CLIMATE CHANGE, SEA-LEVEL RISE AND THE ARCHAEOLOGICAL RECORD

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There is an urgent need for heritage researchers and managers to address the issue of climate change and its impact on archaeological sites. Yet, it was apparent from discussions at the Australian Archaeological Association's annual conference at Townsville in 1990 and a recent workshop in Canberra initiated by the Department of the Arts, Sport the Environment and Territories (DASET) (May 1991) that few heritage researchers are fully conversant with greenhouse issues, and that the process of discussion has only just begun. The DASET workshop will result in a publication outlining a range of potential climate change impacts on heritage resources and a strategy for dealing with these. As a contribution to these discussions this paper attempts to provide an introduction to greenhouse literature and issues, and in particular outlines some of the potential impacts of greenhouse effects on Aboriginal coastal sites. Greenhouse impacts need to be considered in the context of other ongoing impacts and these will be addressed in an upcoming review of coastal sites in Queensland.

THE GREENHOUSE EFFECT

The greenhouse effect is a natural phenomenon in which gases within the earth's atmosphere trap some of the warming energy of the sun. Without this 'blanket' of gases the earth's temperature would be ca 33°C lower than it is and too cold for life. However over the last several decades humans have increased the amount of these gases, particularly carbon dioxide ($C0_2$), methane (CH_4), nitrous oxide (N_20) and added a new family of gases — chloroflurocarbons (CFCs), resulting in an **enhanced** greenhouse effect. This increase in gases has arguably lead to an increase in world temperatures, acid rain, ozone depletion, changing climates and rising seas.

A potential enhanced greenhouse effect was recognised as long ago as the 1850s (Christie 1990; Grove 1990), while ironically in the 1960s and 1970s evidence was being gathered which suggested evidence of planetary cooling and debate centred around the question of whether or not the world was heading toward a new ice age (Pearman 1988). Nevertheless the mid-1970s and early 1980s saw a rapid increase in the volume of evidence and research indicating global warming.

Literature relating to the enhanced greenhouse effect is both voluminous and complex and it is sometimes difficult for the layman to separate the 'hard' from the 'soft' scientific data. The media has shortened, simplified and sensationalised the evidence and dealt with worst case scenarios (Pittock and Pearman 1989). The review presented below is only a brief outline of some of the more reliable literature.

A seminal meeting in the climate change debate held at Villach, Austria in 1985 (Bolin et al 1986) concluded that by 2030 world temperatures would have risen by between 1.5 and 4.5°C and that by 2050 sea-levels would also have risen by between 20 and 140 cm as a result of melting of land-based ice and thermal expansion of the ocean. The potential flooding of low-lying land and river deltas, movement of saltwater into fresh water aquifers and surging seas causing erosion were highlighted as potential impacts. A major meeting organised in Australia to discuss these issues found support for changes at the lower end of the temperature and sea-level range of scenarios (Pearman 1988).

The most recent and influential publications on climate change (and the ones to which archaeologists might refer) are the three summaries produced by the Intergovernmental Panel on Climate Change (IPCC). These documents suggest that given business-as-usual conditions (ie no control over emissions of greenhouse gases), global temperature will rise at about 0.3°C per decade (uncertainty range 0.2°C to 0.5°C) resulting in a global mean temperature of about 1°C above present by 2025 and 3°C by 2100. Control of emissions might reduce this by 0.1-0.2°C per decade. Sea-levels will rise about 6 cm per decade (uncertainty range 3-10 cm) resulting in a rise of about 20 cm by 2030 and 65 cm by 2100. Again this will be reduced by emission controls. It is recognised that regional climatic impacts will be variable.

Given the above figures a **possible** scenario for Australia's climate in 2030 is as follows:

Temperature — Annual mean temperature will increase 1-2°C in northern coastal areas, 1-3°C in southern coastal areas and 2-4°C in the interior.

