

‘Sustainability Archaeology’ and Landscape Transformation in Eastern Micronesia: Kiribati Case Study

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Introduction

With over 40,000 years of human settlement, the Pacific Islands display great ecological and cultural diversity. Yet, the forces of globalization are an ever present threat. Although environmental degradation and the loss of traditional languages and cultures by the advent of modernity are not limited to islands, the latter appear more vulnerable to disturbance compared to continental areas. Until relatively recently, it was generally assumed that anthropogenic impacts on island ecosystems were the result of Western influence via the introduction of alien crops, ornamental plants, and animals, causing widespread damage to the environment (Crosby, 2004). No one can deny that threats to island biodiversity continue at an accelerated rate as a consequence of human population growth, urban expansion, monoculture, pollution, and overfishing. A half century of research has, however, revealed that indigenous people were also capable of altering their terrestrial environments to a significant degree prior to the arrival of outsiders (Kirch and Hunt, 1997). These impacts can sometimes be traced to the early stages of human settlement, leading in some cases to resource depression, extirpation, and extinction. By contrast, the influence of indigenous societies on marine resources is less well documented (Anderson, 2008; Morrison and Hunt, 2007), and remains a fruitful topic for research in light of suggestions that rapid dispersal, notably in the case of the Lapita expansion across the southwest Pacific beginning about 3,500 years ago, could have been driven in part by the impact

of early humans on nearshore and intertidal resources of high value that could be efficiently harvested, such as flightless birds, colony-breeding seabirds, turtles, large reef fish, and invertebrates (Kennett et al., 2006; Szabó and Amesbury, 2011).

Low Coral Islands

It is argued that without a fair amount of human-induced environmental impact, Remote Oceania - the islands lying to the north and east of the main Solomon chain - would not have been successfully colonized by people lacking a well-established agricultural base (Kirch, 1997). While the importance of food production to early colonizing groups needs to be demonstrated (Davidson and Leach 2001), agriculture subsequently expanded to the extent that islands became largely transformed into anthropogenic landscapes. Some human-induced impacts had a destructive effect on island biota, but it is difficult to imagine life on some islands, especially low coral islands - atolls and table reefs or low coral islands lacking a lagoon - without introduced root and tree crops. Kirch (2000, p.181) characterizes such islands as 'consummate man-made environments'.

Low coral islands best exemplify the close links between marine and terrestrial ecosystems. As islands formed by biogenic agents (unconsolidated carbonate sediments deposited by waves on reef platforms), atolls and table reefs can be regarded as especially constraining habitats for human existence. The challenges faced by people, both past and present, include low soil fertility, absence of perennial surface fresh water, and extreme vulnerability to flooding by storm surge because of low elevation of the highly fragmented landmass, only a few meters above mean sea-level. There are some 300 atolls and low coral islands in the Pacific Islands region and many more individual islets. Several archipelagos are dominated by these limestone islands, such as the Tuamotu, Tuvalu, the Marshall Islands, and Kiribati, and their vulnerability to environmental disturbance is well known (Barnett and Adger, 2003). Kiribati (Gilbert Islands Group or Western Kiribati) and the Marshall Islands (Figure 1) have produced some of the earliest dates for the human colonization of eastern Micronesia, about 2,000 years ago coinciding with the post-mid-Holocene drawdown in sea-level, which resulted in the atolls and

table reefs to become emergent and habitable (Di Piazza, 1999; Dickinson, 2003; Weisler et al., 2012).

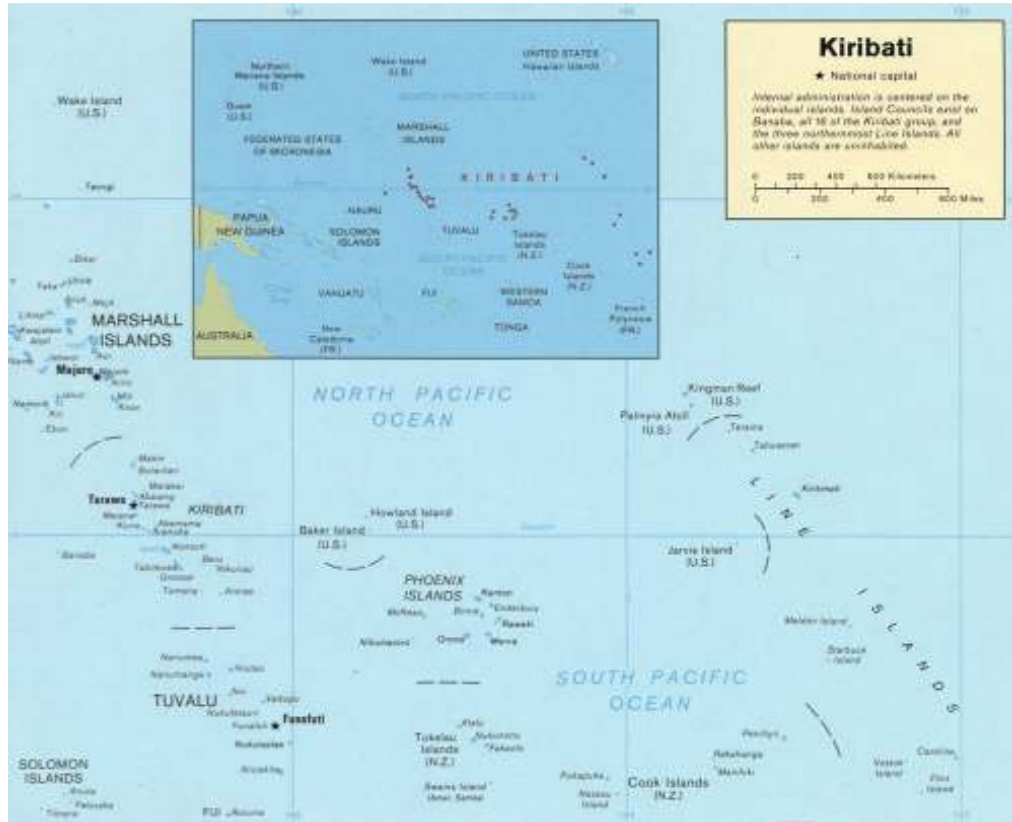


Figure 1: Map of Kiribati (source: Wikipedia) Food Production

As most of Kiribati is located in the dry belt of the equatorial oceanic zone, periods of drought are common. The usual way of accessing water was through the digging of wells, but water was also collected from coconut palm fronds and trunks, as well as empty giant clam shells. Coconut water and toddy (coconut sap) also provided nutrients.

