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Conservation management and mitigation of the impact of tropical cyclones on archaeological sites

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In the following paper, the impact of tropical cyclones on archaeological sites and the effectiveness of the mitigation measures which have been espoused in these cases is assessed. The paper draws on three different examples which vary in terms of geographical spread (Tonga, the Marshall Islands and North Queensland, Australia (Figure 19.1), types of sites (middens, cemeteries, burial monuments) and the level of cultural resource management actions and legislation in place.

Sites on sand dunes

Sites on coastal (and inland) sand dunes are prone to similar erosion processes as open camp sites. Unlike the latter, however, coastal dune systems consist largely of an unconsolidated soil matrix which makes them eminently erodible by wind and wave action. *Dinner-time camps* are discrete dumps of food remains, commonly shellfish, thought to represent a single meal and dumping event by individuals or a small group of people. Ethno-archaeological studies have shown that dinnertime camps were sometimes revisited and a new, discrete dumping event occurred. The archaeologically recognizable food remains varied in amount and species composition. If occupation occurred in well circumscribed areas for a prolonged period of time, or repeatedly over time, the material

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would accumulate and build up raised heaps of refuse intermingled with soil matrix. These *middens* (shell middens, kitchen middens) are especially conspicuous in coastal areas, where much of the refuse comprises shells which decay much slower than bones or even plant remains (Meehan 1982, pp. 112-115).

Erosion by aeolian action

In the 'normal' course of events, if the vegetation of coastal dunes, especially fore dunes, is disturbed due to impact by (hard-hoofed) animals or people, and partial denudation has occurred, that part of the dune becomes prone to wind erosion. As these disturbances are usually perpendicular to the alignment of the dune, and in line with the main wind direction (ocean to inland), the fine sand particles are blown off towards the inland areas and a 'blowout' is created. As the erosion continues unchecked, the blowout deepens and, with the collapse of the sidewalls, also widens. In addition, the blow-out now provides a convenient way to traverse the dune system and attracts even more animals, people and vehicles using it as a thoroughfare, thus exacerbating the problem (Zallar *et al.* 1979). As a result of this erosion, archaeological sites contained in the dunes, such as middens and burials, are exposed.

Continual wind erosion will remove the matrix of the site and effectively collapse and compact the vertical stratigraphy, leading to a concentration and intermingling of artifacts (of different stratigraphic layers). On a slope, a separation of artifactual material will occur, with rounded artifacts rolling down the slope and thin and lightweight artifacts being blown off by the wind. Lightweight organic matter, such as charcoal and small bones, is also dispersed, with larger bones and shells becoming exposed to photo-degradation and trampling by people and animals. Continued unchecked erosion can combine the artifactual content of midden layers, which originally had been separated by sterile horizons, thus permanently confusing site stratigraphy and chronology.

The impact of the erosion is concentrated and occurs horizontally, increasingly exposing lower deposits. Over time, the erosion will remain localized but widen out. The impact on the archaeological record will also remain localized. If the parameters determining the location of sites are defined by local access points or movement corridors, then it is quite likely that modern livestock/people movement is in a similar, if not identical, location and that significant sites are predominantly affected by the erosion.

Erosion by wave action

If, however, coastal middens are exposed to water and especially wave action, the site will be eroded. The erosion impact is diffuse, affecting a large area of dunes and beach, and it is vertical; that is, one section of the dune is eroded away at a time, with the erosion progressively affecting landward sites. In addition, the artifactual material will be sorted according to size and weight. This is a common phenomenon on any given beach and occurs in shells (Baan 1977, 1978a, 1978b; Lever *et al.* 1964) and sand/gravel sediments (Bird 1984: pp. 143 ff).

Beaches normally undergo a cycle of aggradation and erosions, with ‘stable’ beachlines in the long-term perspective (Bird 1984). If the sediment cycle is modified by the development of structures interfering with the currents and associated sand movements, or if the beach is subject to recurrent storm surges, then net sediment loss may occur, which has the potential to foreshorten the beach and thus, ultimately, result in the erosion of foredunes and the sites contained therein/thereon.

