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Review

Marine and coastal ecosystem-based adaptation in Asia and Oceania: review of approaches and integration with marine spatial planning

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Abstract. There is growing interest in using ecosystem-based adaptation (EbA) to maintain or restore ecosystem services to increase human resilience to climate change. However, to date, the focus on EbA has been on conceptualising the approach and encouraging its use, rather than understanding EbA in practice. We review the EbA literature to synthesise where, why and how marine and coastal EbA projects have been implemented and examine how EbA has been integrated with marine spatial planning. We focus specifically on EbA projects in Asia and Oceania, where climate variability and dependence on marine and coastal ecosystems is high. Most projects were found in the grey literature, implemented in developing countries, and targeted extreme events and sea level rise. Mangroves, particularly mangrove restoration, was the most common ecosystem used, followed by coral reefs. EbA across ecosystems commonly targeted capacity building and livelihood enhancement, and maintenance of wildlife, alongside shoreline protection for mangroves and food security for coral reefs. Integrated EbA and marine spatial planning projects were participatory, implemented at local–regional scales, displayed adaptive management, and community-based or shared governance. Our research helps to build an understanding of EbA in practice and a knowledge base to assist coastal communities in adapting to climate change.

Additional keywords: Asia, climate change, ecosystem services, ecosystem-based adaptation, marine and coastal, marine spatial planning, Oceania.

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Introduction

The impacts of rapidly increasing populations and climate change are already being felt by millions of people around the world, particularly those that depend on marine and coastal ecosystems (Hale *et al.* 2009; Halpern *et al.* 2015; Savo *et al.* 2016). Higher sea surface temperatures, marine heat waves, sea level rise, ocean acidification, increased extreme events and changes to precipitation patterns are all threats that coastal and marine ecosystems are facing under changing climatic conditions (Kingsford and Watson 2011; Halpern *et al.* 2015; Milman and Jagannathan 2017; Hoegh-Guldberg *et al.* 2019). Consequently, coastal communities that depend on these ecosystems and the regulating (e.g. shoreline protection), provisioning (e.g. food, economic) and cultural (e.g. recreation) services they provide are especially at risk (MEA 2005; Grantham *et al.* 2011; Selig *et al.* 2018; Thomas *et al.* 2018). Least developed and developing countries that rely more heavily on these ecosystem services for subsistence and livelihoods are generally the most vulnerable to climate-related hazards (McCarthy *et al.* 2001; Olsson *et al.* 2014; Selig *et al.* 2018). However, coastal impacts in developed countries are also likely to increase under future climate change and loss of ecosystems through development (Aerts *et al.* 2014; Head *et al.* 2014; IPCC 2018; Hoegh-Guldberg *et al.* 2019). It has become clear that impacts from 1°C of global warming above preindustrial levels of climate change are occurring, and associated adaptation strategies are necessary (Scarano 2017; IPCC 2018; IPCC 2019*a*, 2019*b*).

Many strategies to adapt to climate-related hazards have focused on using hard-engineered infrastructure, such as seawalls, to provide defence against coastal erosion and inundation (Hale *et al.* 2009; Rosenzweig *et al.* 2011; Mackey and Ware 2018). More recently, there has been growing recognition of the role of healthy ecosystems in buffering the negative effects of climate change on vulnerable people (Colls *et al.* 2009; Andrade *et al.* 2011). International bodies recognise this role under 'ecosystem-based adaptation' (EbA), which is defined as 'the use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people adapt to the adverse effects of climate change' (CBD 2009). In marine and coastal ecosystems, EbA is increasingly being applied in the form of targeted conservation, management, and restoration activities (Hale *et al.* 2009; Jones *et al.* 2012). For example, the use and restoration of mangroves for coastal protection from extreme events (Rahman 2014), the establishment of ecotourism for livelihoods (Primavera 2015), or the implementation of marine protected areas (MPAs) for food security (Lacovino *et al.* 2013). EbA is suggested as a community-based, cost-effective and low-risk approach to adaptation compared with hard-engineered solutions that can sometimes be expensive and result in maladaptation (Colls *et al.* 2009; Jones *et al.* 2012; Mackey and Ware 2018). Consequently, EbA is gaining attention as a climate adaptation approach that is accessible and can provide potential economic, social and cultural co-benefits (CBD 2009; Jones *et al.* 2012; Munang *et al.* 2013).

EbA has emerged on the international climate adaptation agenda, including within the negotiating and work plans of the United Nations Framework Convention for Climate Change and is being promoted widely by international organisations, including the World Bank, International Union for the Convention of Nature (IUCN) and United Nations Development Program, as well as major conservation organisations, such as The Nature Conservancy and Worldwide Fund for Nature (Colls *et al.* 2009; World Bank 2010; Mercer *et al.* 2012; Nalau *et al.* 2018). Despite this widespread recognition and uptake, there are still significant uncertainties surrounding its application and meaning, which have led to difficulties in incorporating it into mainstream adaptation planning and on-ground implementation (Milman and Jagannathan 2017). Some of the proposed reasons for these uncertainties include: a lack of consolidation of existing EbA case studies and their approaches used (Munroe *et al.* 2012), the misuse of the approach (Doswald *et al.* 2014), limited monitoring and evaluation processes (McKinnon and Hole 2015), and an absence of research on its integration with existing policies (Sierra-Correa and Cantera Kintz 2015; Nalau *et al.* 2018).

Although EbA is often considered a relatively new approach (Doswald *et al.* 2014; Scarano 2017), many of the fundamentals and applications used in EbA can be observed in other ecosystem-based or nature-based approaches, including the ecosystem approach of the Convention on Biological Diversity (CBD 2009), as well as ecosystem-based management, marine spatial planning (MSP), disaster risk reduction and nature-based defences (Sierra-Correa and Cantera Kintz 2015; Cohen-Shacham *et al.* 2016; Narayan *et al.* 2016; UNEP 2016). The major difference in EbA lies in its specific focus on reducing human vulnerability to climate change impacts, as opposed to a range of other anthropogenic drivers or natural hazards impacting humans and ecosystems (CBD 2009; Agardy *et al.* 2011; Cohen-Shacham *et al.* 2016). However, building on the knowledge and strategies developed for effective methods from related ecosystem-based approaches could aid EbA in establishing its evidence base and use. For instance, in the context of marine ecosystems, MSP provides a structured framework that allows participatory, forward-looking and consistent decision-making on its use and protection (Gubbay 2004; Gilliland and Laffoley 2008; Ehler and Douvere 2009). Integrating MSP foundations into EbA could potentially streamline the implementation process and help build the standards and success of EbA projects. Yet, within the published literature there is limited reference to the use of MSP in marine and coastal EbA to date (although, see Khan and Amelie 2015; Sierra-Correa and Cantera Kintz 2015).

Previous reviews of the literature on EbA have evaluated its: effectiveness (Doswald *et al.* 2014); evidence base (Munroe *et al.* 2012); use in coastal planning and shoreline protection (Spalding *et al.* 2014; Sierra-Correa and Cantera Kintz 2015); application in small island developing states (Mercer *et al.* 2012); use in marine and coastal ecosystems broadly and in Oceania (Hale *et al.* 2009; Grantham *et al.* 2011); and implementation constraints (Nalau *et al.* 2018). However, despite the emergence of EbA as a practical climate adaptation strategy, there has been no comprehensive review of where, why and how applied EbA projects have been implemented in marine and coastal ecosystems. To address this gap in EbA knowledge, we aim to synthesise information on existing EbA projects that have been implemented in Asia and Oceania, where climate variability and dependence on marine and coastal ecosystems is high in coastal communities (Hay and Mimura 2006; Eckstein *et al.* 2018; Selig *et al.* 2018; ESCAP 2019). Our research aims to build on the understanding of EbA in practice and provide a knowledge base that can be incorporated into the policies and practices of adaptation projects, national adaptation plans and donor funding decision-making.

Here we review marine and coastal EbA projects in Asia and Oceania to identify the aims and approaches used. We summarise the current state of knowledge on (1) where EbA-termed projects are being implemented, (2) what climate-related hazards are driving the need for implementation, (3) what ecosystems they are using, (4) what ecosystem services are being targeted and (5) what specific adaptation approaches are being used in 'conservation and awareness' , 'management and planning' and 'restoration' strategies? We also explore how EbA approaches can be improved and have been integrated with existing policies. We do this by focusing on the specific EbA management and planning approach of MPAs and determine whether they use established best-practice MSP processes. We aim to provide insight on EbA uptake and suggestions to assist in its practical application.

Methods

Literature review of ecosystem-based adaptation projects

We conducted a comprehensive literature review of both peer-reviewed and grey literature to identify projects that had implemented or were in the process of planning an EbA approach in coastal and marine ecosystems in Asia and Oceania (see Supplementary Table 1 for countries list). We adapted

systematic literature review principles from Pickering and Byrne (2014) to search the global literature for project-level references of EbA actions in Asia and Oceania. As our review was aimed at synthesising information on where, why and how EbA is being implemented in practice, we searched only for projects that had either been termed EbA in text or were classified as EbA in a predefined EbA database (see Table 1). Examples were excluded in cases where another approach, e.g. ecosystem-based disaster risk reduction, was used but not explicitly framed or linked to EbA following Nalau *et al.* (2018). The search criteria therefore focus explicitly on EbA because this is an evolving scientific area of research and there is still a need to further examine its usefulness and scope as an approach to climate adaptation in particular.

