Challenging Easter Island's collapse: the need for archaeological-paleoecological synergies

Valentí Rull [a,*], Núria Cañellas-Boltà [a,b], Alberto Sáez [b], Olga Margalef [b], Roberto Bao [c], Sergi Pla-Rabes [d,e], Blas Valero-Garcés [f] & Santiago Giralt [g]

[a] *Botanic Institute of Barcelona (IBB-CSIC-ICUB), Pg. del Migdia s/n, 08038 Barcelona, Spain*

[b] *Faculty of Geology, Universitat de Barcelona, Martí Franqués s/n, 08028 Barcelona, Spain*

[c] *Faculty of Sciences, University of A Coruña, Campus da Zapateira s/n, 15071 A Coruña, Spain*

[d] *Center for Advanced Studies of Blanes (CEAB-CSIC), Cala St. Francesc 14, E-17300 Blanes, Spain*

[e] *Centre for Ecological Research and Forestry Applications (CREAF), Cerdanyola del Vallès, E-08193 Barcelona, Spain*

[f] *Pyrenean Institute of Ecology (IPE-CSIC), Apdo. 13034, E-50080 Zaragoza, Spain*

[g] *Institute of Earth Sciences Jaume Almera (ICTJA-CSIC), Lluís Solé Sabarís s/n, 08028 Barcelona, Spain*

* Corresponding author. Botanic Institute of Barcelona (IBB-CSIC-ICUB), Pg. del Migdia s/n, 08038 Barcelona, Spain. Phone +34 93 2890611, fax +34 93 2890614. *E-mail address*: vrull@ibb.csic.es (V. Rull).

Abstract

We show that the available paleoecological literature on Easter Island already contains the hypothesis and the supporting evidence for a gradual, rather than abrupt and catastrophic, landscape transformation by humans since the initial colonization of Easter Island, as recently proposed by Mulrooney (2013) using archaeological evidence. In this way, the eventual eco-societal collapse assumedly occurred by AD 1000-1200 or later is seriously challenged. We use this particular case study to propose a more close collaboration between archaeology and paleoecology, in order to unravel historical trends in which both environmental changes and human activities might have acted, alone or coupled, as drivers of ecological and societal transformations. For the case of Easter Island, we highlight a number of particular points in which archaeologists and paleoecologists, working together, may enhance the scope and the soundness of historical inferences. These are: 1) the timing of the initial island's colonization and the origin of the settlers, 2) the pace of ecological and societal transformations since that time until the present, and 3) the occurrence of potential climate-human synergies as drivers of eco-societal shifts.

Keywords: Easter Island, ecological breakdown, societal collapse, paleoecology, paleoeclimatology, research synergies

1. Introduction

In a recent paper, Mulrooney (2013) performed a spatial and temporal analysis on over 300 radiocarbon dates from archaeological sites across Easter Island (Rapa Nui) and did not find empirical support for a sudden and widespread abandonment of inland areas prior to the European contact (AD 1722). Rather, chronological evidence shows continuity in settlement and landscape use during the entire cultural sequence since the initial island colonization to the post-European contact period. According to the author, these results contradict previous hypotheses on the existence of a socio-political collapse possibly linked to the overexploitation of natural resources, which would have caused the sudden abandonment of inland sites before the European contact. These findings are relevant not only for island's ecological and human history but also in a more general context, as the assumed Easter Island's collapse had been presented as a human-made ecocide and a paradigmatic model for the potential consequences of the overexploitation of natural resources, at a global level (Flenley & Bahn, 2003; Diamond, 2005).

The main aim of this comment is to show that the proposal of a continuous landscape management and a gradual and maintained, rather than abrupt and catastrophic, landscape transformation since the initial human settlement of the island has already been present in the recent paleoecological literature, with multiproxy empirical data for appropriate testing. Although a direct causal relationship between ecological and social collapses is still to be demonstrated, as Mulrooney (2013) recognizes, the main conclusions of her paper could have been strengthened by adding the relevant paleoecological literature showing the lack of paleoecological support for an eventual sudden ecological catastrophe. Indeed, without the formerly assumedly abrupt forest demise caused by human overexploitation, the ecocidal hypothesis is seriously challenged, which strongly supports Mulrooney's arguments on the gradualism of societal changes. In this commentary, we would like to summarize the existing paleoecological evidence for gradual ecological changes in order to promote the necessary synergies between the archaeological and paleoecological communities. In Easter Island, as in many other areas, archaeology and paleoecology have traditionally progressed as separate disciplines and the potential benefits of their interaction have not been fully exploited. Paleoecological and paleoenvironmental research may provide unique evidence to test the hypotheses about the possible causes (either natural or anthropic, or both) of ecological shifts, which is a landmark in Easter Island's history. So far, archaeological research has rarely addressed the potential role of environmental, specifically climatic, changes as potential drivers for societal transformations in the island. On the other hand, paleoecologists have been unable to capture the full extent and the implications of archaeological evidence for paleoenvironmental reconstruction. We would like to use this particular case to show how archaeology and paleoecology, working together, may notably enhance the scope and robustness of the inferences on past ecological and human trends, which should be part of the same history.