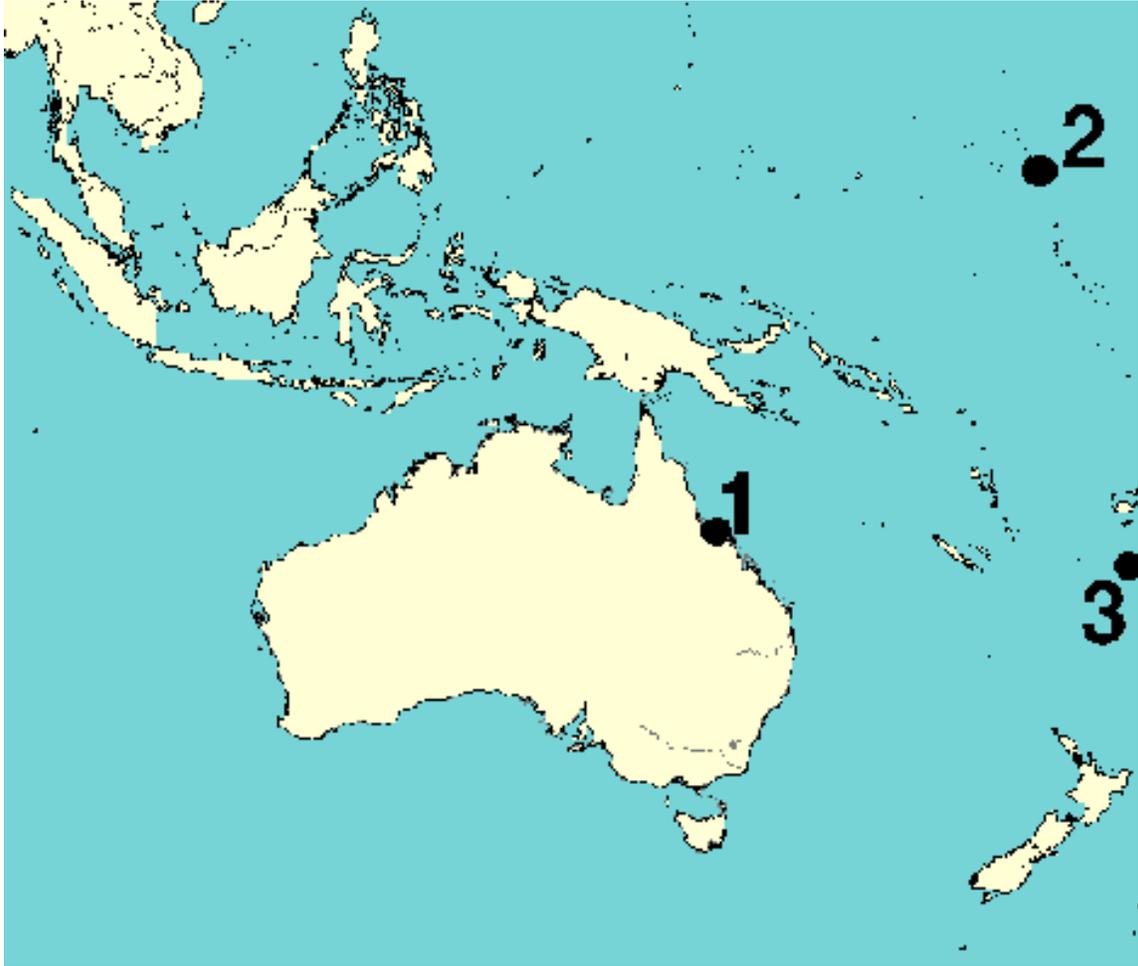


Figure 19.1. Map of the south-west Pacific, showing the location of the sites under discussion. 1-Upstart Bay, North Queensland; 2- Majuro Atoll, Marshall Islands.; 3- Tongatapu, Tonga.

Erosion by storm surge action

The effects of cyclones on the coastal geomorphology of small sand cays and islands have been studied *inter alia* for Tonga (Woodroffe 1983), Jaluit (Blumenstock 1961), Funafuti (Maragos *et al.* 1973) and similar areas. Similar studies for continental shelf areas have been conducted for North Queensland (Hopley 1974a, 1974b). Studies dealing with the impact of cyclones on archaeological sites are few. Bird (1992) has described the impact of cyclones on middens in Queensland, while Hughes and Sullivan (1974) have assessed the impact of storm surges on middens in New South Wales. Spennemann has described the

impact of cyclones on sites in Tonga (Spennemann 1987) and the Marshall Islands (Spennemann 1992a). Storm surges and tsunamis have destroyed entire archaeological assemblages on the Siassi Islands of Papua New Guinea (Lilley 1986) and elsewhere in Melanesia, and have been reworking coastal shell-middens in Australia (Hughes & Sullivan 1974) and in the Andaman Islands (Cooper 1985).

Beyond the Pacific, studies have been conducted in the US Virgin Islands and Texas following Hurricane Hugo in 1989 (Gjeesing & Tyson 1990; Nelson 1991). Three of these case studies will be reviewed below:

- Cyclone Isaac on Tongatapu in 1983;
- A high tide at Majuro, Republic of the Marshall Islands in 1980; and
- Cyclones in Queensland, 1988/89.

Cyclone 'Isaac', Tongatapu (1983)

The setting

Tongatapu (21°8' S, 175°12' W) is the southern-most major island of the Tonga group, a raised coral limestone island covered with tephra-derived soils. The island is dominated by a large shallow lagoon in the northern part with extensive mudflats in the northeast. Beginning at the lagoonal mouth, a fringing reef extends to the north-east, which carries a number of small sand cays (Stoddart 1975; Woodroffe 1983). Two of these, Manima and Makaha'a, are of concern here.

