

Empirical Assessment of a Pre-European Societal Collapse on Rapa Nui (Easter Island)

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Abstract - *Leading archaeologists and popular writers have constructed narratives about pre-European societal collapse on Rapa Nui. The island is thought to have undergone a radical prehistoric shift towards anarchy as the island ecosystem was destroyed by overpopulation and environmental catastrophe. Elements of this story were first told by early 20th century ethnographers. In 1955, Thor Heyerdahl's Norwegian Expedition added to the narrative by recovering archaeological data which they attributed to warfare and destruction. More recent authors have retold the account of prehistoric societal failure, and today Rapa Nui is often depicted as a model for world ecosystem disaster. Despite the popularity of this narrative, there is very little solid evidence that drastic societal change occurred prior to European contact. We review the evidence for pre-European societal collapse, and consider GIS-based methodologies for establishing the dynamic social and environmental landscape to enable the empirical evaluation of whether or not the narrative of Rapa Nui's prehistoric demise is supported.*

Introduction

“The fascination of Easter Island lies, not in the purported ‘mystery’ of its stone statues or *rongorongo* tablets, but rather in its evolutionary record of cultural achievements ... which were inevitably to crumple under pressures of overpopulation and environmental degradation. Easter Island is the story of a society which – temporarily but brilliantly surpassing its limits – crashed devastatingly”
(Kirch 1984:264)

Few places in the world have captured as much attention for their archaeological significance as Rapa Nui (Easter Island). The existing culture-historical model for Rapa Nui's pre-European contact (before AD 1722) cultural trajectory is one in which the island is portrayed as a classic example of “overshoot and collapse” that occurred due to overpopulation and resource depletion (see Anderies 2000; Bahn and Flenley 1992; Brander 2004; Brander and Taylor 1998; Diamond 1994, 2005; Flenley and Bahn 2002; Kirch 1984; Mahon 1998; Rolett and Diamond 2004). These scholars suggest that Rapa Nui society disintegrated and crashed after the islanders degraded their environment and allowed their population to reach an unsustainable level. Authors have gone so far as to use the island as an analogy for the planet (Bahn and Flenley 1992; Diamond 2005; Flenley and Bahn 2002; Ponting 1991; Wright 2005) in their interpretations, suggesting that the Rapanui people brought an ecological catastrophe upon themselves in the late pre-contact sequence.

The notion of ecological collapse due to human-induced environmental change on Rapa Nui has recently been called into question by numerous scholars. Hunter-Anderson (1998) notes that evidence for physical erosion on the island is lacking and that climatic factors may have been more significant than human-induced change (see also McCall 1993), while Rainbird (2002), Peiser (2005) and Hunt (2006) discount the notion of a prehistoric collapse and instead attribute the societal collapse to introduced European diseases. Hunt (2007) suggests that

Polynesian rats were responsible for palm deforestation (said to have been a primary component of the ecological collapse) because they consumed the nuts, prohibiting the forest from regenerating. Tainter (2006) questions the classification of Rapa Nui as a classic example of “overshoot and collapse”, bringing forth evidence that is contradictory to a human-induced ecological collapse, including agricultural intensification, social factors, and the role of rats in the loss of the palm forest. As Hunt and Lipo (2007) point out, no studies have provided sufficient evidence for a cultural and ecological collapse on Rapa Nui prior to European contact. This paper builds on that work by empirically assessing the wide range of archaeological, palaeoecological, and ethnohistoric data that has been used by researchers to construct the collapse narrative.

The Society that Self-destructed?

The majority of archaeological syntheses (Bahn and Flenley 1992; Flenley and Bahn 2002; Heyerdahl and Ferdon Jr. 1961; Kirch 1984, 2000; McCoy 1979; Van Tilburg 1994) and popular accounts (Diamond 2005; Wright 2005) of Rapa Nui prehistory portray the island as the locale of societal collapse brought on by a self-induced ecological catastrophe, namely through deforestation and over-exploitation of natural resources. Although some scholars have proposed different causal mechanisms for the supposed downfall of Rapa Nui society, such as prolonged isolation (Van Tilburg 1994), detrimental effects of climatic change associated with the Little Ice Age or ENSO events (McCall 1993; Orliac and Orliac 1998), or European contact before 1722 (Langdon 1975), most scholars conclude that major environmental changes triggered a detrimental societal change involving the replacement of a hierarchical socio-political system with a new competitive order. The late pre-contact period is generally characterized as a time of fragmentation, warfare and famine.

