (64.7%) of the studies reviewed make only a cursory reference to the potential use of ecosystem service valuation: Specifically, most of the authors merely indicated how the economic valuations of respective services could be used. They fail to describe how they could contribute to policy decisions or practical management. Furthermore, most were piecemeal studies which only evaluated one or a few ecosystem services, and with relatively simple causal links between ecosystem services and the stakeholders. Consequently, valuation in most cases is incomplete and not sufficiently relevant to inform socially optimal decisions. The take home message from most of the valuation studies to their intended stakeholders was a generic suggestion to value more highly the studied ecosystem services.

c. Most of the studies document limited or no clear collaboration between the valuation practitioners and relevant stakeholder groups, including decision makers. Eight out of 17 studies have identified specific and relevant stakeholder groups for their studies, such as the forestry department of the respective state and the local mangrove forest managers. However, engagements with these regulator stakeholders were limited to acknowledgement of permits approved by the local forestry department or mangrove manager to conduct research in mangrove forest (Hong et al., 2017; Hasan-Basri et al., 2020), or to providing valuation information to the regulator stakeholders (Yakob et al., 2009; Shuib et al., 2012; Aziz et al., 2015; Kaffashi et al., 2015). These academic studies reported limited involvement from other stakeholder institutions or with regulators.

d. There was limited documentation concerning valuation outcomes. Most of the valuation studies were published in a scientific journal, some with a high number of citations. However, there is no clear indication that decision makers use the said publications to support the drafting of new mangrove management policies, or revision of existing ones. For example, the valuation studies of Matang Mangrove Forest Reserve, Perak by Ramli et al. (2017), Penang National Park by Kaffashi et al. (2015), and Pulau Payar and Pulau Redang by Yakob et al. (2009) were designed to determine appropriate charging rates for the local mangrove forests. However, they appear to have had no impact on the mangrove managers and the rates charges, specifically no evident changes in the park entrance fees to date (personal comm. with park managers).

Only two valuation studies appeared to have successfully informed the valuation outcome (i.e., been used or acknowledged by decision-makers in some way). The valuation study by Bann (1999) was used to inform the decision to change Benut mangrove forest from a state land forest to permanent forest reserve. As seen from the Summary of the State of Johor Forest Management Plan for the Period Between 2006-2015, the forest was subsequently gazetted as a permanent forest since 2005. The study by Foong et al. (2016) appeared to garner attention in

later years, with an open public talk that was held in 2019 in conjunction with World Wetland Day, re-emphasizing the status of Teluk Air Tawar-Kuala Muda coast as an Important Bird and Biodiversity Area.

4 Discussion

From the five best practice criteria identified for ecosystem service valuation, we found that the limited studies in Malaysia were generally sound in terms of methodology and scope but lacking in terms of key stakeholders' connections and output dissemination. These limitations appeared to have reduced the effectiveness of the studies in terms of uptake of results by decision makers and buy-in from other stakeholder groups. Here, we summarize the identified gaps and discuss the key opportunities and practical way forward for future ecosystem service valuation and broader ecosystem assessment efforts by linking to relevant national policies and international commitments. These recommendations draw from lessons learnt from other case studies outside of Malaysia and are broadly applicable in the Southeast Asian region and for valuation of mangroves and other similar coastal habitats.

4.1 Increased connections/engagements between valuation practitioners and key stakeholder groups

One key best practice of ecosystem service valuation is the importance of stakeholder identification and engagement (Barbier, 2007; Waite et al., 2015; Raum, 2018). Many previous efforts to manage the environment and natural resources in Malaysia and elsewhere were not highly successful due to inadequate consideration given to various stakeholders involved (including their potentially conflicting interests and perspectives) by policymakers or local planners (Grimble et al., 1994; Waite et al., 2015; Marre et al., 2016). Given that values are context and time-specific, the value for different stakeholder groups or communities placed on ecosystem services can vary considerably. Stakeholder analysis is therefore a key practical step to help identify and understand stakeholders: how they are affected by ecosystem services, how they influence them, and their role in (public) decision making (Renard, 2004). Insights into the range of values associated with specific ecosystem benefits held by different stakeholders can in turn be used to support more effective and equitable engagement, and to inform valuation design and delivery, thus enabling informed decision making (Marre et al., 2016).

In the context of forest ecosystem services, crucial stakeholders often include government organizations as regulators; producers who extract forest goods and services; and users who use or benefit from mangrove ecosystem services. In Malaysia, mangrove forest regulators are typically top-down, centralised, and compartmentalised (Hattam et al., 2020). Communication and coordination between different departments and tiers of government are complicated, thereby rendering the mangrove management fragmented and poorly integrated with land-use policy directions (Friess et al., 2016; Amir, 2018). On the other hand, other important stakeholders such as local communities have strong interest in mangroves but are often powerless to affect change (Hattam et al., 2020). In this context, local valuation practitioners should execute stakeholder mapping early in the study design process and include highly influential local state agencies in engagement activities to ensure just, equitable decision making. Incorporating stakeholder-driven scenarios in ecosystem service valuation design can help ensure that the valuations are aligned with the problem statements by decision-makers (Henrichs et al., 2010; McKenzie et al., 2011) and allow for contrasts in gains and losses to ecosystem services for determining win–win solutions (Barnett et al., 2016; Rau et al., 2020).

