MANIHIKI AND RAKAHANGA: THE HISTORICAL ECOLOGY OF A DUAL-ATOLL CLUSTER

By

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(Under the Direction of VICTOR D. THOMPSON)

ABSTRACT

This research uses the perspective of historical ecology to investigate human-environmental interaction on the atolls of Manihiki and Rakahanga in the Northern Cook Islands of East Polynesia. Oral traditions and ethnohistoric documents describe a dual-chiefdom political system, where two chiefs each held power over sacred and secular aspects of life. These sources suggest that the people managed their ecological resources through a cyclical mass-migration system called the *Tûmutu*. Using archaeological, ethnographic, ethnohistoric, chronometric, and zooarchaeological methods and data, I investigated the dynamics of long-term human-environmental interaction on Manihiki and Rakahanga to identify, contextualize, and temporally anchor, the cultural developments and environmental transformations that resulted in long-term socioecological sustainability on the atolls. I then used extant literature and new dating protocols to trace one indicator of environmental change, the introduction and extirpation of the domestic dog, across 35 Pacific island groups. My findings suggest that small-island sustainability is aided through the development and adaptation of flexible social structures that encourage cooperation.

The results of my analysis suggest that the inhabitants Manihiki and Rakahanga first arrived between AD 1200 and 1400. Over the following centuries the population grew, and the people transformed the landscape by digging horticultural pits, planting tree crops, introducing and extirpating plants and animals, and building coral fish traps. They experimented with aggregated and dispersed settlement before the formalizing the dual-chiefdom and the Tûmutu institutions. Both of these appear to be local elaborations on ancestral Polynesian practices that promote polity-wide cooperation, extend the local resource base, and allow for sub-group autonomy. The people of Manihiki and Rakahanga introduced, managed, and eventually extirpated the domestic dog. Comparison of dog introduction and extirpation across the Pacific reveals commonalities in resource management on many atolls as dog introductions were common and loss was nearly universal. As lifeways shifted, and socioecological circumstances changed, atoll dwelling groups, including those on Manihiki and Rakahanga, altered their landscape and their social structures to meet continually changing needs. Low-island environments appear to influence these processes by discouraging the maintenance of domesticates and encouraging the development of flexible, location-specific, cultural institutions.

INDEX WORDS: Oceania; Polynesia; Historical Ecology; Coral Atolls; Sustainability; Dogs; Radiocarbon Dating; Chiefdoms; Island Archaeology; Migration

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BS, Central Michigan University, 2013

A Dissertation Submitted to the Graduate Faculty of The University of Georgia in Partial
Fulfillment of the Requirements for the Degree

DOCTOR OF PHILOSOPHY

ATHENS, GEORGIA

2020

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May 2020

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For Sara

ACKNOWLEDGEMENTS

I am forever grateful to the friends, family, and colleagues who assisted with this research. First, I would like to thank my wife Sara for her endless support, countless hours of fieldwork, and for the innumerable other ways that she labored to make this research possible. Next, I would like to thank my dissertation committee Victor Thompson (Chair), Sharyn Jones, Stephen Kowalewski, Elizabeth Reitz, and Bram Tucker for their patience and guidance. Further thanks go to those that assisted in the field portions of this research on Manihiki and Rakahanga including Justine and Ricaldo William, Thomas Elisa, Haumata Tepania, John Mcleod, Kimiora, Junior, Puna, and Tuatai Mataio, Taunga and Tara Tuteru, Jonathon Elisa, and Tupou Hagainoa. I would also like to thank the landowners that allowed us to work on their property as well as the island councils of Manihiki and Rakahanga, the Cook Islands Library and Museum, the Cook Islands Ministry of Culture, the University of the South Pacific – Rarotonga, and the Cook Islands Government. Special thanks also go to the following individuals who offered support and advice during my time in the Cook Islands: The Honorable Henry Puna, Matangaro and Nga Takai and their children, especially Bordland who was taken from this world far too soon, Temu and Una Banaba, Mata Dean Tarau, Vakai Ezekiela, Ngametua Matangi, Thomas Newnham-Kora, Fred Napara, Ngametua Heretama Tepania, Wireless Pupuke, Papa William, Apii Piho, Apii McLeod, John Koteka Jr., Jane and Bernadino Boaza Kaina, Helen Tuhe Uneke Eli McKenzie, Tobia Metua Kaitara, Luka Kaitara, Jean Marie Williams, Papapia T. Kaisara, Toka Toka, Clarke Toka, Temuvaine Narayan, Teokotai Kopu Temu, Emily Tuteru, Repaio Apolo, Aporo Piho, Mehaurahi, Banaba, and Tiata Tupou, Puapii Hagai, Edward Phillip Patterson, Takai Hagai, Totoo Setephano, Bernado Matakere, Bazza Ross, Sharon Marsters, Rita Repaio, Mama and Mana Papahu Rahi, Teina Rongo, Liam Kokaua, Tuhe and Charlotte Piho, Jean and Brian

Mason, Gerald McCormick, Chantal Napa, Sally Voss, Rod Dixon, Gewn Welland, Justina Nicholas, Anai O'Neil, Croc Tatau, Spike Tuara, Pa, and the people of Manihiki and Rakahanga.

Additional thanks go to the students, interns, and volunteers that gave their time to help with aspects of this research as well as those friends and colleagues that offered their help and advice. These include Brandon Ritchison, Matt Colvin, Isabelle and Jake Holland-Lulewicz, Kathrine Napora, April Smith, Megan Conger, Alex Edwards, Amanda Thompson, Kristine Scheck, Robert Lay, Taesoo Jung, Jana Carpenter, Sarah Jantzi, Christina Crespo, and Melanie Narciso. I also want to thank Carla Hadden, Jeff Speakman, Barry Rolett, Alison Weisskopf, Virginia Butler, Matthew Campbell, Melinda Allen, Jillian Swift, Richard Walter, Ian McNiven, Toru Yamaguchi, and Lee Newsom for their input and advice. Further thanks go to those that guided me down this academic path including Lynn Curry, Dan Pugh, Sarah Surface-Evans, Carmen White, Brooke Harrison, and Scott Beld, as well as the 2011 Central Michigan University McNair Scholars cohort. Finally, I want to thank my family including Charles Wanat, Patricia Dally, Michaella Dinard, and the Griffith Family for all of your support.

This research was completed through grants by the National Science Foundation: Grant Number 1738371 (Manihiki and Rakahanga: Persistence on the Margins of Oceania. National Science Foundation, Doctoral Dissertation Research Improvement Awards. Victor D. Thompson [P.I.] and Justin Cramb [co-P.I.]). I would like to thank the reviewers that helped to strengthen this research through their comments. Additional support came from the American Philosophical Society, the University of Georgia Graduate School, the University of Georgia Center for Archaeological Sciences, and the University of Georgia Department of Anthropology. Further thanks go to the Georgia Museum of Natural History, the University of Georgia Laboratory of Archaeology, and the University of Georgia Center for Applied Isotope Studies for use of facilities, equipment, and collections.

- Thank you all for all that you have done.

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INTRODUCTION AND LITERATURE REVIEW

Introduction

Examples of transformed, or domesticated, landscapes are common throughout the world, as humans shape their existing environments to meet their needs and desires (Dunning et al. 1999:650; Erickson 2010, 2008; McNiven 2008; Rappaport 1963). In Remote Oceania anthropogenic landscape transformation in the form of the "transported landscape" was often a necessary first step in the colonization of previously uninhabited islands (Anderson 2002:376; Anderson 1952:9; Kirch 1984:135-136). These often-dramatic transformations are marked by the importation of domesticates, as well as the extirpation of species, and the alteration of local landforms (Anderson 2002; Kirch 1984:135-139, 1982; Steadman 2006). As humans interacted with and modified environments, these alterations may have influenced the development of new location-specific socioecological structures suited to managing these human-mediated landscapes. Yet, in many cases, the nature, timing, necessity, and overall process of these transformations still elude our understanding (Anderson 2002; Huebert and Allen 2016). This impedes discussion of long-term sustainability in Oceania as well as global discourse regarding the ways that cultural and environmental variables interact to influence the human decision to alter environments and adapt or develop cultural institutions. The case of Manihiki and Rakahanga, two coral atolls in the Northern Cook Islands, offers an ideal small-scale setting in which to investigate the processes that transformed resource-limited environments into a productive landscape and the societal changes that promoted sustainability in one of the most remote island groups in the world.

This research documents the socioecological dynamics on Manihiki and Rakahanga beginning with the first arrival of humans on the atolls through to Christian missionization in the mid-1800s. In this introductory chapter, I outline the methods, theory, and assumptions utilized in this research while presenting the social and ecological background of island transformations and the area of study - Manihiki and Rakahanga. In Chapter 2, I use archaeological, ethnographic, ethnohistoric, and zooarchaeological data combined with AMS radiocarbon dating, genealogical dating, and Bayesian statistical modelling to present and discuss the first archaeologically informed timeline of occupation, ecological change, and political change on Manihiki and Rakahanga. I document key events such as the first known arrival of humans, the introduction and extirpation of domestic animals, and the formation of locally distinct cultural institutions. In Chapter 3, I document patterns of animal translocation and extirpation across 35 Pacific Island groups to expand our understanding of how island type and distance influence changes in local ecologies and how these localized changes reflect region-wide patterns of human environmental interaction. In chapter 4, I refine the dating techniques needed to facilitate better understandings of the timing of animal introduction and extirpation on Polynesian Islands. The results of this research indicate that location-specific patterns of socioecological change occurred on Manihiki and Rakahanga, and that these patterns reflect larger region-wide patterns of human-environmental interaction. From these findings, it is clear that ancestral cultural practices and local ecological conditions influence the ways that humans shape landscapes while they develop the cultural institutions needed to promote sustainability in these human-mediated worlds.

The Historical Ecology of Islands

This research takes a socioecological approach and draws primarily from the perspective of historical ecology, a research program that recognizes that human and nonhuman forces act in a dialectical relationship to shape the landscapes of which they are a part (Crumley 1994:5). To do this, historical ecology combines aspects of history, ecology, anthropology, and geography to explain human-environmental interaction over time (Balée 2006:76; Balée and Erickson 2006:1-2; Crumley 1994:7-8; Gragson 2005:3-5). Historical ecologists frame human-environmental interactions as long-term trajectories of continuity and change driven by human and non-human forces, such as cultural institutions and climate. Practitioners of historical ecology view socioecological interactions as mutually influential and assert that humans possess free will and agency which are viewed through landscape management strategies (Balée and Erickson 2006:5; Crumley 1994:5). The framework of historical ecology also assumes that humans are drivers of local and global environmental change which is manifest in long-term trajectories of socioecological interaction and interdependence (Balée 2006:76, 1998a:14-19, 1998b:6; Balée and Erickson 2006:1-2; Thompson 2013:2). These interactions are framed at the landscape scale, or a scale at which humans live, work, and develop a sense of place. While amorphous in nature, the landscape is a place defined by geographical continuity and socially informed delineations of space identified through physical evidence of human action (Balée and Erickson 2006:1; Gragson 1998:215). Researchers using historical ecology have documented successes and failures in the colonization and attempted transformation of new and extreme environments (McGovern 1994; McGovern et al. 2007). They have also described the explicit and subtle environmental transformations that result in, or accompany, the creation of anthropogenic landscapes including cities, farms, and cultural forests, or wild, yet managed environments (Balée 2013; Erickson 2010, 2008; Habu and Hall 2013; Melville 1998; Rival 1998; Rosen et al. 2015; Schmidt 1994; Thomas 2009).

Historical ecology is often utilized in island settings to understand the environmental indicators of human arrival, the ways that humans shape island environments, and the ways that humans alter islands to create productive landscapes (e.g., Fitzpatrick and Keegan 2007; Kirch 1997; Siegel 2018; Thomas 2009). Archaeologists employ the postulates of historical ecology in efforts to understand human adaptation to island environments and the human ability to overcome the environmental challenges posed by life in island settings (Fitzpatrick and Keegan 2007; Leppard 2018). The ability to explicitly recognize that humans both impact, and are impacted by, island settings is key to understanding initial impacts, as well as long-term changes to local ecologies and human behavior. However, it is often the case that the limited archaeological work on many islands, particularly the coral islands of Oceania, precludes a discussion of the processes through which the reciprocal interactions between humans and their island environments transpired. This results in narratives that track initial impacts and recognize the landscapes of the ethnographic present without the ability to trace the intervening trajectories of change. Further difficulty arises in attempting to understand the impacts of small-scale societies, such as those that inhabited small islands in the Pacific and elsewhere. These groups often leave faint archaeological signatures, leaving the researcher to consider how subtle traces of human activity reflect the human-environmental dialectic (Thompson 2013:7). These challenges to investigating the socioecological trajectories of small-island populations require an approach that begins with the explicit goal of documenting human-environmental interaction through archaeological methods.

This research utilizes the guiding postulates of historical ecology to identify and explain the long-term landscape trajectories that transformed Manihiki and Rakahanga from recently emerged coral-islands into a productive cultural landscape. This allows for a viewpoint that accepts the challenges of environmental conditions, while recognizing that humans can actively manipulate landscapes and resources to mitigate perceived shortfalls. By viewing the landscape alterations and social transformations that took place on Manihiki and Rakahanga as interconnected and mutually influential processes it is possible view the historically known landscape of these atolls as the product of long-term human-environmental interaction and to identify the social and ecological trajectories that resulted in long-term sustainability in the remote Pacific.

Island Transformations, Impacts, and Abandonments in Oceania

To understand the trajectories that transform island environments into socioecological landscapes it is important to first acknowledge human-induced processes of landscape alteration. The construction of cultural landscapes tends to involve three broad sets of processes on islands: 1) inclusions, or the introduction of new species to the island; 2) exclusions, or the purposeful barring of certain species from reaching the island; and 3) transitions, or in situ transformations in the ecology (e.g., species extirpation) or landforms of the island (McNiven 2008:450-451). These processes, including the selective removal of non-desirable species and the introduction, management, or nurturing of useful species, can result in the creation of an anthropogenically-mediated cultural landscape suited to the needs of the population (Erickson 2008:158). In Oceania, initial island settlement was often accompanied by periods of heavy resource exploitation and ecological alteration, resulting in species extinction and extirpation. Following this settlement period, island subsistence frequently became focused on the rearing of domesticated plants and animals in addition to differential exploitation of wild resources as diverse cultures and landscapes developed across the Pacific (Allen and Craig 2009:478).

Near and Remote Oceania

The islands of Oceania (Figure 1.1) were first divided into the regions of Melanesia, Micronesia, and Polynesia by the European explorer Dumont d'Urville (1832). These groups were based on Dumont d'Urville's insights into the landforms and peoples of the Pacific but do not reflect true cultural relationships in most cases (Kirch 2017). The divisions between Near Oceania and Remote Oceania, however, are based on the biogeography of the region and patterns of human settlement that separate the islands of Near Oceania (New Guinea and near-continental islands) which were mostly settled during Pleistocene and the smaller more remote islands of Remote Oceania which were settled during the late Holocene (Figure 1.1; Green 1991). The near/remote division holds greater meaning when discussing the Pacific as a whole, yet the designations of Melanesia, Micronesia, and East and West Polynesia remain useful geographic references and are used regularly in current academic and popular parlance.

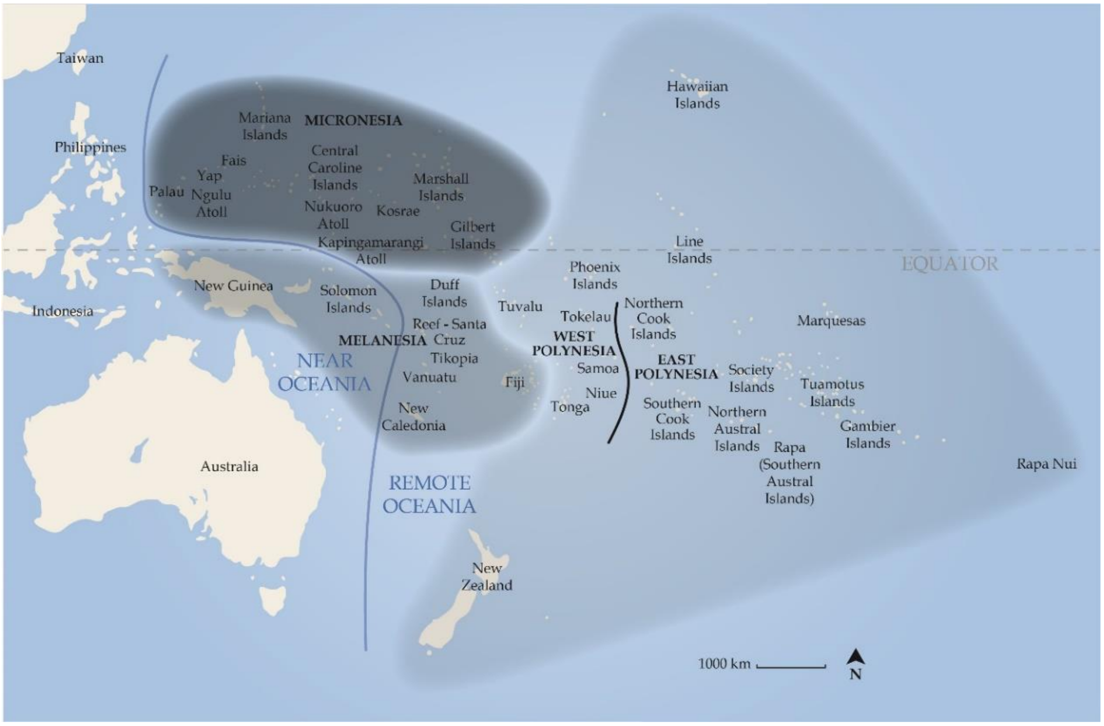

Figure 1.1. Map of Oceania

The islands of Remote Oceania were uninhabited before the first voyagers from Near Oceania arrived in the late Holocene. The arrival of humans on these islands had a number of ecologically significant consequences. This includes the depletion and extinction of local fauna, deforestation, and the introduction of non-native taxa. The voyagers that settled Remote Oceania brought a well-documented assemblage of plant and animal species with them. This “transported landscape” (Anderson 1952; Kirch 1982:1) frequently included four animals - chicken (*Gallus gallus*), dog (*Canis familiaris*), pig (*Sus scrofa*), and the Pacific rat (*Rattus exulans*) (Anderson 2009). Voyagers also transported numerous plant species including breadfruit (*Artocarpus altilis*), pandanus (*Pandanus* spp.), swamp taro (*Cyrtosperma chamissonis*), and possibly some varieties of coconut (*Cocos nucifera*) (Whistler 1991). Humans and their collection of introduced plants and animals transformed the islands that they inhabited, essentially terraforming them into places that held some resemblance to their ancestral homelands. Native species were lost as humans and their domestic/commensal animals predated heavily upon ground-nesting birds, sea turtles, and other local species. Deforestation, over harvesting of marine resources, and alterations to the land itself may have also contributed to the disruption of local ecosystems causing localized faunal depletions and extinctions (Rolett 1998:10-11; Steadman et al. 2002).

The initial transformation of island environments was likely devastating for the indigenous plants and animals of most islands in Remote Oceania. Most Oceanic societies seem to have persisted despite this initial disruption to the native ecosystems. On many islands, including low-coral islands, this is likely due, in part, to the abundance of marine resources and the development of sophisticated agricultural systems (Weisler 2001a:124). Humans utilized their transported crops and animals to transform the islands of the Pacific into anthropogenic landscapes capable of sustaining long-term human occupations (Kirch 2017:100-101). This was arguably a difficult task on many small and remote islands. By the time of European contact in the 1500s-1800s some small islands and island groups in Polynesia were abandoned. These "Mystery Islands" include Suwarrow and Palmerston atolls in the Cook Islands as well as islands in other groups (Bellwood 1979:352; Irwin 1992:176; Kirch 1988). The process of creating a viable and sustainable socioecological system on these islands may have been hindered by geographic remoteness, small landmasses, human impact on ecological resources, and a lack of accessible fresh water (Anderson 2002; Kirch 1988; Weisler 2001b, 1994:99). It remains an important challenge for archaeologists to examine the impacts of human arrival on, and occupation of, diverse Oceanic islands to understand how ecological challenges were overcome and what factors contributed to the development of socioecological sustainability or collapse in disparate island settings, especially remote and marginal environments.

Coral Atolls

Due to their low elevations, often just a few meters above sea level, and relatively impoverished terrestrial ecosystems, coral islands are considered to be one of the most fragile and precarious environments for human habitation (McNiven 2015; Weisler 2001c:31). The small coral atolls of East Polynesia are one of the most commonly abandoned landforms in the Pacific (Kirch 1988). Much of what we know of the atoll dwelling populations of the past is derived from oral histories, ethnographic research, and ethnohistoric texts. Accounts from early European explorers, sailors, missionaries, and others documented plant and animal life as well as cultural institutions on Pacific islands, including atolls (e.g., Boggs 1951; Burney 1803-1817; Gill 1915; 2001 [1871]; Kelly and Parsonson 1966; Maude 1968). Some of these individuals also recorded oral histories and genealogies (e.g., Gill 1915, 2001 [1871]). Researchers of the 1900s such as Hiroa (1932), Emory (1975), Gladwin (1970), and Beaglehole and Beaglehole (1938) recorded oral histories and wrote volumes on atoll life, informing our views on traditional lifeways on differing atolls and providing insights into oral traditions and genealogical records.

William Alkire (1965, 1978) provided an ecological perspective on atolls through ethnographic and ethnohistoric insights. Alkire’s work on Lamotrek Atoll, and his later synthetic approach toward understanding atolls as networks of human-modified islands, recognized the potential of atolls as human environments and documented the ways that humans interacted with atoll landscapes. In recent decades Indigenous oral historians such as Kauraka Kauraka (1989) have committed oral narratives to text, helping to bring an emic viewpoint on atoll life into the academic and popular literature. Due in part to past misconceptions of the quality of archaeological preservation on low-lying islands, coral atolls have received a disproportionately small amount of archaeological research (Weisler 2001a:109, 2001b:4). Davidson (1971), working on Nukuoro, in the Caroline Islands first identified cultural strata on a coral atoll in the 1960s. Her work demonstrated that these landforms, despite their low elevation and the theoretical potential for sediment shifting, could possess well-preserved stratigraphic sequences. Following Davidson's work, archaeologists began conducting excavations in many atoll groups (e.g., Addison et al. 2009; Chazine 1982; Chikamori and Yoshida 1985; Conte and Dennison 2009; Di Piazza and Pearthree 2004, 2001; Nitta 1982; Ono and Addison 2013; Takayama et al. 1985; Weisler 2001a; Yamaguchi et al. 2009). These works demonstrate the archaeological potential found throughout the atolls of the Pacific and form the foundations of our archaeological understandings of atoll life. Combined, the data derived from these oral, textual, and archaeological sources, suggest that atoll life can be challenging, but the difficulties that atoll dwellers face are often mitigated through innovation in social and ecological management.

Atoll Formation

The atolls of the Pacific are numerous and widespread. An east-west arc of coral islands stretches across the tropical Pacific reaching from Palau and the Caroline Islands in the west to the Tuamotu, Gambier, and Pitcairn Islands in the east. This arc contains roughly 300 atolls, thousands of islets, and a few sandy cays. The biogenic landmasses of coral atolls form as corals surround volcanic islands creating a fringing reef. As the volcanic component of the island subsides due to tectonic processes, and as the reef proliferates, a barrier reef and lagoon form. Eventually, the volcanic island subsides beneath the surface leaving a ring of coral enclosing a lagoon (Alkire 1978). This reef becomes the foundation upon which coral islands form. Sea level in the Pacific fluctuates over time. Between 7,600-7,100 years ago much of Oceania experienced near modern sea levels (Nunn 2016:93). A recent period of sea level lowering began in the Pacific roughly 4,000 years ago (Dickinson 2009:4, 2003:490). Over the following millennia falling sea levels began to expose reef flats allowing for the collection of sediments to occur as islands and islets formed. Once regional sea level fell to a point where the ambient high tide level was lower than the low-tide maximum point of the mid-Holocene, paleo-reef flats, and thus biogenic islets, became fully exposed and no longer subject to daily or monthly wash over from tidal cycles (Dickinson 2003:492). It is argued that the crossover point for many Pacific islands occurred Between 1150 and 850 cal. BP suggesting the late formation of many islands (Nunn 2016). However, archaeological evidence demonstrates that some atolls, especially those of the north-west Pacific, were colonized by humans before their respective crossover points (Nunn 2016). This indicates that the dynamics of individual islands and regional tidal activity may allow for the formation of coral islands before regional crossover. It is likely that many atolls were inhabited before or shortly following their respective crossover points (Nunn 2016). It is difficult to say how the emergence point of atoll islets affected local terrestrial ecologies but, depending on the timing of habitation, humans may have arrived to find thriving marine environments and depauperate terrestrial environments in the early stages of ecological development.

Atoll Resources

Regardless of location or the timing of emergence, coral islands lack many of the common terrestrial resources found in volcanic island or continental environments including fertile soils, large tracts of arable land, hard stone for tools, abundant wood, clay for pottery, metals, and surface water. Technological adaptations, seen through archaeological and ethnographic research on coral islands, reflect the resource limitations in these environments (e.g., Hiroa 1932; Weisler 2001b). Lacking hard tool stone and clay for the manufacture of pottery, coral island dwellers use locally available resources such as wood, plant fibers, shell, bone, and coral to manufacture tools. Wood and plant fibers were used to manufacture a wide array of items including clothing, woven baskets, buckets, bowls, bailers, weapons, fishing spears, ships, houses, and many other items (Emory 1975; Hiroa 1932). The robust bivalve shell of the giant clam (*Tridacna* spp.), was often utilized for the manufacture of adzes. Portions of gastropod shells were manufactured into gouges, adzes, and chisels (Emory 1975:108-111;

Weisler 2001b:85-86). Sea turtle shell, wood, and marine shell, including the valve of the black-lipped pearl oyster (*Pinctada margaritifera*), were utilized to craft fishhooks, fishing lures, and adornments (Emory 1975:198-214; Ono and Addison 2013). Finally, the coral that atolls are built upon was used in place of harder stone to craft pounders and net weights. It was also used in building to create walls, pathways, tombs, and fish traps, as well as to line the edges of cultivation pits to facilitate soil retention (Emory 1975, 1939; Thomas 2019). Coral was also used in place of oven stones in traditional earth-oven cooking (Weisler 2001b).

Fresh surface water is absent from atolls; however, rainwater collects in the porous coral matrix of atoll islets forming a lens. This lens floats atop the denser saltwater that permeates coral islets allowing for some transfer of salt into the otherwise fresh rainwater. The resulting fresh or brackish water aquifer, termed a Ghyben-Herzberg lens, is proportionate in size to the islet and is recharged through rainfall. Wells placed into these lenses, especially those placed on islets exceeding roughly 300 m in diameter, can, and often do, produce potable water (Wiens 1962:317-321). This helps facilitate the human habitation of atolls and provides the potential for intensive cultivation. Atoll habitation sites are often situated near the center of the atoll’s largest islet (Thomas 2009:582; Weisler 1999:638). This provides access to the largest freshwater lens and provides a modicum of protection against environmental hazards such as cyclonic activity.

Atoll Subsistence

Though coral islands frequently possess abundant marine resources, including highly productive reef and lagoon systems, they are often considered marginal due to poor coral soils that lack nutrients, a lack of fresh water, and high levels of vulnerability to environmental disaster such as cyclonic storm surge (Thomas 2015). Atoll subsistence is often based around the procurement of native resources including birds, fish, clams, and turtles as well as the cultivation of imported crops. Coral island dwellers likely invested large amounts of energy to initially transform their environments and increase the production capability of the island or island group.

Due to the nature of coral sediments, production options are limited and the storage of surplus is difficult (Sahlins 1958:235). This may have encouraged atoll dwelling populations to focus energy on crops that continually produce food or can be left to grow for long periods of time. Atoll populations often excavate pits into the freshwater lenses of the atolls for the cultivation of swamp taro (*Cyrtosperma chamissonis*). These anthropogenic pits are defining features of many atoll landscapes that form appreciable earthworks consisting of large networks of stone-walled cultivation areas and the spoil mounds that resulted from their creation. Atoll dwellers also relied heavily on agroforestry, or the tending and planting of groves and forests, of tree crops such as coconut (*Cocos nucifera*), breadfruit (*Artocarpus altilis*), and pandanus (*Pandanus* spp.) (Thomas 2015:67; Weisler 2001b:7). These tree crops supplied not only food, but material resources used to create myriad items. It is argued that this type of agroforestry is an inherently sustainable practice on atolls as it requires little by way of human involvement beyond planting, mulching, and harvesting (Thomas 2019:4).

In some cases, atoll dwellers raised domestic animals such as dogs, pigs, and chickens (see Chapter 3). The distribution of these animals is, however, inconsistent from island to island. Atoll dwellers undoubtedly relied heavily on local resources including birds, fishes, turtles, and shellfish. Fishponds and traps were built in reef channels to capture wild resources (Dieudonne 2002; Thomas 2015). Archaeological fishhooks and faunal assemblages, as well as ethnographic studies from atolls in the Tuamotu Islands, Tokelau, the Marshall Islands, and Kiribati, document a diversity of fish and shellfish exploitation practices (e.g., Conte 1988; Ono and Addison 2013; Thomas 2007; Weisler 2001b). While these cases demonstrate high levels of variability in marine resource exploitation it is clear that atoll dwelling populations are highly dependent on these non-terrestrial resource bases.

Atoll dwelling populations face resource limitations due to the size of the islands and the associated reefs, lagoons, and freshwater lenses. This may be the reason that these groups often used multiple islands and islets as extended resource bases (Alkire 1978; Di Piazza and Pearthree 2001). Alkire (1978) defines three types of coral island systems which are characterized by the extensiveness of their resources bases: 1) coral isolates, where a single coral island is utilized as a relatively isolated resource base; 2) coral clusters, where a small number of islands and islets are used by a population as a single resource base; and 3) coral complexes, or large networks of atolls and cays that are used by any number of connected groups. The use of resources beyond the home island or islet allows for the mitigation of many of the hardships of atoll life through controlled processes of inclusion, exclusion, and transition. Certain islands and islets may be protected at a given time, planted for a particular purpose, left fallow for a period, or certain domesticates may be excluded from or confined to certain areas. This can allow for the proliferation of resources and back-up resource stocks that the population can draw upon in times of need or potentially use as surplus (Di Piazza and Pearthree 2001; Thomas 2015). The highly productive marine environments of atolls, landscape transformations in the form of intensive cultivation, innovative resource management, and the use of extended resource bases undoubtedly contributed to the success of many atoll settlements and are reflected in the sociopolitical structures of atoll groups.

Political Systems

The settlers of many of the coral islands of the Pacific likely brought with them the foundations of chiefly forms of political organization. When Europeans arrived in the latter half of the second millennium AD they documented a wide array of chiefly political forms on coral islands. These included multi-tier systems, tributary systems, and counsel structures (e.g., Beaglehole and Beaglehole 1938:234-235; Dening 1962:110; Sahlins 1958; Young 1899:268). The intensification and extensification of subsistence resources in the coral clusters and complexes of Micronesia and Polynesia may have fueled the need for innovative political systems capable of managing widespread resources and in some cases wide-spread populations. However, as Thomas (2009:587) notes, coral islands lack the material resources typically used in monumental expressions of power and large-scale construction. This does not preclude the development of innovative and stratified systems of political management, but it does lessen the archaeological signature of such institutions. This encourages archaeologists to look to oral traditions as well as ethnohistoric and ethnographic text to inform archaeological investigations into the political forms found on coral islands (Thomas 2009:587; See chapter 2). These oral and textual resources enable the development of informed archaeological research questions that are testable through targeted survey, excavation, and analysis. The atolls of Manihiki and Rakahanga have a particularly rich ethnohistoric, ethnographic, and oral history record that documents a political structure that developed out of ancestral chiefly political forms (See Chapter 2; Gill 2001 [1871]; Hiroa 1932).

Manihiki and Rakahanga – On the Margins of East Polynesia

The neighboring atolls of Manihiki and Rakahanga (Figure 1.2) are located in the Northern Cook Islands on the western edge of East Polynesia. Polynesian voyagers first colonized the islands of East Polynesia at roughly AD 900 in the Southern Cook Islands (Sear et al. 2020) and AD 1000–1200 in the Society and Gambier Islands (Schmid et al. 2018; Stevenson et al. 2017; Wilmshurst et al. 2011). Manihiki and Rakahanga appear to have been first colonized in the centuries following these first arrivals in East Polynesia (Di Piazza 2005; Schmid et al. 2018; Wilmshurst et al. 2011; Yamaguchi et al. 2009). Marked by artifact assemblages which lack pottery, but include a wide array of shell and stone tools, ancient East Polynesian peoples are known for their masterful use of marine resources, monumental construction, highly adaptive subsistence systems, massive landscape transformations, and stratified political structures (Bellwood 1979:318-383; Kirch 2017; Sahlins 1958). The people of Manihiki and Rakahanga appear to share many of these features with other East Polynesian groups suggesting a shared ancestry or direct descent (Hiroa 1932).

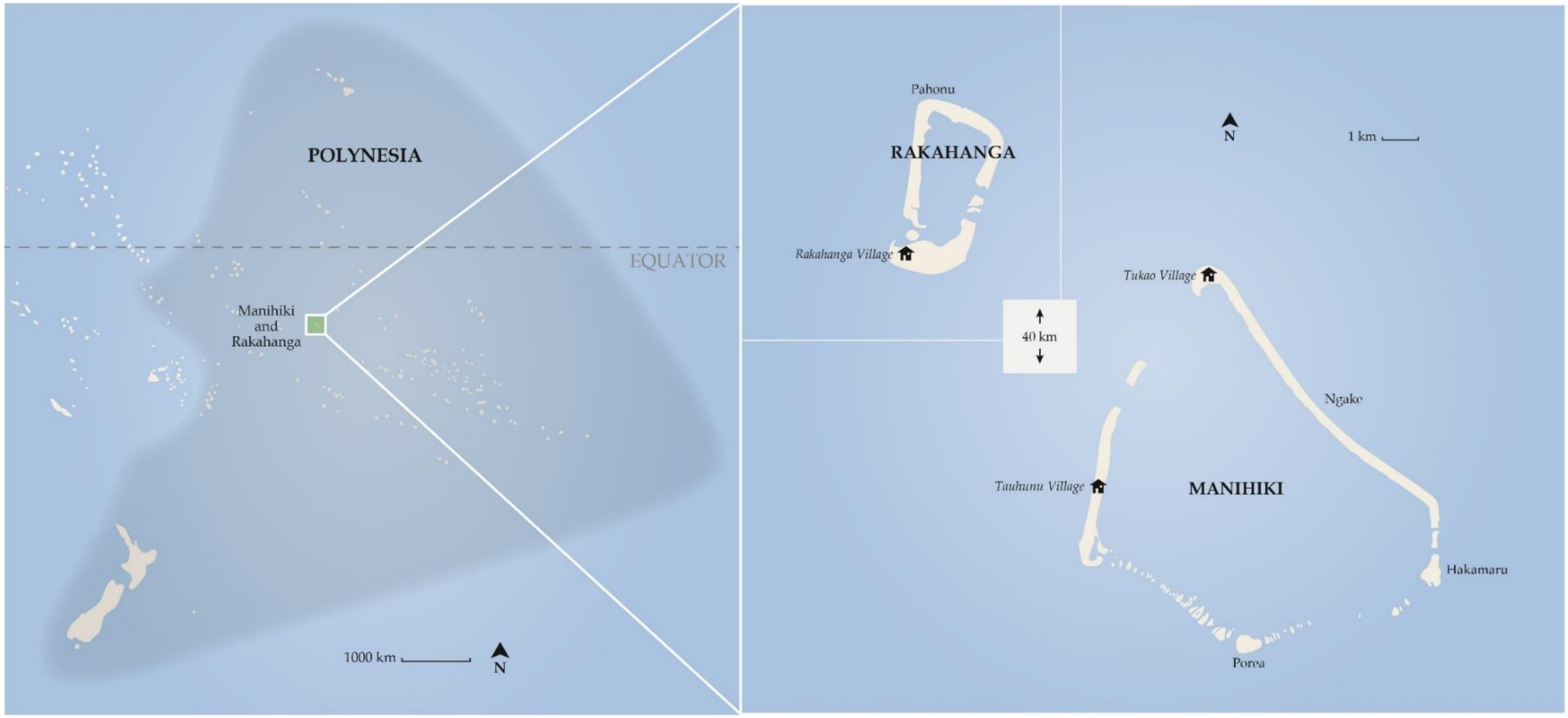

Figure 1.2. Map of Manihiki and Rakahanga in Polynesia with modern villages

The Northern Cook Islands are comprised of five coral atolls (Pukapuka, Penrhyn [also called Tongareva], Suwarrow, Manihiki, and Rakahanga) and one sandy cay (Nassau) spread across roughly 200,000 km^2 of the Pacific Ocean. Manihiki and Rakahanga are roughly 10° South of the Equator and have an equatorial climate with a wet season that lasts from November to April and a dry season lasting from May to October. Historic records for Manihiki report an average of 240.64 cm of rainfall per year in the mid-1900s (Wiens 1962). Cyclone season in the Northern Cook Islands is between November and April (de Scally 2008). Cyclonic winds and storm surge can be devastating to low-lying atolls. The most recent cyclonic event was Cyclone Martin which hit Manihiki on November 1st, 1997 causing the loss of many lives and damaging the infrastructure of the atoll (Reeves 2015). Historic cyclones are known to have hit the Northern Cook Islands in 1914 and 1942 as did a tsunami in 1899 (Alkire 1978:96; de Scally 2008:454; Weins 1962:474-475). Oral histories recorded by Beaglehole and Beaglehole (1938) also suggest that a massive wave devastated the population of Pukapuka atoll at around AD 1600 by genealogical estimates. It seems that this was either a tsunami or a storm surge event (Beaglehole and Beaglehole 1938; de Scally 2008:454). Nevertheless, it is clear that wash-over events can be devastating in these low-lying environments.

Manihiki and Rakahanga differ greatly in size. Rakahanga, traditionally known as *Tapuahua* has a dense ring of land surrounding a shallow lagoon. Rakahanga has a total land area of 4.04 km^2 and a highest elevation of 4.2 m. Rakahanga's small lagoon totals 12 km^2 in area and the fringing reef is 14 km in length (Taporoporo 2012a). Manihiki is roughly 44 km south of Rakahanga. Traditionally called *Te Fuinga o Niva*, Manihiki is the larger of the two atolls with 5.4 km^2 of land area and a 32 km long fringing reef. The land on Manihiki is distributed in five main islets and dozens of smaller islets. Manihiki Lagoon is deeper than Rakahanga's and is 40 km^2 in area (Taporoporo 2012b). Both atolls are considered to have "virtually enclosed lagoons" (Callaghan et al. 2006) that prohibit the passage of large vessels. Together Manihiki and

Rakahanga are 350 km from the nearest neighboring atoll (Penrhyn), and over 900 km from the nearest high island group (the Southern Cook Islands). Today Manihiki and Rakahanga have three villages - Tauhunu and Tukao on Manihiki, and a single village on Rakahanga. The current population fluctuates regularly, but the most recent census reports that Rakahanga has a population of 83 and Manihiki has a population of 212 (CISO 2016). The present-day population of Manihiki and Rakahanga is much smaller than those recorded in previous years and in historic accounts.

The Historic and Ethnographic Past

Manihiki and Rakahanga have a particularly rich ethnohistoric record stretching back to the seventeenth century. In 1606 the first Europeans to make landfall on Rakahanga noted large voyaging canoes (Kelly and Parsonson 1966:174) indicating that the people of Manihiki and Rakahanga were skilled seafarers that were likely in occasional contact with distant islands. The remoteness of the atolls however does suggest that the people of Manihiki and Rakahanga were likely dependent on the localized resources produced by their cluster. The Spanish explorers that landed at Rakahanga in AD 1606 estimated a population of 500 people (Kloosterman 1976:12). Documents chronicling landings by westerners in the following centuries include an encounter with Bellingshausen 1820 (Debenham 2010:301-308), sightings by Patrickson in 1822 (Maude 1961:116), and the arrival of Tahitian missionaries in 1849 (Gill 2001 [1871]). In 1852 the missionary W.W. Gill arrived on Manihiki and Rakahanga and estimated a population of 1,200 individuals (~126 per km^2) (Gill 2001 [1871]:127). This number was down to 884 by the 1902 census and 873 in the 1906 census marking a trend that continues to this day (CISO 2016).

