HISTORICAL ECOLOGY AND COMMUNITY PATTERNING AT RA‘IĀTEA, SOCIETY ISLANDS, FRENCH POLYNESIA

by

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DISSERTATION ABSTRACT

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Title: Historical Ecology and Community Patterning at Raʻiātea, Society Islands, French Polynesia

This dissertation project explores the timing and impacts of Polynesian colonization on the island of Raʻiātea in the Society Islands of French Polynesia. Raʻiātea, also known by the ancestral name Havaiʻi, is the largest island of the Leeward Group and a key location for understanding human settlement and the dispersal of voyaging populations among the islands of East Polynesia prior to European contact in the region. This project examines the position of Raʻiātea in the context of regional settlement with an analysis of East Polynesian cultural transmission networks, a contribution to the radiocarbon chronology of Raʻiātea, and an assessment of landscape change and ecological effects at the megalithic ceremonial center of Marae Tainuʻu on the west coast of the island.

An analysis of morphological variability among 18 artifact fishhook assemblages from 17 East Polynesian islands supports Raʻiātea as a central node in regional cultural transmission networks, an outcome that fits well with other archaeological and linguistic models of dispersal and interaction. Excavations at Marae Tainuʻu exposed a deep history of Maʻōhi settlement existing beneath the surface of the extant megalithic structures. Subsurface architecture, artifacts, and faunal remains suggest culturally dictated patterns

of resource use and landscape modification at the marae complex. Radiocarbon dates reveal a record of human activity beginning as early as ~1520-1665 cal AD. The intellectual merit of this project lies in the advancement of knowledge regarding Society Islands archaeology, a relatively neglected area of study with implications for public policy, local resource protection, and furthering collective knowledge of Polynesia's deep history. The broader impacts of this work include contributions to the assessment of how Polynesian peoples shaped their environment and how this relates to models of anthropogenic environmental change on oceanic islands.

This dissertation includes previously published co-authored material.

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CHAPTER I

INTRODUCTION

The islands of Polynesia evoke images of mystery and exoticism as much today as when European explorers first entered the Pacific realm. The human settlement of Polynesia and the broader radiation of Austronesian-speaking voyagers saw related peoples colonize thousands of islands from Madagascar to Rapa Nui. The archaeologically rapid and sustained movement of people to all habitable islands of the remote Pacific Ocean constitute one of the final chapters in the history of human dispersals to the far ends of the earth (Blust 1995; Kirch 1997a, 2010). It was the ancestors of today's island populations who first traveled beyond the Andesite Line, or the geological boundary that separates the continental islands of the western Pacific Ocean from the volcanic islands of the Pacific Plate, to colonize the islands of Remote Oceania and make a lasting impression on the cultural, ecological, and geographical aspects of the greater Pacific region (Green 1991b; Irwin 2007). The technological and navigational ability of these voyaging groups, the expansive distances covered during dispersal, and the unique cultural trajectories of island communities from Tonga to Tahiti to Hawai‘i have made Polynesia the subject of extensive archaeological and ethnographic study for generations of researchers. The archaeology of voyaging societies in the islands of Central East Polynesia is key to understanding cultural and ecological history of the region at large.

My dissertation project seeks to understand the human impacts of these voyagers on newly encountered islands through questions of chronology and landscape change at Ra‘iātea Island in the Society Islands of French Polynesia. Archaeological mapping and

excavation of near-shore deposits on the coastal flats of Tumaraʻa, Raʻiātea, augment current knowledge regarding the history of the island and provide a case study for ecological change that complements ongoing work in central East Polynesia. Expanded studies of the historical ecology of Raʻiātea will facilitate further evaluation of the influence of early human-environmental interactions on coastal resources and a better understanding of the development of Māʻohi cultural systems and voyaging spheres prior to European contact in the region.

My dissertation research project explores the timing and impacts of human colonization in the Tumaraʻa district of Raʻiātea Island, Society Islands, French Polynesia. The Society Islands are of primary importance for understanding human

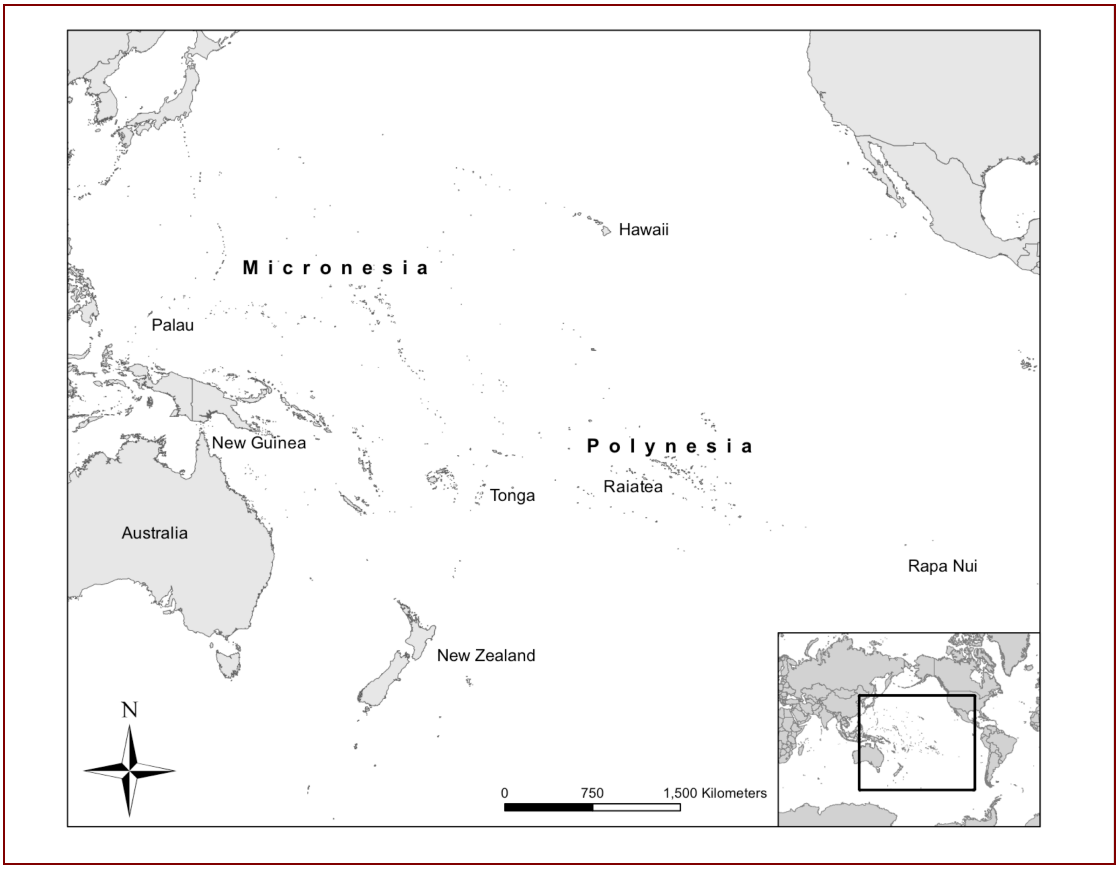


Figure 1. Map of Oceania with locations discussed in text.

impacts on island ecologies and the dispersal of pre-contact voyaging populations among the islands of East Polynesia. Raʻiātea, also known by the ancestral name Havaiʻi, is the largest island of the Leeward Group and recognized through Polynesian oral traditions as a departure point for migrations that colonized the distant islands or archipelagos of Hawaiʻi, Aotearoa (New Zealand), and Rapa Nui in the 12th and 13th centuries AD (Henry 1928; Hiroa 1938; Wilmshurst et al. 2011). Prior research in the Society Islands' Windward and Leeward Groups has revealed dense archaeological deposits with radiocarbon sequences dating from the 11th century AD and major shifts in land use and sediment accumulation in the middle of the last millennium (Anderson and Sinoto 2002; Kahn et al. 2015a, 2015b; Lepofsky 1995).

Raʻiātea is notably underrepresented in the archaeological literature. This project addresses this absence of information with an analysis of East Polynesian cultural transmission networks followed by a comprehensive mapping and excavation program in Tumaraʻa Commune at western Raʻiātea, specifically focusing on the archaeological visibility of early settlement, the role of sample choice in building radiocarbon chronologies, spatiotemporal change in land use and settlement patterns, and the utility of geomorphological and paleoecological evidence as proxies for human colonization. A secure colonization chronology at Raʻiātea is imperative for the refinement of island settlement models in East Polynesia. The examination of regional sociality in combination with the identification local resource use and landscape change aids in explanations of cultural trajectories during the Polynesian voyaging period.

The intellectual merit of this project lies in the advancement of knowledge regarding Society Islands archaeology, a relatively neglected area of study with

implications for public policy, local resource protection, and furthering collective knowledge of Polynesia's deep history. This is important for both scientific interests and social activism in the region. Archaeological research has been fundamental to cultural revival in Polynesia and the reassertion of autonomy among Pacific Islanders following Western colonization. Regional archaeology is paid great attention and is a source of pride among local communities, as evidenced by positive community participation in this study. Project results have been used for local education and will be disseminated through publicly accessible literature in addition to academic journals.

The broader impacts of this work include contributions to the assessment of anthropogenic environmental change on oceanic islands. Archaeologists are uniquely positioned to model patterns of human-environmental interaction that provide insight into cultural development and allow the creation of historical baselines against which to measure contemporary environmental circumstances (Erlandson and Rick 2010; Morrison and Hunt 2007; Rick et al. 2014). Thus, archaeology provides access to environmental and historical data that extend beyond the confines of the discipline. The islands of French Polynesia are central to current discussions of climate change and resource degradation in the Pacific. Studies of community patterning and historical ecology contribute to these conversations, and I hope to make significant contributions to the archaeological literature through my work at Tumaraʻa, Raʻiātea.

Historical Ecology and Island Archaeology

The role of human behavior in shaping our natural world is a primary interest, spanning numerous disciplines of scientific study and millennia of philosophical thought.

Realizing the full extent of socio-ecological interplay and the impacts of human populations on the external environment requires a comprehensive approach to the study of human history, one that assists in recognizing the motivations, constraints, and effects of different strategies of interaction within social groups and in relation to environmental resources. Crucial to this goal is the acknowledgment of *Homo sapiens* as part of the natural world and an intrinsic component of the holistic ecological system (Rindos 1980; Terrell 2006).

This foundational concept allows the exploration of human behavior from an evolutionary ecological perspective, a viewpoint that has contributed much to archaeological research in studies of historical ecology (Braje et al. 2009; Egan and Howell 2005; Erlandson and Fitzpatrick 2006; Erlandson and Rick 2008, 2010; Erlandson et al. 2009; Fitzpatrick and Donaldson 2007; Fitzpatrick and Keegan 2007; Hunt 2007; Jackson et al. 2001; Jones 2009; Kirch 1997b, 2007a; Kirch and Hunt 1997; Moss 2012; Rick and Erlandson 2008; Rick et al. 2014).

Crumley (1994:6) defined historical ecology as "the study of past ecosystems by charting the change in landscapes over time", to which Winterhalder (1994:19) added that historical ecology is based on the epistemological assertion that "a complete understanding of ecological structure and function must reference the timing and sequence of causal events producing them" (e.g., anthropogenic impacts). Therefore, historical ecology explicitly locates archaeology in the domain of human ecology (Butzer 1982), while privileging the analysis of landscape modification and the spatiotemporal trajectories of plant and animal species as dynamic components of human history (Jochim 1991).

The origins of ecological anthropology can be traced to Julian Steward's work in the American Southwest (Steward 1937; see Bettinger 1998; O'Brien et al. 2005; Smith 1983), where he worked to understand non-deterministic cultural patterns overlying those of the natural landscape in a way that profoundly shaped the development of evolutionary ecological approaches to ethnography and archaeology. Steward (1942) championed the direct historical approach with inclusion of the environment as part of the cultural process in ethnographic study. His work greatly influenced the formalization of an ecologically aware settlement pattern archaeology (Parsons 1972; e.g., Green 1967; MacNeish 1964; Willey 1953) and the onset of research programs in ethnoarchaeology (see Gould 1980 for concept of analogous baselines).

In a reversal of ethnographic attempts to recognize a recent baseline from which to work backward (e.g., Binford 1978; Steward 1942), archaeologists working in historical ecology have sought to first understand the complexities of the natural environment prior to human encroachment and the cultural and ecological changes that ensue with the passage of time (Erlandson et al. 2008; Kirch and Hunt 1997). Historical ecology approaches provide deep time perspectives that require a more definitive picture of human impacts in contrast to the often arbitrary and inaccurate "shifting baselines" of comparative historical observations (Braje et al. 2009; Erlandson and Fitzpatrick 2006; Erlandson and Rick 2010; Pauly 1995; Pauly et al. 1998).

Imperative to historical studies of human behavior and settlement patterning is the critical evaluation of anthropogenic impacts on the respective ecosystem of the actors. The juxtaposition of sound archaeological chronologies with analyses of ecological information from different temporal periods creates reference points beneficial for

understanding past human-environmental interactions and the development of unique cultural trajectories. The establishment of these historical baselines is paramount to archaeological research, but is also increasingly relevant in contributions to public policy regarding habitat restoration and conservation biology (Anderson 2005; Jackson et al. 2001; O'Brien 2005; Rick et al. 2014; Swetnam et al. 1999).

Human Behavioral Ecology and Community Patterning

Historical ecology has maintained a synergistic relationship with studies of human behavioral ecology and settlement pattern archaeology due to a shared focus on environmental variability and the ways by which human communities organize their daily lives. Models from human behavioral ecology center on how behavioral trade-offs affect differential fitness in distinct environments as demonstrated in patterns of resource acquisition, subsistence practices, and population distributions. These models have been widely implemented in archaeological studies (Aswani 1998; Bettinger 2006; Broughton 2002; Codding et al. 2014; Giovas and Fitzpatrick 2014; Gremillion et al. 2014; Groesbeck et al. 2014; Hunt and Lipo 2011; Kennett 2005; Kennett and Winterhalder 2008; Morrison and Hunt 2007; Nagaoka 2002; Reeder-Myers 2014; Whitaker and Bird 2014).

Concepts of resource acquisition have also been implicit to studies of ancient migrations and the relationship between people and landscapes as substantiated by settlement pattern research (Anderson 2002; Anderson and Smith 1996; Burley 1994; Erlandson 2001; Erlandson et al. 2007; Hunt and Kirch 1988; Jennings et al. 1982; Maric and Cauchois 2009; Morrison and O'Connor 2015; Rick et al. 2013). Historical ecology

integrates notions from other evolutionary ecological approaches with archaeology, paleoecology, geomorphology, traditional ecological knowledge, and even historic accounts to elucidate a continuous record of human activity and form a complete cultural and ecological history for the targeted locality.

Human Impacts in Polynesia

The relatively late inception of archaeology in Oceania and, specifically, the dearth of durable artifacts in Polynesian archaeological contexts, have encouraged the development of a largely interdisciplinary approach to archaeology in Polynesia congruent with historical ecology models. Evaluating human impacts on marine ecosystems entails a broad interdisciplinary approach with implications for archaeological research and resource conservation efforts (Erlandson and Rick 2010; Erlandson et al. 2009; Kirch 2005), allowing the use of proxy measures to define robust archaeological histories where material culture may be lacking. In island and coastal settings, the impacts of human activity on marine and terrestrial ecosystems are often well represented in the near-shore archaeological record. Likewise, the anthropogenic alteration of natural landscapes is often immediately apparent. Archaeologists are uniquely situated to study these environmental impacts and the role of cultural expression in the transformative process. Clearly defined boundaries and the opportunities for comparative analyses have led researchers to describe islands as model ecosystems in which to study both the cultural and biological development of human populations (Burney 1997; Erlandson and Fitzpatrick 2006; Fitzpatrick and Anderson 2008; Fitzpatrick and Erlandson 2018; Kirch 1997b, 2007a; Kirch et al. 2004; Rick et al. 2013),

and this concept has influenced the ecological mindset of archaeologists working in island environments (Allen 2014; Allen and Morrison 2013; Anderson 2001a, 2009; Fitzpatrick et al. 2015; Hunt 2007; Kennett et al. 2006a; Kirch 1989, 2007b). The islands of Polynesia present an ideal setting for the study of human impacts in maritime environments and a unique history of community interaction among geographically diverse island groups covering a massive expanse of the planet's surface.

Raʻiātea: Geography

The Society Islands are one of the five linear volcanic chains of French Polynesia, comprising nine high volcanic islands and various associated atolls and seamounts roughly aligned in a southeast to northwest orientation on the southern portion of the Pacific tectonic plate (Cordier et al. 2005; Dickinson 2001). The Society Islands are geographically and politically organized into the geologically younger Windward Group in the southeast and the older Leeward Group to the northwest (Figure 2). The Windward Islands include Tahiti, Moʻorea, Maiʻao, Mehetiʻa, and Tetiʻaroa Atoll. The Leeward Group consists of Raʻiātea, Tahaʻa, Huahine, Bora Bora, and Maupiti, with Tūpai Atoll to the north of the high islands and the atolls of Maupihaʻa, Manuaʻe, and Motu One far to the west. The island of Raʻiātea, located at 16º49'S, 151º25'W and comprising ~150 km^2, is the second largest of the Society Islands after Tahiti and is the largest island of the Leeward Group. Raʻiātea is principally an alkali basaltic shield volcano, with exclusively basaltic pāhoehoe lavas emplaced between 2.75 and 2.52 Ma (K-Ar dating) and the intrusion of chemically distinct trachytic flows in areas such as Tauopu and the central Temehani plateau between 2.54 and 2.44 Ma (Blais et al. 1997). The island is located 220

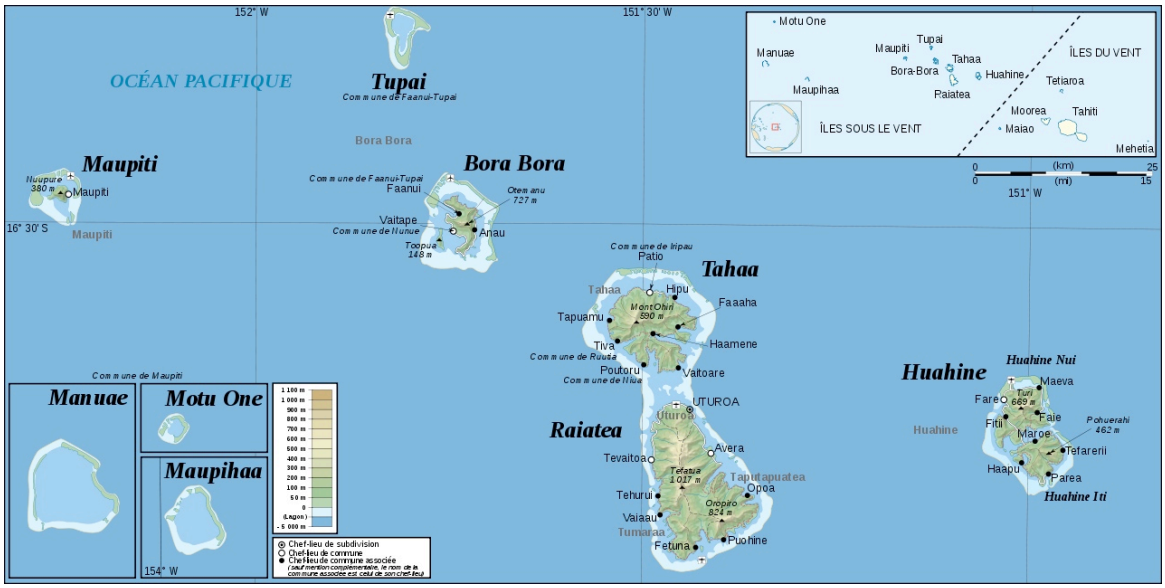


Figure 2. The Leeward Society Islands of French Polynesia (Wikimedia Commons).

km northwest of Tahiti and 350 km northwest from the present locus of the Society Islands hotspot at Meheti‘a, a distance consistent with estimates of 11 cm per year spreading rate for the southern Pacific plate (Blais et al. 1997; Cheng et al. 1993; Cordier et al. 2005).

Dickinson has studied the effects of plate tectonics, volcanism, and eustatic and hydro-isostatic variation in sea level on Pacific islands, contributing to knowledge regarding the stratigraphic position of archaeological deposits in relation to late Holocene hydro-isostatic drawdown and island subsidence (Dickinson 2003, 2004, 2014; Dickinson and Athens 2007; Dickinson and Burley 2007; Dickinson et al. 1994, 1999). Following the mid-Holocene highstand in tropical Pacific sea level, decreases in relative sea level resulting from hydro-isostasy and equatorial ocean siphoning were not uniform among island groups (Dickinson 2001, 2003). The timing of sea level drawdown from a highstand of 1.0 ± 0.1 m is estimated between AD 1-500 for the Society Islands, meaning

that fringing and barrier paleoreef flats at an island such as Raʻiātea would have been exposed by approximately 1500 BP (Dickinson 2003). Dickinson also noted the position of the Leeward Society Islands as geographically beyond the range of flexural upwarp caused by volcanic loading of the oceanic lithosphere at Mehetiʻa. This means that island subsidence at Raʻiātea has been unaffected by local lithospheric upflexure, a situation that potentially places early coastal archaeological sites slightly below modern high tide levels due to a cumulative estimated submergence of <0.4 m over the last millennium from island subsidence, sediment compaction, and modest sea level increase (Dickinson 2001). Projected increases in global sea level will impact the preservation and detectability of archaeological deposits in the future.

Raʻiātea is a high island sharing an extensive barrier reef with the island of Tahaʻa to the north. The lagoon between the two islands creates a refuge from the open ocean and a rich habitat for reef fish and littoral species. Native flora and fauna in the Leeward Group prior to human occupation are believed to be typical of East Polynesian islands, in which deficiencies in terrestrial protein and carbohydrate sources were encountered by early colonists and likely served as a major barrier to be overcome for the successful settlement of East Polynesian islands (Addison 2008; Anderson 2003; Green 1991a, 1991b; Kirch 1997b, 2007a; Oliver 1974). Decreases in biodiversity can be observed along a continuum traveling west to east in the Pacific as the number of floral and faunal species decrease from Near Oceania and West Polynesia to central East Polynesia and the more distant islands of the Hawaiian chain, Rapa Nui, and other outliers (Athens 2009; Hunt 2007; Irwin 2007; Kennett et al. 2006b; Kirch 2010; Steadman 1997).

To compensate for a dearth of terrestrial game, Polynesians transported pigs, dogs, chickens, and rats for consumption throughout Oceania (Anderson 2009; Matisoo-Smith 2009). However, the transformation of Polynesian ecosystems is even more evident in floral communities, where many of the cultivated staples observed at European contact originated from outside the region, evidently introduced following initial human incursion into Remote Oceania (Barrau 1965a, 1965b; Cauchois 2002; Gosden 1992; Hather 1992; Hinkle 2007; Horrocks et al. 2009; Jones and Quinn 2009; Kennedy 2008; Lebot 1999; Zerega et al. 2004). Lepofsky's (2003) review of ethnographic sources and botanical collections details that at European contact, Mā'ohi populations in the Society Islands operated extensive agricultural systems, comprising at least 47 distinct taxa of economic plants and including a variety of non-native cultigens that were imported during the Polynesian voyaging period.

Ra'iātea: Culture

The foundation of Society Islands archaeology is based on early ethnographic observations, oral traditions, and reconstructions from historical linguistics (Beaglehole 1934; Cartwright 1929; Emory 1959, 1963; Green 1966; Handy 1930; Hiroa 1938). Samuel Wallis first approached Tahiti on June 19, 1767 (Henry 1928), after which a succession of European navigators entered the region for activities of trade and conquest. Early accounts from European seamen provide a wealth of information regarding the culture and ecology of Society Islands populations at the time of contact (Beaglehole 1938; Oliver 1974). English missionaries followed shortly thereafter, offering their records of traditional histories and ethnohistorical observations (Ellis 1969; Henry 1928;

Orsmond 1894). Gunson (1963) addressed accuracy and bias in early historical ethnographies of the Society Islands by noting disparities in Tahitian and European sources of cultural information that foster divergent and subjective interpretations of societal development. Regardless of inaccuracies, these records persist as helpful guides for historical reconstruction and archaeological research. Particularly, Teuira Henry's *Ancient Tahiti* (1928) and Douglas Oliver's comprehensive volumes entitled *Ancient Tahitian Society* (1974) have contributed much to Western knowledge of ethnography and history in the Society Islands.

It is from the oral traditions and ethnographies that Raʻiātea emerges as the land of Havaiʻi or Hawaiki Nui, names still used for the island today. Raʻiātea is enshrined as a pivotal location in the cosmogonies of Polynesian peoples and the island is widely accepted as an ancestral homeland for voyaging parties that traveled beyond the archipelago to settle new islands and establish cultural connections throughout the Pacific (Handy 1930; Hiroa 1938; see Kawaharada 1995 and Oliver 1974 for collected stories). Ancient links between island communities are intricately detailed, as illustrated in Henry's (1912) article on the naming of Raʻiātea in which the trajectory of religious-political organization at Havaiʻi is chronicled through the emergence of power at Opoa and the Rotuma-Porapora (Bora Bora) development of the Haufaʻatauaroha (Friendly Alliance) that extended from Raʻiātea to reinforce political alliances throughout East Polynesia.

These original and secondary sources of information have been instrumental to hypotheses of social interaction and the order of island settlement in the Pacific, and many rightly argue for the continued inclusion of oral traditions as a primary component

of historical studies in Polynesia (Anderson 1995; Cachola-Abad 1993; Cauchois 2015; Collerson and Weisler 2007; Finney 1994; Maric and Cauchois 2009; Maric 2016). Though often derided by Western philosophers, oral traditions themselves can become the subject of explanation due to political realities and traditional ecological knowledge presented within the structure of cultural lore. In Polynesia, the knowledge embedded in oral traditions has increasingly been accepted as providing real-world departure points for empirical academic research that often serves to complement indigenous philosophy and culture-specific understandings of history in the region.

Raʻiātea: Archaeology

Polynesian oral traditions served as a departure point for the direct historical approach employed by Emory (1927, 1933), Handy (1930), Hiroa (1938), and colleagues who began with the study of landscape features and the comparison of material culture throughout the Pacific. Tracing the history of pre-contact voyaging populations intensified with archaeological advances in stratigraphic excavation and radiocarbon dating. The research programs of Emory, Sinoto, and Green were instrumental in establishing scientific bases for archaeological inquiry in the Society Islands (Emory 1959, 1962, 1963, 1970, 1980; Green 1961, 1967, 1996; Green and Descantes 1989; Green et al. 1967; Sinoto 1979; Sinoto and McCoy 1975). Green's work at ʻOpunohu, Moʻorea, was among the most productive long-term programs in the Society Islands to date, with decades of intense research by Kirch, Lepofsky, Kahn, Cauchois, and others that have provided the majority of information regarding settlement patterns and human-environmental interactions for this archipelago (Cauchois 2005, 2008, 2015; Descantes

1990, 1993; Kahn 2003, 2004, 2006, 2012; Kahn et al. 2014a; Kahn and Kirch 2014; Kahn et al. 2015b; Lepofsky et al. 1992; Lepofsky et al. 1996; Lepofsky and Kahn 2011; Maric and Cauchois 2009).

Among studies in the Leeward Society Islands are excavations at Motu Paeao, Maupiti, where Emory and Sinoto (1964) uncovered dense cultural deposits containing human burials and an artifact assemblage that supported close associations with Māori (Aotearoa) and Hawaiian collections. Sinoto's (1979; Sinoto and McCoy 1975) work at Vaitoʻotia-Faʻahia, Huahine, also yielded large archaeological collections. Significant among them were components of a large voyaging canoe similar to a specimen recently recovered from New Zealand (see Johns et al. 2014). The work at Maupiti and Huahine contributed greatly to artifact studies, but initial ^{14}C dating that placed the settlement of both Motu Paeao and Vaitoʻotia-Faʻahia in the 9th century AD is problematic due to discordance between estimated date ranges and inter-archipelago artifact comparisons, specimen choice for age determination, and problems with the processing laboratory (Anderson 2001b; Anderson et al. 1999; Anderson and Sinoto 2002; Spriggs and Anderson 1993). Additional dating of these deposits has suggested a period of AD 1400-1450 for interments at Motu Paeao, Maupiti (Anderson et al. 1999), and a period of AD 1050-1450 for marine shell use at Vaitoʻotia-Faʻahia, Huahine (Anderson and Sinoto 2002).

This later time frame of a post-1000 BP human dispersal throughout East Polynesia has been supported by regional syntheses (Allen 2014; Anderson et al. 2003; Wilmshurst et al. 2011). New work at Maupiti has provided information as to the timing of colonization and human impacts on the terrestrial environment, with settlement of the

coastal flats in the 14th century AD (consistent with the Motu Paeao cemetery) and large-scale landscape change from agricultural modification and accompanied colluvial/alluvial sediment re-deposition in the 17th century (Kahn et al. 2015a). These impacts follow a similar, though more recent, course of events evidenced at Mo‘orea in the Windward Group, where anthropogenic effects such as sediment accumulation on coastal flats and the infilling of valley floors appears to have begun between about 460-534 cal BP (Kahn et al. 2015b).

Work on Ra‘iātea has been lacking compared to other islands of the archipelago, with the majority of projects focused on the areas around Fa‘aroa and the site of Marae Taputapuātea at Opoa (Eddowes 2001; Edwards 1990, 1995). Lepofsky (1995) obtained four ^{14}C dates from composite charcoal deposits at Ra‘iātea dating the inception of agricultural practices to approximately 750 ± 60 cal BP at Fa‘aroa Valley on the east side of the island and 470 ± 60 cal BP at Matorea on the west coast. This supported the notion of earlier human impacts in more agriculturally viable areas of the landscape. These dates are congruent with the later period now surmised for East Polynesian expansion, but the absence of a robust chronology of human impacts at Ra‘iātea is of primary concern. Kirch (2010:140) noted that “the large and centrally situated Society Islands archipelago remains a gap in our knowledge of early sites…clearly, more investigation in the Society Islands is warranted.”

The Service de la Culture et du Patrimoine has documented many archaeological features throughout the island (Figure 3), and the ancestral marae of Taputapuātea was confirmed as a UNESCO World Heritage Site of Humanity on July 9, 2017. This



Figure 3. Archaeological features of Ra‘iātea as recorded by the Service de la Culture et du Patrimoine, Bureau Archéologie, Tahiti, with current research area shown in red.

international designation has reinvigorated work in the area (Maric 2016; Valentin *personal communication*). However, the lack of in-depth archaeological investigation at Raʻiātea, particularly on the western side of the island, has left historians to depend on oral tradition as a primary source of information. This lack of empirically defined archaeological knowledge is insufficient for Pacific-wide research interests as well as for local resource management, government planning operations, and the preservation of traditional knowledge in the Leeward Group.

Research Issues and Questions

In this dissertation I seek to address interrelated issues of settlement chronology, land use, human impacts, and the position of Raʻiātean communities in the cultural trajectories of Polynesia. Research questions are addressed through a regional analysis of East Polynesian artifact collections and a multi-year archaeological fieldwork program in the traditional districts of Pūfau, Tuʻu Fenua, and Tevaitoa at Tumaraʻa Commune, Raʻiātea. A regional analysis of related artifact collections serves to position Raʻiātea in the context of regional voyaging and better illustrate the degree to which long-distance voyaging networks allowed Polynesian populations to maintain extensive social ties among distantly located islands. On-island fieldwork at Tumaraʻa serves as a methodological case study for understanding the local cultural activity of Māʻohi populations prior to European contact and the effects of these activities on an archetypal Pacific high island with a barrier reef. Primary research issues include: 1) the position of Raʻiātea in regional voyaging networks, 2) the archaeological visibility of early settlement and valid ^{14}C dating chronologies; 3) spatiotemporal change in land use and

settlement patterns; 4) the relation of geomorphological and paleoecological indicators as evidence for human activity; and 5) anthropogenic impacts on lagoon and coastal environments.

Cultural Transmission and Regional Community Patterning

The colonization of East Polynesia represents the last great human dispersal across the surface of our planet, a demographic expansion made possible by voyaging technology and strategies that effectively erased travel constraints and minimized the costs of long distance travel to new lands. The transmission of cultural knowledge between islands and among island groups is reflected in artifactual evidence and assists in understanding the structure of social networks and the extent of community interaction in the region (Cochrane 2015; O'Connor et al. 2017). How can we map the movement of people throughout the region using empirical artifacts? What do specific artifact attributes tell us about the exchange of cultural information among island populations? What is the position of Raʻiātea and other East Polynesian islands within pre-contact voyaging networks? How do these kinds of analyses inform upon the structure of inter-island communities?

Early Settlement and Radiocarbon Sampling

Radiocarbon samples with inbuilt age (e.g., the "old wood problem") add unknown error to archaeological chronologies. The reevaluation of old ^{14}C dates along with AMS ^{14}C dating of short-lived samples from Polynesian archaeological contexts have consistently narrowed the temporal period between initial human incursion into East

Polynesia and large-scale demographic expansion across all habitable islands of the region (Anderson 1995; Anderson and Sinoto 2002; Kirch 2011; Wilmshurst et al. 2011). Studies of Polynesian expansion typically situate the Society Islands as a dispersal point central to this phenomenon, but recent work supports near contemporaneous settlement for many island groups of East Polynesia in a manner of rapid and continuous dispersal and settlement at variance with models of step-by-step colonization (Allen 2014; Athens et al. 2014; Kahn 2012; Kirch 2010). How does a contemporaneous settlement chronology for East Polynesia fit with the model of the Society Islands as the point of initial colonization? What do earlier dates in the Leeward Society Islands actually mean, and how does this reconcile with the notion of Raʻiātea as a departure point for inter-archipelago voyaging? How can adventive species serve as a proxy for human colonization and the development of a secure chronology?

Land Use and Settlement Patterns

Human-environmental interactions are reflected in patterns of material culture and resource use as evident in the archaeological record. A settlement pattern describes the way in which human populations order themselves across the landscape and spatially organize their lives in relation to daily activities and various elements of the natural environment (Davidson 1969; Green 1967, 1970; Kowalewski 2008; Willey 1953; see Morrison and O'Connor 2015). Research in the Leeward and Windward Society Islands has identified spatiotemporal changes in surface architecture that correspond to variation in subsistence practices and major shifts in sediment accumulation following agricultural intensification (Kahn et al. 2015a, 2015b; Lepofsky and Kahn 2011). Cauchois (2015;

Maric and Cauchois 2009) further documented significant relationships between settlement strategy, resource exploitation, and defensive visibility in geologically and ecologically privileged landscapes. If congruent environmental effects (sediment infilling, biotic shift, etc.) are seen in the archaeological record of diverse regional islands, what does this mean for the littoral zones, coastal flats, and near-shore valleys of leeward Raʻiātea? How do we expect colonizing populations to have modified the landscape upon arrival at Tumaraʻa, and how did they respond to changes in landscape and population needs over time? What does island topography and bathymetry allow us to predict regarding initial settlement and access to necessary resources? How did the configuration of geographic features (e.g., coral reefs, valley slopes and crests) influence societal interaction? What do artifacts tell us about resources, land-use, and community patterning among the Society Islands and beyond?

Geomorphology and Paleoecology

Anthropogenic and natural geographical transformations are inherent to discussions of island archaeology as a basis for understanding deterministic aspects of island geomorphology and the influence of humans on the inhabited environment (Burley 1998; Carson and Athens 2007; Dickinson 2001, 2003, 2004, 2014; Kahn et al. 2015b; Kirch 1996, 1997b; Lepofsky et al. 1996; Thomas 2009). Likewise, paleoecological data from plant macrofossils, archaeofaunal remains, and other paleoenvironmental sources contribute to assessments of human activity at local and regional scales (Anderson 2003; Burney 1997; Fitzpatrick and Keegan 2007; Hunt 2007; Hunt and Lipo 2009; Rick et al. 2013). What were the effects of late Holocene hydro-isostatic drawdown on the local

environment at Raʻiātea? How did this influence the habitability of coastal landforms on the island? How has island subsidence affected the preservation of archaeological deposits, and what environmental elements may have contributed to destruction of the archaeological record? What does variation in the paleoecological record tell us about human behavior and shifts in biome composition following human arrival? Do regional data from pollen cores and other proxy measures fit with archaeological observations at Tumaraʻa?

Human Impacts

Colonization, subsistence practices, and related human-environmental interactions all have effects on the ecosystem. Human populations have been shown to impose variable pressures upon the initial colonization of new lands (Anderson 1995; Hunt and Lipo 2006), and human impacts have been central to archaeological research on the islands of Oceania (Fitzpatrick et al. 2015; Jones 2009; Kirch 2005, 2007a, 2007b, 2010; Kirch and Kahn 2007; Morrison and Hunt 2007; Parkes 1997). Coupled with the intensification of global climate change and disproportionate effects imposed upon Pacific islands and atolls, analyses of island and lagoon ecosystems have been thrust to the forefront of current environmental studies due to 'real life' consequences for current populations and historical connections to ancestral lands and resources.

How do issues of chronology, settlement patterns, and paleoenvironment in the Society Islands contribute to broader assessments of ecological issues in the Pacific? How does research on Raʻiātea complement current information on historical baselines of terrestrial and marine resources? What do studies of subsistence strategies and landscape

modification at Tumaraʻa suggest about past resource use and the potential for future solutions on oceanic islands?

Hypotheses and Expectations

I employ an evolutionary and historical ecology approach for the examination of East Polynesian artifact collections and the analysis of archaeological remains on the west coast of Raʻiātea. Concepts of evolutionary ecology will be incorporated to make sense of the archaeological record and clarify the history of human occupation in this area of the Leeward Society Islands. Hypotheses and archaeological expectations revolve around the structure of cultural transmission among inter-island voyaging populations and the chronological sequence for habitation and human impacts on the local environment at Tumaraʻa deriving from settlement activity, subsistence practices, and resource consumption. Geospatial mapping and targeted subsurface testing will emphasize the location and recovery of ^{14}C samples, floral and faunal remains, and artifacts.

Hypothesis 1: The transmission of cultural information among island communities, as evident in artifact collections, will display patterns of horizontal transmission based on human interaction.

Test: If we are accurately monitoring phylogenetic relationships in the context of highly mobile social interaction, then assemblage relatedness should display patterns of horizontal transmission largely unrelated to other influential factors of sample size and geographic distance (Allen 1996; Cochrane and Lipo 2010). These patterns can be used

to suggest hypotheses of island colonisation and the position of Raʻiātea within East Polynesian voyaging networks.

Hypothesis 2: Radiocarbon dates will support a post-1000 AD chronology for initial settlement at Raʻiātea.

Test: Previous Society Islands work (Anderson and Sinoto 2002; Wilmshurst et al. 2011) suggested an 11th century AD colonization chronology with later inland demographic expansion. Minimization of error between radiocarbon and target events (i.e., short-lived species in stratified cultural contexts) should yield near-shore temporal estimates congruent with this 11th century colonization model prior to inland intensification at Raʻiātea.

Hypothesis 3: Land use and technology patterns in near-shore areas will reflect changes in resource procurement and social interaction.

Test: Local and inter-archipelago Polynesian communities tend toward a dispersed settlement pattern in agreement with economic resource distributions and a great degree of social interaction among agents (Cauchois 2015; Morrison and O'Connor 2015). Settlement pattern imprint and variation in technologies (e.g., fishhooks, lithic tools) should indicate the local expansion of landscape modification and a diversification of technological classes due to *in situ* variation and the introduction of exotic forms.

Hypothesis 4: Subsistence remains will indicate change through time resulting from increases in human predation pressure and the intensification of subsistence strategies.

Test: Subsistence activity has been modeled as an expansion of diet breadth in which human predation pressure on high density/easily accessible species results in the dietary inclusion of less desirable species as primary targets decline (Braje et al. 2007; Erlandson et al. 2009; Morrison and Hunt 2007). Island colonization activities exert immediate environmental impacts that can be monitored through behavioral changes in marine species procurement and the introduction of foreign biota. Variation in exploited floral and faunal remains at Raʻiātea should reflect the stabilization of cultivars and an expansion of utilized faunal species as a consequence of human impacts on the local ecosystem.