4.2 Broadened portfolio of result dissemination platforms for ecosystem service valuation studies

Understanding the influence of the studies assessed in this review has been challenging due to limited evidence. The dissemination of valuation findings is essential for ensuring they are accessible for use in decision making (de Groot et al., 2006), but academic publishing of findings alone is no longer sufficient to ensure research use (Ament, 1994). Publication citation rate indicates some level of study uptake, but is somewhat controversial (Seglen, 1989; Cagan, 2013) and does not necessarily verify the solidity and societal value (Aksnes et al., 2019). On the other hand, ecosystem service valuation studies from grey literature, such as technical reports and case studies, may potentially have wider reach, especially to the decision makers. They are context specific and may contain relevant information for decision makers that are not usually captured by peer-reviewed literature (Rothstein and Hopewell, 2009). Valuation studies by Bann (1999) and Foong et al. (2016) were grey literature article and not published in peer-reviewed journal articles but appeared to have at least successfully informed specific groups of stakeholders.

The lack of uptake of ecosystem service valuation studies may be attributed to at least two barriers, i.e., the research evidence is not available in an accessible format for the policymaker and the evidence is disregarded due to clashes in political or ideological reasons (Hawkins and Parkhurst, 2016; Uzochukwu et al., 2016). To address the first barrier, diversification of strategies using suitable platforms to disseminate valuation outcome is needed (Avishek et al., 2012). A policy brief, i.e., a short document synthesizing the results of one or multiple studies, is one strategy to promote the use of research (Arnautu and Dagenais, 2021) as

well as having more effective science-to-policy dialogues that is free from structural or political barriers (Jones et al., 2008; Young et al., 2014). Significance of policy briefs and science-to-policy dialogues was often recognized in the public health sector (Suter and Armitage, 2011; Kilpatrick et al., 2015; Damani et al., 2016; Nabyonga-Orem et al., 2016). Through these mediums of exchange, valuation practitioners can bring ecosystem service valuation results to policymakers and may gain feedback on how to tailor valuation approaches to meet their needs. To address the second barriers of political or ideological differences between conservation and development (Wiesmann et al., 2005; Apostolopoulou and Pantis, 2010; Scoones, 2016), valuation teams should be transdisciplinary in composition to include economists, political, social, communications, and natural scientists (Costanza and Kubiszewski, 2012; Schneider et al., 2019). The transdisciplinary approach may promote understanding of the realities of evidence-based research and policy making within the team and improve communication outreach to different stakeholder groups. Additionally, the team should identify local champions that are well versed with ecosystem services that can help to communicate valuation outcomes (Cooper et al., 2009; Waite et al., 2015). These individuals or organisations often have established platforms or communication tools to garner support from influential groups to help sway the opposing political stance, and leverage needed change. Working with these local champions for broad result dissemination will likely increase buy-in from key strategic figures including local communities adjacent to affected mangroves, and influence decision making processes. This is evident from some case studies in Indonesia, where local champion successfully empowered local communities in implementing climate change adaptations (Septiarani and Handayani, 2016) and poverty alleviation efforts (Tranggono et al., 2021).

4.3 Congruence within local valuation studies, and with global valuation standards

Due to the complexity of ecosystem services assessment and the nature of policy questions, the metrics employed within each valuation study can be very different from others, thus rendering them incomparable. Lack of comparability translates into difficulties for decision makers or other valuation practitioners in facilitating direct comparison between sites or in transferring values from studied sites to new sites of interest. Aside from comparison within countries, standardization in the framework and reporting of ecosystem service valuation among countries is also crucial, especially the identification of beneficiaries of ecosystem services at different scales (Boyd and Banzhaf, 2007; de Groot et al., 2012) and in facilitating transboundary ecosystem services assessment (Dang et al., 2021). While the units reported may reflect the valuation question being asked, future valuation studies should report values in a range of units where possible to aid study comparability.

One significant global comparative effort is the development of the Ecosystem Services Valuation Database (ESVD) for the study of 'The Economics of Ecosystems and Biodiversity" (TEEB, 2010). The database hosts at least 6,700 value records from over 950 studies globally (Foundation for Sustainable Development 2021), thus supporting the ease of value transfer applications and meta-analysis across multiple studies. While the adopted ecosystem service classification systems in ESVD, i.e., the TEEB classification (TEEB, 2010) and the CICES V5.1 classification (Haines-Young and Potschin, 2018), may require review and adaptation to suit local contexts, there are clear grounds and overall benefits from employing such a global standard for standardization of spatial and temporal units of the ecosystem services. By adopting widely agreed-upon standards of best practices and reporting, the quality and comparability of valuation results can be improved.

4.4 Evolving national policy landscapes for ecosystem services assessment and opportunities

It is recognised that valuation studies are more likely to be accepted or able to inform the decision makers if the ecosystem services being valued are of high importance to the key stakeholders (Waite et al., 2015; Marre et al., 2016). In the context of Malaysia, the importance of ecosystem services and marine goods from intact mangroves are well recognized particularly after the 2004 Indian Ocean tsunami (Asma et al., 2012). This particular disaster had also been identified as wake-up call to galvanize action for mangrove restoration in other countries in the Southeast Asian region (Gaillard and Gomez, 2015). Despite this, mangroves are still being lost post-tsunami by deforestation to enable expansion of agriculture and aquaculture (Omar et al., 2019). Valuation of mangroves is likely to be useful if there is legal protection in place. However, the conflict between instituted federal policies and state-level policy implementation adds complexity to legal protection of mangroves (Amir, 2018).