Coral island communities relied heavily on tree crops, such as breadfruit, pandanus, and coconuts, not only to meet their dietary needs, but also to supply raw material for a host of products (Thaman, 1990). Agroforestry (Figure 2) is a distinguishing characteristic of the earliest agriculture in the Pacific Islands and is still an important component of contemporary atoll landscapes, even in urbanized settings in houseyard and urban gardens. In addition, food preservation technology reached its zenith on coral islands, as people developed ways to

process certain foods that they could last through periods of scarcity and for use as sea rations among communities that regularly travelled between islands. Fermented breadfruit, dried pandanus paste, and dried arrowroot starch could be stored for years (Merlin et al., 1997). Another important traditional food, particularly on the wetter islands, was the giant swamp taro (*Cyrtosperma chamissonis*) (Figure 3).



Figure 2: Atoll agroforestry (photo F. Thomas)



Figure 3: Giant swamp taro (photo: F. Thomas)

Marine Resources

If opportunities for agricultural intensification in the past were limited, the lagoons generally teemed with fish and other marine organisms, providing food as well as raw material (fish bone, shells, coral) for the manufacture of tools and ornaments (Koch, 1986). Fishponds and fish traps made from loosely built walls of coral boulders were extensively used prior to European contact (Dieudonne, 2002; Figure 4). What is less clear, however, is the extent of human impact on the marine environment. Elsewhere in Oceania, there is evidence that overfishing by indigenous communities resulted in a decrease in the average size of available resources, particularly of shellfish, that can sometimes be distinguished from the effects of natural disturbance (Allen, 2003; Spennemann, 1987).



Figure 4: Fishtrap (photo: F. Thomas)

While marine losses have not been widely reported from coral islands and the chronology of some documented losses remains uncertain (Streadman, 1989), the high ratio of reef to land would have ensured abundant protein resources, with little noticeable impact by human communities that remained generally small. However, resident human populations might have had a noticeable effect on less mobile organisms, such as certain shellfish (Weisler, 2001). However, the presence or absence of marine species in a particular habitat is largely determined by chaotic or unpredictable recruiting of juvenile organisms that shape the structure of reef assemblages over time (Paulay, 2001). This is not to deny that some species, by virtue of biological, ecological, and behavioural attributes, display levels of resilience to human exploitation (Catterall and Poiner, 1987; Poiner and Catterall, 1998). Less resilient organisms, like the giant clam, *Tridacna gigas* in the Marianas, New Caledonia, and Fiji disappeared presumably because of being overexploited (Munro, 1989). Along with other members of the

Tridacna family, this species is considered vulnerable to gathering pressure, even when using traditional gathering methods.

Coping with Environmental Stress

Environmental stress can be reduced by the application of indigenous knowledge, as well as the use of social capital (Hermann, 2001; Prasad et al., 2014; Resture, 2009). Land tenure systems and kinship networks enabled people living on coral islands to maximize choice of residence and group affiliation to access resources. Strong mutual social obligations reflected the underlying collective effort required to ensure survival. Land tenure systems developed to safeguard terrestrial production among kin groups, while being flexible enough to enable neighbouring communities to access resources in time of need (Atanraoi, 1995). Various cooperative strategies ensured that people could claim rights to resources, made possible, for example, by adoption and intermarriage, trade, and sometimes cyclical migrations to alleviate problems of over- and under-population, thus contributing to sustainable practices (Alkire, 1978; Ushijima, 1987). Despite their abundance on most atolls, marine resources were at times subjected to avoidance practices, which would have enabled stocks to recover (Akimichi, 1986; Klee, 1985).

On small islands, the need to devise strategies for managing population growth may have arisen quickly, so as not to outstrip resources (Bedford and Macdonald, 1982). Warfare, cannibalism, infanticide, and abortion may contribute to population regulation, but there were also non-destructive means such as ritual celibacy, prolonged lactation, and adoption as an alternative to ensuring continuity of the family line. However, it may be that in some instances under-population was a more serious threat to community survival than population pressure (McArthur et al., 1976). Initially at least, relatively large families and clans would be necessary to ensure adequate levels of resource production (Nason, 1975). Atoll populations used flexible strategies for the control of fertility and rates of reproduction; they actively managed recovery from the demographic challenges of contingency events and ensured their continuity as communities occupying enduring settlements (Green and Green, 2007).

While European-introduced diseases between 1850 and 1900 contributed to population decline in Kiribati and other several other localities because of the inhabitants' relative epidemiological isolation, depopulation also followed in the wake of Western-induced labour migrations during the same time period to various other Pacific Islands and beyond to work on plantations and mines. Another important cause of depopulation was inter-group warfare encouraged by political, economic, and religious rivalries, with the establishment of external trade and missionary influence (Hezel, 1983; Maude and Maude, 1981).

Interisland contacts would confer advantages in the event of demographic instability and shortages in food and raw materials as a result of environmental perturbation, such as that caused by drought or cyclones (Hunt and Graves, 1990). Because of their marginality for human existence, coral islands occupy a prominent position in discussions centered on exchanges. Atolls may be connected to 'high' volcanic islands (Alkire, 1978), but in the absence of the latter, elaborate internal networks were established (Grimble, 1972; Williamson and Sabath, 1984). These networks functioned to redistribute resources between coral islands that differed in terms of productivity, both terrestrial and marine (Williamson and Sabath, 1982). These differences were linked to variation in rainfall, and also to intra- and inter-islet size, as well as the degree of lagoon closure, shape, and depth. Inter-island links in the Gilbert Islands formed several regional network clusters (Alkire, 1978, p. 109).

Historical Ecology

In recent years, historical ecology has emerged as one of the most useful and comprehensive approaches to understanding how environments and landscapes were affected by climate change, early human settlement, historical interactions, and modern development and industrialization (Balée, 2006; Fitzpatrick and Keegan, 2007; Ono and Addison, 2013; Rick and Erlandson, 2008; Russel, 1997). This approach, which combines the natural and social sciences using paleoecology, archaeology, land use history, and long-term ecological research, has potential for examining natural and cultural phenomena that generated changes to island ecosystems (Fitzpatrick and Intoh, 2009; Kirch and Hunt, 1997).

Compared to 'high' volcanic islands, atolls and table reefs have received scant attention from archaeologists focusing on historical ecology. More specifically, little is known about paleoclimatology, the introduction of exotic fauna, the extent of human-induced environmental impacts, and social transformations on low coral islands prior to Western contact (Allen, 2006; Anderson, 2006; Pregill and Weisler, 2007; Sachs et al., 2009). Given the unique environmental challenges posed by coral islands, it is all the more surprising that pre-European ecological research has been largely neglected.

Major environmental disturbances during the first half of the twentieth century and in the years just prior to Kiribati's independence include massive landscape alteration on the raised limestone island of Banaba (Ocean Island) caused by phosphate mining (Macdonald, 2001); the effects of bombings during World War II, particularly on Betio Islet, South Tarawa (McQuarrie, 2000); and nuclear tests near Malden (Southern Line Islands) and Kiritimati (Christmas Island) between 1957 and 1962 (Perry and Garnett, 1998). Owing to population pressure, agrodeforestation continues, with the widespread removal of coastal strand species and mangroves for fuel wood and other uses throughout the Gilberts (Thaman, 1994), and certain marine resources have experienced declines (Paulay, 2001; Thomas, 2003a). Sea-level rise, commonly attributed to global warming, further exacerbates the long-term survival of human settlements, and poses a direct threat to cultural heritage sites via coastal erosion (Blair and Beck, 2008; Henry et al., 2008; SPC, 2013).

