Approaches to Monitoring and Managing Indigenous Australian Coastal Cultural Heritage Places

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Australia’s coastal zone contains a diverse range of cultural heritage places. They are, however, negatively impacted by a multitude of natural and cultural factors. Currently there are few robust site monitoring programmes that focus on identifying the causes and directions of change in the coastal zone and the impacts that these changes have on heritage places. With case studies from Queensland, we outline and evaluate a number of potential approaches to coastal monitoring. They range from localised but inexpensive combinations of anecdotal observations coupled with geoindicators, to the use of more recent and sophisticated technologies such as LiDAR (Light Detection and Ranging) remote sensing. We also propose there is a need to establish cooperative information data sharing arrangements in Australia for coastal monitoring studies.

Introduction

Coastlines, marine resources and ultimately seaborne contacts have played a critical role in human development resulting in a rich legacy of cultural heritage places on the world’s coastlines (Bailey 2004). These coastlines continue to be an important focus of human settlement and consequently a wide range of natural and cultural factors have and continue to impact adversely on coastal heritage places (e.g. Hassler 2006; Rowland 2010; Rowland and Ulm 2012). Cyclones, storms and storm surges, and wave and tidal action, for example, have major impacts on dune systems while sand and coral mining and the spread of tourist, residential and industrial developments have direct impacts on sites resulting in unregulated loss or salvage (Fitzpatrick et al. 2006). In recent years evidence that humans are warming the world’s climate and subsequently causing a rise in sea-levels (Parry et al. 2007), has drawn attention to the potential increased impact of sea-level and related changes on coastal areas. Numerous studies have used future climate change projections to indicate potential impacts of climate change on a number of coastal environmental and cultural features. We emphasise that these are projections based on certain assumptions and computer models and accept this as a valid approach to determining potential impacts on coastlines and cultural heritage places. However, we also stress that regardless of projected or potential sea-level change attributed to anthropogenic global warming there is a critical need to develop methods to measure short- and long-term human- and naturally-induced impacts on the coast before effective decisions can be made concerning the short- and long-term management of cultural heritage places (McIntyre-Tamwoy and Buhrich 2012; Rowland 2008). We are therefore not primarily concerned in this paper with climate change per se but with a range of environmental and cultural changes in general and methods of measuring and monitoring the impact of those changes in the coastal zone.

Currently in Australia, short- and long-term monitoring programmes that might identify the causes and directions of change and impacts on coastal cultural heritage places are rare. Where such studies have occurred there has been little coordination and sharing of information across heritage jurisdictions. At this point in time we concur with the view expressed more generally by Jones (2003:198) that there is a poor record of site monitoring, inadequate protocols on when to intervene and limited professionalism in the area of site management. We outline a number of approaches to overcoming some of these issues in the coastal zone.

We discuss, with examples, a number of approaches to measuring the impacts of climate and sea-level change on cultural heritage places. These range in scale from the localised and cost-effective to the broader scale and more complex. We discuss the use of LiDAR as a more complex and expensive but accurate way of measuring long-term trends in coastal change. We also argue that there is a need to establish a national focus relating to site management in the coastal zone so that the information may be more efficiently and effectively shared between jurisdictions. We highlight the need to align cultural heritage management methodologies more closely with the work of other coastal zone researchers and managers. Our examples are from the Queensland coast but are applicable to the Australian coastline in general.

The Australian and Queensland Coastal Zones

The Australian coastal zone spans 9° to 42°S through extensive and diverse tropical and temperate environments. It comprises reefs, islands, parts of the continental shelf, estuaries, tidal flats, coastal sand dunes and the coastal land margin incorporating a coastline in excess of 60,000km (Department of Resources, Energy and Tourism 2010). Over 80% of Australia’s population lives in the coastal zone (about 22 million in 2010 and an estimated 36 million by 2050) (Commonwealth of Australia 2010) so that human impacts are significant, widespread and diverse. Australian beaches are exposed to tides ranging from less than 1m to 11m and to wave energy ranging from very low seas to the world’s most persistent and energetic swell environments (Short and Woodroffe 2009; Voice et al. 2006:1). Cyclones, wave height and tidal velocity impact at various intensities on
the coastline. The impact of climate and sea-level change on coastal systems is therefore likely to be significant but difficult to predict over such a large and diverse area (e.g. Church et al. 2008a, 2008b; Cowell et al. 2006; Hunter et al. 2010; Nicholls 2002). Sea-level change due to vertical crustal adjustment to changes in ice and water loading must also be considered (Church and White 2006; Forbes and Liverman 1996:179).

