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Resilient Caribbean Communities: A Long-Term Perspective on Sustainability and Social Adaptability to Natural Hazards in the Lesser Antilles

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Citation: Hofman, C.L.; Stancioff, C.E.; Richards, A.; Nanichi Auguiste, I.; Sutherland, A.; Hoogland, M.L.P. Resilient Caribbean Communities: A Long-Term Perspective on Sustainability and Social Adaptability to Natural Hazards in the Lesser Antilles. *Sustainability* **2021**, *13*, 9807. https://doi.org/10.3390/su13179807

Academic Editors: Michelle J. LeFebvre, Jon M. Erlandson and Scott M. Fitzpatrick

Received: 14 July 2021
Accepted: 27 August 2021
Published: 31 August 2021

Abstract: Caribbean islands, like other Small Island Developing States (SIDS), are at the center of the vulnerability debate as current climatic trends predict elevated sea levels and increased frequency of storms, leading to significant challenges for local communities. Caribbean islanders have been exposed to climatic challenges since the initial occupation of the archipelago between five to eight thousand years ago. They have been continually confronted with severe droughts, tropical cyclones, extreme wave events, sea-level changes, and the accompanying impacts. The various phenomena have stimulated island residents both to anticipate and respond to such events, adapting their lifestyles and socio-cultural and political structures and ties across the region over time. In this article, we innovatively combine archaeological and palaeoenvironmental data with longitudinal coastal-erosion data and ethnographic data to further develop and promote sustainable local strategies to mitigate the adverse effects of climate change and increasingly frequent and violent weather events on small-island settings. To find proxies, we first look into the region's pre-colonial archaeological record. Second, we delve into predictive modeling and the current and future climatic challenges for heritage sites and local coastal communities, as well as related collaborative heritage mitigation efforts. Third, we discuss the contribution of traditional knowledge practices to climate change adaptation. The results show how the long-term perspective and multidisciplinary approach adopted here may lead to realistic solutions to seemingly intractable problems. They also reveal how collaborative projects involving all stakeholders on an equal basis in all phases of research have become a top priority in climate change mitigation and heritage safeguarding.

Keywords: Caribbean; Lesser Antilles; sustainability; resilient societies; climate change; long-term perspective; archaeology; predictive modeling; traditional knowledge

1. Introduction

Islands represent a region imagined and re-imagined by outsiders throughout history. The Caribbean islands, in particular, were continually exploited and shaped through external forces, such as island colonization, the colonial construction of their exoticism and abundance (leading to the pillaging of natural and social resources), and, currently, their characterization as idyllic tourism getaways. More and more, these islands are coming to the forefront of climate change discussions, with the prevailing doomsday media frenzy focused on their sinking or disappearance [1].

Climate change will always be an unfair battle. Despite contributing some of the lowest amounts of greenhouse gas emissions, the Caribbean islands are predicted to experience a range of effects due to their small size, limited resource base, growing populations, and relative isolation [2–9]. Often defined by their limitations or constraints, the islands of the Lesser Antilles display a clear vulnerability due to their small size [10–14]. According to recent research, SIDS are often the first to feel the impact of global economic policies, extreme weather events, and climate change (e.g., [6,15–17]). As a majority of the Lesser Antilles has significant infrastructure in the coastal zone, particularly related to tourism, a global sea-level rise of 1 m—as predicted toward the end of the twenty-first century—will undoubtedly be impactful in terms of livelihood and gross domestic product (GDP). For example, it is estimated that Antigua and Barbuda and Saint Kitts and Nevis will face adaptation costs ranging from 27% to 32% of their GDP [18]. These vulnerabilities, therefore, are not without reason.

However, current perceptions and research myopically position these islands, like all places around the globe, at the forefront of the disaster paradigm (see also [19]). This is problematic, as it removes any chance for a global lesson on sustainability and, more importantly, resilience [20,21]. The rich archaeological record, historic accounts, present-day multivocality, and abundant biodiversity of the Caribbean, specifically of the Lesser Antilles [19,22,23], offer a different interpretation to share.

Originally occupied between eight and five thousand years ago by settlers from Central and South America, the islands of the Lesser Antilles (Figure 1) saw a second major migratory movement from the northeastern South American mainland around 2500 years ago [24–27]. Geological, palaeoecological, and archaeological data indicate that from the onset, Caribbean communities in the Lesser Antilles were confronted with extremely variable climatic conditions, including severe droughts and a high risk of floods and landslides caused by extreme weather events such as tropical storms and hurricanes, as well as earthquakes, volcanic action, major surges, and the continuous menace of sea-level fluctuations [28–34]. Such conditions have significantly altered the islands' ecosystems over time, and have undoubtedly impacted Indigenous lifeways (e.g., [35–46]). To improve safety in times of austerity and climatic challenge, the locally and regionally established circuits of mobility and exchange would have been key, particularly due to the diversity of settlement locations, which enhanced diversification within the networks and strengthened existing social ties (e.g., [47–57]). These safety networks were disrupted by the European invasion of 1492 [58].

Though the Indigenous peoples certainly transmitted to the Europeans their local knowledge of how to handle the climatic hazards, such as hurricanes, the Europeans introduced their own lifestyles, which were not always suited to the local conditions or consistent with an understanding of the local environmental context and climatic variations. The dramatic fate of the Indigenous Caribbean peoples and cultures in the wake of European invasion and colonization threatened the Indigenous systems of knowledge that would otherwise have been passed down from generation to generation to help manage the cyclical impacts of climate change (see also [38,59]).

After the Western colonial invasion, bringing people from Africa, Asia, and Europe to the Americas to work as exploited "laborers" alongside the remaining Indigenous peoples, massive deforestation and sharp population growth increased the pressure on natural resources and ecological systems [60,61]. The trans-sociocultural dynamics between Indigenous, African, and mixed descendants since colonial times are still reflected in today's local knowledge practices and lifeways, including those informing perspectives on climate change response [62,63].

Figure 1. Map of the Caribbean with insert detail of the Lesser Antilles. (Map created by Menno Hoogland).

