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# Human impacts and adaptations in the Caribbean Islands: an historical ecology approach

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ABSTRACT: Archaeological investigations demonstrate that peoples first settled the Caribbean islands approximately 6000–7000 years ago. At least four major, and multiple minor, migrations took place over the next millennia by peoples from Mesoamerica and South America who practised various subsistence strategies and had different levels of technology. For decades, researchers have been interested in investigating how these groups adapted to and impacted insular environments through time. This paper combines archaeological, palaeoecological, historical, and modern biological data to examine the effects of humans on Caribbean island ecosystems using a historical ecology approach. By synthesising a wide range of data sources, we take a human/nature dialectical perspective to understanding how peoples adapted to and modified their environments. The data suggest that earlier foraging/fishing Archaic groups (ca. 6000–3000 BP), who used a stone tool and shell technology and transported few, if any non-indigenous plants or animals, still impacted island landscapes as evidenced by bird and sloth extinctions. As more advanced ceramic making horticulturalists entered the Antillean chain around 2500 BP, there is an observable change to island environments as a result of forest clearance, overexploitation of both terrestrial and marine resources, and growing populations. Palaeoecological and palaeoenvironmental records also suggest, however, that an increased moisture regime during the late Holocene probably led to a decrease in near-shore salinity and heavier sediment and nutrient loads in rivers. These conditions would have been exacerbated by land clearance for agriculture, leading to coastline progradation, increased turbidity, and mangrove development resulting in changes to the availability of resources for humans on some islands. Although prehistoric peoples in the Caribbean were certainly impacting their environments, it was not until Europeans arrived and population centres grew that intensive and widespread degradation of island landscapes and resources occurred. Modern ecological studies, along with historical and archaeological data, indicate that hundreds of species have been driven to extinction or extirpation – many others have significantly diminished in number, especially within the last two millennia.

KEY WORDS: biodiversity, environment, prehistoric adaptations.

Oceanic islands (those that develop by processes within ocean basins), are dynamic landscapes that have evolved over time from a variety of different geological, biological, and anthropogenic processes. Charles Darwin was one of the first observers to document how island species were variations of those found on nearby mainlands and to begin contemplating the reasons behind the effects of insularity on plant and animals species via transmutation (e.g. migration and climate change) and other factors. Interest in islands was revitalised by MacArthur & Wilson (1967) in their seminal work on island biogeography. They noted that the levels of biodiversity and change to insular environments seemed to be influenced by their proximity to other land masses, physiography, and regional and global oceanographic and climatic conditions. This highly influential work, and the ideas of their predecessors, brought forth a concerted effort by anthropologists, archaeologists, and biologists in the 1960s and 1970s to discover how island biota evolved and the adaptations of human societies who occupied islands as opposed to continental land masses (e.g. Vayda & Rappaport 1963; Evans 1973, 1977; Terrell 1977, 1986).

These questions are still being asked today (see Patton 1996; Broodbank 2000; papers in Fitzpatrick (ed.) 2004) and are relevant for understanding a host of issues ranging from how islands were colonised (Keegan & Diamond 1987; Irwin 1992; Callaghan 2003), the development of exchange systems and other socioeconomic behaviours (Pearson 1990; Kirch 1991; Bass 1998), and the impact or collapse of ecosystems (Anderson 1989, 1997, 2002; Allen 1997; Martin & Steadman 1999; Grayson 2001; Rainbird 2002; Grayson & Meltzer 2003; Kirch 2004; Wroe *et al.* 2006), to name a few.

Although many forces have structured the development of island communities over the millennia, it is clear that the distance between oceanic islands and mainlands, or between islands themselves, led to many unique species of flora and fauna evolving *in situ* which can be observed in Quaternary palaeoenvironmental and archaeological records. As humans developed the technology and seafaring skills to cross vast distances of open-ocean, however, pristine island environments were no longer safe from the highly adaptable cultures of *Homo sapiens*. Humans reached the shores of distant lands, carried with them the things they needed to survive, and

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eventually began to disrupt these fragile environments through landscape modification and the introduction of non-native plants and animals (Kirch 1997a).

Archaeologists are interested in explaining how island environments changed over time prior to and after human contact, because this lends insight into what phenomena (e.g. climatic or human-induced) are responsible for these changes and how humans adapted socially, economically, and technologically (Steadman & Justice 1998; Martin & Steadman 1999; Steadman & Stokes 2002; Steadman *et al.* 2002; Steadman & Martin 2003; Erlandson *et al.* 2004). Coupled with the analysis of fossil animals and modern biological surveys of coral reef and terrestrial biosystems, we can then provide explanations with even greater resolution of how, when, and the extent to which ecological degradation may have occurred.

The objective of this paper is to use an historical ecological framework to recast the analysis of human adaptations and their impacts to islands in the Caribbean during the Middle to Late Holocene. This use of historical ecology to study ''the complex, historical interactions between human populations and the ecosystems they have inhabited'' (Kirch 1997a, p. 2; see also Crumley (ed.) 1994), has been applied in other parts of the world to observe anthropogenic changes through time. Although length considerations prevent us from completely summarising in detail all of the research that has been done regarding human settlement and adaptations in the Caribbean, we do hope to offer a context for examining the modification of islands in the region by humans prehistorically, emphasising how past and present historical records and more modern studies can help lead us on a path to better understanding human–environmental interactions. For nearly a century, antiquarians and a slew of avocational, amateur, and professional archaeologists have explored these islands in an effort to better explain where these peoples came from, their social behaviours, and how they evolved culturally and biologically through time. But only within the past twenty years or so has archaeological research provided a fuller account of prehistoric settlement, island adaptation, technological developments, and human impacts that could be satisfactorily merged with other sources of data.

This paper illustrates how an historical ecology approach can be used to explore changes to terrestrial and marine ecosystems and human exploitation of these environments. By using this perspective to link past events with present-day conditions, a better sense can be gained of the extent to which anthropogenic changes affected island environments in the Caribbean. First, the geography, palaeoclimate, and culture history of the Caribbean islands is briefly described, in order to contextualise the movements and settlement patterns of prehistoric peoples in the region in relation to fluctuating climatic conditions. The paper then examines what is currently known about native subsistence strategies and adaptations and synthesises these data sources to postulate how Amerindians may have impacted terrestrial and marine resources. The results suggest that islands in the Caribbean, like many others worldwide, were not immune to the destructive forces wrought by humans, but that prehistoric impacts pale in comparison to what occurred after European contact.

## 1. An historical ecology approach

How do we satisfactorily analyse both human adaptations and impacts to an environment? Until the 1950s, many archaeologists were environmental determinists who suggested that humans automatically responded to environmental stimuli. This is now known not to be the case, because humans have the cultural adaptability and technological sophistication to overcome and circumvent many environmental challenges. But this does not mean that the environment has not played a role in structuring human societies. After all, human groups are limited by their surroundings in the types of plants that can be grown, the kinds of animals they can capture and domesticate, and the materials available to accomplish these and other tasks.

Archaeologists, influenced by a wide array of scientific fields, have taken a keen interest in understanding how humans adapted, influenced, modified, and impacted their environment. This is a difficult endeavour, however, because ''environments change and the magnitude of change are never constant'' (O'Brien 2001, pp. 29–30). Historical ecology has been one approach increasingly recognised as a means for exploring these issues. This field of study has proven particularly useful because it combines palaeoecology, archaeological investigation, land use history, and more recent long-term (decadal) ecological research, to help examine the 'life history' of a region (Crumley (ed.) 1994; Kirch & Hunt 1997; Balée 1998; Swetnam *et al.* 1999). This interdisciplinary approach, which couples the natural sciences with anthropology, is particularly amenable for analysing island and coastal ecosystems (Kirch & Hunt 1997; Rick & Erlandson 2007). As Kirch (1997a, p. 2) aptly noted, islands were relatively stable prior to human arrival and Fosberg also (1963) stressed (for the Pacific, but certainly applicable to the Caribbean and elsewhere), that islands are extremely fragile environments more vulnerable to disturbance. Thus, we should expect to see a number of changes to islands after humans arrive, dependent of course on their subsistence strategies, population size, growth over time, and technological repertoire.

In attempting to explain how ecosystems evolved or were impacted by humans, there has been an ''understandable tendency to view [current global climatic] problems as new developments in the time scale of the human career'' (Kirch 1997a, p. 284). But by using a historical ecology approach, it is recognised that combining the efforts and data from a multitude of different scientific disciplines can more effectively answer questions regarding how landscape and marine ecosystems were modified over the course of human intervention. A good case in point of this ''renewed effort to foster collaboration'' (Balée 1998, p. xii) is the recent incorporation of archaeological, historical, and modern data by Jackson *et al.* (2001) to analyse the effects of overfishing and destruction of coastal ecosystems worldwide (named ''science story of the year'' by *Discover* magazine in 2002).

