Article

Challenges of Managing Maritime Cultural Heritage in Asia in the Face of Climate Change

Patrick Daly [1,*], R. Michael Feener [2,3], Noboru Ishikawa [2], Ibrahim Mujah [4], Maida Irawani [2], Alexandru Hegyi [2], Krisztina Baranyai [2], Jedrzej Majewski [1] and Benjamin Horton [1,5]

1   Earth Observatory of Singapore, Nanyang Technological University, 50 Nanyang Ave, Block N2-01a-15, Singapore 639798, Singapore; jmmajewski@ntu.edu.sg (J.M.); bphorton@ntu.edu.sg (B.H.)
2   Center for Southeast Asian Studies, Kyoto University, 46 Yoshidashimoadachicho, Sakyo Ward, Kyoto 606-8304, Japan; feener@cseas.kyoto-u.ac.jp (R.M.F.); ishikawa@cseas.kyoto-u.ac.jp (N.I.); maida.irawani@cseas.kyoto-u.ac.jp (M.I.); hegyi@cseas.kyoto-u.ac.jp (A.H.); krisztina.baranyai@cseas.kyoto-u.ac.jp (K.B.)
3   Associate Member, Faculty of History, University of Oxford, George Street, Oxford OX1 2RL, UK
4   National Center for Cultural Heritage, Maldives Ministry of Arts, Culture and Heritage, Museum Building 2nd Floor, Chaandhanee Magu, Male, Maldives; i.mujah@hotmail.com
5   Asian School of the Environment, Nanyang Technological University, 62 Nanyang Dr., Singapore 637459, Singapore
*   Correspondence: patrickdaly@ntu.edu.sg

Abstract: Changing weather patterns, increasing frequency and intensity of natural hazards, and rising sea levels associated with global climate change have the potential to threaten cultural heritage sites worldwide. This is especially the case for maritime heritage sites located in the low-lying coastal and delta regions of Asia. Maritime heritage can reflect both highly localized cultural products based on the coupling of people and maritime environments and the historic footprints of complex maritime networks that connect people, ideas, and material over vast distances, creating unique cultural spheres. Furthermore, maritime heritage sites potentially serve as or contain records of how past societies have been impacted by and adapted to past environmental stress. Therefore, their degradation threatens local/regional/global cultural patrimony as well as evidence of human resilience and fragility in the face of environmental change. This makes a strong case for urgent preservation. However, the possible damage caused by climate change and the scale of vulnerable maritime heritage pose seemingly insurmountable challenges. In this paper, we present the ways in which maritime heritage sites across Asia are vulnerable to environmental stresses, such as changing sea levels, coastal erosion, flooding, and storm surges. Our objective is to draw upon our experience documenting endangered cultural heritage across South and Southeast Asia to illustrate that there are unique conceptual and practical characteristics of maritime heritage that complicate effective management and conservation efforts on the scale required to prevent massive loss by climate change. We conclude by stressing the need to reconceptualize debates about the custody and stewardship of maritime heritage and the urgency of employing a wide range of innovative preservation solutions to ensure maritime patrimony is not lost to the rising tides.

Keywords: climate change; cultural heritage; Southeast Asia; maritime heritage; heritage management; conservation; digital heritage

1. Introduction

After decades of scientific warnings that increasing concentrations of greenhouse gases in the atmosphere could lead to major changes in Earth's climate system, we are nearing the inflection point where some degree of environmental change is inevitable. The most recent report by the Intergovernmental Panel on Climate Change (IPCC) suggests that half of the global population is highly vulnerable to the environmental effects of climate change, such

as increasing temperatures, rising sea levels, changing weather patterns, and an increasing frequency and intensity of tropical storms [1]. The same report makes it clear that given our current trajectory and failure to limit emissions, societal adaptation might be insufficient to prevent the negative impacts of climate change for many of the most vulnerable members of the global population.

While much attention rightly goes to how climate change will impact human life in the near future, it is starting to be recognized that climate change will also have profound impacts on the material remains of our past—our cultural heritage [2–15]. In all ecological zones, changes in climatic conditions such as temperature, humidity, and precipitation levels will affect the material substance of historic buildings, monuments, and artefacts, leading to decay in the absence of preservation efforts [15–18]. This includes both sites that are directly exposed to the elements, as well as vast collections of objects, artwork, and historic manuscripts stored within museums, archives, and other venues that require climate control for their long-term preservation [2,7,12,19]. There is also significant potential that some of the mechanical forces associated with climate change, such as rising sea levels, powerful storm surges, and heavy precipitation, will cause extensive physical damage to heritage sites and degrade cultural landscapes [20,21]. These impacts have the potential to disproportionately impact heritage sites that are not well protected such as vernacular heritage and the heritage of marginalized and indigenous communities [5,6,22,23].

Accordingly, managing the impacts of climate change and environmental stress on cultural heritage has become an important topic of consideration for academics and heritage practitioners—from the main international bodies such as UNESCO and ICOMOS to national and sub-national organizations [3,6,8,24,25]. An increasing number of research teams and heritage management agencies are mapping out the vulnerability of heritage to climate change on different scales of analysis [8,16,17,21]. This work demonstrates severe threats to cultural heritage from climate change in many parts of the world.

However, this work only accounts for a small sample of the total number of heritage sites potentially endangered by climate change. With a few notable exceptions, most of the attention on the vulnerability of cultural heritage to climate change is largely focused on the United States and Europe, with much less work conducted across the rest of the world, and almost none in Asia, which arguably hosts the largest body of cultural heritage by virtue of both geographic scale and population [6,9,12,13,21,26–29]. Furthermore, most efforts to assess vulnerability to climate change focus on limited databases of heritage resources, such as UNESCO World Heritage sites [5,12,13,19,21,25,30,31]. Therefore, existing heritage vulnerability assessments provide a low estimate for the quantity of heritage sites on a global scale that are potentially endangered by climate change and currently exclude much of Asia's coastal heritage.

To help address this, we have been conducting research on environmental stress and cultural heritage in Asia for more than a decade, including several large projects to locate and document vulnerable coastal heritage. Our Aceh Geohazards Project was a five-year effort to study the history of coastal hazards in areas that were inundated by the 2004 Indian Ocean tsunami in northern Sumatra, Indonesia [32–36]. As part of our efforts, we systematically surveyed over 40 km of coastal areas that were hit by the tsunami and vulnerable to future coastal erosion, tsunamis, and sea-level rise, and documented over 1000 heritage sites, more than 5800 heritage features, and over 48,000 artefacts located through field walking. Building upon this work, we partnered with the Ministry of Arts, Culture, and Heritage of the Maldives in 2017 to begin conducting a systematic survey of heritage sites endangered by sea-level rise in that country [37]. That two-year pilot study was supported by the Arcadia Fund (Grant 3984). In the course of our work, we surveyed 152 islands, documenting 365 sites, 4817 features, and 1022 objects while also digitizing 1091 historic manuscripts.

Upon the foundations of that pilot project, our work has since scaled up into the Maritime Asia Heritage Survey (https://maritimeasiaheritage.cseas.kyoto-u.ac.jp accessed on 25 April 2022), a five-year project to digitally document endangered coastal heritage in

Indonesia, Vietnam, and the Maldives. The primary aim of this work is to create an open-access on-line heritage archive that can serve as a resource for scholars, government heritage agencies, and the interested public. This material is already being used by the Maldives Ministry of Arts, Culture and Heritage to inform impact assessments of development projects on cultural heritage on six different islands, as well as a special report to the Office of the President on threats to cultural heritage sites posed by climate change. At a global scale, our data have also been integral to the recent success of a bid to have the Koagannu Cemetery added to the World Monuments Fund 2022 Watchlist.

Our research on environmental stress and cultural heritage and years of practical experience working with partners in Indonesia and the Maldives to document coastal heritage sites vulnerable to climate change have made it clear to us that safeguarding the maritime heritage of Asia is a daunting task. The costs and technical expertise needed to safeguard coastal heritage sites against climate change, coupled with the relatively limited capacity and resources currently deployed by most countries in the region, make wide-scale physical preservation of heritage untenable. Over the next century, Asia faces the certain and permanent loss of at least some of its coastal heritage sites. Moreover, it is likely that initiatives to preserve cultural heritage will be biased toward monumental and economically valuable heritage sites to the exclusion of the far vaster range of local, vernacular, and indigenous heritage sites spread across Southern Asia [23,38]. Therefore, it is necessary to re-think approaches to cultural preservation to both prevent but also anticipate the eventual permanent loss of heritage sites and cultural landscapes across the coastal areas of Asia.