These relatively recent narratives and case studies contrast with the dearth of evidence for the period preceding Western contact. There is a need to document how natural and anthropogenic influences have shaped socio-cultural trajectories of the various communities that appear to have lived sustainably for generations.

As noted above, a number of studies have looked at the long-term effects of human exploitation and environmental change on fish, invertebrate, and sea mammal populations, resulting in declines in species diversity and reduction in average age and size. It is possible that low coral island societies were more acutely aware of resource limitations than communities on larger

'high' islands, and thus realized early on the need to conserve resources (Wilson, 1994; Zann, 1985). This assumption needs to be critically examined. Optimal foraging models derived from human behavioural ecology (Kaplan and Hill, 1992) have been very useful in distinguishing conservation behaviour per se (conservation by design) from its effects (Alvard, 1998).

Landscape Transformation

Of interest to archaeologists is the timing for the development of stable islet landforms (reef islands) and how local chronologies tie in with the history of human settlement in Remote Oceania. Data for mid- to late-Holocene high sea-level stands have been presented for a number of Pacific localities (Grossman et al., 1998; Nunn, 1998). On Tarawa, a mid-Holocene position (~ 4000 BP) of sea-level 0.7-0.8 m above present is indicated (Falkland and Woodroffe, 1997). Together with evidence from neighbouring atolls, reef island formation would not have begun prior to about 3500 BP. The transition from corals to unconsolidated sediments needed for island build-up varied across time and space, even within the confines of a single atoll (Barry et al., 2007; Woodroffe and Morrison, 2001; Woodroffe et al, 2007), and the emergence of land suitable for permanent human occupation might have required several more centuries. Dickinson (2003) drew attention to the significance of early cultural horizons on central Pacific atolls prior to the inferred drawdown in hydro-isostatic sea-level (AD 1000-1200), which could be attributed to greater tidal range allowing for the accumulation of unconsolidated sediment prior to sea-level decline.

Once Pacific atolls became suitable for human habitation after islets of sufficient size had formed and vegetation taken hold, colonists faced several challenges, particularly in setting up a viable subsistence base given low soil fertility and in some cases inadequate rainfall (Clark, 2010). The range of food crops that could sustain people on low coral islands was limited compared to what could be grown on the more fertile volcanic islands. Nevertheless, coral island societies devised subsistence strategies that took full advantage of available resources, including abundant marine life, in addition to introduced tree and root crops (Di Piazza and Pearthree, 2004).

Pits excavated down to the brackish water lens for the cultivation of giant swamp taro are among the most outstanding features of the landscape, particularly on the wetter islands. In Kiribati, over 20 cultivars have been identified, with some varieties grown mainly for prestige and ceremonies. Swamp taro cultivation entails a sophisticated system of mulching and fertilization using leaves from a variety of trees. Pits were commonly excavated in the middle of islets where the lens is thicker. Some of the pits were lined with coral boulders to stabilize the walls. Those who still practice this form of food production have their own secret techniques of composting.

Taro pit cultivation has witnessed a general decline for variety of reasons, including damage by historically-introduced pigs, crop disease, tropical storms, growing dependence on food imports, and increasing salinization of the water table associated with global warming and sea-level rise (Thomas, 2003b). Given the dynamic nature of atoll geomorphology, anthropogenic traces on the landscape can easily be obliterated unless located well inland, such as swamp taro pits and associated mounds (Figure 5). Like arboriculture, swamp taro pit agriculture has a long sequence in the history of low coral settlements, as illustrated by excavation and dating of ancient surface soils under taro pit spoil dirt in adjacent mounds (Weisler, 1999b). One of the first tasks that colonists needed to perform was to clear vegetation in preparation for taro pit digging, because corms (swollen underground plant stems) can take nine months to several years to mature.



Figure 5: Swamp taro pit (left) and partially excavated mound, Buota, North Tarawa (photo: F. Thomas)

Archaeological research carried out in North Tarawa in 2010 and 2012 yielded evidence of human activity between the 3rd and 7th centuries AD, in mounded areas (Figure 6) adjacent to swamp taro pits (1,895 ± 25 BP - Wk-33517; 1,892 ± 25 BP - Wk -33518; 1,540 ± 30 BP - Wk-28381; 1,526 ± 25 BP – Wk-33522 1,483 ± 30 BP - Wk-28382). These are the oldest radiocarbon dates derived from wood charcoal linked to human settlement on Tarawa, consistent with dates obtained from the southern Gilberts and the Marshall Islands to the north (Di Piazza, 1999; Weisler 1999a). Some of these dates are associated with buried A horizons, indicative of early land clearance. Although excavations had been previously conducted in North Tarawa by a team of Japanese archaeologists (Takayama et al., 1990), no samples were collected for dating. The shallow cultural deposits suggested a late prehistoric to early European contact time frame. Additional samples for radiocarbon dating are required to minimize the problem of 'inbuilt age' in tropical Pacific trees (Allen and Wallace, 2007).



Figure 6: Excavation of a swamp taro pit mound, Buota, North Tarawa (photo: F. Thomas)

Equally significant is the identification of several plant microfossils in sediment bulk samples at Buota Islet of species commonly associated with human occupation of atolls. Pollen, phytoliths, and starch analyses provide evidence for horticulture, including at least two aroids, namely taro (*Colocasia esculenta*) and giant swamp taro (*Cyrtosperma chamissonis*). The very high concentrations of calcium oxalate crystals suggest intensive aroid cultivation or food preparation associated with the sampled deposits. Other cultivated species identified in the microfossil record include pandanus (*Pandanus tectoris*) and coconut (*Cocos nucifera*). The gardening activity is associated with the apparent decline in *Guettarda-Pisonia* forest. Environmental change to wetter conditions is suggested by the appearance of sedges (*Cyperaceae*) after the mid-17th century AD. Abundant microscopic fragments of charcoal in the sediment samples reflect human activity, namely hearth fires and probably burning of vegetation.

In 2013, research was expanded to include neighbouring Abaiang Atoll, 7 km northeast of Tarawa, the second largest atoll in the Gilbert Islands, with a lagoon measuring 208 km² and a total land area of 16km², made up of 30 islets or motu (Figure 7). Average annual rainfall is comparable to Tarawa. At close to 2,000 mm annually, precipitation is intermediate between the northernmost atolls of Makin and Butaritari (3,200 mm) and the atoll and table reefs from Nonouti to Arorae in the south (about 1,300 mm) (Burgess, 1987).

