Ocean and Coastal Management 251 (2024) 107037

Contents lists available at ScienceDirect

Ocean and Coastal Management

journal homepage: www.elsevier.com/locate/ocecoaman

How is mangrove ecosystem health defined? A local community perspective from coastal Thailand

Angie Elwin[a,1], Elizabeth J.Z. Robinson[b,*], Giuseppe Feola[c], Vipak Jintana[d], Joanna Clark[a,2]

[a] Department of Geography and Environmental Science, University of Reading, Reading, UK
[b] Grantham Research Institute on Climate Change and the Environment, London School of Economics and Political Science, UK
[c] Copernicus Institute of Sustainable Development, Utrecht University, the Netherlands
[d] Kasetsart University, Bangkok, Thailand

ARTICLE INFO

Keywords:
Coastal livelihoods
Ocean health
Coupled social-ecological systems
Local ecological knowledge
Mangrove forests

ABSTRACT

Mangroves, intertidal forests, are increasingly considered a high-priority ecosystem for international conservation efforts. Setting targets for future mangrove conservation and restoration requires understanding of the health of the ecosystem. However, the way 'ecosystem health' is defined varies across locations, users, and indices due to differences in knowledge of the ecosystem, scales of the ecosystem being assessed, perceptions of what is 'healthy', or because of differences in the way people use or benefit from ecosystems. This can result in misunderstandings which can undermine effective actions to protect and restore functioning ecosystems. Here, we use a case study of a mangrove fishing community in coastal Thailand to examine how local people assess and define mangrove ecosystem health. Through participatory workshops, we show that local people use at least 27 indicators to define mangrove ecosystem health, including biological, physical, and human indices. Mangrove ecosystem health is defined by both direct material benefits derived from the ecosystem, non-material aspects, and the relational value experienced through 'bundles' of benefits linked to people's livelihood activities. Our findings suggest that ecosystem health frameworks would be more useful if they incorporated social components and metrics, recognising both the interdependencies between ecosystems and human societies, and that ecosystems possess intrinsic value. Local communities that interact most closely with ecosystems can contribute to improving and operationalising frameworks for ecosystem health.

1. Introduction

In tropical and subtropical regions, mangrove forests are an important part of a diverse seascape dominated by functionally interlinked ecosystems, including seagrass meadows and coral reefs (Tomlinson, 2016). These ecosystems are not only highly dependent on each other (Berkström et al., 2020), but they support the livelihoods and well-being of hundreds of millions of people because of the wide range of benefits they provide (Costanza et al., 2017). Benefits include provision of habitat and nursery grounds for species of fish and invertebrates, supply of building materials, water quality regulation, recreation, and ecotourism (Carrasquilla-Henao and Juanes, 2017; Himes-Cornell et al., 2018; Huxham et al., 2017). Mangroves are also crucial for climate mitigation, adaptation and resilience because of their ability to stabilise sediments, store carbon, control erosion, and protect coastal areas against storms, ocean waves, and sea level rise (Howard et al., 2017; Spalding et al., 2014).

Despite their wide ranging benefits, mangroves are vulnerable to increasing human and climatic pressures (Halpern et al., 2019). Approximately a third of global mangrove area has been lost or degraded over the past half century (Barbier, 2017) due to a range of stressors including urban development, nutrient enrichment, aquaculture expansion and climate change (Elwin et al., 2019, 2020; Grech et al., 2012; Richards and Friess, 2016).

However, recent growing awareness of the positive socio-ecological contributions of mangroves has meant that this ecosystem is now

* Corresponding author.
E-mail address: e.j.z.robinson@lse.ac.uk (E.J.Z. Robinson).
[1] Current affiliations: World Animal Protection, 222 Gy Inn Road, London WC1X 8HB and Manchester Metropolitan University, Faculty of Science and Engineering, Manchester, UK.
[2] Professor Joanna Clark passed away in 2022 during the preparation of this article.

https://doi.org/10.1016/j.ocecoaman.2024.107037
Received 24 November 2023; Received in revised form 11 January 2024; Accepted 21 January 2024
Available online 17 February 2024

considered a high-priority for international conservation initiatives (Friess et al., 2020) such as the International Blue Carbon Initiative (https://www.thebluecarboninitiative.org/) and the Global Mangrove Alliance (https://www.mangrovealliance.org/). Increased efforts to protect mangroves in recent years have successfully contributed to reduced annual deforestation rates from 0.7 to 1 % in the 1980–1990s to 0.2–0.4 % in the early 2000s (Goldberg et al., 2020; Hamilton and Casey, 2016). Securing mangrove conservation gains into the future will likely require continued international policy attention, research into the value of mangroves and their ecosystem services, and renewed efforts to improve the success of mangrove rehabilitation at a scale that will be ecologically impactful (Friess et al., 2020). These efforts align with the United Nations (UN) declaring 2021–2030 as the "Decade of Ocean Science for Sustainable Development" and the "Decade on Ecosystem Restoration" to support efforts to reverse the cycle of decline in ocean health.

Healthy ecosystems are now widely thought of in global policy as the basis for the sustainable development of human societies (IPBES et al., 2019), and many of the UN Sustainable Development Goals (SDGs) reflect this target, such as SDG 14 (life below water) and SDG 15 (life on land) (United Nations, 2015). However, the concept of ecosystem health, and approaches to assess it, has evolved in policy and research over the past few decades. For example, in the early 1990s, ecosystem health was defined as "a measure of the resilience, organisation, and vigour of an ecosystem, and its overall ability to maintain structure and function when faced with stress over time" (Costanza et al., 1992), which placed emphasis on the ecological response of an ecosystem to various disturbances. The creation of the Millennium Ecosystem Assessment (MA) framework in 2005 gave rise to the idea that healthy ecosystems provide a diverse range of benefits to support human well-being – "ecosystem services" (Millennium Ecosystem Assessment, 2005). Ecosystem health tends generally to be important for the maintenance of these services: as ecosystem health declines so do the benefits that nature provides (Barnosky et al., 2012). However, in some circumstances, ecosystem services are not dependent on ecosystem health. For example, some forests that are considered attractive are not necessarily in a good ecological state (Carvalho-Ribeiro and Lovett, 2011), and novel ecosystem services may arise from ecosystem change (Woodhead et al., 2019).

Since the MA, there have been substantial changes in global understanding of ecosystem health (IPBES et al., 2019) and a great deal of research has been done to extend and refine the ecosystem services concept (e.g. see (Díaz et al., 2018; Klain et al., 2014; Satterfield et al., 2013)). New frameworks and indices have emerged, such as the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) conceptual framework which builds on the MA ecosystem services concept through the notion of nature's contributions to people (NCP) (Díaz et al., 2018), including recognising the key role that culture plays in defining links between and people and nature and emphasing the role of local and indigenous knowledge in understanding NCP.

Whilst the term "ecosystem health" is widely used by various actors (including scientists, communities, NGOs and policy makers), how this concept is defined can vary considerably, which can undermine effective conservation actions (Franke et al., 2020). Definitions of ecosystem health may vary across locations, users, or indices because of differences in knowledge of the ecosystem, scales of the ecosystem being assessed, perceptions of what is 'healthy', or because of differences in the way people use and/or benefit from ecosystems (Halpern, 2020; Scholte et al., 2015). Perceptions of ecosystem health may also vary because of differences in the way people interact with ecosystems, or due to socio-cultural values or personal factors such as gender, age, locality, occupation, or environmental awareness (Rönnbäck et al., 2007).

Furthermore, because ecosystem benefits are spatially and temporally dynamic (Fisher et al., 2009; Roces-Díaz et al., 2014), differences in cultures and livelihoods may affect the way people experience ecosystems locally which can also influence their perceptions about ecosystem health (Robards et al., 2011; Satterfield et al., 2013). In fact, a key element of the IPBES's NCP framework conceptualises nature's benefits to people through both a generalising perspective (for "Regulating", "Material" and "Non-material" NCP) and a context-specific perspective where such universally applicable categories are thought to be not very meaningful. This is because research shows that individuals perceive different benefits from healthy ecosystems according to the cultural and socio-economic context of the individual (Díaz et al., 2018). Despite this, some of the key frameworks that have been developed in recent years for evaluating coastal ecosystem health fail to adequately represent local values, interests, and worldviews, which together shape the way ecosystem health is assessed and experienced (Klain et al., 2014; Satterfield et al., 2013).

In order to develop effective targets and strategies to restore and protect ecosystems at the local level, it is crucial to understand how people who directly depend on ecosystems define and assess their health. To our knowledge, research examining how mangrove ecosystem health is defined and experienced by local communities has not been done before. To address this research gap, we use a case study of a fishing community on the Andaman coast of Thailand to examine how local people define and experience mangrove ecosystem health. Mangrove forest disturbance is particularly acute in this region. Population growth, tin mining, and the demand for alternative land uses has meant that large areas of mangroves have been removed, or damaged, leading to environmental degradation and fisheries decline (Bennett et al., 2015). In recent decades, the area has also been exposed to the effects of climate change, involving shifting seasons, coastal erosion, and coral bleaching events (Bennett et al., 2015; Phongsuwan and Chansang, 2012). Human populations in this region are particularly sensitive to these changes due to their high dependence on mangroves for their livelihoods and well-being (Bennett et al., 2015; Lin, 2019).

We focus on understanding differences in the way people define and assess mangrove ecosystem health among user groups that vary by their occupation, age, and environmental setting. The study is guided by the following research questions: how do local communities in coastal Thailand define mangrove ecosystem health?; how do they perceive changes in mangrove ecosystem health over time?; and how are local definitions of mangrove ecosystem health related to local knowledge of the ecosystem? In the next section we provide a brief overview of the study site and detail of our methodological approach. This is followed by a presentation of the results. Finally, we discuss the key findings in relation to the wider aims of the study.