In the Caribbean Lesser Antilles, deforestation, sand-mining operations, an increase in extreme weather events, and a dependency on tourism with inherently high ecological costs have all produced environmental impacts as well as social change comparable to other regions of the world (e.g., [64–66]). These effects have influenced the natural physical protection, local economies, land, homes, fisheries, agriculture, local traditions, and people's heritage [59,67–69]. Mitigation and adaptive planning measures are a top priority to safeguard these coastal environments and livelihoods, and to avoid the further and irreversible loss of the archaeological record and often unwritten histories. Understanding the role of heritage and community is key to incorporating long-term processes of social adaptability to climatic challenges and of resilience (see also [35,38,42]). The Kalinago and Garifuna communities of the Windward Islands, who in recent years have been severely impacted by the devastating effects of Hurricane Maria (2017), the eruption of the La Soufrière volcano on Saint Vincent (2021) (Figure 2), and other social threats, such as the COVID-19 pandemic, rely heavily—like other Indigenous and local communities—on traditional knowledge practices for adapting to such crises and building resilience for a sustainable future (e.g., [38,70–72]).

Therefore, in this article, we adopt a long-term perspective and a multidisciplinary approach combining research from archaeology, palaeoenvironmental studies, cultural heritage, and ethnohistory/ethnography to examine the current and often imperceptible relationships between Caribbean island communities and the environment in these case studies [70,73,74]. With insights from the past, island climate responses can provide valuable information for contemporary societies that must cope with similar challenges [75,76]. Furthermore, remembering the historic marginalization of these islands also reveals that the vanishing island is a notion with a historical precedent [77,78]. We first discuss archaeological case studies from the Mid- to Late Holocene in the Lesser Antilles that provide a clear indication of how its early settlers adapted to the environmental challenges with which they were confronted, and what lessons can be learned from the past. Second, we address the current and future challenges of climatic impacts on archaeological sites and local coastal communities, highlighting a case study of collaborative mitigation efforts in Saint Kitts. Third, we share the experiences and knowledge practices, which were passed down from generation to generation, by co-authors Irvince Auguiste and Augustine (Sardo) Sutherland, Kalinago from Dominica and Saint Vincent. These relate how they have adapted to the natural hazards that have recently threatened their respective livelihoods. It is, however, crucial to treat and use this information respectfully and in accordance with human rights and international law surrounding the global climate change debate [79]. Finally, we conclude by discussing the benefit of multidisciplinary and collaborative projects for the safeguarding of SIDS' and other coastal environments, archaeological sites, and livelihoods [80–82]. Further, we propose community engagement, co-creation, and the exchange of usable knowledge for fostering and enhancing historical awareness, appraisal, protections, and preservation as the best solution for developing sustainable heritage safeguarding.

Figure 2. (**a**,**b**) Impact of the eruptions of the La Soufrière volcano (2021) on the livelihoods of the Kalinago in Sandy Bay, Saint Vincent; (**c**) damage to the Kalinago Territory, Dominica, in the wake of Hurricane Maria (2017). (Photos by Irvince Auguiste, Augustine Sutherland, Marvin Pierre, Raydon May, and Danroy Thomas.).

2. Methodology

Working together with local stakeholders in all case studies, we combined data from archaeology, paleoenvironmental studies, cultural heritage, and ethnohistory/ethnography. The archaeological and paleoenvironmental data were collected during (rescue) excavations in the Lesser Antilles between 1995 and 2015 by a team from Leiden University, the Netherlands, in collaboration with local stakeholders. As the sites were threatened by either natural or human impacts or both, rescue interventions were necessary for both the well-being of the communities and their rich cultural heritage.

Observations concerned the resilience of precolonial inhabitants to severe weather events, and special attention was paid to the sustainability of their living conditions, particularly house-building and settlement organization. The team collected palaeoenvironmental data during excavations at two sites (Anse à la Gourde, Guadeloupe and Anse Trabaud, Martinique), in collaboration with colleagues from the Free University of Amsterdam (VU) in the first case and the Université des Antilles and University of Amsterdam (UvA) in the second. In the case of Anse à la Gourde, oxygen isotopic studies on terrestrial molluscs (*Bulimulus guadalupensis*) were performed to study the climatic conditions over time [28]. Predictive modeling was used both at the archaeological site of Morel (Guadeloupe) and in the case study of contemporary Saint Kitts to record longitudinal coastal-erosion processes. In the case of Morel, this was done by carrying out a topographic survey and using aerial photography and satellite imagery [83]. In the case of Saint Kitts, we used satellite imagery and the Digital Shoreline Analysis System (DSAS) [84], a freely available ArcGIS plugin provided by the United States Geological Survey (USGS). We extracted shoreline vectors from LANDSAT MSS, TM, ETM, and OLI-TIRS imagery. To understand the results of this environmental coastal change from the perspective of the individuals living there, a survey and in-depth interviews were conducted in the case study area (see [19] for the reporting of these). Moreover, in order to understand and highlight contemporary local community responses, the participation of and collaboration with the Kalinago communities in Dominica and Saint Vincent and the Grenadines were central to each step of this research in order to highlight the important role of traditional knowledge and Indigenous responses to climate-related, and other, crises.

3. Lessons to Be Learned from the Past: Evidence from the Mid-to Late Holocene

The first Mid- to Late Holocene campsites—and ultimately larger permanent settlements—were often, though not exclusively, located on the islands' coasts and lagoons and in mangrove areas [25,40,55]. Apart from the fact that these habitation sites are susceptible in terms of climate vulnerability, the long-term changing coastal dynamics have impeded their archaeological visibility and distorted its historical reality [85]. The absence of early Archaic Age sites in the Windward Islands may, for example, be explained by increased sea levels over the past millennia, or by changes in coastal configurations due to extreme weather events that led to the disappearance or submergence of sites [42,43,86–90]. Recent archaeological research has shown that climatic variation, coastal erosion, and repeated flooding and heavy droughts must have had significant impacts on pre-colonial settlement locations, organization, and house-building activities [37,42,43,46,85]. Hurricane-proof shelters have been documented throughout the pre-colonial Caribbean during the Ceramic Age (400 cal. BC–cal. AD 1500). These structures could be repaired rapidly after a disaster, since only light construction, such as roofing and walls, would need to be replaced [46]. Windbreaks were sometimes attached to the houses, offering protection against the prevailing northeast trade winds and heavy rains to the entrances and the activity areas of the houses. The main posts of the individual structures have been found to be very sturdy and dug deeply into the ground, fixed with large slabs or dug into the bedrock, providing strong support for the roof-bearing posts, with an outer wall construction sometimes made only of large posts, but occasionally from alternating large and small posts [46,54,91].