We were invited to contribute a conceptual discussion to this Special Issue of *Climate* about some of the main challenges to preserving maritime heritage in Asia in the face of climate change and how approaches to conservation will need to adapt to changing environmental conditions. To do this, we draw upon our collective work related to issues of cultural heritage management and environmental stress and an extensive review of the literature on cultural heritage and climate change to discuss some of the ways in which digital documentation and preservation of coastal heritage and archaeological sites can facilitate both our understanding of how past societies have grappled with changing environmental conditions and provide tools for the management of heritage in an uncertain future [39–47]. To provide some substance to our review, we include data about the condition, preservation status, and vulnerability to environmental stress from our on-going heritage survey in the Maldives and Indonesia. We start with a brief conceptual discussion about the vulnerabilities facing maritime heritage. We then present what we see as some of the main challenges to managing and preserving maritime heritage based upon our work documenting endangered maritime heritage in South and Southeast Asia and propose some recommendations about what is needed to prevent wide-scale loss of Asia's coastal heritage.

2. Maritime Heritage and Climate Change

Maritime heritage is the cultural product of the relationship between people, societies, their immediate maritime environments, and/or their connections to wider maritime trade networks. It would be difficult to travel along the coast in any inhabited part of the world—regardless of geography, climate, or level of economic development—and not encounter people whose lives are intimately connected with their immediate ocean or riverine environment. From indigenous Moken fishing villages in Thailand and quaint port towns in New England, to the island nations of the south Pacific, ways of life, in ways both dramatic and obvious and subtle and nuanced, have been shaped by human interactions with the sea. This can be seen in countless examples of intangible cultural practices born of maritime interactions and embodied in the material culture produced by patterns of interactions with coastal environments.

At a wider scale of analysis, maritime heritage can be the residue of sea-borne connections and interactions such as trading ports, artefacts, and shipwrecks [48]. Contemporary world maps imply that major river systems, large bodies of water, and the oceans are un-

populated places that separate and demarcate our current geopolitical identities. However, historically, maritime worlds have been spheres defined by interaction and connectivity facilitated by the movements of people, ideas, and material cultural as well as the emergence of complex cultural imaginaries across vast distances [49]. This can be seen in the historic trade and religious networks that define the Maritime Silk Road stretching from Japan and China in the east to the Middle East and Europe in the west [50–56]. The historic ports along these trade networks were shaped over the centuries by the diversity of people who populated and transited through them.

There are many compelling reasons to advocate for the preservation of Asia's maritime heritage. All forms of heritage are important sources of identity and tangible markers of human history. Many maritime heritage sites are still used or inhabited in the present. Furthermore, maritime heritage is an important part of local economies, especially as tourist attractions [18,57,58]. However, we want to add to the list that Asia's maritime heritage is an important resource to help us understand and cope with the very kinds of environmental forces that endanger it. In particular, maritime heritage can provide relevant material for studies of climate change; societal resilience, and the long histories of interactions that have come to define human and environmental dynamics.

2.1. Records of Environmental and Social Change

Maritime heritage sites have the potential to record valuable information about the long-term interaction of coastal societies and environmental stress [8,9,26,30,59]. Much of the research on the environmental processes that affect coastal communities is conducted at sites endangered by these same forces. This includes archaeological and historical sites that contain insights into how coastal societies in the past were impacted by environmental stress, changing sea-level, and natural hazards [30,60]. These records can be found in buried cultural and geological deposits, in the fragments of material cultural scattered across the landscape, in the styles and forms of building technologies, on the surface of historic structures, within the text of inscriptions and ancient manuscripts, and in the oral histories of local inhabitants. We have used all of these sources of data to build a comprehensive record of how coastal communities in northern Sumatra have been impacted by major tsunami going back over 7000 years, with all of that data coming from low-lying coastal areas, including sites that are on the verge of being lost due to erosion and sea-level change [33,35,61]. We are currently using such data to build out histories of sea-level change in the Maldives and how changing environmental conditions impacted trade along the Maritime Silk Road. The loss of coastal heritage and archaeological sites will limit our ability to compile the historic datasets needed to model future environmental change in coastal regions.

2.2. Embodied Resilience—Heritage of Sustainability

Maritime heritage captures how our predecessors have adapted (or failed to adapt) to environmental stress. The tangible (buildings, monuments, artefacts, etc.) and intangible (customs, legends, social practices, belief systems, etc.) cultural heritage in areas of the world that deal with environmental stress contain potentially useful lessons about how to adapt to and live with dynamic environments in a sustainable manner and how cultures conceptualize and deal with cycles of loss and recovery [7,8,18,22,30]. There is valuable knowledge about societal resilience embedded within the vernacular heritage and traditional cultural practices of coastal inhabitants around the world—especially within indigenous and other communities which rely upon maritime environments for subsistence [38]. The loss of coastal heritage and disruption of traditional coastal livelihoods reduces our collective knowledge of how to adjust to climate change and other forms of environmental stress and erases some of the only examples of long-term sustainable human interactions with their environments [22,23,62].

2.3. Heritage of Connections

Maritime heritage is a heritage of connectivity, interaction, and adaptation. In a world drifting toward de-globalization in the face of crises such as the COVID-19 pandemic and on-going climate change, it is vital for us to recognize that some of the most dynamic periods of human innovation and development have come from the connections of geographically disparate people through sea-borne trade and travel [63,64]. Maritime heritage can thus serve as a valuable reminder that connectivity is a critical part of human history and that solutions to common problems might derive from engagement, rather than isolation. Port cities of Asia are products of widely diverse cultural influences and are also sites of the creation of unique hybrid forms of cultures and cultural heritage [65–67]. Our work on the islands of Indonesia and the Maldives has not only produced new data on the history of such cultural dynamics but also opened new pathways of connection, with colleagues from each of those Indian Ocean archipelagoes working together to produce a new, integrated source of knowledge on the broader region [68].

3. Environmental Dynamics in Coastal Areas

Maritime heritage is located within Asia's coastal, delta, and riverine regions. These geographic zones are dynamic and prone to powerful environmental stresses that are likely to increase in frequency and intensity due to global warming and associated climatic changes [14,69]. Some of these occur on a regular and even somewhat predictable basis, whereas others are less frequent and can be surprising in occurrence and intensity [60]. As outlined below, the main environmental stresses effecting coastal areas across Asia are difficult to manage at present and will only get worse. These stresses will have profound impacts upon natural environments; our current built environment and infrastructure; the lives and livelihoods of people who inhabit coastal zones; and the accumulated heritage within such regions over the next several centuries [62]. In this section, we outline some of the environmental stressors likely to cause extensive damage to Asia's coastal heritage.

3.1. Ecological Changes

It is anticipated that increased sea temperatures, changes in ocean acidity, and variations in levels of precipitation associated with climate change will alter the physical attributes of coastal and riverine environments, whether broadly or in highly localized contexts [19,70,71]. This can be already seen in the recent mass bleaching events that have stressed approximately 75% of the world's coral reefs over the past decade [72–74]. These events will have profound impacts upon marine and wetland ecologies and the human communities that interact with and/or are dependent upon these ecologies for their subsistence and livelihoods [75,76]. These changes will impact cultural heritage of coastal communities as long-term lifestyles are destabilized, traditional practices become untenable, links to ancestral habitats and practices are eroded, and belief systems/cosmologies interwoven with natural environments are challenged. This is especially the case for the numerous indigenous and fishing communities in the Maldives, the Bay of Bengal, the Indonesian Archipelago, and along the coasts of mainland Southeast Asia. Many of these communities are already threatened by poverty, political marginalization, and non-sustainable development practices and therefore are highly vulnerable to additional stressors.

3.2. Storms and Storm Surges

Coastal areas in sub-tropical regions experience powerful storms (hurricanes, cyclones, and typhoons) that combine heavy rainfall, strong winds, increased tidal action, and storm surges. These cause extensive flooding, erosion, and mechanical damage to tangible heritage sites [22,23,59,62,77]. Major tropical storms occur on a seasonal basis in the sub-tropical zones between 5 and 30 degrees on either side of the equator and are expected to increase in intensity with climate change. Such storms pose threats to coastal heritage in Sri Lanka, India, Bangladesh, Myanmar, Indonesia, Philippines, Vietnam, China, and Japan. We are at a stage where what were once called "one-hundred-year" storms are now

occurring every decade, meaning we have no precedent for properly evaluating how much damage such storms will cause to coastal heritage. Furthermore, the increasing frequency of powerful storms will reduce the time needed to recover from destructive events before the next storm occurs.

3.3. Flooding

On an annual basis, flooding is typically the most damaging form of natural disaster in Asia in terms of persons affected and cost [69]. Changes in precipitation levels combined with anthropogenic causes such as urbanization and subsidence caused by ground water depletion will lead to more regular and severe flooding, with pronounced concentrations in the deltas of Asia's major river systems such as the Ganges-Brahmaputra, Irrawaddy, Mekong, Red, Pearl and Yangtze [78]. These regions are home to hundreds of millions of people and countless heritage resources. Perhaps the most dramatic example of the seriousness of such threats are the on-going plans by the Indonesian government to move the administrative buildings from the capital city of Jakarta to a new city in Borneo because there are questions about the long-term viability of Jakarta, a city of over 20 million inhabitants. A combination of flooding and subsidence will result in degradation of heritage sites and cultural landscapes through mechanical damage, erosion, rot, and salinization [19].