Thor Heyerdahl’s famous 1955 Norwegian Expedition was the first to present the story of prehistoric collapse in developing a culture history for the island (Heyerdahl and Ferdon 1961). Their culture historical model was based on archaeological investigations and information from ethnographic accounts. Recorded oral traditions were combined with limited archaeological data to divide the cultural sequence into three periods. The date of ca. AD 1680 was established as the chronological marker of the fall of Rapa Nui society based on the correlation of ethnographically recorded genealogical estimates combined with a single radiocarbon determination from the so-called ‘Poike Ditch’ (Smith 1961). This date marked the beginning of a period characterized as “unsettled”, where warfare, cannibalism, and famine were rampant (Heyerdahl and Ferdon 1961). In subsequent archaeological studies, this culture-historical scheme provided researchers with a framework within which to interpret various lines of archaeological and palaeoecological data. The adequacy of the archaeological data on which the Norwegian Expedition culture history was based was questioned by Golson (1965), but this critique went largely unnoticed (but see McCoy 1979; Mulrooney *et al.* under review; Vargas *et al.* 2006). In his extensive review of their work, Golson emphasized the unsatisfactory nature of establishing a chronology based on very limited and ambiguous data. He suggested that the dates established by the excavators seemed to be too early based on their limited chronometric data, and he recommended that a date as late as AD 1750 might be more appropriate to use as a chronological marker of the beginning of the Late Period. Significantly, the validity of the Norwegian Expedition’s scheme was generally not questioned by subsequent researchers and has been used to develop a general culture historical model that depicts the rise and fall of a civilization that self-destructed in the pre-contact period.

According to the existing model, three general phases comprise the Rapa Nui cultural sequence. Some researchers (Ayres 1975; Stevenson 1984, 1997; Stevenson and Haoa 2008), following the Norwegian Expedition’s model, place the transition to the third phase at c. AD 1680, while others (Kirch 1984, 2000; Lee 1986; McCoy 1976; Mulloy 1978; Van Tilburg 1986; Vargas *et al.* 2006) argue for societal collapse in the 16th century (Figure 1). In the accepted culture historical model, the first two phases were marked by settlement and expansion into optimal locations, the establishment of territories, rapid population growth, and the development of an ideologically and politically centralized social hierarchy (Stevenson 1997, 2002). The ideological basis of society was expressed through ceremonial architecture and eventually resulted in the alteration of initial settlement locations into centralized sacred locations adjacent to large coastal religious structures (*ahu*) (Stevenson 1986). The population was divided into a number of distinct territories (*mata*) made up of corporate descent groups, with large *ahu* platforms with large statues (*moai*) within each community level division (Stevenson 2002). The movement of key resources, such as volcanic tuff from Rano Raraku used in the carving of *moai*, red scoria from Puna Pau used to fashion *pukao* (topknots, or headdresses for statues), and obsidian from Maunga Orito, Motu Iti and Rano Kau used to make stone tools, shows that there was widespread cooperation amongst territorial groups (Stevenson 2002). During the second phase, major deforestation and widespread physical erosion are thought to have occurred, due to the use of timber to aid in the transport of statues and the clearing of land for intensified agriculture (Mieth and Bork 2004). Toward the end of the second

general phase, the greatest socio-political complexity and the most intensive level of agricultural production are thought to have been developed on the island. Inland regions contained managed field systems (Stevenson 2002; Stevenson *et al.* 1999; Stevenson and Haoa 2008) and status differentiation was manifest in the form and distribution of different types of residential, agricultural, and religious features (Martinsson-Wallin 1994). This phase is thought to have ended abruptly at the beginning of the third general phase some time between AD 1500 and AD 1680 with the onset of warfare and the replacement of the centrally organized chiefdom with a competitive political system (Diamond 2005; Stevenson 1997, 2002).