Some recent national policy developments appear promising in terms of supportive governance that may improve uptake of ecosystem service valuation studies. The recently launched National Forestry Policy 2021 has streamlined what were previously three independent forestry policies by state (Peninsular Malaysia, Sabah and Sarawak). This revised policy places increased importance and focus on ecosystem services, particularly in relation to the implementation of mechanisms such as Payments for Forest Ecosystem Service and carbon emission reduction incentives. Moreover, the importance of

cultural ecosystem services was recognized in the new forestry policy, which included strategies for promoting forestry-based ecotourism and preserving nature and indigenous heritage. Nevertheless, there is still a clear lack of cultural ecosystem services assessment as compared to provisional and regulating services in the Southeast Asian region (Hattam et al., 2021; Broszeit et al., 2022), indicating the need for future valuation studies to advance understanding of the cultural ecosystem services and their value in decision making.

On the other hand, the Central Bank of Malaysia is looking at understanding the risks associated with ecosystem services loss, with a view to incentivize protection of ecosystems *via* monetary practices aligned to sustainable national growth (Malaysia Bank Negara and World Bank, 2022). With the threat to natural resources now being more apparent, the demand for valuation and the likelihood of use of valuation results may be accelerated due to the urgency for action to protect or better manage natural resources (Waite et al., 2015). Therefore, valuation practitioners should carefully assess the current situation circumstances and tailor their valuation design to take full advantage of the enabled contextual conditions.

5 Conclusion

Despite the low number of documented successful applications of ecosystem service valuation in improved mangrove protection, valuation can play an important role in decision-making, when undertaken effectively and following best practices. This study identifies several recommendations for future ecosystem service valuation studies in Malaysia that can enable increased uptake of valuation outputs in support of sustainable mangrove management. The recommendations included strong, continual engagement with multi-stakeholder groups; the inclusion of stakeholder-driven scenarios that are relevant to the stakeholders in question; the adoption of standardised valuation units; and aligning valuation design and recommendation with existing national policies. The changing forest policy landscape within Malaysia provides a window of opportunity for enabling uptake of valuation findings. However, this requires a clear operationalization of ecosystem service concepts within decision making and policy development at all levels, as well as valuation practitioners well versed in valuation best practices.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material. Further inquiries can be directed to the corresponding authors.

Author contributions

SL: Investigation, Data curation, Writing - original draft, Writing - review & editing AT: Funding acquisition, Project administration, Writing - review & editing MA: Project administration, Writing - review & editing HG: Writing - review & editing CH: Funding acquisition, Writing - review & editing AE-J: Writing - review & editing. All authors contributed to the article and approved the submitted version.

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Conflict of interest

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

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fmars.2022.1033200/full#supplementary-material

References

Ahmad, S. (2009). Recreational values of mangrove forest in larut matang, perak. *J. Trop. For. Sci.* 21 (2), 81–87.

Aksnes, D. W., Langfeldt, L., and Wouters, P. (2019). Citations, citation indicators, and research quality: An overview of basic concepts and theories. *SAGE Open* 9 (1), 1–17. doi: 10.1177/2158244019829

Ament, L. A. (1994). Strategies for dissemination of policy research. *J. Nurse-Midwifery* 39 (5), 329–331. doi: 10.1016/0091-2182(94)90134-1

Amir, A. A. (2018). Mitigate risk for malaysia's mangroves. *Sci. March* 359, 1342–1343. doi: 10.1126/science.aas9139

Apostolopoulou, E., and Pantis, J. (2010). Development plans versus conservation: Explanation of emergent conflicts and state political handling. *Environ. Plann. A April* 42, 982–1000. doi: 10.1068/a42163

Arnautu, D., and Dagenais, C. (2021). Use and effectiveness of policy briefs as a knowledge transfer tool: a scoping review. *Humanities Soc. Sci. Commun.* 8, 211. doi: 10.1057/s41599-021-00885-9

Asma, W. I. W. T., Norhayati, M. T., and Lokman, M. H. (2012). The existing legislative, administrative and policy framework for the mangrove biodiversity management & conservation in Malaysia. *J. Politics Law* 5 (1), 180–188.

Avishek, K., Yu, X., and Liu, J. (2012). Ecosystem management in Asia pacific: Bridging science–policy gap. *Environ. Dev.* 3, 77–90. doi: 10.1016/j.envdev.2012.03.014

Aziz, A. A., Dargusch, P., Phinn, S., and Ward, A. (2015). Using REDD+ to balance timber production with conservation objectives in a mangrove forest in Malaysia. *Ecol. Economics* 120, 108–116. doi: 10.1016/j.ecolecon.2015.10.014

Bann, C. (1999). *A contingent valuation of the mangroves of benut, johor state, Malaysia* (Johor Bahru: Johor State Forestry Departmentt/DANCED/Darudec).

Barbier, E. B. (2007). Valuing ecosystem services for coastal wetland protection and restoration: Progress and challenges. *Resources* 2, 213–230. doi: 10.3390/resources2030213

Barbier, E., et al. (2011). The value of estuarine and coastal ecosystem services. *Ecol. Monogr.* Vol. 81 (2), 162–193.

Barnett, A., Fargione, J., and Smith, M. P. (2016). Mapping trade-offs in ecosystem services from reforestation in the Mississippi alluvial valley. *Bioscience* 66 (3), 223–237. doi: 10.1093/biosci/biv181

Bayraktarov, E., Saunders, M. I., Abdullah, S., Mills, M., Beher, J., Possingham, H. P., et al. (2016). The cost and feasibility of marine coastal restoration. *Ecol. Appl.* 26, 1055–1074. doi: 10.1890/15-1077

Beck, M. W., Heck, N., Narayan, S., Menéndez, P., Torres-Ortega, S., Losada, I. J., et al. (2020). *Reducing Caribbean risk: opportunities for cost-effective mangrove restoration and insurance* (Arlington, VA: The Nature Conservancy).

