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Tangatatau Rockshelter

The Evolution of an Eastern Polynesian Socio-Ecosystem

Edited by
Patrick Vinton Kirch

Tangatatau Rockshelter • Kirch



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Tangatatau Rockshelter



The Jo Anne Stolaroff Cotsen Prize Imprint honors outstanding studies in archaeology to commemorate a special person whose appreciation for scholarship was recognized by all whose lives she touched.



Irrigated taro pondfields are central to the Mangaia socio-ecosystem. On the alluvial floor of Tamarua Valley, an irrigation canal feeds water to fields on either side. The massive limestone cliffs of the *makatea* escarpment loom in the distance.

Tangatatau Rockshelter

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Edited by
Patrick Vinton Kirch

With contributions by

Virginia L. Butler, Christelle Carlier, Mireille N. Gonzalez, Jon G. Hather, Mark Horrocks,
Jennifer G. Kahn, Patrick Vinton Kirch, Aimée M. Plourde, and Julie M. E. Taomia

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On front cover: Stalactites hanging down from the limestone cave's ceiling against a view of Tamarua Valley from the seating place of the warrior guard within Tautua cave.

On back cover: Portrait of a man of Mangaia Island, drawn by William Weber, artist on Captain Cook's third voyage in 1777.

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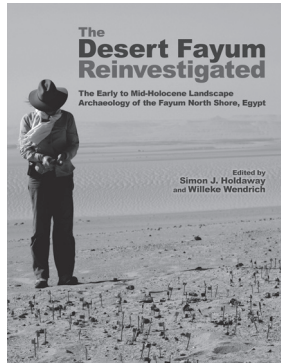
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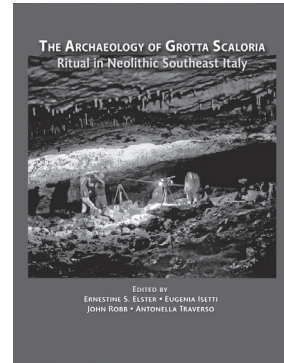
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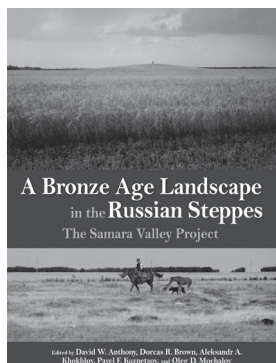
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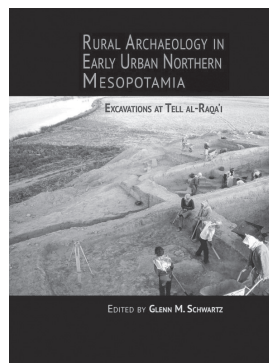
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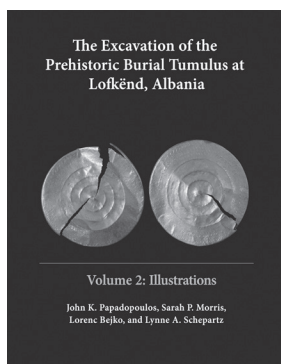
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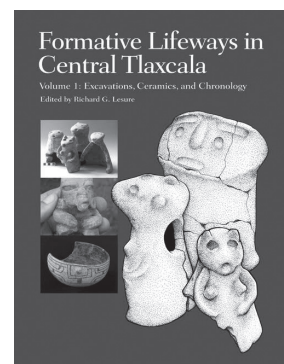
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Preface and Acknowledgments

Archaeological excavations at Tangatatau Rockshelter and other sites on Mangaia, the most southerly of the Cook Islands of Eastern Polynesia, were carried out over two field seasons in 1989 and 1991. Tangatatau proved to be enormously rich not only in cultural artifacts, such as basalt adzes and fishhooks, but also in a diverse array of faunal and floral materials that provided an unusually detailed record of Polynesian exploitation and modification of an island ecosystem. Unusually well stratified for a Polynesian site, the historical record archived within the ashy sediments of Tangatatau holds a key to understanding the prehistory not only of the Southern Cook Islands but of central Eastern Polynesia as a whole.

Although most of the laboratory analyses of materials recovered at Tangatatau had been completed by 1994 and were summarized in an article outlining the rockshelter's sequence (Kirch et al. 1995; see also Kirch 1996, 1997a, 1997b; Kirch et al. 1991, 1992), it was always our intention to publish a full account of this key Eastern Polynesian site in monographic format. It is a longstanding maxim among archaeologists that having dug a site, we have a professional obligation to produce a "final report." For, as Kent Flannery famously quipped, archaeologists are the only kind of anthropologists who "kill" their informants in the process of studying them. Like Humpty-Dumpty, once dug, the stratigraphic and spatial context of an archeological site cannot be put

back together again. But a careful and thorough report, providing details on stratigraphy and context, on associated dating, and linking artifacts with floral and faunal remains does provide a permanent record that can allow future archaeologists to reinterpret the site in light of new methods, approaches, or theories. This is even more the case today with the ability to link a site monograph to digital archives, including original excavation records, photographs, and databases.

The preparation of this final monograph on the Tangatatau Rockshelter was unintentionally delayed for nearly a quarter century, as my colleagues and I turned to other projects and the results of our Mangaia field and laboratory work migrated to the rear of the filing cabinet. In 2014, however, I resolved to take early retirement from the University of California, Berkeley, specifically in order to bring this—and several other equally long delayed projects—to fruition. Excavating not earth this time but the contents of yellowing file folders, resuscitating old .db database files, and pulling the curated artifacts out of their specimen cabinets to examine them with fresh eyes has been an exhilarating (even if sometimes frustrating) experience. Writing this final report on the Tangatatau Rockshelter excavations has reaffirmed for me the importance of this key site and what it has to tell us about how Polynesians interacted with and transformed their island worlds—in the process transforming their cultures as well.

The 1989 and 1991 field seasons on Mangaia were based on close collaboration between myself and avian paleontologist David W. Steadman. Indeed, it was Steadman's prior fieldwork on Mangaia and his discovery of extinct avifauna in the island's limestone caves that precipitated our joint research. Our fieldwork together and subsequent sharing of analytical results epitomized the best of professional collaboration. Consequently it was a great disappointment that—for reasons known only to himself—Steadman in recent years ceased responding to letters, emails, or phone messages. Our plan was to edit this monograph together. Sadly, in the end, I had to make the decision to proceed without him, knowing that otherwise the work would never be completed.

Several funding agencies supported the Mangaia project through generous grants, without which this research could never have been accomplished. The initial 1989 field season was supported by a grant from the National Geographic Society's Committee on Research and Exploration (Grant 4001-89). The major 1991 excavation season and subsequent laboratory analyses were largely funded through National Science Foundation Grant BNS-9020750 to the University of California, Berkeley, with Kirch as principal investigator. Additional support for analysis of the faunal remains came from National Science Foundation Grant BSR-8607535 to the University of the State of New York with David Steadman as principal investigator. Geochemical sourcing of the Mangaia lithics was supported by Grant 5376 from the Wenner-Gren Foundation for Anthropological Research to Marshall Weisler. During the final period of analysis and preparation of materials for publication, additional financial support was provided by the Prentice Fund for Environmental Archaeology at the University of California, Berkeley.

In Rarotonga, Mr. Tony Utanga of the Ministry of Internal Affairs was most gracious in arranging for official permission to conduct research on Mangaia and facilitating our project in various ways. On Mangaia, we were welcomed and assisted in many ways by Tua Uria (head of the island council), Papamama Pokino (chief administrative officer), Ma'ara and Diane Ngu, Peter and Susan Ngatokorua, George Tuara, Alan Tuara, Tuara George, Sonny Taomia, and Nga Ruatoe. The 1989 field team included David and Jenny Steadman, Melinda Allen, John Flenley, Stewart Dawson, and Francis Lamont, ably assisted by Ma'ara Ngu and Sonny Taomia. The 1991 field team comprised David and Jenny Steadman, Pia Anderson, Julie Endicott, Joanna Ellison, Virginia Butler, Jon Hather, and Thérèse Babineau, again assisted by Ma'ara Ngu and Sonny Taomia.

In the initial stages of laboratory work at the Oceanic Archaeology Laboratory, Berkeley, Peter Mills and Julie Endicott cataloged the artifacts and other excavated materials, while Stephen Midgely developed the initial project database. Pia Anderson and Susan Antón assisted in the analysis of vertebrate faunal remains. Marshall Weisler undertook the XRF sourcing analysis of the basalt lithics. Rose Guthrie helped to reorganize the MAN-44 collections prior to their final analysis. Cordelia Nickelsen assisted in various aspects of the laboratory work. The fine black-and-white line illustrations of artifacts that grace this volume were drawn by the late Judith Ogden.

Patrick Vinton Kirch
Quinta Pacifica
October 2016

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1

Introduction

Patrick Vinton Kirch

The Polynesian Triangle—a vast expanse of the Pacific Ocean encompassing some 2 million square kilometers and more than one thousand islands—was the last of Earth’s regions (excepting Antarctica) to be colonized by humans in their inexorable expansion out of Africa. The coral islands of Tonga were the first to be settled, between 2846 and 2830 cal BP (896–880 BC), by voyagers of the Lapita cultural complex (Burley et al. 2015). Fledgling colonies soon expanded to the adjacent islands of Niuaotupapu, ‘Uvea, Futuna, and Samoa. These geographically clustered islands, situated just east of Fiji on the western edge of the Polynesian Triangle, became the “homeland” wherein an Ancestral Polynesian Culture emerged from its Lapita predecessor (Kirch and Green 2001). This homeland, or Hawaiiki as the Polynesians themselves named it, is known to anthropologists as Western Polynesia. Edwin Burrows (1939) long ago demonstrated that the Western Polynesian cultures share many traits—ranging from kava ceremonial and kinship terminology to techniques of barkcloth manufacture—attesting to their common origins and a long period of shared innovations.

The rest of the Polynesian Triangle, stretching eastward to the famed islands of Tahiti and the Society Islands, the Marquesas, Tuamotus, Mangareva, Australs, Cook Islands, and then outward to the apices of the triangle at Hawai‘i, Aotearoa (New Zealand), and Rapa

Nui (Easter Island), makes up Eastern Polynesia. The island cultures of Eastern Polynesia likewise share a host of traits, distinct from those of Western Polynesia, in religion (such as the triad of gods Tane, Tu, and Rongo), social organization, and material culture (Burrows 1939). This cluster of shared traits once again demonstrates a common ancestry of the Eastern Polynesian cultures, as well as a period of common development following their departure from the Western Polynesian homeland but preceding their final diaspora to the farthest corners of the northern, eastern, and southern Pacific.

A half century of archaeological research, augmented by allied investigations in historical linguistics and biological anthropology, has convincingly demonstrated that the settlement of Eastern Polynesia began around the close of the first millennium AD, with voyagers exploring eastward out of the Western Polynesian homeland (Kirch 2010a). The archipelagoes of central Eastern Polynesia (Figure 1.1) were the first to be discovered and settled, some probably as early as AD 900 to 1000. From this core region, the more distant archipelagoes of Hawai‘i and New Zealand were colonized, as was remote Rapa Nui. The precise timing of the Eastern Polynesian diaspora is still the subject of some debate (see, e.g., Mulrooney et al. 2011; Wilmshurst et al. 2011), but all parties agree that the entire period of expansion to the limits of the Polynesian Triangle had been completed by approximately AD 1250.

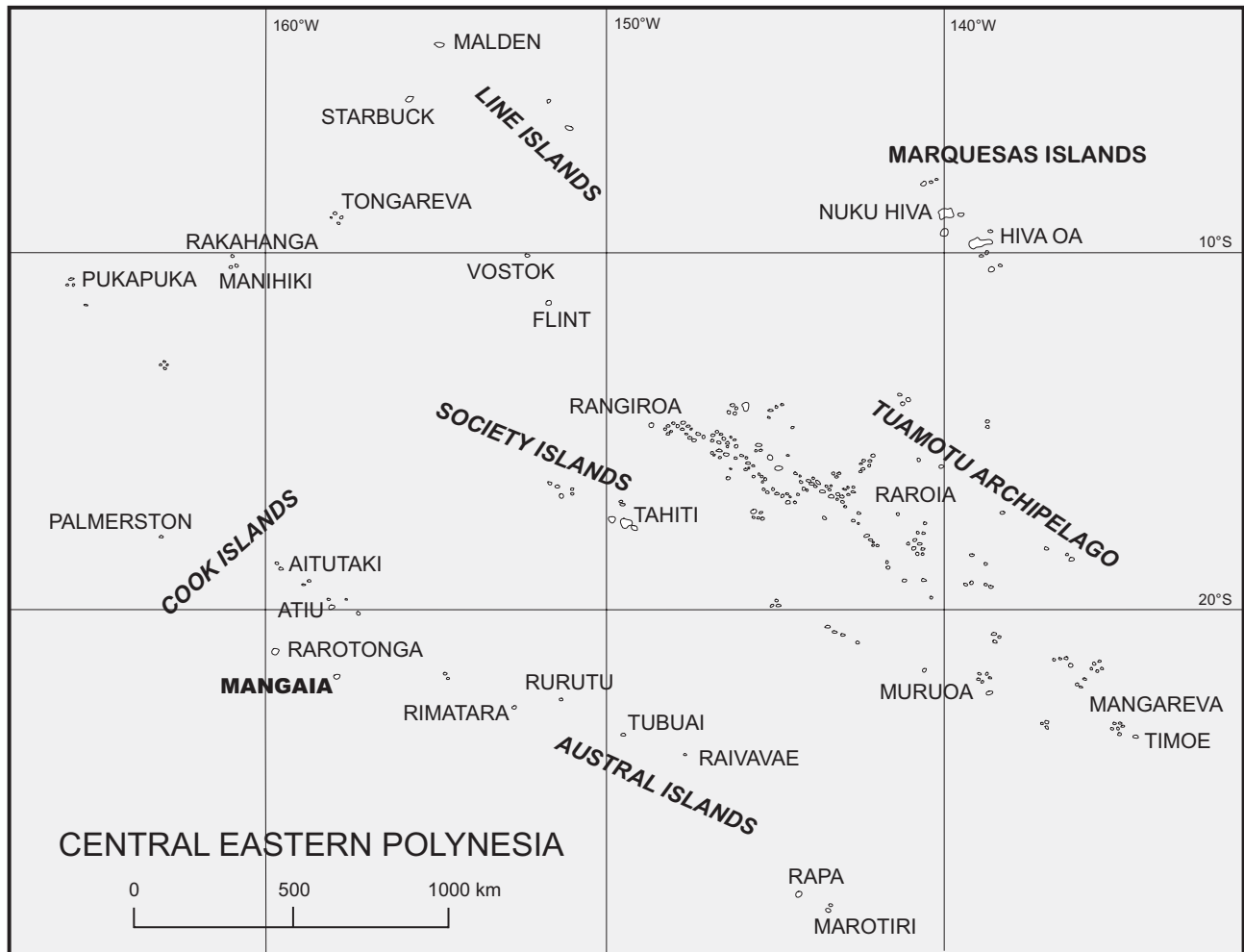


Figure 1.1. Map of central Eastern Polynesia, showing the location of Mangaia Island.

Following this truly remarkable early phase of long-distance voyaging that led to the discovery and settlement of virtually every habitable island within the eastern Pacific (and, indeed, took some voyagers to the shores of South America), the island societies that now occupied each of the archipelagoes of Eastern Polynesia began to gradually diverge and differentiate as the inevitable processes of cultural change and evolution set in. In part, this divergence stemmed from a decline in long-distance voyaging and the sharing of innovations that regular interisland contact ensured; it also reflects local processes of adaptation to distinctive geographic and ecological conditions and challenges. While still sharing many traits in common, each island culture came to be characterized by its own distinctive forms of material arts, subsistence economy, sociopolitical organization, beliefs and ritual practices, and

distinct languages, leading ultimately to the range of Eastern Polynesian cultures encountered by European voyagers in the seventeenth to eighteenth centuries and described by later ethnographers (Goldman 1970; Sahlins 1958). Some of these societies remained small in scale, their cultures conservative in retaining many ancestral traits—hence “traditional” in the classification applied by Goldman (1970). In a few, especially the Society Islands and Hawai‘i, a high degree of social stratification and political complexity developed—in the case of Hawai‘i, ultimately expressed in the emergence of “archaic states” (Hommon 2013; Kirch 2010b). In several others, social and political transformation was more fluid, tending not so much toward increased hierarchy as to heightened competition between chiefs, priests, and warrior classes; these were the societies classed as “open” by Goldman (1970).

The archaeological record of the divergence and evolution of the Eastern Polynesian cultures has accumulated steadily since pioneering stratigraphic excavations began in Hawai'i, New Zealand, the Marquesas, and other islands beginning in the early 1950s (see, e.g., Duff 1956; Emory et al. 1959; Suggs 1961). For the most part, this record has had to be pieced together from countless small sites, each representing but a tiny segment of time and space in the historical sequence of its particular island culture. In a few rare cases, however, well-stratified sites have been discovered and excavated, revealing continuous occupation sequences spanning virtually the entire prehistories of certain islands. Such key sites are of special significance, for in their rich records of material culture as well as their faunal and floral assemblages, they provide a critical scaffolding into which the fragmentary histories from many other, smaller sites can be integrated. Within central Eastern Polynesia, among the best-known examples of such deeply stratified sites with long sequences are the sand dunes of Hane on Ua Huka Island and Hanamiai on Tahuata Island, both in the Marquesas (Conte and Molle 2014; Rolett 1998; Sinoto 1966, 1970, 1979). In the Mangareva Islands, rockshelters on Kamaka and Agakauitai Islands similarly have yielded deeply stratified and nearly continuous sequences (Green and Weisler 2000, 2002; Kirch et al. 2015), while in the southern Cook Islands, the Moturaku rockshelter spans most of the prehistoric sequence for Aitutaki Island (Allen and Morrison 2013; Allen and Schubel 1990).

The Tangatatau Rockshelter on Mangaia Island, most southerly of the Cook Islands, is yet another of those rare sites endowed with complex stratigraphy and a rich record of material culture along with abundant faunal and floral remains. The rockshelter's sequence begins with a prehuman paleontological record of native birds, land snails, and land crabs extending back to 6500 BC, capped by nearly five centuries' accumulation of Polynesian occupation debris that began not long after the island was first colonized; the record continues until just prior to European contact. Tangatatau was excavated under the author's direction over two field seasons in 1989 and 1991. While a summary of the major finds and sequence was published a few years later (Kirch et al. 1995), and while some aspects of the Tangatatau sequence have figured in other publications on Mangaian prehistory (Kirch 1996, 1997a, 1997b, 2007; Kirch et al. 1991, 1992; Steadman 2006;

Steadman and Kirch 1990), a full account of the excavation, stratigraphy, radiocarbon dating, and analysis of artifacts and ecofacts has been too long deferred. This monograph now offers a final report on the Tangatatau Rockshelter, a contribution to the permanent archaeological record of Eastern Polynesia.