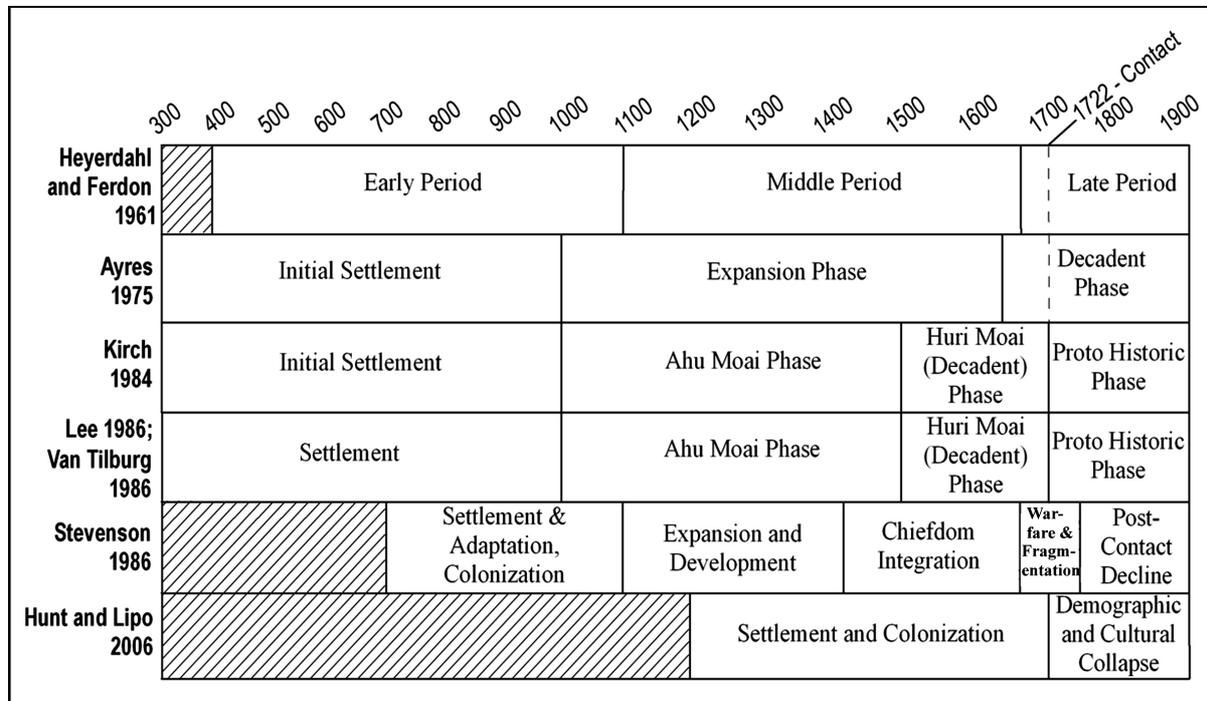


Figure 1. Comparative cultural chronologies (After Lee 1992:9; Figure 2.1, and Shepardson 2006:203, Figure 6.3).

The “political upheaval” that is said to have occurred during the third general phase is thought to have been brought on by massive environmental degradation and subsistence stress, coupled with population overgrowth. According to most researchers, this resulted in changes to the settlement pattern and shared ideological beliefs that continued into the protohistoric phase. As Rapanui people adapted to an impoverished environment, the statue-building industry is thought to have ceased (Diamond 2007; Martinsson-Wallin 1998), inland agricultural fields were abandoned (Stevenson 1997), and the period is characterized as one of fortified settlement in refuge caves and internecine warfare between two loosely defined factions on the western and eastern sides of the island (Flenley and Bahn 2002; Van Tilburg 1994). Scholars agree that these proposed changes were abrupt and radical, and that a drastic shift in the overall socio-political system occurred. The chiefly elite of the hierarchically organized society were displaced from power and replaced by a new warrior class (*matato'a*) and warring groups intentionally toppled the statues of other groups. According to most researchers, long periods of warfare ensued, the society disintegrated into a state of anarchy, and there was a drastic demographic collapse.

Palaeo-ecological Data

In the existing model for societal collapse on the island, detrimental human induced environmental change is conceived as the causal mechanism for the collapse of the society. Human-induced deforestation of the palm forest is said to have been complete by no later than AD 1640, leading to physical erosion (Flenley and Bahn 2002). Mieth and Bork’s study on the Poike Peninsula led them to conclude that “an unstoppable process of degradation set in after deforestation, in the course of which the fertile soils were eroded, re-sedimented and thus withdrawn from horticultural use for a long time”(Mieth and Bork 2004:82). Mann *et al.* (2004:148) also argue, based on their work on Poike, that primeval soils were “severely eroded” beginning abruptly at AD 1200. However, conclusive evidence for the processes of deforestation and resulting physical erosion is limited. The extrapolation of physical erosion on a very restricted area on the Poike Peninsula to the rest of the island is unjustifiable as there is little evidence for the massive island-wide “almost ubiquitous soil erosion” that Mieth

and Bork present (2004:90). A detailed land evaluation study by Louwagie (2004; Louwagie *et al.* 2006) shows that the marginal to moderate soil characteristics on the island had more to do with nutrient availability than they did with water availability or erosion resulting from deforestation. In fact, Louwagie *et al.* (2006:312) note that the marginal status of Rapa Nui soils “did not develop after erosion of a fertile forest soil that may have been present before deforestation.” They go on to conclude that sheet erosion that resulted in the exposure of less fertile strata was limited to small areas and that these events actually pre-date human arrival on the island.

