

2021-09-28

# Enhancing Uptake of Nature-Based Solutions for Informing Coastal Sustainable Development Policy and Planning: A Malaysia Case Study

Chee, SY

<http://hdl.handle.net/10026.1/18332>

---

10.3389/fevo.2021.708507

Frontiers in Ecology and Evolution

Frontiers Media SA

---

*All content in PEARL is protected by copyright law. Author manuscripts are made available in accordance with publisher policies. Please cite only the published version using the details provided on the item record or document. In the absence of an open licence (e.g. Creative Commons), permissions for further reuse of content should be sought from the publisher or author.*



# Enhancing Uptake of Nature-Based Solutions for Informing Coastal Sustainable Development Policy and Planning: A Malaysia Case Study

Su Yin Chee<sup>1\*</sup>, Louise B. Firth<sup>2</sup>, Amy Yee-Hui Then<sup>3</sup>, Jean Chai Yee<sup>1</sup>, Aazani Mujahid<sup>4</sup>, Yang Amri Affendi<sup>5</sup>, A. Aldrie Amir<sup>6</sup>, Chai Ming Lau<sup>7</sup>, Jillian Lean Sim Ooi<sup>8</sup>, Yew Aun Quek<sup>9</sup>, Choo Eng Tan<sup>10</sup>, Tzuen Kiat Yap<sup>11,12</sup>, Chin Aik Yeap<sup>10</sup> and Abigail McQuatters-Gollop<sup>2</sup>

<sup>1</sup> Centre for Marine and Coastal Studies, Universiti Sains Malaysia, George Town, Malaysia, <sup>2</sup> School of Biological and Marine Sciences, University of Plymouth, Plymouth, United Kingdom, <sup>3</sup> Institute of Biological Sciences, Faculty of Science, Universiti Malaya, Kuala Lumpur, Malaysia, <sup>4</sup> Institute of Biodiversity and Environmental Conservation, Universiti Malaysia Sarawak, Kota Samarahan, Malaysia, <sup>5</sup> Institute of Ocean and Earth Sciences, Universiti Malaya, Kuala Lumpur, Malaysia, <sup>6</sup> Institute for Environment and Development (LESTARI), Universiti Kebangsaan Malaysia, Bangi, Malaysia, <sup>7</sup> Reef Check Malaysia, Kuala Lumpur, Malaysia, <sup>8</sup> Department of Geography, Faculty of Arts and Social Sciences, Universiti Malaya, Kuala Lumpur, Malaysia, <sup>9</sup> Biodiversity Management Division, Ministry of Energy and Natural Resources, Putrajaya, Malaysia, <sup>10</sup> Malaysian Nature Society, Kuala Lumpur, Malaysia, <sup>11</sup> Borneo Marine Research Institute, Universiti Malaysia Sabah, Kota Kinabalu, Malaysia, <sup>12</sup> Seagrass Guardians, Kota Kinabalu, Malaysia

## OPEN ACCESS

### Edited by:

J. Guy Castley,  
Griffith University, Australia

### Reviewed by:

Alessandro Pagano,  
Istituto di Ricerca Sulle Acque  
IRSA-CNR, Italy  
Gabriel Kiddle,  
Victoria University of Wellington,  
New Zealand  
Donna Marie Bilkovic,  
William & Mary's Virginia Institute  
of Marine Science, College of William  
& Mary, United States

### \*Correspondence:

Su Yin Chee  
suyinchee@usm.my

### Specialty section:

This article was submitted to  
Conservation and Restoration  
Ecology,  
a section of the journal  
Frontiers in Ecology and Evolution

**Received:** 12 May 2021

**Accepted:** 30 August 2021

**Published:** 28 September 2021

### Citation:

Chee SY, Firth LB, Then AY-H,  
Yee JC, Mujahid A, Affendi YA,  
Amir AA, Lau CM, Ooi JLS, Quek YA,  
Tan CE, Yap TK, Yeap CA and  
McQuatters-Gollop A (2021)  
Enhancing Uptake of Nature-Based  
Solutions for Informing Coastal  
Sustainable Development Policy  
and Planning: A Malaysia Case Study.  
*Front. Ecol. Evol.* 9:708507.  
doi: 10.3389/fevo.2021.708507

Nature-based Solutions (NbS) have been advocated to protect, sustainably manage, and restore natural or modified ecosystems, simultaneously providing human well-being and biodiversity benefits. The uptake of NbS differs regionally with some countries exhibiting greater uptake than others. The success of NbS also differs regionally with varying environmental conditions and social-ecological processes. In many regions, the body of knowledge, particularly around the efficacy of such efforts, remains fragmented. Having an “inventory” or “tool box” of regionally-trialed methods, outcomes and lessons learnt can improve the evidence base, inform adaptive management, and ultimately support the uptake of NbS. Using Malaysia as a case study, we provide a comprehensive overview of trialed and tested NbS efforts that used nature to address societal challenges in marine and coastal environments (here referring to mangroves, seagrass, coral reefs), and detailed these efforts according to their objectives, as well as their anticipated and actual outcomes. The NbS efforts were categorized according to the IUCN NbS approach typology and mapped to provide a spatial overview of IUCN NbS effort types. A total of 229 NbS efforts were collated, representing various levels of implementation success. From the assessment of these efforts, several key actions were identified as a way forward to enhance the uptake of Nature-based Solutions for informing coastal sustainable development policy and planning. These include increasing education, training, and knowledge sharing; rationalizing cooperation across jurisdictions, laws, and regulations; enhancing environmental monitoring; leveraging on existing policies; enabling collaboration and communication; and implementing sustainable finance instruments. These findings can be used to inform the improved application and uptake of NbS, globally.

**Keywords:** sustainable development, conservation, mangrove, seagrass, coral reefs, marine protected areas

## INTRODUCTION

Marine and coastal ecosystems are under threat globally from rising human populations, rapid urbanization, and climate change (European Environment Agency, 2012; Todd et al., 2019; Bugnot et al., 2021). In 2021, the global human population size is 7.8 billion people (United Nations, 2021), with 40% living within 100 km of the coast (Firth et al., 2016). By 2050, this is projected to surpass 9 billion (United Nations, 2019b) with widespread migration toward coastlines driven by benefits that include infrastructure, industrial and urban development, and economic growth (Creel, 2003; McGranahan et al., 2007; Smith, 2011; Neumann et al., 2015). Disproportionately dense human populations coupled with lack of space on land, poor urban planning, and pervasive effects of climate change (sea level rise, coastal erosion, and flooding) are major threats to vulnerable marine and coastal resources and ecosystems (Day and Rybczyk, 2019; Kekeh et al., 2019; Siegel, 2019).

Adopting a sustainable development approach is therefore increasingly promoted as the principal way of maintaining natural resources despite growing population pressure. This approach, that entails meeting the needs of the present without compromising the ability of future generations to meet their own needs is the foundation for current leading global frameworks and international cooperation such as the 2030 Agenda for Sustainable Development and its Sustainable Development Goals (United Nations, 2020). The United Nations has also proclaimed 2021–2030 as the “Decade of Action on Sustainable Development Goals,” “Decade on Ecosystem Restoration,” and “Decade of Ocean Science for Sustainable Development” to support efforts in reversing the decline in natural ecosystems and in gathering stakeholders worldwide behind a common framework to ensure science can fully support nations in creating improved conditions for sustainable development of ecosystems (United Nations, 2020). In all these approaches, nature has been strongly advocated as one of the best ways to achieve human well-being, address climate change, and protect biodiversity.

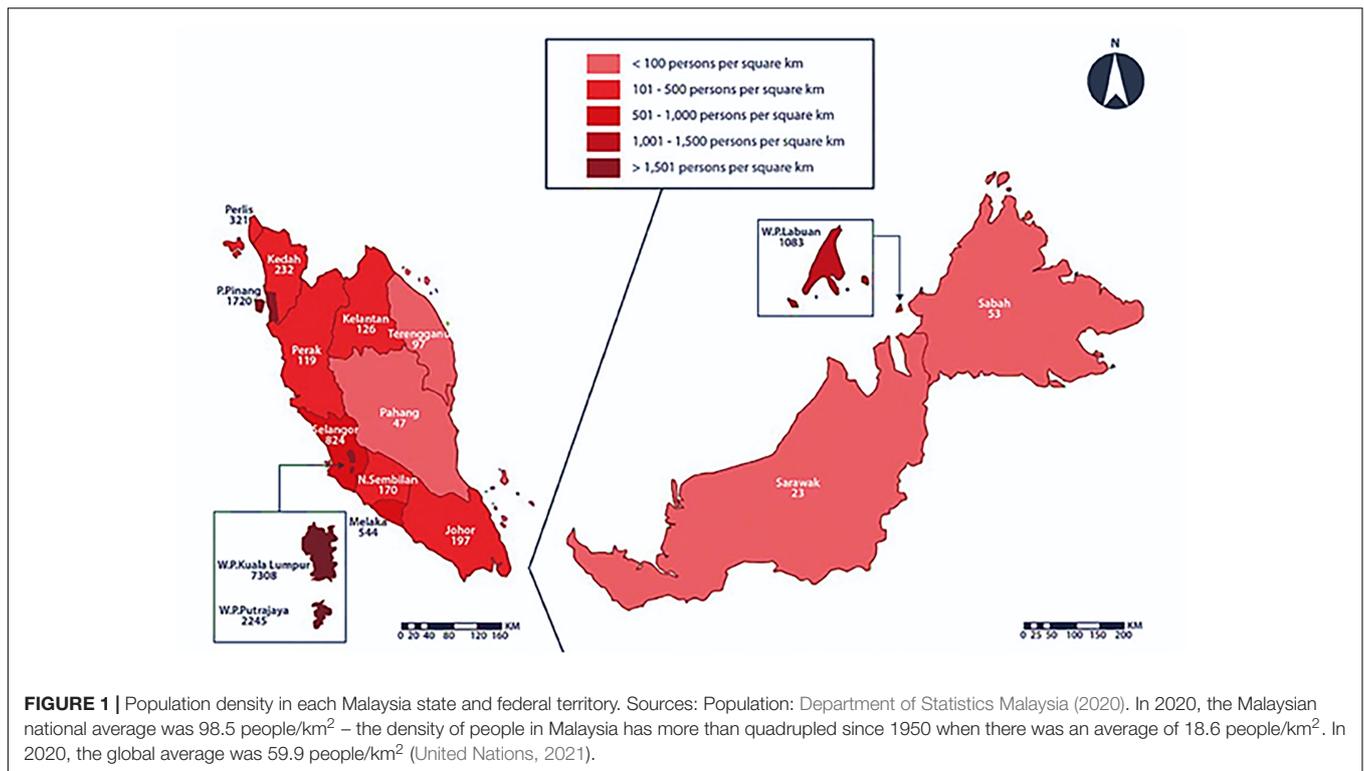
Nature-based Solutions (NbS) encompass a broad range of actions to protect, sustainably manage and restore natural or modified ecosystems that address societal challenges effectively and adaptively, while simultaneously providing human well-being and biodiversity benefits (Cohen-Shacham et al., 2016, 2019). These solutions focus on harnessing the power of nature as a cost-effective answer to broad socio-environmental challenges (European Commission, 2015). The term “NbS” emerged in the late 2000s and has since been used in various international environmental documents and frameworks, with prominence as actions for addressing the climate change and biodiversity loss crises (Li et al., 2021). Additionally, NbS also provide a host of co-benefits including provision of coastal defense to safeguard people and property, support of global economies through enhanced fisheries and tourism activities, improvement of surrounding esthetics, creation of green jobs, and generally increasing the resilience of natural ecosystems to environmental disturbances (Raymond et al., 2017; Giordano et al., 2020). Recently, NbS have been even promoted as sustainable, cost-effective, win-win solutions for countries

designing and implementing pathways to recover from the COVID-19 pandemic. These solutions can do so by creating economic opportunities, employment, and multiple public health and wellbeing benefits (IEEP, 2021).

Despite the simplicity of the NbS concept and their much-touted multiple co-benefits, there remain gaps and barriers in effective uptake and implementation of NbS approaches. Lack of clear definitions, parameters and methodologies had been shown to impact the proper coordination, application, and evaluation of NbS principles (Cohen-Shacham et al., 2019). The lack of communication and cohesiveness among different cross-sectoral stakeholders also complicates uptake and implementation of NbS. At times, state and federal government jurisdictions and legislations contradict instead of complement each other, giving rise to unclear pathways and adding to the complexity of NbS implementation. The issue of funding inadequacy for conservation-based research projects, even more so now under pandemic conditions than before, slows down progress of achieving evidence-based outcomes of nature as solutions to global issues. There are presently very few interventions that have been trialed at a wide geographic scale leading to a lack of confidence that interventions will work under different environmental conditions. In the rare occurrence where these barriers are overcome, the lack of systematic management and long-term monitoring of NbS efforts then need to be addressed to sustain the natural ecosystems and maintain their function over time.

Considered a global biodiversity hotspot (Myers et al., 2000; Hoeksema, 2007; Gaither and Rocha, 2013) with a rapidly growing economy, Malaysia exemplifies the tension between conservation and economic development faced by many developing nations, globally. Malaysia is one of the top three countries with the highest urban populations in Southeast Asia (World Bank, 2020), with many states experiencing rapid increases in population density (Figure 1). Concomitantly, continuous urbanization and land use changes that cater to rising human population needs have led to coastal habitat destruction, and associated biodiversity loss and species extinction (Hezri and Hasan, 2006; Sim, 2019). Malaysians are among the world's top fish consumers with projected annual per capita consumption of 55 kg in 2020 (Goh, 2018), adding further pressure to coastal and marine resources that are already overexploited. Furthermore, the country is home to some of the largest land reclamation megaprojects in the world (Yin and Kwang, 2016; Chee et al., 2017, 2020), with artificial island construction affecting entire ecosystems in several locations around the country. As a result, Malaysia's society is impacted in terms of reduced benefits from coastal and marine ecosystem services (e.g., coastal protection, clean water, culture, esthetics) and increased costs (e.g., restoration efforts, physical displacement, social changes associated with changing patterns of resource use, human-wildlife conflicts) (Masud, 2019).