Field Methods and Data Collection

A reconnaissance archaeological and landscape survey was completed with permission of the Tavana's office, and field excavations proceeded in cooperation with local Māʻohi professionals and community members. Survey and sediment coring took place at the offshore islets of Horea, Tapute, and Punaeroa and in near-shore coastal flats at Pūfau Bay, Tuʻu Fenua, and Tevaitoa. Seven 1 × 1 m test units were excavated under controlled conditions at the megalithic Marae Tainuʻu adjacent to the Tumaraʻa Commune government offices at Tevaitoa (Figure 4). A single 1 × 1 m test unit was excavated at Domain Dehors. All fieldwork was documented with field notes, photographs, maps, and sketches, with additional imagery recorded with airborne satellite sensors. Test units were excavated in natural stratigraphic layers subdivided into arbitrary levels (e.g., 10 cm). Samples were screened using 6 mm, 3 mm and 1.5 mm mesh screen. Subphreatic samples were wet-screened and dried, with unstable specimens

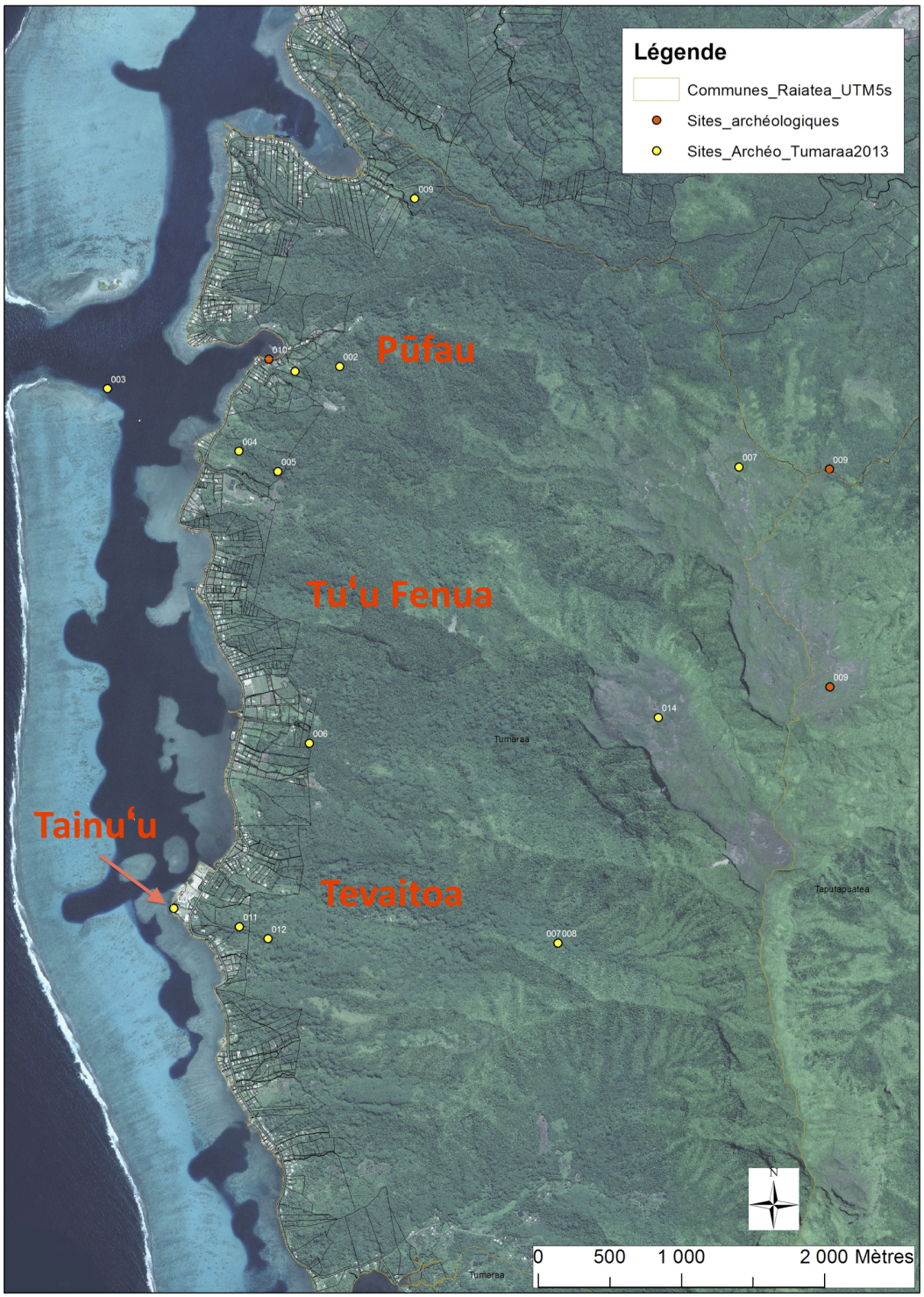


Figure 4. Archaeological features in traditional districts of Pūfau, Tu'u Fenua, and Tevaitoa as recorded by the Service de la Culture et du Patrimoine, Bureau Archéologie, Tahiti.

secured for laboratory transfer and preservation. Materials were catalogued and prepared for curation at facilities approved by the Bureau Archéologie in Papeʻete. Select samples were transported to the University of Oregon for analysis and will later be returned to Tahiti for permanent storage and disposal.

Laboratory Methods

Laboratory work was divided into two phases: 1) the analysis of artifact fishhook assemblages and 2) the analysis of recovered materials from the 2016 and 2017 excavations at Raʻiātea. Morphological variation in artifact fishhooks was analyzed to evaluate specific artifact attributes uncoupled from performance specifications, permitting the observation of design elements that were the product of individual and cultural notions of implement design. Data were created for 1505 fishhooks and fishhook fragments from laboratory and museum assemblages, photographic collections, detailed artist renderings, and previously published material. Published and unpublished collections are held at the American Museum of Natural History in New York, the Bernice Pauahi Bishop Museum in Honolulu, the National Tropical Botanical Garden at Kauaʻi, and the Father Sebastian Englert Anthropological Museum on Rapa Nui. Eighteen archaeological assemblages representing 17 East Polynesian islands were analyzed, including assemblages from the islands of Aitutaki, Bora Bora, Hawaiʻi (Puʻu Aliʻi), Huahine, Kauaʻi (Makauwahi and Nuʻalolo Kai), Maiʻao, Maupiti, Moʻorea, Nuku Hiva, Oʻahu (Kuliʻouʻou), Pukapuka, Raʻiātea, Rapa Nui, Tahaʻa, Tetiʻaroa, Tubuaʻi, and Ua Huka. Artifact class similarity matrices were created based on similarity coefficients to control for sample bias, and matrices values were tested against geographic distance

using unweighted pair group method using arithmetic averages in BIOMstat 3.3 (Rohlf & Slice 1999) statistical software. Chapter III of this dissertation includes previously published co-authored material.

Laboratory work and data creation for archaeological and paleoecological specimens from fieldwork at Raʻiātea took place on-island at field facilities at Tumaraʻa Commune, at Service de la Culture et du Patrimoine facilities in Papeʻete, Tahiti, and at the Island and Coastal Archaeology Laboratory at the University of Oregon. All excavated materials were sorted and quantified by general class. Select lithic materials, archaeofaunal remains, floral macrofossils, and carbonized samples were transported to the University of Oregon for analysis. Artifacts (e.g., lithic and faunal tools) were analyzed in preparation for possible chemical testing and comparative studies with East Polynesian collections at the Musée de Tahiti et des Îles te Fare Manaha, Tahiti, and the Bernice Pauahi Bishop Museum, Oʻahu. Invertebrate and vertebrate remains were identified to genus and taxon, when possible, using photographic collections and comparative collections at the aforementioned institutions. Zooarchaeological remains were quantified according to the number of individual specimens (NISP) and minimum number of individuals (MNI) where feasible (Grayson 1984; Jones and Quinn 2009), though MNI classification was largely impossible due to the nature of recovered deposits. Bulk sample weights for general faunal classes were recorded according to stratigraphic layer and level. Carbonized samples were selected for temporal testing based on availability and contemporary dating protocol (Allen and Huebert 2014; Wilmshurst et al. 2011), and all samples were submitted for AMS ^{14}C dating at DirectAMS in Seattle, WA. Geospatial mapping and image creation took place at field facilities at Raʻiātea and at the

University of Oregon. The Service de l'Urbanisme Polynésie Française provided geospatial data for this project in the form of digital elevation models and geographic information system shapefiles for mapping and future landscape analysis of Raʻiātea.

Research Schedule

This dissertation describes the results of the first several years of a long-term collaboration with French Polynesian colleagues and the local communities of Tumaraʻa Commune, Raʻiātea. I served as Principal Investigator and Project Director for all permits, research activities, and publications. Pre-excavation artifact classification and network analysis took place in 2015-16 at the Bernice Pauahi Bishop Museum at Oʻahu and the University of Oregon, resulting in a 2017 journal publication in *Archaeology of Oceania* with Frances White and Terry Hunt as co-authors (O'Connor et al. 2017). The 2017 publication comprises the majority of Chapter III of this document, with background information added to better contextualize the research and relate the regional study to the local fieldwork that followed. The study of cultural transmission among island communities in East Polynesia better illuminates the history of extreme mobility and inter-island voyaging prior to European contact in the region. The island of Raʻiātea is integral to these voyaging networks and the establishment of sociopolitical alliances throughout the Pacific region.

O'Connor's September 2015 trip to Raʻiātea involved a reconnaissance survey of the island and formal meetings with government officials and community members who expressed overwhelming support for archaeological research in Tumaraʻa commune. Initial fieldwork planning took place in collaboration with Hinanui Cauchois of Pūfau

and Tavana (mayor) Cyril Tetuanui of Tumaraʻa. Tamara Maric of the Service de la Culture et du Patrimoine, Bureau Archéologie, Tahiti, assisted with excavation permits for invasive fieldwork beginning July 2016. The 2016 field season included sediment coring at offshore motu and on-island coastal locations, followed by controlled subsurface testing at Marae Tainuʻu. The 2017 field season involved continued testing at Marae Tainuʻu and inland valley locations, as well as the facilitation of an island-wide cultural day event at the marae. A component of the 2017 field season was my direction of an archaeological field school and cultural immersion program for University of Oregon students in the island of Raʻiātea. Laboratory work, writing, teaching, academic lectures, and public outreach have been ongoing components of this research project. Subsequent academic publications will follow completion of this dissertation.

Intellectual Merit

Despite their centrality, the Society Islands have remained a lacuna in East Polynesian archaeological research (Cauchois 2015; Kahn 2012). The study of social networks and historical ecology at western Raʻiātea will fill significant gaps in the knowledge of central East Polynesian prehistory. Oral histories remain strong in the traditional districts of Raʻiātea, but a comprehensive archaeological study is necessary to refine chronological estimates of human arrival and subsequent impacts on the island's ecology. At the local level, this study will lay the groundwork for cultural resource preservation and provide a definitive outline of human-environmental interaction that will be used as an educational tool for the local community and a reference for government land management. Regionally, this work will serve to integrate Raʻiātea into the

archaeological settlement model of the larger Society Islands archipelago, a necessary charge given the importance of the island to the Polynesian people and the cultural history of Oceania.

Broader Impacts

Archaeological research at Raʻiātea, a small island in the southern Pacific Ocean, has far-reaching implications for human ecology and the study of human impacts on maritime and island terrestrial environments. Humans have had a disproportionate impact on our planetary ecosystem through resource extraction and ecosystemic manipulation (Jackson et al. 2001; Rick et al. 2013). Engaging archaeology as historical ecology, researchers can provide insight regarding historical baselines of environmental health through paleoenvironmental data from archaeological deposits. Work at Tumaraʻa, Raʻiātea, will contribute to discussions of lagoon and landscape change on oceanic islands. This is of primary importance for islander communities because providing empirically grounded assessments of past environmental circumstances assists in creating models for environmental rehabilitation and the preservation of cultural and natural resources in low-lying coastal areas. In the face of projected global rises in sea level (Mengel et al. 2016), now is the time to increase our knowledge base in Pacific Islands archaeology and work with interdisciplinary networks for a better understanding of the ocean world that is our planet.

CHAPTER II

RA‘IĀTEA IN CONTEXT: THE COLONIZATION OF OCEANIA

The colonization of the Pacific Islands represents a remarkable feat of humanity and the final geographic extension of *Homo sapiens* beyond the confines of continental ecosystems to the marine worlds that comprise Oceania. While much archaeological interest has focused on the terminus of human dispersal in the islands of Micronesia and Polynesia (Allen 2014; Fitzpatrick et al. 2003; Goodwin et al. 2014; Hunt 2007; Intoh 1997; Kirch 2011; Kirch and Kahn 2007; Spriggs and Anderson 1993; Weisler et al. 2012), initial human incursions into the Pacific Islands began during the Pleistocene with movements of anatomically modern humans into what are now Island Southeast Asia (ISEA), New Guinea, Australia, and Near Oceania (Anderson and O’Connor 2008; Bulbeck 2007; Codding et al. 2014; Kayser 2010; Kirch 2010; O’Connell and Allen 2012; Reepmeyer et al. 2011; Stoneking and Delfin 2010).

The antiquity of population dispersals over this vast portion of the earth’s surface suggests the human experience of geographical and biological environments very different from those encountered by their descendants over subsequent generations (Allen and O’Connell 2008; Bird et al. 2005; Ono et al. 2009; Woodroffe 1993). Sea-level fluctuations, tectonic and volcanic activity, tsunamis, catastrophic storms, and global climate change all affected the stability of regional ecologies over tens of thousands of years on the margins of the western Pacific Ocean. Additionally, the gradual exposure of early colonizing populations to new and diverse habitats influenced the development of subsistence strategies and the ways in which early populations traversed terrestrial and

aquatic landscapes. This chapter describes the history of the dispersal of *H. sapiens* populations in ISEA and Oceania as a background discussion for ocean voyaging and the human colonization of Raʻiātea and East Polynesia.

Sunda and Sahul

The journey of humans into the Pacific begins with the expansion of hominin species into East Asia and contemporary ISEA beginning approximately 2.0-1.6 million years ago (Ciochon and Bettis 2009; Moore and Brum 2007; Swisher et al. 1994). Paleoanthropological excavations at Sangiran in the Solo Basin on the island of Java have revealed *Homo erectus* remains in sediment deposits ranging from 1.6-0.9 million years old based on the $^{40}Ar/^{39}Ar$ dating of associated volcanic heavy minerals (Zaim et al. 2011). The timing of initial hominin expansion in Southeast Asia, around 1.66-1.57 million years ago, correlates with an extended period of drier environmental conditions in ISEA. Riverine, marsh, and lake-edge habitats persisted throughout the region, with vast expanses of dryland savanna in better drained parts of the landscape. The most significant aspect of the environment at this time is that many of the islands of ISEA were not islands. Rather, fluctuations in Pleistocene eustatic sea-level exposed vast expanses of continental crust incorporating subregions of present-day islands such as Borneo, Sumatra, Java, and portions of the Philippine Archipelago, into a large emergent landmass referred to as Sunda.

The appearance of a central savanna corridor extending from Southeast Asia through the middle of Sumatra and Borneo is believed to have served as a primary migration route for grassland-adapted terrestrial species during glacial periods ranging

from the early Pleistocene through the Last Glacial Maximum (LGM, ca. 20,000 BP) (Bettis et al. 2004; Bird et al. 2005; Zaim et al. 2011). Interglacial periods of elevated sea-level contributed to a dynamic and changing landscape with the alternating emergence and submergence of landbridges and coastal landforms in the Sunda region, perpetuating the opening and closing of discrete subregions and the corresponding accessibility and seclusion of local floral and faunal species (Bulbeck 2007; Reis and Garong 2001). Sea-level fluctuations and related changes in land area through time have contributed substantially to the divergent evolution of plant and animal species throughout the region, contributing to a wide spectrum of biodiversity that can be witnessed today.

The Pleistocene emergence of Sunda as an extension of the Southeast Asian continental landmass occurred simultaneously with the exposure of large landbridges extending northward and southward from Australia to incorporate New Guinea and Tasmania, respectively, as well as other nearby islands. This larger island-continent is referred to as Sahul, and appears as a historical complement to Sunda in the geological and environmental literature (Langley et al. 2011; O'Connell and Allen 2004; Woodroffe 1993). For millions of years Sunda and Sahul have been exposed above the surface of the ocean to varying degrees due to sea-level lowstands of as much as 120 meters below present based on LGM bathymetric estimates (Allen and O'Connell 2008; Bird et al. 2005). However, extended periods of glacio-eustatic depression in sea-level still left a ~1500 kilometer expanse of water between the two landmasses (O'Connell et al. 2010). Therefore, the eastern boundary of Sunda defines the extent of unimpeded migration for terrestrial species during periods of low sea-level and represents a substantial natural

barrier for species diversity. Referred to as Wallace's Line after famed naturalist Alfred Russell Wallace, this aquatic perimeter extends from between Bali and Lombok in the south, northward between Borneo and Sulawesi, and terminating at the water passage between the island of Palawan and the other Philippine Islands (Green 1991b; Irwin 2007; see Mayr 1944 regarding biogeographical variation and later adjustments of this zoogeographic demarcation). Lydekker's Line is the corresponding designation for the extent of Sahul species diversity that follows the western coastline of Australia and New

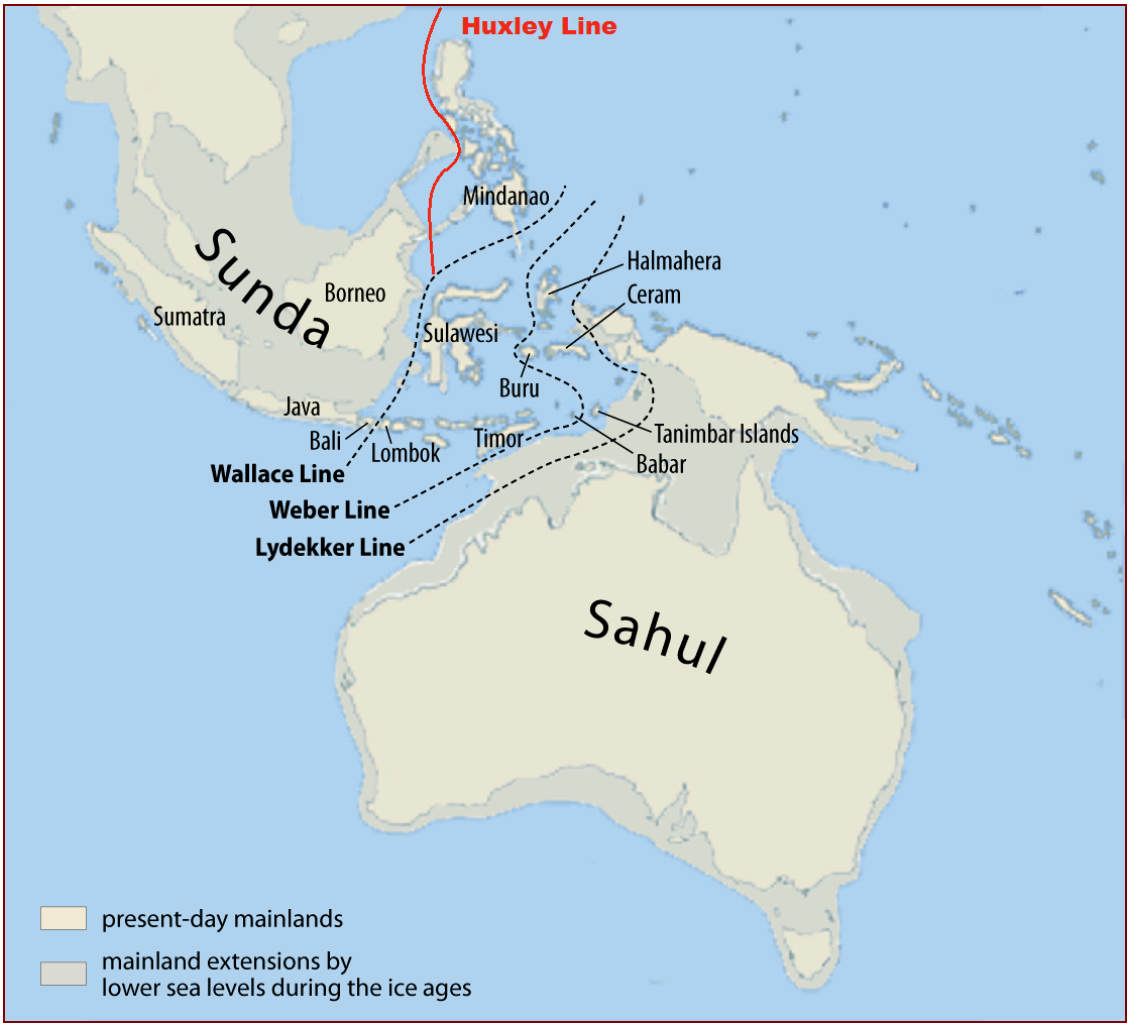


Figure 5. Map of Sunda and Sahul (Wikimedia Commons).

Guinea. All islands between these biogeographic boundaries, including the Lesser Sunda Islands, Maluku, and the Sulawesi subregion, are referred to as Wallacea (Carstensen et al. 2012). The protracted time-depth of evolutionary divergence between mammal species in the Sunda and Sahul bioregions is evidenced by Wallace's Line serving as the eastern boundary for placental-dominated ecosystems and Lydekker's Line serving as the western boundary for the marsupial-dominated ecosystem observable in modern Australian faunal diversity (Cooper and Stringer 2013).

The expansion of *H. sapiens* into East Asia and farther southward through the Sunda region is estimated to have begun with population movements out of Africa sometime between 75,000 and 60,000 years ago (Bulbeck 2007; Stoneking and Delfin 2010). The timing of early *H. sapiens* population dispersal derives from genetic mapping primarily based on the spatiotemporal modeling of mitochondrial DNA (mtDNA) and non-recombining Y-chromosome (NRY) lineage distributions. The genetic picture of East Asia is rather convoluted due to approximately 60,000 years of population dispersal, migration, and interbreeding among *H. sapiens* populations and between *H. sapiens* and other ancestral hominin species (Cooper and Stringer 2013; Reich et al. 2011). There has been some consensus regarding a southern route for human dispersal out of Africa, in which colonizing populations followed the northern rim of the Indian Ocean in an eastward advance toward Southeast Asia (Erlandson and Braje 2015; HUGO 2009; Mellars et al. 2013; Pope and Terrell 2008; Stoneking and Delfin 2010). However, this has been contested by other workers who view coastal ecology as a barrier to the geographical advancement of human populations along the coastlines of southern Asia (Boivin et al. 2013; Field et al. 2007).

Macaulay et al. (2005) reconstructed the phylogeny of mtDNA sequences from Southeast Asian populations for comparison to other Eurasian and Australasian genome data. Temporal estimates for coalescence among founder haplotypes for all regions and the geographic distributions of M, N, and R mtDNA haplogroups show divergence from an ancestral East African L3 haplogroup after 85,000 years ago (Macaulay et al. 2005). These results support the exodus of a single founder population from Africa ca. 85,000-70,000 years ago, the subsequent branching off of a Eurasian founder population, and then a rapid coastal dispersal after 65,000 BP from the littoral Indian Ocean to Southeast Asia and the Sunda region. A southern dispersal route out of Africa followed by a predominant south-to-north population expansion in East Asia was later supported through a massive survey of genotypic variation in Asian and ISEA populations (Field and Lahr 2005; HUGO 2009).

According to the temporal scenario outlined above, the movement of human populations into the region of Southeast Asia occurred at the same time that sea-level was declining from a ca. 125,000 BP interglacial highstand, estimated as comparable to modern sea-level, toward the -120 meter glacio-eustatic lowstand of the LGM (Bird et al. 2005: Pope and Terrell 2008). Sunda and Sahul were approaching the maximum extent of subaerial exposure at a time when human populations became archaeologically visible in the region. Existing environmental circumstances may have provided a greater opportunity for terrestrial dispersal and migration than would be possible today. However, there were four instances of sea-level rise between 60,000 and 40,000 years ago during which variation in coastal morphology and continental land area would have contributed to periods of long-term environmental fluctuation prior to continued sea-level

decline (Allen and O'Connell 2008). Interestingly, the presence of human groups on the Sunda shelf is nearly contemporaneous with the appearance of human activity in Wallacea and Sahul where the earliest archaeological deposits date to approximately 45,000 years ago (Ford 2011; Hill et al. 2007; Kealy et al. 2016; Langley et al. 2011; O'Connell and Allen 2004; Ono et al. 2009; Pawlik 2012).

Kayser (2010) noted that except for Niah Cave on Borneo and similar contexts on the island of Palawan, the oldest securely dated sites in the region appear beyond the continental barrier of Wallace's Line, although sampling is likely impacted by Holocene sea-level rise (see Barker et al. 2007, Mijares et al. 2010, and Pawlik 2012 for reviews of early Borneo and Philippine settlement chronologies). Reepmeyer et al. (2011) have recovered evidence of long-duration lithic manufacture from Jerimalai shelter in East Timor, with the modification of local and imported lithic materials dating to as early as 42,000 cal BP. Associated deposits have revealed evidence for the extensive exploitation of marine faunal species also dating to this period at Jerimalai (O'Connor et al. 2011). Large assemblages comprising lithic artifacts, fishhooks, and shell beads have been recovered with the remains of marine fish and turtles, signifying a sustained maritime subsistence economy persisting for many millenia. Summerhayes et al. (2010) suggested dates of 49,000-44,000 cal BP for initial colonization of the Ivane Valley of highland eastern New Guinea based on thermoluminesence dating of lithic artifacts, radiocarbon age determinations from carbonized plant foods (*Pandanus* and *Dioscorea* spp.), and subsequent increases in charcoal particulate concentrations (see Ford 2011 regarding Ivane lithic manufacture). O'Connell and Allen (2004) reviewed dozens of archaeological sites in Sahul that are estimated to predate 20,000 BP, with particular

focus on >45,000 BP sites in New Guinea and northwest Australia. While retaining a skeptical view of previously determined settlement chronologies, O'Connell and Allen show that numerous sites provide reliable evidence of human occupation prior to 40,000 BP.

It is important to briefly note the presence of a 'relict' hominin species discovered in Late Pleistocene deposits on Flores Island in Indonesia. Skeletal remains, lithic artifacts, and associated faunal remains serve as evidence for a species named *Homo floresiensis* that successfully traversed the water beyond Wallace's Line prior to the presence of *H. sapiens* in the region (Morwood et al. 2004; Moore and Brum 2007). Non-rchaeological deposits at Liang Bua on Flores Island were originally suggested to be between 95,000 and 12,000 cal BP, with lithic artifacts ranging from approximately 190,000 to 50,000 BP, based on stratigraphic evidence and the dating of associated charcoal and faunal remains (Morwood et al. 2004). Recently, the chronology for these deposits has been revised with the $^{234}U/^{230}Th$ dating of *H. floresiensis* skeletal elements in combination with infrared stimulated luminescence (IRSL) and thermoluminescence (TL) of associated sediment samples. This chronological revision places *H. floresiensis* at Liang Bua between 100,000 and 60,000 cal BP, with artifact evidence extending to as recent as approximately 50,000 BP (Sutikna et al. 2016; Sutikna et al. 2017). This revised chronology shows the movement of this species into Wallacea prior to that of *H. sapiens* and the disappearance of archaeological evidence for *H. floresiensis* at Flores Island at time nearly coinciding with the sustained arrival of anatomically modern humans in the region.

The modern human colonization of Sahul by at least ca. 45,000 BP (O'Connell et al. 2010) and the presence of early archaeological deposits in places such as the Talaud Islands (35,000-32,000 BP; Ono et al. 2009) and Gebe Island in Maluku (32,000-28,000 BP; Szabo et al. 2005) support a scenario of archaeologically rapid *H. sapiens* population dispersal throughout the region. Except for the *H. floresiensis* population on Flores Island (Sutikna et al. 2017), there had been no prior hominin intrusion into Wallacea. Indications of human occupation in Wallacea and Sahul within a time-frame coeval with the initial arrival of humans in Southeast Asia illustrate the ability of human populations to effectively negotiate water crossings of substantial distance at this time. Furthermore, the presence of Pleistocene deposits in both coastal and inland habitats emphasizes the ability of populations to adapt and survive in a diversity of environmental circumstances (Langley et al. 2011).

Pope and Terrell (2008) write that the spread of modern humans into Australasia between 47,000 and 40,000 BP coincided with a particularly warm and wet interval, with increased temperatures and summer monsoons as a partial result of an extended period (ca. 55,000-35,000 BP) of decreased El Niño-Southern Oscillation (ENSO) events (see Pope and Terrell 2008 for a comprehensive review of Pleistocene and Holocene coastal climate data). This period of increased precipitation and lower sea-level likely bolstered inland reservoirs and fostered the colonization of continental interiors. Debates of behavioral modernity have largely been settled due to the recognition of complexity in regional tool kits and taphonomic issues affecting previous assessments of 'archaic' humans (Langley et al. 2011; Pawlik 2012; Szabo et a. 2005). Yet, questions have lingered over the subjects of intentionality in voyaging, watercraft technology, and the

actual route taken by the first human groups dispersing to Sahul (Anderson 2000; Birdsell 1977; Butlin 1993; Calaby 1976; Erlandson and Braje 2015; Smith 2001).

Allen, Hawkes, and O'Connell address issues of Pleistocene seafaring, arguing that the swift diffusion of colonizing populations through mainland Southeast Asia, across Wallacea, and into Australia and New Guinea was the result of deliberate migrations involving the participation of substantial human populations with relatively sophisticated watercraft (Allen and O'Connell 2008; O'Connell et al. 2010). O'Connell and Allen (2012; see also Erlandson 2010) summarize the archaeological data supporting their argument, including the narrow time range for the movement of *H. sapiens* through Wallacea, across Sahul, and into the Bismarcks; the time depth of shared genetic variation in Australian and New Guinean populations and the diversity of mtDNA haplogroups (see van Holst Pellekan 2013); and the evidence of human colonization on other islands (e.g. Japan ca. 42,000-40,000 BP) that would have required watercraft. Bulbeck (2007) framed discussion of the coastal 'out of Africa' dispersal in a context of resource use and innovation. He contends that the exploitation of estuarine resources by migrating populations would have facilitated watercraft experimentation and coastal exploration as they moved eastward along the rim of the Indian Ocean (see Erlandson 2001, 2010; Erlandson and Braje 2015; Erlandson et al. 2007 for further discussion of seafaring and maritime dispersals).

The confluence of technological development and specialization in tropical estuarine habitats would have created a situation in which groups could increase their mobility, resource extraction, and overall speed of movement through water travel while decreasing risk by avoiding unknown or less desirable habitat patches. Citing oscillating

sea-level between 60,000 and 40,000 BP (Butlin 1993; Pope and Terrell 2008), Allen and O'Connell (2008) also hypothesize periods of heightened seastand as times of watercraft innovation.

It is important to remember that regardless of sea-level (estimation of -30 to -60 meters at the time of Sahul colonization; see Allen and O'Connell [2008:32] for map with 50 meter and 120 meter bathymetric contour), all water routes to Sahul would have involved at least one open water crossing of 90 kilometers and often multiple others for both a northern and a southern route. Irwin (1992) created intervisibility models for northern and southern routes from Sunda to Sahul that show the ability of human settlers to perceive voyaging direction based on land-visibility during passage from one island to the next across Wallacea. Irwin examined both a northern route through Sulawesi and Halmahera to the western tip of New Guinea (Birdsell 1977) and a southern route through Timor to northwestern Australia (Butlin 1993), with the model favoring the northern route due to unbroken visibility (see Irwin 1992:21 for visibility diagram). Allen and O'Connell extend the notions of intentionality, prior seafaring knowledge, and Irwin's support for the northern colonization route in the context of a behavioral ecology model where technological development is tied to necessity, and foraging-patch choice provides the impetus for dispersals (Allen and O'Connell 2008; O'Connell and Allen 2012). While arguing for the deliberate colonization of Sahul, they contend that settlement was a component of a foraging strategy with varying investment in watercraft technology in relation to environmental parameters. The northern route shown by Irwin would have provided opportunity for two-way voyaging, and colonizing populations could have

moved swiftly through Wallacea and Sahul, proceeding from one high-ranked resource patch to the next, thus traversing the entire region within an archaeologically brief period.

Making the connection between technology and subsistence strategy furthers understanding of population dispersal in a way that somewhat removes the notion of intention from discussion and resets the debate in terms of how people adapted to their surroundings in these new island worlds. Populations are seen to spread or contract through time and space in concert with climatic variation. Consequently, this model moves toward an explanation for why the seafaring ability so necessary to the initial colonization of Sahul persisted in areas of need (i.e., the Bismarck Archipelago) while gradually diminishing in other habitats (i.e., Australia) (Erlandson 2001, 2010; O'Connell and Allen 2012).

Holocene Dispersals and Maritime Voyaging

Initial settlement of Sahul was followed by the rapid movement of people to the continental interior of Australia and New Guinea, as well as gradual dispersal among the islands of Wallacea and expansion to the eastern locales of the Bismarck and Solomon Islands prior to 30,000 BP (Irwin 1992; Kirch 2000; Pavlides and Gosden 1994; Wickler and Spriggs 1988). The review of Pleistocene migrations provided above is necessary to understand the environmental context of human expansion into the area known as Near Oceania. Near Oceania refers to a maritime world encompassing the mostly intervisible continental islands west of the Reef/Santa Cruz Group. It is here to which human interaction was confined until the late-Holocene expansion of Austronesian speaking peoples beyond the sheltered voyaging corridors of New Guinea, the Bismarcks, and the

central Solomon Islands into the widely dispersed islands of Remote Oceania, the Pacific region where sailing vessels, open-ocean navigation, and domesticated plants and animals were required for survival (Green 1991b; Irwin 1998; Sheppard 2011).

Throughout the terminal Pleistocene, human populations in Near Oceania stabilized as coastal habitats were subjected to a sustained global rise in sea-level from the glacio-eustatic lowstand of the LGM toward modern levels. Air temperature and precipitation were variable in Southeast Asia and Near Oceania, with fluctuation between the warming of the Bölling-Alleröd event (ca. 14,000-12,500 BP) and the cooling of the Younger Dryas (ca. 12,500-11,500 BP) (Pope and Terrell 2008). Contrary to increases in monsoon precipitation for mainland Asia at the Pleistocene/Holocene boundary, there is a peak in ENSO activity between 12,000 and 10,000 BP that would have contributed to prolonged dry periods in the western Pacific (Beaufort et al. 2001). Increases in warm and wet conditions resumed for Near Oceania in the early Holocene, transitioning to a period of peak temperature and precipitation during the mid-Holocene climatic optimum (ca. 7000-4000 BP) as the land of Sunda was submerged and permanently transformed from a continental landmass to the islands of Southeast Asia. It is in this time period of many millennia that a sustained voyaging culture developed among the islanders of the present-day Philippines, ISEA, and the Wallacea-New Guinea region, eventually leading to the long-distance interaction spheres and cultural transmission networks predominantly studied by archaeologists.

Below I will discuss Holocene cultural development in Near Oceania as understood through the archaeological record, with a focus on the origin of Austronesian voyaging groups, the phenomenon known as Lapita, and the movement of people to the

perimeter of the oceanic world just prior to expansion into Polynesia and Central Micronesia (see Figure 1 for reference). The focus of archaeological research on Holocene populations is a natural result of empirical inquiry and archaeological visibility due to the increased temporal proximity, improved taphonomic preservation, and enhanced capacity for environmental analogy as one approaches the present time. However, the past 10,000 years were a period of rapid change for humans, particularly with regards to Pacific expansion and the exploitation of island environments (see Erlandson 2001; Erlandson and Fitzpatrick 2006; Erlandson and Rick 2008; and Rick et al. 2013 for global reviews of anthropogenic impacts on island ecosystems).

In Near Oceania, much of this focus has been on the origin of Austronesian language speakers and the expansion of associated cultural and biological characteristics across a large portion of the world's oceans (Anderson and O'Connor 2008; Athens et al. 2008; Bellwood 1995; Bulbeck 2008; Carson et al. 2013; Clark and Bedford 2008; Donohue and Denham 2010; Hill et al. 2007; Kayser et al. 2008; Kirch 2010; Oppenheimer and Richards 2001; Terrell 2004; Xu et al. 2012). Support for these models of cultural expansion derives from the wide-ranging linguistic similarity among Pacific Islanders recognized by Europeans upon entrance into the Pacific theater. Dutch traders documented linguistic similarity among Indonesian populations as early as the 1600s, and later visits from Captain James Cook and Wilhelm von Humboldt initiated the collection of linguistic data that serve as the foundation of Pacific dispersal research and continue to influence historical studies today (Blust 1995; Irwin 2007). The term 'Austronesian' was first used in 1906 by Wilhelm Schmidt to describe the language family now recognized to include roughly 1000 languages and dialects geographically extending from Madagascar

in the west to Rapa Nui in the east (Blust 1995). Research in comparative-historical linguistics and lexical reconstruction has created a relatively robust model for Austronesian language expansion that traces Proto-Austronesian origins to the island of Taiwan between approximately 6000 and 5000 BP (Gibbons 2001; Gray et al. 2009; Greenhill and Gray 2005; Pawley 2010).

As Pacific archaeology increased in the 20th century, observation of an abrupt change in the archaeological signatures of the Bismarck Archipelago became visible with the emergence of a unique pottery design beginning approximately 3500 years ago that was perceived to correlate with apparent changes in tool kit technology, settlement patterns, and subsistence practices (Anderson and O'Connor 2008; Denham et al. 2012; Kirch 2010). These changes in material culture were directly related to the human populations that then voyaged beyond Santa Cristobal Island of the central Solomons to Vanuatu, New Caledonia, Fiji, and onward into West Polynesia; a cultural group collectively referred to as 'Lapita' based on the ceramic style that serves as their primary designating archaeological feature (Bedford et al. 2007; Burley 1998; Butler 1994; Cochrane et al. 2011; Davidson 1977; Green 1991; Rieth and Hunt 2008; Shaw et al. 2009; Sheppard 2011; Terrell and Schecter 2007; Valentin et al. 2010). The distinct dentate-stamped pottery style (see Figure 6) associated with these archaeological deposits was given the name Lapita after the site of E. W. Gifford's excavations on the Kone Peninsula of New Caldeonia (Kirch 1997a).

Strikingly, it is during the period of Lapita's appearance in the Bismarck Archipelago that Pacific voyagers first travelled beyond the Andesite Line, penetrating deep into Remote Oceania with the colonization of the Mariana Islands ca. 3500 BP



Figure 6. Example of dentate stamped Lapita pottery artifact (photograph courtesy of the Bernice Pauahi Bishop Museum).

followed by Palau and the Marianas after 3300 BP (Athens at al. 2008; Callaghan and Fitzpatrick 2008; Carson 2012; Clark et al. 2006; Clark et al. 2010; Fitzpatrick and Donaldson 2007; Intoh 1997; Kirch 2010). The dispersal of Austronesian-speaking peoples to the true oceanic islands of Western Micronesia signified their ability to successfully traverse thousands of kilometers of open sea (Anderson and O'Connor 2008; Fitzpatrick and Callaghan 2013). The co-occurence of initial open-ocean voyaging and the appearance of discernible changes to maritime culture farther south in the region of New Guinea adds weight to the notion of a developing voyaging culture among the islands of Near Oceania with the potential for wide-ranging seafaring and unprecedented exploration. The association of reconstructed language dispersal routes, mid-Holocene agricultural change in Taiwan and the northern Phillipines, and expanded voyaging perimeters, all in combination with archaeological evidence supporting the incursion of cultural traits into ISEA and Near Oceania during the mid- to late-Holocene, has promoted the view among some researchers of a unified Neolithic cultural package (Bellwood 1995, 2005; O'Connor 2006; Pawley 2007).

The general model, dubbed 'Out of Taiwan,' posits the southward expansion of Austronesian-speaking agriculturalists from Taiwan to the Philippines ca. 4,500-4,000 BP through Indonesia and into the Pacific Islands (Specht et al. 2014). This model is often presented as a variation of the 'early farming dispersal hypothesis' in which the adoption and spread of agriculture, in this case rice production from mainland Asia to Taiwan, precipitated human population and language dispersal from identifiable agricultural homelands (Bellwood 2005). Over several decades, 'Out of Taiwan' has assumed the role as the default argument for Lapita origins and the basis for the Austronesian diaspora (Bellwood 1984-1985, 2011; Diamond 1988; Shutler and Marck 1975).

A link between the Austronesian language family and the island of Taiwan is hardly opposed, though some researchers have taken a harsher stance than others regarding the importance of Taiwan as a source for Austronesian linguistic diversity (Donohue and Denham 2010; Oppenheimer and Richards 2001). However, the 'Out of Taiwan' model for the mid-Holocene dispersal of a Neolithic cultural package has been widely criticized on the grounds of substantial archaeological, genetic, and subsistence-related evidence (Bulbeck 2008; Dobney et al. 2008; Green 2000; Hill et al. 2007; Kennedy 2008; Soares et al. 2011; Specht et al. 2014; Terrell 2004). One of the primary problems is that the concept of a Lapita cultural complex was developed while largely ignoring the prior archaeological history of New Guinea and the Bismarck and Solomon Island chains. In reality, there was no cessation of human activity with the onset of the Holocene, and archaeological research has determined the continued use and distribution of certain resources, notably lithics, among the Bismarcks, Solomons, and northern New Guinea for many millenia prior to the appearance of Lapita ceramics (Fredericksen 1997;

Summerhayes and Allen 1993; Torrence et al. 2013; Torrence and Swadling 2008; Wickler and Spriggs 1988). Lithic networks originating in the terminal Pleistocene, particularly the wide-spread distribution of volcanic glass from sources in New Britain and the Admiralty Islands, are seen to have persisted well into the Lapita period and expanded along with the increased range of Pacific voyaging at that time (Green 2000; Reepmeyer et al. 2010; Summerhayes 2003, 2004).