The palynological work of Flenley and his colleagues indicates that deforestation occurred, but these studies have been inconclusive in establishing the exact timing of this process (Flenley *et al.* 2007). Their work at the Rano Kau crater lake is the most extensive palynological study to date on the island, and they conclude, based on two pollen cores at this location, that the process of deforestation occurred from ca. AD 676 to AD 1550 (Flenley 1993, 1996, 1998; Flenley and King 1984; Flenley *et al.* 1991). They assume that the deforestation represents anthropogenic change as people intentionally cut down the entire forest for statue transport and agricultural intensification. However, this assumption may be erroneous, as it is conceivable that rats, not humans, played a major role in preventing forest regeneration through the consumption of palm seeds (Bahn and Flenley 1992; Flenley and Bahn 2002, 2007; Hunt 2006, 2007; Hunt and Lipo 2007; Tainter 2006). Alternatively, the analysis of wood charcoal by Orliac and Orliac (1998; Orliac 2000) suggests that the rapid shift from the use of ligneous fuels to herbaceous fuels during the late 17th century documents a much more rapid environmental change than that suggested by long-term forest clearance. The causal link between palaeoecological and archaeological data is not sufficiently evidenced, and the story of a societal collapse triggered by environmental degradation is based on *a priori* assumptions that are currently not supported by the palaeoecological data.

Archaeological Data

The existing culture historical model described above has shaped interpretations of various lines of archaeological data, and the types of data collected have been shaped by the assumption that this model is accurate and meaningful in Rapa Nui studies. Settlement pattern analyses (McCoy 1976; Stevenson 1984; Vargas 1998; Vargas *et al.* 2006), studies of burial practices (Seelenfreund 2000; Shaw 1996, 2000a, 2000b), stylistic analyses of artifacts and *ahu* structures (Ayres 1975), and rock art studies (Esen-Baur 1998; Lee 1986, 1992, 1993) have all been interpreted within the culture historical framework for societal collapse. The summation of this model in more recent syntheses of Rapa Nui prehistory has drawn from these lines of data, along with palaeoecological data, to reify the prehistoric collapse of Rapa Nui society (Diamond 2005; Flenley and Bahn 2002; Kirch 2000).

According to Kirch’s (2000) synthesis, a societal collapse is “well-marked in the late prehistoric archaeological record” (2000:274). Kirch notes that the collapse of Rapa Nui society is evidenced by the manufacture of obsidian spear points, the destruction of elite dwellings, habitation in refuge caves, cannibalism, a change in burial practice, and a marked ideological shift away from *ahu* structures to the worship of the Birdman (*tangata manu*) cult centered at Orongo. To this, other researchers have added evidence for the abandonment of inland field systems and houses and decreased population levels (Stevenson 1984, 1986, 1997; Stevenson and Haoa 2008). However, in examining the data on which these conclusions are made, it is clear that there is ambiguity.

Artifactual evidence in the appearance of obsidian *mata’a*, which have been interpreted as spear points, in the 15th and 16th centuries, and their proliferation in the 18th and 19th centuries, has been interpreted as evidence of endemic warfare on the island in the collapse literature (Bahn 1993; Flenley and Bahn 2002). Flenley *et al.* (2007) suggest that there is strong evidence for the use of these artifacts as weapons based on early European accounts and ethnohistoric documents. However, as Hunt and Lipo (2007) point out, plant remains found in surface use-wear analyses point to a function as agricultural implements rather than weaponry (Ayres *et al.* 2000; Church 1994, 1998; Church and Ellis 1996). Thus, Flenley *et al.*’s (2007) assertion that these artifacts functioned as weapons ignores the archaeological evidence, instead preferring post-contact observations.

The destruction of elite dwellings has been proposed based on the distribution of individual *hare paenga* stones (well-dressed basalt curbstones used in the foundations of elite houses) across the landscape, and the re-use of these stones in other structures. Although it is evident that elite houses were destroyed and re-fashioned, the timing of such events is unknown. The re-use of *hare paenga* stones in *ana kionga* (fortified refuge caves) is widespread (Stevenson 1997), but the dating of such structures is ambiguous. The interpretation of these features as a new type of habitation feature during the late prehistoric sequence is unsubstantiated based on limited chronometric data obtained from a small sample of these features. To date, only two *ana kionga* have been securely dated on the island, and frequency distributions of 50 obsidian hydration dates from these features have

been interpreted as supporting the collapse model due to an increase in the frequency of dates from the 17th century (Rorrer 1998). However, the dating of these *ana kionga* suggests somewhat continuous occupation throughout the late prehistoric sequence and into the historic period (Figure 2). Possible evidence for a marked increase in occupation is only apparent at one of the two locales during the 17th century, which is insufficient for documenting a dramatic settlement shift. Additionally, the timing of the fortification of these locales has not been firmly established.

