Archaeol. Oceania 45 (2010) 54–65

The Hakaea Beach site, Marquesan colonisation, and models of East Polynesian settlement

MELINDA S. ALLEN and ANDREW J. McALISTER

Keywords: Polynesia, settlement models, coastal geodynamics, climate change, colonisation process, sea level fall

Abstract

Field explorations at the newly recorded Hakaea Beach site, Nuku Hiva, Marquesas Islands were spread across a 12,500 m^2 area on the western coastal flat. The site's geomorphic and cultural history is reconstructed based on nine strata and ten radiocarbon determinations. The Hakaea record illustrates the range of powerful environmental processes, including sea level fall, climate change, tsunamis, and tropical storm surges, which have operated on Marquesan shorelines for the last 800 years, and the ease with which past human activity can be obscured or erased. The results highlight the need to systematically search for protected coastal contexts and geomorphic settings where older surfaces might be preserved. Radiocarbon assemblages from the 13th century Hakaea Beach site and seven other early Marquesan sites are considered in light of three models of East Polynesian dispersal: 1) *Leap-frog*; 2) *Stepping-stone*; and 3) *Advancing Wave*. Along with chronometrics, the processes and mechanisms which might account for regional patterns of mobility and settlement are emphasized. The Marquesan record is unique amongst central East Polynesian archipelagos in the number of pre-14th century sites, a pattern that might relate to the antiquity of human settlement, and one which should be considered alongside the late Holocene sea level record.

The settlement of East Polynesia was one of the most geographically expansive prehistoric colonisations by any one group of closely related peoples. The origins, timing, and mechanisms of that settlement process are of long-standing scholarly and public interest. Over the past 50 years radiocarbon dating has played an integral role in detailing the cultural historical sequences of the archipelagos which comprise this region. Further, recent technological advances in radiocarbon dating, combined with new archaeological protocols, have radically altered ideas about the antiquity and character of the East Polynesian settlement process. In this paper we present evidence from a new early settlement site in the Marquesas Islands, Hakaea Beach on Nuku Hiva Island. We then review the current suite of Marquesan sites with pre-1300 AD age estimates and three models of regional colonisation. The importance of considering not just chronometrics, but also the processes and mechanisms which might account for regional patterns of mobility and settlement, is emphasized.

Department of Anthropology, University of Auckland, Private Bag 92019, Auckland, New Zealand; ms.allen@auckland .ac.nz.

Hakaea Valley

Hakaea is a long narrow valley on the windward coast of Nuku Hiva (Figure 1). It opens onto a ca. 300 m wide coralline sand beach (Figure 2) and a deep narrow bay. This coastline has a dynamic and complex geomorphic history, with the narrow topography of both the valley and the bay potentially aggravating the impact of terrestrial and marine forces, both of which have left dramatic signatures on the contemporary landscape. The western portion of the coastal flat has been scoured by high wave action, and large coral heads (some more than a metre across) have been tossed onto the shore, probably by tsunami (see Schindelé *et al.*

Figure 1. Satellite view (IKONOS) of Hakaea Valley.

Figure 2. Hakaea shoreline, view to west.

2006). Alluvial processes have also been active, with an intermittent stream bisecting the western half of the coastal plain (Figure 3). The now dry channel records past episodes of high-energy deposition in its 2–3 m high banks. East of this is a discontinuous beach ridge that rises to a maximum height of nearly 10 m in the east. The term “beach ridge” is used here as these features parallel the coast and most likely formed by wave action, while dunes are the result of aeolian deposition, the sand accumulations at Ha’atuatua being an example (Dickinson, pers. com. 2010). The near-shore beach ridge at Hakaea is bisected by a spring, a washout gully, and small run-off channels. In the west, the area inland of the ridge is gently sloping, mildly undulating (Figure 4), and dominated by an aging coconut plantation (Figure 5). To the east, a second beach ridge parallels the longer near-shore one, indicative of progressive but intermittent coastal accretion. The higher near-shore eastern ridge segment also shows some evidence of capping dunelets (Dickinson, pers. com. 2010).

During Allen’s initial visit to Hakaea in 1997 a 1–2 m elongate rise, which paralleled the coast at ca. 150 m inland, was noted (Figure 3). This topographic feature suggested a palaeoshoreline, potentially associated with the late Holocene highstand which persisted until AD 500–600 (Dickinson 2009, 2003; Pirazzoli and Montaggioni 1988). Several traditional dry-stone masonry structures occur on this rise, along with evidence of adze-working. The structures are part of an extensive architectural record that extends into the valley interior and is likely to be late prehistoric in age (Allen 2009). Permission to excavate at the coast was granted in 2006.

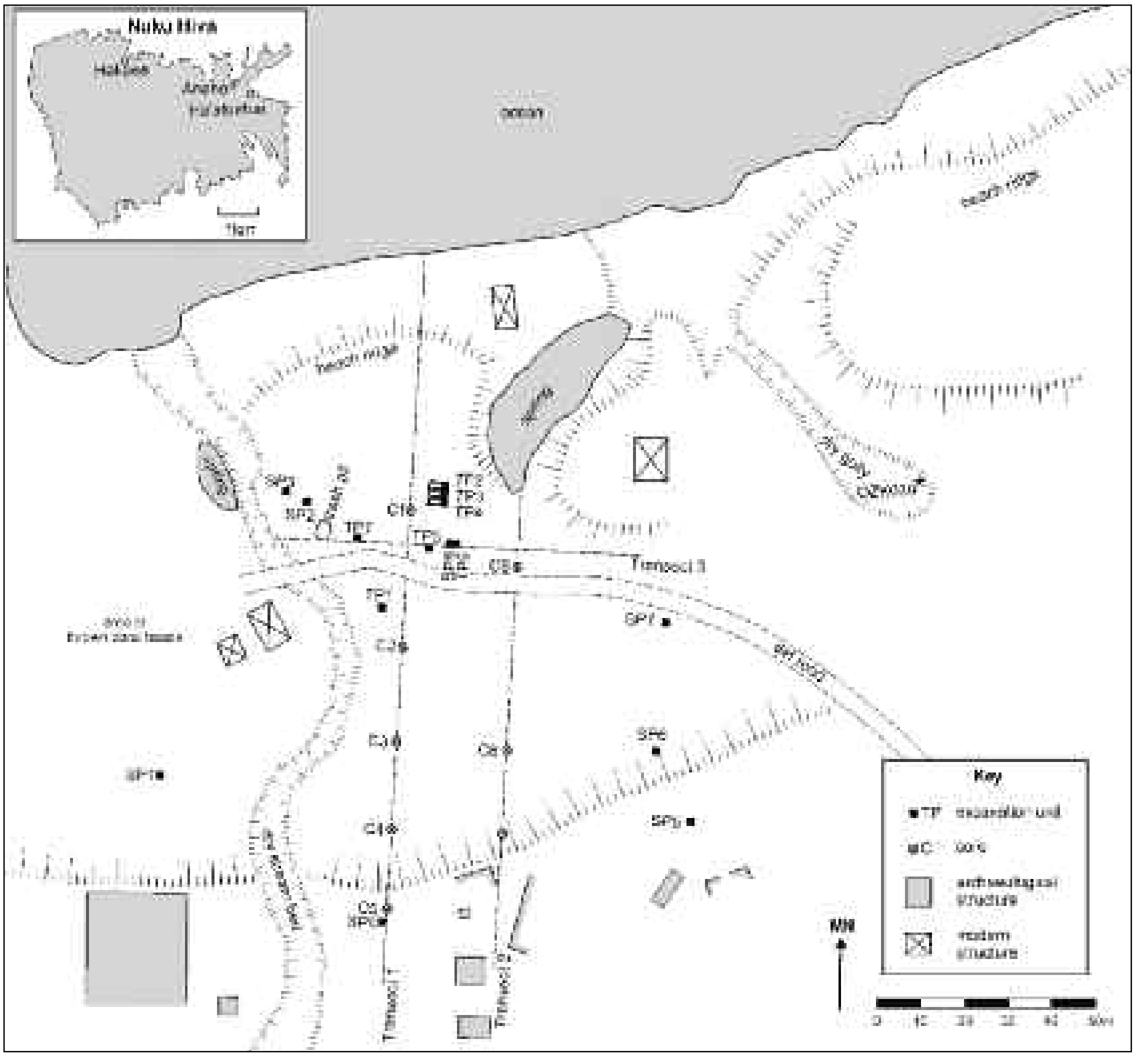

Figure 3. Map of study area and archaeological tests.