Manima is a small oval sand cay, close to the mouth of the inner lagoon, extending some 150 m north-south. The island is covered with coastal broadleaf vegetation and coconut palms (Stoddart 1975; Woodroffe 1983; Spennemann 1986). The eastern and south-eastern shore of the island is dominated by expanses of a sandy beach. Conspicuous are large areas of coarse sediment, which upon close inspection, proves to be the remains of an extensive pottery-bearing midden (TO-Ci-1). Present were shells (mainly *Anadara* sp.), undecorated pottery and volcanic (oven) stones, which do not occur naturally on Tongatapu and must have been imported from volcanic islands in the central part of the Tonga Island chain.

Makaha'a is a small oval sand cay, 310 m long and 170 m in greatest width, on the eastern side of a reef patch isolated from the Tongatapu fringing reefs by a narrow channel about 10 m deep. It is approached through a gap in the encircling reef at its northeast point. The island has aggrading sand beaches on its west and northwest sides and flat (*umu*-/oven) stone spreads fronting eroded sand cliffs on its eastern side. These cliffs are 1.5-2 m high along most of the eastern shore, rising to 3 m in the southeast. Beachrock is extensively exposed, especially in the southeast, and the island is clearly migrating towards the northwest. The eastern cliff is cut in sand, exposing coconut tree roots, and is marked by fallen coconut palms and some large fallen *Hernandia*.



Figure 19.2. An eroded pottery bearing midden in the intertidal zone of Manima Island, Tongatapu, Tonga. The broad dark band indicates the spread of stone material, pottery and large shells. The narrow dark band at the left of the image indicates the high tide mark demarcated by seaweed. (Photo: Dirk Spennemann 1986).

Impact of the cyclone

Tropical Cyclone Isaac, which hit Tonga on 3 March 1982, was undoubtedly one of the worst storms which Tonga has experienced this century. It claimed six lives and caused enormous devastation to buildings and crops. The cyclone developed about 160 km northeast of Western Samoa and traveled southwest at an average speed of 12 knots, traveling directly over the Ha'apai Group and passing some 50 km northwest of Tongatapu.

In Nuku'alofa, a peak gust of 92 knots was measured. Cyclone Isaac coincided with a high spring tide of 1.2 m at Nuku'alofa. Since no tide gauge was in operation at the time of the storm, no exact record of the height of the storm surge is available. Extensive flooding of coastal areas on the northern coast and the fact that Nuku'alofa was entirely under water, testify that the water was several meters above the high-tide level. Much of the storm surge associated with Cyclone Isaac must have been buffered by the great width of reef flat along this coast (Oliver & Reardon 1982; Woodroffe 1983; Spennemann 1987).

On the islet of *Manima*, a pottery-bearing shell midden was completely eroded, today only recognizable as a band of shell and stones in the intertidal zone (Figure 19.2). A close-up view shows that only the heavy elements remain, such as oven stones, large shells and pottery (Figure 19.3), the fine material having been washed out.



Figure 19.3. Close-up of a pottery-bearing midden site in the intertidal zone of Manima Island, Tongatapu, Tonga. The dark spots in the photographs are volcanic oven stones, the rest are shells and some potsherds. Charcoal and fine sediment has been washed out. (Photo: Dirk Spennemann 1986).

The first archaeological survey to take place on *Makaha'a* was conducted in 1957 by Jack Golson. He noted a stone-lined (chiefly) burial mound on the east side of the island; it was badly eroding, with more than half of the site already washed into the sea. He also noted a burial vault, just visible in the profile. His excavation proved that the mound consisted of two construction phases, an earlier house or settlement mound and a later use as a burial mound. On the occasion of the 1986 survey of *Makaha'a*, no trace of the stone lining could be seen and the burial vault mentioned by Golson was standing in the middle of the beach, some 2 to 3 m in front of the present sand cliff (Spennemann 1987). Only a small part (approximately 1 m) of the earth mound is still visible. Since 1957, at least 5 m of shoreline has been eroded here (Figure 19.4).

Cultural resource management actions

In the absence of a Tongan National Heritage Management Authority at the time, the cultural resource management action taken consisted of a survey in 1986, which was conducted as part of the author's survey for his Ph.D. fieldwork. Erosion was also noted on other islands and recorded (for example, Spennemann 1986, 1987). In all cases, artifactual material was collected, as was the case on other sites on the main island. A report of the extent of the erosion and damage to the sites was drawn up for the Ministry of Lands, Survey and Natural Resources, which dealt with matters concerning land management (Spennemann 1986). No further action was taken.