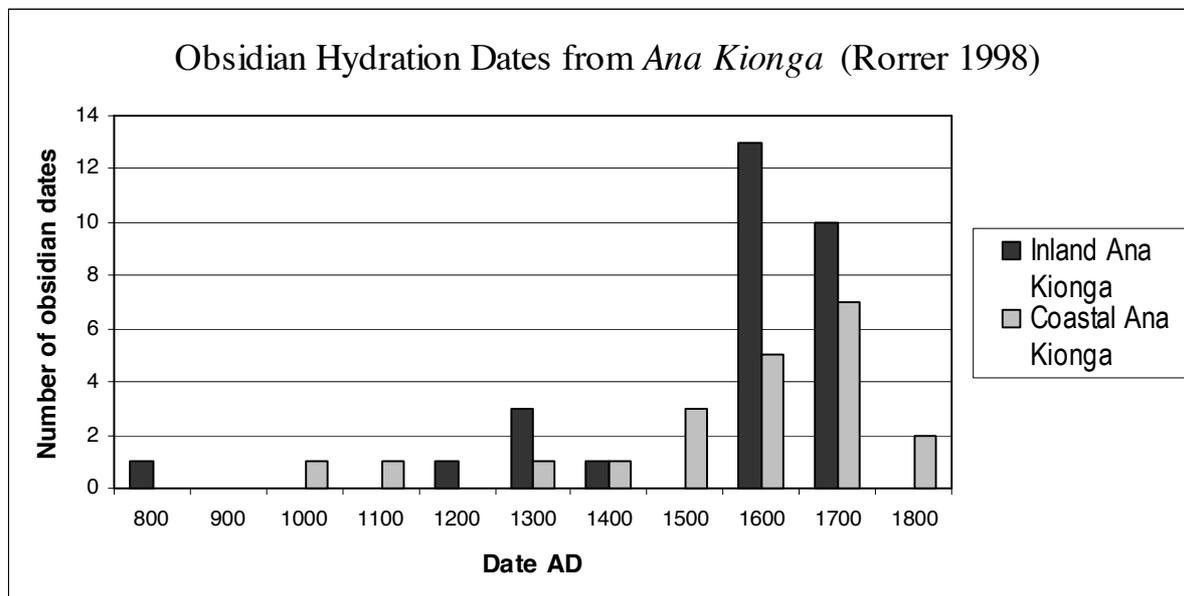


Figure 2. Number of obsidian hydration dates for 2 *ana kionga* on the south coast (Rorrer 1998).

The presence of charred human remains in middens has been documented as evidence for widespread cannibalism on the island, as well as endemic warfare (Kirch 2000). However, as noted by Hunt and Lipo (2007), osteological studies have shown that “few fatalities were directly attributable to violence” (Owsley *et al.* 1994). Although Owsley has been cited as saying that there was evidence of “blunt force trauma” (Flenley *et al.* 2007; Van Tilburg 1994:107), this only occurred in approximately 2.5 percent of the collection of skeletal remains that were examined. In addition, Owsley *et al.*’s sample of 462 individuals is loosely dated to the Late Pre-contact and Proto-Historic Periods (dated to AD 1680-1750 and AD 1750 to 1868, respectively). Therefore, the limited “blunt force trauma” that Owsley *et al.* document is not securely dated to the pre-contact period. Hunt and Lipo (2007:94) also rightly point out that cannibalism “remains unproven for Rapa Nui” and that “to date, no unambiguous evidence for cannibalism has emerged.” Given the prehistoric practice of making fishhooks and needles from human bone, the presence of small pieces of human bone in middens is not surprising, and does not conclusively suggest cannibalism. Furthermore, the occurrence of burnt human bone would be expected, based on the fact that cremation was utilized prehistorically.

