Journal of Island & Coastal Archaeology, 3:214–239, 2008

ISSN: 1556-4894 print / 1556-1828 online
DOI:10.1080/15564890802128975

The Temporal and Spatial Patterning of the Initial Settlement of Sāmoa

Timothy M. Rieth,[1] Alex E. Morrison,[2] and David J. Addison[3]
[1]*International Archaeological Research Institute, Inc., Honolulu, Hawai'i, USA*
[2]*Department of Anthropology, University of Hawai'i-Mānoa, Honolulu, Hawai'i, USA*
[3]*Sāmoan Studies Institute, American Sāmoa Community College, Pago Pago, American Sāmoa*

ABSTRACT

Among the Lapita-bearing island groups of the Pacific, Sāmoa is unusual for having a relatively large land area but only one cultural deposit containing Lapita ceramics. Although it has been proposed that additional Lapita settlements may have been distributed along the coasts of much of the archipelago, investigations have not located these deposits nor reliably dated early Polynesian Plainware deposits older than ~2500 cal BP. We combine a chronometric hygiene protocol and a GIS-based model of the paleoshoreline to examine the temporal and spatial distribution of pre-2000 cal BP archaeological deposits in the islands. Using the currently available suite of radiocarbon dates, it is apparent that only by ~2300–2000 cal BP were a number of settlements occupied across the archipelago. Acknowledging that a variety of geomorphological processes have changed the Sāmoan landscape, we developed a GIS-based model of the ~3000 cal BP coastlines of Tutuila and Aunu'u Islands, which suggest that suitable sandy coastal flats had not formed in many areas prior to ~2500 cal BP, hence limiting settlement by Lapita peoples. Our methodology, which combines an evaluation of early radiocarbon dates with a GIS-based paleoshoreline model, offers a valuable means of incorporating temporal and spatial data for the examination of coastal and island colonization.

Keywords Sāmoa, Lapita, island colonization, chronometric hygiene, GIS

Received 25 October 2007; accepted 15 April 2008.
Address correspondence to Timothy M. Rieth, International Archaeological Research Institute, Inc., 2081 Young St., Honolulu, HI, 96826, USA. E-mail: timothy_rieth@hotmail.com

In Near and Remote Oceania, the Samoan Archipelago is unique among Lapita-bearing island groups in containing a relatively large land area with multiple high islands, but only one site at Mulifanua has produced the distinctive dentate-stamped ceramics of the Lapita complex (Green 1974; see Allen and White 1989:129; Anderson et al. 2002:2; Kirch and Hunt 1988:28). The number of Lapita sites in Sāmoa is equal to Futuna (n = 1) and less than Wallis (n = 3), both of which are significantly smaller than the Sāmoan archipelago (Anderson et al. 2002). Additionally, Sāmoa has garnered the attention of three large research programs from the 1960s to the 1980s in Western Sāmoa (Green and Davidson 1969, 1974a; Jennings and Holmer 1980a; Jennings et al. 1976) and Manu'a (Kirch and Hunt 1993), and scores of additional cultural resource management (CRM) and academic projects in American Sāmoa (e.g., Addison et al. 2006; Ayres et al. 2001; Clark 1989, 1993; Clark and Herdrich 1988, 1993; Cochrane et al. 2004; Elmore et al. 1999; Frost 1976, 1978; Herdrich 2002; Morrison 2005; Morrison and Addison 2008; Pearl 2004, 2006; Silva and Palama 1975; Taomia 2001a, 2001b, 2002; Walter and Addison 2005; Winterhoff 2003). The earliest cultural deposits identified during these projects contain non-Lapita Polynesian Plainware ceramics.

How is Sāmoa different than other islands settled by Lapita colonists? Attempts to answer this question have led researchers to explore the geomorphological and paleoenvironmental contexts of the islands across the archipelago (Clark and Michlovic 1996; Dickinson and Green 1998; Green 2002; Hunt and Kirch 1997; Kirch 1993a). We examine this issue through a critical evaluation of pre-2000 cal BP radiocarbon (^{14}C) dates, and build on previous geomorphological research by creating a geographical information system-based (GIS) model of the Tutuila and Aunu'u Island landscapes at ~3000 cal BP to identify potentially suitable locales for early settlement and future archaeological testing. The results of these analyses suggest a ~500–200 year gap in the radiocarbon record between Mulifanua and subsequent occupations in the archipelago. This may indicate a limited Lapita presence in at least the eastern archipelago, dictated by the restricted availability of suitable coastal settlement locales prior to ~2500 cal BP.

Our methods, combining an evaluation of early ^{14}C dates with a GIS-based paleoshoreline model, provide a means of incorporating temporal and spatial data for the examination of coastal and island colonization in regions beyond Polynesia. Identifying and recording initial colonization deposits in coastal and island settings can be hampered by: taphonomic and geomorphological processes; cultural and environmental factors affecting site selection by colonizers and site preservation; and logistical concerns for researchers including limited budgets and time constraints for fieldwork. Our procedure provides a means to refine the existing temporal data for a colonization period and then apply these data to spatial analyses and geomorphological modeling to identify potential locations for additional early deposits.

LAPITA AND THE INITIAL SETTLEMENT OF SĀMOA

Recent syntheses of the initial Lapita settlement of the Fiji/West Polynesia region indicate that this occurred no earlier than ~2900 cal BP (Anderson and Clark 1999; Burley and Clark 2003; Burley et al. 1999). In conventional models the settlement of Sāmoa is not viewed as dramatically distinct from other islands in the Eastern Lapita region, with the region as a whole characterized by rapid initial settlement by people carrying a rather homogenous material culture. Dentate-stamp decorated ceramics are the hallmark of the earliest ceramic assemblages of these initial colonists, although undecorated sherds dominate these assemblages (at rates of 85–95%). Throughout the region, dentate-stamped decoration and associated vessel types were abandoned within one to two centuries of initial settlement (Anderson and Clark 1999; Burley and Clark 2003; Burley et al. 1999; Clark 1996; Green 2002). A variety of stone, shell, and bone tools and ornaments comprise the non-ceramic component of these assemblages (Green 1979; Kirch 1997). Invertebrate and vertebrate marine taxa dominate faunal assemblages with very limited evidence for the introduction of pig, dog, and chicken (Matisoo-Smith 2007; Nagaoka 1988; but see Butler 1988). Sandy lagoon and embayment settings with reef passages were typical settlement areas, (Burley and Clark 2003; Green 2002), with access to fresh water and cultivable land likely influencing the choice of locales as well (Lepofsky 1988).

In Sāmoa, the Mulifanua deposit off the west coast of 'Upolu Island represents the only evidence of Lapita colonization, dating between ~3000–2600 cal BP (Petchey 2001). This deposit, which is under ~1.5 m of water and ~0.5 m of cemented lagoon sediment, has never been formally excavated and is known only from dredge tailings and geological bores. Although currently submerged, geomorphological and archaeological data indicate that the deposit likely formed in a coastal setting that was subsequently drowned by island subsidence (Dickinson and Green 1998; Green 2002; Leach and Green 1989). Dentate-stamped pottery (Green 1974; Petchey 1995) and lithic artifacts (Leach and Green 1989) were recovered from the dredged sediment. Deposits at 'Aoa, Tutuila Island (Clark and Michlovic 1996) and To'aga, Ofu Island (Kirch and Hunt 1993) have produced radiocarbon dates that are nearly contemporaneous with Mulifanua, although they lack dentate-stamped ceramics. The consensus view is that these deposits, and other more recently identified Polynesian Plainware deposits, are the Sāmoan representation of the regional transition from Lapita to Polynesian Plainware ceramics (but see Addison and Morrison in press).

In examining the initial colonization of Sāmoa, we provide an updated synthesis and evaluation of pre-2000 cal BP ^{14}C dates to determine the temporal relationship between Mulifanua and the other early deposits in the archipelago (Figure 1). We compare this chronological information with a GIS-based geomorphological model as one means of explaining the temporal and spatial patterning of initial settlement.

ANALYSIS OF THE ^{14}C DATES: CHRONOMETRIC HYGIENE

In general, rapid colonization events such as the Lapita expansion into the Fiji/West Polynesia region are at, or surpass, the precision-limits of radiocarbon dating. Hence, we begin with the application of a chronometric hygiene protocol to all of the pre-2000 cal BP ^{14}C dates for Sāmoa in an effort to refine as much as possible the accuracy of these dates for discussing the earliest human presence in the archipelago. Our protocol has been modified from previous chronometric analyses of various

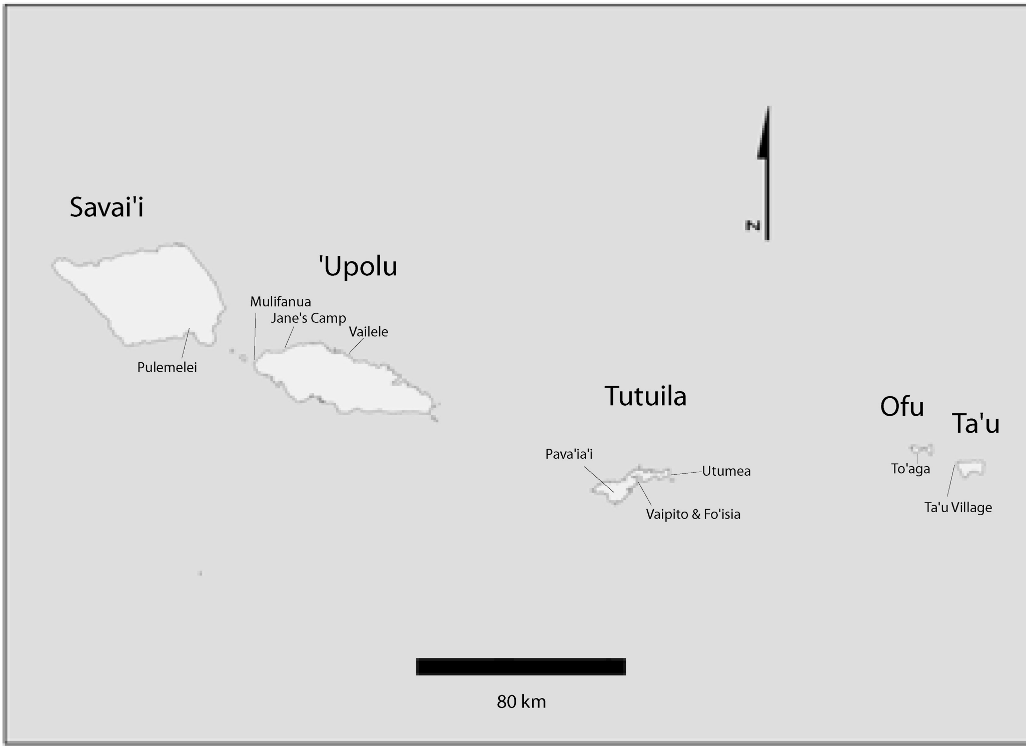

Figure 1. *Map of the Sāmoan Archipelago showing all sites with accepted pre-2000 cal BP dates (base map courtesy of Peter Minton, http://evs-islands.blogspot.com/).*

parts of Oceania (Anderson 1991 for New Zealand; Hunt and Lipo 2006 for Rapa Nui; Liston 2005 for Palau; Smith 2002 for West Polynesia; Spriggs and Anderson 1993 for East Polynesia) and other areas (e.g., Fitzpatrick 2006 for the Caribbean; Spriggs 1989 for the Southeast Asian Neolithic; Waters and Stafford 2007 for the Clovis culture; Zilhao 2001 for the western Mediterranean). Rieth and Hunt (2008) provide a more extensive discussion about the application of this chronometric hygiene protocol for assessing Sāmoan ^{14}C dates.

