J Coast Conserv
DOI 10.1007/s11852-010-0109-0

On the shoals of giants: natural catastrophes and the overall destruction of the Caribbean's archaeological record

Scott Michael Fitzpatrick

Received: 1 April 2010 / Revised: 17 June 2010 / Accepted: 18 June 2010

Abstract In this paper I review a host of natural and cultural processes that have affected the preservation and integrity of archaeological sites on islands in the West Indies, many of which are located in low-lying coastal areas. Given the position of the Caribbean lithospheric plate—juxtaposed between four others—it is no surprise that by its very nature the region is volcanically active and frequently associated with earthquake and tsunami events. This makes coastal zones, and related archaeological sites in the region, highly susceptible to a wide range of destructive natural events. The high frequency of tropical systems (hurricanes and storms) in the Caribbean and rising sea level, coupled with human activities such as sand mining, development, and looting, makes the region's archaeological record one of the most vulnerable and threatened in the world. Ongoing research is dedicated to understanding how past populations may have been affected by these events in the past.

Keywords Prehistory · Tropical storms · Tsunamis · Coastal geomorphology · Sea level rise · West Indies

Introduction

Recent natural catastrophes in the Gulf of Mexico, ranging from major Hurricanes such as Ivan (2004) and Katrina (2005) to the 2010 earthquake in Haiti, serve as stark reminders of the fragility of the human experience for those who live in the Caribbean. Although these two examples are highly visible and have without doubt exacted a terrible cost in terms of human lives and livelihood, they are only a few of many that have occurred in this region over the millennia.

Archaeologists in the Caribbean and elsewhere are becoming increasingly interested in how these and other natural phenomena affected peoples in the past and what this meant for the survival and adaptation of human populations, ranging from Amerindian groups who settled the islands of the West Indies over 6,000 years ago to more recent historic times. We are also recognizing that current human activities in the region, largely revolving around tourism and development, are exacting a heavy toll on the archaeological record from which our interpretations are based.

The title of my paper is both literal and metaphorical—literal in the sense that the majority of islands in the Caribbean, most of which stretch along a fairly continuous arc from South America north and westward toward the Gulf Coast of the United States, are surrounded by shoals: shallow, sandy areas offshore that are a hallmark of tropical island environments. But these shoals are also metaphorical—the islands of the Eastern Caribbean sit at a juncture where natural processes—tectonic, volcanic, and climatic—have continually wreaked havoc on local populations over time. Coupled with issues faced more recently, including large-scale development, agriculture, and sand mining, the Caribbean is an excellent case study with which to examine how islands, islanders, and archaeologists have responded to the continued wrath facing the region's archaeological record.

In this paper, I provide an initial review of what we know thus far about the types of natural catastrophes that have been documented in the Caribbean through the millennia, including earthquakes, volcanic eruptions, paleotsunamis, and tropical storms, and what this meant for human groups who settled, or were beginning to settle, these islands in the past. Given length restrictions this review is not entirely comprehensive,

S. M. Fitzpatrick (✉)
Department of Sociology & Anthropology,
North Carolina State University,
Raleigh, NC 27695, USA
e-mail: scott_fitzpatrick@ncsu.edu

Published online: 10 July 2010

but does build on earlier work that has attempted to understand how human populations in the Caribbean were affected by these processes as well as the major impacts that currently threaten archaeological sites in the region. Overall, I argue that the Caribbean, perhaps more than any other major world region, has succumbed to such a large degree of pronounced and dramatic environmental and anthropogenic impacts that we risk losing a large portion of the available information we have to study the past.

Environmental and archaeological background

The Caribbean Sea is by most accounts considered the second largest sea in the world, ranking seventh overall in terms of size of bodies of water. The Caribbean encompasses an area of approximately 2,754,000 km^2 and stretches 2,300 km east-west from the eastern fringe of the Lesser Antilles chain to the Yucatán and 1,700 km north-south from Florida to Panama (Fig. 1). The Caribbean is home to over 38 million people and is one of the most urbanized island regions in the world. Local populations here had an annual growth rate of 2.4% between 1990 and 1995 (McGregor and Potter 1997). Barbados, for example, with 280,000 residents living in a land area of only 430 km^2 (166 square miles), has over 650 people per square km, making it one of the most densely populated countries in the world.

The islands of the Caribbean are comprised largely of three major geographical groups—the Greater Antilles, Lesser Antilles, and Bahamas Archipelago—but there are those adjacent to the South American mainland (Margarita, Curaçao, Bonaire, and Aruba) as well as the Caymans, Virgin Islands, and Trinidad and Tobago, that geologically are not related to these three major chains. The largest islands of the Caribbean—Cuba, Hispaniola, Puerto Rico, and Jamaica—are comprised of both volcanic rock and limestone, while the Bahamas, Caymans, and Barbados are exclusively limestone or coralline in nature. The smaller islands of the Lesser Antilles, stretching from the Virgin Islands to Grenada 130 km north of Venezuela, lie along the subduction zone that interacts

Fig. 1 Map of the Caribbean (drafted by Michael Scisco, BioGeoCreations)

with the South and North American plates and are mostly composed of volcanic rock. In geological terms, the Antillean Island Arc is relatively young with no atolls indicative of submerged volcanic peaks. The few atolls found in the Caribbean lie along the far western edge fringing Central America.

Biologically, the Caribbean is extremely diverse, containing 2.3% of the world's endemic plant species and 2.9% of endemic vertebrate species which is significant considering that the region encompasses only 0.15% of the Earth's surface. In total, over 1,500 species of fish, 25 coral genera, 630+ mollusc species, and numerous sponges, crustaceans, echinoderms, sea mammals, birds, and reptiles in marine, freshwater, brackish, and terrestrial environments have been recorded. This led to the Caribbean as being listed in the top four of the world's 25 'Hotspots' by Conservation International—regions that are relatively small—but contain high percentages of endemic species.

Archaeological investigations demonstrate that the Caribbean islands were probably settled by "Lithic" peoples around 6000 BP, perhaps from somewhere in Mesoamerica when colonists first reached Cuba and Hispaniola (often referred to as "Casimiroid"); however, the evidence is ephemeral and not well established (Keegan 1994; Rouse 1992; Wilson et al. 1998, 2007). Archaic peoples from South America (called "Ortoiroid") (see Rouse 1992; Petersen et al. 2004:32), then occupied the Lesser Antilles between about 2000–500 BC. Most of the well-known sites during this period are in the Leeward (northern) islands in the Antillean chain. According to conventional thinking, a new migratory group known as "Saladoid" then began moving northward from South America beginning around 500 BC, either displacing remnant Archaic populations or arriving to find them already gone. They settled Puerto Rico and islands throughout the Lesser Antilles (Keegan 2000), but apparently ventured no further west for nearly a thousand years. Saladoid groups produced a rich array of artefacts (see Keegan 2000:143–144 for a brief summary), but are most often recognized for their well-made and beautifully decorated pottery. It should be noted that these convenient labels for various migratory groups, although widely used in the Caribbean today, likely mask more complex social connections between the West Indies and mainland South America that occurred through time (e.g., see Fitzpatrick and Callaghan n.d.; Keegan 2006; Rodríguez Ramos 2007; Rodríguez Ramos and Pagán Jiménez 2006; Rodríguez Ramos et al. 2008). It also appears that these separate migratory groups may not be distinct populations at all given recent research suggesting that pottery was being manufactured by Archaic (pre-Arawak) groups prior to the "Ceramic Age" (see Rodríguez Ramos et al. 2008) and the recognition that frequent movement of populations between the Antilles and South America could have been relatively easy (Fitzpatrick and Callaghan n.d.).