The 2004 Indian Ocean tsunami, which claimed the lives of over 250,000 people in Southeast Asia and left millions homeless, started a wave of conversations on preparedness for future disasters of this nature and magnitude in Malaysia. The aftermath of the tsunami revealed that areas of Malaysia which



had healthy mangrove forests experienced lower death rates and infrastructural loss than those where mangroves had already been lost due to harvesting or development (Dahdouh-Guebas et al., 2005; Ghazali et al., 2016; Nordhaus et al., 2019). In recognition of the natural protective role of mangroves in Malaysia, post-tsunami action plans included allocating government funding for mangrove rehabilitation, protecting existing mangroves, and forming a National Special Task Force for rehabilitation of coastal forests (Abdullah et al., 2005). As of December 2015, about 2,605 hectares had been restored with more than 6.3 million trees planted to rehabilitate these mangrove forests (Ramli and Caihong, 2017).

In addition to mangroves, the restoration and management of seagrass and coral reef ecosystems play a key role as NbS in Malaysia. All three ecosystems are biologically diverse, highly productive, nurture fish populations, weaken storm surges, and provide numerous other services to coastal communities (Doshi et al., 2012; Friess et al., 2020a; Rahman and Yaakub, 2020). Coral reefs, seagrass meadows, and mangroves have been reported to work synergistically to moderate wave energy, inundation levels, and loss of mud sediments (Zhang et al., 2012; Gillis et al., 2014; van de Koppel et al., 2015). The collective conservation of all three ecosystems together has been shown to supply more protection services than any individual or pair of ecosystems (Guannel et al., 2016; Rooker et al., 2018; Berkström et al., 2020).

Despite the importance of these ecosystems in implementing NbS, the term NbS itself has yet to be used formally within environmental-related policies in Malaysia. The National Policy on Biological Diversity (NPBD) 2016–2025, however, does incorporate NbS aspects in its actions and targets,

e.g., Action 4.3 -Implement Ecosystem Approach to Fisheries Management, Target 6 – Protected Area Target, Target 7 – Vulnerable Ecosystems Target, and Target 8 – Ecosystem Corridor Target. Several other policies like the National Policy on the Environment (Ministry of Science, Technology, and Innovation, 2002), National Green Technology Policy (Ministry of Energy, Green Technology and Water, 2009), and the National Policy on Climate Change (Ministry of Natural Resources and Environment, 2009) have also embedded nature into their goals and principles. Increasing and mainstreaming NbS within national governance, climate action, and biodiversity policy-related instruments are priority actions identified by the UN Climate Change Summit (United Nations, 2019a) and Nature-based Solutions have the potential as enablers to meet the targets under the United Nations Framework Convention on Climate Change.

The urgent need for mainstreaming and uptake of NbS within existing policy and governance frameworks is also due to the cross-cutting nature of NbS in addressing many other environmental issues faced by Malaysia. To justify mainstreaming and uptake of NbS in a cohesive manner, there needs to be formal categorization, standardized evaluation and monitoring methods, and hard evidence for nature-based efforts and their purported effectiveness (Firth et al., 2020). In Malaysia, protection, restoration, and management efforts using coral reefs, mangroves, and seagrass meadows have been carried out to address issues such as flooding, erosion, habitat destruction, and biodiversity loss. Whilst some of these efforts are recorded in peer-reviewed scientific literature, most examples are poorly documented and the results of these NbS are difficult to access,

with many only known from grey literature and verbal claims. Much can be gained from data rescue and reuse from disparate sources to address conservation and policy concerns (Hawkins et al., 2013; Firth et al., 2021). Comprehensive NbS records will allow successful attempts to serve as models that can be replicated in Malaysia and elsewhere, while lessons learned from unsuccessful ones can help avoid similar mistakes in the future.

The overarching objective of this paper is therefore, to collate and assess information on past and current NbS efforts in the marine and coastal environment in Malaysia. We then evaluate the efficacy of each type of application where possible, and articulate the lessons learned. Not only will this baseline inventory help facilitate the mainstreaming and uptake of NbS in Malaysia, but it will also help build the global evidence base for NbS thus, addressing societal challenges in a way that is harmonious with both nature and society.

## MATERIALS AND METHODS

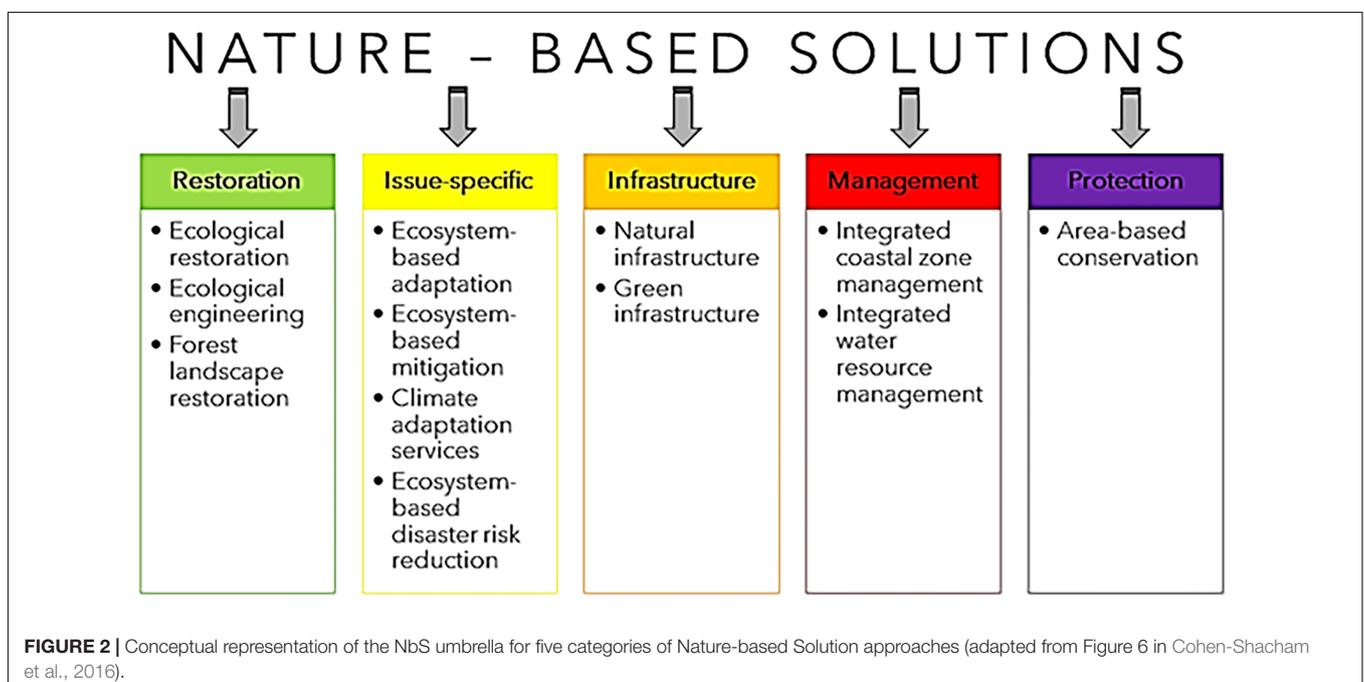
### Study Area

Malaysia, with a population of 32.7 million (Department of Statistics Malaysia, 2020), comprises 13 states and three federal territories that span two non-contiguous regions: West (or Peninsular) Malaysia and East Malaysia (Sarawak, Sabah, and Labuan on Borneo) (Figure 1). Malaysia is part of the Sundaland Biodiversity Hotspot area (Myers et al., 2000) and is ranked 12th globally in terms of its National Biodiversity Index (CBD, 2015). Mangroves forests, seagrass meadows, and coral reefs intermittently line 1,972 km of the Peninsular and 2,828 km of East Malaysia's coastline (MyBIS, 2015). These ecosystems support both high species richness and endemism and are estimated to contain 20% of the world's animal species (Ministry

of Natural Resources and Environment, 2006; CBD, 2019). Some of Malaysia's waters are within the Coral Triangle which is host to 77% of the total recorded marine species in the world (Veron, 1995; Veron et al., 2009; Department of Marine Park Malaysia, 2016). These marine ecosystems provide an array of ecosystem services including provisioning (e.g., food, fresh water, wood, medicine), regulating (e.g., climate regulation, natural hazard regulation, water purification, waste management), supporting (e.g., biomass production, oxygen production, nutrient cycling, provisioning of habitat), and cultural (e.g., spiritual enrichment, intellectual development, recreation, esthetic values) services that are critical to Malaysian citizens (Friess et al., 2020b) and also the biodiversity and ecosystem health of the wider region.

### Categorizing Nature-Based Solutions Efforts

We used the IUCN's universal categorical approaches to organize Malaysian marine and coastal NbS and to ease comparability between approaches and regions (Cohen-Shacham et al., 2016, 2019; Figure 2). The five categories are: (1) Ecosystem restoration approaches which includes ecological restoration, ecological engineering and forest landscape restoration; (2) Issue-specific ecosystem-related approaches which includes ecosystem-based adaptation, ecosystem-based mitigation, climate adaptation services, and ecosystem-based disaster risk reduction; (3) Infrastructure-related approaches which includes natural infrastructure and green infrastructure (combining natural and engineered systems); (4) Ecosystem-based management approaches which includes integrated coastal zone management and integrated water resources management; and (5) Ecosystem protection approaches which includes area-based conservation approaches such as protected



area management. These approaches are employed due to their explicit objectives to ensure sustainable management and conservation of natural ecosystems and natural resources. They also emphasize the complexity and the connectivity of socio-ecological ecosystems, along with their derived ecological goods and services that ultimately can be translated into measurable goals. Notably, NbS efforts can fall under multiple approaches.

## Evidence Synthesis

All co-authors were specifically selected based on their respective expertise that broadly covered the NbS topics relevant to this paper. Collectively, we used a combination of search strategies (published and un-published documents) and expert consultation to collate and build the initial database of efforts that qualify as NbS in Malaysia's marine and coastal environments. Firstly, we conducted a search of publications from June to July 2020 on past and on-going efforts to address coastal erosion, loss of habitat, sea level rise, and climate-related issues that are relevant particularly for the first three categories (ecosystem restoration, issue-specific ecosystem, and infrastructure-related approaches). We used Google Scholar (incognito mode) rather than Web of Science as it casts a broader net and is more likely to capture information from gray literature in addition to peer-reviewed literature. The terms "seagrass," "mangroves," "wetlands" and "coral reefs" together with "Malaysia," "coastal erosion," "habitat loss/destruction," "development," "urbanization," "climate change" and "sea level rise," were used to search for indexed literature without setting publication cut-off date. We then conducted web searches for relevant policy papers, management plans, working papers, unpublished reports, newspapers, and magazines to complement the initial Google Scholar search. For documents that were not available online, we made written requests to procure these in hard copies.

We included in the database an inventory of national or regional policy formulations and management plans which explicitly incorporated NbS aspects in their actions, targets, goals, and principles. Policy-related instruments have been stressed as a key solution to climate change adaptation and biodiversity loss (CBD, 1992; UNGA, 1994). Although government-formulated policies may be cross-cutting and applicable across more than one NbS category depending on degree of implementation (which can be variable across regions and states), we categorized all policy instruments within the fourth category of ecosystem-based management approaches for clarity, simplicity, and consistency.

Protected areas are a key NbS (linked to category 5: ecosystem protection approaches). A shapefile of Malaysian marine and coastal protected areas was retrieved from the World Database on Protected Areas (WDPA; accessed through Protected Planet in March 2021).<sup>1</sup> This dataset consisted of multiple types of spatially-designated protected areas including Marine Protected Areas (designated as such by Malaysia), national parks, state parks, marine parks, forest reserves, turtle sanctuaries, and wildlife reserves. Ramsar sites (from WDPA) and Important Bird and Biodiversity Areas (IBA; supplied upon request by

BirdLife International<sup>2</sup> were included since these designations highlight systems of internationally recognized importance to biodiversity. Though each type of protected area designation confers a different level of protection, we included and classed all of these spatial designations as protected areas; examining level of protection provided is outside the scope of this paper but is a useful future exercise. Using the protected areas shapefile, we first selected all protected areas located in the marine environment as well as those within 5 km inland from the Malaysian coast to capture protected areas containing mangrove forests, which are not systematically designated as "marine." All protected areas were then manually screened, and areas not containing coastal or marine ecosystems were omitted. For example, the Sungai Menyala Forest Reserve is located within 5 km of the coast, but is predominantly freshwater wetlands with no coastal ecosystems, and so has been excluded from this assessment. In instances where a protected area did not contain coastal or marine ecosystems (such as Silabukan Virgin Jungle Reserve) but is spatially entwined and therefore managed together with an adjacent protected area that does contain coastal and marine ecosystems (such as Silabukan Protection Forest), both were jointly included in the assessment. Some sites, such as Tioman Island ("Pulau" in Malay), had multiple restoration projects which are recognized as separate NbS efforts in **Table 1** and **Supplementary Table 1**.

To complement the search results, we also relied on available raw data provided generously by co-authors and their networks. From all the documentation and raw data collated, the following information was extracted and recorded for each NbS effort where available: objectives, methodology, location, areal extent, photographic images, anticipated outcome, actual outcome, and overall implementation costs. The efforts were also reviewed for enablers that attributed to their "success," defined in this review as having reached its stated objective, or barriers attributed to their "failure," here defined as not having reached its stated objective. These enablers and barriers were synthesized as the basis for the "Lessons learned and way forward" section below. There were obvious data gaps in the process of extracting relevant information, particularly on anticipated outcome, actual outcome, and barriers/enablers to failure/success. To address these gaps for selected NbS efforts, we reached out to experts and relevant project leaders for their inputs and insights. All extracted information on each effort, including that from experts, was aggregated into an Excel database (**Supplementary Table 1**). All NbS efforts in the database were assigned to one or more categories of NbS approach as defined by the IUCN (as detailed above) and their spatial distribution across Malaysia was synthesized in a map with summary statistics.