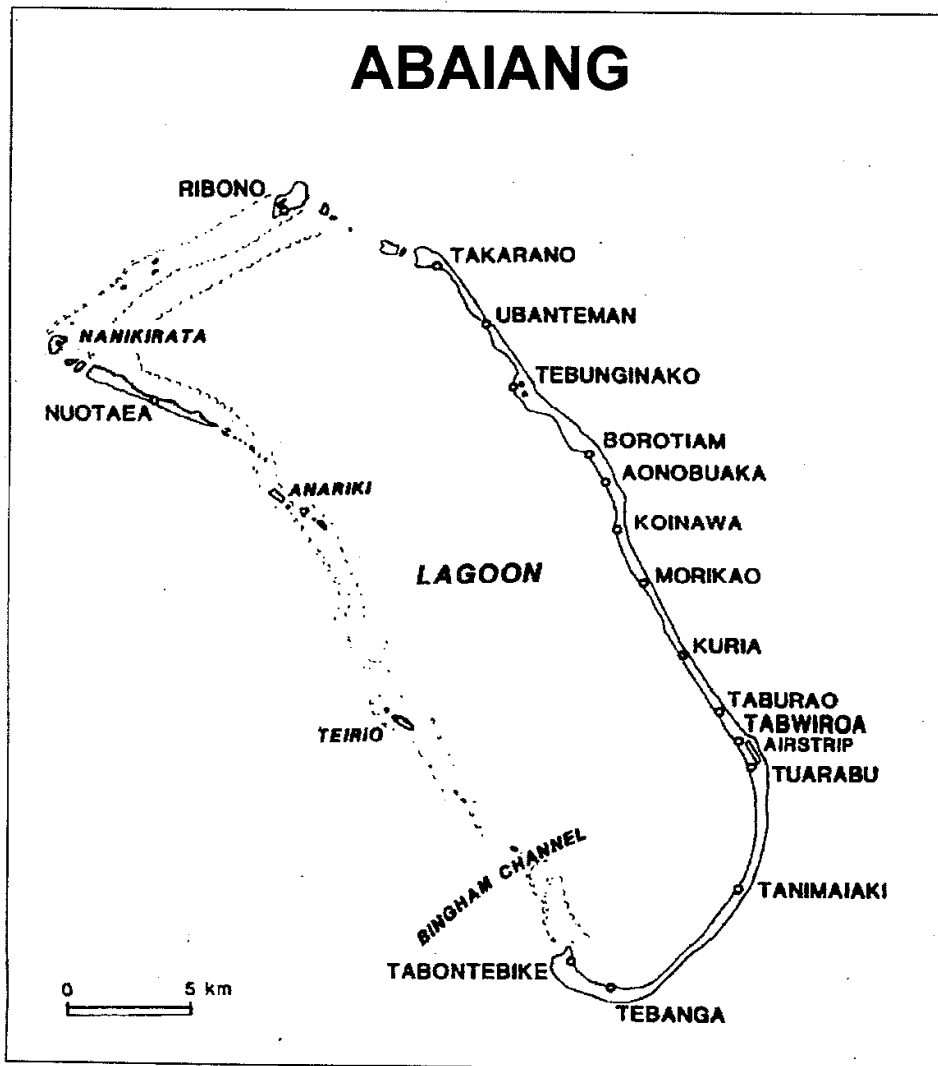


Figure 7: Abaiang Atoll (source: FLORA, C. J., ELY, P. S. & FLORA, A. R. (2007) Radial growth rates of microfossils on a reef flat on Abaiang, Republic of Kiribati. Atoll Research Bulletin. 552. p. 1-8).

Abaiang's culture history was first described by the United States Exploring Expedition (Hale, 1846) and later augmented by Grimble (1933-1934). Oral traditions mention that Abaiang formed part of a sub-regional network where communication with the north central atolls of Marakei, Tarawa, and Maiana was reported as frequent prior to Western contact.

The Kiribati Museum and Culture Centre compiled a list of heritage sites on several islets (Itonga, 2006; Thomas and Teaero, 2010). Prior to 2013 archaeological excavations on the atoll were limited to approximately 7 m³ of sediments, containing primarily shell midden on Manra, a small, intermittently occupied leeward islet that once supported a more stable population until shoreline erosion compelled the inhabitants to abandon their homes (Thomas, 2002). Cultural deposits were shallow, and no samples were collected for radiocarbon dating.

Surface surveys on atoll islets have generally yielded few traces of ancient human activities (Addison et al., 2009). Stratified cultural deposits tend to be concentrated where people live today (i.e., on the larger islets), although later settlements expanded from the centre toward the lagoon, facilitated by land progradation. It has been suggested that smaller islets were later exploited for birds, turtles, fish, and shellfish, perhaps as a result of a decline in resources near populated areas (Weisler, 1999b; 2001). Environmental change, such as the postulated decline in sea level around A.D. 1300 (Nunn, 2000; 2007), may have contributed to settlement dispersal, as the resource base on the larger islets began to decline and people moved to the smaller islets, many of which had appeared only recently as a result of sea-level fall.

Excavations were carried out along a transect measuring about 210 m (Figure 8), beginning from a mid-point near the village of Tuarabu toward the lagoon shore. Foraminifera and charcoal samples were collected for dating the formation of islets and human activities, as well as bulk sediments for microfossil analyses and the possible recovery of land snails indicative of human impact (Hather and Weisler, 2000; Horrocks and Nunn, 2007). Large bulk samples not only increase the possibility of recovering short-lived species, but also provide a better basis for making accurate taxonomic determination on any given charcoal fragment, which can be particularly important for AMS dating (Horrocks and Weisler, 2006).



Figure 8: Transect showing location of excavation units, Tuarabu, Abaiang (courtesy Gennady Gienko)

A swamp taro pit mound was also excavated on Ribono Islet, with results pending (Figure 9). The research was supplemented by interviews of long-term residents to record traditions on population movement and changes to islet size and ecological characteristics, including those pertaining to the surrounding marine environment. As in previous work on North Tarawa, long-term residents were interviewed to gather information on the history of swamp taro pits in an attempt to understand the development and expansion of swamp taro agriculture. This has proved somewhat difficult. Indigenous oral traditions in the Pacific, which are often rich and detailed, are more fragmentary in regards to these features of the landscape (Luomala, 1974).



Figure 9: Pit mound excavation, Ribono, Abaiang (photo: F. Thomas)

Conclusions

Because of their small size, limited and at times fluctuating resources, and relative isolation, low coral islands are of interest for evaluating aspects of past human adaptation to challenging environments. Much remains to be learned regarding their cultural transformation to sustainability before European contact. What stands out is that several communities were able to live sustainably through the interaction of factors such as relatively small populations, low impact technology, efficient use of resources via the application of specialized agricultural techniques and fishing methods and an understanding of environmental cues and fluctuations, and conservation/resource management practices, both intentional or by design such as the presumed deliberate extirpation of resource-competing pigs or the planting of trees on the banks of swamp taro pits to prevent moisture evaporation from hydromorphic soils and unintentional as illustrated by optimal foraging strategies (Giovas, 2006; Thomas, 2014; Yamaguchi et al., 2009).