Peer-reviewed literature was searched in the Scopus database using default search settings and the term 'ecosystem-based adaptation', from January 1960 to November 2018 (Table 1, Fig. 1). We also searched the 'ecosystem-based adaptation' section of the *Nature*-based Solutions Interactive Bibliography which compiles reviews, methodological, commentaries, and perspective peer-review articles from Web of Science and Google Scholar in an online database (Table 1, Fig. 1). To review the grey literature, online EbA databases and published grey literature reports from a subset of key and relevant EbA organisations were searched for applicable projects listed before November 2018 (see Table 1 and Fig. 1 for databases). EbA projects found within the peer-reviewed and grey literature searches were included for further analysis based on eligibility criteria as per Table 1. There were a small number of projects that worked in the same location and they were counted as separate projects, since although there is a geographic overlap, the projects clearly had separate objectives, methods and titles. For a few projects, there were multiple reports of the same project and these were amalgamated into a single project to avoid double-counting. After the amalgamation of duplicates, the total number of EbA projects identified was 79 (see project list in Supplementary Table 2).

Ecosystem-based adaptation project analysis

From the EbA projects identified from the peer-reviewed and grey literature, the following eight variables were recorded: literature type; geographic location; development status; climate-related hazard; ecosystem type; ecosystem service; broad adaptation category; and specific adaptation approach (see Table 2 for descriptions).

Review of integrated marine spatial planning and ecosystem-based adaptation case studies

Designing and implementing MPAs is a well-recognised use of MSP and a common approach in EbA management and planning (Ehler and Douvere 2009; UNEP 2016). To explore the use of MSP in EbA, we first identified all projects that implemented MPAs in Asia and Oceania from the EbA projects found within the peer-reviewed and grey literature search (Fig. 1). We then used the Conservation Planning Database (a global online database of systematic conservation planning studies: Alvarez-Romero *et al.* 2018) as a platform to search for MSP projects that may have taken an EbA approach to implementing MPAs without specifically classifying the project as 'EbA'. We identified a project within the Conservation Planning Database as using EbA based on the framework developed by the Friends of Ecosystem-based Adaptation (FEBA) (Bertram *et al.* 2017), which states that an EbA project: '(1) reduces social and environmental vulnerabilities, (2) generates societal benefits in the context of climate change adaptation, (3) restores, maintains or improves ecosystem health, (4) is supported by policies at multiple levels, and (5) supports equitable governance and enhances capacities'. For EbA projects that had resulted in an implemented marine protected area on-ground, we then identified which cases applied MSP best practices during their design and implementation process, following Ehler and Douvere (2009).

After removing duplicates from our literature and Conservation Planning Database search, five case studies in Asia and Oceania that have implemented MPAs were recognised as having applied EbA criteria and MSP best practices. We included the EbA projects found through the Conservation Planning Database within our integrated MSP and EbA case studies and not within our EbA project database because the EbA project database was intended to review previously termed EbA projects.

Results

Current state of knowledge

Our review of EbA literature identified 79 projects that had planned or implemented an EbA project associated with marine and coastal ecosystems in Asia and Oceania. More EbA projects were found in the grey literature (58%) than peer-reviewed journals (20%), with 22% found from both categories. Across both literature sources, a number of projects were not identified as EbA until post-implementation and re-evaluation (e.g. 'Kubulau MPA Network': Andrade *et al.* 2011) or inclusion within an EbA database (e.g. 'Lauru Ridge to Reef MPA Network' in UNEP online Coastal EbA case studies). In addition, some projects were termed as EbA as well as another nature-based solution, such as ecosystem-based disaster risk reduction (e.g. Buffle *et al.* 2011).

Geographic locations

We identified marine and coastal EbA projects in 24 countries in Asia and Oceania, with 75% of projects in developing, 24% in least developed and 1% in developed countries (Fig. 2*a*, *b*). In comparison, the highest mean number of projects per coastal countries in Asia and Oceania was for least developed countries (mean = 2.4, s.e. = 0.7), followed by developing (mean = 1.2, s.e. = 0.4) and developed (mean = 0.3, s.e. = 0.5). There is a conspicuous hotspot of EbA projects in southeast Asia, particularly in Vietnam (14) and the Philippines (9), followed by southern Asia in India (8) and Pakistan (7) (Fig. 2*a*). In Oceania, the greatest number of EbA projects is in Melanesia in Fiji (5), followed by Solomon Islands (4) and Papua New Guinea (4). Another hotspot of EbA projects is also observed in Samoa (5) in Polynesia. There was only one project termed and recorded as EbA in developed countries, and that was in Australia (Fig. 2*a*).

Climate-related hazards addressed

We identified six main climate-related hazards that EbA projects aimed to address (Fig. 3). Extreme weather events, such as

Table 1. Literature search sources and eligibility inclusion criteria used to review marine and coastal EbA projects

Literature search	Criterion	Eligibility criteria	Exclusion criteria
For all literature	EbA project	Contained an EbA project that had been implemented or was in the process of being implemented in a marine or coastal ecosystem. Human adaptation to climate change was a primary reason for the project.	Projects that focused on ecosystem adaptation, biodiversity conservation or natural hazards, i.e. projects that focused only on biodiversity conservation or natural hazards were not included.
	Coastal and marine ecosystems	Coral reefs, dunes, estuaries (including oyster reefs), mangroves, saltmarshes, or seagrasses.	Freshwater and non-specific tidal marsh
	Location-specific	Implemented for a specific country location.	Global projects
	Language	English	Non-English
Scopus database	Literature period	January 1960–November 2018	Literature outside of this period
	Search term	'ecosystem-based adaptation' found in papers using Scopus default search settings	Other search terms
	Screening	Articles were identified as using EbA 'use of biodiversity and ecosystem services a part of an overall adaptation strategy to help people adapt to the adverse effects of climate change'	Articles not referring to the term EbA
Nature-based Solutions bibliography database through Web of Science and Google Scholar[A]	Literature period	April 1998–November 2018	Literature outside of this period
	Search term	'ecosystem-based adaptation' OR 'nature-based solutions' OR 'nature-based approach' OR 'nature-based approaches' OR 'natural solutions' anywhere in papers and classified in the coastline or marine major habitat types	Other search terms
	Screening	Articles were identified as EbA from the search papers using the definition 'sustainable management, conservation and restoration of ecosystems, as part of an overall adaptation strategy that takes into account the multiple social, economic and cultural co-benefits for local communities'	
Grey literature			
International Union for the Convention of Nature (IUCN) EbA to climate adaptation resources[B]	Literature period	Case studies listed before November 2018	Case studies listed after November 2018
United Nations Framework Convention for Climate Change EbA database[C]	Literature period	Case studies listed before November 2018	Case studies listed after November 2018
United Nations Environmental Program Coastal EbA case studies[D]	Literature period	Case studies listed before November 2018	Case studies listed after November 2018
Asia Pacific Adaptation Network – EbA adaptation theme[E]	Literature period	Case studies listed before November 2018	Case studies listed after November 2018
PANORAMA Solutions for a Healthy Planet EbA database[F]	Literature period	Case studies listed before November 2018	Case studies listed after November 2018
United Nations Development Program Climate Change Adaptation – EBA and Mitigation[G]	Literature period	Case studies listed before November 2018	Case studies listed after November 2018
WeAdapt – EbA adaptation theme[H]	Literature period	Case studies listed before November 2018	Case studies listed after November 2018

[A]Detailed methods of the review process are available at https://www.naturebasedsolutionsinitiative.org
[B]https://www.iucn.org/theme/ecosystem-management/our-work/ecosystem-based-adaptation-and-climate-change/resources
[C]https://www4.unfccc.int/sites/nwpstaging/pages/Search.aspx
[D]https://web.unep.org/coastal-eba
[E]http://www.asiapacificadapt.net/projects?search=&by_themes=269&by_project-status=All&by_regions=All&by_countries=All
[F]https://panorama.solutions/en
[G]https://www.adaptation-undp.org/ecosystem-based-adaptation-and-mitigation
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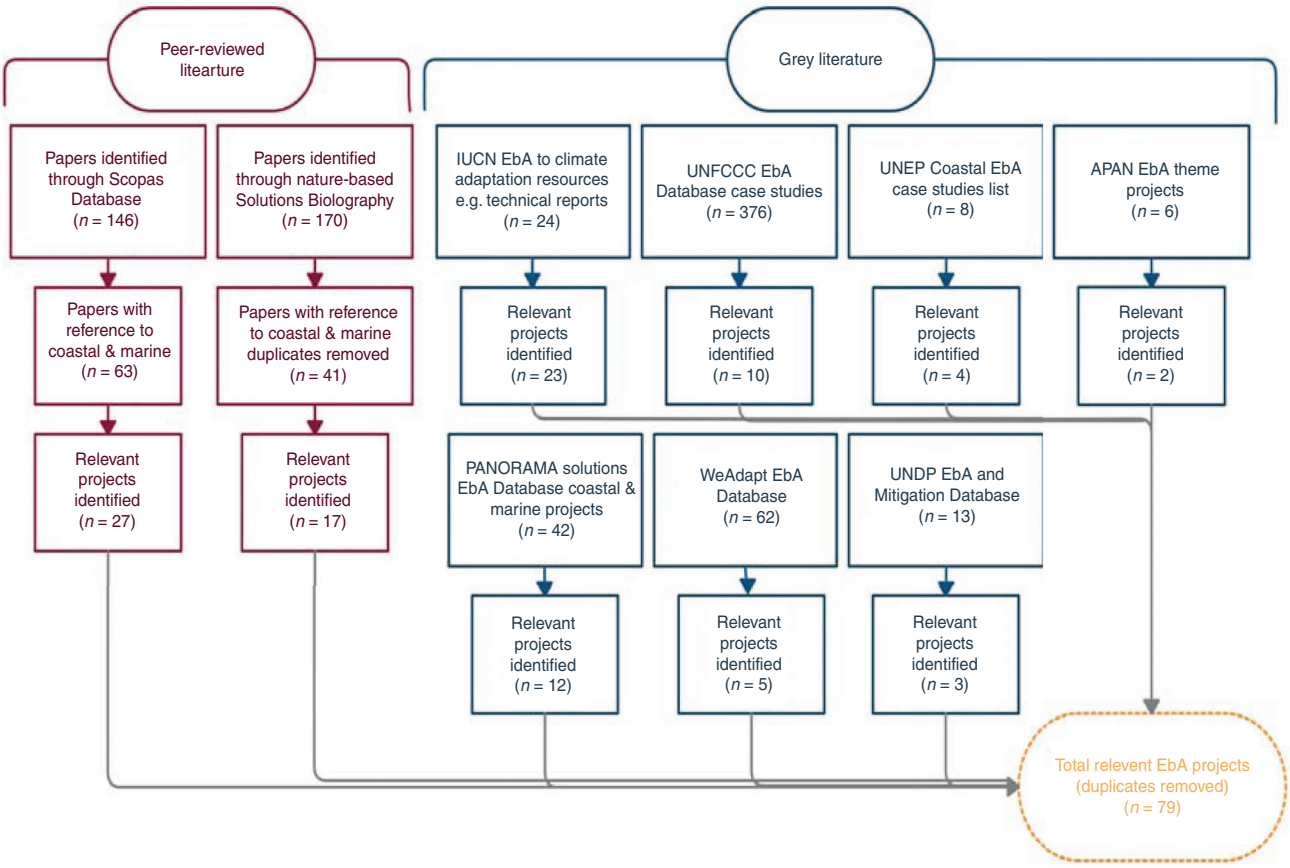


Fig. 1. Review process of relevant marine and coastal EbA projects from the peer-reviewed and grey literature.

