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Journal of Archaeological Science 33 (2006) 1744–1748

Journal of Archaeological SCIENCE

http://www.elsevier.com/locate/jas

ENSO influence on Holocene Aboriginal populations in Queensland, Australia

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Received 10 November 2005; received in revised form 6 March 2006; accepted 16 March 2006

Abstract

In the Pacific region, the onset of modern El Niño/Southern Oscillation (ENSO) activity at approximately 5000 years ago may have played a significant role in the development of cultures in the Pacific basin. Within Australia, similar trends in population and resource use have been identified but largely ascribed to cultural changes. To test human responses to changing ENSO activity through the Holocene we analysed a comprehensive suite of 710 radiocarbon ages from archaeological sites in ENSO-sensitive Queensland. We observe a dramatic and sustained increase in landscape activity at inland sites from 4860 ± 15 years ago, statistically indistinguishable from the timing of the onset of modern ENSO activity. Subsequent changes in long-term activity directly impacted on human populations indicating that once established, ENSO maintained a continuous influence on disparate cultures throughout the Pacific basin.

Keywords: Pacific Ocean El Niño/Southern Oscillation; Mid-Holocene cultural and archaeological change; Resource use; Landscape management; Fire; Rainforest culture

1. Introduction

The changing dynamics of the atmosphere–ocean system driven by the El Niño/Southern Oscillation (ENSO) has received considerable research interest in attempting to understand past climatic, environmental and archaeological changes [9,12,22,27]. Major climatic perturbations associated with the ENSO phenomenon are known to have taken place at a range of different timescales, including the last glacial–interglacial cycle [30,31], the mid-Holocene [10], and in the recent past [15,23]. In the Pacific region, the onset of modern ENSO activity appears to have commenced approximately 5000 years ago [18,20,25], thousands of years after human populations became established over much of the region [1,19,20,28,32].

Forcing changes in human settlement and resource use, the onset of 'modern' ENSO activity may have played a significant role in the development of eastern Pacific cultures [27,29]. Within Australia, similar trends in population and resource use have been identified but largely ascribed to cultural changes, such as stone tool development, economic intensification, changes in settlement patterns and/or exploitation of seashore resources [16,21,27]. Although these all have merit in explaining different aspects of the Australian archaeological record, the potential role of environmental change in contributing to these developments has been often neglected or relegated to a minor role (for exceptions see [8,12,26]).

During El Niño episodes, a northward movement of the Inter-Tropical Convergence Zone and a northeastward migration of the South Pacific Convergence Zone results in a significant decrease in summer precipitation (typically 150–300 mm below seasonal average) over much of Queensland [5,11,18], making it extremely sensitive to changes in ENSO activity. Furthermore, Queensland has a rich archaeological record spanning over 35,000 years [6] that has been

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doi:10.1016/j.jas.2006.03.007

extensively radiocarbon dated since the 1960s, providing an excellent opportunity to test hypotheses regarding human responses to ENSO variability in the southwest Pacific region.

2. Methods

A principal indicator of mid-Holocene change in Australian Aboriginal activity is the significant increase in the number of radiocarbon ages reported from archaeological contexts. Although this has often been interpreted as reflecting a major population increase [21], it is unlikely that a simple relationship exists between population and the number of radiocarbon ages. Although a precise interpretation is probably not possible, the increased number of ages from the mid-Holocene most probably reflects greater activity in the landscape [12,17]; something that does not preclude an increase in population. Individual sites and the generally limited number of associated radiocarbon ages, however, make it difficult to precisely date the onset of increased activity and test whether the timing was synchronous within and across Australia. Where compilations of radiocarbon ages have been investigated they have largely been undertaken on an uncalibrated timescale [12,17], precluding robust comparisons to independently-dated reconstructions of change outside Australia.

To test human responses to changing ENSO activity through the Holocene [20] we analysed a comprehensive suite of radiocarbon ages obtained from Queensland archaeological contexts (Fig. 1) [33,34]. A total of 710 radiocarbon ages were calibrated to 2σ using the IntCal04 and Marine04 datasets [24] with a Southern Hemisphere offset of 40 ± 13 years and the probabilities of individual age distributions for the separate categories summed and normalised to unit area using CALIB5. Sites were independently categorised as inland and coastal (<1 km from present day coastline) [33,34], with the latter separated according to marine (e.g. marine shells) or terrestrial (e.g. charcoal) as a measure of resource use. No selection criteria were used for the available radiocarbon ages; the large number in this study precludes significant skewing of the dataset and provides an excellent opportunity to identify long-term trends. For marine samples, the ages were calibrated against Marine04 with a ΔR for the east central Australian coast of 12 ± 6 years. All ages are given as calibrated years before AD 1950.

3. Holocene changes in landscape activity and ENSO variability

Elevated probability values from 4860 ± 15 years ago indicate a marked increase in landscape activity at inland sites (Fig. 2A), possibly as a result of a significant expansion in the Aboriginal population. Prior to this time, relatively little activity is recognised, which we interpret to reflect a low population density. Activity at coastal locations occurs significantly later in time, however. A small change in probability values at coastal locations characterised by a dominance of terrestrial resource use is broadly coincident with the time of inland expansion (Fig. 2B) but only significantly increases from 3210 ± 10 years ago. In contrast, coastal locations characterised by a dominance of marine resource use (Fig. 2C) are not intensively utilised until much later, with the first significant sustained period of increase commencing around 2140 years ago and culminating 1400 years ago. From this time, there is an almost exponential expansion in activity in both inland and coastal locations (Fig. 2). Differences in the timing of expansion recognised here as a result of sampling bias can be discounted. Any continental shelf population

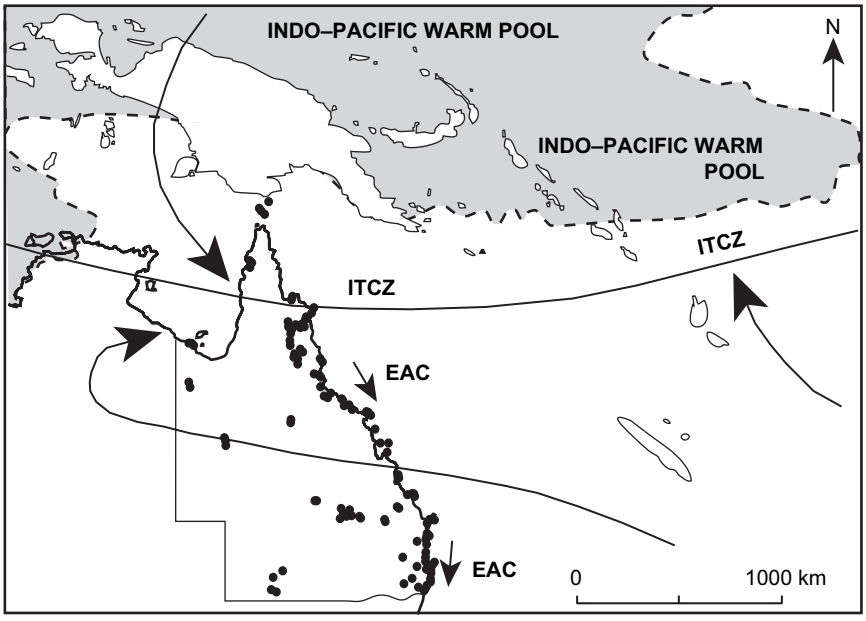

Fig. 1. Location of sites and atmospheric circulation during the austral summer with annual mean location of ocean masses [5,9,33]. Site locations are shown as solid circles. 'ITCZ' denotes Inter-Tropical Convergence Zone and 'EAC' denotes East Australian Current.