Archaeology of the Southern Cook Islands

The Southern Cook Islands comprise seven relatively small islands situated between 18° and 22° S. latitude and 157° to 160° W. longitude. Rarotonga, the largest island and political center of the group, is a young, mountainous volcanic "high" island surrounded by a fringing reef. Mangaia, location of Tangatatau Rockshelter and most southerly of the group, lies 195 km southeast of Rarotonga. Mangaia is a particularly old island, with a central volcanic cone surrounded by a broad ring of upraised coral limestone (see Chapter 2). To the north of Mangaia at a distance of roughly 200 km lies the Ngaputoru cluster of Ma'uke, Mitiaro, and Atiu, along with uninhabited Takutea. These islands are part of an old, age-progressive chain of volcanoes extending eastward into the Austral Islands; like Mangaia, they consist of volcanic cores surrounded by aprons of elevated coral limestone. Northwest of Ngaputoru is the uninhabited atoll of Manuae; further northwest again is the "almost atoll" of Aitutaki surrounded by an extensive barrier reef and lagoon.

Despite a long history of ethnographic field research, much of it carried out by Te Rangi Hiroa (e.g., Hiroa 1934, 1944), no archaeological surveys had been conducted in any of the Southern Cook Islands prior to 1962. In 1962–1963 and again in 1964, the Canterbury Museum of New Zealand sent an expedition to the Cooks under the direction of Roger Duff (Trotter 1974; see also Duff 1968), funded in part by the U.S. National Science Foundation through a grant to the Bernice P. Bishop Museum of Honolulu. The Canterbury team focused primarily on Rarotonga, conducting surface surveys and limited excavations of stone structures, including *marae* (temple foundations) and house sites. Eight radiocarbon dates were obtained, all on unidentified wood charcoal (Trotter 1974:Appendix 2); most dated to the late precontact period, although one date from charcoal in alluvial silt underlying Marae Manuka gave an age of 650 ± 50 BP (NZ-789), which the authors argued should date the "first felling and burning of Tupapa watershed" (Trotter 1974:146).

Peter Bellwood directed the next phase of archaeological research in the Southern Cooks, under the auspices of the University of Auckland, during three field seasons between December 1968 and August 1972 (Bellwood 1969, 1971, 1978). The initial focus of research was once again Rarotonga, with a settlement pattern survey of the Maungaroa Valley and several other localities. Bellwood also excavated at Ngati Tiare (site RAR-40), a stratified open site in Avarua District, where the digging of a drainage ditch had exposed a cache of six basalt adzes with reversed triangular cross sections, regarded by Duff (in Trotter 1974:120–122) as being an early adze type in Eastern Polynesia. Preservation at the site was poor, but the excavations did recover additional adzes as well as fragments of pearl shell fishhooks. Two radiocarbon dates from the early occupation at Ngati Tiare were reported as AD 1230 \pm 70 and 1320 \pm 60 (Bellwood 1978:69). Bellwood also extended the project's fieldwork to Aitutaki Island, surveying the stone foundations of *marae* sites but also testing a stratified site in the coastal plain, at Ureia (site AIT-10), along the western shore of the main island. The site yielded a few fragments of pearl shell fishhooks as well as faunal material. Two charcoal samples from the basal occupation yielded radiocarbon ages reported as AD 981 \pm 83 and 1248 \pm 81, the first of these then being the oldest date then recovered from the Cook Islands (Bellwood 1978:135). Finally, Bellwood also briefly reconnoitered Mangaia Island, concentrating primarily on a surface survey of *marae* structures (see Chapter 3 for more details).

No further archaeological work was carried out in the Southern Cook Islands until 1984, when Richard Walter began fieldwork on Ma'uke Island in the Ngaputoru group, where he located and tested the Anai'o site, returning to excavate there more fully for his doctoral dissertation research at the University of Auckland in 1985 (Walter 1989, 1990, 1998). Anai'o is a stratified beach ridge on the western side of Ma'uke, with good preservation of artifacts and faunal materials. Five radiocarbon dates on shell yielded calibrated ages (with a ΔR value of 45 \pm 30) from as early as AD 1290–1346 to 1395–1446 in the case of the youngest sample (Walter 1998:Table 3.1). Portable artifacts included 40 fishhooks or fishhook fragments, all of pearl shell, as well as abraders, ornaments, tattooing combs, a pearl shell coconut grater, and other objects.

In 1987, David W. Steadman and Melinda S. Allen reopened the Ureia site on Aitutaki, previously tested by Bellwood (1978), with the goal of recovering faunal remains that might shed light on the biogeographical history of birds and other vertebrates in Eastern Polynesia. Their expanded excavations clarified the complex stratigraphy, while six radiocarbon dates were obtained, the oldest of which (Beta-25250), with an age of 1040 \pm 80 BP (cal AD 776–1163), appeared to corroborate Bellwood's earlier date (Allen and Steadman 1990:29, Figure 5). Unfortunately, the artifact assemblage was minimal, although a few pearl shell fishhook fragments and considerable worked basalt was recovered. A rich assemblage of faunal materials was obtained, however, which in addition to abundant fish and turtle bone also included the remains of an extinct whistling duck (*Dendrocygna* sp.) and bones of the locally extirpated spotless crane (*Porzana tabuensis*) (Allen and Steadman 1990:32–33). More recently, Allen and Wallace (2007) redated botanically identified charcoal samples from the Ureia excavations; 14 new accelerator mass spectrometry (AMS) radiocarbon dates now indicate that the early phase at Ureia dates to cal AD 1225 to 1430 (at 1 σ).

Melinda Allen returned to Aitutaki for a nine-month field season in 1989, as part of her doctoral dissertation research at the University of Washington (Allen 1992b). In addition to expanding test excavations throughout the coastal beach ridges on the main island, Allen conducted surveys on the small islets within the lagoon and on the barrier reef, leading to the discovery of Moturakau Rockshelter (site MR-1). Although small in area, the Moturakau shelter proved upon excavation to have a deep and well-stratified series of occupation deposits, with a rich assemblage of artifacts and faunal materials (Allen and Schubel 1990; see also Allen 1992a, 1996a, 1996b, 2002; Allen and Craig 2009). A radiocarbon sample from the basal occupation layer at Moturakau yielded an age of cal AD 1043 to 1263.

On Mangaia Island, archaeological research has included our own project's fieldwork in 1989 and 1991, reported in detail in this volume, as well as the excavation of a coastal midden (the Vairorongo site) and three rockshelters by a team from Kyoto University, Japan (Katayama and Shibata 1999). This research on Mangaia is described in further detail in Chapter 3.

Design of the Research

The Mangaia research reported in this volume proceeded in two discrete phases. The initial phase, in 1989, was designed to build upon and amplify the results of prior fieldwork by David W. Steadman, who had carried out paleontological work on Mangaia in 1984. Steadman had discovered that the island's many caves in the apron of upraised limestone that encircles the much older volcanic cone often contained well-preserved bird bones, including those of a number of extinct or extirpated species, some new to science (Steadman 1985, 1987). Approaching me after his return from the Cook Islands in 1987, Steadman and I agreed to conduct joint fieldwork on Mangaia with the aim of putting the island's avifaunal record into an archaeological—and temporally controlled—context. Having worked previously on the Western Polynesian islands of Futuna and Niutoputapu, as well as on the Polynesian Outliers of Anuta and Tikopia, all of which exhibited evidence of significant human impacts on island ecosystems, I was keen to extend this line of environmental archaeology to Mangaia.

In addition to the paleontological and archaeological evidence we anticipated would be recovered through excavations, Steadman and I recognized that the unique geomorphology of Mangaia offered extraordinary opportunities to apply the methods of stratigraphic coring and palynology to reconstruct a history of vegetation change on the island. Several low-lying swamps, some with small ponds or lakes, are situated at the base of the central volcanic hill, trapped behind the massive upraised limestone rampart (called the *makatea* by the Polynesians). We realized that these swampy basins would surely contain an archive of pollen trapped within stratified sediments eroded from the volcanic interior. To unlock this archive, we invited palynologist John R. Flenley, then of the University of Hull, England, to join our team. Successful application was made to the National Geographic Society's Committee on Research and Exploration, which awarded a grant (No. 4001-89) to support our initial field season in 1989.

As luck would have it, the large and promising Tangatatau Rockshelter (site MAN-44) was discovered within a few days of our commencing fieldwork.¹

A test excavation soon revealed that the rockshelter's deposits were well stratified and rich in artifacts as well as faunal and floral remains. The basal deposits contained precisely the kinds of avifaunal remains that Steadman had hoped to find, in contexts that could be chronologically well controlled. Thus, while Flenley and his two students (Francis Lamont and Stuart Dawson) cored the sediments of Lake Tiriara, Steadman and I, assisted by Melinda Allen and Mangaian workers Ma'ara Ngu and Sonny Taomia, expanded the excavation at Tangatatau.

Returning from the field and working up our first season's data, Steadman and I realized that we had barely tapped the potential of Tangatatau Rockshelter. The avifaunal record itself was one of the best ever recovered from a Polynesian island, as the initial results demonstrated (Steadman and Kirch 1990). The zooarchaeological record also revealed striking changes in the exploitation of marine resources, accompanied by significant shifts in pig husbandry and in the consumption of the diminutive Pacific rat, a commensal animal introduced to the island by the colonizing Polynesians. Nor was the archaeobotanical archive of Tangatatau any less rewarding: among the macrobotanical finds from the 1989 season were pieces of charred tuber (parenchyma) identified as sweet potato (*Ipomoea batatas*). These latter finds provided some of the oldest evidence for the prehistoric introduction of sweet potato—a South American domesticate—into the islands of Polynesia (Hather and Kirch 1991). Meanwhile, the palynological investigations revealed a striking transformation of the island's vegetation, with earlier forest replaced by fernlands, a change that seemed to be clearly associated with Polynesian arrival and intensive land use and one that helped to explain the dramatic decline in the island's avifauna. These initial results were summarized by Kirch et al. (1992).

Given the successes of the 1989 field season, Steadman and I agreed to return and expand the excavations at Tangatatau Rockshelter, as well as to advance other aspects of this interdisciplinary project. In July 1990, I submitted a proposal to the Anthropology Program at the U.S. National Science Foundation with the project title “Anthropogenic Environmental Change, Agricultural Intensification, and Socio-Political Evolution in Polynesia.” Peer reviewers recommended funding, and a grant (BNS-9020750) was awarded to the University of California, Berkeley, in early 1991, in the sum of \$116,500 to support an extended season of fieldwork later that year.

¹ For an informal account of this discovery, as well as of our subsequent fieldwork on Mangaia, including the routine of daily life on the island, see Kirch (2015).

In my proposal to the National Science Foundation, I drew attention to Irving Goldman's (1970) classification of Polynesian societies into (1) traditional, (2) open, and (3) stratified categories. While I rejected the simplistic notion that these societal types represented a unilinear evolutionary continuum, Goldman's careful analysis of the ethnohistorical record had nonetheless drawn attention to critical distinctions in the different contact-era Polynesian societies. The "open" societies of Eastern Polynesia (including Rapa Nui and the Marquesas, in addition to Mangaia) seemed to me to be of particular interest, as these potentially represented cases where significant ecological challenges—quite likely exacerbated by human-induced landscape change—played a key role in the later transformation of economic and sociopolitical structures. Jonathan Friedman (1981, 1982), in two theoretical articles on social evolution in Oceania, had also drawn attention to the potential significance of the so-called open societies:

Societies that Goldman characterizes as 'open' in eastern Polynesia—Mangaia, Easter island, and the Marquesas—were all plagued by intense warfare and unstable political hierarchy. While Goldman suggests that open societies are generally on the way to stratification, it is, perhaps, more likely that these societies represent devolution. They are all characterized by relatively high population density and relatively poor ecological conditions, often themselves the result of overintensification [Friedman 1982:191].

Testing this model of Mangaia as a case of cultural "devolution" in response to ecological constraints and human ecodynamics was thus a central organizing goal of the Mangaia Project.

The core objective of the 1991 field season was expanded excavation at Tangatatau Rockshelter to refine the stratigraphic sequence and to significantly enlarge the assemblages of artifacts, fauna, and floral remains that we knew would provide the essential framework for testing different models of Manganian prehistory. The specific objectives of the 1991 season at Tangatatau are described in greater detail in Chapter 4. In addition to the author and Steadman, the 1991 field team also included a zooarchaeologist specializing in fish remains (Virginia Butler) and an archaeobotanist (Jon Hather), along with two Berkeley archaeology

graduate students (Pia Anderson and Julie Endicott). Berkeley geography graduate student Joanna Ellison was engaged to extend the swamp coring and pollen work to additional localities around the island.

At the time of our 1991 fieldwork, environmental archaeology was starting to develop into the integrative, multidisciplinary endeavor that it has since become, sometimes also referred to as *historical ecology* or as *human ecodynamics* (Crumley 1994; McGlade 1995). The Mangaia Project was actively conceptualized within this emerging tradition in environmental archaeology. Historical ecology has been defined as "the study of past ecosystems by charting the change in landscapes over time," with the implicit understanding that the term *landscape* incorporates "the material manifestation of the relation between humans and the environment" (Crumley 1994:6). This view is echoed by Barton et al. (2004:285) in their concept of *contingent landscapes*, in which "the intertwined social and natural landscapes that are the context of human societies are contingent on socioecological history as well as the physical conditions under which this history took place."

Human ecodynamics (McGlade 1995; van der Leeuw and McGlade 1997) also privileges *landscape* as a core concept and asserts that there is no "environment" or "ecosystem" detached from humans and their behavior; rather, there are only "socio-natural systems" defined as linked sociohistorical and natural processes within specific time-space frameworks. The study of human ecodynamics is thus concerned with "the dynamics of human-modified landscapes set within a long-term perspective, and viewed as a non-linear dynamical system" (McGlade 1995:126). While constantly shaped and transformed by a variety of natural processes, landscapes are also *socially* constructed. Thus, Barton et al. (2004) proposed the term *socio-ecosystems* for landscapes shaped by dynamically linked human-natural processes, a concept that we have adopted as an underlying theoretical principal in the analysis of the Manganian archaeological record.

Given that a quarter of a century has now passed since the completion of the 1991 fieldwork and the preparation of this final site report, the field of Polynesian archaeology has obviously advanced in several respects. I thus conclude this Introduction with some brief comments about how those changes have influenced our final interpretation of the Tangatatau Rockshelter, as well as how what is presented in the

chapters to follow differs in some respects from initial, preliminary reports of the site published soon after the excavations were completed (e.g., Kirch et al. 1991, 1992, 1995; Steadman and Kirch 1990).

In the 1950s, the pioneering excavations of Emory and Sinoto in Hawai'i (Emory et al. 1959), of Robert Suggs in the Marquesas (Suggs 1961), of the Norwegian Expedition in Easter Island (Heyerdahl and Ferdon 1961), and others had exposed early occupation sites with radiocarbon dates that suggested settlement of Eastern Polynesia beginning as early as 150 BC (Suggs 1961:20, 174, Table 1). Continued excavations throughout the 1960s and 1970s, however, began to raise questions regarding the earliest dates. While it was increasingly clear that Western Polynesia (the Tonga-Samoa region) had been settled early in the first millennium BC by people of the Lapita ceramic tradition, the lack of pottery in early Eastern Polynesian assemblages hinted there might have been a substantial pause in the west-to-east movement of ancestral Polynesians from the Western Polynesian "homeland" into the archipelagoes of Eastern Polynesia (especially into the Society Islands and the Marquesas, thought to be the first island groups settled within Eastern Polynesia). By the late 1980s, when the Mangaia Project was first conceived, Polynesian archaeologists were actively debating the chronology of initial human arrival into the islands of Eastern Polynesia (e.g., Irwin 1981; Kirch 1986). At the time that the Tangatatau Rockshelter was excavated—in 1989 and 1991—there was still considerable support for the view that the "pause" between the settlement of Western and Eastern Polynesia had been relatively short and that initial human movement into the islands of central Eastern Polynesia (such as the Southern Cook Islands) could plausibly have occurred as early as the late first millennium BC.

A critical turning point came with the publication of Spriggs and Anderson's (1993) essay advocating the application of "chronological hygiene" to the

radiocarbon dating of Eastern Polynesian sites. They argued that a number of factors had conspired to bias the radiocarbon corpus from early Eastern Polynesian sites in favor of a longer chronology. I was initially resistant to this argument, in part because the radiocarbon dating of the pollen cores we had obtained on Mangaia seemed to suggest human arrival and disturbance of the island's vegetation as early as 2500 cal BP (Kirch and Ellison 1994). In light of these dates from the Mangaia cores, our team also thought that the Tangatatau Rockshelter had not been occupied until well after the initial settlement of the island (Kirch et al. 1995:61). It remained something of a puzzle, however, why direct archaeological evidence for this supposed early phase of habitation and land use seemed to be elusive.

The past 20 years of research in Eastern Polynesia has now unequivocally resolved this debate between "long" and "short" settlement chronologies, in favor of the latter. While there is still some argument about when the initial movement of people into Eastern Polynesia commenced (e.g., Mulrooney et al. 2011; Wilmshurst et al. 2011), there is little doubt that this was not earlier than about AD 850 to 900. The implications for the interpretation of the place of the Tangatatau Rockshelter in Eastern Polynesian prehistory are considerable. First, the dates obtained from the Mangaia pollen cores are clearly too old, possibly the result of dating old soil carbon; this is discussed further in Chapter 2. Second, this alleviates the problem of a putative long period of early land use on Mangaia that was seemingly archaeologically invisible. And third, while we do not believe that Tangatatau was the *first* site to be occupied on the island, it is now evident that the rockshelter became a locus of habitation relatively soon after the first arrival of people. This means that the stratigraphic sequence contained with Tangatatau spans most of the island's prehistory, making the site of even greater significance than we had at first thought.

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2

The Mangaia Socio-Ecosystem: Environmental and Ethnohistoric Perspectives

Patrick Vinton Kirch

Mangaia Island (157° 55' E., 21° 55' S.) is the most southerly of the main Cook Islands of central Eastern Polynesia; the other islands of the archipelago include Rarotonga, Ma'uke, Atiu, Mitiaro, Manuae, Takutea, and Aitutaki. The subcircular island has a land area of 52 km² with a distinctive geomorphology and topography defined by an ancient, deeply weathered, central volcanic cone surrounded by a ring of upraised coral reef limestone (known in Polynesian as *makatea*).