Table 2. Variables recorded from identified EbA projects and their description

Variable	Description
Literature type	The source of the literature: categorised as grey literature, peer-reviewed literature or both.
Geographic location	The country in Asia and Oceania where a project was implemented or projected to be implemented.
Development status	Countries where projects were implemented were categorised as developed, developing and least developed based on the United Nations Standard Country Code.
Climate-related hazard	The climate-related hazards that a project aimed to address. Documented hazards were: decreased rainfall and drought; extreme events; increased rainfall and flooding; increased sea surface temperatures; ocean acidification; and sea level rise.
Ecosystem type	The marine or coastal ecosystems in which a project was implemented. Documented ecosystems were: coral reefs; dunes; estuaries (including oyster reefs); mangroves; saltmarshes; and seagrasses.
Ecosystem service	The ecosystem service targeted by the project. Documented services were: capacity building and livelihoods enhancement; carbon sequestration; food security; maintenance of wildlife; shoreline protection; and tourism and recreation.
Broad adaptation category	Projects were placed in one or more broad adaptation categories: conservation and awareness; management and planning; and restoration.
Specific adaptation approach	Conservation and awareness adaptation approaches documented: awareness events and media outputs; conservation awareness campaigns and groups; and ecotourism. Management and planning adaptation approaches documented: coastal spatial planning; ecosystem assessment; fisheries management (including key species management plans, permits and fish aggregation devices); integrated coastal zone management (including ridge-to-reef plans); mangrove protection zone; marine protected areas (including seasonal closures; tabus; locally managed marine areas); marine spatial planning; and socio-ecological assessment. Restoration adaptation approaches documented: coral reef restoration; crustacean aquaculture; dune restoration; fish aquaculture; mangrove restoration; saltmarsh restoration; and seagrass restoration.

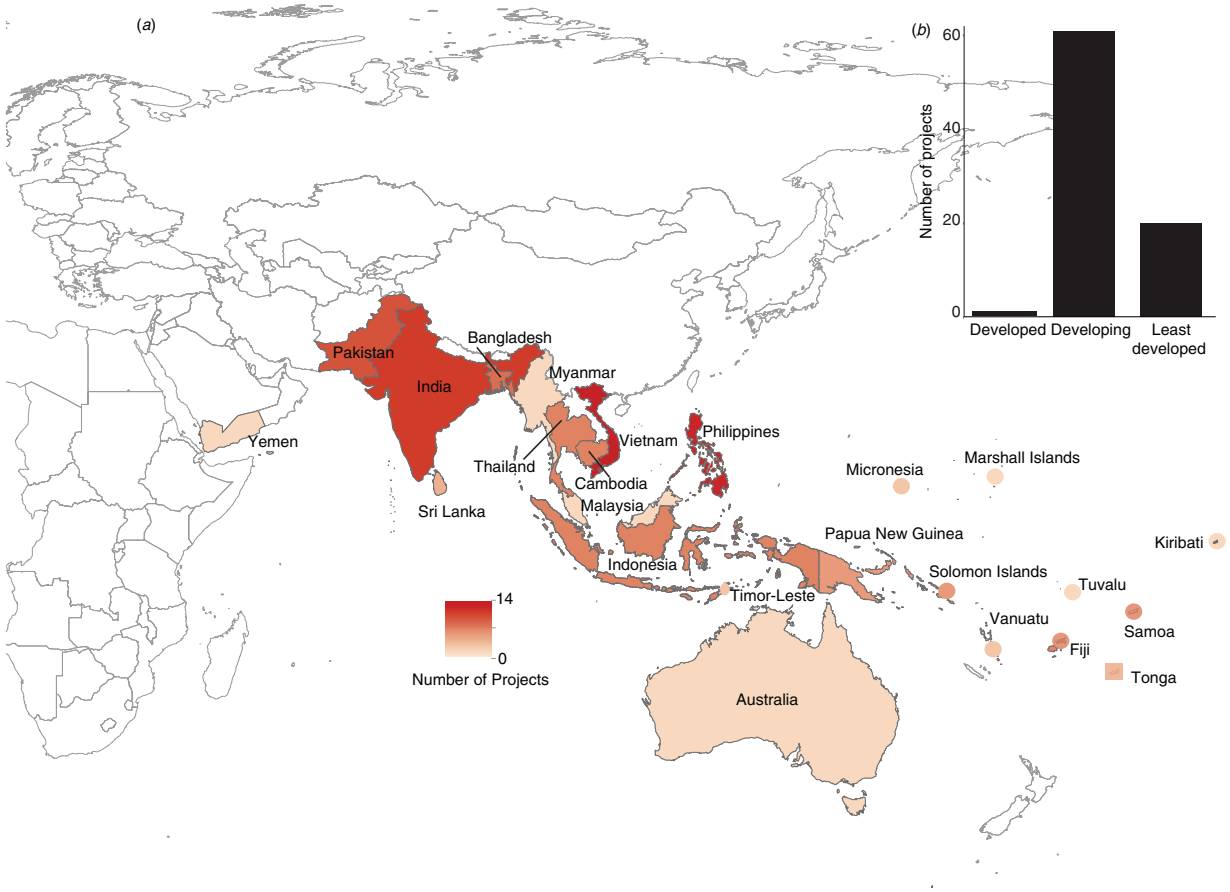


Fig. 2. Geographic summary of marine and coastal EbA projects in Asia and Oceania. (*a*) The location and number of EbA projects by country. (*b*) Total number of EbA projects grouped by development status.

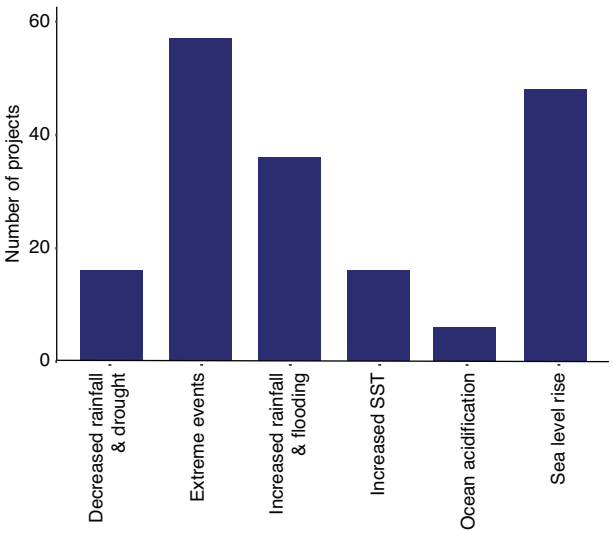


Fig. 3. Number of projects per climate-related hazard addressed in marine and coastal EbA projects. SST stands for sea surface temperature. Note that some projects addressed multiple climate-related hazards, and projects that addressed climate change non-specifically were not included here.

cyclones and typhoons, and sea level rise were the main climate-related hazards of concern when undertaking a marine and coastal EbA project across Asia and Oceania (32% and 27%, respectively), with ocean acidification being of least concern (3%) (Fig. 3).

Ecosystems used and their services

Most projects used a single ecosystem (68%) but some were conducted across two or more (32%). The greatest number of projects were conducted in mangrove ecosystems (72 projects, 60%), followed by coral reefs (23 projects, 19%) (Fig. 4*a*). Projects across all ecosystems targeted capacity building and livelihood enhancement, and, for most, maintenance of wildlife/biodiversity. In mangroves, shoreline protection was also particularly targeted (25%) and in coral reefs, food security (21%) (Fig. 4*b*).