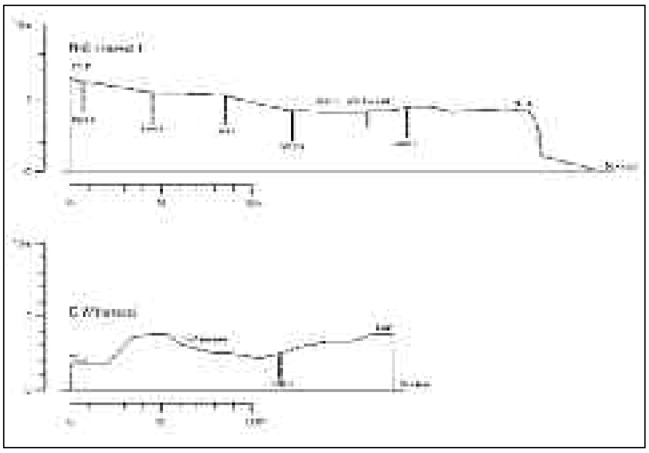

Figure 4. Topographic profiles along probing transects.

Archaeological field study

Initial probing

In 2006, three “shovel pits” (SP1-SP3) were opened over a two-day period (Figure 3). Sediments were removed by a combination of shovel and trowel, following the natural stratigraphy, and the cultural sediments were screened using 6.4 mm (SP1) and 3.2 mm (SP2 and SP3) sieves. Five strata were recognised including at least two *in situ* cultural layers (III and V), along with bird bones and fishhooks. The former included one extinct and another extirpated species (D. Steadman, pers. com.). However, time and weather conditions prevented us from reaching sterile sediments in SP2 and 3.

In 2007 we returned for seven days with the aims of: 1) testing the possible palaeoshoreline feature; 2) obtaining a more complete cultural sequence, and 3) locating an area suitable for areal excavation. Initially, two N-S probing transects were established 25 m apart (Figures 3, 4) and coring carried out along these transects with a Dutch auger. Areas of particular interest were investigated with shovel pits and additional coring from the base of excavation. The largely sterile shovel pit sediments were not screened, with the exception of SP8 (see below).

In brief, SP4 was placed near the crest of the rise (Figure 3), excavated to 80 cmbs (cm below ground surface), and then cored to a depth of 285 cmbs. Only sterile dark reddish brown (5YR 3/3, dry) silt loam, with no sand, gravel or other materials, was observed. Another three pits (SP5, 6 and 7) were opened along an inland-seaward line, placed so as to avoid areas of recent disturbance. SP5, also on the rise, was excavated and cored to a depth of 2 m. Although some modest colour changes were observed, only sterile silt loam was encountered, generally brown (10YR 4/3, dry) in colour. SP6 was excavated to 1.5 m and, other than a thin sand lens at 1 m, consisted entirely of silt loam, albeit with some colour variation. SP7 consisted of dark brown clay loam, and increasing cobbles with depth.

This probing exercise demonstrated that the elongate rise was comprised solely of terrigenous sediments to a depth of 285 cm and the result of low-energy alluvial deposition. Almost no marine sediments or cultural materials were recovered in SP4-7. Although the terrigenous sediments could cap an old shoreline feature, a mechanical digger would be needed to probe deeper. Following this exercise we redirected our efforts to more seaward localities.

In 2007 we found a trash pit (see Figure 3) had been enlarged by the landowner using a mechanical digger and extended to ca. 300 cmbs depth. This expansion revealed an additional cultural layer (Layer VII) which was underlain by light yellow-brown sand (Layer VIII) and a poorly sorted alluvium (Layer IX). Dense cobbles and boulders impeded any further excavation with hand tools; SP8 was opened at some distance from the stream in an attempt to carry the excavations below Layer IX.

Controlled excavations, 2007

The probing work identified areas of significant cultural deposition on and around the western beach ridge. Subsequently, seven 1m^2 excavation units were opened in an effort to identify an area suitable for areal excavation. Excavation followed the natural stratigraphy, sediments were screened with 3.2 mm mesh, and three-dimensional control was maintained. Layer VII, rich in faunal remains, was water-screened and all obvious bones removed prior to transport; the 3.2 mm fraction was retained and further sorted in the laboratory.

TP1, near the stream channel, provided a ca. 1.5 m deep stratigraphic sequence that replicated the modern trash pit stratigraphy. However, stream disturbances were indicated and we moved the excavations to the nearby beach ridge. Avoiding the northern summit area where a modern residence had been located, three 1 by 3 m trenches were opened on the southeastern slope, separated by 50 cm baulks (Figures 3, 5). To facilitate access to the test pits, the upper metre of overburden was removed from each trench, down to the top of Layer III. Subsequently, three 1m^2 test pits (TP2-4) were established (Figure 3) and excavation carried to 230 cmbs. Although the three cultural layers were represented here, cultural deposition was modest. Units TP5–TP7 were placed on the inland side of the beach ridge

Figure 5. Trenching on western beach ridge. Layers I and II are visible in trench face (view to southeast).

and excavated to 200 cmbs; they revealed more intensive occupation.

The Hakaea Beach stratigraphy and cultural features

The area investigated by the seven test units has a complex, spatially variable stratigraphy. Nine layers were identified, three of which derive from cultural activities, as indicated by artefacts, charcoal, faunal remains and *in situ* features (Table 1). The other non-cultural layers provide useful information on the geomorphic history of this locality, the environmental context in which the cultural activities took place, and potential impacts on local resources over time. More specifically, matrix texture and composition, colour and strata boundary characteristics inform on sediment source, transport history, environment of deposition and post-depositional alterations (Stein 2001). The layers are described below using the U.S. Department of Agriculture soil terminology (1951) and the Munsell colour system.

Layer I (modern surface) is a very dark greyish brown (10YR 3/2, dry), loamy fine calcareous sand layer that ranges in thickness from 50 cm in TP6 to 15 cm on the beach ridge where the three trenches were opened. The distinctiveness of the lower boundary varies from clear to abrupt, and the boundary topography is smooth to irregular. Two fire features were observed in this layer. Edible shellfish and mammal bone were recovered from some units indicating cultural deposition, but this was probably recent. The dark colour of Layer I indicates organic deposition, soil forming activities, and by extension, surface stability. Although some cultural activity is suggested, the organic matter probably derives from leaf litter and contributions by horses, goats, and pigs which frequent the beach.