The site of Anse à la Gourde (cal. AD 500–1450) is located on the Pointe des Chateaux peninsula of northeastern Grande-Terre, Guadeloupe, an area that is particularly vulnerable to extreme weather events. Paleoenvironmental data have shown that in the past, this region has been exposed to severe climatic variations, with several relatively wet and dry periods, coinciding with its different phases of occupation [28,42]. Alternate periods of flood and drought, continuous sea-level rise, and coastal erosion have led to internal relocation of the settlement during its four successive phases of occupation [42,54,92] (Figure 3). A shift in the reef barrier, connected with sea-level changes, necessitated the gradual retreat of habitation towards higher settlement grounds. During the earliest occupation phase (cal. AD 500–700/800), there existed a beach barrier with a low-salinity lagoon behind established mangrove forests. The village was situated on the shore of this brackish water lagoon, between 50 and 100 m south of the Atlantic littoral. Unfortunately, a large part of the settlement from that time has been lost to the sea. In approximately cal. AD 800, a rise in the sea level resulted in the breakdown of the coastal barrier as well as the progressive salinization of the lagoon. In response, the inhabitants moved toward the newly formed elevated dunes. This process continued over a period of centuries, with the village moving farther and farther away from the littoral due to the continuing retreat of the coastline [42,54,93]. The last occupation phase of the settlement (cal. AD 1200–1450) was located on the highest elevations, with a fairly intact habitation area showing numerous round and oval house structures with more than eighty burials. To withstand the force of extreme weather events, the posts of the houses were also anchored deeply into the bedrock or secured with large slabstones (Figure 4).

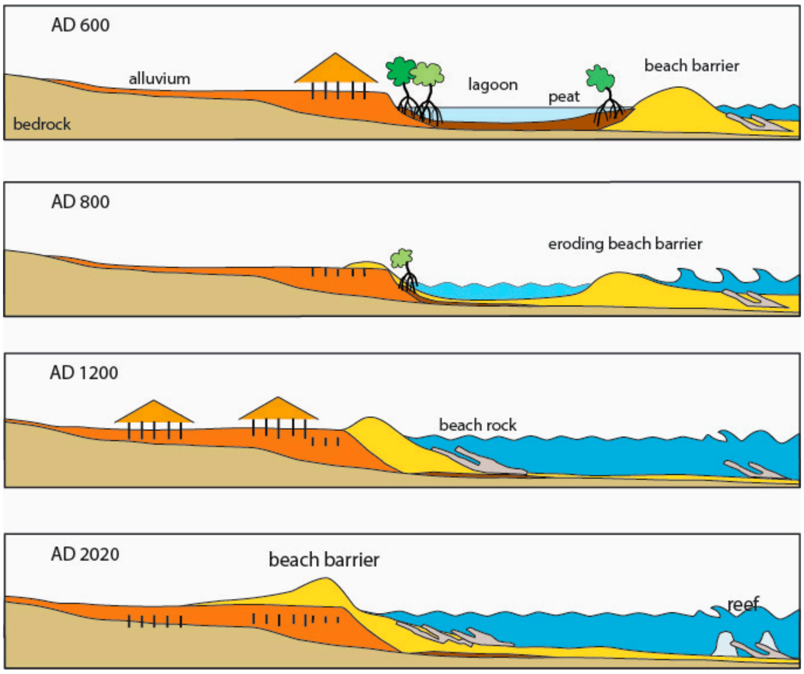

Figure 3. (Re)construction of the coastal changes and gradual retreat of the Indigenous settlement based on paleoclimatic research from Beets et al. 2006 [28]. (Adapted from Hofman and Hoogland 2015 [42]; image created by Menno Hoogland).

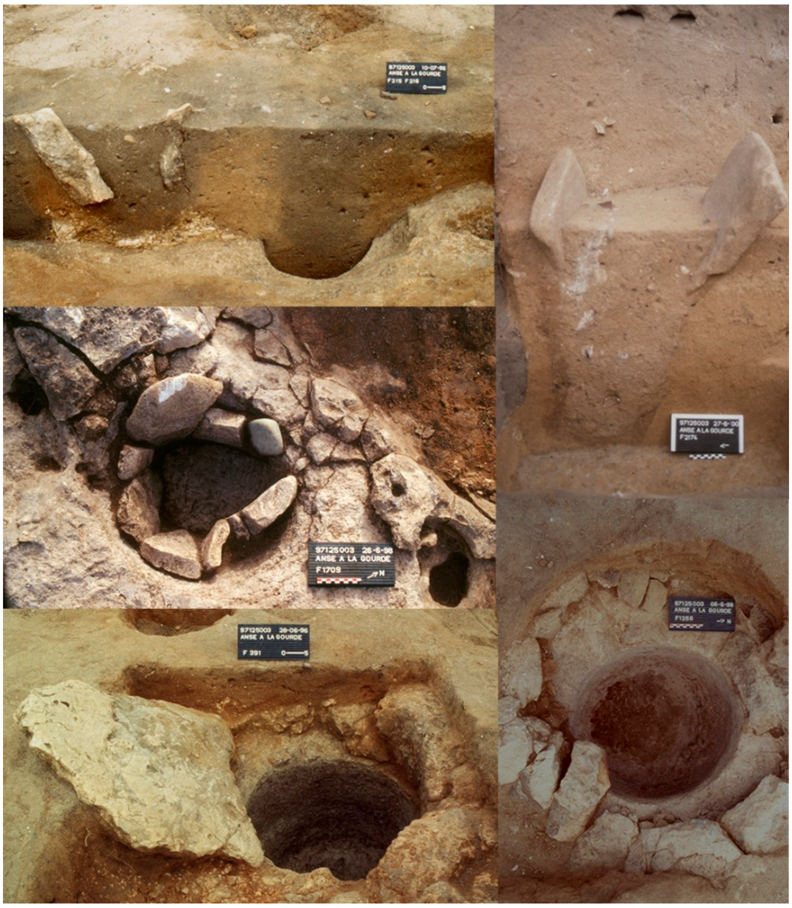

Figure 4. Examples of postholes at the archaeological site of Anse à la Gourde, Guadeloupe showing the resilience of building techniques. Some of the posts were dug deep into the bedrock; others were secured with slabs. (Photos by Corinne Hofman and Menno Hoogland).