However, the introduction of Lapita pottery to the archaeological record of Near Oceania and its rapid dispersal through the efforts of highly mobile oceanic voyagers does indeed signal an incursion of ideas and an association between specific forms of material culture and the wide-ranging ability of Pacific seafaring. Denham et al. (2012) estimated the first appearance of the Lapita pottery style on the island of Mussau at 3470-3250 cal BP through a comprehensive review of available dates analyzed in a Bayesian chronological framework. This pottery style appeared in archaeological deposits in the rest of the Bismarcks at 3360-3240 cal BP, the islands of Vanuatu at 3250-3100 cal BP, and Fiji by 3130-3010 cal BP (Denham et al. 2012). After a period of approximately 150 years, imported Lapita pottery appears at Nukuleka on the island of Tongatapu at 2863-2835 cal BP, and this ceramic style subsequently appears in archaeological deposits associated with the northward movement of initial colonizing populations through the Tongan Islands and terminating in Sāmoa by approximately 2700 BP with a single deposit of Lapita decorated ceramics at Mulifanua on the island of ‘Upolu (Burley et al. 2015; Rieth and Hunt 2008).

The colonization of Tonga and Sāmoa by Austronesian voyagers typically represents the extent to which Lapita-associated populations dispersed in the Pacific, as

the presence of dentate-stamped design quickly disappears from the ceramic record after this time and ceramics nearly completely disappear from much of Remote Oceania in later times. The association of Lapita dispersal in Remote Oceania with the very similar forms of indigenous Austronesian languages spoken in these regions today provides evidence of a historical connection between these ancestral elements of Oceanic culture.

Decorated pottery has been recovered from over 200 sites throughout the Lapita voyaging sphere (Specht et al. 2014) and ceramic variability has been analyzed in detail to provide insight as to the origins of design and the uniformity of pottery collections from different islands (Anderson and O'Connor 2008; Green 2000). The earliest dated ceramic specimens in the Bismarck Archipelago exhibit dentate-stamping in the form of circles, curvilinear panels, and horizontal geometric bands in stylistically homogenous combinations sufficiently identified as part of a single tradition (Green 1991a). A red slip was commonly applied to the decorated vessels, which include a wide variety of rounded and cylindrical forms (Bedford and Spriggs 2007; Kirch 1997a). Temper is generally identified to local sources, yet the widespread movement and exchange associated with Lapita populations is further attested by the presence of exotic tempers, and thus imported materials, at many sites throughout the region (Burley and Dickinson 2010; Kirch 1997a).

As Lapita pottery styles circulated with the dispersal of voyaging groups to Remote Oceania, variation was introduced to a system that exhibits a distinct cohesion that is likely the result of continuous contact between highly mobile populations operating in a non-hierarchical sphere of cultural transmission (Cochrane and Lipo 2010). So what are the implications for the posited model for the appearance of a Lapita-

associated voyaging culture in the Bismarck Archipelago as derived from the dispersal of Taiwanese agriculturalists 1000 years earlier (Bellwood 1995, 2005; Diamond 1988)? Comparisons of Taiwanese and Philippine ceramic assemblages to those of other island groups (e.g., the Marianas and the Bismarcks) have shown some similarity, such as in the application of a red slip and circle-stamping designs (Carson et al. 2013; Hung et al. 2011). Yet, arguments for uninterrupted links between ancestral and descendant groups have been left wanting due to the incomplete transfer of technological units and discordance among classes of evidence that support a history of greater regional complexity than that proposed by linear models of Holocene cultural replacement (Bulbeck 2008; Donohue and Denham 2010; Fitzpatrick and Callaghan 2013; Oppenheimer and Richards 2001). In fact, Soares et al. (2016) recently used mtDNA, Y-chromosome data, and genome-wide data for a comprehensive analysis of regional genetics that shows the vast majority of genetic diversity for modern islander populations in both Near and Remote Oceania was established in New Guinea by the beginning of the Holocene. The fractions of genetic data attributable to an 'Out of Taiwan' dispersal measure approximately 15 to 20% (Soares et al. 2016:322), meaning that there was no large-scale Late Holocene expansion of agricultural voyagers from Taiwan to the rest of Oceania. Rather, this evidence suggests the establishment of ancient interaction spheres long prior to a smaller population dispersal from Taiwan and that the ensuing Austronesian language shift and the expanded use of introduced technologies took place among genetically diverse communities in ISEA and beyond.

The intricacies of biocultural interaction in Near Oceania were cited by Green (1991a, 2000) in his introduction of the 'Triple-I' model of intrusion, integration, and

innovation. Green suggested that the development of an ancestral voyaging culture in Near Oceania involved the intrusion of people from ISEA, the integration of immigrants with existing cultural groups, and the ensuing local innovation of new cultural elements. Many researchers have moved beyond the 'Triple-I' to embrace a more comprehensive view of continuous geographic mobility among the islands, resulting in the cultural groups that ultimately colonized Remote Oceania (Oppenheimer and Richards 2001; Specht et al. 2014; Terrell 2004). The reassessment of the ISEA-Bismarck corridor as a source for Austronesian voyaging culture, in contrast to the 'Out of Taiwan' model, has been supported through studies of biological origins and species transport.

Paleoenvironmental evidence for plant foods has provided some insight into the origin of subsistence agriculture in Near Oceania. Barrau (1965a) employed the concept of 'the wet and the dry' to describe the wet and humid evergreen tropical rainforest of Indo-Malaysia and New Guinea in relation to the drier seasonal/monsoonal forests and savannah environments to the north and south of the equatorial belt. Barrau identified this region as the center of Pacific cultivation, noting that agricultural staples such as yam (*Dioscorea alata* and *D. esculenta*), taro (*Colocasia esculenta*), and giant taro (*Alocasia macrorrhiza*) originate along this east-west corridor.

Further research has supported New Guinea as a locus of early cultivation, alternately as an agricultural origin, center of genetic diversity, and as a species dispersal point to the greater Pacific (Athens et al. 2008; Barrau 1965b; Gosden 1992; Hather 1992; Hinkle 2007; Horrocks et al. 2009; Jones and Quinn 2009). Lebot (1999) reviewed genetic and morphological aspects of many Pacific crops, showing that the primary crops of aibika (*Abelmoschus manihot*), coconut (*Cocos nucifera*), sago (*Metroxylan sagu*), and

sugarcane (*Saccharum* spp.) all originate in the New Guinea region. *C. esculenta* and *A. macrorrhiza* also originate here as proposed by Barrau, though *C. esculenta* varieties appear to have undergone independent evolution and domestication in both New Guinea and the Asian mainland. Genetic and archaeological evidence trace the domestication of banana (*Musa* spp.) to the Kuk highlands of New Guinea as early as 10,000 cal BP with westward dispersal to the Philippines, ISEA, and eventually eastern Africa around 5000 BP (Kennedy 2008). Lastly, the breadfruit (*Artocarpus altilis*) so common in Polynesia and Micronesia is a genetic descendant of the wild *A. camansi* of New Guinea (Zerega et al. 2004).

Genetic studies of transported faunal species (*Sus scrofa*, *Canis familiaris*, *Gallus gallus*, *Rattus exulans*) generally trace their origin west of New Guinea to ISEA and mainland Southeast Asia, though with a great deal of geographic and temporal variability in dispersal patterns to different island groups that does little to map individual migration events (Amano et al. 2013; Anderson 2009; Anderson and O'Connor 2008; Matisoo-Smith 2009). Instead, variation in the distribution of predominant haplotype clades for pig, dog, chicken, and rat lineages provides insight into general spheres of interaction, as with the close relationship between New Guinea singing dogs and Australian dingoes that contrasts with the *C. familiaris* lineages exported from ISEA to Polynesia (Oskarsson et al. 2012) or the dominant haplotype of the Pacific pig that was separate from a specific East Asian clade associated with Taiwan, the Philippines, and the Mariana Islands (Dobney et al. 2008; Larson et al. 2007).

Human genetics for the Holocene have also proven difficult to decipher and will not be reviewed in detail here other than to note that there is little evidence to support the

replacement of any existing ISEA or Near Oceanic human population with a single migratory population during the mid-Holocene (Hill et al. 2007; Kayser et al. 2008; Oppenheimer and Richards 2001; van Holst Pellekan 2013). Specific lineages are identifiable in Remote Oceania due to population bottlenecks at the time of dispersal, as with the mtDNA B4a1a1a 'Polynesian Motif' haplotype so prevalent in East Polynesia (Soares et al. 2011) and the distinct mtDNA lineages linking multiple early dispersals from ISEA to Western Micronesia (Lum and Cann 2000). Yet, among the islands of Near Oceania these studies reveal a situation of several millenia of highly mobile interaction in which genetic information moved freely along the east-west voyaging corridor from northern New Guinea to ISEA, and the history of lineages tracing to northern regions such as Taiwan were established well before the expansion of Austronesian languages (Hill et al. 2007; Soares et al. 2011; Terrell 2010a; see Denham and Donohue 2012, Xu et al. 2012, and Xu and Stoneking 2012 for recent debate).

Onward to the East

A detailed background discussion regarding the movement of human populations into the islands and island continents of the Pacific Ocean is imperative to understanding the origin of Pacific Island populations and the biological and cultural trajectories that provided the basis for human exploration and settlement of Polynesia. Oceania is large by any global measure and represents an incredible display of geological, biological, and cultural diversity. Recognition of the lengthy history of human habitation in Near Oceania and the timing of travel to the more distant islands of Micronesia and West Polynesia provides context for discussions of the archaeologically recent history of

human activity in East Polynesia, the area of the Pacific for which Raʻiātea is seen as a geographic and cultural center. In the next chapter I will cover the dynamics of human activity in East Polynesia following initial colonization and the inter-island networks of social interaction that become apparent through detailed studies of common artifact classes throughout this region of the Pacific.

CHAPTER III

CULTURAL TRANSMISSION IN EAST POLYNESIA

Chapter III was originally published in volume 52 of the journal *Archaeology in Oceania* in April 2017 (O'Connor et al. 2017). John O'Connor designed the research, completed artifact classification and statistical analysis, and wrote the paper. Frances White helped design the research and completed statistical analysis. Terry Hunt helped design the research and edited the document. John O'Connor was the principal investigator for this work. The chapter has been edited for American English spelling in agreement with the greater dissertation document, section titles have been altered, and a "bridge" section has been inserted at the end of this chapter as a lead to subsequent chapters.

East Polynesia describes the vast Pacific region east of Tonga and Sāmoa, a geographic area comprising the islands and archipelagos of French Polynesia, Hawai'i, New Zealand, and Rapa Nui (Easter Island). Questions of settlement chronology figure prominently in the archaeological literature of Polynesia where a clear historical relationship among descendant groups has prompted extensive research on the timing, strategies, and effects of human colonization (e.g., Allen 2014; Anderson 2003; Athens et al. 2014; Bell et al. 2015; Goodwin et al. 2014; Hunt 2007; Hunt and Lipo 2006; Kahn et al. 2015; Kennett et al. 2006; Montenegro et al. 2014). Improvements to radiocarbon dating protocols have focused on the critical evaluation of sample choice to refine chronometric estimates and reduce unknown error in the record (Allen and Huebert 2014; Rieth and Athens 2013;

Wilmshurst et al. 2011). These efforts have supported a relatively recent and rapid colonization chronology, with population dispersals to East Polynesia soon after 1000 BP and the settlement of remaining islands of the remote Pacific by the end of the 13th century (Wilmshurst et al. 2011). The general consensus on a short chronology frames a temporally constrained period of cultural transmission in East Polynesian prehistory and an intensely focused episode of colonization with remarkable success. Furthermore, a congruent settlement chronology for island groups as widely dispersed as Hawai‘i, New Zealand, and Rapa Nui suggests a strengthened and contemporaneous relationship among initial occupying populations throughout the region, as evidenced in recent discoveries (e.g., Johns et al. 2014).

The colonization of East Polynesia unfolded as a rapid dispersal by culturally related groups on a massive geographic scale. In settling distant oceanic islands, Polynesian populations developed new technologies in response to local environments, but also shared selectively neutral aspects of artifact design. Building on the work of Sinoto and Allen, we examined proximal endpoint line-attachment-devices (LAD) in fishhook assemblages from East Polynesia to address issues of interaction and cultural sharing among island communities. We construct relational networks using artifact classes and employ a series of non-parametric randomization tests to directly evaluate the influence of geographic distribution on assemblage similarity in a time-averaged dataset. Our results support a model of cultural transmission through social interaction largely irrespective of geographic distance. Our results show the degree of cultural relatedness among various fishhook assemblages, and we consider some implications for human migrations in East Polynesia.

Comparisons of material culture among East Polynesian artifact assemblages take on new meaning in the context of a concentrated and archaeologically brief settlement history. The analysis of artifacts serves as the basis for understanding how human ideas and environmental pressures influence cultural trajectories among specific populations. Artifact dimensions reflect shared ideas that are stylistically neutral as well as functionally adaptive (Dunnell 1978), and the identification of culturally transmitted artifact attributes holds great potential for defining social interaction in the past.

We extend this notion by looking at morphological similarity among East Polynesian fishhook assemblages as evidence for cultural transmission during regional population dispersal and island settlement. Fishhooks are a common artifact class in East Polynesia, sometimes comprising large assemblages. Subsistence tools, such as fishing gear, are useful for monitoring cultural variation among Polynesian descendant populations given morphological variation among geographically and temporally discrete assemblages. Early studies in Hawai‘i found that aspects of fishhook form exhibit change through time (Emory et al. 1959; Emory and Sinoto 1969), and these observations were used as the basis for inferring relative chronology. This work led to the use of fishhooks for assessing cultural and resource-dependent change at specific locales, the suggestion of chronologies for regional settlement, and the study of Polynesian subsistence practices (e.g., Allen 1992, 1996; Ayres 1979; Goto 1986; Graves and McElroy 2005; Kirch and Dye 1979; Paulin 2007; Reinman 1970; Sinoto 1962, 1983; Swift 2014). In this study we quantify variability in 18 fishhook assemblages from throughout East Polynesia (Figure 7) to examine the structure of inter-island mobility prior to European influence in the region.

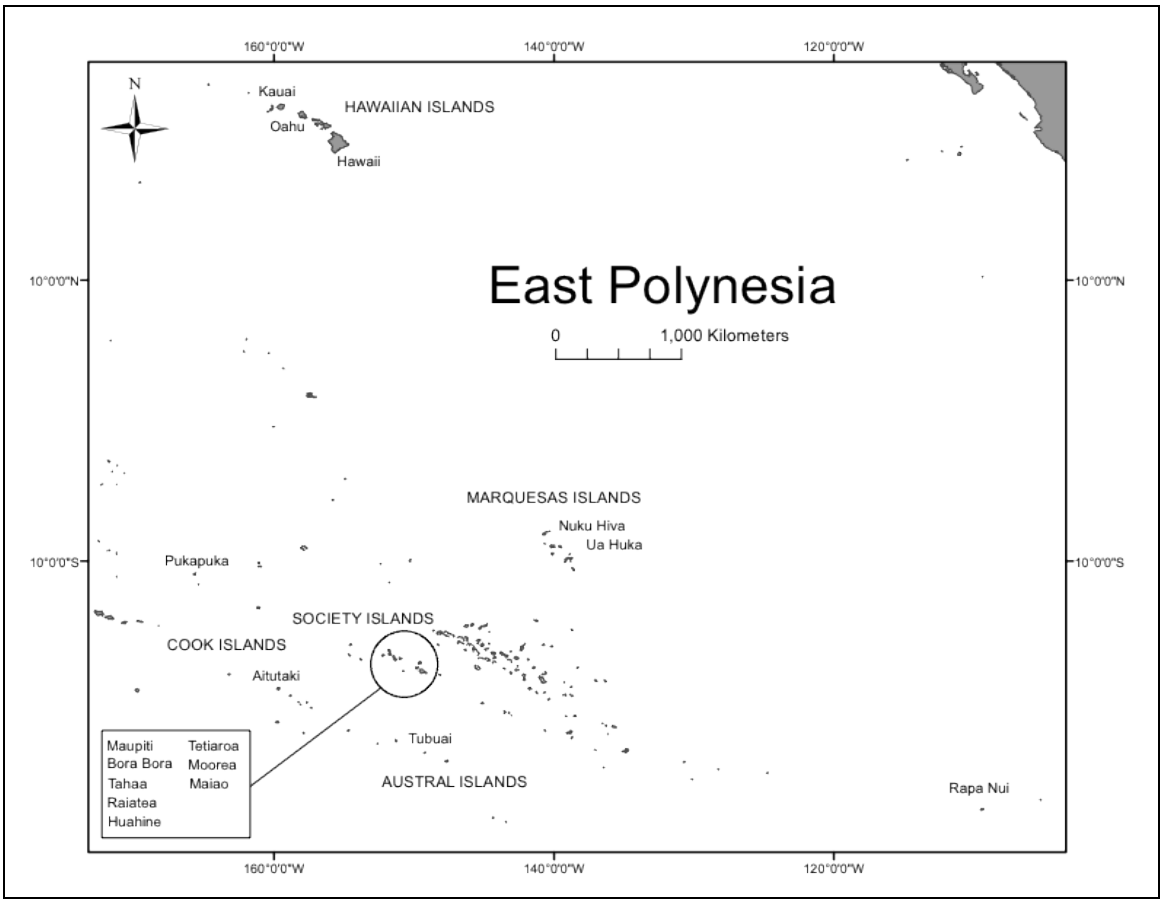


Figure 7. A map of East Polynesia showing islands and archipelagos discussed in the text.

Artifact Classification and Network Analysis

Artifacts are the physical manifestation of cultural ideas, and evolutionary theory provides the basis for a systematic understanding of variation and transmission in material culture (Rorabaugh 2014; Shennan 2009). Evolutionary archaeology considers artifacts a culturally transmitted extension of the human behavioral phenotype, but also posits that artifacts can be arrayed as 'lineages' that demonstrate heritable continuity, or relatedness, between archaeological manifestations (Lipo et al. 2010; O'Brien and Lyman 2002a). Particular to the development of an evolutionary archaeology has been a focus on

neutral and adaptive character states in artifact morphology because these concepts distinguish two classes of variation that, though existing along a heritable cultural dimension, are realized through different evolutionary processes (Hurt and Rakita 2001; O'Brien and Lyman 2003). Adaptive traits are subject to selection in performance and interaction with the environment. Adaptive characters must be distinguished to infer inter-assemblage relations since their similarities may be independently developed solutions to a similar problem (O'Brien and Leonard 2001).

In contrast, neutral character states are recognized as not conforming to selective pressures—one particular form does not exhibit a fitness-enhancing advantage over another character under examination—and can be seen as resulting from cultural processes, such as different forms of transmission bias (Boyd and Richerson 1985) or the introduction of random variability from innovation and/or copying error (Eerkens and Lipo 2005). Homologous transmission may contribute to the persistence of both neutral and adaptive traits in a population, but neutral traits are less likely to result from convergent evolution. Therefore, neutral variation is particularly important for monitoring information transmission in homologous cultural lineages (Crema et al. 2014). The ability to distinguish between neutral and adaptive variants and the processes they reflect provides archaeologists the tools to construct theoretically informed classes that measure not only the passage of time, but interaction among ancient human populations (O'Brien and Lyman 2002b). Patterns in selectively neutral artifact attributes that result from cultural heritability may then be used to map cultural transmission lineages among historical populations (Lipo et al. 2006).

The line-attachment-devices (LAD) observed in Polynesian fishhooks were imperative to proper fishhook function and successful resource acquisition. Yet, variation in LAD morphology does not appear to provide a functional advantage (Allen 1996; Pfeffer 2001a, 2001b). Differences in fishhook size, shape, and manufacturing material may often be related to ecological pressure, raw material availability, and the aquatic species targeted for acquisition, but particular styles of LAD do not demonstrate differential performance values. This is significant because artifact attributes that exhibit design qualities uncoupled from performance specifications are subject to mechanisms unrelated to selective pressure; they are the product of individual and culturally influenced notions of implement design (Dunnell 1978; Neiman 1995). Archaeologically observable changes in fishhook LAD have been explained in terms of *in situ* cultural transition (Allen 1992; Allen and Schubel 1990) as well as evidence for cultural sharing (Emory and Sinoto 1969).

To understand LAD variation unconstrained by typology, a paradigmatic classification is necessary where artifact attributes are unweighted and vary independently (Dunnell 1971). The use of a paradigmatic classification enables construction of replicable and objective analytical units that supersede the limitations of hierarchical typologies to evaluate variation (O'Brien et al. 2014). In her work with Cook Islands assemblages, Allen created a paradigmatic classification for the analysis of fishhook LAD with artifact classes defined by morphological attributes of the proximal, inner (toward the hook point), and outer edges of fishhook hafting portions (Allen 1996:104). Modes are designated to describe the variation independently observed in each of the three LAD dimensions. The modes are mutually exclusive and exhaustive.

The strength of the classification prevails in that only one mode can be displayed at a time in each dimension and new modes may be added to the classification upon encounter. The intersection of modes defines the class, and these classes, in turn, allow comparisons to infer relatedness based upon the degree of similarity between individual artifacts and among artifact aggregates.

Cladistics is a proven method of creating phylogenetic order among homologous artifact classes and demonstrating cultural relatedness, but difficulty arises in accurately portraying the dynamics of social interaction where significant amounts of horizontal transmission took place (Cochrane and Lipo 2010). Social network analysis (SNA) is based upon the "observation that individuals are embedded in thick webs of interaction and social relations" (Terrell 2010a:212). SNA employs analytical tools derived from mathematical graph theory for the refined visualization of relatedness in large interactive networks. Archaeological applications embody this concept of social interaction, revealing complex non-linear relationships among archaeological populations (Hart and Engelbrecht 2012; Knappett et al. 2008; Riede 2008; Terrell 2010b). The examination of social interaction spheres is not new to Pacific archaeology, and differential interaction among Polynesian populations continues to be explored using a variety of data sets (Cochrane 2015; Thomson et al. 2014; Weisler et al. 2016). Network approaches have much to offer researchers who seek to visualize and understand the interplay of human sociality as evidenced in archaeological data (Brughmans 2013).

Classification and Statistical Methods

In this study we measure similarity across LAD assemblages to answer questions about cultural lineages and post-settlement interaction in East Polynesia. What is the degree of similarity between various assemblages? How does inter-assemblage class sharing relate to geographic distributions and current knowledge of East Polynesian settlement? If we are accurately monitoring phylogenetic relationships in the context of highly mobile social interaction, then assemblage relatedness should display patterns of horizontal transmission largely unrelated to other influential factors (e.g., sample size, geographic distance). These patterns can be used to suggest hypotheses of island colonization and settlement.

The method of fishhook LAD analysis applied here is based upon those initiated by Emory and Sinoto (1969; Sinoto 1991) and refined for style by Allen (1996). Our analytic protocol adopts the 14 dimensional modes employed by Allen, with the inclusion of five additional modes created for this research (Figure 8). The intersection of 19 analytic values produces the possibility of 245 different LAD class assignments potentially observed for any particular artefact. LAD data were acquired for 1505 fishhooks and fishhook fragments from observations made with assemblages, photographic collections, highly-detailed artist renderings, and previously published material (Allen 1992; Chikamori and Yoshida 1988; Sinoto 1966; Suggs 1961; Swift 2014). Published and unpublished collections are held at the American Museum of Natural History in New York, the Bernice Pauahi Bishop Museum in Honolulu, and the Father Sebastian Englert Anthropological Museum on Rapa Nui. We include 18 archaeological assemblages representing 17 East Polynesian islands in this study. These

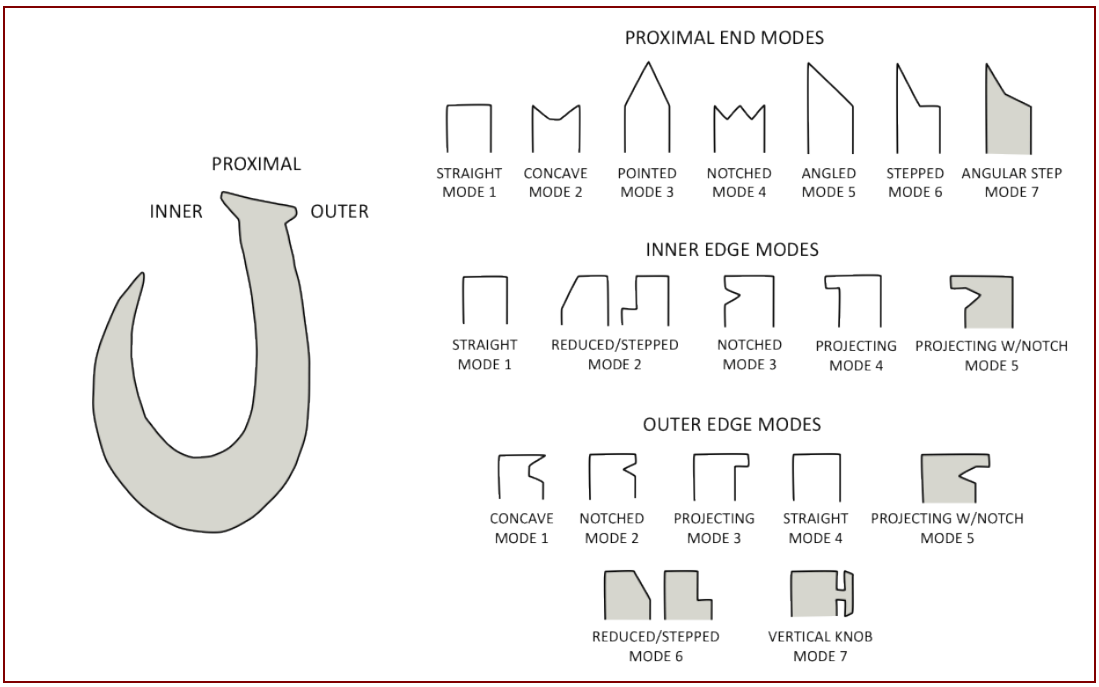


Figure 8. A paradigmatic classification protocol for fishhook LAD morphology. Figure adapted from Allen (1996), with new modes identified by shading.

include assemblages from the islands of Aitutaki, Bora Bora, Hawai‘i (Pu‘u Ali‘i), Huahine, Kaua‘i (Makauwahi and Nu‘alolo Kai), Mai‘ao, Maupiti, Mo‘orea, Nuku Hiva, O‘ahu (Kuli‘ou‘ou), Pukapuka, Ra‘iātea, Rapa Nui, Taha‘a, Teti‘aroa, Tubua‘i, and Ua Huka. A combined total of 110 LAD classes are identified across the 18 artifact assemblages. Of these documented artifact classes, 53 LAD classes are represented in more than one assemblage.

Documented LAD classes were compiled into a presence-absence matrix where classes for each assemblage were registered as 1 for presence or 0 for absence (Table 1), making apparent the cultural relatedness of various assemblages in an easily visualized format. Instances of class sharing are readily identifiable, and the number of classes within each assemblage can be quantified. As widely recognized, sample size differences affect comparisons. Larger samples are correlated with greater class diversity and thus

Table 1. Presence-absence data matrix for fishhook LAD classes from 18 East Polynesian assemblages. *N* = total specimens in each assemblage.

LAD class	Aitutaki	Bora Bora	Huahine	Kuliouou	Maiao	Makauwahi	Maupiti	Moorea	Nualolo Kai	Nuku Hiva	Pukapuka	Puu Alii	Raiatea	Rapa Nui	Tahaa	Tetiaroa	Tubuai	Ua Huka
111	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	1
112	1	0	0	0	0	0	0	0	1	1	0	1	0	1	0	0	1	1
113	1	1	1	0	1	1	0	1	1	1	1	1	1	1	1	1	1	1
114	0	1	0	0	0	0	0	1	1	1	1	1	1	0	0	0	1	1
115	0	0	1	0	0	0	0	0	1	0	0	1	1	1	0	0	1	1
116	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1
117	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0
121	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
122	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
123	1	1	0	0	0	0	0	1	0	1	0	1	1	1	0	0	1	1
124	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	1	1
125	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	0	0	1
126	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
131	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
132	0	0	0	0	0	0	0	0	1	1	0	1	0	0	0	0	0	1
133	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
134	0	0	1	0	0	0	0	0	0	1	0	1	0	1	0	0	0	1
135	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
136	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
141	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1
142	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
143	0	0	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	1
144	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	1
145	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0

Table 1, continued.

146	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
151	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
152	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
154	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
211	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
212	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
213	1	1	0	0	0	0	0	0	1	1	0	1	1	0	0	0	1	1
214	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
215	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1
221	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
222	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
223	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	1
225	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
232	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
233	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
243	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1
244	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
311	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0
312	0	0	0	0	0	0	0	0	1	0	0	1	0	1	0	0	0	0
313	1	1	1	1	0	0	0	1	1	0	1	0	1	0	0	1	0	0
314	0	0	0	0	0	0	0	0	1	0	0	1	0	0	1	0	0	1
315	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0
317	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
321	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
322	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
323	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
324	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
332	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
333	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0

Table 1, continued.

344	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
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414	0	0	0	0	0	0	0	0	1	1	0	0	0	1	0	0	0	1
423	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
425	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
433	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0
443	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
444	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
452	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
511	0	0	0	0	0	1	0	0	1	1	0	1	0	0	0	0	0	1
512	0	0	0	1	0	1	0	0	1	0	0	1	0	1	0	0	0	0
513	0	1	0	1	0	1	0	1	1	1	1	1	1	0	0	0	1	1
514	0	1	0	0	0	0	0	1	1	1	0	1	0	0	0	0	0	1
515	0	0	0	1	0	1	0	0	1	0	1	1	1	0	0	0	0	1
521	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0
522	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
523	0	0	1	0	1	0	1	1	0	0	0	1	1	0	0	0	0	1
524	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
525	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
531	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
532	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
533	0	0	0	0	0	0	0	0	1	0	0	1	1	0	0	0	0	0
534	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
535	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0
536	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
541	0	0	0	0	0	0	0	0	1	0	0	1	0	0	1	0	0	0
542	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
543	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0

Table 1, continued.

544	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	0	1	0
545	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
551	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
552	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
553	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
555	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
561	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
612	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
613	0	0	0	1	0	1	0	0	1	1	1	1	1	0	0	0	1	1
614	0	0	0	0	0	0	0	0	1	1	0	1	0	0	0	0	0	0
615	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0
621	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
623	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0
633	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
635	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
644	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
653	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
712	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
713	0	1	0	1	0	1	0	0	1	0	1	1	0	0	0	0	0	1
714	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
715	0	0	0	0	0	0	0	0	1	0	1	0	0	1	0	0	0	0
722	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
723	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
733	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1
735	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
741	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
743	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
753	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
N =	69	17	10	24	3	32	5	17	142	108	36	489	44	21	4	3	47	434

the opportunity to share more simply as a function of that diversity. We focused on class richness as a way of minimizing the potential for misleading inferences based on class

quantities that may not accurately represent the larger population. A presence-absence approach treats the identified classes as attributes of the assemblage rather than variables (Grayson 1981). Nevertheless, Grayson (1984:132) noted that richness, too, "is tightly correlated with the size of the retrieved sample—the number of identified specimens—and this must be taken into account whenever richness is analyzed." Smaller samples will typically result in lower class richness with bias toward common artifact classes.

To minimize sample size bias, similarity/dissimilarity matrices were created to explore assemblage relatedness. Matrices were calculated using LAD data for all artifacts and organized by 18 individual assemblages (Table 2) as well as seven archipelago groupings (Table 3). Similarity coefficients were calculated as $n_s/\Sigma n$, where n_s is the number of LAD classes shared between two compared assemblages and the cumulative value is that of all classes present in the two samples. This step removes size bias and permits multiple assemblages to be compared simultaneously. Similarity matrices were imported into BIOMstat 3.3 (Rohlf and Slice 1999) statistical software, and a cluster analysis was performed to assess relationships among individual assemblages using unweighted pair group method using arithmetic averages (UPGMA; Sneath and Sokal 1973:230-234).

Next, a series of tests were performed to directly evaluate the influence of sample size and geographic distance on assemblage similarity. Geographic distances between islands and individual assemblage origins (where discrete) were calculated using Google Earth. For archipelagic comparisons, a 500 km buffer was chosen as the minimum distance to encapsulate a single archipelago while still separating island groupings. The Mantel test is a non-parametric randomization technique used to estimate the strength of

Table 2. Similarity/dissimilarity matrix for 18 East Polynesian LAD assemblages. Similarity coefficients indicate strength of relatedness between assemblage pairings.

	Aitutaki	Bora Bora	Huahine	Kuliouou	Maiao	Makauwahi	Maupiti	Moorea	Nualolo Kai	Nuku Hiva	Pukapuka	Puu Alii	Raiatea	Rapa Nui	Tahaa	Tetiaroa	Tubuai	Ua Huka
Aitutaki																		
Bora Bora	0.2273																	
Huahine	0.1176	0.1176																
Kuliouou	0.0556	0.1667	0.1538															
Maiao	0.0714	0.0714	0.2222	0.0000														
Makauwahi	0.0476	0.1429	0.0625	0.2941	0.0769													
Maupiti	0.0000	0.0000	0.1111	0.0000	0.3333	0.0000												
Moorea	0.1579	0.3158	0.2143	0.1333	0.1818	0.1111	0.0909											
Nualolo Kai	0.0976	0.1707	0.0833	0.1622	0.0303	0.2000	0.0000	0.1579										
Nuku Hiva	0.1538	0.1795	0.0588	0.0571	0.0323	0.1053	0.0000	0.1389	0.2069									
Pukapuka	0.1053	0.2632	0.1429	0.3333	0.0909	0.2778	0.0000	0.2500	0.2105	0.1111								
Puu Alii	0.0645	0.0860	0.0568	0.0674	0.0235	0.0761	0.0118	0.0667	0.1875	0.1636	0.0667							
Raiatea	0.1379	0.2069	0.1667	0.1600	0.0952	0.1429	0.0476	0.2308	0.2083	0.1739	0.2308	0.1500						
Rapa Nui	0.1200	0.0800	0.1500	0.0000	0.0588	0.0833	0.0000	0.0909	0.1818	0.1905	0.0909	0.1250	0.1563					

Table 2, continued.

	Aitutaki	Bora Bora	Huahine	Kuliouou	Maiao	Makauwahi	Maupiti	Moorea	Nualolo Kai	Nuku Hiva	Pukapuka	Pua Alii	Raiatea	Rapa Nui	Tahaa	Tetiaroa	Tubuai	Ua Huka
Tahaa	0.0667	0.0667	0.1000	0.0000	0.1429	0.0714	0.0000	0.0833	0.0882	0.0313	0.0833	0.0465	0.0909	0.1111				
Tetiaroa	0.1538	0.1538	0.2500	0.1111	0.2000	0.0833	0.0000	0.2000	0.0625	0.0333	0.2000	0.0119	0.1000	0.0625	0.1667			
Tubuai	0.1923	0.1923	0.0952	0.0909	0.0556	0.1200	0.0000	0.1739	0.2000	0.2558	0.1739	0.1340	0.2424	0.2069	0.0526	0.0588		
Ua Huka	0.1087	0.1739	0.1220	0.1190	0.0526	0.1333	0.0263	0.1395	0.2462	0.2698	0.1395	0.2479	0.2830	0.1837	0.0769	0.0270	0.2600	

Table 3. Similarity/dissimilarity matrix for seven island or archipelago groupings based on 500 km proximity buffer.

	Aitutaki	Hawaii	Marquesas	Pukapuka	Rapa Nui	Societies	Tubuai
Aitutaki							
Hawaii	0.0673						
Marquesas	0.1053	0.2518					
Pukapuka	0.1053	0.0792	0.1111				
Rapa Nui	0.1200	0.1308	0.1667	0.0909			
Societies	0.1220	0.2033	0.2895	0.1842	0.1364		
Tubuai	0.1923	0.1296	0.2295	0.1739	0.2069	0.1778	

association between two independent descriptions of the same entity (Sokal and Rohlf 2012:852-858; see Cochrane and Lipo 2010 and Crema et al. 2014 for archaeological applications). Statistical computation is performed using similarity/dissimilarity coefficients to assess the degree of similarity or difference between the compared measures of relatedness. The Mantel test functions as a sampled permutation test, in which matrix elements are rearranged and the observed *Z* value is compared to the distribution of random permutations. Product-moment correlation coefficients are computed, and matrix correlation is shown as the normalized Mantel statistic *r*. The probability *p* is tested against a null hypothesis of no correlation.

Network visualization was performed to illustrate the degree of relatedness between assemblage and archipelago pairings based on Mantel similarity coefficients. Network graphs depict the network of similarity measures resulting from matrix testing (i.e., graphs in Figure 9 are a visualization of the relational values contained in Tables 2 and 3). Coefficient class intervals are derived from matrix decimal ranges, with

individual bins depicted for inter-assemblage sharing and all bins shown together for inter-archipelago comparisons. Graphs were constructed in Adobe Illustrator.

Statistical Results

Mantel tests were run in BIOMstat 3.3 comparing assemblage similarity, sample size, and geographic distance between each assemblage and archipelago pairing. All tests were run with 3000 iterations, and *p* values are compared at significance level $\alpha = 0.05$. Testing of assemblage similarity and sample size did not return a significant correlation ($r = 0.0406$, $p = 0.4390$), thus validating the use of similarity matrices as an accurate method for mitigating sampling issues in class-presence comparisons. Additionally, no simple statistically significant correlation exists linking LAD class presence to geographic distance, whether comparing individual assemblages ($r = -0.1813$, $p = 0.0665$) or when grouping islands by archipelago ($r = -0.3345$, $p = 0.1347$; 500 km buffer). In other words, there is no linear relationship between increased similarity and closer geographic position.

From these results, questions shift to our understanding of how social interaction may be guiding observed variation. If inter-assemblage relatedness is not solely dependent on geographic proximity or analytical issues, we can suppose that social interaction may have exerted bias on information transmission and artifact class distributions. We tested the hypothesis that assemblages within historical geopolitical groupings (archipelagos) will exhibit greater within-group relatedness than between-group class sharing. A Mantel test comparing inter-assemblage similarity with archipelago membership statistically supports this hypothesis ($r = 0.1761$, $p = 0.0455$).

Network Discussion

Figure 9 provides graphic representation of inter-assemblage relatedness between island communities. These relationships likely result from geographic dispersal, the reciprocal exchange of information during a high-mobility voyaging period, and diversification in technological design among descendant populations. Particular network relationships become apparent, such as the centrality of Raʻiātea (Society Islands) in the network and the similarity of the Pukapuka (northern Cook Islands) and Tubuaʻi (Austral Islands) assemblages to those of more eastern and northern islands. Some have suggested that the Cook Islands were a gateway for colonization of East Polynesia (e.g., Allen and Wallace 2007), and recent research provides evidence for prehistoric movement of lithic materials between the Cooks and other islands of West and East Polynesia (Weisler et al. 2016). The connection of Pukapuka, and to a lesser extent Aitutaki, to the Hawaiian and Society Islands may offer further evidence of the Cook Islands' regional role. Fishhook trait similarity linking Tubuaʻi to Raʻiātea, the northern Marquesas Islands, and Rapa Nui may also point to a west-to-east gateway that incorporated the northern Austral Islands. Goodwin et al. (2014) showed that variation in Southern Hemisphere marine climate and wind patterns increased the viability of voyaging routes from the Austral Islands to Rapa Nui within the time frame of initial colonization (Hunt and Lipo 2006). Lastly, the strong similarity of the Raʻiātea assemblage to Austral, Cook, Hawaiian, and Marquesan collections strategically places Raʻiātea as a fundamental node in the transmission network, and the high degree of similarity between the Society, Marquesan, and Hawaiian archipelagos links to historical connections long recognized in the literature. On this point, our analysis depicts inter-island relationships, but does not allow one to

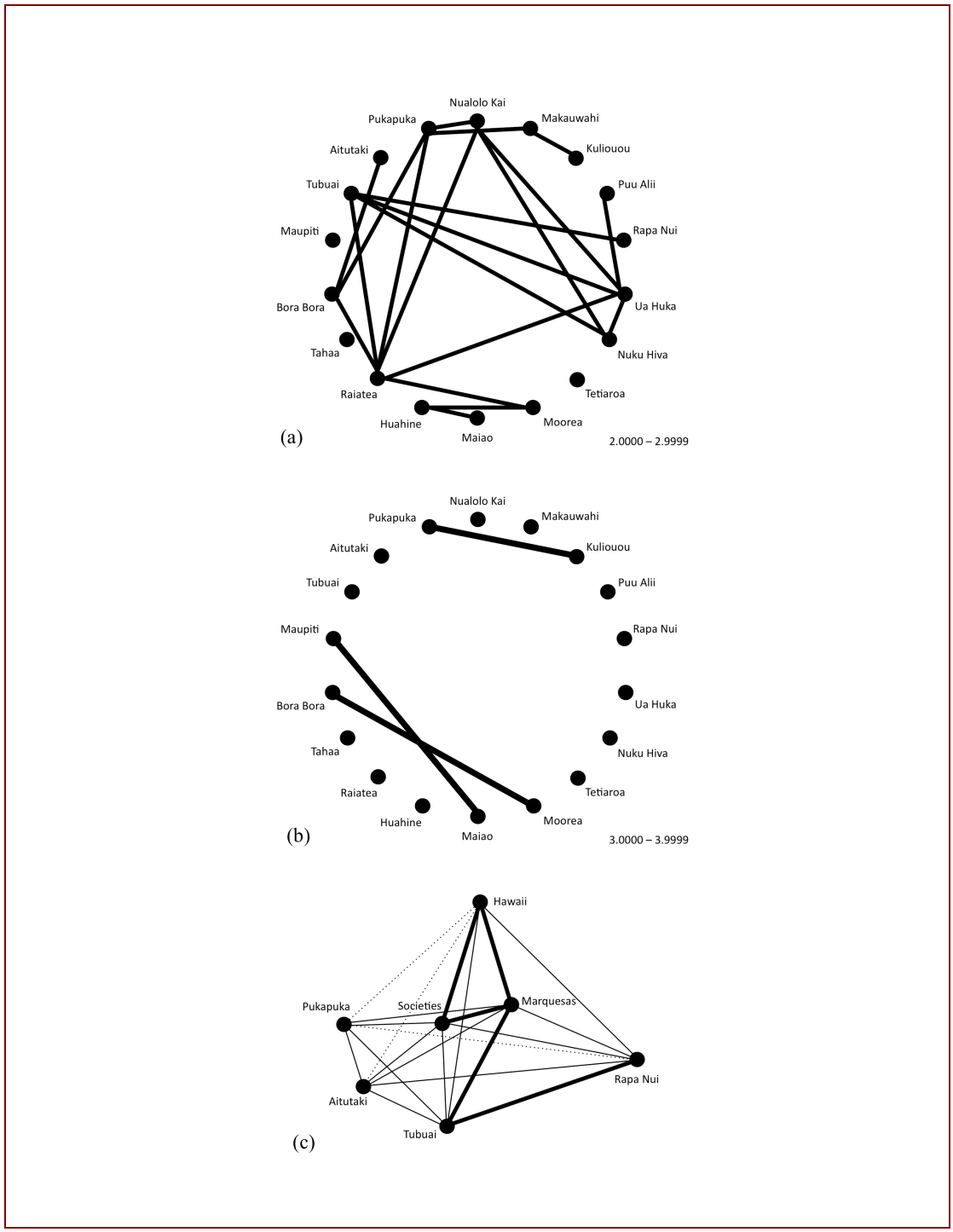


Figure 9. Network graphs displaying strength of relatedness among East Polynesian islands and archipelagos: (a, b) inter-assemblage similarity for the two highest coefficient bin classes; (c) relatedness by archipelago. Thicker lines indicate greater measured inter-assemblage similarity.

posit a unique link either for the Marquesas or the Societies in immediate Hawaiian origins.