Bennet, E. L., and Reynolds, C. J. (1993). The value of a mangrove area in sarawak. *Biodivers. Conserv.* 2, 359–375. doi: 10.1007/BF00114040

Boyd, J., and Banzhaf, S. (2007). What are ecosystem services? the need for standardized environmental accounting units. *Ecol. Economics* 63, 616–626. doi: 10.1016/j.ecolecon.2007.01.002

Brander, L. M., Wagtendonk, A. J., Hussain, S. S., McVittie, A., Verburg, P. H., de Groot, R. S., et al. (2012). Ecosystem service values for mangroves in southeast Asia: A meta-analysis and value transfer application. *Ecosystem Serv.* 1, 62–69. doi: 10.1016/j.ecoser.2012.06.003

Broszeit, S., Hattam, C., Langmead, O., Praptiwi, R. A., Creencia, L., Then, A. Y.H., et al. (2022). *Ecosystem service provision by marine habitats in southeast Asia* (Plymouth, UK: PML Publishing).

Brown, K., Tompkins, E. L., and Adger, W. N. (2001). *Trade-off analysis for participatory coastal zone decision-making* (England: Overseas Development Group, University of East Anglia).

Bunting, P., Rosenqvist, A., Lucas, R. M., Rebelo, L. M., Hilarides, L., Thomas, N., et al. (2018). The global mangrove watch – a new 2010 global baseline of mangrove extent. *Remote Sens.* 10 (10), 1669. doi: 10.3390/rs10101669

Cagan, R. (2013). The San Francisco declaration on research assessment. *Dis. Models Mech.* 6, 869–870. doi: 10.1242/dmm.012955

Chew, L. L., Chong, V. C., Tanaka, K., and Sasekumar, A. (2012). Phytoplankton fuel the energy flow from zooplankton to small nekton in turbid mangrove waters. *Mar. Ecol. Prog. Ser.* 469, 7–14. doi: 10.3354/meps09997

Chong, V. C. (2005). "Fifteen years of fisheries research in the matang mangroves what have we learnt?," in *Sustainable management of matang mangroves: 100 years and beyond.* Ed. M. I. Shaharuddin, et al (Malaysia: Forest Biodiversity Series 4. Forestry Department Peninsular Malaysia.), 411–429.

Chong, V. C., Sasekumar, A., and Zgozi, S. W. (2012). "Ecology of fish and shrimp communities," in *IOES monograph series 14: Mangrove and coastal environment of selangor, Malaysia*. Eds. A. Sasekumar and V. C. Chong (Kuala Lumpur: University of Malaya Press), 215–241.

Cooper, E., Burke, L., and Bood, N. (2009). "Coastal capital: Belize," in *The economic contribution of belize's coral reefs and mangroves* (Washington DC: WRI Working Paper. World Resources Institute).

Costanza, R., de Groot, R., Sutton, P., van der Ploeg, S., Anderson, S. J., Kubiszewski, I., et al. (2014). Changes in the global value of ecosystem services. *Global Environ. Change* 26, 152–158. doi: 10.1016/j.gloenvcha.2014.04.002

Costanza, R., and Kubiszewski, I. (2012). The authorship structure of "ecosystem services" as a transdisciplinary field of scholarship. *Ecosystem Serv.* 1 (1), 16–25. doi: 10.1016/j.ecoser.2012.06.002

Daily, G., et al. (2009). Ecosystem services in decision making: Time to deliver. *Front. Ecol. Environ.* 7, 21–28. doi: 10.1890/080025

Damami, Z., MacKean, G., Bohm, E., DeMone, B., Wright, B., Noseworthy, T., et al. (2016). The use of a policy dialogue to facilitate evidence-informed policy development for improved access to care: the case of the Winnipeg central intake service (WCIS). *Health Res. Policy Syst.* 14, 78. doi: 10.1186/s12961-016-0149-5

Dang, A. N., Jackson, B. M., Benavidez, R., and Tomscha, S. A. (2021). Review of ecosystem service assessments: Pathways for policy integration in southeast Asia. *Ecosystem Serv.* 49, 101266. doi: 10.1016/j.ecoser.2021.101266

de Corte, K., Cairns, J., and Grieve, R. (2021). Stated versus revealed preferences: An approach to reduce bias. *Health Economics* 30, 1095–1123. doi: 10.1002/hec.4246

DEFRA (2007). *An introductory guide to valuing ecosystem services* (United Kingdom: Department for Environment, Food and Rural Affairs).

de Groot, R., Brander, L., van der Ploeg, S., Costanza, R., Florence, B., Braat, L., et al. (2012). Global estimates of the value of ecosystems and their services in monetary units. *Ecosystem Serv.* 1, 50–61. doi: 10.1016/j.ecoser.2012.07.005

de Groot, R. S., Stuip, M. A. M., Finlayson, C. M., and Davidson, N. (2006). "Valuing wetlands: Guidance for valuing the benefits derived from wetland ecosystem services," in *Ramsar technical report no. 3, gland* (Switzerland: Ramsar Convention Secretariat).

