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 2019a, 2019b).
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 insights 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
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. 2a, 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. 2a). 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. 2a).

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     | 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. |
|                                                        |                                  | implemented in a marine or coastal ecosystem. Human adaptation to climate change was a primary reason for the project. | Freshwater and non-specific tidal marsh                                              |
|                                                        | Coastal and marine ecosystems     | Coral reefs, dunes, estuaries (including oyster reefs), mangroves, saltmarshes, or seagrasses. |                                                                                     |
|                                                        | Location-specific                 | Implemented for a specific country location.                                         |                                                                                     |
|                                                        | Language                          | English                                                                               |                                                                                     |
| Scopus database                                        | Literature period                 | January 1960–November 2018                                                           |                                                                                     |
|                                                        | Search term                       | ‘ecosystem-based adaptation’ found in papers using Scopus default search settings     |                                                                                     |
|                                                        | 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’ |                                                                                     |
|                                                        |                                   | Literature outside of this period                                                     | Other search terms                                                                  |
|                                                        |                                   | Literature outside of this period                                                     | Other search terms                                                                  |
|                                                        | Nature-based Solutions bibliography database through Web of Science and Google Scholar\(^a\) | Article 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’ |                                                                                     |
|                                                        | Literature period                 | April 1998–November 2018                                                              |                                                                                     |
|                                                        | 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 |                                                                                     |
|                                                        | Screening                         | Articles were identified as using 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\(^b\) | Case studies listed before November 2018                                             | Case studies listed after November 2018                                            |
|                                                        | United Nations Framework Convention for Climate Change EbA database\(^c\) | Case studies listed before November 2018                                             | Case studies listed after November 2018                                            |
|                                                        | United Nations Environmental Program Coastal EbA case studies\(^d\) | Case studies listed before November 2018                                             | Case studies listed after November 2018                                            |
|                                                        | Asia Pacific Adaptation Network – EbA adaptation theme\(^e\) | Case studies listed before November 2018                                             | Case studies listed after November 2018                                            |
|                                                        | PANORAMA Solutions for a Healthy Planet EbA database\(^f\) | Case studies listed before November 2018                                             | Case studies listed after November 2018                                            |
|                                                        | United Nations Development Program Climate Change Adaptation – EBA and Mitigation\(^g\) | Case studies listed before November 2018                                             | Case studies listed after November 2018                                            |
|                                                        | WeAdapt – EbA adaptation theme\(^h\) | 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](https://www.naturebasedsolutionsinitiative.org)

\(^b\) [https://www.iucn.org/theme/ecosystem-management/our-work/ecosystem-based-adaptation-and-climate-change/resources](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](https://www4.unfccc.int/sites/nwpstaging/pages/Search.aspx)

\(^d\) [https://web.unep.org/coastal-eba](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](http://www.asiapacificadapt.net/projects?search=&by_themes=269&by_project-status=All&by_regions=All&by_countries=All)

\(^f\) [https://panorama.solutions/en](https://panorama.solutions/en)

\(^g\) [https://www.adaptation-undp.org/ecosystem-based-adaptation-and-mitigation](https://www.adaptation-undp.org/ecosystem-based-adaptation-and-mitigation)

\(^h\) [http://www.weadapt.org/case-studies](http://www.weadapt.org/case-studies)
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. |
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. 4a). 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. 4b).

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...
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
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
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 provide 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 (Munang 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
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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