2. Methods

2.1. Study area

The research was conducted on Koh Klang, an island situated in the Krabi River Ramsar site, on Thailand's southern Andaman coast (7.78° N, 99.08° E; Fig. 1). Koh Klang has a total area of around 26 km^2 and is situated administratively in the sub-district of Klong Prasong. Total population in Klong Prasong is approximately 5700 in 1470 households, the majority of which (~90 %) are Muslim families. Klong Prasong has four villages; one located on the mainland (Bang Kanoon) and the other three on Koh Klang island (Koh Klang, Klong Prasong, and Klong Kam). The island's economy is largely centred around local natural resource use. Most people are involved in coastal fishing, aquaculture, or traditional rice agriculture. Tourism and oil palm and rubber plantations are also steadily growing (Bhumibhamorn and Visuthismajarn, 2019). Important crops include coconuts, cashew nuts, and vegetables.

Mangrove forests cover (in parts patchily) ~80 % of Koh Klang and are predominantly found in eastern, northern, and central parts of the island. Local villagers are highly dependent on mangrove forests and tidal channels for provision of food and fuelwood, and for supporting critical spawning and nursery grounds for numerous commercially valuable fishery products, such as the giant mud crab, red snapper, grouper, banana shrimp and giant tiger prawn (Beresnev et al., 2016).

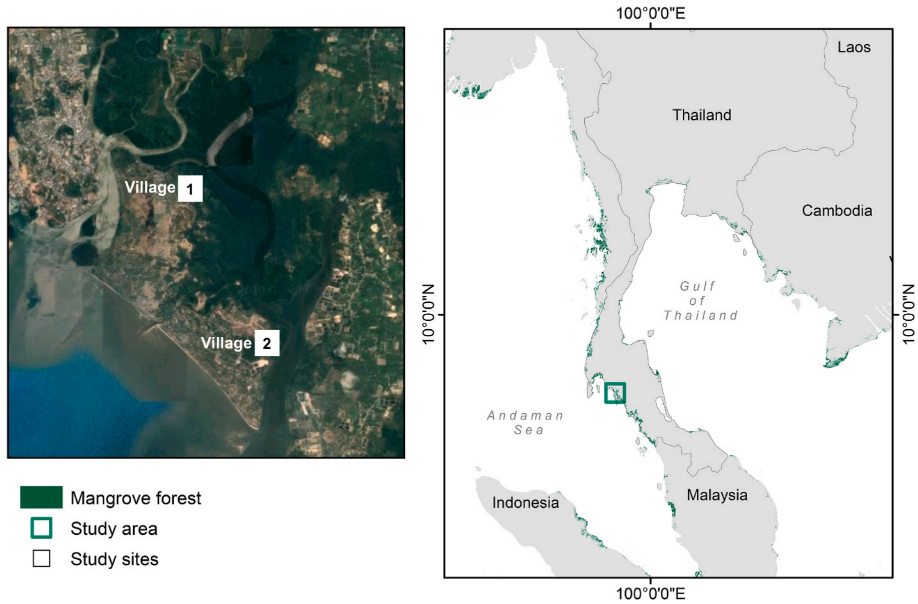

Fig. 1. Map of study area on Koh Klang, Krabi Province. Mangrove distribution data source (Giri et al., 2011): See http://data.unep-wcmc.org. Satellite image of Koh Klang: (Google Maps, 2023).

To the west of the island, the expansive intertidal mudflats are also a focus for traditional fishing practices and shellfish harvesting. The local artisanal fishery is based on various fishing gears such as crab traps, squid traps, cast nets and bamboo stake traps.

Krabi province has suffered huge environmental pressure over the past few decades due to natural and anthropogenic causes (Bennett et al., 2015). Intensive shrimp farming began along the coasts of Thailand during the 1980s and 1990s and grew rapidly over a decade (Elwin et al., 2020). During the 1990s, conversion of mangroves for aquaculture ponds on Koh Klang resulted in around a 25 percent loss of mangrove cover (Upanoi and Tripathi, 2003). The area is also prone to coastal flooding during annual high spring tides and is vulnerable to storms and coastal erosion due to its exposure to the Andaman Sea. The area also experienced ecosystem degradation due to the natural effects of the 2004 Indian Ocean tsunami (Lin, 2019). Anthropogenic stressors such as destructive fishing, pollution, and habitat degradation have also threatened the ecological health of the area (Bennett et al., 2015).

Since the tsunami in 2004, efforts have been made to restore mangroves on the island through projects initiated by the Thai government and non-government organisations (NGOs) (Lin, 2019). For example, between 2012 and 2015, Mangrove Action Project (MAP) in collaboration with the International Union for the Conservation of Nature (IUCN) worked on restoring mangroves in abandoned shrimp ponds using Community Based Ecological Mangrove Restoration (CBEMR) methods (Elwin et al., 2019; Lhosupasirirat et al., 2023). The projects have a strong socio-economic focus with community involvement in ecosystem restoration (King and Cordero, 2015).

2.2. Data collection

In total, eight workshops were conducted with local people over a three-week period in April 2017. The workshops focused on two villages on the island: Village 1 (V1) (Koh Klang) and Village 2 (V2) (Klong Kam) (Fig. 1). Selection of the two villages was based on differences in the proximity to and ease of access to the mangroves, and differences in the type of primary livelihood activities. V1 is located further from the main mangrove area, and villagers are involved in a wider range of livelihood activities, such as rice culture and tourism. V2 is in close proximity to the mangrove forests and main mudflat area, and these resources are the primary source of income for many villagers.

A total of 72 individuals participated in the workshops. The age of participants ranged from 18 to 85 years old. The eight workshop groups were formed of a mixture of both males and females at differing male: female ratios, but the gender distribution overall was biased towards females who made up 63 % of the total sample (see Supplementary Information). Participants from each village were split into four groups representing different ages ($<$35 years and $\geq$35 years) and occupations (people primarily engaged in ecosystem related work, including fishers and farmers, and people primarily engaged in non-ecosystem related work, including taxi boatman and market sellers). This allowed us to make comparisons between different groups based on age, as a proxy for length of time experiencing mangrove ecosystems; occupation, as a proxy for engagement with the mangrove ecosystems; and village of residence, as a proxy for proximity to mangrove ecosystems. In terms of engagement with mangroves, gender roles can broadly be observed on Koh Klang; females tend to primarily focus on inshore fishing, and intertidal shellfish collecting and selling, whereas males usually focus on sea fishing and mangrove crab collecting. Where participants reported having more than one occupation, their primary occupation was defined as the one they spend most time undertaking, and this was used to allocate people into the different occupation categories. A description of the workshop participants and how they were recruited can be found in the Supplementary Information.

Participatory approaches were used during the workshops to elicit local perceptions, definitions and knowledge of mangrove ecosystem health, and drivers of change in ecosystem health over time. Two participatory activities were conducted to aid discussions: participatory map drawing (McCALL and Minang, 2005) of ecological features on the island; and participatory timeline building of changes in ecosystem health (Olsen et al., 2009).

The workshops were conducted entirely in Thai with the aid of a local translator. Transcripts from the recordings of the workshops were later translated into English for analysis. The research was approved by the University of Reading Research Ethics Committee in the United Kingdom, where the first author was based at the time of the study. Participants were provided with an information sheet in Thai to introduce the study. Before data was collected, either verbal or written consent was granted by each participant. Participants were made aware of their rights to voluntarily participate, and no identifying participant or household data were collected. Permission for conducting this research was obtained from the Thai Department for Marine and Coastal Resources.

2.3. Workshop outline

2.3.1. Eliciting perceptions of mangrove ecosystem health

We used participatory mapping as an approach to elicit community perceptions of ecosystem health. Participatory mapping techniques have previously been used in a range of contexts to identify, map, and analyse ecosystems for natural resource management [e.g., see (Levine and Feinholz, 2015; Ramirez-Gomez et al., 2015)], including to gather spatial information of resources and their value and utilization based on communities' knowledge and perspectives [e.g., see (Damastuti and De Groot, 2019; Klain and Chan, 2012)].

As a group, participants were first given a simple, featureless map of the island and were asked to draw on it the coastal ecosystem, including the location of ecosystem features, habitats, species, important areas for livelihood and cultural activities. Open-ended conversational prompts were used to encourage participants to think about their experiences of the ecosystem. For example, "Can you tell me about the natural environment and natural resources on the island?", "Where are the natural resources located and where are they harvested?", "What species are harvested?". An indirect approach enabled participants to freely express their opinions, knowledge, and experiences. Participants were also asked to estimate the relative healthiness of the different natural features that they drew on their maps, using a scale from 1 to 5, where 1 is extremely poor and 5 is perfectly healthy/pristine. The same prompt questions were used in each of the eight workshops.

Participants were then asked to individually write down (1) key indicators of a healthy mangrove ecosystem and (2) a definition of 'mangrove ecosystem health', including any words or phrases they perceive as important in the definition. Participants discussed their individual responses before deciding on a group definition of ecosystem health based on their combined individual responses.