The comment is focused on the same time interval considered by Mulrooney (2013), the last millennia, and is subdivided into three main sections, namely: 1) the initial settlement of the island, 2) the tempo and mode of the ensuing landscape transformations, and 3) the potential role of climate, human activities and climate-human synergies on environmental shifts. Emphasis will be placed in the more recent paleoecological and paleoclimatic results, especially from our own latest investigations, which contain new data and challenging perspectives on the colonization of the island as well as on the ensuing landscape transformations, their nature and potential causes (Sáez et al., 2009; Rull et al., 2010; Cañellas-Boltà et al., 2013). Specifically, the case study of Lake Raraku sediments corresponding to the last millennia (Cañellas-Boltà et al., 2013) will be used as an example to illustrate the paleoecological and paleoclimatic issues discussed in this comment.

2. The first settlers: when and who

The arrival timing and the origin of the first colonizers are crucial aspects to properly understand the ecological and human history of Easter Island. The more accepted dates for the first human arrival range from AD 800-1000 to AD 1200 (Vargas et al., 2006; Hunt & Lipo 2006); however, there are some outliers that are worth mentioning. For example, Flenley & Bahn (2003) considered that the island would have been colonized earlier, around AD 300, whereas Wilmshurst et al. (2011) proposed a late date between AD 1200 and AD 1290. The earliest date proposed so far, around 1900 cal y BP (AD 50), is based on palynological evidence (Flenley & Bahn 2007, Butler & Flenley 2010), but it uses the hypothetical deforestation by humans as a premise, thus involving somewhat circular reasoning (Rull et al., in press).

The more recent empirical evidence suggesting human presence on the island is based on the first appearance and the subsequent successful establishment of an introduced plant (*Verbena litoralis*, locally called “puringa”) at about 450 BC (Fig. 1). Until this first paleoecological record, *V. litoralis* have been absent from the island during the last 34,000 years. As this plant is known to be linked to human activities such as cultivation for medical purposes or as a ruderal weed, its occurrence suggests human presence some 1500 years earlier than is commonly assumed (Cañellas-Boltà et al., 2013). Regarding the origin of the first settlers, genetic studies on prehistoric (pre-European contact) skeletal remains indicated that the original Easter Island inhabitants were Polynesian (Hagelberg et al., 1994). However, ancient Amerindian contribution to the human gene pool of Easter Islanders has been also supported by recent DNA analyses and also by the early presence of cultivated plants of American origin such as the sweet potato (*Ipomoea batatas*) or the bottle gourd (*Lagenaria siceraria*) (Green 2005, Clarke et al. 2006; Thorsby, 2012), thus suggesting eventual prehistoric contacts between South America and Easter Island. According to this body of evidence, the human society of the island prior to the European arrival, might have been primarily Polynesian in origin but with some potential Amerindian genetic and cultural elements. The Amerindian influence since the very beginning of the human presence on Easter Island seem to have been reinforced by the presence and expansion of *V. litoralis*, which is of American origin (Zizka, 1991; Wagner et al., 1999). This hypothesis, however, rely only on indirect paleoecological evidence and needs to be tested with further archaeological and DNA studies.