Layer II is a light brownish grey (10YR 6/2, dry) fine to medium sand, with very little cultural material. It varies from 40 cm thick in TP6 to 110 cm thick on the ridge. In TP6, a sterile clay loam lens occurs in the lower half of Layer II. The lower boundary in TP6 is abrupt and smooth, with a thin lens of charcoal and fine gravel at the Layer II–III contact; this suggests an erosional event, one that is also recorded in other units. Although there are few cultural materials in this layer, a small number of rounded basalt cobbles and one boulder were found in the trenches. It is unclear whether Layer II is the result of a single episodic depositional event (e.g. a storm deposit) or accretional: the few large clasts suggest the possibility of the former.

Layer III (cultural occupation) varies from a dark brown (10YR 3/3, dry) loam with fine gravel and charcoal at the upper boundary in TP 6, to a dark greyish brown (10YR 4/2, dry) fine sand in SP2 and SP3. The cultural materials include artefacts, shell and bone. In TP6 Layer III is ca. 15 cm thick, while on the beach ridge it varies from 10 to 30 cm in thickness. In TP6, the lower boundary is very abrupt to abrupt, and smooth to irregular. On the dune it is generally abrupt and smooth.

A small number of features were found in Layer III, including a post-mould bounded by cobbles (TP5), a scoop hearth (TP6), an oven (TP3) and a pit of uncertain function (TP1). In SP2 a lens of water-worn pebbles, in association

Feature type	Layer	Unit	Fe. No.	Profile (cm) Shape	Length	Max. thickness	Plan (cm) Shape	Length	Width	Excavated depth (cm)	Portion excavated	Contents[a]
hearth	I	TP7	na	lenticular	75	20	circular	75	25	20	1/2	dense charcoal
hearth	I	TP4 trench	na	lenticular	40	25	na	na	na	na	na	charcoal
pit	III	TP1	1	squared	70	10	uncertain	50	25 cm	10	<1/4	white sand
oven?	III	TP3	3	lenticular	na	na	uncertain	55	30	5	<1/4	ash, charcoal, cobbles, oxidised base
post-mould?	III	TP5	8	uncertain	na	na	oval	55	40	20	1/2	outlined by 3 large cobbles; no ash or charcoal
hearth	III	TP6	11	lenticular	70	20	uncertain	na	na	na	<1/4	charcoal at base
hearth	IV	TP3 & 4	4	lenticular	50	10	uncertain	46	45	5	<1/4	charcoal, shell, bone, but no FCR
post-mould	V?	TP2	12	uncertain	na	na	circular	8	8	20	entire	darker sediment
oven	V	TP3	6	basin	40	20	uncertain	30	25	23	<1/4	many rounded cobbles, FCR and charcoal
post-mould	V	TP3	7	uncertain	na	na	circular	18	18	20	entire	grey sand; rock at base
fire feature	V	TP4	5	uncertain	na	na	uncertain	90	30	20	<1/4	charcoal, FCR
oven?	V	TP5 & SP8	9	basin	80	50	oval	60	40	50	1/2	charcoal and ash; cobbles nearby
post-mould	VII	SP8	2	uncertain	na	na	circular	18	13	28	entire	darker sediment
hearth	VII	TP6	10	basin	ca. 30	8	uncertain	na	na	na	<1/4	charcoal

[a] FCR= fire-cracked rock

Table 1. Excavated features. Measurements are in centimetres and relate to actual portions of features observed.

with worked pearl-shell, edible shellfish remains, and charcoal suggested a pavement. The features are widely spaced, suggesting several separate domestic activity areas. Overall, this stratum reflects cultural, aeolian, and alluvial deposition.

Layer IV is a greyish brown (10YR 5/2, dry), fine sand, with infrequent cultural materials. In TP6, it was 35 cm thick and the lower boundary clear and wavy, whereas on the beach ridge it was 60 cm thick with an abrupt to very abrupt and smooth lower boundary. A series of alternating tan and very light, grey-brown lens, indicates periods of relative stability and the gradual development of Layer IV. Occasional short-term cultural use of the summit is suggested by an isolated pit with charcoal and shell (Fe. 4). This feature, along with thin A-horizons, indicates that Layer IV is not a single episodic event but the result of gradual sand accumulation.

Layer V (cultural occupation) varies from a 15 cm dark brown (10YR 3/3, dry) sandy clay loam in TP6, where it contained an abundance of charcoal and some small cobbles, to a 10 cm thick light brownish grey (10YR 6/2, dry) fine loamy sand on the beach ridge. In general, cultural materials increased with depth, and included both artefacts and food remains (shell and bone). The lower boundary was clear and smooth to wavy. Two fire features (TP3 and 5), two post-moulds (TP2 and TP3), and an accumulation of fire-cracked rock (TP4) were identified in this layer.

Layer VI is a light grey (10YR 7/2, dry) fine sand which is unevenly represented across the seven units. In TP6 this stratum was only a few cm thick, whereas on the ridge it averages 40 cm and Layers V and VII can be clearly differentiated. In areas where Layer VI was sufficiently developed to evaluate, it did not contain cultural materials. The contact with Layer VII was typically abrupt and smooth. The fine-grain size of Layer VI is consistent with aeolian deposition but the sharp lower boundary could indicate storm deposition and erosion of the upper surface of VII.

Layer VII (cultural occupation) is a dark brown (10YR 3/3, dry) to black (10YR 2/1, dry) sandy clay loam with an abundance of charcoal and ash in TP6. Shell, bird and other bone, and artefacts were recovered. In several units this layer also contained a considerable amount of angular gravel. The layer is on average 12 to 15 cm thick in all units. The lower boundary is clear and irregular to wavy. Layer VII contained a hearth in TP6 and a post-mould in SP8, indicating *in situ* cultural activities. The highly fragmented cultural remains are likely to have resulted from a combination of trampling and the rough, gravelly surface on which the occupation took place.

Layer VIII (sterile), a thin yellow-brown sand, was only visible in the large trash pit.

Layer IX (sterile) was the most basal deposit encountered and was composed of a dark yellowish brown (10YR 3/ 4, moist) powdery silt loam with an abundance of rounded basalt cobbles and boulders of variable size. Excavation was impossible with hand-tools given the density of rocks, but inspection of the trash pit profile showed that this layer contained no cultural materials, fauna, or charcoal. The terrigenous sediments and large clasts suggest this layer was deposited by high-energy stream action.

In general, the small assemblage of artefacts was dominated by fishing gear and tools related to fishhook manufacture. The fishhooks from Layers VII and V are similar in form to those found in other early East Polynesian sites. Stone tools and flakes were surprisingly limited given the abundance of surface finds along the inland rise. A range of fauna has been identified, including fish, shellfish, pig, dog, and bird. These materials will be reported elsewhere in the near future.

Radiocarbon dating and site chronology

Ten radiocarbon dates form the backbone of the Hakaea chronology (Table 2, Figure 6). WK-19117 was secured in 1997 from an oven exposed on the inland side of the central beach ridge, near the base and under a mature coconut tree. Six samples came from stratigraphic contexts exposed during the 2006–07 excavations. Another two samples (OZM070 and OZM071) were taken from the trash pit profile. A final sample (OZK039) comes from an oven in a buried cultural layer exposed in the profile of a 1.5 m deep wash-out gulch located east of the excavation area (Figure 7). Excavation to a depth of 160 cm below the base of this feature (380 cmbs) failed to identify any lower cultural layers, indicating that Layer VII does not extend to this locality.

