



A SYSTEMATIC REVIEW OF BLUE CARBON ECOSYSTEMS AS NATURE-BASED SOLUTIONS FOR COASTAL PROTECTION: COMMUNITY PERCEPTIONS IN SOUTHEAST ASIA

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| ARTICLE INFO                                                                                                                                                                                                                                                             | ABSTRACT                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
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| <p><b>Article History:</b><br/><i>Received: 6 January 2025</i><br/><i>Revised: 24 June 2026</i><br/><i>Accepted: 5 July 2026</i><br/><i>Published: 15 September 2026</i></p> <p><b>Keywords:</b><br/><i>Mangroves, seagrass, perceptions, governance, resilience</i></p> | <p>Southeast Asia represents a significant blue carbon hotspot and is susceptible to climate-induced coastal hazards; however, there is a lack of comprehensive research on community attitudes and awareness regarding Blue Carbon Ecosystems (BCEs) as nature-based coastal protection strategies. This systematic review analyses the comprehension of BCE climate regulation and coastal protection functions in Southeast Asian communities, identifies social, institutional, and contextual drivers, highlights research gaps, and explores policy implications. Following Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) 2020 requirements, Web of Science (WoS), Scopus, and Google Scholar were searched for peer-reviewed research from January 2015 to December 2024. Research that specifically assessed the perceptions or understanding of BCEs within Southeast Asian communities was deemed acceptable. Two independent reviewers screened the studies, with an agreement rate of 87%. The qualitative and exploratory nature of the evidence necessitated a narrative appraisal of methodological limitations, with findings synthesised thematically. A total of 24 studies met the inclusion criteria, primarily from the Philippines and Indonesia. Mangroves have been the focus of significant attention in the literature, whereas seagrasses and salt marshes have received comparatively little consideration. Dependence on livelihoods, environmental experiences, education, extreme occurrences, and institutional engagement altered community viewpoints. Poor governance and community participation hinder policy awareness and integration. To enhance equality, effectiveness, and long-term coastal resilience, blue carbon governance must incorporate community perceptions, notwithstanding spatial and methodological biases.</p> |

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Introduction

Mangroves, seagrass meadows, and salt marshes are coastal habitats commonly referred to as Blue Carbon Ecosystems (BCEs) (Doolan & Hynes, 2023). These ecosystems have great potential for carbon sequestration and provide critical biophysical protection by lowering wave energy, stabilising shorelines and preventing erosion (Perricone *et al.*, 2023). Therefore, they are among the first lines of defence against climate-induced coastal hazards such

as flooding, intense storms, and rapid sea-level rise (Adeoba *et al.*, 2024). These functional dynamics are increasingly conceptualising BCEs in international environmental policy as a potential Nature-based Solution (NbS) for coastal defence, offering sustainable, adaptive, and cost-effective alternatives to conventional ‘grey’ engineering infrastructure (Jordan & Fröhle, 2022). However, the ability of these ecosystems to provide such important

regulatory services is highly threatened by increasing anthropogenic pressures, including deforestation, rapid coastal development, and aquaculture development (Buelow *et al.*, 2022).

Southeast Asia is one of the global hotspots for blue carbon ecosystems. The region is home to over 35% of the world's mangroves and some 28% of the world's seagrass beds (Endo & Ikeda, 2022), but is also highly vulnerable to climate change, with disproportionate sea level rise, increasing typhoons and devastating chronic flooding (Doelle & Puthucherril, 2023). Southeast Asia's BCEs are thus not only ecological strongholds but also climate-risk hotspots, making them an important instrument for protecting highly populated coastal areas (Dong *et al.*, 2024). The degradation of these ecosystems simultaneously reduces their protective potential, increasing local communities' exposure and socio-economic vulnerability (Vasseur, 2021).

The biophysical and protective mechanisms of BCEs are well known. However, the contemporary literature is biologically biased and largely ignores the critical human dimension: How coastal inhabitants perceive and value these protective roles. Local recognition of BCE-based protection is an important predictor of institutional compliance, local guardianship, and the long-term sustainability of conservation and restoration programmes (Favretto *et al.*, 2022). The literature shows that coastal communities tend to value near-term, market-based provisioning benefits (e.g., fisheries) while undervaluing non-market regulatory benefits (e.g., risk reduction) (Maulidah *et al.*, 2023). Moreover, these perceptions are largely filtered through localised socio-cultural norms, traditional governance systems, and institutional frameworks that highly influence communities' support or resistance to NbS interventions (Palomo *et al.*, 2021).

Regional environmental research is growing, but a global perception-based synthesis for Southeast Asia remains a critical gap. Failure to consider this human-ecological connection

may lead to regional conservation policies that are inconsistent with local socio-economic reality and may compromise adaptive outcomes. This systematic review fills this empirical gap by synthesising the body of information on community awareness and attitudes towards blue carbon habitats in Southeast Asia, with specific attention to their significance as Nature-based Solutions for coastal conservation. The study aims to: (1) assess the current baseline of community awareness and perception on the coastal protection functions of BCEs in Southeast Asia; (2) recognise socio-cultural, economic, and institutional challenges that distort or hinder localised awareness and perceptions; and (3) identify salient gaps in the existing literature to conceive an actionable framework for future research and inclusive policy design to address this ambiguity. This analysis illustrates the social dimension of environmental governance and offers important insights for developing context-specific coastal adaptation programmes, thereby improving community resilience and socio-ecological justice in Southeast Asia.

## Methods

### Data Collection

This study followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines to ensure transparency, rigour, and reproducibility (Page *et al.*, 2021), and the complete PRISMA checklist is provided in Supplementary Materials (S1). A comprehensive search approach was implemented using Web of Science (WoS), Scopus, and Google Scholar. The analysis focused on peer-reviewed studies published between January 2015 and December 2024 to capture the most recent findings. Search terms integrated blue carbon and nature-based solutions concepts with community perception/awareness, ecosystem types, and filters for Southeast Asian countries, employing Boolean operators in the TITLE-ABSTRACT-KEYWORDS fields. The complete Boolean search strings for all databases are provided in Supplementary Materials (S2).

to enhance transparency and reproducibility. The preliminary investigation produced 1,977 records. To maintain a clear focus on peer-reviewed scientific evidence, grey literature such as NGO reports and government documents was excluded from consideration. This approach enhanced transparency and reproducibility through comprehensive documentation of the complete search strings, inclusion criteria, and data extraction methods.