Specific ecosystem-based adaptation approaches

EbA approaches were applied within all three broad adaptation categories, with 31% of projects implementing a conservation action, 31% a management and planning activity, and 38% a restoration process. Across all strategies, mangrove restoration

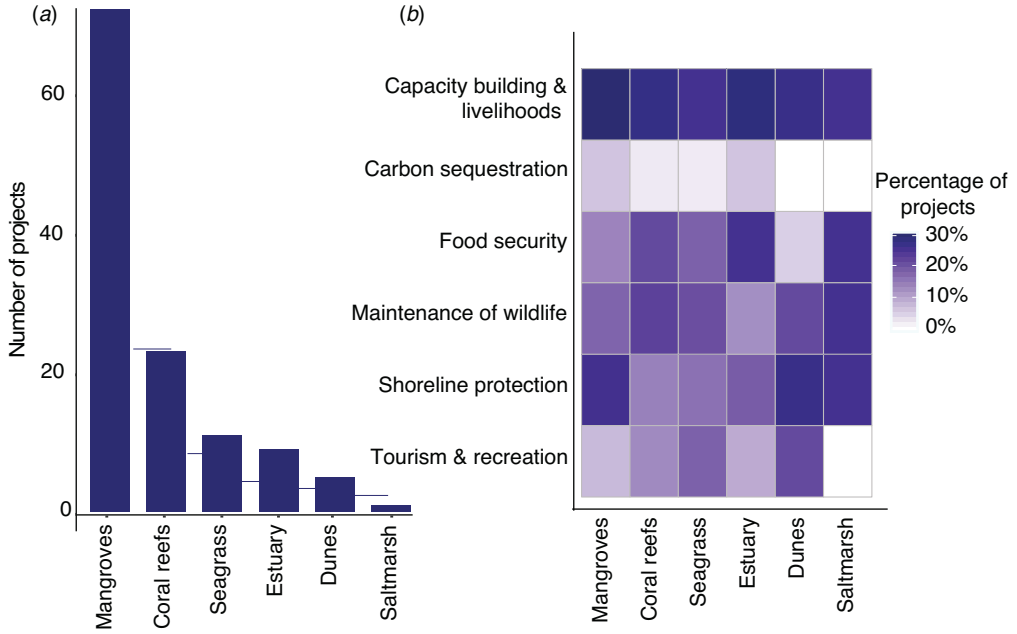


Fig. 4. Summary of ecosystems involved, and ecosystem services targeted in projects. (*a*) Number of projects per ecosystem. (*b*) Heat map of the percentage of projects from each ecosystem providing a specific ecosystem service. Note that some projects were undertaken across multiple ecosystems and for multiple ecosystem services.

was the most frequently implemented approach (51 projects, 23%). Socio-ecological assessments were undertaken the most frequently for management and planning activities and the establishment of community awareness campaigns and groups was the main form of conservation and awareness action (Fig. 5).

Integrated ecosystem-based adaptation and marine spatial planning

We identified five case studies that were implemented on-ground and followed EbA criteria and best practice guidelines for MSP in MPAs (see case studies in Fig. 6). All the integrated EbA and MSP case studies were reclassified as EbA after design and implementation. In addition, no form of climate adaptation was incorporated into the initial design and implementation for the Kubulau MPA Network but it was included during a revision process (Weeks and Jupiter 2013). Some case studies exemplified stronger EbA qualities set against the FEBA criteria (Bertram *et al.* 2017), such as the Kubulau MPA Network and Cham Islands marine reserve. In the Kubulau MPA Network, rigorous data were collected that involved traditional knowledge on resource-use mapping and resilient coral reef hotspots, equity and gender issues were incorporated, and a user fee community revenue scheme was established (Andrade *et al.* 2011; Weeks and Jupiter 2013). In the Cham Islands, implementation was part of a larger climate adaptation strategy and incorporated several alternative livelihood approaches, such as handicraft production workshops and capacity building activities consisting of MPA training courses (Brown 2013). Both case studies are examples of integrated EbA and MSP that clearly reduce social and environmental vulnerabilities and benefit society in terms of climate adaptation.

Common features within the five case studies included; participatory approaches to the design and implementation of the spatial management plan; community-based, co-management or shared governance structures; and local–regional scales of implementation supported by policies or sectors at multiple levels (Fig. 6). Throughout the preparation and data collection of the MSP plan, participatory mapping, 3D modelling, biodiversity surveys, and traditional knowledge gathering were frequently used methods (e.g. Lauru MPA network: Lacovino *et al.* 2013). To generate spatial zoning maps, information on biodiversity, fish biomass, coral resilience hotspots, ecosystem connectivity, resource use, future climate-related hazards and anthropogenic stressors were used in geographic information system programs, such as ArcGIS, and conservation planning tools, such as Marxan (e.g. Kimbe Bay MPA Network: Green *et al.* 2009). In all case studies, communities were responsible for monitoring and enforcement with varying levels of support from partner organisations and/or government. Importantly, all five case studies used adaptive management strategies aimed at evaluating the ongoing performance of the MPA and incorporating climate change.

Discussion

Ecosystem-based adaptation knowledge base

We found that the current EbA project knowledge base is dominated by grey literature. This poses several constraints to synthesising an EbA evidence base as the content and quality of grey literature is variable and reviewing it in a systematic way is difficult. This has limited the use of grey literature in past reviews of EbA (e.g. Doswald *et al.* 2014; Milman and Jagannathan 2017; Nalau *et al.* 2018). However, including grey

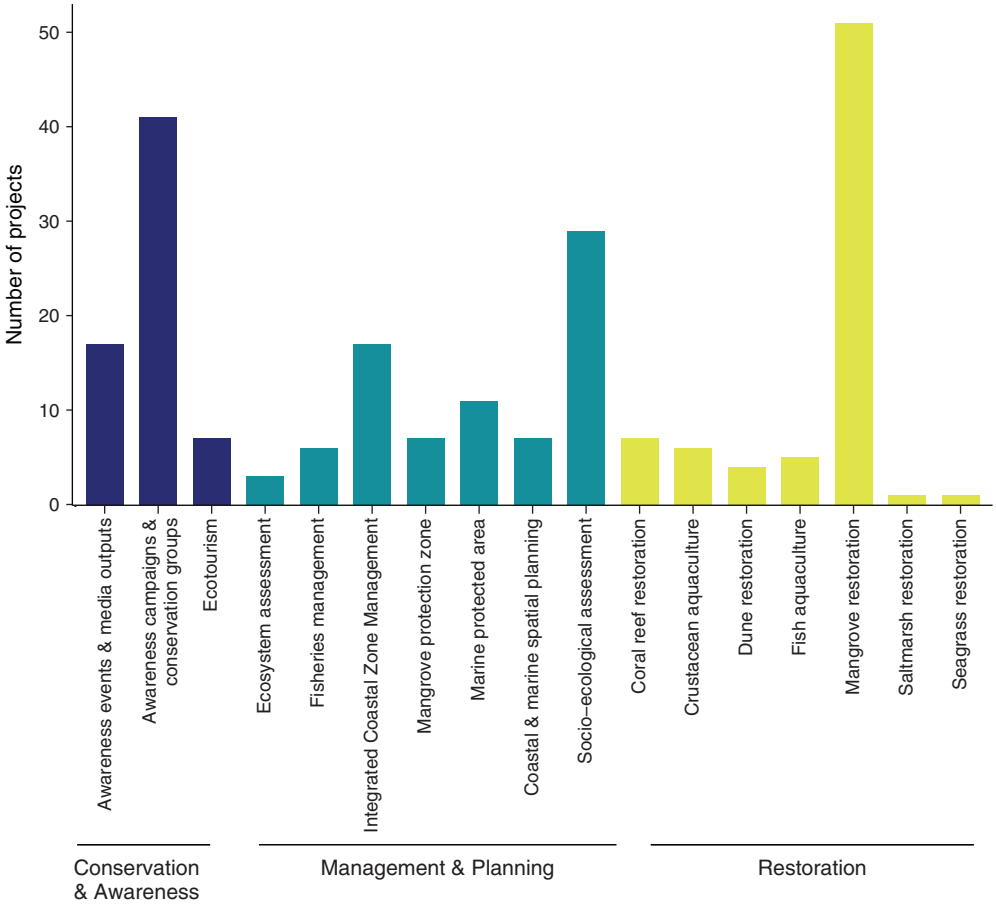


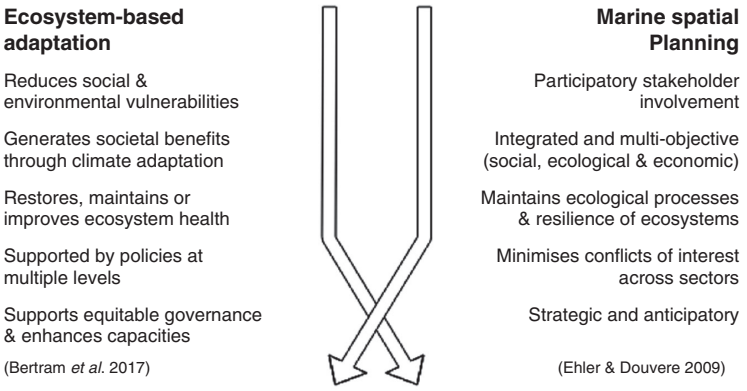
Fig. 5. Number of EbA projects using specific adaptation approaches grouped by the broad adaptation categories of 'Conservation & Awareness', 'Management & Planning' and 'Restoration'. Note that some projects implemented multiple EbA approaches.

literature in our review provided useful insights into project-specific methods and a more complete picture of the current state of EbA application in marine and coastal ecosystems in Asia and Oceania.

There appears to still be some confusion around defining EbA, with some projects being labelled as both EbA and ecosystem-based disaster risk reduction. Some of these projects focus on mitigating the impacts of natural disasters exacerbated by climate change and are appropriately termed EbA (e.g. Buffle *et al.* 2011), whereas others focused solely on natural disasters such as floods or tsunamis, without a clear link to climate change (e.g. Kaplan *et al.* 2009). This highlights the inherently complex nature of adaptation and means that our review protocol may have missed literature that did not explicitly recognise its connection with EBA. Further research is needed on clarifying overlap between EbA and other nature-based solutions at a project level and on why EbA may not be being termed or used more broadly in relevant adaptation applications. To help synthesise the EbA knowledge base, relevant projects should classify EbA at project inception and report project details within established EbA databases or be disseminated into the peer-review literature where appropriate.