In its simplest terms, a chronometric hygiene protocol is a classificatory procedure. It outlines the necessary and sufficient criteria a ^{14}C date must meet to be included in the class of acceptable dates. For our research objectives, this protocol accepts dates from clear cultural contexts that are calibrated to pre-2000 cal BP, that are in chronologically appropriate stratigraphic order, and that produce a relatively tight probability age distribution, therefore providing accurate and precise chronological information regarding initial colonization. Ideally, acceptable ^{14}C dates are part of suite of dates from a cultural deposit, and the sample material and provenience are documented providing a valid link between the ^{14}C event and the target archaeological event (Dean 1978; Taylor 1987).

Applications of chronometric hygiene methods should be viewed as hypotheses requiring testing, and the generation of additional, reliable dates will either falsify or refine these models. By primarily removing poorly provenienced dates or dates with long probability distributions these methods have produced shortened settlement chronologies for East Polynesia (Hunt and Lipo 2006; Spriggs and Anderson 1993) and parts of the Caribbean (Fitzpatrick 2006) as well as for the duration of the Clovis culture (Waters and Stafford 2007). Although often contentious conclusions (see Haynes et al. 2007 in response to Waters and Stafford 2007), the results of chronometric hygiene analyses of colonization or otherwise temporally limited events provide a critical evaluation of current dating results based primarily on issues of sample provenience, stratigraphic associations, and corroboration by additional radiometric dates. There is nothing inherent in the method that creates short chronologies and they explicitly outline criteria for the assessment of future dates.

To assess the acceptability of the Sāmoan dates the following protocol is used. Meeting one of these criteria warrants rejection as an unacceptable date (Table 1):

A. Dates by the Gakushuin Laboratory (Gak-) prior to the 4500 series. Pre-4500 series dates have been anomalous when compared with results from other laboratories (following Spriggs and Anderson 1993).
B. Samples that produce a conventional radiocarbon age (CRA) with a standard deviation greater than, or equal to, 100 years (modified from Smith 2002). Such conventional ages produce probability age distributions that are too large for the examination of rapid colonization events.
C. Stratigraphically inverted dates that do not overlap at two standard deviations (following Spriggs and Anderson 1993).
D. Samples that are not obtained from a cultural context (following Spriggs and Anderson 1993; Smith 2002).

Chronometric Hygiene Results

A total of 47 pre-2000 cal BP dates were analyzed and we accepted 22 of these dates from 10 deposits on the islands of Tutuila, Ofu, Ta'ū, 'Upolu, and Savai'i (Figure 2). This section expands the number of accepted dates discussed in Rieth and Hunt (2008) with the addition of nine dates from Fo'isia, Vaipito, and Pava'ia'i, all on Tutuila. Also, we recalibrated the marine samples using the marine curve (marine04) and a new delta-R of 25 ± 28 as calculated by Petchey and Addison (in press), rather than the delta-R calculated by Phelan (1999). In general, application of the new delta-R results in slightly younger ages for these samples.

We recalibrated the dates, which are denoted by "cal BP", using OxCal v3.10 (Bronk Ramsey 2005; atmospheric data from Reimer et al. 2004). We used the Northern Hemisphere calibration curve (Intcal04) for wood charcoal samples because the boundary between the atmospheres of the Northern and Southern Hemispheres is considered to lie along the thermal equator or the Inter-tropical Convergence Zone (ITCZ) (McCormac et al. 2004:1088). The South Pacific Convergence Zone (SPCZ) merges at its western end with the ITCZ, and the degree of hemispheric mixing associated with this is unclear. The SPCZ sits over or near Sāmoa much of the year and hence, in a conservative approach we use the Northern Hemisphere calibration curve in this analysis. All dates are reported

Table 1. **All pre-2000 cal BP radiocarbon dates from Sāmoa. Accepted dates have "+" in the Criteria column; "–" denotes that data are not available. Rows are organized in descending order by conventional age.**

Sample No.	Island	Site	Provenience	Sample Material	$^{13}C/^{12}C$ Ratio	Conventional Radiocarbon Age	Calibrated Age BP (2σ)	Calibrated Age BC/AD (2σ)	Criteria	Reference
UGa-1671	Savai'i	SS-13-85, Sapapali'i	Earth oven	Charcoal	—	14,920 ± 175	18,750–17,550	16,800–15,600 BC	B	Jennings and Holmer 1980b
Beta-25035	Ofu	AS-13-1, To'aga	Unit 6, L. V	*Asaphis violascens* and *Lunella cincerea*	2.4	3820 ± 70	3900–3470	1950–1520 BC	D	Kirch 1993b
Beta-25673	Ofu	AS-13-1, To'aga	Unit 1, L. V	*Phalium* sp.	2.2	3620 ± 80	3660–3230	1710–1280 BC	D	Kirch 1993b
NZ-1958B	'Upolu	SU-17-1, Mulifanua	Dredging spoils	Marine shell	2.0	3251 ± 155	3400–2600	1450–650 BC	B	Leach and Green 1989
RL-479	'Upolu	SU-18-1, SU-F1-1, Jane's Camp	Test 1, Stratum II	Marine shell	—	3220 ± 130	3300–2650	1350–700 BC	B, C	Jennings and Holmer 1980b; Smith 1976
NZA-5800	'Upolu	SU-17-1, Mulifanua	Dredging spoils	Turtle bone collagen	−16.9	3062 ± 66	2960–2600	1010–650 BC	+	Petchey 2001
Beta-35601	Ofu	AS-13-1, To'aga	Transect 5, Unit 28, L. II (base)	Charcoal	−27.8	2900 ± 110	3350–2750	1400 BC–800 BC	B	Kirch 1993b
Beta-48049	Tutuila	AS-21-5, 'Aoa	Locality 2, XU 7, L. VII	Charcoal	−28.2	2890 ± 140	3400–2750	1450–800 BC	B	Clark 1993; Clark and Michlovic 1996

(Continued on next page)

NZA-4780	‘Upolu	SU-17-1, Mulifanua	Dredging spoils	Marine shell	1.6	2788 ± 67	2650–2250	700–300 BC	D	Petchey 2001
Beta-35604	Ofu	AS-13-1, To’aga	Transect 9, Unit 23, L. IIIB	*Tridacna maxima*	1.7	2770 ± 80	2670–2200	720–250 BC	+	Kirch 1993b
Beta-25033	Ofu	AS-13-1, To’aga	Unit 6, L. IIA-1	*Turbo setosus*	2.3	2640 ± 80	2500–2000	550–50 BC	+	Kirch 1993b
Beta-35602	Ofu	AS-13-1, To’aga	Transect 9, Unit 23, earth oven cut from L. IIIA into L. IIIB	Charcoal	−26.9	2630 ± 100	3000–2350	1050 BC–400 BC	B	Kirch 1993b
Beta-26464	Ofu	AS-13-1, To’aga	Unit 10, L. IIB	Charcoal	−27.8	2620 ± 140	3100–2300	1150 BC–350 BC	B	Kirch 1993b
Beta-35603	Ofu	AS-13-1, To’aga	Transect 9, Unit 23, L. IIIB (base)	Charcoal	−28.4	2600 ± 170	3200–2300	1250 BC–350 BC	B	Kirch 1993b
NZ-2728B	‘Upolu	SU-18-1, SU-F1-1, Jane’s Camp	Test 1, Stratum I	*Tridacna* sp.	—	2590 ± 40	2310–2040	360–90 BC	+	Jennings and Holmer 1980b
Beta-25034	Ofu	AS-13-1, To’aga	Unit 6, L. IIB	*Turbo setosus*	2.5	2570 ± 80	2360–1910	410 BC–40 AD	+	Kirch 1993b
Gak-4289	Tutuila	Tulotu	Structure 11, Trench 4, L. II	Charcoal	—	2560 ± 140	3000–2300	1050–350 BC	A, B	Frost 1978
NZ-2727B	‘Upolu	SU-18-1, SU-F1-1, Jane’s Camp	Test 1, Stratum I	*Tridacna* sp.	—	2550 ± 50	2290–1970	340–20 BC	+	Jennings and Holmer 1980b

(Continued on next page)

Table 1. **All pre-2000 cal BP radiocarbon dates from Sāmoa. Accepted dates have "+" in the Criteria column; "–" denotes that data are not available. Rows are organized in descending order by conventional age. (*Continued*)**

Sample No.	Island	Site	Provenience	Sample Material	$^{13}C/^{12}C$ Ratio	Conventional Radiocarbon Age	Calibrated Age BP (2σ)	Calibrated Age BC/AD (2σ)	Criteria	Reference
NZ-4343B	Manono	SM-17-2, Falemoa	Stratum II	*Tridacna* sp.	—	2540 ± 40	2270–1970	320–20 BC	C	Jennings and Holmer 1980b; Lohse 1980
RL-477	ʻUpolu	SU-18-1, SU-F1-1, Jane's Camp	Test 2, Stratum IV	Marine shell	—	2510 ± 120	2400–1750	450 BC–200 AD	B	Jennings and Holmer 1980b; Smith 1976
NZ-2726B	ʻUpolu	SU-18-1, SU-F1-1, Jane's Camp	Test 1, Stratum I	*Tridacna* sp.	—	2510 ± 60	2270–1900	320 BC–50 AD	+	Jennings and Holmer 1980b; Smith 1976
NZ-1959	ʻUpolu	SU-17-1, Mulifanua	Dredging spoils	Coralline crust cement	3.4	2475 ± 63	2240–1850	290 BC–100 AD	D	Green and Richards 1975; Petchey 2001
Beta-48911	Tutuila	AS-21-5, ʻAoa	Locality 2, XU 8, L. VII	Charcoal	−24.4	2460 ± 110	2800–2300	850–350 BC	B	Clark 1993; Clark and Michlovic 1996
Beta-120571	Tutuila	AS-22-43, Aganoa	Fea. 4, TU AG/5, L. III/1	Charcoal	—	2400 ± 110	2750–2150	800–200 BC	B	Moore and Kennedy 1999
Beta-19742	Ofu	AS-13-1, To'aga	TU 1, L. II	*Turbo setosus*	2.9	2350 ± 50	2050–1730	100 BC–220 AD	+	Hunt and Kirch 1987, 1988