### Screening and Eligibility

All acquired records ( $n = 1,977$ ) were imported into Rayyan.ai (Yu *et al.*, 2022), an online platform designed for systematic reviews. Two reviewers independently conducted title and abstract screening. Duplicate entries were systematically removed, and inconsistencies were addressed through collaborative discussions and agreements among all contributors. Inter-reviewer agreement during title and abstract screening was 87%, indicating a high degree of consistency. Discrepancies were reconciled by dialogue and consensus among all authors. Owing to the qualitative and exploratory characteristics of the review,

Cohen's kappa statistics were not computed; instead, percentage agreement served as a pragmatic measure of reviewer consistency.

Articles that passed the initial screening underwent full-text assessments based on predefined inclusion and exclusion criteria by all authors. Supplementary Materials (S3) present a detailed summary of the inclusion and exclusion criteria. The inclusion criteria were that research must be peer-reviewed journal articles, explicitly examine community perceptions or awareness of blue carbon ecosystems, and be conducted in one of the 10 Southeast Asian countries. Studies were excluded if they concentrated exclusively on biophysical/ecological components without incorporating a human-dimension aspect, were outside the defined geographic scope, did not provide full-text access, or were unavailable in English or translation. A total of 24 studies were included in the final review, all of which met the specified criteria as summarised in the PRISMA flow diagram in Figure 1. No eligible studies were identified for Brunei, Laos, or Myanmar, highlighting considerable knowledge gaps in these areas.

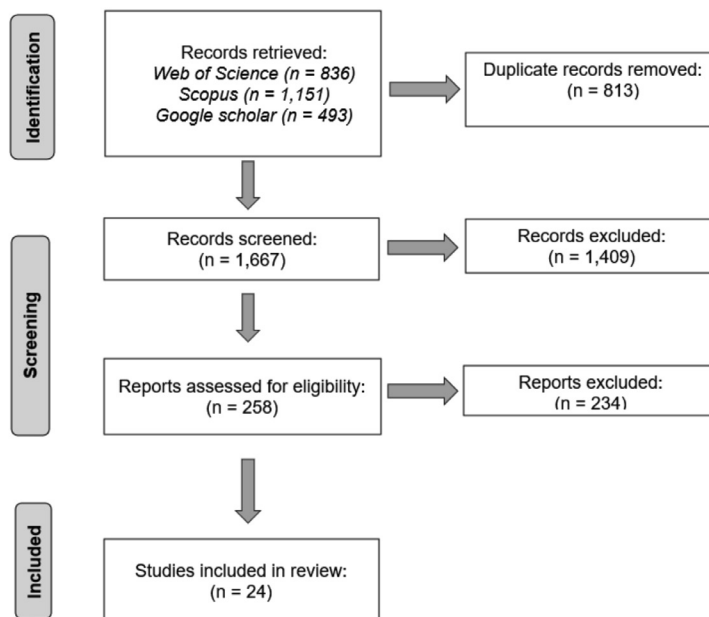


Figure 1: Publication selection and review process

### Data Extraction and Analysis

Data extraction involved documenting publication metadata, study locations, methodologies, and indicators related to community knowledge and perceptions. This information was systematically categorised into four analytical domains: (1) the extent of community perceptions and awareness regarding blue carbon ecosystems; (2) the socio-economic, cultural, environmental, and institutional factors influencing perceptions and engagement; (3) the implications for policy and governance mechanisms; and (4) the regional disparities and research gaps identified throughout Southeast Asia. The study's limitations include limited representation from certain Southeast Asian countries and potential biases in the available literature.

## Results

### Geographic Distribution

At least 24 peer-reviewed publications were selected for the detailed review and analysis. This review revealed a strong geographic concentration, with a larger number of studies in the Philippines (n = 12) followed by Indonesia (n = 9), and limited representation from Malaysia

(n = 2), Vietnam (n = 1), and Thailand (n = 1) (Figure 2). No studies were identified for Laos, Brunei, Myanmar, Cambodia, Singapore, and Timor-Leste, highlighting considerable spatial gaps in the regional literature about community perceptions of blue carbon ecosystems for coastal protection.

The unequal distribution signifies systemic inequalities in research capacity, donor financing, and institutional support across Southeast Asia. Countries with established blue carbon projects, including Indonesia and the Philippines, receive ongoing international financing and have stronger academic infrastructure that supports community-based research. Nations lacking enough institutional support and research funding are significantly underrepresented.

### Ecosystem Type Distribution

Across the reviewed studies, mangrove ecosystems overwhelmingly dominate research on community perceptions of coastal protection functions (Figure 3). This dominance is particularly evident in Philippine-based studies examining awareness of mangroves role in erosion control and storm surge mitigation (e.g.,

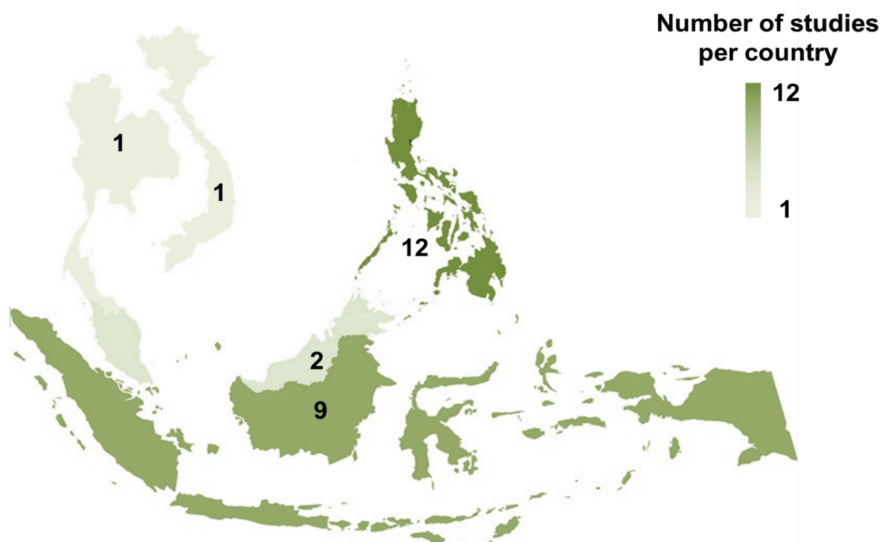


Figure 2: Map of Southeast Asia showing the number of community perception studies of the blue carbon ecosystem