This chapter presents background information on the Mangaian environment and on traditional Mangaian culture as revealed through nineteenth-century ethnohistoric sources, both essential for understanding the evolution of the Mangaian socio-ecosystem as evidenced in the archaeological record of Tangatatau Rockshelter. Because there was direct continuity between the late precontact archaeological record of Mangaia and the culture documented in early postcontact visits by explorers, missionaries, and others, some knowledge of Mangaian ethnohistory is critical for interpreting the *longue durée* of Mangaian prehistory.

Natural History of Mangaia

Being a relatively small and somewhat isolated island, Mangaia has been less investigated by natural scientists than other islands of central Eastern Polynesia. Its intriguing geology and geomorphology have been more

extensively studied than its flora or fauna, which are only incompletely documented from more cursory explorations. There are, for example, no complete checklists of the island's biota, either terrestrial or marine. Accepting these limitations, the following paragraphs synthesize key aspects of the island's natural environment from published and manuscript sources.

Physiography and Topography of Mangaia

Mangaia is not unique in its combined volcanic-*makatea* landscape—several other of the Southern Cook Islands as well most of the Austral Islands to the east are likewise made up in varying degrees of a basaltic mass with an apron of upraised limestone. However, the nearly circular shape of Mangaia and the way in which the *makatea* forms a continuous rampart around the old, eroded volcanic core are not matched in the other cases. This particular configuration gives Mangaia a strongly concentric zonation of microenvironments. Marshall, who pioneered the study of Mangaian geology, described the physiographic progression from fringing reef inland over the *makatea* and across the volcanic slopes to the island's summit in a succinct manner that deserves quoting in full:

The island is surrounded by a coral reef, which in most places has a width of not more than 300 feet; at one place its width is nearly 1,000 feet.

From the inner side of the reef platform the coast rises abruptly to a height of 10 to 30 feet and continues as a gentle and more or less uniform slope, which rises 20 feet in a distance of about 600 feet. From the inner edge of this slope a cliff 65 feet high rises abruptly, forming a wall which may be climbed at very few places. Extending inward from the top of the cliff is a broad surface, from which project innumerable sharp limestone pinnacles, when travel is impracticable except where paths have been made. This raised platform of eroded coral rock is called the Makatea; a little more than half a mile from the coast its surface stands about 200 feet above sea level. At its inner edge, the Makatea is terminated by a steep cliff which descends 150 feet or more—in places almost to sea level—and which is unscalable for the greater part of the circumference of the island. At the foot of this inward-facing escarpment lie extensive swamps, which receive all the run-off from the central part of the island. The swamps are drained by subterranean channels passing to the sea through the Makatea at depths of more than 150 feet. The central part of the island is a dissected mass of volcanic rock, which rises gradually to a height of 554 feet above sea level. Generally, this igneous core is separated from the Makatea by the moat which contains the swamps; but in a few places projecting spurs extend downward to the Makatea platform. The summit of the island is a flat surface three-quarters of a mile long and less than a quarter of a mile wide. The central point of this flat is called Rangimotia, the “Crown of Mangaia” [Marshall 1927:7].

Marshall’s description nicely captures the manner in which the *makatea* forms a kind of fortress wall around the island. Indeed, the island almost appears as if it were designed to repel visitors. There are few passes through the fringing reef (the best being at Avarua on the west coast); upon landing a canoe ashore and climbing up the narrow coastal zone of accumulated sand and coral detritus, a visitor quickly encounters the outer *makatea* cliff, a formidable obstacle. The *makatea* itself, ranging from 0.5 to 2 km wide, is a “no man’s land” of pinnacle karst and treacherous crevasses into which a careless explorer can readily plunge to their death. Even after managing to navigate across

this rough terrain, there is then the yet higher and nearly vertical inner *makatea* escarpment that forms yet another barrier impeding access to the interior volcanic slopes. One can only admire the perseverance of the first Polynesians who discovered and colonized Mangaia for managing to breach this natural “island fortress” and tame its landscape.

In a very real way, Mangaia’s physiography inspired an “inland-centric” perspective in its Polynesian population. Although the fringing reef was an important resource zone, most of their socio-ecosystem revolved around the central volcanic core, protected from the outside world by the formidable *makatea*. Here, in the interior, narrow stream valleys incised into the old volcanic cone carried water down to the low-lying swamps at the base of the inner *makatea* rampart. Six radial drainage basins provided a natural basis for dividing the island into six corresponding sociopolitical districts (clockwise, from the west, Keia, Tava‘enga, Karanga, Ivirua, Tamarua, and Veitatei). Over time, the swamps and lower valley floors were converted into terraced systems of irrigated pondfields where taro (*Colocasia esculenta*) was intensively cultivated (Figure 2.1). At the time of European contact, these taro fields (known in Mangaian as the *puna* lands) were highly prized; rival tribes fought periodic wars over their control. The lower ridge slopes and spurs were the setting for clusters of houses, dotted here and there with temples (*marae*) and surrounded by tree crops and dryland gardens. The higher volcanic slopes and summit were cloaked in ferns, scrub *Pandanus*, and ironwood trees (*Casuarina equisetifolia*), as the deeply laterized, nutrient-depleted soils of this central zone could not support cultivation.

Geology and Geomorphology

New Zealand geologist P. Marshall was the first to undertake field investigations of Mangaia’s geology, over a two-month period in 1923 (Marshall 1927). Working without adequate maps and covering the challenging terrain entirely on foot, Marshall produced a credible description of the island’s geologic structure and a reasonably accurate sketch map of the topography. In his interpretation of Mangaia’s geological history, however, Marshall was mistaken in believing that the *makatea* represented an ancient, uplifted *barrier* reef with the zone of taro swamps between the inner *makatea* escarpment and the steeper volcanic slopes having once been a lagoon. His interpretation was



Figure 2.1. View of the Tamarua Valley, looking inland from the edge of the *makatea* escarpment. Note the irrigation canals and pondfields of the valley floor, and the fern-covered ridges and slopes of the volcanic interior.

challenged by Chubb (1927), who argued (on the basis on his own fieldwork on the similar *makatea*-volcanic island of Rurutu) that there had never been a lagoon and that the nearly vertical, inner *makatea* escarpment was in fact the product of erosion. Marshall (1929) steadfastly defended his position, and the matter was not fully resolved until Stoddart et al. (1985) definitely proved Chubb's hypothesis that the *makatea* consists of an apron of uplifted *fringing* (not barrier) reefs, the inner portions of which have been eroded away (essentially dissolved) by the action of freshwater flowing off the volcanic slopes onto the calcium carbonate limestone.

Building on the original work of Marshall (1927), followed by further field studies by Wood (1967; Wood and Hay 1970) and the Stoddart team (Stoddart et al. 1985; Woodroffe et al. 1991), we now have a reasonably clear understanding of Mangaia's geological evolution. The first surprising fact is that Mangaia is unusually old for a Pacific Plate island, most of which are typically no more than 6 to 7 mya in age. K-Ar

age measurements by Dalrymple et al. (1975:Table 1) on six volcanic rock samples from Mangaia gave ages in the range of 16.6 to 18.9 mya, making it a great deal older than the nearby islands of Rarotonga, Atiu, or Aitutaki. Mangaia evidently originated as an early volcano on a linear age-progressive volcanic alignment whose hotspot (or magma plume) is centered on the Macdonald Seamount at the far eastern end of the Austral Islands chain. The island gradually eroded and subsided as the plate tectonic engine moved it progressively to the northwest. One consequence of this extended period of subaerial erosion is that the volcanic cone of Mangaia is deeply laterized, with virtually no "hard rock" exposures visible (except for a few dykes and other outcrops in the heads of the steep valleys, one of which provided an important source of adze rock).

During the Pleistocene, an extensive fringing reef developed around the nearly submerged volcanic cone. U-series dating of corals collected from the *makatea*, initially by Veeh (1966), yielded ages with a mean

value of $115,000 \pm 7000$ years BP (Woodroffe et al. 1991:257). The next stage in the geological evolution of Mangaia—resulting in the emergence of the fringing reef and its uplifting to a height of some 70 m above sea level—was due to the Pleistocene eruption of nearby Rarotonga Island (about 1.6 mya). The loading of the thin oceanic crust by the basaltic mass of Rarotonga resulted in “lithospheric flexure” (McNutt and Menard 1978), elevating Mangaia, which sits on a circular ridge of thin oceanic crust surrounding Rarotonga and bent slightly upward as a result of this point loading and flexure. Stoddart et al. (1985) show through their detailed traverses across the *makatea* that this uplift did not occur as a single event but gradually with stops and starts, resulting in a series of distinct terraces reflecting different stand-stills. Indeed, uplift has continued into the Holocene (Yonekura et al. 1988), with the modern reef crest beginning to form about 2,000 years ago.

Numerous solution caverns and caves riddle the limestone like a giant block of Swiss cheese (Ellison 1994b), an aspect of the *makatea* of considerable importance to the Polynesian occupants. These caverns, many of which are tunnel-like and run for considerable distances, derived from the action of fresh water flowing off the volcanic slopes and penetrating the porous reef-detritus and coral limestone. Indeed, the contemporary streams all flow into subterranean caverns at the bottoms of their valleys, the water eventually issuing forth beyond the fringing reef. As the *makatea* continued to be uplifted, and the inner escarpment progressively developed, older caverns were cut off from their flow of fresh water. The entrances to these can now be seen at many places high in the inner escarpment cliff. Many of these caverns and caves were used by the precontact Mangaian population, both as temporary refuge places during times of conflict and warfare (as with Tautua cave; see Chapter 13) and as burial places. Moreover, the escarpment itself has frequent overhangs that result in rockshelters—such as Tangatau Rockshelter—that were used for habitation or other purposes.

Climate

Mangaia lies on the southern fringe of “the persistent trade wind zone” of the South Pacific. The climate is subtropical, with a pronounced wet season from November to April and a dry season from May to October. Limited rainfall records for Mangaia

(Thompson 1986:Table 15) indicate average annual precipitation of 1,967 mm, with 1,230 mm of rain falling in the wet season and 737 mm in the dry season. However, rainfall varies considerably from year to year, with a recorded maximum of 2,983 mm and minimum of 1,024 mm (Thompson 1986:Table 16). In dry years, especially during the dry season, this can lead to extended periods of soil moisture deficit (Thompson 1986:Table 33). Mangaian informants told me that during such droughts, water flow to the irrigated taro patches sometimes dried up, resulting in crop losses.

Thompson (1986) does not provide temperature data for Mangaia, but Rarotonga to the north has an average temperature of between 24°C and 26°C. However, during the austral winter, temperatures dip as low as 8.9°C (and during the austral summer occasionally reach highs as great as 35°C). Both of our field seasons were carried out during the Mangaian winter months; I can attest from personal experience that the nights were often quite cold. These colder winter temperatures are at the limits for certain tropical Polynesian crops, especially coconut and breadfruit, which therefore do not yield as prolifically as they do in other archipelagoes such as the Society Islands or the Marquesas.

A final aspect of climate with notable implications for humans is the regular occurrence of cyclones. In the southwest Pacific, tropical cyclones usually develop between December and April, when the South Pacific Convergence Zone moves southward into the Southern Cook Islands. Thompson (1986:Table 3) reports that between 1970 and 1983, 16 storms ranging in force from gale (5 storms) to storm (6 storms) to hurricane (5 storms) affected the Southern Cook Islands. The more powerful of these cyclones can devastate the island, destroying houses, uprooting trees, and flooding the streams and irrigation systems.

Soils

The soils of Mangaia were roughly characterized by Grange and Fox (1953), who produced a general map of the distribution of six soil types over the island. The narrow coastal belt between the shoreline and the outer *makatea* cliff is made up of Makatea Sand soils, consisting of calcareous sand and reef detritus deposited during storm surges. This zone supports coconut palms but otherwise is of little use for cultivation. The surface of the *makatea*, in fissures and gaps between the limestone pinnacles and outcrops, is made up of Oneroa Clay Loam,

which is “derived mainly from basalt alluvium washed from the central volcano” (Grange and Fox 1953:16), prior to the formation of the inner *makatea* escarpment. There are, in fact, two subtypes represented, one with a profile of less than 2 feet (61 cm) depth and one with deeper profiles. Grange and Fox remark that “the shallow soils have derived lime from the weathering of the limestone outcrops” and are as a result more fertile than the deeper clay loams. Both kinds of Oneroa Clay Loam are reasonably fertile, however, supporting tree crops and other dryland crops such as sweet potato, yams, and bananas. The main limitation is that the soil is confined to pockets between the limestone outcrops. Hiroa (1934:129) notes that the *makatea* lands (called *rau-tu-tui*) were cultivated by those who had been defeated in war and dispossessed of the more productive irrigated taro lands.

Moving inland, there are three soil types in the lower elevations abutting the inner *makatea* escarpment. By far the most productive is the Tamarua Clay Loam, consisting of waterlogged, gleyed soils where irrigated taro is grown. These have a typical profile with an upper 10 inches (25.4 cm) of “dark-grey to grey clay loam, soft structure,” overlying “light-grey clay, sticky, mottled greenish and bluish, occasional iron flecking” (Grange and Fox 1953:10). Grange and Fox (1953:15) remark that “taro has been grown in the [pondfield] enclosures for perhaps as long as six hundred years. No fertilizers are used, fertility being maintained by the deposition on them of silt carried from the hill during floods.” In slightly higher areas adjoining the *makatea* cliff, there is Keia Clay Loam, derived from basalt alluvium with decomposed limestone, which helps to maintain fertility. This black to dark-brown sticky clay loam “is a valuable soil for food crops other than taro and coconuts” (Grange and Fox 1953:16). Less fertile is the Ivirua Clay Loam, which occurs on “rolling land on the lower slopes of the central hill composed of basalt” (Grange and Fox 1953:18). Lacking the enrichment provided by decomposed limestone, these soils are deeply weathered and laterized, “so low in fertility that they will not regenerate forest” (Grange and Fox 1953:19). The Ivirua Clay Loam does, however, support coconut palms and, in precontact times, probably some crops such as yams and sweet potato (although not intensively).

The central volcanic cone and moderately steep slopes, along with the narrow interior valleys, are cloaked in Tuapapa Clay Loam, with a shallow profile

of granular clay loam overlying “rotten rock” (saprolite). These deeply laterized soils are highly infertile, the vegetation on them restricted to pyrophytic *Dicranopteris linearis* ferns, scrub *Pandanus*, and scattered ironwood (*C. equisetifolia*) trees.

Flora and Vegetation Patterns

To my knowledge, a comprehensive botanical survey of Mangaia has never been undertaken. However, Merlin (1991; see also Franklin and Merlin 1992) conducted a vegetation survey focused on woody taxa, recording the relative dominance of 30 species across 20 transects. Based on quantitative data from these transects, aided by a statistical similarity analysis, Merlin identified three main types of vegetation. The first, *Barringtonia* Forest, is found near the coast and is dominated by *Barringtonia asiatica*, a large tree whose fruits were widely used by Polynesians for fish poison. The second type, Mixed and Disturbed Native Forest, is typical of the *makatea* zone. Where there has been relatively little human disturbance, the mixed forest is dominated by such indigenous trees as *Elaeocarpus tonganus*, *Hernandia moerenhoutiana*, and *Guettarda speciosa*. In “mixed disturbed” native forest, these indigenous taxa are joined by Polynesian introduced coconut (*Cocos nucifera*), candlenut (*Aleurites moluccana*), and noni (*Morinda citrifolia*), reflecting the influence of many centuries of cultivation and manipulation of fertile soil pockets in the *makatea*. The third vegetation type is *Pandanus* Scrub, “located in the windward areas of Mangaia, where the *makatea* substrate is extremely dissected and usually windswept” (Merlin 1991:141). Here there are only a few woody species, with *Pandanus tectorius* dominating.

Although he does not classify it as a separate type (as his quantitative transects were all confined to the island’s coast or *makatea* regions), Merlin (1991:145) does mention the “almost completely anthropogenic vegetation” that dominates the upland interior of Mangaia on the deeply weathered volcanic cone. These eroded slopes are covered in “the early succession fern *Dicranopteris linearis*,” along with Polynesian-introduced ironwood (*C. equisetifolia*) and noni (*M. citrifolia*), and the historically introduced guava (*Psidium guajava*). This fire-resistant vegetation community periodically burns off. Merlin (1991:145) opines that it is “an artifact of cutting and man-made fires that began during the period before European contact.”

Recent Google Earth aerial photos of Mangaia show that at some time subsequent to our 1991 field-work, the eroded fernlands of the central volcanic cone have been reforested; the regular rows and uniform crowns suggest this was with a species of introduced pine. The lower volcanic slopes also appear to have been invaded by the fast-growing, nitrogen-fixing exotic tree *Falcataria moluccana*.

Terrestrial Fauna

As with virtually all truly “oceanic” islands (i.e., those situated on the Pacific Plate), the terrestrial fauna of Mangaia was highly “disharmonic,” that is, lacking in many major groups of animals. At the species level, the indigenous terrestrial fauna was dominated by arthropods and pulmonate gastropods (land snails), but neither of these groups were of much direct importance to the Polynesian inhabitants. The naturally dispersed terrestrial vertebrate fauna was limited to several species of birds and one species of fruit bat or flying fox (*Pteropus tonganus*). Polynesians introduced the jungle fowl (*Gallus gallus*), the domestic pig (*Sus scrofa*) and dog (*Canis familiaris*), and (either inadvertently or on purpose) the Pacific rat (*Rattus exulans*). At the time of European contact, however, both pig and dog were no longer present (see Chapter 6). Other Polynesian introductions included at least two species of lizard, the oceanic gecko (*Gehyra oceanica*) and the mourning gecko (*Lepidodactylus lugubris*).

In post-European contact times, the avifauna of Mangaia has been limited to 5 species of land birds (Steadman 2006:Table 7-2) and about 12 species of seabirds and migratory shorebirds. Christian (1920) published a short list of 16 Mangaian bird names, of which 7 are seabirds. Also included in this list is the “wild duck” (*mokora'a*), which was said to be abundant around Lake Tiriara. The excavations in Tangatatau Rockshelter, however, demonstrated that the island’s avifauna at the time of initial Polynesian arrival was much richer and that numerous species were extirpated or went extinct during the period of Polynesian occupation. A full discussion of the faunal evidence for this dramatic reduction in bird populations is provided in Chapter 6.

Marine Environment and Resources

Probably the least well-documented aspect of Mangaia’s environment is the island’s fringing reef and adjacent inshore habitats. Google Earth aerial photo imagery shows that at its widest (in the northwestern part of the

island), the fringing reef is barely 200 m across, while in other areas (particularly along the south and east), it is only 45 to 50 m wide. In his monograph on Mangaian geology, Marshall (1927:10–14) included a description of the fringing reef but primarily from a geologic rather than a biological perspective. In part, his description of the main physical aspects of the reef is as follows:

The seaward edge, exposed to a maximum height of two feet at low water, is very irregular; deep chasms, varying in width and in depth but not exceeding 30 feet in width, penetrate far into the rim and in places cross it. The chasms are bounded on both sides by large masses of limestone formed in situ by coral growth, and large masses project seaward beyond the average front of the reef. . . . The fringing reef is always kept awash by surf.