A new pottery series then develops in the Greater Antilles around AD 500/600 called Ostionoid (broken down into various subseries: Ostionan, Meillacan, and Chican) which archaeologists have often attributed to descendent groups of Saladoid who presumably pushed westward into Hispaniola, south to Jamaica, and north into the Bahamas. Alternatively, they could be the product of complex interactions between Archaic, Saladoid, and/or Huecoid groups with people on the South American mainland (Boomert 2000; Curet 2003, 2005; Chanlatte Baik 1990; Rodríguez Ramos 2002, 2007; Rodríguez Ramos et al. 2008). In the Lesser Antilles at about the same time there is a noticeable change in the quality of pottery that led Rouse (1992) to mark this as a distinct style that he called Troumassoid which is then followed by another series known as Suazoid that occurs from roughly AD 1000–1500. Based on more detailed analyses of decorative patterns and manufacturing techniques, it is generally agreed that Troumassoid and Suazoid are variations of the same series of pottery that change over time and as such, the preferred nomenclature is now Troumassan Troumassoid and Suazan Troumassoid, respectively (Petersen et al. 2004). Regardless, Saladoid peoples have traditionally been considered to be ancestral to Arawakan speakers who inhabited the Antilles at European contact.

A phenomenon that occurs throughout the Caribbean, particularly with early settlers during the Ceramic Age c. 500 BC–AD 600, is the placement of villages along the coast (Keegan 2000). This was likely for a number of reasons: 1) it afforded easier access to both terrestrial and marine resources; 2) allowed the use of boats as the primary mechanism for transportation and interaction; and 3) made settlement less challenging given that inland areas in the islands are generally more rugged and mountainous. With this in mind, I turn to examining the natural and cultural processes that would have affected the lifeways of prehistoric coastal inhabitants in the Caribbean as well as the integrity of archaeological sites.

Natural processes affecting archaeological sites

Tectonic and volcanic activity

The geological history of the Caribbean is complex and has been debated by scholars in the geosciences for decades, particularly as it pertains to the origin and movement of the Caribbean plate and whether this represents an allochthonous or in situ phenomenon (e.g., see reviews and discussion in Burke 1988; Iturralde-Vinent and Lidiak 2006; Meschede and Frisch 1998). Nonetheless, the current position of the Caribbean Plate is at the nexus of four other plates—the North American, South American, Nazca, and Cocos—creating several

major faulting and subduction zones, particularly along the junction of the Caribbean and North American plate. This makes the Circum-Caribbean seismically intense with numerous earthquakes, landslides, tsunamis, and volcanic eruptions recorded over the millennia.

The Antillean chain contains 20 active volcanoes (from north to south): Mt. Scenery (Saba), The Quill (St. Eustatius), Mt. Liamuiga (St. Kitts), Nevis Peak (Nevis), Soufrière Hills (Montserrat), La Soufriere (Guadeloupe), Morne au Diable, Morne Diablotins, Morne Trois Pitons, Wotten Waven caldera, Valley of Desolation, Watt Mountain, Morne Anglais, Grande Soufriere Hills, Morne Plat Pays (all on Dominica), Mt. Pelée (Martinique), Qualibou (St. Lucia), Soufriere (St. Vincent), Kick-'em-Jenny (underwater between Grenada and Carriacou), and Mt. St. Catherine (Grenada) (see Sigurdsson and Carey 1991).

Despite the sheer number of volcanoes in the Lesser Antilles, there have been few eruptions over the last century. The most recent and well-documented is that of Soufriere Hills on Montserrat which began erupting on 17 July 1995, displacing most of the 10,000+ inhabitants, but with no fatalities. It erupted again on 25 June 1997 with pyroclastic flows killing 10 people and 10 others that went missing and presumed dead. Fifteen years earlier in 1979, Soufriere on St. Vincent erupted, but prior to that, had stayed dormant until the turn of the 20th century. It began erupting on 6 May 1902 and continued for nearly a year, lasting until 30 March 1903. In total, over 1,500 people were killed. A few days later that same year, Mt. Pelée on Martinique erupted on 8 May 1902 which destroyed the town of St. Pierre and killed over 28,000 people. Apart from Montserrat, the most frequently active volcano has been Kick-'em-Jenny which has erupted at least 11 times since 1939 (Lindsay et al. 2005; Sigurdsson and Carey 1991).

The recently recorded cases of volcanic activity in the Caribbean, although dramatic, conceal the true frequency of these events in the past. Archaeologists, historians, and geologists have looked deeper in time and found abundant evidence of destruction that would have affected prehistoric populations and obscured the archaeological visibility of settlement sites. Watters and Norton (2007) describe archaeological fieldwork on Montserrat prior to the eruption of the Soufrière Hills volcano in 1995 (Druitt and Kokelaar 2002) and later assessed the impact to these sites post-event. They categorized the loss of primarily historical archaeological resources into those that were: 1) destroyed/obliterated; 2) entombed/buried; and 3) off-limits/unavailable. Among other findings, they note that of the 50 identified plantation sites, pyroclastic flows or surges had impacted nearly all of them to some degree, and that the Radio Antilles Saladoid site is probably "too deeply buried to ever again be researched" (Watters and Norton 2007:50). Although this event clearly affected the integrity and visibility of historical and archaeological sites in inland areas on Montserrat, it is also noteworthy that pyroclastic surges extended all the way down to the coast in some places, destroying villages like St. Patrick's which had existed since early historic times. Fortunately, a recent effort by archaeologists from Brown University as part of the Survey and Landscape Archaeology on Montserrat (SLAM) project are documenting and investigating sites on the island that should help determine the current status and integrity of prehistoric and historic sites on the island (Ryzewski et al. 2010).

Apart from the obvious destruction that volcanic events can wreak on archaeological sites today, what about their influence on societies in the past? Armstrong (1980) recorded ash covering the Sugar Factory Pier Archaic site on St. Kitts dating back to c. 2100 BC, emphasizing that there may be many more sites in the Caribbean which are similarly obscured, thereby skewing our interpretations of island occupations across time. On St. Vincent, Callaghan (2007) noted the presence of deep ash fall that had buried several prehistoric sites (in one case, a single event was observed to be 10 metres deep!). Inhabitants also seemed to have preferred settling on parts of the island away from Soufrière volcano which Bullen and Bullen (1972:95) report was active around the time of Saladoid settlement in AD 295. Callaghan (2010) has also explored the idea that volcanic activity may have discouraged prehistoric settlements of Caribbean islands. In his summary of eruptions over the past 4,000 years, he notes that there has been an event every 100 years on average and that during the Archaic Age, volcanic activity was more frequent south of the Guadeloupe Passage than to the north. This suggested to him that eruptions may have been a deterrent to prehistoric settlers, thus helping to possibly explain the paucity of Archaic sites in the southern Lesser Antilles. Both Callaghan (2010) and Armstrong (1980) recognized too that events such as these may render many archaeological sites inaccessible or unobservable to archaeologists.

In another study, Petersen et al. (1995:45) suggested that the Trants site on Montserrat experienced "variably dense concentrations of rocks superimposed on top of Amerindian remains, with more Amerindian deposits clearly present above the sometimes dense rocks." The reason for the distribution of these materials after initial Saladoid occupation around AD 200 was hypothesised to have occurred as a result of a storm surge or pyroclastic event. Closer examination seemed to support the latter, given that eruptions of Mt. Pelée on Martinique around AD 210 and AD 280 were thought to have buried the Vive site located along the coast (Allaire 1989). The Trants site could have either succumbed to Mt. Pelee's eruption 230 km to the south, or been affected by a contemporaneous event, not unknown to occur in the Caribbean where two or more volcanoes can erupt almost simultaneously. As Petersen et al.

(1995:46) remarked, "[t]he rich record of adaptation to local island life may have included by necessity a strong element of catastrophic risk by the Amerindians."

Paleotsunamis

In recent years, much attention has focused on catastrophic tsunami events in the Indo-Pacific that have caused tens of thousands of deaths and widespread destruction. Lesser known are those that have occurred in the Caribbean—and while ones documented historically have not caused the degree of damage seen in the Pacific Basin—they have been both frequent and destructive with at least 88 recorded between 1489 and 1998 (Lander et al. 2002; Scheffers 2004; Pelinovsky et al. 2004).

Tsunamis can be classified into four major categories: 1) *teletsunamis* (those that originate from remote sources); 2) *landslide tsunamis* (generated by the movement of mass debris); 3) *volcanic tsunamis* (from some type of volcanic activity); and 4) *tectonic tsunamis* (those that are produced from sudden movement of the plates or crustal blocks) (see Lander et al. 2002:58, 60–61). All four types are thought to have occurred in the Caribbean, although those deriving from landslides, volcanic eruptions, and tectonic activity are considered to be more common.