Late changes in burial practices from cremation to bundle or extended burials in rebuilt *ahu* structures, below toppled statues, in caves, and in above ground tombs (*avanga*), have been contextualized within ideological changes that occurred as the society collapsed (see Martinsson-Wallin 1994; Shaw 1996, 2000a, 2000b). None of these changes have been securely dated to the prehistoric era, however. Sixty-six dates have been obtained from burial contexts using obsidian hydration dating (Figure 3). However, these dates may be indicative of activities other than interment, such as the construction and refashioning of architectural features. In each of the burial types examined, there is a significant increase in obsidian samples dating to the period from AD 1750 to 1850, which may indicate that the use of the tombs and caves for burials may have only occurred following European contact. Nonetheless, the inherent difficulty in establishing temporal relationships between artifacts and burial events makes this line of data especially difficult to assess.

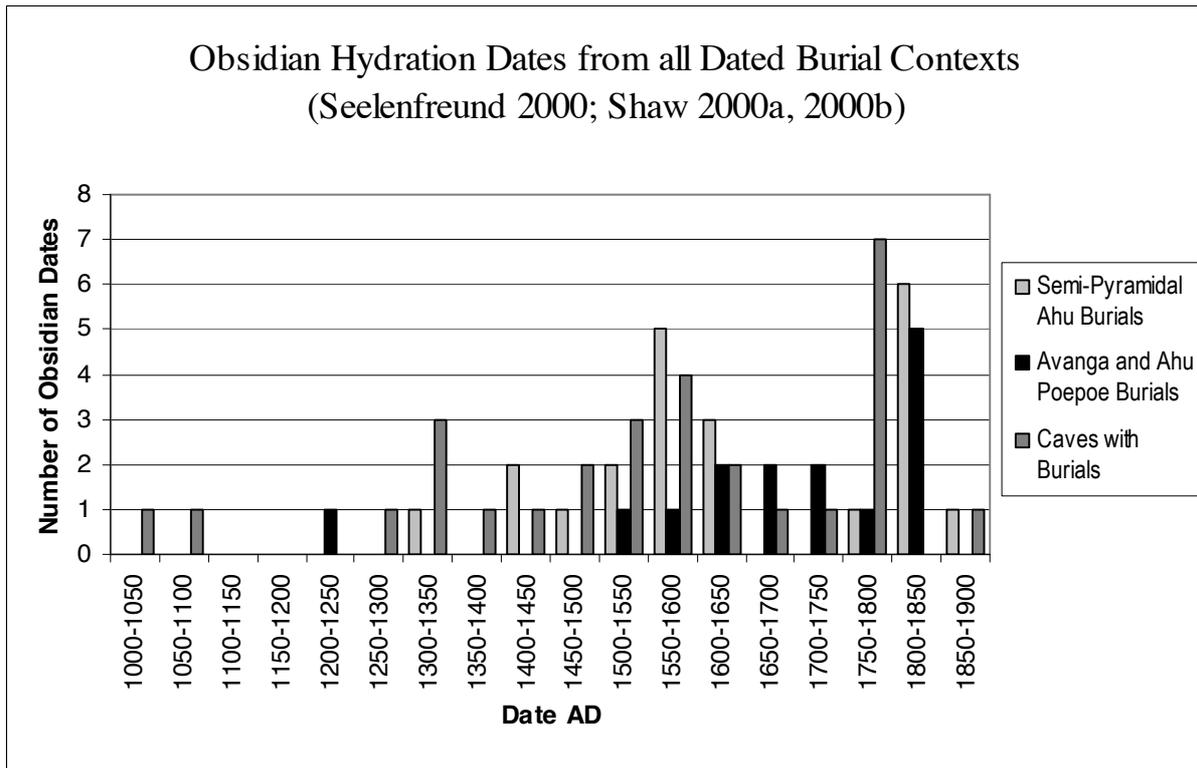


Figure 3. Dates from excavated burial contexts (Seelenfreund 2000; Shaw 2000a, 2000b).

The ideological shift from coastal *ahu* structures around the island to the singular ceremonial centre at Orongo and the emergence of the Birdman cult have been presented as an innovative ideological framework that developed with a new competitive political order as the society collapsed (see Lee 1986, 1993). However, the limited sample of radiocarbon dates from Orongo indicates use from the 15th century until the 18th century (Lee 1986). The characterization of the Birdman cult as “militaristic” has recently been called into question as well (Esen-Baur 1993) and there is no conclusive evidence to show that this ideological framework was separate from the prehistoric statue-building ideological system, nor that it was developed following a prehistoric collapse (see Van Tilburg 2006).