Geographic location and development status

All but one EbA project in Asia and Oceania were in least developed and developing countries that are typically more vulnerable to climate-related impacts due to having higher levels of poverty and population growth (Hay and Mimura 2006; Olsson *et al.* 2014; Savo *et al.* 2016). This suggests that the cost-effectiveness (Jones *et al.* 2012) and accessibility (Mercer *et al.* 2012) of EbA are major reasons for its application in the region. In these countries, the resources required to implement and sustain hard infrastructure solutions are limited and populations have a strong reliance on ecosystem services, so EbA may often be the most feasible option for climate adaptation (McCarthy *et al.* 2001; MEA 2005; Selig *et al.* 2018). The perceived technical and logistical constraints in these regions may also inhibit support from international donors and organisations for countries that are more remote and where access is often weather dependent (e.g. some Pacific Island nations) (McLeod *et al.* 2019). As such, higher EbA application in certain countries, such as Vietnam, may be a result of seemingly lower on-ground implementation difficulties. It is therefore important that EbA project goals are directed at enhancing capacities of locals to sustain longer-term project requirements if funding lapses



Integrated ecosystem-based adaptation & marine spatial planning

Case studies	Goal	Governance	Spatial Management	Scale	Participatory Design
Kubulau MPA Network, Fiji	Healthy, productive & resilient ecosystems that can sustain human use	Community-based comanagement	MPA & Tabus with no-take & periodic closures	District/ Regional	Yes
Cham Islands Marine Reserve, Vietnam	Long-term resilience in the face of climate change	Shared comanagement	MPA with multiple use zones	Local	Yes
Kimbe Bay MPA Network, Papua New Guinea	Design a resilient network of MPAS for biodiversity & livelihoods	Community-based	LMMA network with no-take areas	Local-Regional	Post-design
Lauru Ridges to Reef MPA Network, Solomon Islands	Conservation planning for the future	Community-based	LMMA network	Local-Regional	Yes
Trao Reef LMMA, Vietnam	Capacity building in management of coral reefs	Community-based	LMMA with multiple use zones	Local	Yes

Fig. 6. Conceptual diagram illustrating the main characteristics of EbA (Bertram *et al.* 2017) and MSP (Ehler and Douvere 2009), including a general description of the five case studies found within the review process that are examples of integrated EbA and MSP for marine protected area (MPA) implementation. LMMA stands for locally managed marine areas. See Supplementary Table 2 for case study references.

(e.g. training on monitoring and enforcement). With these goals in mind, we suggest that EbA projects continue to expand in areas that have rapid population growth, low capacity, high dependence on ecosystems and are especially vulnerable to climate change (e.g. Myanmar and many small island developing states) (Eckstein *et al.* 2018; Selig *et al.* 2018; ESCAP 2019).

EbA benefits are also applicable to developed nations as planning for global climate impacts through adaptation can reduce future community vulnerabilities, regardless of current levels of impacts (McCarthy *et al.* 2001; Andrade Pérez *et al.* 2010). For example, coral reef restoration could be implemented alongside seawalls to promote tourism aesthetics while also increasing coastal protection to the increased risk of extreme events in Asia and Oceania (Grantham *et al.* 2011; Mycoo 2014; Eckstein *et al.* 2018; ESCAP 2019). Increasing EbA could be particularly beneficial in developed countries, such as Australia, where coastal communities are exposed to high climate variability and marine and coastal ecosystems play a key role in tourism jobs, recreational activities and fisheries (Figgis and Koss 2012; Head *et al.* 2014). The lack of EbA we observed in developed countries may also be a result of other ecosystem-based approaches used that focus on conserving biodiversity or ecology (e.g. Day *et al.* 2008) or mitigating natural disasters (e.g. in Japan, Takeuchi *et al.* 2016) without a direct human climate adaptation link. In any case, EbA is a low-risk approach that should be considered more in developed countries as a hybrid or alternative to hard-engineering solutions.

Climate-related hazards

Climate-related hazards that often cause direct damage to human populations, services and individual assets appear to be driving EbA project implementation (e.g. extreme events and sea level rise) over hazards that can have lagged or more indirect effects (e.g. increased sea surface temperature) (Graham *et al.* 2007; Merone and Tait 2018; Thomas *et al.* 2018). In recent decades in Asia and Oceania, extreme weather events and sea level rise have caused significant damages to coastal building infrastructure, livelihoods and survival (Colls *et al.* 2009; Rahman 2014; Thomas *et al.* 2018; Chow *et al.* 2019; ESCAP 2019). In response, EbA approaches such as mangrove restoration or protection have been implemented to increase the resilience of communities to these hazards (Macintosh *et al.* 2012; Rahman 2014; Sierra-Correa and Cantera Kintz 2015), whereas EbA responses to other climate-related hazards that have been extensively documented in countries throughout Asia and Oceania, such as coral bleaching from increased sea surface temperature (Green *et al.* 2009; Grantham *et al.* 2011; Hoegh-Guldberg *et al.* 2019), have been fewer. As such, EbA implementation appears to be aimed more at the certain

ecosystem services and community assets most valued, as opposed to the specific likelihood of a climate-related hazard occurring.

Ecosystems and their services

Previous EbA reviews have focused largely on the regulating services provided by marine and coastal EbA, such as the use of mangroves to provide shoreline protection (see Spalding *et al.* 2014; Sierra-Correa and Cantera Kintz 2015). We also found that mangroves were used the most in EbA and for a significant part for their shoreline protection services. The emphasis on mangroves for regulating services should not limit the use of other ecosystems, which can also contribute to EbA (Seddon *et al.* 2019). For instance, coral reefs and seagrass can also provide regulating services through protection from increased wave attenuation and storm surges (Colls *et al.* 2009; Bartlett 2017). Most actions were implemented in coastal and nearshore ecosystems rather than in offshore areas, likely as a result of the inherent nature of EbA being centred around community involvement and accessibility. This spatial pattern may also reflect the current focus on regulatory services, such as coastal protection, which is often provided the most extensively from nearshore environments (Hale *et al.* 2009; Sierra-Correa and Cantera Kintz 2015). Expanding the use of EbA into multiple ecosystems relative to their health status, accessibility and service function at a project location could also help spread the risk associated with increased habitat degradation that is apparent when using an ecosystem-reliant approach (Grantham *et al.* 2011; Chow *et al.* 2019; Seddon *et al.* 2019).

With increasing human populations globally, provisioning and cultural ecosystem services that promote food and livelihood security are increasingly being recognised as a significant part of the climate adaptation agenda (MEA 2005; CBD 2009; Munang *et al.* 2013). In Asia and Oceania, one main reason for EbA projects was to provide community-based benefits, such as enhancing capacity and livelihoods, and, in a number of cases, food security. For instance, nearshore fish aggregation devices are used in Oceania to increase capacity, livelihoods and food security to climate change (SPC and GIZ 2013; Bell *et al.* 2015). Continuing to promote EbA examples in the literature and in awareness campaigns that include these tangible provisioning benefits for communities may help to increase EbA uptake into areas that currently do not perceive the current need for regulating services.

Future studies should evaluate the success of EbA projects in achieving their ecosystem service aims. One way to do this is through return-on-investment, cost-effectiveness or cost–benefit analysis that assesses the social, economic and ecological benefits from implementation and the costs associated with labour, opportunity costs and resources used (Daigneault *et al.* 2016; Emerton *et al.* 2016). These analyses can also be undertaken when planning for adaptation approaches on a case-specific basis (Buckwell *et al.* 2019). However, EbA valuation or planning can be complex, with difficulties associated with defining success, delayed delivery outcomes, limited resources allocated for monitoring and evaluation, and uneven distribution of costs and benefits (Kingsford and Watson 2011; Buckwell *et al.* 2019). In response, conventional microeconomic approaches need to be enriched with methods that capture the value of non-market ecosystem services, uncertainty and feasibility (de Groot *et al.* 2010; Costanza *et al.* 2014; Small *et al.* 2017; Tulloch *et al.* 2020). Considering these trade-offs in investment, biodiversity conservation, and ecosystem service benefits when implementing EbA is important when identifying practical adaptation options (MEA 2005; Kingsford and Watson 2011; Small *et al.* 2017).

Specific EbA approaches

Mangrove restoration was the most implemented EbA approach and has likely been favoured due to its previous application as a shoreline protection measure prior to the emergence of EbA (Mazda *et al.* 1997; Badola and Hussain 2005; Costanza *et al.* 2008). This emphasis on mangrove restoration compared with other coastal ecosystems that are often submerged (e.g. coral reefs, seagrass) may also be a result of easier access to land-based project sites and the resources required for implementation and monitoring (Edwards 2010; Primavera *et al.* 2012) or the capacity of different ecosystems in the local context to adequately reduce the targeted climatic-hazard (Seddon *et al.* 2019). In areas where ecosystems are highly functioning and provide recognisable ecosystem service benefits to communities, proactive actions, such as protected areas, should be considered as an EbA option (UNEP 2016). In many cases, restoration is reactive (e.g. The Green Coast Project: Colls *et al.* 2009) and, although necessary to increase ecosystem services and biodiversity in degraded areas, it can sometimes be costly if not implemented in the appropriate coastal area, planting or growing is of the wrong species and the restoration site is inadequately maintained (Macintosh *et al.* 2012; MMF 2012).

An EbA approach should target its application to the needs of a community, the ecosystems present and their resources available (Grantham *et al.* 2011; Bertram *et al.* 2017). We identified a large number of socio-ecological vulnerability assessments undertaken in our EbA projects in Asia and Oceania. These assessments are fundamental in planning adaptation approaches (McCarthy *et al.* 2001; Bourne *et al.* 2016) and may indicate that EbA is still somewhat in a planning phase with more applied projects to follow. One way to ensure these assessments move into on-ground action is by increasing awareness-raising activities in EbA projects, such as establishing conservation groups and organising climate change awareness campaigns (Andrade *et al.* 2011; MMF 2012). These awareness activities have been shown to generate community support, increase ownership and provide access to additional opportunities for community-based implementation, monitoring, and evaluation, rather than relying on external funding or top-down management (Doswald and Osti 2011; Grantham *et al.* 2011; Spalding *et al.* 2014; Nalau *et al.* 2018).

