FOUR

Fail to Prepare then Prepare to Fail: Rethinking Threat Vulnerability and Mitigation in the Precolumbian Caribbean

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INTRODUCTION AND KEY CHALLENGES

The islands of the Caribbean are a particularly interesting geographical region to examine the dynamic relationship between past human communities and sudden environmental change. This chapter examines how past peoples, living on the islands in the Caribbean Sea, were vulnerable to a number of environmental threats. The focus of this chapter is the impact of floods, droughts, and wind shear created by relative sea level rise, precipitation change, and hurricane activity. These hazards were identified as particularly relevant to current debates, given the predicted increase in the risk of such hazards in the near future (Caribbean Community Climate Change Centre 2009; Intergovernmental Panel on Climate Change 2007). The potential Precolumbian mitigation of these hazards through the development of household architecture, settlement location, food procurement strategies, and networks of community interaction is explored in this chapter; and the relative success in mitigating impact and avoiding disaster is considered. This chapter reviews different scales of analysis, from the global, regional, national, and local, to extract key themes for comparative discussion. These research themes are then examined in more detail using a case study area in north-central Cuba where the author has conducted interdisciplinary collaborative research with Cuban and international colleagues since 2002.

The absence of other causes of sudden environmental change in this chapter—namely earthquakes, volcanoes, and the impacts of El Niño/La Niña—should not be taken as an indication of their relative lack of importance. Rather, these major causes of sudden environmental change would not be given justice in this short chapter; they require, and receive, their own standalone discussion elsewhere (Handoh et al. 2006; Scheffers et al. 2009). However, the key discussions in this chapter that focus on mitigation and resilience to floods, droughts, and wind shear by Precolumbian populations have a direct relevance to all discussions of human engagement with sudden environmental change in the region. In fact, different causes behind sudden environmental change were less important for past human communities than was the similarity in their impacts on the local environment.

Therefore examples of past human engagement with the consequences of sudden environmental change often have relevance beyond their specific source of origin and geographical context. This is not because universal rules can be identified in human mitigation and transferred between different geographical regions and time periods; rather, each case study examined in isolation provides one way in which the variables of climate, environment, and human experience have played out in the past. By increasing the number of "case studies" or "experiments" (Nelson et al. this volume) and looking at the relationship between cause and effect, decisions and decision making, planning and chance, we can improve our understanding of these relationships within a global ecodynamics framework that helps us to better understand hazards, mitigate impacts, and avoid disasters. These wider lessons suggest that this Precolumbian "case study" is relevant for modern-day populations of the Caribbean, and the combination of case studies presented in this book has important lessons for the wider populations of the world that currently face sudden environmental change (Alley et al. 2003: 2005; Lenton et al. 2008).

The terms *vulnerability, hazard, impact*, and *resilience* are increasingly finding their way into academic and policy literature, although their meanings can often be appropriated differently by different disciplines. The term *vulnerability* is used in this chapter to describe exposure to hazards when the *hazard* is a potential threat to a past community that has not yet been manifested. *Impacts* are the consequences of a hazard; they can be both direct and indirect in nature and are relative as a result of potential mitigation strategies that can reduce their impact through intentional or unintentional preparation. *Resilience* is a more complex term to use given the extensive discussion of its role in ecological and social theory; however, in this chapter it is used in its broadest sense to refer to the relative ability and mechanisms with which past communities lived though the impacts of sudden environmental change while maintaining their core lifeways (Redman and Kinzig 2003).

ENVIRONMENTAL AND CLIMATIC CONTEXT

The islands of the Caribbean are an interesting mixture of geologically diverse landforms dotted throughout the Caribbean Sea, bounded by the continental landmasses of North and South America. General trends of smaller coral limestone and volcanic islands in the southern Lesser Antilles and larger, geologically older islands in the northern Greater Antilles are often made, but in reality each island has a very different personality created by its local environment. There is evidence for a diverse range of flora and fauna in the Caribbean islands prior to human colonization, with pre-human residents, such as the giant sloth, living in caves surrounded by temperate forests during the terminal Pleistocene (Steadman et al. 2005). The environments of the different Caribbean islands were changed following the arrival of humans, whose activities and introduction of new species would have a well-discussed and profound impact on the environment (Goudie 2006; Newsom and Wing 2004; Siegel et al. 2005).

The islands of the Caribbean are particularly vulnerable to the dangers of sudden environmental change because of their location within the earth's climate system. Caribbean climate is controlled to a large, though still debated, extent by ocean currents driven by thermohaline systems in the North Atlantic (Lowe and Walker 1997: 362). The Caribbean is a key driver in this system, and consideration of sudden environmental change in the region needs to be contextualized within a global oceanic context. The Caribbean Sea generates movement in ocean currents, as well as climate patterns in the Northern Hemisphere, through the creation of warm salty water in the tropical shallow sea that drives warm energy northward up into the North Atlantic. This movement creates an extremely dynamic flow of ocean currents in and around the Caribbean that is an integral part of the wider Atlantic climatic system, which means the islands themselves are particularly vulnerable to changes and variability within this system (Clarke et al. 2003: 923; Overpeck et al. 1989: 556).