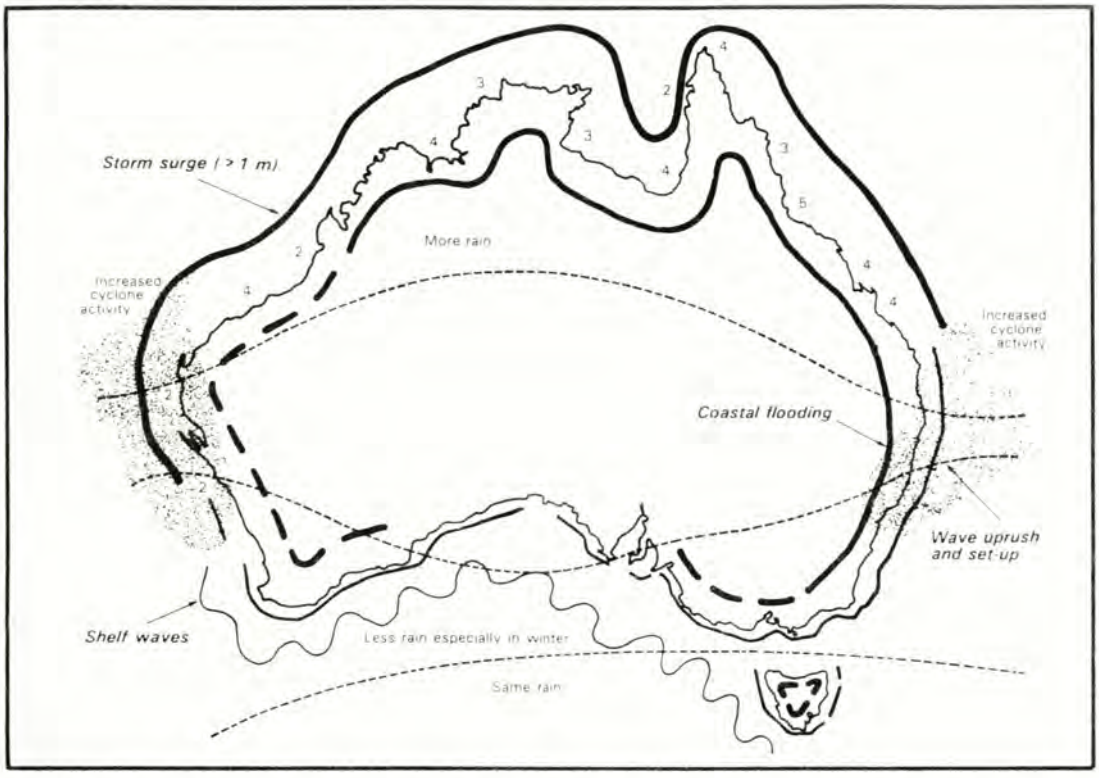

Figure 1 Some predicted impacts of the greenhouse effect on Australia (after Henderson-Sellers and Blong 1989:58, Short 1988:97) (Key: 4 = extreme storm surge in metres)

Precipitation — Higher summer rainfall will occur over northern Australia (+10-20%) and extend further south. Winters will probably be drier (-10%) in southern Australia. Rainfall will be more intense. With every 1°C warming the snowline will recede 100 m.

Evaporation — 5-15% increase.

Sea-levels — A general 3-10 cm rise in sea-level per decade.

Cyclones — The southern limit of tropical cyclones would shift southward. Intensity and frequency may increase.

Extreme events — Magnitude and frequency of extremes likely to be greater and more often (Henderson-Sellers and Blong 1989) (Fig. 1).

SEA-LEVELS

There are numerous mechanisms that can raise or lower sea-levels (Stewart et al 1990; Zillman, Downey and Manton 1989:27) and they are extremely difficult to measure (Everard 1980). Recent summaries of sea-level rise resulting from enhanced greenhouse effects have been more conservative (eg IPCC; Pearman 1988) than earlier attempts (eg Bolin et al 1986; Hoffman 1984) but there is inherent uncertainty in the data and complexities caused by synergetic effects in all the scenarios (Belperio 1989; Bird 1988; Van deer Venn 1988).

World tidal measurements have risen 10-15 cm in the last century, but both Bird (1988) and Belperio (1989) argue that this could be caused by factors other than global warming including subsidence, tectonic emergence or submergence and/or post-glacial rebound. Coastline erosion studies have also demonstrated that 70% of the world's coastlines have retreated over the past few decades, less than 10% have shown substantial progradation and only 20-30% have shown no change or been stable. Bird (1985) however has again cautioned attributing this to greenhouse effects.

There is thus some hesitation in attributing the currently measurable changes to greenhouse effects and while recent reviews have tended to be more conservative, it is generally accepted that changes will occur. There is however enough uncertainty resulting from the complexity and interrelationships of the data that we must also be prepared for surprises. For example, it has been argued that an initial lowering of sea-levels may occur in response to an increase in Antarctic precipitation (Budd 1988:78). On the other hand recent satellite data on sea-surface temperatures (Strong 1989) and corrections for submergence and other factors (Gornitz and Lebedeff 1987) have suggested sea-level rises could be slightly higher than those anticipated by conservative models. Furthermore, on the basis of recent work on the Greenland ice core and research into astronomical forcing it has been suggested that world climates may reach balanced states and that subsequent transitions

between glacial and interglacial conditions may represent jumps between two stable but very different modes of ocean-atmosphere operation (Broecker and Denton 1990; Dansgaard et al 1989; Overpeck et al 1989; Peel 1989; Tooley 1989). For example, it has been argued (Dansgaard et al 1989) that the last near-glacial cold period (the Younger Dryas) which is now thought to have been a global phenomenon (Kudrass et al 1991:407) ended abruptly 10,700 years ago resulting in the climate in the northern Atlantic region turning to a milder less stormy regime in less that 20 years.

Such recent research results have lead Broecker and Denton (1990) to ask the question — 'will forcing by the greenhouse effect cause the world's climates to again respond abruptly, flipping to an entirely new mode?' — and thus cause changes in sea-levels at rates not currently anticipated.