The Queensland coastline which is the focus of our case studies extends over 13,000km and comprises diverse sandy beaches, rocky headlands, low-lying mud and sand islands, coral atolls and rocky islands (Figure 1). On the Queensland coast, 66% of beaches are gently sloping sandy beaches, often backed by beach ridge plains which would have been highly attractive areas for Aboriginal occupation. Global warming is projected to lead to a sea-level rise of 0.26–0.79m by 2100 (Queensland Climate Change Centre of Excellence 2011:2). Other projections include: changes in the regional and local frequency of tropical cyclones, an increase of over 0.1m in storm surge height resulting from changes in cyclone behaviour, an increased frequency of extreme sea-level events and increased coastal erosion. All of these factors are likely to impact on cultural heritage places.

The Australian Coastal Archaeological Record

We are unable to determine the proportion of the Australian or Queensland coast that has been surveyed for archaeological sites. Cane’s (1997:55) review for the entire Australian coast listed 30,000 recorded sites but he suggested that the real figure may be closer to 60,000. We recognise the importance of his review but suggest that the figure for number of sites might be considerably higher. A study of the South African coastline (3000km) indicated that less than 5% of the coastal zone had been searched for archaeological sites of which less than 1% had been systematically surveyed (Coetzee and Kaplan 1996:364) and we would expect the coverage to be broadly similar for Australia. As a first step in site monitoring we recommend that state heritage bodies should produce maps of the coast indicating those areas that have or have not been surveyed together with numbers and types of sites located. Past, present and future cultural and environmental variables likely to impact on the coastal zone should also be mapped.

Indigenous archaeological sites were present on the Australian coast from the time of initial settlement, though early sites are rare due to the destructive impacts of sea-level rise associated with the end of the last ice age around 10,000 years ago (Ulm 2011). As a result of relative sea-level stabilisation in the Holocene, sites belonging to that period are more numerous but there was variability around the coastline. The management and monitoring of coastal heritage sites in Australia has not been widely discussed and there has been little if any coordination between the various studies (but see Aboriginal Affairs Victoria 2000; Bonhomme and Buzer 1994; Cane 1997; Clark and Hope 1985 [see follow up study by ANU Heritage 2007]; Smith 1998; Sneldon et al. 1986; Watson 1993; Zallar et al. 1979). The international literature is more comprehensive and there have been some attempts to coordinate the measurement of key variables (e.g. Bhattacharyya et al. 2010; Britsch and Smith 1989; Crowell et al. 1991; Davis et al. 2000; Fitzpatrick et al. 2006, Hamel and Jones 1982; Lewis 2000; Lynott 1989; Macphail et al. 2010; Moore 2000; Nickens 2001; The Getty Conservation Institute 2003; Thieler and Danforth 1994a, 1994b; Thorne 2004;
Turnbaugh 1978; Williams 2004). The management of coastal sites is challenging due to the wide range of potential impacts that must be considered and also due to the critical issues of scale and cost (for a brief but useful review see Sullivan 1989). There is an extensive literature on methods of dune stabilisation, but the methods only rarely take into account the specific needs of archaeological site protection (Snelson et al. 1986:25). These methods have been developed by beach protection authorities and have rarely been used by cultural heritage management authorities. In the following sections we provide examples of approaches to monitoring change in the coastal zone with examples from the Queensland coast. We commence with an example using general observations and introduce the use of geoindicators and the more recent and powerful LiDAR.