In a general sense, it can be argued that islands, and especially low coral islands, are microcosms of larger, but equally fragile environments (Kirch, 2004). From some of the volcanic islands in the Pacific, archaeologists have uncovered evidence for extensive landscape change resulting from vegetation clearing, soil erosion, and species extinction. Debate continues regarding the role of humans versus climatic factors as the leading cause for these changes, but it is reasonable to assume that human impact on the environment exacerbated in some cases the effects of natural disasters, sometimes resulting in major social disruption. More data are needed to evaluate the degree and main causative agent of environmental change in low coral island settings. It may be that 'transported landscapes' (Smith, 2007, p. 28) to the low coral islands enhanced biodiversity prior to the 20th century rather than reducing it. Several of the indigenous plants had important uses; even to this day, in terms of providing construction material, quality compost, or yielding medicinal properties. Thaman (1987, p. 6) identified eight aboriginal introductions, all food plants, among 183 extant plants with local names. Over one third of these plants are thought to be indigenous and more than half being post-European contact introductions.

The interlinked topics of 'sustainability' archaeology, historical ecology, and conservation biology (van der Leeuw and Redman, 2002; Lyman and Cannon, 2004; Hardesty, 2007; Kirch, 2005; Thomas, 2012; Wolverton and Lyman, 2012) highlight the many challenges faced by contemporary Pacific island communities as they attempt to cope with changing environments, economies, and social values, which more than ever pose a threat to sustainable livelihoods. While the past, as documented through historical ecology, can provide some of the knowledge and tools for sustainable livelihoods, we also need to be critical of the effectiveness of traditional coping strategies under new conditions of growing population, altered land- and seascapes, escalating climate-related hazards, and changes in community and individual needs (Thomas, 1993; Overton, 1999; Beardsley, 2006; Nuttall et al., 2014). Surely, adjustments will have to be made to assist in developing long-term ecologically secure approaches to survival. For example, ethnographic data, primarily collected during the first half of the 20th century, confirmed the existence of traditional fishing regulations in the form of taboos with attendant secular and

supernatural sanctions, and more recently some rural villages and local councils have limited access to certain fishing grounds (Johannes and Yeeting, 2001). Reviving conservation practices could be quite challenging nowadays in a transformed natural and social environment (Thomas, 2001). Hope remains, however, with approaches that can strengthen the resilience of communities and their ecosystems for both sustainable development and climate change adaptation (Storey and Hunter, 2010). The persistence of some conservation practices, albeit on a small scale, is illustrated on outer islands in Kiribati in the form of aquaculture of giant clam and cockle species (Figure 10), representing the live storage of animal meat. Cockles are commonly placed in enclosures demarcated by coral cobbles (Figure 11).



Figure 10: Giant clam aquaculture (photo: F. Thomas)



Figure 11: Cockle aquaculture (photo: F. Thomas)

We should look at culture as a vital link between past, present, and future. Several low coral communities were successful in achieving sustainability for centuries, and their accomplishments deserve to be recognized and celebrated. Knowledge and practices are dynamic, just as cultures are. Culture on low coral islands and elsewhere in the Pacific islands region is still firmly rooted in community obligations. Kin- and community-related activities can reduce risk and uncertainty. Reciprocity as embodied in the Kiribati concept of *bubuti*, a request that cannot be refused, best exemplifies the close ties between people living in a challenging physical environment. As the anthropologist Tony Whincup remarked ‘the integration of people and place’ for I-Kiribati (the people of Kiribati) has indeed become an imperative of survival (Whincup, 2010). An integrated understanding of land- and seascapes for sustainable livelihoods is strongly linked to a sense of place. Historical ecology has often documented the transformation of place, whose custodians today, the local communities will need to take on an increasingly active role to manage their biocultural world successfully.

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References

- ADDISON, D. et al. (2009) Archaeology of Atafu, Tokelau: some initial results from 2008. *Rapa Nui Journal*. 23. p. 5-9.
- AKIMICHI, T. (1986) Conservation of the Sea: Satawal, Micronesia. In ANDERSON, A. (ed.). *Traditional Fishing in the Pacific: Ethnographical and Archaeological Papers from the 15th Pacific Science Congress*. Honolulu: Pacific Anthropological Records No. 37, B. P. Bishop Museum.
- ALKIRE, W. H. (1978) *Coral Islanders*. Arlington Heights, Illinois: AHM.
- ALLEN, M. S. (2003) Human Impact on Pacific Nearshore Marine Ecosystems. In SAND, C. (ed.). *Pacific Archaeology: Assessments and Prospects*. Nouméa: Département d'Archéologie, Service des Musées et du Patrimoine de Nouvelle Calédonie.
- ALLEN, M. S. (2006) New ideas about late Holocene climate variability in the central Pacific. *Current Anthropology*. 47. p. 521-535.
- ALLEN, M. S. & WALLACE, R. (2007) New evidence from the East Polynesian gateway: substantive and methodological results from Aitutaki, Southern Cook Islands. *Radiocarbon*. 49. p. 1163-1179.
- ALVARD, M. S. (1998) Evolutionary ecology and resource conservation. *Evolutionary Anthropology*. 7. p. 62-74.
- ANDERSON, A. (2006) The rat and the octopus: initial colonization and the prehistoric introduction of domestic animals to Remote Oceania. *Biological Invasions*. 11. p. 1503-1519.
- ANDERSON, A. (2008) Short and sometimes Sharp: Human Impacts on Marine Resources in the Archaeology and History of South Polynesia. In RICK, T. C. & ERLANDSON, J. M. (eds.). *Human Impacts on Ancient Marine Ecosystems: Global Perspectives*. Berkeley: University of California press.
- ATANRAOI, P. (1995) Customary tenure and sustainability in an atoll nation. In CROCOMBRE, R. (ed.). *Customary Land Tenure and Sustainable Development: Complementarity or Conflict? Nouméa and Suva: South Pacific Commission and Institute of Pacific Studies, University of the South Pacific*.
- BALÉE, W. (2006) The research program of historical ecology. *Annual Review of Anthropology*. 35. p. 75-88.
- BARNETT, J. & ADGER, W. N. (2003) Climate dangers and atoll countries. *Climate Change*. 61. p. 321-337.
- BARRY, S. J., COWELL, P. J. & WOODROFFE, C. D. (2007) A morphodynamic model of reef-island development on atolls. *Sedimentary Geology*. 197. p. 47-63.