Integrating marine spatial planning into ecosystem-based adaptation

We had difficulties in finding specific information on the design and implementation processes of several MPAs identified as EbA, highlighting a need for better information transparency on project implementation. This is particularly true

for smaller, locally managed marine areas that integrate well into the EbA framework but often do not document objectives, planning processes and tools used to implement management (Jupiter *et al.* 2014). As such, our five identified case studies of integrated MSP and EbA in MPAs may not be a definitive list but do provide examples and information that can assist planners when designing future EbA marine protected areas. Our small number of recorded MSP and EbA case studies suggests that the benefits of building on existing policies may not be occurring to its greatest potential in applied EbA projects.

A significant aspect that EbA can draw from MSP is a clear monitoring and evaluation framework, which is a defined step in MSP (Ehler and Douvere 2009) and often a limiting factor of EbA (McKinnon and Hole 2015). Many EbA projects have not evaluated their approach or defined their success due to a lack of a monitoring and evaluation framework and defined goals (Doswald *et al.* 2014; Nalau *et al.* 2018). In part, this could be due to the challenges associated with conducting monitoring and evaluation approaches for adaptation, where there are great levels of uncertainty surrounding predicted future climatic changes (Silva Villanueva 2011). To mediate some of these inherent uncertainties in monitoring and evaluation frameworks, Ehler and Douvere (2009) suggest that MSP projects should have: realistic expectations; clear key performance indicators and outcomes; participatory designs; periodic evaluations; and include sustained commitment to resources. For EbA, in particular, building the participatory nature of MSP into monitoring and evaluation frameworks is key to ensuring MPAs are performing in terms of enhancing the capacity to adapt in human communities to climate change (Silva Villanueva 2011; Nalau *et al.* 2018). Appropriately designed MSP can promote adaptive monitoring and evaluation frameworks by viewing plans as living documents that are revised with new data and knowledge; are iteratively reviewed; and are edited to address local or regional objectives (Weeks and Jupiter 2013; Mills *et al.* 2015). As in our case studies, incorporating MSP into EBA marine protected area planning may encourage managers to conduct monitoring and evaluation activities and provide established MSP examples to follow (Gilliland and Laffoley 2008; UNEP 2016).

Another important process that EbA projects can draw from MSP are the tools for collaborative management. For instance, the low-cost participatory mapping techniques and structured planning programs commonly used in MSP have contributed to garnering community support of MPAs (see Andrade Pérez *et al.* 2010; Lacovino *et al.* 2013). Under the collaborative MSP framework, community-based or shared governance can be readily established at relevant scales to EbA (Gubbay 2004; Ehler and Douvere 2009; Lacovino *et al.* 2013; UNEP 2016; Bertram *et al.* 2017). By integrating MSP best practices into future EbA applications, communities will likely have reduced user conflicts, more cost-efficient and effective planning, and increased overall resilience.

Conclusions

We found that EbA is being used widely within marine and coastal ecosystems through conservation and awareness, management and planning, and restoration approaches in Asia and Oceania, with the threats of extreme events and sea level rise the main project drivers. Mainstreaming the use of EbA will depend on increased evidence of its effectiveness. Project managers need to incorporate EbA thinking at the onset of planning an adaptation approach and term it as EbA in initial documentation rather than after implementation. Ideally, EbA approaches should be implemented with goals specifically aimed at targeting increased capacity to sustain EbA actions without continued reliance on external funding. Additionally, EbA should be actioned as the result of socio-ecological assessments and cost–benefit analysis inclusive of ecosystem-service valuation that identifies them as a feasible solution to community and ecosystem-specific vulnerabilities to climate change. Where possible, the inclusion of more than one adaptation approach and ecosystem should be aimed for in EbA planning to aid with risk spreading in case of ecosystem degradation. There is much to be learned from existing policy and management tools to aid with the success of EbA approaches which, as we have discussed, could be an outcome of integrating MSP into EbA projects that use MPAs as a management and planning approach.

Conflicts of interest

The authors declare no conflicts of interest.

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References

Aerts, J. C., Botzen, W. J. W., Emanuel, K., Lin, N., de Moel, H., and Michel-Kerjan, E. O. (2014). Evaluating flood resilience strategies for coastal megacities. *Science* **344**(6183), 472–474. doi:10.1126/SCIENCE.1248222

Agardy, T., Davis, J., Sherwood, K. and Vestergaard, O. (2011). Taking steps toward marine and coastal ecosystem-based management: an introductory guide. In 'UNEP Regional Seas Reports and Studies 189'. UNEP, Nairobi, Vol. 189, 68.

Alvarez-Romero, J. G., Mills, M., Adams, V. M., Gurney, G. G., Pressey, R. L., Weeks, R., Ban, N. C., Cheok, J., Davies, T. E., Day, J. C., Hamel, M. A., Leslie, H. M., Magris, R. A., and Storlie, C. J. (2018). Research advances and gaps in marine planning: towards a global database in systematic conservation planning. *Biological Conservation* **227**, 369–382. doi:10.1016/J.BIOCON.2018.06.027

Andrade, Á., Córdoba, R., Dave, R., Girot, P., Herrera-F, B., Munroe, R., Oglethorpe, J., Paaby, P., Pramova, E., Watson, J. and Verger, W. (2011). 'Draft Principles and Guidelines for Integrating Ecosystem-based Approaches to Adaptation in Project and Policy Design: a Discussion Document.' (IUCN-CEM, CATIE: Turrialba, Costa Rica.)

Andrade Pérez, A., Herrera Fernandez, B. and Cazzolla, G. (2010). 'Building Resilience to Climate Change: Ecosystem-based Adaptation and Lessons from the Field.' (IUCN: Gland, Switzerland.)

Badola, R., and Hussain, S. A. (2005). Valuing ecosystem functions: an empirical study on the storm protection function of Bhitarkanika mangrove ecosystem, India. *Environmental Conservation* **32**(1), 85–92. doi:10.1017/S0376892905001967

Bartlett, C. (2017). Coral gardening for climate change adaptation in Vanuatu. PANORAMA Solutions for a Healthy Planet. Available at: https://panorama.solutions/en/solution/coral-gardening-climate-change-adaptation-vanuatu [accessed 20 September 2018]

Bell, J. D., Albert, J., Andrefouet, S., Andrew, N. L., Blanc, M., Bright, P., Brogan, D., Campbell, B., Govan, H., Hampton, J., Hanich, Q., Harley, S., Jorari, A., Smith, M. L., Pontifex, S., Sharp, M. K., Sokimi, W., and Webb, A. (2015). Optimising the use of nearshore fish aggregating devices for food security in the Pacific Islands. *Marine Policy* **56**, 98–105. doi:10.1016/J.MARPOL.2015.02.010

Bertram, M., Barrow, E., Blackwood, K., Rizvi, A., Reid, H. and von Schelihа-Dawid, S. (2017). Making ecosystem-based adaptation effective: a framework for defining qualification criteria and quality standard. FEBA (Friends of Ecosystem-based Adaptation) technical paper developed for UNFCCC-SBSTA 46. GIZ, Bonn, Germany. IIED/IUCN: Gland/London, UK.

Bourne, A., Holness, S., Holden, P., Scorgie, S., Donatti, C. I., and Midgley, G. (2016). A socio-ecological approach for identifying and contextualising spatial ecosystem-based adaptation priorities at the sub-national level. *Plos One* **11**(5), e0155235. doi:10.1371/JOURNAL.PONE.0155235

Brown, P. (2013). Marine protected areas, co-management and livelihoods: coastal change in Vietnam. Ph.D. Thesis, University of Sydney, Australia.

Buckwell, A., Ware, D., Fleming, C., Smart, J. C., Mackey, B., Nalau, J., and Dan, A. (2019). Social benefit cost analysis of ecosystem-based climate change adaptations: a community-level case study in Tanna Island, Vanuatu. *Climate and Development* **12**, 495–510. doi:10.1080/17565529.2019.1642179

Buffle, P., Nguyen, Y. and Fauerby Thomsen, M. (2011). Community-based mangrove reforestation and management in Da Loc, Vietnam. Ecosystems, Livelihoods and Adaptation Network (ELAN). Available at https://www.preventionweb.net/publications/view/25381

CBD (2009). Connecting biodiversity and climate change mitigation and adaptation: report of the second *ad hoc* technical expert group on biodiversity and climate change. CBD Technical Series No. 41, Montreal.

Chow, J., Khanom, T., Hossain, R. and Khadim, J. (2019). Forest management for climate change adaptation in Bangladesh. In 'Confronting Climate Change in Bangladesh'. (Eds S. Huq, J. Chow, A. Fenton, C. Stott, J. Taub, and H. Wright.) Confronting Climate Change in Bangladesh. The Anthropocene: Politik – Economics – Society – Science, vol 28. Springer, Cham. Available at https://doi.org/10.1007/978-3-030-05237-9_4

Cohen-Shacham, E., Walters, G., Janzen, C. and Maginnis, S. (2016). 'Nature-based Solutions to Address Global Societal Challenges.' (IUCN: Gland, Switzerland.)

Colls, A., Ash, N. and Ikkala, N. (2009). 'Ecosystem-based Adaptation: A Natural Response to Climate Change.' (IUCN: Gland, Switzerland.)