**General Observations and Anecdotal Information**

A cost effective but limited approach to monitoring involves the use of general observations and anecdotal information. Rowland (2008), for example, has previously summarised anecdotal observations and other information collected over a period of 30 years in identifying the factors causing damage to coastal archaeological sites on the Keppel Islands off the central Queensland coast. Based on these observations it was apparent that the primary cause of damage over the last 5000 years on the Keppel Islands was due to the long-term action of wind and waves. This 'normal' process of wind and water erosion has been exacerbated in recent times by natural and human-induced vegetation removal. Introduced sheep, goats and possums have been a major source of vegetation destruction on the islands while, contrary to expectations, tourists have probably had a more limited impact on most sites. Stochastic events, such as cyclones, associated storm surges and flood discharges from the nearby Fitzroy River have also had significant impacts.

Rowland (2008) also used geoindicators to measure changes in the coastal zone of the Keppel Islands. Geoindicators are measures (magnitudes, frequencies, rates and trends) in geological processes and phenomena occurring at or near the earth’s surface which are subject to changes that are significant in understanding environmental change over periods of 100 years or less. They measure both catastrophic events and those that are more gradual, but evident within a human lifespan. They measure what is happening in the environment, why is it happening and what impacts it is having (see Berger and Iams 1996 for details). Geoindicators provide a higher-order level of measuring change in coastal processes but at a scale relevant to the management of heritage sites (see Rowland 2008 and Daly 2011 for further details).

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**Figure 2. Impact of cyclones, waves, tides and East Coast Lows along the Queensland coast (Queensland Climate Change Centre of Excellence 2011:Figure 11).**
Aerial photographs have also been used to indicate trends in coastal areas. Aerial photos have been used in archaeology since 1880 (Reeves 1936) with increasing sophistication in recent years (e.g. Risbol et al. in press; Verhoeven et al. 2012). Here we provide an example where aerial photographs covering a limited time span (1958 and 2008) and a small area of the southern section of Moreton Island can be used to interpret coastal trends that can assist in interpreting the potential pattern of site distributions (Figure 3). This area of Moreton Island shows a variable pattern of change in coastal morphology. A number of changes in both the pattern of sand movement and vegetation can be recognised over a relatively short period of time. For example, the area marked ‘A’ on Figure 3 has very recently been built up by sand movement and has become vegetated. The area was low-lying sand flats in 1958 but had built up and was vegetated by 2008. If an archaeological survey were to be undertaken in the area today no archaeological sites are likely to be found since despite appearing to be well-vegetated this is in fact a recent land surface.

A further example again using aerial photographs covering a limited time span shows the location of a number of sites recorded by Ponosov (1964) in 1963 on North Stradbroke Island (Figure 4). It is apparent from the aerial photograph (1965) on which these sites are marked that the dune systems at this time were very exposed. We are currently unable to determine when this erosion may have occurred. However, it may account for the high number of sites (i.e. good site visibility) recorded by Ponosov at the time in this area. It is then apparent, from overlaying the sites on a 2008 aerial photograph that much of the area has revegetated in the intervening period. If fieldwork were undertaken in the area today it might be possible to conclude that many of the sites had been destroyed (which they may have been) since sand mining has been a high level activity on the island. Alternatively, it may be possible that sites have been recovered and revegetated.

The limited use of aerial photographs and anecdotal information on Keppel Islands, Moreton Island and Stradbroke Island could not be used to draw detailed conclusions about coastal changes and impacts on sites in these areas. However, it appears that most of the changes identified could be attributed to ‘normal’ changes in climate patterns and increasing human impacts. At present none of the changes could be attributed to the impact of sea-level change related to accelerated global warming. However, the application of basic geoidicators such as those used on the Keppel Islands should in the future enable clearer trends to be identified. Using geoidicators is an inexpensive means of identifying some broad trends.