The well-established threat of hurricanes to the Caribbean islands exemplifies the importance of the oceanic context of the Caribbean as climatic fronts from the Atlantic and West Africa combine to generate deep low-pressure systems that are pushed westward toward the Caribbean (Donnelly and Woodruff 2007; Hetzinger et al. 2008; Saunders and Lea 2008). Current paleotempestological research examines the ways changes in past climate systems affected the frequency and intensity of prehistoric hurricanes in the Caribbean (McCloskey and Keller 2009). These same Atlantic climate systems also control precipitation on the Caribbean islands, with the movement of the intertropical convergence zone regularly changing the amount of water that falls on the Caribbean (Haug et al. 2001). So when we look at the impacts of sudden environmental change on the Caribbean, we need to consider intra-hemispheric causality and the relative vulnerability of these islands at an important

interface in the global climate system. Therefore it is often necessary and informative to look to non-local data sets to provide paleoclimatic data and proxy evidence for sudden environmental change in the Caribbean (Black et al. 2007; Cronin et al. 2003; Gischler et al. 2008). More regionally specific research on climatic change in the Caribbean can facilitate an improved understanding of the relationship between global and regional climate change and local environmental hazards. Fortunately, climate change in the Atlantic is the focus of urgent and exhaustive research that can be used to explore the scale and timing of impacts in the Caribbean.

ARCHAEOLOGICAL CONTEXT

The Caribbean is an intriguing archaeological region, not least because many of the fundamental questions of Precolumbian colonization and societal development remain embroiled in lively debate. However, painting a broad picture, the islands were colonized at some point after 76,000 BP, with early sites first appearing in Cuba and Hispaniola. These earliest "lithic" societies developed hunter-forager lifestyles in the Greater Antilles until around 4000 BP, when more complex lithic and shell artifacts and the more extensive colonization of other islands led to the "archaic" phase of hunters, fishers, and foragers being defined. Ceramics were first found in the Caribbean in about 2500 BP; during this time period incipient agriculture was developed before larger-scale communities reliant on agriculture emerged sometime around AD 600. Interestingly, "archaic" peoples with these mobile and flexible hunter-forager traditions may have continued up to contact and lived often in close proximity to agriculturalist societies with hierarchical social systems. From around AD 900 to contact, we see the development of more hierarchical societies and extensive networks of inter-island interaction that thrived up until the contact period, during which a population of up to 1 million indigenous peoples was estimated to have been living in the Caribbean (Curet 2005).

This broad overview of the diverse islands in the Caribbean is useful to provide a general framework, but it highlights the major challenge of divergent resolutions at which climatic, environmental, and archaeological data operate in this region. It is clear that the regional perspective is not an effective scale at which to examine archaeological evidence for the human experience of sudden environmental change. It is essential to use site-specific examples that combine local environmental and archaeological data that are informed from a regional perspective but grounded with high-resolution comparative data. Therefore this chapter will attempt to correlate different spatial and temporal scales of cause and effect linking global climatic instability to regional environmental context to local sudden environmental change before considering the relative impact on past human communities at individual Precolumbian settlement

sites.

Another important challenge to this research is the definition and identification of *change*. This brief introduction has highlighted that the Caribbean is perpetually in climatic, environmental, and social flux; therefore "change" is relative to the scale at which the parameters of an assumed equilibrium are defined. However, the time-depth of archaeology provides an excellent framework with which to look at the ways cyclical events operating on inter-annual, inter-decadal, inter-centennial, and inter-millennial timescales can be examined using the human lifetime as the fundamental building block with which to construct a multi-temporal, as well as multi-spatial, structural framework to better understand change (Adam 1994; Ingold 1993). With this framework in mind, the Caribbean provides an interesting backdrop to examine how past human communities lived for thousands of years in a region subjected to the multi-temporal impacts of sudden environmental change.

KEY HAZARDS AND PAST IMPACTS

The three main creators of hazards and subsequent sudden environmental change in the Precolumbian Caribbean focused on in this chapter are relative sea level rise, precipitation change, and hurricane activity. These climate-dependent conditions create key hazards that include floods, droughts, and wind shear; but the hazard to past communities needs to be considered in a wider context in which the potential threat of the hazard is relative and dependent on issues of cyclicity, variability, and predictability. This wider consideration of the hazard requires that the human perspective be taken into account, where hazards are culturally contingent on ecological knowledge (Crate 2008). In many ways, to contextualize the hazard within a culturally, socially, and phenomenologically specific setting is in itself a means of better understanding the reality of vulnerability, impact, and resilience.