These results have two broad implications for cultural transmission and ocean voyaging in Polynesia. First, the lack of a significant correlation between assemblage relatedness and geographic distance at the regional scale reveals widespread cultural transmission between archipelagos. Inter-assemblage class sharing at the levels of the individual assemblage and the archipelago illuminates similarity between specific locales and suggests a high degree of horizontal transmission occurring among various combinations of East Polynesian islands uncharacteristic of nearest neighbour interactions. This is consistent with expectations of a rapid settlement chronology (Wilmshurst et al. 2011). We hypothesize that rapid colonization would be based on high mobility, with island discoveries, colonization events, and multiple contacts among populations on multiple islands—that is, a strong web of interaction as indicated by our results.

Our results find parallels in the linguistic evidence for East Polynesia. Walworth's (2014) revaluation of Proto-Eastern Polynesian (PEP) linguistic subgrouping collapses all East Polynesian languages into a single Proto-Central Eastern Polynesian (PCEP) subgroup, with the exception of Rapa Nui. Walworth argues that a unified PCEP supports a contact-based model for language development in which regional settlement occurred with a single major dispersal event and PCEP languages subsequently developed through several generations of high mobility and long-distance contact between island populations. Cochrane's (2015) analysis of ritual architecture also suggests a high level

of horizontal cultural transmission throughout East Polynesia with substantial trait innovation occurring within island groups.

Second, statistical affirmation of some greater relatedness within archipelagos than between archipelagos suggests that geographic distance was a factor affecting cultural transmission within island groups. One hypothesis is that artifact characters transmitted during initial settlement and subsequent interaction gave way to the introduction of local variation with the cessation of long-distance voyaging and the ensuing geographic isolation of many Polynesian societies. High-mobility voyaging followed by decreased interaction is reflected in regional ethno-histories (Henry 1928; Hiroa 1938), and widespread cultural sharing followed by greater intra-archipelago homogeneity fits expectations of later isolation and social interaction on smaller geographic scales (e.g., Allen 2014; Johns et al. 2014; Weisler et al. 2016). However, it is significant that many of the strongest relationships revealed here are between islands of different archipelagos (see Figures 9a & 9b). The statistical values indicating correlation between similarity and archipelago membership are not that strong, suggesting even greater regional homogeneity among artifact classes. Unequivocal support for this hypothesis is limited due to our time-averaged data. Alternative scenarios must be considered, such as hypotheses of greater intra-archipelago interaction with a low degree of inter-archipelago sharing early or throughout the sequence, or historically sporadic instances of long distance voyaging that affected assemblage composition through sharing. Greater temporal resolution will improve our ability to make additional claims.

Conclusion

We analyzed similarity in fishhook LAD to map patterns of social interaction in East Polynesia and assess regional mobility, revealing unique relationships between island populations and a strong degree of shared variation among archipelagos. These patterns show the distribution of neutral variation among fishhooks reflecting cultural transmission. The variation shared between East Polynesian archipelagos, as unconstrained by geographic distance, represents extensive horizontal and vertical transmission as developed during a period of rapid geographic expansion and high mobility. Our analysis of fishhook assemblages indicates sharing of information that serves as a proxy for human interaction among widely dispersed islands. Our analysis also shows the development of unique LAD as innovations in specific locations (e.g., the Society Islands, Hawai‘i).

We conducted this study on a time-averaged dataset with artifacts collapsed into a single temporal period, a method that limited our analysis and certainly obscured temporal change among the assemblages. Future work might include the refinement of chronologies and analyses of change in class frequencies over time. Our results provide a foundation for continued research of interaction, cultural transmission, and relatedness among Polynesian populations.

Bridge

This analysis of fishhook assemblages from across East Polynesia allowed quantification and mapping of cultural transmission ties among island communities in East Polynesia as related to a specific set of artifacts. Ra‘iātea appears as an integral node

in this particular network analysis, supporting the legendary significance of the island in Polynesian lore and displaying strong relationships to other key Polynesian islands that suggest a history of voyaging and settlement either extending from, descending upon, or in other ways tied to Raʻiātea in a culturally and historically important way. This chapter archaeologically frames Raʻiātea within a cultural context from which to discuss results of archaeological testing at Tumaraʻa Commune and the megalithic Marae Tainuʻu.

CHAPTER IV

ARCHAEOLOGICAL TESTING AT TUMARAʻA COMMUNE, RAʻIĀTEA

This chapter summarizes archaeological fieldwork at Tumaraʻa Commune, Raʻiātea, French Polynesia, as part of the Raʻiātea Historical Ecology Project, an ongoing effort directed by John T. O'Connor of the University of Oregon Department of Anthropology and Museum of Natural and Cultural History in collaboration with Dr. M. Hinanui Cauchois of the Centre International de Recherche Archéologique sur la Polynésie (CIRAP), Université de la Polynésie Française and the College - Lycée Anne-Marie Javouhey of Uturoa. All fieldwork proceeded in cooperation with the office of Tavana Cyril Tetuanui and the local community. An initial field visit was conducted between September 13 and September 19, 2015, and involved an unofficial reconnaissance survey of the island, meetings with local dignitaries, and project coordination with Dr. Cauchois. Two subsequent visits in 2016 and 2017 involved pedestrian survey, sediment coring, and subsurface testing in the form of test unit excavation. The results of archaeological fieldwork during the 2016 and 2017 field seasons are discussed below.

Phase 1 archaeological investigations took place at Tumaraʻa Commune, Raʻiātea, French Polynesia, from July 4 to August 2, 2016. The 2016 field season began with a reconnaissance survey of the coastal and inland landscape at Tevaitoa, Raʻiātea, as well as a survey of Horea, Tapute, and Punaeroa motu (islets) located within the Tumaraʻa administrative area (see Figure 10). Subsurface coring provided stratigraphic profiles for coastal flats and locational data for further testing. Our excavations centered on Marae

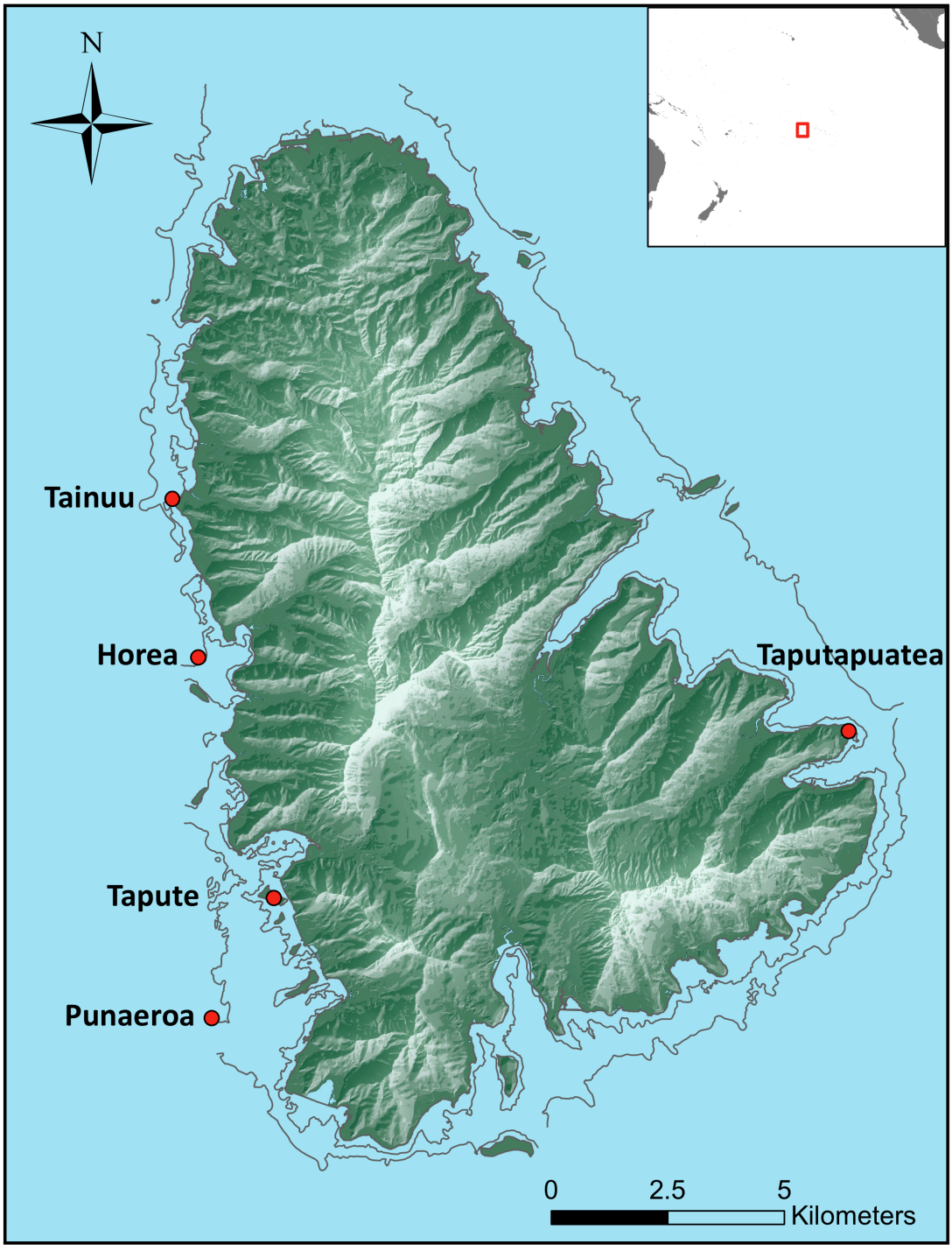


Figure 10. Map of Raʻiātea: five-meter resolution digital elevation model with reef contour line and archaeological points of interest.

Tainuʻu, a megalithic ceremonial structure and archaeological complex of past and present sociopolitical significance on Raʻiātea. Ten sediment core samples were placed along an east-to-west transect across the marae court and in other select locations of the complex. This resulted in a coast-to-inland stratigraphic characterization of the marae. Four 1 × 1 m test pits were excavated at various points along an east-to-west transect from the Paepae Taumatini, or chief's residential platform, to the marae ahu. Two adjacent test pits on the paepae revealed substantial evidence of human occupation, with the exposure of early architecture, hearth features, burned rock, marine and terrestrial faunal remains, and evidence for the manufacture and use of lithic tools.

Phase 2 of the Raʻiātea Historical Ecology Project comprised archaeological investigations at Tumaraʻa Commune from August 12 to August 31, 2017. The 2017 field season involved a continuation of subsurface testing at Marae Tainuʻu at Tevaitoa and the placement of a single test unit at "Domaine Dehors," a privately owned field located at the mouth of an inland valley at Tuʻu Fenua 1 kilometer north of the marae. One 1 × 1 m test pit was excavated in the field approximately 150 meters inland from the coastal road. This test pit was placed to examine valley stratigraphy in an area of anthropogenic infill. The test returned minimal results for cultural material, showing a continuous deposit of relatively uniform sediments emplaced in what was previously a flowing watercourse. Three 1 × 1 m test pits were placed at Marae Tainuʻu in a continuation of the efforts from the prior field season. Two adjacent test pits were placed in the center of the Paepae Taumatini. These tests exposed subsurface architecture similar to that of Test Pit 1 and Test Pit 2 from 2016. Marine shell, terrestrial bone, and charcoal were present in ample quantities between 70 centimeters and 90 centimeters below surface. A single 1 × 1 m

test pit was placed 3.5 meters west of the southern portion of the paepae. This test pit also revealed substantial evidence of human activity with noticeably more fire-affected-rock than seen in the paepae units. Lithic debitage from tool production was present with faunal remains and a series of large boulders in no discernible pattern. A continuous deposit of carbonized samples were retrieved from secure stratigraphy in all test pits excavated at the marae complex, and these specimens will assist in a refined chronological assessment of human activity at Marae Tainuʻu.

The project will contribute toward a detailed analysis of the historical ecology of Tumaraʻa, Raʻiātea, from which to situate this region in the broader context of East Polynesian settlement history and examine the impacts of human activity on coastal and offshore environments. Multiple carbonized organic samples have been processed for radiocarbon age determinations. Coupled with the quantification of recovered materials, these radiocarbon assessments provide temporal context for the history of human activity at the marae at Tevaitoa. Long-term project goals remain to work toward: 1) a radioisotope chronology for pre-contact human activity at Tumaraʻa; 2) an assessment of how land use and technology patterns may reflect changes in resource procurement, community organization, and social interaction; 3) the analysis of environmental impacts on lagoon and coastal resources resulting from human predation pressures and subsistence strategies; and 4) a synthesis of the historical ecology of human colonization at western Raʻiātea. Archaeological survey and sediment coring at western Raʻiātea yielded information that will continue to guide subsequent fieldwork in the area. The 2016 excavations at Marae Tainuʻu uncovered a history of site-use activities that provide context for the role of Tainuʻu in local and regional history. The 2017 season of

fieldwork allowed the recovery of sufficient materials from which to complete our assessment of Marae Tainuʻu. Impending results will be published in academic journals and become publicly accessible for general knowledge and teaching for the people of Raʻiātea and of French Polynesia. I hope to provide insight into the archaeological history of Raʻiātea and contribute to greater discussions of human impacts on island ecosystems in the greater Pacific region. This work will form a foundation upon which future research may be constructed.

Field Methods

A comprehensive mapping and excavation program was developed to address the various research questions discussed above. Phase 1 survey, mapping, coring, and subsurface testing took place at Tumaraʻa Commune between July 4 and August 2, 2016. Phase II fieldwork took place between August 12 and August 31, 2017. Standardized field methods were implemented during both the 2016 and 2017 field seasons. Survey of Tevaitoa, Horea, Tapute, and Punaeroa was completed on foot and by use of motorized boat. Sediment columns were sampled using an 8.25 cm bucket auger in order to observe geological stratigraphy and locate potential archaeological deposits. Test units at Marae Tainuʻu and Domaine Dehors were excavated by trowel, digging stick, brush, and collection pan. Test units were excavated in natural stratigraphic layers subdivided into arbitrary 10 cm levels. Excavated materials were sifted using 3.175 mm (1/8 inch) metal mesh screen. Dry screening was appropriate for the majority of layers encountered during excavation. However, wet screening methods were employed for dense and damp sediments. Recovered archaeological and ecological materials were cleaned, dried,

catalogued, and transported to the University of Oregon by John O'Connor. All fieldwork was documented with field-notes, photographs, maps, sketches, and GPS point data. All excavated non-diagnostic materials were returned to their place of origin, with the exception of those recovered materials still under analysis at the University of Oregon. All auger samples and test pits were backfilled.

Laboratory Methods

Preliminary sorting for archaeological and paleoecological specimens took place at our field site in Tumara'a. Laboratory work, data creation, and technical analysis are currently ongoing at the Island and Coastal Archaeology Laboratory at the University of Oregon. Artifacts (lithics, modified faunal remains) are being analyzed in preparation for comparative studies with East Polynesian collections at the Musée de Tahiti et des Îles te Fare Manaha, Tahiti, and the Bernice Pauahi Bishop Museum, O'ahu. Invertebrate and vertebrate remains have been quantified and representative samples have been identified to taxon, where possible, with reference images and comparative collections at the University of Oregon Museum of Natural and Cultural History. Zooarchaeological remains have been documented according to NISP (MNI was not possible in many cases) and bulk sample weight (Grayson 1984; Jones and Quinn 2009). Carbonized samples have been selected for radiometric dating and are being identified in accordance with contemporary dating protocol (Allen and Huebert 2014; Wilmshurst et al. 2011). All samples are being identified to species by Paleolandscapes Archaeobotanical Services Team, LLC and then prepared and processed for AMS ^{14}C assays at DirectAMS in Seattle, WA. Geospatial modeling is planned utilizing archaeological data in unison with

digital elevation models and ecological information provided by the Service de l'Urbanisme Polynésie Française. This ongoing collaboration with the Service de la Culture et du Patrimoine will merge locally acquired high-resolution photography with Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation Map (GDEM) granules to create an updated bathymetric and digital terrain model (DTM) that will facilitate the study of observed cultural stratigraphies in relation to current landscape configuration.

2016 Survey and Auger Sampling

Archaeological work during the 2016 field season was focused on the west coast of Raʻiātea, primarily in the northwest area of Tumaraʻa Commune. Survey and auger sampling commenced early on in the project with the intention of identifying sufficient locations for archaeological testing during the 2016 and 2017 field seasons of the Raʻiātea Historical Ecology Project. A general reconnaissance survey of coastal flats at Pūfau, Tuʻu Fenua, and Tevaitoa was completed by car and on foot. A more detailed pedestrian survey of four targeted areas was performed in preparation for subsurface testing and future geospatial modeling. These locations included the ridge area located inland (east) from Marae Tainuʻu at Tevaitoa and the three motu of Horea, Tapute, and Punaeroa that span the west coast of the island (see Figure 10). Initial survey provided context for understanding local topography and the relation of cultural and natural resources in the near-shore ecological setting. Bucket auger coring provided stratigraphic information for point locations (Table 4) and helped to assess potential cultural layers for data recovery through targeted subsurface testing.

Table 4. Locations of 2016 auger samples discussed in the text. Global Positioning System latitude and longitude coordinates are displayed in World Geodetic System (WGS84) decimal degrees.

Core ID	Latitude	Longitude	Date
C1Horea	S 16.82332	W 151.48894	7 July 2016
C2Horea	S 16.82298	W 151.48917	7 July 2016
C3Horea	S 16.82309	W 151.48889	7 July 2016
C4Horea	S 16.82319	W 151.48854	7 July 2016
C1Punaeroa	S 16.89242	W 151.48552	7 July 2016
C1Tainuu	S 16.79388	W 151.49226	8 July 2016
C2Tainuu	S 16.79385	W 151.49245	8 July 2016
C3Tainuu	S 16.79381	W 151.49263	8 July 2016
C4Tainuu	S 16.79377	W 151.49281	8 July 2016
C5Tainuu	S 16.79374	W 151.49298	8 July 2016
C6Tainuu	S 16.79370	W 151.49318	8 July 2016
C7Tainuu	S 16.79395	W 151.49229	13 July 2016
C8Tainuu	S 16.79412	W 151.49234	13 July 2016
C9Tainuu	S 16.79384	W 151.49315	21 July 2016
C10Tainuu	S 16.79398	W 151.49281	8 July 2016

Tevaitoa

The Tevaitoa survey was completed on July 4, 2016 by John O'Connor, M. Hinanui Cauchois, Denis Pitomaki, and Béa Tevaearai following an interview with Pastor Philippe Tupu. The Marae Tainu‘u archaeological complex is already well known, with highly visible archaeological features interspersed with post-contact and contemporary structures. Survey of the ridgeline directly inland from Marae Tainu‘u resulted in the re-identification of large modified boulders and a series of disturbed terraces (possibly Tetuira; Handy 1930: 92). The ridgeline is formed by a point of land jutting westward from the interior mountains. A well-preserved marae/fort complex sits atop the hill in a location that provides sweeping views of the coastline. This feature is likely Taputuara‘i, a "warrior's marae" described by Handy (1930: 92-93) as a strategic defensive lookout for the west side of the island. Indeed, if the trees and vegetation were not present, there

is an unobstructed view of the lagoon and reef passes to the north and south, making Taputuara‘i an important location for monitoring movement along the Tumara‘a coast and other human activities in close proximity to the lagoon. Many of these archaeological features have been recorded with geographic point data as part of the 2013 Tumara‘a survey documented by the Service de la Culture et du Patrimoine (see Figure 3 in Chapter I). Detailed mapping and landscape analyses of feature distributions will be forthcoming in subsequent field seasons.

Exploratory auger sampling was completed for the Marae Tainu‘u complex between July 8 and July 21, 2016, prior to and during the excavation of multiple test units at the historical site. An 8.25 cm bucket auger was used to sample point locations across the paepae and marae court in a preemptive effort at stratigraphic characterization and the identification of cultural materials as a guide for further testing. Auger sampling showed relative consistency in stratigraphy across the marae, with the upper organic layer and A-horizon followed by an abrupt transition to a dense coral deposit at about 20-40 cm below surface. This coral layer extended into the water when close to the ahu, but abruptly transitioned back to finer sediment in locations further inland. Coring was difficult and often incomplete due to the presence of coral. However, shell and lithic materials recovered during this process were helpful in our assessment. Stratigraphic information will be detailed below in reference to excavated test units. All material was returned to sample columns following observation and data recording. An interpolated model of the Tainu‘u paleolandscape will be forthcoming as a component of joint efforts with the Service de la Culture et du Patrimoine.

Horea

Survey and coring of three offshore motu took place on July 7, 2016. John O'Connor and M. Hinanui Cauchois were escorted to the islets by Tumara'a Fire Chief Mssr. Robert and his first hand Mssr. Mahuta. Horea is an offshore islet located on the northern edge of Tetuatiare Pass, the result of sediment accumulation on the south point of barrier reef structure. The motu measures approximately 150 × 150 m, and is frequented by surfers and island residents for recreational purposes. There is evidence of recent post-contact occupation and development in the form of an electrical box and subterranean cable protruding from the southern bank of the islet. Basalt cobbles and possible worked lithic flakes were observed falling out of the eroded embankment on the western or ocean side of the motu. The elevation of the motu is approximately 1-1.5 m on the seaward side and apparently extended further westward onto the reef at some point in the past. The wave cut along this area has exposed potential pre-contact cultural layers, and larger shell debris can be seen protruding from the substrate. Four auger samples were taken with an 8.25 cm bucket auger. Two auger samples were placed at 5 m inland from the western shore in a north-south alignment. One sample was placed approximately 40 m inland from the western shore on a raised area relatively central on the motu. A final auger sample was taken at 25 m inland from the southeast shore of the islet in an area of lower elevation. No cultural material was recovered from any of the sample locations. All sediment was returned to the sampled columns following observation and data recording.

Tapute

Tapute is a large motu measuring approximately 650 × 250 m and located only about 50 m from the main island of Raʻiātea. Unlike the reef positions of Horea and Punaeroa, Tapute sits in shallow water on a sandy bank extending westward from Raʻiātea's coastline. The motu is primarily composed of low-lying swampland and was likely connected to the main island in the recent past. The size of the islet, its proximity to the main island, and its ecological condition as a low-lying islet supporting extensive vegetation growth suggest this locale as an ideal place for archaeological testing. However, the immediate environment is rather menacing. Half of the island is under public ownership and accessible for archaeological and ecological research with the permission of Tavana Cyril Tetuanui's office. The other half of the island is privately owned with multiple makeshift structures and the appearance of a deserted tourist resort. The terrain is dangerous due to land mismanagement. Uncleared and mounded vegetation, rusted metal and other industrial debris, decrepit structures, and possible contaminated refuse (e.g. medication bottles) make this a difficult place to rationalize a safe and effective research operation. The entire perimeter of the island was surveyed on foot. Areas of possible excavation were identified, but Tapute will not likely become part of a fieldwork plan. No auger samples were excavated.

Punaeroa

Punaeroa is a small motu located on the interior (lagoon side) portion of the reef just north of Punaeroa Pass. The islet measures 70 × 35 m, with a separate 30 m section jutting to the north. This motu has been heavily modified in recent years and is in very

poor structural condition. The motu was mined for sand for a resort and the transfer of sediment to other coastal areas. This mining activity contributed to substantial erosion and sediment shift on the reef, depleting accumulated sediments and essentially destroying the motu. Sand has recently been brought back out to the motu, and vegetation (i.e., coconut palm, taro) has been planted in an effort to revive the landscape, reestablish natural processes of sediment deposition, and stabilize the land base. Large boulders have also been imported and placed along the edges of the islet as a protective barrier against high-energy wave action, but it appears of little use as erosion is continuing at a rapid rate. A single auger sample was placed in a central area of the motu. Observation of sediments revealed a continuous deposit of low-compaction coral sand that appeared to be from the recent transfer of material to the islet. All material was returned to the sample column after observation and data recording.

2016 Raʻiātea Excavations

Marae Tainuʻu is a well-known marae complex at Tevaitoa and was the seat of power for an autonomous district that exerted control to a greater or lesser degree on the western side of Raʻiātea prior to European contact in the region (see Figures 11 and 12). Today the marae is occupied by the island's oldest Protestant church, with a school and the Tumaraʻa government offices close by to the north. The area remains an important regional center of social, political, and religious significance, and Tainuʻu serves as a gathering place for community events as well as an attraction for tourists. The history of Tainuʻu is not thoroughly documented, but local residents have a great deal of knowledge about the history of the place. Handy's sources referenced Tevaitoa as the only district on



Figure 11. South-facing photograph of the ahu at Marae Tainu‘u. The ahu is made of cut coral limestone and basalt upright slabs as tall as 4 m in height. (photo by J. O’Connor)



Figure 12. West-facing photograph of the Marae Tainu‘u complex, taken from the east side of Paepae Taumatini. The ahu is located behind the church. (photo by J. O’Connor)
the island other than Opoa that was ruled by an ari‘i family, that this ruling family was

related to the island of Rarotonga in the Cook Islands, and that the construction of the marae postdates that of Marae Taputapuatea (Handy 1930: 91).

Pastor Philippe Tupu is the head of the church and lives on the marae grounds. He stated that Tainuʻu was one of the last places in the Society Islands to fall under French rule, and that warfare between Māʻohi locals and the French occurred there between 1888 and 1895 AD. After the French overpowered the local rebels, approximately 500 Raʻiātean men, women, and children were sent to prison camps at New Caledonia and at Ua Huka in the Marquesas archipelago. Only 27 people survived to return home following a French governmental pardon several years later. Pastor Tupu also discussed the history of churches at Tainuʻu, noting that the first church was placed on the marae in the early 1900s, a second church was then located north of the marae area, after which the third and current church was located back on the marae in the late 1950s to early 1960s. Modern structures on the marae also include a concrete outdoor court, an indoor gymnasium, and Pastor Tupu's house.

The archaeological features at Marae Tainuʻu occupy a position of importance and pride in the community, and these cultural resources are managed and looked after by Pastor Tupu, the church congregation, and other district residents. The ahu and paepae features remain in good condition, with upright slabs and relatively little evidence of destruction, though the current appearance of the area is likely far different from how it looked in the past. The persistence of these features on the landscape has perpetuated a connection to archaeological history at this location. However, the subsurface archaeology of Tainuʻu is not well explored. The known history of the site and the location of the marae on a beach promontory situated between reef passes to the north

and south make Marae Tainu‘u a quintessential locale for the archaeological investigation of chronology, coastal settlement, and human landscape management in a coastal environment of prominent archaeological significance.

Controlled subsurface testing in the form of excavated test pits took place at the Marae Tainu‘u archaeological complex between July 11 and August 2, 2016. The 2016 excavations were directed by John O’Connor, with guidance and input from M. Hinanui Cauchois. Denis Pitomaki and Béa Tevaearai played major roles in the materials recovery process. Four 1 × 1 m test units were excavated along a single inland-to-coast oriented transect across the marae complex. This allowed the testing of subterranean cultural layers while simultaneously mapping geological stratigraphic variation in the coastal zone. Point locations were documented for each excavated pit (see Table 5) and mapped in relation to archaeological and historical features at the marae (Figure 13). A total of 2.70 m^3 of sediment was excavated, sifted for archaeological residues, floral and faunal remains, and the recovery of multiple classes of artifacts. Stratigraphic profiles were created for each unit in accordance with standard archaeological practice, and these

Table 5. Locations of 2016 excavated test pits discussed in the text. Global Positioning System latitude and longitude coordinates are displayed in World Geodetic System (WGS84) decimal degrees.

Test Pit ID	**Latitude**	**Longitude**	**Date**
TP1Tainuu	S 16.79390	W 151.49228	11 July 2016
TP2Tainuu	S 16.79390	W 151.49226	13 July 2016
TP3Tainuu	S 16.79371	W 151.49318	21 July 2016
TP4Tainuu	S 16.79375	W 151.49283	25 July 2016

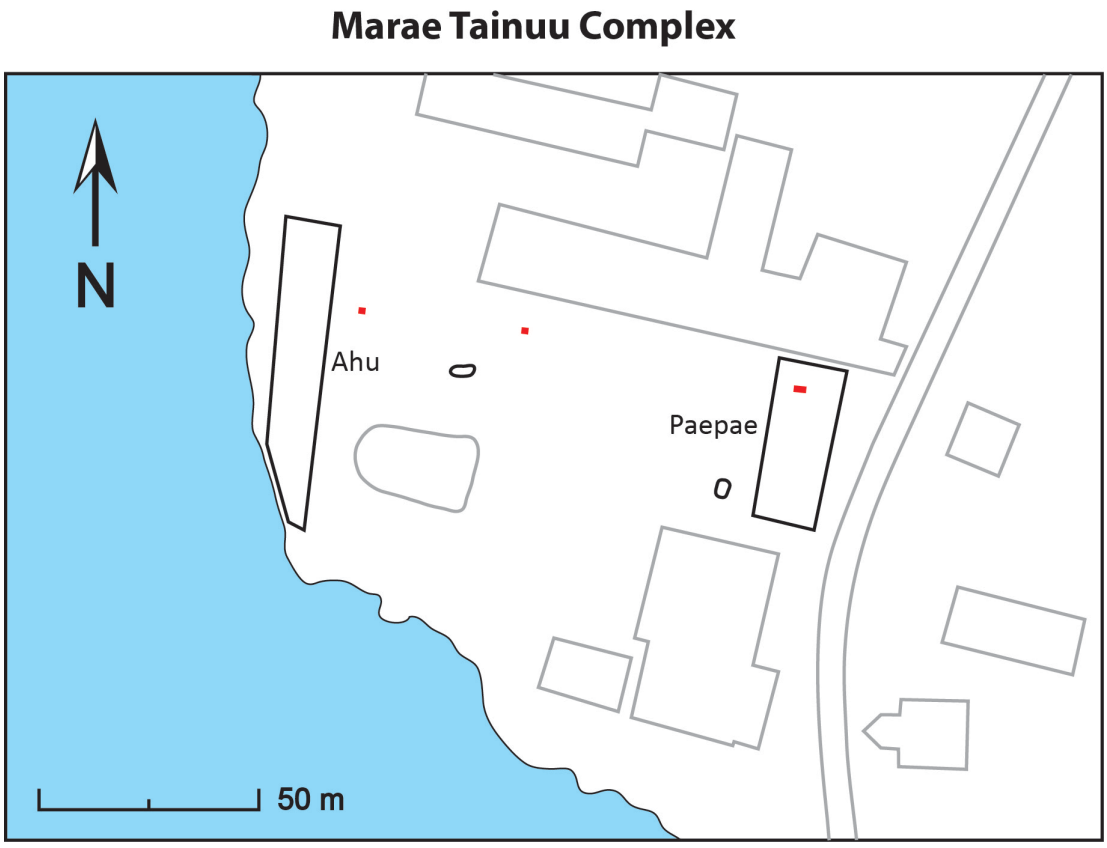


Figure 13. Map of Marae Tainu‘u archaeological complex. Archaeological architecture is in black outline with modern structures in gray. Test pits excavated during the 2016 field season are marked in red.

profiles will be used to interpolate a paleolandscape model for the Tainu‘u promontory. Review of test pits and the results of ongoing analyses at the University of Oregon are detailed below.

Tainu‘u Test Pit 1

Excavation of Test Pit 1 (TP1Tainuu; Figure 14) at Marae Tainu‘u began on July 11, 2016, and continued through July 21, 2016. TP1Tainuu is located on what is locally referred to as the paepae, a 30 × 15 m rectangular feature of upright coral limestone and basalt slabs enclosing a grass surface that is elevated approximately 25-40 cm above


Figure 14. North-facing photograph of TP1Tainuu. (photo by J. O'Connor)

the surrounding area. This feature is named Taumatini and was noted as the chief's residential platform in ethnohistorical literature (Handy 1930). TP1Tainuu was placed on the north end of the paepae, away from tree roots and other plants that exert a greater presence on the southern portion of the feature. The test pit was excavated to a depth of 120 cm, passing through three distinguishable sedimentary layers before plunging below the water line. The unit appears stratigraphically secure, with no evidence of destructive bioturbation resulting from recent development activities or local fauna such as tupa crabs (*Cardisoma carnifex*). Defining stratigraphical features are the three primary layers and the distinctness of transition between them. Layer I spans 0 cm to approximately 20 cm below surface and can be described as a typical surface horizon comprised of recently deposited organic materials and soils (e.g., a well manicured lawn covers the paepae in this area). Layer II extends from ~20 cm below surface to ~80 cm below surface. Coral

limestone cobbles and boulders dominate this layer which has the appearance of intentional fill, an observation bolstered by the acute transition to the Layer III cultural deposit. A basalt boulder alignment is apparent in the lower levels of Layer II (see cross-section profile in Figure 15). The transition from Layer II to Layer III is recognizable by the cessation of coral fill and conversion to fine sandy sediment. The basalt alignment is resting on the top of Layer III, and it is in this location that pig remains (*Sus* sp.) were recovered. Modified lithic materials (basalt, burned rock), hearth features, and changes in marine fauna composition all appear to occur at or below the top of Layer III. Excavation

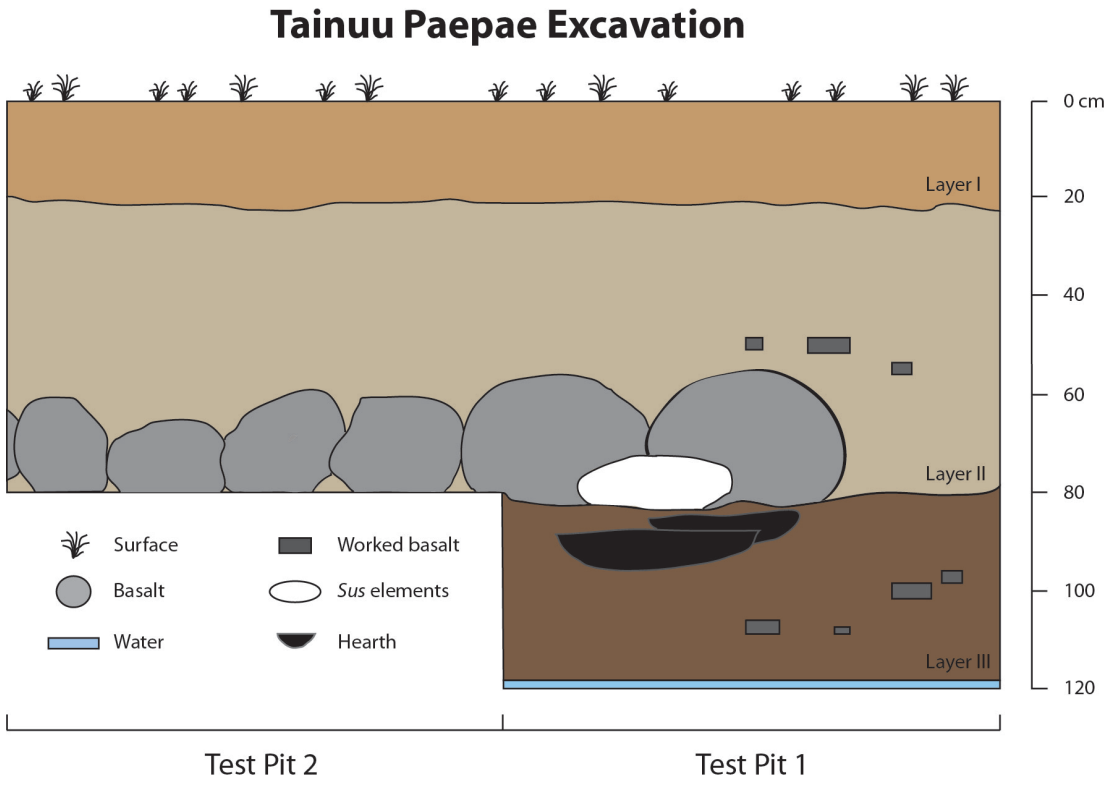


Figure 15. North-facing cross-section profile of Test Pits 1 and 2 at Marae Tainuʻu. Layer I: dark grayish brown fine clayey sediment, Layer II: very dark gray and brown loam with dense coral (calcium carbonate) throughout, Layer III: very dark grayish brown fine sediment interspersed with pale brown sand. Charcoal flecking present throughout the units at varying densities.

was terminated at the water line (~120 cm below surface). Material recovery continued to this point suggesting subphreatic archaeological deposits at this location.

Tainu'u Test Pit 2

Test Pit 2 (TP2Tainuu; Figure 16) was excavated between July 13 and July 19, 2016. TP2Tainuu was placed west of and immediately adjacent to TP1Tainuu, thus creating a 2 × 1 m trench with which to observe the continuation of archaeological features into the west wall of the pits and gain a better understanding of cultural layers and geomorphology in this section of the marae complex (see Figure 16). TP2Tainuu follows the geological trend of TP1Tainuu, with three layered substrates that correspond to transitions in sediment composition and vertical positioning of archaeological



Figure 16. North-facing photograph of TP2Tainuu. (photo by J. O'Connor)

materials. The basalt alignment first uncovered in TP1Tainuu continues westward through TP2Tainuu and into the western sidewall of the unit. Again, the alignment rests on top of the Layer III sedimentary boundary, and the coral limestone fill of Layer II gives the impression of landscape modification in the interest of covering the lower cultural layer, raising the landscape, and modifying the surface of the marae area prior to construction of the archaeological surface features that exist today.

Tainu‘u Test Pit 3

Test Pit 3 (TP3Tainuu; Figure 17) is a 1 × 1 m unit that was excavated on July 21 and July 22, 2016. TP3Tainuu was placed 8 m east of the Marae Tainu‘u ahu along an east-to-west transect in line with Test Pits 1 and 2. TP3Tainuu displayed very different


Figure 17. North-facing photograph of TP3Tainuu. (photo by J. O’Connor)

sedimentary composition from that of TP1Tainuu and TP2Tainuu located another 100 m inland. The organic layer of darker sediment (Layer I/Level 1) seems to only be about 10 cm to 15 cm thick and is much sandier than the upper layer of the inland units. A greater variety of marine shell is present in this layer as well. Both the sandier sediment and the increase in marine species diversity likely correlate with the close proximity of TP3Tainuu to the lagoon. A thin lens of sand is located at the transition from Layer I to Layer II, after which Layer II consists primarily of dense aggregated coral limestone boulders and cobbles similar to Layer II of units TP1Tainuu and TP2Tainuu.