Costanza, R., de Groot, R., Sutton, P., van der Ploeg, S., Anderson, S. J., Kubiszewski, I., Farber, S., and Turner, R. K. (2014). Changes in the global value of ecosystem services. *Global Environmental Change* **26**, 152–158. doi:10.1016/J.GLOENVCHA.2014.04.002

Costanza, R., Perez-Maqueo, O., Martinez, M. L., Sutton, P., Anderson, S. J., and Mulder, K. (2008). The value of coastal wetlands for hurricane protection. *Ambio* **37**(4), 241–248. doi:10.1579/0044-7447(2008)37[241:TVOCWF]2.0.CO;2

Daigneault, A., Brown, P., and Gawith, D. (2016). Dredging versus hedging: comparing hard infrastructure to ecosystem-based adaptation to flooding. *Ecological Economics* **122**, 25–35. doi:10.1016/J.ECOLECON.2015.11.023

Day, V., Paxinos, R., Emmett, J., Wright, A., and Goecker, M. (2008). The Marine Planning Framework for South Australia: a new ecosystem-based zoning policy for marine management. *Marine Policy* **32**(4), 535–543. doi:10.1016/J.MARPOL.2007.10.009

de Groot, R. S., Fisher, B., Christie, M., Aronson, J., Braat, L., Haines-Young, R., Gowdy, J., Maltby, E., Neuville, A., Polasky, S., Portela, R. and Ring, I. (2010). Integrating the ecological and economic dimensions in biodiversity and ecosystem service valuation. In 'The Economics of Ecosystems and Biodiversity: Ecological and Economic Foundations'. (Ed. P. Kumar.) pp. 9–40. (TEEB Foundations, Earthscan: London.)

Doswald, N., Munroe, R., Roe, D., Giuliani, A., Castelli, I., Stephens, J., Moller, I., Spencer, T., Vira, B., and Reid, H. (2014). Effectiveness of ecosystem-based approaches for adaptation: review of the evidence-base. *Climate and Development* **6**(2), 185–201. doi:10.1080/17565529.2013.867247

Doswald, N. and Osti, M. (2011). Ecosystem-based approaches to adaptation and mitigation – good practice examples and lessons learned in Europe. BfN-Skripten 306. German Federal Agency for Nature Conservation (BfN), Bonn, Germany.

Eckstein, D., Hutfils, M.-L. and Winges, M. (2018). Global climate risk index 2019: who suffers most from extreme weather events? Weather-related loss events in 2017 and 1998 to 2017. Germanwatch e.V, Berlin. Available at www.germanwatch.org/en/cri.

Edwards, A. J. (2010). 'Reef Rehabilitation Manual.' (Coral Reef Targeted Research & Capacity Building for Management Program: St Lucia, Australia.)

Ehler, C. and Douvere, F. (2009). Marine spatial planning: a step-by-step approach toward ecosystem-based management. Intergovernmental Oceanographic Commission and Manuals and Guides No. 53, ICAM Dossier No. 6. UNESCO, Paris.

Emerton, L., Huxham, M., Bournazel, J. and Kumara, M. P. (2016). Valuing ecosystems as an economic part of climate-compatible development infrastructure in coastal zones of Kenya & Sri Lanka. In 'Ecosystem-based Disaster Risk Reduction and Adaptation in Practice'. (Eds F. Renaud, K. Sudmeier-Rieux, M. Estrella, and U. Nehren.) Advances in Natural and Technological Hazards Research, vol 42. Springer, Cham. https://doi.org/10.1007/978-3-319-43633-3_2

ESCAP (2019). The disaster riskscape across Asia-Pacific: pathways for resilience, inclusion and empowerment. United Nations publication, Bangkok, Thailand. Available at https://www.unescap.org/publications/asia-pacific-disaster-report-2019 [accessed October 2019].

Figgis, P. and Koss, R. (2012). 'Conserving Australia's Marine Environment: Key Directions Statement.' (Australian Committee for IUCN: Sydney.)

Gilliland, P. M., and Laffoley, D. (2008). Key elements and steps in the process of developing ecosystem-based marine spatial planning. *Marine Policy* **32**(5), 787–796. doi:10.1016/J.MARPOL.2008.03.022

Graham, N. A., Wilson, S. K., Jennings, S., Polunin, N. V., Robinson, J., Bijoux, J. P., and Daw, T. M. (2007). Lag effects in the impacts of mass coral bleaching on coral reef fish, fisheries, and ecosystems. *Conservation Biology* **21**(5), 1291–1300. doi:10.1111/J.1523-1739.2007.00754.X

Grantham, H. S., McLeod, E., Brooks, A., Jupiter, S., Hardcastle, J., Richardson, A. J., Poloczanska, E. S., Hills, T., Mieszkowska, N., and Klein, C. (2011). Ecosystem-based adaptation in marine ecosystems of tropical Oceania in response to climate change. *Pacific Conservation Biology* **17**(3), 241–258. doi:10.1071/PC110241

Green, A., Smith, S. E., Lipsett-Moore, G., Groves, C., Peterson, N., Sheppard, S., Lokani, P., Hamilton, R., Almany, J., Aitsi, J., and Bualia, L. (2009). Designing a resilient network of marine protected areas for Kimbe Bay, Papua New Guinea. *Oryx* **43**(4), 488–498. doi:10.1017/S0030605309990342

Gubbay, S. (2004). Marine protected areas in the context of marine spatial planning – discussing the links. Report to WWF-UK, Godalming, UK.

Hale, L. Z., Meliane, I., Davidson, S., Sandwith, T., Beck, M., Hoekstra, J., Spalding, M., Murawski, S., Cyr, N., Osgood, K., Hatziolos, M., Eijk, P. V., Davidson, N., Eichbaum, W., Dreus, C., Obura, D., Tamelander, J., Herr, D., McClennen, C., and Marshall, P. (2009). Ecosystem-based adaptation in coastal and marine areas. *Renewable Resources Journal* **25**(4), 21–28.

Halpern, B. S., Frazier, M., Potapenko, J., Casey, K. S., Koenig, K., Longo, C., Lowndes, J. S., Rockwood, R. C., Selig, E. R., Selkoe, K. A., and Walbridge, S. (2015). Spatial and temporal changes in cumulative human impacts on the world's ocean. *Nature Communications* **6**, 7615. doi:10.1038/NCOMMS8615

Hay, J., and Mimura, N. (2006). Supporting climate change vulnerability and adaptation assessments in the Asia–Pacific region: an example of sustainability science. *Sustainability Science* **1**(1), 23–35. doi:10.1007/S11625-006-0011-8

Head, L., Adams, M., McGregor, H., and Toole, S. (2014). Climate change and Australia. *WIREs Climate Change* **5**, 175–197. doi:10.1002/WCC.255

Hoegh-Guldberg, O., Pendleton, L., and Kaup, A. (2019). People and the changing nature of coral reefs. *Regional Studies in Marine Science* **30**, 100699. doi:10.1016/J.RSMA.2019.100699

IPCC (2018). Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. (Eds V. Masson-Delmotte, P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P. R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J. B. R. Matthews, Y. Chen, X. Zhou, M. I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield.) World Meteorological Organization, Geneva, Switzerland.

IPCC (2019*a*). Summary for policymakers. In 'Climate Change and Land. IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems'. Available at https://www.ipcc.ch/site/assets/uploads/2019/08/Edited-SPM_Approved_Microsite_FINAL.pdf.

IPCC (2019*b*). Summary for policymakers. In 'IPCC Special Report on the Ocean and Cryosphere in a Changing Climate'. (Eds H.-O. Pörtner, D. C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, M. Nicolai, A. Okem, J. Petzold, B. Rama, and N. Weyer.) In press.

Jones, H. P., Hole, D. G., and Zavaleta, E. S. (2012). Harnessing nature to help people adapt to climate change. *Nature Climate Change* **2**(7), 504–509. doi:10.1038/NCLIMATE1463

Jupiter, S. D., Cohen, P. J., Weeks, R., Tawake, A., and Govan, H. (2014). Locally-managed marine areas: multiple objectives and diverse strategies. *Pacific Conservation Biology* **20**(2), 165–179. doi:10.1071/PC140165

Kaplan, M., Renaud, F., and Lüchters, G. (2009). Vulnerability assessment and protective effects of coastal vegetation during the 2004 tsunami in Sri Lanka. *Natural Hazards and Earth System Sciences* **9**(4), 1479–1494. doi:10.5194/NHESS-9-1479-2009

Khan, A., and Amelie, V. (2015). Assessing climate change readiness in Seychelles: implications for ecosystem-based adaptation mainstreaming and marine spatial planning. *Regional Environmental Change* **15**(4), 721–733. doi:10.1007/S10113-014-0662-4

Kingsford, R. T., and Watson, J. E. (2011). Climate change in Oceania – a synthesis of biodiversity impacts and adaptations. *Pacific Conservation Biology* **17**(3), 270–284. doi:10.1071/PC110270

Lacovino, C., Donohoe, P., Carruthers, T. and Chape, S. (2013). Ecosystem-based adaptation and climate change vulnerability for Choiseul Province, Solomon Islands – a synthesis report. SPREP, Apia, Samoa.

Macintosh, D., Mahindapala, R. and Markopoulos, M. (2012). Sharing lessons on mangrove restoration. Mangroves for the Future, Bangkok, Thailand & IUCN, Gland, Switzerland.

Mackey, B. and Ware, D. (2018). Limits to capital works adaptation in the coastal zones and islands: lessons for the Pacific. In 'Limits to Climate Change Adaptation. Climate Change Management'. (Eds W. Leal Filho, and J. Nalau.) pp. 301–323. (Springer: Cham.)

Mazda, Y., Magi, M., Kogo, M., and Hong, P. N. (1997). Mangroves as a coastal protection from waves in the Tong King delta, Vietnam. *Mangroves and Salt Marshes* **1**(2), 127–135. doi:10.1023/A:1009928003700

McCarthy, J. J., Canziani, O. F., Leary, N. A., Dokken, D. J., and White, K. S. (Eds) (2001). 'Climate Change 2001: Impacts, Adaptations, and Vulnerability. IPCC Working Group II.' (Cambridge University Press: Cambridge, UK.)