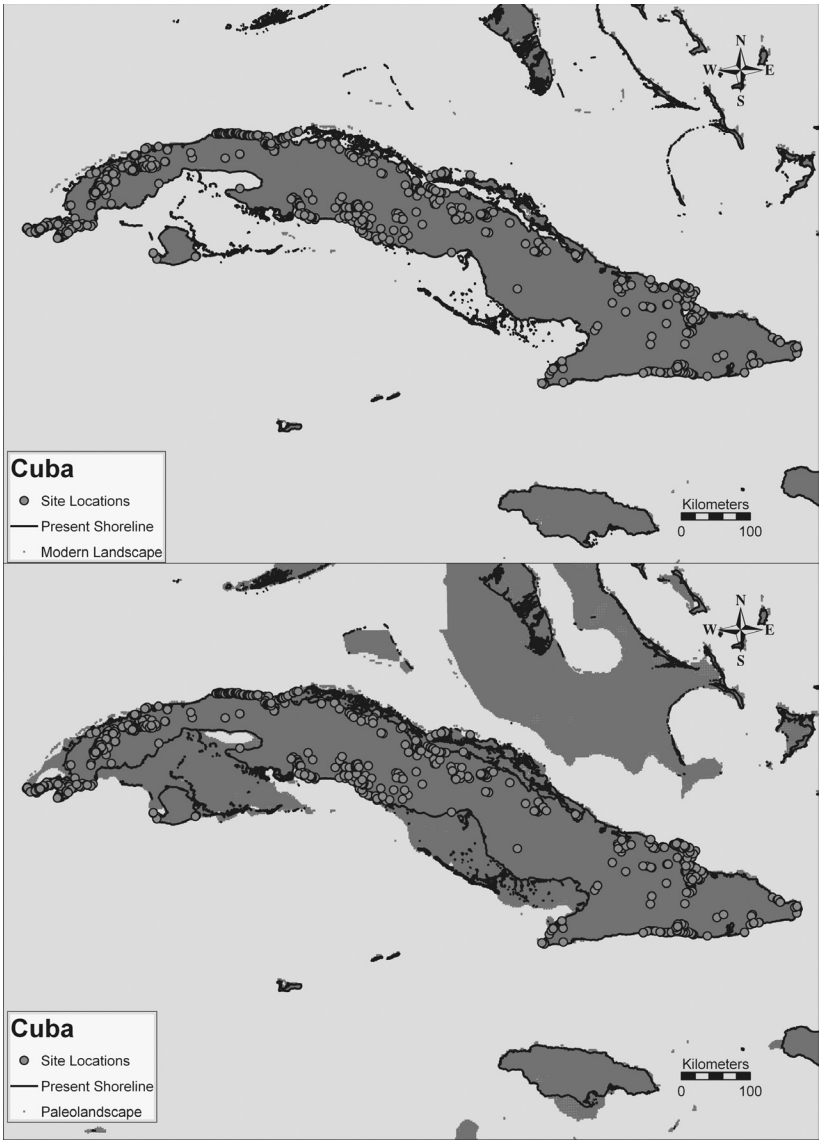
Relative Sea Level Rise

Relative sea level rise can create profound vulnerabilities for island communities. The Caribbean has witnessed dramatic sea level change and is one of the few areas in the world that has experienced regionally increasing relative sea levels throughout the period of human occupation. This is the case because early Holocene eustatic sea level rises were replaced by mid- to Late Holocene isostatic relative sea level rise (Milne, Long, and Bassett 2004: 1183; Toscano and Macintyre 2003). Inevitably, local tectonic activity, coastal sedimentation, and erosion processes affect this picture and highlight the importance of micro-scale case studies to complement the macro-scale regional picture (Cooper and Peros 2010; Peros, Reinhardt, and Davis 2007; Ramcharan 2004).

Since the established colonization of the Caribbean, there has been at least a 5-m rise in regional relative sea levels, which has radically changed the island-scape of the Caribbean (Milne, Long, and Bassett 2004; Toscano and Macintyre 2003). The impacts of relative sea level rise on Precolumbian populations have been raised previously as an important issue for discussion (Keegan 1995; Tabio 1995). However, it is important to consider how the impacts of relative sea level rise actually manifest themselves for coastal communities. Modelers often describe long-term regional figures of relative sea level rise as 1 mm per year over an extended period. However, this is based on mean figures often averaged over thousands of years, and the reality of relative sea level rise for people living in the region is very different. In fact, the impact of relative sea level rise is a punctuated equilibrium in which abrupt coastal flooding events are instigated by catalysts such as hurricane storm surge.