Lastly, as a group, participants built a timeline of changes in mangrove ecosystem health over their lifetime and drivers of change (both positive and negative, such as deforestation, and tourism expansion). The construction of historical timelines of environmental change through collaborative approaches has previously been used in a range of studies to map out trends in the condition and use of ecosystems and the social and natural drivers of change over time [e.g. see (Kalibo and Medley, 2007; Ramesh et al., 2015)]. Initial prompts used to aid discussion included, "Can you remember a time when the mangrove ecosystem was particularly healthy or unhealthy?", and "Why was it so healthy/unhealthy at that time?". Participants were then asked to think about the historical health of the ecosystem over regular time periods (e.g., 5, 10, 15 years ago), going back as far as they could recall. For each year recalled, participants individually scored the overall health of the ecosystem on a scale of 0–10, with zero being extremely poor and 10 being perfectly healthy/pristine. Individual results were then discussed until a group consensus was reached, giving time for each individual score to be considered. Throughout the workshops, attention was paid to ensuring that all participants in the group contributed their knowledge and opinions during the group work to avoid any negative impacts on the data collected caused by power relationships (e.g., resulting from individuals' places in social hierarchies) (Johnson-Bailey and Cervero, 1997).

2.4. Data analysis

Data from the transcripts, maps and timelines were analysed through qualitative selective coding (Maxwell and Miller, 2008) using NVivo 12 software. First, the data was interrogated to explore emerging patterns, ideas and notions of ecosystem health. Comparative analysis of the themes of discussion and the types of words used (Ragin, 2014) was then conducted across groups of different age, occupation and location. We used descriptive statistics, heat maps and bar plots to describe, and to illustrate, patterns in the data. Chi-squared tests of association were used to describe the distribution of ecological knowledge among age groups (<35, >35), location (V1, V2), and occupation (ecosystem related, non-ecosystem related). Data descriptions and statistical analyses were carried out in R (version 4.2.3; R Core Team, 2023). In the results section presented below, codes are used when displaying quotations to identify the individual by age (Younger (<35)/Older (≥ 35)), occupation (ecosystem related (ER)/non-ecosystem related (NER)) and place (Village 1 (V1)/Village 2 (V2).

3. Results

3.1. How do local communities in coastal Thailand define mangrove ecosystem health?

Across groups, ecosystem health was most commonly defined in terms of the biodiversity, fertility, and productivity of the ecosystem, and the rich abundance of marine life which provides essential food supply for people living on the island. Mangrove forests, mangrove channels, and the intertidal mudflats were emphasised as being the community's main food source. Discussions about marine biodiversity and food provision were often intricately linked with the same four types of harvestable species: shrimp, shellfish, crab, and fish. Mangrove forests, the mudflats, and the sea were most frequently cited as the places where these species are found. For example, a young fisher from V1 said, "[Ecosystem health is] *fertile mangrove forests full of animals. The sea is rich in shrimp, shellfish, crab and fish, both in numbers and species. An extensive mudflat where we can go collecting shellfish, and abundant marine animals in the near coastal area so we don't have to go far to collect them*" (V1, ER, <35).

Whilst the general theme across user groups was similar, there were some differences in the way people defined ecosystem health between groups. For example, many younger participants from V2 also referred to the greater diversity of plants and animals, both food and non-food species "[Ecosystem health means] *a mangrove forest that is habitat for many crabs, shellfish, shrimp, and fish, a productive sea for squid, shellfish, crabs, and fish. More shellfish and crabs on the mudflats to provide food for people, and natural diversity of trees, birds, and flowers in the mangrove forest*" (V2, ER, <35).

A fertile, vibrant, and biodiverse mangrove forest was central to many of the discussions around ecosystem health. A diversity of mangrove tree species, including *Nypa fruticans* and *Avicennia officinalis*, was important because of their various uses, such as *Nypa* providing material for roof thatching, tobacco wrappers and dessert wrappers. Discussions about the material use of mangrove species were more frequent among younger NER participants. For example, one younger NER said, "[Ecosystem health is] *more fertile forest and big trees, more green forest area. A diversity of plant species in the forest, such as jak* [*Nypa fruticans*] *and ton samae* [*Avicennia* sp.]" (V2, NER <35).

Across groups, 27 different biological, physical and human indicators of ecosystem health were discussed (Table 1, Fig. 3); the majority of which ($n = 16$, 59.3 %) were biological. Ecosystem health was generally assessed by the productivity of the marine environment, with a focus on the size, diversity, and abundance of marine animals, and the ease of harvesting them. Older fishers and mangrove collectors referred to the relative average size of fish and abundance of animals when describing changing ecosystem health. They often reflected on how, when they were young, they did not have to try hard to catch fish. An elder fisher from V1 said, "*40 years ago, the average size of pla krabok* [mullet fish (*Mugil cephalus*)] *was around* 2 kg. *Nowadays, the average size of that king of fish is only around half a kg. We could collect more mangrove crabs* [mud crab *(Scylla serrata)*] *40 years ago too. We would put one crab trap down and we got over 10 crabs at a time. And it took less time to catch them*". Younger participants discussed other indicators of mangrove forest health, such as the size and density of trees, or the abundance of

Table 1
Summary of the stated indicators of mangrove ecosystem health across all workshop groups, categorised as biological, physical and human indicators.

Biological indicators	Physical indicators	Human indicators
• Forest (re)growth • Verdant green mangrove trees • Larger mangrove trees • Greater abundance of mangrove trees • Greater area of natural forest • Larger marine animals in the mangroves • Abundant marine animals for each season (stable seasons for animals) • Natural plant diversity in the mangroves (trees, flowers) • Productive habitat • Abundant nursery grounds • Abundant fungi in the mangroves • Abundance of fish in the sea, originating from the mangroves • Greater species diversity (shrimp, shellfish, crab, fish) • Abundant fauna in the mangroves - crabs, fish, shrimp, shellfish • Abundant migratory birds (indicating fertile wetlands) • Abundant macaques, monitor lizards and snakes in the mangroves	• Stable soil in the mangrove forests (no erosion) • Fresh air due to abundant trees • Good quality seawater • Stable seasons	• Good quality of life for the community • Healthier local community • No forest degradation • Abundant fisheries/ livelihood resources (fishing, shellfish collecting, crab collecting) • Local community is engaged in forest restoration and conservation activities • Improved livelihood – fishers don't have to travel far to collect produce • Intrinsic value of the ecosystem – its beauty, fertility, vibrancy, capacity • Community well-being - feelings of 'peacefulness' and a 'good quality of life'

Fig. 2. Images depicting some of the 27 indicators of mangrove ecosystem health perceived by the local community on Koh Klang, Krabi Province. First row (left to right): Fisheries species diversity (shrimp, shellfish, crab, fish), verdant green fertile forest, natural floral diversity (credit: Angie Elwin); Second row: Abundant macaques, *Macaca fascicularis* (credit: Peter Prokosch, https://www.grida.no/resources/3494), abundant birds (black-capped kingfisher, *Halcyon pileata*, credit: Picasa), abundant fungi in the mangroves (credit: Angie Elwin); Third row: Stable mangrove soil, abundant shellfish resources, community engaged in conservation and restoration activities (credit: Angie Elwin).

monkeys, "*the number of monkeys in a forest indicates the forest's fertility. It means there is enough food in that forest for monkeys, so they don't invade our community*" (V1, NER, <35).

Indicators of ecosystem health participants used were linked to knowledge about the wider function of mangroves in coastal biological processes. For example, both younger and older generations recognised that mangroves provide nursery habitat for juvenile marine animals that reside part of their life outside of the mangroves, as the following statement shows, "*you can find some marine animals in the forests: crabs, fish, shellfish, and shrimps, but the sizes are smaller than the ones you catch from the sea. The mangrove forests are like their shelters to hide themselves before they are strong enough to go into the sea. It's not safe for them if they are not strong enough. Every mangrove forest is like a safe home to marine animals*" (V1, ER, <35). Elder fishers from V2 also showed an understanding of ecosystem functioning, such as that the coral reefs are habitat for marine animals (Fig. 3).

3.2. How are local definitions of mangrove ecosystem heath related to local knowledge of the ecosystem?

The way local people defined ecosystem health was linked to their knowledge of the ecosystem, which we summarise in Fig. 3. All groups held knowledge of relatively simple ecological information, such as on different species and their habitats. However, knowledge of more complex ecological processes, such as the wider function of mangrove forests in coastal biological processes and understanding of how ecosystems change on temporal scales (daily, seasonally, or in response to disturbance), was unevenly distributed across groups. The distribution of mentions of different types of ecological knowledge between villages (=18.6, df = 11, $p < 0.069$) and occupation (=12.4, df = 11, $p < 0.3329$) did not differ significantly from what might be expected under an equal random distribution, but did differ significantly between age groups (=27.6, df = 11, $p < 0.0037$) (Fig. 4). Older groups referred to a wider range of ecological knowledge including in relation to changes in water quality, climatic changes, coral reefs, and the disappearance and reappearance of species (Fig. 4). Older generations from V2 working in ecosystem-related roles appeared to be the most knowledgeable overall as they discussed the widest range of ecological information (Fig. 3).