Although this approach would seem to be an obvious choice for analysing environmental changes, it has taken decades to reach this stage. The reason for this lies partly rooted in earlier beliefs by anthropologists and other researchers that native groups, particularly those who were hunter–gatherer–foragers, lived in harmony with their environment and enacted little or no visible impact to their surroundings (see Krech 1999; Nadasdy 2005). This idea of the ecologically minded 'noble savage' portrayed ''indigenous people as environmentalists par excellence'' and ''natural allies in particular environmental struggles'' (Nadasdy 2005, p. 292).

This notion, although waning in academic circles in response to recent archaeological, anthropological, and historical studies suggesting otherwise, still cultivates many philosophical dilemmas that centre on whether this is, or ever has been, a possible reality (Nadasdy 2005). However, it is clear that all humans impact their environment in some fashion and that smaller groups generally have less of an impact than larger ones. Despite this recognition having consequences for negotiating scientifically-based conservation models versus

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indigenous ones, more research is needed for understanding how human groups affected or disrupted their environments.

Archaeology is making great strides in demonstrating that humans quite frequently caused dramatic changes to island ecologies by over-harvesting resources and increasing the amount of agriculturally developed land in response to population growth, climate changes, cultural preferences, or a combination of these and other factors (Redman 1999; Carlson & Keegan 2004; Erlandson *et al*. 2004). Balée (1998) has termed the people responsible for these impacts *Homo devestans*, the antithesis of the noble savage. But it should be noted that many Native American groups are known to have enacted various conservation measures to prevent resource depletion, the degree of environmental impact caused by humans covered a wide range of possibilities, and not all impacts will be equally visible archaeologically (if at all). Natural cyclical fluctuations (e.g., El Ninõ/La Niña), which are still not well understood, may have also contributed to environmental changes separate from or in concert with human occupation (e.g. Sandweiss *et al*. 2001, 2004).

As mentioned previously, islands in many ways offer unique opportunities to observe the imprints left by humans on the environment. Not only do they tend to be isolated and ecologically fragile, but evolved over millions of years without humans. Many islands such as those in the circum-Pacific, Mediterranean, and Caribbean were also some of the last major regions to be colonised by humans. Gauging the effects of island peoples, who were in general practising more intensive forms of food production over a relatively shorter period of time (both foraging and agriculturally based), lends itself to analysing human adaptations and impacts at a finer resolution.

To satisfactorily measure the influences and impacts on island ecosystems, it is critical to determine when they were first colonised by humans, using archaeological, palaeoecological, and/or palaeoenvironmental data. With information garnered from subsequent periods of human activity up until the modern era, we can then begin to measure the effects of human arrival on the landscape and whether they are partially or completely attributable to natural, prehistoric, historic, or more recent phenomena. Although a drawback to any modelling of past environments is that it is limited to the data currently available (or 'snapshots in time'), "the more lines of corroborating evidence, the more refined the model will be" (O'Brien 2001, p. 30).

Historical ecology has great potential for understanding the underlying reasons behind landscape modification on islands and the role that human adaptations and climate shifts played in local or regional ecological changes. In contrast to other regions of the world such as the Pacific (Kirch & Hunt 1997), North America (Marquardt 1994; Bettinger 1998; Kidder 1998), South America (Chernela 1998; Rival 1998; Roosevelt 1998; Zent 1998), Mesoamerica (Melville 1998), India (Henderson 1998), Asia (Sponsel 1998) and Africa (Hassan 1994; Schmidt 1994), historical ecology has not been applied in the Caribbean *per se* (although some studies have alluded to the prospect of doing so; see Jackson 1997; Wing & Wing 2001, p. 1; Keegan *et al*. 2003; Deloughrey 2004). This is unfortunate because the present authors believe this approach has many advantages for understanding how insular environments in the region changed through successive periods of human occupation.

For example, there is a high degree of biological diversity within and between islands (Newsom & Wing 2004) that result, in part, from geographical isolation (allopatry). The extensive number of animal and plant species that existed prior to human contact allows researchers to measure, through a variety of means, the populations that existed before the arrival of humans, using this as a rough baseline for analysing subsequent changes to insular biota. Palaeoclimatic studies demonstrate that there was altered climatic variability during the Holocene with extended dry/wet periods and rising sea level that affected faunal composition that may have influenced human migration and settlement patterns. Islands in the Caribbean were settled by at least four different major migratory groups with different levels of technology and socioeconomic pursuits. Lithic foraging populations settled Cuba and Hispaniola around 6000–3000 BP. Archaic (i.e., Pre-ceramic) peoples occupied numerous islands in the Antilles as well as those islands adjacent to the South American mainland by ca. 4000 BP. Later, ceramic making horticulturalists settled the Virgin Islands, Lesser Antilles, and Puerto Rico by as early as ca. 2500 BP. And in AD 1492, European contact led to the first major migration from the Old World to the Americas. The widely varying cultures that were part of these migrations, as well as a rich collection of historical records (Jackson 1997), modern studies of coral reef systems (Lewis 2002; Bak *et al*. 2005), and increasing concern for the conservation of terrestrial and marine flora and fauna (e.g., Jackson *et al*. 2001; Hughes *et al*. 2003), provide a tremendous opportunity to explore anthropogenic changes to the islands over the course of at least six millennia.

Kirch (1997a, p. 3) noted that the Pacific Islands (although distinctly different in terms of number of islands and vastness compared to the Caribbean), have

> *. . . undergone dramatic impacts on their natural biota, in part as a consequence of animal and plant introductions since the arrival of Europeans. What until quite recently has not been generally admitted, however, is that even the preindustrial peoples [of the Pacific region] . . . have also been significant engines for ecological change.*

Although impacts to native island biota and landscape deforestation and erosion in the Pacific and Caribbean accelerated after European contact, there is a need to examine just how intensive and extensive these changes were, both in the past and the present. Because islands are harbingers of what could happen, worldwide, if stricter measures are not taken to protect and manage ecosystem diversity (Bahn & Flenley 1992; Kirch 1997a, b), it is essential that we use all of the tools at our disposal to elucidate what the mechanisms of change were to island ecologies – not just for conservation purposes, but so that island communities can develop satisfactory plans for managing their own resources.

## 2. Environmental background

The Caribbean is the world's second largest sea and seventh largest body of water. It encompasses an area of 2 754 000 km$^2$ (1 063 000 square miles) and stretches 1700 km north-south from Florida to Panama and 2300 km east-west from the Antillean chain of islands to the Yucatán. Geographically, the Caribbean is comprised of several island chains that are typically separated into four major groups – the Greater Antilles, Lesser Antilles, Bahamas, and those adjacent to the South American mainland including Curacao, Bonaire, and Aruba (Fig. 1). This is a general distinction, for other groups such as the Caymans, Virgin Islands, Turks and Caicos, and Trinidad and Tobago do not readily fit into these categories, yet are important nonetheless for examining the region's history and biodiversity.

The larger islands of the Caribbean are volcanic in origin, but those coralline in nature are far greater in number. As a result of the region's tropical climate, oceanography, and