These periodic flooding events are caused by long-term processes of relative sea level rise, but they create very sudden impacts for coastal communities, as paleocoastlines are breached and new coastlines formed (Cooper and Boothroyd 2011). In Cuba, 27 percent of the island was flooded by rising relative sea levels between initial colonization around 6000 BP and the arrival of Columbus in AD 1492 (figure 4.1). Detailed bathymetric models of different areas of the coastline, combined with local relative sea level change data modeled using geomorphological and archaeobotanical data, indicate tipping points at which paleocoastlines are breached and inland areas flooded. These tipping points represent episodes of sudden environmental change in which both the flooding event and subsequent impacts on coastal ecology would have been profound. The dating of such events enables the correlation with archaeological context. In the case study area in northern Cuba we see some interesting patterns of changing settlement location and food procurement strategy during this period of relative sea level rise impacts that can provide indications of Precolumbian mitigation strategies discussed further later in this chapter. Therefore the vulnerabilities created by relative sea level rise in the Caribbean exposed Precolumbian populations to important hazards. Coastal flooding and radical changes in marine and coastal ecology were important for Precolumbian populations, who often lived in coastal settlements with a marine-focused diet. The impact of long-term relative sea level rise needs to be considered in the context of short-term flooding events that occurred on perhaps inter-centennial and inter-millennial timescales. Flooding events created by increasing relative sea levels had a key impact on regional island-scapes and local coastlines through the reaching of tipping points that caused coastal flooding and sudden local environmental change.

Precipitation



4.1. *Comparative map of Cuba showing 27 percent loss of landmass as a result of the 5-m rise in relative sea levels from 6000 BP to present. Map by Jago Cooper.*

Precipitation change has been argued to be an important factor in creating sudden environmental change, and there are many worldwide discussions of the impacts on past human populations (Gill et al. 2007). Unfortunately, the Caribbean lacks the detailed precipitation records found in other regions,

but understanding its climatic context enables the exposure and discussion of human vulnerability to precipitation variation. Much work still needs to be done to reconstruct and understand precipitation change effectively (Broecker 2009), but it is clear that changes in the Atlantic climate system affect precipitation rates in the Caribbean. Fine-grained reconstructions of precipitation change in the Caribbean require additional research; but existing data indicate fluctuating regional precipitation rates over time, with a drier period beginning 10,500 BP, a wetter period beginning 7000 BP, and an intense dryer period beginning 3200 BP (Higuera-Gundy et al. 1999: 159; Hodell et al. 1991; Nyberg et al. 2001).

These broad chronologies for precipitation variation based on lake cores and archaeobotanical evidence are too limited to provide a comprehensive regional picture, but the evidence does suggest the potential importance of such changes on the local environments of the islands of the Caribbean (Siegel et al. 2001). However, an understanding of Caribbean communities' vulnerability to precipitation variability requires a more nuanced understanding of the different spatial and temporal scales at which hazards can have an impact. Paleoprecipitation variation in the Caribbean includes low-frequency regional impacts on an inter-millennial scale that would have substantially changed the terrestrial ecology of the region, but at the same time there would have been cycles of high-frequency, inter-annual impacts on local environments that would have had a more direct and noticeable impact for human communities (Nyberg et al. 2001). Floods and droughts are often assumed to be the main hazards generated by precipitation change, but perhaps we should also consider the hazard of instability or unpredictability as a key threat for Precolumbian communities. The high variability of the frequency, seasonality, and reliability of precipitation created by the exposure to unstable Atlantic weather systems created dramatic regional and local climatic instability and variable precipitation rates (Haug et al. 2001). This hazard of instability has been well established in previous discussions, particularly in respect to the origins of agriculture (Bettinger, Richerson, and Boyd 2009; Rosen in press), and this hazard appears to have been important for the peoples of the Caribbean. While broad regional trends in precipitation variation from lake cores indicate periods of drier and wetter conditions, it is important to consider the microscale of shorter-term and more locally specific variation. These smaller-scale impacts therefore have to be examined locally using relevant paleoclimatic data on a case-by-case basis.

Hurricanes

Hurricanes represent some of the most dramatic and well-publicized hazards Caribbean populations face. The production of intense low pressures in

4.2. *Photographs showing damage caused by Hurricane Ike in 2008, taken by the author and colleagues.* Clockwise from bottom-left*: two different modern house designs destroyed by the hurricane, unusable broken house tiles collected for disposal following the hurricane, and one Precolumbian house from the "Taìno" heritage village of El Chorro de Maìta being rebuilt six days after the hurricane. Photos by (*clockwise from bottom-left*) Roberto Valcárcel Rojas, Roberto Valcárel Rojas, and Jago Sheets.*

the mid-Atlantic creates these seasonal tropical cyclones that move westward into the Caribbean. The hurricane represents one of the most frequent high-impact hazards in the Caribbean with annual regional return rates. It is difficult to appreciate the impact of such wind speeds without having witnessed the effects, but the hurricane creates some of the most profound sudden environmental changes in the Caribbean (figure 4.2). The spatial nature of hurricane impacts can often be fairly local, with wind shear damage limited to perhaps a swath 5–10 km in width. The temporality of the hurricane impacts—namely wind shear, coastal storm surges, and pluvial flooding—has both an immediate as well as a mid- to long-term impact on the local environment. This variation in the temporal scale of impact is important when considering mitigation of these effects by human communities. In many ways the nature of the hurricane impact is defined by the speed and cost at which human communities can "recover."