McKinnon, M. C., and Hole, D. G. (2015). Exploring program theory to enhance monitoring and evaluation in ecosystem-based adaptation projects. *New Directions for Evaluation* **2015**(147), 49–60. doi:10.1002/EV.20130

McLeod, E., Bruton-Adams, M., Förster, J., Franco, C., Gaines, G., Gorong, B., James, R., Posing-Kulwaum, G., Tara, M., and Terk, E. (2019). Lessons from the Pacific islands – adapting to climate change by supporting social and ecological resilience. *Frontiers in Marine Science* **6**, 289. doi:10.3389/FMARS.2019.00289

MEA (2005). Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC.

Mercer, J., Kelman, I., Alfthan, B., and Kurvits, T. (2012). Ecosystem-based adaptation to climate change in Caribbean small island developing states: integrating local and external knowledge. *Sustainability* **4**(8), 1908–1932. doi:10.3390/SU4081908

Merone, L., and Tait, P. (2018). Preventing disaster in the Pacific Islands: the battle against climate disruption. *Australian and New Zealand Journal of Public Health* **42**(5), 419–420. doi:10.1111/1753-6405.12823

Mills, M., Weeks, R., Pressey, R. L., Gleason, M. G., Eisma-Osorio, R.-L., Lombard, A. T., Harris, J. M., Killmer, A. B., White, A., and Morrison, T. H. (2015). Real-world progress in overcoming the challenges of adaptive spatial planning in marine protected areas. *Biological Conservation* **181**, 54–63. doi:10.1016/J.BIOCON.2014.10.028

Milman, A., and Jagannathan, K. J. (2017). Conceptualization and implementation of ecosystems-based adaptation. *Climatic Change* **142**(1–2), 113–127. doi:10.1007/S10584-017-1933-0

MMF (2012). Mangroves for the future: investing in coastal ecosystems. Pakistan Small Grants Programme 2011–2012. Available at http://www.mangrovesforthefuture.org/assets/Repository/Documents/MFF-case-studies-final.pdf. [accessed 19 September 2018].

Munang, R., Thiaw, I., Alverson, K., Goumandakoye, M., Mebratu, D., and Liu, J. (2013). Using ecosystem-based adaptation actions to tackle food insecurity. *Environment: Science and Policy for Sustainable Development* **55**(1), 29–35.

Munroe, R., Roe, D., Doswald, N., Spencer, T., Möller, I., Vira, B., Reid, H., Kontoleon, A., Giuliani, A., Castelli, I., and Stephens, J. (2012). Review of the evidence base for ecosystem-based approaches for adaptation to climate change. *Environmental Evidence* **1**(1), 13. doi:10.1186/2047-2382-1-13

Mycoo, M. (2014). Sustainable tourism, climate change and sea level rise adaptation policies in Barbados. *Natural Resources Forum* **38**(1), 47–57. doi:10.1111/1477-8947.12033

Nalau, J., Becken, S., and Mackey, B. (2018). Ecosystem-based adaptation: a review of the constraints. *Environmental Science and Policy* **89**, 357–364. doi:10.1016/J.ENVSCI.2018.08.014

Narayan, S., Beck, M. W., Reguero, B. G., Losada, I. J., Van Wesenbeeck, B., Pontee, N., Sanchirico, J. N., Ingram, J. C., Lange, G.-M., and Burks-Copes, K. A. (2016). The effectiveness, costs and coastal protection benefits of natural and nature-based defences. *Plos One* **11**(5), e0154735. doi:10.1371/JOURNAL.PONE.0154735

Olsson, L., Opondo, M., Tschakert, P., Agrawal, A. E., Eriksen, S.H., Ma, S., Perch, L. N. and Zakieldeen, S. A. (2014). Livelihoods and poverty. In 'Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change'. (Eds C. B. Field, V. R. Barros, D. J. Dokken, K. J. Mach, M. D. Mastrandrea, T. E. Bilir, M. Chatterjee, K. L. Ebi, Y. O. Estrada, R. C. Genova, B. Girma, E. S. Kissel, A. N. Levy, S. MacCracken, P. R. Mastrandrea, and L. L. White.) pp. 793–832. (Cambridge University Press: Cambridge, UK, & New York, NY, USA.)

Pickering, C., and Byrne, J. (2014). The benefits of publishing systematic quantitative literature reviews for PhD candidates and other early-career researchers. *Higher Education Research & Development* **33**(3), 534–548. doi:10.1080/07294360.2013.841651

Primavera, J. (2015). Community-based mangrove conservation and rehabilitation. PANORAMA Solutions for a Healthy Planet. Available at https://panorama.solutions/en/solutions/community-based-mangrove-conservation-and-rehabilitation [accessed 20 September 2018].

Primavera, J., Savaris, J., Bajoyo, B., Coching, J., Curnick, D., Golbeque, R., Gizman, A., Henderin, J., Joven, R., Loma, R. and Koldewey, H. (2012). 'Manual on Community-based Mangrove Rehabilitation.' Mangrove Manual Series Vol. 1. (Zoological Society of London: London, UK.)

Rahman, M. (2014). 'Framing Ecosystem-based Adaptation to Climate Change: Applicability in the Coast of Bangladesh.' (IUCN: Dhaka, Bangladesh.)

Rosenzweig, C., Solecki, W. D., Blake, R., Bowman, M., Faris, C., Gornitz, V., Horton, R., Jacob, K., LeBlanc, A., Leichenko, R., Linkin, M., Major, D., O'Grady, M., Patrick, L., Sussman, E., Yohe, G., and Zimmerman, R. (2011). Developing coastal adaptation to climate change in the New York City infrastructure-shed: process, approach, tools, and strategies. *Climatic Change* **106**(1), 93–127. doi:10.1007/S10584-010-0002-8

Savo, V., Lepofsky, D., Benner, J. P., Kohfeld, K. E., Bailey, J., and Lertzman, K. (2016). Observations of climate change among subsistence-oriented communities around the world. *Nature Climate Change* **6**(5), 462–473. doi:10.1038/NCLIMATE2958

Scarano, F. R. (2017). Ecosystem-based adaptation to climate change: concept, scalability and a role for conservation science. *Perspectives in Ecology and Conservation* **15**(2), 65–73. doi:10.1016/J.PECON.2017.05.003

Seddon, N., Turner, B., Berry, P., Chausson, A., and Girardin, C. A. J. (2019). Grounding nature-based climate solutions in sound biodiversity science. *Nature Climate Change* **9**(2), 84–87. doi:10.1038/S41558-019-0405-0

Selig, E. R., Hole, D. G., Allison, E. H., Arkema, K. K., McKinnon, M. C., Chu, J., de Sherbinin, A., Fisher, B., Gallagher, L., Holland, M. B., Ingram, J. C., Rao, N. S., Russell, R. B., Srebotnjak, T., Teh, L. C. L., Troëng, S., Turner, W. R., and Zvoleff, A. (2018). Mapping global human dependence on marine ecosystems. *Conservation Letters* **12**, e12617. doi:10.1111/CONL.12617

Sierra-Correa, P. C., and Cantera Kintz, J. R. (2015). Ecosystem-based adaptation for improving coastal planning for sea-level rise: a systematic review for mangrove coasts. *Marine Policy* **51**, 385–393. doi:10.1016/J.MARPOL.2014.09.013

Silva Villanueva, P. (2011). Learning to ADAPT: monitoring and evaluation approaches in climate change adaptation and disaster risk reduction – challenges, gaps and ways forward. Strengthening Climate Resilience Discussion Paper No.9. IDS, Brighton.

Small, N., Munday, M., and Durance, I. (2017). The challenge of valuing ecosystem services that have no material benefits. *Global Environmental Change* **44**, 57–67. doi:10.1016/J.GLOENVCHA.2017.03.005

Spalding, M. D., Ruffo, S., Lacambra, C., Meliane, I., Hale, L. Z., Shepard, C. C., and Beck, M. W. (2014). The role of ecosystems in coastal protection: adapting to climate change and coastal hazards. *Ocean and Coastal Management* **90**, 50–57. doi:10.1016/J.OCECOAMAN.2013.09.007

SPC and GIZ (2013). Coping with climate change in the Pacific island region. Project brief, SPC/GIZ regional programme – Coping with Climate Change in the Pacific Island Region (CCCPIR). Available at https://www.spc.int/sites/default/files/wordpresscontent/wp-content/uploads/2017/01/SPC_GIZ_2013_CCCPIR_projbrief_lowres.pdf

Takeuchi, K., Nakayama, N., Teshima, H., Takemoto, K. and Turner, N. (2016). Ecosystem-based approaches toward a resilient society in harmony with nature. In 'Ecosystem-Based Disaster Risk Reduction and Adaptation in Practice'. (Eds F. Renaud, K. Sudmeier-Rieux, M. Estrella, and U. Nehren.) Advances in Natural and Technological Hazards Research, vol 42. Springer, Cham. https://doi.org/10.1007/978-3-319-43633-3_14

Tulloch, V. J. D., Turschwell, P. M., Giffin, A. L., Halpern, B. S., Connolly, R., Griffiths, L., Frazer, M., and Brown, C. J. (2020). Linking threat maps with management to guide conservation investment. *Biological Conservation* **245**, 108527. doi:10.1016/J.BIOCON.2020.108527

Thomas, A. S., Mangubhai, S., Vandervord, C., Fox, M., and Nand, Y. (2018). Impact of tropical cyclone Winston on women mud crab fishers in Fiji. *Climate and Development* **11**, 699–709. doi:10.1080/17565529.2018.1547677

UNEP (2016). Options for ecosystem-based adaptation (EBA) in coastal environments: a guide for environmental managers and planners. UNEP, Nairobi, Kenya.

Weeks, R., and Jupiter, S. D. (2013). Adaptive comanagement of a marine protected area network in Fiji. *Conservation Biology* **27**(6), 1234–1244. doi:10.1111/COBI.12153

World Bank. (2010). 'Convenient Solutions to an Inconvenient Truth: Ecosystem Based Approaches to Climate Change.' (World Bank: Washington, DC, USA.)