Duarte, C. M., Agusti, S., Barbier, E., Britten, G. L., Castilla, J. C., Gattuso, J. P., et al. (2020). Rebuilding marine life. *Nature* 580, 39–51. doi: 10.1038/s41586-020-2146-7

Ellison, A., Felson, A., and Friess, D. (2020). Mangrove rehabilitation and restoration as experimental adaptive management. *Front. Mar. Sci.* 7, 327. doi: 10.3389/fmars.2020.00327

Emerton, L. (2014). "Valuing & investing in ecosystems as development infrastructure: economic analysis of options for climate-compatible development in coastal zones of Kenya & Sri Lanka," in *iCOAST technical report* (Penicuik: LTS International Ltd).

Foong, S. Y., Yeap, C. A., and Butt, C. (2016). *A pilot rapid assessment of selected ecosystem services provided by the teluk air tawar-Kuala muda coast IBA in pulau pinang* (Kuala Lumpur: Malaysian Nature Society).

Friess, D., Thompson, B. S., Brown, B., Amir, A. A., Cameron, C., Koldewey, H. J., et al. (2016). Policy challenges and approaches for the conservation of mangrove forests in southeast Asia. *Conserv. Biol.* 30 (5), 933–949. doi: 10.1111/cobi.12784

Friess, D., Rogers, K., Lovelock, C. E., Krauss, K. W., Hamilton, S. E., Lee, S. Y., et al. (2019). The state of the world's mangrove forests: Past, present, and future. *Annu. Rev. Environ. Resour.* 44, 1–27. doi: 10.1146/annurev-environ-101718-033302

Gaillard, J. C., and Gomez, C. (2015). Post-disaster research: Is there gold worth the rush? *Jamba: J. Disaster Risk Stud.* 7 (1), 1–6. doi: 10.4102/jamba.v7i1.120

Gilman, E. L., Ellison, J., Duke, N. C., and Field, C. (2008). Threats to mangroves from climate change and adaptation options: A review. *Aquat. Bot.* 89, 237–250. doi: 10.1016/j.aquabot.2007.12.009

Grimble, R. J., Aglionby, J., and Quan, J. (1994). "Tree resources and environmental policy: a stakeholder approach," in *NRI socio-economic series 7* (Chatham: Natural Resources Institute).

Haines-Young, R., and Potschin, M. B. (2018) *Common international classification of ecosystem services (CICES) V5.1 and guidance on the application of the revised structure* (Accessed 22 3 2022).

Haipeng, Z., and Xuxuan, X. (2012). Combining stated preference and revealed preference methods for the valuation of non-market goods*Chinese Journal of population resources and environment* 10, 121–126. doi: 10.1080/10042857.2012.10685119

Hamilton, S. E., and Casey, D. (2016). Creation of a high spatio-temporal resolution global database of continuous mangrove forest cover for the 21st century (CGMFC-21). *Global Ecol. Biogeogr.* 25, 729–738. doi: 10.1111/geb.12449

Hasan-Basri, B., Samdin, Z., and Ghani, A. N. (2020). Willingness to pay for conservation of mangrove forest in Kuala perlis, Malaysia. *Jurnal Ekonomi Malaysia* 54 (3), 89–99. doi: 10.17576/JEM-2020-5403-7

Hattam, C., Goh, H. C., Then, A. Y.H., Edwards-Jones, A., Ruslan, N. F.N., Yap, J. S.E., et al. (2020). Using nexus thinking to identify opportunities for mangrove management in the klang islands, Malaysia. *Estuarine Coast. Shelf Sci.* 247, 106917. doi: 10.1016/j.ecss.2020.106917

Hattam, C., Broszeit, S., Langmead, O., Praptiwi, R. A., Lim, V. C., Creencia, L. A., et al. (2021). A matrix approach to tropical marine ecosystem service assessments in south east Asia. *Ecosystem Serv.* 51, 101346. doi: 10.1016/j.ecoser.2021.101346

Hawkins, B., and Parkhurst, J. (2016). The 'good governance' of evidence in health policy. *Evidence Policy* 12 (4), 575–592.

Henrichs, T., Zurek, M., Eickhout, B., Kok, K., Raudsepp-Hearne, C., Ribeiro, T., et al. (2010). "Scenario development and analysis for forwards-looking ecosystem assessments," in *Ecosystems and human well-being: A manual for assessment practitioners*. Ed. N. Ash, et al (New York: Island Press), 151–220.

Himes-Cornell, A., Grose, S. O., and Pendleton, L. (2018a). Mangrove ecosystem service values and methodological approaches to valuation: Where do we stand? *Front. Mar. Sci.* 5, 376. doi: 10.3389/fmars.2018.00376

Himes-Cornell, A., Pendleton, L., and Atiyah, P. (2018b). Valuing ecosystem services from blue forests: A systematic review of the valuation of salt marshes, sea grass beds and mangrove forests. *Ecosystem Serv.* 30, 36–48. doi: 10.1016/j.ecoser.2018.01.006

Hong, L., Hemati, Z., and Zakaria, R. (2017). Carbon stock evaluation of selected mangrove forests in peninsular Malaysia and its potential market value. *J. Environ. Sci. Manage.* 20, 77–87. doi: 10.47125/jesam/2017_2/09

Jennings, V., Larson, L., and Yun, J. (2016). Advancing sustainability through urban green space: Cultural ecosystem services, equity, and social determinants of health. *Int. J. Environ. Res. Public Health* 13 (2), 196. doi: 10.3390/ijerph13020196

Jones, N., Jones, H., and Walsh, C. (2008). "Political science? strengthening science-policy dialogue in developing countries," in *Working paper*, vol. 294. (London: Overseas Development Institute).