Everywhere the outer margin of the reef descends abruptly, but in the absence of soundings the nature of the slope is not known. It can only be said that no spot has been found where anchorage is practicable and that there are no offshore shallows. . . . Inside the slightly raised outer border of the reef there is a sudden downward step of two or three feet. Here the true reef flat begins and extends to the island shore. The outer ridge present on all exposed Pacific reefs is the well-known “Lithothamnion ridge,” so named from the calcareous seaweed of which it is almost entirely formed. . . .

The small pockets between the projections of the Lithothamnion are much favored as cosy corners by echinoids. On the southern side of Mangaia, in particular, where the surf is almost always fierce and the reef is seldom visited by the natives, echinoderms can be seen in thousands and cannot be extracted from their guarded chambers unless the rock around them is broken with a hammer. Numerous shell fish also live in the crevices, and in the larger ones corals may be seen, though these are not abundant in the more sheltered corners and on the outer slope of the reef below the level of violent surf action [Marshall 1927:10–11].

Being so narrow and with a lagoon entirely lacking (Figure 2.2), Mangaia’s fringing reef has limited potential as a resource base for its human population.



Figure 2.2. View of the narrow fringing reef of Mangaia at low tide.

Unpublished biological surveys (G. Paulay, personal communication, 1993) indicate that about 81 species of gastropods and 19 species of bivalves live on the Mangaia reef, although fewer than 40 species were regularly harvested in precontact times, based on the zooarchaeological evidence from Tangatatau Rockshelter (see Chapter 8). As Marshall observed, sea urchins are abundant in various places and were regularly collected for food. There has been no systematic ichthyological survey of the reef or benthic zone offshore, so the range of fish diversity remains undocumented (but see Chapter 9). Our zooarchaeological investigation of Tangatatau Rockshelter indicates that at least 56 taxa of reef and benthic fishes were exploited throughout prehistory.

Hiroa (1934:145) provides some ethnographic insights to fishing and shellfish gathering on the fringing reef. Women “employed groping with the hands among the rocks, short sticks to drive the octopus out of holes at low tide, and hand nets.” In addition, men “employed larger hand nets within the lagoon [i.e., in the zone between the reef crest and the shore], the

flying fish net outside the reef, and hook and line within the lagoon, on the outer edge of the reef, and in the deep waters beyond.” Fish poisoning (*‘ora*) on the reef was a community event in which the crushed roots of *Tephrosia piscatoria* and grated fruits of *Barringtonia asiatica* were used to stun the fish.

Holocene Environmental Change: Evidence from Swamp Coring

Mangaia’s concentric geological structure with upraised limestone reefs surrounding a central volcanic cone provides an ideal situation for preserving a sedimentary record of Holocene environmental changes. In blocking the radial stream drainages, the *makatea* rampart creates depositional basins at the valley mouths. Recognizing the potential of these depositional basins to yield a stratified record of sedimentation and vegetation history, we incorporated intensive coring and palynological methods as part of our 1989–1991 research design. Twenty-four cores were obtained, in all of the island’s major drainage basins. Three cores (VT-1 to VT-3) taken in and around Lake Tiriara in Veitatei district in 1989, under

the direction of John Flenley (Figure 2.3), were reported in full by Lamont (1990), with summary accounts in Kirch et al. (1991) and Kirch et al. (1992). Additional cores were obtained by Ellison (1994a) during the 1991 field season (Figure 2.4). Eight of the cores were radiocarbon dated, and three of the longest cores (TIR-1, VT-6, and TM-7) were sampled for pollen to reconstruct the island's vegetation history. These cores provide a detailed depositional record spanning the period from about 7000 BP to the present.

The cores exhibit consistent stratigraphic sequences throughout the main drainage basins, with four facies groups. (1) In cores TM-4, TM-7, IV-1, KA-3, and KA-4, a pedogenic mud was reached at 6 to 13 m below the modern land surface. This basal facies represents an early Holocene land surface, which began to be buried between 7260 ± 80 and 6450 ± 80 BP, based on five ^{14}C ages. (2) After 7000 BP, this early Holocene paleosol was buried by thick deposits of black lake peat (gyttja), as the valley floors were drowned due to rapid post-Pleistocene sea-level rise. Solution caverns in the

makatea were open to the sea at this time, providing channels through which seawater could flood the valley bottoms, creating brackish water lakes (Ellison 1994a). This phase is marked in the pollen spectra by high spore concentrations of the brackish water-tolerant fern *Acrostichum aureum*. (3) In most cores, lake peat deposition then changed to red/brown reed peat in the upper levels, signaling the cessation of Holocene sea-level rise; in core TM-4, this transition dates to 4000 ± 70 BP. A mid-Holocene sea-level stand of +1.1 m is also indicated by elevated solution notches in the *makatea* escarpment of five drainage basins, matched by additional coastal evidence for Holocene sea-level change (Yonekura et al. 1988). (4) The uppermost facies in all drainage basins is a reduced gray clay derived from the volcanic cone (mineralogical analysis indicates the presence of smectite, kaolinite, illite, and chlorite). The clay facies vary in depth within each drainage basin but reach up to 6 m depth in the Veitatei Valley. This onset of clay deposition is believed to correlate with human colonization, forest clearance, and horticultural land use.



Figure 2.3. View of Lake Tiriara with coring operations in progress in 1989. Note the massive limestone cliff of the inner *makatea* escarpment.

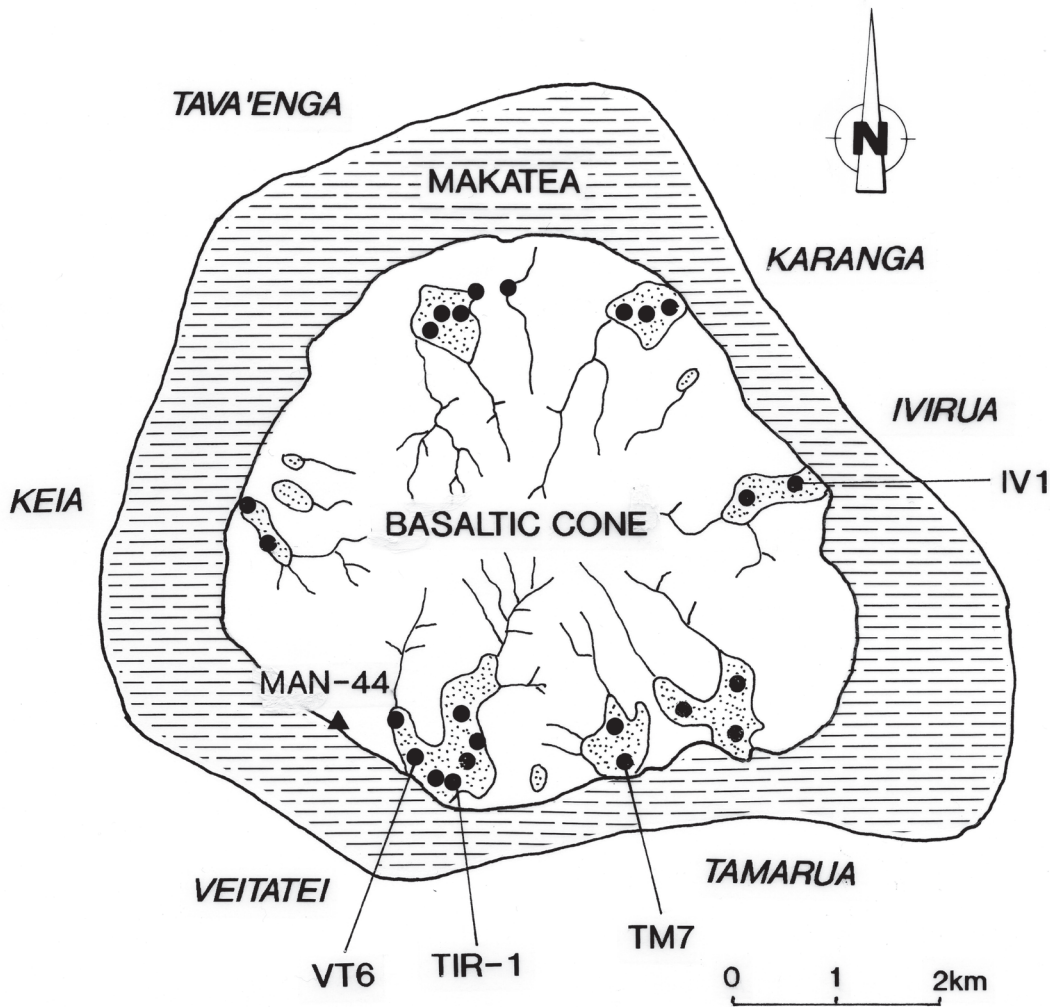


Figure 2.4. Map of Mangaia Island showing the locations of sediment cores (indicated by black dots) taken in the taro swamps in 1989 and 1981. After Kirch and Ellison 1994

The pollen sequences in three cores analyzed from Veitatei and Tamarua Valleys indicate a late phase of human disturbance in their respective drainage catchments, associated with the uppermost facies of gray clay derived from erosion of the volcanic cone. The clearest signal of human presence is the appearance of significant quantities of microscopic charcoal particles in the sediments. Microscopic charcoal particles were counted in samples from cores VT-6 and TM-7 (Ellison 1994a). Microscopic charcoal is absent in the lower sedimentary facies, while in the uppermost facies, charcoal particles are extremely abundant. The absence of microscopic charcoal in the deeper samples indicates that natural fires were rare or absent prior to human arrival, while the onset of microscopic charcoal in the upper facies is interpreted as reflecting the practice of

slash-and-burn horticulture following Polynesian colonization. The onset of microscopic charcoal deposition is matched by significant increases in the ferns *Dicranopteris linearis* and *Cyclosorus interruptus* and in the scrub *Pandanus tectorius* (Figure 2.5), the main dominants of the interior, degraded fernlands. At the same time that this pyrophytic association increases dramatically, there is a concomitant decline or disappearance of a number of woody, forest taxa, such as *Ficus* sp., *Weinmannia samoensis*, *Sophora tomentosa*, and an unidentified Malvaceae. These vegetation changes are accompanied by changes in geochemistry of the core, with significant increases in free iron (ext Fe) and in several oxides (SiO_2 , Al_2O_3 , and SO_3), signaling increased exposure of the lateritic volcanic cone (Figure 2.6).

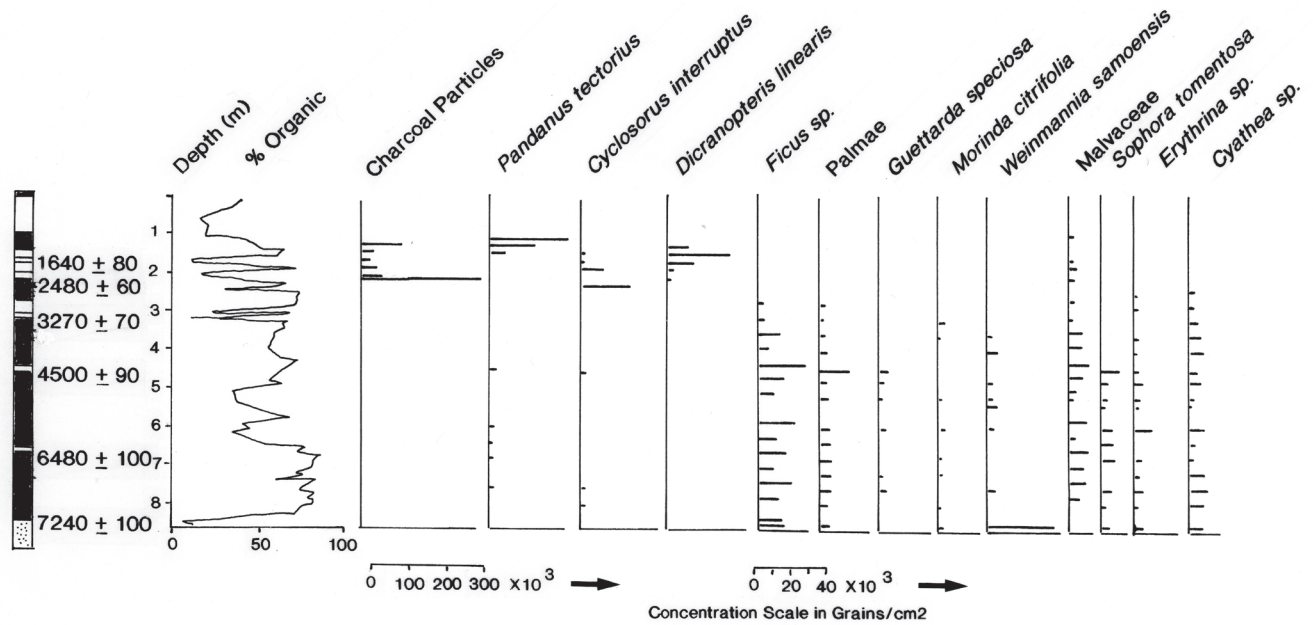


Figure 2.5. Pollen diagram from core TM-7 in the Tamarua Valley. Note the high concentration of charcoal particles, as well as the sudden shift from forest taxa to *Pandanus*, *Cyclosorus*, and *Dicranopteris* above 3 m depth. After Kirch and Ellison 1994

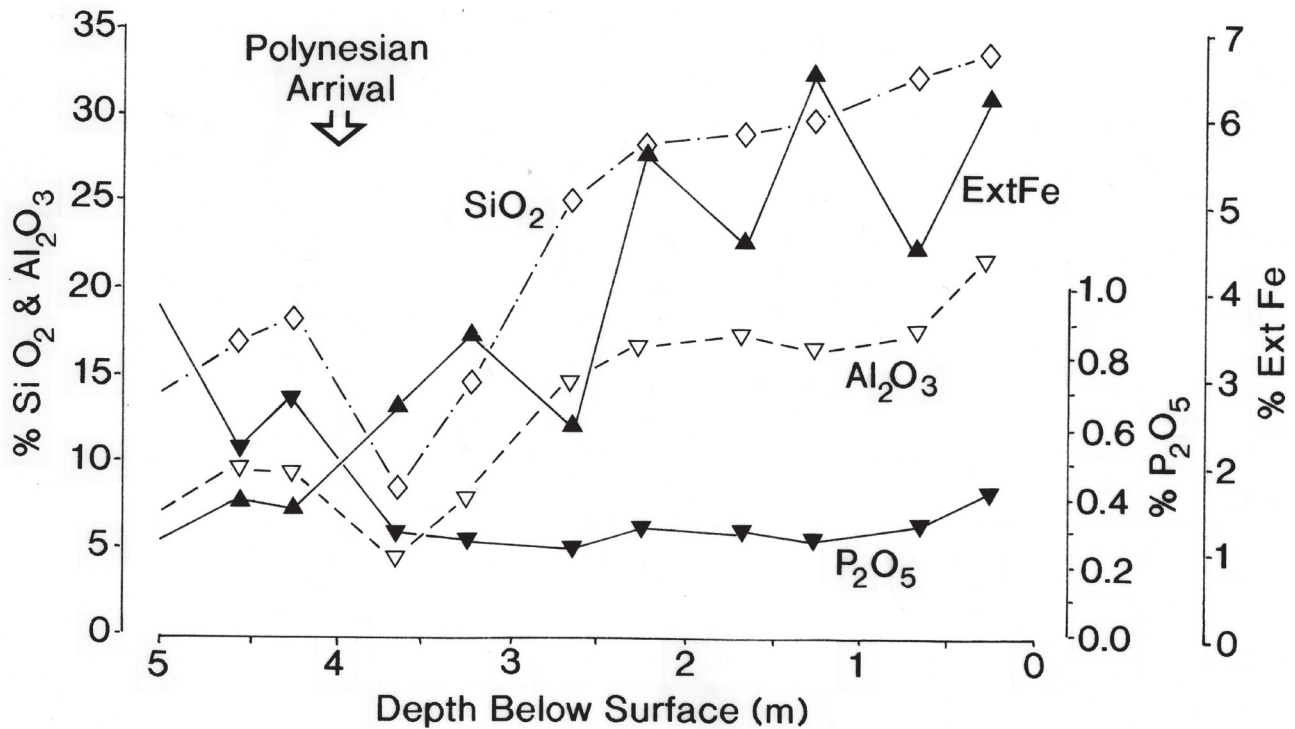


Figure 2.6. Geochemistry of the upper 5 m of core TIR-1 in Lake Tiriara. The rapid increases in free iron, silica dioxide, and aluminum trioxide are all strong indications of the exposure and erosion of the laterite of the volcanic core following forest clearance. After Kirch 1996

The core stratigraphy, geochemistry, and pollen sequences are interpreted as a strong signal of the anthropogenic origins of the interior pyrophytic fernlands, through forest clearance and burning. The degraded fernlands that make up nearly one-quarter of the Mangaian landscape today are thus regarded as a consequence of human interference in this ecosystem.

Radiocarbon dating of the transition from the peat to clay facies representing this major transformation in the island's ecology has, however, proved to be controversial and—in hindsight—almost certainly too old (see Spriggs and Anderson 1993 and Kirch and Ellison 1994 for an initial debate over these dates). Radiocarbon ages of 1930 ± 60 BP (core IV-1), 1830 ± 80 BP (core VT-5), and 1640 ± 80 BP (core TM-7) at the peat-to-clay transition all suggested that the onset of the major phase of erosion on the central volcanic cone, accompanied by deforestation and the transition to fernlands, began around 1800 BP. We initially accepted these dates as proxy evidence for Polynesian colonization of Mangaia early in the first millennium AD, in keeping with then-current archaeological models of Eastern Polynesian settlement commencing in the first few centuries of the Christian era (e.g., Irwin 1981; Kirch 1986; Sinoto 1979). In recent years, however, it has become increasingly certain that Polynesians did not expand into central Eastern Polynesia until after about AD 850 to 900 (at the earliest), and therefore the radiocarbon dates on the upper portions of the Mangaia swamp cores must be called into question. The stratigraphic sequences themselves—and the pollen spectra and microscopic charcoal records within the cores—are not in question. There can be little doubt that the dramatic increase in charcoal, accompanied by a rapid decline in forest taxa and concomitant increase in pyrophytic ferns, are a signal of the arrival of humans and the onset of anthropogenic changes on the island. The problem is that the ^{14}C dates for this transition are roughly 800 to 900 years too old, based on current evidence for human colonization of Eastern Polynesia. The reason for such old dates is not yet clear, although it may be because the dated samples were obtained from organic matter within bulk clay eroded from the adjacent volcanic slopes, which may have incorporated some amount of older soil carbon. Redating of new cores from the Mangaia swamps, using accelerator mass spectrometry (AMS) techniques on extracted seeds or other short-lived plant materials, is necessary to resolve the problem; I predict that such

new dates will correspond more closely with the basal date for human activity at the MAN-44 rockshelter and at the coastal Vairorongo site (see Chapter 3).