Figure 19.4. A burial chamber of a chiefly burial mound, exposed by storm surge erosion of the coastline. Makaha'a Island, Tongatapu, Tonga. The photos show the appearance of the chamber at low (top) and high tide (bottom) (Photos: Dirk Spennemann 1986).



Figure 19.5. Impact of the 1979 high tide event on a cemetery at Uliga Island, Majuro Atoll (Photo: Carol Curtis 1979).

The exposure and erosion of the burial chamber at Makaha'a allowed, for the first and only time, to look at the make-up of a stone-lined burial vault. A human humerus, found wedged in under a fallen slab, thought to originate from the vault, was dated to 690 ± 180 BP (ANU-5716), thus providing the first direct date for a burial in a vault.

Implications

The storm surges destroyed several sites *in toto* and reduced others to relatively meaningless jumbles of intermingled material derived from (possibly) various phases. The late, undecorated pottery on Tongatapu is not very diagnostic (Spennemann 1989a) and with the removal of datable material (charcoal, shell) such midden sites have lost almost all their potential for analysis. This needs to be seen in the context of the horticultural potential of the sand cays compared to the fertile tephra soils of the main island, with the differences in site location likely to be a reflection of different site function. One of the major problems thus posed is that some site types, of which there are only a few (given the size of the sand cays), are disproportionately more prone to decay by storm surges.

High tide Majuro Atoll (1990)

The setting

Majuro Atoll, situated at $7^{\circ}03'$ to $7^{\circ}13'$ N and $171^{\circ}02'$ to $171^{\circ}23'$ E, measuring about 45 km (30 miles) by 11 km (7 miles) in dimensions, is oriented ENE to WSW and covers a total lagoon area of 295 sq km with a total land area of only 9.17 sq km. The atoll can be split

into a north-western, windward side and a south-eastern, leeward one. The north-western part is characterized by large, extended reef flats with very few islands, save for the distinct Enyagin group, which is located at the very north-western tip of the atoll and which consists of two reasonably large islands: Jelte and Rongrong. Towards the east, the islands on the northern side become more numerous and are relatively closely spaced. Located there are the three most populated islands: Djarrit, Uliga and Delap.



Figure 19.6. A burial monument of the Laura Cemetery, collapsed onto the beach after the 1990 high tides on Majuro Atoll, Republic of the Marshall Islands. (Photo: Dirk Spennemann 1990).

The southern side of the atoll consisted, until 1905, of a single continuous island reaching from Rairok to Laura. The typhoons of 1905 and 1918 disrupted this continuous island, especially in its eastern part. In the south-west, the island is still intact, largely only 200 to 300 m wide, with the largest land mass, Laura (Majuro Island) at its western end (US Army Corps of Engineers 1989; Spennemann 1992b). Laura cemetery, site MI-Mj-20, is located at the lagoon side of Majuro Atoll, some 100 m south of the actual tip of Majuro Island. The site consists of an array of concrete grave enclosures and concrete grave monuments. According to historic evidence, the cemetery was in use in the 1910s and 1920s and contains a number of significant graves.

Impact of the cyclone

Stable high pressure systems north-east of Eneen-Kio (Wake Island) or east of the Marshall Islands can create higher-than-normal sea levels which will cause flooding of low-lying areas if they coincide with a spring tide, or with higher wave action. Such high

pressure systems are common and have affected the atolls of the Marshall Islands on numerous occasions (the 1979, 1989, 1990 and 1991 floods on Majuro Atoll for example). During 13 and 14 November 1989, an exceptionally high tide occurred on Majuro Atoll which was connected with heavy swells stemming from a high pressure cell. The high tide caused substantial erosion of parts of the lagoonal shoreline on many parts of the atoll, but especially at the northern tip of Majuro Island where some 3 m in depth disappeared. The wave action had caused several coconut palms to topple over and resulted in substantial erosion of a historic cemetery, which already had been partially eroded in the years before. The eroding shoreline exposed a number of burials and caused other burial vaults to collapse (Figure 19.6). On the visits following the erosion, several bones were found scattered on the beach and a thorough search was made for other bones. All bones were lying in the inter-tidal zone, intermixed with coral rubble and other debris.



Figure 19.7. Burial monuments of the Laura Cemetery, collapsed onto the beach after the 1990 high tides on Majuro Atoll, Republic of the Marshall Islands. (Photo: Dirk Spennemann 1990).