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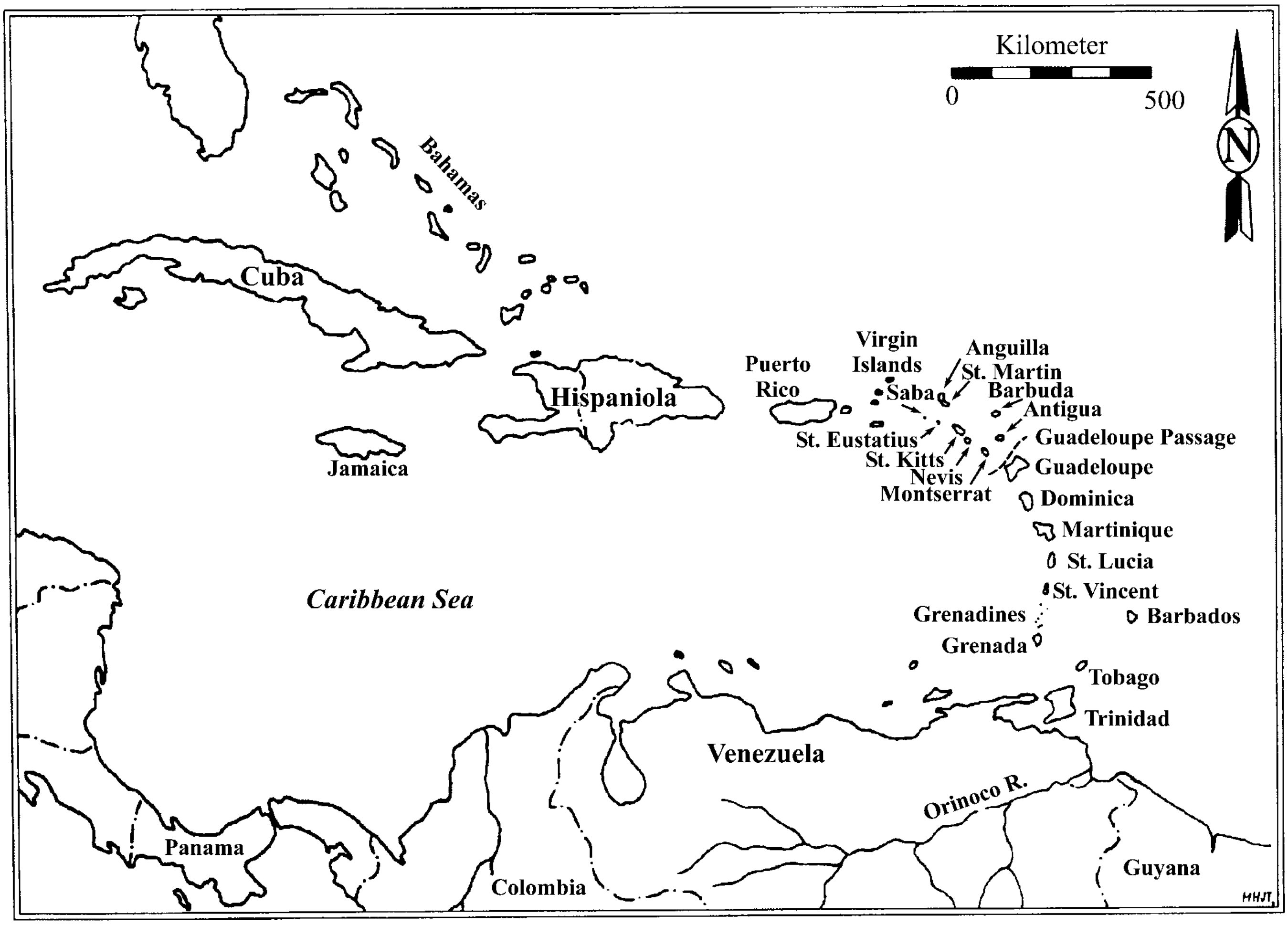


**Figure 1** Map of the Caribbean.

proximity to various physiographically distinct land masses, the Caribbean is extremely diverse ecologically. It is home to 2·3% of the world's endemic plant species and 2·9% of endemic vertebrate species – enormously significant percentages considering that the Caribbean contributes only 0·15% of the Earth's surface. In addition, there are over 1500 species of fish, 25 coral genera, 630+ mollusc species and numerous echinoderms, crustaceans, sea mammals, sponges, birds, and reptiles in marine, freshwater, brackish, and terrestrial environments. This has prompted Conservation International to designate the Caribbean as one of the world's 25 'Hotspots' – regions that are relatively small, but contain high percentages of endemic species. In fact, the Caribbean ranks among the top four of the 'Hotspots' which requires the highest priority for conservation (www.biodiversityhotspots.org).

Palaeoclimatic studies in the Caribbean, although few in number, provide some insight into how the region's biodiversity and climatic patterns changed during the Holocene. Analysis of lake core sediments in Haiti (Hodell *et al.* 1991; Curtis & Hodell 1993; Higuera-Gundy *et al.* 1999), Puerto Rico (Burney *et al.* 1994; Siegel *et al.* 2005), and St. Martin (Bertran *et al.* 2004) suggest that there were alternating wet and dry periods throughout the Holocene. However, it is difficult to say whether these regional climatic data are representative of all local conditions (see Siegel *et al.* 2005).

Higuera-Gundy *et al.* (1999) analysed stable isotopes ($\delta^{18}O$) of ostracod (*Candona* sp.) shells and pollen from Lake Miragoane in Haiti, demonstrating that conditions were generally cool and dry before 10 000 BP (see also Curtis & Hodell 1993). Palaeolimnological studies of cores from Wallywash Great Pond in Jamaica (Street-Perrot *et al.* 1993) also support this finding. Around 7000 BP, forests expanded in response to increased moisture and higher temperatures and continued until around 3200 BP. During the Late Holocene (post-3200 BP), the climate became drier (Hodell *et al.* 1991). Between 2400–1500 BP in Haiti there is a sharp increase in $\delta^{18}O$ in shellfish which are indicative of drier conditions (Hodell *et al.* 1991). But during roughly the same period between 2300–1150 BP on St. Martin, there is evidence for wetter conditions overall (Bertran *et al.* 2004).

In locations where there was heavier rainfall during the Late Holocene, decreases in near-shore salinity and heavier sediment and nutrient loads in rivers would have occurred. As land clearance for agriculture continued, the result would have been coastline progradation, increased turbidity, and mangrove development, leading to dramatic changes in resource availability for humans as clays and silts choked many mollusc and other species thriving in saline sensitive and less cloudy conditions (e.g. Keegan *et al.* 2003).

## 3. Culture history

### 3.1. Lithic and Archaic ages

The earliest colonisation of the northern West Indies dates back to around 6000 BP, when Lithic/Archaic peoples first arrived in Cuba and Hispaniola. These groups, sometimes referred to as Casimiroid (Rouse 1992; see Petersen *et al.* 2004, p. 32), probably originated from somewhere in Mesoamerica (Keegan 1994; Wilson *et al.* 1998). It is likely that Trinidad in the south was settled as early or even earlier by a different group of Archaic peoples from South America, perhaps closer

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**Table 1** List of some of the common plant and animal species introduced by humans in the Caribbean prehistorically (see Newsom & Wing 2004 for detailed lists of flora and fauna recovered from archaeological sites throughout the Caribbean; e.g. Tables 7.7, 7.8)

| | Common name | Scientific name | Age | Reference |
|---|---|---|---|---|
| PLANTS | | | | |
| Definite introduction | | | | |
| | sapodilla-type | *Manilkara* cf. *M. zapota* | Archaic | Newsom & Wing 2004, 120–121 |
| | yellow sapote | *Pouteria campechiana* | Archaic | Newsom & Wing 2004, 120–121 |
| | wild avocado | *Persea Americana* | Archaic | Newsom & Wing 2004, 120–121 |
| | manioc/cassava | *Manihot esculenta* | Ceramic | Newsom & Wing 2004, 120–121 |
| | maize | *Zea mays* | Ceramic | Newsom & Wing 2004, 120–121 |
| | anatto/achiote | cf. *Bixa orellana* | Ceramic | Newsom & Wing 2004, 200–201, table 7.7 |
| | Panama tree | *Sterculia* (*apetalia*) | Ceramic | Newsom & Wing 2004, 120–121 |
| | papaya | *Carica papaya* | Ceramic | Newsom & Wing 2004, 200–201, table 7.7 |
| | tobacco | *Nicotiana rustica* | Ceramic | Newsom & Wing 2004, 120–121 |
| | Cojoba (cojóbana) | *Anadenanthera peregrine* | Ceramic | Newsom & Wing 2004, 4 |
| | pepper | *Capsicum* (*annuum*) | Ceramic | Newsom & Wing 2004, 200–201, table 7.7 |
| | peanut | Fabaceae | Ceramic | Newsom & Wing 2004, 120–121 |
| Probable introduction | | | | |
| | sweet potato | cf. *Ipomea batatus* | Ceramic | Newsom & Wing 2004, 200–201, table 7.7 |
| ANIMALS | | | | |
| Definite introduction | | | | |
| | Dog | *Canis familiaris* | Ceramic | Newsom & Wing 2004 |
| | Opposum | *Didelphis* sp. | Ceramic | Newsom & Wing 2004 |
| | Agouti | *Dasyprocta leporine* | Ceramic | Newsom & Wing 2004 |
| | Guinea pig | *Cavia porcellus* | Ceramic | Newsom & Wing 2004 |
| | Shrew | *Nesophontes edithae* | Ceramic | Newsom & Wing 2004 |
| | Hutia | *Isolobodon portoricensis* | Ceramic | Newsom & Wing 2004 |

to 6000 BP. But its proximity to South America and lower sea-levels (Steadman & Stokes 2002, p. 359), which lessened the distance between these landmasses, makes the island's colonisation history different and peripheral from that of the oceanic islands (Keegan 1994, p. 259).

Archaic peoples from South America (or 'Ortoiroid', see Rouse 1986, 1992; Petersen *et al*. 2004, p. 32), occupied the Lesser Antilles from about 4000–2500 BP, but most of the well-established and dated sites during this period are in the Leeward (northern) islands in the Antillean chain. Some of the better known Archaic age sites are found on St. Thomas (A. E. Figueredo, unpublished data; Lundberg 1989), Anguilla (Crock *et al*. 1995), Barbuda (Watters *et al*. 1992), Guadeloupe (Richard 1994), Antigua (Davis 2000), and Saba (Hofman & Hoogland 2003; Hofman *et al*. 2006). Most Archaic sites are situated in coastal environments with good access to marine resources and in the case of Antigua, flint resources. Artifact assemblages typically consist of flint flakes, some ground stone and shell (*Strombus gigas*) tools, and an absence of blade technology.