3.4. Coastal Erosion and Sedimentation

Heritage sites located in coastal regions are exposed to a range of coastal processes that will most likely be amplified by climate change. Tidal processes constantly erode, fragment, and undermine heritage sites, as has been extensively documented in northern Europe [13,18,19,28,30,58]. Coastal geomorphological processes can lead to both erosion and beach progradation which can wash away or bury heritage sites, block up harbors and waterways [79], and in more extreme cases such as the Maldives, literally remove and construct new landmasses.

3.5. Sea-Level Change

Perhaps the most significant long-term threat to coastal heritage from climate change will come from sea-level rise [9,13,17,20,21,31,80]. While projections of potential sea-level increase vary depending on estimates of climate mitigation efforts, it is likely that by 2100 we could see rises of over 0.5 m [1,43]. Failure to drastically reduce emissions could lead to as much as 5 m of sea-level rise over the next several centuries. Even the more conservative predictions will result in extensive changes in coastal and delta areas and the destruction of heritage and cultural landscapes. In low-lying island nations such as the Maldives and countries in the south Pacific, sea-level rise could lead to the total loss of languages, cultures, and ways of life.

A combination of the environmental forces outlined above pose an existential and inevitable threat to much of Asia's coastal heritage over the next several centuries. Discussions about managing Asia's coastal heritage need to acknowledge that if the currently accepted projections of climate change prove accurate, managing coastal heritage resources will become a salvage operation where catastrophic and permanent loss of much of Asia's coastal heritage is the baseline if extensive and immediate efforts are not made to safeguard it. In the more pessimistic scenarios of climate change, standard approaches to protect and preserve coastal heritage will not be viable on anywhere near the scale needed, requiring us to rethink what heritage management could look like as we shift to the era of climate change.

4. Preserving Maritime Heritage in Asia

Climate change needs to become an essential part of heritage management plans [3,5, 7,9,14,16,25,30]. We hope to add to this discussion based on our experiences working with heritage in different parts of Asia, illustrated by examples from our heritage documentation in the Maldives and Indonesia (Figure 1). We shape our discussion around what we feel

are the main components needed to develop management plans for coastal heritage across Asia. We acknowledge that our list is not exhaustive. For the sake of brevity and cohesion, we focus on five points that are the main pillars of the heritage documentation and management we have participated within across Southern Asia: (1) building and/reinforcing comprehensive heritage inventories; (2) mapping and monitoring vulnerability to environmental stresses; (3) digital documentation; (4) open-access data preservation and archiving; and (5) physical preservation.

Figure 1. Map showing the areas of operation for the Maritime Asia Heritage Survey. The red boxes show areas of the Maldives and Indonesia covered by our survey and documentation as of May 2022.

4.1. Baseline Heritage Inventories

The starting point for managing coastal heritage is having updated and detailed inventories of heritage resources. While most countries in Asia have some form of national heritage register or inventory, these databases are often difficult to access and can be highly variable in quality. At the same time many existing heritage records in countries across the region have not been fully digitized and are in danger of being lost themselves. Even well-developed and maintained heritage inventories are often populated with records of prominent, well-known, or monumental heritage resources and exclude less prominent and vernacular heritage resources. They are also generally limited in terms of the information contained and often lack visual elements and precise geographic coordinates. Moreover, we have not seen many examples of records that contain detailed and updated information about vulnerabilities to on-going and future environmental stress. Constructing reliable heritage inventories to the level needed to develop effective heritage management strategies is an essential but difficult and time-consuming process but it is where we must start.

In both Indonesia and the Maldives, we have worked with national agencies to enhance existing inventories through new field survey work and the application of new digital technologies (Figure 2). This complex dataset is designed to inform heritage management policies, as well as to provide a lasting archive for use by historians, archaeologists and other scholars. Our field teams use tablet-based heritage survey forms to collect basic administrative data (location, ownership/custody, preservation status, etc.); basic descriptive information (type of resource, brief prose description, size/dimensions, material, construction technology, etc.); assessment of condition (damage, weathering, etc.); and vulnerability assessment (current and potential exposure to environmental stress, development, and human vandalism/destruction). Over two phases of field survey and documentation in the Maldives and Indonesia since 2015, we have documented a total of 1620 site records, 11,842 feature records, and 50,207 object records (Table 1).
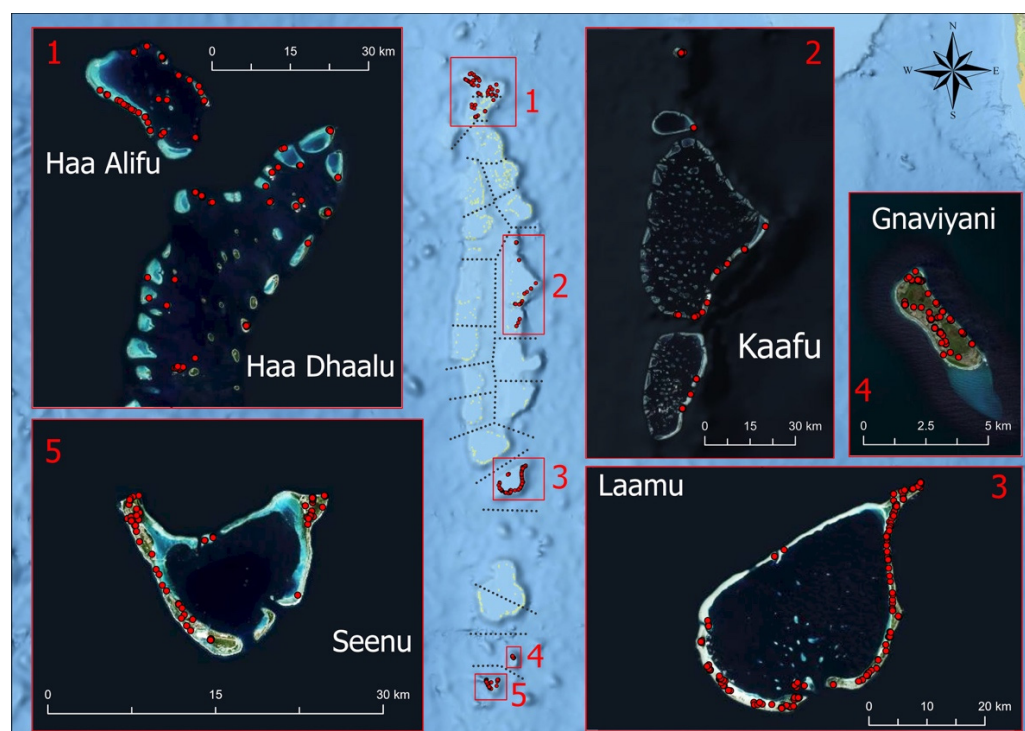
Figure 2. Map showing the areas of the Maldives where we have completed heritage field survey and documentation. Our field team has systematically surveyed all islands in each of the numbered atolls.

Table 1. Total number of heritage site, feature, and object records produced over two phases of documentation in the Maldives and Indonesia.

	Maldives Phase 1	Maldives Phase 2	Indonesia Phase 1	Indonesia Phase 2	Total
Site Records	365	146	1028	81	1620
Feature Records	4817	518	5869	638	11,842
Object Records	1022	280	48,707	198	50,207
Recorded Oral Histories	37	10	N/A	33	80
3d Visualizations	N/A	23	N/A	48	71
Digitized Manuscripts	1091	15	N/A	20	1126

The information we collect is intended to serve as a baseline for monitoring the condition of heritage resources in the face of climate change. At present we lack mechanisms for dynamic updates to our online database. We are familiar with innovative projects such as SCHARP in Scotland that utilize a range of mobile technologies to empower crowd-sourced documentation and continuous monitoring of coastal heritage resources [30]—and consider such projects inspirational for the further work that is needed to test whether such approaches are viable across diverse Asian contexts. It is clear to us that regularly monitored and updated heritage inventories are critical and that such work can only be carried out at an effective resolution and frequency through new models of inclusive and participatory approaches.

4.2. Vulnerability Mapping

Managing coastal heritage in the face of climate change requires integrating these inventories of heritage resources with robust scientific models of potential environmental

impacts such as sea-level rise, coastal erosion, and storm frequency [15,81]. There are some excellent examples of such projects, mainly from Europe, that use GIS and climate models to identify and code types and levels of vulnerability [7–9,13,16,29,82]. However, vulnerability models are not widely accessible to heritage managers in many parts of the world [14]. Our work has attempted to address this by assessing the condition, protection status, and vulnerability to threats within our heritage records. For example, out of 146 heritage sites we documented within five atolls in the Maldives, we found that less than 10% were not partially or completely damaged and approximately 80% of sites were not formally protected (Table 2). A notable percentage of sites has already been damaged by coastal erosion and the 2004 Indian Ocean tsunami and a much higher percent are potentially vulnerable to future environmental stresses. Furthermore, we are using drone photogrammetry to produce high-resolution georeferenced orthophoto maps of entire islands in the Maldives that can serve as baselines for comparing coastal contours over time and to identify factors that make some locations more vulnerable than others.