European accounts of the atolls from the 1800s and 1900s state that the population of Manihiki and Rakahanga had no knowledge of pigs, dogs, or chickens, suggesting that domestic animals never dwelled on the atolls. They also document a verdant landscape planted with coconuts (*Cocos nucifera*) and swamp taro (*Cyrtosperma chamissonis*) (Hiroa 1932:92-97; Gill

2001 [1871]:127). However, oral histories indicate that upon first human arrival the landscape of Manihiki and Rakahanga was barren. They state that when the first human to set foot on Manihiki and Rakahanga, Huku, arrived the land was *hā* (desert) and "scarcely above the face of the sea…" (Gill 2001 [1871]:128, 1915:148-149). Huku is said to have planted the first coconuts which he brought from the island of Rarotonga. The second inhabitant, Featu, is said to have "lived on fish" while attempting to excavate a canoe passage in the reef (Gill 1915:148-149). This suggests that the islands of Manihiki and Rakahanga were ecologically depauperate at human arrival and may indicate later islet emergence than currently hypothesized (Chikamori 1996:46; Gill 1915; Nunn 2016:92). The available European reports do not comment upon the transformation of the atolls from their barren state into an anthropogenic landscape, but they do document a process of institutional development that may suggest how this verdant landscape came to be.

Accounts from the missionization period, following AD 1849, document a regionally novel dual-chiefdom political system and a system of shifting habitation and resource use called the *Tûmutu* (Hiroa 1932; Kauraka 1989; Tereora 1994). The dual chiefdom appears to have enabled a mass-migration-based system of cyclical population aggregation and dispersal that was tied to ritualized restriction and access to certain lands and resources (see Chapter 2). The Tûmutu appears similar in principal and goal to other Polynesian systems of ecological management known as *rahui* (Bambridge 2016). However, it diverges from other forms of rahui by focusing on a process of cyclical mass migration where the population of Manihiki and Rakahanga, as a whole, voyaged between the atolls aggregating in a single village on Rakahanga called *Te Kainga*, literally "the home," and then dispersing to multiple villages on Manihiki before reuniting in the village on Rakahanga at a later point (Hiroa 1932:65-66; Kauraka 1989:1). Manifestations of rahui may have, in one form or another, acted to protect the fragile resources of Manihiki and Rakahanga as the early inhabitants established themselves and transformed the once barren environments into a productive cultural landscape. Many questions remain regarding the nature and formation of the dual chiefdom and Tûmutu institutions (see Chapter 2).

Ethnological and Archaeological Research on Manihiki and Rakahanga

The people of Manihiki and Rakahanga were the subject of ethnological research in the 1920s. Te Rangi Hiroa, also known as Sir Peter Buck, was an accomplished scholar and researcher who conducted cultural studies on islands across the Pacific (Kirch 2017). Hiroa documented many aspects of contemporary and past lifeways on Manihiki and Rakahanga including the formation of the dual chiefdom to which he assigned a date range by tracing genealogies (See Chapter 2). He also documented the foods eaten by the population as well as the function of the Tûmutu in allowing for resource sustainability. Archaeological research was first conducted on Manihiki and Rakahanga in the 1980s by a research team from Japan. Chikamori and Yamaguchi conducted archaeological excavations on two islets on Manihiki (Porea and Hakamaru) and surveyed large portions of the island. On Rakahanga they conducted archaeological excavations on Te Kainga (Chikamori et al. 1991; Yamaguchi 1998). Their work demonstrated that surface features such as *marae* or meeting places, coral-limestone walls and mounds, as well as *puraka* (giant swamp taro) pit fields, were visible on many islets. Their research also identified well-stratified sub-surface deposits with appreciable preservation and superimposed cultural strata on both atolls (Yamaguchi 1998). Their efforts resulted in a suite of radiocarbon dates including the earliest culturally associated date for the atolls – 830±25 years BP (Chikamori et al. 1991:21, 27; Chikamori 1998:50; Yamaguchi et al. 2009:542-543). Years later, Di Piazza (2005) conducted a survey of Rakahanga and excavation on Te Kainga, establishing that archaeological deposits on Te Kainga offer excellent preservation of botanical and faunal remains (Di Piazza 2005:83-84). Di Piazza’s work also produced the first radiocarbon dates from Manihiki and Rakahanga derived from short-lived botanicals (Di Piazza 2005). Combined, these works documented the potential of Manihiki and Rakahanga to provide evidence of atoll life, the development of cultural institutions, and the ability of atoll dwelling populations to live sustainably.

Research Design

This research uses the case of Manihiki and Rakahanga to address the following question: Through what processes and over what time scales, have humans transformed environments and developed socioecological institutions to create sustainable cultural landscapes? To address this question through the case study of Manihiki and Rakahanga it was necessary to create a temporal baseline for site occupation and land use, including first habitations, species introductions and extirpations, and sociopolitical change on Manihiki and Rakahanga. It was then possible to use extant archaeological, ethnohistoric, and ethnographic data to compare specific patterns of resource management (i.e., the introduction and extirpation of domestic dogs) with other islands and island groups. This required extensive archaeological fieldwork in the form of survey and excavation as well as extensive analysis of the excavated materials and ethnohistoric documents. The interpretations found in chapters 2-5 are based on data derived through two field seasons on Manihiki and Rakahanga, and roughly two years of analysis of ethnohistoric documents, archaeological reports, human-manufactured artifacts, stratigraphy, and faunal materials at the University of Georgia. This was accompanied by the acquisition of 22 radiocarbon dates at the University of Georgia Center for Applied Isotope Studies.

Field Methods

I conducted two seasons of archaeological field research on Manihiki and Rakahanga. In 2015 I spent roughly three months on the atolls under Cook Islands research permit #06/15. During this time, I interviewed residents about past lifeways, and I conducted field survey assisted by Justine Tuatai William and Thomas Elisa on Manihiki and Kimiora and Junior Mataio on Rakahanga. In all, the teams surveyed over one third of each atoll and documented and mapped numerous archaeological sites and points of interest. In 2017 I returned to Manihiki and Rakahanga for roughly five months with Sara Cramb to conduct additional interviews and to complete excavations on each atoll under Cook Islands research Permit #03/17. During this time, we were assisted by Haumata Tepania on Manihiki and Tupou Hagainoa on Rakahanga. We excavated habitation and cultivation areas on both Manihiki and Rakahanga and washed and packaged materials for transport to the United States for analysis. The field methods are detailed below, and the findings are documented in Appendices A and B.

Archaeological Survey

Archaeological field research began on Manihiki and Rakahanga in 2015 with a pedestrian survey of large sections of each atoll. I chose survey areas using a purposive sampling strategy. Based on previous research and local insights the survey team identified areas thought to have concentrations of surface features. When possible, we surveyed entire islets. The survey team walked north-south transects across the islets positioned 10-20 m apart based on the density of the vegetation. We mapped, georeferenced, and photographed all evidence of past human activity (e.g., coral structures, artifacts, and anomalous changes in topography). The surveys resulted in the documentation of features such as possible graves and known historic monuments. We recorded these areas of interest in addition to the habitation and farming areas that were the target of these surveys in order to create comprehensive survey maps (Appendix A). Previous researchers on Manihiki and Rakahanga used a variety of site designators including MNH followed by a numeric designator on Manihiki and RAK or TEK followed by a numeric designator on Rakahanga (Chikamori et al. 1991; Di Piazza 2005; Yamaguchi 1998). To avoid confusing surface features with previous site designations we gave each area of interest a numeric designator with the prefix MANI for Manihiki and RAKA for Rakahanga. I present the full results of the survey in Appendix A.

Archaeological Excavations

In 2017 I lead a team in the excavation of sites on each atoll. The team conducted a test-unit survey to assess the temporality and preservation level of one habitation site on each atoll (NG001 and TK001) and an area at the center of the largest islet on Rakahanga (NV001) where a high likelihood of early habitation exists (Figure 1.3). Much of the center of the large islet contains areas flooded for puraka farming so we choose a dryland area near the lagoon side of the islet for testing. We excavated all test units in 50x50 cm squares at intervals of 30 m using a surface datum. The field team excavated in 20 cm levels until we reached water or coral bedrock. In all, we placed eight test units on Te Kainga (TK001), 10 on Ngake (NG001), and four on the main islet of Rakahanga (NV001). We determined the placement of larger excavation units based on the test-unit survey. These include four 1x2 m units at NG001 and one 2x2 m unit on TK001. We placed one additional 1x1 m unit (NM001) on the main islet of Rakahanga to test for evidence of the early construction of puraka pits (Figure 1.3). The team screened all excavated matrix using nested 1/4th inch and 1/8th inch mesh. The team collected all faunal remains and other artifacts, as well as viable carbon samples, and sediment samples. We drew and photographed one profile of each test unit and at least two profiles for the larger units. I describe the excavations and stratigraphic sequences in Appendix B.

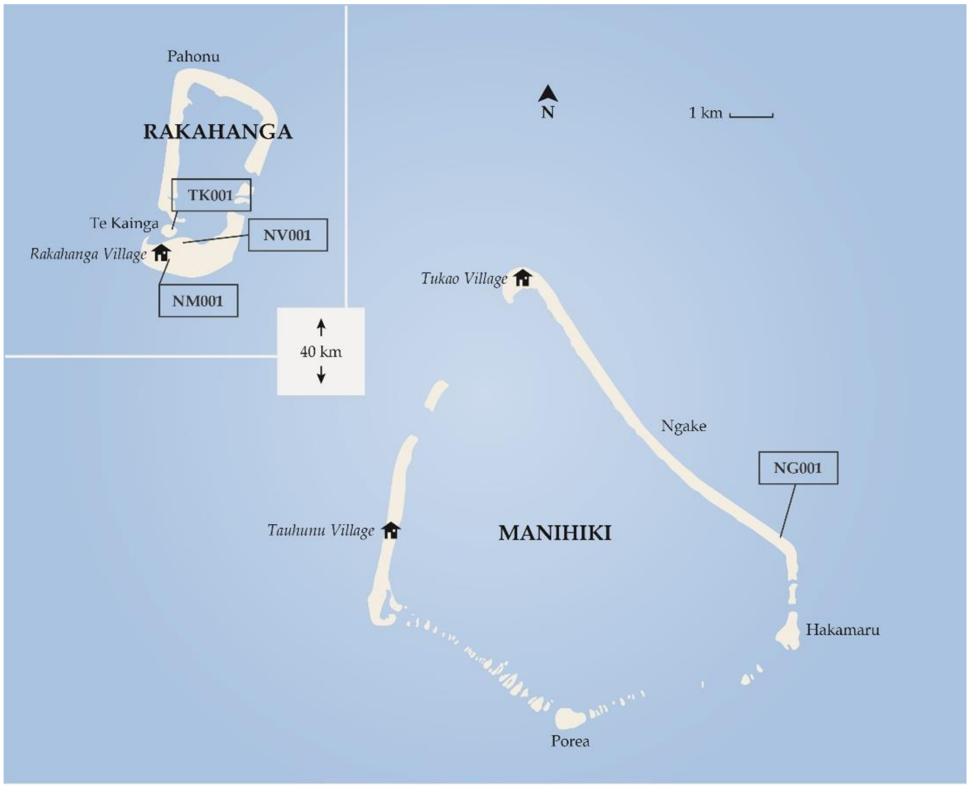

Figure 1.3. Map of Manihiki and Rakahanga with excavation areas and modern villages

Laboratory Methods

The excavation team photographically documented and packaged all excavated artifacts and faunal remains, along with sediment samples and charred botanical samples, in compliance with the standards of the Cook Islands Ministry of Culture. With permission from the landowners and the Cook Islands Ministry of Culture I transported the materials to the University of Georgia Laboratory of Archaeology for analysis and curation. Volunteers and interns assisted with the initial sorting of materials at the Laboratory of Archaeology. I moved all vertebrate faunal remains to the Georgia Museum of Natural History where I completed zooarchaeological analysis. I transported selected botanical samples to Flagler College for identification by Dr. Lee

Newsom. I analyzed all other materials at the University of Georgia Laboratory of Archaeology using the methods that follow.

Artifact Analysis

The peoples who colonized the islands of East Polynesia did not use pottery, and coral atolls do not possess hard stone from which to craft tools. Therefore, any stone, such as basalt, would indicate trade with other islands or items brought with the first settlers. In the 1920s, Hiroa (1932:139-140) collected stone tools from islanders and surface contexts on Te Kainga, but no researchers have identified stone tools in subsurface excavations on Manihiki and Rakahanga. Our team recovered no stone artifacts during the 2015 and 2017 investigations. However, we recovered artifacts made of shell, coral, and urchin spine from these investigations (Appendix C). This includes 30 whole or fragmented pearl shell (*Pinctada margaritifera*) fishhooks/ trolling lures (mostly small fragments with a few near-complete specimens), nine pearl shell "adornments"/ inlays (these include circular disks and lozenge-shaped drilled objects), five pearl-shell scrapers, a pearl-shell gouge, nine clam shell (*Tridacna maxima*) adzes/ adze fragments (most are near complete), three punctured cowrie (Cypraeidae) beads, one possible urchin spine (*Heterocentrotus* spp.) bead, one coral hammer stone, two coral abraders, one worked gastropod columella – possibly a drill, and large amounts of pearl shell debitage. I weighed, measured, described, photographed and scanned all of the artifacts with a 3D scanner. Following existing typologies, I classified all adzes and fishing implements (Allen 1996; Rolett 1998; Weisler 2001a). I detail the methods and results of the artifact analysis in Appendix C.

Faunal Analysis

I analyzed all of the vertebrate faunal remains recovered in 2017 at the Georgia Museum of Natural History following standard protocols (O'Day 2001; Reitz and Wing 2008). I used comparative reference collections from the Georgia Museum of Natural History, Northern

Kentucky University, and Portland State University for comparison. I made attributions to element and the lowest reasonable taxonomic level possible (Appendix D). For boney fishes and bird remains this was most often the family level. Due to a lack of comparative material at lower taxonomic levels I made shark, skate, and ray element attributions at the class level (Chondrichthyes). I identified turtles to the level of Chelonioidea to account for all possible sea turtles in the region. One marine mammal was identified by a single tooth. I attributed it to the parvorder Odontoceti, or toothed whales. I made species level attributions for all terrestrial mammal remains. It is almost certain that most of the rats of Manihiki and Rakahanga are Pacific rats (*Rattus exulans*) brought by Polynesian voyagers. I identified rat bones in pre-European context and the species still thrives on the islands today. However, due to the difficulty of distinguishing between the black rat (*Rattus rattus*) and the Pacific rat (*Rattus exulans*) based on morphology, I designated all members of the *Rattus* genus as probable Pacific rats (cf. *Rattus exulans*). Appendix D presents the Number of Individual Specimens (NISP) and the weight for each taxon for each of the four excavated sites.

Radiocarbon dating

AMS dating was completed at the UGA Center for Applied Isotope Studies to determine date range probabilities for stratigraphic layers in the Manihiki and Rakahanga excavations. We choose short-lived specimens (e.g., coconut endocarp and pandanus drupes) for dating to avoid old wood biases (Allen and Huebert 2014). By dating samples from sequentially superimposed strata and from multiple sites, it was possible to create timelines for habitation on Manihiki and Rakahanga (See chapter 2). Marine samples (*Pinctada margaritifera*) and terrestrial mammal samples (*Canis familiaris*) were also dated to confirm the timing of human and dog arrival, and dog extirpation, on Manihiki and Rakahanga (See chapter 4). My co-authors and I used OxCal v4.3 (Bronk Ramsey 1995) for the calibration of all AMS dates and the creation of statistical models to refine the results of AMS dating in terms of relative measures such as stratigraphy.

This combination of AMS probabilities, bound by a-priori knowledge (the parameters defined by relative groupings such as strata), allows for the generation of date ranges and sequences that are constrained by all known parameters and have a reduced potential for error (Bronk Ramsey 2009:357, 1995:428). We document 22 original dates for Manihiki and Rakahanga in Chapter 2 and Appendix E.

Outcomes

As a whole this dissertation works to further our understanding of coral atolls as human landscapes. In Chapter 2 my co-author Victor Thompson and I explore the timing and processes involved in settlement, societal change, resource management, and landscape transformation on Manihiki and Rakahanga. In this chapter, we combine the data generated through my field and laboratory research methods with that of previous researchers and use the resulting datasets to discuss Manihiki and Rakahanga in terms of diachronic change in sustainable land use and cultural institutions. In doing so, we create the first archaeologically informed timeline of social and ecological change on Manihiki and Rakahanga and demonstrate how small-island sustainability can arise. The conclusions presented in Chapter 2 suggest that the lifeways and cultural institutions that developed on these coral islands mirror those of societies on larger islands, but a greater focus was placed on environmentally sustainable social institutions. These institutions developed out of ancestral traditions as the population grew and expanded. The specifics of the resulting ecological and social management structures are tailored to the dynamics of the coral-island landscape.

In Chapter 3 I discuss the specific dynamics of canine introduction to Manihiki and Rakahanga and how dog management on the atolls compares to other islands in the Pacific. I do this to understand how the environmental setting and remoteness of islands affected the importation and extirpation of domesticates. I compare the data from Manihiki and Rakahanga with archaeological and ethnohistoric data for 35 islands or island groups in Remote Oceania.

This study reveals surprising patterns of dog introduction and loss while suggesting that island type, rather than distance between islands, is a strong predictor for dog loss. This chapter demonstrates that the environmental constraints of coral islands likely influence human decision making and environmental management practices. This implication suggests that the constraints of coral islands can have major impacts on human decision making, supporting the notion that the social and ecological management systems developed on coral islands are often tailored to the specifics of the land and the needs of the population.

In Chapter 4 my co-author Carla Hadden and I work to provide an avenue through which we can further investigate the processes of domesticate introduction and extirpation in the Pacific. We discuss and provide methods to overcome the difficulty of dating the arrival of people and domestic animals on Pacific Islands. While in Chapter 2 I use radiocarbon dates derived from botanicals to define a timeline of change on Manihiki and Rakahanga, in Chapter 4 my co-author and I look to directly confirm the presence of humans and dogs on Manihiki and Rakahanga by developing methods to directly assess the antiquity of terrestrial mammal bones and teeth. We define parameters for accurately dating terrestrial mammal remains on Pacific Islands through stable isotope analysis, Accelerator Mass Spectrometry (AMS), and Bayesian modelling. In doing so, we suggest that dogs likely accompanied the first humans to arrive on Manihiki and Rakahanga. These methods can be used on any Pacific island to confirm the antiquity of domesticate or human remains. This allows for a greater level of temporal accuracy in our attempts to understand human-induced landscape changes in the Pacific Islands.

In the conclusion of this dissertation (Chapter 5) I syntheses the results of the previous chapters and discuss the findings of the research as a whole. I demonstrate how the cultural sequence for Manihiki and Rakahanga, the patterns of dog introduction and loss found across the Pacific, and the dating protocols defined in Chapter 4 all contribute to our understanding of Manihiki and Rakahanga as an example of atoll sustainability and an example of wider patterns of adaptation. I stress that flexibility in cultural institutions and population-wide cooperation are key to developing sustainability out of ecological hardship and changing demographic conditions.

In Appendices A-E I present the archaeological survey, excavation, artifact, faunal, and chronometric data utilized in chapters 2-4. All identified site locations are presented in Appendix A. Stratigraphic and excavation data is presented in Appendix B. Appendix C contains descriptions and classifications for all of the human modified artifacts recovered from the 2015 survey and 2017 excavations. A complete species list for all excavated vertebrate faunal remains with NISP is provided in Appendix D. Finally, the 22 original AMS radiocarbon dates for NG001 and TK001 are provided in Appendix E. All primary zooarchaeological data is housed at the Georgia Museum of Natural History. All primary archaeological data is housed at the University of Georgia Laboratory of Archaeology.

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CHAPTER 2

SMALL-SCALE SUSTAINABILITY IN THE ATOLLS OF THE REMOTE PACIFIC[1]

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[1] Cramb, Justin and Victor Thompson. To be submitted to *The Journal of Anthropological Archaeology*

Abstract

The islands of Polynesia (Figure 2.1) have long been a focal point of research regarding human-induced ecological change and sociopolitical development (e.g., Hommon 2013; Kirch 2010a, 1997; Sahlins 1958; Steadman 1995). The complexities of sociopolitical change in these island environments are documented in large-island groups such as Hawaii, the Society Islands, and the Marquesas Islands (e.g., Kahn 2011; Kirch 2010a; Rolett 1998). Many small islands and small-island groups, namely coral atolls, however, lack the data to formulate a deep-time understanding of how political and ecological systems developed in these settings. This led to past interpretations of atoll dwelling cultures as developing social structures based on survival rather than the production of surplus identified in larger, high-island, settings (Sahlins 1958:234). However, atoll-dwelling cultures often enact cooperative strategies, alter landscapes, and develop creative solutions to the inherent limitations of coral island environments that go beyond survival alone. These strategies provide opportunity for sustainability through cooperation and creative resource management. Here we present the case of Manihiki and Rakahanga, a dual-atoll cluster in the Northern Cook Islands of East Polynesia. On these small and remote atolls, ancestral Polynesian practices engendered the development of an innovative dual-chiefdom political structure and a mass-migration-based system of sustainable resource management. The case of Manihiki and Rakahanga demonstrates how cultural institutions that rely on flexible leadership, creative resource management, and population-wide cooperative effort can aid in long-term population sustainability.

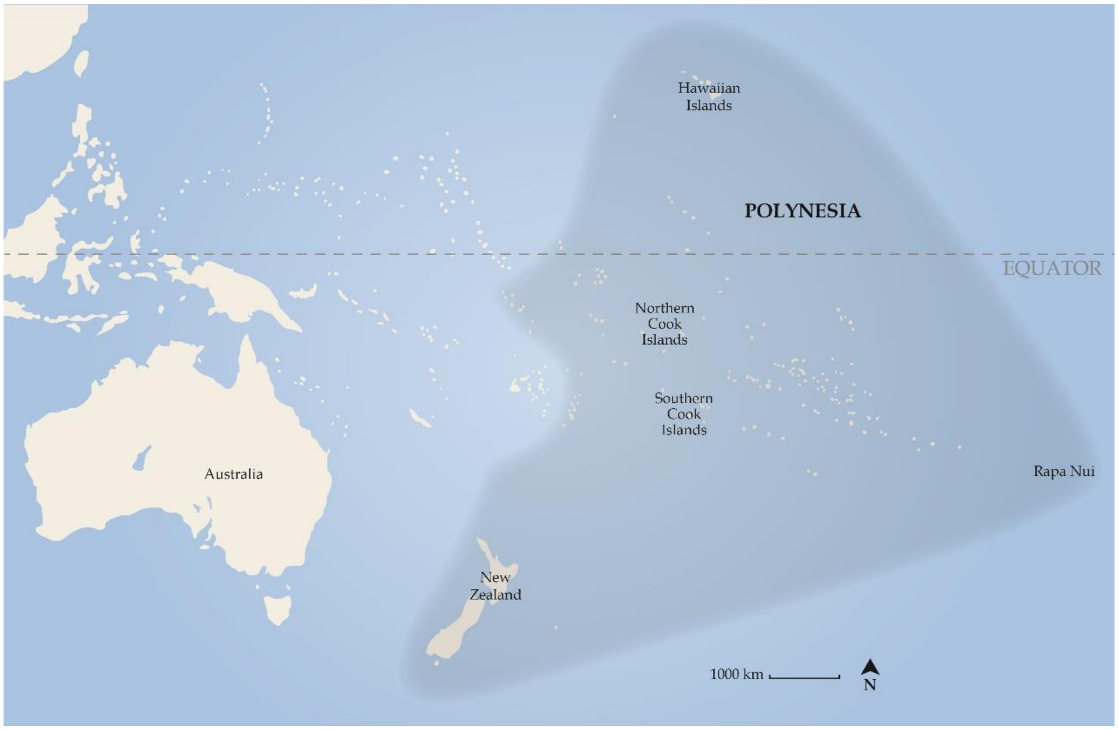


Figure 2.1. Polynesia

By the time Christian missionaries arrived in AD 1849, the people of Manihiki and Rakahanga were organized in a form that resembled other Polynesian systems of chiefly hierarchy in some respects but was widely divergent in others (Hiroa 1932). Oral histories and ethnohistoric accounts (e.g., Gill 2001[1871]; Hiroa 1932) suggest that Manihiki and Rakahanga were inhabited by a single people living in one village on a tiny Rakahangan islet called *Te Kainga*, literally meaning "the home." Hiroa (1932:59) states the that people were divided into four lineage groups. Two *Ariki* or chiefs oversaw these groups in a dual chiefdom or dual *Arikiship*. The people mitigated resource depletion on the small atolls through a system of cyclical migration. When resources ran low on Rakahanga, the entire population voyaged to Manihiki where they split into multiple villages. After some time, they would return to Rakahanga and reunite in the single village (Hiroa 1932:65-66). Maori authors later referred these migrations as the *Tûmutu* (Kauraka 1989; Tereora 1994).

Components of the pre-missionization fission-fusion system of the dual chiefdom and Tûmutu migrations seem to be local developments. However, there are parallels with other traditions in the region and around the world. These similarities and differences with other systems make Manihiki and Rakahanga an interesting case study by which archaeological interpretations of dispersed and aggregated settlement patterns can be evaluated.

Here we present the first archaeological timeline of social and ecological change over the entire occupation of the Manihiki and Rakahanga. We incorporate AMS dating, historical documentation, and oral histories to trace changes from first island colonization to Christian missionization while providing timeframes for the formation of the dual Arikiship and the Tûmutu. Through this research, three specific research questions are addressed. These are: 1) What is the timing and nature of habitation on Manihiki and Rakahanga?; 2) How do patterns of land and resource use on Manihiki and Rakahanga relate to the creation of the dual Arikiship?; and 3) How do patterns of land and resource use on Manihiki and Rakahanga relate to the development of the Tûmutu? In the concluding section, we consider what these histories regarding settlement, political cycling, resource use, and cooperation mean for the cultivation of sustainability in this socioecological landscape.

Polynesia and Traditional Institutions

Roughly 3,100-3,000 years ago the Lapita peoples, known for their distinctive dentate-stamped pottery, voyaged across the 380 km stretch of sea separating the Solomon and Santa Cruz Islands and entered the previously uninhabited islands of Remote Oceania (Petchey et al. 2014). Lapita voyagers colonized much of the western Pacific including Fiji, New Caledonia, and Vanuatu (Petchey et al. 2014). Lapita reached its eastern most point with the colonization of Tonga and Samoa 3000-2800 years ago (Burley et al. 2012; Burley and Dickinson 2001; Rieth et al. 2008). For reasons that are still debated (see Montenegro et al. 2014; Sear et al. 2020), the settlement of West Polynesia was followed by a roughly 2,000-year-long hiatus in eastward expansion known as the “long pause” (Kirch 2010b:140; Wilmshurst et al. 2011). During the long pause, societal changes in West Polynesia led to the emergence of ancestral Polynesian societies, the abandonment of pottery use, and the development of the Polynesian chiefdom political structure (Burley 1998:365; Kirch 2010b:140, 1984:51-52,68).

Eastward expansion began again around AD 900, and soon thereafter the islands of central East Polynesia (e.g., the Southern Cook Islands, Society Islands, Marquesas Islands) were colonized (Kahn et al. 2015; Sear et al. 2020; Stevenson et al. 2017; Wilmshurst et al. 2011). Sea-level lowering around this time exposed many of the reefs in the region leading to the formation of habitable sandy cays and atolls, including those of the Northern Cook Islands and Tuamotu Islands (Dickinson 2009; Nunn 2016:92). This environmental change created new opportunities for expansion as habitable land emerged in large expanses of the Pacific formerly devoid of islands. Climatological changes following AD 1150 may have also increased precipitation in the region making small and remote islands more favorable for colonization (Sear et al. 2020). Shortly after, or concurrent with, these environmental shifts a final voyaging push occurred in East Polynesia, and some of the most remote islands in the world were colonized (e.g., Hawaii, Aotearoa, and Rapa Nui [Wilmshurst et al. 2011:1816]).

Political Structures

Many of the voyagers that colonized the islands of East Polynesia crossed larger ocean gaps than their predecessors and became increasingly far removed from their ancestral homelands. The social traditions brought to East Polynesia included a flexible lineage-based, often-patrilineal, chiefly organization structure with a strong preference toward primogeniture (Kirch 1984:31-34). These ancestral systems were modified into new forms including the diminishment of chiefly power and the rise of inspirational priests in the Marquesas, and the emergence of archaic states in Hawaii (Kirch 2010a; Rolett 1998:44-45). In the low, newly formed, atolls of East Polynesia a wide variety of political systems emerged in relation to the geographies and ecologies found in atoll systems (Sahlins 1958:234-237). Sahlins (1958:237) argues that this variation is due to a lack of surplus food production as well as differential challenges found on different atolls and in different atoll groups. This may suggest that atoll dwelling populations have a different set of socioecological challenges including the management of reefs, tree crops, and long-lived cultivars such as swamp taro (*Cyrtosperma chamissonis*). These factors likely required cooperative management from segments of the population and played an important role in the development of atoll political structures. Numerous atoll polities developed political structures containing multiple levels of hierarchy and community participation through counsels or other structures. DeMarrais and Earle (2017) suggest that the shared need of a population may influence the development of social institutions geared toward collective action. The collective need to manage a small-scale resource base may have influenced the development of many atoll-oriented political institutions.

In the Tuamotu Archipelago, small-scale territorial polities united under a single "supreme chief" (Emory 1975:4-5). These polities maintained high mobility and practiced bilateral descent, an organizational form said to be related to ecological impoverishment and high frequencies of inter-polity conflict (Alkire 1978:105-107). Some groups, such as the Ana'a of the Tuamotus, may have comprised regional chiefdoms with force-based tributary structures (Dening 1962:110; Young 1899:268) and strong trade-based ties to the Society and Marquesas island groups (Dening 1962:122; Rolett 1998:259). Conversely, the remote atoll of Pukapuka in the Northern Cook Islands developed a three-tiered chiefly hierarchy with a sacred supreme chief, two tiers of sub-chiefs, and a counsel structure that afforded political voice to adult men (Beaglehole and Beaglehole 1938:234-235). This political system, with its high leader to commoner, ratio may have managed the social and ecological concerns of a geographically secluded and relatively dense population. An additional example of the political forms that developed in East Polynesia is Manihiki and Rakahanga, where a small, remote, population developed a dual-chiefdom political structure (Hiroa 1932:59) and a coral-cluster resource management system (Alkire 1978:94) linked to cyclical migration, innovative subsistence practices, population-wide cooperation, and fission-fusion political dynamics.

Sustainable Resource Use

Long-term persistence in a given landscape can pose challenges for those that inhabit small islands. Island size, resource availability, rainfall, and the choices made by the population can impact the ability, or desire, to persist on an island or in an island group. The sustainability of a population is defined as their ability to extract, replenish, and maintain the material and social resources needed in order to persist and grow (Millhauser and Morehart 2018; Wikan 1995) as well as the ability to prepare for, and mitigate, the effects of unforeseen events. This often involves protecting resources from overuse or utilizing less detrimental forms of resource production (McNiven 2015; Rolett 2008). Sustainability is argued to be the result of complex social and ecological process involving resource use and production as well as human agency and the desire or ability to persist in a given location (Millhauser and Morehart 2018). Achieving sustainability on islands often requires landscape transformations as well as the careful management of terrestrial and marine resources. It also involves the development of strategies to extend resource bases and buffer against risk (McNiven 2015). While many Polynesian groups developed strategies to live sustainably on small islands, numerous islands and island groups were abandoned by European arrival (Bellwood 1979:352; Irwin 1992:176; Kirch 1988). So, it is important to understand the processes through which humans transformed and managed small islands to ensure the sustainability of their socioecological landscapes.

The East Polynesian founding groups were undoubtedly aware of the challenges posed by the occupation of new islands. They brought with them plants and animals that enabled the transformation of their new environments. These include four domestic or commensal animals - the chicken (*Gallus gallus*), the dog (*Canis familiaris*), the pig (*Sus scrofa*), and the Pacific rat

(*Rattus exulans*) (Anderson 2009) as well as numerous plants including breadfruit (*Artocarpus altilis*), pandanus (*Pandanus* spp.), swamp taro (*Cyrtosperma chamissonis*), and possibly some varieties of coconut (*Cocos nucifera*) (Whistler 1991). In some cases, new settlements and species introductions caused mass extinctions of native fauna (Kirch 1997; Steadman 2006).

The settlers of Polynesia likely shared social rules regarding the management of certain ecological resources. The practice of *rahui* in one form or another, is prevalent throughout East Polynesia (Bambridge 2016). Rahui is a system of ritualized resource prohibition or protections and is typically viewed as a way to preserve fragile resources or to develop a stock of resources for emergency use (Crocombe 1964:118). Portions of the land and sea are placed under protection by a governing body. People can be punished for breaking the rahui; however, when want or need arises, such as before a feast or during a famine, a governing body (e.g., chief or council) could lift the rahui and allow access to resources (Hiroa 1934:141). This allows for the growth and live storage of plants and animals. Rahui is still in use today (Bambridge 2016) and is often coded into law. In the past, as we will discuss, people on Manihiki and Rakahanga seem to have taken rahui practices one step farther, by placing an entire atoll under protection only allowing access through the Tûmutu. This system has its roots in rahui traditions and reflects cycling patterns of aggregation and dispersal in other societies in Polynesia and beyond.

Aggregation, Dispersal, and Fission-Fusion Dynamics

Processes of aggregation and dispersal are common and manifest in a wide range of settings around the globe (e.g., Balikci 1970; Blitz 1999; Chagnon 1997; Lee 1979; Tuzin 2001). Population aggregation can take many forms ranging from the gathering of nomadic groups around a common resource to the coalescence of dispersed villages and culturally diverse groups into larger communities (Birch 2012; Kowalewski 2006; McNiven 2015; Nisengard 2006). Aggregation generally refers to the physical movement of people out of a dispersed state of settlement and into a common location (Adler 1994:85; Cordell 1994:79). Dispersal alternately references the fissioning or fracturing of settlements into smaller independent communities (Turner 1957:169). Aggregation and dispersal are defined based on ethnographic data and archaeologically visible changes in regional homogeneity, settlement organization, house forms, mortuary practices, and trade networks (Parkinson 2002:393).

The aggregation and dispersal of human settlements are often correlated to a number of situation dependent social and environmental factors occurring at time scales ranging from sub-annular to supra-millennial (Adams 1961; Beck 2003; Graves et al. 1982; Lepofsky et al. 2005; Parkinson 2002; Ritchie et al. 2016; Steward 1955; Wilkinson et al. 2004). Aggregation practices can represent cultural flexibility (Nisengard 2006:27) and tend to be associated with intensification in resource production (Adams 1961; Graves et al. 1982) and social engagement (Lee 1979:446-447; Nisengard 2006:22). Aggregation of this nature does not necessarily mean integration between the population segments of aggregated communities (Nisengard 2006:22). Rather, population centers may include a number of political factions drawn together by external threats (Steward 1955:167; Tuzin 2001), responses to environmental stress (Longacre 1966:97), or to take advantage of improvements in resource production (Childe 1950). This suggests inter-polity and intra-polity cooperative effort toward a common goal.

Cyclical patterns of settlement aggregation and dispersal or oscillations can be related to patterned cycles of political change (Anderson 1994). Anderson (1994:1) argues that certain political structures, namely chiefdoms, are prone to cycling or cyclical fluctuations in level of authority. These fluctuations often occur in concert with population movements (e.g., aggregation or dispersal). Cyclical patterns of aggregation, dispersal, and subsequent re-aggregation do not represent exact cycles of oscillation between preset forms, but rather patterns of aggregation and dispersal related to, and embedded within, changing historical trajectories (Parkinson 2002:431). Diachronic patterns of aggregation and dispersal can also define the long-term social and ecological strategies of a polity as cyclical fission-fusion processes may serve to increase social cohesion and cooperation, alleviate social pressure, or address ecological and economic stress (Blitz 1999; Hally and Chamblee 2019; Ritchie et al. 2016). Aggregation and dispersal represent strategies associated with the mitigation of specific and situation dependent social and ecological challenges. Additionally, these processes provide opportunities for political restructuring, the development of hierarchical and heterarchical power structures, the development of new technologies, and the use of un-tapped resources.

Fissioning and fusing are essentially cooperative acts that require a level of community cohesion. The size of the polity, the ability of political leaders to ensure cooperation, as well as group trust and cohesion may affect the ability of a group to act cooperatively (DeMarrais 2016). Concomitant cyclical fission-fusion processes associated with dispersals and aggregations, often represent successful, cooperative sociopolitical strategies capable of mitigating environmental and social stress. The fission-fusion histories of Manihiki and Rakahanga provide a case study by which to evaluate the nature of such dynamics, and its environmental conditions provide insight into the varied ways that such traditions were employed to solve challenges.

Coral Atoll Life

Though highly variable in their age, size, composition, and remoteness, coral islands are arguably among the most precarious and marginal landforms for humans on the planet (Dickinson 2009:4; McNiven 2015; Weisler 2001a:1, 2001b:31; Yamano et al. 2007:409). Comprised of topographically low islets with poor-coral soils, atolls lack certain raw materials (e.g., stone, clay, and large amounts of timber) and possess limited terrestrial biodiversity (Alkire 1978:1; Weisler 2001a:3). Due to the sparseness of resources, many atoll populations relied upon on either imported materials or crafted tools from available resources, such as wood, bone, shell, and coral. Surface water is absent from atolls, and potable water is only accessible through rain catchment or by excavating into the Ghyben–Herzberg fresh, often brackish, water lens, which sit above the dense saltwater that permeates the porous coral of atolls (Thomas 2009:569).

While atolls present a variety of challenges, one of the most important aspects of these islands is their range of highly productive marine environments (e.g., lagoon, reef, offshore, etc.,). Atolls often have an abundance of fishes, as well as sea turtles and marine invertebrates. As such, atoll subsistence is typically based around the procurement of these marine resources. In addition, there are a number of food crops that can be cultivated on coral islands including tree crops (e.g., coconut [*Cocos nucifera*], pandanus [*Pandanus* spp.], and breadfruit [*Artocarpus altilis*]) and swamp taro (*Cyrtosperma chamissonis*) which is grown in cultivation pits excavated into the atolls' fresh water lenses (Weisler 2001b:7). Swamp taro is an aroid of the family Araceae and can grow continuously for years (Thomas 2019). Giant swamp taro plants (*puraka*) grow today with no human intervention in long-abandoned cultivation pits on Manihiki Atoll. This suggests that puraka pits can be abandoned for years or decades and will continue to grow.

Early coral atoll settlements are typically located near the center of the largest islet of the atoll (Thomas 2009:582; Weisler 1999:638). Subsistence and habitation patterns are often related to the greater configuration of the landscape with geographically proximal atolls and islands acting as extensions of the home islet or island resource base (Alkire 1978; Di Piazza and Pearthree 2001). Thus, despite the environmental hardships posed by atoll life, possibilities for the mitigation of challenges exist through landscape transformation, as well as traditional and innovative subsistence practices.

The History of Manihiki and Rakahanga

Located in the Northern Cook Islands (Figure 2.1), the small equatorial atolls of Manihiki and Rakahanga have a combined landmass of 9.5 km^2 and a highest elevation of roughly four meters above sea level (Taporoporo 2012a:5, 2012b:5). Today both atolls are covered in coconut groves, and Rakahanga has large swamp taro pit-fields. Both atolls have numerous stone-walled fish traps that are located in the shallow channels that connect the lagoons to the ocean. Together Manihiki and Rakahanga comprise a geographically secluded coral cluster (Alkire 1978) consisting of two atolls which are 350 km from the nearest neighboring atoll, and over 900 km from the nearest high island.