Archaic sites in the Virgin Islands and Puerto Rico have been classified into three groups and are described by Keegan (1994, p. 268). These include the Coroso complex from Vieques which contains flaked stone, *Strombus* columella tips, quartz, and pebble tools used for percussion and grinding; the Cayo Cofresí complex from eastern Puerto Rico has ground-stone pestles; and Krum Bay on St. Thomas is characterised by flaked stone and pebble hammerstones and grinders, crudely made bifacial celts or wedges, shell beads and disks, coral files, and *Strombus* columella tips (see also Lundberg 1991). On Cuba, sites associated with the Redondan Casimiroid series are found in both open and rockshelter sites along interior and coastal areas. As Keegan (1994, p. 269) notes, the Cuban Archaic has the most extensive shell tool varieties with cups, tips, hammers, gouges, and plates being produced, along with flaked and ground-stone artefacts.

It should be noted that the origins of Archaic peoples in the Greater and Lesser Antilles is still under investigation and highly debated (see Lalueza-Fox *et al*. 2003; Keegan 2006). Despite some apparent features which are common in both the shell and lithic assemblages between the two regions (see Crock *et al*. 1995; Davis 2000, p. 99), the extent of their interconnectivity is unclear (Lundberg 1989, 1991; Keegan 1994, p. 268). Further research is needed to clarify the technological attributes of Archaic age sites and to develop better chronologies of site occupation and use.

### 3.2. Ceramic age

Around 2500 BP, ceramic-making horticulturalists known as Saladoid migrated from South America and reached Puerto Rico and islands throughout the Lesser Antilles (Keegan 2000). During this time, people primarily settled in littoral zones, exploited a wide array of locally available marine and terrestrial resources, and supplemented these with non-indigenous plants and animals transported from the mainland or neighbouring islands, including the hutia (*Islobodon portoricensis*), agouti (*Dasyprocta leporina*), rice rat (*Oryzomys* sp.), guinea pig (*Cavia porcellus*), and a variety of plants, the most important of which was manioc (cassava; *Manihot esculenta*) (see Table 1 for list of introduced plants and animals). Archaeological evidence suggests that coastlines, for a variety of reasons, were essential to the successful long-term occupation of these islands.

Although further research is needed to fully address colonisation strategies, settlement patterns, and radiocarbon chronologies of Ceramic age sites in the Caribbean (see Fitzpatrick 2006), particularly in the southern Lesser Antilles, it is generally agreed that nearly every island in the Caribbean was settled by ca. 2200 BP. After Saladoid peoples arrived, these habitats began to change, due to a combination of horticultural activities, landscape modification, intensive resource exploitation, and newly introduced plants and animals that often disrupted the ecological balance of these islands.

### 3.3. Historic period

Historically, the Caribbean is just as notable, for it was here that Columbus, probably in the Bahamas, first 'discovered' the New World on October 12, 1492. This paved the way for a slew of explorers, traders, and missionaries into the Americas during the next few centuries. Columbus made a total of four voyages to the New World between 1492 and 1502, in which he explored the West Indies and the coasts of South and Central America.

One of the most enduring legacies of European contact was the 'Columbian Exchange' in which innumerable plants, animals, people, and communicable diseases were transferred between the Old and New Worlds (Crosby 1972). This had profound effects on cultures around the world as new foods such as potatoes, tomatoes, and maize were brought to Europe and Africa and in return livestock, breadfruit, and sugarcane was transported and grown in the Caribbean. These and a multitude of other products were incorporated into the daily cuisine of peoples worldwide and began to fuel trade and interaction between Europe, the Americas, Africa, and Asia. One result is what Crosby (1972) has described as the 'homogenization' of the neo-tropics.

One of the most unfortunate consequences of this exchange was the transmission of infectious diseases such as smallpox, measles, and influenza into the New World that indiscriminately wiped out millions of native Amerindians in the New World. The slave trade also had a profound influence on Caribbean island economies as the Dutch, Portuguese, British, Spanish and French competed for control of the West Indies and economic supremacy in Europe.

## 4. Subsistence strategies and anthropogenic changes

### 4.1. Archaic age

One of the main issues for an historical ecology of the Caribbean is deciphering the impact of the islands' earliest human inhabitants. Although foraging communities may enact little disturbance, research shows that the cumulative effects of ongoing cultural development in conjunction with land clearing activities using fire, for example, can be devastating (see Sponsel 1998). In the Caribbean, it has long been assumed that Archaic peoples lived in small, mobile bands and that they lacked ceramics and did not practice agriculture (Rouse 1992). At the extreme they have been characterised as troglodytes (Osgood 1942). Yet there is mounting evidence that they regularly made and used pottery, managed and possibly cultivated plants, lived in permanent villages, and that their impacts on the landscape were substantial (Keegan 1994; Rodríguez Ramos 2005a, b; Siegel *et al*. 2005). Furthermore, they are credited with the extinction of sloths on Hispaniola and the local extirpation of manatees (Veloz Maggiolo & Ortega 1973; Veloz Maggiolo & Vega 1982).

Unfortunately, comparatively little is know about Lithic or Archaic (so-called 'Preceramic') subsistence strategies in the Caribbean. Based on limited information, it appears that Archaic peoples were fisher-foragers and that each site's occupants subsisted on a different set of primary foods (Keegan 1994, p. 270) consisting of fish, turtles, and invertebrates from reef and near shore habitats (Davis 1988; Narganes Storde 1991). It was once thought that Archaic peoples had little effect on the insular environments; however, research on fossil bird (Pregill *et al*. 1994) and other animal remains (Carlson 1999) clearly show that island ecologies were degraded before Saladoid peoples arrived.

In addition to marine foods, recent investigations at the inland site of Plum Piece on Saba (Hofman & Hoogland 2003; Hofman *et al*. 2006) reveal an interesting case of Archaic inhabitants focusing on land crabs (*Gecarcinus ruricola*) and bird species such as the Audubon's Shearwater (*Puffinis lherminieri lherminierii*). According to Hofman & Hoogland (2003) who excavated Plum Piece, the faunal assemblage and stratigraphic details suggest that peoples were seasonally visiting the site and were not transporting marine fish or shellfish inland (based on the low number of bones and mollusc remains). Mortars and pestles also indicate that site inhabitants were processing seeds and/or berries. This supports the likelihood that Archaic peoples were not simply foragers, but also cultivating plants such as zamia or coontie (*Zamia debilis*), cupey (*Clusea rosea*), *Sterculia* sapodilla (*Manilkara* [*zapota*] sp.), yellow sapote (*Pouteria campechiana*), wild avocado (*Persea Americana*), mastic-bully (*Mastichodendron foetidissimum*), primrose (*Oenothera* sp.), trianthema (*Trianthema portulaca*), palm nutshells (*Acrocomia media*), West Indian cherry (*Malphigia* sp.), and wild fig (*Ficus* sp.) as evidenced by palaeobotanical remains (Newsom 1993; Newsom & Pearsall 2002; see also Keegan 1994, p. 270; Newsom & Wing 2004, p. 120). Because some of these plant species such as the sapodilla (which originates from Mexico and Central America (Liogier & Martorell 2000, p. 154)) are not indigenous to the Caribbean, it is likely that they were at least managed, if not totally cultivated (Newsom 1993).

Research on Antigua (Davis 2000, pp. 91, 101) suggests that subsistence strategies during this the Archaic age involved capturing less than ten major mollusc species from shallower marine environments such as mangroves and both sandy and rock shores, with some contribution from a few other shellfish taxa, fish, turtle, and manatee. The Jolly Beach site inhabitants appear to have relied more heavily on terrestrial species, including lizards and birds (Davis 2000), but this is much different than other similarly dated Archaic sites where subsistence has been investigated in any detail.

Overall, archaeological investigation of several Archaic age sites demonstrate that there was heavy exploitation of marine fishes (particularly parrotfish, but also grouper, snapper, and grunts) and sea turtles on some islands such as Tobago (Steadman & Stokes 2002) and that terrestrial vertebrates were uncommon, with no evidence of introduced mammals (see Newsom & Wing 2004, p. 129). Data from Archaic sites in the Caribbean thus far seems to indicate that peoples were fairly mobile, intensively exploited foods that were locally available, and did this by occupying sites seasonally to take advantage of certain resource concentrations.

### 4.2. Ceramic age

Saladoid (ca. 2500 – 1400 BP) peoples during the Ceramic age primarily settled in littoral zones, although both inland and coastal areas were occupied simultaneously (Keegan 2000, p. 141). Saladoid subsistence strategies involved hunting land and sea animals, fishing, collecting shellfish, and the cultivation of root crops, the most important of which was bitter manioc (*Manihot esculenta*), as well as a number of different fruits, tubers, and seeds (Newsom 1993; Keegan 2000, p. 142). Manioc was a South American staple and introduced to the islands by Saladoid peoples who also brought with them the technology for processing and preparing the tuber – ceramic griddle fragments for cooking cassava bread are common at Ceramic age archaeological sites. However, marine foods were extremely important contributions to the diet, probably more so than cultigens and terrestrial animals combined.