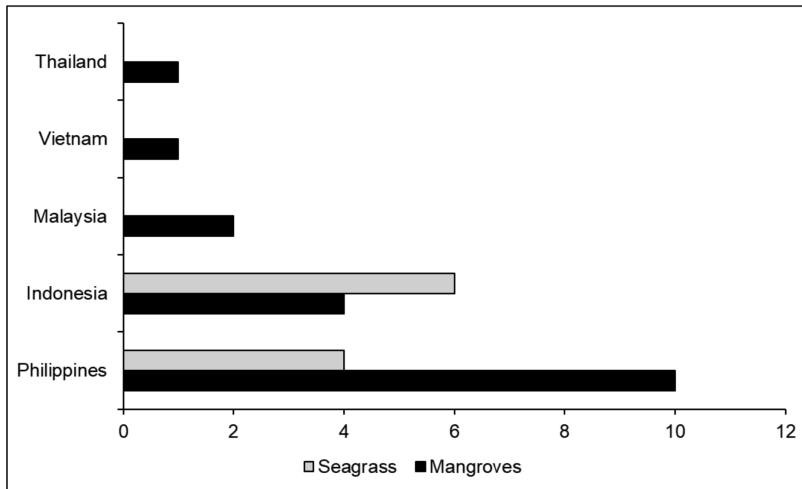


Figure 3: Location of studies and ecosystem types

Idrus *et al.*, 2018; Quevedo *et al.*, 2019; 2020; Alimbon & Manseguiao, 2021; Quevedo *et al.*, 2021a, 2021b, 2021c; Cudiamat & Valdez, 2022; Gagarin *et al.*, 2022; Quitain, 2022; Hilvano, 2023; Quevedo *et al.*, 2023; Reciproco *et al.*, 2023). The prevalence of mangrove-focused studies is partly attributable to their accessibility for fieldwork, the visibility of their ecosystem services, and their direct relevance to coastal livelihoods (Pacyao & Llamag, 2024).

Conversely, seagrass ecosystems are markedly understudied, despite their recognised importance for coastal protection. Limited research on seagrass primarily stems from methodological challenges in valuing and monitoring the ecosystem services it provides, particularly its storm-buffering capabilities. These challenges require complex underwater assessment methods and long-term datasets. Salt marsh ecosystems, often studied in temperate regions, have minimal ecological significance in the geographic context of Southeast Asia. This reflects their limited ecological presence rather than a research omission.

### Community Awareness Levels

Overall, community awareness of coastal protection functions of blue carbon ecosystems is variable but generally moderate, with

consistently higher levels reported in Indonesia and the Philippines. Quantitative assessments indicate awareness levels ranging from 40% to 67% of respondents demonstrating substantial familiarity with the concept of coastal protection (Shah *et al.*, 2016; Syukur *et al.*, 2018; Ambo-Rappe *et al.*, 2019; Gagarin *et al.*, 2022) and a mean awareness score ranging from 3.06 to 4.82 (Marican *et al.*, 2018; Cudiamat & Valdez, 2022; Pratiwi & Nurhayati, 2022; Hilvano, 2023; Reciproco *et al.*, 2023) as presented in Table 1. Awareness is consistently higher in communities with direct exposure to extreme events such as storm surges, flooding, and coastal erosion, reinforcing the tangible protective value of mangroves as natural buffers.

In these areas, the concrete benefits of mangroves and other ecosystems as natural buffers are increasingly apparent. Higher awareness correlates with active involvement in community efforts related to coastal management or blue carbon initiatives. Participation in co-management and conservation initiatives substantially enhances awareness, with reported increases ranging from 58% to 95.5% compared to reliance on passive information dissemination alone (Al Idrus *et al.*, 2018; Quevedo *et al.*, 2020a, 2020b; Vo Trung *et al.*, 2020; Alimbon & Manseguiao, 2021; Quevedo *et al.*, 2021b; Quitain, 2022).

Table 1 (a): Community perception studies using % awareness focusing on coastal protection across Southeast Asia

| Studies                         | Respondents | Ecosystem | Not Aware | Slightly Aware | Moderate | Very Aware | Extremely Aware |
|---------------------------------|-------------|-----------|-----------|----------------|----------|------------|-----------------|
| Alimbon and Manseguiao (2021)   | 154         | Mangroves |           |                |          |            | 74%             |
| Lukman <i>et al.</i> (2021)     | 59          | Seagrass  | 40.7%     |                |          |            |                 |
| Al Idrus <i>et al.</i> (2018)   | 100         | Mangroves |           |                |          |            | 65%             |
| Gagarin <i>et al.</i> (2022)    | 210         | Mangroves |           |                |          | 64.6%      |                 |
| Ambo-Rappe <i>et al.</i> (2019) | 50          | Seagrass  |           |                |          | 29%        |                 |
| Quitain (2022)                  | 24          | Mangroves |           |                |          |            | 95.5%           |
| Quevedo <i>et al.</i> (2021)    | 191         | Mangroves |           |                |          |            | 62%             |
|                                 | 194         | Mangroves |           |                | 42%      |            |                 |
|                                 |             | Seagrass  | 40%       |                |          |            |                 |
| Quevedo <i>et al.</i> (2020a)   | 372         | Mangroves |           |                |          |            | 70%             |
| Quevedo <i>et al.</i> (2020b)   | 372         | Seagrass  |           |                |          |            | 58%             |
| Vo Trung <i>et al.</i> (2020)   | 350         | Mangroves |           |                |          |            | 61%             |
| Syukur <i>et al.</i> (2018)     | 100         | Seagrass  |           |                |          | 40%        |                 |
| Shah <i>et al.</i> (2016)       | 60          | Mangroves |           |                |          | 67%        |                 |
| Rifai <i>et al.</i> (2024)      | 349         | Seagrass  | 51%       |                |          |            |                 |
| Rifai <i>et al.</i> (2023)      | 391         | Seagrass  |           | 31.5%          |          |            |                 |