Information regarding the past lifeways of the people of Manihiki and Rakahanga is derived from ethnohistoric, ethnographic, and archaeological sources as well as oral histories. European accounts of Manihiki and Rakahanga begin in AD 1606 with the arrival of the Spanish explorer Pedro Fernandez de Quiros. Quiros and his crew moored off the coast of Rakahanga and interacted with the islanders. Eventually the encounter turned violent. The sailors went ashore and killed numerous people. Despite this violence, members of Quiros' crew recorded information about the people and environment of the atoll (Burney 1803-1817; Kelly and Parsonson 1966; Markham 1923). In AD 1849, over 200 years after this first encounter, missionaries arrived on Manihiki and Rakahanga. In AD 1852 the Reverend W.W. Gill arrived on the atolls. Gill had a strong penchant for recording the lifeways of the populations that he meant to convert to Christianity. His works include documentation and interpretation of Indigenous lifeways, descriptions of island environments, the recordation of oral histories, as well genealogical and demographic information. While Gill's descriptions and insights provide a wealth of information regarding the populations of Manihiki and Rakahanga, as well as other islands, they are colored by his goals and desire to bring Christianity to the people of the South Pacific. Following Gill's descriptive works the New Zealand Maori ethnologist Te Rangi Hiroa, also known as Sir Peter Buck, recorded life ways on Manihiki and Rakahanga in the 1920s. Hiroa was a very accomplished scholar who conducted cultural studies on islands across the Pacific. He eventually became the Director of the Bishop Museum in Hawaii (Kirch 2017:21). Hiroa documented many aspects of contemporary and past lifeways on Manihiki and Rakahanga by recording extant practices and oral histories. This includes narratives regarding the formation of the dual chiefdom to which he assigned a date range by tracing genealogies. He also documented the foods eaten by the population as well as the function of the Tûmutu in allowing for resource sustainability.

Hiroa's work on Manihiki and Rakahanga is an invaluable resource that holds great meaning to the people of the atolls today. Though it should be noted that Hiroa only spent three weeks on Rakahanga and two days on Manihiki before moving on to Penrhyn Atoll. This brevity of time on the atolls undoubtedly limited his ability to record information about many aspects of culture and the landscape of the atolls.

Oral histories suggest that Manihiki and Rakahanga were colonized from Rarotonga in the Southern Cook Islands. If this is the case, then the original political form on Manihiki and Rakahanga may have resembled that found in the Southern Cook Islands. Ethnohistoric research suggests that Rarotonga was governed by three chiefdoms each of which was led by an Ariki or hereditary chief who controlled a district of the island (Gilson 1980:6). These groups are said to have originated from different *Vaka* or canoes of settlers from different origins, and thus each faction claimed decent from a different ancestral line (Crocombe 1964:31-34). The Arikiships were independent of each other but came together as a whole and cooperated on ceremonial occasions (Gilson 1980:6). The island of Mangaia, 200 km southeast of Rarotonga, was also home to a multi-factional organization structure where multiple chiefdoms existed on the same island. The Ariki whose chiefdom proved dominant in war reigned over the whole of the island and controlled the distribution of resources until the next period of warfare arose (Sahlins 1958:58-59). These examples demonstrate the commonality of social organization patterns involving multiple chiefs on a single island and tentative inter-polity cooperation. If the original inhabitants of Manihiki and Rakahanga arrived from the Southern Cook Islands, then it is likely that they had knowledge of the same ancestral forms that gave rise to the chiefdoms of the Southern Cook Islands. Hiroa (1932:43) suggests that this knowledge was brought with the first settlers who maintained some aspects of the political system from their homeland, though they eventually developed new political forms.

Oral traditions collected in the late 1800s suggest that the first inhabitant of Manihiki and Rakahanga, Huku, was met by a barren terrestrial landscape that was “scarcely above the face of the sea…” (Gill 2001 [1871]:128; 1915:148-149). These oral traditions stand in contrast to reports from the early 1900s that document a verdant terrestrial landscape on Manihiki and Rakahanga (Hiroa 1932:83-84, 92-97). The contrast between these descriptions suggests that Manihiki and Rakahanga were settled shortly after the islets emerged. An estimated population of 1,200 individuals (~126 per km^2) dwelled on Manihiki and Rakahanga when missionaries arrived in AD 1849 (Gill 2001 [1871]:127). Despite the atolls’ increased productivity, the resource base of each atoll, individually, was not sufficient to support this dense population in the long-term.

Hiroa (1932:4) states that in the 1800s the population of Manihiki and Rakahanga lived on the islet of Te Kainga, Rakahanga. However, in times of stress, the islanders implemented a system of ritual migration - the Tûmutu (Kauraka 1989:1; Tereora 1994). In this mass migration system, the entire population relocated to Manihiki where they dispersed into multiple villages. Once the resource base of Rakahanga regenerated, they returned to Te Kainga (Di Piazza 2005:70; Gudgeon 1901:33; Hiroa 1932:65-66). Similar, but equally divergent, practices of inter-island movement related to resource management can be seen in other island groups, such as the Line and Tuamotu Islands (Alkire 1978; Di Piazza and Pearthree 2001).

The oral traditions of Manihiki and Rakahanga trace modern ancestry to one family. They state that, following his arrival, Huku planted the first coconuts on the atolls and returned to Rarotonga. Eventually he sent his kin Toa and Tapairu to care for the atolls (Hiroa 1932:19; Gill 1915). The entire population of Manihiki and Rakahanga is said to have descended from Toa and Tapairu. Toa, as the founding male of the islands, commanded the title of Ariki that he passed to his descendants. Hiroa (1932:57) indicates that within a few generations Te Kainga became a village with the families of two of Toa’s sons Matangaro and Hukutahu forming housing clusters.

The title of Ariki was held by the head of the Hukutahu line (Hiroa 1932:57). A boundary stone was erected to mark the spatial divisions between the two groups (Hiroa 1932:59).

The founding of the first villages on Manihiki took place at an unknown time and there is mystery surrounding their use. Hiroa gives some insight into the timing of settlement on Manihiki by suggesting that a *marae* or meeting place was built on the islet of Tauhunu during the seventh generation following Toa (Hiroa 1932:206). By the tenth generation, formalized subgroupings had developed within the two lineages leading to further separations in settlement. This process of sub-group fissioning or ramification is typical in Polynesian societies and is often associated with the colonization of new territories (Kirch 1984:32). At this time four named subgroups or *matakeinanga* lived on Te Kainga in separated housing clusters under a single Ariki. In the eleventh generation, the Ariki Tautape had sons from two wives. The eldest son of the first wife would normally have claim to the Ariki title, but two of the four subgroupings placed their support behind the son of the second wife. A compromise was struck, and the single Ariki title divided into a dual Arikiship, under the control of two chiefs, each of which held divine and secular powers (Hiroa 1932:22,57). While on Rakahanga, all four subgroupings and both Ariki lived in Te Kainga. When they traveled to Manihiki, Hiroa indicates that they split into two villages each led by one Ariki (Hiroa 1932:65-66). This pattern of mass fissioning and fusing from nucleated to dispersed settlements appears to be a local development that required polity-wide cooperation and likely worked to reduce social and ecological stress, but the details of its origin are unclear in the extant literature.

The Archaeology of Manihiki and Rakahanga

Archaeological investigations on Manihiki and Rakahanga began in the 1980s and consist of excavations on three islets and selective archaeological survey across the atolls (Chikamori et al. 1991; Di Piazza 2005; Yamaguchi 1998). This research determined that Rakahanga possessed a single nucleated village on Te Kainga. The other, larger, islets of Rakahanga appear to have been devoted farming. In contrast, Manihiki contained multiple villages, each located on a large islet. Some of these were adjacent to small cultivation pits. The previous teams excavated at numerous sites including on Te Kainga, Rakahanga (TEK and RAK-1) as well as Porea (MNH-9) and Hakamaru (MNH-7) Islets on Manihiki (Figure 2.2). While the teams provided numerous radiocarbon dates for the occupation of these villages, the nature and timing of the habitation of the atolls, as well as the formation of local cultural institutions, remained unclear.

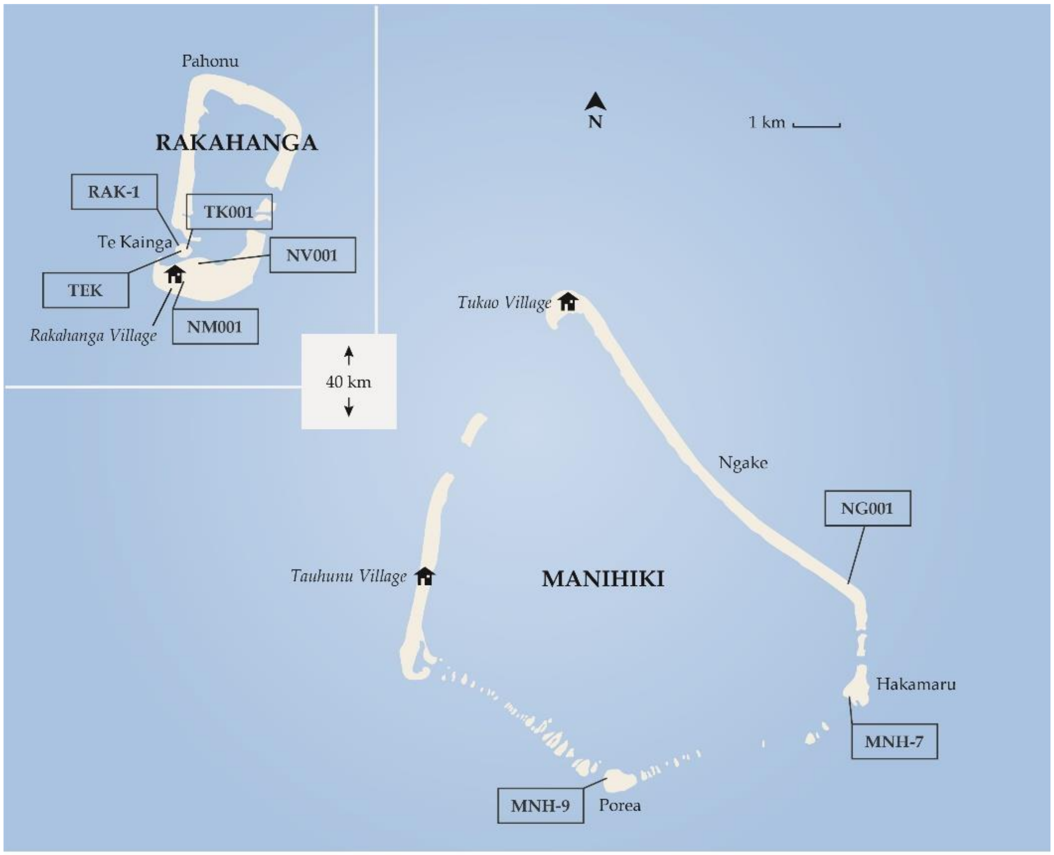


Figure 2.2. Map of Manihiki and Rakahanga with excavation areas

Archaeological Survey

Our team renewed archaeological efforts on Manihiki and Rakahanga in 2015 and 2017 to identify, excavate, and date habitation and cultivation sites on each atoll. In 2015, Cramb conducted semi-structured interviews on Manihiki and Rakahanga with elders and others knowledgeable in local history. The interviews were designed with two goals: 1) to collect local information regarding the presence, antiquity, location, and purpose of former villages; and 2) to identify mutually interesting research questions that could be answered through archaeological research. Using insights from these interactions, we developed and completed a purposive pedestrian survey to investigate places likely to have evidence of past land use (Appendix A).

As suggested in reports, oral traditions, and ethnohistoric narratives, the survey indicated that Rakahanga appears to have had one nucleated settlement, while Manihiki had many dispersed villages. Informants on Rakahanga suggest that a centralized government oversaw the management of a large communal taro field/ coconut grove system on islets other than Te Kainga. *Tapus* or laws were in place to ensure that the lands outside of Te Kainga were preserved for the cultivation of food (Hiroa 1932:66). These pit fields and groves were separated by water from the residential islet Te Kainga. Informants told of strict curfews, enforced by the Ariki, that required that people living on Rakahanga returned to Te Kainga each night and they could only return to the other islets during the day. The survey also documented the presence of numerous fish traps on both atolls and a single large fishpond on Manihiki. There is currently no way of determining the antiquity of these features, but it is likely that past populations used these or similar structures.

Based on the results of the survey we tested three possible habitation sites, one on Manihiki (NG001) and two on Rakahanga (NV001, TK001), with shovel-excavated test pits (Figure 2.2). We positioned larger units on Ngake islet, Manihiki (NG001) and Te Kainga islet, Rakahanga (TK001) based on the test-unit survey (Appendix B). The purpose of these excavations was to: 1) collect samples for radiocarbon dating; 2) evaluate the stratigraphic sequence for some of the larger habitation sites; and 3) collect samples for faunal analysis to evaluate shifts in resource use. Each of these different lines of evidence, when coupled with oral histories and ethnohistoric documents, allows for the evaluation of landscape change and fission-fusion dynamics of Manihiki and Rakahanga.

Stratigraphy and Land Use Histories on Manihiki and Rakahanga

The NG001 site on Ngake Islet possessed dense surface features including four coral-edged courts, a well, and a near-by puraka pit (Appendix A). The stratigraphic sequence of NG001 mirrors those identified by Yamaguchi (1998) on other islets of Manihiki and possesses relatively simple stratigraphic layering. Artifact density was low, only TU12 and unit A-1 produced human-modified artifacts. These include fishhooks and possible adornments (Appendix C). The densest cultural deposits occurred in Layer III of units B-1 and C-1 and included an earth oven and midden deposits. The superior layers contained faunal materials indicating site use, but there was no evidence of intensive cultural activity.

The TK001 site produced numerous artifacts and extremely dense and discontinuous stratigraphic layering (Appendices B-C). This is likely a result of deposition processes caused by changes in sea level, wash-over events, and differential cultural practices, including frequent periods of abandonment or lessening of use. The TK001 excavation yielded a much higher density of faunal materials and artifacts than the NG001 excavations, suggesting more intense/ frequent occupation.

Faunal Resource Use on Manihiki and Rakahanga

The excavations produced 43 kg of faunal materials (Appendix D). At this time, analysis is limited to the vertebrate remains which were analyzed by Cramb. Bird remains were extremely scarce in all of the assemblages; however, the remains of fishes, sea turtles, rats, and dogs were common. Oceanic peoples transported chicken, dog, pig, and rat to Polynesia (Anderson 2009).

Hiroa (1932:83) however states that pig, dog, and chicken were unknown to the people of Manihiki and Rakahanga in the 1900s. Pig, chicken, and rat, as well domestic cats, live on Manihiki and Rakahanga today, dogs however are illegal. Rat remains were present throughout the stratigraphic sequences of TK001 and NG001. One dog (*Canis familiaris*) element was found at NG001 and 33 dog elements were identified throughout the stratigraphic sequence at TK001. Pig (*Sus scrofa*), chicken (*Gallus gallus*), and cat (*Felis domesticus*) were only present in historic or intrusive contexts. Of the imported animals, only dog and rat are in definitively pre-European contexts though dog must have been extirpated before missionization. Pig, chicken, and the domestic cat likely were introduced after sustained European contact in the 1800s.

When humans first arrived on Manihiki and Rakahanga, they likely had a tradition of relying heavily on local animals including fish and birds. Bird remains are extremely scarce in the Manihiki and Rakahanga assemblages, however. This may be due to the late emergence of the atolls, resulting in an underdeveloped bird population. The relative absence of birds in the Manihiki and Rakahanga assemblages also may be a sampling bias as the earliest data from Rakahanga are from a single test unit and the NG001 site may post-date the earliest occupation on Manihiki. Details of faunal remains from earlier excavations were not reported in detail. Regardless, birds are only minor components of the later assemblages from both atolls.

While fragmentary sea turtle remains were common, they were not overly abundant, and the number of individual turtles represented is low. Local informants suggest that turtles were cooked in special locations. Other archaeologists (Chikamori et al. 1991; Di Piazza 2005) have identified, and in the case of Chikamori excavated, “turtle mound” features on Rakahanga. Chikamori and colleagues (1991:20) states that Polynesian peoples “cooked turtles near a marae and ate their meats at the time of rituals.” This information suggests that it is unlikely that large quantities of turtle remains will be identified in domestic refuse on Manihiki or Rakahanga.

In-shore and reef fish species were by far the most common vertebrate remains in the assemblages, which suggests they were the primary source of animal protein in the diets of people on Manihiki and Rakahanga. Parrotfishes (Scaridae) dominate the assemblages followed by triggerfishes (Balistoidea), Porcupinefishes (Diodontidae), and Sea Basses (Serranidae). The remains of larger pelagic fishes such as tuna (Scombridae) are present but rare (for a list of taxa see Appendix D). The numerous stone-walled fish traps discussed in the ethnohistoric accounts (Hiroa 1932:159) and visible on the atolls today further suggest the importance of inshore and reef species. Combined with site stratigraphy and AMS dating these assessments of faunal resource use further our understanding of past lifeways and key events on the atolls.

Radiometric Dating of Manihiki and Rakahanga

The previous researchers working on Manihiki and Rakahanga produced a number of radiocarbon dates that provide some temporal anchoring for events in the Manihiki and Rakahanga past, but alone they do not provide a narrative of site use. We compiled all available archaeological data and radiocarbon dates from the two teams that have worked on the atolls previously (Chikamori et al. 1991; Di Piazza 2005; Yamaguchi 1998; Yamaguchi et al. 2009). We put chronometric hygiene protocols in place to eliminate unreliable dates and removed all dates from marine sources and sources that may have required marine calibration, such as terrestrial mammal that may have eaten fish. This is not to say that there is not value in these dates, just that their use was beyond the scope of this analysis. We removed all dates that were not clearly associated with cultural contexts in stratigraphic excavations or stated to be cultural in nature. We also removed all dates with error ranges of ± 100 years or more. Finally, we removed all dates from mix context. While not as stringent as some recent works (e.g., Wilmshurst et al. 2011), these protocols were meant to reduce error, while making the most of the existing data.

We ran a total of 22 additional AMS radiocarbon dates on samples from the 2017 excavations at the Center for Applied Isotope Studies at the University of Georgia following standard protocols (Chapter 4). We chose botanical, shell, and terrestrial mammal samples from disparate contexts from NG001 and TK001 (Table 2.1) to enable a holistic view of the complex stratigraphy of the atolls. We selected short-lived botanical samples including charred coconut (*Cocos nucifera*) endocarp and charred *Pandanus* spp. drupes for dating. These plant parts represent growth of one year or less and therefore negate possible inbuilt age effects. We selected and documented samples following best practice standards (Allen and Huebert 2014). The marine shell and mammal samples were chosen as part of an additional study meant to confirm the presence of domestic animals on Manihiki and Rakahanga before European contact (Chapter 4).

Table 2.1. New and existing AMS dates on Manihiki and Rakahanga

Laboratory Sample ID	Unit/ Layer	Material	Collagen Yield %	δ13C ‰	δ15N ‰	C:N Ratio	14C Age BP	Calibrated Date Range AD 68.2 % **	Calibrated Date Range AD 95.4 % **
MNH-7	As reported in Yamaguchi 1998; Yamaguchi et al. 2009								
PLD-5831	*	UID Charcoal	-	-	-	-	605 ± 25	1305-1397	1297-1405
N6149	4/ I-4	UID Charcoal	-	-	-	-	400 ± 75	1437-1629	1410-1649
N6145	3/ I-4	UID Charcoal	-	-	-	-	380 ± 70	1447-1630	1425-1648
N6148	4/ I-4	UID Charcoal	-	-	-	-	330 ± 70	1490-1640	1435-1948
N6147	4/ I-4	UID Charcoal	-	-	-	-	400 ± 70	1437-1625	1417-1644
N6146	4/ I-3	UID Charcoal	-	-	-	-	400 ± 70	1437-1625	1417-1644
MNH-9	As reported in Yamaguchi 1998								
N5864	A/ 3	UID Charcoal	-	-	-	-	330 ± 75	1486-1641	1430-….
N5866	A /3	UID Charcoal	-	-	-	-	250 ± 70	1519-….	1461-….
N5867	C/ 2	UID Charcoal	-	-	-	-	200 ± 70	1643-….	1522-….
NG001	This work								
UGAMS 35654	B-1/ III	*Pandanus* spp. drupe	-	-23.77	-	-	320 ± 20	1521-1636	1492-1643
UGAMS 35655	C-1/ III	*Pandanus* spp. drupe	-	-27.10	-	-	310 ± 20	1522-1642	1497-1646
UGAMS 40094	C-1/ I-II	*Cocos nucifera* endocarp	-	-25.1	-	-	140 ± 25	1680-1939	1669-1944
UGAMS 38551	C-1/ II	*Pandanus* spp. drupe	-	-24.75	-	-	100 ± 20	1697-1917	1691-1925
UGAMS 38555	B-1/ III	*Pinctada margaritifera*	-	+2.55	-	-	980 ± 20	-	-
UGAMS 40464	C-1/ II	*Sus scrofa* bone	3.8	-21.6	16.7	3.6	Modern	Modern	Modern
RAK-1	As reported in Di Piazza 2005								
BETA177249	II/ IVb	Mixed short-lived botanicals	-	-25.00	-	-	290 ± 60	1497-1661	1450-….
BETA176304	III/ IVb	*Pemphis acidula*	-	-25.00	-	-	360 ± 60	1459-1631	1442-1646
BETA177248	III/ IVb	Mixed short-lived botanicals	-	-26.00	-	-	380 ± 40	1448-1620	1441-1635
BETA177250	III/ IVb	Mixed short-lived botanicals	-	-25.00	-	-	330 ± 70	1490-1640	1435-1948
TEK	As reported in Yamaguchi et al. 2009								
PLD3918	*	UID Charcoal	-	-	-	-	830 ± 25	1189-1250	1165-1259
TK001	This work								
UGAMS 35651	A-1/ V.1	*Cocos nucifera* endocarp	-	-24.51	-	-	100 ± 20	1697-1917	1691-1925
UGAMS 35650	A-1/ III	*Cocos nucifera* endocarp	-	-24.91	-	-	100 ± 20	1697-1917	1691-1925
UGAMS 35652	A-1/ V.2	*Cocos nucifera* endocarp	-	-25.02	-	-	100 ± 20	1697-1917	1691-1925
UGAMS 35649	A-1/ XIII	*Cocos nucifera* endocarp	-	-24.54	-	-	210 ± 20	1655- ….	1648-….
UGAMS 34018	A-1/ XIII	*Cocos nucifera* endocarp	-	-24.61	-	-	250 ± 20	1644-1664	1530-1799
UGAMS 38552	A-1/ V.2	*Pandanus* spp. drupe	-	-23.01	-	-	110 ± 20	1694-1917	1685-1928

UGAMS 35653	A-1/ IX-X	*Cocos nucifera* endocarp	-	-25.52	-	-	180 ± 20	1668-1950	1664-….
UGAMS 36970	TU5/ VIII-IX	cf. *Pandanus* spp. drupe	-	-25.20	-	-	310 ± 20	1522-1642	1497-1646
UGAMS 40095	TU8/ V-VII	*Cocos nucifera* endocarp	-	-23.60	-	-	660 ± 20	1286-1384	1281-1390
UGAMS 38553	TU5/ VIII-IX	*Pinctada margaritifera*	-	+2.28	-	-	810 ± 20	-	-
UGAMS 40097	TU8/ V-VII	*Pinctada margaritifera*	-	+1.3	-	-	810 ± 30	-	-
UGAMS 38554	A-1/ IX-X	*Pinctada margaritifera*	-	+1.64	-	-	750 ± 20	-	-
UGAMS 40096	TU8/ V-VII	*Canis familiaris* tooth	7.3	-12.2	19.6	3:3	850 ± 25	-	-
UGAMS 36967	TU5/ VIII-IX	*Canis familiaris* tooth	8.3	-13.6	18.8	3:1	740 ± 20	-	-
UGAMS 36968	TU10/ V	*Canis familiaris* tooth	7.2	-12.8	18.2	3:3	830 ± 20	-	-
UGAMS 36969	A-1/ IX-X	*Canis familiaris* tooth	10.6	-11.5	19.2	3:3	670 ± 20	-	-

* The two PLD dates are re-dates of the oldest context on Manihiki and Rakahanga therefore their provenience is presumed to be the deepest strata of MNH-7 and TEK. They are also assumed to equate to a human presence on the atolls.

** All botanical dates were calibrated in OxCal v4.3 using the IntCal 13 calibration curve (Bronk Ramsey 1995; Reimer et al. 2013). The calibrations and modelling of the marine and terrestrial mammal dates can be found in (Chapter 4)

Modelling Details and Results

We chose to include only botanical samples in the following Bayesian models as they present the lowest potential for error. Models were run in OxCal 4.3 (Bronk Ramsey 2009). As the excavations on Manihiki had relative continuity in the stratigraphic sequences at each site, we modelled each site as a sequence. Due to the complex and discontinuous stratigraphy on Rakahanga, we modelled each unit separately as a sequence based the relative stratigraphy (Appendix B). Dates from the same context were modelled as phases. We calibrated dates using the IntCal 13 calibration curve (Reimer et al. 2013) as it is argued that the SHCal curve created for the southern hemisphere may not be representative of the conditions found in tropical Oceania (Chapter 4; Petchey et al. 2014).

Manihiki

We placed all of the dates from Manihiki that passed chronometric hygiene into a Bayesian model. Dates known to be stratigraphically superimposed were modelled as sequences, and dates derived from the same layers or associated zones were modelled as phases. A recent re-dating of charcoal (PLD-5831) from Manihiki, likely form MNH-7 contexts, reported by Yamaguchi and colleagues (2009) provides evidence of a human presence on the atoll at 605 ± 20 BP or cal. AD 1305-1397. Though old wood considerations may indicate that these dates are slightly older than the actual burning events. We included this date in the model to account for possible early landscape modification and other cultural activity on Manihiki. We set a *terminus anti quim* of AD 1850 ± 10 to provide added constraint, as all of the sites dated are thought to have been abandoned by the time missionaries arrived. The components and results of the modelled dates from each Manihikian site are described below.

MNH-7 (Manihiki). The MNH-7 site (Figure 2.2) identified and excavated by Yamaguchi (1998) is located on Hakamaru Islet and described as a “dwelling space” (Yamaguchi 1998:36).

The stratigraphy of the site consists of three main strata (I-III) divided into sub-layers and a bedrock layer (I-IV). Yamaguchi dated each of the four layers, but only indicated cultural material in the top two strata. The date returned for the upper portion of Layer I (I-1), which was the nearest to the surface, indicated that the sample was modern. Dates from the lowest portion of the stratum (I-3 and I-4) including an associated earth oven feature returned dates of (N-6148) 330 ± 70 BP, (N-6145) 380 ± 70 BP, (N6146) 400 ± 70 BP, (N-6147) 400 ± 70 BP, and (N-6149) 400 ± 75 BP. The subdivisions of Layer II returned a wide array of dates ranging from 430 ± 70 BP to 730 ± 75 BP. However, there is no mention of cultural materials in Layer II other than a pit oven associated with Layer II-1. We modelled Layer I as a sequence with the four dates from layer I-4 as a phase within the sequence. The resultant model suggests that Layer I was in use at *cal. AD 1420-1650*. While the PLD-5831 date indicates an earlier presence on Manihiki it is likely that intensive occupational use of MNH-7 began following AD 1400.

MNH-9 (Manihiki). The MNH-9 site on Porea Islet, Manihiki excavated by Yamaguchi (1998) is named Te Marae based on the traditional name for the land. This could indicate a ceremonial purpose, but the structure of the site appears to indicate residential use. The site is 100 m inland and appears to be a residential area with wells, graves, surface structures, and adjacent puraka pits. Yamaguchi's team excavated five units and ran four radiocarbon dates - three on unidentified wood charcoal and one on a Tridacna shell. Excavations of Unit A at MNH-9 revealed well defined stratigraphy with four layers. No cultural materials were reported in Layer 1. Layers 2 and 3 contained pit and combustion features as well as *kirikiri* or coral gravel pavement. They ran two charcoal dates from materials in Layer 3. These dated to 330 ± 75 BP (N-5880) and 250 ± 70 BP (N-5866). An additional date was run on charcoal from a pit oven feature associated with Layer 2 in Unit C. This returned a date range of 200 ± 70 BP (N-5867). Based on the relative position of the layers and features we modelled the dates as a sequence with the Layer 3 dates in a phase. The model suggests that site occupation at *cal. AD 1480-1760.*

NG001 (Manihiki). Our team excavated the NG001 site at the south end of Ngake Islet Manihiki in 2017 as described in Appendix B. We ran radiocarbon dates on materials from units B-1 and C-1 which possessed similar stratigraphy. While neither unit produced cultural artifacts, both possessed a dark layer associated with intensive human activity roughly 40 cm beneath the current ground surface. In unit B-1 this layer (Layer III) consisted of a 15 cm deep earth oven feature that contained heat fractured coral, charcoal, and burnt shell. A charred *Pandanus* spp. drupe from B-1 Layer III (UGAMS 35654) returned a date range of 320 ± 20 BP. In unit C-1, Layer III was a midden deposit which contained dark sediments and a density of faunal materials greater than anywhere else on NG001. A charred pandanus drupe (UGAMS 35655) returned a date of 310 ± 20 BP. This indicates that the B-1 earth oven and C-1 midden were contemporaneous. We ran additional dates on Layers I and II of unit C-1 to understand site use following the deposition of the midden materials. A pandanus drupe and a coconut endocarp fragment returned dates of (UGAMS 40094) 140 ± 20 BP for Layer II and (UGAMS 38551) 110 ± 20 BP for the I/II interface. The four botanical dates were modelled as two phases with the B-1 earth oven and C-1 midden as a single phase and the C-1 layer I and II dates as a single phase. We modelled these dates sequentially. The resultant model suggests that the most intensive occupation of NG001 (Layer III) occurred at *cal. AD 1520-1650*. Less intensive land use (Layers I and II) appears to have persisted at the site until *cal. AD 1670-1750.*

Rakahanga

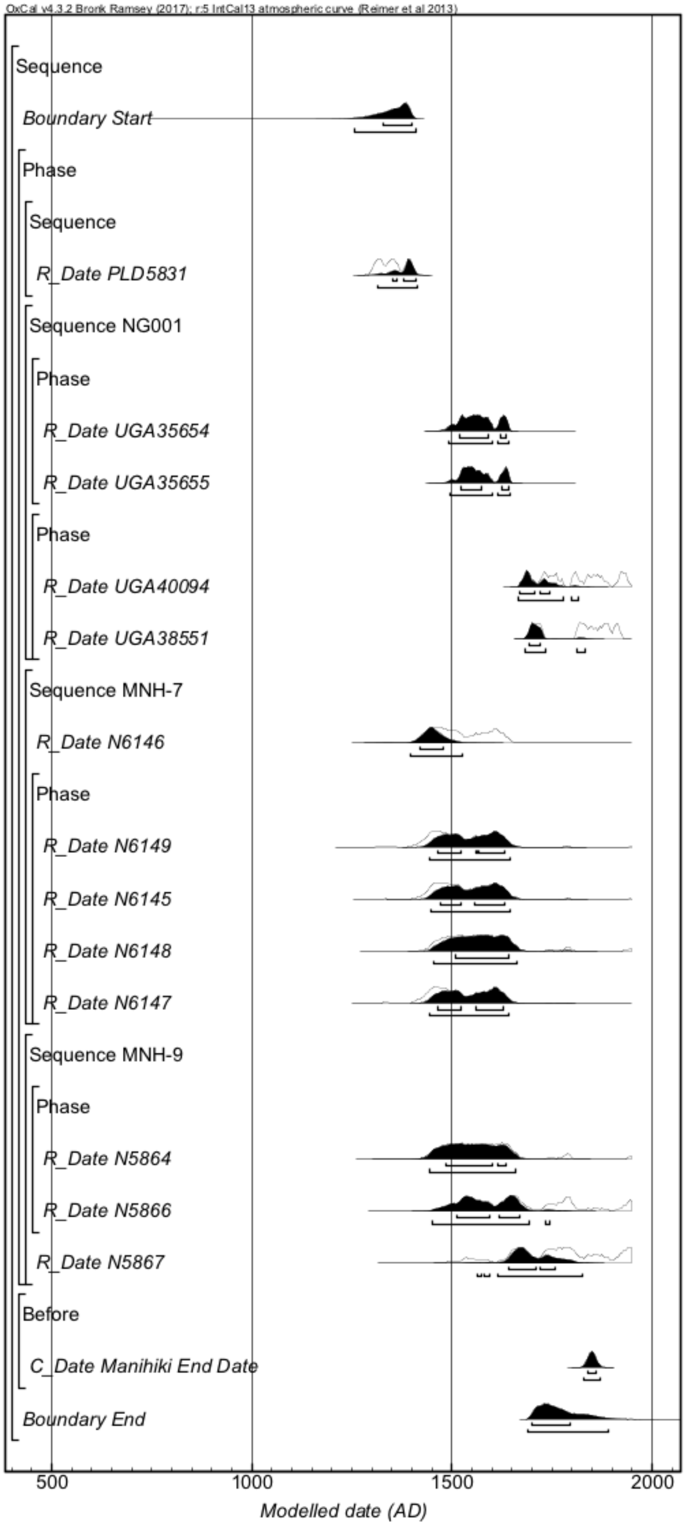
All of the dates from Rakahanga came from materials excavated on Te Kainga islet. We placed all of the dates that passed chronometric hygiene into a Bayesian model (Figure 2.3). Dates known to be in sequence stratigraphically were modelled as sequences, and dates derived from the same layers or associated zones were modelled as phases. A recent re-dating of charcoal (PLD- 3916) from TEK contexts on Rakahanga, reported by Yamaguchi and colleagues (2009) is evidence of a human presence on the atoll at 830 ± 25 BP or cal. AD 1189-1250. Though old wood considerations may indicate that these dates are slightly older than the actual burning events. We included this date in the model to account for possible early landscape modification and cultural activity on Rakahanga. We used a *terminus anti quim* of AD 1850 ± 10 to provide added constraint, as the village on Te Kainga was abandoned shortly following missionary arrival in 1849 (Hiroa 1932). The components and results of the modelled dates from Te Kainga are described below.

TEK (Rakahanga). The TEK site is located at the center of Te Kainga islet, Rakahanga. The site includes the 120 cm tall stone monument purported to have divided the different habitation areas on the islet. Chikimori and Yamaguchi (Chikimori et al. 1991; Yamaguchi 1998) excavated the site. Their report suggests that this is a site called Mua Marae, a marae site used by all four of the matakeinanga (Chikimori et al. 1991:21). Their team excavated four units and identified numerous pit features and stone alignments. Stratigraphic profiles and layer descriptions for the excavations are not available, but they reported numerous radiocarbon dates on charcoal and shell associated with stratigraphic layers. It is not clear which dates are associated with cultural deposits, and many of the dates reported fail the chronometric hygiene protocols due to error ranges exceeding 100 years. However, Yamaguchi and colleagues (2009) recently published the new date for the first occupation of the site discussed above– (PLD-3916) 830 ± 25 BP. When placed in the Rakahanga model (Figure 2.4) this suggests that the first human presence on Rakahanga began at *cal. AD 1210-1260*.

RAK-1 (Rakahanga). The RAK-1 site is also on Te Kainga, to the west of the TEK site. Di Piazza excavated RAK-1 in 2002 (Di Piazza 2005). The excavations produced large amounts of material culture and faunal remains and contained combustion features. The stratigraphy included five main strata. Di Piazza designated Layer IVb a habitation layer and ran four dates on short-lived botanicals from oven features and an associated charcoal lens (Di Piazza 2005:75-77). These dates include (Beta-177249) 290 ± 60 BP, (Beta-176304) 360 ± 60 BP, (Beta-177248) 380

± 40 BP, and (Beta-177250) 330 ± 70 BP. As all of the dates originated from the same cultural layer, we modelled them as a single-phase sequence. The model suggests a date range of *cal. AD 1440-1660* for this habitation layer.

TK001 (Rakahanga). Our team dated four units of TK001 - TU5, TU8, TU10, and Unit A-1 using AMS (See Appendix B). We chose these units based on clear evidence of cultural activity and the presence of short-lived charred botanicals. The materials that we dated included short-lived botanicals, marine shell, and terrestrial mammal bone. We chose the latter two material types for a separate study and did not include them in the following models (Chapter 4). Furthermore, only animal gelatin was dated from TU10, so the unit is not included in the following model. The stratigraphy of TK001 is complex and discontinuous so we treat each unit as a separate sequence. A single *Cocos nucifera* endocarp date from layer V/VI of TU8 returned the oldest dates at 660 ± 25 BP (UGAMS 40095). A single date on a pandanus drupe from layer VIII of TU5 dated to 310 ± 20 BP (UGAMS 36970). We modelled each of these dates as a sequence. Unit A-1 produced charcoal throughout the complex stratigraphic sequence. Three coconut endocarp dates from layers III and V returned ranges of 100 ± 20 BP (UGAMS 35650, UGAMS 35651, UGAMS 35652). A coconut endocarp sample from Layer IX returned a date of 180 ± 20 BP (UGAMS 35653) and a pandanus drupe sample from IX/X returned a date of 110 ± 20 BP. Two additional coconut endocarp fragments from Layer XIII returned the dates of 210 ± 20 BP (UGAMS 35649) and 250 ± 20 BP (UGAMS 34018). The resulting model indicates that the center portion of Te Kainga (TU5 and TU8) was inhabited before the coastal margins with TU8 having a modelled date range of *cal. AD 1280-1390* and TU5 having a modelled date range of *cal. AD 1520-1650.* Unit A-1 modelled to a date range of *cal. AD 1640-1840.* As the oldest dates for unit A-1 were derived from materials collected at the terminal depths of the unit, where bed rock was reached, this suggests that the paleo-shoreline of the islet was much further inland in the past.