In their review of paleotsunami events worldwide over the last 4,000 years or so, Scheffers and Kelletat (2003) provide descriptions of the varying types of sediments in coastal environments that could be indicative of tsunamis occurring. They note that in the circum-Caribbean there have been tsunamigenic sediments recorded (north to south) in the Caymans, Bahamas, Puerto Rico, Nicaragua, Curaçao, Bonaire, Aruba and Venezuela (see also Scheffers 2004). In some cases, events like these in the Holocene are considered responsible for having moved boulders in excess of 50 metric tonnes (mt) in Grand Cayman, 135mt in Bonaire, and 281mt in Curaçao. Some of these were transported 100–160 m inland and several metres above sea level. Scheffers (2002) also estimated that the amount of sediment transported by a tsunami in the Netherlands Antilles exceeded more than 1 million mt. Although the chronology for many paleotsunamis in the Caribbean is still under investigation, Scheffers' (2004:171) work in the Netherlands Antilles indicates that there were at least three tsunami impacts during the Late Holocene at 500, 1500, and 3500 BP, well within the timeframe of human occupation here and elsewhere in the Caribbean during the Ceramic Age.

In a critical review of the historical literature from the Caribbean, Lander et al. (2002) developed criteria for estimating the validity of probable tsunami events over the last 500 years dating back to AD 1498. They suggest that there were at least 91 waves reported that could have been tsunamis; of these 27 were determined to be tsunamis, while the other 53 lacked sufficient detail to make an unequivocal assessment. Given the historical frequency of tsunamis in the Caribbean (which occur every 26 years on average in the Intra-Americas Sea Region), "the risk of potentially destructive tsunamis is greatest from the West Indies island arc with its sub-aerial and submarine volcanoes, steep underwater slopes and the active subduction zones of the Caribbean Plate boundary marked by numerous earthquakes" (Scheffers 2004:171–172). Although the possible effects of past tsunamis on archaeological sites in the Caribbean have not been investigated in detail, it is quite probable that they have affected them to some degree given the propensity for pre-Columbian settlements to be located along the littoral zones of islands. Future geoarchaeological research at archaeological sites that focuses on examining evidence for tsunamigenic sediments would surely be productive.

Hurricanes and other tropical storms

There is perhaps no other natural catastrophe more closely associated with the Caribbean than hurricanes, and any archaeologist who has spent time conducting fieldwork here usually has at least one story of these interrupting research activities. A hurricane is defined as "a tropical cyclone with winds of 74 miles (119 km) per hour or greater that occurs especially in the western Atlantic, that is usually accompanied by rain, thunder, and lightning" (Merriam-Webster Dictionary 2010). The Caribbean Hurricane Climatology web page <http://stormcarib.com/climatology/> provides a comprehensive database of past hurricane and other tropical storm activity in the Caribbean that has occurred between 1851 and 2008. It is important to note that only since 1944 have reliable observations of tropical systems (those hurricanes and tropical storms which are officially named) been made. Over this 159 year period, the Eastern Caribbean experienced 260 named tropical systems that came within 60 nautical miles of an island, averaging 1.6 per year. Those that reached category 3 or higher occurred 39 times during this same time interval, with 23 of those happening since 1944. Nonetheless, the data provide a good indication of the frequency and pathways for these events over the last century which can be used as a proxy for what was happening in the past.

The powerful winds, torrential rain, and surges that accompany tropical storm systems make them particularly destructive to coral reef systems (Lewis 2002) and low lying coastal areas where populations are concentrated and which are extremely susceptible to flooding and other associated processes. Scholars working in the Pacific Basin, including Australia (Bird 1992; Przywolnik 2002) and Tonga (Spenneman 1987), have documented the impact of storms on archaeological sites. These have various effects, ranging from the displacement and/or erosion of cultural remains to the complete obliteration of sites. Although storm-induced beach erosion is a major concern in the

Caribbean (see Daniel and Abkowitz 2005), there has been little work on the effects of these events on the archaeological record, although they are widely recognized (e.g., Delpuech et al. 1999:158; see Crock and Petersen 2001 for one of the few descriptions for the region).

In one case, Watters and Petersen (1993:350) suggested that a rapid sedimentation event at the Rendezvous Site on Anguilla could have been the result of a hurricane. In another, Clark et al. (2003) found what appears to be discernible storm events at the Paso del Indio site in Puerto Rico which dates between AD 450–1500. They analyzed rates and levels of sedimentation at the site, observing periodic flood events that, for the most part, would have been attractive for site inhabitants growing crops along the Río Indio. However, they also recorded "a period of frequent disturbance by large magnitude flows (c. AD 1000–1100)…represented by deposition of the storm sequence…and [which] resulted in a drastic increase in the rate of deposition" (Clark et al. 2003:646). Some of the storm layers also contained remixed cultural material suggesting movement and redeposition of site constituents; considering that these were frequent events of great magnitude, "the effects on the inhabitants were probably severe" (Clark et al. 2003:646) and possibly the result of "several storms occurring within a relatively short time" (Clark et al. 2003:64). Although speculative, given that Paso del Indio would have been only a few km from the coast, the possibility exists that some of these depositional sequences could have been caused by tsunamis which have been seen in recent times to reach between 3 and 6 km inland even in areas devoid of extensive drainage systems.

Climate change: coastal geomorphology and sea level rise

Decades of scientific research by climatologists worldwide demonstrate that global sea levels are rising. Due to their low-lying nature, this will disproportionately affect smaller island nations such as those found in the Caribbean (e.g., see London 2004; Ramcharan 2004). Although there is general agreement that sea levels will be variable across the world's seas and oceans depending on a local oceanographical and geological factors, it is becoming clear that this will lead to a host of deleterious effects that will only increase over the next century, threatening to inundate coastal communities and with that, the finite remains of the past.

Erlandson (2008), in an essay entitled "Racing a Rising Tide", outlines these threats which he reinforces in a paper in this special issue of *JCC* (Erlandson 2010). This has been a major topic for coastal archaeologists in the past decade or so (see Erlandson and Fitzpatrick 2006; papers in Rick and Erlandson 2008) and will continue to be at the forefront of our concerns given the obvious impacts these pose to coastal archaeological sites.

Caribbean archaeologists have noted a number of cases where climate change has led to coastal geomorphological and sea level changes during the Holocene that likely influenced settlement patterns, affected the visibility and interpretation of site locations, and impacted archaeological deposits (Littman 2001). Cooper and Peros (2010) provide an overview of a newly developed research programme geared toward three major impacts of climate change: sea level rise on a relative scale; 2) shifts in precipitation; and 3) examination of the frequency and intensity of storm events; and how these may have influenced: 1) prehistoric settlement strategies; 2) food procurement; and 3) architectural features. Although the project is in its infancy, it will surely lend new insight into how pre-Columbian populations reacted and adapted to changing climatic conditions in the Caribbean as has already been alluded to, but never firmly established, by a number of previous studies.

Keegan (1995) provides a brief review of how sea level fluctuations may have affected interpretation of site location in the Caribbean. He notes how the anomalous inland location of sites in the Turks and Caicos may only be the result of slightly lower sea levels during the period of occupation. Delpuech et al. (2001) describe sea levels on Guadeloupe being about 1.8 m higher over the past millennium which they attribute to a combination of tectonic activity and subsidence. This served to submerge large areas of land in a number of places, including several islets of the Petit Cul de Sac marin that were shown on a map produced in 1667 (Delpuech et al. 2001:103). Their findings suggest that these coastline modifications may explain the absence of earlier Archaic sites which are more abundant on nearby northern islands such as Antigua and thus require investigation underwater to discover. These results are supported by work at the site of Los Buchillones in Cuba where a partially submerged Taíno village was dated to c. AD 1220–1640 and contains well preserved palm thatch and wooden structures—relative sea level here had risen over the last few thousand years, but remained stable during the period of occupation (Peros et al. 2006). Littman (2001) notes that in general, sea level and shoreline stabilization after c. 4500–5000 BP allowed people to settle coastal areas and river drainages more easily, but that many would now be submerged.