Many participants held ecological knowledge useful for finding and harvesting marine resources, such as detailed information about the location of species. Younger groups from V2 were specific when describing species of importance and their location and described how different tidal stages provide a different diversity of shellfish species in the mangroves, "*Periwinkles* [*Cerithidea obtuse, Littorina littorea*], *babylonia* [*Babylonia areolata*] *and mangrove snail are found in the mangrove forest. Root clams* [*Lingula anatina*] *and horse mussels* [*Arcuatula arcuala*] *are from the mudflats. In the mangroves, people go collecting periwinkles at high tide and babylonia at low tide*" (V2, ER, <35). Other participants held specific knowledge about the seasonal shifts in species abundance, biodiversity, and temporal patterns in productivity. For instance, one younger group from V2 associated changing species diversity with

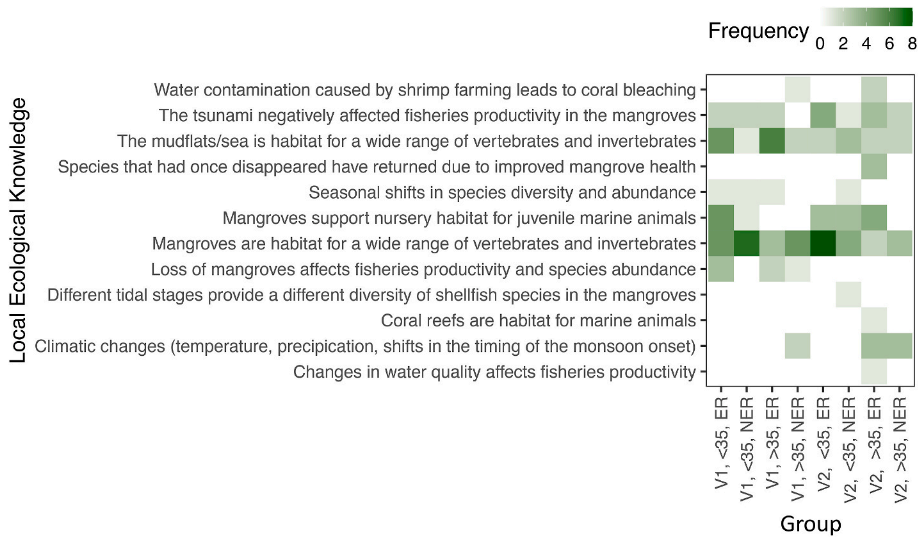

Fig. 3. Summary of local ecological knowledge held among groups of different age (≥35 years/<35 years), occupation (ecosystem related (ER)/non-ecosystem related (NER)), place (village 1 (V1)/village 2 (V2)) on Koh Klang. Frequency refers to the number of times the type of knowledge was mentioned by each group during the workshop discussions (n = 72).

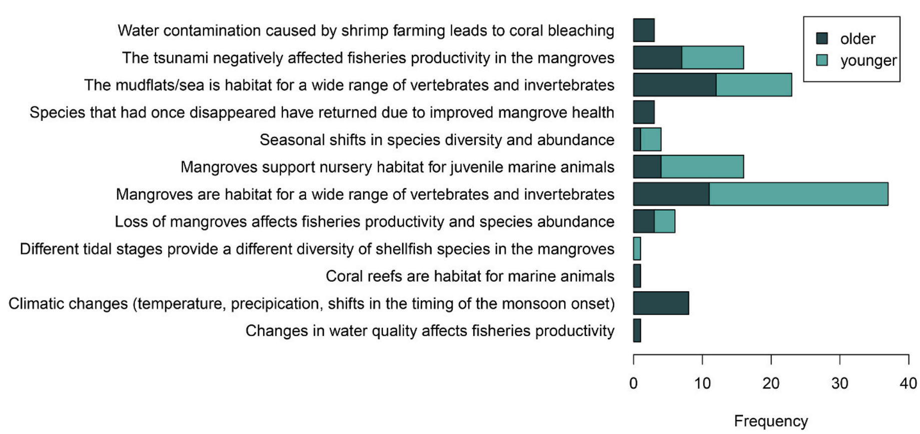

Fig. 4. Differences in the frequency of mentions of different types of ecological knowledge among the age groups "older" (>35) and "younger" (<35) of participants of the 8 workshops (n = 72).

changing seasons and stated that a healthy ecosystem provides a variety of marine resources for each season, "*There are abundant marine animals for each season, stable seasons for animals, stable seasonal productivity in the sea. For example, jellyfish can be found in its own season, which is November-February. If in November the ecosystem is healthy, we can find these species*".

3.3. How do local communities perceive changes in mangrove ecosystem health over time?

Each group felt that the ecosystem had been at its healthiest in the past, and that there had been a decline in ecosystem health over time until the mid 2000s (Fig. 4). For the groups comprising older villagers, most of the participants felt that the decline in ecosystem health had begun back in the 1970s. The perceived rate of decline in ecosystem health prior to the early 2000s varied between groups. For instance, elders from V2 involved in ecosystem related work perceived a dramatic decline in ecosystem health, reflected in a score of 10 (100 % healthy) in 1980 to a score of 3 (30 % healthy) in 2001. In contrast, NER elders from V2 perceived a much smaller decline over the same period from a score of 9.8 (98 % healthy) in 1980 to 9 (90 % healthy) in 2001 (Fig. 5). For the groups comprising younger villagers, ecosystem health was perceived to decline from the 1990s to early 2000s suggesting that they did not know that ecosystem health could have been better in the past.

Several drivers of changing ecosystem health during the 1980s and 1990s were discussed, including coastal erosion, shrimp farming expansion, urban development, population growth, forest cutting and destructive fishing methods. Participants associated shrimp farming expansion with deforestation and water contamination, which they believed had negative impacts on coral reefs and marine species abundance.

For seven of the eight groups, the year 2004, when the Indian Ocean tsunami hit the island, was perceived as the lowest point for ecosystem health over their lifetime. Participants associated the tsunami with alterations to the seabed, destruction of fish habitat (coral reefs), decline in fisheries production and stability, water turbidity, pollution (garbage), beach erosion, destruction of coastal beach forest (such as *Casuarina equisetifolia*) and destruction of aquaculture cages in the mangrove channels. Two groups from V1 perceived a relatively small decline in ecosystem health due to the tsunami, which they stated was because the mangrove forests had protected the island from the impact, suggesting a particularly important ecosystem service being provided by the mangroves. Older fishers in V1 stated that the ecosystem was relatively resilient to the effects of the tsunami, "*In the two-year period straight after the tsunami it was very bad, but a few years later it began to get*

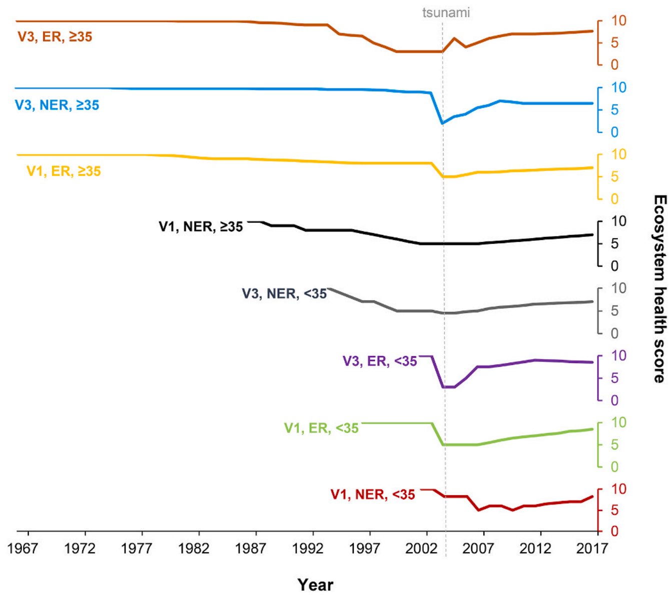

Fig. 5. Perception of change in ecosystem health. Ecosystem health was scored by each of the eight workshop groups from 0 to 10 (where 0 = extremely poor and 10 = perfectly healthy/pristine) for a period of a lifetime. The eight groups differed by age (≥35/<35 years), occupation (ecosystem related (ER)/non-ecosystem related (NER)) and place (village 1(V1)/village 3(V2)).

better. Some shellfish habitat was impacted, and the amount of shellfish was less, but only for around 2 years. After that, shellfish populations increased again". Some related the observed resilience of shellfish populations to their adaptation to natural fluctuations in environmental conditions caused by the monsoon.

For the present-day, many participants felt that the state of the mangrove ecosystem was relatively unstable and fluctuated year by year, which they related to both positive and negative drivers of change. Negative drivers included urbanisation, population growth, pollution (garbage), tree cutting, floods, coastal erosion and climate change (which they referred to as 'unstable seasons'). Perceived positive drivers of change included environmental campaigns, mangrove tree planting, and new fishing restrictions. Participants discussed how ecosystem health was improving due to an increase in forest area, which they associated with larger nursery grounds and more productive fisheries. Some older participants related changes in mangrove health to the disappearance and reappearance of marine species. For example, an older participant from V2 stated, "*It's getting better. If we look at the forest, there's more area and there's more marine species. Species that had once disappeared have started to come back. Jinga shrimp* [*Metapenaeus affinis*] *disappeared but they have now come back because the forest is more fertile*" (V2, ER, ≥35).

4. Discussion

To our knowledge, this is the first study of its kind to evaluate how local communities define and assess mangrove ecosystem health, the findings of which could help to shape frameworks to operationalise conservation and restoration efforts. We show how placed-based assessments and narrative elicitation can offer valuable information and a rich, context-specific understanding of ecosystem health, which is not currently captured very well by leading global frameworks for ecosystem health measurement. For example, current frameworks for assessing coastal ecosystem health often only partially capture the broader social components of human interrelation with the ecosystem (Franke et al., 2020). The Ocean Health Index (Halpern et al., 2012), which has been applied in more than eight global and 20 regional assessments of ocean health to date (Halpern, 2020), uses broad categories that social and cultural indicators are measured against, focused largely on economic/instrumental assets (e.g., fishing opportunity, tourism and recreation, coastal livelihoods and economies). For mangroves specifically, the Mangrove Quality Index (MQI) incorporates socio-economic variables alongside factors such as biotic integrity, mangrove soil, hydrology, and the surrounding marine ecosystem, but these variables are limited to education level and time spent fishing in mangrove areas (Faridah-Hanum et al., 2019). Other studies on mangrove ecosystem health have focused solely on bio-physical parameters [for example, see (Bakhtiyari et al., 2019; Chellamani et al., 2014; Parman et al., 2022)].