Kaffashi, S., Radam, A., Shamsudin, M. N., Yacob, M., and Nordin, N. (2015). Ecological conservation, ecotourism, and sustainable management: The case of penang national park. *Forests* 6, 2345–2370. doi: 10.3390/f6072345

Kenter, J. O., O'Brien, L., Hockley, N., Ravenscroft, N., Fazey, I., Irvine, K. N., et al. (2015). What are shared and social values of ecosystems? *Ecol. Economics* 111, 86–99. doi: 10.1016/j.ecolecon.2015.01.006

Khuzaimah, Z., Ismail, M. H., and Mansor, S. (2013). "Mangrove changes analysis by remote sensing and evaluation of ecosystem service value in sungai merbok's mangrove forest reserve," in *Peninsular Malaysia* (Berlin, Heidelberg: Springer, Berlin, Heidelberg).

Kilpatrick, K., Carter, N., Bryant-Lukosius, D., Charbonneau-Smith, R., and DiCenso, A. (2015). The development of evidence briefs to transfer knowledge about advanced practice nursing roles to providers, policymakers and administrators. *Nurs. Leadership (Toronto Ont.)* 28 (1), 11–23. doi: 10.12927/cjnl.2015.24236

Lange, G.-M., and Jiddawi, N. (2009). Economic value of marine ecosystem services in Zanzibar: Implications for marine conservation and sustainable development. *Ocean Coast. Manage.* 52, 521–532. doi: 10.1016/j.ocecoaman.2009.08.005

Laurans, Y., Rankovic, A., Billé, R., Pirard, R., and Mermet, L. (2013). Use of ecosystem services economic valuation for decision making: Questioning a literature blindspot. *J. Environ. Manage.* 119, 208–219. doi: 10.1016/j.jenvman.2013.01.008

Leong, L. F., Kwan, K. H., Chong, V. C., and Sasekumar, A. (2005). "Resource valuation of Kuala selangor mangrove forest," in *Ecology of klang strait*. Eds. A. Sasekumar and V. C. Chong (Kuala Lumpur: University of Malaya Press), 237–259.

MacKinnon, A. J., Duinker, P. N., and Walker, T. R. (2018). *The application of science in environmental impact assessment* (England: Routledge Taylor & Francis Group).

Malaysia Bank Negara and World Bank (2022). *An exploration of nature-related financial risks in Malaysia* (Kuala Lumpur: International Bank for Reconstruction and Development/The World Bank).

Marre, J.-B., et al (2016). Is economic valuation of ecosystem services useful to decision-makers? lessons learned from Australian coastal and marine management. *J. Environ. Manage.* 178, 52–62. doi: 10.1016/j.jenvman.2016.04.014

Matthew, N. K., Shuib, A., Ramachandran, S., and Mohammad-Afandi, S. H. (2019). Economic valaution using travel cost method (TCM) in kilim karst geoforest park, langkawi, Malaysia. *J. Trop. For. Sci.* 31 (1), 78–89. doi: 10.26525/jtfs2019.31.1.078089

McKenzie, E., Irwin, F., Ranganathan, J., Hanson, C., Kousky, C., Bennett, K., et al. (2011). "Incorporating ecosystem services in decisions," in *Natural capital: Theory and practice of mapping ecosystem services*. Ed. P. Kareiva, et al (Oxford: Oxford University Press), 339–355.

McLeod, E., and Salm, R. V. (2006). *Managing mangroves for resilience to climate change* (Gland, Switzerland: IUCN).

McVittie, A., and Moran, D. (2010). Valuing the non-use benefits of marine conservation zones: An application to the UK marine bill. *Ecol. Economics* 70, 413–424. doi: 10.1016/j.ecolecon.2010.09.013

Mojiol, A. R., Kodoh, J., Wahab, R., Majuki, M., and Wahyudi, . (2016). Contribution of non-wood forest product to the local community living near mangrove forest in kudat, sabah. *J. Trop. Resour. Sustain. Sci.* 4, 38–41. doi: 10.36873/jht.v14i1.327

Mokthsim, N., and Osman Salleh, K. (2014). Malaysia's efforts toward achieving a sustainable development: Issues, challenges and prospects. *Proc. - Soc. Behav. Sci.* 120, 299–307. doi: 10.1016/j.sbspro.2014.02.107

Muhammad-Nor, S. M., Huxham, M., Salmona, Y., Duddy, S. J., Mazars-Simon, A., Mencuccinid, M., et al. (2019). Exceptionally high mangrove root production rates in the kelantan delta, malaysia; an experimental and comparative study. *For. Ecol. Manage.* 444, 214–224. doi: 10.1016/j.foreco.2019.04.026

Mukherjee, N., Sutherland, W. J., Dicks, L., Hugé, J., and Koedam and Dahdouh-Guebas, N. F. (2014). Ecosystem service valuations of mangrove ecosystems to inform decision making and future valuation exercises. *PLoS One* 9, 1–9. doi: 10.1371/journal.pone.0107706

Muralikrishna, I. V., and Manickam, V. (2017). "Environmental accounting," in *Environmental management: Science and engineering for industry*. Eds. I. V. Muralikrishna and V. Manickam (Oxford: Butterworth-Heinemann), 113–134.

Nabyonga-Orem, J., Gebrikidane, M., and Mwisongo, A. (2016). Assessing policy dialogues and the role of context: Liberian case study before and during the Ebola outbreak. *BMC Health Serv. Res.* 16 (Suppl. 4), 315–325. doi: 10.1186/s12913-016-1454-y

National Research Council (2005). *Valuing ecosystem services: Toward better* (Washington, DC: The National Academies Press).