The few cases presented here are indicative of the need to explore past climate fluctations as an influential factor in shaping how pre-Columbian peoples responded to the effects of sea level change and coastal landscape modification. They are also emblematic of the need for archaeologists to consider these processes when constructing models of behavior (e.g., subsistence, conflict, settlement) that may have been influenced by altered climatic regimes during the Middle to Late Holocene. These are also important considerations when selecting sites for future research that may be under immediate threat as was stressed 30 years ago by Ruppé (1980).

Cultural activities affecting archaeological sites

Sand mining and erosion

As noted previously, coastlines are vulnerable to a variety of natural erosive factors. The degree to which they erode, however, depends on many things such as on the proximity and size of adjacent reef structures, lithology (basalts and granite, for example, are more resilient to wind and wave action than are looser soils and beach aggregates), wave patterns, and local climatic regimes. Although beaches can be comprised of varying lithological structures such as clays, silts, gravels, cobbles, and boulders, sand (0.08–4.6 mm in size) is often the most common sediment type. In some cases, dunes may form, creating a natural buffer between land and sea. Given the coastal and sandy nature of many archaeological sites in the Caribbean, erosion by the wave, tidal, and storm action is causing, and will continue to cause, widespread destruction (for just a few examples, see Watters 1983; Watters and Donahue 1990:375; Drewett 1991:221; Courtaud et al. 1999:278; Pulsipher and Goodwin 1999:11; Wilson 2007; Reid 2008; Schleupner 2008; see also Bruun 1962, 1983)

One of the major issues in the Caribbean, however, is that dunes and other sources of beach sand have often been targeted for mining by locals and developers to manufacture cement or to replenish beaches in other locations. This is a well-documented problem not only in the Caribbean, but worldwide, and has drastically transformed coastal environments. Sand mining is considered to be one of the primary agents for altering or destroying coastlines in Africa (Mensah 1997; Masalu 2002), the Pacific Islands (Hesp and Hilton 1996; Hesp et al. 1999; Nunn 2000), Azores (Borges et al. 2002), Maldives (Brown and Dunne 1988), Taiwan (Hou et al. 2002), and Korea (Cho 2006), to name a few.

In the Caribbean, dunes at Josiah's Bay in Tortola, Diamond Bay on St. Vincent, and probably Grande Anse Beach on Grenada, have completely disappeared due to sand mining (Huber and Meganck 1990:103). Studies by Daniel and Abkowitz (2003, 2005) illustrate the severity of erosion—not only related to mining—but the effects this has had in association with storm events. Baldwin (2000) notes how the Red Jacket Mines Company, based in Antigua, mined for sand on the neighbouring island of Barbuda. In a single year (1990), the Company extracted 350,000 tonnes of sand from Barbuda and in 1994 the island "was identified as the single most significant source of sand in all of the eastern Caribbean (Baldwin 2000:210). Despite some efforts by local Barbudans to attain an injunction against this activity in 1993, it continued up through 1997 and ultimately destroyed the largest source of acquifer on the island (Baldwin 2000:210).

Ironically, one of the major problems is that when sand is mined for use in construction, it often is not adequately rinsed of salt using fresh water. This results in corrosion of rebar-reinforced structures that compromise their stability. It was perhaps no surprise then that when Hurricane Ivan crashed into Grenada in 2004, over 90% of the structures sustained some type of damage— many were simply turned to powder from using inferior materials and building techniques. This has also proved disastrous in Haiti where there is little governmental oversight on building or the quality of sand, mortar, and other binding agents used in construction (Kidd 2010).

Unfortunately, there has been almost no attempt to calculate how storms or sand mining may be affecting the integrity of archaeological sites in the Caribbean. To help ameliorate this issue, I began conducting the first systematic survey of the small island of Carriacou in the southern Grenadines with colleagues from the Netherlands and UK. We identified over a dozen sites, including two (Grand Bay and Sabazan) that had exceptional evidence for deep stratified deposits and remnants of a large prehistoric settlement (Kaye et al. 2004; Fitzpatrick et al. 2010).

In 2003, we began investigating Grand Bay in more detail and something we noticed immediately was that photos taken by my colleague Michiel Kappers in 1999 showed a gradually sloping coastline for much of the site—this, however, looked nothing like what we saw 4 years later in 2003. Over the past 7 years we have mapped the site and coastline in detail nearly every year with our Total Station. Surprisingly, we found that Grand Bay was eroding at an average rate of over 1 metre per year (Fig. 2). Storms and tidal action were certainly obvious culprits, but hurricanes are rare in the southern Caribbean. This changed when Ivan came through in 2004 (the first in over 50 years) and Emily the following year. Luckily our crew had left before the former, but not the latter. Despite some of our crew having to wait out Emily in 2005, it also gave us an opportunity to examine the rate of erosion at Grand Bay immediately pre- and post-hurricane. We noticed some major impacts as a result, but primarily to those areas where inlets had already been carved into the coastal profile.

A bigger problem as we came to realise was the nearly constant sand mining taking place directly in front of the site by locals. Each day, lorries or tractors would arrive with a crew of three or four men shoveling sand into the back. On some mornings we witnessed ten or more vehicles on the beach engaged in this activity (Fig. 3). And while removing such large quantities of sand alone can change erosion and accretion patterns or interrupt and modify sand supply (see Nairn et al. 2004:128), locals on Carriacou would often target sand closest to the coastal profile at low tide which was free from beach detritus like seaweed and garbage. The undercutting of the profile to obtain cleaner sand ultimately

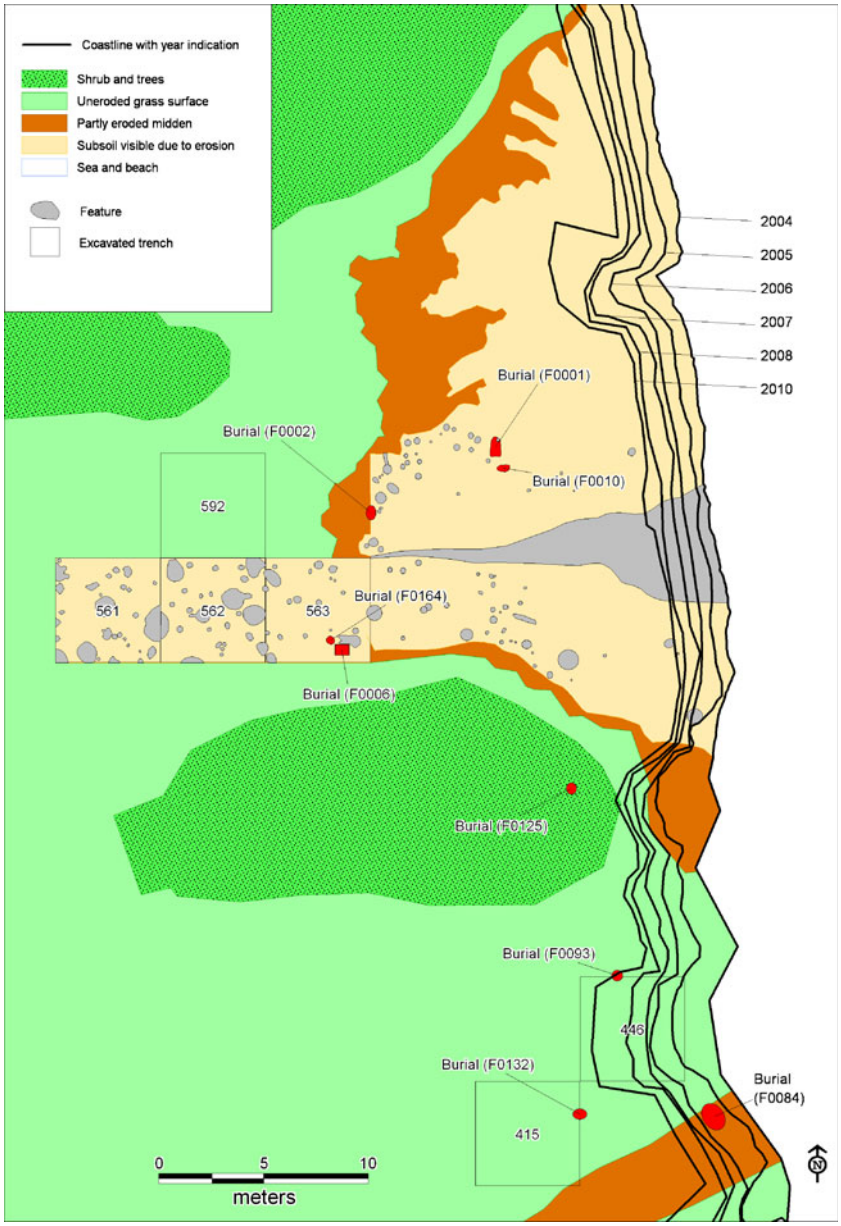

Fig. 2 Map of the Grand Bay site on Carriacou showing location of 5×5 metre excavation units and sequential lines of erosion between 2004 and 2010