A similar case of settlement relocation was observed at the semi-contemporaneous multi-component site of Anse Trabaud (cal. AD 700–1200), which is situated in the south-eastern part of Martinique. It is located on a tombolo that comprises a number of successive beach barriers and connects a small island to the mainland of Martinique. The area is heavily susceptible to extreme weather events, and the peninsula of Pointe Baham shows the most convincing evidence for sudden storms in this area [43]. The change in landscape from an open beach setting to a closed mangrove forest, potentially driven by a storm event, required a reorganization of offshore/near-shore water currents. Between the tombolo and the mainland, a shallow lagoon with mangrove vegetation has formed. The archaeological stratigraphy in the mangrove area shows a thick layer of sediment with a succession of compact marine sand layers caused by tidal and other dynamics in the mangrove area. A reduction zone between 0.5 m and 1.80 m is present, with extremely well-preserved organic materials due to excessive moisture in the sediment. It is hypothesized that the inhabitants of Anse Trabaud adapted to the gradually rising sea level by moving to the outer and higher beach barriers over time [43,89]. The earliest inhabitants (cal. AD 700–900) may have lived in stilt houses built around a lagoon. A limited number of posthole features in the moist layers confirm the presence of structures in the area. Stilt houses have also been documented at the site of Los Buchillones in north-central Cuba, dating to cal. AD 1250–1500, which today is situated 150 m out into the sea [94]. At this site, the mahogany posts of the stilt houses were dug up to 1.70 m deep into a lagoon deposit; these may have offered resistance to hurricanes and other extreme weather events, floods, and gradual sea-level rise. Starch grain and phytolith analysis of the Anse Trabaud archaeobotanical assemblage has provided unique insight into changes in food procurement, production, and consumption during periods of environmental transformation and harsh climate [43]. Due to the waterlogged conditions at both Anse Trabaud and Los Buchillones, organic materials, such as wood, gourd fragments, seeds, diatoms, and starch grains, have been extremely well preserved [43,89,94–96].

4. The Impacts of Natural Crises on Archaeological Sites and Current Coastal Communities: Present and Future Challenges

The detrimental effects of coastal degradation and the very real possibility of instant devastation caused by hurricanes that are increasing in frequency and strength are telling signs of the menace that the Caribbean islands and islanders face. Irma's total destruction of Barbuda, Saint Martin/Sint Maarten, the Virgin Islands, and Puerto Rico; Maria's devastation of Dominica in September 2017; and Dorian's incursion into the Bahamas in 2019 all happened in a matter of hours, though the havoc they wreaked will be felt for years. Extreme weather and storm events continue to affect shorelines in terms of submerging, covering, severely eroding, and/or eradicating coastal archaeological sites [35,39,45,85,97,98]. The dramatic impact of such events on the archaeological record and cultural heritage of the Caribbean is often accelerated due to adverse human impacts arising from uncontrolled construction activities, sand mining, and looting (e.g., [35,68,97,99]). As suggested above, the almost complete absence of Archaic Age sites in the Windward Islands, several of the Virgin Islands, Jamaica, and the Bahamas may partially be the result of these impacts too. For example, at the site of Morel (300 cal. BC–cal. AD 1400), located on the exposed northeastern coast of Grande-Terre, Guadeloupe, a change in coastline of 60 m was noted between 1948 and 2020 based on a topographic survey in 1993, aerial photographs, and satellite images. The damage to the coastal landscape was accompanied by the loss of a large portion of the archaeological deposits [83] (Figure 5). Rescue excavations at the site in collaboration with the local partners of the Service Régional de l'Archéologie (SRA) between 1993 and 1999 uncovered an archaeological layer with numerous human and dog burials dating to the earliest Ceramic Age occupation of the site. Sand mining and looting, especially after the archaeological deposits were laid bare as a result of Hurricane Luis in 1995, have accelerated the deterioration of the site (Figure 6). The site has continued to lose surface, and the context of the remaining deposits has been reduced to a minimum.

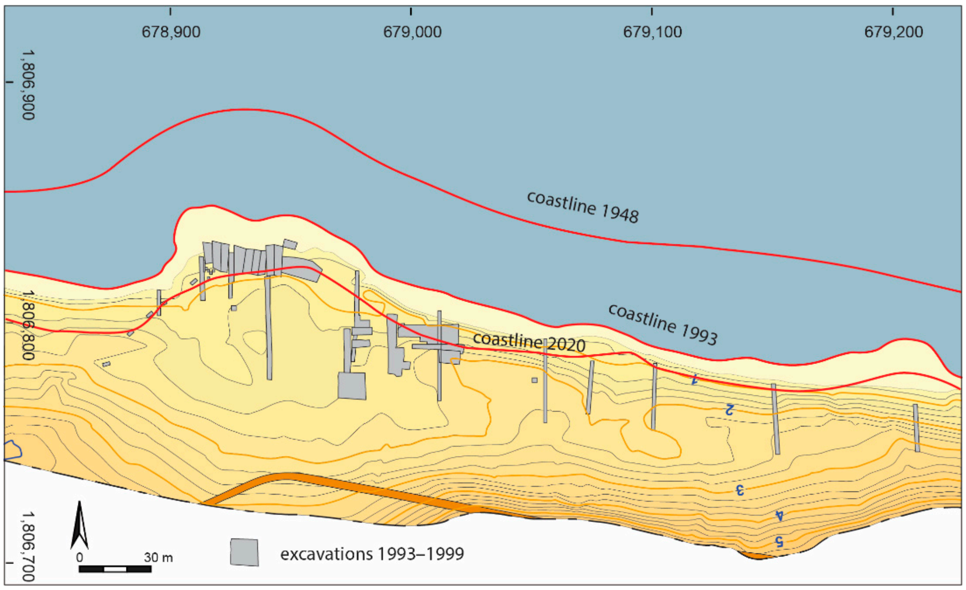

Figure 5. Retreat of the coastline recorded through topographical survey data at the archaeological site of Morel on Grande-Terre, Guadeloupe in 1993, and from aerial and satellite images made in 1948 and 2020. (Image created by Menno Hoogland).

Figure 6. (**a**) Archaeological deposits at the site of Morel laid bare after Hurricane Luis (1995); (**b**) excavation of pot stag; (**c**) salvage of burial in beach rock. (Photos by Corinne Hofman and Menno Hoogland).