Table 2. Assessment of the condition, vulnerability to environmental stress, and preservation status for 146 heritage sites documented in Haa Alifu, Haa Dhaalu, Kaafu, Noonu, and Shaviyani atolls in the Maldives.

	Count	Percent of Total Sites
Condition of Heritage Site		
Excellent	13	9%
Partially Damaged	101	71%
Completely destroyed	24	16%
No Longer Extent	1	0.70%
Submerged	3	2%
Source of Attrition		
Coastal Erosion	54	38%
Flooding	14	9%
Salt Intrusion	1	0.7%
Sea-Level Change	9	6%
Tsunami	27	19%
Future Environmental Vulnerabilities		
Coastal Erosion	61	43%
Flooding	17	12%
Salt Intrusion	5	3%
Sea-Level Change	82	57%
Tsunami	73	51%
Preservation Status		
Not Preserved	114	80%
Preserved	28	19%
Need for Preservation		
Immediate	2	1%
Urgent	12	8%
Moderate	53	37%
Low	51	35%
N/A	24	16%

We are also witnessing in near real-time some of the devastating effects of climate change and environmental degradation, as for example the island of Dheruhhuraa in Shaviyani Atoll which has only recently disappeared below sea level. This was formerly a large island known for its forest of ironwood trees. They were nearly all felled to burn for the production of coral lime used in construction of the new administrative capital on the

nearby island of Fonadhoo. This resulted in severe coastal erosion that made the island vulnerable to complete submersion when struck by the 2004 Indian Ocean tsunami.

For vulnerability models to be effective, they need to be dynamic and continually adjust to new data. This lack of baseline heritage and environmental data is a pressing concern that needs to be addressed for much of the coastal regions of Asia. It is critical to develop tools and resources that will allow a wide range of stakeholders across Asia to evaluate the vulnerability of heritage resources using up-to-date environmental data and projections. Our work takes a step in this direction by working simultaneously in multiple countries of the region in engagement with—and opening channels of communication between—national agencies in each. Facilitating international collaboration between climate scientists and heritage experts could support the development a comprehensive coastal vulnerability mapping system. A dynamic and open-access form of such mapping would, at the least, provide the potential for any level of heritage stakeholder or concerned member of the public to have geographical information about heritage vulnerability in their locale. Nothing like this currently exists.

4.3. Digital Documentation

Even under the most conservative estimates of how climate change will affect coastal regions over the next several centuries, it is inevitable that a significant amount of maritime heritage will be destroyed or made inaccessible. There is simply no pathway to avoid the impacts of environmental stress in coastal regions and no feasible way to physically preserve the vast bulk of coastal heritage resources. This means that digital documentation will be the only way to preserve at least some of Asia's maritime heritage in perpetuity and make it widely accessible.

The shift to documentation as preservation will require extensive debate about documentation approaches that take into consideration feasibility, localized value, and the specifications of what documentation should capture and in what format. Our documentation efforts are shaped by a combination of what information we feel is needed to allow people to understand and interact with a heritage resource if it is lost and what can we realistically accomplish given time and resource constraints. Our digital heritage archive weaves together standard heritage documentation approaches with 3D visualizations, orthophoto maps and drone-based LiDAR mapping of heritage resources within their environmental context, IIIF deep-zoom manuscript digitization, and local oral histories and knowledge about heritage and environmental change (Figures 3–5). Such approaches are within the general tool kit of digital heritage documentation employed by projects all over the world, but very few projects in Asia combine this all together with a quality control system and extensive cross-referencing of different data sources within an open access platform [68].

Digital heritage documentation requires levels of dedicated equipment, trained personnel, and infrastructure that many national heritage ministries or organizations across Asia do not have. Over the past four years, our field teams in the Maldives and Indonesia, in cooperation with local partners, have generated over 60,000 heritage records for our open access online archive. This illustrates that if national heritage authorities have even small, well-trained, and properly equipped digital heritage survey teams, they can slowly but surely conduct systematic survey and documentation of coastal heritage resources. The ideal solution is that countries across Asia train, equip, and field dedicated coastal heritage survey and documentation teams. If such resources and capacities are not available locally, then partnerships and support from donors and international heritage organizations such as what we have been able to do with the Arcadia Fund, national heritage agencies, and our respective academic institutions are needed to augment these capacities.

Figure 3. 3-d visualization of Benteng Indrapatra, a fort complex built during the 16th or 17th century CE along the coast of Aceh, Indonesia. The image was produced using drone photogrammetry.
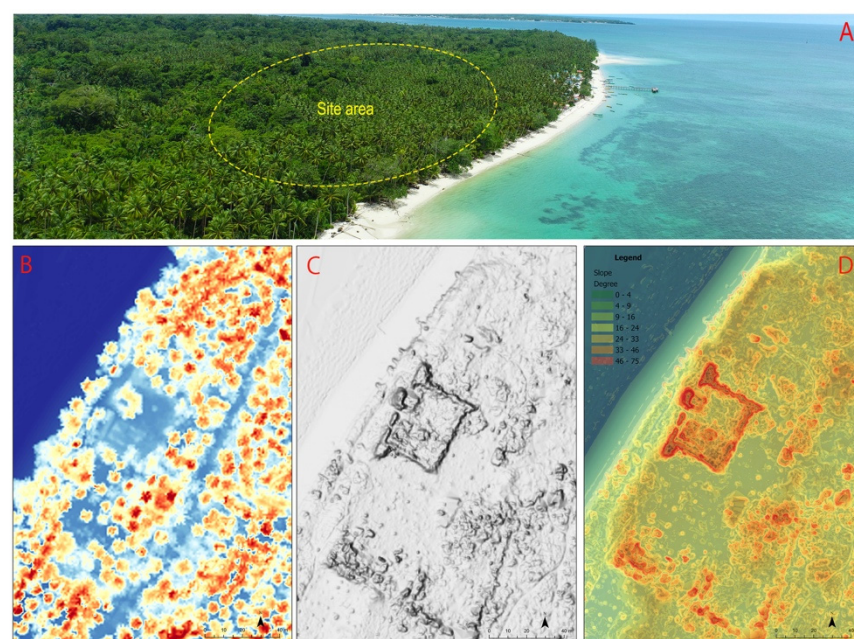

Figure 4. Remains of a 17th century CE Dutch settlement located using drone LiDAR at Kota Lama, Pulau Wokam, Aru, Maluka, Indonesia. Data captured with a Matrice 300 RTK drone with L1 LiDAR sensor payload. Images processed using DJI Terra and ArcGIS Pro. Panel (**A**) Drone photo showing site covered in dense vegetation. Panel (**B**) Digital Surface Model (DSM) generated by interpolating points acquired by the L1 sensor. Panel (**C**) Hillshaded Digital Elevation Model (DEM) interpolated from ground points following point cloud classification. Panel (**D**) Slope map showing the topographical variation in the DEM—slope values in degrees.
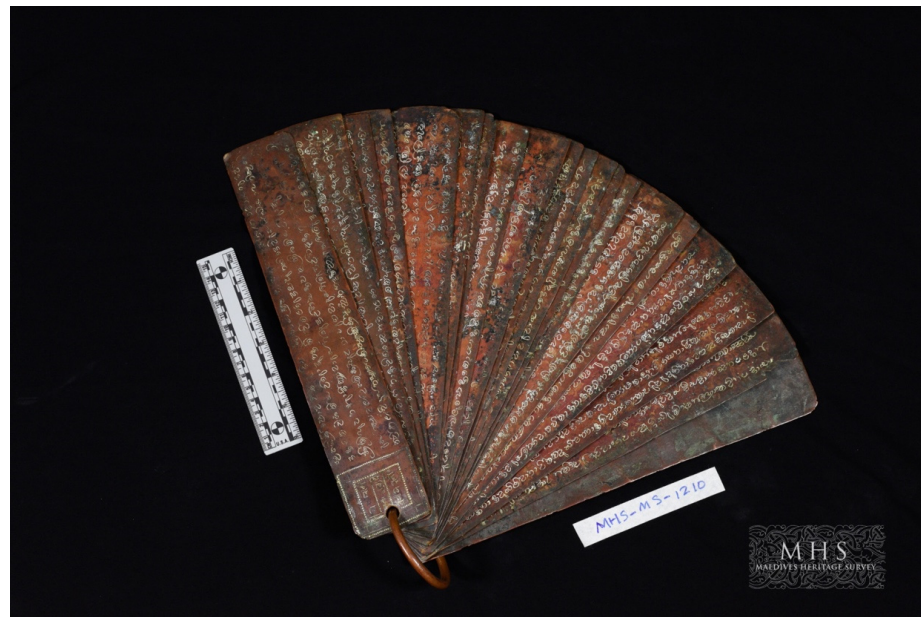
Figure 5. A 12-century copper-plate inscription digitized by the Maldives Heritage Survey. The full text of this and hundreds of other manuscripts are open-access available on the project website: https://maritimeasiaheritage.cseas.kyoto-u.ac.jp/manuscript-viewer/waqf-endowment/ (accessed on 25 April 2022).