has led to widespread slumping that only increases after periods of rain. Overall, we estimated that based on materials recovered from excavation, we are losing on average over 280–300 cubic metres of soils (150+ anthropogenic), 13,000 kg of cultural remains, and dozens of features such as burials and habitational remants (e.g., hearths, postholes) each year (Fitzpatrick et al. 2006). Ironically, sand mining had been done at other sites around Carriacou, but was stopped after it became apparent that this was leading to the erosion of historic graves (Fig. 4). Fortunately, efforts to document the effects of erosion and sand mining is becoming more sophisticated, with concerted efforts by a number of archaeologists and other scientists in the Caribbean to record sites using geographic information systems (GIS) and various remote sensing techniques (see Robinson 2004; Reid 2008).

Cultural heritage management: looting and development

The removal of artefacts and other cultural remains from archaeological sites is pervasive, and the Caribbean is not immune to the destructive effects of this activity. The Caribbean, like many other parts of the world is dominated by small island states, has relatively few natural resources with which to sustain themselves economically, and often resort to tourism on a mass scale. The combination of these two issues, and multiple related ones, has caused an indeterminable number of valuable archaeological remnants to be destroyed or removed from their original context.

The Caribbean has long been recognized by antiquarians and archaeologists for the beautifully made pottery and other artefacts such as shell adzes and ornaments, stone objects,

Fig. 3 Excavation of Trench 446 at Grand Bay (looking north) in 2007. Note several lorries on the beach in top right hand corner engaged in sand mining and erosion of the 5×5m excavation unit on the right which was intact when work began in 2004

bone tools, and lapidary items that were produced by ancient Amerindians, as well as historic structures and shipwrecks. Unfortunately, the attractive qualities of these remains have not gone unnoticed by visitors, souvenir collectors, and looters as Roe (1985) and other scholars have noted for sites throughout the Caribbean (e.g., Conrad et al. 2001:8–9; Spooner 2004). Each year my colleagues and I go back to the Grand Bay site on Carriacou where we see visible evidence in the form of pottery sherd piles and holes from people who have scoured the surface and coastal profile for mementos to take home. The slight irony here, however, is that the collection of material by non-archaeologists at some sites may save them from being eroded away into the sea.

The Pearls site on Grenada is one of the more famous examples in the Caribbean of digging, looting, and selling of cultural remains (e.g., Bullen 1964; Cody 1991). This is the site of the former international airport, but which was later moved to Pt. Saline near St. George's. The resultant downturn in the local economy as a result led to locals looting the site for artefacts to sell to tourists. Today, this continues unabated and has turned the largest and most important pre-Columbian site in Grenada to a pock-marked moonscape of holes and trenches (Fig. 5). This has the obvious effect of compromising the integrity and interpretation of these sites by removing or displacing in situ remains. The unrestricted seeking of artefacts for non-scientific purposes is problematic, but cannot be stopped or easily regulated. One effort to ameliorate this situation on a region-wide scale, however, was a workshop conducted by Henri Petitjean Roget and Gerard Richard and sponsored by the International Association of Caribbean Archaeology that demonstrated ways for locals to create replicas to sell instead of actual artefacts (*sensu* Keegan and Phulgence 2010), something that locals in Grenada are doing, but not exclusively (Fig. 6).

Keegan and Phulgence (2010) in their paper "Patrimony or Patricide" discuss some of the other major problems surrounding the preservation of archaeological sites and associated remains in the Caribbean. One of the bigger issues is that many countries here lack protective legislation and have few (or no) trained archaeologists or dedicated agencies on island that can respond to cases of impact or destruction. This was certainly the case for Barbados when I began working there in the early 1990s. During fieldwork in 1995 with Peter Drewett, we became aware of a plan to turn the large Heywoods site, located on the northwest coast of the island (Drewett 2000, 2002) into a series of high-end condominiums with an artificial marina. Luckily, Drewett was able to convince developers to provide us with time and resources (albeit limited) to investigate the site

Fig. 4 Erosion of historic cemetery on Carriacou along the northeast part of the island. Sand mining at this site was stopped after public outcry

Fig. 5 Series of trenches dug by locals into the Pearls site in Grenada to apparently build a residence. It is clear, however, that this also provided an opportunity for others to collect artefacts (June 2005)

Fig. 6 A collection of authentic ceramic adornos (*top left and bottom right*) along with replicas made from stone sold by locals near the Pearls Site in Grenada (June 2005)

that year; he was subsequently allowed to continue work during later field seasons. What was surprising to me was that developers were not required to conduct a comprehensive environmental impact assessment that took into consideration the effect the project might have on cultural resources and make efforts to protect them.

According to the EIA, the marina plan emphasized development that would attract upper income sections of the tourism market. It was also to provide new high standard of accommodation within existing tourism zones "in proximity of the prime beach attractions" (Richard Gill Associates Ltd. 1995:2). The "Extensions of Tourism Development Plan" stated that this site was to be specifically allocated for tourism and recreational uses. The 1994 Manifesto of the Government of Barbados provided a means for achieving maximum tourist potential to earn foreign exchange and create jobs, and was the political prelude for allowing such development. Perhaps most noteworthy was one of the three principal impacts identified under the section "Landscape and the Environment." This impact simply noted the "*potential loss of Arawak remains*," and suggested the possibility that an indigenous Arawak settlement existed on or near the site. "However, the previous cultivation of the land reduces any potential archaeological importance" (Richard Gill Associates Ltd. 1995:15).

Suffice to say, the Heywoods site is now almost completely destroyed and now known as Port St. Charles, one of the most exclusive villa resorts in the Caribbean. In this case, the desire to generate much needed revenue trumped concerns for long-term archaeological research and preservation of the site. The Heywoods case study shows how impacts to a site can be on the order of catastrophic when one considers the amount of information lost archaeologically and environmentally. But, the Heywoods salvage project can also serve as an example of a cooperative effort between developers and archaeologists to collect archaeological data in the absence of laws requiring them to do so.

Large scale development on many Caribbean islands during the last 50 years or so has primarily revolved around mass tourism geared toward European and North American travelers, although agriculture and animal grazing from the historic period to the present has also had major impacts along coastal zones (Bélisle 1983; McElroy et al. 1990; Ellison and Farnsworth 1996). The iconic palm-lined beaches and tropical resorts are major attractants to visitors, but these developments and their associated landscape and infrastructure modifications are centred along the coast. The Organization of American States (1983) estimated that in the Caribbean, the majority of resorts are built within 800m of the shoreline. As a result, this has tremendously affected both the cultural and natural environment within the littoral zone.