In sum, the consistent stratigraphy within the Mangaia taro swamps indicates an island-wide sequence commencing with a stable early Holocene land surface that was inundated at lower elevations around 7,000 years ago, following rapid post-Pleistocene sea-level rise. As brackish lakes began to fill the valley bottoms, peat deposition commenced, until sea level reached a mid-Holocene maximum (about +1.1 m above the modern level) around 4,000 years ago. Most recently, at a time younger than 1,800 years ago but whose exact date remains to be determined, a rapid and radical change in depositional environment ensued, with clay infilling of the valley bottoms due to burning and deforestation on the volcanic hill and its consequent erosion.

The sequence of environmental changes signaled in the sedimentary records of the valley bottoms has major implications for the prehistory of Mangaian agricultural practice. First, it suggests that the initial emphasis in agricultural practice was probably shifting cultivation, accompanied by burning, on an originally forested volcanic interior. Because this forest and the ancient weathered volcanic terrain on which it grew were fragile and vulnerable to degradation and erosion, these interior ridges and hills were fairly rapidly transformed into pyrophytic fernlands, stripped of their thin soils and no longer useful for agriculture. At the same time, clearance of the forest vegetation exposed the interior slopes to erosion, resulting in heightened sediment loads in the valley streams. Originally the valley bottoms, where the streams are ponded against the *makatea* escarpment, consisted of open water lakes (marked by peat deposition in the cores), which became filled in with clay sediments. Thus, in our interpretation of the sedimentary record, an indirect consequence of human land use practices on the volcanic interior was the creation of rich alluvial terrain in the valley bottoms, terrain eminently suited to the development of pondfield irrigation.

Mangaian Ethnohistory and Ethnography **Ethnohistoric and Ethnographic Sources**

The first European explorer to sight Mangaia was Captain James Cook in the *Resolution* and *Discovery*, on March 29–30, 1777 (Beaglehole 1967:78–81, 826–830). The island offered no anchorage, and an attempted landing party was thwarted by high surf on the fringing reef. But a small canoe came offshore,

allowing Cook and his officers to glean some information from a Mangaian man who came on board and conversed with the Tahitian Omai (Figure 2.7). The tattooed Mangaian, who had pierced earlobes (into one of which he promptly cached a metal knife given to him), indicated that the island was called “Mang’aeaa or Mang’la” (Beaglehole 1967:827) and told the English that it had taro, breadfruit, plantains, and coconuts but no “yams, Hogs, nor Dogs” (Beaglehole 1967:80).

In 1823, a London Missionary Society ship under the command of Rev. John Williams (1837:76–80) landed a party of three converted Tahitian missionaries (two with their wives) on Mangaia, but a mob on the beach seized their possessions and the two women were “carried into the woods.” Cannon fire from the ship halted the attack and the five were rescued; this first attempt at establishing a mission was abandoned.

In June 1824, however, two Society Island missionaries named Davida and Tiera from Taha’a Island were dropped off at Mangaia by a ship en route to Sydney (Hiroa MS B:641). As Williams recounts, “These two devoted men . . . leaped into the sea and swam to the shore taking nothing with them but the light dresses which they wore, and a portion of the New Testament in the Tahitian language” (Williams 1837:81). By sheer force of personality, Davida converted the high chief Numangatini and his followers. A war between the converts and pagans followed, in which the Christians triumphed. By the time Williams returned to Mangaia in 1830, he encountered a scene to warm any missionary’s heart, with a “large chapel in the centre [of the village] . . . whilst the neat white cottages of the native Christians, stretching along to the right and left . . . gave variety and animation to the scene” (1837:239).

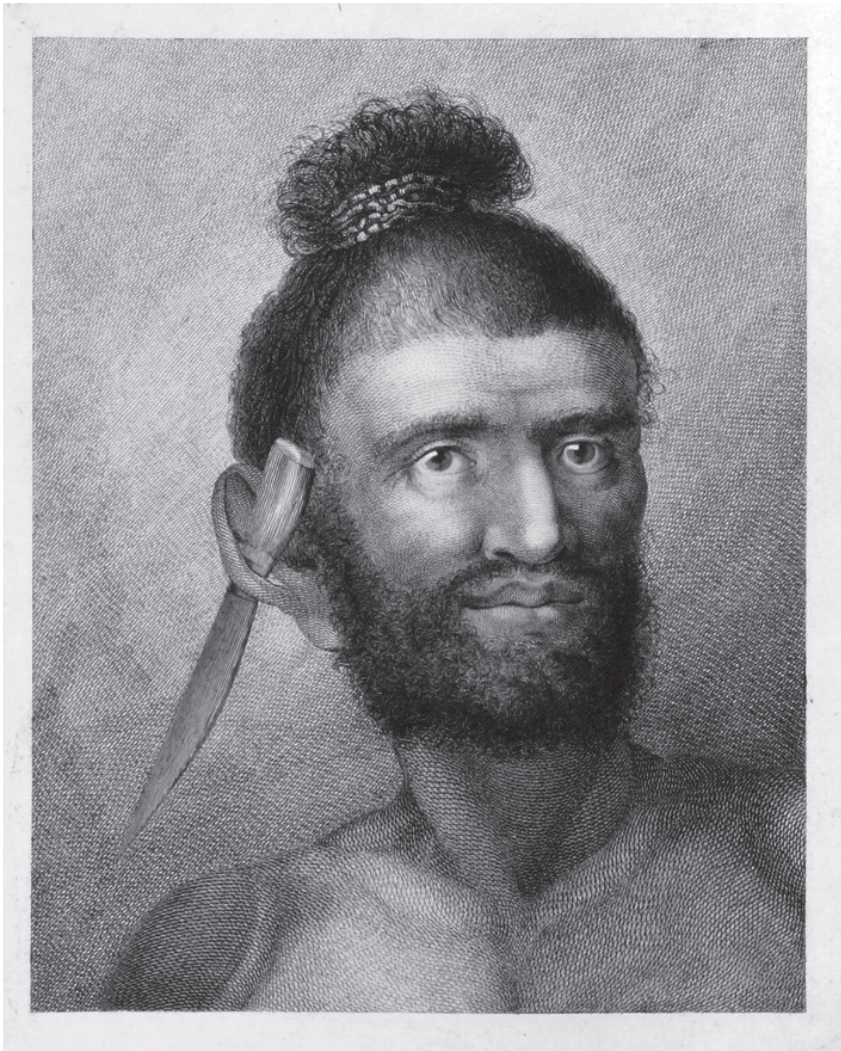


Figure 2.7. Portrait of a man of Mangaia Island, drawn by William Weber, artist on Captain Cook’s third voyage in 1777. From P. V. Kirch, *personal collection*

Much of our knowledge regarding traditional Mangaian society comes from a collaboration between Mamae, a native pastor (*‘orometua*) and the English missionary William Wyatt Gill who resided on the island from 1852 to 1872 (Reilly 2003:12). Mamae was a member of the Ngati Vara clan who acquired a store of traditional knowledge, including chiefly genealogies and oral histories from his grandfather, Koroa (who had held the title of *mangaia* or paramount chief; Reilly 2009:20–21). Mamae wrote several manuscript accounts in the Mangaian language, some of which were drawn upon by Hiroa (1934); these have been more recently transcribed and edited by Reilly (2003, 2009). For his part, Rev. Gill (1876, 1894) wrote a number of books about Mangaia, incorporating much that he learned from Mamae.

The first modern ethnographic study of Mangaia was conducted by Te Rangi Hiroa from December 1929 to April 1930 when Hiroa (a trained medical doctor as well as anthropologist) stood in for the island’s resident agent on behalf of the Cook Islands administration. Hiroa was “authorized to use the resources of the government. . . . The government, therefore, devoted its attention to the ethnological survey” (Hiroa 1934:3). Although Hiroa obtained some new information from his informants, he recognized that the traditional culture had undergone dramatic changes in the preceding one hundred years and therefore drew extensively upon the writings of Gill and from one of Mamae’s manuscripts that he was able to consult (Hiroa 1934:7–8). Nonetheless, Hiroa’s account is valuable as the first attempt to synthesize Mangaian culture and traditional history in a systematic manner.

Recently, Mangaian traditional history has received renewed ethnohistorical scrutiny from the work of Michael Reilly (2003, 2009), who has drawn upon and retranslated Mamae’s texts and also carried out his own fieldwork on Mangaia with contemporary elders. Reilly’s (2009) *Ancestral Voices from Mangaia* is a particularly valuable interpretation of Mangaian traditional history.

Population

Williams (1837) estimated the population of Mangaia as between 2,000 and 3,000 in 1823. However, this followed some years of direct and indirect contact with Europeans and probably reflects some reduction due to introduced diseases such as syphilis and measles. Williams records a devastating epidemic that

struck the island immediately after the first visit of the Tahitian missionaries in 1822: “soon after our visit, a disease broke out which proved exceedingly fatal; the infant and the aged, the chieftain and the peasant, falling alike beneath its deadly influence” (Williams 1837:81). Even at 3,000 people, however, the population density would have been 150 persons/km² of arable land, one of the highest density levels recorded for central Polynesia (Kirch 1984:98–99, Table 10). Such a high population density is reflected in abundant ethnohistoric evidence for intensive and frequently violent competition among social groups for control of food production zones, especially the irrigated lands (Hiroa 1934).

Sociopolitical Organization and Land Tenure

As is common throughout much of Polynesia, Mangaian society was organized into descent groups, called *kopu*, often named for eponymous ancestors (Reilly 2009:136–137); Hiroa (1934:101–105) calls these “tribes.” Among the most influential *kopu* were the Ngariki, Ngati-Vara, Tonga‘iti, and Ngati-Tane. Particular *kopu* were originally associated with certain lands, with each *kopu* having one or more *marae* at which their tribal gods were worshipped (Reilly 2009:138). However, the frequent wars and dispossession of lands from conquered groups that characterized later Mangaian history led to a more complex system of land tenure.

Mangaian political organization corresponded only partly with the descent group structure, as power was shared among a secular paramount called the *mangaia* (Hiroa [1934:122] calls him the Temporal Lord) and the holders of three hereditary priestly titles: the *ariki pa uta* (Inland High Priest), *ariki pa tai* (Shore High Priest), and *ariki i te ua i te tapora kai* (Ruler of Food) (Hiroa 1934:112–119). It is curious that the word *ariki* is used for these priestly titles, as elsewhere in Polynesia, *ariki* generally refers to a chief (Kirch and Green 2001:227–231); it may be that at an early period in Mangaia, these titles had more secular functions. As Hiroa (1934:122) explains, the *mangaia* was not an inherited title but was held “by the leader supreme on the field of battle.” His installation required the offering of a human sacrifice to the war god Rongo at the principal *marae* or temple of Orongo.

Mangaia is politically divided into six districts (*puna*), each corresponding to a main drainage basin. Clockwise, from the west, these districts are Keia, Tava‘enga, Karanga, Ivirua, Tamarua, and Veitatei. Each district was under the control of a chief, known as

the *pava*, these being appointed by the newly installed *mangaia* from among the warriors who supported him (Hiroa 1934:124; Reilly 2003:10). The districts themselves were subdivided into still smaller land sections called *tapere*, each of these being under the control of a subdistrict chief (*kairanga-nuku*). These subchiefs “saw to the distribution of the taro lands within the subdistrict” (Hiroa 1934:124). Thus, land was controlled through a hierarchical system of *mangaia*, *pava*, and *kairanga-nuku*, with the title holders and lands themselves being redistributed after wars of succession for the *mangaia* title. The most desirable land was the irrigated pondfields in the valley bottoms; conquered groups were often dispossessed of their irrigated holdings, relegated to the *makatea* or less fertile mountain slopes. As Hiroa writes,

The frequency of intertribal wars, however, placed an increasing emphasis on individual valor as against hereditary chieftainship. The *puna* lands of the conquered became the sport of the victors, so that with each battle the land ownership changed. Land tenure came to depend on conquest, which obliterated the rights of previous occupation and cultivation. In the redivision of conquered land, the largest shares went to the principal warriors (*toa*). The large landholders today claim the right to their lands through their warrior ancestors [Hiroa 1934:129].

Religion and Ritual

As throughout Eastern Polynesia, the Mangaiaans were polytheistic; Reilly (2009:42–46) summarizes 13 main gods. Of these, the most important was Rongo, “the tutelary god of Mangaia, who dwelt in ‘Avaiki [the ancestral homeland] and fed exclusively on humanity,” this being a reference to the human sacrifices demanded by Rongo (Reilly 2009:43, quoting Gill). Other major deities included Mоторo and Tane. Each god had his own *marae* or temple, at which prayers were made and sacrifices offered (although human sacrifices were restricted to Rongo). More will be said of *marae* in Chapter 3, where they are considered part of the archaeological landscape of Mangaia.

I have already noted the important role played by the three *ariki* or high priests. Reilly (2009:47) writes that “being literally descended from the great Rongo, the three *ariki* together participated in all the important ritual occasions celebrated by Mangaian society.”

The Inland High Priest was “the head of all the priestly orders,” whom Gill called the “pontifex maximus” (Reilly 2009:47). He officiated at Aka‘oro *marae* in Keia district, where human sacrifices were brought before they were taken to the “national *marae*” at Orongo (Hiroa 1934:180–183). The Shore High Priest resided on the coast next to Orongo *marae*, where he officiated when the sacrifices were brought from Aka‘oro and placed on a special slab altar (see Chapter 3). The primary duty of the Ruler of Food (*te ariki i te ua i te tapora kai*, ‘the chief presiding at the head of the food baskets’) was the “distribution of the portions of the human sacrifice divided among the ruling chiefs at the ceremony held on the Orongo *marae*” (Hiroa 1934:118).

Below the level of the three *ariki* were lesser priests or spirit mediums known as *pi‘a atua*, who officiated at the various tribal *marae*. They were ranked by the importance of the gods they served, with Mоторo and Tane being the most venerated (Reilly 2009:49–50).

Mangaian Land Use

The Mangaian environment consists of four main land use zones: (1) the *makatea*, (2) the lower volcanic ridges and narrow valley slopes, (3) the alluvial basins with intensive taro irrigation, and (4) the heavily eroded interior ridges of the volcanic cone. The areas of each of these zones are given in Table 2.1.

Zone 1, the *makatea*, includes extensive pinnacle karst regions that are largely barren of vegetation and virtually impenetrable (zone 1A), totaling about 20 percent of the island’s surface area. Other parts of the *makatea* with soil cover between the limestone outcrops (zone 1B, with Oneroa Clay Loam) can be cultivated with dryland tuber crops, including sweet potato, *Dioscorea* yams, dryland aroids, and tree crops such as coconut, breadfruit, and Tahitian chestnut (*Inocarpus fagiferus*). However, no more than 50 percent of the surface area of zone 1B is arable (i.e., about 9.4 km²). “The old channels and hollows where soil has been deposited, termed *puta ko‘atu* (holes in the rock), are of value in the cultivation of the sweet potato and paper mulberry” (Hiroa 1934:126). The Mangaiaans call the vegetated parts of the *makatea* the *rau-tuitui* (Hiroa 1934:125) because the candlenut tree (*Aleurites moluccana*) or *tuitui* is dominant there.

Zone 2 consists of the lower, gentler volcanic ridges that abut the inner *makatea* cliff, along with the narrow valley interiors. This terrain is today

Table 2.1 Mangaian Land Use Zones

Environmental Zone	Area (km ²)	Percent of Area
1. <i>Makatea</i> and coastal strip	29.0	56
1A. Barren (unvegetated) <i>makatea</i>	(10.2)	(20)
1B. Vegetated <i>makatea</i> , poor soil	(18.8)	(36)
2. Lower volcanic slopes and valley interiors	9.2	18
3. Irrigated alluvial basins	1.3	2
4. Degraded <i>Dicranopteris</i> fernlands	12.5	24
Total land area	52.0	100

dominated by *Hibiscus tiliaceous*, with coconut and Tahitian chestnut trees. The Keia Clay Loam soils here, derived from erosion of the volcanic core, are suitable for dryland cropping of aroids, bananas, sweet potatoes, and yams.

Zone 3, the irrigated taro lands (*puna* in Mangaian) with Tamarua Clay Loam soils, are the single most productive and valued land class, even though they make up only 2 percent of the total land area. I calculated the area of irrigated taro lands from the 1974 1:25,000 topographic map (New Zealand Department of Lands and Surveys) using a digital planimeter, aided by a set of color aerial photographs, with a total result of 130.1 ha (1.3 km²) for the nine principal irrigation systems. Small sets of abandoned terraces in the valley interiors were not included in these calculations but would not increase the total by more than 2 or 3 ha. Allen (1971:372) estimates the total area under irrigation at 310 acres, or 125 ha, closely matching my own results.

Finally, the interior volcanic ridges (zone 4), called the *rau-tuanu'e* by the Mangaians (Hiroa 1934:125) after the *anu'e* fern (*Dicranopteris linearis*), dominate the landscape. This zone consists of deeply weathered, lateritic basalt with virtually no soil cover. This terrain supports only a degraded, fire-resistant association of stunted ironwoods (*Casuarina equisetifolia*), scattered *Dodonea* sp. shrubs, scrub *Pandanus tectorius*, *Dicranopteris linearis* fern, and some grasses, with large erosional scars along the ridge tops (Figure 2.8). This zone, comprising fully 24 percent of the island's land area, is wholly unusable for cultivation. (In the twentieth century, aborted efforts to use this zone for commercial pineapple cropping only resulted in acceleration of the already severe erosion.)

Mangaia is readily divisible into six radial territories, on the basis on its steam-valley topography, and this natural division into drainage basins provided the basis for political segmentation, as described above. Like slices of a pie, each Mangaian valley-polity included a core sector of wet *puna* land, amenable to landesque capital intensification through irrigation. Surrounding the *puna* were the broader expanses of low-lying volcanic slopes and the *makatea*, lands suited to dryland cropping. Thus, in Mangaia, a wet-dry agricultural dichotomy was fully incorporated within each political unit.

The total of all agriculturally usable lands is 29.3 km², but this is reduced to about 19.9 km² when we subtract the 50 percent of zone 1B, which is not arable. Thus, only about 38 percent of the total island land area is capable of food production.