## RESULTS AND DISCUSSION

A total of 229 efforts related to using marine ecosystems as nature-based solutions was identified across the thirteen states and federal territories of Malaysia (**Table 1**; see

<sup>1</sup><https://www.protectedplanet.net/en>

<sup>2</sup><http://www.birdlife.org/>

**TABLE 1** | Summary of case studies categorized according to IUCN NbS approaches.

IUCN NbS approach	Number of NbS efforts	NbS efforts	References
Ecosystem restoration approach	12	1–12	Tamin et al., 2011; Syed, 2016; Chen et al., 2018; Yap, 2019; YTL Group, 2019; Saleh et al., 2020; Versteeg, 2020 <a href="https://tracc.org/www.reefcheck.org.my">https://tracc.org/www.reefcheck.org.my</a>
Issue-specific ecosystem approach	6	11, 13–17	AM18013 Grant Report; Miki, 2019 <a href="http://www.reefcheck.org.my">www.reefcheck.org.my</a>
Infrastructure-related approach	3	13–15	Joibi, 2018 <a href="http://www.reefcheck.org.my">www.reefcheck.org.my</a>
Ecosystem management based approach	86	18–103	Pedersen et al., 2005; Ministry of Science, Technology, and Innovation, 2002; Azman et al., 2008; Teh et al., 2008; Ministry of Natural Resources and Environment, 2006, 2014, 2016; WWF, 2009; Ramsar Convention Secretariat, 2010; Manaf et al., 2011; Ooi et al., 2011, 2017; PLANMalaysia, 2011; Reef Check Malaysia, 2011; Islam et al., 2013, 2017; Economic Planning Unit, 2016; Department of Statistics Malaysia, 2018; Albotoush and Tan, 2019; Lai, 2019; Mokhtar et al., 2019; Sabah Wetlands Conservation Society, 2019; Forestry Department of Peninsular Malaysia, 2020; The Borneo Post, 2020
Ecosystem protection approach	205	13, 18–95, 104–229	Gan, 1995; Chong, 2006; Teh et al., 2008; Reef Check Malaysia, 2011; Islam et al., 2013, 2017; Ministry of Natural Resources and Environment, 2014; Tangah et al., 2015; Sabah Wetlands Conservation Society, 2019; Forestry Department Sarawak, 2020; Johor National Parks Corporation, 2020 World Database on Protected Areas, WDPA; accessed through Protected Planet in March 2021 <a href="https://www.protectedplanet.net/en">https://www.protectedplanet.net/en</a> <a href="http://www.birdlife.org/">http://www.birdlife.org/</a>

Details to each case study can be found in **Supplementary Table 1**.

**Supplementary Table 1** for cross-referencing of codes used below). The earliest effort was carried out in the mangroves of Matang (E114) in 1906 (Shukor, 2004; Yeap et al., 2007; Jusoff and Taha, 2008) indicating that although not specifically termed NbS (the term only emerged in the 2000s), marine and coastal ecosystems have been used as solutions to address pressing environmental challenges in Malaysia for at least 115 years. Geographically, more efforts were recorded in East (115 efforts) than Peninsular Malaysia (107) (**Figure 3**), where human population densities are generally low (except Labuan, **Figure 1**). Seven national and one regional policy and management efforts were identified; these all fell under ecosystem-management based approaches (**Figure 3** inset). The highest number of NbS efforts were of the ecosystem protection type (205), followed by ecosystem-management based approaches (86), ecosystem restoration approaches (12), issue-specific ecosystem approaches (6), and infrastructure-related approaches (3). Many NbS efforts (82) qualified for multiple NbS categories.

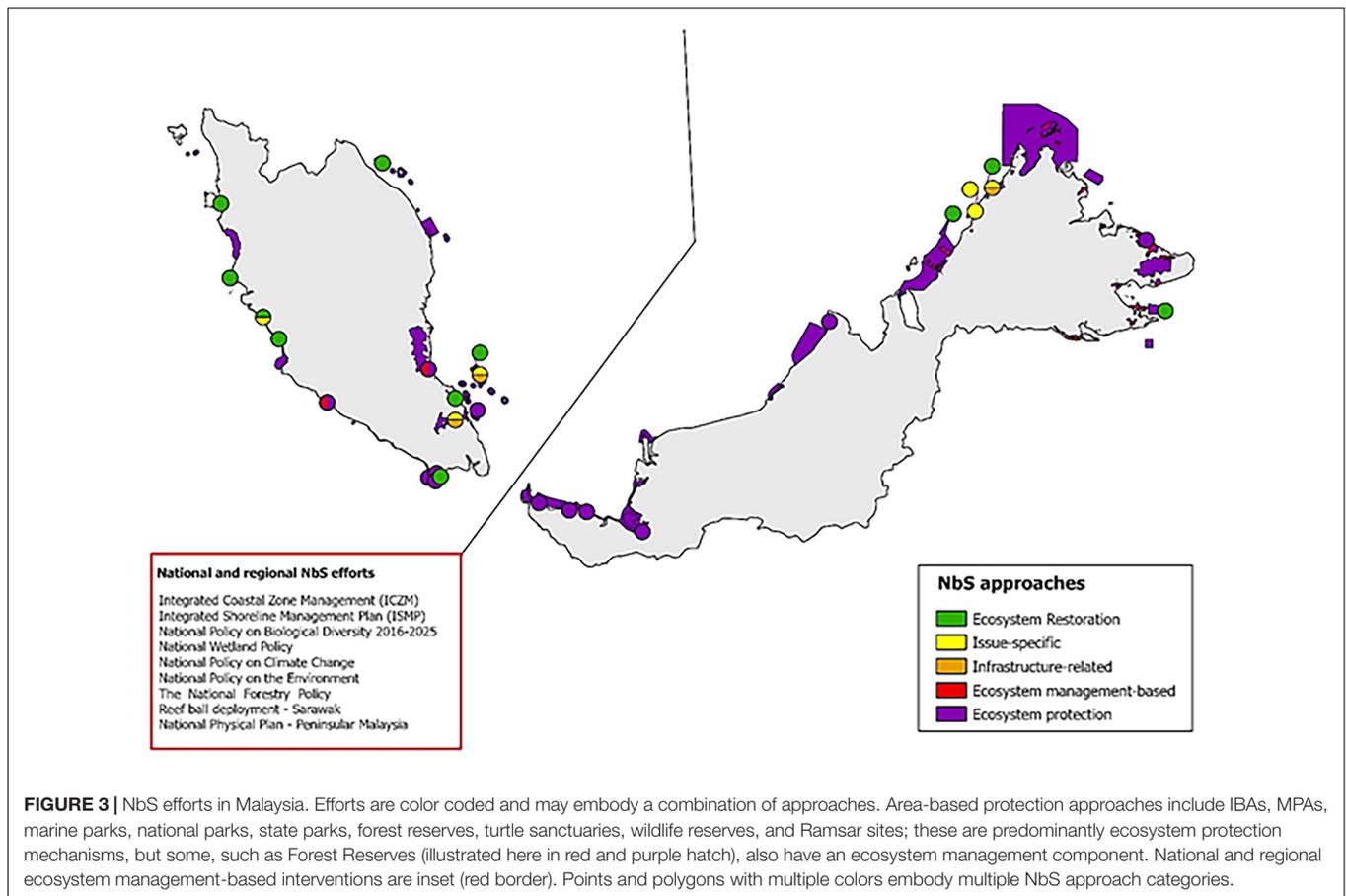
## Ecosystem Restoration Approaches

Twelve out of 229 efforts (5.2%) qualified as ecosystem restoration approaches (**Supplementary Table 1**, E1–12). Of these, seven were applied to coral reefs (E4–10), three to mangroves (E3, 11 and 12), and two to seagrass meadows (E1 and 2). Coral reef restoration efforts in Peninsular Malaysia were executed for different reasons than those in Sabah. In Peninsular Malaysia, three efforts were carried out within marine parks to address physical damage to corals due to tourism-related impacts (i.e., diving, anchor damage from boating) and strong wave action (E7, 8, and 9) with the objectives of building ecological resilience, creating awareness, and promoting tourism. In Sabah, reef restoration efforts outside of marine parks were carried out to build ecological and social resilience

and address damage caused by destructive fishing practices (i.e., fish bombing) (E4 and 6). Mangrove restoration was conducted to rehabilitate eroded coastlines and degraded mangroves previously cleared for aquaculture activities (E3, 11, and 12). Seagrass restoration was used to restore seagrass meadows degraded by natural and anthropogenic drivers including loss from land reclamation (E1 and 2).

A variety of transplantation methods, ranging from conventional to innovative, fell within this approach. Innovative methods involved the introduction or ecological engineering of additional engineered structures, for example geotubes were installed to slow erosion and allow higher success rates in mangrove transplantation in Selangor (E11) (Tamin et al., 2011; Motamedi et al., 2014). Another innovation involved the development of recycled glass-cement structures to aid coral reef transplantation in Terengganu and Pahang (E7 and 9) (Chen et al., 2018). Some efforts were conducted at small spatial scales (0.002–0.003 ha) (E4 and 6) without replication, while others were conducted at larger scales (>2 ha) or in multiple replicates of various scales, e.g., all around Pulau Tioman (E9).

In efforts ( $n = 4$ ) where we were able to evaluate actual outcomes, 50% did not achieve their stated objectives, 25% yielded successful outcomes, whilst another 25% reported mixed outcomes. In one effort where mangrove restoration failed [i.e., in Sungai Haji Dorani, Selangor (E11)], the use of inappropriate species was thought to be the cause (S. Y. Foong, Personal Communication), as is often the case for failed restoration efforts, globally (Bayraktarov et al., 2016). Species like *Rhizophora mucronata*, *Sonneratia alba*, and *Avicennia alba* are tolerant to high frequency water inundations, whereas *Bruguiera gymnorrhiza*, *Lumnitzera* spp. and *Exoecaria agallocha* are less tolerant to inundation (Watson, 1928; Marchand et al., 2008). Therefore, choice of appropriate species for restoration, coupled



with appropriate ecological understanding of the degraded site, is pivotal, exemplifying the need for communication with experts or local communities to ensure success. Conversely, in the effort where mangrove restoration was perceived to be successful, i.e., at Sungai Semilang, Penang (E12), the use of larger, mature saplings for replanting was thought to contribute to successful mangrove establishment (Abbot and Marohasy, 2014). Success rates are reportedly higher with mature trees compared to transplanting younger trees (Pryor and Watson, 2016). However, this is highly species dependent as large trees may have higher mortality even though they may establish faster than small trees (Struve et al., 2000).

Where seagrass restoration efforts failed (E2), strong water currents from monsoons were cited as the main contributing factor (Yap, 2019). Whether stochastic or periodic, high wave energy such as those brought about by monsoons in Malaysia, can either mobilize sediments that bury seagrass or erode planted areas (van Katwijk et al., 2016; Yap, 2019). This is especially true for young meadows that have not yet reached sufficient abundance or fully taken root to overcome the disturbance. Therefore, sediment stabilization plays an important role, in addition to other parameters like appropriate light levels, keeping sediment and sprigs in place and preventing them from being swept away by strong currents and waves (van Kuelen et al., 2003; Lanuru, 2011).

## Issue-Specific Ecosystem-Related Approaches

Six out of the 229 NbS efforts (2.6%) qualified as issue-specific ecosystem-related approaches (**Supplementary Table 1**, E11, 13-17). Two of these efforts were carried out to address the lack of a co-management system in marine protected areas (E14-15).<sup>3</sup> Specifically, stakeholders were brought together to manage the coral reefs and protect resident marine species on the islands of Sibutu-Tinggi (Johor) and Tioman (Pahang).

The effort on Pulau Tioman in particular, aimed at establishing a long-term functioning coral reef co-management and conservation system (E14). The project costed USD146,514 (see text footnote 3). The other two efforts were carried out to offset the impacts from planned developments in Sabah (E16 and 17). In these efforts, seagrass sprigs were translocated from planned development areas to Sepanggar Bay and to ODEC Beach in two separate projects (E16 and 17) (Miki, 2019). Each translocation project cost USD700 for areas between 100 to 150 m<sup>2</sup>. Sprig translocation was partially successful in Sepanggar Bay but did not meet expected outcome of self-sustainable seagrass ecosystem in ODEC beach due to stunted growth and uprooting events from strong waves and wind (Miki, 2019). In this effort, ecologically engineered habitat enhancements

<sup>3</sup>www.reefcheck.org.my

(e.g., seagrass planters or wave barriers made from upcycled materials) could be positioned strategically to attenuate wave and wind forces so that the sprigs can take root (T.K. Yap, Personal Communication).

One of these efforts, E11, was mentioned under the ecosystem restoration approach demonstrating how efforts using nature as solutions can qualify for multiple categories. This effort also aimed to solve the issue of erosion in Sungai Haji Dorani, Selangor (Tamin et al., 2011).

## Infrastructure-Related Approaches

Three out of the 229 NbS efforts (1.3%) qualified under infrastructure-related approaches (**Supplementary Table 1**, E13-15) as well as under other approaches mentioned earlier. The breakwaters used to restore mangroves (Motamedi et al., 2014) and the recycled glass-cement structures used to restore coral reefs (Chen et al., 2018) qualify as both ecosystem restoration and infrastructure-related approaches. These examples of green infrastructure incorporate both the natural environment and engineered systems to conserve ecosystem values and functions and reportedly provide a wider array of benefits to people and nature, than hard engineered structures alone. As mentioned previously, the breakwater structure did not achieve its anticipated outcome, likely due to the use of inappropriate mangrove species. This suggests that the use of appropriate species in an NbS effort carries more weight in determining the success of the approach than provision of infrastructural support.