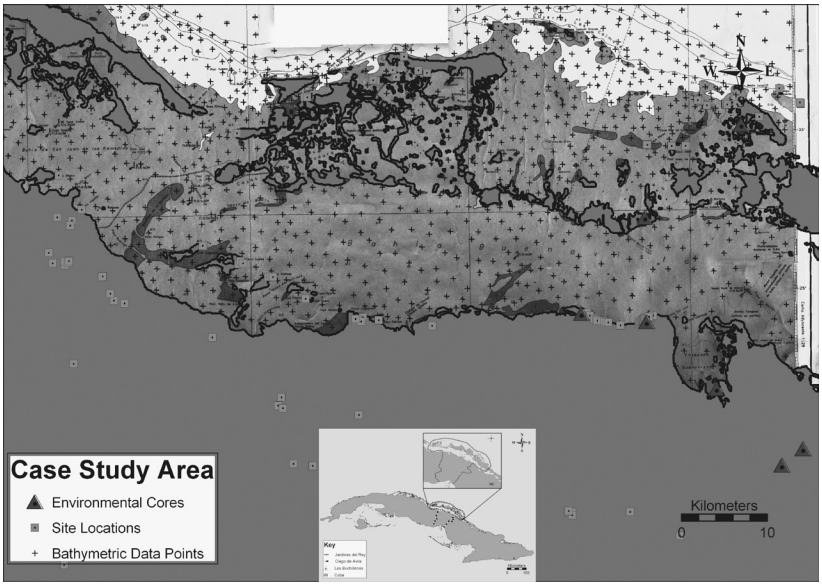
The first written record of extreme weather events appears in Columbus's diary of his first voyage (Dunn and Kelley 1989), the start of a long historical record of hurricane landfalls in the Caribbean. Evidence for prehistoric hur-

ricane activity in the Caribbean is available from geomorphological studies of environmental cores and also the use of proxy evidence, such as coral isotope data, for changing North Atlantic sea surface temperatures that are argued to affect the frequency and intensity of hurricane activity (Beck et al. 1997: 705; Donnelly and Woodruff 2007; Elsner 2007; McCloskey and Keller 2009; Nyberg et al. 2007). These proxy data for hurricane activity are an interesting avenue for future research, but existing data show the presence and impacts of hurricanes in the Precolumbian Caribbean (Hetzinger et al. 2008). This discussion highlights that the high-frequency local impact of hurricanes should not only focus on the "event" itself but should also consider the medium- to long-term "impacts" in which reconstruction is part of the impact and essential to the development of any mitigation strategy.

HUMAN MITIGATION AND RESILIENCE

Ethno-historical records from the contact period Caribbean suggest that Precolumbian populations had complex belief systems in which weather and the process of environmental change were well established (Oviedo 1959 [1526]). Different deities associated with different aspects of precipitation and the stages of hurricanes—Boinayel, Coatrisque, and Guabancex—show an understanding and communication of meteorological knowledge through an active symbology alive within the human community (Drewett 2003; Pané 1999 [1498]). It is intriguing to consider the role such oral histories might have played in enabling intergenerational knowledge transfer for hazards that might have had inter-decadal and inter-centennial timescales, such as different coastal flooding events on different islands. However, from an archaeological perspective this nuance of ecological understanding and knowledge transfer is more challenging to identify. This raises the important point that it is not the aim of this chapter to identify cause and effect between sudden environmental change and socio-behavioral change. Rather, this chapter has a wider aim: to examine through archaeology how Precolumbian populations lived through periods of sudden environmental change and whether their now extinct lifeways have useful lessons for mitigating similar impacts faced by populations living in the Caribbean today.

Therefore, while the causality of human behavioral change is interesting, this overview of human mitigation in the face of sudden environmental change focuses instead on whether household architecture, settlement location, food procurement strategies, and interaction networks—as understood through archaeological analysis—provided resilience to the established dangers of sudden environmental change.



4.3. *Map of the case study area in north-central Cuba where fieldwork has been carried out since 2003. Map by Jago Cooper.*

Household Architecture

Archaeological excavations of Precolumbian house structures in the Caribbean reveal the consistent use of wooden poled structures, predominantly circular or oval and ranging between 6 and 9 m in diameter (Curet 1992; Samson 2010; Schinkel 1992). Historically, the wood's poor preservation has limited the degree to which the design of these structures can be examined and fully understood. However, the recent discovery and excavation of well-preserved house structures in waterlogged conditions at the site of Los Buchillones (Valcárcel Rojas et al. 2006) has enabled a better understanding of Precolumbian household architecture and the potential resilience of these forms to known hazards.