**Predictive Modelling Using LiDAR**

Predictive modelling studies incorporating sea-level changes based on IPCC projections indicating the potential impacts of sea-level rise have been undertaken for a number of coastal areas of the world, including Australia (e.g. Abuodha and Woodroffe 2010; Akumu et al. 2010; Ghilardi and Desruelles 2008; Kvanme 1999; McInnes et al. 2013; Stevens and Collins 2011; Zhang et al. 2004). These are important studies but need to be coupled with long-term monitoring to determine what changes are actually occurring on the coast.

An approach to mapping with considerable potential to monitor the short- and long-term extent and direction of coastal changes and therefore impacts on coastal heritage sites is the application of LiDAR (Light Detection and Ranging) remote sensing (see Hesse 2010 for a useful introduction; see also Chase et al. 2011). Ground-based fixed LiDAR instruments or those attached to aircraft or satellites fire rapid pulses of light at the landscape and a sensor mounted on the instrument measures the amount of time taken for each light pulse to bounce back. Because light moves at a constant and known speed, the LiDAR instrument can then calculate the distance between itself and the target with high accuracy. It is therefore able to build up a complex picture of the terrain and landscape features it is measuring (CSIRO 2013). For example, it is possible to model sea-level rise impacts on coastal features at the sub-metre scales outlined in IPCC reporting (Gesch 2009).
LiDAR was introduced into archaeology in 2002 (see Challis et al. 2011a, 2011b; Hesse 2010) and its potential use in Australian archaeology has been recently recognised (McIntyre-Tamwoy and Buhrich 2012). It has been used in mapping geomorphic events and coastal evolution to a high degree of accuracy (e.g. Bull et al. 2010; Hugenholztz et al. 2012; Irvine-Fynn et al. 2011; Oskin et al. 2012; Revell et al. 2002; Sallenger et al. 2003; Shrestha et al. 2005; Stockdon et al. 2002; White and Wang 2003). LiDAR has the potential to date the age of beaches (e.g. Yang and Teller 2012) and to identify land vulnerable to sea-level rise (Gesch 2009; McInnes et al. 2013). LiDAR has been used to map the impacts of mining activities (Kerfoot et al. 2012; Yousef et al. 2013) which could be usefully coupled with archaeological mapping on many sections of the Australian coast impacted by mining. It has been applied to a wide and increasing range of cultural heritage issues outside of Australia (Bennett et al. 2012; Bernardini et al. 2013; Challis et al. 2011a, 2011b; Gontz et al. 2011; Johnson and Ouimet 2014; Ladefoged et al. 2011; Maio et al. 2012). New and more sophisticated versions of the technology continue to be developed (Corns and Shaw 2009). We briefly introduce LiDAR here together with other techniques as an introduction to the potential of these methods for site identification, management and monitoring of coastal cultural heritage sites.

Figure 5 shows the distribution of sites recorded since 1973 on Bribie Island, southeast Queensland by Stockton (1973) and others. These were recorded variously as middens, artefact scatters and campsites. Overlaying a 1m contour using LiDAR data as an approximate height of sea-level rise by 2100 demonstrates that at least two sites (marked A and B) would be completely lost to sea-level rise. Other sites, however, might also be lost or at least heavily damaged by changes in coastal geomorphology since erosion is ongoing, with at least 70% of sandy beaches around the world being recessional in nature (Zhang 2011:41). Using high-level LiDAR data Figure 6 shows areas of Bribie Island that would be inundated by 1m and 2m sea-level rises (Map 1 and 2) and also the level of detail that can be defined by using LiDAR data (Map 3). Figure 7 shows the level of detail that can be generated in 3D using LiDAR data.

LiDAR data when combined with archival aerial photographs, historical photographs and ground truthing can be used to identify and recover ‘lost landscapes’ (Randall 2014). LiDAR provides a snapshot of the ground surface at the time of collection but when combined with aerial photographs a model of past landscapes can be developed. LiDAR and additional tools such as the Digital Shoreline Analysis System (DSAS) can improve understanding of long-term geomorphic processes and allow for the analysis of beach micro-topography and quantification of local sediment budgets (Brock and Purkis 2009; Liu et al. 2007); the calculation of shoreline change (Gontz et al. 2011); and identification of potential flood prone areas (Brock and Purkis 2009). DSAS is
computer software that computes rate-of-change statistics from multiple historic shoreline positions in GIS. It is also useful for computing rates of change for just about any other boundary change problem that incorporates a clearly identified feature position at discrete times (it is freely available for download at Woods Hole Science Center 2013). It could be used in areas where aerial photographs or satellite imagery are available over an extended period of time.