## Ecosystem-Based Management Approaches

Eighty-six out of the 229 efforts (37.6%) qualified as ecosystem-based management approaches. These were implemented either at state, regional, or national levels (**Supplementary Table 1**, E18-103). Forest reserves constituted the highest number of efforts (78) within this approach followed by national and regional policies and plans (8). Integrated Coastal Zone Management (ICZM) (E96) is a planning framework used worldwide to reconcile conflicting cross- and intra-sectoral uses of the coastal area and to ensure sustainability of coastal resources. In response to the multiple challenges faced by Malaysia's coastal regions (reviewed by Abdullah, 1999) and to strengthen federal and state cooperation, ICZM was adopted firstly as a pledge within the 8th Malaysia Plan (Mokhtar and Aziz, 2003). While a national ICZM policy has yet to be formalized, ICZM pilot projects had reportedly been undertaken in three states - Sarawak, Sabah, and Penang. The implementations faced challenges in Penang where issues such as overlapping jurisdiction, lack of clear legislation, and assumed favor of profit (from coastal reclamation projects) over conservation hampered efforts (Pedersen et al., 2005; Albotoush and Tan, 2019).

The Integrated Shoreline Management Plan (ISMP) (E97), implemented by the Department of Irrigation and Drainage (DID), uses ICZM principles to focus on shoreline issues within the 4 km coastal fringe that extends 1 km inland and 3 km offshore (Mokhtar et al., 2019). Here, we treated ISMP and ICZM efforts separately. In Penang, the ISMP helped to address many

vital coastal management issues such as the loss of mangroves, overexploitation of coastal fisheries and poor water quality (NRE and PKSD, 2010; Albotoush and Tan, 2019).

The National Physical Plan (NPP) (E103), approved in 2005, is the country's strategic spatial planning policy for determining the direction of the physical development of Peninsular Malaysia. Clear principles and strategies on coastal spatial planning and developments along the Peninsular Malaysia coastline were outlined (NPP-CZ; Mohamad et al., 2018). These principles have guided coastal developments including large-scale reclamation projects in Melaka (Ishak et al., 2016) as well as flooding mitigation in Klang and Kuala Langat, Selangor (Mohamad et al., 2018). The NPP is currently undergoing the third revision for the fourth version and is expected to be launched by end of 2021.

Other national policies also qualify under the ecosystem-based management approach. The National Policy on Biological Diversity (NPBD) (2016–2025) (E98) was formed to address pressures that threaten the biodiversity in Malaysia including habitat fragmentation, invasive species, pollution, poaching, increasing competition for land, and climate change (Ministry of Natural Resources and Environment, 2016).

The National Wetland Policy (Ramsar Convention Secretariat, 2010) (E101) aims to ensure conservation and wise use of wetlands (including seven Ramsar sites), as well as fulfill Malaysia's obligations under the Ramsar Convention. The policy's objectives include protection and conservation of different types of wetlands, integration of wetlands conservation interests into overall natural resource planning, increase scientific and technical knowledge and public appreciation of wetlands functions and benefits; and restoration of degraded wetlands (Ministry of Natural Resources and Environment, 2014). Wetland protection remains challenging due to disconnects with land use policies which is designed for development of land resources and therefore provides a legal standing to convert wetlands to agricultural and residential use (Olorunfemi, 2017).

The National Policy on Climate Change (Ministry of Natural Resources and Environment, 2009) (E99) aims to provide a framework to mobilize and guide government agencies, industry, and local communities, as well as other stakeholders in addressing climate change challenges in a holistic manner. Actions include harmonizing existing legislation, policies and plans related to coastal and marine natural resources as well as to land use and land use change (including land reclamation); incorporating climate change as priority area in national development planning; and establishing inter-ministerial and cross-sectoral committees to enable implementation of climate change measures (Ministry of Natural Resources and Environment, 2009). This policy has been embedded into local development plans in Shah Alam City, Selangor, to mitigate flooding (Perera and Khailani, 2017) and enhancing fishermen's access to credit to adapt to climate change (Shaffril et al., 2017).

The National Policy on the Environment (Ministry of Science, Technology, and Innovation, 2002) (E100) fosters economic, social, and cultural progress and to enhance the quality of life of Malaysians via environmentally sound and sustainable development. This policy protects the marine environment by promoting active stewardship and sustainable resource use, and

bolstering improvement in the quality of the marine environment (Ministry of Science, Technology, and Innovation, 2002). In 2020, the policy was reviewed to address pending issues concerning the marine environment including marine debris and plastic pollution and this would include a revision of this policy (Bernama, 2020).

Finally, the National Forestry Policy (E102) protects forests, including those found in coastal areas such as mangroves (Forestry Department of Peninsular Malaysia, 2020). The policy supports regeneration and rehabilitation of forests, protection of biodiversity and preservation of unique flora and fauna, promotion of forestry education and scientific research, and forging of international cooperation for shared benefits through technology transfer and exchange of scientific information. For example, the Matang Mangrove Forest Reserve has management objectives such as shoreline protection from coastal erosion, to assure functionality of the forest as breeding/nursery ground and wildlife habitat, and as support for forest conservation, research, education, and ecotourism (Azahar and Nik, 2003; Chong, 2006; Goessens et al., 2014).

Many of the aforementioned policies and plans are ongoing but there has been limited information on implementation status, save for the National Policy on Biodiversity 2016–2025 – to which progress was reported in the 6th National Report to the Convention on Biological Diversity.

## Ecosystem Protection Approaches

Two hundred and five out of the 229 NbS efforts (89.5%) qualified under ecosystem protection approaches (E13, 18–95, 104–229). These spatially protected areas are designated by different legislation or regulations (Islam et al., 2017) but can all be broadly classed as Marine Protected Areas (MPAs). They include 78 forest reserves, 42 no-take marine parks, 18 Important Bird and Biodiversity Area (IBAs), 17 wildlife reserves, 12 national parks, ten state parks, seven turtle sanctuaries, six Ramsar sites, five fisheries prohibited areas, five nature reserves, one nature park, one designated MPA, and one sea cucumber protection area (**Supplementary Table 1**). In general, the activities conducted in these areas (if permitted) are restricted to prevent degradation of marine ecosystems, although the level of protection varies (Kamil et al., 2017). Some key MPA efforts are discussed in detail below.

To protect mangrove and other key ecosystems, 78 coastal and marine forest reserves have been gazetted in Malaysia (E18–95). These reserves are part of the country's Permanent Forest Reserve and are managed by Forestry Departments in respective states that provide general supervision and policy guidelines in the management, conservation, and preservation of these reserves (Shukor, 2004). The Matang Mangrove Forest Reserve in the state of Perak is globally recognized as the best example of a well-managed mangrove forest reserve on a sustainable basis in Malaysia (Chong, 2007). Contrastingly, many other forest reserves have reported a decrease in mangrove forest area (Latiff, 2012). The Klang Islands Mangrove Forest Reserves, Selangor, for example has been declining in biomass due to degazettement, land reclamation, oil pollution, and coastal erosion (Norhayati et al., 2009), questioning the effectiveness of forest reserves in protecting these ecosystems.

Malaysian marine, national, and state parks are established with the goal of conserving and managing significant marine ecosystems so that they remain undamaged for future generations. Water quality and esthetics in sensitive areas of the world-renowned diving destination, Pulau Sipadan (Sipadan Island), have improved after the area was established as a state park in 2004 (Musa, 2003; Kamil et al., 2017). The establishment of MPAs have been effective in building ecological and social resilience in places like Pulau Tioman Marine Park (E164). Local stakeholder involvement is a key feature of Pulau Tioman Marine Park. *Cintai Tioman* is a long-term program which has introduced a co-management approach and management plan involving local stakeholders in conservation and marine resource management. Additionally, Tioman Marine Conservation Group is responsible for ghost net removals and maintenance of reef rehabilitation sites (Reef Check Malaysia, 2020). Lack of community involvement in many other MPAs had been cited as one reason for their ineffectiveness (Rahman et al., 2019).

Malaysia is also a party to the Ramsar Convention on Wetlands that provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources (Cohen-Shacham et al., 2016). Of Malaysia's seven Ramsar sites (E189–194), six are mangroves (Ong, 2017). Strict conservation rules restricting public access to Ramsar sites such as Pulau Kukup, Johor, have improved the ecological integrity of the mangrove island, with little negative impact on the locals. Although restrictions in access may be a trade-off for local communities wanting to pursue cultural activities, tourism linked to the island's Ramsar designation has boosted the local economy (Barau and Stringer, 2015). The establishment of Ramsar sites have also resulted in a sustainable approach in tourism development in Johor involving careful decision-making and planning of tourism activities to conserve the mangroves there (Aminu et al., 2013). However, it has also been reported that the existence of Ramsar sites had not prevented some large-scale reclamation of these sites (Bernama, 2019).

Out of 55 Important Bird and Biodiversity Areas (IBA) in Malaysia, 18 of these are in coastal areas (E109–126) (Yeap et al., 2007). Coordinated internationally by BirdLife International and locally by Malaysian Nature Society (MNS), the IBA program identifies and promotes coherent and organized action for priority sites for birds and biodiversity at the regional, national, and local levels. These areas are known to regularly support significant numbers of (i) globally threatened, (ii) restricted-range, (iii) biome-restricted, and/or (iv) congregatory bird species (BirdLife International, 2020). In Tanjung Tuan, Melaka (E124), the IBA secures migration routes of 37,615 migrating raptors from eleven species – one of the highest proportions of migratory raptors along the East Asian–Australasian Flyway (Puan et al., 2014). IBAs could form the basis of future protected areas.

Each of these ecosystem protection efforts aims to promote conservation and wise use of natural marine ecosystems. However, protection status is not a long-term guarantee especially in the case of state parks (e.g., the degazettement of Pulau Kukup by the Johor state government in 2018).

Additionally, it has been reported that encroachment (Noh et al., 2018), illegal development (Hashim et al., 2019), deforestation caused by agriculture (Hezri and Hasan, 2006; Hamdan et al., 2016; Sarmin et al., 2016), aquaculture (Hamdan et al., 2016; Sarmin et al., 2016), urban expansion (Aisyah et al., 2015; Islam et al., 2017; Hashim et al., 2019), pollution and excessive tourism activities (Sarmin et al., 2016; Islam et al., 2017), and mass tourism (Hashim et al., 2019) have endangered the biodiversity in many of these areas. These factors attributed to weaknesses in the implementation of management plans (Pourebahim et al., 2015; Marzukhi, 2020) which is now adding pressure for Malaysia to move toward a more sustainable future.

## LESSONS LEARNED AND WAY FORWARD

The number of NbS efforts in each IUCN category varied widely, with, for example, 89.5% of the 229 Malaysian NbS efforts categorized as “ecosystem protection approaches,” with only 1.3% categorized as “infrastructure-related approaches” and only 2.6% as “issue-specific ecosystem-related approaches.”

The lack of funding may likely be the reason for the low percentage of “infrastructure-related approaches” and “issue-specific ecosystem-related approaches.” Funding is usually limited and often insufficient for governmental organizations to carry out infrastructure building or to address particular specific issues (e.g., E16 and 17 in this study), while allocations to non-governmental organizations only allow for small-scale efforts. In addition, there are often complications in gaining approval to build infrastructure (e.g., environmental impact assessments, government approvals for infrastructure planned for government-owned land and approvals from private entities to build infrastructure privately-owned land). The lack of awareness and initiative to explore and embark on new technologies among policymakers and practitioners could also have contributed to low percentages in some of the approaches. More often than not, stakeholders tend to fall back on affordable and familiar practices which are less risky and more predictable in their outcomes (T.K. Yap, Personal Communication). Finally, each individual MPA was considered a single NbS effort, which contributes to the relatively high number of efforts linked to category 5 ecosystem protection approaches.

From the NbS efforts collated in this study and from the evaluation of success or lack thereof for each type of approach, we summarize below key lessons learned and way forward for advancing future uptakes of NbS (Figure 4). Although these findings are based on the Malaysian case study, lessons drawn are relevant and applicable, globally.

### Appropriate Application of Targeted Knowledge

Informed application of both scientific and local knowledge is important in increasing probability of success in NbS efforts. In Pulau Pom Pom, Sabah (E6), deployment of artificial modules using both local knowledge and scientific

expertise ultimately contributed to a fivefold increase in marine biodiversity of the reefs, likening them to natural reef biodiversity levels.<sup>4</sup> Specifically, local knowledge on how to provide structural strength and stability to the substrate where corals are transplanted and rigorous scientific testing showing that larger coral fragments used yielded higher survival rates than smaller fragments.

In the case of mangrove replanting in Seberang Perai Tengah, Penang (E12), local ecological knowledge about using older mangrove saplings led to successful rehabilitation. The older tree saplings took root faster than younger saplings, improving their hold on soft, muddy sediments preventing them from being washed away by strong waves and currents (S.Y. Foong, Personal Communication).

Careful choice of site and timing for NbS application is equally important for NbS to result in positive outcomes. Site characteristics like the areal extent, soil type, wave climate, and availability of similar species in the vicinity, need to be considered for the ecosystem used in NbS (Sarabi et al., 2020). For heavily developed coastlines, like the east coast of Penang Island, these considerations are even more critical due to space limitation and reduced connectivity among patches, limiting self-recruitment or species dispersal (Chee et al., 2017). It is important to recognize when available spaces may not be ideal for certain NbS efforts. This is apparent from some seagrass efforts where selected sites constantly bore effects from strong waves and other harsh environmental conditions (Miki, 2019).

To increase confidence in the functionality of solutions and to provide support for NbS uptake, education and capacity building programs for stakeholders including citizens and professionals, should be prioritized, and up-scaled (Figure 4; Davies and Laforteza, 2019; Sarabi et al., 2019). Formal education in classrooms and informal education through the media, internet, and tourism opportunities can facilitate uptake of NbS (Chen et al., 2019). Online repositories of NbS efforts, with transparent documentation of successes and failures, can enable sharing of knowledge and experiences, access to feedback and professional consultation, incorporation of citizen knowledge, mapping of NbS issues, and showcasing of best practices in implementing NbS (Faivre et al., 2017)<sup>5,6</sup>; such efforts will aid in assessment of NbS effectiveness and trade-offs for better decision making (Bayraktarov et al., 2016; Firth et al., 2020; Seddon et al., 2020) and may in turn promote future investments in natural infrastructure (van Ham and Klimmek, 2017; Airoidi et al., 2021).