A similar situation occurred at the site of Anse Lavoutte (cal. AD 1000–1500) in northeastern Saint Lucia. This well-known site, researched by the Bullens and the Saint Lucia Archaeological and Historical Society (SLAHS) in the 1960s and 70s [100], has been subject to heavy erosion due to a retreating coastline and slope wash, causing archaeological materials to be continuously exposed. In 2007, Hurricane Dean laid bare numerous burials and the area was left unprotected, with cars and horses trampling the remains on a daily basis. The construction of a hotel on the bay has accelerated the changes in the landscape. During rescue excavations at the site in collaboration with the Saint Lucia government and SLAHS in 2009, human remains and archaeological materials brought to the surface were salvaged [68,97,101]. A recent assessment of Anse Lavoutte, in the context of the area's development for construction, has again attested to severe damage to the site. However, despite its detrimental condition, it remains a key site of memory for the island(ers), and it is the opinion of the archaeologist who carried out the assessment, as of several Saint Lucian stakeholders, that this should be commemorated on the spot. Similar situations revealing the destructive nature of catastrophic events on archaeological sites, such as sea-level rise and coastal erosion, are reported throughout the Caribbean (e.g., [30,35,39,97,102–104]).

The geopolitical setting of the Caribbean, marked by its complex colonial history, has resulted in varied and sometimes insufficient political awareness, environmental policies for building, and enforcement of heritage legislation to protect coastal infrastructure [105,106]. There is an urgent need to strengthen and implement existing heritage legislation, develop monitoring programs, and develop viable coastal-management plans throughout the region to manage and prevent further loss of the rich archaeological record and to help provide safety for current coastal communities [68,97,107,108]. This calls on cultural managers to find ways to utilize available data from coastal-management studies as well as to map the locations of known sites and create relevant inventories, highlighting those that are particularly in danger based on specific coastal studies of vulnerable areas. The fragmented and complex colonial and current geopolitical histories of the Caribbean islands often make it difficult to raise local interest, to create and enforce heritage legislation, and for different agencies and bodies to work together effectively [19,97,107–109]. Notable exceptions include the French islands of Guadeloupe, Martinique, Saint Martin, and Saint-Barthélemy (Départements d'Outre-Mer), where the European Malta Treaty (Valetta Convention) provides the legal framework for preventative archaeology and its funding (see also [110]). The Dutch Caribbean islands of Saba, Sint Eustatius, Sint Maarten, Saba, Bonaire, Curacao, and Aruba now often work in the spirit of the Malta Treaty as well, although it is not implemented as effectively as in the French islands [109]. There are also interesting case studies emanating from various other SIDS or countries around the globe, which could provide useful guidance to the Caribbean (e.g., [111]).

Mitigation, Recovery, and Adaptation

Today, more and more studies present research on the intersection between cultural heritage and climate change, highlighting the absence of cultural heritage from global climate change adaptation and mitigation planning. In the Caribbean, this is often more pronounced, as heritage is often seen as expendable [108]. However, in this research, we propose that heritage can actually determine how people respond, prepare, mitigate, recover, and adapt to environmental changes [112] through utilizing local ecological knowledge systems. Considering heritage within climate change planning could have an important role to play in reducing vulnerability to the various natural and cultural processes prevalent in the region (see also [38,65]).

Between 2015 and 2017, we undertook a collaborative project with the government of Saint Kitts and community members to measure the impact of coastal erosion on the environment and livelihoods. On the Leeward side of the island, the villages are traditionally fishing villages with a rich archaeological record, such as the Indigenous settlements and petroglyphs at Carib Rock and Bloody River. Tourism is limited, mainly concentrated on Brimstone Hill. This area was chosen as a focus because stakeholders described the road leading from Challengers to Fig Tree as eroding into the sea [113], bringing the coastline villages precariously close to destruction. Together with local partners, we determined that it was important to create a baseline management system to help policy makers and officials plan actions and next steps. The baseline would include not only the actual state of the coastline, but would also capture perspectives on coastal erosion, as the intent was not only to help protect the archaeological heritage in the area but, above all, community livelihoods [19].

Due to the limited amount of data for the island of Saint Kitts, we used freely available satellite imagery and the Digital Shoreline Analysis System (DSAS) [84], a freely available ArcGIS plugin provided by the United States Geological Survey (USGS), to measure coastal erosion in the study area. First, we extracted shoreline vectors from the LANDSAT MSS, TM, ETM, and OLI-TIRS imagery for the years 1986, 1989, 1999, 2003, 2006, 2013, and 2015 (see Table 1). Given the high number of images with cloud coverage, creating a data set with regular time intervals proved impossible.

Table 1. Selected shoreline data, Saint Kitts.

Date	Landsat Scene ID	Landsat	Time
12 December 2015	LC80020482015010LGN00	Landsat 8, OLI_TIRS	14:32:11
16 August 2013	LC80020482013116LGN01	Landsat 8, OLI_TIRS	14:33:49
25 January 2006	LE70020482006025EDC00	Landsat 7, ETM	14:22:02
2 February 2003	LE70020482003129EDC00	Landsat 7, ETM	14:20:49
8 December 1999	LE70020481999342EDC00	Landsat 7, ETM	14:24:59
17 October 1989	LT50020481989274XXX09	Landsat 5, TM	13:57:46
15 March 1986	LM50020481986074AAA03	Landsat 5, MSS	13:58:10

As part of this effort, we built a twenty-year period of shoreline dates (1986 to 2015) to align with the possible historical impacts of the thriving fishing communities (1988), the construction of Port Zante, a new twenty-seven-acre cruise-ship marina located at Basseterre (1996), Hurricane George (1998), and the end of the sugar cane industry (2005) [113] (120). The year 2015 was selected as having the most recent cloud-free satellite image available at the time of study. After shoreline extraction, the normalized difference vegetation index (NDVI) of each image was calculated to separate water pixels from land pixels [114–116]. The net shoreline movement (NSM) and end point rate (EPR) were calculated. The NSM of the present case study is shown below (Figure 7). The NSM determines the overall movement as either accretion or erosion. The three highest NSMs for the aforementioned twenty-nine-year period were found to be in Village Group A (−75.13 m), Village Group D (−89.55 m), and Village Group E (−65.94 m).