Cultural resource management actions

The management actions espoused by the Historic Preservation Office of the Republic of the Marshall Islands, was to investigate the tip of Laura on the day after the high tide to monitor the extent of erosion. This occurred mainly as part of long-ranging interest in the geomorphological changes on Majuro Atoll; a survey of the effects of the erosion was conducted by the author on repeated occasions. In the process, the erosion of the cemetery was noted and all human bones found on the beach were picked up. This was repeated a couple of days later. The bones were identified (see below) and prepared for reburial, which

took some time to be organized. Discussions with relevant local planning authorities (Environment Protection Authority, Capital Infrastructure Program, Majuro Local Government) ensued, resulting in the conclusion that any protection against further erosion was impossible in view of both the costs involved and the potential for increased erosion at other localities due to shoreline protection works at the cemetery. It was then raised to move the cemetery to a new location, further inland, but public and informal calls through the traditional channels brought little response as to whose relatives are buried there. As it was felt that reburial without permission of every descendant involved would not be appropriate, the initiative was called off. Thus, overall, the management was reactive, content to document the changes and the impact.

Implications

Given their location close to the shore, and given the relative instability of the shorelines of the islands making up an atoll, eroding cemeteries are a common occurrence in the Marshall Islands (Spennemann 1990a) and isolated human bones are often found in the inter-tidal zone (Adams *et al.* 1990; Spennemann 1989a, 1990b, 1990c, 1990d). More often than not, however, the human remains recovered are isolated pieces, mainly of the cranium or long bones. The differential sorting of beach sediments as discussed above, also applies to human bones of cemeteries eroding due to water and wave action. The underlying phenomenon is the differential in the velocity of the water, and hence its capability to move heavier, and hence larger, items of the same material. In addition, some of the human remains have a natural buoyancy (such as the vertebrae which are filled with spongiotic cavities trapping air) which facilitates sea-borne movement. Table 19.1 shows the representation of human remains found on the shore near the Laura cemetery.

Table 19.1. Representation of human remains found on the beach (Majuro Atoll).

Class	Percentage	Bones involved
I	100-85%	Cranium, Mandible
II	85-50%	Tibia, Femur, Humerus, Fibula
III	50-25%	Pelvis, Radius, Ulna, Axis, Clavicula
IV	25-10%	V. cervicalis, Costae, Atlas, Os sacrum
V	10-0%	Patella, V. lumbalis, V. thoracica, Metacarpus, Phalanges manus, Scapula, Ossa carpalia, Tarsus, Astragalus, Ossa tarsalia, Metatarsus, Phalanges pedis

The two major factors involved in the observed differential preservation of skeletal elements appear to be (i) the overall weight of the bone and (ii) its ability to float. Light-weighted bones, such as the phalanges, or heavily spongiotic bones, such as vertebrae and patellae, float easily and - by wave and tidal action - can be carried out to sea, leaving the heavier bones, such as femora, tibiae, or non-floating bones, such as the crania and mandibles, behind. Given the thorough search for bones along the shoreline, both parallel and perpendicular to the water's edge, the differential representation observed is not a factor of

selective recovery. However, the overall size of a bone is, on the whole, correlated with its overall weight which is the determining factor in sediment distribution along beach transects.

It needs to be kept in mind however, that the impact of the high tide system was limited. The impact of devastating typhoons is on record for the Marshall Islands. These have eroded entire islets down to the bare reef platform, washing everything on it (houses, people, trees, soil) into the lagoon or sea (cf., Spennemann & Marschner 1994 for compilation).

Cyclones North Queensland (1988/89)

The setting

Upstart Bay is located about 120 km south of Townsville, Queensland, between Cape Upstart and the southern end of the Burdekin River delta. The sandy beach of a shallow bay measures 13 km in length and comprises a narrow band of Holocene foredunes backed by a series of older beachridges. The beachridges are vegetated with coastal vines and an open woodland unless modified by blowouts. Archaeological surveys in the early 1980s had located a number of sites, mainly shell middens. This was followed by an intensive survey in 1987 which located and mapped 93 sites (Bird 1992).