### Multiple Stakeholder Engagement, Partnerships, and Communication

High levels of community involvement and buy-in are also important enablers in increasing probability of success in NbS efforts. Community engagement programs such as *Cintai Tioman* (E14) encouraged local stakeholders on Pulau Tioman, Pahang, to connect with conservation organizations and participate in their coral reef protection activities enabling

<sup>4</sup><https://tracc.org>

<sup>5</sup><https://www.think-nature.eu/>

<sup>6</sup><https://oppla.eu/about>



**FIGURE 4 |** To increase application and uptake of NbS in Malaysia and elsewhere, scientific and local knowledge should be shared through education and training programs to increase the probability of success of NbS efforts; jurisdictions, legislations, and regulations should be rationalized or standardized to eliminate contradictions and close gaps; long-term, sustained observations should be used to monitor the success of NbS efforts; existing policies should be strengthened and made more inclusive of NbS; communication and collaborative efforts among all stakeholders should be strengthened to best use resources and facilitate ecosystem stewardship; and funding for NbS schemes should be sufficient and consistent.

sustainability of this program beyond its establishment (Joibi, 2018). Similarly, Kepulauan Sibul-Tinggi, Johor (E15), has a Community Consultative Committee that functions as a core management platform for the community to express opinions about development projects to State and Federal agencies (United Nations, 2019b). Such community-focused initiatives help build ecological and social resilience (Reef Check Malaysia, 2015) and empower the community members to be involved directly in these NbS efforts.

Collaborative management of Marine Protected Areas has been explored, particularly in the state of Sabah (CBD, 2019). For example, Reef Guardian Sdn. Bhd. – a private entity, has been appointed by the Sabah State Government to manage the 46,317 ha Sugud Islands Marine Conservation Area (SIMCA) situated within the Coral Triangle and Sulu-Sulawesi Tri-National Sea Turtle Corridor. The company has been entrusted to enforce regulations in SIMCA, implement marine conservation efforts, and promote education and awareness in return for the right to operate tourism facilities on the island. This collaborative effort has shown a reduction in cases of encroachment into the protected areas. For Tun Mustapha Park, the second largest marine park in Malaysia, Sabah Parks have appointed Honorary Wildlife Wardens from local communities to assist in patrolling the protected waters (WWF, 2008).

Successful partnerships allow for effective communication of scientific knowledge and experiences between different

experts and decision makers, thus allowing for high-quality decision-making. In the case of Malaysian IBAs, consistent communication between experts and decision makers from relevant ministries was the key enabler for their general success (C.E. Tan, Personal Communication). Continuous adherence to standardized methodology of IBA assessment, coupled with updated expert communication of current IBA conditions with top-level decision makers of these areas, collectively enabled their protection from encroachment and human activities (C.E. Tan, Personal Communication). Benefits of communication and co-decision making were also demonstrated in the case of Ramsar sites where the federal government decided that it will no longer consider approval for pre-development environmental impact assessments (EIA) on Ramsar sites, thereby safeguarding these sites from future development (Bernama, 2019).

For international efforts, partnerships with local organizations were important. The IBA program initiated by BirdLife International ([www.birdlife.org](http://www.birdlife.org)) in partnership with a local organization, the Malaysian Nature Society for example, enabled nationwide monitoring of the biodiversity and status of wetland IBAs through an annual census. The partnership helped strengthen the conservation and protection of several wetland IBAs primarily in Bako-Buntal Bay (Sarawak), Teluk Air Tawar-Kuala Muda coast (Penang), Matang coast (Perak), and the north-central Selangor coast (Selangor) (C.A. Yeap, C.E. Tan, Personal Communication). Similarly, stakeholder collaborations

between the Sarawak state government and Sarawak Forestry Corporation enabled coral rehabilitation using reef balls in Sarawak (Lai, 2019; *The Borneo Post*, 2020). This collaboration has kept illegal trawlers out of key marine habitats so that corals and other marine species can grow and reproduce. As a result, fish catches have increased significantly (E. U-H. Sim, Personal Communication) and resulting in increased income for local fishermen.

As NbS are multifunctional solutions that cut across multiple disciplines and institutions (Davis and Naumann, 2017; Frantzeskaki et al., 2017; Seddon et al., 2021), there is a need to strengthen communication and collaborative efforts among all stakeholders including local communities, government agencies, NGOs, private sectors, and academic institutions (**Figure 4**). Each of these entities has its own strength in terms of technical expertise, financial capacity, knowledge on policy, and local knowledge. Communication and collaboration among these groups can encourage trust, while facilitating ecosystem stewardship (Rusli and Lee, 1999; Muhammad et al., 2017; Waris et al., 2019). Citizens can empower the NbS planning and management process by contributing local knowledge, which can substantially increase the likelihood of a successful NbS outcome for instance, providing citizen science data to map different conservation zones for marine protected area (Lau et al., 2019; Rahman et al., 2019). Communication between academia and industry can produce various benefits via the enhancement of research and innovation through joint research projects and delivery of innovative commercial products. Private sectors can offer support by sharing their experiences and knowledge in project implementation as well as through the contribution of financial resources. Public-private partnerships can combine the top-down regulation of the government sector with the flexibility of the private sector (Rahman et al., 2019). Partnerships between businesses and other stakeholders can showcase the potential and value of NbS for economic prosperity and human well-being. For NbS to bridge different disciplines and institutions, inclusion is pivotal (Frantzeskaki et al., 2017) and sometimes, knowledge brokers (e.g., WWF, Wetlands International) will need to be appointed to develop a shared understanding of NbS and their benefits as they can speak the language of different groups and connect them with one another (Sarabi et al., 2019).

## Streamlining of Nature-Based Solutions Policy and Cooperation Across Jurisdictions, Legislation, and Regulations

Mainstreaming of NbS within a coherent framework is an important step forward for countries like Malaysia where governance of natural resources are often confined to respective sectors; and jurisdiction for biodiversity divided between federal and state governments as provided by the Federal Constitution. NbS efforts conducted “in silos” can be a major impediment to their sustainability (Jomo and Wee, 2003; Kangayatkarasu, 2018). Depending on scale, NbS efforts may involve actions in multiple habitats that transcend jurisdictional boundaries (Seddon et al., 2020). For instance, mangrove reserves come

under the state Forestry Department, while all mangrove habitats outside reserve boundaries largely come under the state Lands and Mines Department, which has limited capacity to manage these environments (Rahman et al., 2019). Additionally, not all mangroves are categorized as reserves; some are outside Forestry Department remit and fall into a legislative gap when it comes to management and conservation. Similarly, in ICZM, overlapping jurisdiction and lack of legislation that directly addresses coastal zone management also exists and this affects the performance of different departments within the federal government (Pedersen et al., 2005; Albotoush and Tan, 2019).

Given the extensive amount of NbS efforts and opportunities for national climate mitigation and adaptation strategies, policy amendments could explicitly include recognition of NbS and mainstreaming of the climate change agenda. Such amendments should be included alongside policy integration across multiple tiers of government, the closure of policy loopholes that disincentive protection of existing NbS efforts, policy reforms toward decentralization, and co-management of NbS efforts. National and state policies need to be aligned to provide supportive institutional settings where short-term state-wide objectives are aligned with long-term national goals (Sarabi et al., 2020).

Due to the dichotomy in jurisdiction on natural resource use (Reef Check Malaysia, 2019), state and federal governments may have conflicting priorities which, in turn, can potentially affect the success of NbS implementation. Therefore, cooperation and coordination of the offices involved needs to be strengthened to close disparities that may affect decision-making and subsequent outcomes. Ideally, actors at the local level such as municipal councils, and those at the national, regional, and international levels, should provide supportive and clear legislation (Sarabi et al., 2019). Cooperation through decentralization of power and upgrading national and municipal regulations may also support nationwide efforts (Hezri and Hasan, 2006; Loh, 2010). Supportive regulatory arrangements will also promote compliance and collaboration between private and public entities (Islam et al., 2017; Sarabi et al., 2020).

## Implementation of Sustainable Finance Instruments

Inadequate and intermittent funding was cited as one barrier to the upkeep of MPAs and other NbS efforts such as mangroves (Teh et al., 2008; Lahasing et al., 2015). Sole reliance on governmental and municipal resources to finance solutions places pressure on these institutions and highlights the need for long term, sustainable funding mechanisms. It is critical to invest in and finance NbS well beyond the completion of establishment as the expected success and other co-benefits associated with NbS can be realized only in the long-term. Unfortunately, specific funding opportunities to facilitate the implementation of NbS in Malaysia are often limited (Kangayatkarasu, 2018).

Sustainable financing is one of the most important enablers in the way forward for the successful implementation of NbS (Airoldi et al., 2021). Carbon credit initiatives which have already been employed by several other countries globally,

should be explored and implemented in Malaysia. Other types of economic instruments that could be incorporated include price instruments, quantity instruments, and fiscal instruments (Droste et al., 2017; Sarabi et al., 2019). In price and quantity instruments, private parties can adjust the fees and charges of using ecosystem services or limit the activities affecting nature. In fiscal instruments, decision makers in the public sector can create incentives for developing green infrastructure and NbS through the inclusion of ecological criteria in fiscal transfer processes. These economic instruments can encourage stakeholders to uptake and implement NbS as the alternative that can provide the best value for money. They can also be in the form of grants that enable community led NbS projects. One promising initiative by the Malaysian government to bridge the financial gap faced by states is the Ecological Fiscal Transfer (EFT) initiative. First announced in 2019, EFT allocates federal funds to states based on the amount of protected area (both terrestrial and marine) conserved.

## Systematic Management With Long Term Monitoring

Collated efforts showed that systematic management can enable NbS uptake and safeguard sustainability. The Matang Mangrove Forest Reserve, Perak (E114), is a fitting example of systematic management as an enabler to local NbS effort. Since 1908, the reserve has been systematically managed using fixed rotation age management system on a sustained basis for fuelwood and poles. Consequently, no more than 3% of the original mangrove habitat has been lost (Gan, 1995; Chong, 2007) and sediment accretion has gained 1,500 ha of forest (Gan, 1995). This successful NbS implementation controls shoreline erosion, supports research, educational and training activities, plays a crucial role in protecting bird migration routes, and even promoting sustainable ecotourism (Chong, 2007). Lack of systematic management on the other hand (e.g., shortage of or a poorly equipped workforce), can be a barrier to NbS implementation. This was observed in Mersing Marine Park Islands, Johor, where manpower shortage adversely affected daily operations resulting in encroachment by foreign trawlers in marine park waters (Ooi et al., 2011, 2017).

Generally, there is a need to increase the evidence base of NbS (Chausson et al., 2020; Li et al., 2021) with explicitly designed measurable benefits for biodiversity (Seddon et al., 2021). Investment into long term systematic research and monitoring of individual marine NbS efforts is important to assess success, benefits, and cost-effectiveness of these efforts. The ability of the NbS applied to withstand fluctuations in environmental conditions allows for assessment of the NbS effectiveness in mitigating changes from natural and anthropogenic pressures and global climate change (Navarrete et al., 2010; Giani et al., 2012; Sukhotin and Berger, 2013; Mieszkowska et al., 2014). In addition to mangroves, seagrass, and coral reef ecosystems that are predominantly used as NbS in Malaysia, efforts need to be given to other understudied marine ecosystems that have similar potential. These include, but are not limited to, submerged reefs, tidal flats, and estuarine swamps. Research should also be carried out to determine how different NbS can be implemented

jointly, adding value by achieving greater outcomes and synergistic benefits. Finally, policy and management mechanisms implementing NbS efforts should include long-term monitoring as part of their NbS implementation strategies.

## Ethical Considerations

The application of NbS raises some challenging ethical considerations. While NbS aim to protect, sustainably manage, and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits, there is scope for it to be misused in several ways. Firstly, there is scope for “greenwashing,” where environmental harm is caused by businesses incorrectly implementing NbS, particularly restoration projects (as part of so-called Corporate Social Responsibility) that fail. Secondly, through implementation of the Mitigation Hierarchy (CSBI, 2015), there is scope for NbS to be misused to make new coastal developments be viewed more favorably by regulators and the public. This can be particularly harmful as it can expedite the regulatory process and increase likelihood of consent of coastal development projects which damage key biodiversity and habitats (Rijks et al., 2015). This practice is akin to greening of gray infrastructure and biodiversity offsetting being used to facilitate coastal development by creating small increases in biodiversity when in fact the actual development causes net biodiversity loss (Firth et al., 2020). Finally, perhaps the most dangerous consideration is the naïve assumption that humans can “fix” and “engineer” their way out of environmental problems. Much greater emphasis should be placed on ecosystem protection over other approaches if we are to avoid NbS being misused for environmental harm.

## CONCLUSION

NbS are increasingly being recognized as a promising means to achieve sustainable development and to address climate change related issues with multiple co-benefits to the economy, society, and environment. For decades, Malaysia has been actioning efforts that qualify as NbS in marine and coastal environments, but the body of knowledge is fragmented and sometimes difficult to access. To chart a way forward and to promote a widespread uptake and implementation of NbS not just in Malaysia, but elsewhere globally, there is a need to critically review past efforts for lessons they can provide and build on them. Here, we collated 229 NbS efforts and categorized them according to IUCN NbS approach typology. In some cases, these efforts achieved their anticipated outcomes highlighting the enablers for NbS but in others, it was apparent that there were barriers and challenges that needed addressing. Adopting a similar approach for other regions will improve the evidence base, inform adaptive management and ultimately the uptake of NbS, globally.

We found that factors such as communication, institutional uniformity, community engagement, partnerships and collaborations, knowledge, funding, and management, in part or collectively, affected the actual outcomes of each effort.