In contrast, our findings reveal that, though local people do highlight the mangrove ecosystem as a source of essential food supplies, they experience ecosystem health not simply as the economic and livelihood benefits derived from the ecosystem, but also in terms of the relational value through social interactions with the ecosystem (for example, engagement in conservation actions) and its intrinsic value (for example, its "beauty", "vibrancy", "fertility", and "productivity"). These new insights can be used to better integrate social and cultural factors into a more holistic global index for mangrove ecosystem health.

Understanding local perceptions of ecosystems is important because they can influence the extent to which practices are sustainable or unsustainable, as well as providing hints as to the commitment of individuals and communities to support conservation and restoration efforts (Elias et al., 2022). Our finding that local people define and measure ecosystem health in part by the level of community engagement in conservation and restoration activities suggests that they feel some level of power and capacity as a community to enact change. This finding resonates with Elias et al. (2022), which suggests that ecosystem restoration initiatives should centre on communities and their values, priorities and aspirations as agents of change.

Our finding that mangroves have relational value to people (Chan et al., 2018) is also significant because this is sometimes dismissed as being less scientific, and as a consequence is often not adequately incorporated into ecosystem health frameworks, decision-making and policy (Chan et al., 2012). Specifically, we found that local experiences of ecosystem health are linked to people's livelihood activities and their perceptions about the wider non-material benefits from the ecosystem. For example, daily shellfish harvesting in the intertidal zone was perceived not only as bringing benefits in the form of livelihood opportunities and essential food and nutrients, but also as creating social-cohesion, feelings of 'peacefulness' and a 'good quality of life', and a sense of pride and enjoyment from the 'beautiful' surroundings. Klain et al. (2014) similarly found that beneficiaries of marine ecosystems perceive person-specific 'bundles' of social and cultural ecosystem services that are influenced by an individual's social and environmental context. They argue that rather than primarily conceiving the importance of nature in terms of an ecosystems' production of benefits, we should embrace people's experiences of ecosystems as primary.

Human-nature relationships are critical to conservation (Dahdouh-Guebas et al., 2020); in particular, the non-material social and cultural benefits of ecosystems have been found to play an influential role in the sustainability of ecosystem conservation initiatives (Satterfield et al., 2013), and in helping to understand why individuals care for nature and why they might be motivated to protect it (Chan et al., 2016). Therefore, recognising that ecosystems can possess relational and intrinsic value in ecosystem health indices could be crucial for justifying and setting goals for ecosystem conservation at the local level (Sandler, 2012). Sharing of local perceptions about the "beauty" and "vibrancy" of iconic species and landscapes (for example, through social media) can also influence public perceptions (Wu et al., 2018), helping to attract public attention to drive biodiversity conservation efforts (Thompson and Rog, 2019). Even though understanding of the importance of mangroves for people and the environment is increasing, negative perceptions of these wetlands are still sometimes reinforced by the way they are framed in the media. For example, recent social media posts by the IUCN, among others, have referred to mangroves as being "not pretty to look at", "mosquito-infested", or "dirty" (Dahdouh-Guebas et al., 2020). Therefore, creating a holistic framework for mangrove ecosystem health that brings attention to positive local perceptions of the intrinsic and relational value of mangroves could also help to frame mangroves in ways that can better promote their protection.

4.1. Local ecological knowledge

Our fieldwork also revealed that the way local people define ecosystem health is linked to their knowledge of the ecosystem. Local ecological knowledge ranged from an understanding of individual species and their habitats, knowledge of seasonal shifts in species abundance, biodiversity, and temporal patterns in productivity, to wider and more detailed understanding of ecosystem functions, dynamics, and interactions. Ecosystem health assessments and management interventions have often failed to engage the knowledge, views and interests of local and indigenous people (Díaz et al., 2018; Satterfield et al., 2013). Highlighting that such local knowledge exists could, therefore, have implications for informing policy, conservation planning, and ecosystem management decisions, that has, for example, the potential to reduce conflict between local populations and policy makers, increase success and support for community-based ecosystem governance and restoration, and the maintenance of culture and livelihoods (Carrasquilla-Henao et al., 2019; Loch and Riechers, 2021). This is also emphasised by the IPBES's NCP approach which recognises that a wide range of perspectives are important in understanding nature's contribution to people (Díaz et al., 2018).

Of note is that whilst more simple ecological knowledge was distributed relatively uniformly across groups in our study, understanding of more complex ecosystem processes was heterogeneously distributed and more variable across different age groups. As expected, older groups appeared to be the most knowledgeable, referring to a wider range of ecological information, which probably results from them experiencing mangrove harvesting activities over a longer period. However, we found no significant differences in the range of knowledge among groups of different proximity to natural resources (place of residence) and engagement with ecosystems for their livelihood. Other studies have identified more group-specific patterns of complex knowledge development (Crona and Bodin, 2006; Ghimire et al., 2004), and that knowledge is influenced by how close a person lives to the mangrove (Longépée et al., 2021).

The fact that there was no obvious differentiated group-specific knowledge among different occupations and places of residence in this study could suggest either that there is more social homogeneity on Koh Klang, or that the social ties within user groups are weaker thus resulting in a lower level of group-specific complex knowledge development (Reagans and McEvily, 2003). Our findings could be explained by two key factors. Firstly, Koh Klang participants share strong cultural and religious links that may facilitate greater communication and social cohesion (Reagans and McEvily, 2003). Second, given that Koh Klang is a relatively small island, and most people rely heavily on the natural resources for their livelihoods and well-being, it was difficult to recruit individuals who had no previous direct or indirect experience related to coastal resource extraction (see Supplementary Information).

4.2. Temporal changes in ecosystem health

An important aspect of ecosystem health frameworks is the recognition of ecosystem feedbacks and recovery times. Communities living near to ecosystems are observing these changes over generational timeframes. Our study demonstrates that these feedbacks are perceived locally as temporal changes in parameters such as fertility, productivity, and the capacity of the ecosystem to recover from disturbance. Such perceptions of mangrove ecosystem health (as well as coastal use practices influencing ecosystem health) can help to improve understanding of drivers of ecosystem change.

On the elicitation of perceptions of changing mangrove ecosystem health, two key findings can be highlighted. First, we found that the way individuals were personally affected by fluctuations in ecosystem health may have influenced how they perceived the health of the ecosystem to change (consistent with (O'Brien and Wolf, 2010)). For example, the impact of the 2004 tsunami on ecosystem health was perceived to be greater among resource users in V2, reflecting how these villagers were more personally affected due to their stronger reliance on the ocean for their livelihood. This could also be linked to differences in their knowledge about specific features of the ecosystem (Loch and Riechers, 2021). For example, Halpern (2020) notes that most people base their impression of ocean health on a few key attributes, indicators, or just the places they know. In this study, historical accounts indicate that several negative drivers of ecosystem change were occurring before the tsunami in 2004, for example related to the expansion of shrimp farming on the island and associated deforestation (Elwin et al., 2019). Yet, we found that only some user groups had knowledge of the pre-tsunami ecosystem decline. This suggests that, while individual perceptions of ecosystem health are important for informing ecosystem management at the local level, the perception of one or a few specific groups of people, such as fishers, alone cannot accurately describe the health of all aspects of an ecosystem. Instead, individual perspectives should be part of a larger picture that incorporates multiple social, ecological and livelihood scales and perspectives (Halpern, 2020).

These findings also have implications for the sustainability of ecosystems in areas affected by ecosystem degradation, because if a community perceives no change in ecosystem health during periods of gradual anthropogenic-driven ecosystem decline, the drivers of degradation may continue, and the erosion of important benefits may go unnoticed (Alfonso et al., 2017). However, personal experience of extreme events does not necessarily lead people to be motivated to enact change (Sambrook et al., 2021).

Second, we found that both young and old generations perceived the ecosystem to be at its most healthy at the start of their earliest relevant memories, suggesting that perception may be influenced by the length of time someone has experienced a particular evolving event (Fernández-Llamazares et al., 2015), which could be interpreted as 'shifting baseline syndrome' (SBS) (Pauly, 1995). That is, each generation bases their perception of the level of change in ecosystem state on the level they observed at the start of their relevant lifetime memories (Jones et al., 2020). Alternatively, some generations might inaccurately remember or perceive the state of the ecosystem in the past, thinking, for example, that it was better than it actually was, or inaccurately recount memories of past ecosystem states because of a desire to please (Leleu et al., 2012). SBS can lead to under-estimation of the true magnitude of long-term ecosystem change and therefore needs to be considered when local ecological knowledge and participatory approaches form part of setting targets for conservation action (Jones et al., 2020). Caution should also be taken when using retrospective recalled accounts of ecosystem change to investigate change over time (Jones et al., 2020 and references therein). Some have suggested that when these approaches are employed in the development of conservation initiatives, greater emphasis should be placed on involving older more experienced generations because they tend to have greater awareness of historical ecological conditions (Jones et al., 2020).