In eight cases, either coconut endocarp or other short-lived materials were obtained (Table 2). Sample WK-19117 was comprised of *Hibiscus*, a native species that grows quickly. For WK-19934, *Barringtonia* was the only material that wood charcoal specialist Rod Wallace was able to identify. Given a known life span of 80–90 years (Allen and Wallace 2007, Table 2) there is some potential for in-built age but the sample results are consistent with other determinations made on short-lived materials.

All but one of the ten determinations are AMS analyses. The three samples from Layer VII are close in age, with a 1σ age range of AD 1252–1286. The fourth sample has a slightly earlier age range AD 1188–1259 (1σ), but the recent end of the distribution has a higher probability. As a whole, the four samples place occupation of Layer VII in the mid-13th century AD. The coconut endocarp samples suggest that mature coconut trees were locally available at this time.

Layer V, on the basis of three samples of short-lived materials (OZM072, OZM071 and OZM073), is fairly close in age to Layer VII, dating to the 14th century. The oven in the eastern gulch is contemporaneous, based on OZK039.

Layer III probably dates to the early 15th century but could be as early as the 14th century AD, based on OZM070 (Figure 6). Layer III is not represented in the gulch wash-out profile but may have been eroded by the high-energy alluvial events recorded there (Figure 7). Following occupation of Layer III, the area of our test units was abandoned.

Lab No.	Unit	Layer	Provenience notes	Material dated	Conventional ^{14}C age BP	cal BP 2σ range[a]	cal AD 2σ range
WK-19117	none	na	fire feature	mainly *Hibiscus*	169 ± 29	>290	1661-1954
OZM070	none	III	from large trash pit, 77-94 cmbs	endocarp, cf. coconut	525 ± 35	633-506	1318-1444
OZM073	1	V	from screen, 86/92 to 97/104 cmbs	coconut endocarp	615 ± 35	659-545	1291-1405
OZM071	none	V	from large trash pit, 107-117 cmbs;	endocarp, cf. coconut	600 ± 40	565-539	1294-1411
OZM072	3	V	from small oven (Fe. 6)	monocot stem	670 ± 40	683-555	1268-1396
OZK039	none	na	from oven in E profile of wash-out gulch	unid. fruit/nut endocarp	690 ± 35	689-560	1261-1391
WK-19934	SP2	VII	basal cultural layer in this unit, 133 cmbs	*Barringtonia asiatica*	744 ± 33	730-659	1220-1292
WK-22226	1	VII	from N profile	endocarp, cf. coconut	744 ± 30	728-661	1222-1290
WK-22228	6	VII	from hearth (Fe. 10) in N profile	endocarp, cf. coconut	746 ± 30	729-662	1222-1289
WK-22227	5	VII	top of greasy black sediment	endocarp, cf. coconut	824 ± 30	787-685	1164-1265

[a] All analyses except WK-19117 are AMS. OZ samples were run at the Australian Nuclear Science and Technology Organisation, while WK samples were prepared at Waikato Radiocarbon Laboratory and the graphite targets analyzed by National Isotope Centre, GNS Science. Samples were calibrated with OxCal Ver. 4.1.4 (Bronk Ramsey 2009) using the Marine09 calibration curve (100% marine assumed), with a Nuku Hiva Island delta r value of 45± 48 for shell samples (in Table 2) (Petchey *et al*. 2009) and Northern Hemisphere calibration curve (IntCal09) for terrestrial samples (Reimer *et al*. 2009).

Table 2. Radiocarbon determinations from Hakaea.

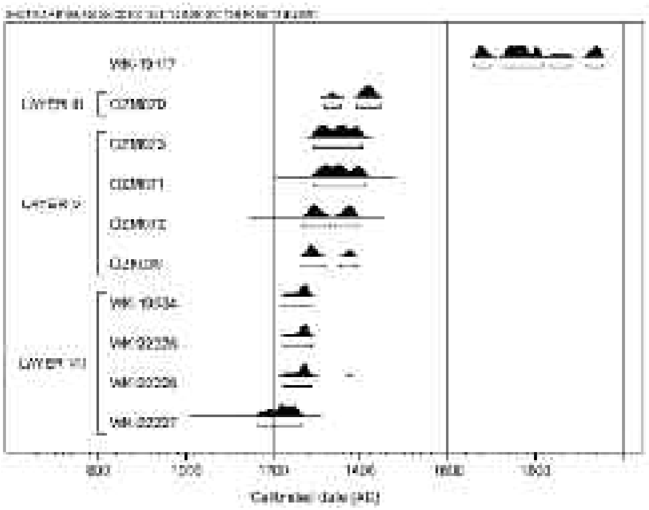

Figure 6. Hakaea radiocarbon sequence.

Figure 7. Wash-out gully profile and feature sampled for radiocarbon dating.

Environmental reconstruction and cultural sequence

Drawing on the overall site stratigraphy, the record of human activities, and the radiocarbon chronology, the geomorphic and cultural history of Hakaea is outlined below. Late Holocene sea level decline, climate variability, and possibly tropical storms are proposed as important forces which have shaped this coastal area. Human activities appear to have been minor landscape influences until the late 14th century AD. In periodising the sequence, attention is given to the dominant forces of landscape development at particular points in time, but it is recognised that multiple processes were usually operative.

Period I: Post-sea level decline and shoreline adjustment

The basal layer IX indicates rapid and high-energy deposition of poorly sorted terrigenous sediments over an area of 50 m^2 or more on the eastern side of the current stream channel. An upward fining sequence is indicated, suggesting Layer IX is a single massive depositional event. Sea level fall from around AD 500–600, with stabilisation not until around AD 900 (Dickinson 2009, 2003; Pirazzoli and Montaggioni 1988), is likely to have played a role in sediment build-up, exacerbating valley incision, increasing the volume of terrigenous sediments to the coast, and over time, facilitating shoreline progradation.

Period II: Beach ridge formation

Shortly before human arrival, beach ridge building was initiated (Layer VIII). Sea level decline may also have played a role here, exposing the local coral reef to wind and wave erosion. Calcareous sediments began to accumulate on the shoreline before human settlement (Layer VII) at AD 1188–1286 (1σ range). The early Marquesans presumably positioned their camps to take advantage of the fresh water resources. Domestic activities were carried out on the recently accumulated sands (Layer VIII) alongside the stream channel, or perhaps directly on alluvial outwash where Layer VIII is not recorded. Following a period of further sand accumulation, modest cultural deposition (Layer V) resumed at ca. AD 1275 to 1400 (1σ range). Subsequently, the site was abandoned and ridge building continued (Layer IV), with infrequent small-scale cultural activities and only occasional periods of surface stability until ca. the 15th century.

Period III: Intensified anthropogenic influences

Around AD 1299–1436 (1σ range) human activities and their effects on the coastal flat became more pronounced (Layer III). A marked increase in cultural deposition and organic matter accumulation is represented in Layer III. Domestic activities were now spread over a relatively large area of $50m^2$ or more. Simple structures were built along the stream, where they are today exposed in profile. Deposition of calcareous sand also continued.

Period IV: Coastal instability

In several test units, gravel and charcoal at the upper boundary of Layer III, along with a sharp Layer II–III boundary, signal the onset of erosion. This may be the result of vegetation clearance and subsequent disruption of the local sediment regime but other geomorphic processes also seem to be underway. Several centimetres of sand accumulated over the next few centuries (Layer II), with a considerable (110 cm) build-up in the beach ridge test pits. In general the grain size is fine, but at least one large boulder and a few smaller cobbles in Layer II leave open the possibility that all or part of Layer II is the result of storm deposition.