Hence, several areas were determined as the way forward to enhance the uptake of Nature-based Solutions for informing coastal sustainable development policy and planning. These include increasing education, training, and knowledge sharing, rationalizing cooperation across jurisdictions, laws, and regulations, enhancing environmental monitoring, leveraging existing policies, enabling collaboration and communication, and implementing sustainable finance instruments. Ideally, research should also be conducted to elucidate understudied marine ecosystems and the potential synergy from combining ecosystems. Such findings are globally applicable to policy makers, whose work will likely benefit from expanding policy implementation efforts to include these enablers.

It should be cautioned, however, that nature should not be exploited in the name of finding “solutions” to the crises caused by unchecked economic growth. For research, policy, and practice on NbS to support transformative change, there must be a move away from the narrow framing of what nature can “do” for the society to an integrated approach, where solutions are understood as place-based, activated by people in partnership with nature (Welden et al., 2021). This study demonstrates and stresses how real solutions to global environmental crises should come from the ground up, where governments, local communities, and all other stakeholders commit to supporting transformational change centered on ecosystem-based, community-led approaches. These findings can be used to inform the improved application and uptake of NbS globally, and provide critical steer for generating policy buy-in from the communities who are most vulnerable to climate and biodiversity changes and who will benefit most from NbS efforts.

## 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 author/s.

## REFERENCES

- Abbot, J., and Marohasy, J. (2014). The excavation and cultivation in containers of mature grey mangroves. *Avicennia marina*. *Wetlands Ecol. Manage.* 22, 641–646.
- Abdullah, K. (1999). *Malaysian coastal environment: Planning, development, and management of the environment in preparation for the next millennium. Proceeding of the International Symposium and Exposition on Coastal Environment and Management: Challenges in the New Millennium*. Kuala Lumpur: UTM.
- Abdullah, K., Tan, K., and Ghazali, N. (2005). “NO MORE IN THE COMFORT ZONE – Malaysia’s response to the December 2004 Tsunami,” in *International Hydrography and Oceanography Conference and Exhibition* (Kuala Lumpur: Department of Irrigation and Drainage Malaysia).
- Airoldi, L., Beck, M. W., Firth, L. B., Bugnot, A. B., Steinberg, P. D., and Dafforn, K. A. (2021). Emerging solutions to return nature to the urban ocean. *Annu. Rev. Mar. Sci.* 13, 445–477. doi: 10.1146/annurev-marine-032020-020015

## AUTHOR CONTRIBUTIONS

SC led the writing of the manuscript. AM-G, LF, and AY-HT contributed substantially to the writing of the manuscript and data assessment. AM-G contributed the infographic and map of NbS efforts in Malaysia. JY arranged and validated data. AM, YAA, AAA, CL, JO, YQ, CT, TY, and CY contributed case studies and efforts in different marine environments, contributed to the writing of this manuscript. All authors contributed to the article and approved the submitted version.

## FUNDING

AM-G is supported by the UK Natural Environment Research Council (NE/R002738/1) Knowledge Exchange fellowship scheme, the EMFF-funded NEA PANACEA project (110661/2020/839628/SUB/ENV.C.2.RWS), and the UK Department of Food, Environment, and Rural Affairs Systems Research Programme. AT is partly funded by the Newton Fund Impact Scheme (IF025-2020).

## ACKNOWLEDGMENTS

We thank Foong Swee Yeok (School of Biological Sciences, Universiti Sains Malaysia) for contributing an effort on mangroves.

## SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fevo.2021.708507/full#supplementary-material>

**Supplementary Table 1** | Nature-based Solutions (NbS) efforts in Malaysia. **(A)** Number of case studies in each IUCN Nature-based Solution approach categorized according to type of effort and site. **(B)** Details of each Nature-based solution effort carried out in Malaysia.

- Aisyah, A., Shahrul, A., Zulfahmie, M., Sharifah Mastura, S., and Mokhtar, J. (2015). Deforestation analysis in Selangor, Malaysia between 1989 and 2011. *J. Trop. For. Sci.* 27, 3–12.
- Albotoush, R., and Tan, S. H. (2019). Evaluating Integrated Coastal Zone Management efforts in Penang Malaysia. *Ocean Coastal Manage.* 181:104899.
- Aminu, M., Matori, A. N., Yusof, K. W., and Zainol, R. B. (2013). A Framework for sustainable tourism planning in Johor Ramsar sites, Malaysia: A geographic information system (GIS) based analytic network process (ANP) approach. *Res. J. Appl. Sci. Engine. Technol.* 6, 417–422.
- Azahar, M., and Nik, M. S. (2003). *A working plan for The Matang Mangrove Forest Reserve, Perak - Fifth revision*. Perak: State Forestry Department of Perak.
- Azman, B. A. R., Ramlan, O., Wan-Lotfi, W. M., Zaidi, C. C., and Othman, B. H. R. (2008). “Seagrass biodiversity of Pulau Tinggi, Johor,” in *Research & Information Series of Malaysian Coasts (2nd Series)*. *Malaysia Marine Ecosystem: Opportunities & Recent Researches*, eds C. A. R. Mohamed, et al. (Bangi: Pusat Penyelidikan Ekosistem Marin).
- Barau, A. S., and Stringer, L. C. (2015). Access to and allocation of ecosystem services in Malaysia’s Pulau Kukup Ramsar Site. *Ecosyst. Serv.* 16, 167–173.

- 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.
- Berkström, C., Eggertsen, L., Goodell, W., Cordeiro, C. A. M. M., Lucena, M. B., Gustafsson, R., et al. (2020). Thresholds in seascape connectivity: the spatial arrangement of nursery habitats structure fish communities on nearby reefs. *Ecography* 43, 882–896.
- Bernama (2019). *No more approval for EIAs on Ramsar sites*. Selangor: Free Malaysia Today.
- Bernama (2020). *NGO urges government to improve existing environment policies*. Selangor: Malay Mail.
- BirdLife International (2020). *Important bird and biodiversity areas (IBA)*. Cambridge: BirdLife International.
- Bugnot, A. B., Mayer-Pinto, M., Airoidi, L., Heery, E. C., Johnston, E. L., Critchley, L. P., et al. (2021). Current and projected global extent of marine built structures. *Nat. Sustainabil.* 4, 33–41.
- CBD (1992). *The Convention on Biological Diversity of 5 June 1992 (1760 U.N.T.S. 69)*. New York, NY: CBD.
- CBD (2015). *Convention on biological diversity (CBD)—Malaysia overview*. New York, NY: CBD.
- CBD (2019). *Sixth national report of Malaysia to the Convention on Biological Diversity (CBD)*. New York, NY: CBD.
- Chausson, A., Turner, B., Seddon, D., Chabaneix, N., Girardin, C. A., Kapos, V., et al. (2020). Mapping the effectiveness of nature-based solutions for climate change adaptation. *Glob. Change Biol.* 26, 6134–6155. doi: 10.1111/gcb.15310
- Chee, S. Y., Othman, A. G., Sim, Y. K., Mat Adam, A. N., and Firth, L. B. (2017). Land reclamation and artificial islands: Walking the tightrope between development and conservation. *Glob. Ecol. Conservat.* 12, 80–95.
- Chee, S. Y., Wee, J. L. S., Wong, C., Yee, J. C., Yusup, Y., and Mujahid, A. (2020). Drill-Cored Artificial Rock Pools Can Promote Biodiversity and Enhance Community Structure on Coastal Rock Revetments at Reclaimed Coastlines of Penang, Malaysia. *Tropic. Conservat. Sci.* 13, 1940082920951912.
- Chen, S. Y., Chelliah, A. J., Lau, C. M., Nadhirah, R., and Hyde, J. (2018). *Reef rehabilitation experiments edition 2: A review of various approaches*. Kuala Lumpur: Reef Check Malaysia.
- Chen, W., He, B., Nover, D., Lu, H., Liu, J., Sun, W., et al. (2019). Farm ponds in southern China: Challenges and solutions for conserving a neglected wetland ecosystem. *Sci. Total Environ.* 659, 1322–1334. doi: 10.1016/j.scitotenv.2018.12.394
- Chong, V. C. (2006). Sustainable utilization and management of Mangrove ecosystems of Malaysia. *Aquat. Ecosyst. Health Manage.* 9, 249–260.
- Chong, V. C. (2007). Mangroves and fisheries linkages: the Malaysian perspective. *Bull. Mar. Sci.* 80, 755–772.
- Cohen-Shacham, E., Andrade, A., Dalton, J., Dudley, N., Jones, M., Kumar, C., et al. (2019). Core principles for successfully implementing and upscaling Nature-based Solutions. *Environ. Sci. Policy* 98, 20–29.
- Cohen-Shacham, E., Walters, G., Janzen, C., and Maginnis, S. (2016). *Nature-based solutions to address global societal challenges*. Gland: IUCN International Union for Conservation of Nature.
- Creel, L. (2003). *Ripple effects: Population and coastal regions*. Washington, D.C.: Population Reference Bureau.
- CSBI (2015). *Mitigation Hierarchy Guide*. London: CSBI
- Dahdouh-Guebas, F., Jayatissa, L. P., Di Nitto, D., Bosire, J. O., Lo Seen, D., and Koedam, N. (2005). How effective were mangroves as a defence against the recent tsunami? *Curr. Biol.* 15, R443–R447. doi: 10.1016/j.cub.2005.06.008
- Davies, C., and Laforteza, R. (2019). Transitional path to the adoption of nature-based solutions. *Land Use Policy* 80, 406–409.
- Davis, M., and Naumann, S. (2017). “Making the Case for Sustainable Urban Drainage Systems as a Nature-Based Solution to Urban Flooding,” in *Theory and practice of urban sustainability transitions*, eds D. Loorbach, H. Shirokawa, J. M. Wittmayer, J. Fujino, and S. Mizuguchi (Cham: Springer), 123–137. doi: 10.1016/j.jenvman.2020.111173
- Day, J. W., and Ryczyk, J. M. (2019). “Global change impacts on the future of coastal systems: Perverse interactions among climate change, ecosystem degradation, energy scarcity, and population,” in *Coasts and estuaries: The future*, eds E. Wolanski, J. Day, M. Elliott, and R. Ramesh (Netherlands: Elsevier).
- Department of Statistics Malaysia (2018). *The initial assessment of the sustainable development goals indicators for Malaysia*. Putrajaya: Department of Statistics Malaysia.
- Department of Marine Park Malaysia (2016). *Total economic value of marine biodiversity*. Kuala Lumpur: Department of Marine Park Malaysia.
- Department of Statistics Malaysia (2020). *Demographic statistics fourth quarter 2020, Malaysia*. Putrajaya: Department of Statistics Malaysia.
- Doshi, A., Pascoe, S., Thébaud, O., Thomas, C. R., Setiasih, N., Hong, J. T., et al. (2012). “Loss of economic value from coral bleaching in SE Asia,” in *12th International Coral Reef Symposium* (Cairns: ICRS).
- Droste, N., Schröter-Schlaack, C., Hansjürgens, B., and Zimmermann, H. (2017). *Implementing nature-based solutions in urban areas: Financing and governance aspects*. In *Theory and practice of urban sustainability transitions*. Cham: Springer, 307–321.
- Economic Planning Unit (2016). “Enhancing environmental sustainability through Green Growth,” in *Mid-term review of the Eleventh Malaysia Plan, 2016–2020. New priorities and emphases* (Putrajaya: Economic Planning Unit).
- European Commission (2015). “Towards an EU research and innovation policy agenda for nature-based solutions & re-naturing cities,” in *Final report of the Horizon 2020 expert group on 'nature-based solutions and re-naturing cities'* (Luxembourg: European Commission).
- European Environment Agency (2012). *Climate change impacts and vulnerability in Europe 2012 (EEA Report No 12/2012) - Version of 20.06.2013*. Copenhagen: European Environment Agency.
- Faivre, N., Fritz, M., Freitas, T., de Boissezon, B., and Vandewoestijne, S. (2017). Nature-Based Solutions in the EU: Innovating with nature to address social, economic, and environmental challenges. *Environ. Res.* 159, 509–518. doi: 10.1016/j.envres.2017.08.032
- Firth, L. B., Airoidi, L., Bulleri, F., Challinor, S., Chee, S. Y., Evans, A. J., et al. (2020). Greening of grey infrastructure should not be used as a Trojan horse to facilitate coastal development. *J. Appl. Ecol.* 57, 1762–1768.
- Firth, L. B., Harris, D., Blaze, J. A., Marzloff, M. P., Boyé, A., Miller, P. I., et al. (2021). Specific niche requirements underpin multidecadal range edge stability but may introduce barriers for climate change adaptation. *Divers. Distribut.* 27, 668–683.
- Firth, L. B., Knights, A. M., Bridger, D., Evans, A., Mieskowska, N., Moore, P. J., et al. (2016). Ocean sprawl: Challenges and opportunities for biodiversity management in a changing world. *Oceanogr. Mar. Biol. Annu. Rev.* 54, 193–269.
- Forestry Department of Peninsular Malaysia (2020). *National Forestry Policy*. Kuala Lumpur: Forestry Department of Peninsular Malaysia.
- Forestry Department Sarawak (2020). *Report of the sharing session on revised reduced impact logging guidelines for Sarawak*. Kuching: Forest Department Sarawak.
- Frantzeskaki, N., Borgström, S., Gorissen, L., Egermann, M., and Ehnert, F. (2017). “Nature-Based Solutions Accelerating Urban Sustainability Transitions in Cities: Lessons from Dresden, Genk and Stockholm Cities,” in *Theory and practice of urban sustainability transitions*, eds D. Loorbach, H. Shirokawa, J. M. Wittmayer, J. Fujino, and S. Mizuguchi (Cham: Springer), 65–88.
- Friess, D. A., Yando, E. S., Alemu, J. B. I., Wong, L. W., Soto, S. D., and Bhatia, N. (2020a). Ecosystem services and disservices of mangrove forests and salt marshes. *Oceanogr. Mar. Biol.* 58, 107–142.
- Friess, D. A., Yando, E. S., Wong, L. W., and Bhatia, N. (2020b). Indicators of scientific value: An under-recognised ecosystem service of coastal and marine habitats. *Ecol. Indic.* 113:106255.
- Gaither, M. R., and Rocha, L. A. (2013). Origins of species richness in the Indo-Malay-Philippine biodiversity hotspot: Evidence for the centre of overlap hypothesis. *J. Biogeogr.* 40, 1638–1648.
- Gan, B. (1995). *A working plan for the Matang mangrove forests Perak (fourth revision)*. Perak: State Forest Department of Perak Darul Ridzuan.
- Ghazali, N., Zainuddin, K., Zainal, M. Z., Dali, H. M., Samad, A. M., and Mahmud, M. R. (2016). “The potential of mangrove forest as a bioshield in Malaysia,” in *Proceeding - 2016 IEEE 12th International Colloquium on Signal Processing and its Applications, CSPA 2016* (Melaka: Faculty of Electrical Engineering, UiTM).
- Giani, M., Djakovac, T., Degobbis, D., Cozzi, S., Solidoro, C., and Umani, S. F. (2012). Recent changes in the marine ecosystems of the northern Adriatic Sea. *Estuar. Coast. Shelf Sci.* 115, 1–13.