A significant shift in the settlement pattern of the late cultural sequence has also been proposed (McCoy 1976; Stevenson 1984, 1986, 1997; Vargas 1998; Vargas *et al.* 2006), with a shift in habitation areas from inland regions back to the coast as the population decreased following cultural and ecological collapse. The abandonment of inland agricultural fields and residential features has been proposed based on the dating of five residential features in Maunga Tari (Stevenson 1997). Of 105 dates obtained using obsidian hydration dating and radiocarbon analysis, 101 fall before A.D. 1600, leading Stevenson to extrapolate a model for the entire island based on this limited sample, which is insufficient for documenting an island-wide trend. Based on the cumulative probability distribution of over 1000 obsidian hydration dates from residential features on the south coast, Stevenson (1997) also concludes that demographic collapse is evidenced by a drastic decline in settlement from AD 1650 to 1699, which is manifest in decreased obsidian consumption (Figure 4). However, this interpretation is far from conclusive. This decrease in obsidian consumption from AD 1650 to 1699 may not necessarily reflect demographic change. The subsequent increase in obsidian consumption during the 18th century does not support the notion that a dramatic demographic collapse occurred previously. Flenley and Bahn (2002; Bahn and Flenley 1992) attribute this increase to the increased manufacture of obsidian *mata'a*. However, the fact that these artifacts do not appear to have been used as weapons does not support the notion that they proliferated as a by-product of a disintegrated, competitive political system that was apparently in place at this time. A dramatic decrease in obsidian consumption does not appear to have occurred until well after European contact (also see Vargas *et al.* 2006).

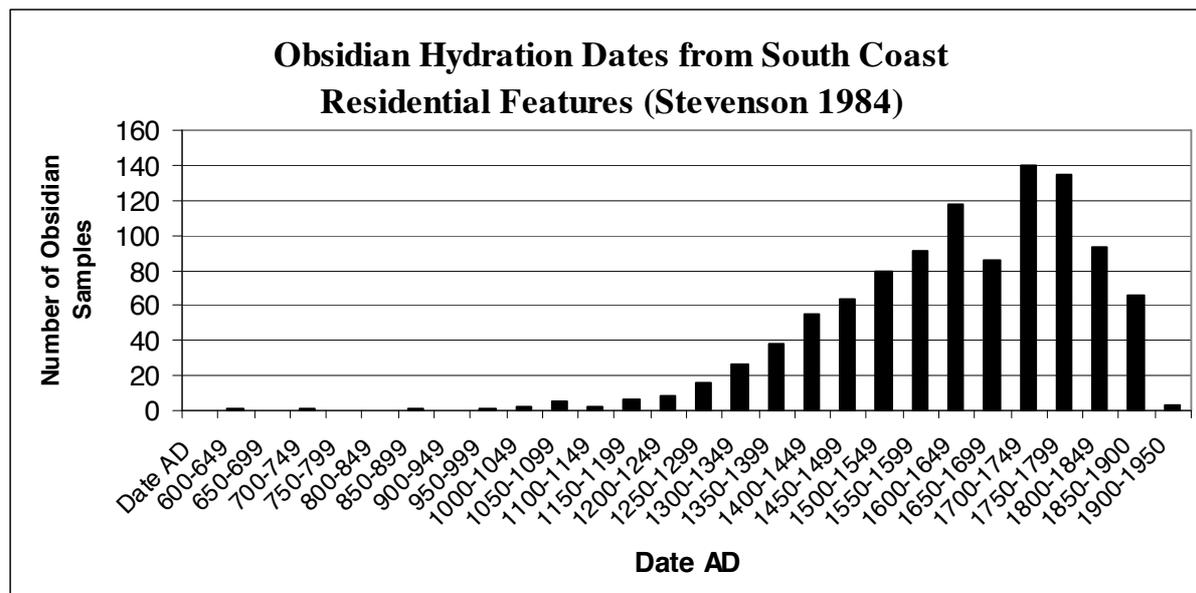


Figure 4: Obsidian hydration dates from all residential features on the south coast (Stevenson 1984).

It is clear, based on the archaeological data, that a dramatic shift is not “well-marked” in the archaeological record from the late pre-contact period. The collapse narrative is based on assumptions about human remains representing cannibalism, the ambiguous dates from two refuge caves and 18 burial contexts, an ideological shift with limited temporal precision, and an island-wide settlement model that is based on limited settlement shifts (the ambiguous dating of residential features and five sites associated with an inland field system) projected onto island-wide changes. The supposed artifactual evidence for warfare, a shift in habitation to refuge caves, and a major ideological change are scarcely substantiated by the present data. Limited dating of burials, residential features, and ceremonial features lends little support to the notion that the use of these features drastically changed during the late pre-contact period. In addition, the supposed demographic collapse that is said to have occurred is speculative, given that it is based on a decrease in obsidian consumption that was followed by an increase in obsidian consumption. Likewise, the proposed abandonment of inland agricultural field systems is in need of validation. It is clear that the orthodox model for prehistoric collapse has been established and reified based on very limited archaeological data.