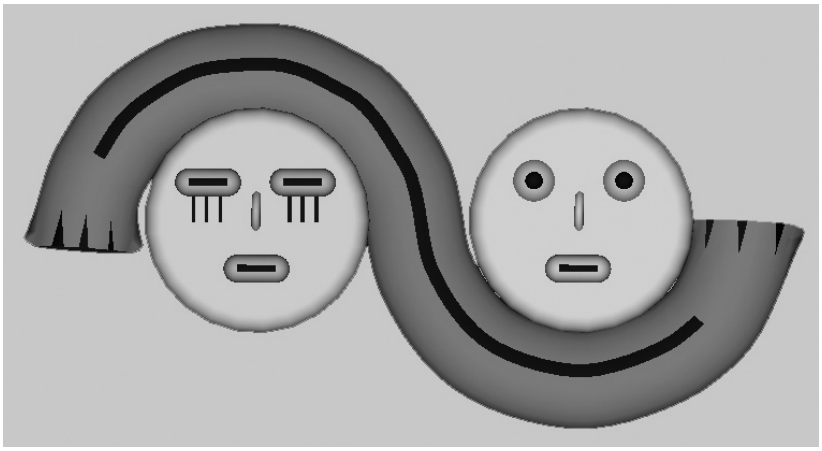
Los Buchillones is a late Precolumbian settlement site dating AD 1250 to contact. The site is located within the case study area in north-central Cuba (figure 4.3). The house structures at Los Buchillones use two concentric rings of substantive mahogany (*Swietenia mahagoni*) posts, with diameters up to 33 cm, to form the structural framework for the house. These posts are deeply embedded up to 1.7 m into the ground. This hardwood permanent structural framework was then dressed with a lighter-weight superstructure including a slender rafter, stringer, and thatched roof. It has been hypothesized that these structures used suspended woven matted floors over lightweight timber struts,

but at this stage the floors have not been excavated. However, local paleoenvironmental cores at the site indicate that these structures were located in waterlogged conditions during their occupation (Peros, Graham, and Davis 2006), so it seems likely that the floors were suspended between the structural posts.

Modern-day residents in the two neighboring coastal villages of Punta Alegre and Maximo Gomez, 2 km west and 4 km east of Los Buchillones, respectively, predominantly live in concrete structures and initially considered these Precolumbian structures to be *debil* (weak) against the hazards of wind shear, coastal storm surge, and pluvial flooding (Nelson Torna, personal communication). However, this categorization of weakness or vulnerability requires careful consideration in light of the earlier discussion of past impacts. Radiocarbon dating of different elements of the house structures and the artifact assemblages contained within them shows that the structural posts have remained in situ and in use for hundreds of years (Cooper 2010a; Cooper and Thomas in press). Excavations showed that these posts had been cut for immediate use and had not been removed from their original location or reused (Valcárcel Rojas et al. 2006). However, radiocarbon dates suggest that these structural posts appeared to have been "re-dressed" with the lighter-weight superstructures over time as roofs were replaced. This finding raises the interesting question of how weakness or vulnerability is judged in the face of specific hazards. Initially, the lightweight wooden and thatch superstructure would have been a more vulnerable place to be than a concrete structure during the high wind speeds of a hurricane, but this focus on the short-term "event" of the hazard ignores the medium- to longer-term impacts of post-hazard reconstruction that are often more destructive for Caribbean communities. Therefore, if we take the ethno-historical sources at face value and argue that Precolumbian communities had management strategies in place to identify oncoming hurricanes, alert the community, and retreat to nearby caves for shelter during a hurricane's short-term impact, then their Precolumbian house structures were extremely resilient to the mid- to long-term "impacts" because they could be rebuilt within days of a hurricane using locally available and easily sourced materials (see figure 4.2). Therefore the potential resilience of these house structures needs to be considered in light of the different timescales at which the impacts of hazards occurred.

Settlement Location

The majority of modern-day settlements in the Caribbean were located and founded by post-contact communities, predominantly using European settlement planning traditions. Modeling the vulnerability of different settlement locations to wind shear and flooding at a regional scale is problematic because the parameters of local topography and environment are crucial fac-



4.4. *Logo for the Save the Children–sponsored resettlement initiative in Holguin inspired by the iconographic representation of Guabancex, the Precolumbian deity associated with the hurricane's destructive force. Photo by Roberto Valcárel Rojas.*

tors that can be overlooked at this macro-scale. Therefore models that show that most Precolumbian settlements in Cuba are located in close proximity to caves that could be used as hurricane shelters or that topographic modeling suggests a preference for leeward settlement locations in upland areas is somewhat a statistical argument that requires a case-by-case analysis (Cooper 2010a). This caveat is particularly important when considering the changing nature of the Cuban archipelago over time and the impacts of relative sea level rise and changing climatic and environmental conditions. However, before we focus on a case study site, it is interesting to note observations by modern-day inhabitants of Cuba who consider Precolumbian settlements to be located in more flood-protected areas of the landscape.

An example of this observation put into action comes from a recent Save the Children–sponsored urban planning initiative in Holguin in eastern Cuba, which uses as its logo the Precolumbian deity Guabancex, the symbolic representation of the destructive force of the hurricane (figure 4.4). This project has identified a pattern in Precolumbian settlement locations and argues that their use of leeward hillside brows for settlements, in contrast to the more common post-contact use of river valleys, provides better protection from the common tropical storm and hurricane pluvial flooding in the region (Valcárcel Rojas 2002). Inevitably, such regional generalizations are susceptible to oversimplification, as without doubt many Precolumbian settlements do appear to be located in positions more traditionally considered "vulnerable." Therefore general observations surrounding the relative vulnerability of Precolumbian settlement locations need to be evaluated within their individual topographic and

paleoenvironmental settings if useful interpretations are to be made regarding their relative resilience.