- Gillis, L. G., Ziegler, A. D., van Oevelen, D., Cathalot, C., Herman, P. M., Wolters, J. W., et al. (2014). Tiny is mighty: Seagrass beds have a large role in the export of organic material in the tropical coastal zone. *PLoS One* 9:e111847. doi: 10.1371/journal.pone.0111847
- Giordano, R., Pluchinotta, I., Pagano, A., Scricciu, A., and Nanu, F. (2020). Enhancing nature-based solutions acceptance through stakeholders' engagement in co-benefits identification and trade-offs analysis. *Sci. Total Environ.* 713:136552. doi: 10.1016/j.scitotenv.2020.136552
- Goessens, A., Satyanarayana, B., van der Stocken, T., Zuniga, M. Q., Mohd-Lokman, H., Sulong, I., et al. (2014). Is Matang Mangrove Forest in Malaysia sustainably rejuvenating after more than a century of conservation and harvesting management? *PLoS One* 9:e105069. doi: 10.1371/journal.pone.0105069
- Goh, E. (2018). *The status of fish in Malaysian diets and potential barriers to increasing consumption of farmed species*. Ph. D. thesis. Selangor: University of Nottingham Malaysia Campus.
- Guannel, G., Arkema, K., Ruggiero, P., and Verutes, G. (2016). The power of three: Coral reefs, seagrasses and mangroves protect coastal regions and increase their resilience. *PLoS One* 11:e0158094. doi: 10.1371/journal.pone.0158094
- Hamdan, O., Abd Rahman, K., and Samsudin, M. (2016). "Quantifying rate of deforestation and CO2 emission in Peninsular Malaysia using Palsar imageries. IOP Conference Series: Earth and Environmental Science," in *8th IGRSM International Conference and Exhibition on Geospatial & Remote Sensing (IGRSM 2016)* (Kuala Lumpur: IOP Publishing Ltd).
- Hashim, Z., Abdullah, S. A., and Nor, S. M. (2019). "The Perceptions of Local Communities toward Penang National Park," in *IOP Conference Series: Earth and Environmental Science. The 12th International Interdisciplinary Studies Seminar - Environmental Conservation and Education for Sustainable Development*, (Malang: IOP Publishing Ltd).
- Hawkins, S. J., Firth, L. B., McHugh, M., Poloczanska, E. S., Herbert, R. J. H., Burrows, M. T., et al. (2013). Data rescue and re-use: Recycling old information to address new policy concerns. *Mar. Policy* 42, 91–98.
- Hezri, A. A., and Hasan, M. N. (2006). Towards sustainable development? The evolution of environmental policy in Malaysia. *Nat. Resour. Forum* 30, 37–50.
- Hoeksema, B. W. (2007). "Delineation of the Indo-Malayan centre of maximum marine biodiversity: The Coral Triangle," in *Biogeography, time, and place: distributions, barriers, and islands*, ed. W. Renema (Dordrecht: Springer), 117–178.
- IEEP (2021). *Nature-based solutions and their socio-economic benefits for Europe's recovery*. London: IEEP.
- Ishak, N. S., Yusup, M., Arshad, A. F., and Abdullah, Y. A. (2016). "Review on the significance of local plan for coastal reclamation development: The case of Malacca, Malaysia," in *MATEC Web of Conferences, Volume 66. The 4th International Building Control Conference 2016 (IBCC 2016)* (Kuala Lumpur: EDP Sciences).
- Islam, G. M., Kusairi, M. N., Yew, T. S., and Aswani, F. M. N. (2013). Assessing environmental damage to marine protected area: A case of Perhentian Marine Park in Malaysia. *J. Agricult. Sci.* 5, 132–141.
- Islam, G. M., Yew, T. S., Kusairi, M. N., Ahmad, S., Aswani, F. M., Muhamad Senan, M. K., et al. (2017). Community perspectives of governance for effective management of marine protected areas in Malaysia. *Ocean Coast. Manag.* 135, 34–42.
- Johor National Parks Corporation (2020). *Ramsar sites. Wetlands of international importance*. Kota Iskandar: Johor National Parks Corporation.
- Joibi, N. (2018). 'Love Tioman' campaign is paying off with healthy coral reefs on Malaysian diver's paradise. Malaysia: The Star.
- Jomo, K. S., and Wee, C. H. (2003). The political economy of Malaysian federalism: Economic development, public policy and conflict containment. *J. Int. Dev.* 15, 441–456.
- Jusoff, K., and Taha, H. B. D. H. (2008). Managing sustainable mangrove forests in Peninsular Malaysia. *J. Sustainable Dev.* 1, 88–963.
- Kamil, K. A., Hailu, A., Rogers, A., and Pandit, R. (2017). An assessment of marine protected areas as a marine management strategy in Southeast Asia: A literature review. *Ocean Coastal Manage.* 145, 72–81.
- Kangaytkarasu, N. (2018). *Biodiversity Governance in Peninsular Malaysia: Identifying Conservation Priorities, Evaluating the Impact of Federalism and Assessing the Governance of Protected Areas*. Ph. D. thesis. Nottingham: University of Nottingham.
- Kekeh, M., Akpinar-Elci, M., and Allen, M. J. (2019). "Sea level rise and coastal communities," in *Extreme weather events and human health: International case studies*, ed. R. Akhtar (Switzerland: Springer International Publishing), 171–184.
- Lahasing, G., Ignatius, R., and Anton, A. (2015). *Kota Kinabalu Wetlands towards its Ramsar status*. Kota Kinabalu: Sabah Wetlands Conservation Society.
- Lai, Q. (2019). *Artificial reefs create fish paradise*. Kuching: New Sarawak Tribune.
- Lanuru, M. (2011). "Bottom sediment characteristics affecting the success of seagrass (*Enhalus acoroides*) transplantation in the west coast of South Sulawesi (Indonesia)," in *3rd International Conference on Chemical, Biological and Environmental Engineering*, Vol. 20 (Singapore: LACSIT Press).
- Latiff, A. (2012). Conservation strategies for endangered mangrove swamp forests in Malaysia. *Pak. J. Bot.* 44, 27–36.
- Lau, C. M., Kee-Alfian, A. A., Affendi, Y. A., Hyde, J., Chelliah, A., Leong, Y. S., et al. (2019). Tracing coral reefs: A citizen science approach in mapping coral reefs to enhance marine park management strategies. *Front. Mar. Sci.* 6:539. doi: 10.3389/fmars.2019.00539
- Li, L., Cheshmehzangi, A., Chan, F. K. S., and Ives, C. D. (2021). Mapping the research landscape of nature-based solutions in urbanism. *Sustainability* 13:3876. doi: 10.3390/su13073876
- Loh, F. K. (2010). Restructuring federal-state relations in Malaysia: From centralised to co-operative federalism? *Round Table* 99, 131–140.
- Manaf, A. A., Shamsuddin, M., and Omar, M. (2011). Marine park gazettement impacts on Pulau Tinggi community in Mersing, Johor. *J. Trop. Mar. Ecosyst.* 1, 35–43.
- Marchand, C., Lallier-Vergès, E., Disnar, J. R., and Kérais, D. (2008). Organic carbon sources and transformations in mangrove sediments: A Rock-Eval pyrolysis approach. *Organic Geochem.* 39, 408–421.
- Marzuki, M. A. (2020). Sustainability discourse in participatory planning: the case of Malaysia. *Int. J. Urban Sustainable Dev.* 12, 236–250.
- Masud, M. (2019). *Conservation of marine resources and sustainable coastal community development in Malaysia*. Singapore: Palgrave Pivot.
- McGrath, G., Balk, D., and Anderson, B. (2007). The rising tide: Assessing the risks of climate change and human settlements in low elevation coastal zones. *Environ. Urbanizat.* 19, 17–37.
- Mieszowska, N., Sugden, H., Firth, L. B., and Hawkins, S. J. (2014). The role of sustained observations in tracking impacts of environmental change on marine biodiversity and ecosystems. *Philosoph. Transact. R. Soc. Mathemat. Phys. Engine. Sci.* 372:20130339. doi: 10.1098/rsta.2013.0339
- Miki, E. (2019). *Seagrass transplanting activities case study: Coastal area of Universiti Malaysia Sabah, Kota Kinabalu, Sabah*. BSc. thesis. Kota Kinabalu: Borneo Marine Research Institute.
- Ministry of Energy, Green Technology and Water (2009). *National Green Technology Policy*. Putrajaya: Ministry of Energy, Green Technology and Water, Malaysia.
- Ministry of Natural Resources and Environment (2006). *Biodiversity in Malaysia*. Putrajaya: Ministry of Natural Resources and Environment, Malaysia.
- Ministry of Natural Resources and Environment (2009). *National Policy on Climate Change*. Putrajaya: Ministry of Natural Resources and Environment, Malaysia.
- Ministry of Natural Resources and Environment (2014). *Fifth national report to the Convention on Biological Diversity*. Putrajaya: Ministry of Natural Resources and Environment, Malaysia.
- Ministry of Natural Resources and Environment (2016). *National Policy on Biological Diversity 2016 - 2025*. Putrajaya: Ministry of Natural Resources and Environment, Malaysia.
- Ministry of Science, Technology, and Innovation (2002). *National Policy on the Environment*. Putrajaya: Ministry of Science, Technology and Innovation, Malaysia.
- Mohamad, M. F., Abd Hamid, M. R., Awang, N. A., Shah, A. M., and Hamzah, A. F. (2018). Impact of Sea Level Rise Due to Climate Change: Case Study of Klang and Kuala Langat Districts. *Int. J. Engine. Technol.* 10, 59–64.
- Mokhtar, A., Ghazali, N. H. M., Isnin, A., Savioli, J., Lee, V. Z., and Golingi, T. (2019). "Planning the Malaysian coastline – Integrated Shoreline Management Plan," in *International Conference on Asian and Pacific Coasts, APAC 2019* (Vietnam: Springer Nature Singapore Pte Ltd).