LiDAR has considerable potential to identify geomorphological landscape features and archaeological features at high levels of resolution. For example, after mapping 5.5% of the German state of Baden-Württemburg Hesse (2010:70) was able to identify 25,597 pre-modern anthropogenic features and potential archaeological sites compared with a previous record of 4,037. While LiDAR might be less successful in Australia due to the less structural nature of the archaeological record, features such as shell mounds, fish traps and historical sites could be identified. It would also be particularly useful in interpreting geomorphological changes in coastal areas and therefore assist in accounting for the presence or absence of sites.

**Discussion**

Early coastal dwellers had significant physical impacts in the coastal zone and on marine ecosystems (e.g. Erlandson and Rick 2010). Much of the evidence for this is locked up in coastal dunes. Coastal dunes, however, are fragile systems impacted by the dynamic nature of weather and wave climates and a complex range of human-induced impacts that occur on a number of timescales. The magnitude of these changes may also be largely random and unpredictable. Given the range of potential impacts that may occur on the coast it is critical that broad-scale and long-term monitoring is undertaken so that long- and short-term trends in a range of variables may be identified. Cultural heritage professionals need to continue to assess their expertise, and the extent of resources available to deal with these levels of change. In particular, there is a need to address the ability of professionals to design, implement and manage large-scale salvage projects where loss of sites is likely. Strategies for responding to change need to be framed in terms of the uncertainty of potential global warming, the extent of normal variability in environmental factors, the impact of other perhaps more dominant human-induced changes and the concerns of heritage owners or users (Rowland 2008). Significantly, climate scientists have themselves noted an important shift in focus from assuming that climate change is the major cause of change in coastal environments to one in which there is a need to better understand climatic and non-climatic drivers and their interactions at different spatial and temporal scales (Brown et al. 2014).

Environmental changes and increasing human development in the coastal zone will continue to impact on coastal heritage places whether or not sea-levels change as a result of human-induced global warming. The potential impact of global warming should, however, heighten the need to continue to define and refine the processes impacting on coastal archaeological sites. The principal threats to heritage sites are the same as those endangering coastal morphology and related biodiversity and cultural heritage managers should therefore become more involved on a multidisciplinary basis with scientists and planners dealing with these issues. Archaeology can provide unique data on the long-term environmental and cultural histories of coastal zones and the long-term impacts of people on marine resources and ecosystems. There is therefore a need to integrate archaeology into contemporary coastal research conducted by other scientists. Cultural heritage managers also need to align their research and planning policies with state planning policies and national coastal management plans (e.g. Department of Climate Change 2009) and with integrated coastal zone management (Norman 2009:298). There are a number of ways in which this can be achieved.

Firstly, the International Geosciences Programme (IGCP) of UNESCO and the INQUA Commission on Coastal and Marine Processes (CMP) has provided a framework for the worldwide exchange of scientific information and common research in sea-level change and coastal evolution (see Boski and Long 2010 for a brief introduction) and cultural heritage managers should be aware of these links and align their research and monitoring with these programmes.

Cultural heritage managers in Australia also need to establish new lines of communication between people working on coastal cultural heritage management. Currently there is no organised avenue for the sharing of information, in part, owing to the very different State and Commonwealth heritage jurisdictions. By way of comparison the federal United States National Park

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**Figure 5. Potential impact of IPCC predicted 1m sea-level rise on an area of Bribie Island (data supplied by Department of Natural Resources and Mines, The State of Queensland).**
Figure 6. LiDAR data for southern Bribie Island indicating high-level precision mapping (25cm contours) (data supplied by Department of Natural Resources and Mines, The State of Queensland).