TP3Tainuu stratigraphy appears coherent with distinct layer boundaries, but a great deal of mixing between stratigraphic layers is apparent due to the presence of historical materials (e.g., glass, ceramic) throughout the unit. This is probably due to bioturbation from faunal activity (*C. carnifex*), with the possibility of high-energy water events in a near-shore context. A worker noted that mixing could be the result of materials deposited from dredging activities over the past 50 years. Dredging of the lagoon immediately offshore (west) of the marae has destabilized the protective properties of the reef, expediting erosion of the coastal buffer between the lagoon and the marae ahu that once existed and creating a situation in which destruction of the ahu appears imminent due to further lagoon encroachment and future rises in sea level. Our understanding is that the dredged material was used to construct the promontory to the north of Marae Tainu‘u on which the school and government buildings now sit.

Another gentleman by the name of Mssr. Franklin mentioned that he assisted Emory and Sinoto several decades ago as Sinoto worked to repair the marae by righting fallen slabs and shoring up the base of the structure which may have contributed to

infilling and the mixing of modern materials. Whether recent material was deposited eastward of the ahu or not, stratigraphic levels in TP3Tainuu appear consistent with inland layers in terms of a surface horizon followed by a dense layer of coral fill.

Tainu'u Test Pit 4

Test Pit 4 (TP4Tainuu; Figure 18) was excavated between July 25 and July 27, 2016. TP4Tainuu is located immediately southwest of C4Tainuu, a core point located 40 m east of TP3Tainuu and 60 m west of TP1Tainuu. Layer I is comprised of a fine dark grayish brown sediment and exhibits stratigraphic consistency for a much greater depth than in other units, extending from 0 to ~40 cm below surface. The transition from Layer I to Layer II is marked by a distinct ~5 cm thick layer of light sand at 33 to 38 cm below


Figure 18. North-facing photograph of TP4Tainuu. (photo by J. O'Connor)

surface on the east side of the unit and 38 to 43 cm below surface on the west side of the unit, thus simulating a down-slope grade toward the ocean that aligns with the thin lens of yellowish sand seen in TP3Tainuu located 40 m to the west. Smooth basalt boulders became visible in the lower levels of Layer I, with several of these resting at the layer change or in the upper level of Layer II. Layer II consists of a dark sandy matrix with yellowish brown mottled clay inclusions. More smoothed boulders were present under the first layer, and these sit on the stratigraphic boundary between Layer II and Layer III at about 70 cm. This is also where the soil becomes heavily saturated. Layer III was excavated to 10 cm below the water line, and excavation was terminated at 90 cm below surface.

2017 Raʻiātea Excavations

Archaeological work during the 2017 field season resumed focus at northwest Tumaraʻa Commune on the west coast of Raʻiātea. Coring and excavation during the 2016 field season provided direction for 2017 fieldwork. The offshore motu (islets) of Horea, Tapute, and Punaeroa underwent reconnaissance survey and sediment coring in anticipation of further investigation during the 2017 work period. However, these motu were not revisited in 2017 and will remain untested for the time being due to variability in research potential and the logistical planning necessary for a safe work environment at Tapute. A single bucket auger core (C1Dehors) was taken at Domaine Dehors, followed by the excavation of a single test pit (TP1Dehors). Work at Domaine Dehors was initiated for the observation of stratigraphy and evaluation of potential archaeological deposits in anthropogenically modified coastal flats at Tuʻu Fenua north of Tevaitoa (see

Figure 4 in Chapter I for reference). Further testing at Marae Tainuʻu (TP5Tainuu, TP6Tainuu, and TP7Tainuu) was encouraged due to the revelation of dense archaeological deposits during previous excavations, the relative lack of archaeological knowledge regarding the marae, and the prominence of the marae in the collective consciousness of local peoples. Point location coordinates of the sediment core and all test pits from the 2017 season may be found in Table 6.

The 2017 excavations are discussed below, beginning with testing at Domaine Dehors and followed by discussion of testing and results from the TP5Tainuu, TP6Tainuu, and TP7Tainuu. The 2017 excavations complement prior research at Tumaraʻa and help to complete the picture of pre-contact habitation and practices on the western side of Raʻiātea Island and the sociopolitical center of Mara Tainuʻu. Results are covered in subsequent sections.

Table 6. Locations of 2017 auger sample and test pits discussed in the text. Global Positioning System latitude and longitude coordinates are displayed in World Geodetic System (WGS84) decimal degrees.

Core/Test Pit ID	**Latitude**	**Longitude**	**Date**
C1Dehors	S 16.78450	W 151.48790	14 August 2017
TP1Dehors	S 16.78453	W 151.48795	14 August 2017
TP5Tainuu	S 16.79398	W 151.49229	16 August 2017
TP6Tainuu	S 16.79399	W 151.49228	16 August 2017
TP7Tainuu	S 16.79402	W 151.49240	24 August 2017

Domaine Dehors Test Pit 1

Excavation of Test Pit 1 (TP1Dehors; Figure 19) at the Domaine Dehors location began on August 14, 2017, and was completed on August 15, 2017. TP1Dehors is located 150 meters east/inland of the coastal road, or 180 meters from the current lagoon coastline, at the western mouth of the inland valley at Tuʻu Fenua approximately 1.1

kilometers north-northeast of the Marae Tainu‘u complex at Tevaitoa. TP1Dehors was placed immediately south of core C1Dehors, a bucket auger test core placed in the center of an open field at the center of the valley on a north-to-south trajectory. C1Dehors was cored to a depth of 180 cm below surface. Brackish water was encountered at 130 cm. No archaeological material was recovered during coring. However, a test pit was placed near this location to further assess the research potential of the coastal flat in this area for future archaeological, geological, or ecological testing.



Figure 19. South-facing photograph of TP1Dehors. (photo by J. O’Connor)

TP1Dehors was excavated to a depth of 120 cm below surface. The pit was initially excavated as a 1 × 1 m unit to a depth of 60 cm. After this, excavation continued from 60 cm to 120 cm only in the southwest and southeast quadrants of the unit due to the lack of substantial archaeological material being recovered and the continuity of sedimentary composition. Layer I comprised the first ten 10 cm levels (i.e., 100 cm) of material. This stratigraphic layer is defined as a continuous section of dark brown clayey

soil with intermittent appearances of archaeological materials throughout a relatively sterile layer. The upper layer appears to have been disked or graded recently. Burned rock, charcoal, and gourd were noted in Layer I Level 2 (10-20 cm below surface), with apparently burned rock increasing between 20 cm and 60 cm below surface. The appearance of seemingly burned rock in these lower levels may actually be the result of water staining, as no charcoal or other evidence of anthropogenic burning was observed at these levels. Water-worn cobbles appear between 50 and 60 cm below surface. Basalt boulders appear at seemingly random intervals below 50 cm depth and do not appear to be consolidated into any sort of discrete feature. Layer II began with a transition between sediments from dark brown clayey soil to a very dark gray clay at 100 cm depth. This layer displays characteristics of an older, more clayey matrix that is part of a previously existing marsh-like surface. No archaeological materials were recovered from this layer. Excavation of the two southern quadrants continued to 120 cm at which point water inundation prompted abandonment of the unit. The unit was immediately backfilled following photographic recording and documentation.

Nothing of archaeological significance was recovered from TP1Dehors. I spoke with Denis Pitomaki about the valley. Mr. Pitomaki stated that the entire area was a river when he was a child (i.e., 40-50 years ago), and the area experienced variability in flow level based on seasonal rainfall. He said that a section of the coastal valley was filled in during the 1980s for agricultural and later domestic use. The river was then configured into the current arrangement, with two streams to the north of the TP1Dehors location and one stream immediately to the south. No records could be located documenting this construction work, but this information appears to be accurate based on the appearance of

the landscape, where a heightened section of field borders a lower swamp-like forest. Mr. Pitomaki said that a portion of the river was filled in, the forest took over, and then the forest was bulldozed to create open land for modern use.

Results from Layer I support a temporally constricted fill event. Layer I matrix is relatively uniform and artifactual evidence is minimal, with potentially burned rock throughout, bits of charcoal, and a single turbo shell. The transition to very dark gray clay below 100 cm represents the predevelopment layer and fits with expectations of a recently developed marshy riparian zone. Layer II consists of a very dense wet mud that is nearly impossible to screen. This was formed by deposition of very fine silt over time that had been compacted into a stratigraphic layer that would be ideal for fine-grained core analysis. The potential for this area as a source of undisturbed sediment cores is substantial. Locations of low energy wetland sediments are rare in Polynesian high islands, and the Domain Dehors location should be investigated for paleolandscape and palynological evidence in the future.

Marae Tainu'u 2017

Controlled subsurface testing took place at the Marae Tainu'u archaeological complex between August 16 and August 30, 2017. The 2017 excavations were directed by John O'Connor, with assistance from Dr. M. Hinanui Cauchois. Denis Pitomaki and Béa Tevaearai assisted in the materials recovery process. University of Oregon students Sierra Battan, Katie Kelley, Kris Ranney, Madeline Smith, and Austin Wright worked as field crew for the excavations. Three 1 × 1 m test units were excavated at Marae Tainu'u as follow-up to the previous year's investigative work. Point locations were documented

for each excavation unit and mapped in relation to archaeological and historical features at the marae. A complex map depicting test units excavated during both the 2016 and 2017 field seasons is shown in Figure 20 below. A total of 4.01 m^3 of sediment were excavated and screened for archaeological remains. A summary of the 2017 excavation results and ongoing analyses at the University of Oregon is presented below.

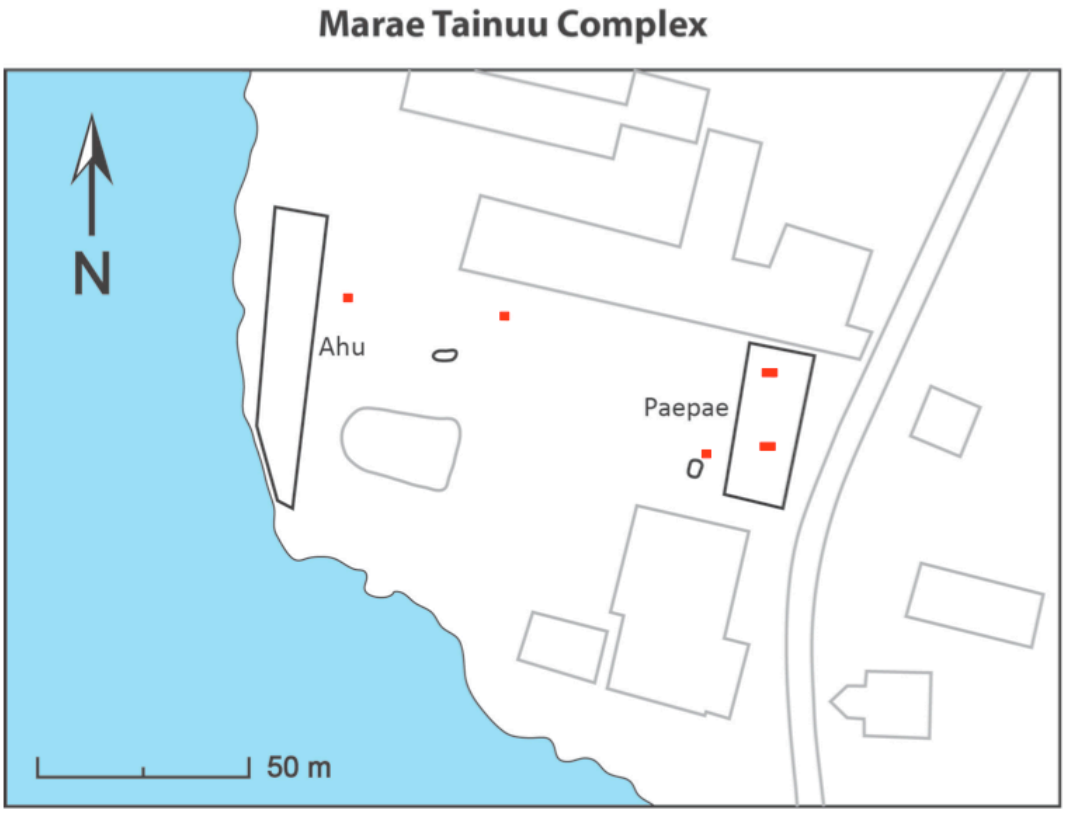


Figure 20. Map of Marae Tainu‘u archaeological complex showing seven 2016 and 2017 excavation units. Archaeological architecture is in black outline with modern structures in gray. Excavated test pits are marked in red.

Excavations at Marae Tainu‘u were restarted on the morning of August 16, 2017. Two adjacent 1 × 1 m test pits were opened in the center of Paepae Taumatini (18 m south × 7 m west of the outer paepae megaliths). These two units make up a west-to-east oriented 2 × 1 m trench, but were excavated individually for control. TP5Tainuu is the

eastern of the two units. TP6Tainuu is located immediately to the west of TP5Tainuu. TP7Tainuu was opened on August 23, 2017, 3.5 m west of the southern paepae section. The decision to reopen excavations at the marae followed the lackluster results from the Domaine Dehors test pit and encouragement from local government officials and community leaders. Further testing in the vicinity of Paepae Taumatini provides better areal coverage for an important pre- and post-contact archaeological feature. This information complements existing knowledge and ongoing analysis from this project.

Marae Tainu'u Test Pit 5

Excavation of Test Pit 5 at Marae Tainu'u (TP5Tainuu; Figure 21) began on August 16, 2017, and continued through August 24, 2017. TP5Tainuu was excavated concurrently with TP6Tainuu. TP5Tainuu is located 10 m south of TP1Tainuu in the center of the paepae. TP5Tainuu is immediately east of TP6Tainuu. TP5Tainuu was excavated to a depth of 140 cm below surface, at which point water inundation made continued excavation impossible without the use of a sump pump or some water removal system. Four distinct stratigraphic layers were visible during excavation. Layer I comprises the first three 10-cm levels (0 to 30 cm below surface). This layer consists of a dark brown fine sandy soil with grass on top. Recovered materials include marine shell, land snails, charcoal, terrestrial faunal bone, and an assortment of historic debris that has made its way into the matrix. Layer II begins at ~30 cm below surface with an abrupt increase in coral fill and the appearance of a basalt and coral boulder alignment in the northern wall of the unit. The boulder alignment extends into the east sidewall of the unit and westward into unit TP6Tainuu, mimicking the position of the alignment revealed in



Figure 21. North-facing photograph of TP5Tainuu. (photo by J. O'Connor)

TP1Tainuu and TP2Tainuu. This stratigraphic layer extends to 70 cm below surface. The Layer II matrix is represented by a dark brown soil with less sand than Layer I, and there are observable increases in burned rock and charcoal mixed with coral cobbles and boulders. Dense deposits of charcoal are visible at the base of the layer on the transition between Layer II and Layer III. Historic glass is present in small quantities within Layer II. However, historic materials are absent from the unit below 60 cm.

Layer III begins at 70 cm below the surface with a visible cultural floor and dense archaeological layer that extends to approximately 110 cm depth. The boulder alignment sits atop this level at 70 cm, below which a marked increase in human activity is apparent. This is comparable to the stone alignment and associated layer transition seen in TP1Tainuu and TP2Tainuu which supports vertical and horizontal continuity in the use of this space. The Layer III matrix consists of a very dark gray to dark brown mix of fine

sand and clay. The decline in coral fill from Layer II to Layer III is immediate. Basalt flakes from lithic manufacturing, terrestrial mammal bone, marine shell, burned rock, and charcoal were all collected in substantial quantities from Layer III, although evidence of human behavior is primarily visible between 70 and 100 cm. Increased quantities of edible marine shell species (e.g. *Turbo setosus*, *Tridacna maxima*) are particularly evident between 80 and 100 cm. Increased evidence of lithic tool manufacturing is also present in Layer III, though no larger worked lithic artifacts were recovered. Faunal remains and lithic debitage all but disappear between 100 and 110 cm as there is an observable transition from the very dark gray and brown cultural sediments to a light brown sandy matrix.

Level 12 (110-120 cm) marks the beginning of stratigraphic Layer IV, which extends from 110 cm to 140 cm where excavation was stopped. Brackish water was encountered at 135 cm below surface. Cultural materials persist in Layer IV, with the recovery of animal bone, marine shell, and basalt debitage continuing below the water line. Areas of very dark gray sediment are present in random configurations. These appear to be temporary use hearth features and charcoal flecking is present throughout the layer, though it was difficult to extract larger charcoal specimens due to the dispersed and irregular nature of the deposits. Layer IV almost certainly continues below the water line and the continuation of excavations with proper water removal equipment would likely be fruitful in this coastal area.

Marae Tainu'u Test Pit 6

Test Pit 6 (TP6Tainuu; Figure 22) at Marae Tainuu was excavated simultaneously with TP5Tainuu in the approximate center of Paepae Taumatini. Excavation of the unit began on August 16, 2017, and continued through August 24, 2017. The unit was excavated to slightly below the waterline at a depth of 140 cm. The composition of sediments in TP6Tainuu stratigraphic layers largely mirror those of TP5Tainuu with some variations in the presence of reddish clay in Layer III and the intrusion of darker sediments in the light sand that characterizes Layer IV. Layer I extends from the surface to 30 cm depth. This layer is a dark brown sandy soil with charcoal flecking throughout. Recovered materials include marine shell, terrestrial animal bone, and a variety of historic debris. Layer II extends from 30 to 70 cm below surface and consists of a dark



Figure 22. North-facing photograph of TP6Tainuu. (photo by J. O'Connor)

brown soil with a decrease in sand content. Layer II is primarily defined as the coral fill layer seen in TP5Tainuu and in units TP1Tainuu and TP2Tainuu. This layer of mixed-size coral limestone cobbles and boulders is uniformly spread across the paepae and sits atop the basalt alignment features and cultural floor of Layer III. Materials recovered from Layer II include marine shell, land snails, terrestrial faunal remains, lithic debitage, FAR, and charcoal. Historic debris is present as deep as Layer II/Level 5 (40-50 cm depth), but disappears from the deposit after 50 cm. The east-west oriented basalt alignment in the north sidewall becomes fully apparent at 70 cm. Basalt boulders are also present at the base of Layer II along the west sidewall of TP6Tainuu and in the southwest quadrant of the unit.

As in TP5Tainuu, Layer III of TP6Tainuu begins at about 70 cm below surface, immediately below the coral layer. The transition is characterized by a very dark gray matrix of fine sandy clay. Coral is absent from the layer, and there is a notable increase in pig bone (*Sus* sp.) and basalt flakes in Layer III/Level 8 (70-80 cm). Substantial quantities of animal bone and marine shell are present between 80 and 100 cm depth, as well as increased levels of a reddish clay scattered throughout the level that is different from corresponding levels in TP5Tainuu. Bone, shell, basalt, and charcoal were still recovered at the lower level of Layer III, where the density of archaeological materials decreases as there is a transition from darker soil to a light brown sand beginning at about 110 cm. Layer IV of TP6Tainuu contained animal bone, marine shell, burned rock, and lithic debitage throughout the levels and the presence of these archaeological residues continues below the waterline (~135 cm) as in TP5Tainuu. A noticeable difference in Layer IV of TP6Tainuu is the continued intrusion of dark gray sediment between 110 cm

and 140 cm in the west half of the unit. Whereas the light brown sand is present, it is not uniform throughout the basal layer of the unit as in adjacent TP5Tainuu. Random spots of dark gray sediment in Layer IV of TP5Tainuu suggest temporary hearth features or other brief use events. The split composition of very dark gray sandy clay and light brown sand in TP6Tainuu suggests a more prolonged usage or more intense single-impact event to the west of these test units.

Marae Tainu'u Test Pit 7

The final test unit excavated at Marae Tainu'u (TP7Tainuu; Figure 23) was placed 3.5 m west of the southern portion of the paepae and 4.5 m north of the upright stone monument. The location of this unit was chosen in comparison to those units on the paepae to test archaeological stratigraphy in a neighboring location to the circumscribed feature of the paepae platform. The paepae sits approximately 25-40 cm above the surrounding surface. Therefore, the surface elevation of TP7Tainuu is that much lower than the surface of units TP1Tainuu, TP2Tainuu, TP5Tainuu, and TP6Tainuu.

Layer I of TP7Tainuu extends from the surface to 30 cm below surface. The sediment appears as a dark brown sandy clay with mixed quantities of marine shell, animal bone, and historic materials dispersed throughout the layer. The transition between Layer I and Layer II is marked by change to a nearly black soil after about 28 cm depth. Faunal remains increase greatly just prior to the Layer II transition, with marine shell dominating the collection. Historic materials are still abundant between 30 and 40 cm, but disappear below 40 cm depth. Layer II extends to 60 cm below surface and maintains a composition of black and very dark gray soil with increased charcoal

flecking. Burned rock is present in the layer, along with marine shell, animal bone, basalt lithics, and charcoal collected in varying quantities. Basalt boulders became visible in the south half of the unit below 40 cm. These do not form a discernible feature, but are concentrated in a way that does appear to be the result of human activity. Some of these boulders were removed in Layer II/Level 6 (50-60 cm). Shell, larger charcoal deposits, and basalt debitage including an adze preform were located beneath. Sediment color became lighter at approximately 60 cm depth, changing from black and very dark gray to a dark brown sandy sediment at the upper horizon of Layer III. There is a marked decrease in recovered archaeological materials here.



Figure 23. North-facing photograph of TP7Tainuu. (photo by J. O'Connor)

Layer III extends for two levels to a depth of 80 cm. Marine shell, terrestrial animal bone, basalt flakes, and charcoal were collected from between 60 and 70 cm, with an absence of smaller basalt lithics in Level 8. Larger basalt boulders remain present in the southwest quadrant of the unit. The sediment becomes sandier in Layer III, with light brown sand inclusions noticeable in Level 8. Layer IV begins at 80 cm below surface and extends below the waterline at 105 cm. Excavation was stopped at 110 cm below surface. Brown sand constitutes the majority of Layer IV. Possible hearth features are present in Level 9 (80-90 cm), but no evidence of concentrated burning is evident in underlying levels. Marine shell, burned rock, some bone, charcoal, and basalt are present throughout the layer. Recovered materials decrease approaching the waterline at which point the sediment begins to transition to a gray calcareous sand. Piled basalt boulders continue from upper layers, through Layer IV, and below the water. This feature was not dismantled and excavated. Additionally, it is important to note that the layer of apparent coral fill that is so prominent in Layer II of the paepae test units is absent from TP7Tainuu. This supports the notion of continuous delineation between the paepae and immediate surrounding area through time, whether for ritualistic or mudane purposes.

Stratigraphy and Landscape Change

Stratigraphic variation observable in excavated core columns and test pits has provided information regarding the paleolandscape and cultural layers at the Marae Tainuʻu archaeological complex. Notable revelations include distinct transitions between geological layers, as with the coral fill substratum in TP1Tainuu, TP2Tainuu, and TP3Tainuu, the thin lens of yellow sand that appears to grade seaward between

TP4Tainuu and TP3Tainuu, and the presence of basalt boulders resting on cultural layers. Particular attention is warranted to the coral fill and underlying cultural layer of the TP1Tainuu and TP2Tainuu trench (see Figure 24), where a 60 cm thick layer of coral limestone boulders and cobbles (Layer II) is located immediately above a cultural layer (Layer III), appearing to cap the cultural floor upon which rests a basalt alignment and from which was recovered evidence of cultural activities, including hearth features, worked lithic materials, and faunal remains. The boundary between Layer II and Layer III is explicit to the extent that the presence of such material is either due to a high-energy natural event or is the result of anthropogenic landscape modification. The TP1Tainuu/TP2Tainuu basalt alignment (see also Figure 15) is a discernible archaeological feature, and its presence and uninvestigated continuation to the west of TP2Tainuu on a cultural stratum at 80 cm below surface gives semblance of an architectural or structural element that was covered at a time prior to the construction the archaeological surface features visible today.

Relative uniformity in the size of coral boulders and cobbles of Layer II suggest human activity as the proximate cause for the coral layer. Vertically, Layer II extends upward to approximately 20 cm below surface, a position that correlates with the base of upright slabs surrounding the paepae feature itself. Horizontally, the coral fill does not appear to expand across the entire marae, as demonstrated by the absence of a definitive coral layer from TP4Tainuu located 60 m west of TP1Tainuu/TP2Tainuu on the northern edge of the marae court. However, core sampling was hampered by dense subsurface sediments or clasts in several areas of the marae, and Layer II of TP3Tainuu (~15 cm to 60 cm below surface at the waterline) consists of densely packed coral. Further testing



Figure 24. Southeast view of TP1Tainuu and TP2Tainuu. Dense coral deposits are visible in Layer II. Fire-affected-rock was present in mixed quantities within the coral layer. Marine shell was common along with limited pig elements, but few fish bones were recovered. (photo by J. O'Connor)

will provide insight as to the extent of this stratum and its potential as an anthropogenically modified landscape element.

2017 excavations at Marae Tainu'u further defined the history of land use at Tevaitoa and confirmed the circumscribed use of specific sections of the marae grounds for particular activities over time. Important to understanding settlement patterns and landscape change, TP5Tainuu and TP6Tainuu display the same stratum of coral limestone fill seen further north on Paepae Taumatini (see Figure 25). Detailed observation of coral-rock size, dispersal, and placement confirms this layer as an intentional human deposit. This type of landscape modification is seen in other areas of the Pacific (David Burley, 2017 *personal communication*), as either an extension of

coastal land for human activities or as a modification (e.g., paving, elevation, etc.) of preexisting structures for both extraordinary and mundane uses. The appearance of a basalt boulder alignment at a corresponding depth to that of the comparable feature in the TP1Tainuu/TP2Tainuu trench, and the presence of this feature directly above dense archaeological deposits, justifies the sustained utilization of the landscape within the current paepae boundaries over several hundred years. Similar archaeological features in both the 2016 trench and the 2017 trench demonstrate the likelihood of buried features across the paepae and throughout the marae complex that spatially correspond to traditionally recognized land use patterns at this location.



Figure 25. Southeast view of TP5Tainuu and TP6Tainuu. Dense coral deposits are visible in Layer II with basalt boulders present on the cultural floor at 70 cm below surface. Charcoal flecking and cultural residues can be seen above light brown sand in Layers III and IV. (photo by J. O'Connor)

TP7Tainuu displays evidence of multipurpose use that differs from that seen in the paepae units. The most notable aspect of this test unit is the lack of coral limestone fill seen in the paepae trenches. This means that when the paepae was paved over, those areas of the marae court located west of the paepae were not filled in. TP4Tainuu shows this same lack of fill. Regardless of reason, there was an effort at some time in the past to cover the earlier remains of Paepae Taumatini and further elevate the platform to a height above the surrounding landscape. This height corresponds with the upper edge of the surrounding megaliths. However, a clear understanding of the timing of coral fill placement in relation to the surrounding worked basalt slabs is unlikely at this time. TP7Tainuu reveals a greater intensity of fire use than seen in other areas of the marae. Layer II (30-60 cm depth) consists of a nearly black soil with substantial deposits of charcoal at greater densities than that seen in other test pits throughout the Marae Tainu‘u complex. This shows intentional and consistent long-term use of fire at this location on the marae court (southeast) in a way that differs from other areas. Current decision making processes in relation to these activities are unknown, but the spatial organization of these tasks on the marae, but outside of the paepae boundary, points to the explicit and delineated separation of activity areas.

Bucket auger coring and test unit excavation at the Domaine Dehors location provided insight into recent landscape change and the potential for paleoecological analysis in areas of low energy water flow on the island. Sediments below 100 cm depth appear as part of an older predevelopment layer that may hold potential for palynological studies and the analysis of particulate matter that settled in marsh-like environments. Paleoenvironmental coring has proven successful for expanding our understanding of

climate change and the impacts of early human colonization on Pacific Islands (Athens et al. 2014; Athens and Ward 2004; Burney and Burney 2003). Subphreatic sediment cores retrieved from a location such as the Domaine Dehors test unit should provide clues to pre-human and anthropogenic environmental change at Raʻiātea. Though no obvious pre-contact archaeological materials were recovered, the possibility of archaeological deposits in the vicinity of the coastal valley and below the waterline is quite likely (see Sinoto 1979 for analogous example).

A radiocarbon chronology for Marae Tainuʻu and an analysis of recovered archaeological materials from these excavations is covered in Chapter V and Chapter VI, respectively. The relation of archaeological and geological stratigraphy to radiometric temporal assessments (i.e., radiocarbon dates) is of the utmost importance for development of a chronology for human activity at Tainuʻu that may be compared to other historical sites and archaeological deposits on Raʻiātea Island and in the Pacific region. A study of the artifacts and, particularly, the ecofacts associated with human activity at this location allow a more holistic model of human environmental impacts following initial colonization of the island by Polynesian voyagers. The following assessments of chronology and material evidence support a sustained use of land and coastal subsistence resources over several centuries of habitations at the location of Marae Tainuʻu.

CHAPTER V

RADIOMETRIC TESTING AND ARCHAEOLOGICAL CHRONOLOGY

Radiocarbon (^{14}C) dating of carbonized floral specimens from the Marae Tainuʻu excavations provides a chronological context for the analysis of recovered archaeological materials and an understanding of human history at this important historical site. Seven samples from four different test pits at Marae Tainuʻu were submitted for macrobotanical identification and ^{14}C dating. These new dates suggest that sustained human activity took place at Tainuʻu as early as the year 1521 cal AD (2σ confidence interval, IntCal13 calibration curve), although an earlier presence at the site is likely due to our collective understanding of regional settlement chronology and geological matters unique to the Society Islands. Issues pertaining to the ^{14}C dates and their calibrated age ranges are discussed in this chapter.

I provide a general background of radiocarbon dating and discuss new ^{14}C dates from Raʻiātea in relation to previously published information on regional and local island settlement chronology. Radiocarbon dates from Tumaraʻa are a welcome addition to the growing corpus of local and regional chronological data in the Society Islands. Importantly, the age determinations discussed below also provide the first ^{14}C chronology for Marae Tainuʻu, one of the larger ceremonial centers in the Leeward Society Islands. These data help situate western Raʻiātea in the context of the population dispersals, island settlement, and inter-island voyaging for which this region is well known, but for which such archaeological investigation is still a necessity.

Chronology and the Radiocarbon Method

History is a process of recounting the past so as to establish an orderly understanding of our position in the present. The documentation of sequential events allows perception of cause and effect, and provides clarity to various aspects of the natural world. In the absence of prerecorded textual information, archaeologists create data from empirical proxies and impose order on the past to construct a narrative of human experience. Chronology is the result of a temporal element imposed upon the archaeological record. The development of reliable scientific methods for the imposition of temporal order on the material residues of human history is a primary goal of archaeology. Radioisotope dating methods have revolutionized the ability of archaeologists to make reliable chronological assessments, and no other method has been utilized more widely than ^{14}C dating.

The theoretical principles of ^{14}C dating were first established by the chemist Willard Libby and his colleagues, following Libby's recognition that the natural interaction of thermal neutrons with nitrogen (^{14}N) atoms leads to a series of transformations resulting in the dispersal of radioactive carbon-dioxide ($^{14}CO_2$) throughout the atmosphere and the infusion of ^{14}C into all living matter in trace quantities equivalent to atmospheric concentrations (Libby 1946). The prediction of ^{14}C presence in living matter, and a ^{14}C half-life initially estimated at 5720 ± 47 years, was proven by demonstrating that methane (CH_4) gas produced at the Patapsco Sewage Plant in Baltimore contained trace amounts of ^{14}C that were absent from the methane found in petroleum deposits of much greater age (Anderson et al. 1947). Because carbon intake ceases upon death, Libby reasoned that the ratio of residual radioactive ^{14}C to the stable

carbon isotopes of ^{12}C and ^{13}C found in ancient organic materials could be used to assess a date for the cessation of metabolic processes and, therefore, the age of the object being studied. Radiocarbon dating was quickly applied to organic artifacts and other biological materials in a series of papers assessing the degree of error for ^{14}C dates on objects of known age, such as seal bones, trees, sea shells, and wood from ancient Egyptian tombs (Anderson and Libby 1951; Arnold and Libby 1949, 1951; Libby 1951; Libby et al. 1949). These studies tranformed archaeological and biological research by providing an alternative to relative dating models through the absolute dating of individual specimens as recovered from the empirical record.

Stable isotopes accumulate over time in a given reservoir (Pate 1994). The decay of radioactive isotopes is measured in reference to stable isotopes of the same chemical element, and age determinations are based on the element's half-life, an estimated rate of decay representing the amount of time necessary for an element to decrease in value by half. ^{14}C breaks down through a process of beta decay whereby ^{14}C is converted to ^{14}N (Bronk Ramsey 2008). Radiocarbon half-life was originally estimated at 5720 ± 47 years (Anderson et al. 1947; Arnold and Libby 1949), though this was later adjusted to 5568 ± 30 years (Anderson and Libby 1951). ^{14}C age determinations are still calculated based on the so-called Libby half-life of 5568 ± 30 years, but regularly discussed referencing the Cambridge half-life of 5730 ± 40 years as reported by Godwin (1962). Bronk Ramsey (2008) notes that the half-life of radiocarbon is not as well understood as accepted in the literature, with some estimates of ^{14}C half-life at ~6000 years (Chiu et al. 2007).

Stable isotope proportions can change through time based on the ratios of heavy to light isotopes in other associated chemical elements (Chiu et al. 2007; Knudson and

Buikstra 2007; Macko et al. 2009). After adjusting for fractionation, ^{14}C decay is measured in reference to $^{14}C/^{12}C$ and $^{13}C/^{12}C$ ratios as relative to proportions of atmospheric concentration estimated for the year AD 1950. The choice of 1950 as the year against which to compare carbon concentrations is due to the massive influx of anthropogenically produced radiocarbon during the nuclear testing of the 1960s (Taylor 2000). A ^{14}C date, that is the actual measured age estimate of the organic sample, is then reported in years before present (BP; i.e. before AD 1950) based on the assumption of consistency in natural atmospheric concentrations since that time (Reimer et al. 2004a). The choice of AD 1950 also created a temporal benchmark for the standardized reporting of ^{14}C dates in future studies.

In recent years, other radioactive isotopes have been utilized for the development of archaeological chronologies, notably the increased use of uranium-thorium (i.e., U/Th or U-series) dating techniques to substantially increase the temporal resolution of Polynesian archaeological sites (Burley et al. 2015; Clark et al. 2016; Weisler et al. 2009). U/Th dating has been applied to unmodified and modified coral (e.g., *Acropora* spp., *Pocillopora* spp.) from archaeological contexts to assess human activity in West and East Polynesia with a degree of precision and accuracy unattainable by ^{14}C methods, often obtaining error ranges of less than a decade for tested samples. This approach represents a step forward for the dating of relatively recent archaeological deposits in Polynesia and will be applied with increasing frequency in decades to come.

Date Calibration and Sample Choice

The constant mixing of elements in the atmosphere, chemical exchange between the troposphere and the hydrosphere, and variation in carbon uptake through terrestrial biological pathways mean that the presence of radiocarbon is not constant, instead fluctuating through time in relation to ^{12}C and ^{13}C in different geological and biological systems. Small discontinuities were recognized early on in materials such as marine shell (Libby et al. 1949), but it was during the 1960s that the need for a reliable method of calibration was realized to correct for the Libby half-life, long-duration temporal variability, and other issues (Balter 2006; Bayliss 2009; Taylor 2000). Tree rings of known age used by dendrochronologists were a focus of early dating by the Libby group for testing the reliability of dating procedures (Arnold and Libby 1949, 1951). These tree rings were later identified as an independent data source to calibrate raw ^{14}C dates to calendar year age ranges, and calibration curves based on the ^{14}C dating of long tree ring sequences of known age were developed (Pearson et al. 1986; Ralph and Michael 1974; Suess 1967). These calibration curves have been continuously reassessed and extended further back in time through the use of paleofloral remains, coral fossils, foraminifera, and other comparative specimens, contributing to the calibration curves employed in modern date assessments (Hogg et al. 2013; Hughen et al. 2004a; Reimer et al. 2004b, 2009, 2013; Stuiver et al. 1998).

Isotopic discontinuities are also present in contemporaneous organic materials from different environmental habitats. Though a general equilibrium exists between the air and the sea, the dynamic exchange of carbon between the ocean and the troposphere is subject to differential isotope distributions due to slower exchange between the two, as

well as slower mixing between the ocean surface and the deep sea. This contributes to an average global estimate of ~5% ^{14}C depletion at the surface of the ocean, an offset that translates to an global average radiocarbon estimate of 400 years older than expected (Bronk Ramsey 2008; Hughen et al. 2004b; Stuiver and Braziunas 1993). Additionally, differences in ocean current patterns and bathymetric variability introduce local or regional "reservoir effects" in island and coastal archaeological contexts that differentially impacts the chronometric results of ocean-derived materials and the dating of human or other faunal remains from subjects that may have ingested marine species. The offsets recognized in relation to the irregular mixing of atmospheric and oceanic carbon are known as the marine reservoir effect. In order to account for these offsets, radiocarbon dates must ideally be corrected based on the calibration of local marine reservoir values. Regional correction values are noted as ΔR error (Bronk Ramsey 2009; Petchey 2008).

Global marine calibration curves have been constructed to correct for ΔR offsets, but variation in ^{14}C for marine mollusks and other classes of ocean species remains highly localized (Bronk Ramsey 2009; Reimer et al. 2013). Several issues affecting radiocarbon estimates from marine shell include the anomalous values in algal and deposit feeders in limestone environments as compared to basaltic habitats, variation in upwelling and ocean currents, and differences between protected and open-ocean areas in which ΔR values can vary through time as well as space (Petchey 2008). The carbon offsets in maritime specimens require local corrections for precise ^{14}C age calibration that can be achieved by paired dating with corals or shells of known age (Rieth and Athens 2013).

The IntCal13, Marine13, and SHCal13 curve estimations presented by Reimer et al. (2013) and Hogg et al. (2013) are the most recent assessment of global atmospheric calibration curves applicable to ^{14}C dating. These calibration curves provide comparative estimates of mid-latitude atmospheric reservoirs for the Northern Hemisphere (IntCal13) and the Southern Hemisphere (SHCal13) and a global marine reservoir (Marine13) for use as a baseline for comparison of regional oceanic variations (Reimer et al. 2013:1870). The creation of separate calibration curves for terrestrial samples is based on the recognition that ^{14}C ages from contemporaneously formed tree rings in the Northern and Southern Hemispheres result in relatively older ages from the Southern Hemisphere (McCormac et al 2004). This interhemispheric offset and older measured age for Southern Hemisphere samples is due to higher sea-to-air $^{14}CO_2$ flux from greater expanses of Southern Hemisphere oceans, culminating in an estimated average offset of 43 ± 23 years (Hogg et al. 2013).

The Northern and Southern Hemisphere atmospheric calibration curves are broadly similar, and the SHCal13 dataset largely draws from the IntCal13 dataset with the addition of hemisphere-specific information (Hogg et al. 2013; Remier et al. 2013). However, the subtle differences in the curve and the interhemispheric offset for older measured ^{14}C ages in Southern Hemisphere terrestrial samples are central to regional chronology building within the last two millenium because estimated offsets can appear to become accentuated in archaeological datasets of lesser time-depth. Recognition of hemispheric variation and application of the appropriate atmospheric calibration curve is most important for radiocarbon dating of archaeological specimens in Central East

Polynesia because of the relatively recent archaeological history and the geographic location of many Pacific Island groups.

Petchey et al. (2009) noted that, for the purposes of ^{14}C measurement, the boundary between Northern and Southern Hemispheres lies along the thermal equator, known as the Intertropical Convergence Zone (ITCZ). Many island groups essential to studies of Polynesian settlement lie within the ITCZ or the Southern Pacific Convergence Zone (SPCZ) which merges with the ITCZ to the west. Seasonal shifts in atmospheric CO_2 occur in these zones, and this adds variation and uncertainty to calibration curve models (Hogg et al. 2013; McCormac et al. 2004). Radiocarbon samples from locations within the ITCZ and SPCZ have been calibrated using IntCal13, regardless of geographic presence south of the hemispheric equator, and Southern Hemisphere areas outside these zones have been calibrated using SHCal13 (Allen and Morrison 2013; Cochrane et al. 2013; Petchey et al. 2009). However, there is no broad consensus among researchers regarding application of these calibration curves in Central East Polynesia (Tim Rieth 2018 *personal communication*).

Inbuilt age describes discordance in the radiocarbon age of a dated material and the use of that material by humans, resulting in an age determination (dated event) that may be far older than the human activity which is the subject of investigation (target event). Inbuilt age may be the result of the marine reservoir effect described above, the variable carbon levels of long-lived faunal and floral species, or the dating of organic materials for which metabolic processes had ceased long prior to anthropogenic use (Anderson and Sinoto 2002; Beavan-Athfield et al. 2008; Kennett et al. 2002; Petchey 2008; Rieth and Athens 2013; Rick et al. 2005; Schiffer 1986). Taphonomic issues also

play an influential role in changes to isotopic concentrations in organic remains, particularly through the process of diagenesis in bone deposits where the chemical composition of the bone changes in mineral and chemical exchange with the surrounding environment, leading to degradation of the sample and uncertainty regarding the integrity of chemical composition (Ambrose 1990; Ambrose and Krigbaum 2003; Pate 1994; Stafford et al. 1991). Improvements have been made in the pretreatment of bone apatites and collagen to minimize inaccuracies, but extra care must be taken regarding sample contamination (Higham et al. 2006; Lee-Thorpe 2008).