3. Landscape transformations: timing and pace

The bases for the understanding of Easter Island's ecological history were settled by the pioneering works of Flenley and collaborators (Flenley & King, 1984; Flenley et al., 1991), without which the present state of knowledge on island's paleoecology would have not been possible. A number of patterns and processes established by these early surveys are still valid but, as research progresses and new empirical observations are made, the initial framework of understanding Easter Island's history may require some modifications, even reconsiderations. In Easter Island, the presumed ecological collapse was inferred mainly from a sudden change in the palynological record interpreted as the island-wide replacement of palm-dominated forests by grasslands, which was considered the result of either extensive human-made deforestation by AD 1000-1200 (Mann et al., 2008) or massive palm-fruit consumption by human-introduced rats, some 600 years later (Hunt, 2006; Hunt & Lipo, 2006). The scenario of a sudden forest demise has established itself as the dominant paradigm and is still the prevailing view for the island's history, although it has been criticized from two main angles. First, it has been noted that the high percentages of palm pollen do not necessarily imply that the whole island was forested, as local forest stands surrounding the coring sites would have provided similar pollen assemblages, a common feature within present-day tropical and sub-tropical palm stands (Rull et al., 2010). Second, the abruptness of change may be an artifact due to the existence of a sedimentary hiatus (the Critical Sedimentary Gap or CSG; Rull et al., in press), as is the case of Lake Raraku sediments, initially ranging from ca. 7000 to 500 ^{14}C y BP (Flenley & King 1984, Flenley et al. 1991), recently constrained to ca. 4200 cal y BP to AD 1200 (Mann et al. 2008) (Fig. 1). More recent studies have shed more light on the tempo and mode of ecological shifts by finding more continuous sedimentary records that constrained the missing record (e.g. Butler & Flenley, 2010); however, a substantial part of the interval of interest, containing the replacement of palm forests by grasslands, was missing thus making impossible to know when and how (and possibly why) this ecological shift actually took place.

The more continuous record of the last millennia obtained so far was from Lake Raraku (the quarry of the famous Rapanui stone statues or *moais*), encompassing the last ~3700 cal y BP, with a minor sedimentary gap of less than 700 years at the interval of interest (Cañellas-Boltà et al., 2013) (Fig. 1). This represented a reduction of 80-90% in the missing interval with respect to previous works (Flenley et al., 1991; Mann et al., 2008; Sáez et al., 2009). As a result, it was possible to realize that the replacement of palm forests by grasslands took place in a gradual manner between approximately 500 BC and AD 1500 (Fig. 2). During these 2000 years, the forest decline and the progressive establishment of grasslands proceeded at fairly constant rates (ca. 3% reduction per century, in palm pollen units), with some minor accelerations. The onset of this replacement roughly coincided with the first appearance of *V. litoralis* (Fig. 2), which was used as an indirect evidence for island colonization; hence, it could be hypothesized that human activities could have played a role in the palm forest demise since the very beginning but, as defended by Mulrooney (2013), in a gradual, rather than catastrophic, manner.

4. Natural and anthropic drivers of environmental change

The proponents of the eco-societal collapse excluded natural climatic drivers as the cause for such event. Their main argument is that non-equivalent palm-forest demise was recorded since the Last Glacial Maximum (ca. 21,000 y BP), a period when the climate is known to have significantly changed worldwide, including Easter Island (Sáez et al., 2009; Margalef et al., 2013). Therefore, it is not expected that minor climatic variations occurred during the last millennium could have caused the total replacement of palm forests by grass meadows, as observed in the palynological records

(Azizi & Flenley, 2008). Other collapse defendants argue that palm demise would have been caused by active and extensive palm-fruit eating by rats (*Rattus exulans*) introduced from Polynesia by the original settlers, thus preventing forest recovery by seed removal (Hunt, 2006, 2007). This hypothesis is based on the finding of fossil palm endocarps with signs of gnawing by rats. Some theoretical speculations exist about the potential role of recent climatic events as for example the Little Ice Age (LIA) or an eventual intensification of the ENSO variability (McCall, 1993; Nunn, 2000; Nunn & Britton, 2001) but these proposals have not been able to provide the required supporting evidence.

In the almost continuous Raraku sequence mentioned before, a variety of paleoenvironmental proxies independent of pollen were analyzed in order to infer paleoclimatic trends (Cañellas-Boltà et al., 2013). The more informative in this sense were diatoms and carbon to nitrogen (C/N) atomic ratios. Diatoms were used as proxies for lake levels, considering that the dominance of benthic diatoms was indicative of low water level phases, whereas the prevalence of thychoplanktonic (i.e. facultative planktonic) diatoms occurred during higher lake-level intervals. In the Raraku sequence, a shift from benthic to tychoplanktonic dominance occurred around AD 1200 suggested a shift from mire to shallow-lake conditions similar to present, which is paralleled by a sedimentary change from peat to silt deposition at approximately the same time (Fig. 2). The C/N ratio is a proxy for the origin of sedimentary organic matter. Values between 4 and 10 are typical of phytoplankton, whereas ratios of 20 and greater are the more common in the cellulose-rich and protein-poor organic matter from land plants (Meyers & Teranes, 2001). Intermediate values indicate different mixing degrees of these two sources. In our case, C/N ratios typical from land plants prevail in the phase of lower lake levels and shifted to intermediate values during the higher lake-levels interval, thus supporting the interpretation based on diatoms and sediment characteristics (Fig. 2). As lake level oscillations are one of the more reliable indicators of variations in the hydrological balance (i.e. the precipitation/evapotranspiration ratio or P/E), Cañellas-Boltà et al. (2013) inferred a shift from drier to wetter climates around AD 1200, roughly coeval with a phase of rapid cooling and and wetter conditions, especially in the eastern Pacific Basin, which has been linked to an increase in the frequency of El Niño events (Nunn, 2007).