Baldwin (2000) describes the problem this has created in Antigua, Schleupner (2008) for Martinique, and Siung-Chang (1997:53) for the Caribbean in general, where development, much of it geared toward tourism, is considered to be one of the major agents in altering the environment. Problems range from dredging channels for harbors and marinas, yachts and cruise ships, beach nourishment or replenishment, and concrete aggregate in construction that has led to, among other things, the killing of coral reefs due to increased sedimentation, illegal sewage dumping in salt ponds, resort landscape creation that has impacted mangrove swamps and salt ponds, boating and diving activities that use reefs as anchors, and sand mining that blocks tidal inlets and prevents tidal flushing. With marine pollution resulting from agriculture, tourism, and population growth becoming more widespread, the "long-term" impacts on the ecological integrity of coastal ecosystems and fisheries, and water quality for sustainable tourism development, would make them among the most serious pollution problems in the Caribbean" (Siung-Chang 1997:53). As Yaw (2005) demonstrates, however, there are signs that some of these problems are being addressed as a growing sector of the tourist industry begins focusing on cleaner technologies to ensure the attraction of their products to foreign visitors. One hopes that this kind of effort becomes the norm, not the exception.

The cases I describe above demonstrate the added challenge of archaeologists having to become advocates for preserving the past. In places where local populations have little or no connection to the prehistoric past and limited financial resources, as is the case for much of the Caribbean, it is often more difficult to convince governments that archaeological remains, particularly those prehistoric in nature, are worth saving. My colleagues and I have had some success in this regard on Carriacou though, where in 2008 the new Prime

Minister made a special visit to observe our fieldwork, saw what sand mining had done to the site, and placed a ban on further sand removal. Suffice to say, it appears to be business as usual—reports from colleagues on island indicate that this activity is continuing unabated and now being done under cover of darkness.

Although it is not the goal of this paper to provide a comprehensive review on the status of legislation in the Caribbean, Keegan and Phulgence (2010) provide a short summary on the current status of preservation laws and which are explained more fully in various case studies found in Righter and Siegel (2010). But it is worth noting that many of the islands who have not enacted laws such as Grenada, St. Vincent, and St. Lucia, have instead formed National Trusts based on the British model and been fairly successful at regulating archaeological research and working with local governments on important preservation issues.

Discussion and conclusions

The Caribbean compared to other world regions seems to be disproportionately vulnerable to natural and coastal processes which have affected human populations both today and in the past. As one might imagine, this does not bode well for the long-term preservation of archaeological sites. As I have demonstrated, the wide range of cataclysmic events that have been documented—volcanism, tsunamis, earthquakes, and hurricanes—coupled with human related activities such as development, sand mining, and looting, provide the perfect storm for large-scale destruction of the Caribbean's archaeological record in the not so distant future. As global climate continues to change, which climatologists predict will lead to an increase in sea level rise and sea surface temperature, shifts in precipitation patterns, and more intense and/or frequent tropical events, among many other problems, it is likely that the Caribbean will experience other related catastrophes, including landslides, coastal erosion, flooding, loss of protective sandy beaches and coral reefs, and contamination of freshwater sources that will only exacerbate the dire situation at hand. As Pelling and Uitto (2001:50) note, the Caribbean already has the most disaster prone island group in the world—the Greater Antilles—in which Jamaica, Cuba, and Haiti alone reported 44, 47, and 48 disaster events, respectively, between 1990–1997. Given that the economies of these islands are unstable and have weaker "political and institutional development...[they] are heavy losers to repeated disaster shocks" (Pelling and Uitto 2001:50). This certainly rings true for Haiti, which of all small island developing states (SIDS) ranks second in the world in number of deaths (n=13,372) from disasters between 1900–97 and number one (n=342) from 1987–1997 (Pelling and Uitto 2001:51). The recent earthquake, with an estimated death toll that may reach 230,000, will represent an unfortunate spike in future statistical comparisons.

The Caribbean is truly a remarkable place geologically, biologically, geographically, oceanographically, and archaeologically. As we ponder the ways to best understand how humans in the past colonized the West Indies, the natural events they responded to, and what this means for archaeologists today, we should remind ourselves and others that preserving the past is a tremendous and challenging responsibility. The shoals of the Caribbean, and the giants that sleep within—whether they refer to erupting volcanoes, shifting tectonic plates, hurricanes, rising sea levels, or hotels and machinery—are on our shoulders. They require our upmost attention, and if we fail to be proactive about investigating and preserving these sites to the best of our ability, we face a much greater archaeological calamity than we could ever have imagined—the wholesale and catastrophic loss of a people's (and region's), history.

Acknowledgements Thanks go to Torben Rick for reading on an earlier version of this paper and two anonymous reviewers who provided useful comments and additional references.

References

Allaire L (1989) Volcanic chronology and the early Saladoid occupation of Martinique. In: Sigel PE (ed) Early ceramic population lifeways and adaptive strategies in the Caribbean. BAR International Series 506, Oxford, pp 147–168

Armstrong D (1980) Shellfish gatherers of St. Kitts: a study of Archaic subsistence and settlement patterns. In: Lewenstein S (ed) Proceedings of the eighth International Congress for the Study of the Pre-Columbian Cultures of the Lesser Antilles. Arizona State University Anthropological Research Papers, Tempe, pp 152–167

Baldwin J (2000) Tourism development, wetland degradation and beach erosion in Antigua, West Indies. Tour Geogr 2:193–218

Bélisle FJ (1983) Tourism and food production in the Caribbean. Ann Tour Res 10:497–513

Bird CF (1992) The impact of tropical cyclones on the archaeological record: an Australian example. Archaeol Ocean 27:75–86

Boomert A (2000) Trinidad, Tobago and the Lower Orinoco interaction sphere: an archaeological/ethnohistorical study. Cairi Publications, The Netherlands

Borges P, Andrade C, Carmo Freitas M (2002) Dune, bluff and beach erosion due to exhaustive sand mining—the case of Santa Barbara beach, Sao Miguel (Azores, Portugal). J Coast Res S136-89-95

Brown BE, Dunne RP (1988) The environmental impact of coral mining in the Maldives. Environ Conserv 15:159–166

Bruun P (1962) Sea-level rise as a cause of shoreline erosion. J Waterw Harb Div 88:117–130

Bruun P (1983) Review of conditions for uses of the Bruun rule of erosion. Coast Eng 7:77–89

Bullen RP (1964) The archaeology of Grenada, West Indies. Contributions of the Florida State Museum. No. 11. University of Florida, Gainesville

Bullen RP, Bullen AK (1972) Archaeological investigations on St. Vincent and the Grenadines West Indies. American Studies, Report Number Eight. The William Bryant Foundation, Orlando