(Continued on next page)

Beta-19741	Ta'ū	AS-11-51, Ta'ū village	Unit 1	Marine shell	—	2330 ±50	2030–1700	80 BC–250 AD	+	Hunt and Kirch 1988
Beta-120575	Tutuila	AS-22-44, Utumea	TU UT/3, L. IIb	Charcoal	—	2310 ± 50	2470–2290 (61.6%), 2280–2150 (33.8%)	520–340 BC (61.6%), 330–200 BC (33.8%)	+	Moore and Kennedy 1999
UGa-1484	Manono	SM-17-2, Falemoa	Stratum II	*Tridacna* sp.	—	2260 ± 65	1970–1590	20 BC–360 AD	C	Jennings and Holmer 1980b; Lohse 1980
RL-481	'Upolu	SU-18-1, SU-F1-1, Jane's Camp	Test 2, Stratum IV	Marine shell	—	2220 ± 120	2050–1400	100 BC–450 AD	B	Jennings and Holmer 1980b
RL-464	'Upolu	SU-18-1, SU-F1-1, Jane's Camp	Test 1, Stratum I	*Tridacna* sp.	—	2220 ± 110	2050–1450	100 BC–500 AD	B	Jennings and Holmer 1980b; Smith 1976
Gak-1444	'Upolu	SU-Le-12, Leuluasi	Pit feature, L. 5b, Sq. F-7	Charcoal	—	2210 ± 100	2500–1900	550 BC–50 AD	A, B	Davidson and Fagan 1974; Green and Davidson 1974b
WK-15029	Tutuila	Fo'isia	TU 1, L. II	Charcoal	−27.3	2172 ± 38	2320–2060	370–110 BC	+	Addison and Asaua 2006

(Continued on next page)

Table 1. **All pre-2000 cal BP radiocarbon dates from Sāmoa. Accepted dates have "+" in the Criteria column; "–" denotes that data are not available. Rows are organized in descending order by conventional age. (*Continued*)**

Sample No.	Island	Site	Provenience	Sample Material	$^{13}C/^{12}C$ Ratio	Conventional Radiocarbon Age	Calibrated Age BP (2σ)	Calibrated Age BC/AD (2σ)	Criteria	Reference
Gak-1339	'Upolu	SU-Lu-53, Lu-atuanu'u	Firepit, L. 1; under terrace	Charcoal	—	2170 ± 100	2360–1920	410 BC–30 AD	A, B	Green and Davidson 1974b; Peters 1969
Gak-1194	'Upolu	SU-Va-4, Vailele	Hearth Horizon, Sq. N-2	Charcoal	—	2150 ± 100	2350–1920	400 BC–30 AD	A, B	Green and Davidson 1974b
RL-478	'Upolu	SU-18–1, SU-F1–1, Jane's Camp	Test 1, Stratum III	Marine shell	—	2130 ± 130	1950–1400	0–550 AD	B	Jennings and Holmer 1980b; Smith 1976
WK-15033	Tutuila	Fo'isia	TU 5, L. III/2	Charcoal	−23.5	2119 ± 38	2300–2240 (9.4%), 2160–1990 (86.1%)	350–290 BC (9.4%), 210–40 BC (86.1%)	+	Addison and Asaua 2006
Beta-120576	Tutuila	AS-22–44, Utumea	TU UT/5, L. II/9	Charcoal	—	2110 ± 100	2340–1880	390 BC–70 AD	B	Moore and Kennedy 1999
WK-12996	Tutuila	Vaipito	TU 23, L. VI	Charcoal	−28.8	2101 ± 42	2300–2260 (4.1%), 2160–1950 (91.3%)	350–310 BC (4.1%), 210–0 BC (91.3%)	+	Addison and Asaua 2006
WK-19410	Tutuila	Pava'ia'i		Charcoal	−25.9	2097 ± 37	2300–2270 (1.7%), 2160–1970 (93.7%)	350–320 BC (1.7%), 210–20 BC (93.7%)	+	Addison and Asaua 2006
WK-14530	Tutuila	Vaipito	Profile 1, L. II	Charcoal	−28.3	2085 ± 40	2160–1940	210 BC–10 AD	+	Addison and Asaua 2006

(Continued on next page)

WK-15501	Savai'i	Pulemelei-Early Settlement	Trench 9, earth oven	Charcoal	−28.0	2058 ± 38	2130–1920	180 BC–30 AD	+	Martinsson-Wallin et al. 2005
WK-15030	Tutuila	Fo'isia	TU 2, L. II/2	Charcoal	−27.2	2041 ± 44	2130–1890	180 BC–60 AD	+	Addison and Asaua 2006
WK-15031	Tutuila	Fo'isia	L. III	Charcoal	−27.3	2004 ± 43	2110–2080 (2.1%), 2070–1860 (93.3%)	160–130 BC (2.1%), 120 BC–90 AD (93.3%)	+	Addison and Asaua 2006
WK-13868	Savai'i	Pulemelei-Early Settlement	Trench 7, earth oven	Charcoal	−27.5	1993 ± 55	2110–2080 (3.3%), 2070–1820 (92.1%)	160 BC–130 BC (3.3%), 120 BC–130 AD (92.1%)	+	Martinsson-Wallin et al. 2005
WK-18327	Tutuila	Pava'ia'i	Cultural layer, 244–272 cmbs	Cocos nucifera	−24.1	1979 ± 31	2000–1870	50 BC–80 AD	+	Addison and Asaua 2006
WK-15032	Tutuila	Fo'isia	TU 5, L. II/1	Charcoal	−27.7	1978 ± 37	2010–1860 (92.8%), 1850–1820 (2.6%)	60 BC–90 AD (92.8%), 100–130 AD (2.6%)	+	Addison and Asaua 2006
NZ-363	'Upolu	SU-Va-1, Vailele	beneath L. V	Charcoal	—	1950 ± 70	2070–1710	120 BC–240 AD	+	Green and Davidson 1965, 1974b

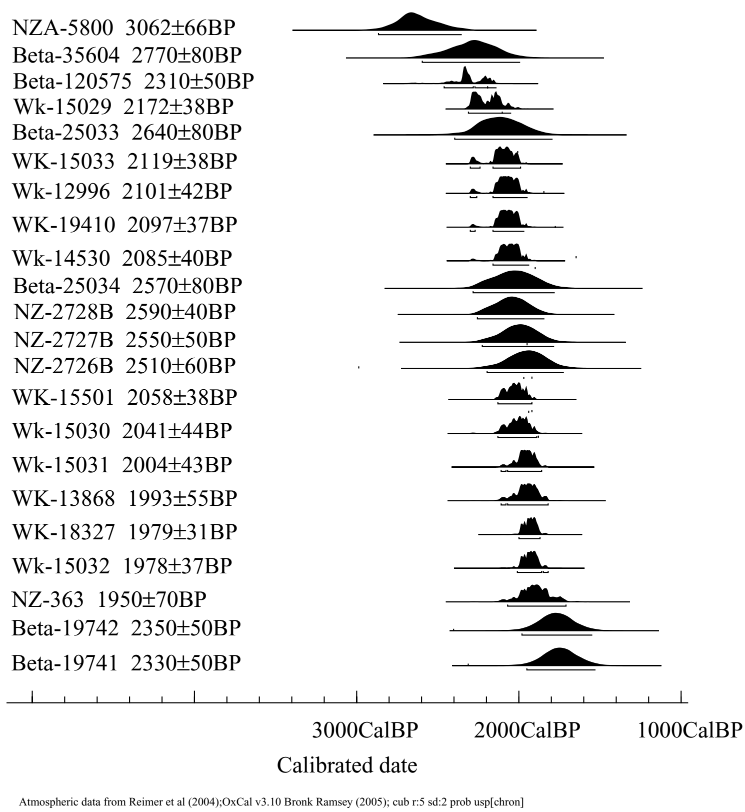

Figure 2. *OxCal graph of calibrated pre-2000 BP dates for Samoa.*

at two standard deviations (95.4% probability). Dates followed by "BP" (e.g., 1247 ± 36 BP) are uncalibrated ^{14}C determinations.

Most dates were rejected because of large standard deviations and consequently large probability distributions. Although the associated cultural deposits may contain early assemblages, processing of additional ^{14}C samples is necessary to refine the chronology of their deposition.

As noted above, Mulifanua has produced the oldest radiocarbon date for Sāmoa (NZA-5800, 3062 ± 66 BP) and contains the only known Lapita ceramics. The current recalibration of the one accepted ^{14}C date from the deposit places settlement there at ~3000–2600 cal BP, which is in line with Petchey's (2001) earlier analysis. Following Mulifanua, the next deposits in the chronological sequence are located at To'aga, Ofu and Utumea, Tutuila. We accept four early dates from To'aga (Kirch 1993b) and a single date from Utumea (Moore and Kennedy 1999), which identifies occupation at both locations by ~2500–2300 cal BP. The earliest date from To'aga (Beta-35604, 2770 ± 80 BP) just overlaps with the accepted date from Mulifanua, but the highest probability for the sample falls within ~2500–2400 cal BP, comparable to the other accepted dates from the deposit (Beta-25033, 2640 ± 80 BP; Beta-25034, 2570 ± 80 BP; Beta-19742, 2350 ± 50 BP). The date from Utumea (Beta-120575, 2310 ± 50 BP), on the southeast coast of Tutuila, offers a comparable date for the initial occupation of that coastal flat. Based on the three earliest deposits for the archipelago, there is a gap in the radiocarbon sequence of approximately 100 to 500 years between Mulifanua and subsequent evidence for human settlement.

By ~2300–2000 cal BP, the occupation and use of multiple locations throughout the archipelago is evident. Occupation at To'aga and Utumea continued, and settlements were occupied at Jane's Camp, 'Upolu (~2300–2000 cal BP) (Jennings and Holmer 1980b), Fo'isia (~2300–1900 cal BP), Vaipito (~2200–1900 cal BP), and Pava'ia'i (~2000–1900 cal BP), Tutuila (Addison and Asaua 2006), the Pulemelei area of Savai'i (~2100–1800 cal BP) (Martinsson-Wallin et al. 2005), Vailele, 'Upolu (~2100–1800 cal BP) (Green and Davidson 1974b), and Ta'ū village, Ta'ū (~2100–1800 cal BP) (Hunt and Kirch 1988).

Six additional deposits have produced early dates associated with Polynesian Plainware ceramics, which were not accepted for various criteria. However, the deposits at 'Aoa (Clark and Michlovic 1996) and Aganoa (Moore and Kennedy 1999), on Tutuila, Leuluasi (Davidson and Fagan 1974) and Luatuanu'u (Peters 1969), on 'Upolu, and Potusā (Jennings and Holmer 1980c) and Falemoa (Lohse 1980), on Manono merit further testing and dating to assess the individual site chronologies.