Table 1 (b): Community perception studies using 1–5 Likert scale focusing on coastal protection across Southeast Asia

| Studies                          | Respondents | Ecosystem | Not Aware | Slightly Aware | Moderate | Very Aware | Extremely Aware |
|----------------------------------|-------------|-----------|-----------|----------------|----------|------------|-----------------|
| Marican <i>et al.</i> (2018)     | 871         | Mangorves |           |                |          | 4.16       |                 |
| Reciproco <i>et al.</i> (2023)   | 335         | Mangorves |           |                |          | 4.18       |                 |
| Jumnongsong <i>et al.</i> (2015) | 180         | Mangroves |           |                | 3.4      |            |                 |
| Hilvano (2023)                   | 99          | Mangroves |           |                |          | 3.06       |                 |
| Cudiamat and Valdez (2022)       | 20          | Mangroves |           |                |          | 3.75       |                 |
| Pratiwi and Nurhayati (2022)     | 50          | Mangroves |           |                |          | 4.82       |                 |
| Quevedo <i>et al.</i> (2023)     | 148         | Seagrass  |           |                | 3.1      |            |                 |
| Quevedo <i>et al.</i> (2021a)    | 145         | Mangroves |           |                | 2.95     |            |                 |
|                                  |             | Seagrass  |           |                | 2.7      |            |                 |
| Rumondang <i>et al.</i> (2023)   | 973         | Mangroves |           |                | 4.12     |            |                 |

Factors Influencing Community Perceptions

Across the reviewed studies, community perceptions of blue carbon coastal protection are shaped by four interrelated factors: (1) intensity of ecosystem interaction; (2) livelihood dependency; (3) educational attainment; and (4) perceived benefits (Syukur *et al.*, 2018) (Table 2). Regular and direct engagement in daily activities such as fishing, gleaning, or resource extraction is consistently associated with enhanced awareness and precise comprehension of ecosystem services. Communities that engage intermittently such as through tourism or sporadic harvesting, demonstrate reduced ecological literacy, suggesting that experiential knowledge is a crucial mechanism linking interaction to perception (Shah *et al.*, 2016; Ambo-Rappe *et al.*, 2019; Gagarin *et al.*, 2022).

The dependency on livelihood further influences perception. Research demonstrates that communities dependent on fisheries and mangrove or seagrass resources acknowledge their protective and provisioning roles. This relationship is not universal; some highly dependent communities may underestimate ecosystem benefits because knowledge dissemination is limited or environmental stressors obscure perceived advantages. This indicates that dependency alone is inadequate; the interplay between livelihood reliance and knowledge access significantly influences perceptions (Quevedo *et al.*, 2020a; Rifai *et al.*, 2023, 2024; Rumondang *et al.*, 2023).

Educational attainment serves as a moderating variable. Communities with higher levels of formal education, especially when coupled with direct resource dependence, show a deeper understanding of ecosystem functions and the benefits of blue carbon. In contrast, insufficient education hinders the ability to understand scientific and policy narratives, creating barriers even among resource-dependent populations (Quevedo *et al.*, 2023; Rumondang *et al.*, 2023). This highlights a mechanistic relationship: Education enhances the capacity to transform experiential interactions into accurate perceptions.

Table 2: Barriers to community awareness of blue carbon ecosystem coastal protection function

| Study                           | Intensity Of Interaction in Ecosystem                                                                                                           | Degree of Dependency                                                                                                                                   | Education Leve                                          | Perceived Benefits (Coastal Protection) |
|---------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------|-----------------------------------------|
| Rumondang <i>et al.</i> (2023)  | Daily interaction via fishing and mangrove resource use                                                                                         | High: Fishing primary livelihood; heavy reliance on mangrove products                                                                                  | Majority are unschooled (42%)                           | Benefits recognised (moderate)          |
| Shah <i>et al.</i> (2016)       | Occasional harvesting (crabs, mollusks, nipa fruit/leaves); regular fishing nearby                                                              | Moderate to low: Direct use limited; main livelihood is fishing                                                                                        | Most respondents educated only to primary level (78.3%) | Benefits recognised (very aware)        |
| Syukur <i>et al.</i> (2018)     | Fishermen working daily in/around seagrass beds                                                                                                 | Very high: Seagrass central to fish stocks and eco-friendly aquaculture                                                                                | Education not emphasised                                | Benefits recognised (very aware)        |
| Vo Trung <i>et al.</i> (2020)   | Interaction via local livelihoods and park resources                                                                                            | High: Provisioning services (fish, timber) plus indirect protection                                                                                    | Below high school (91.9%)                               | Benefits recognised (very aware)        |
| Pratiwi <i>et al.</i> (2022)    | Community engagement in eco-tourism, mangrove planting, education campaigns                                                                     | Moderate: Some supplementary income, but not primary livelihood                                                                                        | Bachelor's degree (44%)                                 | Benefits recognised (extremely aware)   |
| Alimbon and Manseguiao (2021)   | Daily proximity to mangrove park; some use mangroves for food but limited other uses; interaction mainly through settlement near mangroves      | Low to moderate: Most respondents are not fishers (only 5.8% fishing-related), so dependency is not strongly economic.                                 | Secondary education (55.8%)                             | Benefits recognised (very aware)        |
| Ambo-Rappe <i>et al.</i> (2019) | Workshop participants (fishers, students, officers) are highly engaged in marine activities and have frequent contact with seagrass ecosystems. | High: Livelihoods (fisheries, crabs, sea cucumbers, siganids) directly depend on seagrass meadows for income and food.                                 | Education not emphasised                                | Benefits recognised (extremely aware)   |
| Cudiamat and Valdez (2022)      | Fisherfolk directly use mangroves for gleaning, fishing, and post-harvest activities; frequent resource-based interaction.                      | Moderate to high: The community relies on mangroves for fisheries and protection, but the study notes only moderate awareness despite this dependency. | High school graduate (45%)                              | Benefits recognised (very aware)        |
| Gagarin <i>et al.</i> (2022)    | Residents exposed to mangrove decline and typhoon impacts; interaction framed by valuation survey on mangrove rehabilitation                    | High: Dependency evident in willingness to pay (79% expressed WTP) for coastal protection, showing strong recognition of mangroves' role in survival   | Education not emphasised                                | Benefits recognised (very aware)        |