The Traditional Agricultural System

Mangaian subsistence agriculture comprises two main sectors: taro cultivation in permanent irrigation complexes in the alluvial basins (zone 3) and shifting cultivation in consort with arboriculture in zones 1B and 2. Although there has been some retraction in the total area of irrigated fields in response to population decline, these fields continue to provide the staple basis of Mangaian subsistence. The dryland agricultural sector has undergone significant disintensification in historic times, with the cessation of barkcloth cultivation, for example. (Mangaian agriculture has also been affected, in the twentieth century, by various commercial schemes, including orange production on the *makatea* in the early part of the century [Scott 1991] and pineapple monocropping on the degraded volcanic lands in the 1960s and 1970s.) The following



Figure 2.8. View of the pyrophytic fernlands, the *rau-tuanu'e*, dominated by *Dicranopteris linearis*, along with scrub *Pandanus* and ironwood, and with scattered coconut palms in the valley bottoms.

account is a historical ethnographic reconstruction of Manganian agriculture as practiced in the early nineteenth century, prior to major changes.

There are nine main irrigation systems dispersed around the island. The largest single complex, in Veitatei district, covers 26.9 ha, while the smallest, Kirikiri, incorporates only 1.5 ha. The missionary Williams gave the following description of Manganian taro fields:

The valleys generally contain from thirty to fifty acres each, and entirely laid out in taro plantations. These are gradually raised above each other, from the lower to the upper part of the valley, from whence water is conveyed to them in wooden pipes. When I saw the excellent order in which they were kept, I ceased to wonder that the men wished the females to continue to cultivate them, for not a weed was to be seen [Williams 1837:261].

The alluvial basins in which these systems are situated are low-lying and swampy, with the fields separated by earthen embankments or bunds without stone facings. Rather than ditches feeding off of stream channels as in some other Polynesian islands, the Manganian streams have been channeled to become irrigation canals (*aravai*). In the lower reaches of the irrigation systems, these canals are frequently bounded by levees in a deltaic manner (Figure 2.9). Both inundated fields (*repo taro*) and raised beds (*taro pa'i*) are used, and individual plots are converted from one type to the other successively (Figure 2.10). The raised beds are elaborately mulched with coconut and banana leaves. Taro is planted in these beds with the aid of a special planting tool (*pao*), which creates a large depression in which the growing corm can expand (Figure 2.11). The reticulate landscape of a typical Manganian irrigation system, the main alluvial basin of Tamarua Valley, is shown in Figure 2.1.



Figure 2.9. Irrigation channel (*aravai*) with leved banks and taro pondfield (*repo taro*) to the right, Tamarua Valley, 1991.

While irrigated taro formed the core of Manganian agriculture, both shifting cultivation and tree cropping on the *makatea* and on the lower colluvial slopes and ridge spurs provided other essential foods and industrial materials. Shifting cultivation in zones 1B and 2 consisted primarily of mixed cropping of *Colocasia* and *Alocasia* aroids with *Dioscorea* spp. yams, bananas, and sweet potato (*Ipomoea batatas*). While lacking the high-status cultural associations of wet-land taro, these crops contributed significantly to subsistence, especially for those who had been disenfranchised of their irrigated fields by war. Also grown in these zones was the paper mulberry (*Broussonetia papyrifera*) used to manufacture barkcloth. A significant arboricultural element was represented by stands of coconut, breadfruit, and Tahitian chestnut tree crops. The breadfruit trees are found primarily on the *makatea* lands, while Tahitian chestnut trees are especially plentiful in the interior valleys. Coconut is distributed throughout.

Early missionary accounts make it clear that the bulk of agricultural field labor, including tending of the irrigated taro fields, fell upon the Manganian women. Williams (1837:245), for example, reports that “the work of planting and keeping the taro-beds in order is assigned to girls under sixteen years of age, and to women who have passed the prime of life.” The labor required them to “wade for hours in mud from two to three feet deep.”

Irrigation and the Manganian Polity

In late prehistory up until the arrival of the mission in 1823, Manganian political history was dominated by a succession of intertribal wars, for which the primary impetus was control of the valuable irrigated *puna* lands. Hiroa (1934:36–83) related this history of “intertribal strife” in some detail, drawing upon a wealth of indigenous oral traditions; more recently, Reilly (2003, 2009) has expanded greatly on the oral history, drawing primarily on the writings of Mamae.



Figure 2.10. Two methods of taro cultivation are practiced in the Mangaia irrigation systems: the plants in the foreground and on the right are planted in standing water, while those on the left have been planted in a raised bed (*taro pa'i*).



Figure 2.11. Traditional wooden planting tool (*pa'o*) used to make a depression in the raised bed for insertion of the taro slips.

Hiroa summarized the results of intertribal war over control of the irrigated lands in Mangaia:

When the peace drum sounded and the fugitives emerged from their refuges, the victors gave them a feast (*taperu kai*) in public recognition of their safety. The conquered, however, had lost their holdings in the rich taro lands of the *puna* districts. They were awarded shares in the upper narrow ends of the valleys where they could still grow a certain amount of taro. They were also given land in the *makatea*, where sweet potatoes and paper mulberry plants could be produced. The conquered were rather unjustly blamed for the shedding of blood that had occurred and therefore became servitors in the households of the victors. They grew the paper mulberry, caught fish, and grated the taro (*poke*) for their masters to pay for the blood which had been spilt (*ei tutaki i te toto i ta'e*). Their masters then allowed them some share in the taro land which is expressed by the phrase, '*Ka 'angai i roto i te puna.*' (They fed them in the irrigated taro lands.) [Hiroa 1934:111].

The tribes originally occupied definite continuous areas, but the subsequent wars led to a break in the continuity of the areas occupied. The conquerors, in annexing food lands from the conquered, took subdistricts which were remote from their original lands. The food lands and the rule over districts and subdistricts were the important spoils of victory. The redistribution of food lands led to the scattering of tribes; some families remained on the original land, but others settled on land awarded them in other districts. The tribe was nevertheless held together by the social mechanism which decided the grouping of individuals at birth and by the necessity for protection against other tribes [Hiroa 1934:107].

This cyclical pattern of territorial conquest and of repeated usurpation of temporal power, as well as the emphasis on a war cult requiring human sacrifice, are themes reminiscent of some other Eastern Polynesian societies, notably Tahiti and Hawai'i. In Mangaia, however, where the pressures on limited land were far greater, the war cult was intimately connected with

taro irrigation. Thus, the Mangaian war god was a transformation of the ancient Polynesian god of agriculture and fertility, Rongo (the equivalent of Lono in Hawai'i). As Hiroa (1934:162) writes, "Retention of [Rongo's] original association with the fertility of the land is seen in that parts of the human sacrifice offered to him after a victory were taken to different districts in order that food might grow plenteously during the new reign." Indeed, Rongo's association with taro is clear, for the keeper of the national god-house made daily offerings of taro to Rongo. "For this purpose, he made an oven (*umu*) in which he cooked or partly cooked a number of taro. He then took up one in his hand saying, '*To taro e Rongo, a kai!*' (Your taro, O Rongo, eat!)" (Hiroa 1934:178). The symbolic associations between taro, Rongo, and human sacrifice are further revealed by traditions of intertribal war that relate the interment of war victims in the mud of the taro pondfields. Hiroa (1934:43) records, for example, the tradition of the Te-Kama tribe, who enticed others to their taro fields, only to kill them and press their bodies into "the soft mud of the taro patch." Similarly, Tiauru sought revenge against the Tonga'iti tribe who had killed his father and buried him in a taro swamp (Hiroa 1934:51). Gill relates the tradition of Utoe, of Tamarua district, in which the symbolic link between taro and human sacrifice is unmistakable. Utoe "lined the banks of his fine taro patch with the bodies of thieves slain by his own hand. Nine are known to have been thus disposed of. The bright redness of the clay of the said banks is superstitiously believed to be owing to the soil being sodden with human blood" (Gill 1876:51). The ideological relationships between the paramount Mangaia, the god Rongo, and taro irrigation are diagrammatically represented in Figure 2.12.

Warfare and Violence

The pervasive role of warfare in Mangaian life has been amply documented by Gill (1856, 1876), Hiroa (1934), and Reilly (2003, 2009). Battles involving opposing groups of warriors were the means by which the succession from one *mangaia* to the next was determined; some 42 such battles are recorded in Mangaian oral traditions (Reilly 2003:94). Equally well documented is the role that ritual homicide played both in the challenge of a would-be usurper to the reign of a *mangaia* and in the ceremonies of installation of a new *mangaia* once warfare had been concluded (Reilly

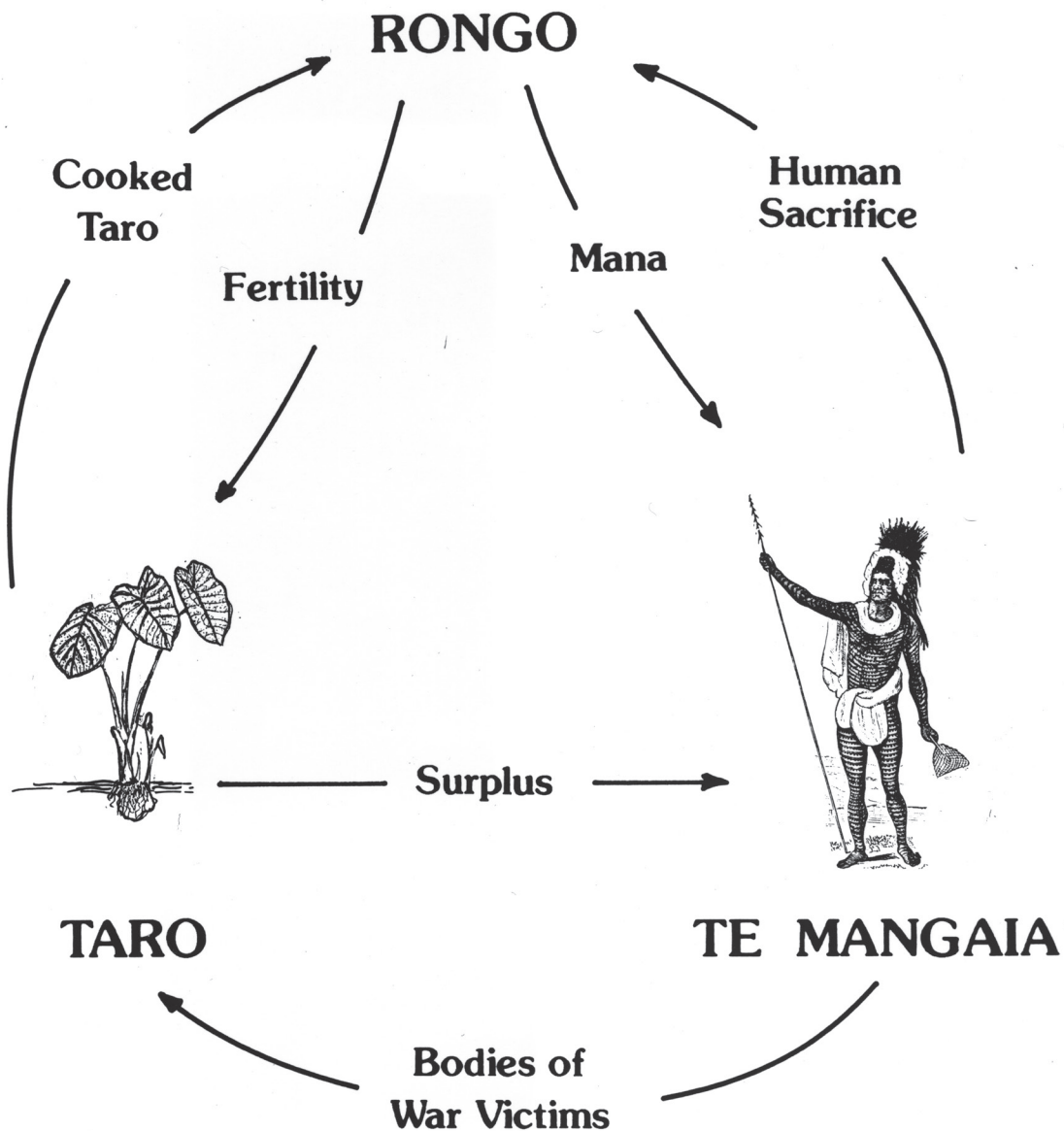


Figure 2.12. Schematic diagram showing the relationships between Rongo, the god of war and agriculture in traditional Mangaia, the paramount chiefship (Te Mangaia), and taro cultivation.

2009:250). The peaceful reign of a *mangaia* “would be deliberately ‘severed’ (*motu*) by a challenger who killed a victim,” known as the “fish [*ika*] to sever the reign” (Reilly 2009:249). At the conclusion of hostilities, another victim, the “fish to sound the [peace] drum,” was killed, his body carried first to Aka’oro *marae* in Keia and then to the great *marae* of Orongo on the coast (Reilly 2009:250–261).

Less certain is the extent to which other forms of violence—less ritualized perhaps—may have pervaded Mangaian society. Certainly the oral traditions

are replete with accounts of various forms of violence, ranging from the accounts of the killing of members of the Ngati-Tane clan by their enemies who on two occasions cast them into large earth ovens prepared for baking *ti* roots (Hiroa 1934:46–47), to the notorious cannibal Mautara (Hiroa 1934:51). Indeed, there are a number of references to cannibalism in the traditions (e.g., Hiroa 1934:66, 73). Reilly (2003:95–96) opines that “the practice [of anthropophagy] emerged at a particularly dangerous period in Mangaia’s history, when numerous refugees ate either friend or foe

that happened to come their way. The stresses upon leaders at this time turned some of them to officially sanctioning such actions: Gill described cannibalism as a form of terrorism used against a tribe's opponents." As we shall see in later chapters of this monograph, archaeological evidence is consistent with the practice of cannibalism during at least some periods of Mangaian history.

The Mangaian emphasis on intertribal warfare and territorial conquest is similar to that of certain other Polynesian islands, such as Easter Island (Kirch 1984:264–278), Mangareva (Hiroa 1938a), and the Marquesas (Kirch 1991; Thomas 1990). In all of these islands, extreme pressure on food production and high population density, combined with environmental degradation, were common factors. Goldman (1970) classified these islands as "Open" societies in his comparative study of Polynesian chiefship. According to Goldman (1970:20), such Open societies were "more strongly military and political than religious," and stability was "maintained more directly by the exercise of secular powers." Goldman elaborated on the Mangaian case as follows:

What is remarkable about the Mangaian political organization is its consistent inability to transcend the temporal authority by any means

other than force. So consistently was the hereditary succession avoided that we are moved to suspect the emergence here of a new and formal system of complementary power relationships: a genealogical succession for religious authorities and a military succession for secular authorities. Such a formal system achieves a conceptual coherence within a religious setting that raised up Rongo as the God of War and as the high god of the island, in contrast to traditional eastern Polynesia, where Rongo was the peaceable god of agriculture. The Temporal Lordship [*mangaia*] as a "military dictatorship" was a late development in Mangaia; it was also the logical development of an older religious idea [Goldman 1970:86].

Goldman envisioned Open societies such as Mangaia as lying midway along an evolutionary continuum (from Traditional to Stratified in his classification). However, a more accurate view might be that rather than occupying an incipient stage leading to increased hierarchy and stratification, the Open societies represent a divergent evolutionary pathway in which severe ecological constraints—in large part exacerbated by human actions—created situations of intense conflict and competition for limited resources.

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3

Overview of Manganian Archaeology

Patrick Vinton Kirch

Archaeological Research on Mangaia

Te Rangi Hiroa (aka Sir Peter H. Buck) carried out ethnographic fieldwork on Mangaia from December 1929 to April 1930. Although archaeology per se was not his interest, Hiroa solicited from his informants a list of *marae* or former temple sites (Hiroa 1934:173–177, Table 17), a number of which he visited “on a tour of inspection” with the district chiefs. Hiroa (1934:174) writes, “Of the 40 *marae* named, the sites of only 27 could be located at the time. . . . With more time, more sites could have been located.” Hiroa gave only a generalized description of a typical *marae* and no detailed plans of individual temple foundations. However, his field notebook preserved in the Bishop Museum archives contains rough sketch maps and measurements of a number of these sites (Hiroa MS A).

The first true archaeological research on Mangaia was conducted by Peter S. Bellwood, in 1970, as a part of the University of Auckland’s program on Cook Islands archaeology (Bellwood 1978). Bellwood spent just two weeks on the island, accompanied by two assistants, focusing his time on the surface survey of the *marae* sites previously identified by Hiroa (1934). Bellwood’s team made plan maps of 12 *marae*, as well as notes on various other sites. In addition, he excavated a 2-m x 1.5-m trench in a rockshelter (site MAN-9) in Tamarua district and visited the Te Rua Rere (MAN-24) burial cave. Bellwood drew upon his

brief survey of Manganian sites, combined with ethno-historic information from Hiroa (1934), to sketch the rough parameters of traditional Manganian settlement patterns in an article that compared Mangaia with Rarotonga and Aitutaki (Bellwood 1971).

In 1989 and continuing intermittently until 1998, Kyoto University in Japan carried out a program of anthropological research in the Cook Islands that included physical anthropology, archaeology, and linguistics (the Kyoto University Cook Islands Scientific Research Programme), under the overall direction of Kazumichi Katayama (Katayama and Shibata 1999). In 1989, the Kyoto team excavated in three rockshelter sites on Mangaia: Ngaaitutaki and Tapaopao in Ivirua district and Erua in Karanga district (Oshima et al. 1999). Faunal remains from these three rockshelters were described by Leach et al. (1994). In 1991, Yuriko Igarashi commenced excavations at the coastal midden site of Vairorongo, work that continued for a second season in 1993 (Igarashi 1999a, 1999b; Oda et al. 1999; Oyama 1999).

As described in the Introduction (Chapter 1), our own research team carried out fieldwork on Mangaia in 1998 and again in 1991. One member of the 1991 team, Julie Endicott Taomia, returned to Mangaia in 1992 and 1993 to excavate open habitation sites for her Berkeley doctoral dissertation (Endicott 2000; see also Taomia 2001, 2002). Endicott Taomia’s areal excavations at

several terraced residential sites in Veitatei Valley (especially MAN-92, MAN-95, MAN-97, and MAN-100) provided valuable insights into the organization of household space in later Manganian prehistory.

The Manganian Archaeological Landscape

The archaeological landscape of Mangaia is made up of several distinctive kinds of site, each of which is briefly summarized below. In the final section of this chapter, I review how the various site components are integrated in an island-wide settlement pattern. The distribution of all archaeological sites recorded by our team on Mangaia is shown in Figure 3.1.