In the eastern washout profile, at least two massive flood events are registered (Figure 7). Given two hundred years of prior human activity in the valley, it is unlikely that forest clearance alone could be responsible for these new sedimentation patterns. However, the onset of warmer and wetter conditions associated with the Little Ice Age (LIA; AD 1550–1900) in the central eastern Pacific (see Cobb *et al*. 2003; Allen 2006) in combination with the intensified human activity of Period III could be responsible.

This post-1450 period also sees the cessation of occupation on the immediate coast, at least in the area we investigated. People may have shifted their residences to more elevated positions, for example to the rise which parallels the beach. A similar settlement shift is suggested in Anaho Valley where the coastal flat is occupied until ca. the 16th century, after which habitation sites are found a few hundred metres inland, in undefended locations, and on stone foundations (Allen 2009). These settlement pattern changes may be in response to stormier conditions associated with the LIA.

Period V: Modern conditions

The contemporary A-horizon is probably a relatively recent development. Layer I produced few traditional artefacts but at least a couple of in situ features. People continue to camp on the beach today, but there is only one permanent resident.

The Hakaea site and East Polynesian colonisation

The geographic position of the Marquesas Islands, on the northeast border of the East Polynesian core, potentially informs on the character and pace of prehistoric exploration in the larger region. Relevant to this, the newly reported Hakaea site joins a small cadre of Marquesan localities with dates between the 9th and 14th centuries AD (Table 3). This assemblage is considered here in the context of three models of regional dispersal and settlement, the *Leap-frog*, *Stepping-stone*, and *Advancing Wave* models.

Leap-frog model

Emory and Sinoto's (1965; Sinoto 1970) notion of the Marquesas Islands as an East Polynesian "homeland" was built on a handful of undecorated ceramic sherds and a small number of radiocarbon dates, some no longer considered valid. Their proposal, that islands closer to West Polynesia were initially by-passed, is akin to a *Leap-frog* dispersal pattern (see Sheppard and Walter 2006). As other archipelagos have been more thoroughly investigated (e.g. Allen and Wallace 2007; Bollt 2008; Conte and Kirch 2006; Kirch *et al*. 1995; Walter 1998), and known sites re-investigated (e.g. Anderson and Sinoto 2002, Conte and Anderson 2003; Hunt and Lipo 2007), the Marquesan homeland model has lost favour. Rolett and Conte's (1995) return to the Marquesan site of Ha'atuatua, and their failure to find evidence of human activity prior to the 9th century AD, was a particularly important challenge.

Computer simulations also provide insights, highlighting the difficulty of reaching the Marquesas directly from West Polynesia. Irwin's (1992) experiments indicated a 12% chance of a direct Marquesas landing, compared to 15% for the northern Cook Islands, and 24% for the Society Islands. Based solely on East Polynesian geography, wind systems, and currents, leap-frogging directly from West Polynesia to the Marquesas is unlikely.

Dickinson (2003, 2009), however, gives further currency

Island	Site and Provenience[a]	Lab No.	Conventional ^{14}C age BP	cal AD 2σ range[b]	Material dated	Type of Analysis	Reference
Nuku Hiva	Hatiheu coast	Beta-170319	1190 ± 90	665-1011	unid. charcoal	regular?	Orliac 2003
Nuku Hiva	Ha'atuatua, TP14	CAMS-8664	1570 ± 90	665-1067	*Cellana radiata* shell	AMS	Rolett & Conte 1995
	Ha'atuatua, TP14	CAMS-8865	970 ± 70	898-1218	unid. charcoal	AMS	Rolett & Conte 1995
	Ha'atuatua, TP12	I-17, 152	570 ± 80	1273-1455	unid. charcoal	regular	Rolett & Conte 1995
	Ha'atuatua, TP12	I-17, 157	560 ± 80	1275-1466	unid. charcoal	regular	Rolett & Conte 1995
Ua Huka	Manihina Dune, basal stratum	not provided	not provided	980-1260	*Cypraea* shell	AMS	Conte 2002: 260
Nuku Hiva	Anaho, below Structure 8	OZI977	855 ± 45	1042-1264	unid. nutshell, cf. coconut	AMS	Allen 2009
Nuku Hiva	Anaho, Teavau'ua, Layer IV	WK-20133	1172 ± 30	1160-1391	*Periglypta reticulata* shell	AMS	Petchey *et al*. 2009
	as above	WK-13833	1169 ± 36	1155-1398	*Pinctada margaritifera*	regular	Petchey *et al*. 2009
	as above	OZI976	835 ± 45	1046-1275	monocot wood	AMS	Allen in prep.
	as above	OZI975	805 ± 40	1162-1278	unid. broadleaf	AMS	Allen in prep.
	as above	WK-20135	751 ± 31	1220-1287	nutshell, cf. coconut	AMS	Petchey *et al*. 2009
	as above	OZI974	730 ± 40	1216-1384	unid. nutshell	AMS	Petchey *et al*. 2009
	as above	WK-20134	696 ± 31	1262-1387	nutshell, cf. coconut	AMS	Petchey *et al*. 2009
Nuku Hiva	Hakaea, Layer VII	see Table 1	see Table 1	see Table 1	see Table 1	AMS	this paper
Ua Huka	Hane, Area B, Layer V, 190 cmbs	ANU-11385	970 ± 60	972-1212	unid. charcoal	regular	Anderson & Sinoto 2002
	Hane, Area B, Layer VI, below paving 3	WK-8594	1340 ± 50	981-1265	*Pinctada* (pearl-shell)	regular	Anderson & Sinoto 2002
	Hane, Area B, Layer VI, below paving 3	WK-8595	1240 ± 50	1054-1313	*Cassis* (shell)	regular	Anderson & Sinoto 2002
	Hane, Area B, Layer VI, 220 cmbs	WK-8590	640 ± 130	1044-1616	unid. charcoal	regular	Anderson & Sinoto 2002
	Hane, Area B, Layer V, 160 cmbs	ANU-11376	1210 ± 60	1055-1381	*Pinctada* (pearl-shell)	regular	Anderson & Sinoto 2002
	Hane, Area A, Layer IV, 440 cmbs	WK-8591	1030 ± 150	688-1260	unid. charcoal	regular	Anderson & Sinoto 2002
	Hane, Area A, Layer IV, 440 cmbs	WK-8596	1230 ± 50	1059-1320	*Cassis* (shell)	regular	Anderson & Sinoto 2002
	Hane, Area A, Layer IV, 416 cmbs	WK-8592	690 ± 60	1223-1399	unid. charcoal	regular	Anderson & Sinoto 2002
Ua Huka	Hokatu, Layer F: 1	Wk-8059	860 ± 60	1037-1264	unid. charcoal	AMS	Conte & Anderson 2003
	Hokatu, trench base	Wk-8060	890 ± 50	1027-1238	unid. charcoal	regular	Conte & Anderson 2003
Tahuata	Hanamiai, Layer H	AA2, 820-V3, 738	890 ± 80	1015-1273	unid. charcoal	regular	Rolett 1998
	Hanamiai, Layer H	AA2, 819-V3, 737	790 ± 80	1037-1385	unid. charcoal	regular	Rolett 1998
	Hanamiai, Layer G/H	Beta-15567	850 ± 60	1040-1270	unid. charcoal	regular	Rolett 1998
	Hanamiai, Layer G	AA2, 822-V3, 740	870 ± 80	1022-1273	unid. charcoal	regular	Rolett 1998
	Hanamiai, Layer G	Beta-17468	1250 ± 100	621-988	unid. charcoal	regular	Rolett 1998

[a] Only the new Hane dates are provided here. [b] Samples were calibrated as in Table 1.