|                                |                                                                                                                    |                                                                                                                          |                                              |                                                                                               |
|--------------------------------|--------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------|----------------------------------------------|-----------------------------------------------------------------------------------------------|
| Hilvano (2023)                 | Island households directly exposed to typhoons/storm surges; daily interaction with mangrove protection functions. | Very high: Fishing primary livelihood (78%), mangroves crucial for disaster protection; strong survival-based dependency | High school (48.48%)                         | Benefits recognised (very aware)                                                              |
| Quevedo <i>et al.</i> (2019)   | Daily subsistence activities: Fishing, gleaning, mangrove wood (though low illegal cutting due to policies)        | High: Reliance on mangroves for food, fuelwood, and protection; awareness varied by education level                      | High school (22%)                            | Benefits recognised (extremely aware)                                                         |
| Quevedo <i>et al.</i> (2020)   | Occasional to daily use for gleaning and fishing; low recreational use                                             | Moderate: Seagrass less central than mangroves; mainly food and storm protection                                         | Education not emphasised                     | Benefits recognised (extremely aware)                                                         |
| Quevedo <i>et al.</i> (2021)   | Very frequent interaction through eco-park tourism, mangrove planting, and gleaning                                | High to very high: Livelihood from eco-tourism and fisheries; strong cultural link                                       | Primary school (42%); secondary school (42%) | Benefits recognised (moderate)                                                                |
| Quevedo <i>et al.</i> (2021)   | Mixed: Tourism-related activities, fishing, gleaning; recreation in seagrass and mangroves                         | Moderate to high: Livelihood partly tied to tourism and fisheries                                                        | Primary (49%)                                | Benefits recognised (extremely aware)                                                         |
| Quevedo <i>et al.</i> (2021)   | Daily-frequent interaction via fishing and gleaning; eco-tourism                                                   | High: Fisheries and alternative income                                                                                   | Primary (49%)                                | Benefits recognised in Mangroves (moderately aware) than in seagrass; benefits not recognised |
| Quevedo <i>et al.</i> (2023)   | Rural: Daily fishing, gleaning; Urban: Tourism-linked, less direct use                                             | Rural–high: Food, livelihood; Urban–moderate: Tourism economy, indirect use                                              | Elementary (51.7%)                           | Benefits recognised (moderate)                                                                |
| Quitain (2022)                 | Frequent subsistence use (fuel, food, wood) and indirect protection                                                | High: Both community and LGU value habitat and storm protection strongly                                                 | Education not emphasised                     | Benefits recognised (extremely aware)                                                         |
| Reciproco <i>et al.</i> (2023) | Daily interaction through fishing, gleaning, shoreline protection                                                  | High: Livelihoods, protection, and participation in management                                                           | Education not emphasised                     | Benefits recognised (very aware)                                                              |
| Rifai <i>et al.</i> (2023)     | Daily-frequent interaction, especially fishers; some tourism                                                       | High: Fisheries, coastal protection, food                                                                                | Elementary (47.83%)                          | Benefits recognised (slightly aware)                                                          |
| Rifai <i>et al.</i> (2024)     | Daily use (fishing, gleaning); eco-tourism emerging in MPAs                                                        | Moderate to high: Mixed dependence on fisheries, emerging tourism                                                        | Elementary (42%)                             | Benefits not recognised                                                                       |

Perceived benefits are ultimately shaped by direct experience and the broader societal context. Communities benefiting from direct protective services such as storm surge mitigation demonstrate an increased awareness of ecosystem value, whereas urban or indirectly engaged populations may not fully recognise these advantages. Engagement in conservation initiatives, including mangrove planting and eco-tourism, enhances awareness and fosters positive perceptions, demonstrating a feedback loop in which action improves understanding and subsequently promotes further involvement (Afifah *et al.*, 2023; Mohamed *et al.*, 2023; Temmerman *et al.*, 2023).

### ***Barriers to Community Awareness and Understanding***

The research findings indicate that community awareness and understanding were limited by various educational, socio-economic, cultural, and institutional barriers. Insufficient formal education and low environmental literacy hindered the understanding of technical concepts like carbon sequestration, especially when information was conveyed using scientific terminology instead of language that resonated locally (Oramah *et al.*, 2025). The accessibility of information was further impeded by inadequate extension services, restricted outreach initiatives, and the lack of resources in local dialects (Yu *et al.*, 2024).

Socio-economic pressures significantly influenced community priorities, as reliance on coastal and marine resources redirected focus toward immediate economic needs, thereby reducing time and motivation for environmental learning (Staniškis, 2022). Cultural perceptions further influenced awareness, leading to the view that abstract climate-related benefits are less pertinent than direct ecosystem services like fisheries and coastal protection (Maharja *et al.*, 2023). In many instances, environmental

degradation has been normalised, reducing awareness of long-term ecological changes.

Institutional factors exacerbated these challenges. Top-down governance methods, insufficient community engagement (Jumnongsong *et al.*, 2015), and inadequate coordination among implementing agencies diminished trust and ownership of conservation initiatives (Kiss *et al.*, 2022). The absence of observable benefits from awareness programmes has further reduced motivation for engagement, thereby perpetuating low levels of understanding despite the ecological significance of blue carbon ecosystems.

### **Discussion**

Perceptions of Blue Carbon Ecosystems (BCEs) across Southeast Asia are not uniform. However, they are shaped by a combination of ecological visibility, livelihood relevance, socio-economic conditions, and governance arrangements (Syukur *et al.*, 2018). Mangroves are acknowledged for their coastal protection advantages, particularly in the Philippines and Indonesia, where they are regarded as “green infrastructure” (Shah *et al.*, 2016; Quevedo *et al.*, 2021b). This repeated interaction between hazard experience and ecosystem services explains why mangroves are more salient in community narratives than other BCEs.

Conversely, seagrass meadows, despite their essential function in sediment stabilisation and wave attenuation (Infantes *et al.*, 2022; Neto *et al.*, 2022), are predominantly undervalued and eclipsed by more prominent ecosystems such as mangroves (Rumondang *et al.*, 2023). Their underwater location, diffuse benefits, and weaker symbolic association with risk reduction limit both public awareness and political prioritisation. Salt marshes are largely absent from tropical Southeast Asia due to biogeographical limitations rather than study bias (Adams *et al.*, 2021), underscoring that

perception gaps are ecosystem-specific rather than universal across all blue carbon habitats.