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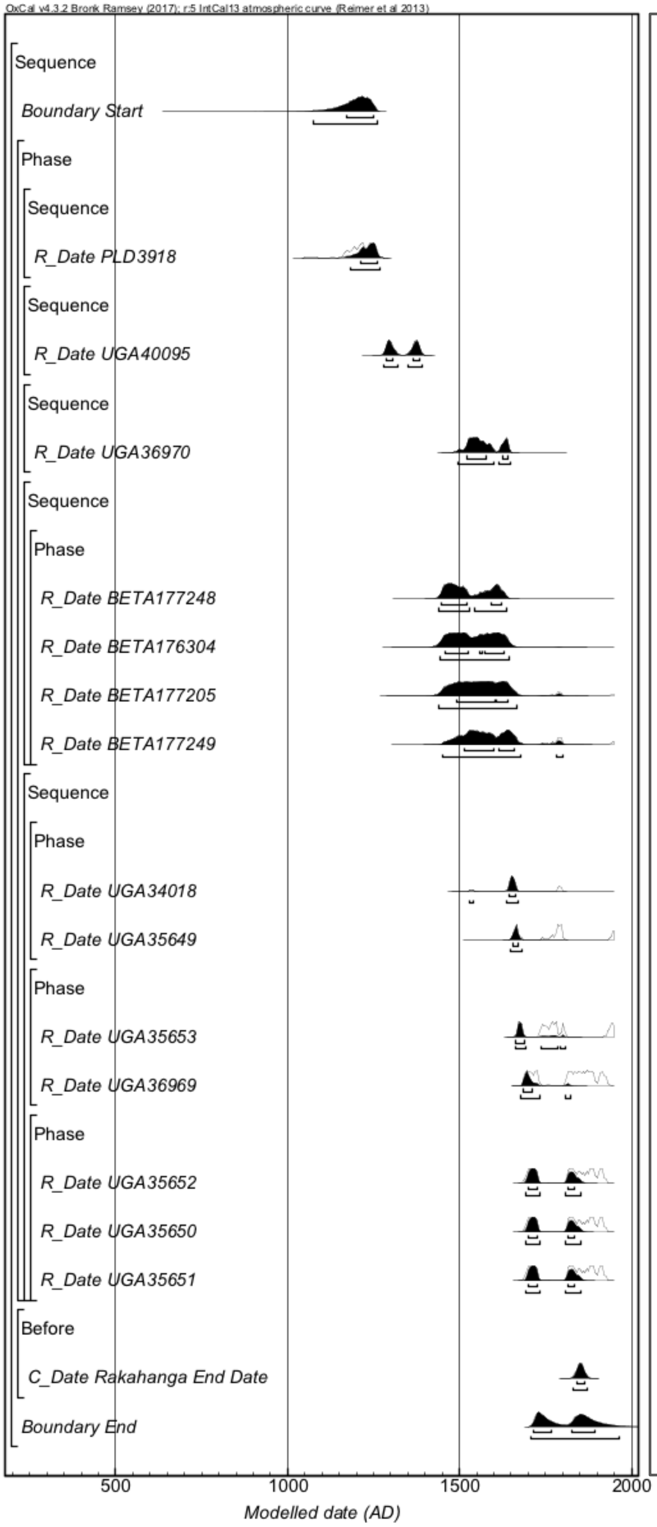
 {
  Sequence()
  {
   Boundary("Start");
   Phase()
   {
    Sequence()
    {
     R_Date("PLD5831", 605, 25);
    };
    Sequence("NG001")
    {
     Phase()
     {
      R_Date("UGA35654", 320, 20);
      R_Date("UGA35655", 310, 20);
     };
     Phase()
     {
      R_Date("UGA40094", 140, 25);
      R_Date("UGA38551", 100, 20);
     };
    };
    Sequence("MNH-7")
    {
     R_Date("N6146", 400, 70);
     Phase()
     {
      R_Date("N6149", 400, 75);
      R_Date("N6145", 380, 70);
      R_Date("N6148", 330, 70);
      R_Date("N6147", 400, 70);
     };
    };
    Sequence("MNH-9")
    {
     Phase()
     {
      R_Date("N5864", 330, 75);
      R_Date("N5866", 250, 70);
     };
     R_Date("N5867", 200, 70);
    };
   };
   Before()
   {
    C_Date("Manihiki End Date", 1850,
10);
   };
   Boundary("End");
  };
 };
```

Figure 2.3. Bayesian multi-plot output and code for the Manihiki model



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 {
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  {
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   Phase()
   {
    Sequence()
    {
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    };
    Sequence()
    {
     R_Date("UGA40095", 660, 25);
    };
    Sequence()
    {
     R_Date("UGA36970", 310, 20);
    };
    Sequence()
    {
     Phase()
     {
      R_Date("BETA177248", 380, 40);
      R_Date("BETA176304", 360, 60);
      R_Date("BETA177205", 330, 70);
      R_Date("BETA177249", 290, 60);
     };
    };
    Sequence()
    {
     Phase()
     {
      R_Date("UGA34018", 250, 20);
      R_Date("UGA35649", 210, 20);
     };
     Phase()
     {
      R_Date("UGA35653", 180, 20);
      R_Date("UGA36969", 110, 20);
     };
     Phase()
     {
      R_Date("UGA35652", 100, 20);
      R_Date("UGA35650", 100, 20);
      R_Date("UGA35651", 100, 20);
     };
    };
   };
   Before()
   {
    C_Date("Rakahanga End Date", 1850,
10);
   };
   Boundary("End");
  };
 };
```

Figure 2.4. Bayesian multi-plot output and code for the Rakahanga model

Genealogical Chronology of Manihiki and Rakahanga

To anchor events discussed in the oral histories from Manihiki and Rakahanga with archaeologically visible phenomena we turned to genealogical dating methods. By counting the number of generations and assigning time spans to each, genealogical dating allows for temporal estimations of events in a people's past, such as the founding of a new settlement. The use of chiefly genealogies to temporally place events in the past is well known in Polynesian cultures whose knowledge-keeping priests mentally recorded chiefly lineages (Hiroa 1932:20; Hommon 2013:212). According to Hiroa (1932:20), the founders of Manihiki and Rakahanga, Toa and Tapairu, however, brought no priests with them to record this knowledge so estimation of generations and lines of descent were kept by various individuals. In 1929, local knowledge keepers recorded these lineages as best they could. Hiroa (1932) relied on the genealogy of a man named Kairenga, who traced direct lineage to the founder Toa, to estimate the number of generations separating the twentieth century population from the founding population of Manihiki and Rakahanga. He suggested that 22 generations separated Toa from the extant population in the 1920s (Hiroa 1932:22). Another means of temporally situating events in the past, based on genealogy, was to trace parallel lineages of known figures from Rarotonga with the founders of Manihiki and Rakahanga. Gill (1915) proposed a tie between Tapairu and another figure in the oral traditions, Hiro. He suggests that Hiro is the grandfather of Tapairu, and that Hiro was a voyager from Havaiki, the legendary Polynesian homeland. Hiro was of the same generation as Tangiia of Rarotonga who is said to have lived 26 generations before the year 1900 (Gill 1915:149-151). The documentation of these generational counts combined with Hiroa's (1932) assertion that the dual Arikiship began in the twelfth generation provided the first recorded estimations of date ranges for the settlement of the atolls and the formation of the novel political system.

The time span assigned to each generation can vary based on the average age that an individual would produce their successor, in the case of Manihiki and Rakahanga, this was often their first son as primogeniture of the male line often determined succession (Hiroa 1932:43). Scholars working to date events in other parts of East Polynesia have used generational spans ranging from 20 to 30 years with a standard deviation of two years (Hommon 2013:213). This number can be refined through knowledge of average age of marriage in chiefly lines. However, in the case of Manihiki and Rakahanga, the recorded genealogies do not necessarily trace chiefly descent and it is difficult make an informed estimation of generational span beyond the 25 years proposed by both Hiroa (1932) and Gill (1915). Using a standard deviation of two years and a generational span of 25 years, Hiroa's methods produce a date range for the generation of Toa and Tapairu of AD 1336-1424 and Gill's methods result in a date range of AD 1198-1302. The dual Arikiship begins in generation twelve of Hiroa's chronology (with Toa and Tapairu as generation one), AD 1650-1690. Gill's methods do not provide information on events following Tapairu's departure from Rarotonga and therefore cannot be used to estimate events that occurred after the couple reached Rakahanga.

Discussion – Social and Ecological Change on Manihiki and Rakahanga

The radiocarbon dates combined with the data derived from oral histories, subsistence patterns, historic documents, and genealogical records form the foundation of a cultural sequence on Manihiki and Rakahanga. The resulting site sequence contains four phases, I through IV, separated by major shifts in habitation patterns. Taken as a whole, this sequence shows how shifting patterns of settlement, migration cycles, landscape use, and population-wide cooperation articulate into a larger socioecological system, which ultimately allowed the inhabitants of Manihiki and Rakahanga to remain sustainable.

Phase I - AD 1200-1400 - Arrival Period

By as early as AD 600 sea level lowering began to permanently expose previously submerged reef flats in East Polynesia (Nunn 2016). Manihiki and Rakahanga became habitable over the following centuries. The Southern Cook Islands were likely inhabited by AD 900 (Sear et al. 2020). Following AD 1150, wetter conditions may have made the habitation of small and remote islands more favorable and much of East Polynesia was colonized by AD 1300 (Sear et al. 2020). It is in this time period that we believe Polynesian voyagers first reached Manihiki and Rakahanga beginning the Arrival Period or Phase I of the Manihiki and Rakahanga sequence. The oral histories suggest that the land was barren when the first inhabitant planted coconuts and began ecological transformations (Gill 1915:7). Genealogical dating suggests this occurred between AD 1198 and 1424 (Hiroa 1932; Gill 1915). The AMS dates from our recent investigations, as well as those of Yamaguchi and colleagues (Yamaguchi 1998; Yamaguchi et al. 2009), suggest a modelled starting boundary of *cal. AD 1170-1250.* Both teams identified the center of the islet of Te Kainga on Rakahanga as the earliest point of settlement. Yamaguchi's team dated carbonized plant remains from Manihiki that fell into the later portion of this range indicating that the islets of Manihiki may have come into use at *cal. AD 1350-1410*. Based on our current evidence, however, it is likely that during this Arrival Period, the first inhabitants of Manihiki and Rakahanga lived in a nucleated village on Te Kainga as oral histories suggest.

Anthropogenic ecological change during the Arrival Period likely included the planting of agroforests in the form of coconut and pandanus trees, as well as the excavation of some puraka pits. The settlers introduced the domestic dog and the Pacific rat at this time. The first inhabitants of many Polynesian islands and their introduced fauna preyed heavily upon sea birds at first arrival (Steadman 1995). If a sea bird colony was present on the recently emerged islets it is likely that that the first settlers on Manihiki and Rakahanga exploited it. However, the small amount of faunal material recovered from these early contexts does not contain avifauna. The oral histories that describe the first people on the atolls mention that the second man to land on Manihiki and Rakahanga, Featu, “lived on fish,” but they do not mention birds (Gill 1915:7). This may suggest that bird populations were not fully established at the time of human arrival on Rakahanga, possibly due to the barren nature of the recently emerged islets. The initially small human population of Manihiki and Rakahanga was likely able to rely on marine resources and the imported plants and animals.

Phase II - AD 1400 to 1650 - Expansion/ Dispersal Period

Following the Arrival Period, we define an Expansion/ Dispersal Period from AD 1400 to 1650. Evidence of intensive habitation appears on numerous Manihikian islets (Chikamori et al. 1991; Yamaguchi 1998). No less than three Manihikian habitation areas (MNH-7, MNH-9, NG001) were in use during this period (Table 2.1; Figures 2.3 and 2.4). Currently there is no archaeological evidence to indicate if the extant villages of Tukao and Tauhunu were occupied at this time. However, Hiroa (1932:48-51, 206) mentions that the people built a marae at Tauhunu in the 7th generation (AD 1515-1575 by genealogical estimations) and that Tauhunu was occupied by the 12th generation (AD 1650-1690 by genealogical estimations). The village at Te Kainga, also appears to have remained in use during this time based on the dates reported by Di Piazza (2005). It seems that this was a time of expansion as well as sociopolitical and socioecological experimentation as the people inhabited new environments and founded new villages.

The atolls’ ecologies would have likely experienced anthropogenic change as the human population increased and spread. Each Manihikian village resembles a microcosm of the Rakahangan village and its associated subsistence system. The villages on Manihiki contain living areas and swamp-taro pits. These puraka pits were likely dug when the villages were first founded. However, we have not yet established direct dates of puraka pit excavation. If these features were established at this time, their small size, when compared to the pit-field networks on Rakahanga, suggest short-term occupation periods, small populations sizes or both.

Political change on the atolls likely involved semi-permanent fissioning processes including the founding and management of dispersed Manihikian villages. This pattern of habitation is in stark contrast to the nucleated settlement on Rakahanga and is indicative of socioecological experimentation. Cases of locational and political fissioning can be related to efforts to reduce social and ecological stresses (Blitz 1999; Ritchie et al. 2016). While the exact causes of this expansion are unknown, it is likely related to population increase on Rakahanga and a need for an expanded resource base. It is probable that the growing population on Rakahanga looked to establish territory on Manihiki on a semi-permeant to occasional basis. Alkire (1978:97) estimates that the population of Rakahanga would have needed to reach 600-700 individuals before the limits of Rakahanga's resources necessitated such an expansion. Hiroa (1932) suggests that the Matangaro and Hukutahu lineage groups had created their own housing clusters on Te Kainga prior to habitation on Manihiki. By the end of this period, in the tenth generation, there were four subgroupings (matakeinanga) of housing clusters on Te Kainga. This may indicate that formalized subgroupings of families were becoming established during the time of the first intensive occupations of Manihiki and that these groups preferred to live in close proximity. Fissioning and establishing individual villages may have bolstered the autonomy of the lineage-based subgroups. It is also possible that this expansion was related to building social pressure between descent groups that dwelled in close proximity on Te Kainga. As with the ecological setting, the sociopolitical structures of the Manihikian villages were likely smaller-scale versions of that found on Te Kainga.

The end of this period, the early to mid-1600s, coincides with two potentially influential external forces acting upon the population of Manihiki and Rakahanga – environmental upheaval and European contact. At roughly AD 1600, by genealogical estimations, the Northern Cook Islands are said to have been impacted by a large wave that killed the majority of the population of the island of Pukapuka, 525 km west of Manihiki and Rakahanga (Beaglehole and Beaglehole

1938; de Scally 2008). The type of wave, cyclonic storm surge or a tsunami, is unknown as are its impact on Manihiki and Rakahanga. However, deep deposits of light-colored sand appear in the stratigraphy of the NG001 site at this time marking the termination of the most intensive period of occupation on Manihiki (Appendix B). This may indicate that like Pukapuka, Manihiki was affected by this event. If this is the case, then environmental upheaval may have influenced the aggregation seen in the following period.

The first European contact on Manihiki or Rakahanga occurred in AD 1606 when the Spanish explorer Pedro Fernandez de Quiros appears to have visited Rakahanga (Kloosterman 1976:12; Markham 1923 [1904]:209-217). The two ships of the Quiros expedition anchored off the reef of Rakahanga and had numerous encounters with the islanders. Sailors' accounts describe the village and large voyaging canoes. The presence of these *vaka* may suggest regular travel between Manihiki and Rakahanga or to other islands or island groups. The accounts also discuss sailors making landfall and killing numerous Indigenous individuals. Accounts estimate that there were 500 people on Rakahanga at the time (Kloosterman 1976:12). This is less than half the size of the population suggested by Gill in AD 1852 (2001[1871]:127) and suggests that either the population had yet to reach higher numbers or that the entire population of the atolls was not present at the time of Quiros' arrival. The latter may have been the case if a portion of the population was on Manihiki at the time. While the naming conventions of the Spaniards varied, from *Peregrina* (Pilgrim Island) to *Gente Hermosa* (Island of Beautiful People), the name given by Luis Vaes de Torres, may characterize the traumatic experience that this meeting really was, as he named Rakahanga *La Matanza* or The Slaughter (Kloosterman 1976:12). This encounter may have had lasting repercussions as oral histories involving the formation of the dual Arikiship in the following period state that one of the two major subgroupings, the Matangaro, were affected by a sickness by the twelfth generation (Hiroa 1932:48-51). At this time, there is no way of knowing how severe this sickness was, when it began, or if it was of European origin, but it is closely tied to the creation of the dual Arikiship in the following period.

Phase III - AD 1650 to 1849 - Dual-Ariki Period

Phase II was a period of experimentation, culture contact, and environmental upheaval. By contrast Phase III was a time of renewed consolidation and continued experimentation. The Dual-Ariki Period lasted from roughly AD 1650 to 1849 and was the final period of occupation on Te Kainga. During this period, following the abandonment of dense occupation at the NG001 site, we see lessened use of Manihikian sites and expansion of the village at Te Kainga. Hiroa suggests that the land area of Te Kainga had increased by this time and that the population moved into these areas which had “grown up” (Hiroa 1932:58). We see this expansion archaeologically as cultural materials, dated to *cal. AD 1640-1680*, are found in basal deposits near the lagoon shore of the islet. This suggests continued sea-level fall. While it is not possible to know the full circumstance of this aggregation, we can speculate that the external threats of the previous period may have encouraged population consolidation and intra-group cooperation. The oral traditions suggest that in the twelfth generation, roughly AD 1650-1690, a problematic case of succession occurred with each of the main lineages standing behind one of two half-brothers, Temu-matua and Tianewa-matua, both sons of the final single Ariki - Tautape (Hiroa 1932:47). The single Arikiship that ruled the islands divided into a dual Arikiship, under the control of two chiefs, each of which held divine and secular powers (Hiroa 1932:22,57). It was at this time that the aforementioned sickness affected the Matangaro lineage prompting the actions of the culture hero Temu-matua who became the first *Whainga-aitu* Ariki. The formation of the dual Arikiship, demonstrates the power of the populace to exercise freewill and alter the dynamics of the leadership structure of the atolls through the appointment of the second Ariki. This implies that community benefit was more important than the maintenance of a rigid power structure. We also see the extirpation of the domestic dog during this period. This suggests changes in the social and ecological setting as well as possible increases in population pressure as the Te Kainga settlement became crowded.

At least two of the Manihikian sites suggest lessening occupation in the 1600s-1800s but surface features suggest renewed use in the years leading up to the arrival of missionaries in 1849. It is difficult to pinpoint the beginning of the Tûmutu migrations, but it is likely that rahui prohibitions on certain resources began at the time of human arrival. The complex stratigraphic layering at the TK001 site may indicate frequent periods of abandonment during the Dual-Ariki Period, suggesting that the ethnohistorically known version of the Tûmutu migrations took shape during this time. This cultural institution seems to have grown out of rahui traditions combined with the social and ecological experiments of the prior centuries. This resulted in a system in which a single people were able to manage and maintain a widespread, and potentially vulnerable, land area through innovative ecological stewardship and political leadership drawn from ancestral traditions.

The dynamics of the Tûmutu represent not just a pattern of fissioning and fusion, but a case of collective action or cluster-wide cooperation where the entire population is said to have conformed to the rules of this system indicating that the betterment of the population outweighed the benefit to leaders, individuals, or subgroups. Just as Ariki imposed sanctions on those that broke the curfew on Te Kainga, sanctions likely ensured that everyone participated in the Tûmutu and rahui. This suggests that, while flexible enough to allow for changes in the political system, the centralized authority of Manihiki and Rakahanga was powerful enough to ensure that the population participated in the migrations. In this way, the dual chiefdom with its ability to fission and fuse may have acted to promote cohesion and cooperation by giving autonomy and delegated power to groups when dispersed on Manihiki and by reasserting authority and strengthening familiar ties when aggregated on Rakahanga. Through this population-wide cooperation, the people of Manihiki and Rakahanga developed and maintained a human-mediated landscape capable of supporting a large population. Rather than store surplus as harvested crops or food for feasts, the people of Manihiki and Rakahanga stored living resources through social institutions including the dual Arikiship and the Tûmutu. By placing an entire island's resource base under rahui restrictions and allowing it to regenerate, stocks of coconut, puraka, fish, turtles, and other resources were always available in time of need. The use of surplus as tribute to the Ariki is unclear, but the ability to store food in its living state would have allowed for large harvests of fish, shellfish, and puraka upon arrival to whichever island was in disuse. This form of living surplus ensured the sustainability of the population while influencing the development and maintenance of the social institutions needed to preserve it.

Phase IV – Post AD 1849 – The Three Village Period

In AD 1849, a process began that resulted in sustained external contact and a cascade of changes to the social and ecological systems of Manihiki and Rakahanga. During a crossing between the atolls, a group of voyagers were lost at sea. A European ship eventually picked up these individuals. After some time, and movement between the islands of the Southern Cooks, they returned to Manihiki along with Tahitian missionaries (Hiroa 1932:8). Three years later the missionary W.W. Gill arrived. The missionaries worked to convert the population to Christianity but also documented the dual Arikiship and the migrations between the islands. Gill suggested that the population consisted of roughly 1200 individuals, a marked increase since Quiros' estimate of 500 in AD 1606 (Hiroa 1932:8; Kloosterman 1976:12). This may represent not just a population increase, but the coalescence seen in Phase III. In AD 1852, 20 lives were lost crossing between the islands during a storm, this led to the cessation of the migrations and three permanent villages were established. The people abandoned the settlement on Te Kainga and divided themselves between the villages of Tukao and Tauhunu on Manihiki and a new village on the main islet of Rakahanga. This was the final Tûmutu migration, though the people of Manihiki and Rakahanga remained connected throughout the Three Village Period and consider themselves one people on two atolls.

Conclusion

Manihiki and Rakahanga represent a case of small-scale social and ecological change in a challenging environment. The creative and innovative management of people and resources on these atolls demonstrates that despite environmental limitations populations can achieve sustainability. Voyagers first inhabited the recently emerged and likely ecologically impoverished atolls of Manihiki and Rakahanga in the thirteenth to fourteenth centuries AD. They transformed the landscape by planting coconuts and digging puraka pits. They built large coral-walled fish traps and introduced dogs and rats. Building off of ancestral traditions, the people of Manihiki and Rakahanga enacted ecological management policies and lived under a chiefly political structure. At first, they lived in a single village on Rakahanga, but a growing population and possible ecological pressure likely led to expansion onto Manihiki. This may have begun with short term habitations while people transformed the landscape to meet their needs. After centuries of experimentation with nucleated, dispersed, and possibly cycling habitation patterns the people developed a dual-chiefdom political system that enabled cycling patterns of aggregated and dispersed habitation and population fissioning and fusion.

By the time of sustained European contact in the mid-1800s the domestic dog was extirpated, and the Tûmutu migrations were in use. The Tûmutu was an elaboration upon, and a mechanism through which, the people enacted traditional rahui practices. The creation of the dual chiefdom and the Tûmutu cyclical migration system appear closely tied to population expansion, possible external threat in the form of Europeans and environmental upheaval, and a continued need to closely manage the landscape of both atolls. For the Tûmutu to function in the way Hiroa (1932) suggests, as a system of mass migration coupled with cyclical aggregation and dispersal, it must have required the cooperation of the entire population. The process of fissioning and fusing likely worked to bolster the autonomy of lineage groups during periods of dispersal and to establish communal ties and the solidarity of the population against external threats during periods of aggregation. Under the flexible management of the dual Arikiship, the Tûmutu extended and protected the resources of Manihiki and Rakahanga as a whole while encouraging population-wide cooperation. The population was able to effectively store living surplus on one atoll by allowing time for resource stocks to regenerate. This allowed them to not only survive, but to thrive and grow in a sustainable human-mediated landscape. This demonstrates the importance of flexibility in leadership and collective action in promoting long-term sustainability.

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CHAPTER 3

THE MYSTERY DOGS OF REMOTE OCEANIA: AN ARCHAEOLOGICAL AND ETHNOHISTORICAL VIEW OF DOMESTIC DOG INTRODUCTION AND LOSS IN THE SOUTH PACIFIC [2]

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[2] Cramb, Justin. Submitted to *American Antiquity*

Abstract

The “Mystery Islands” of Oceania are islands that were uninhabited at European arrival but contain archaeological evidence of previous human settlement (Bellwood 1978:352; Kirch 1988a). The reasons that humans abandoned these places constituted the “mystery” that gave them their name. It is likely, however, that environmental factors including diminutive size, remoteness, and lack of water contributed to their abandonment. Extending this concept of enigmatic disappearance, I define “Mystery Fauna” as those animals introduced to and then later lost from Oceanic islands before the arrival of Europeans. To investigate this phenomenon through the example of a single species – the domestic dog – I synthesize available archaeological and ethnohistoric documents from 35 islands/ island groups and add new archaeological data from the Northern Cook Islands. This synthetic approach allows for the documentation of pre-European and contact-era dog presence and absence across Remote Oceania. I then compare patterns of dog introduction and loss with remoteness and island type to identify patterns of human/ dog interaction. The findings indicate that people introduced dogs to over two-thirds of the locations studied. Of these, roughly 61% experienced dog extirpation (localized extinction) before European arrival. We did not identify a link between remoteness and dog introduction or loss. Island type however has an appreciable effect on dog survivability, with low islands having higher rates of dog extirpation. This study demonstrates that while the processes of animal extirpation are different on each island/ group, the mysteries of domesticate loss are often linked to island type, population size, and overall vulnerability to cultural, environmental, and biological stresses.

Dogs and People in Remote Oceania

The islands of Oceania (Figure 3.1) were historically divided into the regions of Melanesia, Micronesia, and Polynesia. While these groupings do not, in all cases, reflect cultural or even temporal relationships, they are frequently used to reference geographic space (Kirch

2010). The more recently defined division between Near Oceania and Remote Oceania acts as a useful heuristic for patterns of human settlement that illuminates the biogeographic and temporal divisions between the larger landmasses of Near Oceania (New Guinea and near-continental islands) which were settled, in part, during the Pleistocene and the smaller, more recently settled, islands of Remote Oceania which stretch eastward into the Pacific (Figure 3.1; Green 1991). Here the terms Melanesia, Micronesia, and Polynesia, as well as directional divisions within, are used as geographic references for areas in the regional designation of Remote Oceania.

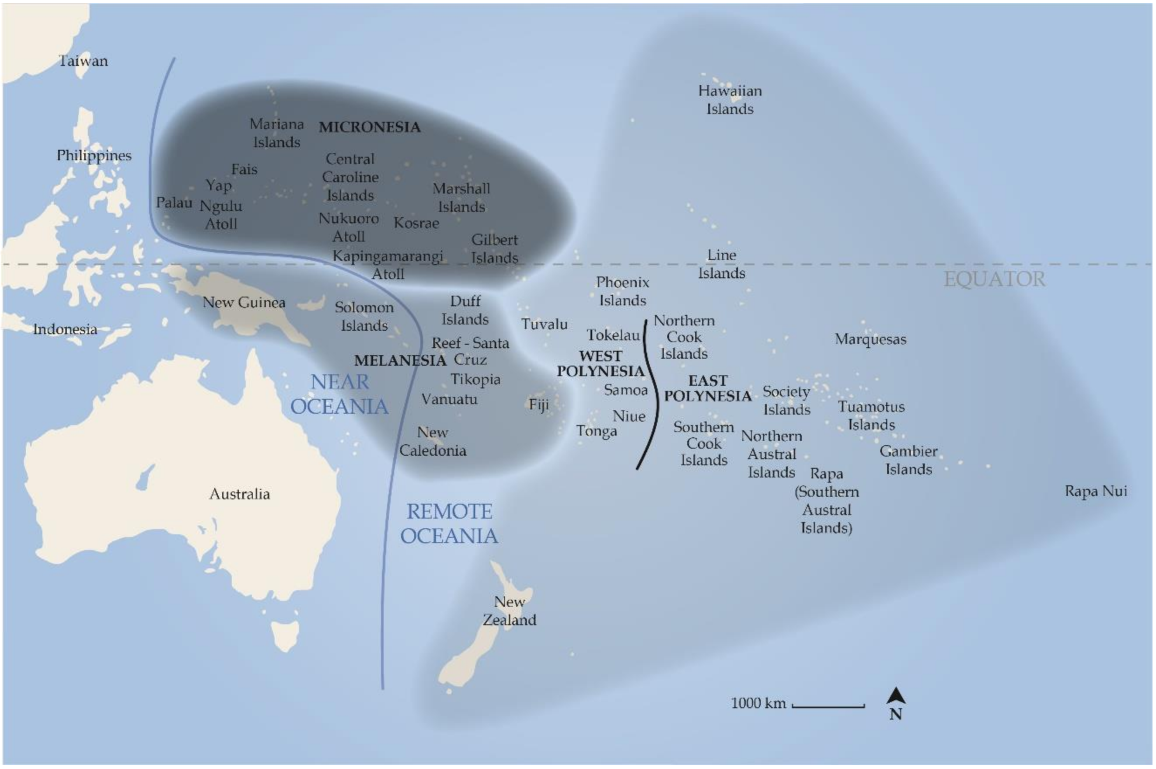

Figure 3.1. Divisions of Melanesia, Micronesia, Polynesia, Near Oceania, and Remote Oceania

When voyagers colonized the islands of Remote Oceania, they brought a well-documented assemblage of plant and animal species. This "transported landscape" (Anderson 1952; Kirch 1982:1) frequently included four animals - chicken (*Gallus gallus*), dog (*Canis familiaris*), pig (*Sus scrofa*), and the Pacific rat (*Rattus exulans*) (Anderson 2009). However, the distribution of these animals varies across time and space (Anderson 2009; Bay-Petersen 1983). The colonization of the region took place over a period of roughly 3,500 years. First, the islands of Eastern Micronesia (e.g., the Mariana Islands) were settled by 1250 BC or slightly earlier by peoples of Southeast Asian origins that appear to have lacked dogs (Liston 2009; Wickler 2004). Next, the previously uninhabited Melanesian islands of Remote Oceania (e.g., Fiji, Vanuatu, and New Caledonia) and Western Polynesia (e.g., Tonga and Samoa) were colonized by Lapita voyagers by around 900 BC (Burley et al. 2012; Green et al. 2008). Lapita sites are marked by distinctive dentate-stamped pottery that is often used as a marker of relative chronology. Archaeological evidence suggests that dogs were absent from most Lapita sites (Anderson 2009:1509; Greig et al. 2018:4; Greig et al. 2016:472), though researchers identified dog remains with Lapita pottery in Fiji (Jones 2016:68; Jones and Quinn 2009:2746; Nunn et al. 2007:115). This suggests that, while early introductions occurred, dogs were a scarce and often late introduction to Lapita communities. The settlement of much of the remainder of Micronesia occurred by 250-50 BC, but dog is absent from the earliest deposits (Anderson 2009). A final wave of Pacific Island colonization occurred after AD 900 when the islands of East Polynesia were first colonized (Kahn et al. 2015; Sear et al 2020; Wilmshurst et al. 2011). During this final pulse of colonization, some of the most remote islands in the world were first inhabited by dog-bearing human groups.

Evidence of dogs on individual islands or in specific island groups in Remote Oceania is scattered in archaeological reports and ethnohistoric text limiting our current understanding of dog distribution and extirpation across the region. Contributions from Anderson (2009), Bay-

Petersen (1983), Greig and colleagues (2016; 2018), Matisoo-Smith (2007), and Wickler (2004) synthesized archaeological and genetic data in parts of the Pacific, shedding light on patterns of dog introduction and loss. Likewise, multiple historians, including Titcomb (1969) and Luomala (1960a, 1960b), complied ethnohistoric accounts of contact-era dogs on Pacific Islands. These studies provide the foundation for understanding dog introduction and loss in Remote Oceania.

The Dog in Oceanic Cultures

The dog was the first animal domesticated by humans, though the details of this process, including the location and timing of domestication events, are still debated (Botigué et al. 2017; Larson et al. 2012; Perri 2016). The dogs introduced to the islands of Remote Oceania appear to be of a unique breed. They were small, did not bark, and were "characterized by a long muzzle, narrow head, [and] upstanding ears" (Titcomb 1969:80). Archaeological data suggest that dog populations were small in most locations typically represented by a handful of skeletal elements (e.g., Allen 1992:429; Athens 1995:140; Bollt 2008:176; Davidson 1969; Green and Weisler 2004:37; Jones et al. 2007:91; Kirch 2017:86-92; Nunn et al. 2007:116; Rolett 1998:37,102; Shutler et al. 1984:23; Sinoto 1979:113-114). However, ethnohistoric accounts from Hawaii note that people raised hundreds of dogs for feasts (Ellis 1836:346-348). This may indicate that dog population size fluctuated over time and may have been larger and more visible in times of feasting.

As dog population size varied so did the use of dogs. The inhabitants of many islands ate dogs (e.g., Christian 1899:367; Churchwood 1887:355; Ellis 1836:146; Emory 1975:39; Hawkesworth 1775:10; Intoh and Shigehara 2004:263; Lucett 1851:247; Rolett 1998:92; Titcomb 1969). Given the small numbers of dogs in the archaeological record, it is likely they were not a daily food source in most locations but may have been an occasional or ritual food (Kirch and O'day 2003). In the Caroline Islands dogs were used as a means of housekeeping as they would eat the unwanted entrails of the animals killed for human consumption (Christian 1899:367).

Samoan dogs were used to hunt pig (Churchwood 1877:355) and Hawaiians kept dogs as household companions (Ellis 1836:218, Titcomb 1969:8-10). Valeri (1985:47,52,117) suggests that people treated some Hawaiian dogs in a manner similar to humans and that the animals carried value as offerings and had certain taboos associated with them. Dog burials in numerous island groups indicate that some dogs were held in esteem (Bryan 1906:14; Conte and Dennison 2009, 1995; Leach and Leach 1979:209; Sinoto 1979:119; Titcomb 1969:10). Oceanic dogs also served as sources of raw materials. The canines of esteemed Hawaiian dogs were used as ornamentation and spiritual protection (Titcomb 1969:10). Dog bones were also used as needles, awls, and fishhooks (Emory and Sinoto 1961:19). In the Society Islands, dog fur was used for wigs, adornment, and in tools including fishing lures, and dog skulls were kept and placed as offerings to the gods (Hawkesworth 1775: 2:23,2:43,2:64). These data show that dogs held a diversity of use and meaning to peoples across the Pacific. Yet, they were unknown on many islands at European contact.

The Mystery Dogs of the Northern Cook Islands

Containing five coral atolls and one sandy cay, the Northern Cook Islands of East Polynesia are geographically widespread and remote (Figure 3.1). Dogs were unknown in the group during the early 1900s (Beaglehole and Beaglehole 1938:27; Hiroa 1932a:83, 1932b:106). Archaeologists first identified dogs in the Northern Cook Islands with the discovery of the remains of at least three individual dogs on the atoll of Pukapuka (Chikamori and Yoshida 1985:19). The original dating of the layer containing the Pukapuka dogs returned an uncalibrated radiocarbon date range of 2240 ± 60 years BP (Chikamori 1998). Subsequent direct dating of the dog remains produced an uncalibrated date of 240 ± 150 BP (Shigehara et al. 1993). Morphological analysis later determined that the Pukapuka dogs were not likely an indigenous Polynesian breed but possibly a European introduction (Clark 1998).

The atolls of Manihiki and Rakahanga are located 525 km east of Pukapuka, in the Northern Cook Islands. The ethnologist Te Rangi Hiroa (Hiroa 1932a:83) states that “the pig, the dog, and the domestic fowl were not known” on the atolls at the time of his research in 1929. Dog remains were identified in excavations on Rakahanga in 2002 (Di Piazza 2005). In 2017, I completed archaeological excavations of two village sites, one on Rakahanga and one on Manihiki, coupled with full zooarchaeological analysis of the vertebrate remains from the sites. Both sites produced dog remains. The excavations on Rakahanga (TK001) yielded 28 dog teeth, one cranial fragment, and four post-cranial elements in contexts throughout the stratigraphic sequence. Dog remains from Manihiki (NG001) consisted of a single tooth. A short-lived botanical sample (*Cocos nucifera* endocarp) from the deepest cultural layer on Rakahanga returned a date range of cal. AD 1280-1390 (68% probability) (Table 3.1). Dog teeth were present in this context indicating that dogs may have accompanied the first voyagers to Manihiki and Rakahanga.

Table 3.1. AMS dates associated with Rakahangan dog remains

UGAMS Sample ID	Site	Context	Material	δ13C ‰	14C Age BP	Calibrated Date Range 68.2 %
38552	TK001	92	*Pandanus* spp. drupe (Pandanus)	-23.01	110 ± 20	AD 1690-1920
35653	TK001	129 (92)	*Cocos nucifera* endocarp (Coconut)	-25.52	180 ± 20	AD 1660-1950
36970	TK001	48	cf. *Pandanus* spp. drupe (Pandanus)	-25.20	310 ± 20	AD 1520-1650
40095	TK001	60	*Cocos nucifera* endocarp (Coconut)	-23.60	660 ± 20	AD 1280-1390
Dates were calibrated using the IntCal 13 calibration curve in OxCal v4.3 (Bronk Ramsey 1995; Reimer et al. 2013)						

The first European contact in the Northern Cook Islands occurred on Rakahanga in AD 1606 with the arrival of the Spanish explorer Pedro Fernandez de Quiros. This was a very early contact event that transpired in the first century of European exploration in Remote Oceania. Accounts by members of the Quiros expedition reported “dogs of a small breed” (Burney 1803-1817:2:286), “little dogs” (Burney 1803-1817:2:470), and "dogs like those of Castille” (Kelly and Parsonson 1966:1:174). A dog canine tooth and atlas from the TK001 excavations are associated with a charred pandanus drupe that returned the date of cal. AD 1520-1650 (*68% probability*), confirming the presence of dog on Rakahanga around the time European contact. Dog remains persist on Rakahanga following the arrival of Quiros. Short-lived botanicals in context with dog teeth provide dates of cal. AD 1690-1920 and cal. AD 1660-1950 (*68% probability*). The next known European visitor to the islands arrived in AD 1820 (Debenham 2010:301-308) and missionaries arrived in AD 1849 (Gill 2001 [1871]). None of the accounts from the 1800s mention dogs on Manihiki or Rakahanga. Therefore, it is likely that the dogs mentioned by the Quiros expedition and seen in the archaeological record were extirpated between AD 1606 and AD 1820. They remain absent from the atolls today. This raises the question of why the dogs of the Northern Cook Islands were introduced and then extirpated and how their introduction and loss relate to wider patterns of human/dog interaction in Remote Oceania.

Dog Presence and Absence across Remote Oceania

Ethnohistoric texts and archaeological data provide additional information regarding dog introduction and extirpation in locations across Remote Oceania. Archaeological excavations cannot prove the absence of a species on a given island, but they can confirm presence. In Remote Oceania, archaeological techniques are extremely varied. Some areas lack subsurface archaeological investigations, some have archaeological reports but lack analysis or reporting of faunal data, and others have full zooarchaeological reports from excavated sites. For the 35 islands/ island groups shown in Figure 3.2 and listed in Table 3.2, the presence of archaeological dogs is noted when reference to the species appears in pre-European archaeological context. The persistence of dogs on a given island is assessed by determining if they were present at or around European contact. The sailors that traveled the South Pacific from the 1500s to the 1800s documented a wide array of information on island cultures and often reported the presence and absence of domestic animals. These travelers' accounts were sometimes based on visits of a few days or less and the actual presence of an animal could have easily eluded these individuals. Dog presence/ absence is listed in Table 3.2 as it appears in ethnohistoric texts. The presence or absence of dogs in archaeological and ethnohistoric records is also plotted in Figure 3.2. This permits quantification of dog introductions and losses and a comparison of dog persistence across island types.

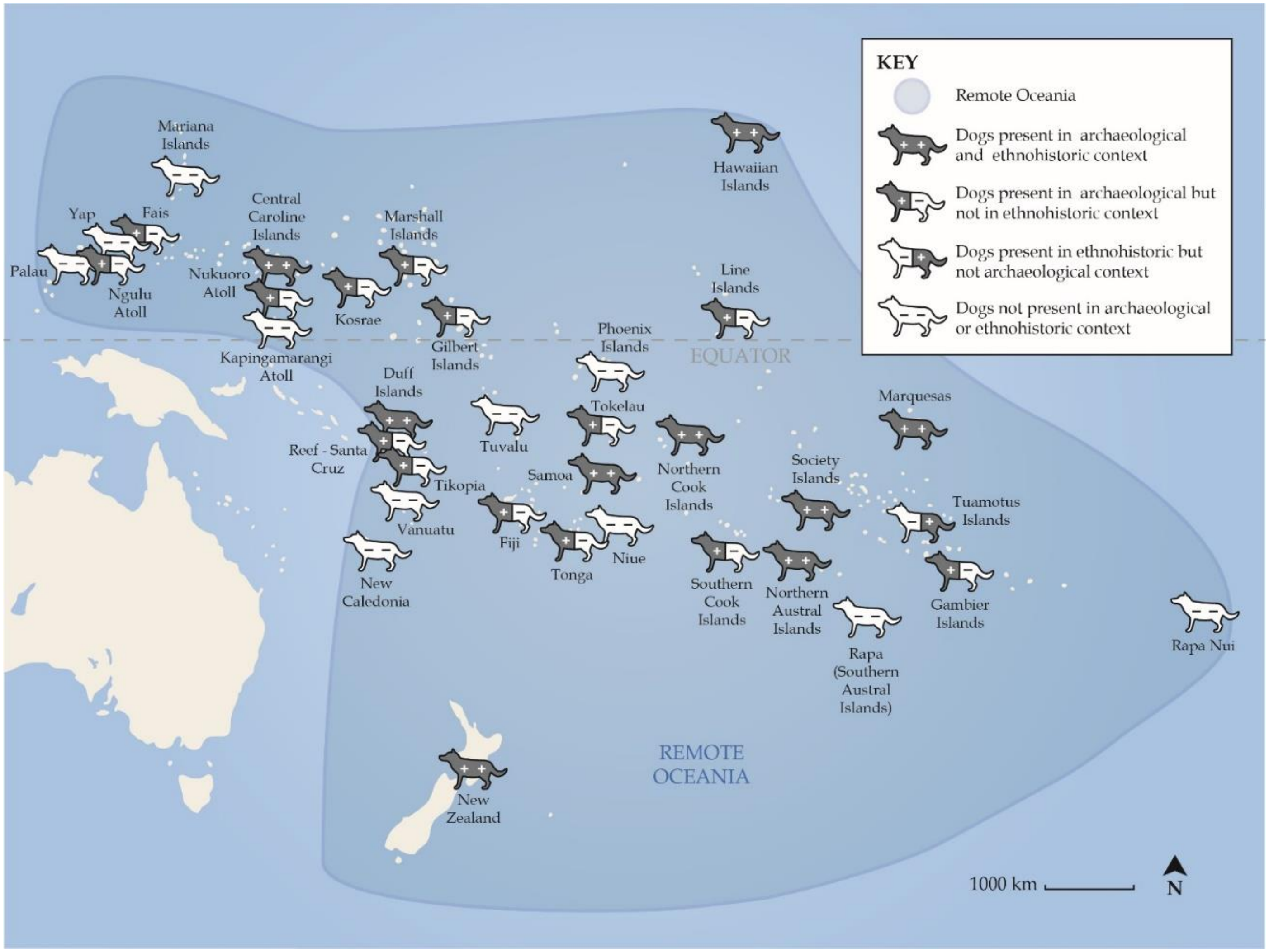

Figure 3.2. Dog presence and absence for the 35 islands/ island groups discussed in Table 3.2

Table 3.2. Dog presence and absence in Remote Oceania

Island/Group	Archaeological Presence	Ethnohistoric Presence	Island Type*	Notes
Mariana Islands	-	-	High	Dogs are absent from archaeological context and early European accounts (Spoehr 1957:25; Wickler 2004).
Palau	-	-	High	Dogs were not present on Palau at, or prior to, European contact (Bellwood 1978:286; Osborne 1961:160; Ritter and Ritter 1982:73).
Yap	-	-	High	The presence of dogs on Yap is ambiguous (Bellwood 1978:286; Intoh 2008:124; Intoh and Leach 1985; Osborne 1961:160).
Fais Island	+	-	High	Intoh and Shigehara (2004) identified archaeological dog remains on Fais Island but ethnohistoric evidence is lacking.
Ngulu Atoll	+	-	Low	Intoh (2008:125; 1981:75-77) identified archaeological dog on Ngulu and states that dogs were not kept historically.
Central Caroline Islands	+	+	High	Archaeological dog remains were found in the region including on Pohnpei and Fefan (Kataoka 1996:149; Shutler et al. 1984:23). Dogs were present on Pohnpei in the mid-1800s (Cheyne 1852:113).
Nukuoro Atoll	+	-	Low	Dogs are present in the earlier archaeological layers but are gone by European contact (Davidson 1971:27; 1992:294).
Kapingamarangi	-	-	Low	Leach and Ward (1981:88) state that dog was never present.
Kosrae	+	-	High	Athens (1995:99, 140) identified small amounts of dog remains on Lelu island. Dog was not present at the time of European contact (Athens 1995:357; Ritter and Ritter 1982:12, 47).
Marshall Islands	+	-	Low	Weisler (2001a:126) identified dog remains on Utrōk dating from the eleventh to sixteenth centuries AD. Early ethnohistoric references from the sixteenth century fail to mention dog (e.g., Boggs 1951; Burney 1803-1817; Maude 1968) but Weisler's dates suggest they were present on some islands during this period. Kotzebue (1821:2:55) noted that dogs were unknown on Wotje atoll in 1817. Combined with some archaeological evidence of historic-era dogs on Ujae (Weisler 1999:38), this suggests either differential dog distribution/ loss throughout the group, a lack of historical accounting, or loss and historic reintroduction.
Gilbert Islands	+	-	Low	Takayama and colleagues (1985:92) identified dog remains on Makin. Dogs were unknown at European contact (Rainbird 2004:233).
Reef-Santa Cruz Islands	+	-	High	Doherty (2007:424) notes the presence of dog remains in post-Lapita (plainware) periods. Quiros' expedition did not mention native dogs (Markham 1923 [1904]). Titcomb (1969:57) presents no additional evidence of dogs at European contact and seems to suggest they were reintroduced in the 1900s.
Duff Islands	+	+	High	Leach and Davidson (2008:90) found scarce dog remains on Taumaco. Dogs were reported by Quiros in AD 1606 (Markham 1923 [1904]:230).
Tikopia	+	-	High	Kirch and Yen (1982:277) document prehistoric dog remains. Dogs were not present in the 1920s (Firth 2004 [1936]:142).
Vanuatu	-	-	High	Overall evidence of dog is lacking. Bedford (2006:220) did not identify dog in Vanuatuan assemblages. Forster (1777:2:289) describes Captain James Cook gifting dogs to Vanuatuans who did not know the animal.