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The Caribbean islands have an impoverished terrestrial fauna that included smaller rodents such as rice rats, hutia, and agouti (only the former of which was native), birds, iguanas, and land crabs. Marine resources, a prime attractant to colonists, included sea turtles (Cheloniidae), parrotfishes (Scaridae), jacks (Carangidae), snappers (Lutjanidae), grunts (Haemulidae), groupers (Serranidae), the Queen conch (*Strombus gigas*), and West Indian Topshell (*Citarrium pica*; Newsom & Wing 2004, pp. 67–68). Technologies for fishing included hook and line, spears, traps, poison, and nets, to name a few. Turtles could be easily captured on beaches during egg-laying cycles and many molluscs could simply be collected from beach and rocky shores without any special tools.

Analyses of plant and animal remains throughout the Antilles reveal a diversified subsistence and economic base that changed through time during the Ceramic age. When the Saladoid site of Hichmans on Nevis is compared to two other post-Saladoid sites on the island, Indian Castle and Sulphur Ghaut, there is an observable transition between the most commonly found taxa based on the Minimum Number of Individuals (MNI; Newsom & Wing 2004, p. 100). For example, there is a significant decrease in rice rats (30% versus 7% and 5%) and land crabs (38% versus 5% and 1%), and an increase in *Donax* shells (0% versus 14% and 78%). The average weight of the major fishes and landcrabs also decreases through time at the Nevis sites, Hope Estate on St. Martin, and Tutu on St. Thomas (Newsom & Wing 2004, pp. 102–104, 139), suggesting that taxa were stressed, smaller individuals were more commonly taken as time progressed, and that this was a result of overexploitation.

Beginning around 1000 BP, there appear to be some major social and environmental transitions seen in the archaeological record. The reasons for the changes are not yet clear, in part because they involve the complex interplay of nature and culture that is at times difficult to decipher given the current evidence. Environmental data indicate a period of extremely dry conditions that within four centuries would change to a period of wetter conditions and an episode of eustatic sea-level rise (Hoddell *et al.* 1991; Scudder 2001). A wetter climate would have had a significant influence on agricultural potentials, whilst a rise in sea level would have impacted the distribution and availability of near shore environments. During this period, the pottery styles in the islands changed dramatically (Rouse 1992), although subsistence practices seem to have remained relatively unchanged (Stokes 2005). In the southern Lesser Antilles, the shift from the Saladoid to Troumassoid (ca. 1400 – 600 BP) series of pottery might be explained as the reconfiguration of interaction spheres (Keegan 2004), new influences from South America (Boomert 2000), or as a loss of confidence in the old gods that promoted a change in the iconography presented on pottery vessels (Petitjean Roget 2001). There are numerous co-determined variables that have not yet been completely analysed or resolved. One is that in Puerto Rico, we see the development of Ostionoid pottery beginning around 1400 BP, which is then seen in Hispaniola. Does this mean that a new style spread west from Puerto Rico or does it reflect the adoption of pottery by Archaic peoples (Keegan 2006)?

Much of the data on plant and animal exploitation during the Ceramic age in the Greater Antilles comes from Puerto Rico, and to a lesser extent Jamaica and Hispaniola. Although this somewhat limits our interpretation of what is happening culturally in this part of the Caribbean, the data do seem to suggest that the number of trees found in archaeological sites, for example, are more extensive due to the size of the islands and richer biodiversity (Newsom & Wing 2004, pp. 142–153). In addition, marine foods and manioc cultivation, still important contributors to the diet, were complemented with maize (*Zea mays*) and possibly sweet potato (cf. *Ipomoea batatas*), perhaps a wild variety of *Ipomoea* spp. (Newsom & Wing 2004, p. 154).

In general, the trend overall during the Ceramic age is the expansion of Amerindian groups from South America into virtually every island group in the Caribbean (with the exception of the Caymans), the introduction of several new species of plants and animals, a general decrease or extermination of several indigenous species of fish on many islands, crabs, rats, and birds, and an increased reliance on terrestrial and/or horticulturally important foods that required the clearance of forests.

### 4.3. Historic period

The historic period saw a great deal of changes to terrestrial and marine ecosystems. Some of the larger anthropogenic effects resulted from deforestation, to create arable land for growing a variety of indigenous and non-native plants brought in from Europe or other parts of the world as global trade and European influence spread to Africa, the Pacific, and Asia. Commercially or economic important crops included coconut, ginger, plantains, potatoes, sugarcane, taro, tobacco, cotton, and coffee. Sugarcane, indigenous to Oceania and brought into the Caribbean, was by far the most lucrative and profitable product, with numerous plantations built in the beginning of the 16$^{th}$ century to produce raw sugar, molasses, and rum for export (see Mintz 1985; various chapters in Farnsworth 2001).

Some of the most prolific changes to terrestrial and marine environments in the Caribbean were the result of agricultural activities. This is clearly evident during the last 200 years, in which large scale development, population growth, and agricultural land has expanded for economically important crops (Higuera-Gundy *et al.* 1999, p. 166). Richardson (2004) demonstrates how fire was used (and feared) by colonists throughout the British West Indies to clear forests of native vegetation (as is easily seen on Barbados, Anguilla, and Antigua) (Richardson 2004, pp. 26–27). There was probably no other agent as effective in permanently altering the ecologies of Caribbean island landscapes as fire.

Other industries such as whaling and fishing were also extremely important to the livelihoods of people in the Caribbean (Jackson 1997), with manatees, humpback whales (Romero *et al.* 2002), and turtles (Jackson 1997; Carrillo *et al.* 1999) the most commercially harvested historically. Efforts to capitalise on the local availability of these and other large sea mammals and vertebrates have been intense and not typically managed with conservation in mind, leading to significant reductions in modern-day populations (Marmontel *et al.* 1997; NOAA 2004).

## 5. Impacts and modifications to floral and faunal populations

Thus far, the general chronologies and subsistence strategies of different migratory groups in the Caribbean have been reviewed, as well as some of the major climatic trends that are observable in palaeoenvironmental records. The paper now turns to discussing how these various sources of data can be used to reconstruct how humans impacted these island environments.

### 5.1. Flora

Environmental changes during the Late Pleistocene are known to have affected the insular flora and fauna of the Caribbean prior to human contact. It was during the Younger Dryas

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(ca. 10 000 BP) that sea level rise and increasingly wet and humid conditions reduced habitats and drove many vertebrates to extinction (Pregill & Olson 1981). As humans began to settle islands in the Greater Antilles and those adjacent to the South American mainland, what effect did they have on insular floral biota?

Palaeobotanical evidence from Haiti, in the form of increasing charcoal counts around 5400–2500 BP, suggests that humans may have been clearing forested land (Higuera-Gundy *et al*. 1999). Burney *et al*. (1994) also made a similar argument for Puerto Rico beginning around ca. 5300 BP (see Siegel *et al*. 2005). Both of these signals may coincide with human arrival, although the archaeological evidence for Archaic age sites on both islands is sparse.

With drying conditions leading up to the Late Holocene, forest expansion in Haiti is evident by higher percentages of *Cecropia* and *Celtis* pollen from 1730–1000 BP (Higuera-Gundy *et al*. 1999, p. 166). It is possible that this temporary return of forest during the increased moisture regime ''stabilized watershed soils and reduced sedimentation rates'' (Higuera-Gundy *et al*. 1999, p. 166). By around 1000 BP, Ostionoid peoples practising agriculture had settled the area when drier conditions returned, although it is debatable whether Ostionoid was part of a new settling group from Puerto Rico around this time, or if they were simply descendants of earlier Archaic peoples in Haiti (Keegan 2006). Regardless, the last 3000 years saw marsh expansion and a decline in the level of Miragoane Lake, possibly as a result of siltation from clearing agriculturally productive land. On Andros Island in the Bahamas, there is a higher incidence of charcoal in pond sediments dated to the time of human occupation and evidence that the hardwood forest was being replaced by pines (Kjellmark 1996).

Based on palaeobotanical evidence from several archaeological sites (Newsom 1993), it is likely that even the earliest settlers during the Archaic age were practising some form of cultivation. ''A tradition for gardening and cultivating useful plants was derived from the mainland and undoubtedly modified for each island's ecosystem'' (Newsom & Wing 2004, p. 108; see also deFrance & Newsom 2005). Fruit trees such as the sapodilla, guava, sea grape, hog-plum, and soursop are found, as are a number of other plants that were important for medicinal purposes, fuel, or constructing houses and canoes. Some preliminary evidence from Nevis and St. Martin suggest that there was a prevalence of secondary growth and weeds during the later prehistoric period indicative of disturbed conditions (Newsom & Wing 2004, pp. 108–109). Herbaceous plants typically found in disturbed habitats (e.g. purslane, trianthema, croton, panicoid grass) suggest ''landscape changes that were probably brought about by human pressure on mature forests . . .'' (Newsom & Wing 2004, p. 110).