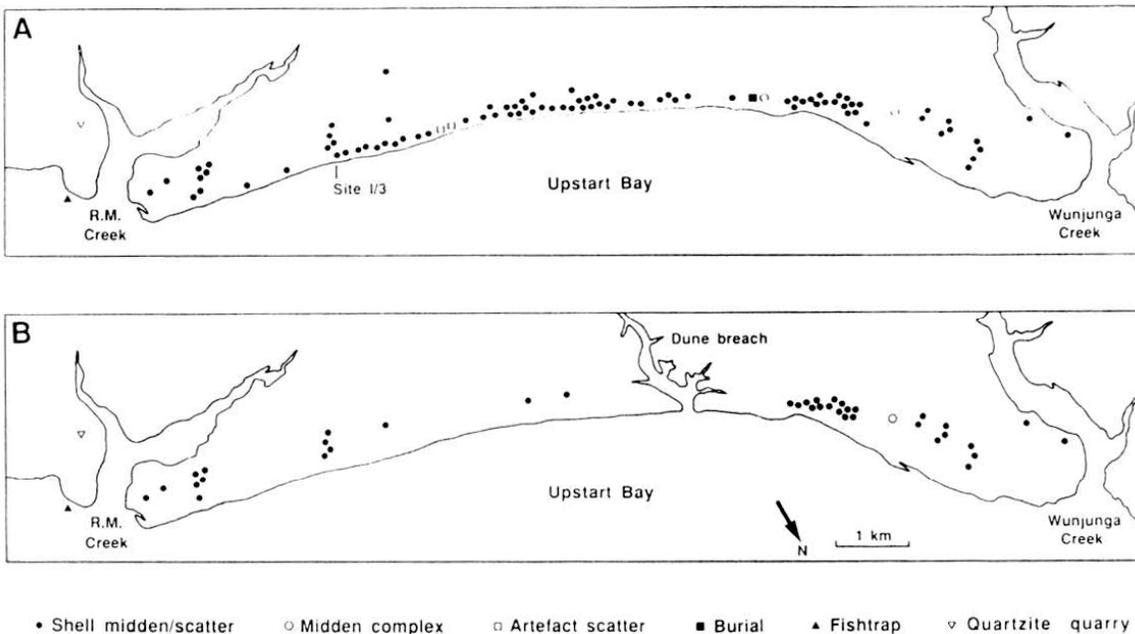


Figure 19.8. Distribution of archaeological sites at Upstart Bay, N. Queensland before (left) and after (right) the cyclones 'Charlie' and 'Aivu' (after Bird 1992).

Impact of the cyclone

Cyclone ‘Charlie’ made landfall on 1 March 1988. The cyclone reached gusts of 160 km/h and created a maximum storm surge of 0.5 m at the nearest recording station, Bowen. Bird (1992) assumes the local surge height to be greater given the inshore topography of the bay. The typhoon surge breached the dune system and created an estuary at a point where the dune had been degraded by human interference. Of the 93 sites found in 1987, fourteen (15%) were completely destroyed as a result of the cyclone, and a further 23 (25%) were substantially impaired. Some of the sites in the foredune were truncated, while the seaward margins of others were reworked. The sites not affected by wave action seemed to exhibit evidence of deflation by aeolian action (Bird 1992).

Cyclone ‘Aivu’ made landfall on 4 April 1989. The cyclone reached wind gusts of up to 200 km/h, with a maximum recorded storm surge of 1.2 m. Again, the local storm surge at Upstart Bay was much greater, approximately 3 m on the outgoing high tide. The storm surge caused substantial foredune erosion and recession of beaches; as a collateral a large number of archaeological sites was affected. Of the 78 archaeological sites that survived cyclone ‘Charlie’, 37 were destroyed and a further five were modified or otherwise impaired (Bird 1992).

The eroding shoreline dramatically reduced the number of sites, especially in the central section of the bay (Figure 19.8). If we compare the loss of sites from 1987 to 1988, then about 40% of all sites were either destroyed or modified as a result of cyclone ‘Charlie’. Of the 78 sites surviving from the previous cyclone, another 42 sites were destroyed or (further) modified as result of cyclone ‘Aivu’. In the final account, only 39% of all 1987 sites survived the two typhoons unscathed, 6% were reduced or modified and 55% were totally destroyed (Figure 19.9). In the time interval between the two cyclones, no significant redeposition of sediment had occurred and the damaged sites had been exposed to aeolian decay as well. Only in the years after cyclone ‘Aivu’ did the dune system recover in part - resulting in the reburial of some of the archaeological deposits (Bird 1992).

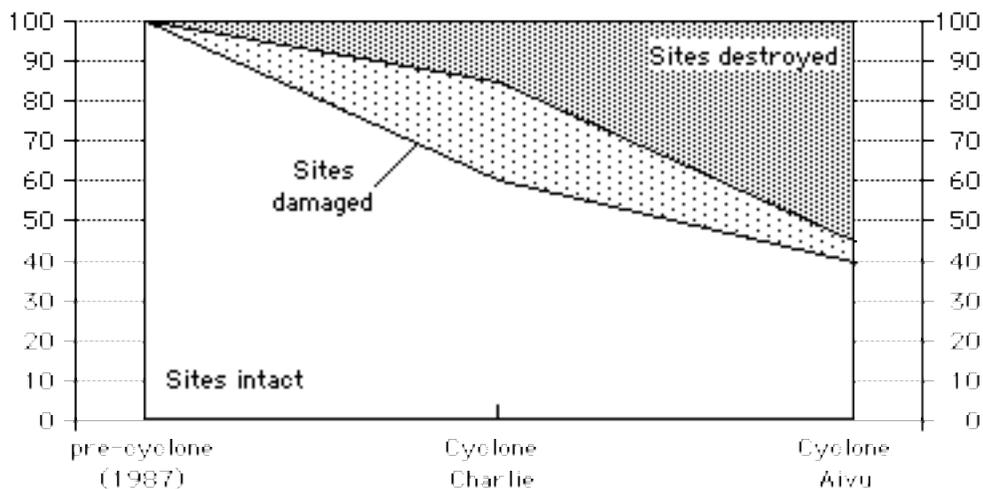


Figure 19.9. Survival of coastal midden sites after the cyclones ‘Charlie’ and ‘Aivu’ (data after Bird 1992).