Marae

As elsewhere in Eastern Polynesia (Emory 1970), *marae* were ritual spaces where lineage members or tribal groups performed ceremonies to honor their ancestors and gods and to conduct other kinds of ritual activities. Hiroa (1934:174) writes that “the marae was not only necessary to the worship of a god, but it associated the ancestor or tribe with a particular district and, in a way, established their right to the land.” Each *marae* had a proper name and was dedicated to one particular god (in some cases two gods) (Hiroa 1934:Table 17). Two *marae* in Keia district (Aka’oro, Orongo) and one in Ivirua district (Ivanui) were considered to be “national”

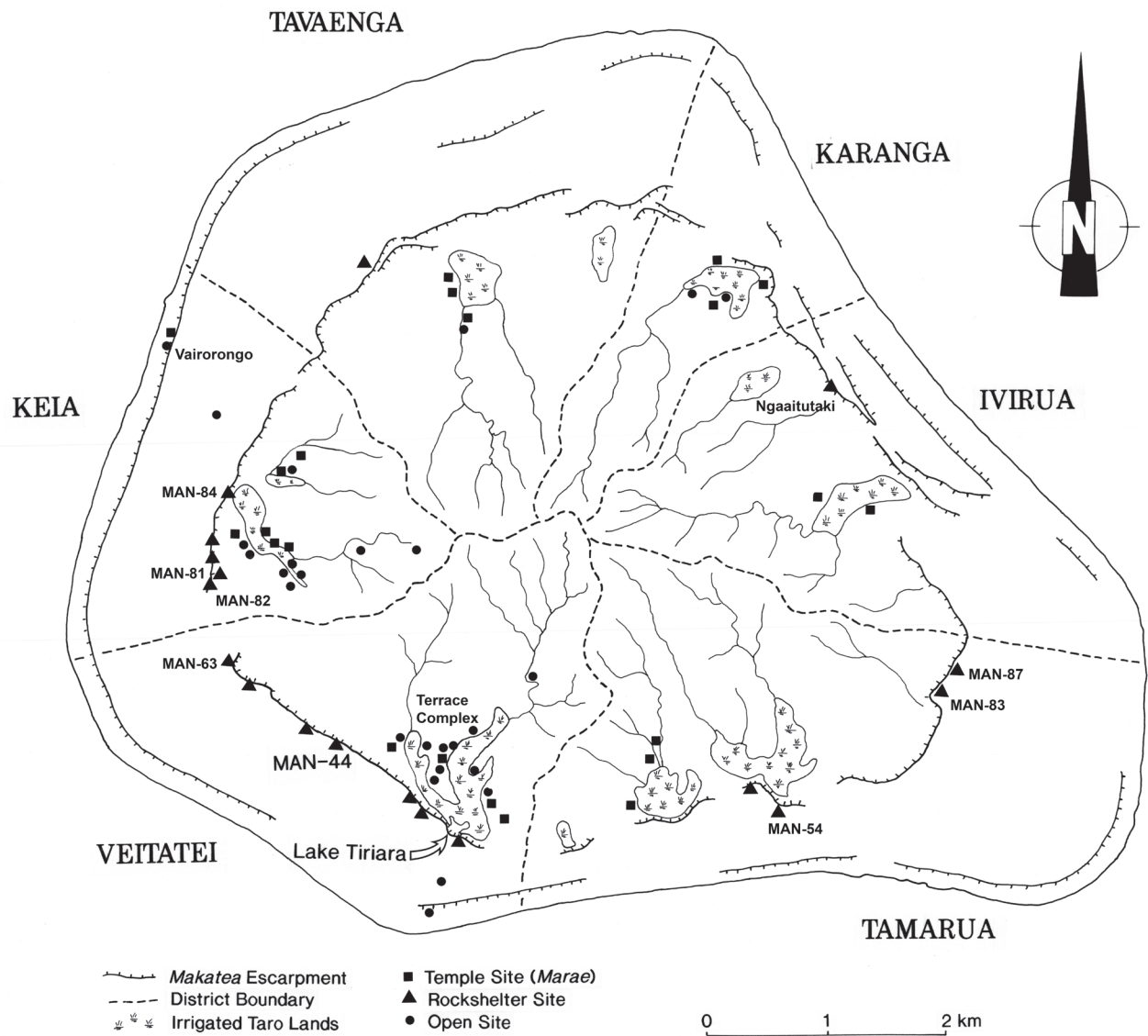


Figure 3.1. Map of archaeological sites recorded on Mangaia Island in 1989 and 1991.

marae dedicated to Rongo, the god of war (see Chapter 2). At the time of European contact, Aka'oro was the principal inland *marae* of Rongo, while Orongo was the main coastal *marae*. The location of Orongo, not far from the main reef pass of Avarua, is also likely to have been the site of an initial founding settlement on the island, hence its special status (see Vairorongo site, below).

Hiroa's (1934:174) description of the physical remains of *marae* is very brief: "The general plan was to form a rectangular court by defining the boundaries with a line of coral rocks embedded in the ground and placed closely together. The interior was then filled in with stones and earth to form a level terrace." Bellwood (1978:141) notes that this description is essentially correct, except that Hiroa failed to note the presence of upright stones that were still visible at 13 of the *marae* visited by Bellwood; such uprights were likely to have been a key architectural feature at virtually all *marae*, given that uprights were representations of the deities.

The *marae* visited by Bellwood had between 2 and 11 uprights. Many of the uprights consist of calcite stalactites that had been removed from caves in the *makatea* (Figure 3.2). Bellwood gives the surface area of various *marae* terraces, which range from as small as 25 m² up to 400 m² in the case of 'Are-vaka in Karanga district.

With the exception of the important "national" *marae* of Orongo situated on the western coastal plain, all of the recorded *marae* are located inland of the *makatea*, typically on ridge spurs or lower hillslopes just above the terraced pondfield irrigation systems (Figure 3.1). As such, they were closely associated with the dwelling terraces occupied by the house sites of the various tribes.

The Orongo *marae* (MAN-29), "seat of the Shore High Priest (*ariki-pa-tai*) of Mangaia, and the site of ceremonies essential to the installation of every Inland High Priest (*ariki-pa-uta*) and every Temporal Lord of Mangaia" (Bellwood 1978:159–161), exhibits unique architecture. Unfortunately, part of the site was



Figure 3.2. Calcite upright stone at a Manganian *marae*.

destroyed by removing the stones for a pig pen, but what remained was mapped by Bellwood (1978:Figure 77). At the eastern end of the *marae*, the whole of which was paved, the focal point was a platform (*atarau*) of coral blocks two courses high, capped with a large slab. This platform is presumably the “altar” mentioned by Gill (1876:304), where human sacrifices were laid out and offered to Rongo. Evidently, two stone statues of Rongo also once stood here, although they no longer exist (Bellwood 1978:159).

Inland Valley Terrace Complexes

Without question the most ubiquitous type of archaeological feature on Mangaia is the simple earthen terrace made by cutting and filling into the valley sides and ridges on the lower slopes of the volcanic hill. Clustered around the irrigation systems, these level terraces provided the foundations for dwellings and associated cook houses or other residential structures. Hiroa (1934:135) says almost nothing regarding traditional Mangaian houses, presumably because by the time of his fieldwork, the entire population had abandoned the interior and was living in stone or wooden houses in the new missionary-inspired

villages. The nineteenth-century missionary Williams (1837:248), however, describes “a beautiful valley, around which the huts of the natives were erected,” while Gill (1856:156) mentions that houses in Ivirua were constructed on “detached spots of rising ground” (presumably the terraces), surrounded by the taro fields and yam gardens, and shaded by coconut trees. He describes the houses themselves as long, low “reed” huts.

During our fieldwork in 1989 and 1991, we recorded several dozen terraces or terrace complexes during inland reconnaissance surveys, primarily in Keia and Veitatei districts but elsewhere as well; these are plotted on the site distribution map shown in Figure 3.1. Although these terraces were not the main objective of our project, we also mapped one terrace complex in Veitatei and conducted limited test excavations there, as described in Chapter 14. We also measured the lengths and widths of 23 terraces during the course of our reconnaissance surveys, as plotted in Figure 3.3. As is evident in the scatterplot, most terraces fall in the range from about 7 to 32 m long and 4 to 15 m wide, although one very large terrace in Veitatei (MAN-97) has a length of 52 m.

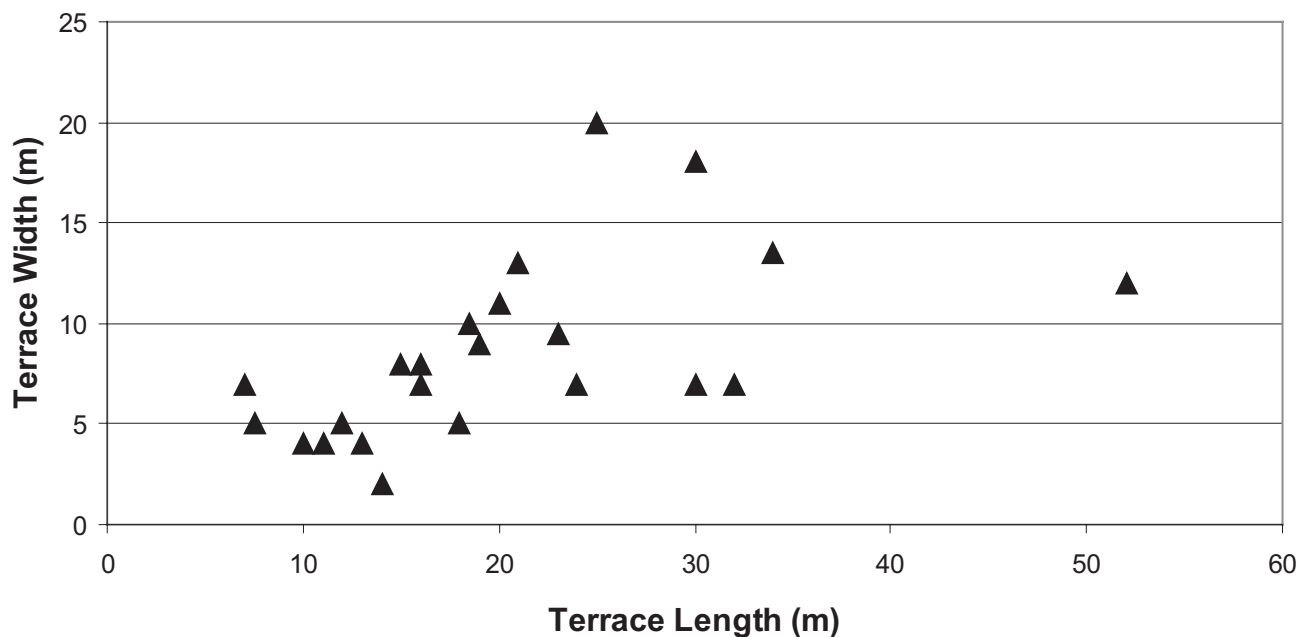


Figure 3.3. Dimensions of Mangaian earthen terraces.

Endicott (2000; Taomia 2001, 2002) conducted extensive areal excavations at nine residential terraces in 1992 and 1993, primarily in Veitatei Valley. The occupation deposits were typically shallow but sometimes complex, with evidence for multiple occupation episodes. Waterworn coral gravel and limestone slab pavements, earth oven pits and shallower hearths, and postholes were all commonly encountered features in these sites. The highly acidic soils retained little in the way of bone or shell faunal remains; artifacts were limited primarily to basalt and chert flakes, basalt adzes or adze flakes, basalt scrapers, and hammerstones.

***Makatea* Caves and Caverns**

The *makatea* of Mangaia is riddled with extensive cave systems, formed by the solution of former streams permeating the porous limestone (Ellison 1994b) at different periods during the gradual uplifting of the *makatea* (see Chapter 2). As a result, the caves are found at different elevations within the *makatea* and typically have floors that are either flat or gently sloping toward the sea. Most of the caves have ceilings high enough to allow one to walk upright; in some caves, there are quite expansive chambers.

Prior to missionization, the Manganians made use of these caves and caverns in several ways, primarily as mortuary facilities but also as refuges during times of conflict and intertribal warfare. Hiroa (1934:191) describes the practice of disposing of corpses in “secret caves.” “The different tribes had their own chasms and caves which were named, as Auraka, Raupa.” Antón and Steadman (2003) studied four caves with burials (Piri Te Umeume, Te Rua Rere, Kauvava, and Tautua), providing maps and descriptions. The first three of these were used primarily if not exclusively for burial, while Tautua was also used as a refuge cave.

Investigations at Tautua cave, which included mapping several stone structures situated within the chambers, are described in greater detail in Chapter 13. We also mapped and test excavated another, smaller refuge cave in Keia district (MAN-82), which is likewise summarized in Chapter 13.

Rockshelters

As noted in Chapter 2, the inner cliff or escarpment of the *makatea* has gradually formed through the chemical solution due to surface water running off of the island’s central volcanic cone and ponding against the limestone. Consequently, the base of the cliff becomes

undercut in places, and periodically large blocks of *makatea* become detached from the main mass, gradually leaning over and thus providing natural rockshelters. This is the case with Tangatatau, the subject of this monograph. Although Tangatatau is the largest and best stratified of any known rockshelter on the island, there certainly are many other shelters that were used or occupied for periods of time. We recorded and tested several other rockshelters in Keia, Veitatei, and Tamarua districts, as reported in Chapter 13.

The Kyoto University team excavated at three rockshelters in Karanga (Erua site) and Ivirua (Ngaaitutaki and Tapaopao sites) in 1989 to 1990 (Oshima et al. 1999). The largest and most important of these is Ngaaitutaki, which has a floor area 25 m long and 6 m wide. The Japanese team excavated four trenches, running perpendicularly out from the rear wall of this rockshelter (Oshima et al. 1999:Figure 3). The stratigraphy is described as having three or four layers (depending upon the trench), with more than 30 intercutting and overlapping earth ovens (1999:Figure 4). A single radiocarbon date of 700 ± 180 BP (KSU-2122) was reported from the lowest cultural layer at Ngaaitutaki.

Unfortunately, the deposits at Ngaaitutaki were excavated without screening the sediments (according to statements by Manganians who participated in the work), presumably resulting in the loss of much faunal material and smaller artifacts. Nonetheless, a significant assemblage of material culture was recovered, including 29 basalt adzes or adze fragments, 21 adze preforms, 85 “scrapers” (retouched basalt lithics of various kinds), and 62 shell fishhooks (Oshima et al. 1999:Table 1), making this the most important Manganian rockshelter assemblage after that from Tangatatau. The faunal material from these three rockshelter sites was reported on by Leach et al. (1994), but given that the assemblage was obtained without screening, its comparative value is questionable.

Vairorongo Coastal Site

As mentioned earlier in the discussion of *marae*, the coastal temple of Orongo and seat of the Shore High Priest (*ariki pa tai*) was one of the most important ritual centers on Mangaia, associated in oral tradition with Tui, the first Shore High Priest who was said to have come from Rarotonga (Hiroa 1934:22). Orongo is situated on the coastal plain near the main pass through the fringing reef (Avarua) and may well owe its sanctity to having been the location of one of the earliest settlements on the island.

In 1991 and 1993, Yuriko Igarashi excavated in two areas (designated A and B) on the coastal flats in a locality called Vairorongo, near the Orongo *marae* and the Avarua pass (Igarashi 1999a; Oshima et al. 1999). The stratigraphy in both areas was fairly shallow but complex, with numerous combustion features and pits, made more complicated by the burrowing of land crabs and other disturbances (Figure 3.4). Igarashi collapsed this complex stratigraphy into “upper” and “lower” layers for purposes of analysis. Area A in particular was quite rich in artifacts, including 33 fishhooks, 59 basalt tools (adzes, scrapers, drills), and other objects. Oda et al. (1999) carried out 24 accelerator mass spectrometry radiocarbon assays on charcoal samples from Vairorongo, making this the second most thoroughly dated site on Mangaia, after Tangatatau. The dates from the “lower” layer at Area A are of particular interest (Oda et al. 1999:Table 1) as they indicate that the earliest deposits here began to accumulate as early as cal AD 1060 to 1250, consistent with the oral

traditions suggesting that this may have been a founding settlement on the island. In aggregate, seven radiocarbon dates from the earlier stratigraphic layers indicate a time range of between cal AD 1060 and 1302, overlapping with the deepest stratigraphic deposits in Tangatatau Rockshelter (zones SZ-1B, SZ-2, and SZ-3; see Chapters 4 and 5).

Mangaian Settlement Patterns

As will have been evident from the preceding discussion of sites and their distributions (see also Figure 3.1), the island-wide settlement pattern of Mangaia was highly influenced and constrained by the island’s peculiar—and distinctly circular and concentric—geology and topography. The narrow fringing reef and equally narrow coastal plain, followed by the massive rampart of *makatea* with its inner and outer escarpments, and the interior, dissected volcanic cone with its radiating stream valleys, led to a particular form of ecological adaptation, as Bellwood (1971) first recognized.



Figure 3.4. Excavation in progress by the Kyoto University team at Vairorongo in 1991.

With the exception of the Vairorongo area, adjacent to the main pass of Avarua and the ancient temple of Orongo (seat of the Shore High Priest), the coastal plain seems not to have been much inhabited in pre-contact times. Doubtless there were temporary shelters or campsites used by fishing parties, but the main residential complexes were all situated inland, as were the tribal *marae*. The main attractors were of course the swampy valley bottoms, where small freshwater streams running down from the volcanic cone ponded against the *makatea* escarpment, providing ideal environments for the construction of irrigated pond-field complexes. Each of these swampy areas, the *puna* lands (see Chapter 2), became the focus of a concentrated cluster of *marae* and residential terraces carved out of the lower slopes and ridge spurs surrounding the swamps. These dense clusters of houses and temples were surrounded with house gardens (primarily sweet potato, yam, and banana to judge from the limited ethnohistoric accounts) as well as by groves of coconut and Tahitian chestnut trees.

The Manganians also made use of the natural caves and rockshelters in the adjacent *makatea*, for residential sites (as with Tangatatau), and as refuges in times of conflict, and for the burial of their dead. The volcanic uplands, with their deeply weathered, lateritic soils, were essentially worthless for cultivation and became a kind of no-man's land.

The role of the *makatea* is somewhat more enigmatic. We know that parts of the *makatea* were covered in fertile soil, although this was largely confined to small pockets. Hiroa (1934) tells us that defeated tribes were dispossessed of their fertile *puna* lands and relegated to the *makatea* after being defeated in war. This suggests that there must also be clusters of residential sites, at least in certain parts of the *makatea*. Indeed, during our fieldwork, we did encounter a few locations on the *makatea* where surface artifacts such as concentrations of basalt flakes and occasional adze fragments were evident. One objective of future fieldwork on Mangaia should be to determine the extent and nature of occupation on these lands.