New Caledonia	-	-	High	Dog remains do not appear in the archaeology of New Caledonia (e.g., Gifford and Shutler 1956:28). Luomala (1960b:212) states that dogs "were introduced into dogless New Caledonia… by Captain Cook on his second expedition."
Fiji	+	-	High	Archaeological dog remains are reported on numerous islands in Fiji (e.g., Best 1989:544; Burley 2005:332; Frost 1979:68; Jones 2016; Jones et al. 2007:91; Nunn et al. 2007:115; Worthy and Clark 2009:253-254). Much ambiguity surrounds European-contact-era dogs in Fiji. Smythe and Smythe (1864:170) claim dogs were historic introductions to Fiji while Cook (Synge 1897:374) notes that dogs were introduced to Tonga from Fiji in the 1770s.
Tuvalu	-	-	Low	Archaeological data for Tuvalu is scarce. Oral histories tell of early dogs that had since died out (Koch 1983:61). It is likely that pre-European introduction and extirpation occurred followed by a post-European reintroduction, but data are lacking.
Tokelau	+	-	Low	Dog remains were identified on Fakaofo and Atafu, but dogs were extirpated by European contact (Addison et al. 2009:5-6; Best 1988:116).
Tonga	+	-	High	Archaeological dog remains were found on islands throughout Tonga (Kirch 1988b:220; Steadman et al. 2002:3677; Steadman 1993:818). Forster (1777:1:459-460) stated that on Tongatapu the chief knew of dogs, but that there were none on the island. Cook also noted that dogs were introduced to Tongatapu between AD 1773 and AD 1777 (Synge 1897:374).
Samoa	+	+	High	Davidson (1969:239) suggests that dogs are rare in Samoan archaeology. Stair (1897:187) states that dogs were present on all of the islands of Samoa in the mid-1800s. Churchwood (1877:355) cites large populations in the late 1800s.
Niue	-	-	High	Dog is absent from archaeological deposits on Nuie and oral/ ethnohistories state that dogs were not introduced until the 1800s (Loeb 1926:40; Walter and Anderson 2002:7, 1995:479).
Phoenix Islands	-	-	Low	Di Piazza and Pearthree (2004) omit dogs from discussion. These were mystery islands, so ethnohistoric data is lacking.
Line Islands	+	-	Low	Fanning island was uninhabited at European contact (Kirch 1988a:28). However, a landowner on Fanning in AD 1906 unearthed dog bones in a pre-European human burial indicating pre-European dogs were present in the Line Islands (Bryan 1906:14).
Northern Cook Islands	+	+	Low	Dog remains were found on Pukapuka by Chikamori and Yoshida (1985) and reanalyzed by Shigehara et al. (1993) and Clark (1998). The Pukapuka dogs are likely European introductions. Dog remains were identified in archaeological context on Rakahanga (Di Piazza 2005:82). The dates provided in Table 3.1 solidify the antiquity of dogs in the Northern Cook Islands. The Quiros expedition encountered dogs on Rakahanga in AD 1606 (Burney 1803-1817:2:286, 2:470; Kelly and Parsonson 1966:1:174). Later visitors to the group (e.g., Beaglehole and Beaglehole 1938:27; Hiroa 1932a:83, 1932b:106; Debenham 2010; Gill 2001 [1871]; Gudgeon 1901; Maude 1961) did not note dogs suggesting extirpation after AD 1606.
Southern Cook Islands	+	-	High	Kirch (2017:93) notes the presence of dogs in Mangaia but suggests that they died out prior to European arrival. Bligh (1792:147) saw no dogs on Aitutaki. Gill (1876:318) states that "The dog was unknown in the Hervey Group until one was obtained from the *Resolution*, in 1777." Allen (1992:429), reports dog remains on Aitutaki. She notes that the European accounts may be in error as dogs are present into the contact era.

Northern Austral Islands	+	+	High	Bollt (2005:115) states that all of the Austral islands except for Rapa had dog at European contact. Bollt (2008:176) identified small amounts of dog in excavations on Rurutu.
Rapa (Southern Austral Islands)	-	-	High	Anderson and colleagues (2012:249) state that there is no evidence of prehistoric dog remains on Rapa. Bollt (2005:115) states that all of Austral islands except for Rapa had dog at European contact.
Society Islands	+	+	High	Sinoto and McCoy (1975:177) note dog remains in deeply stratified deposits at Huahine. European contact era dogs are well documented in the Society Islands beginning with Samuel Wallis in 1767 (Hawkesworth 1775:1:213; Titcomb 1969:24).
Tuamotu Islands	-	+	Low	Conte and Dennison (2009:112,118,120, 1995:416) identified a post-European contact dog burial on Tepoto. Dogs were spotted by a number of European expeditions beginning in AD 1606 at Hao (Kelly and Parsonson 1966:1:65; Titcomb 1969:30). It is very likely that pre-European dogs existed on the Tuamotu islands, but the area has seen little by way of subsurface investigations and zooarchaeological research. Those that do discuss pre-European faunal assemblages (e.g., Chazine 1982; Nitta 1982) do not mention dogs. Emory (1975:7) does however suggest dogs were present in the Tuamotus in “ancient times.”
Marquesas Islands	+	+	High	Sinoto (1979:119-120) and Rolett (1998:92) identified archaeological dog remains on Nuku Hiva and Tahuata respectively. Markham (1923 [1904]:21) states that a dog was stolen from the Quiros expedition in 1595 and apparently taken to Tahuata marking a historic period introduction that, unless pregnant at the time, would need an extant population to persist. Porter (1822:2:127), spending a year on Nuku Hiva in AD 1812 only sighted two dogs, indicating the population was near extinct.
Gambier Islands	+	-	High	Green and Weisler (2004:37) found dog remains on Mangareva. Dogs were unknown in 1826 (Beechey 1832:101).
Hawaiian Islands	+	+	High	The Hawaiian dog is well known from archaeological sites (e.g., Kirch and O’Day 2003:491; Tuggle 1979:191;) and was present at European contact (Cook 1784:3:118).
New Zealand	+	+	High	Dogs are well known in the history of New Zealand and were present in AD 1773 (Hawkesworth 1775:2:141). Davidson (1979:229) states that dog remains are common in New Zealand sites.
Rapa Nui	-	-	High	Steadman and colleagues (1994:91) state that there is no evidence of prehistoric dogs on Rapa Nui. Titcomb (1969:34) suggests that there were never dogs on Rapa Nui.

(+) indicates presence and (-) indicates absence. *Island groups were placed into high (volcanic or uplifted) or low (atoll or cay) categories. If an island group has multiple types of islands, I define the location’s island type based on the island where dogs are documented. Island groups with differences in intra-group presence/ absence were separated to note internal diversity.

Patterns of Dog Introduction and Extirpation in Remote Oceania

The results shown in Table 3.2 and Figure 3.2 suggest that dogs were introduced unevenly across Remote Oceania. Eleven islands or island groups do not have a record of dog introduction. Twenty-three locations have evidence of dog introduction at some point before European arrival. Of these, 14 have no ethnohistoric reference to dogs, which could indicate that people introduced dogs to these locations but extirpated them before European arrival. This is an apparent extirpation rate of 61% across the Pacific (Table 3.3). Only 9 islands/ groups have both archaeological and ethnohistoric evidence of dogs, suggesting long-term survivorship was not the norm.

Table 3.3. Presence/ absence totals and summaries of dog distribution in Remote Oceania

Island Type	Presence/ Absence Pattern				Totals
	+ +	- +	+ -	- -	
High	8	0	8	7	23
Low	1	1	6	4	12
Total	9	1	14	11	35
Total number of islands/ groups with archaeological evidence of pre-European dog					23
Total number of islands/ without archaeological evidence of pre-European dog					12
Percent of islands/ groups surveyed with archaeological evidence of pre-European dog					65.7%
Percent of islands/ groups surveyed without archaeological evidence of pre-European dog					34.3%
Percent of islands/ groups surveyed with archaeological evidence of pre-European dog introduction that also experienced extirpation					60.9%
Percent of islands/ groups surveyed with archaeological evidence of pre-European introduction but not extirpation					39.1%
Percent of high islands/ groups surveyed with archaeological evidence of pre-European dog introduction					69.6 %
Percent of low islands/ groups surveyed with archaeological evidence of pre-European dog introduction					58.3%
Percent of high islands/ groups surveyed with archaeological evidence of pre-European dog introduction that also experienced extirpation					50%
Percent of low islands/ groups surveyed with archaeological evidence of pre-European dog introduction that also experienced extirpation					85.7%

Continuing Lineages and Reintroductions (+ +)

In 9 cases, dogs are represented in archaeological and ethnohistoric context. It is likely that these populations are derived from the dog populations originally introduced to the islands. However, they may also be the product of reintroduction events by Oceanic voyagers or European explorers.

Introduction and Extirpation (+ -)

The most frequent pattern is the introduction of dogs followed by their localized extinction. This occurred in 14 cases, not including instances where dogs were reported by Europeans and then died out, as happened in the Northern Cook Islands and possibly the Marquesas (Rolett 1998:92). If these cases were included, the number of extirpation events would increase.

No Dogs Allowed (- -)

Seven high islands/ groups and four low islands/ groups seem to have never received dogs. If small populations were introduced, they are not archaeologically or historically visible. In some areas, such as Tuvalu, this may be a result of limited archaeological research. In other well-studied groups, however, the absence of dogs is likely a real occurrence (Wickler 2004:37).

A Lack of Evidence (- +)

Only one island group, the Tuamotu Islands, displays the (- +) pattern. This is almost certainly due to a lack of subsurface archaeological research in the archipelago. It is likely that future investigations will identify pre-European dog remains throughout the group.

A Fifth Pattern - European Interactions and Post-European Dog Loss

The data presented in Table 3.2 also suggests that dog loss was a regular occurrence during the European-contact era. On Manihiki and Rakahanga, dog extirpation occurred between the arrival of Quiros in AD 1606 and missionization in AD 1849. On Aitutaki, in the Southern Cook Islands, while no Europeans reported dogs, dog remains appear archaeologically well into the historic period (Allen 1992). One possible explanation for post-contact dog loss is that Oceanic dogs were vulnerable to diseases introduced by Europeans and their dogs, as they may have been in the Americas (Leathlobhair et al. 2018:85). Gill (1876:318) notes that Europeans introduced fleas to the Southern Cook Islands during the historic period. It is likely that early European ships carrying European dogs also spread insects, possibly increasing the spread of European pathogens. In the Marquesas, dogs were few in number when sustained European contact began (Rolett 1998:37). Quiros seems to have introduced a single dog to the Marquesan island of Tahuata in AD 1595 (Markham 1923[1904]:21). This introduction could have spread pathogens and fleas, devastating an archaeologically small dog population. If this is the case, it is a testament to the fragility of island populations.

Discussion

The Effects of Distance on Introduction and Extirpation

The presence and absence of dogs in the archaeological and ethnohistoric records indicates surprising patterns of dog distribution. Some distant islands such as Rapa Nui, 2,600 km from the nearest archaeological dog-bearing island, Mangareva (Gambier Islands), lack dog whereas other distant archipelagos such as Hawaii, 1,700 km from nearest dog-bearing neighbor Tabuaeran (Line Islands), received and maintained dog populations (Cook 1784:118; Steadman et al. 1994:91; Tuggle 1979:191). Conversely, geographically close islands such as Rapa and the Northern Austral Islands, separated by roughly 500 km, show differential patterns of dog distribution with Rapa being the only island in the chain to lack dogs (Bollt 2005:115). This may indicate that geographic proximity has little impact on the initial introduction of dogs to islands. The same is true for the survivorship of dog populations. Islanders in the Duff Group maintained dogs while their neighbors in the Reef-Santa Cruz (100 km distant) did not. The same pattern exists between the Gambier islands and the Tuamotus (200 km distant) as well as between the Central Caroline islands and Nukuoro (500km distant) or Kosrae (100 km distant). It is also possible that a falloff in voyaging and an increase in societal insularity that affected some parts of the Pacific by AD 1450 affected reintroduction (Rolett 2002). However, this is unlikely to explain a lack of introduction or reintroduction on islands where interaction persisted into the European contact era. This is the case for the members of the sawei voyaging system, which is known for established trade networks connecting dog-less Yap with Fais which experienced dog loss, and the Central Caroline Islands which maintained dogs (Alkire 1978; Intoh 2008:124; Rainbird 2004:158; Wickler 2004:33-34). This demonstrates that some islanders with knowledge of dogs chose not to introduce them or reintroduce them after extirpation, suggesting that factors other than remoteness have a strong influence on introduction and reintroduction.

Low and High Islands

Oceanic Islands can be categorized in a number of ways, but the four main types are typically volcanic, upraised coral (*makatea*), coral atoll, and sandy cay. High islands (volcanic and makatea) often have larger land masses and sources of fresh water. Low islands (coral atolls and cays) often possess highly productive marine environments but have small land areas, lack surface water, and their low elevations make them susceptible to environmental catastrophe such as cyclonic storm surge (Weisler 2001b:31). Archaeologically identified dogs are present in 23 locations (16 high and 7 low). Rates of introduction varied between island types with 70% of high islands and 58% of low islands having archaeological evidence of dogs. High island locations have a 50% rate of extirpation while low islands have a higher (86%) rate of loss. This suggests that that island type is a strong predictor for dog loss.

If we consider Manihiki and Rakahanga as an example of eventual extirpation of dogs in the Northern Cook Islands, that leaves only one case of dog persistence in a low island group anywhere in Remote Oceania. While archaeological evidence is still lacking, numerous early accounts of dogs in the Tuamotu Islands (e.g., Kelly and Parsonson 1966:1:65) suggest their pre-European presence. Tuamotu islanders were known to travel between the islands of the Tuamotus and to other archipelagos such as the Society Islands and the Marquesas Islands (Alkire 1978:105). The long, white fur of Tuamotuan dogs was distinctive and highly valued in trade (Emory 1975:39; Titcomb 1969:32). These dogs, among other goods, were used as tribute to Tahiti (Bellwood 1978:337). The dynamics of this large network of small islands combined with interaction with dog-bearing high island groups, and the value of a rare resource may have influenced the decision to maintain and propagate dog populations in the Tuamotu group. These pressures and/or opportunities may have not existed in other low islands/ groups.

Toward Explaining the Mystery of Dog Extirpation

Eleven of the 35 island groups surveyed lacked evidence of dogs. This may be due to a lack of documentation. Alternately, the lack of dog remains can be attributed to a purposeful choice to exclude dogs or a failed attempt at transporting dogs across long open-ocean voyages to new islands (Allen et al. 2001:7). Locations such as Rapa suggest that a choice was made to keep the island dog free. It is likely that the occupants of Rapa and other islands in close proximity to, or in regular contact with, dog-bearing islands had access to dogs at some point in their history but chose not to bring them to, or keep them on, their island. Fourteen of the 23 archaeological dog-bearing islands resulted in localized extinction. Why would such a high percentage of dog introductions end in loss?

Numerous arguments are made to account for domesticate extirpations in Oceania (e.g., Allen et al. 2001; Bay-Petersen 1983; Kirch and Yen 1982; Giovas 2006). The first argues that domesticates, determined to be in competition for the same resources as humans, are purposefully extirpated. This is applied more often to pigs than dogs and may explain the numerous cases of pig extirpation across the Pacific (Allen et al. 2001; Goivas 2006; Kirch and Yen 1982). A similar proposition argues that dogs and pigs were inefficient as a resource. Perhaps the protein provided by a dog was no longer worth the effort to raise and manage it (Bay-Petersen 1983:125). Another cause for the purposeful extirpation of domesticates is their destructive capability. It seems that pig was purposefully exterminated on Tikopia because they harmed the local crops (Firth 1959:34). Dogs also may have had a destructive or competitive impact on island environments. Accounts from the early 1900s document dogs hunting fish in shallow waters (Hall 1928:53-54; Titcomb 1969:31). Today dogs on Pacific Islands forage on reef-flats. The self-feeding behavior of dogs was likely detrimental to island resources such as crustaceans and echinoderms, as well as ground-nesting birds and their eggs.

Other explanations for dog extirpation are based on environmental factors, the spread of disease, or the long-term viability of small dog populations on scattered islands. Dogs likely experienced multiple genetic bottleneck effects while being transported across Oceania. This can lead to the accumulation of deleterious genes and a reduction in biological fitness (Marsden et al. 2016). Introduced European pathogens may have entered islands at contact and spread through Indigenous trade allowing European disease to reach islands before Europeans could document the local fauna. As discussed above, dog populations were small on many islands, especially low islands with limited land and terrestrial resources. Cases like Manihiki and Rakahanga also suggest that low-island dogs were occasionally left to their own devices. Ethnohistoric accounts state that the people of Manihiki and Rakahanga periodically and alternately abandoned each atoll (Hiroa 1932a). The relative dearth of dog remains on Manihiki may indicate dogs were left on Rakahanga during periods of relocation to Manihiki. Ethnohistoric accounts document dogs on periodically abandoned islands in the Tuamotus (Titcomb 1969:31), but evidence of long-term survivability is lacking. It is possible that a prolonged abandonment of dogs on some small islands resulted in their extirpation; though this does not apply to, or explain, localized extinctions where this cultural pattern of cyclical migration does not exist. Overall, this study indicates that on some islands the exclusion or elimination of dogs was a purposeful act by human groups and on others it was an unintentional consequence of life in Remote Oceania.

Conclusion

Dogs served many roles in Oceanic societies including as pets, food sources, custodians, and ritual or tributary offerings. Despite their varied roles, dogs never gained a foothold on some islands and were extirpated from others. The dogs of Manihiki and Rakahanga present a complicated example of introduction and extirpation amid island colonization, migration, and European contact. The eventual localized extinction of dogs on these two islands is part of a larger pattern of dog extirpation across Remote Oceania. Pre-European dog populations were introduced to 23 of the 35 islands/ groups surveyed in this study but were not sustained in 14 of the 23 locations. Dogs were much less likely to survive on low islands than on high islands. Distance from non-dog-bearing to dog-bearing islands may be a factor, but numerous cases suggest that, even in instances of close proximity, the human decision to adopt or exclude dogs plays a major role in their introduction and reintroduction. The small size and increased environmental vulnerability of low coral islands likely influenced the human decision to keep dog populations small increasing their vulnerability to cultural, environmental, and biological stresses. This means that any one choice to remove dogs, a temporary abandonment, the introduction of a new pathogen, or a catastrophic event such as a cyclone or drought could have been the only catalyst needed to result in local extinction.

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CHAPTER 4

FROM LAND AND SEA: OVERCOMING THE CHALLENGES OF DIRECTLY DATING DOG REMAINS ON POLYNESIAN ISLANDS[3]

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[3] Cramb, Justin and Carla Hadden. Accepted by *Radiocarbon*.

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Abstract

Difficulty in determining the timing of colonization for many of the islands of Remote Oceania encourages continual reassessment and debate (e.g., Anderson 1991, 2003; Anderson et al. 2003; Kirch 1986, 2000; Kirch and Ellison 1994; Kirch and Kahn 2007; Schmid et al. 2018; Spriggs and Anderson 1993; Wilmshurst et al. 2011). This has led to sample selection strategies focused on dating short-lived terrestrial plants, especially fruits, seeds, and twigs recovered from clearly anthropogenic deposits (Allen and Hubert 2014; Wilmshurst et al. 2011). There remains considerable interest and value in the direct radiocarbon dating of terrestrial vertebrate remains. The voyagers that settled many of the islands of Oceania introduced domestic and commensal animals including dogs (*Canis familiaris*), pigs (*Sus scrofa*), chickens (*Gallus gallus*), and the Pacific rat (*Rattus exulans*). The presence of these taxa on a given island is direct evidence for a human presence. Therefore, the ability to reliably date the remains of these animals will contribute significantly to our understanding of the chronology of human activity in the region. Dating the faunal remains of introduced species is problematic (e.g., Anderson 1996, 2000; Athfield et al. 1999; Hedges 2000; Holdaway 1999; Petchey et al. 2015). Key sources of uncertainty include dietary variance and the calibration procedures used. This includes the selection of the appropriate calibration curve—IntCal, SHCal, Marine, or a mix of two or more curves—in addition to correcting for relevant local carbon reservoir offsets.

In this study we present a model-based approach to obtain accurate calibrated ages for a suite of AMS dates on dog remains excavated from Rakahanga Atoll in the Northern Cook Islands. Extending the model-based "paired sample" approach for estimating ΔR from archaeological materials (e.g., Hadden and Schwadron 2019; Macario et al. 2015), we focus on "triads" of radiocarbon samples, groups of samples excavated from the same archaeological context, consisting of (1) a short-lived terrestrial plant; (2) a marine shell; and (3) gelatin extracted from a tooth from the dog of interest. The terrestrial, marine, and "mixed" reservoir

sample dates are modelled together as a phase within a Bayesian chronological framework (Bronk Ramsey 2009). The model includes *a priori* information on parameters related to the potential for mixing between IntCal/SHCal/Marine calibration curves, as well as likely values for ΔR. In this manner, the modelled ages account for spatially and temporally specific mixed carbon reservoirs and offsets, as well as providing updated estimates for other model parameters (e.g., ΔR, %Marine, and %IntCal) that can be applied to additional samples from Rakahanga. Though dogs are the focus of the present case study, the method could be applied to dating the remains of any marine-influenced terrestrial vertebrate in Remote Oceania.

Chronology-building in Oceania

Current data suggest that the first colonization of the islands of Polynesia began ca. 850 BC by pottery-bearing peoples voyaging out of the western Pacific (Burley et al. 2012). These voyagers, referred to as the Lapita peoples, sailed eastward across the Pacific, founding settlements as far east as Tonga and Samoa in West Polynesia. Current models suggest that following a nearly 2,000-year voyaging hiatus, the first human colonization of East Polynesia began at roughly AD 900 in the Southern Cook Islands (Sear et al. 2020) and AD 1000–1200 in the Society and Gambier Islands (Schmid et al. 2018; Stevenson et al. 2017; Wilmshurst et al. 2011). Over the following centuries voyagers colonized much of the remainder of East Polynesia including Hawaii, New Zealand, and Easter Island (Dye 2016; Schmid et al. 2018; Wilmshurst et al. 2011).

Current and past debate regarding the timing of events in the Oceanic past often include issues related to the accuracy and precision of the chronometric datasets, largely derived from ^{14}C dates on botanicals, soils, bones, and shells, and more recently, by U/Th dating of corals from archaeological contexts (e.g., Burley et al. 2012; Kirch et al. 1995; Niespolo et al. 2019 Wilmshurst et al. 2011). The reliability of these dates involves assessing both context and material type. The primary problems are summarized as follows:

1. A direct relationship between the dated sample and the event of interest—human activity—should be demonstrated. For this reason, dates from questionable contexts, such as dispersed charcoal or bulk sediments, are often considered suspect (Spriggs and Anderson 1993; Wilmshurst et al. 2011).
2. Certain materials have potential for large inbuilt ages, e.g., samples from long-lived trees, with the resulting dates reflecting an event some time prior to its use (or re-use) by humans. For this reason, dates on charcoals from long-lived tree species and unidentified charcoals are often considered suspect (Allen and Hubert 2014; Spriggs and Anderson 1993; Wilmshurst et al. 2011). This argument likewise extends to corals, which could have been collected and used by people many years after the organisms died.
3. The Southern hemisphere (SH) is depleted in atmospheric ^{14}C compared to the Northern hemisphere (NH), with the SH having a north-to-south gradient of roughly 1‰ per 10° of latitude, a difference of 36 ± 27 ^{14}C yr (Braziunas et al. 1995). This creates additional uncertainty when calibrating terrestrial samples from Pacific locales, where many island groups straddle the division between the NH and SH requiring the researcher to make a decision as to whether to employ the IntCal, SHCal, or a "mixed" atmospheric calibration curve (Petchey et al. 2009, 2014).
4. Ocean waters are depleted in ^{14}C relative to the atmosphere, meaning that samples of marine origin yield radiocarbon ages older than contemporaneous samples of terrestrial origin (Stuiver et al. 1986), necessitating the use of a separate calibration curve, e.g., Marine13 (Reimer et al. 2013). Differences in coastal geomorphology, ocean circulation, upwelling, and island geology produce localized deviations from the global-averaged marine reservoir age, requiring a local correction term (ΔR) which ranges in scale from decades to centuries in the Pacific Islands (e.g., Petchey 2019; Petchey and Kirch 2019).
5. In island and coastal settings many terrestrial animals obtain dietary protein from both terrestrial and marine sources, including reefs. Their tissues, including the bone gelatin

extracted for radiocarbon dating, represent a mix of terrestrial and reef/marine carbon reflecting the composition of the animals' diets which would vary among individuals, species, and island populations (e.g., Petchey et al. 2014). In other regions of the world, researchers have applied a Bayesian statistical approach to quantify the marine protein in diet (e.g., Fernandes et al. 2015).

Oceanic Dogs and the Northern Cook Islands

Dogs are omnivorous animals, and the ethnohistoric and stable isotopic records support the assumption that the dogs of Remote Oceania consumed a combination of marine and terrestrial foods just as humans did (Allen and Craig 2009; Bay-Petersen 1983:125; Cumming 1882:69; Richards et al. 2009; Titcomb 1969). It is likely that dogs in most settings scavenged scraps from human meals. Ethnohistoric accounts suggest dogs on different islands and in different contexts consumed different foods. Accounts of Hawaii, Samoa, and the Society Islands state that the dogs of tropical Polynesia ate a plant-based diet, often including breadfruit, coconut, and taro (Bay-Peterson 1983:125; Cumming 1882:69; Titcomb 1969:6). In New Zealand, it seems dogs were often fed fish (Forster 1777:189). Atoll dogs in central Polynesia acquired their own food by hunting fish on the reefs using pack tactics (Hall 1928:53-54; Titcomb 1969:31). From these and other Pacific Island accounts, Oceanic dog diet ranged from vegetarian, to carnivorous, and everything in between, depending on the location. As dogs can survive on a range of diets it is likely that local ecologies and cultural norms dictated variations in dog diet in different islands and groups.

The Cook Islands (Figure 4.1) consist of 15 islands spread over 2,200,000 km^2 of the South Pacific Ocean, lying between 8° and 23° S latitude and between 156° and 167° W longitude. The northern island group (Northern Cook Islands) consists of the coral atolls Rakahanga, Manihiki, Penrhyn, Suwarrow, and Pukapuka as well as the sandy cay Nassau. Current assessments point to human settlement of these islands after AD 1400 (Di Piazza 2005;

Schmid et al. 2018). Previous excavations on Pukapuka Atoll in the Northern Cook Islands led to some speculation over the antiquity of both humans and dogs in the island group. Radiocarbon dates on marine *Tridacna* shell from cultural contexts which contained dog remains returned the uncalibrated radiocarbon date range of 2240 ± 60 ^{14}C yr BP (Chikamori and Yoshida 1988; Chikamori 1998). Later, direct dating of the Pukapuka dog yielded an uncalibrated date of 240 ± 150 ^{14}C yr BP (Shigehara et. al 1993). Uncertainties regarding the marine contribution to the diet coupled with the low precision of the measured ^{14}C age and the idiosyncrasies of the calibration curve during this period leave substantial doubt as to the true age of the Pukapuka dogs.

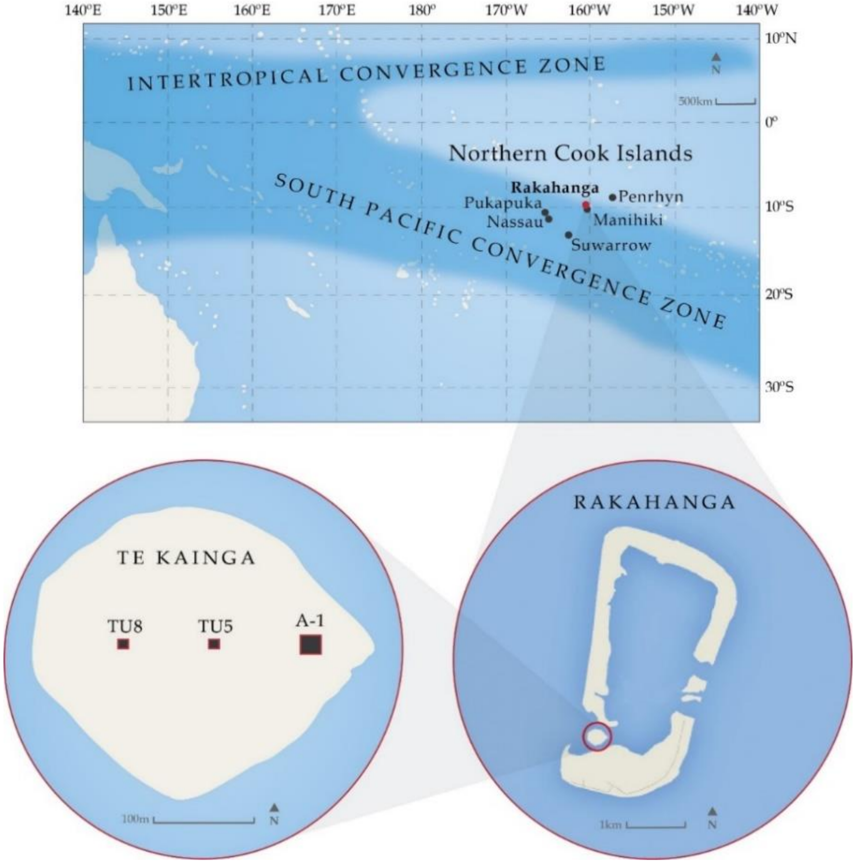

Figure 4.1. Rakahanga in reference to the current position of the South Pacific (SPCZ) and Intertropical Convergence Zones (ITCZ); Te Kainga in reference to greater Rakahanga; and the locations of the excavation units discussed herein (excavation units are not to scale). SPCZ and ITCZ locations based on Jaffrés and colleagues (2018).

Manihiki and Rakahanga (M&R) are coral atolls in the Northern Cook Islands located 525 km to the east of Pukapuka (Figure 4.1). Oral histories state that all of the inhabitants of M&R initially lived in a single village called Te Kainga on a small islet on Rakahanga. When resources ran low, the entire population is said to have voyaged 40 km to Manihiki, where they split into multiple villages. After some time, they returned to Rakahanga to reunite in the single village of Te Kainga. This process then repeated in a cyclical manner (Hiroa 1932a). The first European contact on M&R seems to have occurred in AD 1606, when Spanish explorer Pedro Fernandez de Quiros made landfall at Rakahanga. Numerous members of Quiros' crew noted the presence of dogs on the island (Kloosterman 1976:12; Markham 1923:209–217). By the time of European missionization (ca. AD 1849) dogs had been completely extirpated from M&R; later accounts state that dogs had never been present on the atolls of the Northern Cook Islands, suggesting that they were no longer a part of cultural memory (Beaglehole and Beaglehole 1938:27; Hiroa 1932a:83, 1932b:106).

Recent excavations at Rakahanga by Di Piazza (2005) and the lead author in 2017 identified numerous dog remains. Many of the 33 dog skeletal elements identified by the lead author were in contexts with short-lived botanicals; others were in strata lacking these preferred dating materials. While initial dating efforts at Rakahanga focused on short-lived botanicals, the research design sought direct dates on the dog remains to avoid any possible ambiguity regarding their antiquity.

Materials and Methods

In order to date the Rakahanga dog remains as accurately as possible, we developed a sampling strategy centered on three sample "triads." Three archaeological contexts which contained multiple datable materials were targeted. The sample triads consisted of (1) a short-lived terrestrial plant; (2) a fragmentary marine bivalve shell; and (3) dentine extracted from a dog tooth. Each triad was selected from a unique context and each context was derived from a different excavation unit (Figure 4.1; Table 4.1). Te Kainga is a small (~300 m by 300 m) nearly circular islet on Rakahanga atoll. The stratigraphy of the low-lying TK001 site (Te Kainga) is complex and discontinuous. The strata therefore require direct dating to place into a chronological framework. Collecting triads from hearth features was not possible due to the rarity of finding all three materials in such a feature. Dog-bearing layers were considered cultural layers as dog presence is assumed to equate to human presence. Two of the three contexts (R-48 and R-60) consist of 20 cm levels of 50-cm-by-50-cm test units excavated at Te Kainga in 2017. R-48 was recovered from test unit 005 (TU5) near the center of Te Kainga, and R-60 was recovered from test unit 008 (TU8), on the western side of the islet. Both contexts were 60–80 cm below surface. R-60 also contained a pearl shell fishhook fragment. R-92 consists of a 10-cm level (~ 60–70 cm below surface) from unit A-1, a 2-m-by-2-m unit excavated on the east end of TK001 in 2017. This context contained three dog teeth as well as cut and drilled pearl shell artifacts. As each triad set is from a different unit and context they are considered to be from different individual dogs, clams, and botanicals.

Table 4.1. Results for Rakahanga sample triads

UGAMS	Sample Genus	Gelatin yield, %	δ^{13}C, ‰	δ^{15}N, ‰	Atomic C:N ratio	^{14}C age, yr BP	±	Offset (D-T), ^{14}C yr	% Marine
Triad 1: FS R-92 – Unit A-1 – Level 8									
38552 T	*Pandanus*	—	-23.0	—	—	110	20	—	0
38554 M	*Pinctada*	—	+1.6	—	—	750	20	—	100
36969 D	*Canis*	10.6	-11.5	19.2	3.3	670	20	560	85 ± 10
Triad 2: FS R-48 – Test Unit 5 – Level 4									
36970 T	*Pandanus*	—	-25.2	—	—	310	20	—	0
38553 M	*Pinctada*	—	+2.3	—	—	810	20	—	100
36967 D	*Canis*	8.3	-13.6	18.8	3.1	740	20	430	64 ± 10
Triad 3: FS R-60 – Test Unit 8 – Level 3									
40095 T	*Cocos*	—	-23.6	—	—	660	25	—	0
40097 M	*Pinctada*	—	+1.3	—	—	810	30	—	100
40096 D	*Canis*	7.3	-12.2	19.6	3.3	850	25	190	78 ± 10

Note: UGAMS suffix T=terrestrial sample; M=marine sample; D=dog sample. %Marine estimated from δ^{13}C as described in text.

Sample Selection and Pretreatment

Charcoal samples from short-lived botanicals were used to help resolve issues related to the local atmospheric radiocarbon reservoir, as well as to refine local ΔR corrections. Samples consisted of the endocarp of coconut (*Cocos nucifera*) or *Pandanus* spp. drupes. These particular plant parts were selected following best practice protocols for dating botanicals in Polynesia (Allen and Huebert 2014). Both plants are grown and consumed by people on Rakahanga today and the parts selected for dating (endocarp and drupe) represent growth of one year or less. Botanical samples were pretreated according to an acid/base/acid (ABA) protocol and combusted at 900° C in an evacuated and sealed quartz tube in the presence of CuO to produce CO_2 for AMS analysis (see AMS Methods).

Pearl shell (*Pinctada margaritifera*) fragments were selected due to the prevalence of the species in archaeological context on Rakahanga. The meat of this bivalve was, and is, consumed on the atoll and the shell was used to make fishhooks, fishing lures, adornments, and other items of subsistence and economic value. The shell selected was fragmentary, had no signs of human modification, and is here considered to be a product of food waste or debitage limiting concerns of inbuilt age. Shell samples were acid-etched with dilute HCl to remove the outer shell layer, which is most likely to be affected by secondary or diagenetic carbonates. Samples were reacted with 100% phosphoric acid in evacuated reaction vessels to produce CO_2 for AMS analysis.

Domestic dogs (*Canis familiaris*) were identified with reference to the Zooarchaeology Comparative Collection at the Georgia Museum of Natural History. Teeth from three different contexts were selected for analysis. The sample selected from context R-48 (TU5) was an intact lower right adult canine, R-60 (TU8) was an intact upper left adult canine, and R-92 (A-1) was a fragmentary upper left adult second molar. Due to the provenience of the samples they are considered to be from different individuals. Gelatin was extracted from dentine following a modified Longin (1971) procedure that included an alkaline wash to remove humic substances.

Gelatin samples were combusted at 575° C in evacuated and sealed Pyrex tubes in the presence of CuO to produce CO_2 for radiocarbon dating by AMS.

AMS Methods

CO_2 from botanical, shell, and gelatin samples were cryogenically purified from the other reaction products and catalytically converted to graphite using the method of Vogel et al. (1984). Graphite $^{14}C/^{13}C$ ratios were measured using 500 keV accelerator mass spectrometer at the University of Georgia Center for Applied Isotope Studies (Cherkinsky et al. 2010). The sample ratios were compared to the ratio measured from the Oxalic Acid I standard (NBS SRM 4990). For shell samples, Carrara marble (IAEA C1) was used as the background, and travertine (IAEA C2) was used as a secondary standard. Stable isotope ratios were measured separately using a dual-inlet or elemental analyzer isotope ratio mass spectrometer (IRMS) and expressed as $\delta^{13}C$ with respect to PDB and $\delta^{15}N$ with respect to AIR, with an error of less than 0.1‰. The quoted uncalibrated dates are given in radiocarbon years before 1950 (years BP) and percent Modern Carbon (pMC) using the ^{14}C half-life of 5568 years. The error is quoted as one standard deviation and reflects both statistical and experimental errors. The dates were corrected for isotope fractionation using the IRMS-measured $\delta^{13}C$ values.