- BEARDSLEY, F. R. (2006) Restoration of traditional knowledge to enhance self-sufficiency. *Micronesian Journal of the Humanities and Social Sciences*. 5 (1/2). p. 594-604.
- BEDFORD, R. and MACDONALD, B. (1982) *The Population of Kiribati: A Review of some Myths about Migration and Depopulation*. Christchurch: Department of Geography, University of Canterbury.
- BLAIR, A. & BEK, C. (2008) Inundation. *Cultural Survival Quarterly*. Summer. p. 21-29.
- BURGESS, S. M. (1987) *The Climate and Weather of Western Kiribati*. Wellington: New Zealand Meteorological Service.
- CATTERALL, C. P. & POINER, I. (1987) The potential impact of human gathering on shellfish populations with reference to some NE Australian intertidal flats. *Oikos*. 50. P. 144-122.
- CROSBY, A. W. (2004) *Ecological Imperialism: The Biological Expansion of Europe, 900-1900*. 2nd Ed. Cambridge: Cambridge University Press.
- CLARK, G. (2010) Micronesia. In LILLEY, I. (co-ordinator). *Early Human Expansion and Innovation in the Pacific: Thematic Study*. Paris: ICOMOS.
- DAVIDSON, J. and LEACH, F. (2001) The Strandlooper Concept and Economic Naivety. In CLARK, G. R., ANDERSON, A. D. & VUNIDILO, T. (eds.). *The Archaeology of Lapita Dispersal in Oceania: Papers from the Fourth Lapita Conference, June 2000, Canberra, Australia*. Canberra: Pandanus Press.
- DI PIAZZA, A. (1999) Te bakoa. Two old earth ovens from Nikunau Island (Republic of Kiribati). *Archaeology in Oceania*. 34. p. 40-42.
- DI PIAZZA, A. and PEARTHREE, E. (2004) *Sailing Routes of Old Polynesia: Prehistoric Discovery, Settlement and Abandonment of the Phoenix Islands*. Honolulu: Bishop Museum Press.
- DICKINSON, W. R. (2003) Impact of mid-Holocene hydro-isostatic highstand in regional sea level on habitability of islands in Pacific Oceania. *Journal of Coastal Research*. 19. p. 489-502.
- DIEUDONNE, F. (2002) *The Pacific Islands and the Sea: 350 Years of Reporting on Royal Fishponds, Coral reefs and Ancient Fish Weirs in Oceania*. Encinitas, CA: Neptune House.
- FALKLAND, A. C. and WOODROFFE, C. D. (1997) Geology and Hydrogeology of Tarawa and Christmas Island, Kiribati. In VACHER, H. L. & QUINN, T. M. (eds.). *Geology and Hydrogeology of Carbonate Islands*. Amsterdam: Elsevier.
- FITZPATRICK, S. M. & INTOH, M. (2009) Introduction: archaeology and historical ecology in the Pacific Basin. *Pacific Science*. 63. p. 463-464.
- FITZPATRICK, S. M. & KEEGAN, W. F. (2007) Human impacts and adaptations in the Caribbean Islands: an historical ecology approach. *Earth and Environmental Science Transactions of the Royal society of Edinburgh*. 98. p. 29-45.
- GIOVAS, C. M. (2006) No pig atoll: island biogeography and the extirpation of a Polynesian domesticate. *Asian Perspectives*. 45. p. 69-95.
- GREEN, V. J. and GREEN, R. C. (2007) An Accent on Atolls in Approaches to Population Histories of Remote Oceania. In KIRCH, P. V. & RALLU, J.-L. (eds.). *The Growth and Collapse of Pacific Island Societies: Archaeological and Demographic Perspectives*. Honolulu: University of Hawai'i Press.
- GRIMBLE, A. F. (1933-1934) *The Migration of a Pandanus People*. Auckland: The Polynesian Society. Memoir No. 12.
- GRIMBLE, A. (1972) *Migration, Myth and Magic from the Gilbert Islands*. London: Routledge and Kegan Paul.
- GROSSMAN, E., FLETCHER, C. & RICHMOND, B. (1998) The Holocene sea-level highstand in the equatorial Pacific: analysis of the insular paleosea-level database. *Coral Reefs*. 17. p. 309-327.
- HALE, H. (1846) *The United States Exploring Expedition during the Years 1838, 1839, 1840, 1841, and 1842 under the Command of Charles Wilkes, U.S.N., Vol. 6: Ethnography and Philology*. Philadelphia: C. Sherman.
- HARDESTY, D. L. (2007) Perspectives on global-change archaeology. *American Anthropologist*. 109. p. 1-7.

- HATHER, J. G. & WEISLER, M. I. (2000) Prehistoric giant swamp taro (*Cyrtosperma chamissonis*) from Henderson Island, southeast Polynesia. *Pacific Science*. 54. p. 149-156.
- HENRY, R., JEFFREY, W. and PAM, C. (2008) Heritage and Climate Change in Micronesia: A Report on a Pilot Study Conducted on Moch Island. Mortlock Islands, Chuuk, Federated States of Micronesia January 2008. Townsville, Australia: Department of Anthropology, Archaeology and Sociology, School of Arts and Social Sciences, James Cook University.
- HERMANN, E. (2014) Social Capital in the Face of Climate Change: Voices of Emotional Belonging from Kiribati. In QALO, R. (ed.). *Pacific Voices: Local Government and Climate Change*. Suva: University of the South Pacific Press.
- HEZEL, F. X. (1983) *The First Taint of Civilization: A History of the Marshall Islands in Pre-colonial Day 1521-1885*. Honolulu: University of Hawai'i Press.
- HORROCKS, M. & NUNN, P. D. (2007) Evidence for introduced taro (*Colocasia esculenta*) and lesser yam (*Dioscorea esculenta*) in Lapita-era (c. 3050-2500) cal. yr BP deposits from Bourewa, southwest Viti Levu Island, Fiji. *Journal of Archaeological Science*. 34. p. 739-748.
- HORROCKS, M. & WEISLER, M. I. (2006) Analysis of plant microfossils in archaeological deposits from two remote archipelagos: the Marshall Islands, eastern Micronesia, and Pitcairn Group, southeast Polynesia. *Pacific Science*. 60. p. 261-280.
- HUNT, T. L. & GRAVES, M. W. (1990) Some methodological issues of exchange in Oceanic prehistory. *Asian Perspectives*. 29. p. 107-115.
- ITONGA, N. (2006) *Abaiang Report: Cultural Mapping*. Tarawa: Ministry of Internal Affairs, Culture & Museum Division.
- JOHANNES, R. E. & YEETING, B. (2001) I-Kiribati knowledge and management of Tarawa's Lagoon resources. *Atoll Research Bulletin*. 489. p. 1-24.
- KAPLAN, H. and HILL, K. (1992) The Evolutionary Ecology of Food Acquisition. In SMITH, E. A. & WINTERHALDER, B. (eds.). *Evolutionary Ecology and Human Behavior*. New York: Aldine de Gruyter.
- KENNETT, D., ANDERSON, A. and WINTERHALDER, B. (2006) The Ideal Free Distribution, Food Production, and the Colonization of Oceania. In KENNETT, D. & WINTERHALDER, B. (eds.). *Behavioral Ecology and the Transition to Agriculture*. Berkeley: University of California Press.
- KIRCH, P. V. (1997) *The Lapita People: Ancestors of the Oceanic World*. Oxford: Blackwell.
- KIRCH, P. V. (2000) *On the Road of the Winds: An Archaeological History of the Pacific Islands before European Contact*. Berkeley: University of California Press.
- KIRCH, P. V. (2004) Oceanic Islands: Microcosms of 'Global Change'. In REDMAN, S. R. et al. (eds.). *The Archaeology of Global Change: The Impact of Humans on their Environment*. Washington, D.C.: Smithsonian Books.
- KIRCH, P. V. (2005) Archaeology and global change: the Holocene record. *Annual Review of Environment and Resources*. 30. p. 409-440.
- KIRCH, P. V. and HUNT, T. L. (eds.) (1997) *Historical Ecology in the Pacific Islands: Prehistoric Environmental and Landscape Change*. New Haven: Yale University Press.
- KLEE, G. A. (1985) Oceania. In KLEE, G. A. (ed.). *World systems of Traditional Resource Management*. New York: John Wiley & Sons.
- KOCH, G. (1986) *The Material Culture of Kiribati*. Suva: Institute of Pacific Studies, University of the South Pacific.
- LUOMALA, K. (1974) The *Cyrtosperma* systemic pattern: aspects of production in the Gilbert Islands. *Journal of the Polynesian Society*. 83. p. 14-34.
- LYMAN, R. L. and CANNON, K. P. (eds.) (2004) *Zooarchaeology and Conservation Biology*. Salt Lake City: University of Utah press.
- MACDONALD, B. (2001) *Cinderellas of the Empire: Towards a History of Kiribati and Tuvalu*. Suva: Institute of Pacific Studies, University of the South Pacific.
- MAUDE, H. C. & MAUDE, H. E. (1981) Tioba and the Tabiteuean Wars. *Journal of the Polynesian Society*. 80. p. 307-336.