Burke K (1988) Tectonic evolution of the Caribbean. Ann Rev Earth Planet Sci 16:201–230
Callaghan RT (2007) Prehistoric settlement patterns on St. Vincent, West Indies. Carib J Sci 43:11–22
Callaghan RT (2010) Crossing the Guadeloupe passage in the Archaic Age. In: Fitzpatrick SM, Ross AH (eds) Island shores, distant pasts: archaeological and biological approaches to the pre-Columbian settlement of the Caribbean. University Press of Florida, Gainesville (in press)
Chanlatte Baik LA (1990) Cultura Ostionoide: un desarrollo algroal-farero antillano. In: Pantel Tekaks AG, Vargas I, Sanojas M (eds) En Actas del onceavo Congreso Internatcional de Arqueología del Caribe. Fundación Arqueológica, Antropologica e Histórica de Puerto Rico, San Juan
Cho D-O (2006) Challenges to sustainable development of marine sand in Korea. Ocean Coast Manag 26:1–21
Clark JJ, Walker J, Rodriguez Ramos R (2003) Depositional history and evolution of the Pas del Indio Site, Vega Baja, Puerto Rico. Geoarchaeol 18:625–648
Climatology of Caribbean Hurricanes <http://stormcarib.com/climatology/>. Accessed March 18, 2010
Cody AK (1991) From the site of Pearls, Grenada: exotic lithics and radiocarbon dates. In: Ayubi EN, Haviser JB (eds) Proceedings of the thirteenth congress for Caribbean archaeology. Reports of the Archaeological-Anthropological Institute of the Netherlands Antilles, No. 9. Curaçao, Netherlands Antilles, pp 589–604
Conrad GW, Hammond W, Foster JW (2001) Organic artefacts from the Manantial de la Aleta, Dominican Republic: preliminary observations and interpretations. J Caribb Archaeol 2:1–20
Cooper J, Peros M (2010) The archaeology of climate change in the Caribbean. J Archaeol Sci 37:1226–1232
Courtaud P, Delpuech A, Romon T (1999) Archaeological investigations at colonial cemeteries on Guadeloupe: African slave sites or not? In: Haviser J (ed) African sites archaeology in the Caribbean. Ian Randle Publishers, Kingston, pp 277–290
Crock JG, Petersen JB (2001) Stratified sites and storm events: the formation and destruction of beach sites in Anguilla, West Indies. In: Alofs L, Dijkhoff ACF (eds) Proceedings of the nineteenth Congress of the International Association of Caribbean Archaeology. Dijkhoff. Publications of the Archaeological Museum Aruba 9, pp 204–213
Curet LA (2003) Issues on the diversity and emergence of Middle-Range societies of the ancient Caribbean: a critique. J Archaeol Res 11:1–42
Curet LA (2005) Caribbean paleodemography: population, culture history, and sociopolitical processes in ancient Puerto Rico. University of Alabama Press, Tuscaloosa
Daniel EB, Abkowitz MD (2003) Development of beach analysis tools for Caribbean small islands. Coast Manage 31:255–275
Daniel EB, Abkowitz MD (2005) Predicting storm-induced beach erosion in Caribbean small islands. Coast Manage 33:53–69
Delpuech A, Hofman CL, Hoogland MLP (1999) Excavations at the site of Anse a la Gourde, Guadeloupe: organisation, history and environmental setting. In: par l'Association Internationale d'Archéologie de la Caraïbe Région Guadeloupe Mission Archéologique (eds) Proceedings of the eighteenth Congress of the International Association of Caribbean Archaeology. St. Georges, Grenada, pp 156–161
Delpuech A, Hofman CL, Hoogland MLP (2001) Amerindian settlements and archaeological reality in the Lesser Antilles: the case of Grande Terre, Guadeloupe. In: Alofs L, Dijkhoff ACF (eds) Proceedings of the nineteenth Congress of the International Association of Caribbean Archaeology. Dijkhoff. Publications of the Archaeological Museum Aruba 9, pp 99–108
Drewett P (1991) Landscape change and the prehistoric settlement of Barbados. In: Ayubi EN, Haviser JB (eds) Proceedings of the thirteenth congress for Caribbean archaeology. Reports of the Archaeological-Anthropological Institute of the Netherlands Antilles, No. 9. Curaçao, Netherlands Antilles, pp 221–231
Drewett P (2000) Prehistoric settlements in the Caribbean: fieldwork in Barbados, Tortola and the Cayman Islands. Archetype Publications, London
Drewett PL (2002) Amerindian stories: an archaeology of early Barbados. Barbados Museum and Historical Society, Bridgetown
Druitt TH, Kokelaar BP (eds) (2002) The eruption of Soufrière Hills volcano, Montserrat, from 1995–1999. Geological Society Memoir 21. Geological Society, London
Ellison AM, Farnsworth EJ (1996) Anthropogenic disturbance of Caribbean mangrove ecosystems: past impacts, present trends, and future predictions. Biotropica 28:549–565
Erlandson JM (2008) Racing a rising tide: global warming, rising seas, and the erosion of human history. J Island Coast Archaeol 3 (2):167–169
Erlandson JM (2010) As the world warms: rising seas, coastal archaeology, and the erosion of maritime history. J Coast Conserv. doi:10.1007/s11852-010-0104-5
Erlandson JM, Fitzpatrick SM (2006) Oceans, islands, and coasts: current perspectives on the role of the sea in human prehistory. J Island Coast Archaeol 1:5–32
Fitzpatrick SM, Callaghan RT (n.d.) Saladoid Seafarers: on the origins and migration of early Ceramic Age Amerindian Populations (Submitted for publication)
Fitzpatrick SM, Kappers M, Kaye Q (2006) Coastal erosion and site destruction on Carriacou, West Indies. J Field Archaeol 31:251–262
Fitzpatrick SM, Kappers M, Kaye Q, Giovas CM, LeFebvre MJ, Harris MH, Burnett S, Pavia JA, Marsaglia K, Feathers J (2010) Precolumbian settlements on Carriacou, West Indies. J Field Archaeol 34:247–266
Hesp PA, Hilton M (1996) Nearshore-surfzone system limits and the impacts of sand extraction. J Coast Res 12:726–747
Hesp PA, Shepherd MJ, Parnell K (1999) Coastal geomorphology in New Zealand, 1989–99. Prog Phys Geogr 23:501–524
Hou H-S, Lin T-Y, Hsu T-W (2002) Beach erosion along the I-Lan coast, northeastern Taiwan. In the conference proceedings of Littoral 2002: the changing coast. Porto, Portugal: EUROCAST/EUCC, 453–459
Huber R, Meganck R (1990) The management challenge of Grand Anse Beach Erosion, Grenada, West Indies. Ocean Shorel Manag 13:99–109
Iturralde-Vinent MA, Lidiak EG (2006) Caribbean tectonic, magmatic, metamorphic, and stratigraphic events. Implications for plate tectonics. Geol Acta 4:1–5
Kaye Q, Fitzpatrick SM, Kappers M (2004) A preliminary report on the excavation at Grand Bay, Carriacou, West Indies, June 28th–July 31st, 2004. Pap Inst Archaeol 15:82–89
Keegan WF (1994) West Indian archaeology. 1. Overview and foragers. J Archaeol Res 2:255–284
Keegan WF (1995) Recent climatic and sea level fluctuations in relation to West Indian Prehistory. In: Proceedings of sixteenth Congress of the International Association of Caribbean Archaeology. Conseil Régional de la Guadeloupe et Auditorium de la Ville de Basse Terre, Guadeloupe, pp 95–104
Keegan WF (2000) West Indian archaeology. 3. Ceramic Age. J Archaeol Res 8:135–167
Keegan WF (2006) Archaic influences in the origins and development of Taino societies. Carib J Sci 42:1–10
Keegan WF, Phulgence W (2010) Patrimony or patricide? In: Righter E, Siegel P (eds) Protecting heritage in the Caribbean. University of Alabama Press, Tuscaloosa (in press)
Kidd J (2010) Can Haiti rebuild to save lives? Better supplies, methods needed to withstand earthquakes, experts say. The Star.com <http://www.thestar.com/news/world/article/776172–can-haiti-rebuild-to-save-lives>. Accessed on March 18, 2010

Lander JF, Whiteside LS, Lockridge PA (2002) A brief history of tsunami in the Caribbean Sea. Sci Tsunami Hazards 20:57–94

Lewis JB (2002) Evidence from aerial photography of structural loss of coral reefs at Barbados, West Indies. Coral Reefs 21:49–56

Lindsay J, Robertson R, Shepard J, Ali S (eds) (2005) Volcanic hazard atlas of the Lesser Antilles. Seismic Research Unit of the University of the West Indies, Trinidad and Tobago

Littman SB (2001) Quaternary sea level change in the Caribbean: implications for archaeology. In: Alofs L, Dijkhoff ACF (eds) Proceedings of the nineteenth Congress of the International Association of Caribbean Archaeology. Dijkhoff. Publications of the Archaeological Museum Aruba 9, pp 58–64

London JB (2004) Implications of climate change on small island developing states: experience in the Caribbean region. J Environ Plan Manag 47:491–501

Masalu DCP (2002) Coastal erosion and its social and environmental aspects in Tanzania: a case study in illegal sand mining. Coast Manage 30:347–359

McElroy JL, Potter B, Towle E (1990) Challenges for sustainable development in small Caribbean islands. In: Beller W, d'Alaya P, Hein P (eds) Sustainable development and environmental management of small islands. UNESCO, Paris, pp 299–316

McGregor DFM, Potter RB (1997) Environmental change and sustainability in the Caribbean: terrestrial perspectives. In: Ratter BMW, Sahr WD (eds) Land, sea, and human effort in the Caribbean. University of Hamburg Press, Hamburg, pp 1–17

Mensah JV (1997) Causes and effects of coastal sand mining in Ghana. Singap J Trop Geogr 19:69–88

Merriam-Webster Dictionary (2010) http://www.merriam-webster.com/dictionary/hurricane. Accessed March 18, 2010