Table 3. Radiocarbon determinations from other Marquesan settlement sites.

to the possibility of a Marquesan "homeland" in his suggestion that early settlements here could be the result of poor quality shorelines (and resources) elsewhere prior to sea level decline around the 10th century AD. The Marquesas are one group in a handful of high islands that might have been attractive for human settlement prior to the 10th century AD and might have been colonised before low-lying islands to the west – a leap-frog pattern of dispersal.

Stepping-stone model

The *Stepping-stone* model is loosely linked to MacArthur and Wilson's (1967) theory of island biogeography. Best articulated by Irwin (1992), this model proposes a gradual and regular process of colonisation, in which voyagers systematically explored and settled the region. Islands in the central area were occupied first, with subsequent dispersal north (to Line Islands and Hawaii) and south (to Kermadecs and New Zealand). As developed by Irwin (1992, 2006, 2008), variables such as distance, angle and size of target, coupled with information on winds and currents, help predict and explain the sequence of island settlement. The pace of island colonisation is seen to be driven by a combination of ever-improving voyaging skills and increased knowledge of regional conditions. Green and

Weisler's (2002) Y-settlement hypothesis might be considered a subset of the *Stepping-stone* model, one that incorporates archaeological, linguistic, and traditional information on inter-island relations, but assumes geography played a significant role in structuring the colonisation process. This model predicts that Marquesan settlement will lag behind that of the Cooks, the Societies, and possibly the Tuamotus, assuming the latter were sufficiently elevated and stable. Current evidence is not particularly supportive but systematic efforts to locate early sites in both the Societies and the Cooks have been limited.

Advancing Wave model

Increasing evidence for established human settlement (sensu Graves and Addison 1995) throughout central East Polynesian by ca. AD 1000–1300 (Anderson 2004, Anderson and Sinoto 2002), point to the possibility of a third model, which we refer to as the *Advancing Wave*. The interpretation of sites from this time period as "colonial Polynesian" is typically supported by the basal position of a given occupation in stratified sequence, associations with extinct or extirpated fauna, indicators of landscape disturbance, and/or exotic Polynesian plant and animal introductions (e.g. Anderson and Sinoto 2002; Bollt 2008; Kirch *et al*. 1995; Prebble and Wilmshurst 2008; Rolett 1998). Nevertheless, distinguishing first use of a catchment from initial colonisation of an archipelago remains a challenge in settings where archaeological explorations have been minimal and the most favourable and productive settings not fully explored (see also Weisler 1996). The *Advancing Wave* model draws attention to processual aspects of the record, especially the apparent uniformity of settlement timing across multiple archipelagos, and the mechanisms which might underlie such a pattern.

If we draw only on the most secure East Polynesian radiocarbon dates (following Spriggs and Anderson 1993), then a colonisation event on par with Lapita expansion into Fiji-West Polynesia is suggested. The East Polynesian case, however, is even more extraordinary (assuming it is valid) given the exceptional geographic area (on the order of 22 million km^2) which was searched and settled within a few generations. The number of voyaging expeditions required to account for such a rapid and extensive dispersal would have been considerable, raising questions about where these migrants originated and why they left. Widespread similarities in material culture point to voyagers who were closely related peoples from a common source area, rather than a mass exodus out of numerous unrelated western archipelagos.

West Polynesia is, on several accounts, a likely epicentre for this wave. Three mechanisms might account for emigration on this scale: sea level fall, population pressure, and climate variability; Anderson (2004; also Anderson *et al*. 2006) adds maritime technological innovations to this mix. With respect to mechanisms, Dickinson (2003) observes that East Polynesian coastal regions became increasingly attractive following late Holocene sea level decline. But importantly, sea level decline in West Polynesia was considerably earlier (ca. 3200 BP) and East Polynesian shoreline improvements could only have been known if there had been exploration prior to shoreline stabilisation, estimated at ca. AD 900 (see Dickinson 2003: 497). Such exploration might account for the wide-spread, but numerically rare, early dates scattered across the East Polynesian region (see also below).

Anderson (2004: 8) considers briefly the possibility of population pressure on West Polynesian resources but suggests that "the demographic crunch would have arisen very much sooner, and at different times between archipelagos of very different land area and resource array". Nevertheless, contemporaneous resource deterioration could have been climate related. Nunn (2000), for example, argues that the transition from the "Medieval Climatic Anomaly" to the "Little Ice Age" was "catastrophic". While his analysis lacks chronological precision, and many of the social changes he attributes to climate can have other potential causes, the impact of changing climate on Polynesian resources in the period AD 1100–1300 warrants evaluation. Mechanical disruption to reefs from intensified storm surf, and possibly coral bleaching, could have adversely affected fish and shellfish (Allen 2006). So far, however, evidence for a "crisis" sufficient to drive large scale emigration is lacking, with overall stability in marine resources during the period in question (Nagaoka 1993; Morrison and Addison 2008, 2009).

While the assemblage of widely accepted East Polynesian settlement dates are consistent with the *Advancing Wave* model, they also could be an artefact of "chronometric hygiene" (Spriggs and Anderson 1993). In particular, the practice of discarding isolated early dates, which could be accurate indicators of ephemeral human activity, is problematic. Examples of potentially valid early determinations which fail to meet the stringent chronometric hygiene criteria can be found in the Societies (Anderson and Sinoto 2002), Henderson (Weisler 1995), Rapa Nui (Green and Weisler 2002:235-6), Marquesas (Orliac 2003) and elsewhere. Dating issues aside, more attention needs to be directed to explaining and empirically documenting the processes which might underlie such a large-scale migration event (see also Anderson 2004; Irwin 2006, 2008).

The Marquesan record and East Polynesian settlement models

There are now eight Marquesan sites with pre-14th century radiocarbon ages. These sites are spread throughout the archipelago, occurring in both the northern and southern groups. The majority are located on Nuku Hiva, the largest island (330 km^2), where four early sites are found. The AD 1042–1264 (2σ) date from Anaho is the earliest for which in-built age can be discounted. The most securely dated site, with four AMS determinations on nutshell, is Hakaea Beach with an age range of AD 1164–1292 (2σ). However, Hane with eight recently run pre-14th century determinations from two excavation areas also should be considered well dated; these determinations range from AD 688 to 1616 (2σ), with five falling between AD 1000 and 1350. Three earlier dates from Hatiheu and Ha'atuatua, on unidentified wood charcoal and shell, provide an age range of AD 660 to 1230 (2σ). The assemblage as a whole provides unambiguous evidence for established Marquesan settlement by AD 1000–1250, and the possibility of colonisation a few hundred years earlier.

Of note is the comparatively large number of early Marquesan sites relative to other archipelagos, nearly three times as many (cf. Kirch 2000, Table 7.2; Bollt 2008). Three factors might account for the Marquesan record: 1) the intensity of archaeological investigation; 2) a geomorphic context that contributes to site preservation and/or visibility; or 3) the duration of human settlement. With respect to hypothesis 1), several other island groups also have long histories of archaeological research (e.g. Societies) and/or have recently been the subject of intensive investigation (e.g. Gambiers). With respect to site preservation, the windward Societies are at a particular disadvantage, given that they are subsiding, potentially placing early sites under water. But there are also limiting factors in the Marquesas where coral reefs and sand accumulations are rare; notably nearly all of the known early Marquesan sites occur in coastal sand deposits suggesting this is indeed an important factor. Tsunamis also have adversely affected site preservation here, particularly on windward coasts (examples in Suggs 1961), with Schindelé *et al*. (2006:1135) observing that the Marquesas are the most vulnerable archipelago in the region.