Although Archaic peoples likely cultivated a variety of plants, it was the arrival of Saladoid horticulturalists who brought with them not only new plant species, but a number of different animals such as the dog (*Canis familiaris*). The effect of increased land clearance for manioc production, along with a spike in number of archaeological sites found during the Ceramic age (Keegan 2000), placed even greater pressure on terrestrial and marine ecologies.

Within the past few decades, widespread deforestation, increasingly sophisticated forms of agriculture, eutrophication, oil pollution, and industrialisation have caused ''widespread and dramatic decline of coral reefs and associated marine communities throughout the region'' (Jackson 1997, S28; see also Cortes & Risk 1985; Rogers 1985; Jackson *et al*. 1989). On Barbados, aerial photographs from 1950–1991, and direct examination of coral reef health (Lewis 2002), clearly show the decimation of reef structures. Both natural and cultural factors may be to blame (Lewis 2002, p. 54), although storm damage could have also possibly played a role. Sugarcane production on Barbados, which began in the early 1600s, led to extensive deforestation and only a fraction of the original flora present at contact still exists today. Along with several hurricanes that occurred during that same century, sediment runoff was probably tremendous (see Jackson 1997, S28; Lewis 2002).

## 5.2. Fauna

Higuera-Gundy *et al*. (1999, p. 169) suggest that faunal extinctions followed climatically dry (xerophytic) conditions and that human activities may not have drastically affected terrestrial biota. Some endemic rodents, mammal species, and ground sloths persisted until ca. 5000–3000 BP, overlapping with human occupation for a period of several thousand years (Woods 1989). Despite humans and many now extinct animals coexisting together during the Middle Holocene, Higuera-Gundy *et al*. (1999) suggest that human impact may not have been the driving force behind the disappearance of many land taxa (see also Steadman *et al*. 2005).

However, it does appear that Amerindian populations played a key role in driving many animals to extinction through forest clearance, predation, and the introduction of non-native species that out-competed or preyed upon indigenous species. Steadman *et al*. (2005) argue that in the case of the sloths at least (Phyllophaga and Senarthra), the dates of extinction on continents and islands in the West Indies correspond with that of human arrival and do not follow an established period of climate change. The Couri culture in Haiti, who produced blade tools into spear points, backed knives, and end scrapers (Keegan 1994, p. 268), and probably used them for hunting manatees, whales, crocodiles, and sloths (Veloz Maggiolo 1991, p. 101; Rouse 1992, p. 58), may have contributed to these extinctions.

Although palaeobotanical studies and the extinction of some land taxa appear to coincide with human occupation, there is a dearth of archaeological evidence of peoples settling the Antilles prior to around 2500 BP, particularly in the southern islands. Much better documentation exists for Saladoid peoples who migrated from South America. How did this event change the course of the island histories in terms of faunal populations?

The decline of land crabs (both in size and numbers) during the Terminal Saladoid (ca. 2000–1400 BP) period is one of the more noticeable impacts. This was first noted by Rainey (1940) who deemed it the 'crab culture' because of the abundance of crab remains in lower strata and a commensurate decrease of them in upper strata along with an increase in molluscs. The decline of crabs is also known to occur during subsequent phases of human occupation (Newsom & Wing 2004, pp. 110–111) and is probably a result of both increased aridity and overexploitation by humans (Carlson & Keegan 2004, p. 88).

There is also evidence that marine fish, particularly those from reef environments, were being overharvested throughout the Caribbean during the Ceramic age (Wing & Wing 1991). This decrease is also accompanied by a decline in the estimated reef fish biomass, the mean trophic level (Wing & Wing 2001), and ''average size of the individuals in each family, and relative decrease in more aggressive carnivorous species with a corresponding increase in herbivorous and omnivorous species'' (see Newsom & Wing 2004, p. 111, tables 6.7 and 6.8).

This is particularly evident at the sites of Hichmans and Indian Castle on the island of Nevis where the abundance of carnivorous reef fish (e.g. groupers) in earlier deposits are twice that of herbivorous fish (e.g. parrotfish, surgeonfish), and then decline to only 10% of the total (Wing 2001). Coinciding with


**Figure 2** *Strombus gigas* was one of the most important resources in the Caribbean for food and producing tools such as adzes. They are common constituents of Ceramic Age sites as can be seen from this photo from the Grand Bay site on Carriacou (note shells in both foreground and in excavation unit).

changes in reef fish assemblages is an increase in pelagic fish such as tuna, jacks, and flying fish (Newsom & Wing 2004, pp. 111–112). The move from nearshore to offshore fisheries (an arguably riskier endeavour), may have resulted from the overpredation of reef taxa and also led to a heavier focus on horticulturally important food crops such as manioc to compensate for more widely available and easily accessible marine species. It is important to note that evidence from Anguilla suggests that not all prehistoric inhabitants of the Caribbean overharvested fish (Carder *et al*. 2007). With increased pressure to provide food to a growing population, land clearance for producing fuel and arable land would have also increased, and with it, erosion and infilling of local embayments and expansion of mangrove habitats.

The overexploitation of shellfish species such as *S. gigas* has also been documented during the late Ceramic age in Jamaica (Keegan *et al*. 2003). From Ostionan to Meillacan times here (ca. 1200–600 BP), there are shifts in mollusc use that appears to be due to the replacement of seagrass habitats by mangrove and muddy substrates and overfishing of strombids that were continually reduced as environments changed. Part of this depletion may also be related to the need for additional molluscan biomass as sea turtles, larger fish, and *S. gigas* declined (Keegan *et al*. 2003, p. 1615; Fig. 2).

The depletion of other faunal resources is also evident throughout the northern Caribbean in Jamaica, the Bahamas, and Haiti (Carlson & Keegan 2004). When available, sea turtles, birds, iguanas, and land mammals were typically targeted first and in many cases, later inhabitants could no longer exploit them. On Grand Turk, both marine and terrestrial resources were overexploited, but not completely eliminated (Carlson & Keegan 2004, p. 102). Evidence from both preceramic and ceramic age sites on Tobago demonstrates that there was an emphasis on sea turtles which rarely nest on the island today (Steadman & Stokes 2002).

Historically, the effects of new European-based technologies for farming, extensive land clearing for agriculture and settlement, the introduction of Old World plants and animals such as cattle, horses, pigs, and sheep (Salvaggio 1992), and overfishing and hunting led to major alterations of island ecosystems in the Caribbean. Jackson (1997) describes some of the biggest impacts to marine fauna since the arrival of Columbus, focusing, in part, on the decrease of turtles from overhunting, and the general overexploitation of fish.

Larger marine animals such as manatees, stingrays, and whales are extremely important ecologically, but are much rarer today than historical records suggest was present at contact. Today there are very few manatees left in the Caribbean due to poaching, pollution of habitats, and accidental deaths (Romero *et al*. 2002; Mignucci-Giannoni *et al*. 2000). Whaling, never a focus for prehistoric peoples, was a primary source of income for Europeans, especially in the early to mid-1800s. Humpbacks (*Megaptera novaeangliae*), in particular, were hunted extensively. Although they still occupy

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waters where they were known historically, their numbers are severely depleted (Reeves *et al.* 2001; Romero *et al.* 2002; Smith & Reeves 2003).

In Jamaica, there was little agriculture when the British captured the island in 1655, and so locals began harvesting green turtles on Grand Cayman which provided a majority of meat consumed up until the 1730s (Sloane 1707–1725; Long 1774; from Jackson 1997, S26). The Caymans are an especially interesting case, because present evidence indicates that they were not settled prior to the arrival of Europeans (Scudder & Quitmyer 1998; Stokes & Keegan 1996). Based on his calculations using historical sources, Jackson (1997, S26–27) estimated that there may have been between 33–39 million total adult turtles in the Caribbean. This would seem to support accounts from chroniclers such as Andres Bernaldez on Columbus' second voyage in 1494 (from Jackson 1997, S27), who said:

*But in those twenty leagues, they saw very many more, for the sea was thick with them, and they were of the very largest, so numerous that it seemed that the ships would run aground on them and were as if bathing in them.*

Although we should be cautious in taking these historical descriptions at face value, it is clear that turtle populations today, based on chronicler accounts and more detailed surveys (e.g. Carrillo *et al.* 2002), are nowhere near the numbers that were present before European contact. Turtles have felt the brunt of human exploitation, especially evident during the 1700s and 1800s when hawksbill (*Eretmochelys imbricata*) shells became highly prized in Europe and where the eggs and meat were harvested for consumption. Even in the late 1800s, people were still migrating to Cuba to establish turtle fisheries (Carrillo *et al.* 2002, p. 266) and the heavy exploitation of turtles here continued throughout the 1900s. It was not until the early 1990s that the Cuban government moved away from turtle fisheries – not as a part of CITES (Convention on International Trade in Endangered Species) *per se* (they lodged a reservation for hawksbills so that they could continue trading the shell internationally) – but so they could focus on more profitable fishery exports. Carrillo, *et al.* (1999, p. 264) report that approximately 170 000 hawksbill turtles, equalling 8600 metric tons live body weight, were harvested in Cuba between 1935 and 1994. Although it is difficult to quantify the numbers of turtles taken prior to detailed record keeping and whether historical captures were actually sustainable, research does suggest that Cuba did not completely overexploit hawksbill populations which may be partly a result of most nesting areas being located on uninhabited offshore islands (Carrillo *et al.* 2002, p. 278). Regardless, six out of seven species of turtle in the Caribbean today are in danger of extinction from human overexploitation and loss of nesting beaches.