We recognise that mapping perceptions of changes in ecosystems through time can be affected by multiple biases (Daw et al., 2011) and more robust methods have been developed to capture these changes (Selgrath et al., 2018). Our results imply divergent age-related differences in the perception of ecosystems through time. Capturing change through time is highly challenging and often relies on the anchoring effect of memorable events, such as the 2004 tsunami. However, it was beyond the scope of our study to triangulate the information elicited during the workshops with other types of technical knowledge. Rather, we wanted to illustrate that local communities hold a wealth of potentially valuable information about the ecosystem (such as on forest condition, the location of fish breeding habitat or changes to the ecosystem following disturbance) and that this significant knowledge base should be drawn on for devising ecosystem health indices, ecosystem health measurements, and when planning ecosystem management initiatives. Our approach could be improved in future work through incorporating internal triangulation to the workshop process (Mathison, 1988), whereby key information is asked about during multiple questions, enabling cross-check of the consistency of responses (Selgrath et al., 2018).

5. Concluding comments

There is opportunity for providing more encompassing indices into frameworks for measuring mangrove ecosystem health to better recognise that nature has both intrinsic and relational value to local people. Incorporating these elements into a more holistic global index for mangrove ecosystem health would not only help to address and potentially overcome conflicting societal interests but would also better recognise that mangroves, and coastal ecosystems more generally, are social-ecological systems (Elwin, 2019). The development of a standardised participatory mapping tool that can be utilised in local communities across the world's mangroves could be a valuable next avenue for future research and to operationalise social and cultural indicators for monitoring future progress towards global conservation and sustainability goals.

During this "Decade of Ecosystem Restoration", there is a need for a transdisciplinary approach to setting targets for ecosystem health-not only integrating scientific disciplines but also NGOs, industries and importantly the local communities who most closely interact with ecosystems. Building on local knowledge and supporting the collective agency of local communities would enable a more equitable societal response for protecting and restoring ecosystems, to safeguard their vital functions into the future.

Authors' contributions

AE, GF, JC, EJZR conceived the ideas and designed methodology; AE collected the data, analysed the data and led the writing of the manuscript. All authors contributed critically to the drafts and gave final approval for publication.

Funding

This work was supported by the Economic and Social Research Council [grant number ES/J500148/1].

CRediT authorship contribution statement

Angie Elwin: Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Elizabeth J.Z. Robinson:** Writing – review & editing, Supervision, Funding acquisition, Conceptualization. **Giuseppe Feola:** Writing – review & editing, Supervision, Conceptualization. **Vipak Jintana:** Writing – review & editing, Supervision. **Joanna Clark:** Writing – review & editing, Supervision, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Acknowledgements

We thank the community on Koh Klang who gave their time to take part in this research, and Chantida Paphol (Tammy) for facilitating the workshops and translating and transcribing the data. Thanks also to Jim Enright (Mangrove Action Project, Thailand) for his insightful comments on an earlier version of this manuscript. Lastly, thanks to the late Professor Joanna Clark, without whom this research would not have been possible.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ocecoaman.2024.107037.

References

Alfonso, A., Zorondo-Rodríguez, F., Simonetti, J.A., 2017. Perceived changes in environmental degradation and loss of ecosystem services, and their implications in human well-being. Int. J. Sustain. Dev. World Ecol. 24, 561–574. https://doi.org/10.1080/13504509.2016.1255674.

Bakhtiyari, M., Lee, S.Y., Warnken, J., 2019. Seeing the forest as well as the trees: an expert opinion approach to identifying holistic condition indicators for mangrove ecosystems. Estuar. Coast Shelf Sci. 222, 183–194. https://doi.org/10.1016/j.ecss.2019.03.003.

Barbier, E.B., 2017. Marine ecosystem services. Curr. Biol. 27, R507–R510. https://doi.org/10.1016/j.cub.2017.03.020.

Barnosky, A.D., Hadly, E.A., Bascompte, J., Berlow, E.L., Brown, J.H., Fortelius, M., Getz, W.M., Harte, J., Hastings, A., Marquet, P.A., Martinez, N.D., Mooers, A., Roopnarine, P., Vermeij, G., Williams, J.W., Gillespie, R., Kitzes, J., Marshall, C., Matzke, N., Mindell, D.P., Revilla, E., Smith, A.B., 2012. Approaching a state shift in Earth's biosphere. Nature 486, 52–58. https://doi.org/10.1038/nature11018.

Bennett, N.J., Dearden, P., Peredo, A.M., 2015. Vulnerability to multiple stressors in coastal communities: a study of the Andaman coast of Thailand. Clim. Dev. 7, 124–141. https://doi.org/10.1080/17565529.2014.886993.

Beresnev, N., Phung, T., Broadhead, J., 2016. Mangrove-related Policy and Institutional Frameworks in Pakistan, Thailand and Viet Nam. Food and Organization Organization (FAO) of the United Nations and IUCN, Bangkok.

Berkström, C., Eggertsen, L., Goodell, W., Cordeiro, C.A.M.M., Lucena, M.B., Gustafsson, R., Bandeira, S., Jiddawi, N., Ferreira, C.E.L., 2020. Thresholds in seascape connectivity: the spatial arrangement of nursery habitats structure fish communities on nearby reefs. Ecography 43, 882–896. https://doi.org/10.1111/ecog.04868.

Bhumibhamorn, P., Visuthismajarn, P., 2019. A model for environmentally-friendly food tourism in ban Koh Klang, Khlong Prasong sub-district, Mueang district, Krabi, Thailand. Afr J Hosp Tour Leis 8.

Carrasquilla-Henao, M., Ban, N., Rueda, M., Juanes, F., 2019. The mangrove-fishery relationship: a local ecological knowledge perspective. Mar. Policy 108, 103656. https://doi.org/10.1016/j.marpol.2019.103656.

Carrasquilla-Henao, M., Juanes, F., 2017. Mangroves enhance local fisheries catches: a global meta-analysis. Fish Fish. 18, 79–93. https://doi.org/10.1111/faf.12168.

Carvalho-Ribeiro, S.M., Lovett, A., 2011. Is an attractive forest also considered well managed? Public preferences for forest cover and stand structure across a rural/urban gradient in northern Portugal. For. Policy Econ 13, 46–54. https://doi.org/10.1016/j.forpol.2010.09.003.

Chan, K.M., Gould, R.K., Pascual, U., 2018. Editorial overview: relational values: what are they, and what's the fuss about? Curr. Opin. Environ. Sustain. 35 (A1–A7) https://doi.org/10.1016/j.cosust.2018.11.003.

Chan, K.M.A., Balvanera, P., Benessaiah, K., Chapman, M., Díaz, S., Gómez-Baggethun, E., Gould, R., Hannahs, N., Jax, K., Klain, S., Luck, G.W., Martín-López, B., Muraca, B., Norton, B., Ott, K., Pascual, U., Satterfield, T., Tadaki, M., Taggart, J., Turner, N., 2016. Why protect nature? Rethinking values and the environment. Proc. Natl. Acad. Sci. 113, 1462–1465. https://doi.org/10.1073/pnas.1525002113.

Chan, K.M.A., Guerry, A.D., Balvanera, P., Klain, S., Satterfield, T., Basurto, X., Bostrom, A., Chuenpagdee, R., Gould, R., Halpern, B.S., Hannahs, N., Levine, J., Norton, B., Ruckelshaus, M., Russell, R., Tam, J., Woodside, U., 2012. Where are cultural and social in ecosystem services? A framework for constructive engagement. Bioscience 62, 744–756. https://doi.org/10.1525/bio.2012.62.8.7.

Chellamani, P., Singh, C.P., Panigrahy, S., 2014. Assessment of the health status of Indian mangrove ecosystems using multi temporal remote sensing data. Trop. Ecol. 55, 245–253.

Costanza, R., De Groot, R., Braat, L., Kubiszewski, I., Fioramonti, L., Sutton, P., Farber, S., Grasso, M., 2017. Twenty years of ecosystem services: how far have we come and how far do we still need to go? Ecosyst. Serv. 28, 1–16. https://doi.org/10.1016/j.ecoser.2017.09.008.

Costanza, R., Norton, B.G., Haskell, B.D., 1992. Ecosystem Health: New Goals for Environmental Management. Island Press.

Crona, B., Bodin, O., 2006. What you know is who you know? Communication patterns among resource users as a prerequisite for co-management, 2006. Crona, B., & Bodin, Ö Ecol. Soc. 11.

Dahdouh-Guebas, F., Ajonina, G.N., Amir, A.A., Andradi-Brown, D.A., Aziz, I., Balke, T., Barbier, E.B., Cannicci, S., Cragg, S.M., Cunha-Lignon, M., Curnick, D.J., Duarte, C. M., Duke, N.C., Endsor, C., Fratini, S., Feller, I.C., Fromard, F., Hugé, J., Huxham, M., Kairo, J.G., Kajita, T., Kathiresan, K., Koedam, N., Lee, S.Y., Lin, H.-J., Mackenzie, J. R., Mangora, M.M., Marchand, C., Meziane, T., Minchinton, T.E., Pettorelli, N., Polanía, J., Polgar, G., Poti, M., Primavera, J., Quarto, A., Rog, S.M., Satyanarayana, B., Schaeffer-Novelli, Y., Spalding, M., Van Der Stocken, T., Wodehouse, D., Yong, J.W.H., Zimmer, M., Friess, D.A., 2020. Public perceptions of mangrove forests Matter for their conservation. Front. Mar. Sci. 7, 603651 https://doi.org/10.3389/fmars.2020.603651.

Damastuti, E., De Groot, R., 2019. Participatory ecosystem service mapping to enhance community-based mangrove rehabilitation and management in Demak, Indonesia. Reg. Environ. Change 19, 65–78. https://doi.org/10.1007/s10113-018-1378-7.