- McARTHUR, N., SAUNDERS, I. W. & TWEEDIE, R. L. (1976) Small population isolates: a microsimulation study. *Journal of the Polynesian Society*. 85. p. 307-326.
- McQUARRIE, P. (2000) *Conflict in Kiribati: A History of the Second World War*. Christchurch: Macmillan Brown Centre for Pacific Studies.
- MERLIN, M. et al. (1997) *Keinikkan Im Mejan Aelōñ Kein (Plants and Environments of the Marshall Islands)*. Honolulu: East-West Center.
- MORRISON, A. E. & HUNT, T. L. (2007) Human impacts on the nearshore environment: an archaeological case study from Kauai'i, Hawaiian Islands. *Pacific Science*. 61. p. 325-345.
- MUNRO, J. L. (1989) Fisheries for Giant Clams (Tridacnidae: Bivalvia) and Prospects for Stock Enhancement. In CADDY, C. F. (ed.). *Marine Invertebrate Fisheries: Their Assessment and Management*. New York: John Wiley and Sons.
- NASON, J. D. (1975) The Strength of the Land: Community Perception of Population on Etal Atoll. In CARROLL, V. (ed.). *Pacific Atoll Populations*. Honolulu: University of Hawai'i Press.
- NUNN, P. D. (1998) *Pacific Island Landscapes*. Suva: Institute of Pacific Studies, University of the South Pacific.
- NUNN, P. D. (2000) Environmental catastrophe in the Pacific around A.D. 1300. *Geoarchaeology*. 15. p. 715-740.
- NUNN, P. D. (2007) *Climate, Environment and Society in the Pacific during the Last Millennium*. Amsterdam: Elsevier.
- NUTTAL, P. et al. (2014) A review of sustainable sea-transport for Oceania: providing content for renewable energy shipping for the Pacific. *Marine Policy*. 43. p. 283-287.
- ONO, R. and ADDISON, D. J. (2013) Historical ecology and 600 Years of Fish Use on Atafu Atoll, Tokelau. In ONO, R., A. MORRISON & ADDISON, D. (eds.). *Prehistoric Marine Resource Use in the Indo-Pacific Region*. Canberra: Terra Australia 39, ANU Press.
- OVERTON, J. (1999) A Future in the Past? Seeking Sustainable Agriculture. In OVERTON, J. & SCHEYVENS, r. (eds.). *Strategies for Sustainable Development: Experiences from the Pacific*. London: Zed Books.
- PAULAY, G. (2001) Benthic ecology and biota of Tarawa Lagoon: influence of equatorial upwelling, circulation, and human harvest. *Atoll Research Bulletin*. 487. p. 1-41.
- PERRY, R. and GRANETT, M. (1998) *Ana Otabwanin Kiritimati (The Environment of Christmas Island)*. Tarawa and Cambridge: Ministry of the Line and Phoenix Islands, Wildlife Conservation Unit, and BirdLife International.
- POINER, I. & CATTERALL, C. P. (1988) The effects of traditional gathering on populations of the marine gastropod *Strombus luhuanus* linne [sic] 1758, in southern Papua New Guinea. *Oecologia*. 76. p. 191-199.
- PRASAD, S., MCNAMARA, K. and HEMSTOCK, S. (2014) Learning from the Past to Assist Local Climate Change Adaptation Planning: Case Study from Two Communities in the Pacific. In QALO, R. (ed.). *Pacific Voices: Local Government and Climate Change*. Suva: University of the South Pacific Press.
- PREGILL, G. K. & WEISLER, M. I. (2007) Lizards from prehistoric sites on Ebon Atoll, Marshall Islands. *Micronesica*. 39. p. 107-116.
- RESTURE, A. (2009) Utilising Indigenous Knowledge for Building Resilience. In SHAW, R., SHARMA, A. & TAKEUCHI, Y. *Indigenous Knowledge and Disaster Risk Reduction: From Practice to Policy*. New York: Nova Science.
- RICK, T. C. and ERLANDSON, J. M. (eds.) (2008) *Human Impacts on Ancient Marine Environments: A Global Perspective*. Berkeley: University of California Press.
- RUSSEL, E. W. B. (1997) *People and the Land through Time: Linking Ecology and History*. New Haven: Yale University Press.
- SACHS, J. P. D. et al. (2009) Southward movement of the Pacific intertropical zone AD 1400-1850. *Nature Geoscience*. 2. p. 519-525.
- SMITH, A. (2007) Thematic Essay: The Cultural landscapes of the Pacific Islands. In SMITH, A. & JONES, K. L. *Cultural Landscapes of the Pacific islands: ICOMOS Thematic Study*. Paris: ICOMOS.