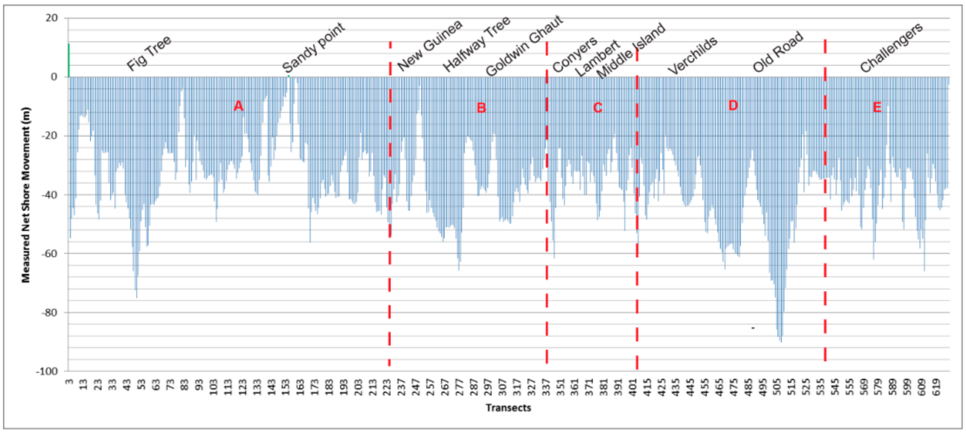

Figure 7. Net Shoreline Movement (2006–2015) of the coastal villages, Saint Kitts. Figure created with the assistance of Julijan A. M. Vermeer (ERC Synergy NEXUS1492) [19].

Figure 7 presents the area's NSM, which determines the overall movement (accretion or erosion) of a given area. The three highest NSMs during the twenty-nine-year period were found to be in areas of Village Group A (−75.13 m), Village Group D (−89.55 m), and Village Group E (−65.94 m). As these are all negative measures, this shows erosion has taken place.

The end point rate (EPR) for each transect is displayed graphically (see Figure 8). Dark blue represents the most negative rates of erosion, and green represents positive rates of accretion. Erosion is concentrated in Village Groups A, B, and D, indicated by means of high negative EPR values. Only one point of accretion is found in Village Group A, indicated by a positive EPR value. This positive value may be related to the position of the natural high and low tides on the island and the island's point. The mean calculated EPR for the villages of Sandy Point, Halfway Tree, Old Road, and Challengers have a rate of more than −3.0 m over the twenty-nine-year period (1986–2015). Such a high rate could present an even more serious public safety issue for daily life during extreme storm events. Based on these results, coastal erosion has occurred in this area for the given period.

What remains to be seen is how these results reflected in quantitative data can impact the livelihoods and culture of the villagers. A survey was administrated to 174 households in the case study area with the collaboration of local partner, Graeme Brown. Additionally, 30 in-depth interviews were done with individuals living in the case study area (see [19]). From the combined results of the survey and interviews, coastal erosion has led to adverse impacts on community livelihoods. Natural resources (e.g., sea grass beds, fish) have declined due to the shoreline erosion. Furthermore, social activities linked to the coast (e.g., bathing, swimming) have all been negatively affected, as there is less beach access so fewer people can go swimming together. Taken together with the political and economic changes on the island of Saint Kitts, the eroding shoreline becomes more serious. With declining fish catch, individuals are forced to look for other work that may not exist. Social activities that were once a part of daily life decline without a replacement. Building resilience in the face of coastline changes, in this case, does not mean reversing the coastline damage, per say, as that would be a continual battle. Rather, it means considering how communities can build resilience in the face of natural or human-made changes for the better [19].

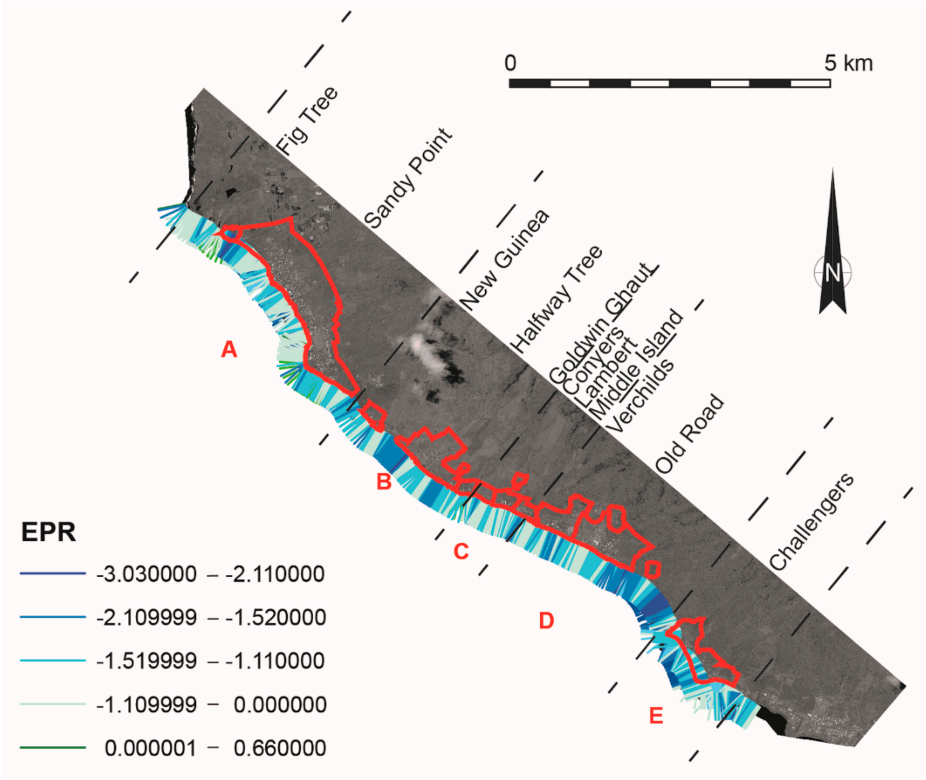

Figure 8. Visualized end point rate (2006–2015) of the coastal villages of Saint Kitts. Figure created with the assistance of Julijan A. M. Vermeer (ERC Synergy NEXUS1492) [19].

5. Traditional Knowledge in Response to Crisis and Building Resilience

The recent threats from Hurricane Maria in 2017 and the eruption of La Soufrière volcano in 2021 have had devastating effects on the livelihoods of the Kalinago and Garifuna on the islands of Dominica and Saint Vincent. Dominica and Saint Vincent are among the most hazard-prone islands of the region, and the Kalinago and Garifuna Indigenous people, living in the more remote, less accessible Atlantic side of both islands, are heavily affected by natural hazards time and time again. The Indigenous communities in the northeastern part of Saint Vincent, for example, have undergone several episodes of heavy flooding, extreme weather events, and volcanic eruptions over the past few decades [117]. As these communities often also face serious socio-economic problems and are mostly dependent on their natural environment, the climatic challenges are taking a toll on the well-being of the inhabitants of both islands, emphasizing the intricate link between fighting climate change and environmental justice [19,65].