Could the abundance and distribution of early Marquesan sites be indicative of a longer settlement history, the earliest portion being poorly documented? Allen (2004) offers several reasons why earlier settlement sites might be forthcoming: 1) the largest and best well-watered Marquesan valleys have not been well studied; the known early sites occur in locations that are less than ideal for establishing secure agro-economies (see also Weisler 1996 on Mangareva); 2) the artefact assemblages associated with known early sites indicate familiarity with distant off-island resources; 3) early settlements reliant on vulnerable fauna may have been short-lived, and by extension difficult to detect; and lastly 4) 13th century migrations out of the Marquesas to Mangareva (Weisler 1998; Weisler and Green 2001) and possibly elsewhere, are more consistent with reaching a resource threshold (e.g. faunal depletion) or disruption of an established population (e.g. climate variability), rather than with first arrival,

Importantly, radiometric evidence for earlier human activity is not altogether lacking. Although Rolett and Conte (1995) established that the main occupation at Ha'atuatua dated to AD 1270–1450, they also found evidence for more ephemeral cultural activity dating to the 9th to 11th centuries AD. Similarly, Orliac recovered an early radiocarbon determination (AD 665–1011) from a coastal hearth in the large windward valley of Hatiheu, probably the most favourable locality for human settlement on the island. These age assessments are consistent with the 10th century sea level decline. Together with evidence for pre-11th century occupations in the southern Cooks (Allen and Wallace 2007), the Societies (Lepofsky *et al*. 1996), and Hawaii (Athens *et al*. 2002), the Marquesan site assemblage may point to an early human arrival, possibly via a northern route and perhaps paralleled by a southern expansion (see Green and Weisler 2002). These ideas would go some ways towards explaining the number and widespread distribution of sites in the Marquesas in the 13th century AD.

Conclusions

What the Hakaea record best demonstrates is the range of powerful environmental processes that have operated on Marquesan shorelines for the last 800 years and the ease with which past human activity might be obscured or altogether erased. Sea level fall, climate change, local alluvial processes, tsunamis, and maritime storms are all indicated in the Hakaea Beach sequence, along with anthropogenic influences. The record here highlights the need to systematically seek out protected coastal contexts and identify geomorphic situations where older landscapes are likely to be preserved if the region's earliest settlement localities are to be identified. Unsurprisingly, half of the known Marquesan settlement sites are located on the more protected leeward coasts.

The Hakaea Beach site is also of interest as one of eight localities scattered throughout the Marquesas Islands with evidence for pre-14th century human occupation. This is an unusually large site inventory relative to the rest of the region and could be indicative of a longer settlement history in this group. This proposition is considered in relation to past and recent ideas about the East Polynesian settlement process and three specific models. Although the idea of a Marquesan homeland has fallen into disfavour, Dickinson's (2003) proposal that shorelines here may have been more favourable than those in many other parts of the region prior to late Holocene sea level decline allows for a *Leap-frog* type migration. The *Stepping Stone* model also warrants continued consideration in light of a handful of early dates from the East Polynesian core. Both models easily accommodate Marquesan settlement after the 9th century but before the 11th century AD; they also highlight the need to more fully explore subsiding coastal areas of the Societies, windward valleys of the Marquesas, and additional areas in the southern Cooks. Finally, the *Advancing Wave* model is supported by an assemblage of secure dates which unambiguously represent established settlement (*sensu* Graves and Addison 1995) but may not accurately represent initial human arrival in the central East Polynesian islands. In evaluating the possibility that East Polynesian settlement represents a rapid and massive population movement out of islands to the west, attention needs to be directed to the natural and social processes that might underpin a dispersal event of this magnitude and geographic scale. Attention also might be directed to the timing of primary and secondary settlement in certain

Polynesian outliers, some which received new migrants around the 11th to 13th centuries AD (see Kirch 1984). The general conclusion is that more systematic and geomorphically-informed field studies are needed to accurately establish past migration patterns and fully characterise East Polynesia's human settlement history.

Acknowledgements

Major funding was provided by *Wenner-Gren Foundation for Anthropological Research* and *University of Auckland Research Committee*. A generous grant from the *Green Foundation for Polynesian Prehistory* supported the 2007 field study and an AINSE grant funded several AMS dates. Iris Tetohu and Patrick Dourlet are thanked for their support and considerable hospitality to the team. The field conditions were exceptionally demanding and we thank the field team for their perseverance. Invaluable assistance in obtaining permits was provided by Patricia Frogier, Teddy Tehei and Tamara Maric in Tahiti. The radiocarbon samples were identified by charcoal specialist Rod Wallace. Particular thanks to Bill Dickinson who helped us with the nomenclature and formation history of the Hakaea sand accumulations. Thanks also to helpful comments from Marshall Weisler, Peter White and one anonymous reviewer.

References

Allen, M.S. (2004) Revisiting and revising Marquesan culture history: New archaeological investigations at Anaho Bay, Nuku Hiva Island, Marquesas. *Journal of the Polynesian Society* 113:143-196 and 224-5.

Allen, M.S. (2006) New ideas about late Holocene climate variability in the central Pacific. *Current Anthropology* 47: 521-535.

Allen, M.S. (2009) Morphological variability and temporal patterns in Marquesan domestic architecture: Anaho Valley in regional context. *Asian Perspectives* 48. In press (production delayed).

Allen, M.S. and R. Wallace (2007) New evidence from the East Polynesian gateway: substantive and methodological results from Aitutaki, southern Cook Islands. *Radiocarbon* 49: 1163-1179.

Anderson, A.J. (2004) Taking to the boats: the prehistory of Indo-Pacific colonisation. NIAP Lecture Series, National Institute for Asia and the Pacific, The Australian National University, Canberra.

Anderson, A., J. Chappell, M. Gagan and R. Grove (2006) Pre-historic maritime migration in the Pacific islands: an hypothesis of ENSO Forcing. *The Holocene* 16: 1-6.

Anderson, A. and Y. Sinoto (2002) New radiocarbon ages of colonisation sites in East Polynesia. *Asian Perspectives* 41: 242-257.

Athens, S.J., H.D. Tuggle, J.V. Ward and D.J. Welch (2002) Avi-faunal extinctions, vegetation change, and Polynesian impacts in prehistoric Hawai'i. *Archaeology in Oceania* 37:57-78.

Bollt, R. (2008) *Peva: The Archaeology of an Austral Island Settlement*. Bishop Museum Bulletin in Anthropology 12. Honolulu.

Bronk Ramsey, C. (2009) Bayesian analysis of radiocarbon dates. *Radiocarbon* 51: 337-360.

Cobb, K.M., C.D. Charles, H. Cheng and R.L. Edwards (2003) El Niño/Southern Oscillation and tropical Pacific climate during the last millennium. *Nature* 424:271–76.

Conte, E. (2002) Current research on the island of Ua Huka, Marquesas Archipelago, French Polynesia. *Asian Perspectives* 41:258-268.

Conte, E. and A. Anderson (2003) Radiocarbon ages for two sites on Ua Huka, Marquesas. *Asian Perspectives* 42:155-160.

Conte, E. and P.V. Kirch (2006) *Archaeological Investigations in the Mangareva Islands (Gambier Archipelago), French Polynesia*. Contribution No. 62, Archaeological Research Facility, University of California, Berkeley.

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* 19:489-502.

Dickinson, W.R. (2009). Pacific atoll living: How long already and until when? *Geological Society of America Today* 19: 4-10.