- SPC (2013) Endangered Cultural heritage Mapping in Kiribati: The Nnabakana (Stone Warriors). Suva: Secretariat of the Pacific Community.
- SPENNEMANN, D. H. R. (1987) Availability of shellfish resources on prehistoric Tongatapu, Tonga: effects of human predation and changing environment. *Archaeology in Oceania*. 22. p. 81-96.
- STEADMAN, D. W. (1989) Extinction of birds in eastern Polynesia: a review of the record and comparisons with other Pacific island groups. *Journal of Archaeological Science*. 16. p. 177-205.
- STOREY, D. & HUNTER, S. (2013) Kiribati: an environmental 'perfect storm'. *Australian Geographer*. 41 (2). p. 167-181.
- SZABÓ, K. & AMESBURY, J. R. (2011) Molluscs in a world of islands: the use of shellfish as a food resource in the tropical island Asia-Pacific region. *Quaternary International*. 239. p. 8-18.
- TAKAYAMA, J., TAKASUGI, H. and KAIYAMA, K. (1990) Test Excavation of the Nukantekainga Site on Tarawa, Kiribati, Central Pacific. In USHIJIMA, I. (ed.). *Archaeological Research on the Atoll Cultures of Micronesia, 1988*. Tsukuba-shi, Japan: Committee for Micronesian Research 1988, University of Tsukuba.
- THAMAN, R. R. (1987) Plants of Kiribati: a listing and analysis of vernacular names. *Atoll Research Bulletin*. 296. p. 1-42.
- THAMAN, R. R. (1990) Kiribati agroforestry: trees, people and the atoll environment. *Atoll Research Bulletin*. 333. p. 1-29.
- THAMAN, R. R. (1994) Pacific Island Agroforestry: An Endangered Science. In MORRISON, J., GERAGHTY, P. & CROWL, L. (eds.). *Land Use and Agriculture*. Suva: Institute of Pacific Studies, University of the South Pacific.
- THOMAS, F. R. (1993) Successes and Failures on Atolls: A Review of Prehistoric Adaptation and Contemporary Lessons. In JAMIESON, E. W., ABONYI, S. & MIRAU, N. A. (eds.). *Culture and Environment: A Fragile Coexistence*. Calgary: Archaeological Association, university of Calgary.
- THOMAS, F. R. (2001) Remodeling marine tenure on the atolls: a case study from Western Kiribati, Micronesia. *Human Ecology*. 29. p. 399-423.
- THOMAS, F. R. (2002) An evaluation of central-place foraging among mollusk gatherers in Western Kiribati, Micronesia: linking behavioral ecology with ethnoarchaeology. *World Archaeology*. 34. p. 182-208.
- THOMAS, F. R. (2003a) Fisheries development in Kiribati: sustainability issues in a 'MIRAB' economy. *Pacific Studies*. 26 (1/2). p. 1-35.
- THOMAS, F. R. (2003b) Kiribati: 'some aspects of human ecology' forty years later. *Atoll Research Bulletin*. 510. p. 1-40.
- THOMAS, F. R. (2012) The value of historical ecology in planning for sustainable livelihoods: Kiribati case study. *Journal of Pacific Studies*. 32. p. 137-152.
- THOMAS, F. R. (2014) Shellfish gathering and conservation on low coral islands: Kiribati perspectives. *Journal of Island & Coastal Archaeology*. 9. p. 203-218.
- THOMAS, F. R. and TEAERO, T. (2010) Learning the Past Today to Map Future Routes: Historic Preservation and Education in Kiribati. In NABOBO-BABA, U., KOYA, C. F. & TEAERO, T. (eds.). *Education for Sustainable Development: Continuity and Survival in the Pacific*, Vol. 1. Suva and Tokyo: School of Education, University of the South Pacific & Asia/Pacific Cultural Centre for UNESCO.
- USHIJIMA, I. (1987) A reinterpretation of the Sawai Overseas Exchange System of the Caroline Islands. In ISHIKAWA, E. (ed.). *Cultural Adaptation to Atolls in Micronesia and West Polynesia: A Report of the Cultural Anthropological Research in the Caroline, Marshall and Ellice Islands*. Tokyo: Committee for Micronesian research 1985, Tokyo Metropolitan University.
- van der LEEUW, S. and REDMAN, C. L. (2002) Placing archaeology at the center of socio-natural studies. *American Antiquity*. 67. p. 597-605.
- WEISLER, M. I. (1999a) Atolls as settlement landscapes: Ujae, Marshall Islands. *Atoll Research Bulletin*. 460. p. 1-51.

- WEISLER, M. I. (1999b) The antiquity of aroid pit agriculture and significance of buried A horizons on Pacific atolls. *Geoarchaeology*. 14. p. 621-654.
- WEISLER, M. I. (2001) Life on the edge: prehistoric settlement and economy on Utrök Atoll, northern Marshall Islands. *Archaeology in Oceania*. 36. p. 109-133.
- WEISLER, M. I., YAMANO, H. & HUA, Q. (2012) A multidisciplinary approach for dating human colonization of Pacific atolls. *Journal of Island & Coastal Archaeology*. 7. p. 102-125.
- WHINCUP, T. (2010) Te wa: the traditional canoe of Kiribati. [Online] Available from: <http://www.spasifikmag.com/freetravelarticlelewaphotoesay>. [Accessed: 2nd November 2010].
- WILLIAMSON, I. & SABATH, M. D. (1982) Island population, land area, and climate: a case study of the Marshall Islands. *Human Ecology*. 10. p. 71-84.
- WILLIAMSON, I & SABATH, M. D. (1984) Small population instability and island settlement patterns. *Human Ecology*. 12. p. 21-34.
- WILSON, C. (1994) Kiribati: State of the Environment Report. Apia: Pacific Environment Programme.
- WOLVERTON, S. and LYMAN, L. (eds.) (2012) *Conservation Biology and Applied Zooarchaeology*. Tucson: University of Arizona press.
- WOODROFFE, C. D. & MORRISON, R. J. (2001) reef-island accretion and soil development on Makin, Kiribati, central Pacific. *Catena*. 44. p. 245-261.
- WOODROFFE, C. D. et al. (2007) Incremental accretion of a sandy reef island over the past 3000 years indicated by component-specific radiocarbon dating. *Geophysical Research Letters*. 34 (L03602). p. 1-5.
- YAMAGUCHI, T., KAYANNE, H. & YAMANO, H. (2009) Archaeological investigations of the landscape history of an Oceanic atoll: Majuro, Marshall Islands. *Pacific Science*. 63. p. 537-565.
- ZANN, L. P. (1985) Traditional Management and Conservation of Fisheries in Kiribati and Tuvalu Atolls. In RUDDLE, K. & JOHANNES, R. (eds.). *The Traditional Knowledge and Management of Coastal Systems in Asia and the Pacific*. Jakarta: UNESCO/Regional Office for Science and Technology for Southeast Asia.