The chronometric hygiene results provide a temporal pattern for settlement of the Sāmoan islands, with the earliest known occupation at Mulifanua between 3000–2600 cal BP, two occupations in the eastern half of the archipelago by about 2500–2300 cal BP, and after 2300 cal BP numerous settlements across the islands. Although this temporal patterning likely reflects a number of interrelated social and environmental factors, the following section provides a GIS-based model of Tutuila and Aunu'u Islands as one means of assessing some of these factors as they may have affected the spatial distribution of settlement at ~3000 cal BP.

A GIS-BASED PREDICTIVE MODEL FOR TUTUILA AND AUNU'U ISLANDS

The gap, both chronologically and artifactually, between Mulifanua and subsequent deposits has been explained with reference to various geological factors that have buried, displaced, or submerged additional early deposits (e.g., Clark and Michlovic 1996; Dickinson and Green 1998; Green 2002; Kirch and Hunt 1993). A general consensus is that additional Lapita and early Polynesian Plainware deposits are present in Sāmoa, likely at densities comparable to other areas of the Fiji/West Polynesia region, but are difficult to prospect for and investigate (Green 2002; but Clark 1996 suggests lower densities). As the review of the current assemblage of ^{14}C dates reveals, archaeological evidence for pre-2300 cal BP settlements in the archipelago is scarce. It is clear that geomorphological factors have affected site preservation and discovery, but factors affecting settlement site selection and successful colonization ~3000 cal BP have not been adequately addressed in Sāmoan research, although Green (2002) has posited possible additional Lapita site locations on 'Upolu and Savai'i. Our GIS-based modeling for Tutuila and Aunu'u Islands suggest that the interrelated factors of coastal access, slope, relative sea level, and available settlement area limited settlement prior to ~2500 cal BP and are thus compatible with our current radiocarbon results.

Methods

ARC GIS 9.1 software was used to develop a model in which multiple environmental variables are analyzed using a combination of raster surfaces and remote sensing imagery. The final goal is the identification of areas along the coastal landscapes of Tutuila and Aunu'u Islands that would have been attractive for initial settlement ~3000 cal BP. Coastal access, slope, sea level, and settlement space were the four variables analyzed in this model.

Justification for coastal access as an important model variable comes from both empirical evidence of the location of Lapita settlements (e.g., Kirch and Hunt 1988; Lepofsky 1988; Nunn 2005) as well as theoretically derived hypotheses developed in human behavioral ecology (HBE). For example, Kennett et al. (2006) recently used the ideal free distribution (IFD) model to examine the timing and causes of island colonization in Oceania (see also Cashdan 1992). Importantly, the model considers differences in temporal and spatial habitat characteristics which can vary according to human impacts and population density. Specifically, when initial population densities are low, the ideal free distribution model predicts subsistence economies will be organized around low-level food production (e.g., Smith 2001). Human spatial organization will be centered in areas suitable for easy acquisition of wild marine resources (i.e., fish and marine invertebrates). Therefore, coastal access is an important variable affecting the availability of marine resources and ocean travel. To model this variable, raster cells were developed for sandy beaches and easily accessible low shorelines. A cost-distance analysis produced a set of cells increasing in cost with distance from coastal access areas (Figure 3). The most attractive zones correspond to 500 meter catchments around coastal access areas.

Slope grade is an important factor in modeling residential settlement for several reasons (Figure 4). First, steep slopes are generally correlated with the increased probability of mass wasting events and subsequent negative environmental conditions. Although landscape adjustments such as terracing, and other types of stabilization can decrease the risks associated with environmental hazards, the production of these structures requires considerable energy expenditure (Allen 2004:209). Second, assuming the expectations of the free ideal distribution model, initial colonists would have engaged in at least moderate levels of foraging (see also Anderson 2003). Central place foraging models developed in behavioral ecology are based on the reasonable notion that a central place (in this case a residential settlement) should be strategically located to minimize travel time, and consequently energy expenditure to foraging locales (Cashdan 1992:250; Field et al. 2007; Krebs and Davies 1993). Therefore, a human energy cost associated with traversing steep slope grades has been added to the model. The coastal access cost distance raster and slope zone raster were combined into one friction surface (Figure 5). This raster layer models landscapes in close proximity to easily accessible coastal areas that are relatively flat.

Any model developed as an aid for locating early prehistoric deposits must take into consideration landscape changes that have occurred since human settlement. Changes in relative sea level (RSL) are of particular relevance for locating Lapita-aged deposits in Oceania.

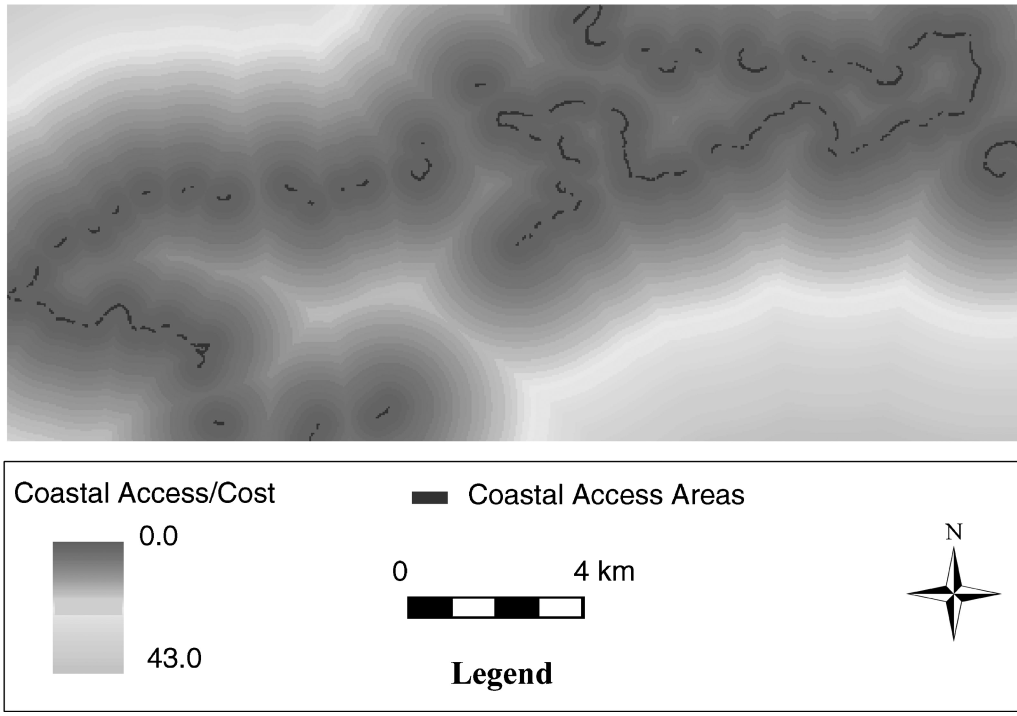

Figure 3. *Coastal Access/Cost Surface for Tutuila Island. Cells increase in value with distance from Coastal Access areas. Cells with values of 0.0 represent land within 500 meters of coastal access.*

In general, the Pacific Basin experienced a well documented mid-Holocene highstand in sea level of approximately 1.5–2.6 m (Dickinson and Green 1998; Fletcher and Jones 1996; Grossman et al. 1998; Mitrovica and Peltier 1991). While other localized tectonic processes associated with volcanic loading are known to have caused subsidence of ʻUpolu and possibly Ofu, present evidence suggests that paleoshoreline features on both Tutuila and Aunu'u appear directly related to the height of the mid-Holocene stand of the sea (Dickinson and Green 1998; Nunn 1998). To model an approximately two-meter higher than present sea level at ~3000 cal BP, a two-meter contour was placed on the slope/coastal access friction surface, and a new raster was created that highlights relatively flat areas with easy access to the coast that would have been above the ~3000 cal BP sea level.

The final constraining variable in the model is settlement space. Three important considerations were attended to when modeling the amount of available land for settlement. First, errors in the digitization of GIS layers from United States Geological Service (USGS) contour maps may lead to inaccuracies in model results. The USGS contour maps also contain systematic error when compared to more precise mapping conducted with on-the-ground survey equipment such as total stations. Second, because the areas we are modeling are located along the coast,

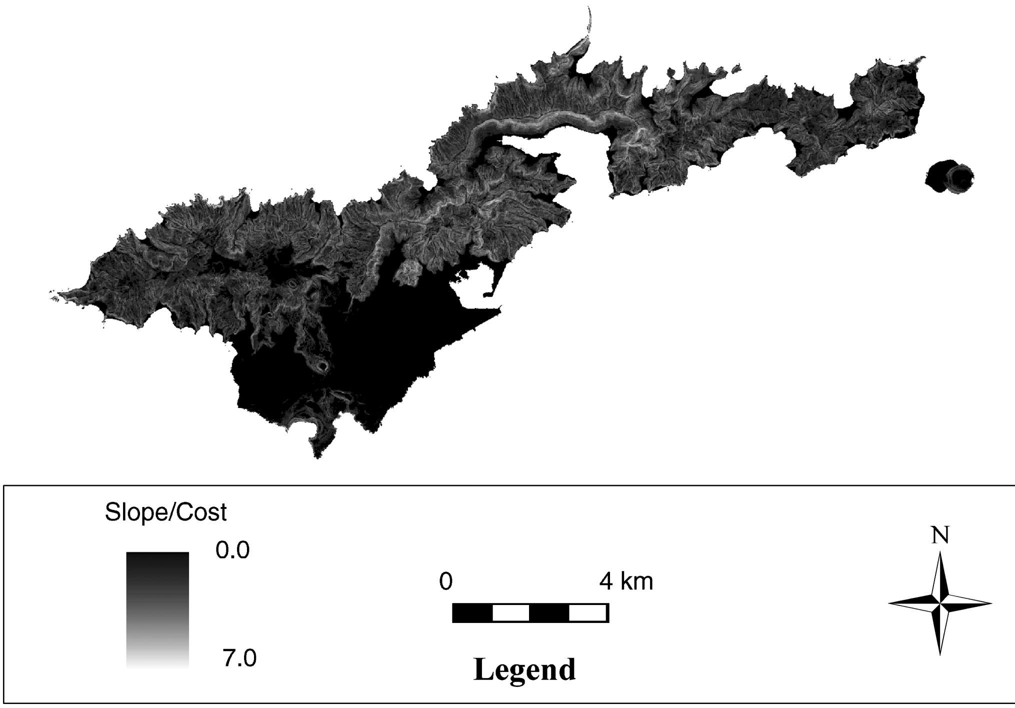

Figure 4. *Slope Classification for Tutuila Island. Slope classes were created every 12°. Cells with values of 0.0 correspond to land area with slopes between 0° and 12°.*

parameters should consider tidal range. Finally, available land must be large enough to allow the necessary requirements for habitation and related subsistence activities. Factoring all of these variables, the final model returned areas on Tutuila and Aunu'u that would have met the following requirements at ~3000 cal BP: (1) they are located within a 500 m catchment of coastal access areas; (2) with slopes between 0–12°; (3) they are elevated more than two meters above sea level, and; (4) provide at least 300 m squared of available settlement space.