Importantly, though, the Indigenous peoples of these islands, as well as Caribbean islanders in general, have been taking matters into their own hands and are prepared to monitor and adapt to climate change. For example, on some islands, local communities have found ways of creating and maintaining intra- and interisland sociality to safeguard their livelihood in skillful ways [62]. As part of their relationship with the environment, the Kalinago and Garifuna communities have an in-depth understanding of the cyclical changes brought about by natural hazards, particularly because their environment is a source of sustenance and livelihood. In addition, they have relied on their traditional knowledge practices in relation to, for example, housing construction, farming practices, and methods of adapting to environmental changes, critical to their survival. This awareness of or reliance on traditional knowledge systems has implications for food security, water management, and the understanding of changes in biodiversity. All of these factors have implications for resilience in small island states within a vast ocean. The Kalinago in Dominica, for example, have observed that both the devastation of Hurricane Maria (2017) and the COVID-19 pandemic (2020–2021) have created a strong consciousness within their communities in terms of the use of traditional knowledge. Young people are seeking answers in construction practices, traditional practices, sustainable agriculture, and traditional medicine, recognizing that national governments might not and do not have all the right answers when responding to changes in their environment (see also [118]).

Irvince Auguiste (former chief of the Kalinago Territory in Dominica) and Sardo Sutherland (Kalinago from Sandy Bay, Saint Vincent) have highlighted that the use of local raw materials is acknowledged as an integral part of maintaining sustainability and how communities adapt and build resilience. Traditional ways of constructing houses, for example setting up rafters and utilizing "jets" to anchor lumber, have proved beneficial in mitigating the impact of storms, and many modern houses now use this technique. This means that many traditional houses still stand throughout the Kalinago Territory, although there is an increased desire to own houses constructed with cement in keeping with modern times, as a symbol of status, and with changing cultural practices. However, it was noted that after Hurricane Maria, many traditional houses in general, not just those in the Kalinago Territory, had withstood the punishing winds of this strong hurricane. This is also known from other SIDS, for example in the Pacific islands, where traditional houses (e.g., the Samoan *fale*), which are still used today by many people, are more resilient to high winds and storms than modern concrete structures (e.g., [119]). In 2016, the Kalinago and Garifuna of Saint Vincent participated in the experimental reconstruction of the Argyle village site in Saint Vincent (Figure 9). The village was built using information gleaned from the excavation of an early colonial Kalinago site by a team from Leiden University in collaboration with the Saint Vincent and the Grenadines National Trust, the Ministry of Culture, and the International Argyle Airport Development Company Ltd. [120,121]. The experimental reconstruction and the use of building materials were based on excavation data, ethnohistoric accounts from the seventeenth century, and the traditional knowledge of the Kalinago and Garifuna. Despite the fact that the constructions have not been maintained since, and that cows have eaten and impacted the roofs, these houses all have endured several storms and ashfall from the recent volcanic eruption.

Knowledge regarding the environment is handed down orally, and specific information may be passed within or between families based on the activities practiced. This is often the case with those who fish, farm, or construct: members of these descendant communities would speak of these knowledge bases passed down by elders. Carpenters, for example, would construct residential structures in a specific way so as to deal with strong hurricane winds, and homeowners would prepare every June and July by adding extra support to the outsides of their houses and storing food from the harvest. Meat and fish would be dried in large quantities in preparation for periods when agricultural fields might be damaged and food temporarily unavailable.

As environmental changes were communicated throughout the generations, elders stressed an awareness of the height and movement of the clouds, and specific attention was paid to certain trees to forecast whether winds would be strong and how to adapt accordingly. The phases of the moon and other environmental changes would also signal potential periods of drought that would require preparation to manage properly.

Over several centuries, the Kalinago community of Saint Vincent, most recently impacted by the volcanic eruptions of La Soufrière, utilized the natural environment of the island's mountains as a safe space where its members could seek shelter in the event of storms or eruptions. Their "early warning systems" would be noted through environmental changes, and so communities paid close attention to the behavior of animals within the context of their natural environment. If animals were fleeing from the mountains, communities would do the same, as this meant a volcanic eruption, and animals fleeing from the sea signaled changes at sea that required actions to ensure safety. This is well-documented globally, where Indigenous knowledge is key to the well-being of communities before, during, and after natural disasters [122–124]. Further research, which could prove useful to the wider Vincentian population, would involve observing the specific local knowledge that could be integrated into the present scientific observation of volcanoes in order to develop specific mitigation and adaptation strategies. Changes noted with regard to certain plants are also used as key environmental monitoring indicators, such as the blooming of the small wild onion for hurricanes and silk cotton seeds being linked to particularly stormy conditions.

Figure 9. Experimental construction of a Kalinago roundhouse at Argyle, Saint Vincent in 2016, based on archaeological data from excavations at the site in 2009 and 2010; (**a**) configuration of an oval house (2016); (**b**) roof construction (2016); (**c**) finished oval house (2016); (**d**) overview of Argyle experimental village (2017); (**e**) decay of a round-house in 2019 (photos (**a**–**e**) by Menno Hoogland); (**f**) decay of a round-house in 2021 (photo by Augustine Sutherland).

The Kalinago have observed coastal change taking place, and even the disappearance of portions of their villages into the sea. In these cases, settlements have been relocated and the stories of these places and what impacted them have been ingrained in local knowledge. These actions have helped the Kalinago to utilize other adaptive practices to ensure that they had enough clean water, primarily through the use and burial of clay pots as catchments. Through traditional knowledge passed down over the centuries, the Kalinago are also aware of safe places to go and obtain fresh water, even in the midst of an eruption. In addition, while this is practiced less and less, the Kalinago of Saint Vincent utilize a cone-shaped roof in house construction to avoid the accumulation of debris that might affect the structure's integrity. Overall, both communities acknowledge that certain intangible elements are key to their sustainability and resilience, evidenced by community kinship ties that promote providing food for each other and rebuilding after a disaster through communal service.

6. Conclusions

What used to be referred to as future climate change impacts have now become *reality* in the Caribbean and other island states, with both long-term historical and short-term predictive models of climate change suggesting continued sea-level rise, an increase in temperatures, severe weather fluctuations, unpredictable precipitation patterns, stronger and more frequent tropical cyclones, and the threat of other natural hazards. The recent hurricane seasons offer a stark reminder of this, and scientists anticipate that it will only get worse.