Disparities in perceptions of mangroves and seagrasses reflect underlying socio-economic and political factors. Mangroves are intrinsically linked to concrete livelihoods (e.g., fisheries, fuelwood, coastal protection), rendering their advantages readily apparent and socially integrated (Golebie *et al.*, 2022). Conversely, seagrass advantages are often indirect, long-term, or spatially distant, reducing their perceived impact on local populations and policymakers (Unsworth *et al.*, 2022). Methodological limitations further exacerbate these perceptual discrepancies. Monitoring seagrass is technically challenging, resource-demanding, and less standardised compared to mangrove evaluation (Johannessen, 2023; Comte *et al.*, 2024). Restricted economic valuation and uneven carbon accounting systems hinder the incorporation of seagrasses in policy instruments and climate finance mechanisms (Doolan & Hynes, 2023; Zhao *et al.*, 2025). Consequently, scientific invisibility results in policy invisibility, thereby continuing a cycle of neglect.

These perceptual tendencies have immediate ramifications for the adoption of Nature-based Solutions (NbS). Nature-based solutions (NbS) efforts in Southeast Asia predominantly emphasise mangroves because they align with donor priorities centred on disaster risk mitigation, rapid carbon sequestration, and apparent co-benefits (Afonso *et al.*, 2022). This emphasis has accelerated mangrove restoration but may narrow the Nature-based Solutions (NbS) portfolio and overlook complementary ecosystems like seagrasses that bolster coastal resilience at seascape scales. Political economy dynamics significantly affect the outcomes of Nature-based Solutions (NbS). Nature-based Solutions centred on mangroves receive financial backing, media attention, and institutional support, but seagrasses occupy a marginal position due to weaker advocacy coalitions and limited livelihood narratives (Dahdouh-Guebas

*et al.*, 2020; Shilland *et al.*, 2021). Without deliberate policy modifications, implementing NbS may sustain the existing ecosystem hierarchy rather than promote cohesive coastal solutions.

Addressing inconsistencies in perception and policy requires methodological advancements in social-ecological research. Participatory approaches such as community-based monitoring and participatory GIS enhance data accessibility and strengthen local stewardship of lesser-known BCEs (Malakar & Roy, 2024; James, 2025). Collaborative study design with communities allows local knowledge, values, and concerns to shape research themes, hence improving relevance and validity (Robinson *et al.*, 2024). Longitudinal perception research is significantly lacking in Southeast Asia. Tracking how awareness and viewpoints on governance reforms, nature-based solutions, or climate disruptions develop is crucial for understanding long-term commitment and policy sustainability (Nahuelhual *et al.*, 2024). Future research should address geographic gaps, particularly in under-researched nations such as Myanmar, Cambodia, Laos, and Timor-Leste, and expand sociological studies of seagrasses and associated salt marshes where applicable (Cunha-Lignon *et al.*, 2022).

Governance frameworks significantly influence perceptions, engagement, and outcomes of blue carbon programmes. Decentralised, community-oriented systems such as those in the Philippines typically promote greater local ownership and understanding (Quevedo *et al.*, 2021). Conversely, more centralised approaches, as demonstrated by Malaysia and Vietnam, often achieve rapid ecological progress but limit community involvement and the equitable distribution of benefits (Mustaffa *et al.*, 2021). Hybrid governance models, exemplified by Indonesia's integration of community restoration with government REDD+ frameworks, enhance global visibility but are impeded by land ownership conflicts and equity concerns (Wahyudi *et al.*, 2024).

These findings underscore the significance of governance legitimacy, inclusion, and equity in NbS policy. Policies that do not ensure tenure, equitably distribute benefits, or acknowledge local knowledge jeopardise long-term efficacy (Dencer-Brown *et al.*, 2022). Incorporating seagrasses into coastal NbS necessitates specific policy instruments, standardised metrics, and interdisciplinary planning frameworks that extend beyond mangrove-focused policies (Dolge *et al.*, 2023).

The underrepresentation of seagrasses in blue carbon research on social aspects represents a notable gap, driven by multiple interconnected factors (Do Amaral Camara Lima *et al.*, 2023; Foster *et al.*, 2025). Although seagrasses generally have lower visibility than mangroves, it is essential to address the methodological challenges that impede their study (Comte *et al.*, 2024). Monitoring seagrass ecosystems consistently presents challenges because of their underwater environment and the technical difficulties of accurately assessing their carbon sequestration potential (Johannessen, 2023). The absence of economic valuation for seagrasses contributes to their continued neglect in research and conservation initiatives (Caparrós-Martínez *et al.*, 2025). In contrast, mangroves are frequently recognised for their coastal protection benefits and have more developed financial and policy incentives, while seagrasses are seldom included in climate finance mechanisms, resulting in limited funding for their restoration and conservation (Doolan & Hynes, 2023). This underrepresentation is exacerbated by inconsistent methodologies for assessing seagrass ecosystems (Zhao *et al.*, 2025). Standardised research methods are essential for replication across various regions, enhancing the comparability of findings and informing policy more effectively (Strachan *et al.*, 2022). Recognising and addressing these methodological challenges is essential to increasing the visibility of seagrasses within the blue carbon discourse.

Perceptions of mangroves and seagrasses differ for several reasons, notably their visibility (Quevedo *et al.*, 2025). Mangroves are frequently featured in media and environmental efforts, highlighting their role in flood protection (Dahdouh-Guebas *et al.*, 2020). Seagrasses are frequently neglected and rarely incorporated into local environmental education initiatives (Barañano *et al.*, 2022). Donor priorities primarily emphasise mangrove conservation because of their recognised contributions to climate resilience and disaster risk reduction (Afonso *et al.*, 2022). In contrast, seagrasses, despite their ability to sequester carbon, receive comparatively less attention and financial backing (Shilland *et al.*, 2021). A comprehensive analysis of perception biases shaped by ecological, social, and political factors is necessary. This may involve analysing the political economy of mangrove conservation, as local livelihoods often rely on mangrove ecosystems, increasing incentives for their protection and restoration (Golebie *et al.*, 2022). Seagrasses often receive less communal or governmental support, largely because of their weaker ties to the livelihoods of many coastal communities (Unsworth *et al.*, 2022).