Results

Eight areas on Tutuila and Aunu'u meet the criteria of this model. At the eastern end of Tutuila, 'Aoa Valley and Maliuga Point to Matuli Point are identified (Figure 6). Across the channel from Matuli Point, the western half of Aunu'u is identified (Figure 6). Along the central portion of Tutuila, Pago Pago, Utulei, and Vatia meet the specified requirements (Figure 7), while Leone and Vaitogi are areas identified on western Tutuila (Figure 8).

As a model, the GIS results provide working hypotheses to test with subsequent fieldwork. It should not be presumed that the eight areas identified in the model will contain early cultural deposits, nor should it be uncritically assumed that areas that do not meet these criteria lack early deposits. However, based on knowledge regarding the location and characteristics of

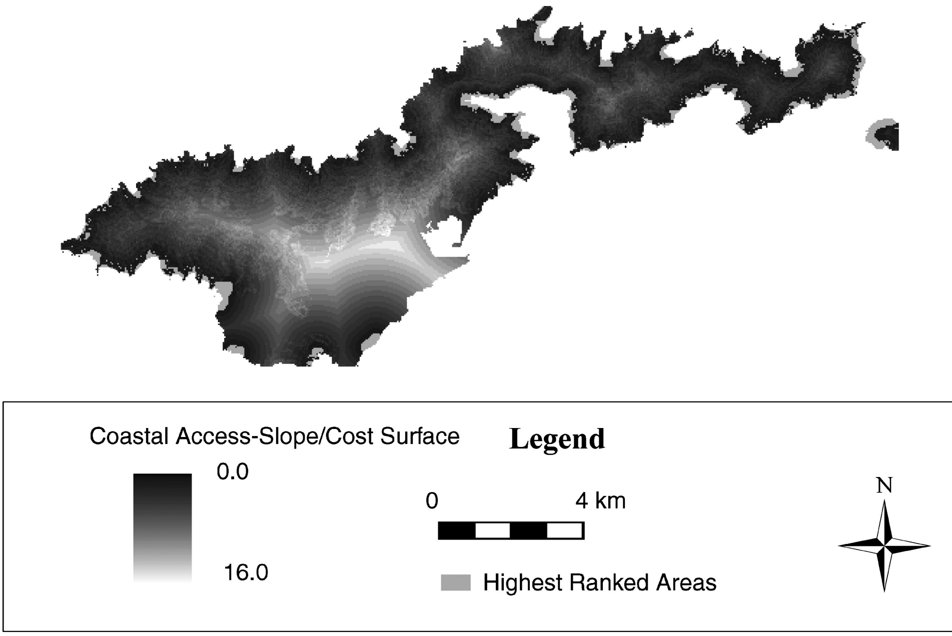

Figure 5. *Coastal Access-Slope/Cost Surface for Tutuila Island. Cell values represent a combination of the Coastal Access Distance Cost Surface (Figure 3) and Slope (Figure 4) raster layers. Highest ranked areas are highlighted in grey.*

Lapita deposits and certain geomorphological factors, these eight areas are primary candidates for future investigations. As we are operating within an explicit hypothetico-deductive research strategy (*sensu* Winterhalder and Smith 1992), we view model development and testing as a cyclical process requiring continued movement between model abstraction and empirical phenomena (Winterhalder and Smith 1992:11). Consequently, mismatches between model predictions and the real world do not negate the model's usefulness, as doing science is ultimately an iterative process (Richerson and Boyd 1987:41–43).

With these thoughts in mind, it is interesting to note that the limited number of locales meeting these criteria suggest that Tutuila at ~3000 cal BP may have offered few coastal locations comparable to other Lapita settlements in the region (Kirch 1997; Kirch and Hunt 1988). Although it is inappropriate to extrapolate this model beyond Tutuila and Aunu'u, it brings into consideration another factor—limited suitable land areas—affecting the number and distribution of early settlement deposits elsewhere in the archipelago.

A review of the available archaeological data from the eight identified locales generally corroborates this GIS-based model. Limited subsurface survey on Aunu'u found plainware ceramics (Best 1992), although their areal extent and chronology remain to be defined. Limited archaeological research has been conducted along the eastern coastline from Maliuga Point to Matuli Point; but this area consists of a large coastal flat with a paleodune fronting

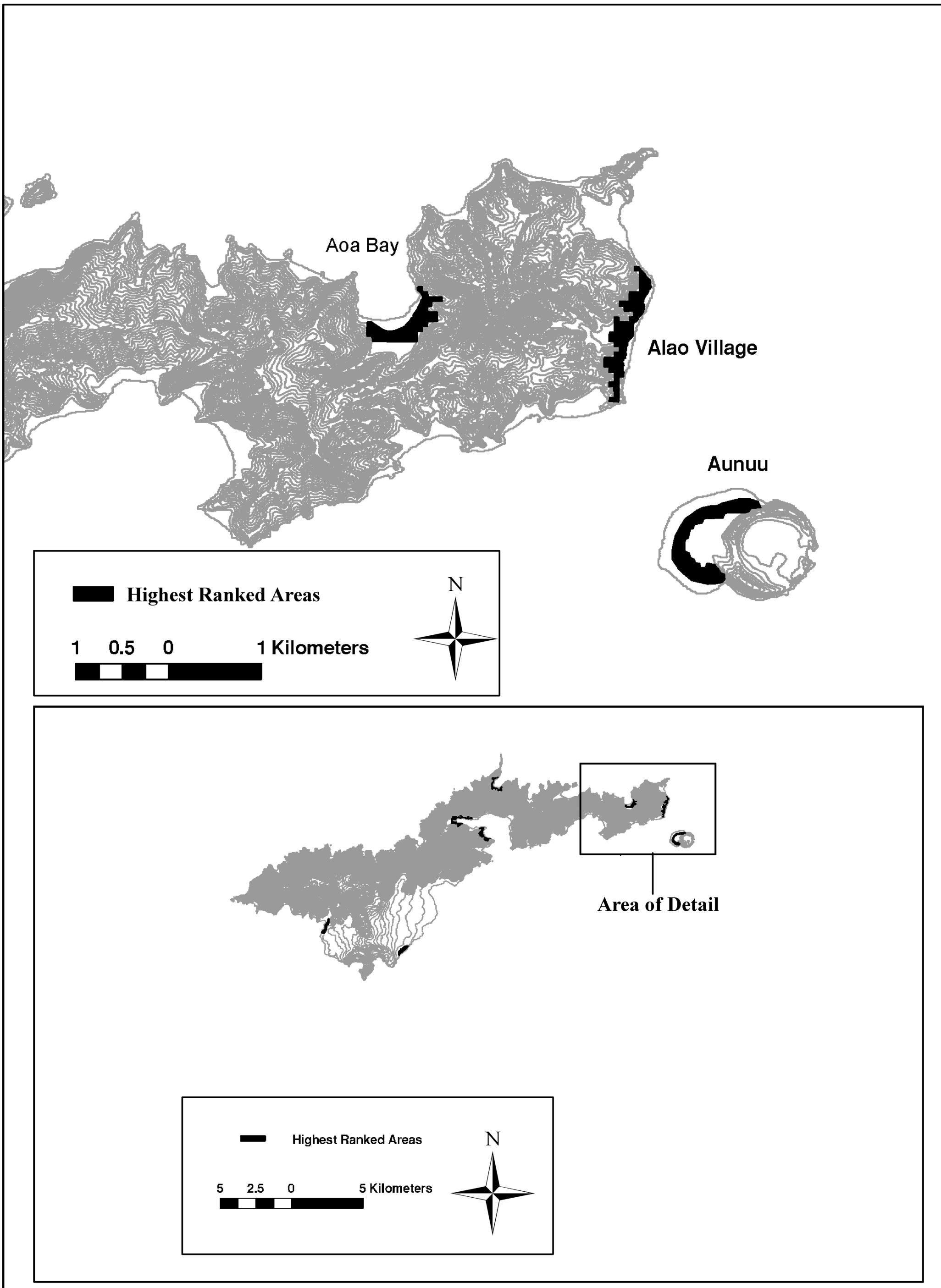

Figure 6. *Optimal Areas for Lapita Settlement, Eastern Tutuila and Aunu'u. Areas must be greater than 300 m squared at elevations greater than 2 meters. Submerged shorelines less than 2 meter elevations in proximity to optimal areas circa 3000 cal BP are circled.*