Bayesian Chronological Modelling

“Mixed” calibration curves are used in situations where a radiocarbon sample may reflect a mix of more than one carbon reservoir. For example, radiocarbon researchers around the world regularly use a mixed atmospheric/marine calibration curve for dating human or animal remains when the individual is suspected to have consumed a mix of terrestrial and marine foods (e.g., Fernandes et al. 2015; Petchey et al. 2014). More recently, Marsh et al. (2018) used a mixed atmospheric calibration curve (IntCal/SHCal) to account for the possibility of inter-hemispheric mixing of air masses in the tropics of South America, and a latitudinal gradient in atmospheric ^{14}C concentration (Braziunas et al. 1995). As noted by Marsh and colleagues (2018), IntCal and

SHCal were constructed predominantly from samples from temperate latitudes (Reimer et al. 2013; Hogg et al. 2013), therefore a mixed IntCal13/SHCal13 calibration curve may be more appropriate for use in the tropics than either curve alone. Located at 10˚S, the tropical island of Rakahanga is positioned within the South Pacific Convergence Zone. The potential for atmospheric mixing between NH and SH air masses, and possible implications for radiocarbon dating, has been discussed by Petchey et al. (2009, 2014:237). Thus, the ^{14}C content of the Rakahanga dogs may be influenced by atmospheric mixing, in addition to a mixed marine/terrestrial diet.

Here, we incorporate radiocarbon dates from purely terrestrial, purely marine, and mixed terrestrial/marine reservoirs, as well as parameters related to the possibility of mixing between IntCal13, SHCal13, and Marine13 calibration curves, within a Bayesian chronological framework. Models were run in OxCal 4.3 (Bronk Ramsey 2009). Each sample triad was modelled as an independent uniform phase, nested within a larger phase with a TAQ of AD 1849, the year when missionaries arrived on the island, by which point dogs are thought to have been extirpated from the island group. The OxCal code is presented in Figure 4.2. For botanical samples, we specified a mixed curve allowing %SHCal to take any value between 0 and 100, i.e., %SHCal ~ U (0,100). An updated estimate (posterior probability) for %SHCal is derived from the model data and other model parameters. Marine shell dates were assumed to be derived from a purely marine carbon reservoir. Petchey et al. (2008) report a $\Delta R = -2 \pm 14$ ^{14}C yr for the eastern portion of the Northern Cook Islands on the basis of known-age, "pre-bomb" shell specimens. To account for the added uncertainty related to temporal variations in ΔR, we specified a prior probability for $\Delta R \sim U(-100,100)$, allowing ΔR to take any value between -100 and +100 ^{14}C yr. By modelling these data together with the short-lived botanicals, an updated estimate (posterior probability) for ΔR is calculated as well.

```
Plot()
 {
  Sequence()
  {
   Boundary();
   Phase()
   {
    Curve("SHCal13","SHCal13.14c");
    Curve("IntCal13","IntCal13.14c");
    Curve("Marine13","Marine13.14c");
    Sequence()
    {
     Boundary();
     Phase("TK001 R-92")
     {
      Mix_Curves("MixedTerrestrial1","SHCal13","IntCal13",U(0,100));
      R_Date("38552 pandanus", 110, 20);
      Curve("=Marine13");
      Delta_R("Regional Marine1", U(-100,100));
      R_Date("38554 shell", 750, 20);
      Mix_Curve("MixedMarineTerrestrial1","MixedTerrestrial1","Regional Marine1",85,10);
      R_Date("36969 dog", 670, 20);
     };
     Boundary();
    };
    Sequence()
    {
     Boundary();
     Phase("TK001 R-48")
     {
      Mix_Curves("MixedTerrestrial2","SHCal13","IntCal13",U(0,100));
      R_Date("36970 pandanus", 310, 20);
      Curve("=Marine13");
      Delta_R("Regional Marine2",  U(-100,100));
      R_Date("38553 shell", 810, 20);
      Mix_Curve("MixedMarineTerrestrial2","MixedTerrestrial2","Regional Marine2",64,10);
      R_Date("36967 dog", 740, 20);
     };
     Boundary();
    };
    Sequence()
    {
     Boundary();
     Phase("TK001 R-60")
     {
      Mix_Curves("MixedTerrestrial3","SHCal13","IntCal13",U(0,100));
      R_Date("40095 cocos", 660,25);
      Curve("=Marine13");
      Delta_R("Regional Marine3",  U(-100,100));
      R_Date("40097 shell", 810,30);
      Mix_Curve("MixedMarineTerrestrial3","MixedTerrestrial3","Regional Marine3",78,10);
      R_Date("40096 dog", 850, 25);
     };
     Boundary();
    };
   };
   Boundary();
   Before("Ethnohistoric Record",C_Date(1849,10));
  };
 };
```

Figure 4.2. OxCal code for Rakahanga sample triads

Gelatin extracted from dog teeth was assumed to be derived from a mix of terrestrial and marine dietary protein. A new “mixed mixed” calibration curve was specified to calibrate each dog date: the IntCal13/SHCal13 mix and Marine13. Stable isotopes of dog tooth gelatin were used to estimate the prior probabilities for the marine component of the mix (%Marine diet). Following Petchey et al. (2014), we used a linear mixing model for estimating the contribution of marine/reef protein to dog diet from bone collagen δ^{13}C, using -20‰ and -10‰ as values for terrestrial and marine endmembers, respectively. An arbitrary value of ±10% was assigned for the uncertainty in the estimate of %Marine diet. Although we recognize that more sophisticated techniques for reconstructing diet from stable isotope data exist (e.g., Hopkins and Ferguson 2012; software developed by Fernandes et al. 2014), for our purposes the simple linear mixing model produces a sufficient first-approximation for the marine component of dog diet. Updated estimates for %Marine are included in model outputs as posterior probability distributions. The modelled “triads” thus account for multiple sources of uncertainty in calibrating terrestrial animal ages: atmospheric mixing; dietary sources; and ΔR offsets.

Results and Discussion

Sample descriptions, stable isotope results, and measured ^{14}C ages are presented in Table 4.1. The dog teeth yielded well-preserved gelatin, with yields ranging from 7–10%, and atomic C:N ratios within acceptable ranges (Ambrose 1990). On the basis of $\delta^{13}C_{gelatin}$, diets of dogs on Rakahanga were dominated by marine protein, with estimates ranging from 64–85% marine protein. In all three sample triads the measured ^{14}C ages for dogs (denoted “D” in Table 4.1) were within 100 ^{14}C yr of associated marine materials (denoted “M”), but offset from associated terrestrial materials (denoted “T”) by ~200 ^{14}C yr or more, consistent with a predominantly marine source of carbon in dogs.

Results of the Bayesian chronological model are presented in Table 4.2 and Figure 4.3 (Modelled parameter values) and Figure 4.4 (Modelled ages). The overall model offers OxCal diagnostic values (A_{model} = 81.3, and $A_{overall}$ = 71.7) above the satisfactory threshold value of 60. The modelled local reservoir offsets at Rakahanga range from -*38* to *+48* ^{14}C yr (Table 4.2), larger in magnitude than those previously reported by Petchey and colleagues (2008). Posterior probabilities for mean %IntCal13 for the atmospheric/terrestrial carbon reservoir are in the range of *46–65%*; mean %Marine13 for the mixed dog diets range from *73–85%* (Table 4.2 and Figure 4.3).

Table 4.2. Model results for Rakahanga sample triads (A_{model} = 81.3 $A_{overall}$ = 71.7)

	Unmodelled (cal AD)						**Modelled (cal AD)**						
	68.2% probability		**95.4% probability**				**68.2% probability**		**95.4% probability**				
	from	**to**	**from**	**to**	**μ**	**σ**	**from**	**to**	**from**	**to**	**μ**	**σ**	**A**
Boundary: Start Te Kainga							1180	1380	900	1400			
Boundary: Start TK001 R-92							1470	1670	1320	1700			
%IntCal13 in mixed atmospheric	0	100	0	100	50	29	53	100	15	100	65	25	100
R_Date 38552 pandanus	1700	1930	1690	1930			1690	1720	1680	1730			81.2
Delta_R	-100	100	-100	100	0	57	20	100	-41	101	40	42	99.2
R_Date 38554 shell	1500	1630	1460	1670			1570	1680	1490	1700			99.6
%Marine13 in mixed marine/atm.	76	94	68	100	84	9	77	94	72	100	85	8	105.1
R_Date 36969 dog	1510	1650	1450	1690			1580	1690	1500	1710			91.5
Boundary: End TK001 R-92							1690	1750	1680	1800			
Boundary: Start TK001 R-48							1390	1550	1270	1630			
%IntCal13 in mixed atmospheric	0	100	0	100	50	29	43	100	8	100	59	28	100
R_Date 36970 pandanus	1520	1650	1510	1660			1510	1570	1500	1650			92.7
Delta_R	-100	100	-100	100	0	57	38	101	-69	101	48	46	100
R_Date 38553 shell	1440	1570	1420	1650			1480	1590	1440	1640			94.5
%Marine13 in mixed marine/atm.	54	74	44	84	64	10	66	85	52	91	73	10	75.8
R_Date 36967 dog	1400	1490	1320	1550			1430	1550	1400	1620			60.4
Boundary: End TK001 R-48							1520	1660	1510	1750			
Boundary: Start TK001 R-60							1300	1390	1210	1400			
%IntCal13 in mixed atmospheric	0	100	0	100	50	29	0	64	0	93	46	28	100
R_Date 40095 cocos	1290	1390	1280	1400			1350	1400	1290	1400			101.8
Delta_R	-100	100	-100	100	0	57	-101	-17	-101	75	-38	54	100
R_Date 40097 shell	1440	1570	1420	1650			1400	1510	1340	1570			99.2
%Marine13 in mixed marine/atm.	68	88	59	97	78	10	68	87	60	96	78	9	102.3
R_Date 40096 dog	1330	1460	1300	1500			1350	1440	1310	1480			104.7
Boundary: End TK001 R-60							1410	1580	1360	1710			
Boundary: End Te Kainga							1720	1820	1700	1850			

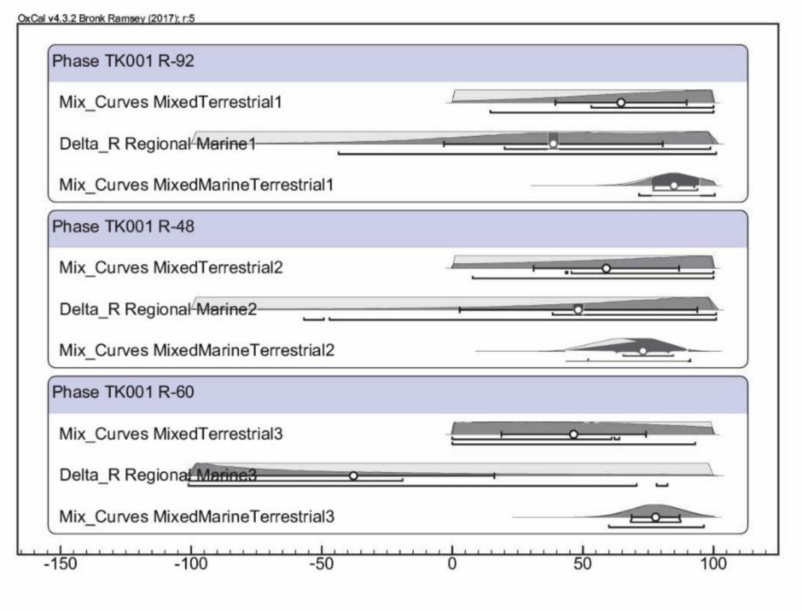

Figure 4.3. Posterior probability for model parameters %IntCal13 (%), ΔR (^{14}C yr), and %Marine13 (%) with mean and sigma (open circle and whiskers) and 68% and 95% HPDs (brackets). A_{model} *= 81.3* $A_{overall}$ *= 71.7*

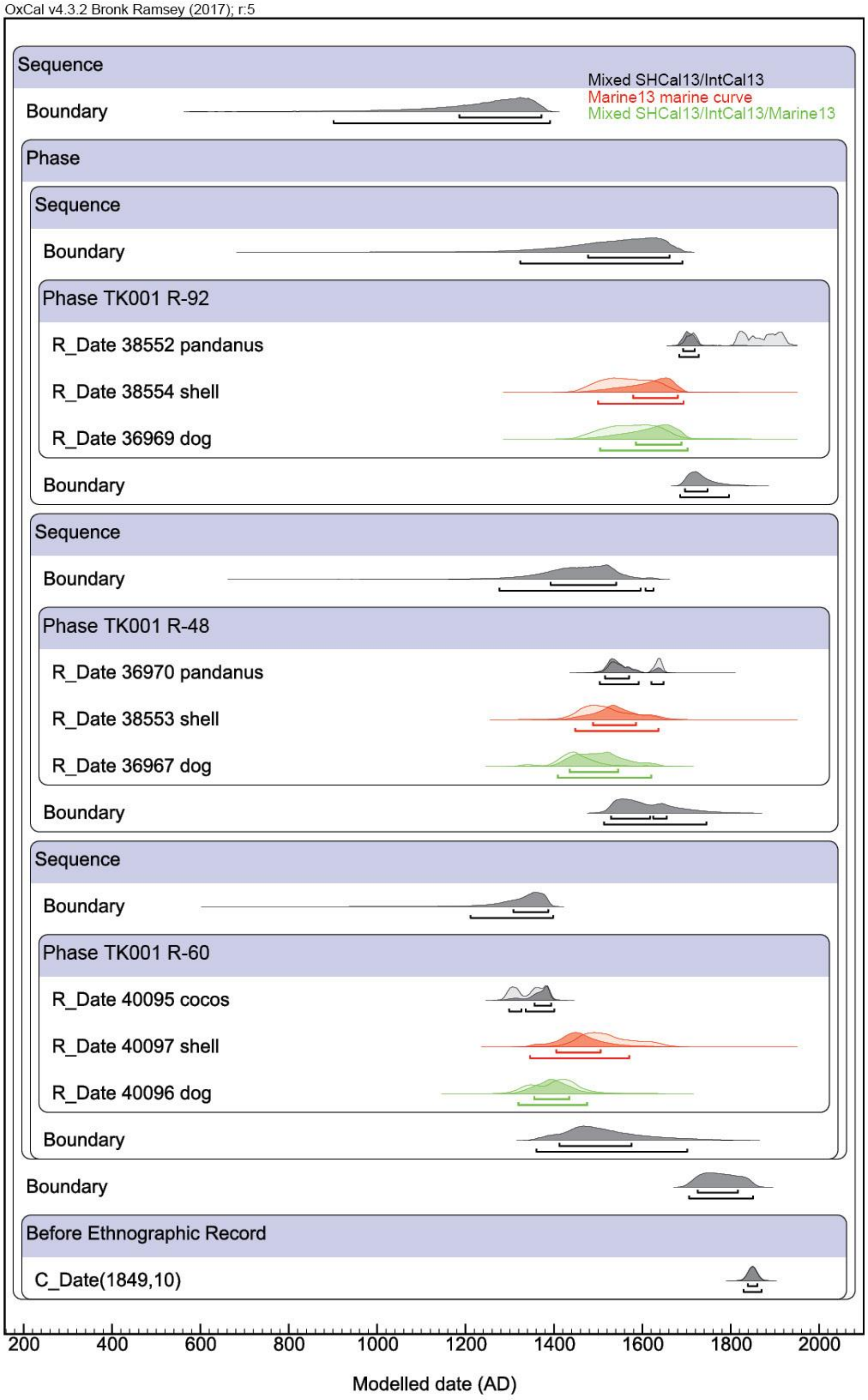

Figure 4.4. Modelled calendar dates for Te Kainga village on Rakahanga with 68% and 95% HPDs (brackets). $A_{model} = 81.3$ $A_{overall} = 71.7$

The nine AMS dates place the starting boundary for Te Kainga village on Rakahanga at *cal. AD 1180–1380* (68.2% HPD). This range is earlier than the time frame of colonization for the Northern Cook Islands estimated by Schmid and colleagues (2018). Our starting boundary is however consistent with the general conclusion that many East Polynesian Islands were occupied at roughly AD 1150–1300 (Schmid et al. 2018; Sear et al. 2020; Wilmshurst et al. 2011). The model results place the earliest dog known on Rakahanga at *cal. AD 1350–1440* (68.2% HPD), while the latest dog dates to *cal. AD 1580–1690* (68.2% HPD) (Table 4.2 and Figure 4.4). As only a fraction of the excavated dog remains have been dated, it is unlikely that we dated the first and last pre-European dogs on the island. Additional direct dates on dog remains are needed to fully resolve the timing of introduction and extirpation of Polynesian domestic dogs in the Northern Cook Islands.

The results of this study indicate that by applying the methods described herein, researchers can identify an appropriate model for calibrating collagen-derived AMS dates for terrestrial fauna on a given island. Once this model is established for a location, the parameters can be utilized to model additional dates from terrestrial fauna recovered in context without other, more suitable, dateable materials. This allows researchers to establish or confirm the antiquity of importation and extirpation of domesticates on specific islands. While not aiming to determine first habitations, this method also provides a way to accurately date archaeologically visible human activity on individual islands by providing a means of modelling dates from human bones as well as the bones of the animals that people brought with them.

Conclusion

The archaeological excavations on Rakahanga produced a rich faunal assemblage which included remains of numerous domestic dogs, representing possibly the earliest examples of pre-European dogs found on East Polynesian atolls. Direct dating of dog remains is complicated by several factors, the most problematic being a mixed marine/terrestrial diet, combined with a potential for local offsets from both atmospheric and marine calibration curves. In this paper we demonstrated that robust age estimates can be obtained by (1) estimating the marine contribution to dog diet using gelatin stable isotope values, which are now routinely reported with ^{14}C results; (2) focusing on sample triads consisting of short-lived botanicals, marine shells, and the dog bone of interest, all excavated from the same archaeological context, to constrain the marine and terrestrial offsets; and (3) combining these data along with other relevant *a priori* information in a Bayesian chronological model. For the case of Rakahanga, the model results suggest a “mixed–mixed” calibration curve for dogs, composed of ~75% Marine13, and 10% IntCal13, and 15% SHCal13. The resulting calendar age estimates place the earliest dog as yet identified in the Northern Cook Islands at *cal. AD 1350–1440* (68.2% HPD), shortly after the initial habitation of the region. This suggests that dogs likely accompanied Polynesian voyagers as they settled new islands and created new societies.

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CHAPTER 5

CONCLUSIONS

Due to their remoteness, lack of terrestrial resources, lack of surface water, and vulnerability to drought and inundation, Pacific atolls are precarious settings for human societies. However, when molded through collective effort and ingenuity these environments can become productive socioecological landscapes capable of supporting sustainable long-term human habitation. In turn, the dynamics of these landscapes encourage new sociopolitical forms and continual adaptation. As discussed in Chapter 1, the first of these processes is well known as archaeologists have documented the ecological and physical changes that human societies make to atolls. These include the introduction and extirpation of plants and animals, the excavation of cultivation pits, and the construction of fish traps and fishponds. The second half of the socioecological transformation process, the adaptation of cultural institutions, is less understood and is often discussed through the endpoints of human arrival and European contact. However, the intervening periods represent the processes of social and ecological change that result in the lifeways represented in the ethnographic and ethnohistoric literature as well as oral histories.

The coral atolls of Manihiki and Rakahanga have a rich ethnohistoric, ethnographic, oral-historic, and archaeological record. Through archaeological methods and the theoretical framework of historical ecology, my co-author and I built off of this existing record to document localized change in the dual-atoll cluster of Manihiki and Rakahanga (Chapter 2). I then used the data derived from these investigations as a starting point from which to trace an individual variable of landscape change, the introduction and extirpation of domestic dogs, across the Pacific (Chapter 3). Finally, my co-author and I addressed the issue of accuracy in the dating of these events and suggested new protocols for the direct dating of terrestrial animal remains on Pacific islands (Chapter 4).

The findings of this research indicate that the environmental precariousness of coral island groups likely influenced human decision making as populations grew and new variations on cultural institutions emerged. The population of Manihiki and Rakahanga arose from a single family and grew over time. The earliest identified village, Te Kainga, on Rakahanga was inhabited by AD 1200-1400 and remained a population center until the mid-1800s. Between these endpoints, the people of Manihiki and Rakahanga experimented first with dispersed habitation by creating numerous villages and sacred sites on Manihiki and later with reaggregation on Te Kainga. They altered the landscape with the introduction of dogs and rats, eventually extirpating the former. They also excavated massive networks of swamp taro cultivation pits on Rakahanga and smaller cultivation pits on Manihiki. We currently do not know the date of excavation for these features, but they were likely built when the villages were first inhabited and expanded over time. At an as-of-yet unknown point, the people of Manihiki and Rakahanga built numerous coral fish traps and at least one large fishpond. Through all of these transformations the population seems to have continued to grow. The processes of landform alteration likely kept pace with the needs of the growing population.

Following AD 1650 the single chiefdom of Manihiki and Rakahanga split into a dual chiefdom or *Arikiship*. This change appears to have occurred shortly following a period of ecological and social upheaval that included a bloody first encounter with those aboard European ships and a potentially large-scale wash-over event. One of the indicators of change that occurred during the time of the dual Arikiship was the extirpation of the domestic dog. Historic accounts place dogs on Rakahanga as late as AD 1606 and radiocarbon dating suggests that dogs persisted on Rakahanga as late as *cal. AD 1580–1690* (68.2% HPD). This comes at a time of reconsolidation into the village at Te Kainga. The extirpation of these animals, while possibly caused by external factors such as European disease, appears intertwined with demographic changes on the atolls caused by aggregation. Dog remains on Manihiki are scarce with only a single tooth identified. It is possible that the *Tûmutu* mass migrations took their ethnohistorically identified form around this time. This may suggest that the presence of dogs was not compatible with cyclical island abandonment and that dogs were purposefully exterminated or were unable to cope when left unattended on Rakahanga during periods abandonment.

A survey of the archaeological and ethnohistoric literature from across the Pacific (Chapter 3) suggests that similar cases of dog extirpation are common. Dog extirpation on low-coral islands was nearly universal. The data indicate that as populations grew throughout the Pacific the benefits of keeping the potentially destructive domestic dogs on low-coral islands no longer outweighed the cost. This is likely complicated by a number of factors including land area, human population size, dog population size, genetic diversity, and local cultural differences. However, the overwhelming trend toward dog extirpation on coral islands suggests a commonality in causal mechanisms and process. The case of Manihiki and Rakahanga can help to fill in the gaps between dog introduction and extirpation by offering one example of the interconnections between changes in settlement, ecological management, political organization and the extirpation of domesticates. However, the lack of direct dating of dog introduction and extirpation, as well as a lack of established cultural sequences, on most coral atolls currently prevents a comparative analysis of the ways that dog extirpation is interrelated to wider patterns of cultural change on coral atolls.

New dating methods will help us to not only understand instances of introduction and extirpation, but also processes of ecological and social change in coral-island environments. Equatorial and coastal environments pose challenges to radiocarbon dating (Chapter 4). Numerous factors produce uncertainty in radiocarbon dates derived from the bones and teeth of terrestrial animals living in coastal environments. However, as discussed in Chapter 4, these challenges can be overcome though the dating of triads of botanical, shell, and terrestrial animal bone, combined with stable isotope analysis and Bayesian modelling. My co-author and I used these methods to directly date three dog samples from Rakahanga. The Bayesian model refined the date ranges produced from the Rakahanga dog samples. This produced highly accurate ranges for the samples in question and therefore a minimum range for dog introduction by *cal. AD 1350–1440 (68.2% HPD)* and dog persistence until at least *cal. AD 1580–1690 (68.2% HPD)*. Additional archaeological work on coral atolls across the Pacific, and the use of these methods to refine the dates of domesticate introduction and extirpation, will help us to understand how domesticate extirpation relates to instances of social or environmental upheaval and the transition to new cultural institutions.

Unlike the mystery islands of Polynesia, including two of the Cook Islands (Palmerston and Suwarrow), which experienced human abandonment before European contact, the people of Manihiki and Rakahanga appear to have thrived throughout the centuries. This research suggests that this is likely due to a number of factors including: 1) the initial transformations to the local ecological resource base in the form of domesticate introduction and landform alteration; 2) the implementation and alteration of the ancestral Polynesian institution of environmental management known as *rahui*; 3) the use of both atolls as an extended resource base in a coral-cluster model of subsistence; and 4) the development of a novel dual chiefdom form of political organization capable of managing a growing population and a widely dispersed territory. These factors likely acted together to mitigate the hardships of atoll life, promoted polity-wide cooperation, and provided the flexibility to alter habitation patterns and adapt cultural institutions to cope with population growth, external threat, and environmental instability.

The cultural sequence developed for Manihiki and Rakahanga in Chapter 2, the patterns of dog introduction and extirpation discussed in Chapter 3, and the dating protocols defined in Chapter 4 all contribute to a broader picture of Manihiki and Rakahanga as an example of how the trajectories of socioecological change on coral atolls can manifest in the development of sustainable systems. The people of Manihiki and Rakahanga undoubtedly faced hardship in their precarious atoll environments, but they built off of ancestral traditions such as the rahui and the Polynesian chiefdom to create new sociopolitical structures and environmental management strategies suited to their particular needs in this coral cluster. Because of this, Manihiki and Rakahanga demonstrate that flexibility in cultural institutions and cooperative effort allow for the mitigation of disparate hardships without necessarily assigning a causal role to any single driver of change beyond the decision to adapt extant lifeways, landscapes, and cultural institutions.

Future Research Directions

Manihiki and Rakahanga have a rich history that is informed through archaeology, oral history, ethnohistory, ethnology, and scientific methods. This research has demonstrated that by combining these disparate lines of evidence we can develop understandings of humanity that avoid privileging one line of evidence over the others. The materials and data from Manihiki and Rakahanga have the potential to inform on additional questions beyond the scope of the current research. Comparing these with data from other locations provides an opportunity to approach broad-anthropological questions in new ways. As this research moves forward, I will address large-scale issues regarding carrying capacity, sustainability through cooperation, and socioecological resilience. I hope to do so through regional, environmental, and global comparative studies.

First, reassessments of Malthusian ideas of carrying capacity and population viability have the potential of altering our current understanding of life on East Polynesian atolls as well as other ecologically marginal settings. The population of Manihiki and Rakahanga appears to have reached its maximum size in the 1800s. At this time, we see estimates of 1200 individuals on 9.5 km^2 of land (~126 individuals per km^2). However, the population seemed to maintain sustainability (Chapter 2) at this density. This raises questions regarding how carrying capacity and sustainability are related to human-induced ecological change and the creation of socioecological institutions used to manage a given landscape. Furthermore, it begs the question of how migratory populations should be viewed in terms of population density. I plan to approach these questions through a comparative study of populations in marginal environments. Through the use of ethnohistoric and archaeologically-based estimates of population density coupled with accounts of resource availability and management, I hope to identify trends in the ways that the population density of marginal landscapes influences sustainability.

In Chapter 2 of this dissertation I argue that small-scale sustainability on Manihiki and Rakahanga is intricately tied to the creation of socioecological institutions that promote cooperation and collective action. To add to this discussion, I aim to compare the sociopolitical systems of different societies that maintained long-term sustainability and those that did not. In doing so I hope to identify aspects of cooperation and competition as they manifest in persistent or sustainable systems. This will demonstrate the variability that exists in the development of long-term sustainability and may lead to informed assessments of collapse in certain societies.

Small-scale socioecological systems that remained sustainability over time are often considered resilient. However, what variables define this resilience? Through archaeological, zooarchaeological, isotopic, and ethnohistoric assessments of Manihiki and Rakahanga, I hope to identify the key variables (e.g., migration, diet, resource use, resource protection, cooperation, etc.) that facilitated the resilience of this system. I will then look to compare these variables with those in other locations to identify trends in the foundations of socioecological resilience in small-scale societies.

Through the use of materials and data from Manihiki and Rakahanga, these forthcoming studies will result in broad understandings of the ways that humans interact with marginal and small-scale environments and the variables that lead to long-term sustainability and socioecological resilience in these systems. I hope to also demonstrate the importance of combining disparate lines of evidence in generating our understandings of past societies. In doing so, the continued benefit of this research will go beyond the Northern Cook Islands to help us all understand the dynamics of human-environmental interaction in disparate socioecological settings around the globe.

APPENDIX A - ARCHAEOLOGICAL SURVEY DATA

The Manihiki Survey

On Manihiki we surveyed three areas, the south end of Ngake Islet, Porea Islet, and Hakamaru Islet. The survey revealed 23 areas of interest and a wide array of site types, some of which were known from the surveys by Yamaguchi (1998) (Table A.1; Figures A.1-A.4). Hakamaru produced eight areas of interest. Four of these, identified by locals and previous researchers (Yamaguchi 1998) as grave sites, resemble burials or burial complexes denoted by small coral-upright-edged enclosures. The largest contains three possible graves and a rectangular platform. The largest surface feature on Hakamaru is a walled swamp taro patch that measures roughly 28 m by 16 m and includes four walled divisions. The remaining three areas of interest on Hakamaru include two unidentified coral structures, *kirikiri* or coral-gravel pavements, and a coral-edged enclosure adjacent to a World War II era coral lookout tower. On Porea the team identified another seven areas of interest. The largest consists of an enclosure adjacent to a stone-walled puraka patch only a short distance away from a large fishpond. Survey of Porea also allowed for the identification of numerous coral walls, one coral mound, a pearl-shell tool found on the surface, an area with six small coral structures, possibly graves, and a larger coral-edged enclosure. The south end of Ngake yielded perhaps the most beneficial results of the archaeological survey. Here the team uncovered eight areas with surface features. One of these, MANI 015, may represent a village complex previously identified by archaeologists as MNH-5 (Yamaguchi 1998). At this location we identified a number of small enclosures in association with a pearl-shell tool and two coral walls that follow the lagoon shoreline. We also found similar walls to the south of this site location. All of these wall features are in alignment with the lagoon shore. In addition to these sites we identified two sets of possible graves on Ngake. Finally, we identified four features that seem to form a large site complex which may be a former village centered at the south end of Ngake (Table A.1; Figures A.5-A.7). We excavated at this location (NG001) in 2017.

Table A.1. Surface features and artifacts on Manihiki identified in 2015 and 2017

Manihiki Survey Data		
Catalog #	Islet	Description
MANI 001	Hakamaru	Four possible coral-upright-edged graves; one coral upright; pearl shell scatter
MANI 002	Hakamaru	A coral-upright-edged puraka (swamp taro) pit-field; possibly part of MNH-7
MANI 003	Hakamaru	Two possible coral-upright-edged graves; MNH-7
MANI 004	Hakamaru	Two coral-upright-edged structures, one is possibly a grave; MNH-7
MANI 005	Hakamaru	Four possible coral-upright-edged graves; MNH-7
MANI 006	Hakamaru	Coral uprights; MNH-7
MANI 007	Hakamaru	A coral-upright-edged enclosure, kirikiri; an historic watch tower; MNH-6
MANI 008	Hakamaru	One coral-upright-edged enclosure possibly a large grave; kirikiri
MANI 009	Ngake	Two possible coral-upright-edged graves
MANI 010	Ngake	A coral-upright alignment following the lagoon shore
MANI 011	Ngake	One possible coral-upright-edged grave; scattered coral uprights
MANI 012	Ngake	A coral mound
MANI 013	Porea	A coral-upright-edged enclosure; a coral-upright-edged puraka pit-field
MANI 014	Porea	A coral-upright alignment, possibly a retaining wall
MANI 015	Ngake	Two possible coral-upright-edged graves; a partially submerged, coral-upright lagoon shore alignment; coral uprights; a pearl shell scraper (FS# M-001); MNH-5
MANI 016	Ngake	A coral-upright-edged enclosure; worked pearl shell (FS# M-015); a clam shell adze (FS# M-016); a pit, possibly a former well; NG001

MANI 017	Ngake	A partial coral-upright-edged enclosure; NG001
MANI 018	Ngake	A partial coral-upright-edged enclosure; NG001
MANI 019	Porea	Eight possible coral-upright-edged graves; pearl shell scatters; pit, possibly a former well
MANI 020	Porea	A pearl shell scraper (FS# M-003)
MANI 021	Porea	Coral mound
MANI 022	Porea	Two coral-upright alignments; MNH-8
MANI 023	Porea	A coral-upright alignment
MANI 024	Ngake	A partial coral-upright-edged enclosure; NG001
MANI 025	Ngake	A coral-upright-edged puraka pit; NG001
The site designator is listed if the identified features are connected to, or are part of, previously documented sites. Yamaguchi (1998) identified sites MNH 1-9. NG001 designates the site excavated in 2017.		

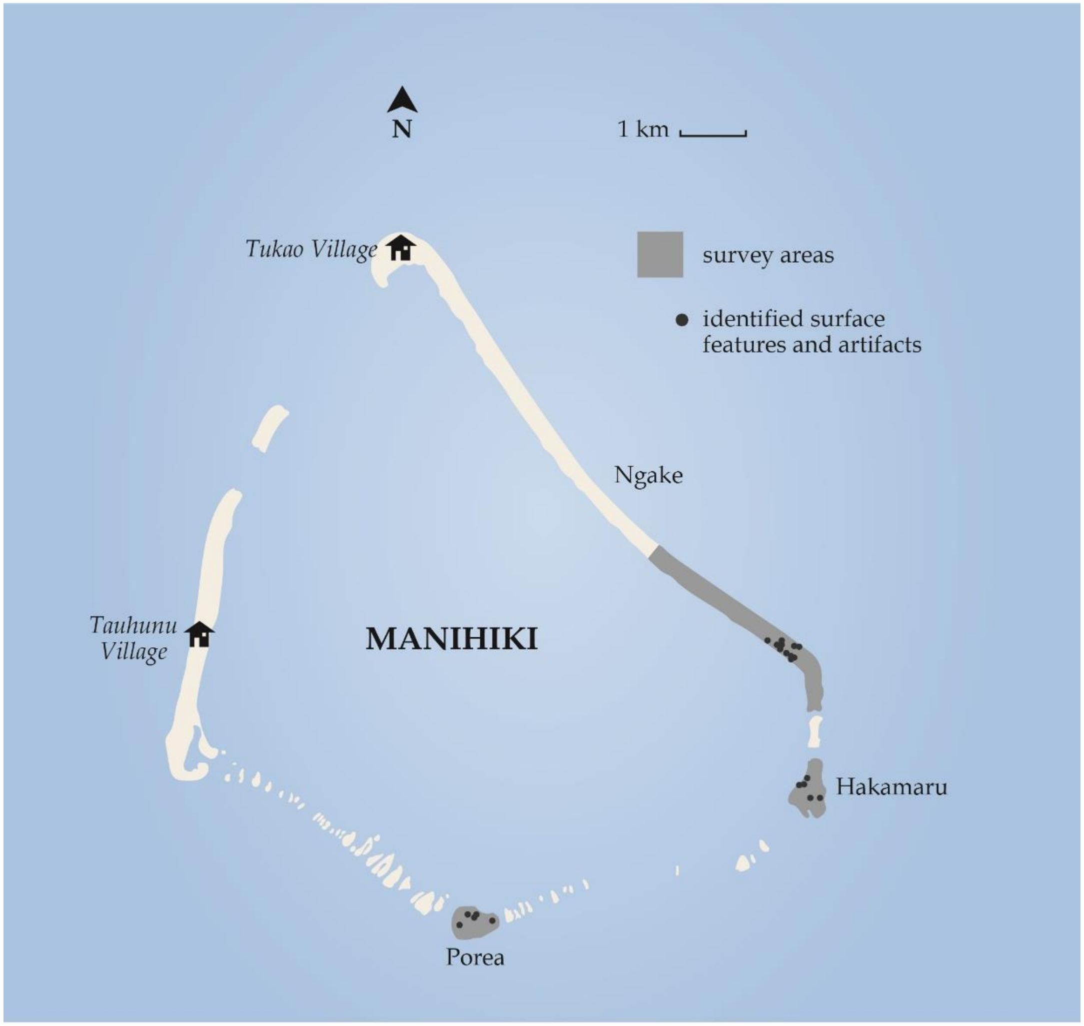

Figure A.1. Manihiki atoll with modern villages, survey areas, and identified features and artifacts

Figure A.2. Hakamaru Islet, Manihiki with survey areas and identified features and artifacts

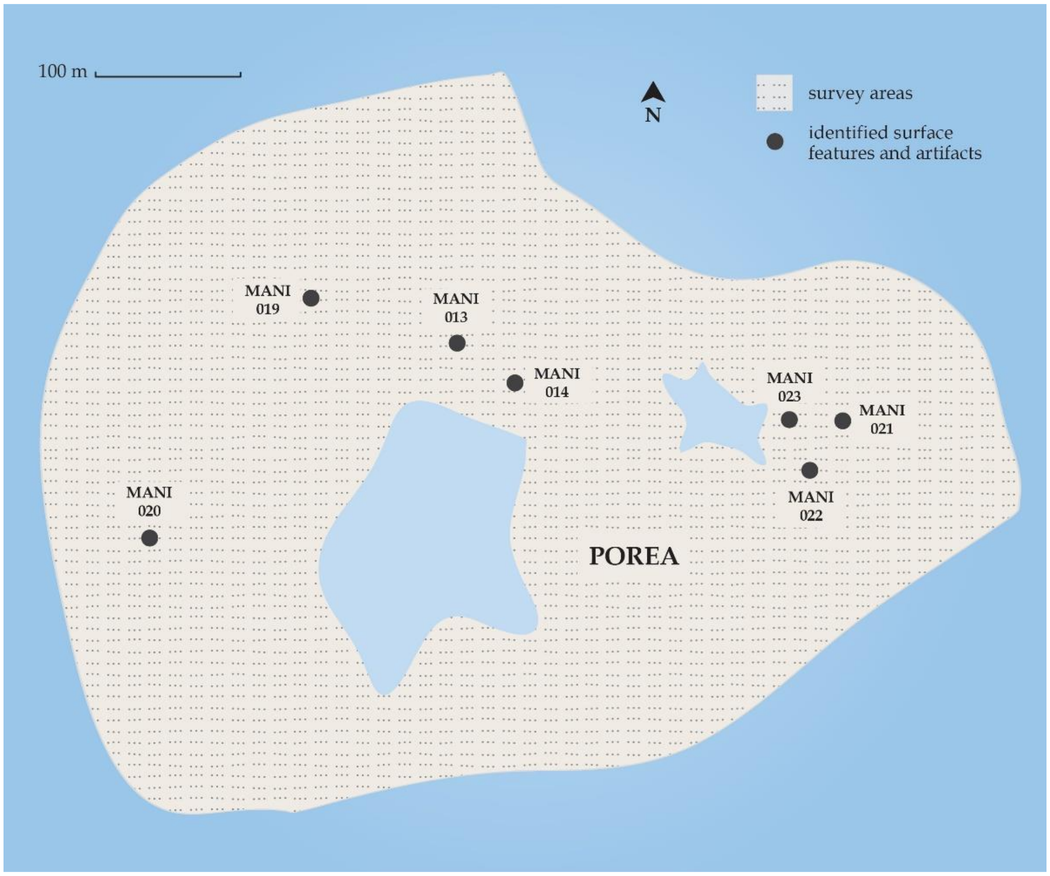

Figure A.3. Porea Islet, Manihiki with survey areas and identified features and artifacts