It is essential that local populations are involved in heritage management, preservation, and monitoring efforts. Inclusive community-based heritage management initiatives can be a force multiplier in terms of personnel, while also making it more likely that potentially underrepresented heritage resources are included into national inventories, vulnerability mapping, documentation, and preservation programs. Our heritage documentation is conducted by teams from our partner countries. We engage extensively with local communities and stakeholders and recorded oral history interviews are an important part of our database. However, we are well aware that our efforts to facilitate and encourage more autonomous participation of coastal inhabitants are lacking and we are exploring ways to address this.

4.4. Secure and Accessible Archives

The value of heritage documentation is only as good as the systems that store, archive, and present the data captured in the field. This can be conducted through on-line heritage databases and archives. There are countless examples of heritage management systems developed by museums, national heritage agencies, local heritage organizations, and academics. These systems all have different standards and systems for storing data. However, we have significant concerns with this patch-work approach even as we contribute to it. We are, however, attempting to mitigate the situation through the employment of a standardized data model for records in each of the countries where we work on Arches, an open-source software package developed by the Getty Conservation Institute and the World Monuments Fund, that is becoming widely adopted across a diverse range of global contexts. Beyond the field records, photographs, architectural drawings and orthophoto maps integrated into the MAHS Arches database, we also make the digital heritage assets generated by the project accessible on a number of popular platforms: 3D visualizations on Sketchfab (https://sketchfab.com/MaritimeAsiaHeritageSurvey/collections accessed on 25 April 2022), full spatial data point clouds on OpenHeritage 3D (https://openheritage3d.org/news.php?p=digitally-documenting-the-endangered-cultural-history-of-the-maldives accessed on 25 April 2022), and YouTube for videos (https://www.youtube.com/channel/UCZQEeI_JO23QfBuj5MsDGjQ accessed on 25 April 2022).

Securing such records in an on-line archive requires constant updating and maintenance and ideally systems and budgets that are allocated in perpetuity. This is generally only feasible when conducted by established universities, governments, and INGOs that can allocate long-term funding and support. The MAHS preserves copies of its digital archives in the libraries of Kyoto University and the University of Oxford. We also provide our complete dataset to each of our national partners.

All levels of cultural heritage form part of a shared global patrimony and therefore there are strong arguments that heritage documentation should be an open-access resource. Our project is committed to this ideal. There have been over twenty years of evolving debates about the appropriate standards for digital heritage documentation and archiving [83–86]. However, it seems that most projects, including our own, develop and use their own unique systems. While these systems might contain generally similar records, this fragmented digital heritage landscape makes it difficult to integrate data into the kinds of overarching heritage management systems and archives that are needed to provide both long-term safeguarding and also allow for heritage records to be viewed holistically. It is clear that some countries or localities will want to have their own exclusive systems, but maritime heritage—reflecting as it does dynamics of cross-regional engagement—would be better served by international collaborations that can support secure, user-friendly, open-access management systems with the resources and technical expertise to ensure quality control and long-term data security.

Much work is needed to find a more consolidated and secure long-term repository for the many digital heritage records produced by projects and institutions across Asia. The OpenHeritage3D initiative is one example of the kinds of partnerships developing open access digital heritage platforms; MAHS works with them to make our large spatial datasets available under Creative Commons licensing terms.

4.5. Physical Preservation

Heritage custodians at all levels across Asia need to start making decisions now about the potential damage or loss of cultural heritage under their jurisdiction to climate change and start enacting plans for mitigating this damage. Prioritizing, scheduling, and implementing such work will be very challenging, expensive, and almost certainly a contested political process that could take decades [3]. There are a range of approaches that can be used to blunt the impact of climate change on coastal heritage sites. This can involve physical stabilization of heritage resources and protecting sites by creating coastal barriers and other defenses (beach walls, mangroves, etc.) [14,30]. In some cases, heritage sites can be moved away from exposed and vulnerable locations. There are precedents for this occurring at a large scale, in particular the massive rescue operations to disassemble and move major historic sites in areas of Egypt flooded by the Aswan Dam [87,88]. However, these processes are complex and expensive and will most likely only be used for a very small sample of what are deemed to be high-priority heritage sites.

We do not deal directly with physical preservation of cultural heritage within the scope of our work. However, our experiences make it clear that it is highly unlikely that many of the heritage resources that we document, regardless of our assessment of condition and vulnerability, will receive any physical preservation or conservation. Over the next several decades, heritage authorities and their constitutes will increasingly be forced to decide which heritage resources to preserve and which to leave to the elements. This process could be made easier and more transparent if there are frameworks to support, justify, and communicate such decision-making to the wider public. Coastal heritage management plans across Asia need to start anticipating that many of what are now terrestrial heritage resources will eventually become underwater resources that will require different management approaches [89].

5. Discussion and Recommendations

We are fortunate to have committed partners in the Maldives and Indonesia, generous financial support from the Arcadia Fund, dedicated and passionate field documentation teams, and institutional support from Kyoto University and the Earth Observatory of Singapore. However, documenting and preserving Asia's coastal heritage is a daunting task and we know that our efforts are only scratching the surface. We will briefly discuss what we feel are the main challenges that need to be overcome to better manage Asia's coastal heritage: (1) scale and accessibility; (2) logistics, budgets, and capacity; (3) criteria for prioritizing; (4) governance and transboundary management; and (5) institutional limitations.

5.1. Scale and Accessibility

Asia has over 170,000 km of coastline, which is settled by hundreds of millions of people. An unknown but clearly significant amount of Asia's cultural heritage is located within these low-lying coastal and delta regions most vulnerable to climate change. The sheer scale of the problem—in terms of surface area and number of heritage resources—is a major challenge for preserving coastal heritage. This is compounded in countries such as Indonesia and the Maldives by how remote some of the coastal areas are for both documentation and physical preservation (Figure 6). There is bound to be a bias towards sites that are more centrally located, more convenient and accessible, and easier to work at, and against sites in remote and challenging locations. This has the potential to create uneven preservation approaches based in part upon proximity to contemporary infrastructure and population centers. Our project specifically targets for documentation geographic areas and types of heritage that are neglected and/or beyond the capacity of national governments or other agencies to effectively document and monitor. Thus, for example, our work in the Maldives started with some of the southernmost (Seenu and Gnyaviyani) and northernmost (Haa Alif and Haa Dhaalu) atolls in the country and at the greatest distance from the capital in Male'. In Indonesia, we have been focusing work on the environmentally vulnerable coast of Aceh and in the remote eastern island groups of Aru, Kei, and Tanimbar. Decisions will be needed to prioritize where to survey and document heritage. Given the time-sensitive nature of climate change, a combination of environmental vulnerability, concentration of heritage resources, and representation of heritage should be used to determine priorities.

Figure 6. The MAHS field team carrying survey gear from a recently surveyed island back to the boat in the Maldives. Heritage survey and documentation for many remote islands in Southern Asia are logistically challenging and sometimes requires extraordinary efforts to access sites. (Photo Credit P. Daly.)

5.2. Logistics, Budgets, and Capacity

Heritage survey, documentation, and physical preservation all require significant amounts of resources, technical skills, equipment, and human capital. Heritage agencies worldwide are chronically under-budgeted, with this especially the case within the less-developed countries in Asia. Many of the most thorough efforts to manage coastal heritage are being carried out within wealthy developed nations, or in less-developed countries through projects supported by donors. This means that the heritage located in wealthier parts of the world will be allocated more resources and therefore higher levels of preservation, irrespective of other values and importance of heritage and that external donors might have significant influence selecting which heritage resources are preserved across the global south. As climate change takes its toll, there is the very real possibility that the world's maritime heritage will increasingly be dominated by select—but not necessarily representative—preserved examples that represent a small segment of the global population.

Therefore, it is vital to form international collaborations between national and local heritage managers, the main INGOs involved in heritage; the heritage ministries and agencies within nations that have the will and capacity to support work in other countries; and academic institutions. In our project, for example, we leverage generous financial support from the Arcadia Fund with the human capacity and institutional infrastructure at Oxford, Kyoto, and Nanyang Technological universities to support heritage documentation and archiving. In the absence of governments across Asia dramatically increasing budgets for heritage conservation, such collaborations will be vital for safeguarding Asia's coastal heritage. Furthermore, these collaborations need to break the standard model of heritage development and cultural diplomacy initiatives that support heritage preservation only at selected prestigious and highly visible sites.