IMPLICATIONS

Elsewhere I have proposed (Rowland 1983) that interpretations of the Holocene coastal prehistory of Australia must be tempered by the knowledge that sea-level change and coastal erosion have been responsible for selectively removing some of the evidence (see also Head 1987) and that for at least one area of the Queensland coast (the humid tropic zone) cyclones and storm surges have had a similar and substantial impact (Rowland 1989). These processes will continue and be enhanced by greenhouse effects. Unfortunately, with rare exceptions (Bird 1991) archaeologists have not yet begun to monitor these changes.

The impact of sea-level rise on Australia's heritage could be substantial. Shoreline retreat will result directly from thermal expansion of the oceans while sediment supply, storm conditions, tidal ranges, rainfall and water table levels will also change and cause further erosion of the coastline. For every metre of sea-level rise it is estimated that sedimentary coasts will retreat by 20-200 m (Henderson-Sellers and Blong 1989:89). Flooding of large coastal areas will occur on a temporary basis and saltwater will intrude into coastal lands. Significantly, it is also predicted that the tropical cyclone belt will move 200-400 km southward resulting in wind/rain/storm surge impacts on previously untouched stretches of coast (Pittock 1988).

Australia has over 30,000 km of mainland coast (including Tasmania) plus an equal magnitude of coastline contained in the surrounding 12,000 islands and in the several hundred estuaries, coastal lagoons, lakes and bays, producing a total coastline in excess of 70,000 km. All of these coasts will be vertically inundated to some degree by rising seas. Inundation would be greatest on low gradient beaches such as the mud and sand flat and chenier and beach ridge plains of northern Australia and parts of southern Australia (60,000 km^2). Slightly steeper gradients covering an area of 1250 km^2 in southern Australia and parts of northern Australia would also be inundated along with river mouths, estuaries, coastal lagoons and bays. A number of areas of coastline would also be inundated on a periodic basis depending on the effects of astronomical (tides) or atmospheric (waves, set-up, storm surges and flooding) forcings. These may be predicted on the basis of current patterns, however there will also be substantial shifts due to such influences as the southward movement of the cyclone belt (Short 1988) (Fig. 1).

DISCUSSION AND CONCLUSION

Archaeologists are not in a position to evaluate which scenario of climate change and therefore which models of sea-level change are most probable, and indeed it appears that there is no overall consensus amongst the specialists at this time. Nevertheless there seems little doubt that the greenhouse effect will impact on climate and sea-levels (Manton 1989) and the summaries provided by IPCC indicate the most likely direction and magnitude of change. Archaeologists and cultural resource managers therefore need to begin addressing the potential impacts of these changes on coastal archaeological sites. With this in mind the following priorities are suggested:

1. An increased effort to record coastal archaeological sites. In Queensland, at least, substantial areas of the coastline have not yet been surveyed, so that it is not yet possible to determine if all coastal environments have been sampled.
2. To identify coastal areas that are likely to be impacted in the short and long term and where possible identify time frames of potential change and likely impacts.
3. To commence monitoring some of the better recorded coastal sites over time to determine the nature of ongoing impacts on coastal sites in general.
4. To assess as a profession our expertise and the extent and quality of resources available to undertake salvage work. Should impacts occur as predicted heritage sites will have a relatively low priority and it is unlikely that funds would be available to preserve sites in situ.
5. To discuss with Aboriginal owners the potential impact of greenhouse changes on coastal sites. This will be particularly important since as noted above the major emphasis in management will of necessity be on salvage.
6. To become more involved on a multi-disciplinary basis with scientists and planners dealing with greenhouse issues.
7. To become more aware of greenhouse issues ourselves as a profession and communicate our concerns generally. In Queensland, it can be noted for

example, that while most environmental impact studies now address greenhouse issues, none of the archaeological reports that form a component of these studies have done likewise.

For Queensland, I am about to commence an overview of coastal sites utilising environmental data, ethnohistoric records and the Heritage Branch site data base to determine the pattern and distribution of coastal sites. While some sections of the coast are well surveyed the majority of the Queensland coast is not. It is therefore anticipated to take from one to two years to come up with some meaningful results. The review will particularly focus on potential greenhouse effects. However, there are many other factors which will impact on coastal sites in the future and we should be cautious of getting side-tracked by the current high profile of the greenhouse debate. For example, by the year 2030 a key date for greenhouse predictions, there will also be 11-15 million extra Australians, and it is likely that they will be found in and around the existing major metropolitan and provincial centres, in coastal zones, as are 85% of the present population (Department of Immigration, Local Government and Ethnic Affairs 1987).

The coast will therefore continue to be a 'battlefront' where land, sea and air meet and which changes from second to second, season to season, decade to decade and millennium to millennium (Rowland 1990), and where there will continue to be competition for space and economic resources. If nothing else the current greenhouse debate will heighten our awareness of all possible impacts in developing cultural resource management strategies.

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