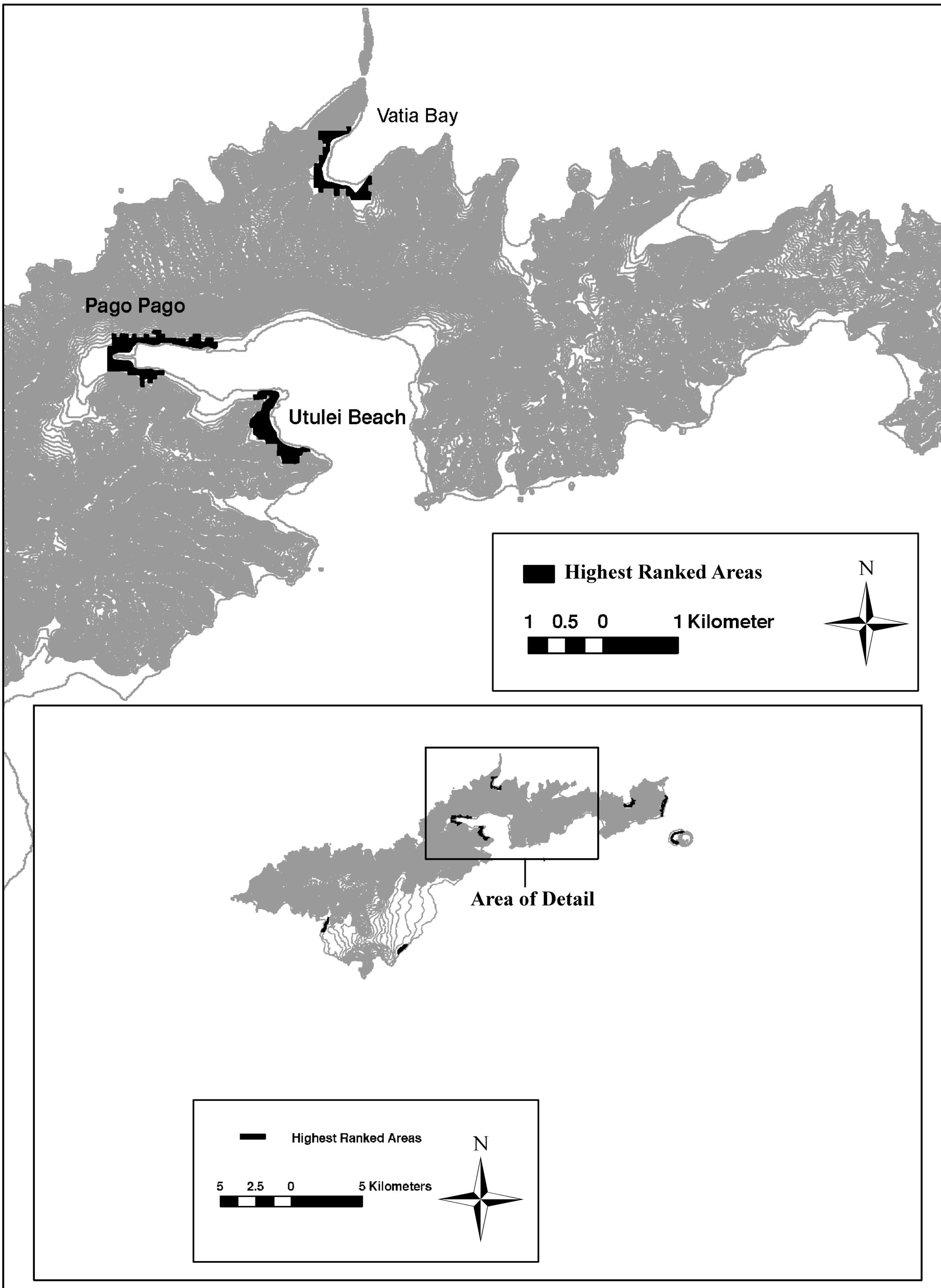

Figure 7. *Optimal Areas for Lapita Settlement, Central Tutuila. Areas must be greater than 300 m squared at elevations greater than 2 meters. Submerged shorelines less than 2 meter elevations in proximity to optimal areas circa 3000 cal BP are circled.*

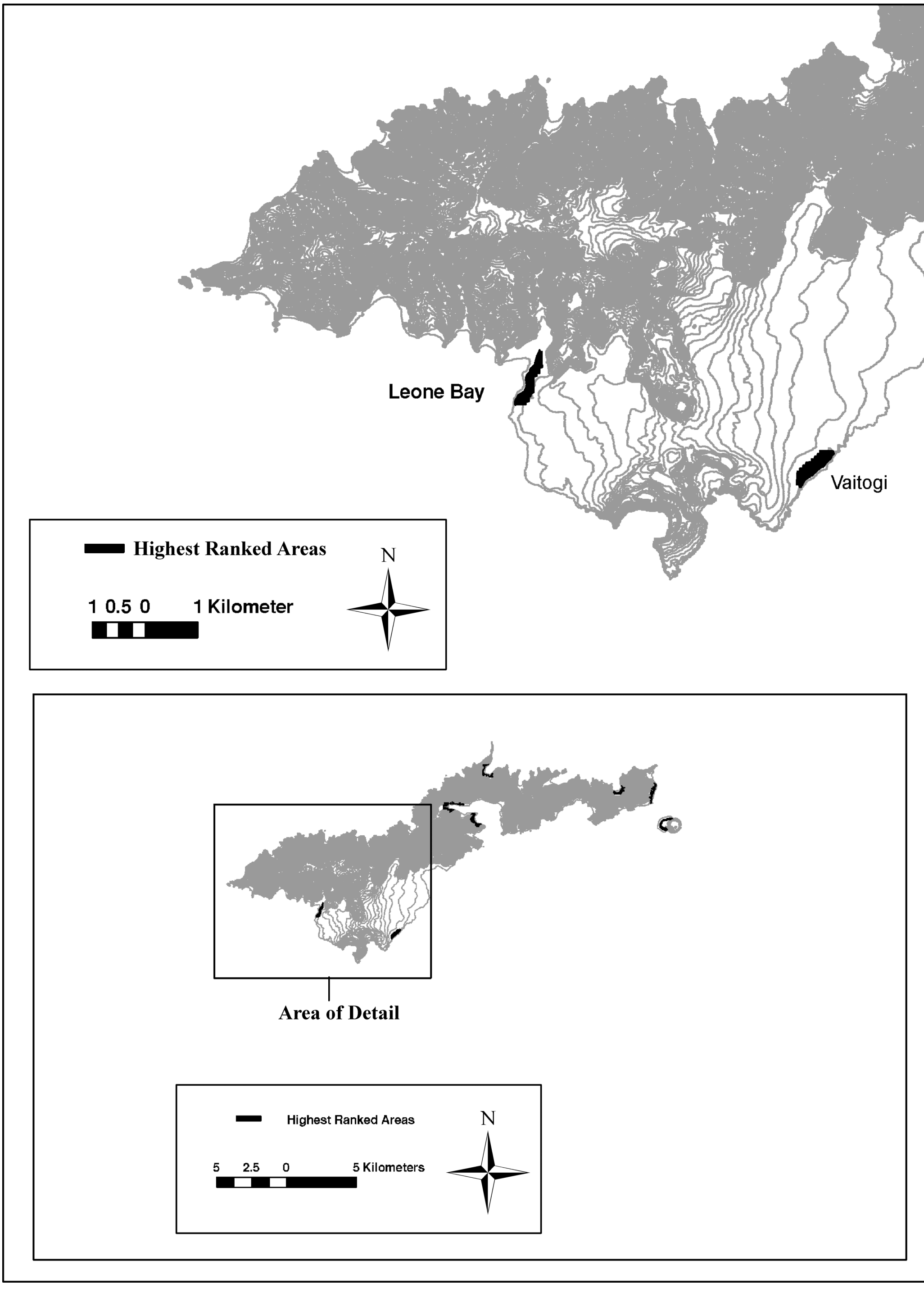

Figure 8. *Optimal Areas for Lapita Settlement, Western Tutuila. Areas must be greater than 300 m squared at elevations greater than 2 meters.*

a low back-dune area. Recent investigations at Alao village along this stretch of coast conducted by the American Samoa Power Authority have recovered ceramics, lithics, and burials (Herdrich, personal communication 2007). Immediately west of Matuli Point along the south shore are Utumea and Aganoa, where cultural deposits that have produced early dates and include plainware ceramics were not identified in the current GIS model because they did not fulfill the land area requirement. Their exclusion from the locations identified by the model suggests that a future iteration of the model with a land area requirement less than 300 m squared may provide a group of secondary locales for research on early settlement. Investigations by Moore and Kennedy (1999) and Eckert and Pearl (Eckert, personal communication 2006) at Aganoa identified plainware pottery–bearing deposits dating to at least 2000 cal BP and possibly as old as 2500 cal BP. For ʻAoa, Clark and Michlovic (1996) described plainware pottery deposits, but questions remain about the integrity and age of the deposit.

The remaining five areas on Tutuila require further evaluation. Along the south and north coasts of central Tutuila, Pago Pago, Utulei, and Vatia have been deemed suitable. The south shore locations at Pago Pago and Utulei offer several challenges for investigating potential early deposits because this area has substantial residential and commercial development and incorporates large sections of twentieth-century fill. Consequently, the baseline GIS data from post-fill topographic information may not accurately reflect the size and shape of the shoreline 3000 years BP. Only Vatia Bay appears to be a promising area for assessing early settlement in central Tutuila, although the dates from more interior deposits at Fo'isia and Vaipito suggest the possibility of additional pre-2000 BP deposits away from the coast.

At the western end of Tutuila, Leone and Vaitogi are suggested as candidate areas for early deposits. The geological substrate of both these areas derives from the Leone Volcanic Series, recent dating of which suggests that Leone and Vaitogi may not have existed in the Lapita colonization period or may have been inhospitable and relatively new basalt flows (Addison et al. 2006). In both areas underlying lava flows are capped by layers of lithified volcanic ash from volcanics active as recently as ~1500 cal BP (Addison and Asaua 2006). Currently, archaeological and geological data from this area, including the Tāfuna Plain, indicate that contrary to the GIS model, the southern portion of western Tutuila was not suitable for early colonization. However, the presence of multiple pre-2000 BP dates inland at Pava'ia'i (from deposits buried by layers of volcanic ash) indicates settlement of interior areas at a relatively early date.

CONCLUSIONS

The initial Lapita settlement of Sāmoa is represented by a single deposit at Mulifanua dating to ~3000–2600 cal BP. Although it has been proposed that additional Lapita settlements may have been distributed along the coasts of much of the archipelago, investigations have not located these deposits nor reliably dated early Polynesian Plainware deposits older than ~2500 cal BP. It is only by ~2300–2000 cal BP that a number of settlements appear to have been occupied across the archipelago.

A suite of geomorphological processes has changed the Sāmoan landscape during the last 3,000 years, affecting the preservation and discovery of early cultural deposits. Using a

GIS-based model for Tutuila and Aunu'u Islands, we propose that sandy coastal flats had not formed in many areas prior to ~2500 cal BP, limiting suitable area for Lapita settlement. Although this does not deny the possibility that additional Lapita and early Polynesian Plainware deposits are present, either deeply buried or submerged on other islands across the archipelago, the model results offer a compatible match with the current radiocarbon chronology and suggest a valuable method for developing hypotheses regarding paleo-landscapes and their affects on colonization and settlement.

Current GIS modeling is underway for the remaining islands of Sāmoa. The history of island tectonics as well as regional sea level change requires that model parameters, such as relative sea level (RSL) be adjusted to meet the specifics of each local context (see Dickinson and Green 1998; Goodwin and Grossman 2003; Nunn 1998). Additionally, the unique geography of each island will lead to outcomes that vary accordingly. Our future research will be directed by the modeling results, and will include subsurface testing and dating of both cultural and geological deposits at Alao and Aunu'u to refine the chronology of coastal geomorphology and human settlement. Future investigations at all of the locales identified in our GIS model, as well as the deposits at Utumea and Aganoa, are needed to understand the history of their geological formation processes and their human settlement and use.

To better ensure the generation of robust radiocarbon chronologies, future dating efforts should focus on: 1) well provenienced samples, ideally collected from discrete cultural features (e.g., hearths); 2) charcoal samples that have been identified as short-lived taxa or short-lived plant parts; and 3) multiple dates from individual stratigraphic units and stratigraphic sequences to bracket, and hopefully, tighten age probability distributions. Our present example for the Sāmoan Archipelago demonstrates the value of combining a critical evaluation of a radiocarbon chronology with GIS-based paleoshoreline modeling for investigating the temporal and spatial extents of island and coastal colonization and settlement.

ACKNOWLEDGEMENTS

We acknowledge two anonymous reviewers for providing helpful comments that have improved this paper. Terry Hunt, Michael Graves, and Jim Bayman read multiple versions of this paper as a part of Rieth's M.A. thesis and offered invaluable advice and criticisms. Comments from Dave Burley, Mike Carson, Geoff Clark, Jeff Clark, Sean Connaughton, Janet Davidson, Bill Dickinson, Lisa Matisoo-Smith, and Fiona Petchey on earlier versions of this paper greatly improved the present article. Any errors, omissions, or mistakes are solely the responsibility of the authors.