Los Buchillones is an interesting site at which to explore these issues of settlement vulnerability in more detail. Paleoenvironmental evidence shows that the site was a Precolumbian residential settlement that straddled the coastline using stilted wooden structures over waterlogged environments. This coastal location, similar to the neighboring modern-day villages of Punta Alegre and Maximo Gomez, exposes the settlement to the impacts of the hazards discussed earlier. Therefore each of these potential hazards can be evaluated using this site-specific example. Located 1 km south of Los Buchillones is a range of hills called the Lomas de Punta Alegre, which contain a number of large limestone caves that could have been used as hurricane shelters. Precolumbian artifacts in these caves indicate their use, or at least knowledge of their location, by Precolumbian populations. Therefore these caves offered potential shelter for the occupants of Los Buchillones during the wind shear "event" of past hurricanes.

A topographic and hydrographic model of the coastal region around Los Buchillones enables the modeling of the impacts of coastal storm surges on this Precolumbian settlement (Cooper and Boothroyd 2011). Bathymetric models show that the flow of water through the offshore island archipelago is greatly restricted by a prominent reef located 30 km north of Los Buchillones, by the shallow depth of the intervening Bahia de Buena Vista, and by a series of narrow channels that limit the flow of water through a network of low-lying mangrove islands. This suggests that the location of the site behind the Jardines del Rey archipelago would have mitigated the impact of hurricane coastal storm surges.

The potential for pluvial flooding at Los Buchillones is high, as the Lomas de Punta Alegre behind the site is a water catchment area that channels rainwater down the hillsides to the coast. However, the location of the house structures in a waterlogged environment with potentially suspended floors mitigates against the impact of pluvial flooding because the water ran off the hills into the wetlands—unlike today, when the houses of Punta Alegre are regularly flooded.

Los Buchillones is just one site in the densely populated Precolumbian island-scape of the Cuban archipelago; therefore it is not possible to take these "lessons" of potential resilient settlement location and apply them elsewhere. However, this case study does show how the study of settlement location within an established paleoenvironmental setting, combined with an improved understanding of household architecture used at the site, can provide a better understanding of the vulnerabilities and potential resilience of Precolumbian communities. This study shows the importance of evaluating vulnerability contingent on the local environmental context, and, while not transferable to

other sites in different environmental contexts, some of the findings are certainly relevant to the modern-day populations of Punta Alegre and Maximo Gomez.

Food Procurement Strategies and Interaction Networks

Changing patterns in Precolumbian resource and subsistence strategies are subject to a large number of influences over time, from changing settlement locations to demographic fluctuations, seasonality, overexploitation, and new technologies. Therefore linking the impact of sudden environmental change with changes in past food procurement strategies identified in faunal assemblage analyses is often too simplistic and deterministic to be meaningful. However, it is interesting to consider how reconstructed food procurement strategies during particular points in time would have helped mitigate against the impacts of known hazards in a particular case study area.

In the case study area around Los Buchillones, faunal assemblages from a number of sites have been studied, and they reveal some general patterns in the diversification of environmental niches exploited over time (Cooper, Valcárcel Rojas, and Calvera Rosés 2010). During the occupation of Los Buchillones, we can reconstruct a diverse and wide-reaching food procurement strategy that utilized resources from pelagic, reef, mangrove, littoral, lowland agricultural, and upland forested environments with a large catchment area drawn around each site. Evidence shows direct access by inhabitants of Los Buchillones to all of the marine environments, but the links with the upland regions in Cuba's interior raise the probability of trade and exchange networks (Cooper 2008). The use of food resources from a diverse range of different environments highlights a strategy that provides resilience against sudden disruptions to local environments.

It is clear from this discussion that sudden environmental change can occur in the Caribbean at different spatial scales, but the diversification of resource sources facilitates the mitigations of these impacts. The local impacts of relative sea level rise and hurricanes indicate that to successfully live through these impacts, communities require access to resources and support beyond the affected areas. In the case study area at Los Buchillones, interaction models have been constructed using the movement of sourced materials through the island-scape (Cooper 2010b). These networks of interaction show that established relationships based on exchange and reciprocity between different coastal sites and the interior upland areas exist up to 50 km inland. References to social relationships in the late Precolumbian Caribbean indicate that these networks would have been firmly established, with strong intermarriage and social reticulation. Therefore this network of interaction provides an important framework for management following localized impacts of hazards such

as hurricanes (Cooper and Peros 2010).