Norhayati, A., Shukor, M. N., Juliana, S., and Wan Juliana, W. A. (2009). Mangrove flora and fauna of klang islands mangrove forest reserve, selangor, Malaysia. *Malaysian J. Sci.* 28 (3), 275–288. doi: 10.22452/mjs.vol28no3.6

Nursey-Bray, M. J., Vince, J., Scott, M., Haward, M., O'Toole, K., Smith, T., et al. (2014). Science into policy? discourse, coastal management and knowledge. *Environ. Sci. Policy* 38, 107–119. doi: 10.1016/j.envsci.2013.10.010

Olander, L., Johnston, R., Tallis, H., Kagan, J., Maquire, L., Boyd, J., et al. (2015). *Best practices for integrating ecosystem services into federal decision making* (Durham: National Ecosystem Services Partnership, Duke University).

Omar, H., Misman, M. A., and Musa, S. (2019). "GIS and remote sensing for mangroves mapping and monitoring," in *Geographic information system and science*. Eds. J. Rocha and P. Abrantes (London, UK: IntechOpen), 1–15.

Pendleton, L., Mongruel, R., Beaumont, N., Hooper, T., and Charles, M. (2015). A triage approach to improve the relevance of marine ecosystem services assessments. *Mar. Ecol. Prog. Ser.* 530, 183–193. doi: 10.3354/meps11111

Pourebrahim, S., Hadipour, M., and Mokhtar, M. B. (2011). Integration of spatial suitability analysis for land use planning in coastal areas; case of Kuala langat district, selangor, Malaysia. *Landscape Urban Plann.* 101, 84–97. doi: 10.1016/j.landurbplan.2011.01.007

Ramli, F., Sandin, Z., and Abdul Ghani, A. N. (2017). Willingness to pay for conservation fee using contingent valuation method: The case of matang mangrove forest reserve, perak, Malaysia. *Malaysian Forester* 80 (1), 99–110.

Rau, A.-L., Burkhardt, V., Dorninger, C., Hjort, C., Ibe, K., Keßler, L., et al. (2020). Temporal patterns in ecosystem services research: A review and three recommendations. *Ambio* 49 (8), 1377–1393. doi: 10.1007/s13280-019-01292-w

Raum, S. (2018). A framework for integrating systematic stakeholder analysis in ecosystem services research: Stakeholder mapping for forest ecosystem services in the UK. *Ecosystem Serv.* 29, 170–184. doi: 10.1016/j.ecoser.2018.01.001

Razak, N. A., Afandi, S. H. M., Shuib, A., and Ghani, A. N. A. (2018). Visitors travelling time cost for ecotourism at matang mangrove forest reserve. *Int. J. Business Soc.* 19 (1), 117–127.

Renard, Y. (2004). *Guidelines for stakeholder identification and analysis: A manual for Caribbean natural resource managers and planners* (Jamaica: Caribbean Natural Resources Institute).

Rivera-Planter, M., and Muñoz-Piña, C. (2005). Fees for reefs: economic instruments to protect mexico's marine natural areas. *Tourism* 8 (2-3), 195–213. doi: 10.1080/13683500508668214

Rogers, A. A., Kragt, M. E., Gibson, F. L., Burton, M. P., Petersen, E. H., Pannell, D. J., et al. (2015). Non-market valuation: usage and impacts in environmental policy and management in Australia. *Aust. J. Agric. Resource Economics* 59, 1–15. doi: 10.1111/1467-8489.12031

Rothstein, H. R., and Hopewell, S. (2009). "Grey literature," in *The handbook of research synthesis and meta-analysis*. Eds. H. Cooper, L. V. Hedges and J. C. Valentine (New York: Russell Sage Foundation), 103–125.

Ruslan, N. F. N., Goh, H. C., Hattam, C., Edwards-Jones, A., Moh, H. H., et al. (2022). Mangrove ecosystem services: Contribution to the well-being of the coastal communities in klang islands. *Mar. Policy* 144, 105222. doi: 10.1016/j.marpol.2022.105222

Salem, M. E., and Mercer, D. E. (2012). The economic value of mangroves: A meta-analysis. *Sustainability* 4, 359–383. doi: 10.3390/su4030359

Sasekumar, A., and Chong, V. C. (1991). *Fish and prawn communities in mangrove estuaries and mudflats in selangor (Malaysia)* (Manila: Marine Sciences Institute, University of Philippines).

Schneider, F., Giger, M., Harari, N., Moser, S., Oberlack, C., Providoli, I., et al. (2019). Transdisciplinary co-production of knowledge and sustainability transformations: Three generic mechanisms of impact generation. *Environ. Sci. Policy* 102, 26–35. doi: 10.1016/j.envsci.2019.08.017

Schuster, E., and Doerr, P. (2015). *A guide for incorporating ecosystem service* (Delmont, NJ: The Nature Conservancy, New Jersey Chapter).

Scoones, I. (2016). The politics of sustainability and development. *Annu. Rev. Environ. Resour.* 41, 293–319. doi: 10.1146/annurev-environ-110615-090039

Seglen, P. O. (1989). From bad to worse: Evaluation by journal impact. *Trends Biochem. Sci.* 14, 326–327. doi: 10.1016/0968-0004(89)90163-1

Seppelt, R., Fath, B., Burkhard, B., Fisher, J. L., Grêt-Regamey, A., Lautenbach, S., et al. (2012). Form follows function? proposing a blueprint for ecosystem service assessments based on reviews and case studies. *Ecol. Indic.* 21, 145–154. doi: 10.1016/j.ecolind.2011.09.003

Septiarani, B., and Handayani, W. (2016). The role of local champion in community-based adaptation in semarang coastal area. *Jurnal Pembangunan Wilayah Kota* 12 (3), 263–276. doi: 10.14710/pwk.v12i3.12901

Shahbudin, S., Zuhairi, A., and Kamaruzzaman, B. Y. (2012). Impact of coastal development on mangrove cover in kilim river, langkawi island, Malaysia. *J. Forestry Res.* 23 (2), 185–190. doi: 10.1007/s11676-011-0218-0

Shuib, A., Yii, A. B. S., and Edman, S. (2012). Conservation of deltaic mangrove forest resources in kuching, Sarawak: Local communities' willingness to pay. *Malaysian Forester* 75 (1), 65–72.