The study discusses the challenges of investigating blue carbon ecosystems but lacks a comprehensive analysis of the methodological innovations needed to address them. For example, participatory Geographic Information System (GIS) can enable local communities to actively participate in the mapping and monitoring of seagrass and other Blue Carbon Ecosystems (BCEs) (James, 2025). This method not only enhances data collection but also encourages community ownership and stewardship of these ecosystems (Malakar & Roy, 2024). Additionally, research that integrates local knowledge and concerns can achieve greater contextual relevance through co-design approaches, wherein communities collaborate with scientists to jointly develop research agendas and methodologies (Robinson

*et al.*, 2024). It is essential to conduct studies on attitudes and perceptions that track the evolution of community awareness and attitudes over time to understand how perceptions shift in response to blue carbon initiatives and governance changes (Nahuelhual *et al.*, 2024). These studies are crucial for identifying the factors that affect long-term engagement with blue carbon conservation efforts and for maintaining policies that can adapt to changing socio-ecological contexts.

The challenges faced in Southeast Asia may not be unique. Countries such as Australia, Mexico, and the United States offer significant governmental support for blue carbon habitats; however, public awareness predominantly centres on flood prevention, resulting in insufficient recognition of seagrasses and salt marshes (Macreadie *et al.*, 2019; Amone-Mabuto *et al.*, 2023). The carbon contributions of seagrasses and salt marshes in Europe are often overlooked, hindering restoration initiatives (Gouldsmith & Cooper, 2022). These examples show that knowledge gaps in blue carbon ecosystems are prevalent, especially for less conspicuous ecosystems that do not fit conventional policy frameworks.

Governance structures and socio-ecological factors significantly affect community perceptions and engagement with BCEs. Coastal communities with mangroves, especially in disaster-prone areas, exhibit heightened awareness of their protective value (Vo Trung *et al.*, 2020; Pratiwi & Nurhayati, 2022). Seagrasses often receive minimal attention because of their limited visibility, scattered educational efforts, and inadequate institutional involvement (Rumondang *et al.*, 2023). Mangroves receive enhanced institutional support, but ecosystems such as seagrasses frequently garner insufficient attention in conservation and policy initiatives.

The governance structures in Southeast Asia play a crucial role in determining the effectiveness of blue carbon initiatives. Table 3 compares governance styles, outcomes, and

challenges in key Southeast Asian countries, offering a clear overview.

The comparative analysis reveals several overarching patterns. Decentralised governance, exemplified by the Philippines, often increases community ownership and participation in blue carbon initiatives (Quevedo *et al.*, 2021). In contrast, centralised or top-down systems, such as those in Malaysia and Vietnam, often achieve more immediate ecological outcomes but at the cost of local involvement and trust (Mustaffa *et al.*, 2021). Hybrid systems, exemplified by Indonesia, gain advantages from national initiatives like REDD+, which elevate the significance of blue carbon. However, they continue to face considerable challenges related to land tenure and equitable benefit-sharing (Wahyudi *et al.*, 2024). The patterns highlight the importance of governance legitimacy, local participation, and equity in achieving sustainable blue carbon outcomes (Zaid *et al.*, 2025). Community engagement is crucial for promoting sustainable ecological and social resilience (Shemshad *et al.*, 2025). Strengthening governance systems to promote equity, secure land tenure, and support adaptive management is crucial to enhancing the effectiveness of blue carbon initiatives (Dencer-Brown *et al.*, 2022).

The results underscore the need for additional investigation into the relationship between governance structures, community engagement, and ecological outcomes in blue carbon environments (Pricillia *et al.*, 2021; Raihan, 2023). To enhance the effectiveness of these initiatives, research must investigate Socio-ecological Systems (SES) that accurately reflect local contexts and the intricacies of BCEs (Refulio-Coronado *et al.*, 2021). Improved regional and ecosystem representation is essential in blue carbon research. Many regions, particularly vulnerable coastal communities in Southeast Asia, including Myanmar, Cambodia, Laos, and Timor-Leste, lack adequate research. Future research must encompass seagrasses and salt marsh ecosystems, which are crucial for

Table 3: Comparative governance patterns influencing community perceptions of blue carbon ecosystems in Southeast Asia

| Country     | Governance Style / Institutional Arrangement                                                                                                                                                  | Observed Outcomes                                                                                                          | Key Challenges                                                                                            | Representative Sources                                                     |
|-------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------|
| Philippines | Decentralised and community-based coastal resource management institutionalised through the 1991 Local Government Code; strong NGO–LGU collaboration and Locally Managed Marine Areas (LMMAs) | High community ownership and awareness; participatory mangrove rehabilitation and sustainable use of blue-carbon resources | Dependence on project funding and political turnover; uneven technical capacity among LGUs                | Primavera and Esteban (2008), Hilvano (2023), Quevedo <i>et al.</i> (2024) |
| Malaysia    | Predominantly top-down, state-led mangrove forest reserve system emphasising protection and timber regulation                                                                                 | Effective forest protection and monitoring; limited livelihood diversification                                             | Restricted community participation; weak trust and benefit-sharing mechanisms                             | Friess <i>et al.</i> (2016), Almasi <i>et al.</i> (2019)                   |
| Vietnam     | Hybrid governance: centralised coastal planning with emerging community-based disaster-risk-reduction initiatives                                                                             | Enhanced storm protection and hazard mitigation through large-scale mangrove planting                                      | Inconsistent implementation; tendency toward monoculture plantations with low ecological and social value | Nguyen <i>et al.</i> (2016)                                                |
| Indonesia   | Mixed approach combining community-based restoration and REDD+ programmes integrated in national climate policy                                                                               | Expanded mangrove restoration and international visibility of blue-carbon policy                                           | Land-tenure conflicts; inequitable benefit distribution; limited inclusion of local knowledge             | Myers <i>et al.</i> (2018), Syukur <i>et al.</i> (2018)                    |

climate resilience yet frequently overlooked (Cunha-Lignon *et al.*, 2022).

Furthermore, integrating governance frameworks with socio-ecological perspectives is essential (Bebbington *et al.*, 2024). Examining the impact of various governance styles on community engagement, adaptive capacity, and the incorporation of local knowledge is essential for formulating more effective and inclusive blue carbon policies (Dencer-Brown *et al.*, 2022). Mixed-methods approaches are crucial for accurately capturing the complexity and dynamic nature of blue

carbon ecosystems (Quiros *et al.*, 2021). The creation of standardised indicators is essential for enhancing comparability among nations and ecosystems, facilitating comprehensive cross-country assessments and more effective policy recommendations (Dolge *et al.*, 2023). This project seeks to enhance blue carbon initiatives by incorporating socio-ecological perspectives, broadening the scope to include marginalised ecosystems and regions, and ensuring that governance frameworks are equitable and locally grounded.