The 'old wood' problem of inbuilt age, evidenced in the radiocarbon dating of long-lived plant species or combustion events involving long dead specimens, has fueled a redirection of pre-processing sample selection toward short-lived specimens for which the period of interspecies association is limited, so narrowing the distance between targeted and dated events (Athens 2011; Clark et al. 2010; Hunt and Lipo 2006). The "old wood" effect is based on the notion that the dated age of a sample reflects when the plant (or animal) grew, not when it died or was used by humans. An illustrative example of this phenomenon may be useful: a tree may be centuries old when it dies, the dead wood sits on a beach or becomes driftwood for over a hundred years, the driftwood is later found by humans and used for economic purposes, and even later a sample of this wood is radiocarbon dated by archaeologists seeking to identify when humans were present on the beach. In this example, the radiocarbon date reflects an age range considerably earlier in time that the human activity in which the archaeologists are interested.

Recognition of this issue has led to an intense focus on the identification of floral and faunal taxa prior to radiocarbon dating (Allen and Huebert 2014). The move toward

the selection of short-lived taxa as an issue of best practices in Pacific archaeology has been paired with the recognition that a thorough comprehension of island historical ecology is necessary to understand species distributions and identify those plant and animal remains whose presence are likely to be the result of human activity. Culturally associated seeds and twigs, as well as short-lived herbivore species and eggs from terrestrial species, provide samples with a short life history that helps to minimize error in age determinations (Reimer et al. 2004a; Wilmshurst et al. 2011). Recognition of specimen lifespan, a strict reliance on the dating of identified short-lived specimens, and the avoidance of bulk charcoal age determinations can improve the reliability of archaeological chronologies (Allen and Huebert 2014; Bronk Ramsey 2009; Rieth and Athens 2013).

Standards for sample choice and methods for minimizing variance between the target event and the dated material manifested in the form of 'chronometric hygiene,' a series of approaches in which a given set of criteria are applied to the evaluation of individual samples and/or dates and their use in chronological models (Allen 2014; Fitzpatrick 2006; Rieth and Hunt 2008; Wilmshurst et al. 2011). The goal of chronometric hygiene protocols is to account for known factors influencing the accuracy and precision of ^{14}C dates, thus creating conservative and defensible estimates of the target event (Anderson 1995). Increased scrutiny in archaeological sampling has played a large role in the shortening of the East Polynesia settlement chronology through the elimination from consideration those samples with high inbuilt age, large margins of error, no clear cultural association, or other attributes that may increase chronological inaccuracy in ^{14}C dating (Allen and Wallace 2007; Anderson and Sinoto 2002;

Fitzpatrick 2006; Kahn et al. 2014; Rieth et al. 2011; Spriggs and Andersn 1993; Tuggle and Spriggs 2000).

Radiocarbon Dating at Marae Tainuʻu

The first radiocarbon sample in the Pacific was submitted in 1950 by Kenneth Emory, returning an uncalibrated date of 946 ± 80 RYBP from bulk charcoal excavated at Kuliʻouʻou rockshelter on Oʻahu as part of a University of Hawaiʻi at Mānoa field class (Emory and Sinoto 1961; Libby 1951; see Kahn et al. 2014 for recent evaluation of Kuliʻouʻou). Thus, post-WWII archaeology in Polynesia began with an emphasis on radiometric dating techniques as a means of sorting out both regional and local chronologies, and these models have become increasingly refined in subsequent decades. The chronology of Pacific Island settlement has been covered in previous chapters. Discussion of radiocarbon dating at Raʻiātea will proceed in the context of this model, with initial landfall at Tongatapu at ~2838 ± 8 cal BP (Burley et al. 2102, 2015), expansion throughout Sāmoa by 2600 cal BP (Rieth and Hunt 2008), movement into the Society Islands of Central East Polynesia at 925-830 cal BP (Wilmshurst et al. 2011), and subsequent dispersal throughout East Polynesia in the 11th to 13th centuries AD.

Charcoal flecking and small aggregated deposits of carbonized material are present throughout the test units excavated at Marae Tainuʻu. This was not the case for the Domaine Dehors core and test pit, although microscopic deposits of charcoal particulate matter may be present in those sediments. Seven samples containing carbonized plant materials were submitted for macrobotanical identification and ^{14}C dating. Submitted samples were retrieved from stratigraphic contexts in various units and

levels at Marae Tainu‘u to gain an accurate chronological assessment of human history at this location. DirectAMS Radiocarbon Dating Service completed radiocarbon dating of these samples using the AMS method of age determination. Returned ^{14}C ages have been calibrated using both the SHCal13 (Hogg et al. 2013; Table 7) and the IntCal13 (Reimer et al. 2013; Table 8) atmospheric calibration curves in OxCal version 4.3.2 (Bronk Ramsey 2009). The decision was made to present ^{14}C dates at both 1σ and 2σ confidence

Table 7. Radiocarbon dating results from Marae Tainu‘u, with dates for carbonized plant remains calibrated at 1σ (68.2%) and 2σ (95.4%) confidence ranges using the Southern Hemisphere (SHCal13) atmospheric calibration curve.

Lab # & Provenience	Material Dated	Measured ^{14}C age BP	Calendar Age Range (SHCal13 AD @ 1σ)	Calendar Age Range (SHCal13 AD @ 2σ)
D-AMS-27252 (TP1-8.1) 70-80 cmbs	*Clematis* sp., *Morinda* cf. *citrifolia*	171 ± 22	1678-1711 (19.7%) 1720-1733 (7.7%) 1800-1812 (7.0%) 1837-1848 (6.2%) 1856-1880 (13.5%) 1927-modern (14.1%)	1672-1745 (34.1%) 1758-1780 (2.9%) 1796-1820 (9.9%) 1826-1895 (30.4%) 1906-modern (18.0%)
D-AMS-27253 (TP1-10.1) 90-100 cmbs	*Hibiscus tiliaceus*, *Morinda* cf. *citrifolia*	162 ± 21	1687-1711 (15.0%) 1719-1728 (5.3%) 1804-1813 (5.3%) 1837-1883 (25.4%) 1925-modern (17.2%)	1676-1735 (29.0%) 1798-1820 (9.0%) 1825-1896 (35.6%) 1904-modern (21.8%)
D-AMS-27254 (TP1-12.1) 110-120 cmbs	*Hibiscus tiliaceus*	280 ± 22	1636-1667 (68.2%)	1518-1539 (3.2%) 1626-1674 (78.0%) 1742-1771 (6.3%) 1780-1798 (7.9%)
D-AMS-29780 (TP4-8.1) 70-80 cmbs	*Aleurites moluccana* endocarp	126 ± 26	1708-1721 (7.9%) 1811-1837 (17.4%) 1846-1866 (8.7%) 1879-1930 (34.2%)	1696-1726 (14.7%) 1806-modern (80.7%)
D-AMS-29781 (TP5-7.1) 60-70 cmbs	*Swietenia* sp.	58 ± 23	1817-1829 (30.4%) 1894-1918 (37.8%)	1710-1720 (2.3%) 1811-1838 (38.2%) 1847-1855 (1.0%) 1880-1930 (53.8%)
D-AMS-29782 (TP5-13.1) 120-130 cmbs	*Swietenia* sp.	218 ± 31	1665-1680 (11.2%) 1732-1802 (57.0%)	1647-1710 (24.9%) 1720-1812 (63.0%) 1836-1848 (1.6%) 1857-1880 (3.0%) 1928-modern (2.9%)
D-AMS-29783 (TP7-11.1) 100-110 cmbs	*Hibiscus tiliaceus*, *Swietenia* sp. (dated)	88 ± 24	1815-1833 (24.6%) 1892-1923 (43.6%)	1705-1723 (6.6%) 1809-1839 (29.2%) 1844-1868 (6.3%) 1878-1945 (53.3%)

intervals using both Northern and Southern Hemisphere calibration curves so readers could compare my results to dates reported in other publications.

Macrobotanical analysis of samples from Marae Tainuʻu resulted in the identification of purau (*Hibiscus tiliaceus*), noni (*Morinda citrifolia*), kukui (*Aleurites moluccana*), *Clematis* sp., and *Swietenia* sp. in the samples submitted for dating. Although initially thought to be single fragments, several of the submitted samples were identified as containing elements of multiple floral species in a single charcoal specimen, thus creating a less than ideal situation for ^{14}C assay. However, all species have been

Table 8. Radiocarbon dating results from Marae Tainuʻu, with dates for carbonized plant remains calibrated at 1σ (68.2%) and 2σ (95.4%) confidence ranges using the Northern Hemisphere (IntCal13) atmospheric calibration curve.

Sample ID and Depth	Material Dated	Measured ^{14}C age BP	Calendar Age Range (IntCal13 AD @ 1σ)	Calendar Age Range (IntCal13 AD @ 2σ)
D-AMS-27252 (TP1-8.1) 70-80 cmbs	*Clematis* sp., *Morinda* cf. *citrifolia*	171 ± 22	1669-1682 (12.2%) 1736-1781 (41.4%) 1799-1805 (5.8%) 1935-1945 (8.8%)	1663-1694 (17.7%) 1726-1814 (57.1%) 1918-modern (20.6%)
D-AMS-27253 (TP1-10.1) 90-100 cmbs	*Hibiscus tiliaceus*, *Morinda* cf. *citrifolia*	162 ± 21	1672-1684 (9.6%) 1733-1778 (40.3%) 1799-1807 (6.8%) 1929-1942 (11.4%)	1666-1696 (16.5%) 1725-1785 (43.8%) 1795-1815 (10.6%) 1836-1877 (5.1%) 1916-modern (19.5%)
D-AMS-27254 (TP1-12.1) 110-120 cmbs	*Hibiscus tiliaceus*	280 ± 22	1527-1553 (33.8%) 1633-1652 (34.4%)	1521-1592 (51.3%) 1620-1663 (44.1%)
D-AMS-29780 (TP4-8.1) 70-80 cmbs	*Aleurites moluccana* endocarp,	126 ± 26	1683-1707 (12.4%) 1719-1735 (8.1%) 1806-1826 (9.5%) 1832-1885 (29.4%) 1913-1930 (8.8%)	1678-1765 (33.8%) 1773-1776 (0.6%) 1800-1895 (46.2%) 1904-1940 (14.9%)
D-AMS-29781 (TP5-7.1) 60-70 cmbs	*Swietenia* sp.	58 ± 23	1707-1719 (11.4%) 1820-1833 (8.6%) 1883-1914 (48.2%)	1695-1727 (20.3%) 1812-1854 (17.6%) 1868-1919 (57.5%)
D-AMS-29782 (TP5-13.1) 120-130 cmbs	*Swietenia* sp.	218 ± 31	1648-1675 (29.0%) 1777-1800 (27.3%) 1941-modern (11.8%)	1642-1684 (34.8%) 1735-1806 (45.5%) 1931-modern (15.0%
D-AMS-29783 (TP7-11.1) 100-110 cmbs	*Hibiscus tiliaceus*, *Swietenia* sp. (dated)	88 ± 24	1697-1725 (21.4%) 1815-1835 (15.3%) 1877-1917 (31.5%)	1691-1730 (25.6%) 1810-1925 (69.8%)

identified, and the radiocarbon results are discussed in relation to knowledge of plant lifespans. *H. tiliaceus* has often been dated in the Pacific due to its prevalence throughout the region, association with traditional cultural uses, and identification as a Polynesian introduction. However, the species is sometimes considered problematic for dating because of its expedited growth rate as a "pioneer" plant species and unknown maximal lifespan (Allen and Huebert 2014). *M. citrifolia* is known as a medium-lived species, with average lifespan between 40 and 50 years. Noni, as the plant is known, was utilized in the past and is still used today for a variety of medicinal and economic purposes (Kahn 2018). *A. moluccana*, known as kukui or candlenut, is a Polynesian introduction whose presence is diagnostic of Polynesian settlement. The kukui nut is an ideal specimen for ^{14}C dating due to its brief carbon uptake (~1 year) and durability of kukui nut endocarp in the archaeological record (Kirch, Asner et al. 2012).

Clematis is a genus in the Ranunculaceae family representing over 300 species of mostly woody climbing vines (Allaby 2006). Most recognized *Clematis* species are of East Asian origin, though reference to *Clematis* spp. appears with Māori names in botanical studies from Aotearoa New Zealand (e.g. Pikiarero, Puawananga; Hamilton 1905). *Clematis* species are medium-lived species with an estimated lifespan of up to 50 years. *Swietenia* is a genus in the Meliaceae family, comprising the species of deciduous trees collectively referred to as mahogany (Allaby 2006). *Swietenia* species originate in the Americas, and although present at Raʻiātea and Tahaʻa (*Swietenia macrophylla*; Meyer and Malet 1997), should be viewed as a post-contact European introduction. The various species within the *Swietenia* genus are long-lived trees.

Tables 7 and 8 display the ^{14}C dates using both available calibration curves. Although potentially confusing, this is done because there is currently a lack of consensus on how archaeological dates are reported for Polynesian Islands that fall within the variable boundaries of the SPCZ and ITCZ. For example, Wilmshurst et al. (2011) calibrated all collected Southern Hemisphere dates at 1σ using SHCal04 (McCormac et al. 2004). In contrast, Kahn (2018) reported age ranges at 2σ with the IntCal13 (Reimer et al. 2013) calibration curve in her most recent syntheses of old and new ^{14}C dates from Raʻiātea. Raʻiātea falls within the boundaries of the SPCZ (Petchey et al. 2009), suggesting the use of the Northern Hemisphere calibration curve is appropriate for this specific geographic location. However, uncertainty introduced through seasonal and long-term variation may exaggerate the age of samples calibrated with the Northern Hemisphere curve. Application of the Southern Hemisphere offset correction to ^{14}C dates from Raʻiātea result in more conservative (i.e., recent) estimates (see Figures 26 and 27 for example of how calibration curve affects date age ranges in this study). This is an issue that will only be mitigated through future refinement of calibration models for equatorial Oceania.

Calibrated radiocarbon dates from Marae Tainuʻu display a wide range of values. No sample returned a calibrated age range earlier than the 16th century AD, and most of the ^{14}C dates exhibit age ranges that extend into the post-contact period. The most reliable dates as determined by material and stratigraphy come from Test Pit 1 (TP1-8.1, TP1-10.1, TP1-12.1) and Test Pit 4 (TP4-8.1). The earliest date, TP1-12.1 (D-AMS-27254), is on carbonized *H. tiliaceus* with a calendar age range of AD 1521-1663 (2σ,

Intcal13). This sample was recovered in close spatial proximity to a basalt adz found in Layer III/Level 12 of TP1Tainuu.

More recent dates within Test Pit 1 come from directly below and above the basalt alignment that rests at approximately 80 cm below surface. Sample TP1-10.1 (D-AMS-27253) was recovered from a hearth feature that extends below the base of the basalt alignment. Radiocarbon dating provided a calendar age range of AD 1666-modern (2σ, IntCal13), with most of the range spanning the middle of the 18th century. Sample TP1-8.1 (D-AMS-27252) displayed a similar age range, but was recovered from directly above the 80 cm cultural floor. The similarity of dates between these samples is likely due to the depth of the hearth depression from which TP1-10.1 was recovered. Although these samples were retrieved from separate strata, the contemporaneous age estimates are expected due to the specific context of the sample deposits and do not indicate stratigraphic disturbance in this unit.

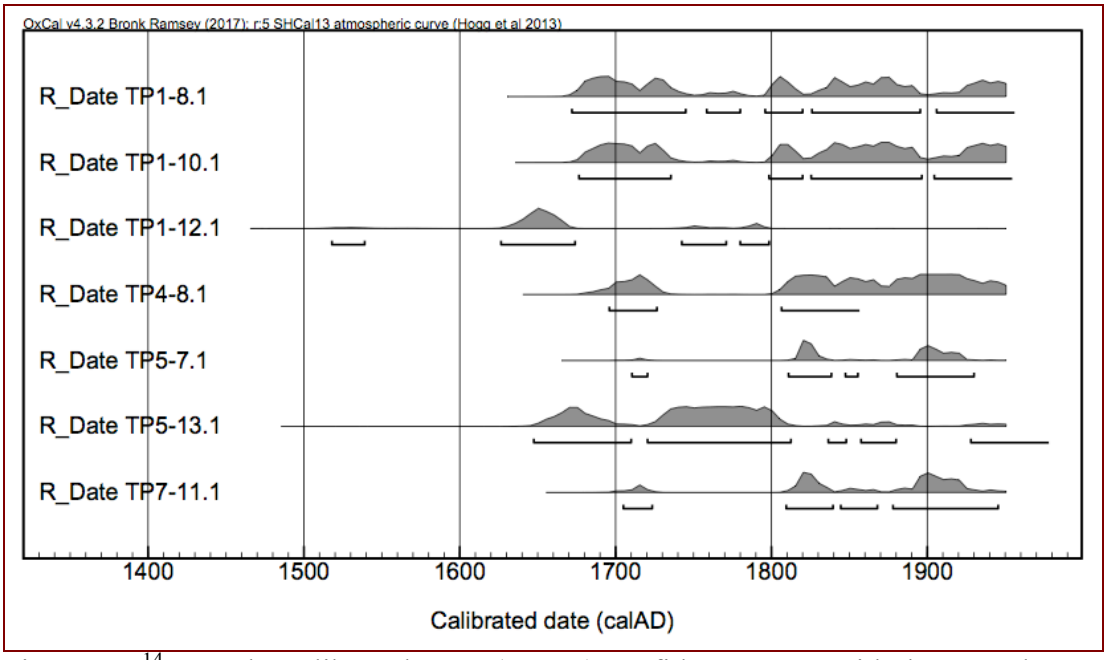


Figure 26. ^{14}C results calibrated at 2σ (95.4%) confidence range with the SHCal13 atmospheric calibration curve and plotted using OxCal 4.3.2.

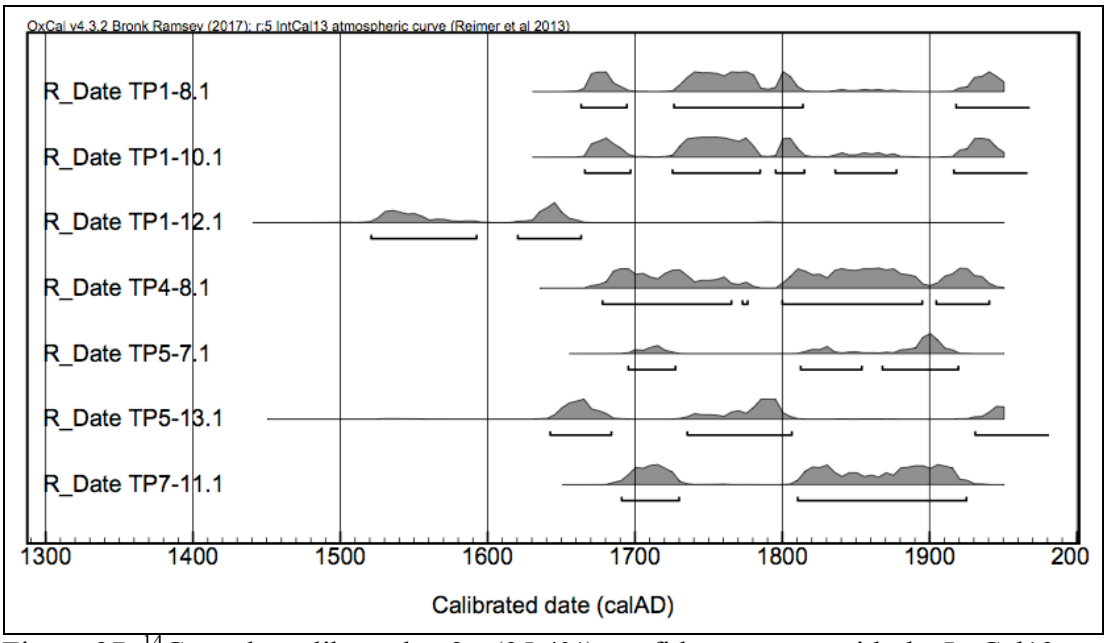


Figure 27. ^{14}C results calibrated at 2σ (95.4%) confidence range with the IntCal13 atmospheric calibration curve and plotted using OxCal 4.3.2.

Sample TP4-8.1 (D-AMS-29780) is probably the most reliable date returned from the Marae Tainu‘u excavations based on the dated material (Wilmshurst et al. 2011). This sample is carbonized *A. molucanna* endocarp, a burned kukui nut and short-lived specimen for which a briefer period of carbon uptake allows increased certainty regarding the relationship between the dated event and the targeted event (i.e., more accurately reflects the age of burning by humans). This sample, recovered from Layer III/Level 8 of Test Pit 4 located in a north central area of the marae court, has a calendar age range of 1678-1940 cal AD (2σ, IntCal13), suggesting an early 19th century (post-contact) combustion. This sample was found in association with smoothed basalt boulders that appear similar to those found in lower levels of the paepae units, but found in a seemingly disorganized position. The position of this date should correspond to approximately 90–120 cm below surface in the paepae units due to the elevated platform of that section of the marae. However, the elevational differences between archaeological

feaures seen today at the marae may not have remained static over the course of several centuries.

The two dates from Test Pit 5 in the southern section of the paepae and the single date from Test Pit 7 immediately adjacent to the paepae pose an interesting issue with regards to material and measured ^{14}C. All three samples were identified as *Swietenia* sp., likely *Swietenia macrophylla* that today is present throughout the Leeward Society Islands. As discussed above, *Swietenia* spp. are long-lived exotic species. The choice to date the *Swietenia* sp. samples was made based on available samples from test units at the southern portion of the research area. Sample TP5-13.1 (D-AMS-29782) was retrieved from Layer IV/Level 13 of Test Pit 5. The date for this sample has a calendar age range of AD 1642-modern (2σ, IntCal13) with 80.3% of the range falling between AD 1642-1806. This sample is from below a basalt alignment and cultural layer that corresponds to that seen further north in Test Pits 1 and 2. However, sample TP5-13.1 was located deeper in the ground.

Sample TP5-7.1 (D-AMS-29781) was recovered from much closer to the surface, is also comprised of *Swietenia*, and has a calendar age range of AD 1695-1919 (2σ, IntCal13). Sample TP7-11.1 (D-AMS-29783) was recovered from the basal layer and level of Test Pit 7 and has a calendar age range of AD 1691-1925 (2σ, IntCal13). Radiocarbon dates derived from long-lived floral specimens will be avoided in subsequent studies. However, the identification and dating of introduced *Swietenia* sp. specimens in what were thought to be undisturbed, secure stratigraphic contexts provides valuable information about post-contact land use at the study area.

The materials, ^{14}C dates, and calibrated calendar age ranges from Marae Tainu‘u reveal two primary trends in relation to stratigraphy across the site. The first is that samples retrieved from more northerly contexts (i.e., north section of the paepae, northern boundary of the court) appear to be more stratigraphically secure. Dated materials include endemic species or Polynesian introductions, and the samples come from strata that appear to be undisturbed and sequentially oriented in relation to identified archaeological features. The second issue raised by these results is that two of the three samples from units in more southerly areas of the site display more recent date ranges, and all three samples were identified as exotic post-contact plant materials. The age of sample TP5-13.1 may be a correct measurement of cultural activity in the respective stratum, but the fact that this sample is comprised of an extremely long-lived tree species that was introduced after European contact throws the accuracy and precision of the date into question. The presence of this sample at the base of Test Pit 5 and the relatively recent dates of samples TP5-7.1 and TP7-11.1 suggest disturbance of these sedimentary contexts within the post-contact period in a way that contrasts with stratigraphic evidence from other areas of the paepae.

Tainu‘u in Chronological Context

Comparison of ^{14}C dates to previously developed local and regional chronologies helps to situate the Marae Tainu‘u archaeological complex within greater Polynesian history. Wilmshurst et al. (2011) took a conservative approach to sample classification that has been embraced by archaeologists working in the Pacific (Allen and Huebert 2014; Rieth and Athens 2013). The classification and calibration of dates from the

Society Islands posits initial settlement in Central East Polynesia at around AD 1025-1120 (1σ, SHCal04 calibration curve). The dates I obtained from Raʻiātea fall in a later period of Polynesian settlement that fits within the perception of population expansion and intensification of land use in the middle of the second millenium. Dates from Maupiti (Anderson et al. 1999; Kahn et al. 2015a) and Huahine (Anderson and Sinoto 2002) point to instensification of land use in coastal flats in the 14th and 15th centuries and landscape change due to population and agricultural expansion by the 17th century. Work at Moʻorea (Kahn et al. 2015b) supports a slightly later continuation of this trend in the Windward Society Islands. Initial dates from Marae Tainuʻu fit into this period of settlement during which populations had been established and voyaging to other islands throughout Polynesia had already occurred.

Kahn (2018) published new dates for western Raʻiātea and recalibrated older dates from around the island to provide the best comparative dataset for chronology at Marae Tainuʻu. She reports date ranges at 2σ using the IntCal13 atmospheric calibration curve, but does not explain the basis for her choice of confidence range and calibration curve. The majority of previous ^{14}C dates obtained from archaeological contexts at Raʻiātea fall within the range reported here for Marae Tainuʻu including those from Marae Taputapuātea, although considerably earlier dates have been acquired for samples from the upper Faʻaroa Valley (see Table 1 in Kahn 2018:27). Eight new dates reported by Kahn are from a west coast excavation site called Sunset Beach, located 7 km north of Marae Tainuʻu, and two dates are on samples from Faʻaroa (Kahn 2018:29). The dated samples are all short-lived specimens, comprising charred kukui nut (*A. moluccana*) endocarp and coconut (*Cocos nucifera*) endocarp. One coconut sample (Beta-424711)

has a calibrated age range of AD 778-994 (2σ, IntCal13). Kahn notes that this date appears as an anomaly and, although thought to have been a carbonized specimen, should be treated with skepticism because of its presence in a waterlogged layer. All other dates reported by Kahn fall within the ranges reported from Marae Tainuʻu. Sample Beta-424718, the earliest date reported from Kahn's excavations, has an age range of AD 1446-1634 (2σ, IntCal13). All other calibrated ages post-date AD 1646.

Kahn's date of AD 1446-1634 on a *C. nucifera* sample is the earliest ^{14}C date reported thus far from a coastal context on Raʻiātea. At AD 1521-1662, sample TP1-12.1 from Marae Tainuʻu is slightly later but overlaps Kahn's date range. TP1-12.1 is carbonized *H. tiliaceus*, a medium-lived species, which lends some uncertainty to comparison with short-lived specimens. However, the *A. moluccana* sample (TP4-8.1, dated to AD 1678-1940) for a mid-level layer in the Marae Tainuʻu court, overlaps the age ranges for most of Kahn's samples from Sunset Beach. This is the best support for a period of consistent coastal habitation up and down the west coast of Raʻiātea in the two centuries prior to European contact in AD 1767.

The calibrated ^{14}C age ranges reported here also correspond with those from Marae Taputapuātea on the east side of the island. The contemporaneous nature of ^{14}C dates from the large ritual complexes of Tainuʻu and Taputapuātea is an interesting facet of this study. Taputapuātea is seen as infinitely more important within Polynesian voyaging spheres, and the Faʻaroa Valley located just north of Taputapuātea is recognized as a departure point for pre- and post-contact voyaging parties. The similar age ranges between the two sociopolitical sites does not necessarily detract from the regional importance of Taputapuātea or place greater cultural value on Tainuʻu. Rather,

the contemporaneous dates for these two marae complexes support the timing for the consolidation and establishment of various Māʻohi political divisions (i.e., chiefdoms) perhaps by the end of the 15th century, but certainly no later than the 17th century at different locations throughout the Leeward and Windward Islands (Maric 2016).

The ^{14}C dates and stratigraphic evidence from Marae Tainuʻu suggest regular occupation of the marae complex by the 16th century AD, with intense human activity continuing into the modern era. The evidence presented here does not provide any justification for a date of construction for the megalithic structures that currently comprise the visible features of Marae Tainuʻu. However, human habitation and land use at this location spanned several centuries, and the timing of this activity corresponds with temporal estimates from other coastal areas of Raʻiātea. Radiocarbon dates from the upper Faʻaroa Valley (Kahn 2018; Lepofsky 1995) support an earlier and so far undetected presence on the coastal flats of the island. We cannot make assumptions based on what we do not know, but the possibility of earlier archaeological deposits in subphreatic coastal contexts is high based on results from excavations in other areas of the Leeward Group (Sinoto 1979) and collective knowledge of local sea level change in the Society Islands over the past millenium (Dickinson 2001). Current ^{14}C evidence is a step toward better understanding the deep history of human alterations of the Raʻiātea coastal landscape.

CHAPTER VI

ARTIFACTS AND ECOFACTS AT MARAE TAINUʻU

In this chapter I discuss the recovered artifact, faunal, and floral assemblages from Marae Tainuʻu. The effect of human populations on reef ecosystems and terrestrial environments prior to European contact has been a primary research objective of Polynesian archaeology. Artifacts and ecological remains recovered from Test Pits 1 through 7 provide a window into these effects at Marae Tainuʻu and the deep history of human activity in the coastal environment of a Pacific Island. Lithic materials, historic artifacts, floral residues, and faunal remains are reviewed in the context of stratigraphic and chronological data. A detailed analysis of faunal specimens, particularly those of marine species, is included as an attempt to address issues of historical ecology at Tevaitoa and the relation of human populations to lagoon resources through time.

The resulting data illuminate trends in resource use before and after European contact, although the extrapolation of knowledge from Marae Tainuʻu to other coastal areas of Raʻiātea may not be appropriate due to the historical circumscription of certain behavioral practices at marae and other locations of sociopolitical significance. Anomalous aspects of assemblage composition can often be attributed to cultural practices and regulations imposed upon or adopted by people at places of cultural importance. The presence or absence of particular artifact classes and subsistence remains that depart from accepted environmental models create knowledge of divergent cultural trajectories and the historical paths of human behavior.

Artifacts

Pre-contact Polynesian societies utilized a variety of organic and non-organic materials for daily subsistence activities and the creation of material culture. Due to the absence of metal production in traditional Polynesian societies, exploited materials consisted of plant materials, animal-derived materials, stone, and limited use of clay and tempering agents. Documentation and analysis of anthropogenically altered lithic materials from Polynesian archaeological contexts remains a dominant interest throughout the region because of how basalt, obsidian, coral limestone, and other region-specific rocks were used for the creation of everything from small woodworking tools to some of the largest archaeological monuments in the world (Cochrane 2015; Lipo et al. 2010). Discussions of portable lithic artifacts as evidence for trade and exchange persist in the literature, although the movement of lithic materials throughout Polynesian interaction spheres appears mostly limited to intra-archipelago transport, with East Polynesian societies overwhelming exploiting local materials found in relatively close proximity to the location of actual use (Ditchfield et al. 2014; Kirch, Mills et al. 2012; Walter et al. 2017). However, long distance artifact exchange has been documented and provides the basis for arguments of sustained inter-archipelago voyaging and down-the-line trade of portable artifacts throughout the region (Weisler et al. 2016)

The use of bone, shell, and coral for industrial purposes is also ubiquitous across East Polynesia (Anderson and Smith 1996; Emory et al. 1969). Whereas the exchange of ideas and manufacturing practices often follows information transmitted along voyaging routes (e.g., O'Connor et al. 2017), the sources of raw technological materials remain predominantly local due to the relatively continuous presence of similar plant and marine

Table 9. Pre-contact and post-contact artifacts recovered from archaeological excavations at Marae Tainu‘u.

Unit and layer/level	Adze	Adze preform	Adze fragment	Scraper	Grinding stone	Urchin spine abrader	Coral abrader	Metal	Glass	Ceramic	Plastic	Concrete
TP1Tainuu												
Layer I / Level 1	0	0	0	0	0	3	1	4	5	2	0	0
Layer I / Level 2	0	0	0	0	0	2	0	2	3	2	0	0
Layer II / Level 3	0	0	0	1	0	3	0	0	3	0	0	0
Layer II / Level 4	0	1	0	0	0	0	0	0	0	0	0	0
Layer II / Level 5	0	0	0	0	0	0	0	0	0	0	0	0
Layer II / Level 6	0	0	3	0	0	0	0	0	0	0	0	0
Layer II / Level 7	0	0	0	0	0	0	0	0	0	0	0	0
Layer II / Level 8	0	0	0	0	0	0	0	0	0	0	0	0
Layer III / Level 9	0	0	0	0	0	0	0	0	0	0	0	0
Layer III / Level 10	1	0	0	0	0	0	0	0	0	0	0	0
Layer III / Level 11	0	1	0	0	1	0	0	0	0	0	0	0
Layer III / Level 12	0	0	0	0	0	0	0	0	0	0	0	0
TP2Tainuu												
Layer I / Level 1	0	0	0	0	0	0	0	2	3	2	0	0
Layer I / Level 2	0	0	0	0	0	2	0	0	15	0	0	0
Layer II / Level 3	0	0	0	0	0	6	0	2	0	1	0	0
Layer II / Level 4	0	0	0	0	0	1	0	0	0	0	0	0
Layer II / Level 5	0	0	1	0	0	0	0	0	0	0	0	0
Layer II / Level 6	0	0	0	0	0	0	0	0	0	0	0	0
Layer II / Level 7	0	0	0	0	0	0	0	0	0	0	0	0
Layer II / Level 8	0	0	0	0	0	0	0	0	0	0	0	0
TP3Tainuu												
Layer I / Level 1	0	0	0	0	0	0	0	0	1	0	8	0
Layer II / Level 2	0	0	0	0	0	6	0	3	11	8	3	0
Layer II / Level 3	0	0	0	0	0	1	0	0	1	3	0	0
Layer III / Level 4	0	0	0	0	0	0	0	1	11	9	0	0
Layer III / Level 5	0	0	0	0	0	1	0	1	16	3	1	0
Layer III / Level 6	0	0	0	0	0	0	0	0	7	1	0	0
TP4Tainuu												
Layer I / Level 1	0	0	0	0	0	0	0	0	0	0	0	0
Layer I / Level 2	0	0	0	0	0	5	0	4	3	8	3	1
Layer I / Level 3	0	0	0	0	0	3	0	0	3	1	1	0
Layer I / Level 4	0	0	0	0	0	4	0	3	6	0	0	1
Layer II / Level 5	0	0	0	0	0	3	0	1	3	1	3	0
Layer II / Level 6	0	0	0	0	0	2	0	1	1	1	0	0
Layer II / Level 7	0	0	0	0	0	1	0	0	1	0	0	0
Layer III / Level 8	0	0	0	0	0	0	0	0	0	0	0	0
Layer III / Level 9	0	0	0	0	0	0	0	0	0	0	0	0

Unit and layer/level	Adze	Adze preform	Adze fragment	Scraper	Grinding stone	Urchin spine abrader	Coral abrader	Metal	Glass	Ceramic	Plastic	Concrete
TP5Tainuu												
Layer I / Level 1	0	0	0	0	0	0	0	0	19	1	1	0
Layer I / Level 2	0	0	0	0	0	0	0	0	23	8	1	0
Layer I / Level 3	0	0	0	0	0	0	0	1	6	1		0
Layer II / Level 4-5	0	0	0	0	0	0	0	0	10	1	1	0
Layer II / Level 6	0	0	1	0	0	0	0	0	1	0	0	0
Layer II / Level 7	0	0	0	0	0	0	0	0	1	0	0	0
Layer III / Level 8	0	0	0	1	0	0	0	0	0	0	0	0
Layer III / Level 9-10	0	0	0	0	0	0	0	0	0	0	0	0
Layer III / Level 11	0	1	0	0	0	0	0	0	0	0	0	0
Layer IV / Level 12	0	0	0	0	0	1	0	0	0	0	0	0
Layer IV / Level 13	0	0	0	0	0	2	0	0	0	0	0	0
Layer IV / Level 14	0	0	0	0	0	0	0	0	0	0	0	0
TP6Tainuu												
Layer I / Level 1	0	0	0	0	0	0	0	0	3	5	1	0
Layer I / Level 2	0	0	0	0	0	2	0	3	28	2	0	0
Layer I / Level 3	0	0	0	0	0	0	0	2	7	1	0	0
Layer II / Level 4-5	0	0	0	0	0	0	0	3	8	0	0	0
Layer II / Level 6	0	0	0	0	0	0	0	0	0	0	0	0
Layer II / Level 7	0	0	0	0	0	0	0	0	0	0	0	0
Layer III / Level 8	0	0	0	0	0	0	0	0	0	0	0	0
Layer III / Level 9-10	0	0	0	0	0	0	0	0	0	0	0	0
Layer III / Level 11	0	0	0	0	0	0	0	0	0	0	0	0
Layer IV / Level 12	0	0	0	0	0	0	0	0	0	0	0	0
Layer IV / Level 13	0	0	0	0	0	0	0	0	0	0	0	0
Layer IV / Level 14	0	0	0	0	0	0	0	0	0	0	0	0
TP7Tainuu												
Layer I / Level 1	0	0	0	0	0	0	0	1	3	0	0	0
Layer I / Level 2	0	0	0	0	0	0	0	10	22	3	52	0
Layer I / Level 3	0	0	0	0	0	0	0	22	12	3	32	0
Layer II / Level 4	0	0	0	0	0	0	0	1	1	1	0	0
Layer II / Level 5	0	0	0	0	0	0	0	0	0	0	0	0
Layer II / Level 6	0	0	0	0	0	0	0	0	0	0	0	0
Layer III / Level 7	0	0	0	0	0	0	0	0	0	0	0	0
Layer III / Level 8	0	0	0	0	0	0	0	0	0	0	0	0
Layer IV / Level 9	0	0	0	0	0	0	0	0	0	0	0	0
Layer IV / Level 10	0	0	0	0	0	1	0	0	0	0	0	0
Layer IV / Level 11	0	0	0	0	0	0	0	0	0	0	0	0

species across East Polynesian archipelagos and the near universal, though differential, import of useful terrestrial species during initial settlement of East Polynesian islands (Irwin 2007). The retention of more durable materials in the archaeological record favors dense, non-biodegradable remains over less durable materials as the evidence of deep history in tropical and sub-tropical environs. However, the preservation of holistic archaeological assemblages is still possible in particular archaeological contexts (e.g., anaerobic, subphreatic), as shown with Sinoto's (1979) work at Huahine. All artifacts recovered from the Marae Tainu'u excavations are listed in Table 9, organized by test unit and stratigraphic level.

Lithic Artifacts

A complete ground stone adze of high quality fine-grained basalt was recovered from TP1Tainuu at 100 cm below surface, a level 20 cm below the Layer III cultural floor. The adze was the only essentially complete and formal artifact recovered from the Marae Tainu'u excavation, although several fragments of adzes or adze preforms were also recovered. The whole adze was found in close spatial association with carbonized plant material that was radiocarbon dated to 1521-1663 cal AD, an age range that can be posited as the temporal period of artifact deposition. The basalt adze displays excellent manufacture and uniformity in design (Figure 28). Geochemical testing of this artifact will provide information as to its geographic origin (i.e., local versus exotic) and could be used to further elaborate regional exchange networks and Polynesian voyaging models based on worked basalt artifacts (e.g., Mills et a. 2011; Weisler et al. 2016). However, I was not permitted to export this object for analysis. The adze remains in possession of M.


Figure 28. Basalt adze found at 100 cm below surface in TP1Tainuu.

Hinanui Cauchois at Raʻiātea and was not accessible to me during subsequent visits to the island.

Several other fragments of similar worked basalt artifacts were identified at the marae complex. Three adze preforms and five adze fragments were found in Test Pits 1, 2, and 5, comprising the total number of modified basalt tools or tool fragments found during subsurface investigation (see Figure 29 for example). All artifacts appear to be consistent in composition with local geological materials.

A single basalt scraper was also found at the Layer II/Layer III interface of TP5Tainuu. This artifact is of a more coarse-grained material than the adze and adze fragments. It appears to be an expedient tool, though the purpose and duration of use can not be determined. A grinding or polishing stone was recovered from Layer III/Level 11 of TP1Tainuu. This smoothed basalt stone may have been used on lithic or organic



Figure 29. Basalt adze fragment recovered from 60 cm below surface in TP5Tainuu.

materials, but specific remains unknown pending further analysis.

Basalt lithic flakes were recovered in varying quantities from all units excavated at Marae Tainuʻu during the 2016 and 2017 field seasons. No lithic artifacts or manufacturing debris were recovered from Domaine Dehors. Recovered lithic debitage is geologically consistent with locally acquirable stone that is of limited quality, although the possibility of exotic materials exists. Debitage consists of tertiary and secondary flakes of relatively poor quality basalt. These materials primarily exhibit a porphyritic grain structure that visually matches the composition of the recovered adze preforms and the scraper, but is different from the complete adze and adze fragment depicted in Figures 28 and 29. Debitage densities vary by stratum and unit, as would be expected, but do not at this time appear to show any particular spatial pattern or quantifiable association with formal artifacts. The number of individual specimens (NISP) and weight of recovered manufacturing debris is shown in Table 10, organized by test unit and stratigraphic level. Burned rock is present throughout the seven test units at Marae Tainuʻu, but little of this

Table 10. Basalt debitage recovered from archaeological excavations at Marae Tainu‘u.