Meschede M, Frisch W (1998) A plate-tectonic model for the Mesozoic and Early Cenozoic history of the Caribbean plate. Tectonophys 296:269–291

Nairn R, Johnson JA, Hardin D, Michel J (2004) A biological and physical monitoring program to evaluate long-term impacts from sand dredging operations in the United States Outer Continental Shelf. J Coast Res 20:126–137

Nunn PD (2000) Coastal changes over the past 200 years around Ovalau and Moturiki Islands, Fiji: implications for coastal zone management. Aust Geogr 31:21–39

Organization of American States (1983) Report on August 1983, OAS mission on tourism infrastructure. OAS Department of Regional Development, Washington

Pelinovsky E, Zahibo N, Dunkley P, Edmonds M, Herd R, Talipova T, Kozelkov A, Nikolkina I (2004) Tsunami generated by the volcano eruption on July 12–13, 2003 at Montserrat, Lesser Antilles. Sci Tsunami Hazards 22:44–57

Pelling M, Uitto JI (2001) Small island developing states: natural disaster vulnerability and global change. Environ Hazards 3:49–62

Peros MC, Graham E, Davis AM (2006) Stratigraphic investigations at Los Buchillones, a coastal Taino site in north-central Cuba. Geoarchaeol 21:403–428

Petersen JB, Bartone RN, Watters DR (1995) Pyroclastic, storm surge and Saladoid villager deposits: the archaeological and geological stratigraphy of the Trants Site, Montserrat. In Proceedings of sixteenth Congress of the International Association of Caribbean Archaeology. Conseil Régional de la Guadeloupe et Auditorium de la Ville de Basse Terre, Guadeloupe, pp 40–51

Petersen JB, Hofman CL, Curet AL (2004) Time and culture: chronology and taxonomy in the eastern Caribbean and the Guianas. In: Delpuech A, Hofman CL (eds) Late Ceramic Age societies in the Eastern Caribbean. British Archaeological Reports 1273, Oxford

Przywolnik K (2002) Coastal sites and severe weather in Cape Range Peninsula, northwest Australia. Archaeol Ocean 37:137–152

Pulsipher LM, Goodwin CM (1999) Here where the old people be: reconstructing the landscapes of the slavery and post-slavery era in Montserrat, West Indies. In: Haviser J (ed) African sites archaeology in the Caribbean. Ian Randle Publishers, Kingston, pp 9–37

Ramcharan EK (2004) Mid-to-late Holocene sea level influence on coastal wetland development in Trinidad. Quat Int 120:145–151

Reid BA (2008) Archaeology and geoinformatics: case studies from the Caribbean. In: Reid BA (ed) Archaeology and geoinformatics: case studies from the Caribbean Tuscaloosa: The University of Alabama Press, pp 1–9

Richard Gill Associates Ltd (1995) Executive summary of impact assessments—Port St. Charles waterfront development, Heywoods, St. Peter, Barbados. Report submitted by Guy M. Griffith Engineers, Associated Consulting Engineers, Inc., and Richard Gill Associates Ltd

Rick TC, Erlandson JM (eds) (2008) Human impacts on ancient marine ecosystems: a global perspective. University of California Press, Berkeley

Righter E, Seigel P (eds) (2010) Protecting heritage in the Caribbean. University of Alabama Press, Tuscaloosa (in press)

Robinson E (2004) Coastal changes along the coast of Vere, Jamaica over the past two hundred years: data from maps and air photographs. Quat Int 120:153–161

Rodríguez Ramos R (2002) Dinámicas de intercambio en el Puerto Rico prehispánico. Caribe Arqueol 6:16–22

Rodríguez Ramos R (2007) The Puerto Rico Precolonial History etched in stone. Unpublished Ph.D. Dissertation, Department of Anthropology. Gainesville, University of Florida

Rodríguez Ramos R, Pagán Jiménez J (2006) Interacciones multivectoriales en el Circum-Caribe Precolonial un vistazo desde las Antilles. Caribb Stud 34(2):103–143

Rodríguez Ramos R, Babilonia E, Curet LA, Ulloa J (2008) The Pre-Arawak pottery horizon in the Antilles: a new approximation. Latin Am Antiq 19:47–63

Roe P (1985) A preliminary report on the 1980 and 1982 field seasons at Hacienda Grande (12 PSJ-7): overview of site history, mapping and excavations. In: Allaire L, Mayer F-M (eds) Proceedings of the tenth International Congress for the Study of the Pre-Columbian Cultures of the Lesser Antilles, Centre de Recherches Caraïbes Université de Montreal

Rouse I (1992) The Tainos: rise and decline of the people who greeted Columbus. Yale University Press, New Haven

Ruppé RJ (1980) Sea-level rise and Caribbean prehistory. In: Lewenstein S (ed) Proceedings of the eighth International Congress for the Study of the Pre-Columbian Cultures of the Lesser Antilles. Arizona State University Anthropological Research Papers, Tempe, pp 331–337

Ryzewski K, Cherry JF, Leppard T, Murphy E, Faro EZ (2010) Survey and landscape archaeology on Montserrat: a report on the pilot season, January 2010. Report submitted to the Montserrat National Trust

Scheffers A (2002) Paleotsunami in the Caribbean, field evidences and datings from Aruba, Curaçao, and Bonaire. Essener Geographische Arbeiten, 33

Scheffers A (2004) Tsunami imprints on the Leeward Netherlands Antilles (Aruba, Curaçao, Bonaire) and their relation to other coastal problems. Quat Int 120:163–172

Scheffers A, Kelletat D (2003) Sedimentologic and geomorphologic tsunami imprints worldwide—a review. Earth Sci Rev 63:83–92

Schleupner C (2008) Evavluation of coastal squeeze and beach reduction and its consequences for the Caribbean island Martinique. Ocean Coast Manag 51:383–390

Sigurdsson H, Carey S (1991) Caribbean volcanoes: a field guide. Geological Association of Canada, Toronto

Siung-Chang A (1997) A review of marine pollution issues in the Caribbean. Environ Geochem Health 19:45–55

Spenneman DHR (1987) The impact of cyclonic surge on archaeological sites in Tonga. Indo-Pac Prehist Assoc Bull 7:75–87

Spooner SQ (2004) Protecting the Caribbean's historic shipwrecks: a new model for success. Tutela, conservazione e valorizzazione del patrimonio culturale subacqueo, ICCROM, pp 331–341

Watters D (1983) Assessing the ocean's roles in Antillean prehistory. In: Allaire L, Mayer F-M (eds) Proceedings of the ninth congress for the study of the pre-Columbian cultures of the Lesser Antilles. Centre de Recherches Caraïbes, Universite de Montréal, pp 531–541

Watters D, Donahue J (1990) Geoarchaeological research on Barbuda, Antigua, and Montserrat. In: Takakis AGP, Arenas IV, Obediente MS (eds) Proceedings of the eleventh congress for International Association for Caribbean Archaeology. La Fundacion Arqueologica, Antropologica e Historica de Puerto Rico, La Universidad de Puerto Rico, Recato de Rio Piedras, United States Department of Agriculture and Forest Service. San Juan, Puerto Rico, pp 375–379

Watters D, Norton GE (2007) Volcanically induced loss of archaeological sites in Montserrat. In: Reid B, Petitjean Roget H, Curet LA (eds) Proceedings of the twenty-first congress of the International Association of Caribbean Archaeology. University of the West Indies, St. Augustine, Trinidad, pp 48–55

Watters D, Petersen J (1993) Preliminary report on the archaeology of the Rendezvous Bay site, Anguilla. In: Cummins A, King P (eds) Proceedings of the fourteenth congress for Caribbean archaeology. Barbados Museum and Historical Society, Bridgetown, pp 348–359

Wilson S (2007) The archaeology of the Caribbean. Cambridge University Press, Cambridge

Wilson S, Iceland HB, Hester TR (1998) Preceramic connections between Yucatan and the Caribbean. Latin Am Antiq 9:342–352

Yaw F Jr (2005) Cleaner technologies for sustainable tourism: Caribbean case studies. J Clean Prod 13:117–134