Figure 7. LiDAR elevation models for Bribie Island (Figure 6, Maps 2 and 3) presented in 3D (data supplied by Department of Natural Resources and Mines, The State of Queensland).
Service (NPS) has taken a lead in providing critical information regarding the protection of archaeological sites. Site preservation articles regularly appear in two widely distributed Park Service periodicals, the Federal Archaeological Report and CRM. The NPS Archaeological Assistance Program Technical Briefs series also includes issues on relevant site protection topics (e.g. Thorne 2004). The National Clearinghouse for Archaeological Site Stabilization (2010), a division of the Centre for Archaeological Research at the University of Mississippi, also serves as a source for technical support and training for in-place archaeological site stabilization technologies. The Florida Department of State Division of Historical Resources (Florida Heritage 2004) also provides similar guidelines. The US Army Corps of Engineers, conducted several years of archaeological site preservation research which resulted in 55 technical notes comprising The Archaeological Sites Protection and Preservation Notebook. The technical notes cover several topics, including the nature of various impacts to archaeological sites and summary discussion of site protection projects from around the country. Although the research and development aspects of the Corps of Engineers have concluded, technical assistance is still available through the Center for Cultural Site Preservation Technology at the Waterways Experiment Station (Nickens 2001).

There is little doubt that detailed, long-term monitoring is the ideal way to obtain information about the current state of the environment, rates of change, and the appropriate management techniques required to deal with the changes. However, such monitoring is rare. Detailed monitoring is expensive and suffers from the reality that it is, in fact, long-term. Predictive modelling is also rare due to the uncertainty of many variables (e.g. Bernier et al. 2007; McInnes et al. 2003). Because of the expense and time-consuming nature of such monitoring it may be necessary to concentrate on areas of known significance and also to focus on digitising geoindicators so that long-term assessment and comparisons can be facilitated. It would be costly, time-consuming and impossible to maintain a comprehensive and sophisticated monitoring system for all coastal sites. Nevertheless, the approaches to monitoring outlined in this paper could be usefully developed in areas of development or high significance.

Conclusion

Anecdotal information can be used along with occasional observations to identify general trends in coastal change. Observations can be undertaken on an annual basis, but in the case of major climate events observations should follow as soon as practical after the event. Second, major projects could be developed that focus more broadly on coastal areas. This would require a risk management analysis of sections of the coast, mapping such factors as landform type, vegetation coverage, climate, storm surge, and predicted global sea-level rise. It would also involve mapping past and present impacts, such as past urban development, present and future development, and other coastal works, including mining, tourism, agricultural, and industrial developments. Third, at a broader scale, geoindicators could be mapped as indicators of trends in respect to potential global warming and other natural and human-induced changes (see also Rowland 2008). A series of risk assessment maps could then be produced for the coastline. Importantly, digital models of the coastline could also be developed that could be rapidly updated as new data become available. The application of LiDAR and other remote sensing techniques as briefly outlined in this paper have great potential both for predictive modelling and monitoring. With LiDAR use continuing to expand among a number of disciplines, a multidisciplinary approach to LiDAR data capture could become cost effective for archaeologists and cultural heritage managers seeking to monitor inundation risk and other changes to coastal heritage sites. We appreciate that the size of the Australian coastal zone and the multiplicity of heritage jurisdictions works against coordination of approaches to coastal cultural heritage management but recommend that a group be established to share information and discuss principles and guidelines on how we might better achieve monitoring and management of Australian coastal archaeological heritage.

Numerous cultural and environmental factors have impacted on coastal cultural heritage sites in Australia over a long period of time. More recently, human-induced global warming has become a focus of projected impacts on the coastline. However, we must not lose sight of the vast range of more immediate threats to coastal areas including those associated with population growth and economic development. Such a view has also recently been articulated by climate scientists (Brown et al., 2014). The threats to the coast can be identified by undertaking coastal monitoring using a range of information and techniques, from the anecdotal to the more complex as briefly outlined in this paper.

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