- Mokhtar, M. B., and Aziz, S. A. G. (2003). Integrated Coastal Zone Management using the ecosystems approach, some perspectives in Malaysia. *Ocean Coastal Manage.* 46, 407–419.
- Motamedi, S., Hashim, R., Zakaria, R., Song, K.-I., and Sofawi, B. (2014). Long-term assessment of an innovative mangrove rehabilitation project: Case study on Carey Island, Malaysia. *Sci. World J.* 2014, 1–12. doi: 10.1155/2014/953830
- Muhammad, Z., Zulkipli, G., and Haseeb, U. R. (2017). “Sustainable education: A buzzword of Universiti Teknologi PETRONAS, Malaysia,” in *Managerial strategies and solutions for business success in Asia*, ed. P. O. de Pablos (Hershey, PA: IGI Global), 255–279.
- Musa, G. (2003). “Sipadan: an over-exploited scuba-diving paradise? An analysis of tourism impact, diver satisfaction and management priorities,” in *Marine Ecotourism: Issues and Experiences*, eds B. Garrod and J. C. Wilson (Clevedon: Channel View), 122–137.
- MyBIS. (2015). *Marine and coastal biodiversity*. Malaysia: Malaysia Biodiversity Information System (MyBIS).
- Myers, N., Mittermeier, R. A., Mittermeier, C. G., Da Fonseca, G. A., and Kent, J. (2000). Biodiversity hotspots for conservation priorities. *Nature* 403, 853–858.
- Navarrete, S. A., Gelcich, S., and Castilla, J. C. (2010). Long-term monitoring of coastal ecosystems at Las Cruces, Chile: Defining baselines to build ecological literacy in a world of change. *Rev. Chilena Hist. Nat.* 83, 143–157.
- Neumann, B., Vafeidis, A. T., Zimmermann, J., and Nicholls, R. J. (2015). Future coastal population growth and exposure to sea-level rise and coastal flooding - A global assessment. *PLoS One* 10:0118571. doi: 10.1371/journal.pone.0118571
- Noh, A. F., Shui, A., Tai, S. Y., and Noh, K. M. (2018). Indicators of governance of marine ecotourism resources: Perception of communities in Pulau Perhentian, Terengganu. *Int. J. Bus. Soc.* 19, 17–25.
- Nordhaus, I., Siriwardane, R., Gillis, L. G., Chee, S. Y., Chong, L., Firth, L., et al. (2019). *The Future of Mangroves in Penang*. Malaysia: Bridging Science, Policy & Perspectives.
- Norhayati, A., Shukor, M. N., Juliana, S., and Wan Juliana, W. A. (2009). Mangrove flora and fauna of Klang Islands mangrove forest reserves, Selangor, Malaysia. *Malays. J. Sci.* 28, 275–288.
- NRE, and PKSD. (2010). *Integrated Shoreline Management Plan for negeri Pulau Pinang*. Georgetown: Ministry of Natural Resource and Environment & Putra Konsult Sdn Bhd.
- Olorunfemi, F. (2017). “The drivers of wetland use in Temerloh District, Pahang, Malaysia,” in *Malaysia Sustainable Cities Program, Working Paper Series* (Massachusetts: Massachusetts Institute of Technology).
- Ong, J. (2017). “A mangrove-centric view of wetlands for future sustainable use in Malaysia,” in *2nd Sabah’s Ramsar Conference 2016 Proceedings* (Kota Kinabalu: Sabah Forestry Department).
- Ooi, J. L., Kendrick, G. A., van Niel, K. P., and Affendi, Y. A. (2011). Knowledge gaps in tropical Southeast Asian seagrass systems. *Estuar. Coast. Shelf Sci.* 92, 118–131.
- Ooi, J., Goh, H., Then, A., Affendi, Y., Repin, I., and Abd Muntalib, J. (2017). *Status report on the marine environment of the Mersing Marine Park islands, and indicative proposal for a Marine Protected Area (MPA) network*. Putrajaya: Department of Marine Park Malaysia.
- Pedersen, J. D., Beck, S., Johansen, H. B., and Jensen, H. B. (2005). Capacity development in Integrated Coastal Zone Management: Some lessons learned from Malaysia. *Coastal Manage.* 33, 353–372.
- Perera, R., and Khailani, D. K. (2017). “Development plan as a tool to improve the disaster resilience of urban areas,” in *Rethinking Resilience, Adaptation and Transformation in a Time of Change*, eds W. Yan and W. Galloway (Cham: Springer), 199–221.
- PLANMalaysia. (2011). *Rancangan Fizikal Negara*. Putrajaya: Department of Town and Country Planning.
- Pourebahrahim, S., Hadipour, M., and Mokhtar, M. B. (2015). Impact assessment of rapid development on land use changes in coastal areas; case of Kuala Langat district, Malaysia. *Environ. Dev. Sustainabil.* 17, 1003–1016.
- Pryor, M., and Watson, G. (2016). Mature tree transplanting: Science supports best management practice. *Arboricult. J.* 38, 2–27.
- Puan, C. L., Yeap, C. A., Lim, K. C., Lim, A. T., Khoo, S. S., and Cheung, N. (2014). Northbound migration count of raptors at Tanjung Tuan, Peninsular Malaysia: Magnitude, timing, and flight behavior. *J. Raptor Res.* 48, 162–172.
- Rahman, A. A., Ghazali, F., Rusli, M. H. M., Aziz, N., and Talaat, W. I. A. W. (2019). Marine Protected Areas in Peninsular Malaysia: Shifting from Political Process to Co-Management. *J. Polit. Law* 12, 22–30.
- Rahman, S. A., and Yaakub, S. M. (2020). Socio-economic valuation of seagrass meadows in the Pulau River Estuary, Peninsular Malaysia, through a wellbeing lens. *Mar. Freshw. Res.* 71, 877–891.
- Ramli, S. F., and Caihong, Z. (2017). National mangrove restoration project in Malaysia. *J. Environ. Earth Sci.* 7, 119–125. doi: 10.3389/fmich.2019.02456
- Ramsar Convention Secretariat (2010). “National Wetland Policies: Developing and implementing National Wetland Policies,” in *Ramsar handbooks for the wise use of wetlands*, 4th Edn, Vol. 2 (Gland: Ramsar Convention Secretariat).
- Raymond, C. M., Frantzeskaki, N., Kabisch, N., Berry, P., Breil, M., Nita, M. R., et al. (2017). A framework for assessing and implementing the co-benefits of nature-based solutions in urban areas. *Environ. Sci. Policy* 77, 15–24.
- Reef Check Malaysia (2011). *Status of coral reefs in Malaysia, 2011*. Kuala Lumpur: Reef Check Malaysia.
- Reef Check Malaysia (2015). *Status of coral reefs in Malaysia, 2015*. Kuala Lumpur: Reef Check Malaysia.
- Reef Check Malaysia (2019). *Status of coral reefs in Malaysia, 2019*. Kuala Lumpur: Reef Check Malaysia.
- Reef Check Malaysia (2020). *Status of coral reefs in Malaysia, 2020*. Kuala Lumpur: Reef Check Malaysia.
- Rijks, D., Aarninkhof, S., van Spreken, A., and Legierse, E. (2015). “Eco-engineering opportunities for offshore marine infra-structure projects,” in *Offshore Technology Conference (pp. OTC-26207-MS)* (Rio de Janeiro: OTC).
- Rooker, J. R., Dance, M. A., Wells, R. J., Quigg, A., Hill, R. L., Appeldoorn, R. S., et al. (2018). Seascape connectivity and the influence of predation risk on the movement of fishes inhabiting a back-reef ecosystem. *Ecosphere* 9:e02200.
- Rusli, M., and Lee, K. C. (1999). Tactics of Environmental NGOs in Influencing Public Policy in Malaysia. *Pertanika J. Soc. Sci. Humanit.* 7, 71–77.
- Sabah Wetlands Conservation Society (2019). *Newsletter December 2019*. Likas: Sabah Wetlands Conservation Society.
- Saleh, E., Yap, T. K., and Gallagher, J. B. (2020). Seagrass coverage and associated fauna at Gaya Island, Sabah, Malaysia: A pilot seagrass transplantation. *Borneo J. Mar. Sci. Aquacult.* 4, 14–16.
- Sarabi, S. E., Han, Q., Romme, A. G., de Vries, B., and Wendling, L. (2019). Key enablers of and barriers to the uptake and implementation of nature-based solutions in urban settings: A review. *Resources* 8:121.
- Sarabi, S., Han, Q., Romme, A. G., de Vries, B., Valkenburg, R., and den Ouden, E. (2020). Uptake and implementation of Nature-Based Solutions: An analysis of barriers using Interpretive Structural Modeling. *J. Environ. Manage.* 270:110749. doi: 10.1016/j.jenvman.2020.110749
- Sarmin, N. S., Mohd Hasmadi, I., Pakhriazad, H. Z., and Khairil, W. A. (2016). The DPSIR framework for causes analysis of mangrove deforestation in Johor, Malaysia. *Environ. Nanotechnol. Monit. Manage.* 6, 214–218.
- Seddon, N., Chausson, A., Berry, P., Girardin, C. A., Smith, A., and Turner, B. (2020). Understanding the value and limits of nature-based solutions to climate change and other global challenges. *Philosoph. Transact. R. Soc. B* 375:20190120. doi: 10.1098/rstb.2019.0120
- Seddon, N., Smith, A., Smith, P., Key, I., Chausson, A., Girardin, C., et al. (2021). Getting the message right on nature-based solutions to climate change. *Glob. Change Biol.* 27, 1518–1546. doi: 10.1111/gcb.15513
- Shaffril, H. A., Hamzah, A., D’Silva, J. L., Abu Samah, B., and Abu Samah, A. (2017). Individual adaptive capacity of small-scale fishermen living in vulnerable areas towards the climate change in Malaysia. *Clim. Dev.* 9, 313–324.
- Shukor, A. (2004). *The use of mangroves in Malaysia. In Promotion of mangrove-friendly shrimp aquaculture in Southeast Asia*. Tigbauan: Aquaculture Department, Southeast Asian Fisheries Development Center, 136–144.
- Siegel, F. R. (2019). *Adaptations of coastal cities to global warming, sea level rise, climate change and endemic hazards*. Washington, DC: Springer.
- Sim, L. L. (2019). *Malaysia set to lose biodiversity as species go extinct*. Malaysia: The Star.
- Smith, K. (2011). We are seven billion. *Nat. Clim. Change* 1, 331–335.
- Struve, D. K., Burchfield, L., and Maupin, C. (2000). Survival and growth of transplanted large- and small-caliper red oaks. *J. Arboricult.* 26, 162–169. doi: 10.1093/treephys/tpu103

- Sukhotin, A., and Berger, V. (2013). Long-term monitoring studies as a powerful tool in marine ecosystem research. *Hydrobiologia* 706, 1–9.
- Syed, S. (2016). *Saving our corals*. Kuala Lumpur: New Straits Times.
- Tamin, N. M., Zakaria, R., Hashim, R., and Yin, Y. (2011). Establishment of *Avicennia marina* mangroves on accreting coastline at Sungai Haji Dorani, Selangor, Malaysia. *Estuar. Coastal Shelf Sci.* 94, 334–342.
- Tangah, J., Bajau, F. E., Jilimin, W., Baba, S., Chan, H. T., and Kezuka, M. (2015). *Rehabilitation of mangroves in Sabah – The SFD-ISME collaboration (2011–2014)*. Sandakan: Sabah Forestry Department.
- Teh, L. C., Teh, L. S., and Chung, F. C. (2008). A private management approach to coral reef conservation in Sabah, Malaysia. *Biodivers. Conservat.* 17, 3061–3077.
- The Borneo Post (2020). *SFC deploys 1,200 artificial reef balls at Muara Tebas-Sebuyau coastal waters*. Kuching: Borneo Post.
- Todd, P. A., Heery, E. C., Loke, L. H., Thurstan, R. H., Kotze, D. J., and Swan, C. (2019). Towards an urban marine ecology: characterizing the drivers, patterns and processes of marine ecosystems in coastal cities. *Oikos* 128, 1215–1242.
- UNGA (1994). *UN General Assembly, United Nations Framework Convention on Climate Change*. New York, NY: United Nations.
- United Nations (2019b). *World population prospects 2019*. New York, NY: United Nations.
- United Nations (2019a). *The nature-based solutions for climate manifesto – developed for the UN Climate Action Summit 2019*. New York, NY: United Nations.
- United Nations (2020). *The sustainable development goals report 2020*. New York, NY: United Nations.
- United Nations (2021). *Department of Economic and Social Affairs World Population Prospects 2019. Total Population - Both Sexes. De facto population in a country, area or region as of 1 July of the year indicated*. New York, NY: United Nations.
- van de Koppel, J., van der Heide, T., Altieri, A. H., Eriksson, B. K., Bouma, T. J., Olf, H., et al. (2015). Long-distance interactions regulate the structure and resilience of coastal ecosystems. *Annu. Rev. Mar. Sci.* 7, 139–158. doi: 10.1146/annurev-marine-010814-015805
- van Ham, C., and Klimmek, H. (2017). “Partnerships for Nature-Based Solutions in Urban Areas – Showcasing Successful Examples,” in *Theory and practice of urban sustainability transitions*, eds D. Loorbach, H. Shiroshima, J. M. Wittmayer, J. Fujino, and S. Mizuguchi (Cham: Springer), 275–289.
- van Katwijk, M. M., Thorhaug, A., Marbà, N., Orth, R. J., Duarte, C. M., Kendrick, G. A., et al. (2016). Global analysis of seagrass restoration: The importance of large-scale planting. *J. Appl. Ecol.* 53, 567–578.
- van Kuelen, M., Paling, E. I., and Walker, C. J. (2003). Effect of planting unit size and sediment stabilization on seagrass transplants in Western Australia. *Restorat. Ecol.* 11, 50–55.
- Veron, J. (1995). *Corals in space and time: The biogeography and evolution of the Scleractinia*. New York, NY: Cornell University Press.
- Veron, J., Devantier, L. M., Turak, E., Green, A. L., Kininmonth, S., Stafford-Smith, M., et al. (2009). Delineating the Coral Triangle. *Galaxea J. Coral Reef Stud.* 11, 91–100.
- Versteeg, M. (2020). Why are our reefs collapsing? *Environ. Coastal Offshore* 2020, 110–113. doi: 10.1111/gcb.14941
- Waris, M., Azlan, Z. S., Tamyez, P. F. M., Ullah, M., and Khan, A. (2019). Analyzing the constructs of stakeholder engagement towards renewable energy projects success in Malaysia: A PLS approach. *KnE Soc. Sci.* 3, 818–843.
- Watson, J. (1928). *Mangrove forests of the Malay Peninsula. Malayan forest records no. 6*. Kuala Lumpur: Jabatan Perhutanan.
- Welden, E. A., Chausson, A., and Melanidis, M. S. (2021). Leveraging nature-based solutions for transformation: Reconnecting people and nature. *People Nat.* 2021:10212.
- World Bank (2020). *Urban population (% of total population) Malaysia*. Washington, D.C.: World Bank.
- WWF (2008). *Stronger enforcement in proposed Tun Mustapha Park*. Gland: WWF.
- WWF (2009). *Annual review 2009*. Selangor: WWF Malaysia.
- Yap, T. K. (2019). *Seagrass conditioning in husbandry tanks and transplanting at Gaya Island, Kota Kinabalu, Sabah*. MSc. thesis. Kota Kinabalu: Borneo Marine Research Institute.
- Yeap, C. A., Sebastian, A. C., and Davison, G. W. H. (2007). *Directory of Important Bird Areas in Malaysia: Key Sites for Conservation (MNS Conservation Publication No. 8)*. Kuala Lumpur: Malaysian Nature Society.
- Yin, C. S., and Kwang, S. Y. (2016). Coastal Macroinvertebrate Study in Penang Island, Malaysia. *Tropic. Life Sci. Res.* 27(Suppl.1):39. doi: 10.21315/tlsr2016.27.3.6
- YTL Group (2019). *Sustainability report 2019*. Kuala Lumpur: YTL Group.
- Zhang, K., Liu, H., Li, Y., Xu, H., Shen, J., Rhome, J., et al. (2012). The role of mangroves in attenuating storm surges. *Estuar. Coast. Shelf Sci.* 102–103, 11–23. doi: 10.1093/aob/mcz204

**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:** All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

Copyright © 2021 Chee, Firth, Then, Yee, Mujahid, Affendi, Amir, Lau, Ooi, Quek, Tan, Yap, Yeap and McQuatters-Gollop. This is an open-access article distributed under the terms of the Creative Commons Attribution License (CC BY). The use, distribution or reproduction in other forums is permitted, provided the original author(s) and the copyright owner(s) are credited and that the original publication in this journal is cited, in accordance with accepted academic practice. No use, distribution or reproduction is permitted which does not comply with these terms.