Interestingly, the incoming of wetter climates coincided with an acceleration of palm demise and a significant increase in charcoal influx, a proxy for fire incidence (Fig. 2). This combination strongly suggests increased vegetation disturbance by humans, likely favored by wetter conditions. So far, any interpretation in this sense is highly speculative but it is possible that the moisture increase favored human population growth resulting in increased landscape disturbance. Further archaeological evidence is needed to test this hypothesis. The potential occurrence of climate-human feedbacks seems crucial to properly understand Easter Island's history. Another acceleration of palm demise, linked to a major peak of charcoal influx, occurred between AD 1400 and 1500. In this case, biological and geological indicators do not show any significant change in climate; therefore, the more likely causes might be related to societal changes. Once more, archaeological input is required to clarify this point.

5. Conclusions and final remarks

The already available paleoecological evidence shows that Easter Island's landscape transformations, notably the replacement of palm-dominated forests by grasslands, have proceeded in a gradual manner since the early human colonization of the island. These observations challenge the current paradigm of a human-driven catastrophic deforestation causing a societal collapse, assumedly occurred around AD 1000-1200 or later, and are in agreement with the recent Mulrooney's (2013) argument that societal changes were also gradual. To encourage archaeology-paleoecology synergies, we highlight a number of specific points in which collaboration between these disciplines is mandatory for appropriate hypothesis testing. The first concerns the initial colonization of the island. Recent paleoecological records seem to favor that landscape transformation by humans might have commenced ~1500 years earlier than formerly thought and that a more complex pattern for the origin of the first successful colonizers should be envisaged. If this is further confirmed by archaeological evidence, the interpretation of Easter Island's prehistory might need a deep revision. Concerning the gradual pace of ecological and societal changes, there is a promising agreement, as noted before; however, this line of research should be continued for a more sound and general assessment from both archaeological and paleoecological perspectives. The third point deals with the potential causes of landscape and societal transformation. The role of either climate or human activities, or both, should be thoroughly investigated in each particular case. For example, we have suggested possible climate-human feedbacks as the cause for an acceleration in the forest demise occurred around AD 1200, and the eventual absence of climatic changes linked to a second forest retreat that took place between AD 1400 and 1500. These and other Easter Island's enigmas may only be solved by coupled archaeological-paleoecological studies. As paleoecologists and paleoclimatologists, we need and welcome archaeological feedback on the ideas and hypotheses presented in this comment, to pave the way towards potential future collaborations to advance in the understanding of Easter Island human and ecological history.

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Figure captions

1. Progressive reduction in the extent of the Critical Sedimentary Gap (CSG, blue bars) on Lake Raraku sedimentary record. Radiocarbon ages from Flenley et al. (1991) and Dumont et al. (1998) have been calibrated with CALIB 6.0 (http://calib.qub.ac.uk/calib/). The grey area is the time interval covered by the study of Cañellas et al. (2013), covering most of the previously missing interval for the last ~3700 cal years BP.

2. Summary multiproxy diagram from Lake Raraku corresponding to the last ~3700 years interpreted in vegetation and lake-level (i.e. climatic) terms. Charcoal influx was measured in particles cm^{-2} $year^{-1}$; the small fraction is considered to be representative of widespread fires while the large fraction reflects more local burning activities. The grey area is the interval missing in former surveys on Lake Raraku sediments (Flenley et al., 1991; Dumont et al., 1998; Mann et al., 2008). Note that some keystone events occurred during this interval; for example, the gradual replacement of palm-dominated forests by grasslands, the first appearance of *Verbena litoralis* (red arrow), the onset of charcoal deposition and the shift from drier to wetter climates. Redrawn from Cañellas-Boltà et al. (2013).