Cultural resource management actions

The cultural resource management action comprised a survey of the area after the storm event and an assessment of the survival of the sites. As such then, this work is more detailed than that conducted in the previous case studies. The situation in Upstart Bay is fortuitous as a cyclone event had been preceded by a systematic site survey and all sites had been mapped. This then allowed a systematic investigation of the cyclone impact after each cyclone event. Apart from the removal of a threatened burial, which had occurred well before the cyclone events, no proactive management was undertaken. Sites had been recorded and on occasions sampled, but no systematic sampling and data recovery had been undertaken (Bird 1992).

Implications

Even though the data retrieval has been very limited, the cultural resource management actions taken give us an insight into the extent and speed of site decay and total site loss incurred as a result of tropical cyclones. As Bird (1992) has pointed out, the number of cyclones that hit the Queensland coast each year amounts, over time, to an exorbitant impact. If the devastation of cultural sites observed at Upstart Bay is any guide, the remaining - or surviving - archaeological record is more than impoverished.

Discussion

The three case studies have shown that ongoing coastal erosion poses a major threat to the conservation of cultural resources and that catastrophic events, such as cyclones, increase the impact significantly.

- The Marshall Islands site was only affected by a high pressure system and a higher than normal sea-level and greater current activity. As a result the erosion was 'gentle', exposing human remains and causing a sorting of these remains according to size classes with the lightweight bones being lost from the record.
- The Tongan example is similar, although caused by stronger storm surges. Again, an artifact sorting occurred, with much of the midden material washed away and any stratigraphy combined into a single artifact horizon. However, parts of the sites remain, and this is in part due to the reef platform extending from the islands, and the overall shallow nature of the beach profiles.
- In the North Queensland scenario, the beach profiles are steeper, and without the benefit of an adjacent reef platform, the storm surge is stronger and the erosive forces greater, leading to a total removal of the sites into the subtidal zone.

Geomorphological studies have shown that much of the island formation on coral atolls is due to cataclysmic events (Maragos *et al.* 1973) which, on the other hand, may destroy the entire island and all the cultural deposits on it (cf., Nadikdik Atoll in Spennemann &

Marschner 1994). As the examples document, the variation of the impact depends not only on the strength of the event, but also, and significantly, on the subtidal topography of the shoreline. In addition, the frequency of the cyclones affects the long-term survival of sites, as cyclones may well occur so frequently that there is little chance of a replenishment of sediment, resulting in a net sediment loss and thus a rapid decay of the sites.

'Benefits' of storm surges

The destructive effects of cyclonic storm surges, and the mud and sand masses carried by them, must have had their effects throughout prehistory. At times, one effect was the archaeological preservation under the mudflows of the village destroyed by them. A good example is the site of Vaito'otia-Fa'ahia on Huahine in the Society Islands (Sinoto 1983a, 1983b). Similarly, at Anuta (Kirch 1982), a cyclonic storm surge apparently capped a prehistoric settlement with a roughly 0.5 m thick layer of sand, producing a hiatus in the occupation.

Low-intensity, continual erosion of beaches on Taroa Island, Maloelap Atoll, Marshall Islands, caused by current changes due to a World War II-period causeway, has gradually exposed a series of human remains, suggesting the presence of a cemetery nearby (Spennemann 1989b, 1990b). This was later found to be correct when an unmarked (and unrecorded) Japanese war cemetery adjacent to the shore was found after it had been vandalized by people looking for gold-filled teeth (Spennemann 1993b). In Fiji, cyclones frequently expose hitherto unknown archaeological deposits along the shoreline, so that monitoring the effects of cyclonic storm surges can be used as a 'surveying' technique (Clunie, F. 1986, pers. comm.). Unfortunately, however, this is only the 'poor cousin' of proper surveys (including auger surveys), as the sites thus found are usually destroyed or already severely impaired. The observations of Bird (1992) showed that large-scale cyclones were only destructive and did not expose hitherto unknown sites.

However, when assessing the actions we may wish to take, we need to consider both the likelihood and frequency, as well as strength of future hazards, and the constraints which act upon the mitigation options.

Implications of climatic change

One of the issues we need to consider are the implications posed by climatic change due to greenhouse gas-generated warming of the atmosphere and the related warming of the oceans. A rise in the atmospheric temperature and the sea surface temperature will generate climatic conditions favorable to more frequent and also more severe storms (Holland *et al.* 1988). As the sea surface temperature stands in direct correlation with the minimum sustainable pressure and hence intensity of tropical typhoons (Emanuel 1987), an increase in sea surface temperature, either during El Niño/Southern Oscillation (ENSO) events, or as a result of Greenhouse gas-induced global warming, is likely to (Wendland 1977):

- facilitate the occurrence of typhoons in areas hitherto not affected;
- shift the area of typhoon generation further eastward into the central Pacific;
- increase the frequency of storms and typhoons; and

- increase the severity of typhoons in areas already affected by typhoons.