Other larger sea mammals like the Caribbean monk seal (*Monachus tropicalis*), have not been so fortunate. *M. tropicalis*, the only seal native to the Gulf of Mexico, was first reported by Columbus in 1494. It was last seen in 1952 on the banks between Jamaica and Honduras and was declared extinct in 1996. The monk seal was harvested extensively for its oil and was easily captured, thus leading to its early demise.

Evidence has shown too that molluscs such as the queen conch (*S. gigas*), a ubiquitous component of Caribbean archaeological assemblages, were being overharvested prehistorically and have declined from fishing pressure throughout the circum-Caribbean (Brownell & Steveley 1981; Weil & Laughlin 1984; Stager & Chen 1996; Torres 2003). It should be noted, however, that although fishing pressure may have been selecting for faster maturation rates of *S. gigas* (Stager & Chen 1996, p. 18) at different points in time, that this could also be related to the alteration of suitable habitats for planktonic veligers into nurseries, leading to a decline in near shore populations (Keegan *et al.* 2003, p. 1614). It is critical to note that when attempting to model changes in the quantity and size of certain animal species through time, it is necessary to determine the availability of resources, environmental conditions, and cultural factors (Torres 2003).

## 6. Discussion

In this paper we have highlighted some of the factors that led to the successful adaptation of humans to islands in the Caribbean and the resulting impacts they had on terrestrial and marine biota. Archaeological research throughout the region demonstrates that prehistoric human populations were maritime oriented, but also exploited a wide range of native flora and fauna, and brought with them non-native species that were critical components to the prehistoric diet. These subsistence strategies, including horticulture, impacted island ecologies and are visible in archaeological and palaeoecological records.

At present, all we can offer is initial observations and the call for more a detailed consideration of the historical ecology of the West Indies. At issue is what ecologists have called a 'shifting baseline' (see Pauly 1995; Bohnsack 2003; Myers & Worm 2003). At first it was presumed that Archaic groups had no significant impact on the ecologies of the islands. It is now known that this belief is false. Furthermore, ecologists have assumed that human impacts were minimal during all of prehistory with regard to near-shore habitats and certain marine species. For example, Karen Bjorndal, Director of the Center for Sea Turtle Research at the University of Florida, recently acknowledged that she was wrong in thinking that there were no major impacts on sea turtle populations prior to the arrival of Europeans. Her change of heart was based on archaeological evidence from the Turks & Caicos Islands (Carlson 1999).

Analyses of faunal assemblages demonstrate that human groups overexploited a number of resources (Table 2). This appears to be especially evident during the last 2000 years or so, after Saladoid peoples entered the Antilles from South America. Wing (2001), in her examination of archaeofish and shellfish remains on St. Thomas, St. Martin, Saba, and Nevis, noted a decline in the size of land crabs, West Indian top shell, and reef fishes, probably as a result of overexploitation. With a decline in reef fishes also came an increase in the capture of offshore fish.

Here again is another misplaced baseline. It is assumed that Ceramic Age groups had a limited impact on the ecology of the islands and to some degree (e.g. fishing in Anguilla during the post-Saladoid; Carder *et al.* 2006), this may have been the case. But, this is an assumption that needs to be investigated. On Grand Turk, the one small island that we seem to have good evidence for the first human inhabitants, the seasonal population extirpated sea turtles, iguanas, large fishes, and an indigenous tortoise (Carlson 1999; Carlson & Keegan 2004). If the first inhabitants on Grand Turk had such a profound impact on the local marine and terrestrial ecology, then why do we not see birds and other species that disappeared first when humans arrived at supposedly early sites throughout the Caribbean?

Moreover, on other small islands, the prehistoric record shows a reliance on *S. gigas* in the one-to-two-year-age class (Carlson & Keegan 2004). Yet only recently have biologists begun to investigate the local impacts on mollusc populations

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**Table 2** List of the most common terrestrial and marine taxa exploited over time by humans in the Caribbean based on current data. It is important to note that the intensity of exploitation of certain species such as Queen Conch has varied geographically and some populations may be under less threat than others depending on legislation and restrictions implemented by host countries. Bird species have not been included due to the sheer number known to have been exploited by humans prehistorically, but see Steadman & Stokes 2002; Steadman *et al.* 1984a, b, 2005. (X)=intensively; (O)=occasionally; (N)=never; (U)=unknown; (E)=extinct; (EP)=extirpated; (N/A)=not applicable)

| | Common name | Scientific name | Captured prehistorically? | Captured historically? | Currently captured legally? | Current general status (year listed on endangered list) | Reference |
|---|---|---|---|---|---|---|---|
| MARINE | | | | | | | |
| Molluscs | Queen conch | *Strombus gigas* | X | X | X | overfished; threatened | Keegan *et al.* 2003; Newsom & Wing 2004; Theile 2001 |
| | West Indian topsnail | *Cittarium pica* | X | X | X | unknown | Newsom & Wing 2004 |
| Finfish | parrotfish | Scaridae | X | X | X | generally not harvested | Carlson & Keegan 2004; Newsom & Wing 2004; NOAA Office of Sustainable Fisheries |
| | grouper | Serranidae | X | X | X | overfished (e.g., Bahamas) | Newsom & Wing 2004; NOAA Office of Sustainable Fisheries (2004 Stock assessment report) |
| | snapper | Lutjanidae | X | X | X | many species overfished | Newsom & Wing 2004; NOAA Office of Sustainable Fisheries (2004 Stock assessment report) |
| | grunts | Haemulidae | X | X | X | unknown | Newsom & Wing 2004; NOAA Office of Sustainable Fisheries (2004 Stock assessment report) |
| | surgeonfish | Acanthuridae | X | X | X | unknown | Newsom & Wing 2004; NOAA Office of Sustainable Fisheries (2004 Stock assessment report) |
| | jacks | Carangidae | X | X | X | unknown | Newsom & Wing 2004; NOAA Office of Sustainable Fisheries (2004 Stock assessment report) |
| Sea turtles | hawksbill | *Eretmochelys imbricata* | X | X | N | endangered (1970) | Newsom & Wing 2004; NOAA Office of Sustainable Fisheries (2004 Stock assessment report) |
| | loggerhead | *Caretta caretta* | X | X | N | endangered (1978) | Carlson & Keegan 2004; Newsom & Wing 2004 |
| | green | *Chelonia mydas* | X | X | N | endangered (1978) | Carlson & Keegan 2004; Newsom & Wing 2004 |
| | leatherback | *Dermochelys coriacea* | X | X | N | endangered (1970) | NOAA Office of Sustainable Fisheries |
| | Kemp's ridley | *Lepidochelys kempii* | O | X | N | endangered (1970) | NOAA Office of Sustainable Fisheries |
| | olive ridley | *Lepidochelys olivacea* | O | X | N | endangered (1978) | NOAA Office of Sustainable Fisheries |
| Marine mammals | West Indian manatee | *Trichechus manatus* | O | X | N | endangered (1973) | McKillop 1985; Mignucci-Giannoni *et al.* 2000 |
| | Caribbean monk seal | *Monachus tropicalis* | N | X | E | extinct (1967) | NOAA Office of Sustainable Fisheries |
| | humpback whale | *Megaptera novaeangliae* | N | X | N | endangered (1970) | NOAA Office of Sustainable Fisheries |
| Reptilia | Crocodile | *Crocodylus acutus* | O | O | O | generally not harvested | Keegan 1992 |
| | Giant tortoise | — | O/X | E | N/A | extinct | Carlson 1999; Carlson & Keegan 2004 |
| TERRESTRIAL | | | | | | | |
| | Dog | *Canis familiaris* | O | N | N/A | N/A | Newsom & Wing 2004 |
| | Opposum | *Didelphis* sp. | O | U | O | N/A | Newsom & Wing 2004 |
| | Agouti | *Dasyprocta leporine* | O | O | O | N/A | Newsom & Wing 2004 |
| | Guinea pig | *Cavia porcellus* | O | U | N | N/A | Newsom & Wing 2004 |
| | Shrew | *Nesophontes edithae* | O | U | N | N/A | Newsom & Wing 2004 |
| | Rice rat | Oryzomyini | O/X | X | E | N/A | Newsom & Wing 2004 |
| | Iguana | *Iguana* sp. | O/X | O/X | O/X | N/A | Newsom & Wing 2004 |
| | Land crab | Gecarcinidae | X | O | O | N/A | Newsom & Wing 2004 |
| | Lizards | Varies | O | O | O | N/A | Newsom & Wing 2004 |
| | Hutia | *Isolobodon portoricensis* | O | O | O/EP | N/A | Newsom & Wing 2004 |
| | Sloths | Phyllophaga, Xenarthra | O/X | E | N/A | N/A | Steadman *et al.* 2005 |

(Torres 2003). The problem is that conservation biologists have for too long assumed that the native peoples of the islands had a very limited impact, especially on near-shore marine resources. Archaeological evidence is showing that such studies are inaccurate in the baselines they have set.