SUMMARY AND FUTURE RESEARCH

The intentionality behind human decision-making processes is challenging to identify through archaeological data alone. Consequently, it is very difficult to differentiate between deliberately planned disaster management strategies that have been intentionally adopted and cultural practices that have the benefit of mitigating potential hazards. Therefore this chapter is not arguing for a monocausal link among Precolumbian household architecture, settlement location, food procurement strategies, interaction networks, and the dangers of sudden environmental change. Rather, it uses paleoclimatic and paleoenvironmental data at different spatial and temporal scales to identify the hazards experienced by Precolumbian populations in the Caribbean. It then uses detailed archaeological investigation at different spatial and temporal scales to assess the potential resilience of their lifeways to these impacts, occasionally using modern-day comparisons for contrast (Peterson and Broad 2009). This study suggests that hazards need to be considered as culturally contingent and based on the ecological knowledge with which societies understand the nature and threat of potential hazards. In the Caribbean, Precolumbian lifeways appear to have offered some important advantages in mitigating the impacts of known hazards in the region. These advantages helped mitigate the impacts of hazards and reduced the vulnerability of Precolumbian communities to sudden environmental change.

The scaled temporality of hazard return rates in the Caribbean raises the interesting topic of intergenerational knowledge transfer and the cultural transmission of ecological knowledge over time. Archaeology, through case studies such as this one from the Caribbean, provides a deep time perspective of human engagement with environmental change that challenges the use of concepts such as stability and equilibrium. The constantly changing dynamics of human-climate-environment relations need to be understood in terms of flux rather than equilibrium; therefore hazards can only be properly understood within their individual geographic, temporal, and cultural contexts. In the Caribbean, archaeology provides one of the few tools available to access this important knowledge following the loss of an entire way of life after European contact. Therefore archaeologists can make an important contribution to ongoing debates over disaster management in the Caribbean where concepts of threat, vulnerability, and resilience can be better understood using the time depth of human experience. In this way, archaeologists should be involved in future disaster management strategies to enable a better understanding of hazards, provide critical discussion of potential mitigation strategies, and contribute to a wider interdisciplinary debate that enables modern-day communi-

ties to avoid the impending dangers of sudden environmental change in the region.

Future research needs to concentrate on providing more interdisciplinary case studies in which paleoclimatic, paleoenvironmental, and archaeological data can be brought together in an informative way. The discussion in this chapter raises some interesting observations that merit more extensive comparative discussion. More fine-grained proxy data for local paleoclimates and paleoenvironments are required to bring the impacts of sudden environmental change to the archaeological scale of human occupation at individual settlements. However, perhaps most important, an improved dialogue needs to be opened among archaeologists, climatologists, and disaster management experts, as there is no doubt that archaeology has innovative perspectives and important lessons to contribute to a much wider debate (Anderson et al. 2007; Giddens 2009; Jansen et al. 2007).

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STATEMENT FOR POLICY MAKERS AND THE DISASTER MANAGEMENT COMMUNITY

Five thousand years of human experience in the Caribbean can provide important lessons for modern-day policy makers and practitioners working with the impacts of climate change in the region. Case studies in this chapter show that regional climate change creates unavoidable threats to everyone living in the islands of the Caribbean. However, different communities' relative experience of these threats is entirely dependent on very local conditions and the lifestyle choices of different societies. The importance of the way local conditions affect the experience of environmental hazards highlights the fact that centralized planning strategies at national or international scales currently fail to prepare people for what they will experience and how they should best prepare themselves.

The reliance of Precolumbian mitigation strategies on local preparation for local threats greatly helped reduce vulnerability in the past. This chapter reveals that the Precolumbian selection of secure settlement locations, the creation of diverse food distribution networks, and the use of readily rebuilt household architecture maximized the potential for mitigation based on local environmental conditions. These Precolumbian lifeways contrast strongly with modern-day lifestyles in the Caribbean that have been strongly influenced by non-local European and North American traditions. Examples such as the colonial legacy of European selection of river valley settlement locations or more recent developments, such as the centralized distribution of non-local food staples and the development of architectural designs reliant on imported materials, highlight changes in the Caribbean that have increased vulnerability to known hazards in the region.

A clear argument arises from this research that the current focus on short-term "impact" mitigation in the Caribbean is emphasized at the expense of more robust preparation and reconstruction strategies that take into account the complexity of decision-making in human societies and the need for long-term strategies to change human behavior. Such a lesson shows the importance of local education strategies that try to foster improved traditional ecological knowledge within communities that helps people understand the nature of the threats they face and feel empowered to plan for themselves. Both in the past and in the present, the real "cost" of an environmental disaster is often not from the "event" itself but from the weeks, months, and years of devastation that ensue. The devastating impacts of sea level rise, rainfall change, and hurricane activity are inevitable for modern-day communities in the Caribbean. Therefore this research suggests adopting the perspective of how quickly human communities can return to "life as before" rather than focusing on how robustly they can "withstand" the inevitable hazards that

loom on the horizon. Practitioners' work should emphasize local education, decentralized planning empowerment, and post-impact reconstruction. The current reliance on centralized power structures for dealing with the impacts of climate change in the Caribbean fosters a dangerous sense of absolved responsibility and highlights why the lessons from the past, contained in this chapter, are important for the challenges of the future.