Ethnohistorical Data

The logs of early explorers (Roggeveen in 1722, González de Haedo in 1770, Cook in 1774, and La Pérouse in 1785) lend insights into the social and environmental conditions on Rapa Nui during early encounters, and these logs do not support the orthodox model for prehistoric collapse on Rapa Nui. The earliest reports do not depict an anarchic society characterized by famine and warfare. Conversely, Jacob Roggeveen’s crew, the first European visitors to the island, described the people as tall, muscular, and well-proportioned (Behrens 1903), and noted that they had a variety of agricultural foodstuffs, which they traded with the explorers. He noted that the women “...sat before us and disrobed, laughed, and were very friendly...and beckoned us to come with them...”(Behrens 1903:136). He did not observe any evidence of warfare amongst the people, and did not note that any of the *moai* were toppled. In fact, his logs describe a ritual in which people knelt before the statues and bowed their heads, which suggests that the *ahu* and *moai* still had an important ideological role. Similarly, the Spaniards who briefly visited part of the island in 1770 noted that the islanders had a “docile disposition” and did not mention any indication of warfare or that statues had been toppled (Fischer 2005:62). In contrast, during Cook’s visit in 1774, he noted that many of the statues had been pushed over, cultivations had been destroyed or abandoned, there was little fresh food to be had, and the people were “small and miserable” (Brander 2004; Fischer 2005).

Based on the observations of these early explorers, it appears that the “*Huri Moai*” (statue toppling) or Decadent Phase did not occur until well after European contact. Therefore, these reports would indicate that any cultural collapse, as evidenced by warfare and an ideological shift, occurred during the late 18th century. In his ethnography, Métraux (1957:169) notes that during the late 18th century or the early 19th century, a series of

inter-tribal wars were waged, resulting in the intentional destruction of statues on ceremonial *ahu* platforms. These conflicts were known as “the wars of the throwing down of the statues”, and it is clear that the society underwent significant changes during this post-contact time period.

Limited information also comes from later explorers, traders, and missionaries who visited the island during the 19th century. During this century, the island experienced a “fatal impact” with westerners, resulting in a high mortality rate due to introduced diseases and the removal of islanders by the blackbirding trade in the early 1860s. The population reached a mere 110 individuals in 1877 (Fischer 2005:121), which resulted in the loss of a wealth of information in the form of oral traditions and traditional knowledge of the past.

The period from the 1880s to the 1940s saw the arrival of ethnographers and the first scientific expeditions to the island. The ‘salvage ethnographies’ of Thomson (1891), Routledge (1919), Englert (n.d., 1948, 1970) and Métraux (1940, 1957) have become indispensable accounts of traditional Rapanui society as it was described by local informants. These ethnographies contain extensive information on Rapa Nui social structure, customs, and beliefs. However, these documents must be examined with caution due to the context in which they were recorded. The severe decline in population experienced during the 1870s would have resulted in the loss of knowledge from oral traditions, and those stories that were subsequently collected may have been shaped more by the contemporary social context than the historical period that they were supposedly describing. It has been hypothesized that these ethnographies “relate principally to the final century of Rapa Nui political history as an independent island, and reveal little about the organization of the chiefdom prior to the impacts of western culture” (Stevenson 2002:213-214).

Conclusion

The inadequacies of archaeological, palaeoecological, and ethnohistorical data are clear, but have been largely ignored in the popular and academic literature. To date, there is no conclusive evidence for the proposed pre-contact collapse of Rapa Nui society. Although researchers have begun to question the existing model in the archaeological literature in recent years (e.g. Hunt 2006, 2007; Hunt and Lipo 2007; Hunter-Anderson 1998; Peiser 2005; Rainbird 2002; Tainter 2006; Young 2006), these critiques have offered limited evidence to the contrary. By reviewing the evidence for pre-contact collapse, we have shown that the empirical evidence for prehistoric collapse is lacking. The ambiguous nature of many lines of data does not warrant asserting claims of “environmental suicide” (Diamond 1994:366) and a “downward spiral of cultural regression” (Kirch 1984:264) during the late pre-contact period. The question of whether or not a prehistoric ecological and societal collapse occurred on Rapa Nui is still debatable, and further archaeological data is needed to refute this widely accepted model.

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