REFERENCES

Addison, D. J. and T. S. Asaua. 2006. 100 new dates from Tutuila and Manu'a: Additional data addressing chronological issues in Samoan prehistory. *Journal of Samoan Studies* 2:95–117.

Addison, D. J. and A. Morrison. In press. The Lapita settlement of Samoa: Is a continuous occupation model appropriate? In *Proceedings of the VII International Conference on Easter Island and the Pacific Islands: Migration, Identity, and Cultural Heritage, 20–25 August 2007, Gotland, Sweden* (C. M. Stevenson, G. Lee, and F. J. Morin, eds.). Los Osos: Easter Island Foundation.

Addison, D. J., T. Tago, J. Toloa, and E. Pearthree. 2006. Ceramic deposit below 5th–6th century AD volcanic ash fall at Pava'ia'i, Tutuila Island, American Samoa: Preliminary results. *New Zealand Journal of Archaeology* 27:5–18.

Allen, J. and J. P. White. 1989. The Lapita homeland: Some new data and an interpretation. *Journal of the Polynesian Society* 98:129–146.

Allen, M. S. 2004. Bet-hedging strategies, agricultural change, and unpredictable environments: Historical development of dryland agriculture, Kona, Hawaii. *Journal of Anthropological Archaeology* 23:196–204.

Anderson, A. 1991. The chronology of colonization in New Zealand. *Antiquity* 65:767–795.

Anderson, A. 2003. Entering uncharted waters: Models of initial colonization in Polynesia. In *Colonization of Unfamiliar Landscapes: The Archaeology of Adaptation* (M. Rockman and J. Steele, eds.):169–189. New York: Routledge.

Anderson, A., S. Bedford, G. Clark, I. Lilley, C. Sand, G. Summerhayes, and R. Torrence. 2002. An inventory of Lapita sites containing dentate-stamped pottery. In *The Archaeology of Lapita Dispersal in Oceania* (G. Clark, A. Anderson, and T. Vunidilo, eds.):1–13. Canberra: Australian National University Centre for Archaeological Research.

Anderson, A. and G. Clark. 1999. The age of Lapita settlement in Fiji. *Archaeology in Oceania* 34:31–39.

Ayres, W. C., J. A. Wozniak, G. Robbins, and E. Suafo'a. 2001. Archaeology in American Samoa: Maloata, Malaeimi, and Malaeloa. In *Pacific 2000: Proceedings of the Fifth International Conference on Easter Island and the Pacific* (C. M. Stevenson, G. Lee, and F. J. Morin, eds.):227–235. Los Osos: Bearsville Press.

Best, S. 1992. *The Aunu'u Island Sewer Project: Archaeological Survey and Excavation*. Pago Pago: Report on file at the American Samoa Historic Preservation Office.

Bronk Ramsey, C. 2005. *OxCal version 3.10 manual*. Oxford: University of Oxford Radiocarbon Accelerator.

Burley, D. V. and J. T. Clark. 2003. The archaeology of Fiji/West Polynesia in the post-Lapita era. In *Pacific Archaeology: Assessments and Prospects* (C. Sand, ed.):235–254. Noumea: Département Archéologie, Services des Musées et du Patrimoine de Nouvelle-Calédonie.

Burley, D. V., E. Nelson, and R. Shutler, Jr. 1999. A radiocarbon chronology for the eastern Lapita frontier in Tonga. *Archaeology in Oceania* 34:59–72.

Butler, V. L. 1988. Lapita fishing strategies: The faunal evidence. In *Archaeology of the Lapita Cultural Complex: A Critical Review* (P. V. Kirch and T. L. Hunt, eds.):99–115. Seattle, WA: Thomas Burke Memorial Washington State Museum.

Cashdan, E. 1992. Spatial organization and habitat use. In *Evolutionary Ecology and Human Behavior* (E. A. Smith and B. Winterhalder, eds.):237–266. New York: Aldine de Gruyter.

Clark, J. T. 1989. *The Eastern Tutuila Archaeological Project: 1988 Final Report*. Pago Pago: Report on file at the American Samoa Historic Preservation Office.

Clark, J. T. 1993. Prehistory of Alega, Tutuila Island, American Samoa, a small residential and basalt-industrial valley. *New Zealand Journal of Archaeology* 15:67–86.

Clark, J. T. 1996. Samoan prehistory in review. In *Oceanic Culture History: Essays in Honour of Roger Green* (J. M. Davidson, G. Leach, B. F. Pawley, and D. Brown, eds.):445–460. Auckland, NZ: New Zealand Journal of Archaeology Special Publication.

Clark, J. T. and D. J. Herdrich. 1988. *The Eastern Tutuila Archaeological Project: 1986 Final Report*. Pago Pago, American Sāmoa: Report on file at the American Samoa Historic Preservation Office.

Clark, J. T. and D. J. Herdrich. 1993. Prehistoric settlement systems in eastern Tutuila, American Samoa. *Journal of the Polynesian Society* 102:147–185.

Clark, J. T. and M. G. Michlovic. 1996. An early settlement in the Polynesian homeland: Excavations at Aoa valley, Tutuila island. *Journal of Field Archaeology* 23:151–167.

Cochrane, E. E., M. T. Carson, and J. S. Athens (eds.). 2004. *Archaeological Inventory Survey for the Tualauta County Phase IIb Sewerline Project, Tutuila, American Samoa*. Honolulu, HI: International Archaeological Research Institute, Inc.

Davidson, J. M. and J. Fagan. 1974. Excavations at SU-Le-12, Leuluasi. In *Archaeology in Western Samoa, Volume 2* (R. C. Green and J. M. Davidson, eds.):72–90. Auckland, NZ: Bulletin of the Auckland Institute and Museum 7.

Dean, J. S. 1978. Independent dating in archaeological analysis. In *Advances in Archaeological Method and Theory, Volume I* (M. B. Schiffer, ed.):223–258. New York: Academic Press.

Dickinson, W. R. and R. C. Green. 1998. Geoarchaeological context of Holocene subsidence at the Ferry Berth Lapita site, Mulifanua, Upolu, Samoa. *Geoarchaeology* 13:239–263.

Elmore, M., J. Kennedy, and J. R. Moore. 1999. *An Archaeological Investigation with Subsurface Testing for the Route 1 Road Reconstruction Project, Ma'oputasi County, Island of Tutuila, American Samoa*. Hale'iwa, HI: Archaeological Consultants of the Pacific Inc.

Field, J. S., M. D. Petraglia, and M. M. Lahr. 2007. The southern dispersal hypothesis and the South Asian archaeological record: Examination of dispersal routes through GIS analysis. *Journal of Anthropological Archaeology* 26:88–108.

Fitzpatrick, S. 2006. A critical approach to ^{14}C dating in the Caribbean: Using chronometric hygiene to evaluate chronological control and prehistoric settlement. *Latin American Antiquity* 17:389–418.

Fletcher, C. H. and A. T. Jones. 1996. Sea-level highstand recorded in Holocene shoreline deposits on Oahu. *Journal of Sedimentary Research* 66:632–641.

Frost, J. O. 1976. Summary report of archaeological investigations on Tutuila Island, American Samoa. *Newsletter of the New Zealand Archaeological Association* 19:30–37.

Frost, J. O. 1978. *Archaeological investigations on Tutuila Island, American Samoa*. Ph.D. Dissertation. Eugene, OR: University of Oregon.

Goodwin, I. D. and E. E. Grossman. 2003. Middle to late Holocene coastal evolution along the south coast of Upolu Island, Samoa. *Marine Geology* 202:1–16.

Green, R. C. 1974. Pottery from the lagoon at Mulifanua, Upolu. In *Archaeology in Western Samoa, Volume 2* (R. C. Green and J. M. Davidson, eds.):170–175. Auckland, NZ: Bulletin of the Auckland Institute and Museum 7.

Green, R. C. 1979. Lapita. In *The Prehistory of Polynesia* (J. D. Jennings, ed.):27–60. Cambridge, MA: Harvard University Press.

Green, R. C. 2002. A retrospective view of settlement pattern studies in Samoa. In *Pacific Landscapes: Archaeological Approaches* (T. N. Ladefoged and M. W. Graves, eds.):125–152. Los Osos: Easter Island Foundation - Bearsville Press.

Green, R. C. and J. M. Davidson. 1965. Radiocarbon dates for western Sāmoa. *Journal of the Polynesian Society* 74:63–69.

Green, R. C. and J. M. Davidson (eds.). 1969. *Archaeology in Western Samoa, Volume 1*. Auckland, NZ: Auckland Institute and Museum Bulletin 6.

Green, R. C. and J. M. Davidson (eds.). 1974a. *Archaeology in Western Samoa, Volume 2*. Auckland, NZ: Auckland Institute and Museum Bulletin 7.

Green, R. C. and J. M. Davidson. 1974b. A radiocarbon and stratigraphic sequence for Samoa. In *Archaeology in Western Samoa, Volume 2* (R. C. Green and J. M. Davidson, eds.):212–224. Auckland, NZ: Bulletin of the Auckland Institute and Museum 7.

Green, R. C. and H. G. Richards. 1975. Lapita pottery and a lower sea level in Western Samoa. *Pacific Science* 29:309–315.

Grossman, E. E., C. H. Fletcher and B. M. Richmond. 1998. The Holocene sea-level highstand in the equatorial Pacific: Analysis of the insular paleosea-level database. *Coral Reefs:* 17:309–327.

Haynes, G., D. G. Anderson, C. R. Ferring, S. J. Feidel, D. K. Grayson, C. V. Haynes, V. T. Holliday, et al. 2007. Comment on "Redefining the age of Clovis: Implications for the peopling of the Americas." *Science* 317:320b.

Herdrich, D. J. 2002. *Results of a Cultural Resource Evaluation for the Route 1 Phase 4 Reconstruction and Drainage Project, Tutuila Island, American Samoa*. Pago Pago, American Sāmoa: Report on file at the American Samoa Historic Preservation Office, Pago Pago.

Hunt, T. L. and P. V. Kirch. 1987. Radiocarbon dates from two coastal sites in the Manu'a Group, American Samoa. *Radiocarbon* 29:417–419.

Hunt, T. L. and P. V. Kirch. 1988. An archaeological survey of the Manu'a islands, American Samoa. *Journal of the Polynesian Society* 97:153–183.

Hunt, T. L. and P. V. Kirch. 1997. The historical ecology of Ofu island, American Samoa: 3000 BP to the present. In *Historical Ecology of the Pacific Islands: Prehistoric, Environmental and Landscape Change* (P. V. Kirch and T. L. Hunt, eds.):105–123. New Haven, CT: Yale University Press.

Hunt, T. L. and C. P. Lipo. 2006. Late colonization of Easter Island. *Science* 311:1603–1606.

Jennings, J. D. and R. N. Holmer (eds.). 1980a. *Archaeological Excavations in Western Samoa*. Honolulu, HI: Bernice P. Bishop Museum.