Daw, T.M., Robinson, J., Graham, N.A.J., 2011. Perceptions of trends in Seychelles artisanal trap fisheries: comparing catch monitoring, underwater visual census and Fishers' knowledge. Environ. Conserv. 38, 75–88. https://doi.org/10.1017/S0376892910000901.

Díaz, S., Pascual, U., Stenseke, M., Martín-López, B., Watson, R.T., Molnár, Z., Hill, R., Chan, K.M.A., Baste, I.A., Brauman, K.A., Polasky, S., Church, A., Lonsdale, M., Larigauderie, A., Leadley, P.W., Van Oudenhoven, A.P.E., Van Der Plaat, F., Schröter, M., Lavorel, S., Aumeeruddy-Thomas, Y., Bukvareva, E., Davies, K., Demissew, S., Erpul, G., Failler, P., Guerra, C.A., Hewitt, C.L., Keune, H., Lindley, S., Shirayama, Y., 2018. Assessing nature's contributions to people. Science 359, 270–272. https://doi.org/10.1126/science.aap8826.

Elias, M., Kandel, M., Mansourian, S., Meinzen-Dick, R., Crossland, M., Joshi, D., Kariuki, J., Lee, L.C., McElwee, P., Sen, A., Sigman, E., Singh, R., Adamczyk, E.M., Addoah, T., Agaba, G., Alare, R.S., Anderson, W., Arulingam, I., Bellis, S., K̲ung, V., Birner, R., De Silva, S., Dubois, M., Duraisami, M., Featherstone, M., Gallant, B., Hakhu, A., Irvine, R., Kiura, E., Magaju, C., McDougall, C., McNeill, G.D., Nagendra, H., Nghi, T.H., Okamoto, D.K., Paez Valencia, A.M., Pagella, T., Pontier, O., Post, M., Saunders, G.W., Schreckenberg, K., Shelar, K., Sinclair, F., Gautam, R.S., Spindel, N.B., Unnikrishnan, H., Wilson, G.T.G., Ng, A.N., Winowiecki, L., 2022. Ten people-centered rules for socially sustainable ecosystem restoration. Restor. Ecol. 30, e13574 https://doi.org/10.1111/rec.13574.

Elwin, A., 2019. Social-ecological Resilience of Mangrove-Shrimp Farming Communities in Thailand (Doctoral Dissertation). University of Reading.

Elwin, A., Bukoski, J.J., Jintana, V., Robinson, E.J.Z., Clark, J.M., 2019. Preservation and recovery of mangrove ecosystem carbon stocks in abandoned shrimp ponds. Sci. Rep. 9, 18275 https://doi.org/10.1038/s41598-019-54893-6.

Elwin, A., Jintana, V., Feola, G., 2020. Characterizing shrimp-farm production intensity in Thailand: beyond technical indices. Ocean Coast Manag. 185, 105019 https://doi.org/10.1016/j.ocecoaman.2019.105019.

Faridah-Hanum, I., Yusoff, F.M., Fitrianto, A., Ainuddin, N.A., Gandaseca, S., Zaiton, S., Norizah, K., Nurhidayu, S., Roslan, M.K., Hakeem, K.R., Shamsuddin, I., Adnan, I., Awang Noor, A.G., Balqis, A.R.S., Rhyma, P.P., Siti Aminah, I., Hilaluddin, F., Fatin, R., Harun, N.Z.N., 2019. Development of a comprehensive mangrove quality index (MQI) in Matang Mangrove: assessing mangrove ecosystem health. Ecol. Indic. 102, 103–117. https://doi.org/10.1016/j.ecolind.2019.02.030.

Fernández-Llamazares, Á., Díaz-Reviriego, I., Luz, A.C., Cabeza, M., Pyhälä, A., Reyes-García, V., 2015. Rapid ecosystem change challenges the adaptive capacity of Local Environmental Knowledge. Glob. Environ. Change 31, 272–284. https://doi.org/10.1016/j.gloenvcha.2015.02.001.

Fisher, B., Turner, R.K., Morling, P., 2009. Defining and classifying ecosystem services for decision making. Ecol. Econ. 68, 643–653. https://doi.org/10.1016/j.ecolecon.2008.09.014.

Franke, A., Blenckner, T., Duarte, C.M., Ott, K., Fleming, L.E., Antia, A., Reusch, T.B.H., Bertram, C., Hein, J., Kronfeld-Goharani, U., Dierking, J., Kuhn, A., Sato, C., Van Doorn, E., Wall, M., Schartau, M., Karez, R., Crowder, L., Keller, D., Engel, A., Hentschel, U., Prigge, E., 2020. Operationalizing Ocean health: toward integrated research on Ocean Health and recovery to Achieve ocean sustainability. One Earth 2, 557–565. https://doi.org/10.1016/j.oneear.2020.05.013.

Friess, D.A., Yando, E.S., Abuchahla, G.M.O., Adams, J.B., Cannicci, S., Canty, S.W.J., Cavanaugh, K.C., Connolly, R.M., Cormier, N., Dahdouh-Guebas, F., Diele, K., Feller, I.C., Fratini, S., Jennerjahn, T.C., Lee, S.Y., Ogurcak, D.E., Ouyang, X., Rogers, K., Rowntree, J.K., Sharma, S., Sloey, T.M., Wee, A.K.S., 2020. Mangroves give cause for conservation optimism, for now. Curr. Biol. 30, R153–R154. https://doi.org/10.1016/j.cub.2019.12.054.

Ghimire, S.K., McKey, D., Aumeeruddy-Thomas, Y., 2004. Heterogeneity in ethnoecological knowledge and management of medicinal plants in the Himalayas of Nepal: implications for conservation. Ecol. Soc. 9.

Giri, C., Ochieng, E., Tieszen, L.L., Zhu, Z., Singh, A., Loveland, T., Masek, J., Duke, N., 2011. Status and distribution of mangrove forests of the world using earth observation satellite data. Global Ecol. Biogeogr. 20 (1), 154–159. https://doi.org/10.1111/j.1466-8238.2010.00584.x.

Goldberg, L., Lagomasino, D., Thomas, N., Fatoyinbo, T., 2020. Global declines in human-driven mangrove loss. Glob. Change Biol. 26, 5844–5855. https://doi.org/10.1111/gcb.15275.

Google Maps, 2023. Koh Klang, Krabi. Available at: http://maps.google.co.uk.

Grech, A., Chartrand-Miller, K., Erftemeijer, P., Fonseca, M., McKenzie, L., Rasheed, M., Taylor, H., Coles, R., 2012. A comparison of threats, vulnerabilities and management approaches in global seagrass bioregions. Environ. Res. Lett. 7, 024006 https://doi.org/10.1088/1748-9326/7/2/024006.

Halpern, B.S., 2020. Building on a decade of the Ocean Health index. One Earth 2, 30–33. https://doi.org/10.1016/j.oneear.2019.12.011.

Halpern, B.S., Frazier, M., Afflerbach, J., Lowndes, J.S., Micheli, F., O'Hara, C., Scarborough, C., Selkoe, K.A., 2019. Recent pace of change in human impact on the world's ocean. Sci. Rep. 9, 11609 https://doi.org/10.1038/s41598-019-47201-9.

Halpern, B.S., Longo, C., Hardy, D., McLeod, K.L., Samhouri, J.F., Katona, S.K., Kleisner, K., Lester, S.E., O'Leary, J., Ranelletti, M., Rosenberg, A.A., Scarborough, C., Selig, E.R., Best, B.D., Brumbaugh, D.R., Chapin, F.S., Crowder, L. B., Daly, K.L., Doney, S.C., Elfes, C., Fogarty, M.J., Gaines, S.D., Jacobsen, K.I., Karrer, L.B., Leslie, H.M., Neeley, E., Pauly, D., Polasky, S., Ris, B., St Martin, K., Stone, G.S., Sumaila, U.R., Zeller, D., 2012. An index to assess the health and benefits of the global ocean. Nature 488, 615–620. https://doi.org/10.1038/nature11397.

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

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

Howard, J., Sutton-Grier, A., Herr, D., Kleypas, J., Landis, E., Mcleod, E., Pidgeon, E., Simpson, S., 2017. Clarifying the role of coastal and marine systems in climate mitigation. Front. Ecol. Environ. 15, 42–50. https://doi.org/10.1002/fee.1451.

Huxham, M., Dencer-Brown, A., Diele, K., Kathiresan, K., Nagelkerken, I., Wanjiru, C., 2017. Mangroves and people: local ecosystem services in a changing climate. In: Rivera-Monroy, V.H., Lee, S.Y., Kristensen, E., Twilley, R.R. (Eds.), Mangrove Ecosystems: A Global Biogeographic Perspective. Springer International Publishing, Cham, pp. 245–274. https://doi.org/10.1007/978-3-319-62206-4_8.

IPBES, 2019. In: Brondizio, E.S., Settele, J., Díaz, S., Ngo, H.T. (Eds.), Global Assessment Report on Biodiversity and Ecosystem Services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. IPBES Secr, Bonn Ger.

Johnson-Bailey, J., Cervero, R.M., 1997. Negotiating power dynamics in workshops. New Dir. Adult Contin. Educ. 41–50. https://doi.org/10.1002/ace.7604, 1997.

Jones, L.P., Turvey, S.T., Massimino, D., Papworth, S.K., 2020. Investigating the implications of shifting baseline syndrome on conservation. People Nat 2, 1131–1144. https://doi.org/10.1002/pan3.10140.