TP1Tainuu	NISP	Wt (g)	TP2Tainuu	NISP	Wt (g)
Layer I / Level 1	11	33.41	Layer I / Level 1	13	46.23
Layer I / Level 2	33	59.98	Layer I / Level 2	25	51.28
Layer II / Level 3	29	105.55	Layer II / Level 3	31	58.74
Layer II / Level 4	31	164.01	Layer II / Level 4	20	40.17
Layer II / Level 5	43	228.34	Layer II / Level 5	17	45.77
Layer II / Level 6	41	182.77	Layer II / Level 6	20	30.89
Layer II / Level 7	44	244.11	Layer II / Level 7	31	107.26
Layer II / Level 8	38	333.51	Layer II / Level 8	49	160.77
Layer III / Level 9	14	107.61			
Layer III / Level 10	25	162.06			
Layer III / Level 11	33	137.23			
Layer III / Level 12	37	87.84			
Total	379	1846.42	Total	206	541.11

TP3Tainuu	NISP	Wt (g)	TP4Tainuu	NISP	Wt (g)
Layer I / Level 1	16	33.9	Layer I / Level 1	10	62.14
Layer II / Level 2	4	12.59	Layer I / Level 2	24	86.19
Layer II / Level 3	2	9.09	Layer I / Level 3	20	40.75
Layer III / Level 4	2	0.92	Layer I / Level 4	9	43.79
Layer III / Level 5	0	0	Layer II / Level 5	12	37.93
Layer III / Level 6	0	0	Layer II / Level 6	7	52.27
			Layer II / Level 7	13	66.32
			Layer III / Level 8	11	31.37
			Layer III / Level 9	10	28.41
Total	24	56.5	Total	116	449.17

TP5Tainuu	NISP	Wt (g)	TP6Tainuu	NISP	Wt (g)
Layer I / Level 1	2	2.76	Layer I / Level 1	0	0
Layer I / Level 2	0	0	Layer I / Level 2	1	0.53
Layer I / Level 3	9	13.47	Layer I / Level 3	26	73.02
Layer II / Level 4-5	9	63.79	Layer II / Level 4-5	10	47.38
Layer II / Level 6	0	0	Layer II / Level 6	4	38.7
Layer II / Level 7	9	33.37	Layer II / Level 7	7	142.33
Layer III / Level 8	33	230.09	Layer III / Level 8	43	415.04
Layer III / Level 9-10	33	227.24	Layer III / Level 9-10	17	180.99
Layer III / Level 11	9	24.49	Layer III / Level 11	12	158.9
Layer IV / Level 12	3	22.84	Layer IV / Level 12	7	128.56
Layer IV / Level 13	8	13.51	Layer IV / Level 13	18	55.19
Layer IV / Level 14	16	42.91	Layer IV / Level 14	8	10.21
Total	131	674.47	Total	153	1250.85

TP7Tainuu	NISP	Wt (g)
Layer I / Level 1	0	0
Layer I / Level 2	13	52.87
Layer I / Level 3	63	255.6
Layer II / Level 4	23	218.65
Layer II / Level 5	13	147.97
Layer II / Level 6	17	324.52
Layer III / Level 7	9	86.15
Layer III / Level 8	5	80.02
Layer IV / Level 9	19	312.72
Layer IV / Level 10	9	32.01
Layer IV / Level 11	17	21.39
Total	188	1531.9

material was collected or catalogued due to its ubiquitous nature and the project emphasis on the retention of more diagnostic materials. Burned rock was not analyzed in this study.

Faunal Tools

A curious aspect of the Marae Tainuʻu assemblages is the dearth of faunal material modified for industrial purposes. No fishhooks were recovered from any test units excavated as a part of this study. This can be seen as anomalous to expectations of the archaeological record in a Central East Polynesian coastal context of close proximity to highly productive lagoon and ocean fisheries (Kahn 2018; Sinoto 1979). However, the absence of fishing gear at Marae Tainuʻu conforms to the relative dearth of fish remains at the site, a detail that is further explored in relation to Māʻohi cultural practices below. No formally modified bone or shell tool artifacts were evident in the recovered materials. Several expedient abraders of urchin spine and branch coral were identified during subsurface testing. With the exception of urchin spine abraders, terrestrial and marine animal remains appear only as the byproduct of subsistence and consumption activities.

Coral and urchin spine abraders are common tools seen throughout Polynesian archaeological sequences (Allen and Morrison 2013; Burley et al. 2015), although the specific function of such tools is poorly understood. Modified branch coral (*Acropora* sp.) and large sea urchin (*Heterocentrotus mamillatus*) spines that show evidence of human use as abraders or filing tools for craft and tool manufacture were recovered in Tainuʻu Test Pits 1 through 7 (see Table 9, Figure 30). However, the presence of abraders was most prevalent in the test units along the more northern portion of the marae.



Figure 30. Urchin spine abraders recovered from 50 cm below surface in TP4Tainuu. (photo by J. O'Connor)

Spines and tests (shells) from a small urchin (*Echinostrephus aciculatus*) species are also present throughout the test units. Small black sea urchin spines have been identified as artifacts in some Polynesian archaeological deposits (Dye 2011), but they are not viewed as the preferred source for industrial implements. The small urchins are viewed as subsistence remains at Marae Tainuʻu.

The recovery of utilized coral and urchin spine abraders contrasts with the identification of any materials upon which these implements were used. The use of these filing tools remains a mystery at this location due to the lack of a direct relationship between tool and manufacture use. Given the lack of formal bone or shell tools in the Marae Tainu'u assemblage, the abraders could potentially have been used to shape

wooden artifacts or other materials that have not preserved. Differential preservation of organic materials in tropical and semi-tropical environments has long been recognized as an issue affecting the structure of archaeological assemblages in Polynesia.

Historic Materials

A variety of historic artifacts, or post-contact archaeological materials, were recovered from the upper layers of all test units (see Table 9). These materials included metal, glass, ceramic, plastic, and concrete artifacts. Identifiable artifacts consist of metal nails, a glass marble, a button, ceramic fragments, etc. Few artifacts are temporally diagnostic to the early post-contact period. Rather, remains are predominantly fragments of refuse broadly accumulated from day-to-day recreational activities at Marae Tainuʻu over the past several decades. Some refuse appears to originate from the elementary school that is located immediately to the north of the marae archaeological complex. Historic-period materials are generally limited to the upper levels of the excavated test pits, or have stratigraphically descended due to surface disruption from landscape modification activities. These tend to appear in the upper levels of Test Pits 1, 2, 4, 5, 6, and most of Test Pit 7 as would be expected in secure stratigraphic sequences and irrespective of the chronological issues associated with *Swietenia* sp. specimens discussed in the previous chapter.

TP3Tainuu is a unique case in that historic materials were recovered from all layers/levels of the excavated unit. TP3Tainuu is located 8 m east of the ahu in an area closer to the lagoon than the other test units. This area shows evidence of extreme bioturbation from tupa crabs (*Cardisoma carnifex*), and the presence of materials such as

glass in the lower levels of this unit just above the waterline is likely due to crab activity. The presence of historic material as deep as 40 cm in TP7Tainuu also suggests the influence of local fauna (i.e., *C. carnifex*) in bioturbation processes, with a result similar to but less disruptive than that seen in TP3Tainuu. Historic-period construction and gardening activity has likely also influenced the distribution of historic materials in strata close to the water table at this particular location of the marae complex.

Ecofacts

Analyses of human-environmental interactions constitute the principal research interest of historical ecology, or human ecodynamics, as a program of inquiry for understanding the ecosystem-wide effects of ancient human activity (Kirch 2005; Rick and Erlandson 2008; Rick et al. 2013). The study of impacts to floral and faunal species in deep history provides the basis for textbook archaeological studies as well as variable baselines for modern environmental assessments and resource management (Erlandson and Rick 2010; Morrison and Hunt 2007; Rick et al. 2014). Below are discussed those floral and faunal remains recovered from Marae Tainu‘u that appear to have been influenced by human behavior, but for which any modification or disturbance was an indirect result of subsistence practices or other cultural activity. These ecofacts provide a window into the world as experienced by Mā‘ohi populations at Tevaitoa prior to European encroachment and the changes that occurred following sustained European contact.

Faunal remains have been quantified for Test Pits 1 through 7. Gross weights for general vertebrate and marine invertebrate categories are shown by test unit and stratigraphic layer in Tables 11 and 12, respectively. The vertical and horizontal distributions of these faunal classes are discussed in greater detail below. Recovered faunal materials from Test Pit 1 were identified to genus and species, where possible, to serve as a representative characterization of faunal remains in units at Marae Tainuʻu. I identified invertebrate species using a variety of reference sources (e.g., Abbott and Dance 1982, Cernohorsky 1967 and 1972, Dance 2002, Trondle and Boutet 2009, IUCN 2018, and WoRMS 2018). Many shell fragments could not be identified to a genera or species due to lack of diagnostic attributes. Vertebrate remains were identified to genus and species for terrestrial mammals (i.e., *Sus* sp., *Canis familiaris*), where possible.

Table 11. Bulk vertebrate bone weights (grams) by unit and stratigraphic layer.

Unit	Layer I	Layer II	Layer III	Layer IV
TP1Tainuu	8.47	88.57	44.03	
TP2Tainuu	10.56	29.53		
TP3Tainuu	0	12.06	1.43	
TP4Tainuu	0.54	10.65	7.62	
TP5Tainuu	0.6	16.94	161.21	5.51
TP6Tainuu	30.32	17.28	114.01	9.88
TP7Tainuu	2.47	42.83	6.64	7.42

Table 12. Bulk marine shell weights (grams) by unit and stratigraphic layer.

Unit	Layer I	Layer II	Layer III	Layer IV
TP1Tainuu	241.89	843.97	685.8	
TP2Tainuu	260.15	979.86		
TP3Tainuu	455.76	1597.45	607.04	
TP4Tainuu	2045.62	1462.58	654.63	
TP5Tainuu	560.5	478.93	1960.22	560.13
TP6Tainuu	564.46	576.04	1524.79	462.92
TP7Tainuu	1708.14	1525.53	447.32	1146.77

However, bird and fish remains were only organized according to general class of fauna due to the minimal presence of these fauna and the lack of diagnostic elements on most recovered specimens. Several skeletal elements for all vertebrate specimens where listed as miscellaneous due to inability to associate specimens with a specific animal.

Terrestrial Vertebrates

Terrestrial vertebrate remains were abundant in the excavated test pits at Marae Tainu'u, although recovered specimens were primarily small fragments as opposed to complete skeletal elements. Bone fragments from large terrestrial mammals dominate the bone assemblage, with pig (*Sus* sp.) elements, dog (*Canis familiaris*), and unidentified bird bone present in the collection. The *Sus* elements (see Figure 31) recovered from TP1Tainuu are of particular importance because they were found in close vertical and horizontal proximity to the basalt alignment at the top of Layer III. Terrestrial animal bone elements appear throughout the stratigraphic sequence of the TP1Tainuu/TP2Tainuu trench, but the concentration of larger elements above, at, and below the Layer II/Layer III transition (~80 cm below surface) in association with hearth features and the basalt alignment suggests purposeful use of the area for food preparation or consumption (refer to Figure 15 cross-section profile). However, there is no evidence of burning on any recovered bone specimens. This observation precludes the preparation of animal foods over a fire, instead supporting methods of indirect heating, such as through the use of pit ovens (imu) that are common throughout Polynesian in the past and to the present day. The concentrated pig elements were recovered from the southern half



Figure 31. Portion of pig mandible recovered from 80 cm below surface in TP1Tainuu. (photo by J. O'Connor)

of TP1Tainuu. The presence of terrestrial mammal bone fragments throughout the marae point to the processing of these animals at or near the marae complex.

Bones from non-human terrestrial vertebrates (i.e., *Sus* sp., *Canis familiaris*, unidentified bird bone) are present in greater quantities than fish bone. Identified species are all Polynesian and post-Polynesian introductions. A preference for terrestrial mammals at Marae Tainu'u was recognized during the 2016 excavations, whether as food sources or for other uses. This trend is supported in the 2017 faunal collection. Terrestrial vertebrate elements are present throughout the stratigraphic sequence in TP5Tainuu, TP6Tainuu, and TP7Tainuu. Teeth (*Sus* sp. and *C. familiaris*) exhibit a

greater stratigraphic dispersion, particularly in TP5Tainuu where pig and dog teeth were recovered between 40 cm and 110 cm depth. The TP5Tainuu/TP6Tainuu trench holds a greater overall quantity of bone elements than seen further north on the paepae, but these elements share stratigraphic concentration in the upper levels of Layer II (i.e., ~70-90 cm below surface). This spatiotemporal concentration of elements is not shared in TP7Tainuu, where terrestrial vertebrate remains are present in lesser quantities and more evenly dispersed through the strata. Bulk vertebrate bone counts and weights for terrestrial and marine species are shown in Table 13.

Marine Vertebrates

Marine vertebrate remains are scarce in the recovered record at Marae Tainuʻu. No marine mammal or sea turtle specimens were identified in any test unit. Fish bones were collected, but only in minimal quantities. I identified only 21 individual elements as fish specimens in the 2016 collection, and 77 individual fish specimens were found scattered throughout the 2017 test pits. Diagnostic elements are mostly lacking and identification to taxon was not possible for the vast majority of recovered elements. The relative lack of fish bone is consistent with the absence of fishing equipment at the paepae and across the greater marae complex

Marine Invertebrates

Marine shell makes up the majority of faunal specimens recovered from the excavated test pits. My excavations produced a total of 21.42 kg of marine shellfish remains. Varying quantities of marine shell were found in every level of each of the

Table 13. Bulk vertebrate bone recovered from archaeological excavations at Marae Tainu‘u.

TP1Tainuu	NISP	Wt (g)	TP2Tainuu	NISP	Wt (g)
Layer I / Level 1	5	4.8	Layer I / Level 1	1	1.75
Layer I / Level 2	7	3.67	Layer I / Level 2	15	8.81
Layer II / Level 3	6	0.51	Layer II / Level 3	10	5.44
Layer II / Level 4	11	2.04	Layer II / Level 4	7	4.79
Layer II / Level 5	7	5.19	Layer II / Level 5	2	4.03
Layer II / Level 6	3	3.81	Layer II / Level 6	5	1.39
Layer II / Level 7	1	2.02	Layer II / Level 7	4	3.94
Layer II / Level 8	10	75	Layer II / Level 8	5	9.94
Layer III / Level 9	9	9.56			
Layer III / Level 10	23	22.52			
Layer III / Level 11	2	1.23			
Layer III / Level 12	12	10.72			
Total	96	141.07	Total	49	40.09

TP3Tainuu	NISP	Wt (g)	TP4Tainuu	NISP	Wt (g)
Layer I / Level 1	0	0	Layer I / Level 1	0	0
Layer II / Level 2	8	9.93	Layer I / Level 2	0	0
Layer II / Level 3	4	2.13	Layer I / Level 3	0	0
Layer III / Level 4	1	1.33	Layer I / Level 4	2	0.54
Layer III / Level 5	1	0.1	Layer II / Level 5	0	0
Layer III / Level 6	0	0	Layer II / Level 6	2	0.47
			Layer II / Level 7	16	10.18
			Layer III / Level 8	7	4.61
			Layer III / Level 9	8	3.01
Total	14	13.49	Total	35	18.81

TP5Tainuu	NISP	Wt (g)	TP6Tainuu	NISP	Wt (g)
Layer I / Level 1	0	0	Layer I / Level 1	2	2.41
Layer I / Level 2	0	0	Layer I / Level 2	8	3.71
Layer I / Level 3	1	0.6	Layer I / Level 3	13	24.2
Layer II / Level 4-5	16	6.62	Layer II / Level 4-5	20	15.58
Layer II / Level 6	3	2.77	Layer II / Level 6	2	1.21
Layer II / Level 7	3	7.55	Layer II / Level 7	2	0.49
Layer III / Level 8	26	36.71	Layer III / Level 8	33	54.3
Layer III / Level 9-10	57	122.11	Layer III / Level 9-10	25	41.85
Layer III / Level 11	7	2.39	Layer III / Level 11	11	17.86
Layer IV / Level 12	6	2.07	Layer IV / Level 12	4	4.54
Layer IV / Level 13	4	0.79	Layer IV / Level 13	6	2.8
Layer IV / Level 14	10	2.65	Layer IV / Level 14	4	2.54
Total	133	184.26	Total	130	171.49

TP7Tainuu	NISP	Wt (g)
Layer I / Level 1	0	0
Layer I / Level 2	4	1.33
Layer I / Level 3	5	1.14
Layer II / Level 4	6	3.89
Layer II / Level 5	11	11.45
Layer II / Level 6	12	27.49
Layer III / Level 7	5	4.37
Layer III / Level 8	1	2.27
Layer IV / Level 9	7	2.47
Layer IV / Level 10	10	4.32
Layer IV / Level 11	4	0.63
Total	65	59.36

seven test pits at Marae Tainu‘u. Bulk counts (NISP) and weights were obtained for recovered specimens from all test units (see Table 14). Marine shell was separated by morphological characteristics and grouped by general class, wherever possible. Certain species were harvested as food resources for human populations at the study area, such as *Turbo setosus* (a gastropod known as the rough turban), *Tridacna maxima* (also known as the small giant clam), and *Echinostrephus aciculatus* (a species of small black sea urchin). However, many of the recovered specimens are from species of mollusks that are not regularly considered food sources for pre-contact and historic-period Pacific Island populations. These include species such as *Monetaria annulus*, also known as the ring or “money” cowry, that were regularly collected for economic and craft purposes unrelated to sustenance, and smaller *Rhinoclavis* spp. that appear to be byproducts of close spatial association to a marine environment.

Marine shell constituted the majority of faunal remains recovered on the paepae and in other areas of the marae complex. Turbo shell (*Turbo setosus*; Figure 32) and giant clams (*Tridacna maxima*; Figure 33) often comprise the majority of weight, and in some cases, make up the most individual specimens. However, bulk counts reflect inclusion of smaller non-edible species. The combination of primarily targeted species and those species less likely to be sought as subsistence resources may obscure variation in species distributions that can add to understanding of ecological changes through time at Marae Tainu‘u. A complete review of the collection and the identification of other marine shell species represented in the excavated sample will expand knowledge as to other species that may have been potentially targeted as resources for food or raw materials for craft and tool production.

Table 14. Bulk marine shell recovered from archaeological excavations at Marae Tainu‘u.

TP1Tainuu	NISP	Wt (g)	TP2Tainuu	NISP	Wt (g)
Layer I / Level 1	81	168.33	Layer I / Level 1	41	85.01
Layer I / Level 2	148	73.56	Layer I / Level 2	236	175.14
Layer II / Level 3	307	310.64	Layer II / Level 3	274	412.99
Layer II / Level 4	160	63.62	Layer II / Level 4	268	88.16
Layer II / Level 5	249	73.78	Layer II / Level 5	209	53.51
Layer II / Level 6	80	41.02	Layer II / Level 6	308	52.99
Layer II / Level 7	182	38.16	Layer II / Level 7	419	146.14
Layer II / Level 8	211	316.75	Layer II / Level 8	403	226.07
Layer III / Level 9	119	114.64			
Layer III / Level 10	237	218.43			
Layer III / Level 11	249	218.16			
Layer III / Level 12	339	134.57			
Total	2362	1771.66	Total	2158	1240.01

TP3Tainuu	NISP	Wt (g)	TP4Tainuu	NISP	Wt (g)
Layer I / Level 1	604	455.76	Layer I / Level 1	129	42.06
Layer II / Level 2	501	1410.89	Layer I / Level 2	586	1134.52
Layer II / Level 3	241	186.56	Layer I / Level 3	383	276.64
Layer III / Level 4	77	330.53	Layer I / Level 4	350	592.4
Layer III / Level 5	60	51.43	Layer II / Level 5	366	592.13
Layer III / Level 6	43	225.08	Layer II / Level 6	257	429.85
			Layer II / Level 7	443	440.6
			Layer III / Level 8	313	471.6
			Layer III / Level 9	317	183.03
Total	1526	2660.25	Total	3144	4162.83

TP5Tainuu	NISP	Wt (g)	TP6Tainuu	NISP	Wt (g)
Layer I / Level 1	167	79.27	Layer I / Level 1	171	133.76
Layer I / Level 2	326	267.51	Layer I / Level 2	261	280.15
Layer I / Level 3	314	213.72	Layer I / Level 3	532	150.55
Layer II / Level 4-5	425	235.94	Layer II / Level 4-5	441	160.52
Layer II / Level 6	282	62.07	Layer II / Level 6	371	237.67
Layer II / Level 7	338	180.92	Layer II / Level 7	93	177.85
Layer III / Level 8	257	350.26	Layer III / Level 8	279	594.11
Layer III / Level 9-10	729	1029.86	Layer III / Level 9-10	409	378.87
Layer III / Level 11	459	580.1	Layer III / Level 11	491	551.81
Layer IV / Level 12	518	333.61	Layer IV / Level 12	452	252.19
Layer IV / Level 13	214	97.74	Layer IV / Level 13	248	124.72
Layer IV / Level 14	322	128.78	Layer IV / Level 14	336	86.01
Total	4351	3559.78	Total	4084	3128.21

TP7Tainuu	NISP	Wt (g)
Layer I / Level 1	8	5.9
Layer I / Level 2	264	572.41
Layer I / Level 3	483	1201.83
Layer II / Level 4	153	401.15
Layer II / Level 5	263	535.85
Layer II / Level 6	398	588.53
Layer III / Level 7	168	308.06
Layer III / Level 8	98	139.26
Layer IV / Level 9	436	564.97
Layer IV / Level 10	517	310.28
Layer IV / Level 11	338	271.52
Total	3126	4899.76



Figure 32. *Turbo setosus* shell with operculum recovered from 80 cm below surface in TP6Tainuu. (photo by J. O'Connor)

TP1Tainuu Representative Shellfish Sample Analysis

Marine invertebrate remains from TP1Tainuu were analyzed in totality as a representative subsample of the overall excavations (see Table 15). Species identifications and counts for TP1Tainuu are provided as NISP (number of individual specimens), MNI (minimum number of individuals), and weight in grams. Some miscellaneous categories remain due to the unidentifiable nature of some specimens. The choice of TP1Tainuu for detailed assessment was based on the secure stratigraphy and dating of the unit in contrast to the southerly paepae test units. Greater quantities of shell remains were found in TP5Tainuu and TP6Tainuu, but the ability to judge changes in



Figure 33. *Tridacna maxima* shells recovered from 80 cm below surface in TP6Tainuu. (photo by J. O'Connor)

species representation and importance through time was a strong determining factor in the analysis.

Identified taxa are dominated by coral reef mollusk species, a collection that is emblematic of the coral reef ecosystem represented at Raʻiātea. Raʻiātea is a high island with an extensive barrier reef that creates a wide lagoon with little to no sandy shorelines.

Table 15. Faunal remains recovered from TP1Tainuu identified by taxa and general class.

Species	Metrics	LRI/LV1 10cm	LRI/LV2 20cm	LRII/LV3 30cm	LRII/LV4 40cm	LRII/LV5 50cm	LRII/LV6 60cm	LRII/LV7 70cm	LRII/LV8 80cm	LRIII/LV9 90cm	LRIII/LV10 100cm	LRIII/LV11 110cm	LRIII/LV12 120cm	Total	% Wt
Turbo setosus	Wt (g)	112.71	36.23	191.85	22.75	34.4	8.53	2.04	128.63	79.59	114.37	71.49	20.76	823.35	42.98
	NISP	29	26	34	8	2	26	9	8	8	29	13	6	198	
	MNI	4	4	9	1	2	1	1	2	3	8	8	3	46	
Tridacna maxima	Wt (g)	26.33	5.62	23.29	0	0	0	0	79.61	0	12.17	22.5	15.47	184.99	9.66
	NISP	4	5	6	0	0	0	0	1	0	1	4	2	23	
	MNI	2	1	1	0	0	0	0	1	0	1	1	1	8	
Lithophaga spp.	Wt (g)	0	12.7	0	0	0	0	0	0	1.02	0	6.18	7.65	27.55	1.44
	NISP	0	4	0	0	0	0	0	0	4	0	29	54	91	
	MNI	0	2	0	0	0	0	0	0	2	0	2	10	16	
Gyrineum lacunatum	Wt (g)	1.26	0	0	0	0	0.8	1.1	0	0	1.41	7.09	0.89	12.55	0.66
	NISP	1	0	0	0	0	1	1	0	0	3	5	2	13	
	MNI	1	0	0	0	0	1	1	0	0	2	5	1	11	
Rhinoclavis sp.	Wt (g)	1.52	0	0	0	0	0	0	0	0	2.65	1.42	1.01	6.6	0.35
	NISP	1	0	0	0	0	0	0	0	0	4	1	1	7	
	MNI	1	0	0	0	0	0	0	0	0	4	1	1	7	
Periglypta reticulata	Wt (g)	1.58	3.28	7.07	0	0.58	0	7.19	19.56	8.13	14.68	32.95	16.51	111.53	5.82
	NISP	1	25	53	0	5	0	6	23	14	45	59	45	276	
	MNI	1	9	15	0	2	0	6	17	4	17	20	29	120	
Conus spp.	Wt (g)	6.03	0.67	11.55	2.11	2.85	0	2.59	0	1.71	18.51	12.06	7.24	65.32	3.41
	NISP	3	1	6	1	2	0	2	0	2	16	19	15	67	
	MNI	1	1	4	1	2	0	2	0	2	7	11	7	38	
Cellana sp.	Wt (g)	0.94	2.37	0	0	0	0	0	0	0	0	0	0	3.31	0.17
	NISP	5	11	0	0	0	0	0	0	0	0	0	0	16	
	MNI	4	2	0	0	0	0	0	0	0	0	0	0	6	
Chama cf. *asperella*	Wt (g)	0	0	6.99	0	0.81	0.2	1.51	0	0	0	0	0	9.51	0.5
	NISP	0	0	5	0	0	1	2	0	0	0	0	0	8	
	MNI	0	0	5	0	0	1	2	0	0	0	0	0	8	
Monetaria (Cypraea, Erosaria) obvelata	Wt (g)	2.87	1.49	11.47	5.06	0	0	0	1.43	0	10.08	9.23	9.85	51.48	2.69
	NISP	2	6	18	5	0	0	0	1	0	5	6	7	50	
	MNI	2	3	13	4	0	0	0	1	0	5	6	7	41	
Monetaria (Cypraea) moneta	Wt (g)	0	3.36	1.27	0	0	0	0	0	0	2.01	1.63	0	8.27	0.43
	NISP	0	5	1	0	0	0	0	0	0	1	1	0	8	
	MNI	0	2	1	0	0	0	0	0	0	1	1	0	5	
Monetaria (Cypraea) annulus	Wt (g)	0	0	2.78	0	9.5	14.83	2.76	3.58	1.12	12.1	18.05	15.49	80.21	4.19
	NISP	0	0	9	0	1	7	2	5	8	30	31	35	128	
	MNI	0	0	6	0	1	6	2	4	3	13	16	11	62	
Cypraea tigris	Wt (g)	0.69	0	3.13	0	0	0	0	0	0	0	0	0	3.82	0.2
	NISP	1	0	1	0	0	0	0	0	0	0	0	0	2	
	MNI	1	0	1	0	0	0	0	0	0	0	0	0	2	
Saccostrea cucullata	Wt (g)	0	0	27.09	13.07	21.16	11.83	12.24	24.72	6.09	6.14	5.16	10.39	137.89	7.2
	NISP	0	0	145	27	190	39	125	114	43	24	16	22	745	
	MNI	0	0	48	14	83	20	42	76	18	10	5	10	326	
Nassarius spp.	Wt (g)	0	0	0.54	0.18	0	0.5	0	1.07	0	0.99	0	0	3.28	0.17
	NISP	0	0	1	1	0	2	0	1	0	2	0	0	7	
	MNI	0	0	1	1	0	2	0	1	0	2	0	0	7	
Cuspidaria sp.	Wt (g)	0	0	0	0	0.17	0	0	0	0	0	0	0	0.17	0.01
	NISP	0	0	0	0	1	0	0	0	0	0	0	0	1	
	MNI	0	0	0	0	1	0	0	0	0	0	0	0	1	

Species	Metrics	LRI/LV1 10cm	LRI/LV2 20cm	LRII/LV3 30cm	LRII/LV4 40cm	LRII/LV5 50cm	LRII/LV6 60cm	LRII/LV7 70cm	LRII/LV8 80cm	LRIII/LV9 90cm	LRIII/LV10 100cm	LRIII/LV11 110cm	LRIII/LV12 120cm	Total	% Wt
Asaphis violascens	Wt (g)	1.79	0.45	10.89	7.94	0	1.45	5.44	7.62	11.64	7.16	24.17	16.62	95.17	4.97
	NISP	6	2	21	22	0	2	6	15	13	28	31	61	207	
	MNI	3	2	6	10	0	2	4	8	9	17	19	21	101	
Trochus sp.	Wt (g)	0.03	0	0	3.16	0	0	0	47.75	0	0	0	0	50.94	2.66
	NISP	1	0	0	1	0	0	0	5	0	0	0	0	7	
	MNI	1	0	0	1	0	0	0	3	0	0	0	0	5	
Heterocentrotus mamillatus	Wt (g)	8.56	3.4	3.63	0	0	0	0	0	0.41	0	0	0	16	0.84
	NISP	4	4	4	0	0	0	0	0	1	0	0	0	13	
	MNI	2	1	1	0	0	0	0	0	1	0	0	0	5	
Echinostrephus aciculatus	Wt (g)	0	0.3	0.31	0	0.36	0.02	0.7	0.61	0.12	0	0	0.05	2.47	0.13
	NISP	0	1	2	0	13	1	23	22	6	0	0	3	71	
	MNI	0	1	1	0	1	1	1	1	1	0	0	1	8	
miscellaneous marine shell	Wt (g)	13.52	6.27	6.18	8.55	1.51	0	1.44	4.32	1.89	5.12	8.45	12.2	69.45	3.63
	NISP	20	51	12	140	23	0	6	23	21	44	34	91	465	
	MNI	X	X	X	X	X	0	X	X	X	X	X	X	X	
Pointed land snail	Wt (g)	1.42	0.13	0.04	0	0.02	0	0.06	0	0	0	0.09	0.61	2.37	0.12
	NISP	69	1	3	0	2	0	3	0	0	0	2	9	89	
	MNI	69	1	3	0	2	0	3	0	0	0	2	9	89	
Round land snail	Wt (g)	0	0.05	2.84	3.53	1.18	0	0.1	0	0	0.04	0.53	0.14	8.41	0.44
	NISP	0	1	52	86	26	0	3	0	0	1	8	2	179	
	MNI	0	1	52	86	26	0	3	0	0	1	8	2	179	
Sus sp.	Wt (g)	0	0	0	0	0	3.81	2.02	75	9.41	22.52	1.23	5.93	119.92	6.26
	NISP	0	0	0	0	0	3	1	10	8	23	2	6	53	
	MNI	0	0	0	0	0	1	1	1	1	1	1	1	7	
Canis familiaris	Wt (g)	0	0.49	0.03	0	0	0	0	0	0	0	0	0	0.52	0.03
	NISP	0	1	1	0	0	0	0	0	0	0	0	0	2	
	MNI	0	1	1	0	0	0	0	0	0	0	0	0	2	
miscellaneous terrestrial	Wt (g)	3.97	3.18	0.13	2.04	3.85	0	0	0	0	0	0	4.79	17.96	0.94
	NISP	2	6	1	11	6	0	0	0	0	0	0	6	32	
	MNI	X	X	1	X	X	0	0	0	0	0	0	X	X	
miscellaneous bird	Wt (g)	0.06	0	0	0	0	0	0	0	0	0	0	0	0.06	0
	NISP	1	0	0	0	0	0	0	0	0	0	0	0	1	
	MNI	1	0	0	0	0	0	0	0	0	0	0	0	1	
miscellaneous fish	Wt (g)	0.77	0	0.35	0	1.34	0	0	0	0.15	0	0	0	2.61	0.14
	NISP	2	0	4	0	1	0	0	0	1	0	0	0	8	
	MNI	X	0	X	0	1	0	0	0	1	0	0	0	X	

The coastal topography at Marae Tainu‘u, and much of the west side of the island, is defined by an abrupt transition from coastal land to water. Submerged sandy areas exist along the coastline before the drop-off into deeper lagoon waters. However, much of the area immediately offshore is a coral limestone reef flat minimally exposed during tidal fluctuation, followed by a living reef system and rich fishery environment as one progresses further from the coast. Both the near-shore rocky reef and the barrier reef that surrounds the island supply a wealth of marine resources today as they did in the past.

Twenty genera and/or species of marine invertebrates were identified in the TP1Tainuu faunal remains. These include coral reef species such as *Tridacna maxima* and *Turbo setosus* that served as major species for dietary and technological purposes. *T. maxima* and *T. setosus* are widely dispersed large mollusk species that have been exploited through time across Polynesia (Allen and Huebert 2014; Morrison and Hunt 2007; WoRMS 2018). These species comprise the largest and heaviest shellfish specimens recovered at Marae Tainu‘u and, therefore, dominate the weight distributions of recovered specimens (see Figure 34 for vertical weight distribution in TP1Tainuu). *T. maxima* and *T. setosus* supply a large proportion of edible meat per collected specimen, and the shells themselves can become useful secondary tools for a variety of craft and economic purposes (Kahn 2018). *Periglypta reticulata* and *Asaphis violascens*, two other bivalves found in coral reef habitats, are present in quantifiable numbers and may have been exploited for nutritional purposes. Urchin species (i.e., *Echinostrephus aciculatus*, *Heterocentrotus mamillatus*) that serve as dietary resources throughout the Pacific appear in minimal quantities insufficient to represent a significant level of consumption at the marae.

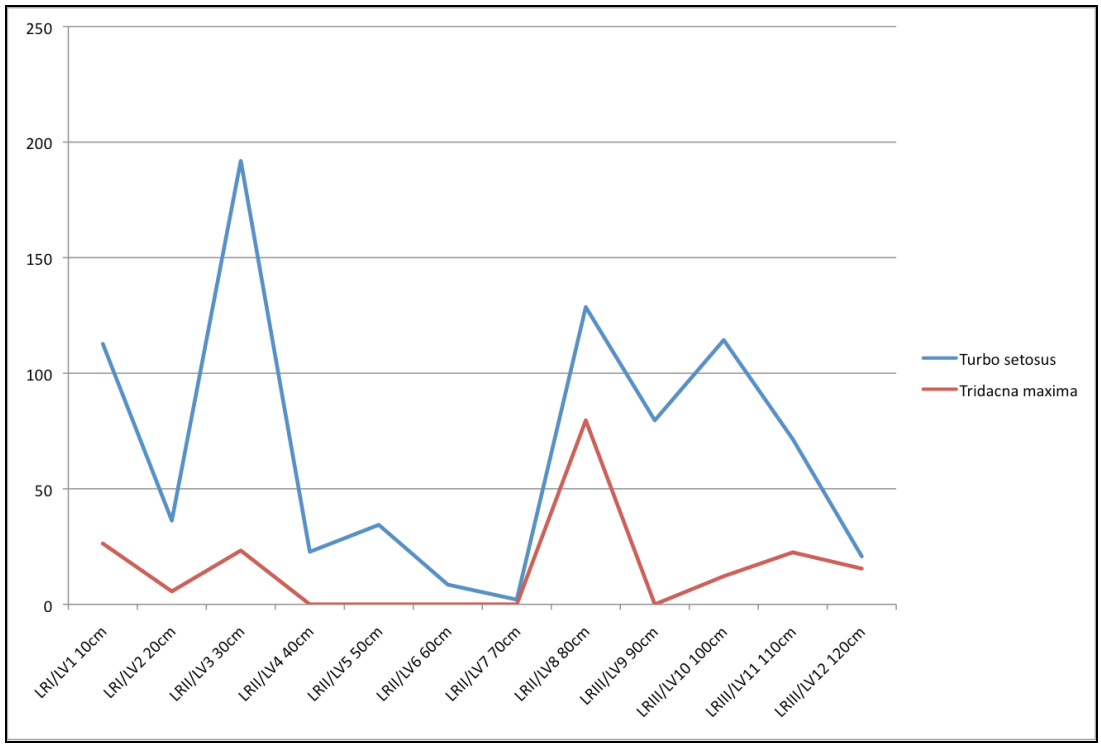


Figure 34. Weight distribution (in grams) of *Turbo setosus* and *Tridacna maxima* remains in layers and levels of TP1Tainuu.

Other economically viable species identified in the Marae Tainu‘u assemblage are the *Monetaria* spp. (*Monetaria obvelata*, *M. moneta*, *M. annulus*; formerly *Cypraea* and *Erosaria*: see Abbott and Dance 1982, Trondle and Boutet 2009, and WoRMS 2018). These are the small cowrie shells that have been utilized as a primary ornamental species for jewelry and clothing, as well as serving as a form of currency in the western and eastern Pacific. *Monetaria* spp. are derived from coral reef habitats and may be collected from the rocky headlands and reef flats that exist in the Leeward Society Islands (Kahn et al. 2015a). These specimens exhibit a limited, but noticeable, presence in the TP1Tainuu materials and are observable in the faunal remains from other Marae Tainu‘u test units. A lesser species that appears in recognizable weights in TP1Tainuu are the very small specimens of hooded oyster (*Saccostrea cucullata*). Whereas this reef species can grow

to sizes that provide a sufficient nutritional return to warrant harvesting, the *S. cucullata* remains identified at Marae Tainu‘u appear to be spoils associated with anthropogenically emplaced coral fill in the coral limestone strata of the paepae. The small size of these specimens precludes utilization as a dietary staple.

Some marine shells were found mixed with denser deposits of charcoal, and these specimens show evidence of burning. However, this is not broadly perceived on whole shells and is not likely due to a regular practice of cooking shellfish over fire. Shells display minimal amounts of water-worn abrasion or encrustation or boring by other marine organisms that would be present if the shells spent considerable time in a marine environment after death. Instead, marine invertebrates were likely removed from the reef ecosystem prior to death and shells were then immediately deposited in a terrestrial context.

The shellfish data from TP1Tainuu show a relatively constant presence of certain marine species through time. Continuity in marine shell presence among stratigraphic layers supports a spatio-temporal trajectory of long-term site usage on both the paepae and the marae court. However, bulk weights for marine invertebrate remains from the seven test pits at Marae Tainu‘u display horizontal and vertical variation based on stratigraphic layer and arbitrary 10 cm levels applied during excavation. This variation in weight is tied directly to the presence and absence of the larger and more sought after dietary species of .*T setosus* and *T. maxima*. Therefore, changes in bulk weights among natural strata listed above in Table 12 become a good temporal indicator of when greater quantities of edible species were deposited in the archaeological record. Variation in the density of shellfish deposits among the stratigraphic layers and arbitrary excavation

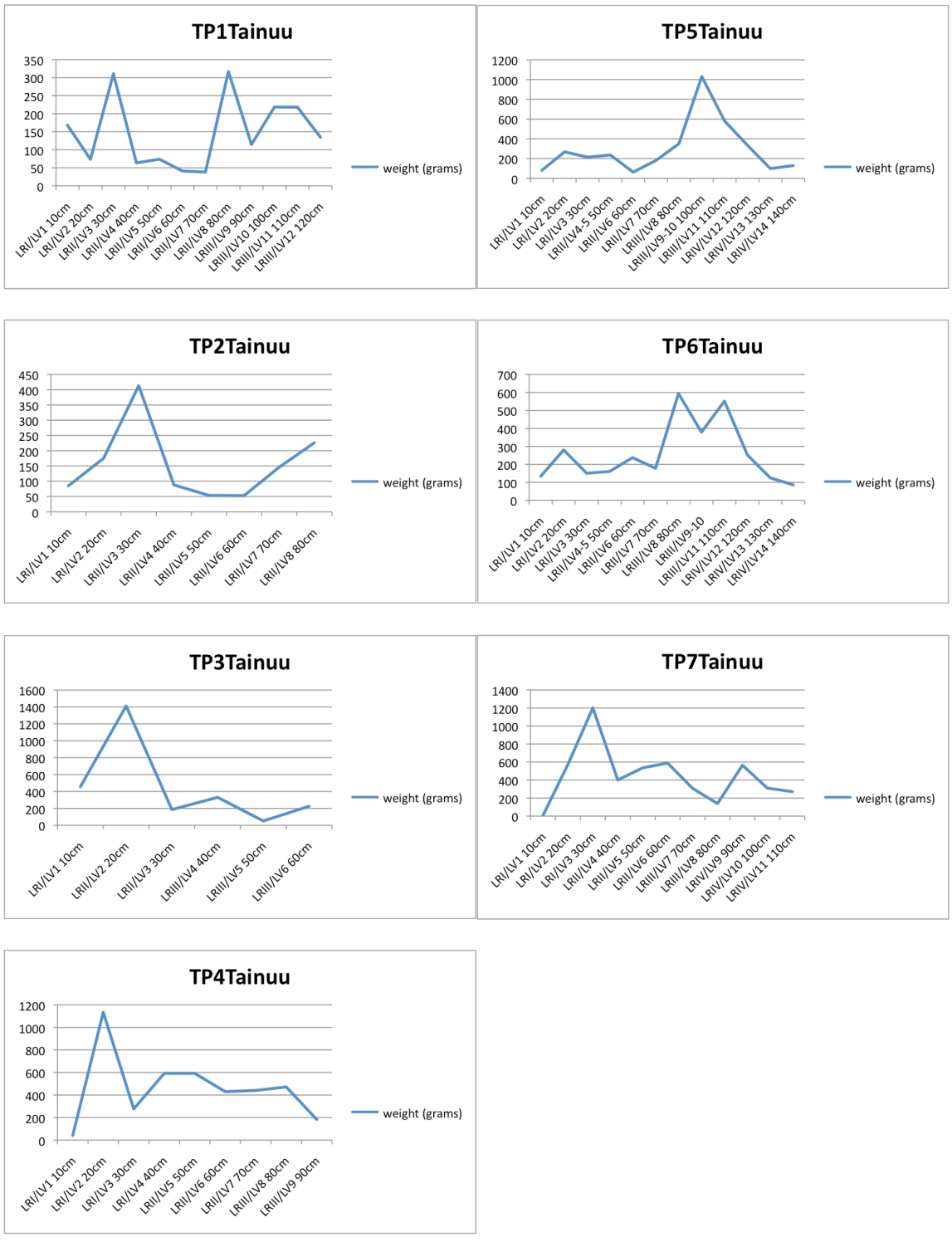


Figure 35. Distribution of marine shell remains as measured by weight (g) for all layers and levels of Test Pits 1 through 7 at Marae Tainu‘u.

levels of all test units can be compared in Figure 35.