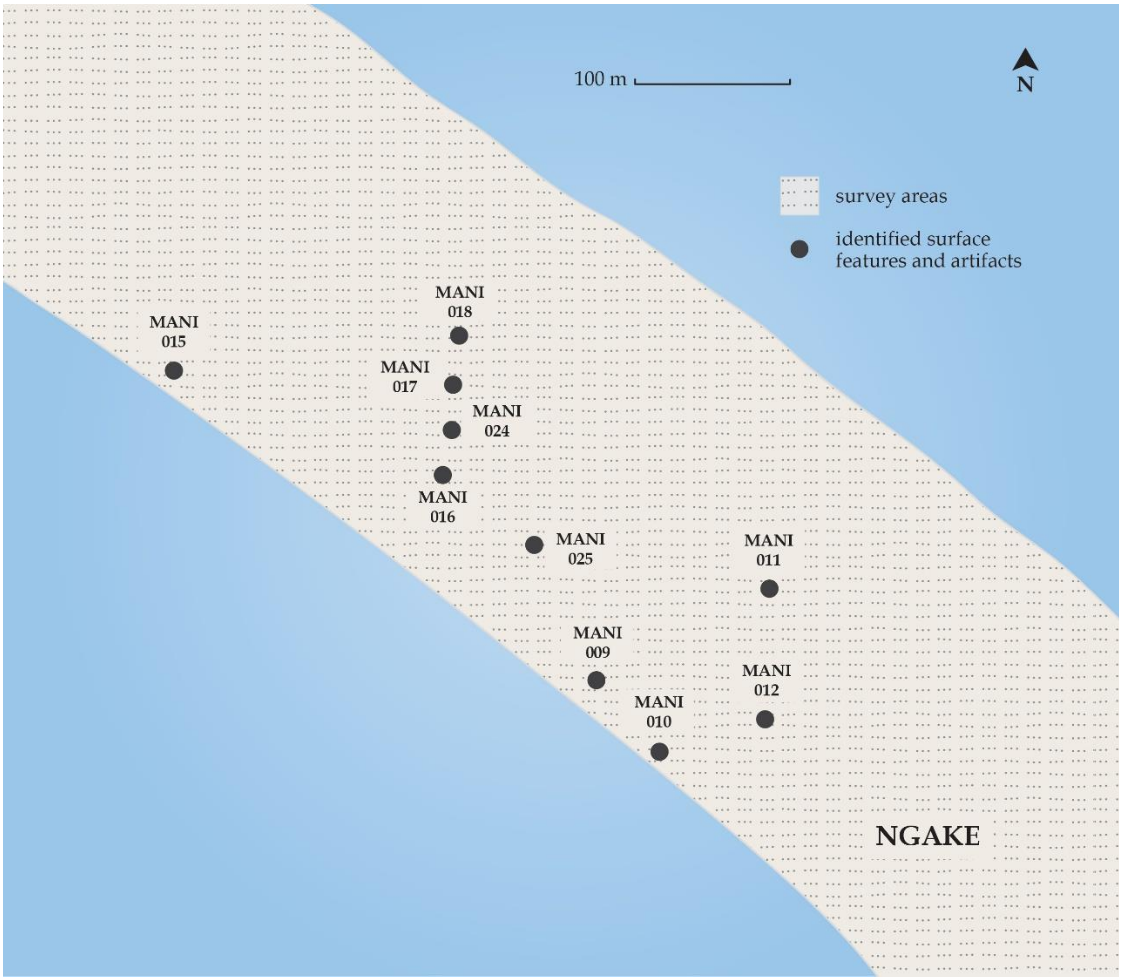

Figure A.4. Ngake Islet, Manihiki with survey areas and identified features and artifacts

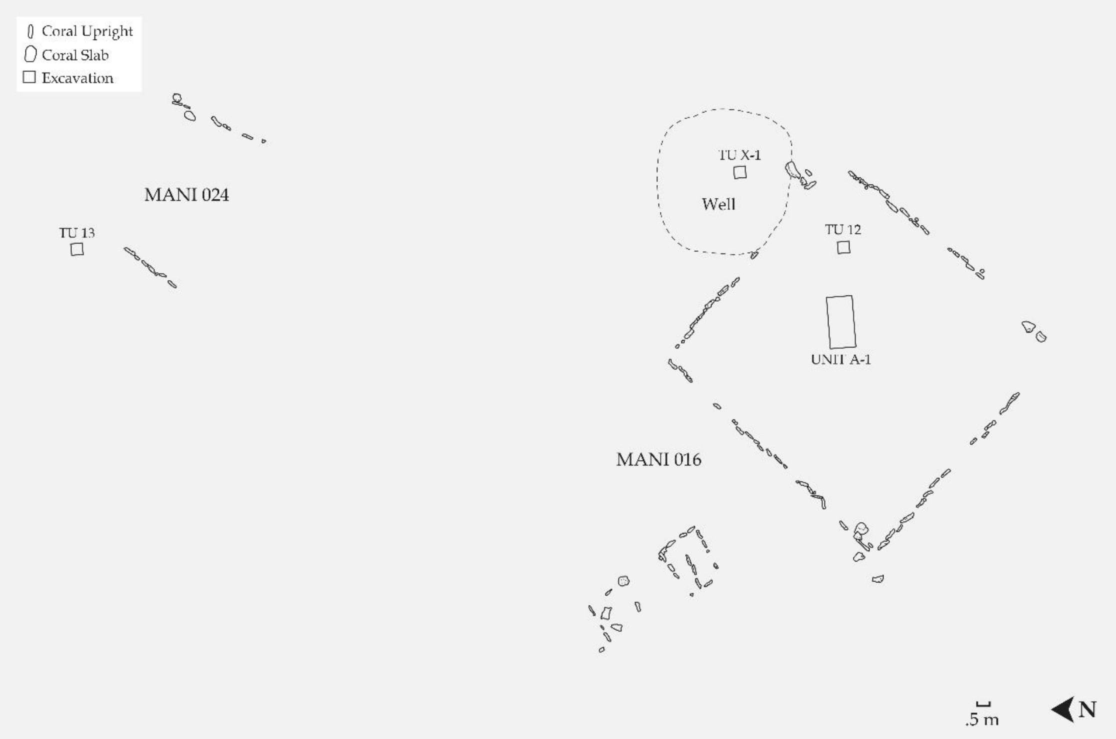

Figure A.5. Surface map of MANI 016 and 024 with excavation units and coral uprights

Figure A.6. Surface map of MANI 017 and 018 with excavation units and coral uprights

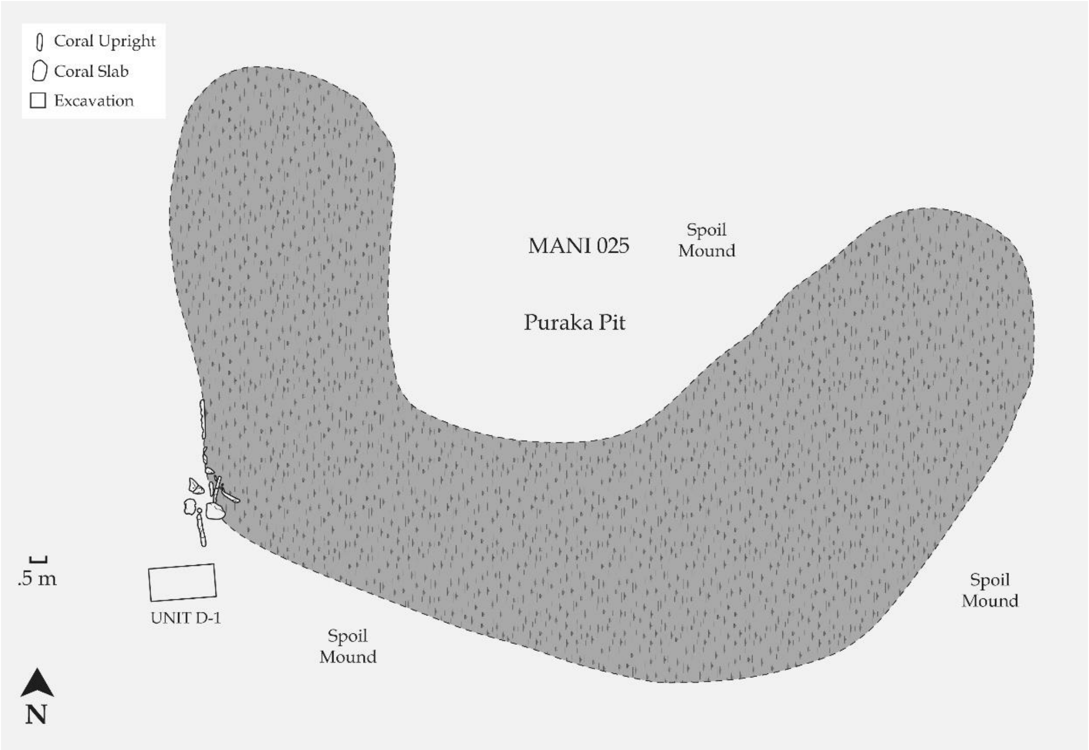

Figure A.7. Surface map of MANI 025 with excavation unit D-1, uprights, and spoil piles

The Rakahanga Survey

The archaeological survey of Rakahanga focused on three areas - the main islet where the extant village is today, Pahonu, and Te Kainga - the site of the former village. We documented 35 areas of interest including surface features and artifacts (Table A.2, Figures A.8-A.10). The main islet contained four locations associated with human burial and a number of monuments constructed during the 20th century. This islet also contained a network of mounds and valleys associated with the excavation of puraka cultivation pits. At Pahonu we identified the largest structures found anywhere on the atolls. The area is one large site complex (RAKA 013), contains numerous mounds of coral, and is associated with the life and death of the legendary warrior Temu Kaekae. Coral curb stones may have once held the mounds together in a platform shape but only a few remain standing. This is unlike any other architecture known on Manihiki and Rakahanga, but it is similar to building methods used to construct tombs in other island groups (e.g., Duff 1974; Emory 1939:12). Finally, we surveyed the islet of Te Kainga, the former home of the Rakahangan people, at length. The site density on Te Kainga is astounding; thus, lending credence to the narratives that suggest that a large population lived on the tiny 7-hectare islet. We documented previously identified sites such as a large standing stone (RAKA 10) (Hiroa 1932) and a stone mound (RAKA 26) (Chikamori et al. 1996) among the 26 areas of interest inventoried during the survey (Table A.2). Of these sites, six contained stone arrangements resembling graves. However, oral narratives insist that burials never occurred on Te Kainga, so it is difficult to assess the true function of these stone arrangements without excavating them. In addition, we noted two depressions, possible wells, a low mound of coral, a possible midden or refuse pile, five unidentified stone structures, and five areas that yielded surface artifacts. It is important to note that all previous surveys of Te Kainga failed to locate sites on the lagoon side of the islet. Through this survey we located a wealth of surface finds on the lagoon side of Te Kainga including one unidentified structure (RAKA 021) in close proximity to a clam-shell adze, a pearl-shell gouge, and faunal remains.

Table A.2. Surface features and artifacts on Rakahanga identified in 2015 and 2017

Rakahanga		
Catalog #	Islet	Description
RAKA 001	Te Kainga	Pit, possibly a former well
RAKA 002	Te Kainga	One coral-upright-edged enclosure, possibly a grave
RAKA 003	Te Kainga	Coral uprights, possibly part of an enclosure
RAKA 004	Te Kainga	An exposed beach berm with stratigraphic layering
RAKA 005	Te Kainga	Coral uprights, possibly part of an enclosure
RAKA 006	Te Kainga	A pit, possibly a former well
RAKA 007	Te Kainga	Coral uprights, possibly part of an enclosure
RAKA 008	Te Kainga	A coral upright; *kirikiri*
RAKA 009	Te Kainga	Four possible coral-upright-edged graves; coral uprights
RAKA 010	Te Kainga	The “Kingstone” an upright coral slab monument; Mua Marae; TEK-B
RAKA 011	Te Kainga	Two possible coral-upright-edged graves; possibly part of TEK-B
RAKA 012	Te Kainga	One possible coral-upright-edged grave; possibly part of TEK-B
RAKA 013	Pahonu	A coral mound complex; *kirikiri*; coral uprights; RAK-2
RAKA 014	Main Islet	One possible coral-upright-edged grave
RAKA 015	Main Islet	The “Turtle Stone” an historic upright coral monument
RAKA 016	Main Islet	A large earth mound, reported as an ancient place of burial
RAKA 017	Main Islet	A large earth mound, extant place of burial
RAKA 018	Main Islet	A large earth mound with four possible coral-upright-edged graves at its top
RAKA 019	Main Islet	A purported ancient burial ground

RAKA 020	Main Islet	An historic coral monument
RAKA 021	Te Kainga	Coral uprights; a conical coral upright; scattered faunal remains, a pearl shell gouge, and a clam shell adze (FS# R-002)
RAKA 022	Te Kainga	A pearl shell lure fragment (FS# R-003)
RAKA 023	Te Kainga	A punctured cowrie Shell (FS# R-001)
RAKA 024	Main Islet	A coral-upright alignment
RAKA 025	Main Islet	Two subdivided coral-upright-edged enclosures, possibly four graves
RAKA 026	Te Kainga	A coral mound; possibly TEK-A
RAKA 027	Te Kainga	A coral mound
RAKA 028	Te Kainga	One possible coral-upright-edged grave; possibly part of TEK-B
RAKA 029	Te Kainga	Coral uprights, possibly part of an enclosure
RAKA 030	Te Kainga	A clam shell adze and pearl shell scraper (FS # R-004)
RAKA 031	Te Kainga	A clam shell adze (FS# R-006)
RAKA 032	Te Kainga	A pearl shell scraper and pearl shell fishhook fragment (FS# R-007)
RAKA 033	Te Kainga	A small depression with possible midden materials
RAKA 034	Te Kainga	Two clam shell adzes (FS# R-008)
RAKA 035	Te Kainga	A clam shell adze fragment (FS# R-009)

If the identified features are a connected to, or are part of, previously documented sites, the site designator is listed. Yamaguchi and Chikamori (Chikamori et al. 1991; Yamaguchi 1998) identified sites TEK A-D; Di Piazza (2005) identified sites RAK 1-2; TK001 designates the sites excavated in 2017.

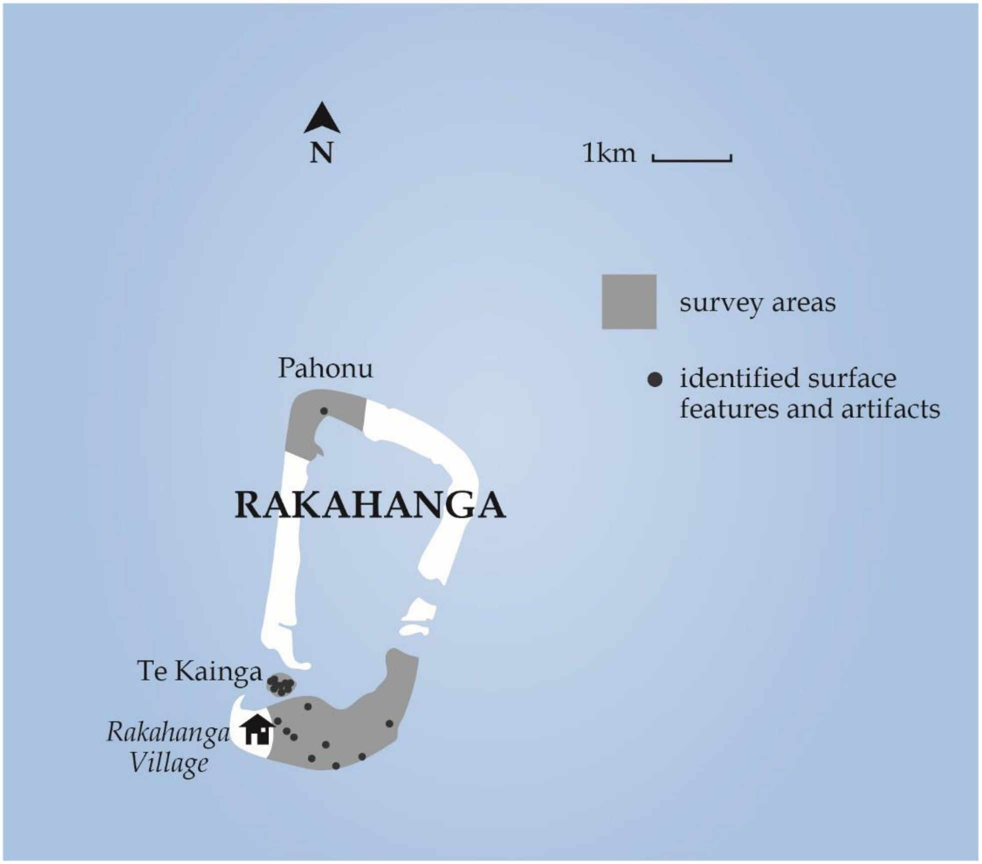

Figure A.8. Rakahanga atoll with modern village, survey areas, and identified features and artifacts

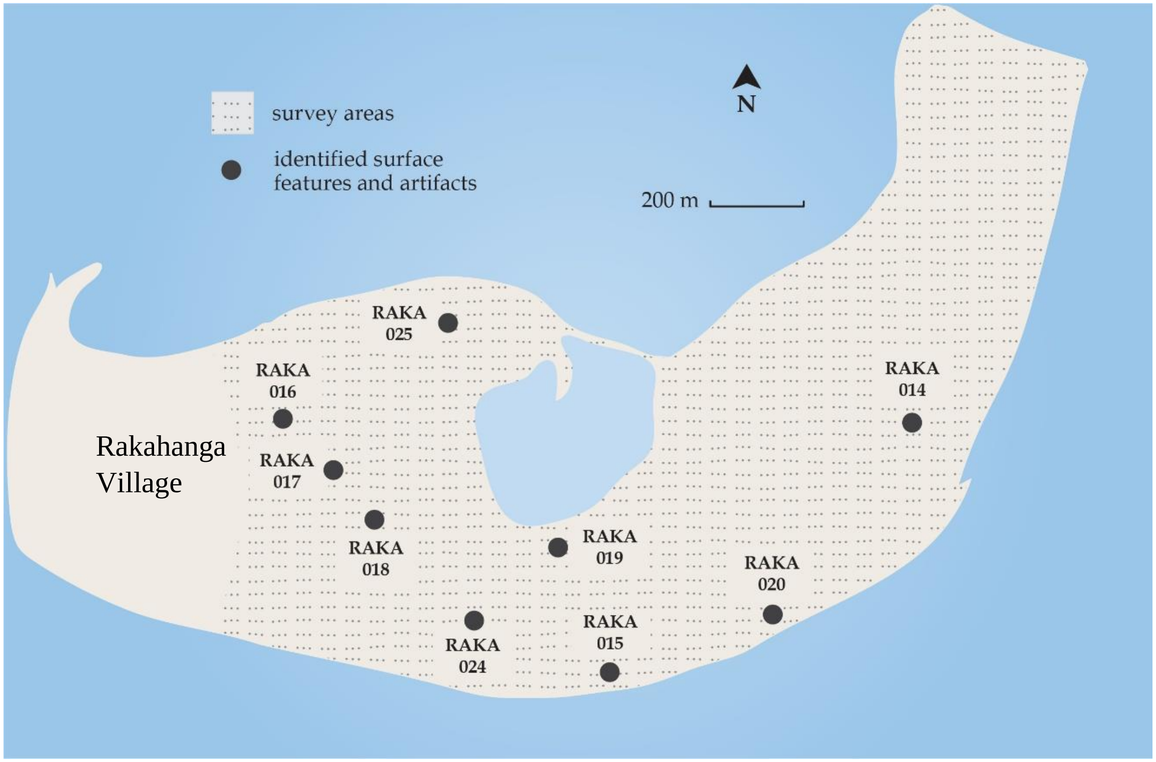

Figure A.9. The main islet of Rakahanga atoll with survey areas and identified features and artifacts

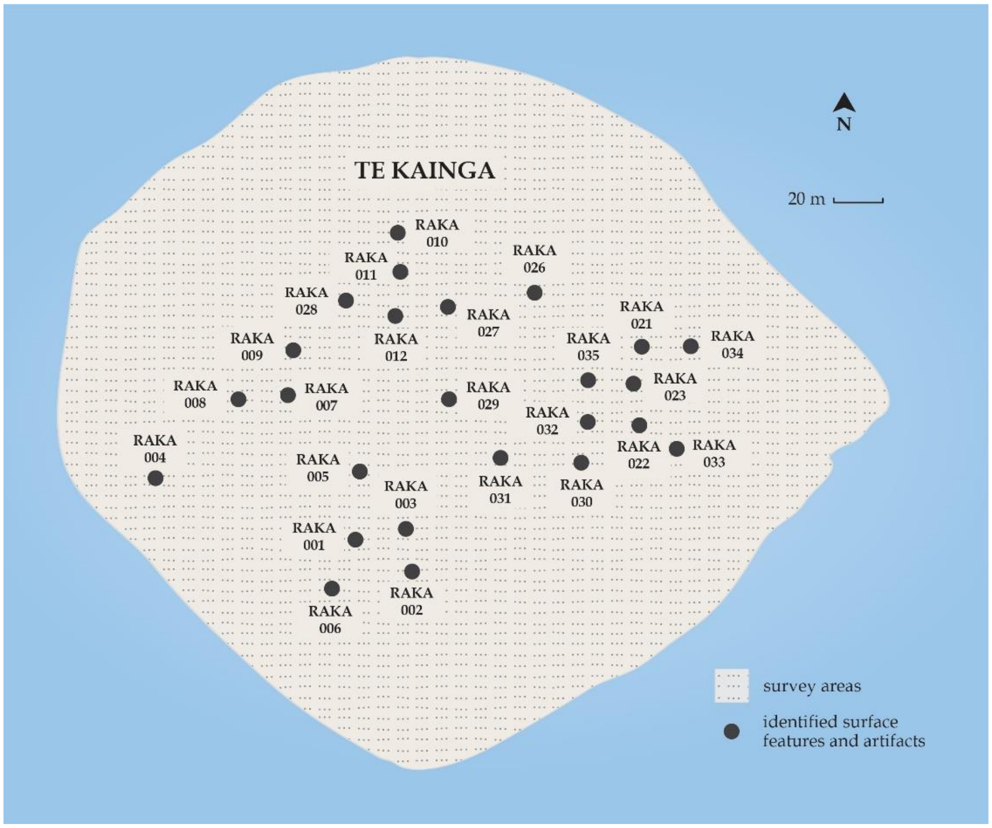

Figure A.10. Te Kainga Islet, Rakahanga atoll with survey areas and identified features and artifacts

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APPENDIX B – ARCHAEOLOGICAL EXCAVATION DATA

Excavation Methods

We used a test-unit survey to assess the temporality and preservation level of one habitation site on each atoll (NG001 and TK001) and an area at the center of the largest islet on Rakahanga (NV001) where a high likelihood of early habitation exists. The teams placed test unit transects in all three locations (Figure B.1). We excavated all of the test units in 50x50 cm squares at intervals of 30 m using a surface datum. The field team excavated the test units in 20 cm levels until they reached water or coral bedrock. In all, we placed 8 test units on Te Kainga (TK001), 10 on Ngake (NG001), and 4 on the main islet of Rakahanga (NV001). Based on the test-unit survey we determined the placement of larger excavation units including four 1x2 m units at NG001 and one 2x2 m unit on TK001. We placed one additional 1x1 m unit on the main islet of Rakahanga to test for evidence of the early creation of swamp-taro pits. The team screened all excavated matrix using nested 1/4th inch and 1/8th inch mesh. We collected all artifacts, faunal remains, viable carbon samples, and sediment samples. We also drew and photographed one profile of each test unit and at least two profiles for each larger unit. Stratigraphic layers are described below. I define all sediment color descriptions using Munsell Color Guide (Munsell 2010).

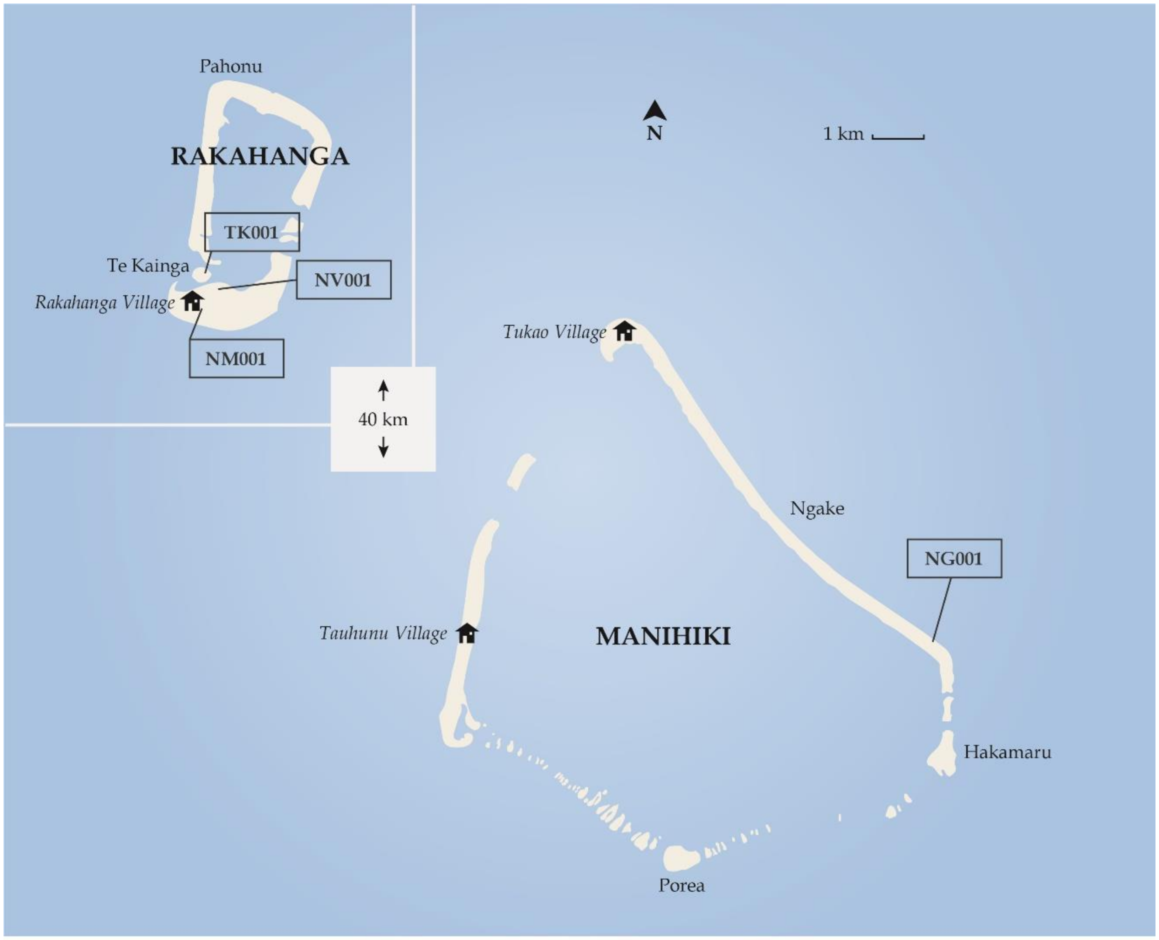

Figure B.1. Excavation areas on Manihiki and Rakahanga

The NG001 Excavations

We conducted the subsurface investigations on Ngake (NG001) in the area of the village complex on the south end of the islet (MANI 016, MANI 017, MANI 018, MANI 024, MANI 025) (Appendix A). The largest islet of Manihiki, Ngake, was likely attractive to early settlers. Its size suggests the presence of a large freshwater lens and a high potential for swamp taro cultivation. During the surface survey we identified rectangular courts edged with coral blocks on the south end of the islet that appear to be of late-pre-missionization construction. No European documents discuss this location, but the local people suggest that a small village once existed in the area. The field team mapped each surface feature (Appendix A). We excavated 10 test units in a south-north orientation stretching from lagoon shore to ocean shore. We placed one additional test unit in the center of a depression thought to be a long abandoned well. The test units yielded only one artifact of human construction (M-012) but contained multiple combustion features and faunal remains. Combined, the test unit excavations document relatively simple and consistent stratigraphy across the site. Large deposits of clean white sand likely indicate wash-over events. Based on the results of the test unit excavations three 1x2 m excavation units we placed along the transect. Unit A-1 was placed near the center of the largest and most intact stone-edged court; B-1 was placed near the center of the islet in an area with deep deposits of mounded sand and a stone-edged court; and C-1 was placed near the ocean side of the islet in an area with large amounts of faunal material. We placed an additional 1x2 m unit (D-1) in the berm of the adjacent puraka pit.

We excavated each unit to bedrock in arbitrary 10 cm levels. Unit A-1 (Figure B.2) contained faint layers or stratigraphic divisions and large coral slabs. A-1 was the only unit to produce cultural artifacts including pearl shell fishhooks as well as possible adornments and inlays. We excavated B-1 (Figure B.3) through the wall of a stone-edged court (MANI 017). Unit B-1 contained the thickest white sand deposits on the island and clear stratigraphic layering. The deep sandy Layer II was directly superior to a large earth oven that extended beyond the bounds of the unit. This combustion feature included large amounts of ash, burnt coral, and some faunal material. C-1 (Figure B.4) contained dense faunal material throughout. We excavated unit D-1 into the berm of the nearby puraka pit. Weisler (1999) dated the construction of cultivation pits in the Marshall Islands, by dating buried A horizons in the berms, or spoil piles created during the excavation of these pits. Unfortunately, unit D-1 (Figure B.5) produced simple stratigraphy and no short-lived botanicals. The unit also contained no cultural artifacts.

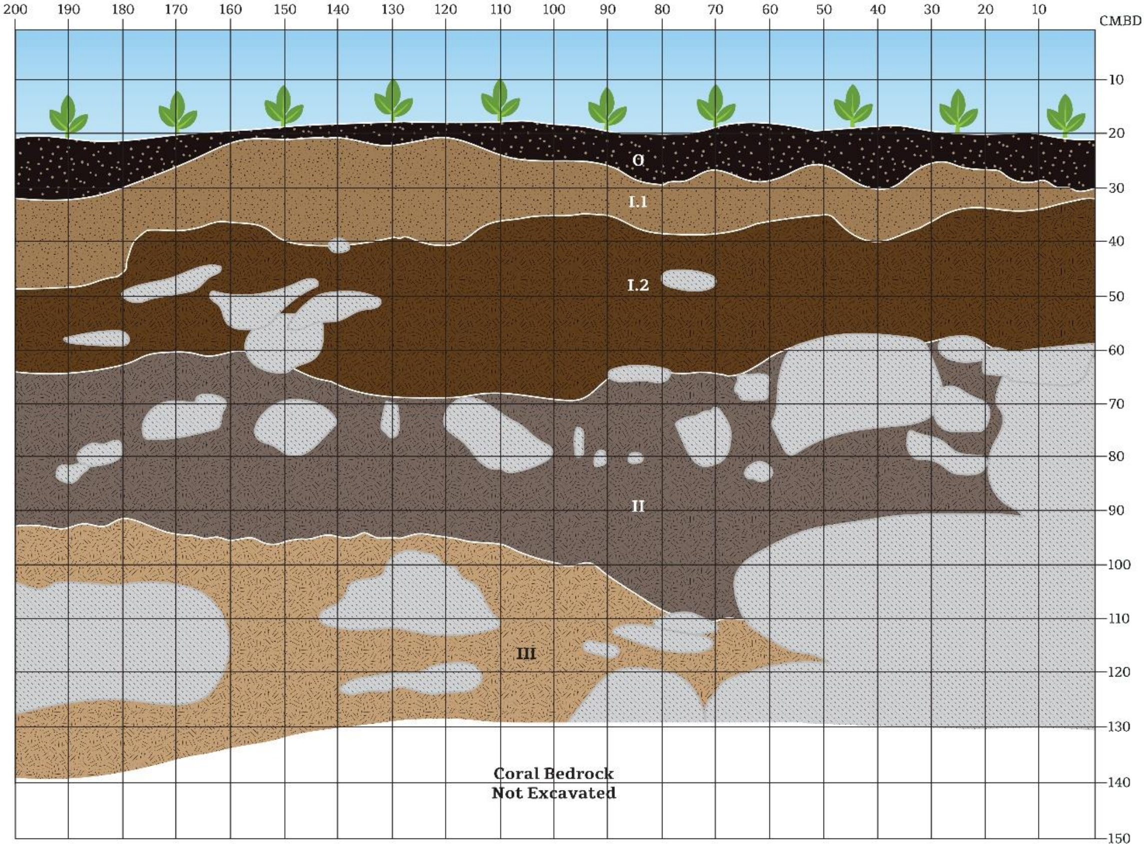

Figure B.2. Excavation profile for the south wall of Unit A-1 at NG001

NG001 Unit A-1 Stratigraphy Description

Layer O consists of black (10yr 2/1) organic soil.

Layer I is a layer of dark sand that contains cultural materials. It is divided into two sub-layers based on subtle changes in sediment color and consistency. A pit feature associated with Layer I intrudes into layer II.

> **Layer I.1** is comprised of fine to medium pale brown (10YR 6/3) sand with some organic humus. This layer contained worked pearl shell fragments, two pearl shell fishhooks (FS# M-040-A-D), and one cowrie shell bead (FS# M-40-E) and other faunal remains.

Layer I.2 consists of brown (10YR 4/3) medium to coarse sand with coral pebbles. The layer contained worked pearl shell fragments, two cowrie beads (FS# M-041-A, M-042-B), two pearl shell disks (FS# M-042-A&C), a fishhook fragment (FS# M-043-A) and other faunal remains.

Feature 01 consists of a pit feature extending down from Layer I.2. Feature 01 contains light gray (10YR 7/1) coarse sand with worked pearl shell, two drilled pearl shell adornments (FS# M-047-A&B), and other faunal materials.

Layer II is comprised of fine to very coarse gray (10YR 5/1) sand with large fragments of coral in the upper part of the stratum. We recovered a fragment of a fishhook (FS# M-046-A) from Layer II as well as other faunal materials.

Layer III abuts coral bedrock and contains very pale brown (10YR 7/3) coarse to very coarse sand with large coral fragments. We identified no definitively cultural materials, but we were able to collect some charcoal, shell, and urchin spines.

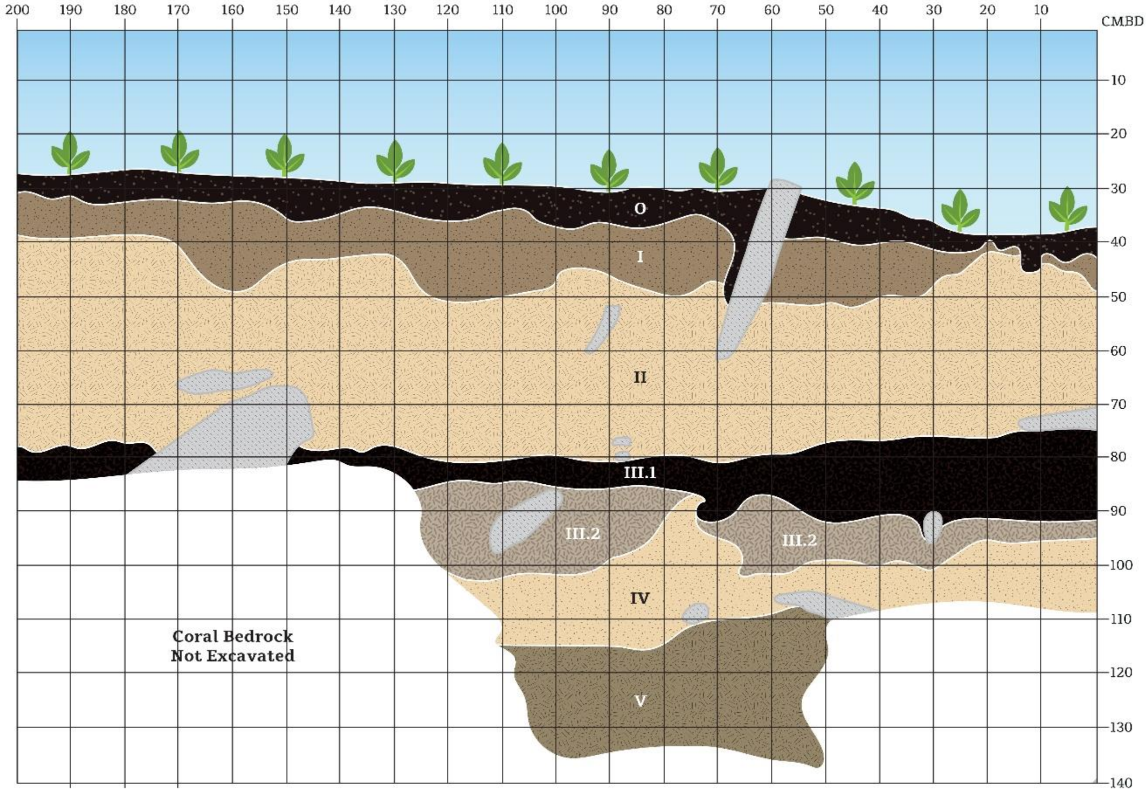

Figure B.3. Excavation profile for the east wall of Unit B-1 at NG001

NG001 Unit B-1 Stratigraphy Description

Layer O consists of black (10YR 2/1) organic soil.

Layer I is a layer of light grayish brown (10YR 6/2) fine to coarse sand. The layer contains faunal materials and charcoal but no other cultural materials.

Layer II is a deep deposit of pale-yellow (2.5YR 8/2) medium to coarse sand with large amounts of coral pebbles. This layer contains small amounts of faunal material and charcoal.

Layer III consists of an earth oven (III.1) and the grey ashy sediments beneath it (III.2).

> **Layer III.1** is an earth oven combustion feature. The deepest portions of the oven are located in the south end of the unit and extend beyond its southern limits. The layer

contains very dark brown (10YR 2/2) medium to coarse sand and ashy material with heat-fractured coral. Some charred faunal materials were present. Two radiocarbon dates were run on Layer III.1 the first on a pandanus drupe (UGAMS 35654) returned a date of 320 ± 20 BP and the second on a fragment of pearl shell (UGAMS 38555) from the interface of III.1 and III.2 returned a date of 980 ± 20.

Layer III.2 contains light grey (10YR 7/1) medium to coarse ashy sand with some faunal and charcoal.

Layer IV consists of pale yellow (2.5YR 8/2) medium to coarse sand with some faunal and charcoal.

Layer V is comprised light brownish gray (2.5YR 6/2) medium to very coarse sand with shell, urchin and coral inclusions, but no cultural materials. The layer terminates at coral bedrock.

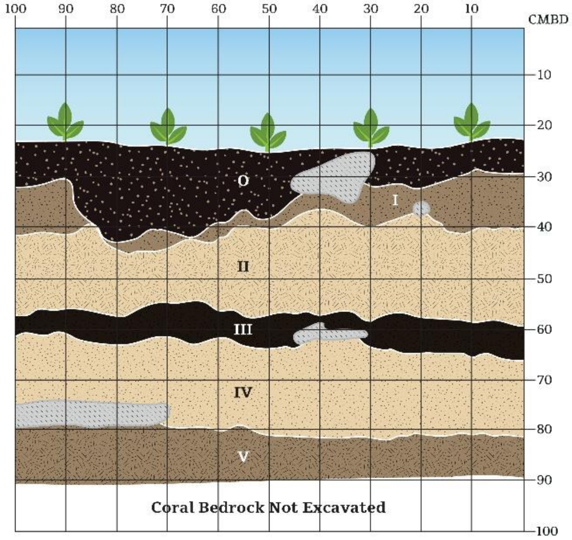

Figure B.4. Excavation profile for the south wall of Unit C-1 at NG001

NG001 Unit C-1 Stratigraphy Description

Layer O consists of black (10YR 2/1) organic soil.

Layer I contains light grayish brown (10YR 6/2) fine to very coarse sand with charcoal and faunal materials. A date run on a charred pandanus drupe (UGAMS38551) from the interface between Layers I and II provided a date range of 100 ± 20.

Layer II is comprised of pale yellow (2.5YR 8/2) medium to coarse sand with large amounts of coral granules and pebbles. Layer II contains large amounts of faunal materials and charcoal. A date run on charred coconut endocarp (UGAMS 40094) returned a date of 140 ± 25. A sample of bone gelatin from a neonatal pig (*Sus scrofa*) vertebra (UGAMS 40464) found in Layer II was dated and returned modern values, indicating that it was intrusive to the deposit. This suggests mixing occurred in Layer II.

Layer III consisted of very dark gray (2.5YR 3/1) medium to very coarse sand with large amounts of faunal material. Considered to be a midden deposit, a pandanus drupe (UGAMS 35655) from the layer dated 310 ± 20. Layer III appears contemporaneous with the earth oven layer in Unit B-1.

Layer IV contains pale yellow (2.5YR 8/2) medium to coarse sand and contained some faunal and charcoal.

Layer V is comprised of light grayish brown medium to very coarse sand, broken coral, and coral granules. The layer contains some faunal remains and charcoal.