## Conclusions

This study presents a rigorous systematic synthesis of community perceptions of Blue Carbon Ecosystems (BCEs) for coastal preservation in Southeast Asia, demonstrating severe geographic, ecological, and institutional inequalities across the area. The literature remains highly polarised, with a dominant cluster of studies in the Philippines and Indonesia, an overwhelming focus on mangrove ecosystems, and serious empirical blind spots in mainland Southeast Asia and key seagrass areas. Synthetic data indicate that community awareness is generally moderate, driven not by passive information spread but by direct exposure to disasters, formal education, and active participation in co-management initiatives. Persistent impediments such as top-down institutional settings, urgent socio-economic vulnerabilities, and insufficient environmental literacy continue to hinder conservation efficacy. Future policy needs to go beyond the purely ecological mandates to ensure that regional frameworks like ASEAN's blue carbon initiatives do not underperform. It should use mixed-methods socio-ecological research

to build equitable, participatory governance structures that transform local experiential knowledge into long-term coastal resilience.

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## Author Contributions Statement

Charlen Mae Gaab-Canales: Carried out the research, wrote and revised the article, and conceptualised the central research idea. Hernando Bacosa: Writing–review and editing.

## Conflict of Interest Statement

The authors agree that this review was conducted without any self-benefit, commercial, or financial conflicts and declare no conflicting interests with the funders.

## Supplementary Materials

### S1: PRISMA 2020 checklist item

| Section                       | Item | Checklist Item                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|-------------------------------|------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Title</b>                  | 1    | Identify the report as a systematic review                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| <b>Abstract</b>               | 2    | Provide a structured summary that includes (as applicable): background, objectives, methods, results, and discussion                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| <b>Introduction</b>           |      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| Rationale                     | 3    | Describe the rationale for the review in the context of existing knowledge                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| Objectives                    | 4    | Provide an explicit statement of the objective(s) or question(s) the review addresses                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| <b>Methods</b>                |      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| Eligibility criteria          | 5    | Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| Information sources           | 6    | Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted                                                                                                                                                                                                                                                                                                                                                                     |
| Search strategy               | 7    | Present the full search strategies for all databases, registers and websites, including any filters and limits used                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| Selection process             | 8    | Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process                                                                                                                                                                                                                                                                                              |
| Data collection process       | 9    | Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process                                                                                                                                                                                                                                                                          |
| Data items                    | 10   | List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g., for all measures, time points, analyses), and if not, the methods used to decide which results to collect                                                                                                                                                                                                                                                                                                |
| Study risk of bias assessment | 11   | Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process                                                                                                                                                                                                                                                                                                             |
| Effect measures               | 12   | Specify for each outcome the effect measure(s) (e.g., risk ratio, mean difference) used in the synthesis or presentation of results                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| Synthesis methods             | 13   | Describe the processes used to decide which studies were eligible for each synthesis (e.g., tabulating the study intervention characteristics and comparing against the planned groups for each synthesis. Describe any methods used to tabulate or visually display results of individual studies and syntheses. Describe any methods used to synthesise results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used |

|                               |    |                                                                                                                                                                                                                                                                                     |
|-------------------------------|----|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Reporting bias assessment     | 14 | Describe any methods used to assess risk of bias due to missing results in a synthesis                                                                                                                                                                                              |
| Certainty assessment          | 16 | Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome                                                                                                                                                                                |
| <b>Results</b>                |    |                                                                                                                                                                                                                                                                                     |
| Study selection               | 17 | Give numbers of sources of evidence screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally using a flow diagram                                                                                                         |
| Study characteristics         | 18 | For each source of evidence, present characteristics for which data were charted and provide the citations                                                                                                                                                                          |
| Risk of bias in studies       | 19 | Present assessments of risk of bias for each included study                                                                                                                                                                                                                         |
| Results of individual studies | 20 | For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate)                                                                                                                                                                                |
| Results of syntheses          | 21 | Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect |
| Reporting biases              | 22 | Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed                                                                                                                                                              |
| Certainty of evidence         | 23 | Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed                                                                                                                                                                                  |
| <b>Discussion</b>             |    |                                                                                                                                                                                                                                                                                     |
| Summary of evidence           | 24 | Summarise the main results (including an overview of concepts, themes, and types of evidence available), link to the review questions and objectives, and consider the relevance to key groups                                                                                      |
| Limitations                   | 25 | Discuss any limitations of the review processes used                                                                                                                                                                                                                                |
| <b>Conclusions</b>            | 26 | Discuss implications of the results for practice, policy, and future research                                                                                                                                                                                                       |
| <b>Funding</b>                | 27 | Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review                                                                                                                                                        |

Source: Page *et al.* (2021)

#### S2: Boolean search strings

| Keyword                 | Operator | Habitat   | Location      |
|-------------------------|----------|-----------|---------------|
| “Blue carbon”           | and      | Seagrass  | “Brunei”      |
| “Nature-based solution” | in       | Mangroves | “Cambodia”    |
| “Community perceptions” | of       | Saltmarsh | “Indonesia”   |
| “Coastal communities”   | or       |           | “Laos”        |
| “Southeast Asia”        |          |           | “Malaysia”    |
|                         |          |           | “Myanmar”     |
|                         |          |           | “Philippines” |
|                         |          |           | “Singapore”   |
|                         |          |           | “Thailand”    |
|                         |          |           | “Vietnam”     |

## S3: Inclusion/exclusion criteria

| Screening Dimension | Inclusion                                                        | Exclusion                                                                  |
|---------------------|------------------------------------------------------------------|----------------------------------------------------------------------------|
| Publication type    | Peer-reviewed journal articles                                   | Grey literature, reports, theses, conference papers                        |
| Study focus         | Community perceptions and/or awareness of blue carbon ecosystems | Purely biophysical or ecological studies with no human-dimension component |
| Geographic scope    | Conducted in Southeast Asia (10 countries)                       | Studies conducted outside Southeast Asia                                   |
| Accessibility       | Full-text available                                              | Full-text unavailable                                                      |
| Language            | English or available translation                                 | Non-English with no accessible translation                                 |

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