Overall, greater quantities of marine invertebrate remains were present in the upper layer of those test units in various areas of the marae court to the west of the paepae: TP3Tainuu, TP4Tainuu, and TP7Tainuu. This likely results from the continued use of these areas for human activity and social engagement in the post-contact era. Coral reef shellfish are still consumed today in this area of the island due to the accessibility of these species in the lagoon habitat and the continuation of traditional dietary practices in the context of modern cultural practice. On the paepae, TP1Tainuu and TP2Tainuu display peaks in both the historic period and at the interface of Layer II and Layer III at what is seen as a stratigraphic transition to pre-contact times. These weights are considerably less than the later shellfish densities seen off of the paepae. However, TP5Tainuu and TP6Tainuu do show an increase in shell density at and below the Layer III cultural floor associated with earlier basalt alignments and architecture. The greater presence of marine shell in these strata support the differential use of northern and southern portions of the paepae at around the time of European contact, through radiocarbon dating issues discussed in Chapter 5 may complicate the definitiveness of chronological statements about this section of the marae complex.

Land Snails

In addition to terrestrial vertebrate remains, recovered terrestrial invertebrates in the form of land snail shells, may provide information as to broader ecological change at Marae Tainuʻu. Analyses of spatio-temporal variation in land snail species observed in the archaeological record have helped broaden collective understanding of

paleoenvironmental changes resulting from pre-contact and historic-period impacts to local island ecologies (Christensen et al. 2018). Temporal changes in the presence of different land snail species can illustrate low-level effects to the environment at a scale not often paid great attention in the archaeological literature.

The presence of exotic and introduced species at western Raʻiātea was noted in earlier reports for this project, but species identifications have been complicated. Initially, a noticeable change in land snail species richness was observed in the upper stratigraphic levels at Marae Tainu'u. Shells identified as the small pointed snail (Figure 36a) (*Prietocella barbara)*, a European introduction, are plentiful in the upper layers of the paepae test units. Assemblage composition switches from *P. barbara* to specimens of



(a) (b)

Figure 36. Small pointed snail (a) recovered from 10 cm below surface, and small rounded snails (b) recovered from 30 cm below surface in TP1Tainuu. (photos by J. O'Connor)

what appear to be small round Polynesian tree snails (Figure 36b), *Partula* sp., below about 30 cm to 40 cm below surface at TP1Tainuu and TP2Tainuu. A similar trend in the differential distribution of small pointed snails between the upper levels and small round snails in lower levels is apparent in other areas of the research area (see Figure 37 for distribution). This information is important because various *Partula* spp. have become critically endangered or gone extinct due to the introduction of exotic species over the past 200+ years (IUCN 2018). However, species identifications have been called into question based on review of Kahn's work to the north of the project area. Kahn (2018) noted the presence of different, though morphologically similar, species at the Sunset Beach location at western Raʻiātea. The prehistorically introduced *Allopeas gracile*, also a small pointed snail, was identified at that location, and no discussion of the small rounded snails (*Partula* sp.?) is mentioned.

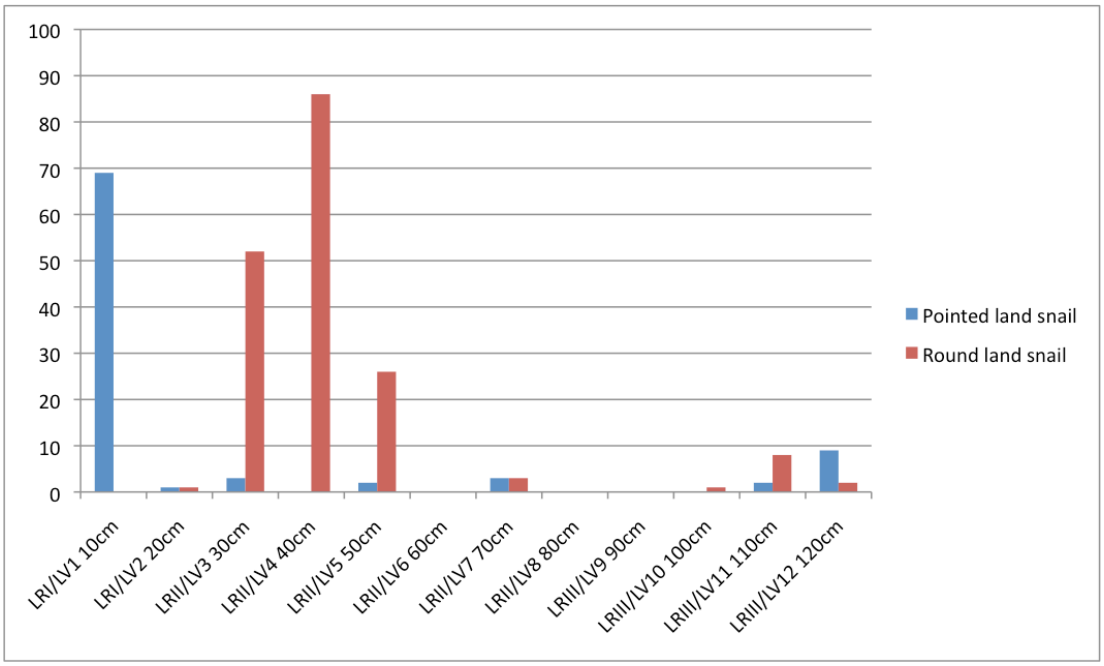


Figure 37. Land snail distributions by stratigraphic layer and level for TP1Tainuu.

The confirmation of species identifications from the Tainuʻu excavations will only be achieved through future collaboration. This is important because the observation of species replacement in small land snails may be representative of a larger shift of influence regarding native and introduced species at western Raʻiātea. This may represent a later-than-expected human impact on the terrestrial ecosystem of Raʻiātea resulting from European activity. If this conclusion is correct, the shift in land snail species composition is an example of how the variable presence of small peripheral species in archaeological contexts is important to understanding the historical ecology of coastal ecosystems and the shifting baselines of human impacts in pre-contact and modern temporal periods (Erlandson and Rick 2010).

Floral Remains

Floral remains are sparse, except for carbonized samples. No modified floral artifacts were recovered during the 2016 or 2017 excavations. Some small wood fragments were recovered from dry and wet deposits at Marae Tainuʻu, but the diagnostic potential of these materials remains to be assessed. The carbonized samples and an additional kukui nut (*Aleurites moluccana*) endocarp are the only specimens currently identified from the excavations. An intact carbonized fragment of kukui nut shell was recovered from 80 cm below surface in TP4Tainuu Layer III/Level 8. Radiocarbon dating of this specimen returned a calendar age range of 1678-1940 cal AD (see Table 7 and 8 in Chapter 5). A non-carbonized kukui nut (*A. moluccana*) endocarp was also identified in Layer III/Levels 9-10 of TP6Tainuu. This corresponds spatially to the kukui endocarp recovered from Layer III/Level 8 of TP4Tainuu for which a ^{14}C date was obtained.

Table 16. Floral species identified at Marae Tainuʻu.

Species	Test Unit(s)	Layer(s) / Level(s)	Origin
Aleurites moluccana	TP4Tainuu; TP6Tainuu	Layer III/Level 8; Layer III/Level 9-10	Polynesian introduction
Clematis sp.	TP1Tainuu	Layer II/Level 8	Polynesian introduction, possible native
Hibiscus tiliaceus	TP1Tainuu; TP7Tainuu	Layer III/Level 10, Layer III/Level 12; Layer IV/Level 11	Polynesian introduction, possible native
Morinda citrifolia	TP1Tainuu	Layer II/Level 8, Layer III/Level 10	Polynesian introduction
Swietenia cf. *macrophylla*	TP5Tainuu; TP7Tainuu	Layer II/Level 4-5, Layer IV/Level 13; Layer IV/Level 11	European introduction

Table 16 shows the distribution of identified floral samples recovered from the Marae Tainuʻu excavations. These samples are discussed in detail in Chapter 5. The majority of identified species are Polynesian introductions (Allaby 2006; Allen and Huebert 2014; Hamilton 1905; Kahn 2018; Meyer and Malet 1997), though *H. tiliaceus* may be a native in this area of Polynesia. The origin of the *Clematis* sp. sample is questionable pending a more refined identification due to the possibility of related native Ranunculaceae species and the appearance of the *Clematis* spp. descriptions in early Polynesian language studies (Hamilton 1905). *Swietenia* sp. (i.e., mahogany) is a known European introduction during the historic period. The presence of *Swietenia* sp. in deep deposits at the southern end of the paepae creates an issue as to the integrity of archaeological stratigraphy in those test units and/or the accuracy of species identification prior to ^{14}C dating of those samples. The presence of *A. moluccana*, *H. tiliaceus*, and *M. citrifolia* at Marae Tainuʻu are consistent with the presence of these medicinal and economic plants throughout traditional pre- and post-contact archaeological contexts in Central East Polynesia (Allen 2014; Kirch 1996; Lepofsky 2003).

Material Culture and Subsistence at Marae Tainuʻu

A rich history of human activity exists in the archaeological assemblages of Marae Tainuʻu. Temporal variation in architecture is evident in test units on the paepae and the marae court, as exemplified by the presence of basalt architecture in stratigraphic levels within the boundaries of the current monumental megaliths on the paepae. Artifact use is supported by the presence of basalt tools and lithic manufacturing debris in layers associated with pre-contact ^{14}C dates. Observable cultural layers correlate with stratigraphic changes in sediment composition, artifact and architecture presence, and ^{14}C age ranges that provide a view of landscape change and site usage over several centuries from pre-contact Māʻohi times, through European contact, to the present day. Changes and consistencies in human activity tell us about the history of land use at Marae Tainuʻu and the effects of human activity on the landscape in terms of community patterning and spatial organization of concentrated activity areas for specific uses over time.

Of note is the absence of fish remains and fishing activity in a regional and local ecosystem known for its healthy fisheries, past and present. This observation presents a quandary that suggests cultural motives directing the dearth of fish remains on the marae grounds. Whereas evidence of collection and consumption of shellfish is relatively abundant, few fish remains and no identifiable fishing tackle have been recognized purporting a preference for certain behavior or subsistence resources. The notion of preference among protein sources prepared or consumed at Marae Tainuʻu may be evidence of formally or informally restricted behavior at the site as a component of adherence to specific cultural practices and management strategies.

The configuration of subsistence data from Marae Tainuʻu may not facilitate the most apt discussion of historical ecology and human impacts on the coastal ecosystem at western Raʻiātea. The limited densities of marine shell, fish remains, stone tools, and other common implements associated with Central East Polynesian material culture contrast with the archaeological record of other ecologically comparable coastal areas of lesser religious and socio-political significance (see Kahn 2018; Morrison and Hunt 2007; Sinoto 1979). The ritual nature of the site may limit my ability to make definitive statements about resource use and ecological change, or compare the patterns seen with other studies. Yet, work at Marae Tainuʻu illustrates the development of the Tevaitoa landscape in a way that extends knowledge of land use intensification for a prominent ritual center at Raʻiātea.

Studies of similar East Polynesian ritual complexes show a departure from the mundane, with a focus on monumental architecture and a lack of standard tool kits and archaeological remains in contrast to deposits more strictly associated with habitation sites (Kirch 2014; Maric 2016; Molle 2016; Suggs 1961: see Kahn 2018 for comparison to local non-ritual site). Bollt's (2008) work at the Peva Valley of Rurutu, Austral Islands, illustrates this contrast with the excavation of test units before and after the use of the site as a marae. The pre-marae cultural layers, Bollt's "Archaic" period, yielded a wide variety of artifacts, including pearlshell fishhooks, urchin and coral abraders, shell chisels, basalt adzes and preforms, and lithic debitage (Bollt 2008:167). Those strata associated with the use of the location as a ritual site, Bollt's "Classic" or Marae period, revealed considerably lower densities of artifacts than the Archaic period and contained no fishing tackle or shell manufacturing debitage. The lesser overall presence of cultural

materials and the absence of certain artifact classes in this example are similar to what is seen at Marae Tainuʻu. Thus, the technological and ecological remains excavated at Marae Tainuʻu are intricately linked to the development of this place as a ritual complex and the largest marae of the Leeward Society Islands.

CHAPTER VII

ARCHAEOLOGY AND MĀʻOHI LIFEWAYS AT WESTERN RAʻIĀTEA

In this dissertation I have written about archaeological investigations along the west coast of Raʻiātea in the Leeward Society Islands of French Polynesia. Raʻiātea, also known by the ancestral name of Havaiʻi, is recognized as a central point for pre-contact ocean voyaging in East Polynesia. The island is widely regarded as a cultural and spiritual center of the region. My research at Raʻiātea has built on this notion of cultural importance and worked to explicate the relationship of early human populations to this Pacific Island environment in both extraordinary and customary ways. Detailed excavations at Marae Tainu'u at Tevaitoa serve as a case study for human history that will facilitate comparisons to the archaeology of other areas of the island, and indeed, other islands of Central East Polynesia.

Marae Tainuʻu is the largest marae in the Leeward Group (Figure 38), a place of great importance in pre-contact times and to Māʻohi people in the post-contact era. Research at Marae Tainuʻu has provided a baseline archaeological study from which to build upon for the sake of archaeological knowledge and for the interest of the local community at Tevaitoa in the administrative district of Tumaraʻa Commune. My study provides chronological and quantitative material data—artifactual, faunal, and floral—that may be used to generate further archaeological information through incorporation into future research. This work has been a collaborative effort among local researchers and myself. I hope to continue my work with Tahitian colleagues and the broader community at Raʻiātea, and I look forward to future research collaborations.



Figure 38. The upright basalt and coral slabs of the ahu of Marae Tainuʻu, with colleagues for scale. (photo by J. O'Connor)

Research goals for this project were originally summarized under the topics of cultural transmission and community patterning, the chronology of early island settlement, land use and settlement patterns, and the archaeological history of the island in relation to geomorphological and paleocological variability through time. Hypotheses were developed within an evolutionary framework to better understand sociality and human-environmental interactions in East Polynesia and specifically at western Raʻiātea, as well as for the simple purpose of developing a baseline study for an area of the island that has until now been underrepresented in the archaeological literature of the Pacific Islands. The hypotheses listed below are restated from pages 23 and 24 of Chapter 1:

Hypothesis 1: The transmission of cultural information among island communities, as evident in artifact collections, will display patterns of horizontal transmission based on human interaction.

Hypothesis 2: Radiocarbon dates will support a post-1000 AD chronology for initial settlement at Raʻiātea.

Hypothesis 3: Land use and technology patterns in near-shore areas will reflect changes in resource procurement and social interaction.

Hypothesis 4: Subsistence remains will indicate change through time resulting from increases in human predation pressure and the intensification of subsistence strategies.

Answers to these hypotheses have not been straightforward. The statement of testable hypotheses is a necessary exercise as a guide for research, and the issues outlined above have formed the basis of my work with East Polynesian artifact collections and archaeological materials excavated at Marae Tainuʻu. The structure of cultural transmission patterns among East Polynesian island locales has been successfully addressed through the comparison of specific artifact classes, and a baseline ^{14}C chronology has been created for the area of Marae Tainuʻu. However, questions of local land use patterns and the evaluation of human impacts through changes in subsistence practices have not yielded such clear results. These research issues have been treated in detail throughout the chapters of this dissertation, and whereas some ambiguity remains, my work has created knowledge that I hope may be of great use to other researchers of Polynesian history.

Raʻiātea in Polynesian History

The notion of Raʻiātea as a central node in East Polynesian expansion and regional population dispersals is grounded in a vast collection of oral histories and anthropological studies (e.g., Hiroa 1938; Kawaharada 1995; Oliver 1974). Based on this history of dispersal and cultural exchange, Raʻiātea has played a central role in 20th century Polynesian cultural movements and the resurgence of ocean voyaging throughout the Polynesian interaction sphere (see Finney 1994). The island remains an essential element in Polynesian cosmogony and origin stories, as well as a point of geographical, political, and social relevance for contemporary Polynesian populations in French Polynesia and throughout the Pacific. A history of research at Raʻiātea and its position in the Society Islands is detailed in Chapter 1. The island is placed in greater regional context with a history of Pacific settlement outlined in Chapter 2.

My study of cultural transmission based on traditional fishing technologies (Figure 39) provides archaeological support for the prominent position of Raʻiātea in Polynesian voyaging networks (O'Connor et al. 2017; see Chapter 3). The analysis of artifact morphology observed in East Polynesian fishhook assemblages was used to test the relatedness of culturally transmitted character states as a proxy for social interaction at a time when ideas were exchanged through face-to-face contact. I quantified variability in line-attachment-device (LAD) morphology among 18 artifact fishhook assemblages from throughout East Polynesia. The LAD morphology of artifact fishhooks was examined because the morphological appearance of specific LAD modes has been determined as unrelated to performance value (Allen 1996). That is, these artifact attributes are subject



(a) (b)

Figure 39. Examples of shell (a) and bone (b) artifact fishhooks from East Polynesia. (images courtesy of T. Hunt)

to stylistic mechanisms unrelated to functional selective pressure and can be seen as the result of individual and culturally influenced ideas of how to construct these tools.

My colleagues and I tested relatedness among these assemblages based on the presence or absence of fishhook LAD classes in relation to geographical distance and group similarity. Results showed no statistically significant correlation between assemblage similarity and sample size, and that no significant correlation exists linking LAD class presence to geographic distance for individual assemblages or when grouping islands by archipelago. When testing within group versus between group similarities, a Mantel test statistically supported greater class sharing within historical archipelago groups than between island groups. Statistical testing rules out geographic proximity as the primary factor in the transmission of LAD technological ideas, instead supporting

LAD variability as related to cultural transmission during human dispersals via ocean voyaging and the subsequent diversification of design among descendant populations at particular locations. A network analysis of assemblage relatedness confirmed Raʻiātea as a point of centrality in the network, a node with strong ties to islands of the Austral, Cook, Hawaiian, and Marquesas archipelagos. Archaeological studies such as this place Raʻiātea squarely in line with geopolitical, historical, and linguistic studies of Polynesian interaction and cultural exchange (Henry 1928; Walworth 2014; Weisler et al. 2016).

Archaeology at Marae Tainuʻu

As a component of my dissertation project, on-island archaeological research began with an evaluation of several locations along the west coast of Raʻiātea that included pedestrian survey and sediment coring on coastal flats and offshore islets throughout Tumaraʻa Commune. Preliminary investigations provided a characterization of coastal and offshore islet geology (Figure 40), an assessment of potential archaeological deposits, and the basis for targeted subsurface testing at Marae Tainuʻu. Archaeological testing at Marae Tainuʻu and the placement of a single inland test unit (Domaine Dehors) comprise the bulk of this study and provide data from which to better understand the deep history of human activity at Tevaitoa. Applicable field and laboratory methods are reviewed in Chapter 1, and the discussions of results are presented in Chapters 4, 5, and 6.

The archaeological record of Marae Tainuʻu represents a departure from the more mundane activities of human existence. The marae is a parcel of land defined by its use



Figure 40. Looking northward up the west coast of Raʻiātea from Punaeroa Motu, an offshore islet. (photo by J. O'Connor)

for more lofty purposes consistent with the history of megalithic ritual centers throughout Polynesia (Cochrane 2015; Hunt and Lipo 2011; Kirch 2000). Maric (2016) has detailed the development of monumental ritual centers in the Society Islands, including Marae Tainuʻu, and the role such centers played for the evolution of Māʻohi chiefdoms prior to and during European contact. Marae Tainuʻu is the largest marae of the Leeward Island Group by area, and according to traditional lore, served as a base for spiritual and political power for the Tevaitoa political elite (Handy 1930). Documenting the development of increased architectural complexity (e.g. simple basalt alignments followed by infill and megalithic construction) during the late pre-contact period of Taputapuātea may prove to be one of the more important aspects of my study.

Excavations at Marae Tainuʻu involved exploratory sediment coring across the marae complex, culminating in the placement of seven test units in various locations of Paepae Taumatini and the marae court to the west of the paepae feature. Excavations took place during the 2016 and 2017 field seasons, with materials analysis occurring between Summer 2016 and Fall 2018 at field facilities on Raʻiātea and at the University of Oregon Island and Coastal Archaeology Laboratory. The single test unit at Domaine Dehors contained essentially sterile sediments and revealed no evidence of pre-modern human activity. However, subsurface exploration at Marae Tainuʻu revealed a rich collection of artifacts, subsistence remains, and ancient architectural elements that form an assemblage from which to address issues of archaeological importance. These issues include observations of stratigraphy and the structure of archaeological deposits as related to community patterns (Chapter 4), the creation of a ^{14}C chronology for human activity at Marae Tainuʻu (Chapter 5), and the use of artifacts and ecofacts for mapping environmental effects and changes in site use through time (Chapter 6).

Landscape Change

Human modification of the landscape at Marae Tainuʻu is undeniable due to the structural nature of this megalithic architectural complex. Dressed basalt boulders and upright coral limestone slabs, some measuring four meters in height, constitute the walls of the ahu and provide a fine example of Leeward Society Islands ritual architecture. The basalt cobbles and boulders that once paved the marae court have been repurposed in the walls of the Protestant church that now stands on the marae grounds (Figure 41). The placement of Western churches atop previously existing structures of cultural and



Figure 41. Twentieth century church constructed atop the Marae Tainuʻu at Tevaitoa, Raʻiātea. Basalt stones, visible in building exterior, were removed from the marae pavement and used for construction of the church. (photo by J. O'Connor)

religious significance to indigenous peoples is a common worldwide phenomenon, with many examples in Polynesia (Descantes 1993; Wallin 2004). This process of cultural change serves as powerful symbol of 'new conquering old' while drawing upon the preexisting importance of a location in a manner that blends contemporary religious practices and the perpetuation of traditional cultural heritage. For instance, Pastor Tupu of the church is the official caretaker of Marae Tainuʻu, a responsibility that he fulfills with the utmost dignity and respect for Māʻohi tradition. The ahu at the western end of the complex and the Paepae Taumatini, an elevated area of dirt and coral fill surrounded by dressed basalt and coral limestone boulders, at the east end of the complex remain intact and are cared for by the local community today.

The excavation of test units in the central area of the marae and on the paepae revealed distinct strata that appear to correspond to discrete periods of human use of the marae. Notable stratigraphic elements include the intrusion of a thin layer of yellow sand between TP3Tainuu and TP4Tainuu in the northern portion of the marae, the 60 cm thick layer of coral fill comprising Layer II of the paepae units, and Layer III of the paepae units which revealed a cultural floor with evidence of hearth features, cultural detritus, and basalt boulder alignments representing architectural features that appear to precede the megalithic structures witnessed at the time of European contact. The stratigraphic relationships in the test units support a sustained use of the marae site with intentional modifications and revision in site usage over time. Uniformity in the size and placement of coral boulders and cobbles supports the creation of the coral fill layer as an anthropogenic modification and not the result of a high-energy wave event. Likewise, the organization of basalt stones underlying the coral layer and the association of these basalt features with other cultural materials is evidence for concerted landscape modification at this location in the distant and not so distant past.

Chronology

Multiple carbonized floral samples were submitted for species identification and ^{14}C dating in an effort to create a baseline chronology for the marae construction and use, an effort heretofore not attempted. Some confusion has been created due to the identification and dating of *Swietenia* sp. (mahogany) samples in the three southern units on the marae, Test Units 5, 6, and 7. The identification of this long-lived European introduction—along with artifacts of recent historic origin—in some of the deepest layers

of these test units calls in to question the stratigraphic integrity of these deposits. However, the identification and dating of short-lived and medium-lived plant species that are recognized as Polynesian introductions provides valuable data for understanding the antiquity and development of the marae complex and contribute valuable data to the island-wide chronological sequence (see Allen and Huebert 2014; Rieth and Athens 2013; and Wilmshurst et al. 2011).

The most reliable date for the pre-contact use of the marae comes from short-lived sample TP4-8.1 (D-AMS-29780), a carbonized kukui nut (*Aleurites molucanna*) endocarp fragment from 80 cm below surface in the northern central section of the marae court that returned a calendar age range of 1678-1940 cal AD (2σ, IntCal13). The earliest date came from sample TP1-12.1 (D-AMS-27254) on carbonized *Hibiscus tiliaceus*, a Polynesian introduction with a moderate lifespan of 25-50 years. Sample TP1-12.1 was retrieved from the basal layer of TP1Tainuu and this sample returned a calendar age range of 1521-1663 cal AD (2σ, Intcal13). Samples TP1-8.1 (D-AMS-27252) and TP1-10.1 (D-AMS-27253) are also from carbonized medium-lived species (*Clematis sp., Hibiscus tiliaceus, Morinda citrifolia*) and were found above and below the 80 cm depth cultural floor in TP1Tainuu. These samples returned calibrated age ranges of 1663-modern cal AD (2σ, Intcal13) and 1666-modern cal AD (2σ, Intcal13), respectively.

The majority of statistical variation in the TP1-8.1 and TP1-10.1 dates centers on the early 18th century, creating a temporal barrier at the Layer II/Layer III interface that places the level of cultural activity immediately under the coral fill layer in the early post-contact era. These ^{14}C dates are not the earliest on the island, but they align the earliest measured human activity at Marae Tainu‘u with that of the Sunset Beach site to the north

(Kahn 2018). More importantly, the calibrated age ranges of the Marae Tainu‘u samples are contemporaneous with those from Marae Taputapuātea at Opoa. These ^{14}C dates support a concurrent timeframe for development of large-scale ritual architecture at major ceremonial centers on both the west and east coasts of the island, developments that are hypothesized to be associated with the consolidation of power by political elites and the enshrinement of this power in megalithic structures on the island of Ra‘iātea (Maric 2016).

Material Culture and Subsistence

Cultural materials recovered from Marae Tainu‘u provide artifactual and biological (non-human fauna and flora) evidence for human activity spanning several centuries. A wide variety of modern and historic-era refuse was present in the upper layers of all test units. These materials had few diagnostic attributes and did not contribute to archaeological assessment of the site other than by providing a valuable reference for the degree of bioturbation or other disturbances that had taken place in various areas of the marae complex. Lithic artifacts and associated debitage support a lengthy history of site use for craft or economic purposes reaching back to well before European contact, although stone tool abundance is relatively minimal, with the presence of only a single complete formal stone artifact. This fine-grained basalt adze was found in TP1Tainuu located in association with, though above, the TP1-12.1 ^{14}C sample dated to 1521-1663 cal AD. Adze preforms, adze fragments, a scraper tool, and an apparent polishing or grinding stone were also recovered from among the test units at the marae. A single piece of worked branch coral was found in the top level of TP1Tainuu, but urchin

spine abraders were present in all test units at varying depths. Significantly, no shell or bone fishhooks were recovered in the test pits and the general scarcity of common utilitarian tools seems consistent with the ritual and ceremonial function of the marae complex.

Faunal remains provide another window into human activity and the use of particular species for sustenance over time. Polynesian animal introductions, such as pig (*Sus* sp.) and dog (*Canis familiaris*), are present in the test units. Yet, it is the collection and deposition of shellfish remains throughout the marae complex test units that may provide the most information about how different areas of the marae were used for daily activities. Bulk shell weights show a greater general presence of marine shell in test units located off of the paepae. However, spatial differences can be observed between the northern and more central-southerly portions of the paepae feature based on the abundance of shell in Test Units 5 and 6 that is nearly double that of Test Units 1 and 2.

A detailed analysis of shellfish remains from TP1Tainuu serves as an example for species diversity and richness among the excavated units. Identified species are all recognized as those that inhabit reef habitats, as opposed to sandy beaches, estuarine, or deep offshore environs. My taphonomic observations suggest that several of the major shellfish species were collected, consumed, and deposited at the marae as subsistence remains. Shellfish remains were not deposited for engineering purposes or as architectural fill. Two species in particular, *Turbo setosus* and *Tridacna maxima*, make up 54% of the total weight of all shellfish remains. These species were regularly exploited in pre-contact times and are present in archaeological assemblages throughout the Pacific Islands. Shellfish species harvested for craft and economic purposes, such as

Monetaria spp., are also present among the assemblages providing evidence for non-subsistence related faunal exploitation at the site.

The lack of any fishhooks or other apparent fishing equipment in the Marae Tainu‘u assemblage is consistent with a dearth of marine fish remains across the site, in contrast to what would be expected for a healthy coral reef fishery adjacent to residential areas. This might seem anomalous in coastal habitations sites associated with Polynesian settlement and ocean voyaging cultures. However, the absence of fish-related artifacts and ecofacts suggests a lengthy history of the marae grounds as something different or held apart from ordinary activities associated with day-to-day life. Why shellfish, pigs, and dogs appear to have been regularly consumed at the site, but not fish, is not currently known. The absence of fish remains in the archaeological record indicates that societal or ritual prohibitions may have been in effect for this area during pre-contact and early post-contact times. Other than for alcohol, no food or drink prohibitions are currently enforced at the marae.

Earlier architecture was found in the form of the basalt alignments that underlie the layer of coral fill of Paepae Taumatini. These constructions may be part of an earlier spatial delineation for social, political, or religious purposes that preceded the grand monuments that exist at Marae Tainu‘u today. Choices in resource acquisition and species exploitation appear to have remained consistent at this location through time as a component of culturally dictated behavioral practices specific to the long-term ceremonial use of the immediate area.

Marae Tainuʻu Today

Today, Marae Tainuʻu serves as a de facto community center for Tevaitoa and rural communities that exist up and down the west coast of Raʻiātea. A primary school sits north of the marae complex and serves as the educational center for children along this stretch of coast. Immediately beyond the school are the government offices of the Tavana and the administrative base of Tumaraʻa Commune. Tevaitoa is where one goes to engage with the government system. The marae grounds are the location of political rallies and elections, and the greater area surrounding the government buildings is the site of massive community festivals, such as Heiva (Figure 42), an annual cultural festival held simultaneously on islands throughout Central East Polynesia. The centralization of government at Tevaitoa and the use of Marae Tainuʻu as a center of social, political, and spiritual activity is not a coincidence. Rather, the intense social activity at this coastal location may be viewed as a continuation of the ancestral form of spatial organization and land use that was present at the time of European contact and likely long before then.



Figure 42. Māʻohi dance competition at Tevaitoa for Heiva, a traditional cultural festival held throughout French Polynesia during the month of July. (photo by M. H. Cauchois)

The marae is also a tourist attraction, predominantly for European visitors to the island. The church that was built on the marae holds title as the oldest Protestant church on Raʻiātea and has become a unique spectacle itself due to its idiosyncratic architectural design and the use of the ancient marae stones in its construction. However, it is the traditional features of the marae that draw visitors from throughout the Polynesian region. The upright slabs of the ahu walls, the paepae platform near the coastal road, and the few remains of other basalt features scattered throughout the complex invite speculation about the early Māʻohi settlers and impart an air of mystery across this historical site.

The prominence of the marae on the landscape and the history behind this structure allow the site to be used as an ideal location for cultural education and the passing down of traditional cultural practices (Figure 43). Marae Tainuʻu serves as a sort of outdoor classroom for the community. It is because of this function that my colleagues and I organized a "culture day" field program for students during the 2017 field season. Hinanui Cauchois and I coordinated with Pitate Mama of the Tavana's office, Pastor Philippe Tupu, and many other local educators and social leaders for the creation of a day-long event to teach about the archaeology and history of the island. Secondary school students were bussed in from as far as Taputapuātea, and a series of educational stations were set up to talk of the oral traditions, the arts, the archaeology, and the modern significance of Marae Tainuʻu to the people of the Society Islands. Community elders and local schoolteachers taught about various elements of the marae, and we were able to give basic lessons in stratigraphy and archaeological techniques with open excavations as our visual aids. Laughter was ubiquitous as we communicated in French, English,



Figure 43. Dr. Hinanui Cauchois teaches local students and elders about archaeological stratigraphy as part of the 2017 Marae Tainuʻu field program. (photo by J. O'Connor)

Tahitian, and Hawaiian languages, an experience that recollects the centuries of interaction and cross-cultural exchange that have taken place at Raʻiātea, the Society Islands, and broader Polynesia.

Conclusion

The 2016 and 2017 field seasons of the Raʻiātea Historical Ecology Project established the basis for archaeological research that will continue during future work at Tumaraʻa Commune, Raʻiātea. Survey and subsurface testing at Marae Tainuʻu, Domaine Dehors, and three offshore motu in the Tumaraʻa administrative area provided information about the location and structure of archaeological deposits and the geological

history of coastal and lagoon landscapes. This information will be used to guide further investigations in the area. Excavations at Marae Tainuʻu revealed evidence of human activity and landscape change that is instrumental to understanding the chronology and geographical extent of human activity at western Raʻiātea. Artifacts and ecofacts recovered from excavated test pits at the Marae Tainuʻu archaeological complex form an assemblage from which we expect to establish a baseline radiometric chronology for human occupation at Tevaitoa and expand knowledge of human-environmental interactions in island and coastal contexts.

The research partnership between myself and Dr. Cauchois will continue as our focus switches to understanding inland settlement patterns and the modification of ancient landscapes across the island of Raʻiātea. Excavations at Marae Tainuʻu and the valley location referred to as Domaine Dehors have further contributed to collective understanding of environmental effects and landscape change at Tumaraʻa following the arrival of Polynesian settlers. My continuing analysis and subsequent field and laboratory work will result in academic and professional publications, with the intention of providing an archaeological synthesis of western Raʻiātea that will be accessible to local, governmental, and scientific communities.

The proximate goals of this project address provincial chronology and anthropogenic environmental effects—including human impacts, management practices, and long-term cultural resilience—in the local archaeological record. Ultimate goals of the Raʻiātea Historical Ecology Project will be to provide research findings that bolster the archaeological literature of the Society Islands and East Polynesia with knowledge of human modification of island ecosystems in this unique area, as well as comparison to

other islands and archipelagos in Polynesia and around the world. Ra‘iātea is a case study for Pacific island colonization and subsequent involvement in long-distance networks of social development and cultural exchange. My work at western Ra‘iātea aims to better situate this geographical location within the corpus of knowledge regarding human dispersals, island settlement and the colonization, and unique cultural developments of the Pacific Islands, and others worldwide.

APPENDIX A

^{14}C DATING AND BOTANICAL IDENTIFICATION REPORTS

Appendix A contains the results of accelerated mass spectrometry (AMS) ^{14}C dating by DirectAMS Radiocarbon Dating Service and the results of botanical identification for charcoal samples by Paleoscapes Archaeobotanical Services Team, LLC. Sample identification numbers correspond between dating reports and botanical identification reports.

Report: **1927-027525-027254** 27 March 2018

Customer: 1927
John O'Connor
University of Oregon
Department of Anthropology
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Eugene, OR 97403
USA

Samples submitted for radiocarbon dating have been processed and measured by AMS. The following results were obtained:

DirectAMS code	Submitter ID	Sample type	Fraction of modern		Radiocarbon age	
			pMC	1σ error	BP	1σ error
D-AMS 027252	TP1-8.1	charcoal	97.89	0.27	171	22
D-AMS 027253	TP1-10.1	charcoal	98.00	0.26	162	21
D-AMS 027254	TP1-12.1	charcoal	96.58	0.26	280	22

Results are presented in units of percent modern carbon (pMC) and the uncalibrated radiocarbon age before present (BP). All results have been corrected for isotopic fractionation with an unreported $\delta^{13}C$ value measured on the prepared carbon by the accelerator. The pMC reported requires no further correction for fractionation.

Paleoscapes Archaeobotanical Services Team, LLC

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March 20, 2018

PAST Project 18011

Identification results for charcoal from Tainuu are as follows:

D-AMS ID	Sample ID	Material	Identification		Number	Weight
			Scientific Name	Common Name		
D-AMS 027252	TP1-8.1	Charcoal	*Clematis* sp.	Clematis	1	0.032 g
			Morinda cf. *citrifolia*	probable Indian mulberry, *noni*	6	0.213 g
D-AMS 027253	TP1-10.1	Charcoal	*Hibiscus tiliaceus*	Beach hibiscus, *purau*	5	0.153 g
			Morinda cf. *citrifolia*	probable Indian mulberry, *noni*	3	0.352 g
D-AMS 027254	TP1-12.1	Charcoal	*Hibiscus tiliaceus*	Beach hibiscus, *purau*	2	0.427 g

Charcoal fragments were broken to expose fresh tangential, radial, and cross-sections, then examined under a Bausch and Lomb Stereozoom microscope at a magnification of 70x. Some specimens were also examined using a Nikon Optiphot 66 microscope at magnifications of 100-600x. Charcoal fragments were identified using identification manuals (Schweingruber et al. 2008), internet web sites (InsideWood 2004; Schweingruber and Landolt 2005), and a modern comparative collection. Please feel free to contact me if you have any questions.

Sincerely,

Kathryn Puseman

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InsideWood
2004 InsideWood Database. Electronic document, http://insidewood.lib.ncsu.edu/search, accessed 2013-2018.

Schweingruber, Fritz Hans, Annett Börner, and Ernst-Detlef Schulze
2008 *Atlas of Woody Plant Stems: Evolution, Structure, and Environmental Modifications*. Springer-Verlag, Berlin.

Schweingruber, Fritz Hans, and W. Landolt
2005 The Xylem Database. A Web Product of the Swiss Federal Research Institute WSL. electronic document, http://www.wsl.ch/dendropro/xylemdb/index.php?BNAM=Bilder, accessed October 2013-2018.

DirectAMS
RADIOCARBON DATING SERVICE
measure more. learn more.

Report: **1927-029780-029783** 19 September 2018

Customer: 1927
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Samples submitted for radiocarbon dating have been processed and measured by AMS. The following results were obtained:

DirectAMS code	Submitter ID	Sample type	Fraction of modern		Radiocarbon age	
			pMC	1σ error	BP	1σ error
D-AMS 029780	TP4-8.1	kukui nut	98.44	0.32	126	26
D-AMS 029781	TP5-7.1	charcoal	99.29	0.29	58	23
D-AMS 029782	TP5-13.1	charcoal	97.32	0.37	218	31
D-AMS 029783	TP7-11.1	charcoal	98.90	0.30	88	24

Results are presented in units of percent modern carbon (pMC) and the uncalibrated radiocarbon age before present (BP). All results have been corrected for isotopic fractionation with an unreported $\delta^{13}C$ value measured on the prepared carbon by the accelerator. The pMC reported requires no further correction for fractionation.

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September 18, 2018

PAST Project 18024

Identification results for charcoal from Tainuu are as follows:

			Identification			
D-AMS ID	Sample ID	Material	Scientific Name	Common Name	Number	Weight
D-AMS 029781	TP5-7.1	Charcoal	*Swietenia* sp.	Mahogany	1	0.420 g
D-AMS 029782	TP5-13.1	Charcoal	*Swietenia* sp.	Mahogany	1	0.170 g
D-AMS 029783	TP7-11.1	Charcoal	*Hibiscus tiliaceus*	Beach hibiscus, *pura*	1	0.104 g
			Swietenia sp. **	Mahogany	1	0.024 g
			Unidentified R	Unidentified	1	0.073 g

** Indicates charcoal fragment that had been selected for radiocarbon analysis

Charcoal fragments were broken to expose fresh tangential, radial, and cross-sections, then examined under a Bausch and Lomb Stereozoom microscope at a magnification of 70x. Some specimens were also examined using a Nikon Optiphot 66 microscope at magnifications of 100-600x. Charcoal fragments were identified using identification manuals (Ogata et al. 2008; Schweingruber et al. 2008), internet web sites (InsideWood 2004; Schweingruber and Landolt 2005), and a modern comparative collection. *Swietenia* is one of many plants that have been introduced to French Polynesia by Europeans in the last two centuries, while *Hibiscus tiliaceus* is an indigenous species (Bonnetaud 2003). Please feel free to contact me if you have any questions.

Sincerely,

Kathryn Puseman

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