Kalibo, H.W., Medley, K.E., 2007. Participatory resource mapping for adaptive collaborative management at Mt. Kasigau, Kenya. Landsc. Urban Plan. 82, 145–158. https://doi.org/10.1016/j.landurbplan.2007.02.005.

King, J., Cordero, O., 2015. Socioeconomic Assessment of the EPIC Mangrove Restoration Project in Thailand. Center for Public Policy and Administration.

Klain, S.C., Chan, K.M.A., 2012. Navigating coastal values: participatory mapping of ecosystem services for spatial planning. Ecol. Econ. 82, 104–113. https://doi.org/10.1016/j.ecolecon.2012.07.008.

Klain, S.C., Satterfield, T.A., Chan, K.M.A., 2014. What matters and why? Ecosystem services and their bundled qualities. Ecol. Econ. 107, 310–320. https://doi.org/10.1016/j.ecolecon.2014.09.003.

Leleu, K., Alban, F., Pelletier, D., Charbonnel, E., Letourneur, Y., Boudouresque, C.F., 2012. Fishers' perceptions as indicators of the performance of Marine Protected Areas (MPAs). Mar. Policy 36, 414–422. https://doi.org/10.1016/j.marpol.2011.06.002.

Levine, A.S., Feinholz, C.L., 2015. Participatory GIS to inform coral reef ecosystem management: mapping human coastal and ocean uses in Hawaii. Appl. Geogr. 59, 60–69. https://doi.org/10.1016/j.apgeog.2014.12.004.

Lhosupasirirat, P., Dahdouh-Guebas, F., Hugé, J., Wodehouse, D., Enright, J., 2023. Stakeholder perceptions on community-based ecological mangrove restoration (CBEMR): a case study in Thailand. Restor. Ecol. 31, e13894 https://doi.org/10.1111/rec.13894.

Lin, P.-S.S., 2019. Building resilience through ecosystem restoration and community participation: Post-disaster recovery in coastal island communities. Int. J. Disaster Risk Reduct. 39, 101249 https://doi.org/10.1016/j.ijdrr.2019.101249.

Loch, T.K., Riechers, M., 2021. Integrating indigenous and local knowledge in management and research on coastal ecosystems in the Global South: a literature review. Ocean Coast Manag. 212, 105821 https://doi.org/10.1016/j.ocecoaman.2021.105821.

Longépée, E., Ahmed Abdallah, A., Jeanson, M., Golléty, C., 2021. Local ecological knowledge on mangroves in Mayotte island (Indian ocean) and influencing factors. Forests 12, 53. https://doi.org/10.3390/f12010053.

Mathison, S., 1988. Why triangulate? Educ. Res. 17, 13–17. https://doi.org/10.3102/0013189X017002013.

Maxwell, J.A., Miller, B.A., 2008. Categorizing and connecting strategies in qualitative data analysis. Handbook of Emergent Methods. The Guilford Press, Washington.

McCALL, M.K., Minang, P.A., 2005. Assessing participatory GIS for community-based natural resource management: claiming community forests in Cameroon. Geogr. J. 171, 340–356. https://doi.org/10.1111/j.1475-4959.2005.00173.x.

Millennium Ecosystem Assessment, 2005. Ecosystems and Human Well-Being: Synthesis. Island Press, Washington, DC.

O'Brien, K.L., Wolf, J., 2010. A values-based approach to vulnerability and adaptation to climate change. WIREs Clim. Change 1, 232–242. https://doi.org/10.1002/wcc.30.

Olsen, S.B., Page, G.G., Ochoa, E., 2009. The analysis of governance responses to ecosystem change. A Handbook for Assembling a baseline. In: GKSS Res. Cent. LOICZ Int. Proj. off. Inst. Coast. Res. Max-Planck-Str. 1 -21502 Geesthacht Ger.

Parman, R.P., Kamarudin, N., Ibrahim, F.H., Nuruddin, A.A., Omar, H., Abdul Wahab, Z., 2022. Geostatistical analysis of mangrove ecosystem health: mapping and Modelling of sampling Uncertainty using Kriging. Forests 13, 1185. https://doi.org/10.3390/f13081185.

Pauly, D., 1995. Anecdotes and the shifting baseline syndrome of fisheries. Trends Ecol. Evol. 10, 430.

Phongsuwan, N., Chansang, H., 2012. Repeated coral bleaching in the Andaman Sea, Thailand, during the last two decades. Phuket Mar. Biol. Cent. Res. Bull. 71, 19–41.
Ragin, C., 2014. The Comparative Method: Moving beyond Qualitative and Quantitative Strategies. Univ of California Press.
Ramesh, R., Chen, Z., Cummins, V., Day, J., D'Elia, C., Dennison, B., Forbes, D.L., Glaeser, B., Glaser, M., Glavovic, B., Kremer, H., Lange, M., Larsen, J.N., Le Tissier, M., Newton, A., Pelling, M., Purvaja, R., Wolanski, E., 2015. Land–Ocean interactions in the coastal zone: past, present & future. Anthropocene 12, 85–98. https://doi.org/10.1016/j.ancene.2016.01.005.
Ramirez-Gomez, S.O.I., Torres-Vitolas, C.A., Schreckenberg, K., Honzák, M., Cruz-Garcia, G.S., Willcock, S., Palacios, E., Pérez-Miñana, E., Verweij, P.A., Poppy, G.M., 2015. Analysis of ecosystem services provision in the Colombian Amazon using participatory research and mapping techniques. Ecosyst. Serv. 13, 93–107. https://doi.org/10.1016/j.ecoser.2014.12.009.
Reagans, R., McEvily, B., 2003. Network structure and knowledge Transfer: the effects of cohesion and range. Adm. Sci. Q. 48, 240–267. https://doi.org/10.2307/3556658.
Richards, D.R., Friess, D.A., 2016. Rates and drivers of mangrove deforestation in Southeast Asia, 2000–2012. Proc. Natl. Acad. Sci. 113, 344–349. https://doi.org/10.1073/pnas.1510272113.
Robards, M.D., Schoon, M.L., Meek, C.L., Engle, N.L., 2011. The importance of social drivers in the resilient provision of ecosystem services. Glob. Environ. Change 21, 522–529. https://doi.org/10.1016/j.gloenvcha.2010.12.004.
Roces-Díaz, J.V., Díaz-Varela, E.R., Álvarez-Álvarez, P., 2014. Analysis of spatial scales for ecosystem services: Application of the lacunarity concept at landscape level in Galicia (NW Spain). Ecol. Indic. 36, 495–507. https://doi.org/10.1016/j.ecolind.2013.09.010.
Rönnbäck, P., Crona, B., Ingwall, L., 2007. The return of ecosystem goods and services in replanted mangrove forests: perspectives from local communities in Kenya. Environ. Conserv. 34 https://doi.org/10.1017/S0376892907004225.
Sambrook, K., Konstantinidis, E., Russell, S., Okan, Y., 2021. The role of personal experience and prior Beliefs in shaping climate change perceptions: a narrative review. Front. Psychol. 12, 669911 https://doi.org/10.3389/fpsyg.2021.669911.
Sandler, R., 2012. Intrinsic value. Ecol. Conserv. Nat. Educ. Knowl. 3.
Satterfield, T., Gregory, R., Klain, S., Roberts, M., Chan, K.M., 2013. Culture, intangibles and metrics in environmental management. J. Environ. Manage. 117, 103–114. https://doi.org/10.1016/j.jenvman.2012.11.033.
Scholte, S.S.K., Van Teeffelen, A.J.A., Verburg, P.H., 2015. Integrating socio-cultural perspectives into ecosystem service valuation: a review of concepts and methods. Ecol. Econ. 114, 67–78. https://doi.org/10.1016/j.ecolecon.2015.03.007.
Selgrath, J.C., Gergel, S.E., Vincent, A.C.J., 2018. Shifting gears: Diversification, intensification, and effort increases in small-scale fisheries (1950-2010). PLoS One 13, e0190232. https://doi.org/10.1371/journal.pone.0190232.
Spalding, M.D., Ruffo, S., Lacambra, C., Meliane, I., Hale, L.Z., Shepard, C.C., Beck, M. W., 2014. The role of ecosystems in coastal protection: Adapting to climate change and coastal hazards. Ocean Coast Manag. 90, 50–57. https://doi.org/10.1016/j.ocecoaman.2013.09.007.
Thompson, B.S., Rog, S.M., 2019. Beyond ecosystem services: using charismatic megafauna as flagship species for mangrove forest conservation. Environ. Sci. Policy 102, 9–17. https://doi.org/10.1016/j.envsci.2019.09.009.
Tomlinson, P.B., 2016. The Botany of Mangroves. Cambridge University Press.
United Nations, 2015. Transforming Our World : the 2030 Agenda for Sustainable Development [WWW Document]. URL. https://www.refworld.org/docid/57b6e3e44.html. (Accessed 23 November 2023).
Upanoi, T., Tripathi, N.K., 2003. A satellite based monitoring of changes in mangroves in Krabi, Thailand. In: Proceedings of the Map Asia Conference, pp. 1–10.
Woodhead, A.J., Hicks, C.C., Norström, A.V., Williams, G.J., Graham, N.A.J., 2019. Coral reef ecosystem services in the Anthropocene. Funct. Ecol. 33, 1023–1034. https://doi.org/10.1111/1365-2435.13331.
Wu, Y., Xie, L., Huang, S.L., Li, P., Yuan, Z., Liu, W., 2018. Using social media to strengthen public awareness of wildlife conservation. Ocean Coast. Manag. 153, 76–83. https://doi.org/10.1111/j.1466-8238.2010.00584.x.