5.3. Criteria for Prioritization

Given limited resources, heritage survey, documentation, and preservation are shaped within countries by a number of priorities that have the potential to further exacerbate uneven and exclusive patterns of heritage preservation and loss [3,30]. Heritage resources that are economic assets through cultural tourism are commonly prioritized for preservation [18]. It is also established that there is a bias toward preserving heritage resources that fit within, or otherwise support, dominant national historical and political narratives [90]. Finally, regardless of the theoretical advances made to move heritage away from the 19th century fascination with large, monumental heritage sites, there is still a strong tendency for documentation and preservation efforts to focus on sites based upon size, construction material, aesthetics, etc. [91]. If preservation of heritage continues to be shaped by these factors, it will lead to the slow eradication of many kinds of heritage resources that do not fit into these molds and create a situation where we are increasingly left with only a very select range of heritage resources that reflect contemporary economic and political values.

5.4. Governance and Transboundary Management

Maritime networks are expansive and cannot be fully appreciated, understood, or effectively managed in a patchwork manner. The myriad of administrative frameworks that govern and implement heritage conservation are grounded in contemporary social, political, and economic factors that are not always aligned with the nature, historic logic, and essence of maritime heritage. Unfortunately, there are many examples across Asia of heritage that is neglected because it does not align with the current dominant political, cultural, or religious narratives of countries [92–94]. This raises questions about who should be responsible for managing maritime heritage associated with the vast trading networks that are no longer in sync with the political geography, cultures, linguistics, and religious beliefs/practices in place today. Preserving Asia's maritime heritage will require a major shift to transboundary heritage management. This will allow for more representative and inclusive engagement with heritage that transcends political boundaries, sharing of

resources and expertise, and also foster areas for productive international collaboration and engagement.

5.5. Institutional Limitations

Large-scale documentation of cultural heritage is a service project that requires significant resources and interdisciplinary academic expertise to develop and sustain. Furthermore, running large heritage survey and documentation projects can be difficult, frustrating, time-consuming processes that are plagued with setbacks and challenges. In short, it can be a thankless task. Part of what makes it difficult for academics to participate within heritage documentation projects is that such work does not neatly fit into the usual research-driven career pathways for academics and is generally not funded by most of the usual funding bodies that support academic work. Primary research on the history and archaeology of specific sites and regions also falls outside the remit of most organizations that focus on heritage management. These institutional limitations need to be overcome to safeguard cultural heritage from climate change. Two major changes are needed to promote innovative heritage management projects. Academic funding agencies and institutions need to see documentation as well as the creation and maintenance of open access archives as core responsibilities that they should support. We have had to make arguments to our respective academic institutions to justify our work on the Maritime Asia Heritage Survey because it does not neatly align with the kinds of academic outputs that most academic institutions expect of their faculty. The flip side is that donors and agencies that promote heritage preservation need to acknowledge that valid academic research initiatives need to be an integral part of the structure and output of heritage preservation projects. False dichotomies between 'documentation' and 'research' create unnecessary institutional impediments to academics who may otherwise have initiative to develop and undertake the kind of large-scale projects required to address the pressing issues presented above.

6. Conclusions

It is likely that much of Asia's maritime heritage will face increasing pressure over the next century and that environmental processes projected to accompany climate change will be difficult, if not impossible, to blunt. The scale and scope of work needed to build up comprehensive and inclusive heritage inventories, to provide for both open-access and long-term storage of that data, and to develop effective management plans for transnational maritime heritage are considerable—and far beyond the current pace of heritage preservation in most parts of coastal Asia. To accomplish this will require forging collaborations between a wide range of stakeholders and sustained multi-decadal documentation efforts. It will also be necessary for us to dramatically re-think heritage management in ways that appreciate the urgency and potential loss if preservation and documentation are not supported.

At present, it is easy to advocate for the allocation of more resources to protect cultural heritage management from climate change. However, the same environmental forces that will devastate coastal heritage will also cause large-scale human disruption and displacement and almost certainly usher in a new age of resource scarcity. It is likely that as the human costs of climate change increase, allocating resources towards preserving cultural heritage will understandably be reduced to a lower priority than other more immediate concerns for safety and sustainability. Therefore, it is vital to scale-up heritage preservation efforts now to ensure that adequate and resilient systems are in place before time, attention, resources, and capacities are diverted to manage other critical dimensions of the complex impact of accelerated climate change.

Author Contributions: Conceptualization, P.D. and R.M.F.; funding acquisition, P.D., R.M.F. and N.I.; investigation, I.M., M.I., A.H., K.B., J.M. and B.H.; project administration, M.I.; writing—original draft, P.D.; writing—review and editing, P.D., R.M.F., N.I. and B.H. All authors have read and agreed to the published version of the manuscript.

References

1. IPCC. *Climate Change 2022: Impacts, Adaptation, and Vulnerability*; IPCC: Cambridge, UK, 2022.
2. Bertolin, C. Preservation of cultural heritage and resources threatened by climate change. *Geosciences* **2019**, *9*, 250. [CrossRef]
3. Casey, A.; Becker, A. Institutional and conceptual barriers to climate change adaptation for coastal cultural heritage. *Coast. Manag.* **2019**, *47*, 169–188. [CrossRef]
4. Cazenave, A. Anthropogenic global warming threatens world cultural heritage. *Environ. Res. Lett.* **2014**, *9*, 051001. [CrossRef]
5. Dastgerdi, A.S.; Sargolini, M.; Pierantoni, I. Climate change challenges to existing heritage policy. *Sustainability* **2019**, *11*, 5227. [CrossRef]
6. Fatoric, S.; Seekamp, E. Are cultural heritage and resources threatened by climate change? A systematic literature review. *Clim. Change* **2017**, *142*, 227–254. [CrossRef]
7. Garcia, B. Resilient cultural heritage for a future of climate change. *J. Int. Aff.* **2020**, *73*, 101–120.
8. Hambrecht, G.; Rockman, M. International approaches to climate change and cultural heritage. *Am. Antiq.* **2017**, *82*, 627–641. [CrossRef]
9. Harkin, D.; Davies, M.; Hyslop, E.; Fluck, H.; Wiggins, M.; Merritt, O.; Barker, L.; Deery, M.; McNeary, R.; Westley, K. Impacts of climate change on cultural heritage. *MCCIP Sci. Rev.* **2020**, *16*, 616–641. [CrossRef]
10. Haugen, A.; Mattsson, J. Preparations for climate change's influences on cultural heritage. *Int. J. Clim. Change Strateg. Manag.* **2011**, *3*, 386–401. [CrossRef]
11. Jigyasu, R. Managing cultural heritage in the face of climate change. *J. Int. Aff.* **2020**, *73*, 87–100.
12. Orr, S.; Richards, J.; Fatoric, S. Climate change and cultural heritage: A systematic literature review (2016–2020). *Hist. Environ. Policy Pract.* **2021**, *12*, 434–477. [CrossRef]
13. Reimann, L.; Vafeidis, A.; Brown, S.; Hinkel, J.; Tol, R. Mediterranean UNESCO World Heritage at risk from coastal flooding and erosion due to sea-level rise. *Nat. Commun.* **2018**, *9*, 4161. [CrossRef] [PubMed]
14. Sesana, E.; Gagnon, A.; Bertolin, C.; Hughes, J. Adapting cultural heritage to climate change risks: Perspectives of cultural heritage experts in Europe. *Geosciences* **2018**, *8*, 305. [CrossRef]
15. Sesana, E.; Gagnon, A.; Bonazza, A.; Hughes, J. An integrated approach for assessing the vulnerability of World Heritage Sites to climate change impacts. *J. Cult. Herit.* **2020**, *41*, 211–224. [CrossRef]
16. Carroll, P.; Aarrevaara, E. Review of potential risk factors of cultural heritage sites and initial modelling for adaptation to climate change. *Geosciences* **2018**, *8*, 322. [CrossRef]

17. Ezcurra, P.; Rivera-Collazo, I. An assessment of the impacts of climate change on Puerto Rico's cultural heritage with a case study on sea-level rise. *J. Cult. Herit.* **2018**, *32*, 198–209. [CrossRef]

18. Hall, M.; Baird, T.; James, M.; Ram, Y. Climate change and cultural heritage: Conservation and heritage tourism in the anthropocene. *J. Herit. Tour.* **2015**, *11*, 10–24. [CrossRef]

19. Sesana, E.; Gagnon, A.; Ciantelli, C.; Cassar, J.; Hughes, J. Climate change impacts on cultural heritage: A literature review. *Clim. Change* **2020**, *12*, e710. [CrossRef]

20. Ciski, M.; Rzasa, K. Threats to cultural heritage caused by the global sea level rise as a result of global warming. *Water* **2021**, *13*, 2577. [CrossRef]

21. Vousdoukas, M.; Clarke, J.; Ranasignghe, R.; Reimann, L.; Khalaf, N.; Trang, M.D.; Ouweneel, B.; Sabour, S.; Iles, C.; Trisos, C.; et al. African heritage sites threatened as sea-level rise accelerates. *Nat. Clim. Chang.* **2022**, *12*, 256–262. [CrossRef]

22. Cherry, K.; Marks, L.; Adamek, R.; Lyon, B. Younger and older coastal fishers face catastropic loss after Hurricane Katrina. In *Traumatic Stress and Long-Term Recovery*; Cherry, K., Ed.; Springer: Cham, Switzerland, 2015; pp. 327–348.