Some of this can be observed today. The waters of the south-eastern equatorial Pacific Ocean undergo a quasi-cyclic phenomenon with a moving time interval of three to five years. During these effects, which have been termed the ENSO, global atmospheric disturbances develop. Based on an analysis of modern and historic data, Spannemann and Marschner (1994, 1995) have shown that the likelihood of a cyclone affecting the Marshall Islands during ENSO years is 2.6 times greater than during a non-ENSO year.

The implications of this then, are that cyclones will become an ever-increasing threat to the cultural resource base (Rowland 1992). However, as Murphy (1990) has shown, not all events of sea-level rise need result in the devastation of coastal sites by wave erosion. In his study of site 8SL-17, he found that the site, located on the backbeach of a sand cay, was covered by a sand dune system which did not erode during the Holocene rising sea-level, but was flooded, thus preserving *in situ* the archaeological site underneath.

Constraints on management options

Above we have established that archaeological sites located on low-lying, exposed islands are highly threatened by wave-generated erosion, through both occasional storm surges and day-to-day wave action. Further, it has been shown that the climate change in train is set to increase the threat on such sites. In order to preserve the richness of our cultural heritage, the protection of such sites is of importance. Since the conservation of these coastlines is almost always rendered impossible because of the horrendous costs involved or because the conservation action can in fact make matters worse (cf., Bird 1992 for Upstart Bay), it would appear that a sensible solution is that most of the threatened sites should be test-excavated as soon as possible in order to recover information. If the sampling shows the site's value, the majority of the site should be open for examination. Further, more detailed excavations should follow, wherever and whenever necessary.

However, the call to excavate is somewhat prescriptive and insensitive in view of issues such as these:

- traditional ownership of cultural resources;
- significance of the site to the traditional owners;
- advances in archaeological field and laboratory methodology.

Traditional ownership of cultural resources

Recent advances in cultural resource management in Australia (Frankel 1984) as well as the United States have taken the view that the indigenous population of the country needs to be consulted when it comes to site management options. Ethically speaking, ex-colonial powers hold little moral ownership and control over the heritage created by the people they conquered. Whilst the legal parameters governing control and management of cultural heritage may permit a number of actions, one should remember that these parameters were

drawn up and defined by the ‘powers-that-be’ and only very rarely by those whose heritage is thus governed (Spennemann 1993a).

Significance of the site to the traditional owners

The requirement to consult with the traditional owners of the area following appropriate procedures is paramount if long-term management is to be successful (Spennemann & Look 1994). It needs to be considered that some of the management options, even though well-intended, may be deemed culturally inappropriate at best, and outright offensive at worst.

Advances in archaeological field and laboratory methodology

In past years, archaeological method and theory has advanced on a wide front and there is no reason to assume this will not continue. A vast array of tools has become available, ranging from optical dating to DNA analysis. Thus, it is prudent to leave sites in the ground, as they provide future generations of archaeologists with information hitherto inaccessible.

Implications

The above discussion has shown that cyclonic storm surges impact on shell middens and other coastal sites. From an archaeological viewpoint, abnormally strong wave action on the shoreline offers advantages and disadvantages. While wave action may expose hitherto unknown archaeological sites however, the negative impact of sites being washed away is greater. Thus, at first hand, excavation has some advantages in as much as some of the information contained in the sites can be collected and save. Yet, the excavation itself may not be an acceptable management option to the indigenous community. Site loss cannot be avoided - its impact on the level of heritage knowledge can only be minimized.

As the Queensland case study has shown, systematic survey of the coastal shell middens and other sites allows one to accurately assess the impact of cyclones on the middens. If the survey is accompanied with a representative sampling and/or auguring program (following consultation with, and consent by, the traditional owners) some of the data can be retrieved before the sites are devastated by the cyclones. The systematic resurvey of the area after the cyclone allows one to assess the extent of the erosion and site loss.

Cultural resource management should ensure that all sites are *regularly* monitored to ensure documentation of all sites and their changing fate over time. This allows one to project the observed site loss back into the past and so understand the changes the archaeological record may have undergone.

It is clear that appropriate level of management is a costly affair. Every time a cyclone strikes, the area affected by the storm surge and/or the winds, needs to be resurveyed. Ideally, the entire coastline affected by the cyclone would be resurveyed at regular intervals to monitor the gradual site erosion or site burial.

The case studies have shown that cyclones pose a major threat to the cultural heritage and that there is no easy solution.

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