As highlighted in this paper, the Caribbean's coastal areas are rich in heritage and livelihoods, with archaeological sites and a significant portion of the islands' infrastructure. Climate change will clearly impact these islands, as it will other SIDS on a global scale. However, we have aimed to show that multiple scenarios can exist, and one of resilience is possible if action is taken to include island perspectives, rather than only measuring impacts.

A long-term perspective on social adaptation to climate challenges has proven beneficial in showing how peoples over time have developed sustainable strategies to these challenges, especially in the SIDS, where current viewpoints on climate change present only one version of how impacts will prove daunting to local communities. The archaeological case studies have shown that reorganization of the settlement, building hurricane-proof shelters, and relocating villages accordingly, all present alternative options for social adaptability [37,42,46]. Additionally, past records prove that the extensive circuits of mobility and exchange that existed and still exist between communities in the Lesser Antilles, like in other island environments, play(ed) a major role in social cohesion and strengthening these social ties to help ensure survivability, and to effectively respond to catastrophes that may occur [43].

The case study of Saint Kitts has shown how the domain of environmental management research leads to beneficial results for archaeology, heritage, and the contemporary communities. Creating a shoreline database from past to present has enabled predictions to be made about future shoreline change. The ease of access to and use of the tools provided within this formulated model provide an excellent foundation from which to build coastal-management programs.

To overcome simplistic viewpoints of a climate doomsday that consider only disappearance, local island community perspectives are of the utmost importance if we are to adapt and mitigate climate change. Such work and research are valuable to climate change adaptation if we aim to overcome the misrepresentation of small-island communities as vulnerable or passive in the face of climate change. The role of Indigenous and islander worldviews in climate change mitigation and adaptation is still underutilized in the Caribbean, yet it is evident that there is a wealth of knowledge in how peoples have responded to climate and other environmental changes, which can be applied today.

Indigenous, local, and/or coastal communities, as users and observers of the natural environment over decades or centuries, are in a unique position to provide observational and monitoring data, which is valuable for land-use planning and future development. This information is critical not only for planning and supporting decision-making, but also for assisting contemporary communities to understand what certain coastal changes mean and what actions need to be taken, particularly within the context of an increasing rate of climate change and associated impacts [19,59]. Collaborative projects in which research interests are combined with preventative incentives, and where stakeholders are involved on an equal basis and jointly formulate the research questions, have shown to have been a success on several islands discussed here.

Further multidisciplinary and multi-stakeholder approaches to protecting coastal archeological sites and current coastal villages with heavy emphasis on the involvement of local communities is the proposed way to go forward [59,97,125]. The restoration of ecosystems such as coastal dunes and mangroves, coupled with suitable nature-based solutions, will become important components of protecting the coastal areas. Although archaeologists in the Caribbean have utilized protective measures such as sandbags to attempt some localized protection, rescue archaeology has remained the most utilized medium for preventing this irreversible loss [39,97]. Despite these short-term strategies and rescue archaeology, we nevertheless continue to lose much of the archaeological record, and so strategies that address medium- and long-term mitigation are needed. These can be addressed by ongoing monitoring programs and citizen-science initiatives involving local communities and their valuable knowledge systems, which have often been sidelined in the past. These are areas that are underutilized and have not caught on sufficiently in the region, but hold significant promise for the future, and so further research in this area would be an important mitigation action.

One strategy for the future is the continued integration of culture in national disaster and climate change adaptation planning (in line with the Sustainable Development Goals, SDG 13). This is an area that has also experienced minimal growth in the past years, but a new initiative being supported by UNESCO in the Caribbean is working with some countries to build resilience in the various components of the culture section, and helping countries to work towards developing implementable actions for archaeological and built heritage. These actions should also guide the development of sector strategies in addressing present and future loss, in bringing awareness to this loss, and in working with partners such as those responsible for coastal planning.

Author Contributions: Conceptualization, C.L.H., C.E.S. and A.R.; methodology, C.L.H., C.E.S. and A.R.; software, C.E.S.; formal analysis, C.L.H. and C.E.S.; investigation, C.L.H., C.E.S. and A.R.; data curation, C.L.H.; writing—original draft preparation, C.L.H., C.E.S., A.R., I.N.A. and A.S.; writing—review and editing, C.L.H. and M.L.P.H.; visualization, C.L.H., C.E.S., M.L.P.H., I.N.A. and A.S.; supervision, C.L.H.; project administration, C.L.H.; funding acquisition, C.L.H. All authors have read and agreed to the published version of the manuscript.

Funding: The research leading to the results presented in this paper has received funding from the European Research Council for the project *Nexus 1492: New World Encounters in a Globalizing World* (ERC grant no. 319209), and the NWO project SPINOZA/CaribTRAILS.

Informed Consent Statement: Not applicable.

Data Availability Statement: Original paleoclimatic data for the site of Anse à la Gourde are available in Beets et al. 2006, *Climate and pre-Columbian settlement at Anse à la Gourde, Guadeloupe, Northeastern Caribbean*, and original data on landscape change for the site of Anse Trabaud are available in Hofman et al. 2021, *Mangrove Archives: Unravelling human-environment interactions from deeply buried deposits at the site of Anse Trabaud, Martinique, Lesser Antilles (1290–780 cal BP)*. Original shoreline data for Saint Kitts are available in Stancioff 2018, *Landscape, Land-Change & Well-Being in the Lesser Antilles: Case Studies from the Coastal Villages of St. Kitts and the Kalinago Territory, Dominica*. Original data on traditional knowledge practices are contained within the article.

Acknowledgments: A first version of part of this paper was presented at the European Association of Archaeologists (EAA) meetings in Maastricht, the Netherlands, in 2017, in the symposium Archaeology in a Changing Climate (session 297). The Saint Kitts case study was part of the PhD research of Eloise Stancioff in the context of the ERC Synergy Nexus 1492 project. The research has also been supported by the NWO project 'Island(er)s at the Helm: Co-creating sustainable and inclusive solutions for social adaptation to climate challenges in the (Dutch) Caribbean'. The authors especially acknowledge the institutions and communities on the islands for their participation, knowledge exchange, and collaboration. We thank Julijan Vermeer, Marvin Pierre, Raydon May, and Danroy Thomas for their figure and photo contributions. David Tonks, Arie Boomert, Kristen de Joseph, and Emma de Mooij are thanked for English-language editing and editorial help. Finally, the authors acknowledge the editors of this special volume and the reviewers for their useful comments.

Conflicts of Interest: The authors declare no conflict of interest.

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