23. McKernan, J.; Mulcahy, K. Hurricane Katrina: A cultural Chernobyl. *J. Arts Manag. Law Soc.* **2008**, *38*, 217–230. [CrossRef]

24. ICOMOS. *The Future of Ourt Pasts: Engaging Cultural Heritage in Climate Action*; International Council on Monuments and Sites: Paris, France, 2019; pp. 1–63.

25. Seekamp, E.; Jo, E. Resilience and transformation of heritage sites to accommodate for loss and learning in a changing climate. *Clim. Chang.* **2020**, *162*, 41–55. [CrossRef]

26. Hollesen, J.; Callanan, M.; Dawson, T.; Fenger-Nielson, R.; Friesen, T.; Jensen, A.; Markham, A.; Martens, V.; Pitulko, V.; Rockman, M. Climate change and the deteriorating archaeolgical and environmental archives of the Arctic. *Antiquity* **2018**, *92*, 573–586. [CrossRef]

27. Holmgaard, S.; Thuestad, A.; Myrvoll, E.; Barlinghaug, S. Monitoring and managing human stressors to coastal cultural heritage in Svalbard. *Humanities* **2019**, *8*, 21. [CrossRef]

28. Nicu, I.; Stalsberg, K.; Rubensdotter, L.; Martens, V.; Flyen, A.-C. Coastal erosion afftecting cultural heritage in Svalbard. A case study in Hiorthhamn (Adventfjorden)—An abandoned mining settlement. *Sustainability* **2020**, *12*, 2306. [CrossRef]

29. Reeder-Myers, L. Cultural heritage at risk in the twenty-first century: A vulnerability assessment of coastal archaeolgical sites in the United States. *J. Isl. Coast. Archaeol.* **2015**, *10*, 436–445. [CrossRef]

30. Graham, E.; Hambly, J.; Dawson, T. Learning from loss: Eroding coastal heritage in Scotland. *Humanities* **2017**, *6*, 87. [CrossRef]

31. Marzeion, B.; Levermann, A. Loss of cultural world heritage and currently inhabited places to sea-level rise. *Environ. Res. Lett.* **2014**, *9*, 034001. [CrossRef]

32. Daly, P.; Edwards McKinnon, E.; Feener, R.M.; Tai, Y.S.; Ardiansyah; Parnell, A.; Nizamuddin; Sieh, K.; Majewski, J. The historic trading port of Lamri on the North Sumatran Coast. *Bull. L'Ecole Fr. D'Extreme-Orient* **2020**, *105*, 115–144. [CrossRef]

33. Daly, P.; Sieh, K.; Tai, Y.; McKinnon, E.E.; Parnell, A.; Ardiansyah; Feener, R.M.; Ismail, N.; Nizamuddin; Majewski, J. Archaeological evidence that a late 14th-century tsunami devastated the coast of northern Sumatra and redirected history. *Proc. Natl. Acad. Sci. USA* **2019**, *116*, 11679–11686. [CrossRef]

34. Feener, R.M.; Daly, P.; Lum, L.; Edwards McKinnon, E.; Ardiansyah; Nizamuddin; Ismail, N.; Tai, Y.S.; Sieh, K. Islamization and the formation of vernacular burial monuments in 15th-century northern Sumatra. Indones. *Malay World* **2021**, *49*, 1–41. [CrossRef]

35. Sieh, K.; Daly, P.; Edwards McKinnon, E.; Pilarczyk, J.; Chiang, H.; Horton, B.; Rubin, C.; Shen, C.; Ismail, N.; Vane, C.; et al. Penultimate predecessors of the 2004 Indian Ocean tsunami in Aceh, Sumatra: Stratigraphic, archaeological, and historical evidence. *J. Geophys. Res.-Solid Earth* **2015**, *120*, 308–325. [CrossRef]

36. Tai, Y.S.; Daly, P.; Edwards McKinnon, E.; Parnell, A.; Feener, R.M.; Majewski, J.; Ismail, N.; Sieh, K. The impacts of Ming and Qing dynasty maritime bans on trade ceramics recovered from coastal settlements in northern Sumatra, Indonesia. *Archaeol. Res. Asia* **2020**, *21*, 100174. [CrossRef]

37. Feener, R.M.; Daly, P.; Frachetti, M.; Mujah, I.; Irawani, M.; Taran, J.; Zaki, A.; Maasa, F.; Shamran, M.; Zahara, M.; et al. The Maldives Heritage Survey. *Antiquity* **2021**, *95*, E16. [CrossRef]

38. Brabec, E.; Chilton, E. Toward an ecology of cultural heritage. *Chang. Time* **2015**, *346*, 266–307. [CrossRef]

39. Daly, P.; Feener, R.M. *Rebuilding Asia Following Natural Disasters: Approaches to Reconstruction in the Asia-Pacific Region*; Cambridge University Press: Cambridge, UK, 2016.

40. Daly, P.; Rahamayati, Y. Cultural heritage and community recovery in post-tsunami Aceh. In *From the Ground Up: Persepectives on Post-Tsunami and Post-Conflict Aceh*; Daly, P., Feener, R.M., Reid, A., Eds.; ISEAS Press: Singapore, 2012; pp. 57–78.

41. Daly, P.; Winter, T. *The Routledge Handbook of Heritage in Asia*; Routledge: London, UK, 2011.

42. De Jong, W.; Snelder, D.; Ishikawa, N. *Transborder Governance of Forests, Rivers, and Seas*; Routledge: London, UK, 2010.

43. Horton, B.; Khan, N.; Cahill, N.; Lee, J.; Shaw, T.; Garner, A.; Kemp, A.; Engelhart, S.; Rahmstorf, S. Estimating global mean sea-level rise and its uncertainties by 2100 and 2300 using an expert survey. *npj Clim. Atmos. Sci.* **2020**, *3*, 18. [CrossRef]

44. Majewski, J.; Meltzner, A.; Switzer, A.; Shaw, T.; Li, T.; Bradley, S.; Walker, J.S.; Kopp, R.; Samanta, D.; Natawidjaja, D.H.; et al. Extending instrumental sea-level records using coral microatolls, an example from Southeast Asia. *Geophys. Res. Lett.* **2022**, *49*, e2021GL095710. [CrossRef]

45. Saintilan, N.; Khan, N.; Ashe, E.; Kelleway, J.; Rogers, K.; Woodroffe, C.; Horton, B. Thresholds of mangrove survival under rapid sea-level rise. *Science* **2020**, *368*, 1118–1121. [CrossRef]

46. Walker, J.S.; Kopp, R.; Little, C.; Horton, B. Time of emergence of modern rates of sea-level rise by 1863. *Nat. Commun.* **2022**, *13*. [CrossRef]

47. Walker, J.S.; Kopp, R.; Shaw, T.; Cahill, N.; Khan, N.; Barber, D.; Ashe, E.; Brain, M.; Clear, J.; Corbett, D.; et al. Common era sea-level budgets across the U. S. Atlantic coast. *Nat. Commun.* **2021**, *12*, 1841. [CrossRef]

48. Winter, T. *Geocultural Power: China's Quest to Revive the Silk Roads for the Twenty-First Century*; University of Chicago Press: Chicago, IL, USA, 2019.

49. Cohen, M. *Cultural History of the Sea: Volumn 1*; Bloomsbury Academic: New York, NY, USA, 2021.

50. Abu-Lughod, J. *Before European Hegemony: The World System A. D. 1250–1350*; Oxford University Press: Oxford, UK, 1989.

51. Chaudhuri, K. *Trade and Civilisation in the Indian Ocean: An Economic History from the Rise of Islam to 1750*; Cambridge University Press: Cambridge, UK, 1985.

52. Hamashita, T.; Selden, M.; Grove, L. *China, East Asia and the Global Economy: Regional and Historical Perspectives*; Routledge: London, UK, 2008.

53. Miksic, J. *Singapore & the Silk Road of the Sea: 1300–1800*; NUS Press: Singapore, 2013.

54. Reid, A. *Southeast Asia in the Age of Commerce, 1450–1680*; Yale University Press: New Haven, CT, USA, 1990.

55. Reid, A. *Southeast Asia in the Early Modern Era: Trade, Power, and Belief*; Cornell University Press: Ithaca, NY, USA, 1993.