Emory, K.P. and Y.H. Sinoto (1965) Preliminary Report on the Archaeological Investigations in Polynesia. Mimeographed report for the National Science Foundation. B.P. Bishop Museum, Honolulu.

Graves, M.W. and D.J. Addison (1995) The Polynesian settlement of the Hawaiian Archipelago: integrating models and methods in archaeological interpretation. *World Archaeology* 26:380-99.

Green, R.C. and M.I. Weisler (2002) The Mangarevan sequence and dating of the geographic expansion into southeast Polynesia. *Asian Perspectives* 41:213-241.

Hunt, T. and C. Lipo (2007) Late colonization of Easter Island. *Science* 311:1603-1606.

Irwin, G. (1992) *The Prehistoric Exploration and Colonization of the Pacific*. Cambridge University Press, Cambridge.

Irwin, G. (2006) Voyaging and Settlement. In *Vaka Moana: Voyages of the Ancestors*, K.R. Howe (ed), pp. 54-99. David Bateman Ltd., Auckland.

Irwin, G. (2008) Pacific seascapes, canoe performance, and a review of Lapita voyaging with regard to theories of migration. *Asian Perspectives* 47:12-27.

Kirch, P.V. (1984) The Polynesian outliers; continuity, change, replacement. *The Journal of Pacific History* 19:224 -238.

Kirch, P.V. (2000) *On the Road of the Winds*. University of California Press, Berkeley.

Kirch P.V., D.W. Steadman, V.L. Butler, J. Hather and M.I. Weisler (1995) Prehistory and human ecology in Eastern Polynesia: excavations at Tangatatau Rockshelter, Mangaia. *Archaeology in Oceania* 30:47-65.

Lepofsky, D., P.V. Kirch and K.P. Lertzman (1996) Stratigraphic and paleobotanical evidence for prehistoric human-induced environmental disturbance on Mo'orea, French Polynesia. *Pacific Science* 50:253-73.

MacArthur, R.H. and E.O. Wilson (1967) *The Theory of Island Biogeography*. Princeton University Press, Princeton.

Morrison, A.E. and D.J. Addison (2008) Assessing the role of climate change and human predation on marine resources at the Fatu-ma-Futi site, Tutuila Island, American Samoa: an agent based model. *Archaeology in Oceania* 43:22–34.

Morrison, A.E. and D.J. Addison (2009). Examining causes and trends in marine trophic level change: 1500 years of fish exploitation at Fatu-ma-Futi, Tutuila Island, American Sāmoa. *Journal of Island and Coastal Archaeology* 4:177–194.

Nagaoka, L. (1993) Faunal assemblages from the Toaga site. In P.V. Kirch and T.L. Hunt (eds), *The To'aga Site: Three Millennia of Polynesian Occupation in the Manua Islands, American Samoa*, pp. 189–214. Contributions of the University of California Archaeological Research Facility No. 51. Berkeley.

Nunn, P.D. (2000) Environmental catastrophe in the Pacific Islands around AD 1300. *Geoarchaeology* 15:715-740.

Orliac, M. (2003) Erosion, sédimentation, et aménagements hydrauliques des sites de Tahakia, Kamuihei et Teiipoka. In H. Marchesi (ed.), *Bilan de la Recherche Archeologique en Polynésie Française, 2001-2002*. pp. 97-100. Service de la Culture et du Patrimoine, Punaauia, French Polynesia.

Petchey, F., M.S. Allen, D.J. Addison, A. Anderson (2009) Stability in the South Pacific surface marine ^{14}C reservoir over the last 750 years. Evidence from American Samoa, the southern Cook Islands and the Marquesas Islands. *Journal of Archaeological Science* 36:2234-2243.

Pirazzoli, P.A. and L.F. Montaggioni (1988) Holocene sea-level changes in French Polynesia. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 68:153-175.

Prebble, M. and J.M. Wilmshurst (2008). Detecting the initial impact of humans and introduced species on island environments in Remote Oceania using palaeoecology. *Biological Invasions* 11:1529-1556.

Reimer, P.J., Baillie, M.G.L., Bard, E., Bayliss, A., Beck, J.W., Blackwell, P.G., Bronk Ramsey, C., Buck, C.E., Burr, G.S., Edwards, R.L., Friedrich, M., Grootes, P.M., Guilderson, T.P., Hajdas, I., Heaton, T.J., Hogg, A.G., Hughen, K.A., Kaiser, K.F., Kromer, B., McCormac, F.G., Manning, S.W., Reimer, R.W., Richards, D.A., Southon, J.R., Talamo, S., Turney, C.S.M., van der Plicht, J., & Weyhenmeyer, C.E. (2009). IntCal09 and Marine09 radiocarbon age calibration curves, 0–50,000 years cal BP. *Radiocarbon*, 51(4), 1111-1150.

Rolett, B.V. (1998) *Hanamiai: Prehistoric colonization and cultural change in the Marquesas Islands (East Polynesia)*. Yale University Publications in Anthropology 81, New Haven.

Rolett, B.V. and E. Conte (1995) Renewed investigation of the Ha'atuatua Dune (Nuku Hiva, Marquesas Islands): a key site in Polynesian prehistory. *Journal of the Polynesian Society* 104:195-228.

Schindelé, F., H. Hebert, D. Reymond and A. Sladen (2006) L'aléa tsunami en Polynésie française: synthèse des observations et des mesures. C. R. *Geoscience* 338:1133–1140.

Sinoto, Y.H. (1970) An archaeologically based assessment of the Marquesas Islands as a dispersal center in East Polynesia. In R.C. Green and M. Kelly (eds), *Studies in Oceanic Culture History Press*, pp. 105-32. Pacific Anthropological Records 11. B.P. Bishop Museum Press, Honolulu.

Sheppard, P.J. and R. Walter (2006). A revised model of Solomon Islands culture history. *Journal of the Polynesian Society* 115: 47-76.

Spriggs, M. and A. Anderson (1993) Late colonisation of East Polynesia. *Antiquity* 67:200-217.

Stein, J.K. (2001) Archaeological sediments in cultural environments. In J.K. Stein and W.R. Farrand (eds), *Sediments in Archaeological Context*, pp. 1-28. University of Utah Press, Salt Lake City.

Suggs, R. (1961) *The Archaeology of Nuku Hiva, Marquesas Islands, French Polynesia*. Anthropological Papers of the American Museum of Natural History 49, Part 1. New York.

Walter R. (1998) *Anai'o: The archaeology of a Fourteenth Century Polynesian community in the Cook Islands*. N.Z. Archaeological Association Monograph 22. New Zealand Archaeological Association, Auckland.

Weisler, M.I. (1995). Henderson Island prehistory: colonisation and extinction on a remote Polynesian island. *Biological Journal of the Linnean Society* 56:377-404.

Weisler, M.I. (1996) An archaeological survey of Mangareva: implications for regional settlement models and interaction studies. *Man and Culture in Oceania*. 12:61-85.

Weisler, M.I. (1998a) Hard evidence for prehistoric interaction in Polynesia. *Current Anthropology* 39:521-32.

Weisler, M.I. and R.C. Green (2001) Holistic approaches to interaction studies: A Polynesian example. In M. Jones and P. Sheppard (eds), *Australian Connections and New Directions. Proceedings of the 7th Australasian Archaeometry Conference*, pp. 413-453. Research in Anthropology & Linguistics 5. Department of Anthropology, University of Auckland, Auckland.

U.S. Department of Agriculture (1951) *Soil Survey Manual*. U.S.D.A. Handbook No. 18. Washington.