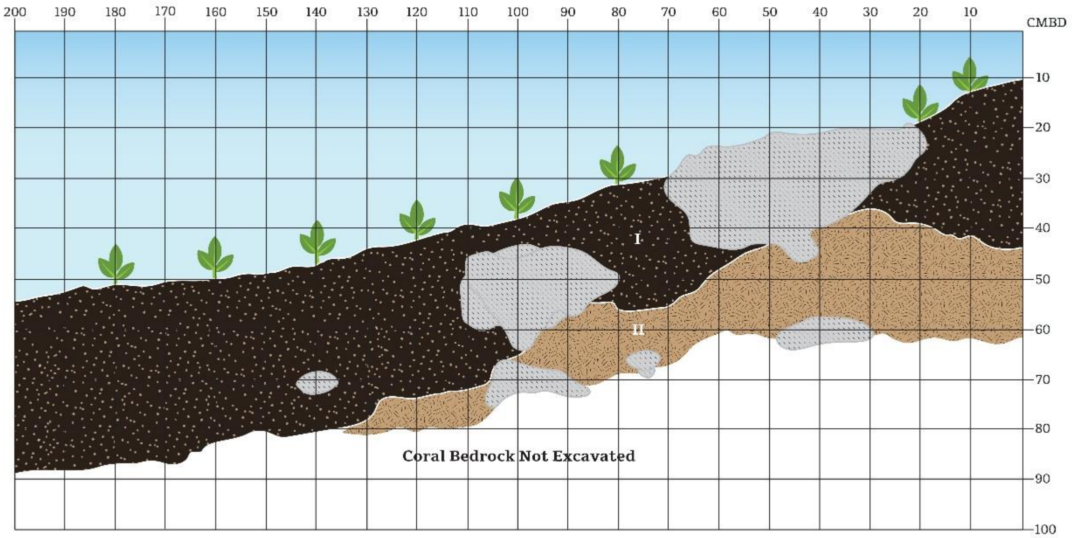

Figure B.5. Excavation profile for the south wall of Unit D-1 at NG001

NG001 Unit D-1 Stratigraphy Description

Layer O/I consists of fine to coarse very dark gray (10YR 3/1) sand with coral and a high percentage of organic material. The layer slopes from a spoil pile toward a puraka pit.

Layer II is comprised of very pale brown (10YR 7/3) medium to coarse sand.

The TK001 Excavations

The survey of Te Kainga indicated that the entire islet is an archaeological site complex with numerous habitation and social areas. Therefore, the site designation TK001 refers to the entire islet, unit designations and area designations made by previous researchers indicate areas within the site. We placed eight test units on Te Kainga (TK001) in an east-west, lagoon to ocean transect bisecting the 300 m diameter of Te Kainga. Appendix A includes all known feature designations and surface artifacts. The test unit excavations produced complex stratigraphy that was discontinuous from one unit to the next (Figure B.6). The units on the lagoon side of the islet had the most complex stratigraphic profiles. Every test unit produced a relative abundance of faunal materials when compared to NG001; pearl shell artifacts were common. We placed a 2x2 m excavation unit adjacent to the test unit with the most complex stratigraphy (TU2). Hiroa (1932) described this area as emerging around the time of the formation of a dual-chiefdom political structure (Chapter 2). We excavated this unit (A-1) to bedrock. It contained 17 layers (Figure B.7). It also contained two small combustion features, plentiful faunal material, and numerous modified shell and coral artifacts.

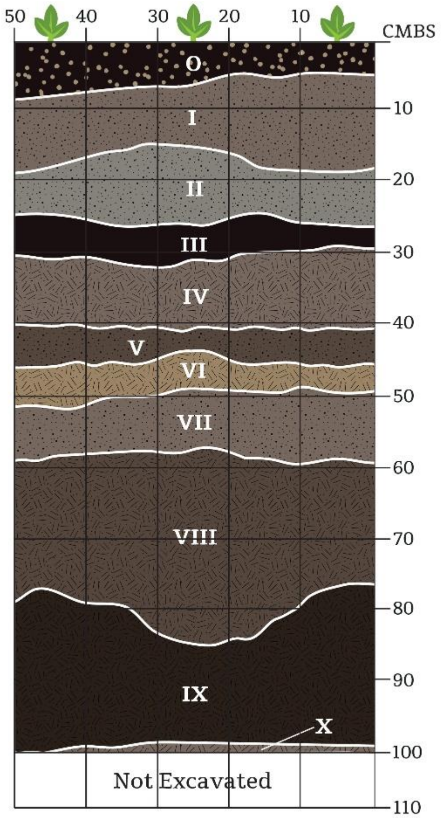

Figure B.6. Excavation profile for the north wall of Test Unit 5 at TK001

TK001 Test Unit 5 Stratigraphy Description

Layer O of consists of black (10YR 2/1) organic soil.

Layer I contains gray (10YR 5/1) fine to coarse sand with coral granules, worked pearl shell, and some faunal materials.

Layer II contains gray (2.5YR 6/1) fine to very coarse sand with coral granules, faunal materials, charcoal, and worked pearl shell.

Layer III consists of black (10YR 2/1) fine to coarse sand with, faunal materials, and charcoal.

Layer IV consists of gray (10YR 5/1) fine to coarse sand with coral granules, faunal materials, and charcoal.

Layer V contains dark gray (10YR 4/1) fine to coarse sand with coral granules, faunal materials, and charcoal.

Layer VI consists of light brownish gray (10YR 6/2) fine to very coarse sand with coral pebbles, faunal materials, and charcoal.

Layer VII contains gray (10YR 5/1) fine to very coarse sand with coral pebbles, faunal materials, and charcoal.

Layer VIII contains dark gray (10YR 4/1) fine to very coarse sand with coral pebbles, faunal materials, and charcoal.

Layer IX contains very dark gray (10YR 3/1) fine to coarse sand with coral pebbles, faunal materials, and charcoal. Three dates were run on materials from TU05 Level 4, which contained parts of the stratigraphic Layers VIII and IX. We ran the first on a charred pandanus drupe (UGAMS 36970) and returned a date of 310 ± 20. We ran the second on a *Canis familiaris* tooth

(UGAMS 36967) and it returned a date of 740 ± 20. We ran the third on a fragment of pearl shell (UGAMS 38553) and it returned a date of 810 ± 20.

Layer X consists of gray (10YR 5/1) medium to coarse sand with coral pebbles and granules, faunal materials, charcoal, and a pearl shell fishhook fragment (FS#-R-049A).

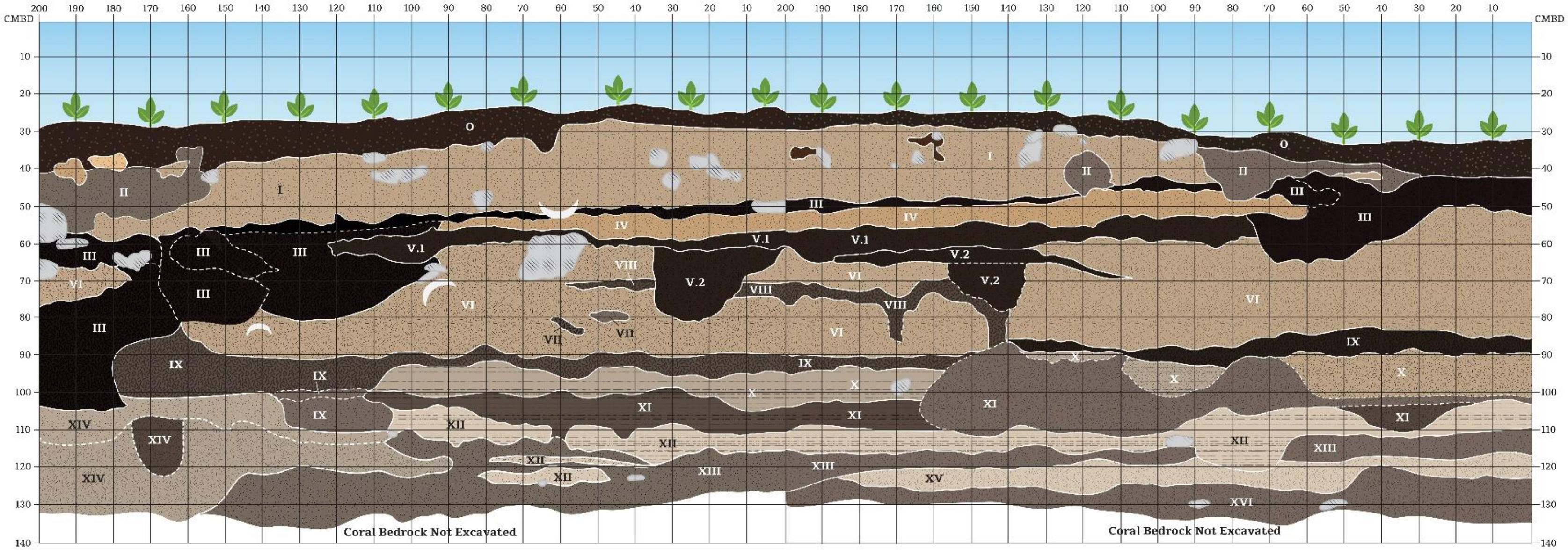

Figure B.7. Excavation profile for the east and south walls of Unit A-1 at TK001

TK001 Unit A-1 Stratigraphy Description

Layer O of consists of very dark grey (10YR 3/1) organic soil with some sand, coral, and historic metal.

Layer I consists of mainly light gray (10YR 7/2) fine to medium sand with pocketed inclusions, likely disturbance due to bioturbation. The layer contains historic deposits and worked pearl shell.

Layer II is a discontinuous possibly disturbed layer that consists of mainly gray (10YR 5/1) fine to medium sand with pocketed inclusions. Layer II includes cultural materials including historic metals, charcoal, faunal materials, worked pearl shell, and pearl shell objects (FS# R-075-A&C).

Layer III consists of black ashy (10YR 2/1) sand, faunal materials, charcoal, burnt coral and artifacts. The layer includes two combustion features combustion features and a thin layer of ashy sand. It is likely that multiple burning events are represented in Layer III and the associated features. A radiocarbon date was run on coconut endocarp (UGAMS 35650) from layer III. It returned the date 100 ± 20 BP.

Layer IV is comprised of very pale brown (10YR 7/3) coarse to very coarse sand with coral pebbles and cobbles as well as some charcoal and faunal materials. We identified a fishhook (FS# R-077-B) in this layer.

Layer V consists of a layer of a thin deposit of black to dark gray (10YR 2/1 to 10YR 3/1) fine to medium ashy sand.

> **Layer V.1** consists of very dark gray (10YR 3/1) fine to medium sand, coral pebbles and charcoal. We ran a radiocarbon date on coconut endocarp (UGAMS 35651) from layer V.1. It returned the date 100 ± 20 BP.
>
> **Layer V.2** is a small combustion pit feature (Feature 01) that consists of very compact gray (10YR 3/1) fine to coarse sand and charcoal. We ran a radiocarbon date on coconut

endocarp (UGAMS 35652) from Feature 01 of layer V.2. It returned the date 100 ± 20 BP. This indicates that the deposition of Layers III-V occurred in a very short span of time.

Layer VI is a thick layer of light gray to light grayish brown (10YR 7/2 to 10YR 6/2) fine to very coarse sand, coral granules, and light charcoal flecking. This layer also contained faunal remains and cultural artifacts including a pearl shell fishhook blank and pearl shell scraper (FS# R-085-A, R-080-B).

Layer VII consists of patches of ashy dark gray to gray (10YR 5/1 to 10YR 4/1) very fine to coarse sand within layer VI.

Layer VIII consists of ashy gray to dark gray (10YR 5/1 to 10YR 4/1) very fine sand with charcoal and possible microstratigraphic layering.

Layer IX cross cuts the entire unit and contains ashy gray to dark gray (10YR 5/1, 10YR 4/1, 10YR 3/1) very fine to very coarse hard packed sand with a high density of coral pebbles and granules. Some faunal materials and charcoal were present. We ran a radiocarbon date on a charred coconut endocarp fragment (UGAMS 35653) and returned a date of 180 ± 20. We ran additional dates on a pandanus drupe (UGAMS 38522), a pearl shell fragment (UGAMS 38554), and a dog tooth (UGAMS 36969) from a level containing the interface between layers IX and X. The resulting dates were 110 ± 20, 750 ± 20, and 670 ± 20 BP respectively.

Layer X consists of light gray (10YR 7/1 and 10YR 7/2) very fine to very coarse sand with large amounts of coral granules. The layer contains possible microstratigraphic layering and small amounts of charcoal flecking.

Layer XI consists of dark gray to gray (10YR 4/1 and 10YR 5/1) fine to very coarse sand with coral granules. The layer contains possible microstratigraphic layering and charcoal. Faunal remains including dog remains are associated with this layer, as are worked pearl shell and a pearl shell adornment (FS# R-095-C).

Layer XII is comprised of white (10YR 8/1) fine to coarse sand. The layer appears to contain very fine microstratigraphic layering. It is discontinuous with white lenses appearing within the matrix of layer XIII.

Layer XIII is the terminal layer for much of the unit. It is comprised of ashy gray (10YR 5/1) fine to coarse sand with coral granules and pebbles throughout. Small amounts of charcoal and faunal materials are present in the layer. We ran two radiocarbon dates on charred coconut endocarp samples (UGAMS 34018 and UGAMS 35649) from this layer. They returned the dates of 250 ± 20 and 210 ± 20 respectively.

Layer XIV is the terminal layer for a portion of the unit. This layer consists of patchy light (10 YR 7/1) fine to very coarse sand with a patch of dark gray (10YR 4/1) very fine to fine sand. The layer has coral granules throughout.

Layer XV consists of white (10YR 8/1) fine to very coarse sand with coral granules and pebbles.

Layer XVI is the terminal layer for the remainder of the unit. It consists of gray (10YR 5/1) very fine sand with coral granules.

NV001

We placed the NV001 test units in an area deemed as a likely first habitation location, near the center of the largest islet. On many atolls the initial settlement takes place on the largest islet as it would have the greatest freshwater lens and most protection from wave action (Weisler 1999). The test units at NV001 had only faint traces of human activity, containing limited bone, shell, and sediment staining. The area tested showed no indications of use for habitation or any other intensive activities before missionization in AD 1849. The wet nature of the sediments may suggest that this area was better suited to cultivation than habitation.

NM001

As there were no puraka pits to sample on Te Kainga, we placed a 1x1 m excavation unit in the extant village on the main islet. We excavated this unit on the edge of a puraka pit that is in use today. The unit was sterile other than a few, shells, bones, and modern material culture near the surface. The faint strata consisted of lightly colored sands. It is likely that this is spoil from the excavation of the puraka pit, but we did not identify a buried A horizon.

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APPENDIX C - ARTIFACT DATA

Artifact Analysis

All human modified artifacts recovered from the 2015 archaeological survey and the 2017 archaeological excavations on Manihiki and Rakahanga are described below.

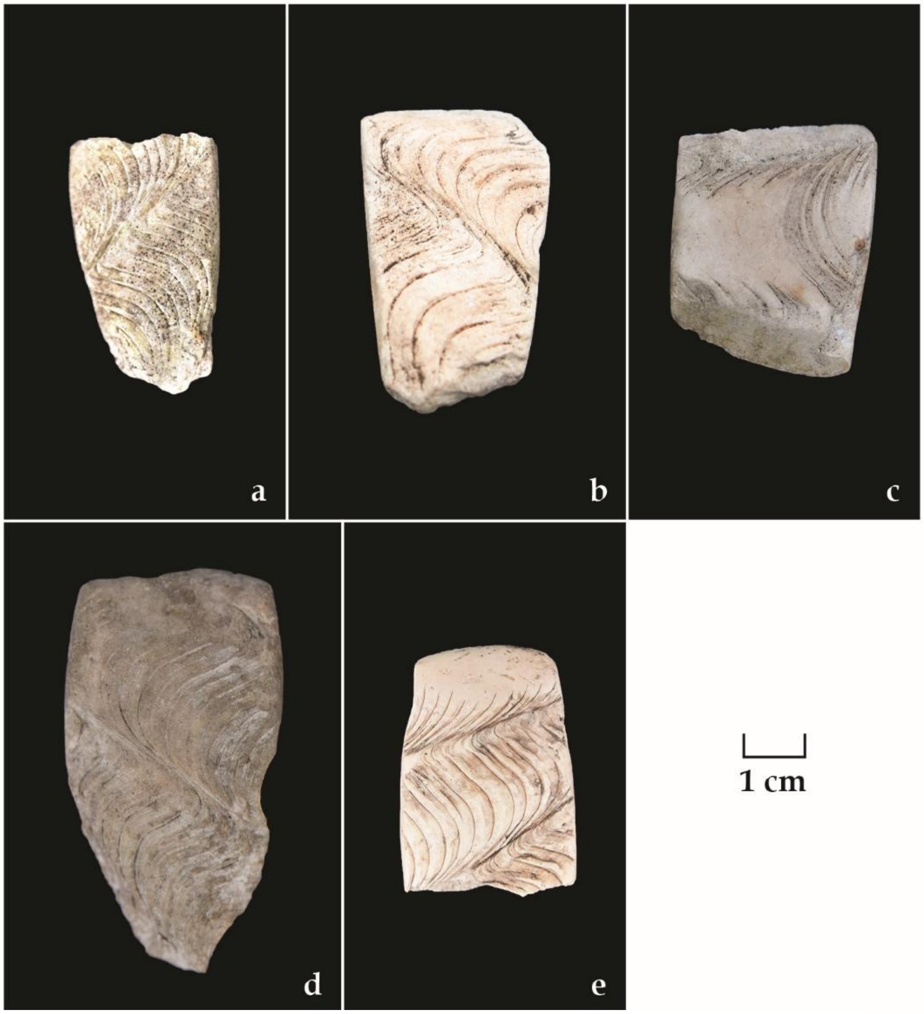
Clam-Shell Adzes

Although the geology of Manihiki and Rakahanga, like that of other atolls, lacks hard stone, such as the fine-grain basalt used to make adzes elsewhere in the Pacific, the lagoons of Manihiki and Rakahanga contain large bivalve clams. The dorsal region of the valve of lesser giant clam (*Tridacna maxima*), or *pahua* as it is known locally, was used to craft adzes. All of the adzes identified from Manihiki and Rakahanga were found on the surface or in shallow deposits. The team only found one adze on Manihiki. It was on the surface near unit A-1 at NG001, Manihiki. We identified the remaining eight adzes at the TK001 site. I classified all adzes following Weisler (2001) (Table C.1; Figure C.1).

Table C.1. Adze typology

Provenience		Portion			Grinding Location			Cutting Edge		Measurements						
Site	FS#	Edge	Mid	Butt	Front	Side	Back	Shape in Plan	Bevel	Length, mm	Edge Width, mm	Midpoint Width, mm	Midpoint Thickness, mm	Butt Thickness, mm	Weight, g	Edge Angle
MANI 016	M-016	-	+	+	-	+	+	-	-	-	-	27.00	18.20	7.69	16.08	-
RAKA 021	R-002-1	+	+	-	+	+	-	straight	flat	-	32.45	31.58	8.20	-	2.79	46°
RAKA 030	R-004-2	-	+	+	-	+	+	-	-	-	-	24.61	7.50	4.29	12.61	-
RAKA 031	R-006	-	+	+	-	+	+	-	-	-	-	43.55	9.41	7.61	71.05	-
RAKA 034	R-008-1	+	+	-	+	+	-	curved	flat	-	32.52	34.90	7.85	-	21.89	35°
RAKA 034	R-008-2	+	+	+	+	+	-	straight	flat	68.36	33.80	35.50	11.10	10.65	41.18	31°
RAKA 035	R-009	+	+	-	+	+	-	straight	flat	-	29.18	30.41	8.50	-	14.09	50°
TK001	R-040-A	+	+	-	+	+	-	curved	flat	-	24.90	30.25	7.40	-	15.78	28°
TK001	R-084	-	+	-	-	+	-	-	-	-	-	21.43	5.78	-	5.25	-

Analysis follows that completed by Weisler (2001). All adzes from the Manihiki and Rakahanga investigations appear finished, are quadrangular in cross section, and are crafted from the dorsal portion of the *Tridacna maxima* clam. I use (+) to indicate the presence of a portion of the adze or grinding on a surface and (-) to indicate the absence an adze portion or a lack of grinding on a surface.



A (M-016); B (R-002-1); C (R-08-1); D (R-008-2); E (R-040-A).

Figure C.1. Examples of the adzes described in Table C.1

Fishing Implements

Fishing played a key role in most East Polynesian societies. Past researchers have documented hundreds of fishing techniques on coral atolls in East Polynesia (e.g., Conte 1988) and many of these involve the use of shell implements including one-piece fishhooks, composite fishhooks, and trolling lures. While fishing implements of bone and wood are common throughout the Pacific, many implements were crafted from marine shell such as the iridescent shell of the black-lipped pearl oyster (*Pinctada margaritifera*). On Manihiki and Rakahanga the pearl oyster is very abundant and numerous pearl-shell tools were identified in this and previous studies (Di Piazza 2005; Hiroa 1932). Fishhooks and lures are utilitarian items designed to capture animals through a variety of techniques, though they do have stylistic properties (Allen 1996). There is no standard system of fishhook classification system in the region. Some researchers favor overall form and others focus on individual elements of the implements such as the head (line attachment point), curve, and point (Allen 1996; Rolett 1998). We identified thirty fishing implements in various stages of manufacture in the Manihiki and Rakahanga assemblages. These include blanks or preforms, as well as complete and fragmentary hooks and lure shanks. Due to the small number of diagnostic hooks and the fragmentary nature of fishing implements recovered from the Manihiki and Rakahanga excavations, comparison with other island groups is difficult. However, I report the results of typological and attribute-based analysis in Tables C.2 and C.3 and provide example images in Figure C.2.

Table C.2. Fishhook classifications by stylistic traits

Provenience		Head Class			Alignment		Measurements (mm)	
Site	FS#	Proximal End	Inner Edge	Outer Edge	Shank	Point	Hook Width, mm	Hook Length, mm
NG001	M-040-B	1	2	3	1	1?	18.68	-
NG001	M-040-D	1	2	3	1	1	20.40	12.65
NG001	M-046-A	1	2	3	1	-	18.25	-
TK001	R-007-2	5	2	3	2?	-	-	-
TK001	R-079-A	2	4	3	1	-	-	-
TK001	R-080-D	1	2	3	2	2	17.50	14.80
TK001	R-080-E	2	2	3	2	-	-	-

I classified specimens using methods described in Allen (1996). I only list specimens complete enough for full or partial classification. Dashes indicate a lack of data due to fragmentation. All fishing implements listed here are pearl shell (*Pinctada margaritifera*).

Table C.3. Fishhook classifications by overall morphology

Provenience		Completeness				Type
Site	FS#	Finished	Unfinished	Blank	Fragmentary	
NG001	M-040-A	+	-	-	+	nd
NG001	M-040-B	+	-	-	+	jabbing
NG001	M-040-C	+	-	-	+	nd
NG001	M-040-D	+	-	-	-	jabbing
NG001	M-043-A	+	-	-	+	cf. jabbing
NG001	M-047-C	-	+	+	-	blank
RAKA022	R-003	?	?	-	+	lure shank
RAKA032	R-007-2	+	-	-	+	cf. heavy shank
TK001	R-027	+	-	-	+	nd
TK001	R-033-B	?	?	-	+	nd
TK001	R-035-B	-	+	+	-	blank
TK001	R-049-A1	-	+	-	+	cf. heavy shank
TK001	R-049-A2	-	+	-	+	nd
TK001	R-052	?	?	-	+	lure shank
TK001	R-059-A	?	?	-	+	nd
TK001	R-060-A	+	-	-	+	nd
TK001	R-069-A	+	-	-	+	nd
TK001	R-077-A	+	-	-	+	cf. jabbing
TK001	R-077-B	+	-	-	+	cf. heavy shank
TK001	R-079-A	+	-	-	+	cf. jabbing
TK001	R-080-D	-	+	-	-	cf. heavy shank
TK001	R-080-E	+	-	-	+	heavy shank jabbing
TK001	R-085-A	?	?	-	+	heavy shank jabbing
TK001	R-087-B	+	-	-	+	cf. obtuse recurved
TK001	R-087-D	+	-	-	+	jabbing
TK001	R-104	?	?	-	+	nd
TK001	R-108-B	-	+	+	-	blank
TK001	R-147	-	+	+	-	blank

The morphological types follow Rolett (1998). I use (+) to indicate affirmative, (-) to indicate negative, and (?) to indicate unknown. If no typological classification was possible, I use (nd) to indicate that the specimen is non-diagnostic. All fishing implements listed here are pearl shell (*Pinctada margaritifera*).

A (M-040-B); B (M-040-D); C (R-079-A); D (R-080-D); E (R-080-E); F (R-003); G (R-0870D)

Figure C.2. Examples of the fishing implements described in Tables C.2 and C.3

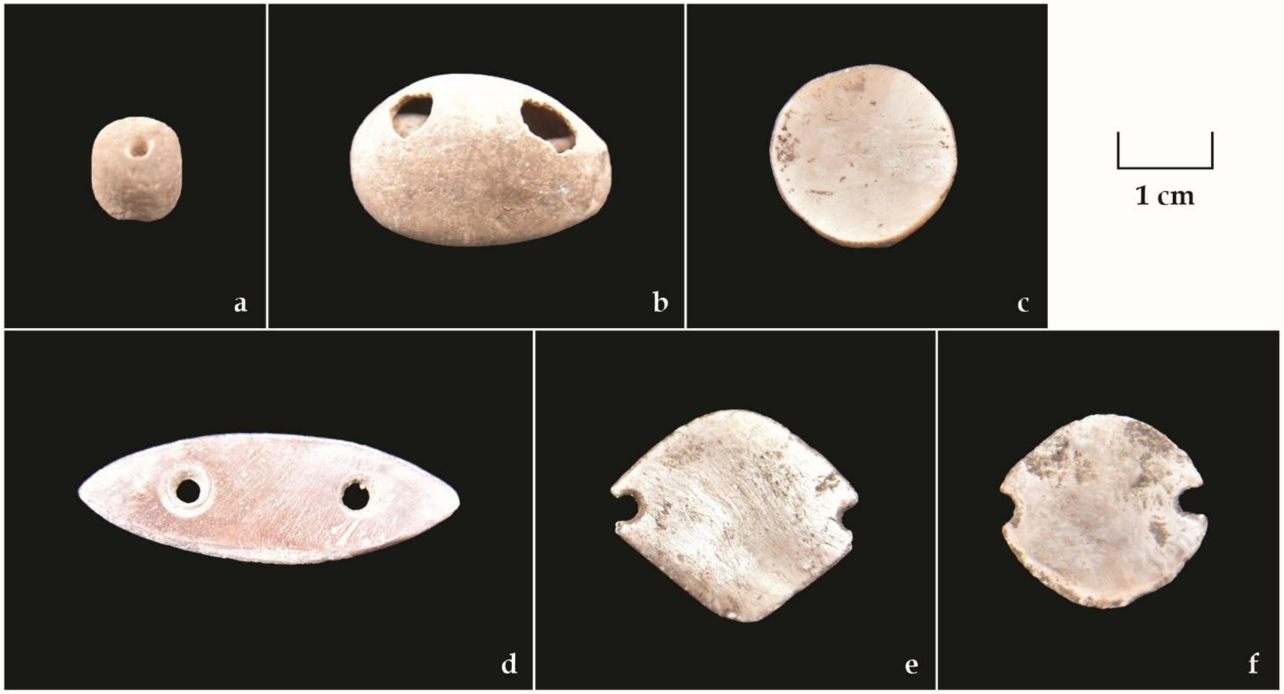
Adornments and Inlays

Additional artifacts from the Manihiki and Rakahanga excavations include three flat disks cut from pearl shell. These disks resemble inlays that are depicted in Hiroa (1932: plate 7C). The discs seem to be a common decorative element on wooden objects ranging from ships to drums. We identified five diamond to lozenge shaped adornments in the Manihiki and Rakahanga excavations. The more complete examples of these objects have two holes drilled through them, presumably for attachment to a person or object via plant fibers (Table C.4; Figure C.3). These objects are likely decorative. They have a similar appearance to modern pearl-shell plates woven into *rito* (woven coconut) hats on Manihiki and Rakahanga today. Di Piazza (2005) suggests that similar objects were a local innovation, likely decorative in nature. Similar drilled pearl-shell plates are pictured alongside pearl-shell inlay disks on a model canoe from the AD 1900s (Hiroa 1932). We recovered four possible beads. Three of these are cowrie punctured in two locations along the dorsum of the shell. The fourth is a section of cut and drilled urchin spine.

Table C.4. Possible adornments and inlays from Manihiki and Rakahanga

Provenience		Material	Object Description	Measurements			
Site	FS#			Maximum Length, mm	Maximum Width, mm	Maximum Thickness, mm	Weight, g
NG001	M-012	Urchin Spine	A drilled section of urchin spine, likely a bead	9.19	8.83	8.60	0.55
NG001	M-040-E	Cowrie Shell	A small shell with two holes through the dorsum, likely a bead	27.34	20.25	14.68	5.68
NG001	M-041-A	Cowrie Shell	A small shell with two holes through the dorsum, likely a bead	40.51	27.40	21.57	12.12
NG001	M-042-A	Pearl Shell	A flat circular disk of finely ground pearl shell, likely an inlay	20.14	20.14	2.91	1.73
NG001	M-042-B	Cowrie Shell	A small shell with two holes through the dorsum, likely a bead	32.63	24.33	17.05	8.69
NG001	M-042-C	Pearl Shell	A flat circular disk of finely ground pearl shell, likely an inlay	15.56	15.56	1.67	0.58
NG001	M-047-A	Pearl Shell	A flat lozenge-shaped object with two drilled holes	38.15	13.34	2.84	1.89
NG001	M-047-B	Pearl Shell	A flat lozenge-shaped object	20.88	9.46	1.92	0.45
TK001	R-087-A	Pearl Shell	A flat diamond to lozenge-shaped object with two drilled holes	26.8	23.18	1.55	1.42
TK001	R-092-A	Pearl Shell	A flat object with one drilled hole, fragmentary	17.48	9.66	3.42	0.75
TK001	R-092-C	Pearl Shell	A flat round to lozenge-shaped object with two drilled holes	20.2	19.31	1.36	0.77
TK001	R-095-C	Pearl Shell	A flat lozenge-shaped object with a hole drilled in one end. The opposite end is broken.	16.4*	16.03	1.83	0.71
TK001	R-113	Pearl Shell	A flat near-circular disk of finely ground pearl shell, likely an inlay	14.32	12.86	2.04	0.61

*denotes that the object is broken in the axis of that measurement.



A (M-012); B (M-040-E); C (M-042-A); D (M-047-A); E (R-087-A); F (R-092-C).

Figure C.3. Examples of the adornments and inlays described in Table C.4

Scrappers, Abraders, Gouges, Drills, etc.

Polynesian peoples used shell and other materials to craft a variety of tools. These include pearl-shell scrapers/ graters cut from the dorsal surface and hinge portion of a pearl shell. These tools, typically called “hand graters,” often had teeth carved into the flat end and were used to grate coconut meat and other foods (Hiroa 1932). We found five pearl-shell scrapers meeting Hiroa’s (1932) description during surface survey and excavation. Additionally, we identified a pearl shell gouge as a surface artifact on Te Kainga. Additional tools include a possible drill crafted from the columella of a large gastropod, a possible coral pounder, and two coral abraders (Table C.5; Figure C.4).

Table C.5. Additional tools from Manihiki and Rakahanga

Provenience		Material	Object Description	Measurements			
Site	FS#			Maximum Length, mm	Maximum Width, mm	Maximum Thickness, mm	Weight, g
MANI 015	M-001	Pearl Shell	The end of grater or scrapper	35.98*	30.47	3.34	5.61
MANI 020	M-003	Pearl Shell	A large grater or scrapper	122.22	38.10	4.34	29.40
RAKA 030	R-004-1	Pearl Shell	The end of grater or scrapper	83.12*	35.19	4.53	22.01
RAKA 032	R-007-1	Pearl Shell	The end of grater or scrapper	53.71*	35.32	3.48	10.52
TK001	R-080-B	Pearl Shell	A large grater or scrapper	111.77	36.75	13.10	38.16
RAKA 021	R-002-2	Pearl Shell	An object ground to a point at one end, possibly a gouge	56.24	20.38	11.76	12.24
TK001	R-040-B	Coral	A small piece of coral flattened on one side, possible abrader	44.96	22.95	15.01	18.44
TK001	R-044-A	Pearl Shell	A fragmentary object that appears to have been drilled	63.66	43.49	11.89	34.57
TK001	R-054	Coral	A small piece of coral flattened on one side, possible abrader	27.7	20.36	13.59	4.73
TK001	R-075-B	Pearl Shell	An oddly shaped ground object	74.73	45.12	21.41	49.01
TK001	R-075-C	Pearl Shell	A flat triangular object, two sides are finely ground the third is broken	37.33	31.25	5.01	7.31
TK001	R-087-1	Coral	A small, hand sized, water worn object with some evidence of grinding, one end is pock-marked suggesting use as a pounder	113.41	58.76	27.55	311.3
TK001	R-080-A	Pearl Shell	A large object including the dorsal and hinge portion of the shell; cut and finely ground perpendicular to the hinge, and at leading edge; a depression is drilled along the worked side	110.77	73.12	26.39	122.14
TK001	110-E	Gastropod Columella	A gastropod columella with use wear on one end, possibly a drill	47.75	14.9	14.9	10.89
*denotes that the object is broken in the dimension of that measurement							

A (M-003); B (R-002-2); C (R-004-1); D (R-080-B)

Figure C.4. Three examples of scrapers and one gouge described in Table C.5

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APPENDIX D – FAUNAL DATA

Table D.1. Faunal remains from the 2017 excavations on Manihiki and Rakahanga

		NG001		**TK001**		**NV001**		**NM001**	
Taxa	**Common Name**	**NISP**	**Weight, g**	**NISP**	**Weight, g**	**NISP**	**Weight, g**	**NISP**	**Weight, g**
Chondrichthyes	Sharks, Skates, and Rays	13	0.974	255	104.569	-	-	-	-
Actinopterygii	Bony fishes	2571	97.283	10181	574.774	2	0.038	2	0.048
Chanos chanos	Milkfish	-	-	2	0.129	-	-	-	-
Muraenidae	Moray Eels	1	0.382	6	4.08	-	-	-	-
Holocentridae	Soldierfishes and Squirrelfishes	9	1.114	9	0.62	-	-	-	-
Serranidae	Sea Basses and Groupers	2	0.327	66	12.535	-	-	-	-
Lethrinidae	Emperors and Breams	4	0.41	7	8.817	-	-	-	-
Carangidae	Trevally, Jacks, and Scads	6	0.413	27	6.589	-	-	-	-
Lutjanidae	Snappers	15	2.663	52	12.325	-	-	-	-
Cirrhitidae	Hawkfishes	3	0.12	5	0.188	-	-	-	-
Sphyraenidae	Barracuda	1	0.081	24	4.516	-	-	-	-
Labridae	Wrasses	16	2.663	28	12.75	-	-	-	-
Scaridae	Parrot Fishes	100	11.283	181	42.447	-	-	-	-
Acanthuridae	Surgeonfishes, Tangs, and Unicornfishes	1	0.027	-	-	-	-	-	-
Scombridae	Mackerels, Tunas, and Wahoos	-	-	4	7.662	-	-	-	-
Bothidae	Flounders	-	-	1	0.574	-	-	-	-
Balistoidea	*Trigger Fishes and File Fishes	12	1.276	69	15.062	-	-	-	-

Tetraodontidae	Puffer Fishes	4	1.591	9	6.784	-	-	-	-
Diodontidae	Porcupinefishes	37	5.281	45	25.674	-	-	-	-
Chelonioidea	Sea Turtles	1	0.431	197	177.699	-	-	-	-
Aves	Birds	7	0.222	24	4.226	2	0.496	-	-
Gallus gallus	Domestic Chicken	-	-	4	4.226	-	-	-	-
cf. Procellariidae	Gannets and boobies	-	-	1	0.138	-	-	-	-
cf. Sulidae	Petrels and Shearwaters	2	0.154	4	1.51	-	-	-	-
Laridae	Gulls and Terns	-	-	6	0.934	-	-	-	-
Mammalia	Mammals	-	-	8	2.045	-	-	-	-
cf. *Rattus exulans*	Pacific Rat	30	0.78	104	3.737	1	0.023	-	-
Canis familiaris	Domestic Dog	1	0.087	33	19.084	-	-	-	-
Felis domesticus	Domestic Cat	-	-	1	0.403	-	-	-	-
Odontoceti	Toothed Whales and Dolphins	-	-	1	0.403	-	-	-	-
Sus scrofa	Domestic Pig	7	1.516	2	0.942	-	-	1	0.374
Vertebrata	Vertebrates	31	3.394	264	23.646	4	0.446	7	1.32
Total		2874	132.472	11620	1079.088	9	1.003	10	1.742
* Listed as the super family Balistoidae to include Monocanthidae and Balistidae as they are difficult to distinguish.									

APPENDIX E – CHRONOMETRIC DATA

Table E.1. Radiocarbon dating results for samples from NG001 and TK001

Sample ID	Unit/ Layer	Material	Collagen Yield %	δ13C ‰	δ15N ‰	C:N Ratio	14C Age BP	Calibrated Date Range AD 68.2 % **	Calibrated Date Range AD 95.4 % **
NG001									
UGAMS 35654	B-1/ III	*Pandanus* spp. drupe	-	-23.77	-	-	320 ± 20	1521-1636	1492-1643
UGAMS 35655	C-1/ III	*Pandanus* spp. drupe	-	-27.10	-	-	310 ± 20	1522-1642	1497-1646
UGAMS 40094	C-1/ I-II	*Cocos nucifera* endocarp	-	-25.1	-	-	140 ± 25	1680-1939	1669-1944
UGAMS 38551	C-1/ II	*Pandanus* spp. drupe	-	-24.75	-	-	100 ± 20	1697-1917	1691-1925
UGAMS 38555	B-1/ III	*Pinctada margaritifera*	-	+2.55	-	-	980 ± 20	-	-
UGAMS 40464	C-1/ II	*Sus scrofa* bone	3.8	-21.6	16.7	3.6	Modern	Modern	Modern
TK001									
UGAMS 35651	A-1/ V.1	*Cocos nucifera endocarp*	-	-24.51	-	-	100 ± 20	1697-1917	1691-1925
UGAMS 35650	A-1/ III	*Cocos nucifera* endocarp	-	-24.91	-	-	100 ± 20	1697-1917	1691-1925
UGAMS 35652	A-1/ V.2	*Cocos nucifera endocarp*	-	-25.02	-	-	100 ± 20	1697-1917	1691-1925
UGAMS 35649	A-1/ XIII	*Cocos nucifera* endocarp	-	-24.54	-	-	210 ± 20	1655- ….	1648-….
UGAMS 34018	A-1/ XIII	*Cocos nucifera* endocarp	-	-24.61	-	-	250 ± 20	1644-1664	1530-1799
UGAMS 38552	A-1/ V.2	*Pandanus* spp. drupe	-	-23.01	-	-	110 ± 20	1694-1917	1685-1928
UGAMS 35653	A-1/ IX-X	*Cocos nucifera* endocarp	-	-25.52	-	-	180 ± 20	1668-1950	1664-….
UGAMS 36970	TU5/ VIII-IX	cf. *Pandanus* spp. drupe	-	-25.20	-	-	310 ± 20	1522-1642	1497-1646
UGAMS 40095	TU8/ V-VII	*Cocos nucifera* endocarp	-	-23.60	-	-	660 ± 20	1286-1384	1281-1390
UGAMS 38553	TU5/ VIII-IX	*Pinctada margaritifera*	-	+2.28	-	-	810 ± 20	-	-
UGAMS 40097	TU8/ V-VII	*Pinctada margaritifera*	-	+1.3	-	-	810 ± 30	-	-
UGAMS 38554	A-1/ IX-X	*Pinctada margaritifera*	-	+1.64	-	-	750 ± 20	-	-
UGAMS 40096	TU8/ V-VII	*Canis familiaris* tooth	7.3	-12.2	19.6	3:3	850 ± 25	-	-
UGAMS 36967	TU5/ VIII-IX	*Canis familiaris* tooth	8.3	-13.6	18.8	3:1	740 ± 20	-	-
UGAMS 36968	TU10/ V	*Canis familiaris* tooth	7.2	-12.8	18.2	3:3	830 ± 20	-	-
UGAMS 36969	A-1/ IX-X	*Canis familiaris* tooth	10.6	-11.5	19.2	3:3	670 ± 20	-	-