56. Schottenhammer, A. *The East Asian Mediterranean: Maritime Crossroads of Culture, Commerce and Human Migration*; Harrassowitz Verlag: Wiesbaden, Germany, 2008.

57. Alexandrakis, G.; Manasakis, C.; Kampanis, N. Economic and societal impacts on cultural heritage sites, resulting from natural effects and climate change. *Heritage* **2019**, *2*, 279–305. [CrossRef]

58. Nguyen, T.; Nguyen, T.; Luong, T.; Luc, H. Tourism and beach erosion: Valuing the damage of beach erosion for tourism in the Hoi An World Heritage site, Vietnam. *Environ. Dev. Sustain.* **2019**, *21*, 2113–2124. [CrossRef]

59. Reeder-Myers, L.; McCoy, M. Preparing for the future impacts of megastorms on archaeolgical sites: An evaluation of flooding from Hurricane Harvey, Houston, Texas. *Am. Antiq.* **2019**, *84*, 292–301. [CrossRef]

60. Liritzis, I.; Westra, A.; Miao, C. Disaster geoarchaeology and natural cataclysms in world cultural evolution: An overview. *J. Coast. Res.* **2019**, *35*, 1307–1330. [CrossRef]

61. Rubin, C.; Horton, B.; Sieh, K.; Pilarczyk, J.; Daly, P.; Ismail, N.; Parnell, A. Highly variable recurrence of tsunamis in the 7400 years before the 2004 Indian Ocean tsunami. *Nat. Commun.* **2017**, *8*, 16019. [CrossRef]

62. Boger, R.; Perdikaris, S.; Rivera-Collazo, I. Cultural heritage and local ecological knowledge under threat: Two Caribbean examples from Barbuda and Puerto Rico. *J. Anthropol. Archaeol.* **2019**, *7*, 1–14. [CrossRef]

63. Abulafia, D. *The Boundless Sea: A Human History of the Oceans*; Oxford University Press: Oxford, UK, 2019.

64. Paine, L. *The Sea and Civilization: A Maritime History of the World*; Atlantic Books: London, UK, 2014.

65. Gipouloux, F. *The Asian Mediterranean: Port Cities and Trading Networks in China, Japan and Southeast Asia, 13th—21st Century*; Edward Elgar: Cheltenham, UK, 2011.

66. Graf, A.; Chua, B. *Port Cities in Asia and Europe*; Routledge: London, UK, 2009.

67. Haneda, M. *Asian Port Cities, 1600—1800: Local and Foreign Cultural Interactions*; NUS Press: Singapore, 2009.

68. Feener, R.M.; Ishikawa, N.; Daly, P. Big data in the humanities: New interdisciplinary opportunities and new challenges for data management. *J. Jpn. Soc. Inf. Knowl.* **2021**, *31*, 440–445. [CrossRef]

69. Daly, P. Cycles of destruction and reconstruction: Responding to disasters in the Asia-Pacific region. In *Rebuilding Asia: Approaches to Post-Disaster Reconstruction in the Asia-Pacific Region*; Daly, P., Feener, R.M., Eds.; Cambridge University Press: Cambridge, UK, 2016; pp. 1–56.

70. Anthony, A.; Atwood, J.; August, P.; Bryron, C.; Cobb, S.; Foster, C.; Fry, C.; Gold, A.; Hagos, K.; Heffner, L.; et al. Coastal lagoons and climate change: Ecological and social ramifications in the US. Atlantic and Gulf coast ecosystems. *Ecol. Soc.* **2009**, *14*, 1–29. [CrossRef]

71. He, Q.; Silliman, B. Climate Change, human impacts, and coastal ecosystems in the Anthropocene. *Curr. Biol.* **2019**, *29*, 1021–1035. [CrossRef]

72. Hughes, T.P.; Kerry, J.T.; Simpson, T. Large-scale bleaching of corals on the Great Barrier Reef. *Ecology* **2018**, *99*, 501. [CrossRef]

73. Pisapia, C.; Burn, D.; Prachett, M. Changes in the population and community structure of corals during recent disturbances (February 2016–October 2017) on Maldivian coral reefs. *Sci. Rep.* **2019**, *9*, 8402. [CrossRef] [PubMed]

74. Stuart-Smith, R.; Brown, C.; Ceccarelli, D.; Edger, G. Ecosystem restructuring along the Great Barrier Reef following mass coral bleaching. *Nature* **2018**, *560*, 92–96. [CrossRef] [PubMed]

75. Chaijaroen, P. Long-lasting income shocks and adaptatons: Evidence from coral bleaching in Indonesia. *J. Dev. Econ.* **2019**, *136*, 119–136. [CrossRef]

76. Hoegh-Guldberg, O.; Pendleton, L.; Kaup, A. People and the changing nature of coral reefs. *Reg. Stud. Mar. Sci.* **2019**, *30*. [CrossRef]

77. Ives, T.; McBridge, K.; Waller, J. Surveying coastal archaeological sites damaged by Hurricane Sandy in Rhode Island, USA. *J. Isl. Coast. Archaeol.* **2018**, *13*, 66–89. [CrossRef]

78. Li, K.; Gong, P.; Hu, H.; Jia, W.; Liu, X.; Gao, W. Spatial variability of human subsistence strategies during the Longshan period and its possible physical environmental contexts in the Yellow-Huai River area, East China. *Sci. Cult.* **2021**, *7*, 105–116.

79. Chapkanski, S.; Brocard, G.; Lavigne, F.; Tricot, C.; Meilianda, E.; Ismail, N.; Majewski, J.; Goiran, J.-P.; Alfian, D.; Daly, P.; et al. Fluvial and coastal landform changes in the Aceh River delta (northern Sumatra) during the century leading to the 2004 Indian Ocean tsunami. *Earth Surf. Process. Landf.* **2021**, *47*, 1127–1146. [CrossRef]

80. Poulos, S.E.; Panagopoulou, A.; Kotinas, C. An oceanographic insight in the submergence and resilence of the Pavlopetri archaeological site. *Sci. Cult.* **2022**, *8*, 161–173. [CrossRef]

81. Sevieri, G.; Galasso, C.; D'Ayala, D.; DeJesus, R.; Oreta, A.; Grio, M.; Ibabao, R. A multi-hazard risk prioritisation framework for cultural heritage assets. *Nat. Hazards Earth Syst. Sci.* **2020**, *20*, 1391–1414. [CrossRef]

82. Cook, I.; Johnston, R.; Selby, K. Climate change and cultural heritage: A landscape vulnerability framework. *J. Isl. Coast. Archaeol.* **2021**, *16*, 553–571. [CrossRef]

83. Choy, S.; Crofts, N.; Fisher, R.; Choh, N.L.; Nickle, S.; Oury, C.; Slaska, K. *The UNESCO/PERSIST Guidelines for the Selection of Digital Heritage for Long-Term Preservation*; UNESCO: Paris, France, 2016.

84. MacDonald, L. *Digital Heritage: Applying Digital Imaging to Cultural Heritage*; Routledge: London, UK, 2006.

85. O'Neill, B.; Stapleton, L. Digital cultural heritage standards: From silo to semantic web. *AI Soc.* **2022**. [CrossRef]

86. Parry, R. *Recoding the Museum: Digital Heritage and the Technologies of Change*; Routledge: London, UK, 2007.

87. Alberts, H.; Hazen, H. Maintaining authenticity and integrity at cultural World Heritage sites. *Geogr. Rev.* **2010**, *100*, 56–73. [CrossRef]

88. Tamborrino, R.; Wendrich, W. Cultural heritage in context: The temples of Nubia, digital technologies and the future of conservation. *J. Inst. Conserv.* **2017**, *40*, 168–182. [CrossRef]

89. Galili, E.; Rosen, B. Preserving the maritime cultural heritage of the Mediterranean, a cradle of cultures, religions and civilizations—The holy land perspective. *J. Coast. Conserv.* **2010**, *14*, 303–315. [CrossRef]

90. Smith, L. *Uses of Heritage*; Routledge: New York, NY, USA, 2006.

91. Winter, T.; Daly, P. Heritage in Asia: Converging forces, conflicting values. In *The Routledge Handbook of Heritage in Asia*; Daly, P., Winter, T., Eds.; Routledge: London, UK, 2011.

92. Lee, R.; Zarandona, J. Heritage destruction in Myanmar's Rakhine state: Legal and illegal iconoclasm. *Int. J. Herit. Stud.* **2019**, *26*, 519–538. [CrossRef]

93. Maarleveld, T. The maritime paradox: Does international heritage exist? *Int. J. Herit. Stud.* **2012**, *18*, 418–431. [CrossRef]

94. Manhart, C. The Afghan cultural heritage crisis: UNESCO's response to the destruction of statues in Afghanistan. *Am. J. Archaeol.* **2001**, *105*, 387–388. [CrossRef]