Terrestrial and coastal ecosystems were further and more severely degraded after European contact, long before ecologists began intensively studying them in the late 1950s (Goreau 1959; Randall 1965; Jackson 1997). There is a great concern for coral reefs in particular because human activities such as "increased predation pressure, hyper- and hypothermic stress, reduced water quality associated with terrestrial runoff and poor watershed management, overgrowth by macroalgae, boat groundings and anchor damage, and disease" (Precht 2002, p. 42), have all led to long-term or irreversible impacts to these environments. Gardner *et al.* (2003) demonstrated that in the last 30 years, coral cover in the Caribbean has been reduced from about 50% to 10%. As Hughes *et al.* (2003, p. 929) note, many reefs worldwide have experienced reduced stocks of herbivorous fishes and added nutrients from land-based activities that have "caused ecological shifts, from the original dominance by corals to a preponderance of fleshy seaweed". Greenhouse gases are also causing global climate changes and are thought to weaken coral skeletons and prevent further accretion; tropical storms can shorten the time for recovery (Hughes *et al.* 2003). Fortunately, for now, the coral reef crisis seems relegated to shallow waters and not the deeper reef systems (Bak *et al.* 2005, p. 1), although there will surely be a trickle down effect as anthropogenic influences continue (Bellwood *et al.* 2004).

On Caribbean seagrass beds and coral reefs, large herbivores and carnivores such as the Caribbean monk seal, turtles, manatees, and humpback whales are ecologically extinct and small fishes and invertebrates now dominate the food chains (Jackson 1997, S28). The overfishing of herbivorous species, particularly parrotfish and surgeonfish, not only affects the size of harvestable stocks, but can completely alter the dynamics of a reef system (Jackson *et al.* 2001). Turtle and fish populations have decreased substantially since European contact, although many were already under duress. The loss of turtles to feed people on Jamaica in the late 1600s and early 1700s, for example, led to heavy overfishing – by the early 1970s, it was "accepted as an established fact" (Jackson 1997, S29). Fisheries in Jamaica have never recovered, a situation not unique to the island or even the Caribbean as a whole, but seen worldwide (Jackson *et al.* 2001). The transport of non-indigenous plants and animals from the Old World – grasses, palms, vegetables, sugarcane, breadfruit, cattle, horses, chickens, and pigs to name only a few – has drastically altered Caribbean island environments to the point where many no longer have even a small percentage of their endemic flora and fauna.

There is also a multitude of other issues that have arisen in the past few decades that deserve further study, but are beyond the scope of this paper. A rise in global temperature is expanding the world's oceans and along with melting of the polar ice caps, is leading to coral mortality (Aronson & Precht 2006) and raising sea level that will drown coastlines and low-lying islands at a pace that may exceed coral reef growth. Bilge water, garbage, petroleum, and other pollutants dumped from ships or leached from landfills, sewage treatment centres, and factories within the region are poisoning both land and sea. The destruction of mangroves for housing, road, and tourist development destroys habitats and nursery grounds for lobsters and other species as well as providing a natural near-shore buffer to pollutants and contaminants. The mining of beach sand on many Caribbean islands to manufacture cement, which is inexpensive (and to many local populations and governments, an inexhaustible resource to be taken as needed), is seen as a way to help fuel the growth of development and infrastructure projects. However, these activities are altering wave patterns, modifying shorelines, causing sedimentation that stresses coral and other suspension-feeders, destroying animal habitats and dunes that naturally protect coastlines, and causing massive erosion. On the island of Carriacou in the southern Lesser Antilles, for example, sand mining along the east coast appears to be the major cause behind the destruction of two major archaeological sites. These are eroding at a rate of around 1 metre per year, thereby erasing the very evidence used to help analyse past human events (Fig. 3; Kaye *et al.* 2005; Fitzpatrick *et al.* 2006).

## 7. Conclusions

In this paper various data sets have been combined to provide a temporal and disciplinary synthesis of human movement and occupation in the Caribbean islands and the resulting effects that humans had on these ecosystems. Kirch (1997a, p. 286) states that:

*before the interdisciplinary collaboration of the past decade or two, independent research by anthropologists, archaeologists, biogeographers, and ecologists had led to little historical understanding of the long term dynamism of island environments or of the critical role of human populations in shaping island landscapes.*

With an increase in archaeological, palaeoenvironmental, historical, and ecological research in the Caribbean islands, it has now become necessary to combine the various areas of expertise to discuss issues of human adaptations and impacts in the region which until now has been sorely neglected. Multidisciplinary approaches to conducting research in other parts of the world have proven useful for understanding temporal changes to both island and terrestrial environments. The Caribbean, by virtue of its relatively long history of human settlement, growing efforts to collect palaeoecological, archaeological, and biological data and, and abundant historical records, represents an untapped resource for examining human impacts and changes to these island environments throughout the Holocene.

This is not to say that human impact on Caribbean island ecosystems has not been recognised by researchers in the social and natural sciences. But the interweaving of data collected by scientists and historians has yet to be fully explored to its potential. Historical ecology represents a paradigm shift where changes to ecosystems, whether they are insular or not, are approached from a long-term perspective using a host of different and constantly evolving analytical techniques. This human/nature dialectical approach recognises that adaptations to (and impacts on) environments, are more effectively discerned by determining historic reference conditions, an essential part of analysing landscape change.

Kirch correctly notes that it is archaeologists who have played a central role in organising and synthesising these types of research projects because we are at the nexus of where social science meets natural science:

*As natural scientists, we can understand and appreciate the work of our natural science colleagues in helping us to reconstruct past environments. As social scientists, we realise that humans have highly complex reasons for undertaking the behavior that they do, and also that ecological changes may have social, political, religious, and economic consequences that are often overlooked by natural scientists* (Kirch 2003, p. 23).

**Figure 3** Locals mining sand at the Grand Bay prehistoric site on the island of Carriacou, southern Grenadines (photo by Michiel Kappers; east side, looking north). Based on detailed mapping and photographs taken at the site over the past six years, it is estimated that uncontrolled mining of sand here is leading to the erosion of at least 1 m of coastline per year and with it, hundreds of thousands of artefacts and other archaeological remains (Fitzpatrick *et al.* 2006). Note the exposed coastal profile at the left, the top half of which contains dense midden dating from ca. 1600–400 BP.

Historical ecological studies show how environments changed over time through the in-depth and comparative analyses of ecosystems using tools from a wide range of disciplines. As has been noted for the Caribbean (and recognised elsewhere in the world), islands and coastlines are integral pieces of the global puzzle that hold important clues for understanding the complex interrelationships between humans and other species. Unfortunately, as Edward Towle (from Nunn 2004, p. 311) noted, islands themselves have become an endangered species due to the unrelenting pressure applied by humans to adapt to and modify their environments through time.

The Caribbean Sea is one of the most traversed seas in the world and bordered by 36 independent nations who bear the responsibility for managing marine resources. Thus, there is a dire need for regional cooperation to better understand, from a historical point of view, the availability and changes to both marine and terrestrial ecosystems. Human societies are the primary cause behind changes to Caribbean island biodiversity which can be traced archaeologically, historically, and ecologically. To effectively confront and analyse the engine of human modification on island landscapes in the Caribbean, we must take a proactive, multidisciplinary approach. By applying historical ecology, and hence working in close collaboration with scientists in a variety of disciplines, we will be able to provide more comprehensive and well-hypothesised explanations of human-environmental interactions and develop strategies for ecological conservation that would not have been possible without these integrative efforts. As Bellwood *et al.* (2004, p. 827) said: ‘‘Managing for improved resilience, incorporating the role of human activity in shaping ecosystems, provides a basis for coping with uncertainty, future changes, and ecological surprises’’. The present authors could not agree more.

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