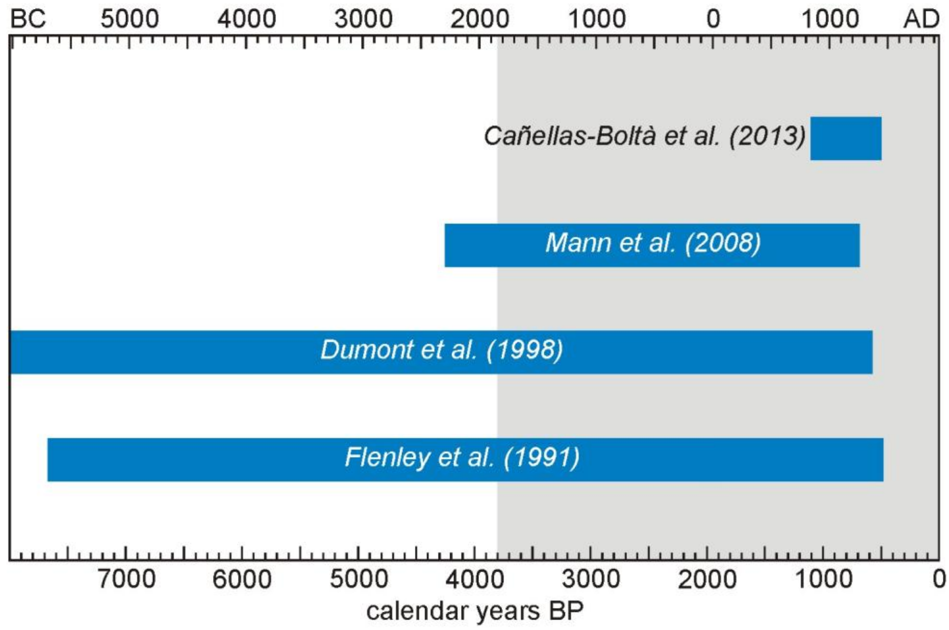

Figure 1

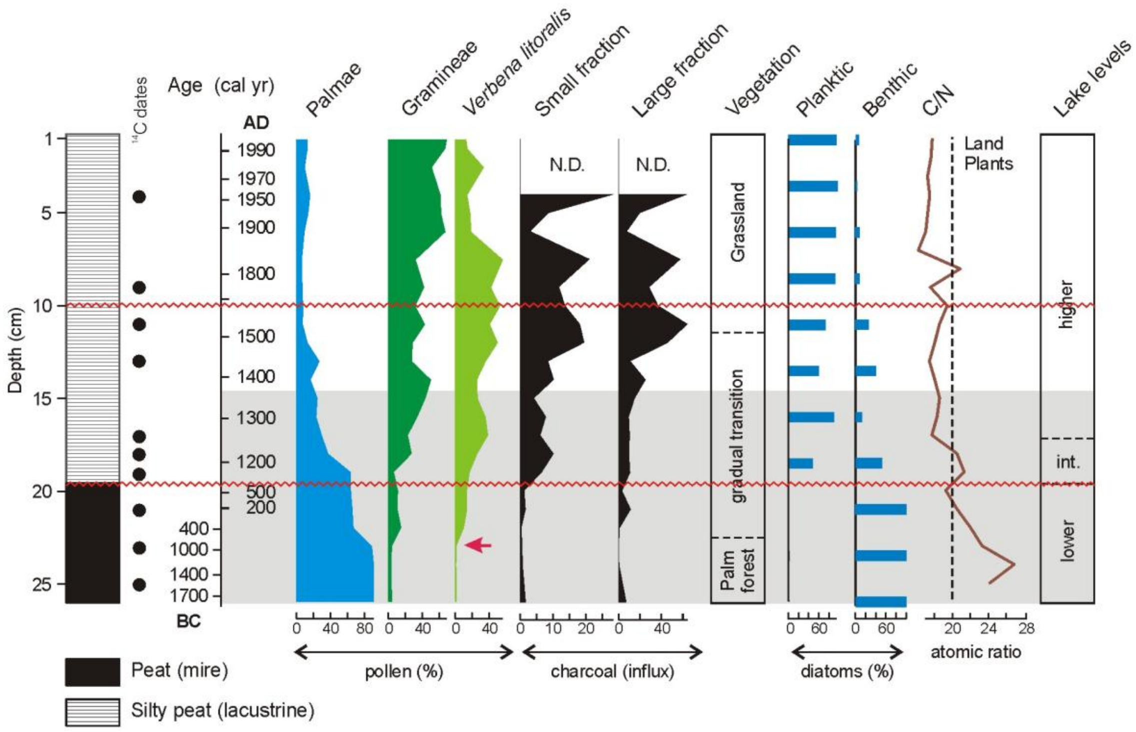

Figure 2