Stelk, M. J., and Christie, J. (2014). *Ecosystem service valuation for wetland restoration: What it is, how to do it, and best practice recommendations* (Windham, Maine: Association of State Wetland Managers).

Sunoto, Y. N., Fatiah, A. A., Ponrahono, Z., and Osman, M. M. (2020). Profiling the perceived mangrove forest use value and community's willingness to pay for mangrove conservation. *Plann. Malaysia: J. Malaysian Institute Planners* 18 (3), 229–240. doi: 10.21837/pm.v18i13.788

Suter, E., and Armitage, G. D. (2011). Use of a knowledge synthesis by decision makers and planners to facilitate system level integration in a large Canadian provincial health authority. *Int. J. Integrated Care* 11, e011. doi: 10.5334/ijic.576

TEEB (2010). *The economics of ecosystems and biodiversity ecological and economic foundations* (London and Washington: Earthscan).

Then, A. Y. H., and Chong, V. C. (2022). Trophic guild structure and dietary patterns of a juvenile-dominated demersal fish community in a tropical mangrove estuarine system. *Bull. Mar. Sci* 98, 271–296. doi: 10.5343/bms.2022.0001

Tisdell, C. A., and Xue, D. (2013). "Managing ecosystem services for human benefit: Economic and environmental policy challenges," in *Environmental policy: Management, legal issues and health aspects*. Eds. E. Crighton and P. Davovich (New York: Nova Science Publishers), 87–106.

Torres, C., and Hanley, N. (2017). Communicating research on the economic valuation of coastal and marine ecosystem services. *Mar. Policy* 75, 99–107. doi: 10.1016/j.marpol.2016.10.017

Tranggono, D., Nuryananda, P. F., and Putra, A. Y. T. (2021). Local champion: Communication characteristics in community empowerment based on local innovation. *J. Students Acad. Res.* 7, 72–84. doi: 10.35457/josar.v7i1.1535

Uzochukwu, B., Onwujekwe, O., Mbachu, C., Okwuosa, C., Etiaba, E., Nyström, M., et al. (2016). The challenge of bridging the gap between researchers and policy makers: Experiences of a health policy research group in engaging policy makers to support evidence informed policy making in Nigeria. *Globalization Health* 12, 67. doi: 10.1186/s12992-016-0209-1

van Oudenhoven, A. P. E., Siahainenia, A. J., Sualia, I., Tonneijck, F. H., van der Ploeg, S., de Groot, R. S., et al. (2015). Effects of different management regimes on mangrove ecosystem services in Java, Indonesia. *Ocean Coast. Manage.* 116, 353–367. doi: 10.1016/j.ocecoaman.2015.08.003

Vatn, A., and Bromley, D. W. (1994). Choices without prices without apologies. *J. Environ. Economics Manage.* 26, 129–148. doi: 10.1006/jeem.1994.1008

Wainger, L., and Mazzotta, M. (2011). Realizing the potential of ecosystem services: A framework for relating ecological changes to economic benefits. *Environ. Manage.* 48, 710. doi: 10.1007/s00267-011-9726-0

Waite, R., Kushner, B., Jungwiwattanaporn, M., Gray, E., and Burke, L. (2015). Use of coastal economic valuation in decision making in the Caribbean: Enabling conditions and lessons learned. *Ecosystem Serv.* 11, 45–55. doi: 10.1016/j.ecoser.2014.07.010

Wiesmann, U., Liechti, K., and Rist, S. (2005). Between conservation and development: Concretizing the first world natural heritage site in the Alps through participatory processes. *Mountain Res. Dev.* 25, 128–138. doi: 10.1659/0276-4741(2005)025[0128:BCAD]2.0.CO;2

Yakob, M. R., Radam, A., and Shuib, A. (2009). A contingent valuation study of marine parks ecotourism: The case of pulau payar and pulau redang in Malaysia. *J. Sustain. Dev.* 2 (2), 95–105. doi: 10.5539/jsd.v2n2p95

Young, J. C., Waylen, K. A., Sarkki, S., Albon, S., Baibridge, I., Balian, E., et al. (2014). Improving the science-policy dialogue to meet the challenges of biodiversity conservation: having conversations rather than talking at one-another. *Biodiver. Conserv.* 23 (2), 387–404. doi: 10.1007/s10531-013-0607-0

Zelenski, J. M., Dopko, R. L., and Capaldi, C. A. (2015). Cooperation is in our nature: Nature exposure may promote cooperative and environmentally sustainable behavior. *J. Environ. Psychol.* 42, 24–31. doi: 10.1016/j.jenvp.2015.01.005

Zeng, Y., Friess, D. A., Sarira, T. V., Siman, K., and Koh, L. P. (2021). Global potential and limits of mangrove blue carbon for climate change mitigation. *Curr. Biol.* 31 (8), 1737–1743. doi: 10.1016/j.cub.2021.01.070