Jennings, J. D. and R. N. Holmer 1980b. Chronology. In *Archaeological Excavations in Western Samoa* (J. D. Jennings and R. N. Holmer, eds.):5–10. Honolulu, HI: Bernice P. Bishop Museum.

Jennings, J. D. and R. N. Holmer 1980c. Potusa (SM17-1). In *Archaeological Excavations in Western Samoa* (J. D. Jennings and R. N. Holmer, eds.):22. Honolulu, HI: Bernice P. Bishop Museum.

Jennings, J. D., R. N. Holmer, J. C. Janetski, and H. L. Smith (eds.). 1976. *Excavations on Upolu, Western Samoa*. Honolulu, HI: Bernice P. Bishop Museum.

Kennett, D. J., A. J. Anderson, and B. Winterhalder. 2006. The ideal free distribution, food production and the colonization of Oceania. In *Behavioral Ecology and the Transition to Agriculture* (D. Kennett and B. Winterhalder,

eds.):265–288. Berkeley, CA: University of California Press.
Kirch, P. V. 1993a. The To'aga site: Modeling the morphodynamics of the land-sea interface. In *The To'aga Site: Three Millennia of Polynesian Occupation in the Manu'a Islands, American Samoa* (P. V. Kirch and T. L. Hunt, eds.):31–42. Berkeley, CA: University of California Archaeological Research Facility.
Kirch, P. V. 1993b. Radiocarbon chronology of the To'aga site. In *The To'aga Site: Three Millennia of Polynesian Occupation in the Manu'a Islands, American Samoa* (P. V. Kirch and T. L. Hunt, eds.):85–92. Berkeley, CA: University of California Archaeological Research Facility.
Kirch, P. V. 1997. *The Lapita Peoples: Ancestors of the Oceanic World*. Cambridge: Blackwell.
Kirch, P. V. and T. L. Hunt. 1988. The spatial and temporal boundaries of Lapita. In *Archaeology of the Lapita Cultural Complex: A Critical Review* (P. V. Kirch and T. L. Hunt, eds.):9–31. Seattle, WA: Thomas Burke Memorial Washington State Museum.
Kirch, P. V. and T. L. Hunt (eds.). 1993. *The To'aga Site: Three Millennia of Polynesian Occupation in the Manu'a Islands, American Samoa*. Berkeley, CA: University of California Archaeological Research Facility.
Krebs, J. R. and N. B. Davies. 1993. *An Introduction to Behavioral Ecology*. Oxford: The Alden Press.
Leach, H. M. and R. C. Green. 1989. New information for the Ferry Berth Site, Mulifanua, Western Samoa. *Journal of the Polynesian Society* 98:319–329.
Lepofsky, D. 1988. The environmental context of Lapita settlement locations. In *Archaeology of the Lapita Cultural Complex: A Critical Review* (P. V. Kirch and T. L. Hunt, eds.):33–47. Seattle, WA: Thomas Burke Memorial Washington State Museum.
Liston, J. 2005. An assessment of radiocarbon dates from Palau, Western Micronesia. *Radiocarbon* 47:295–354.
Lohse, E. S. 1980. Falemoa (SM17-2). In *Archaeological Excavations in Western Samoa* (J. D. Jennings and R. N. Holmer, eds.):23–32. Honolulu, HI: Bernice P. Bishop Museum.
Martinsson-Wallin, H., G. Clark, and P. Wallin. 2005. The Pulemelei project, Samoa, Savai'i. In *The Renaca Papers, VI International Conference on Easter Island and the Pacific* (C. M. Stevenson, J. M. Ramirez Aliaga, F. J. Morin, and N. Barbacci, eds.):225–232. Los Osos: Easter Island Foundation.
Matisoo-Smith, E. 2007. Animal translocations, genetic variation and the human settlement of the Pacific. In *Genes, Language and Culture History in the Southwest Pacific* (J. S. Friedlander, ed.):157–170. Oxford: Oxford University Press.
McCormac, F. G., A. G. Hogg, P. G. Blackwell, C. E. Buck, T. F. G. Higham, and P. J. Reimer. 2004. SHCAL04 southern hemisphere calibration, 0-11.0CAL KYR BP. *Radiocarbon* 46:1087–1092.
Mitovica J. X. and W. R. Peltier. 1991. On postglacial geoid subsidence over the equatorial oceans. *Journal of Geophysical Research* 96(B12):20053–20071.
Moore, J. R. and J. Kennedy. 1999. *Results of an Archaeological Cultural Resource Evaluation for the East and West Tutuila Water Line Project, Tutuila Island, American Samoa*. Hale'iwa, HI: Archaeological Consultants of the Pacific, Inc.
Morrison, A. E. 2005. Shell analysis from two test units at Fatu-ma-Futi. In *Fatu-ma-Futi Water Mitigation Project, Tutuila Island, Territory of American Samoa: Excavation Report and Preliminary Findings (Draft)* (G. Walter and D. J. Addison, eds.):45–69. Pago Pago: American Samoa Power Authority.
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(1):22–34.
Nagaoka, L. 1988. Lapita subsistence: The evidence of non-fish archaeofaunal remains. In *Archaeology of the Lapita Cultural Complex: A Critical Review* (P. V. Kirch and T. L. Hunt, eds.):117–33. Seattle, WA: Thomas Burke Memorial Washington State Museum.
Nunn, P. D. 1998. *Pacific Island Landscapes*. Suva: Suva Institute of Pacific Studies, The University of the South Pacific.
Nunn, P. D. 2005. Reconstructing tropical paleoshorelines using archaeological data. *Journal of Coastal Research Special Issue* 42:15–25.
Pearl, F. B. 2004. The chronology of mountain settlements on Tutuila, American Samoa. *Journal of the Polynesian Society* 113:331–348.
Pearl, F. B. 2006. Late Holocene landscape evolution and land-use expansion in Tutuila, American Samoa. *Asian Perspectives* 45:48–68.
Petchey, F. J. 1995. *The Archaeology of Kudon: Archaeological Analysis of Lapita Ceramics from Mulifanua, Samoa and Sigatoka, Fiji*. M.A. Thesis. Auckland, NZ: University of Auckland.
Petchey, F. J. 2001. Radiocarbon determinations from the Mulifanua Lapita site, Upolu, Western Samoa. *Radiocarbon* 43:63–68.

Petchey, F. J. and D. J. Addison. In press. Radiocarbon dating marine shell in Samoa: A new delta-R from known-age specimens. In *Recent Archaeology in the Fiji/West-Polynesia Region: Papers from the Archaeology of the Polynesian Homeland Conference* (D. J. Addison, T. S. Asaua, and C. Sand, eds.).

Peters, K. M. 1969. Excavations of a star mound and earthen terrace at SU-Lu-53. In *Archaeology in Western Samoa, Volume 1* (R. C. Green and J. M. Davidson, eds.):210–221. Auckland, NZ: Bulletin of the Auckland Institute and Museum 6.

Phelan, M. B. 1999. A ΔR correction value for Samoa from known-age marine shells. *Radiocarbon* 41:99–101.

Reimer, P. J., M. G. L. Baillie, E. Bard, A. Bayliss, J. W. Beck, C. J. H. Bertrand, P. G. Blackwell, et al. 2004. IntCal04 terrestrial radiocarbon age calibration, 0–26 kyr BP. *Radiocarbon* 46:1029–1958.

Richerson, P. J. and R. Boyd. 1987. Simple models of complex phenomena: The case of cultural evolution. In *The Latest on the Best: Essays on Evolution of Optimality* (J. Dupree, ed.):27–52. Cambridge, MA: MIT Press.

Rieth, T. M. and T. L. Hunt. 2008. A radiocarbon chronology for Sāmoan prehistory. *Journal of Archaeological Science* 35(7):1901–1927.

Silva, T. E. and S. L. Palama. 1975. *Archaeological Reconnaissance Survey: Proposed Shoreline and Highway Improvements, Tutuila Island and Aunu'u Boat Harbor Aunu'u Island, American Samoa*. Honolulu, HI: Archaeological Research Center Hawaii, Inc.

Smith, A. 2002. *An Archaeology of West Polynesian Prehistory*. Canberra, Australia: Pandanus Press—Research School of Pacific and Asian Studies, Australian National University.

Smith B. D. 2001. Low-level food production. *Journal of Archaeological Research* 9:1–43.

Smith, H. L. 1976. Jane's Camp (SUF1-1). In *Excavations on Upolu Western Samoa* (J. D. Jennings, R. N. Holmer, J. C. Janetski, and H. L. Smith, eds.):61–74. Honolulu, HI: Bernice P. Bishop Museum.

Spriggs, M. 1989. The dating of the island Southeast Asian Neolithic: An attempt at chronometric hygiene and linguistic correlation. *Antiquity* 63:587–613.

Spriggs, M. and A. Anderson. 1993. Late colonization of East Polynesia. *Antiquity* 67:200–217.

Taomia, J. M. E. 2001a. *Results of an Historical Properties Identification Survey of Western Tafuna Plain, Tualauta County, Tutuila Island, American Samoa During July 1997*. Pago Pago, American Sāmoa: Report on file at the American Samoa Historic Preservation Office.

Taomia, J. M. E. 2001b. *Results of an Inventory Survey in Pava'ia'i, Faleniu and 'Ili'ili Villages, Tualauta County, Tutuila Island, American Samoa July–August 1998*. Pago Pago, American Sāmoa: Report on file at the American Samoa Historic Preservation Office.

Taomia, J. M. E. 2002. *Results of an Inventory Survey on the Tafuna Plain, Tualauta County, Tutuila Island, American Samoa July–August 1996*. Pago Pago, American Sāmoa: Report on file at the American Samoa Historic Preservation Office.

Taylor, R. E. 1987. *Radiocarbon Dating: An Archaeological Perspective*. New York: Academic Press.

Walter, G. and D. J. Addison. 2005. *Fatu-ma-Futi Water Mitigation Project, Tutuila Island, Territory of American Samoa: Excavation Report and Preliminary Findings (Draft)*. Pago Pago, American Sāmoa: American Samoa Power Authority.

Waters, M. R. and T. W. Stafford, Jr. 2007. Redefining the age for Clovis: Implications for the peopling of the Americas. *Science* 315:1122–1126.

Winterhalder, B. and E. A. Smith. 1992. Evolutionary ecology and the social sciences. In *Evolutionary Ecology and Human Behavior* (E. A. Smith and B. Winterhalder, eds.):3–23. New York: Aldine de Gruyter.

Winterhoff, E. Q. 2003. *Ma'a a Malaeloa: A Geochemical Investigation of a New Basalt Quarry Source on Tutuila, American Samoa*. M.A. Thesis. Eugene, OR: University of Oregon.

Zilhao, J. 2001. Radiocarbon evidence for maritime pioneer colonization and the origins of farming in west Mediterranean Europe. *Proceedings of the National Academy of Science* 98(24):14180–14185.