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4

Excavations at Tangatatau Rockshelter (Site MAN-44)

Patrick Vinton Kirch

Tangatatau Rockshelter and Its Environs

Occupying a large part of the southwestern quadrant of Mangaia Island, Veitatei Valley is one of several drainages descending from Rangimotia, the 169-m-high island's summit (see Figure 3.1). A prominent ridge divides the valley into two main branches, and there are in addition a number of smaller tributary and side streams. These watercourses merge at the swampy valley floor, covered in deep, reddish alluvial sediment, which the Mangaians extensively modified into a network of canals and irrigated taro pondfields (see Chapter 2). Some of these pondfields were still in use at the time of our fieldwork, whereas many others had already been abandoned but could be discerned on aerial photographs (Figure 4.1). At the lowest point in the valley floor, the water flowing through these terrace systems divulges into Lake Tiriara, which ponds against the massive inland escarpment of the *makatea*. In this part of Mangaia, the *makatea* ranges from about 0.75 to 1 km wide, reaching a maximum height of about 42 m above sea level. That Lake Tiriara's waters are brackish indicates an underground connection between the lake and the sea, via a submerged solution cavern. Lake Tiriara also exhibits slight tidal variations in its surface level.

Tangatatau Rockshelter, site MAN-44 in our inventory of Mangaian archaeological sites, consists of a conspicuous overhang in the *makatea* escarpment, roughly 0.85 km west of the edge of Veitatei swamp and 1.1

km west of Lake Tiriara. The rockshelter's coordinates in the Universal Transverse Mercator (UTM) system, zone 4, are 609100E and 573100N. A narrow, rutted track descends from the main dirt road running through Veitatei, passing a few meters northeast of the rockshelter. Although several other rockshelters are found along the Veitatei *makatea* escarpment (see Chapter 13), none is as spacious as Tangatatau, and no other shelter is known to have a similar depth or richness of cultural deposits.

Tangatatau would have offered an inviting natural space for human habitation, with ready access to several micro-environments and resource zones within Veitatei Valley. The gentle colluvial slopes extending north from the shelter's mouth (classified as Keia Clay Loam by Grange and Fox [1953]), today covered in second growth, would have offered suitable terrain for dryland cultivation of yams, bananas, sugarcane, or similar crops. Several ethnobotanically important trees grow near the site today, including *Pandanus tectorius*, coconut (*Cocos nucifera*), and candlenut (*Aleurites moluccana*). A short walk to the east, the valley's alluvial floor offered ideal terrain for wetland taro cultivation, as well as a permanent source of drinking water in the small streams. Lake Tiriara, originally more extensive than today, is the habitat for *Anguilla* eels and eeltrid fishes, both of which were extensively fished and eaten by the rockshelter's inhabitants (see Chapter 7).

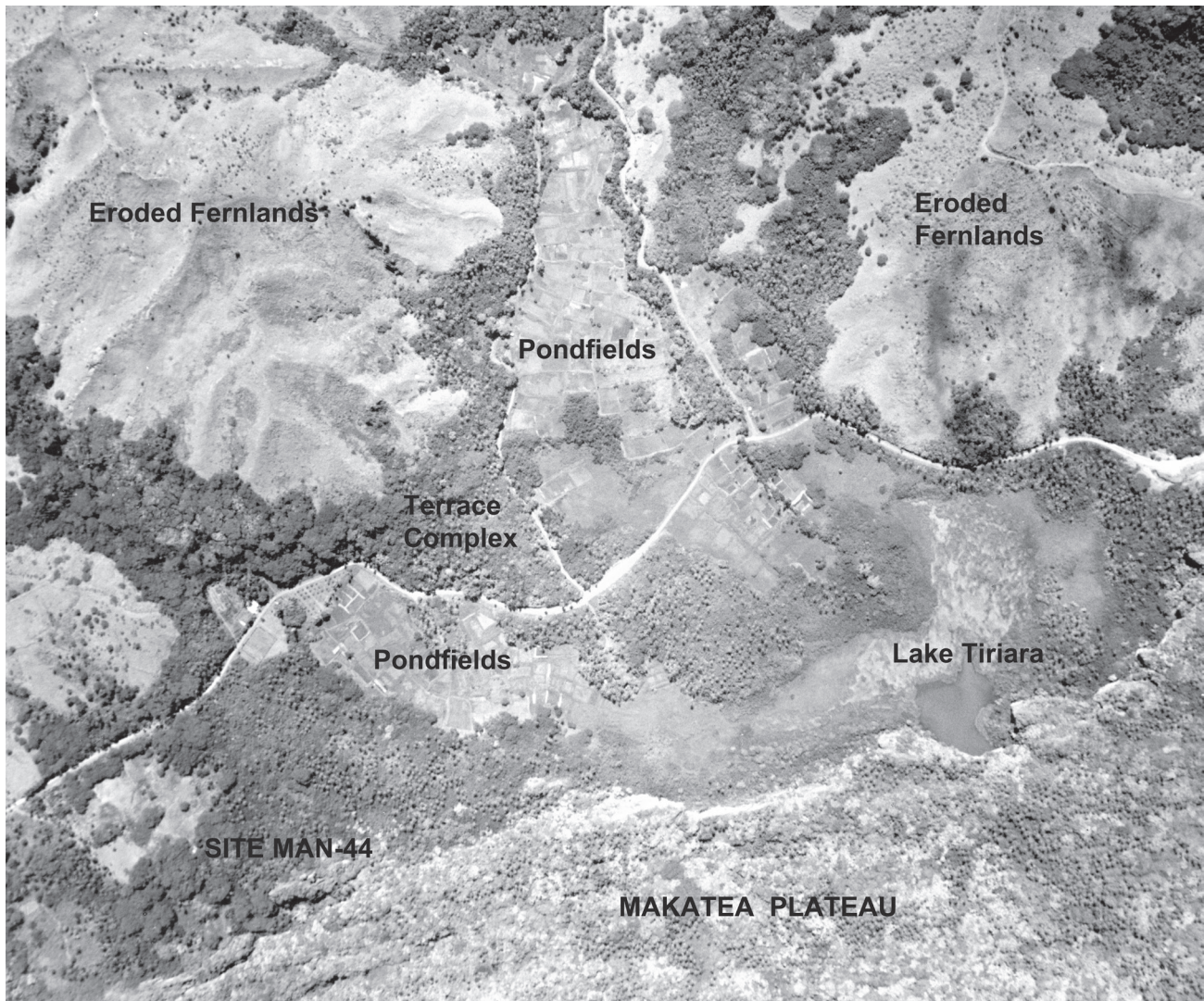


Figure 4.1. Aerial photo of the Veitatei Valley, showing the location of rockshelter site MAN-44 in relation to terraced pondfields, Lake Tiriara, and the *makatea* plateau.

Access to the coast and the narrow fringing reef would have been via one or more trails across the *makatea*, which in this part of the island is somewhat less rugged than in the north. The *makatea*, which has pockets of soil that can be cultivated, is covered in native forest, offering wild plant resources as well as habitats for various native birds.

Tangatatau Rockshelter is formed by a massive block of *makatea* limestone that has fractured away from the 25-m high escarpment and leans inland, providing a large overhang facing the island's interior (Figure 4.2). Open to the north, the shelter receives ample light through most of the day. In addition to the economic trees noted above, vegetation in the

immediate vicinity of the site today includes the indigenous *Hibiscus tiliaceus*, *Ficus tinctoria*, and *Hernandia moerenhoutiana*, as well as the introduced trees *Ceiba pentandra* and *Albizia lebbek*. The clay loam ridge inland of the shelter continues to be cultivated in dry-land crops, including elephant-ear taro (*Alocasia macrorrhiza*), banana (*Musa* sp.), and historically introduced manioc (*Manihot esculenta*).

There are approximately 225 m² of floor area under the drip line of Tangatatau Rockshelter (Figure 4.2). The main floor area is located in the central and eastern half of the shelter; the presence of occupation deposits was indicated by the surface contours, which sloped steadily upward toward the rear wall. Our main

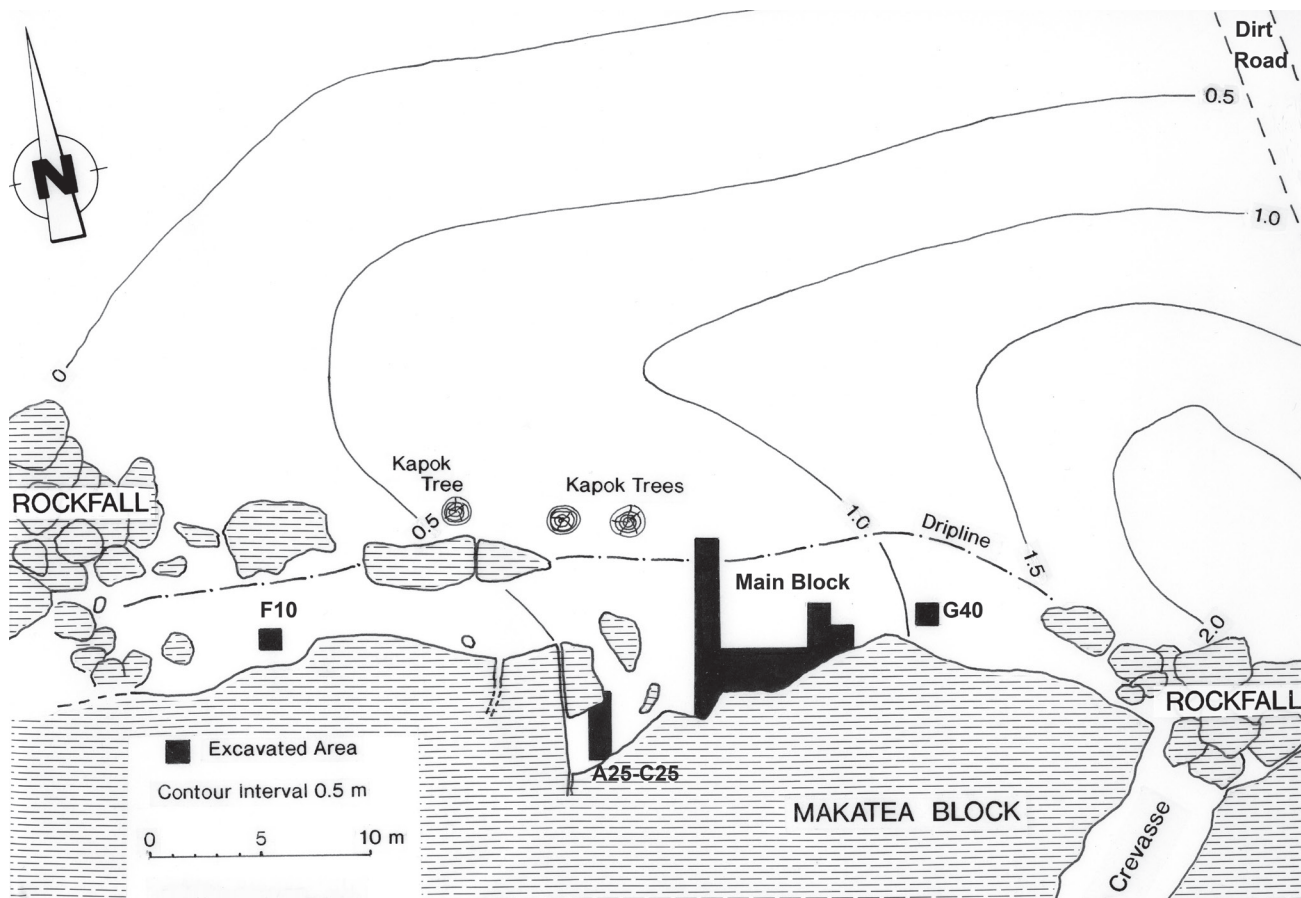


Figure 4.2. Plan of Tangatatau Rockshelter (MAN-44) showing areas excavated in 1989 and 1991.

excavation block was situated in this central-eastern part of the site. A gallery between the shelter wall and two large rockfall boulders (Figure 4.3) leads to a smaller floor area in the western part of the shelter (location of test unit F10). This western floor area ends abruptly in a massive rockfall talus. At the eastern end of the shelter is another large talus, behind which is a deep crevasse where the *makatea* has split.

The rockshelter’s dry surface consists of powdery silt mixed with coconut husks, wood chips (cut with bush knives), sliced coconut endocarps, and *Pandanus tectorius* leaves. The landowner informed us that the shelter had been intermittently used during his lifetime to store coconuts and to crate oranges gathered from groves on the *makatea*, during the New Zealand colonial period (see Scott 1991:189–205). According to this informant, the toponym Tangatatau means “gathering place of men” (*tangata*, ‘man’ or ‘person,’ *tau*, a polysemic word that in this case probably refers to ‘time’ or ‘period,’ hence ‘time when people gather’).

Objectives of the Tangatatau Excavations

Although we carried out systematic archaeological survey in various parts of Mangaia, the initial discovery of site MAN-44 was serendipitous. We would likely have come across this spectacular rockshelter in the course of subsequent survey work—since our field strategy involved systematic reconnaissance survey of the *makatea* edge in search of rockshelters with stratified deposits—but as it was, we were fortunate enough to find the site early during our 1989 field season. On the morning of July 20, guided by Ma’ara Ngu in his well-worn Toyota pickup truck, we explored a rutted dirt track descending off the main road, seeking a good route for our palynology colleagues to gain access to Lake Tiriara with their raft and heavy coring gear. Riding in the open back of the truck, as we approached the looming *makatea* escarpment, I noticed a deep shadow in the limestone face behind two large kapok trees, suggesting the presence of a rockshelter. Ma’ara halted the truck, and Dave Steadman and I clambered



Figure 4.3. View of Tangatatau Rockshelter prior to the commencement of excavations in 1989, showing the northern gallery between the rock face and two large rockfall boulders.

through the *Hibiscus*-dominated second growth a short distance to the *makatea* cliff. The rockshelter floor was open and clearly undisturbed, while the existence of stratified deposits was suggested by the rising slope of the floor. The site appeared promising, as reflected in my fieldnotes penciled in at 10:45 that morning:

Now at large, excellent (!) looking rockshelter in inner face of the *makatea* cliff somewhat W (~ 1 km?) of Lake Tiriara. Large, level, undisturbed floor with basalt flakes and some midden on the surface. Excavation potential looks great. Name = Tangata Tau 5730N 6091E. [Kirch Notebook "Mangaia Survey 1989," p. 12]

Given that one of our principal objectives was to excavate one or more well-stratified sites that would yield a zooarchaeological sequence, we decided to test Tangatatau Rockshelter as soon as possible. On July 24, we began excavating an initial test square, designated E30 on our metric grid. Excavations continued until August 7, with the initial 1-m² unit being expanded in a 5-m-long trench. A sixth unit (F10) was opened up in the western part of the floor. The results from this first season of test excavations convinced us that expanded work at the rockshelter was in order, this becoming the principal aim of our second expedition in 1991. With an expanded field team, we dug at Tangatatau from June 10 through August 6, 1991, opening up a large contiguous block of units in the central part of the shelter floor, as well as a smaller 3-m trench (units A25–C25) west of the main block, and a single 1-m² test unit (G40) to the east of the main block. In all, our 1989 and 1991 excavations totaled 29 m² in area, representing a 13 percent sample of the total floor area under the rockshelter's dripline.

The overall research goals of the Mangaia Project are outlined in Chapter 1. Within this framework, several specific objectives guided our excavations at Tangatatau, and these in turn dictated certain aspects of our field strategy and excavation methods and tactics.

1. *Zooarchaeological Objectives.* Steadman's prior fieldwork in Mangaia had indicated the former existence of several species of land birds on the island, taxa that are absent from the historical avifaunal records. It seemed probable that the extinction or extirpation of these species occurred within the period of Polynesian occupation, but testing this hypothesis—and developing a detailed chronological record of the process of

avifaunal change—would require recovery of zooarchaeological assemblages containing bird bones. Tangatatau promised to offer a well-stratified sequence of bird bones along with other faunal materials, possibly spanning much of the time frame within which Polynesians occupied the island. In addition to the avifauna, moreover, we were interested in recovering a zooarchaeological record of human exploitation of the island's littoral and marine resources (shellfish, fish, turtles) to determine the role these played in local subsistence patterns and to track possible changes through time. A third aspect of our zooarchaeological objectives concerned animals introduced to Mangaia through Polynesian agency, either purposively as domestic animals (pigs, dogs, chicken) or inadvertently as commensal or synanthropic species (rats, geckos, land snails). As noted in Chapter 2, the ethnohistoric record from Mangaia indicated that pigs had at one time been present on the island but were absent when the first missionaries arrived in 1824. Thus, one objective was to obtain a faunal sequence that might inform us as to the history of pig husbandry on the island, including the timing of its elimination by Polynesians. These zooarchaeological objectives dictated the use of stratigraphic excavation combined with careful screening through mesh down to 1/16-in. size for full recovery of small-sized taxa. Steadman, as avian paleontologist, oversaw this aspect of our fieldwork. Moreover, in the expanded 1991 season, we engaged Virginia Butler as our zooarchaeologist specializing in fish remains. Butler worked with us in the field and undertook the specialized analysis of our large sample of fish bones using a reference collection she obtained on Mangaia (see Chapter 7).

2. *Paleobotanical Objectives.* A major part of our goal of reconstructing the environmental history of Mangaia before and after Polynesian colonization involved tracking changes in vegetation and flora. At a landscape level, this objective was achieved through our program of sediment coring and pollen analysis (see Chapter 2). The palynological record, however, while clearly demonstrating significant effects of human land use such as forest clearance and burning, does not provide a record of cultigens or their use. For this, a stratified cultural site with good plant preservation was again necessary. As a relatively dry rockshelter with stratified deposits containing substantial quantities of carbonized macrobotanical remains, Tangatatau offered the possibility of developing a record of plant use, particularly of cultivated plants. When the 1989

test excavations revealed that the site was indeed rich in plant materials, we invited John Hather, a paleoethnobotanist who had developed techniques for the identification of carbonized tuber crops such as taro and sweet potato, to assist us in the 1991 excavations. In addition to working with us in the excavation, Hather and Kirch made a reference collection of the island's woody plants to assist in the identification of charcoal recovered from the excavations.

3. *Cultural Chronological Objectives.* Although the Mangaia Project was focused first and foremost on questions of historical ecology and human-environment interactions, excavations at Tangatatau also afforded the opportunity to obtain a rich record of material culture, one that would be relevant to long-standing debates concerning the prehistory of Eastern Polynesia and the chronology of its settlement by Polynesian voyagers (e.g., Irwin 1981; Kirch 1986; Rolett 1993, 1998; Sinoto 1970, 1996; Spriggs and Anderson 1993; Suggs 1961). While sequences of material culture, demonstrating significant temporal changes in such artifact classes as adzes, fishhooks, and ornaments, had been established for some Eastern Polynesian archipelagoes, primarily the Marquesas Islands (Suggs 1961; Sinoto 1979, 1996, 1996), the Hawaiian Islands (Emory et al. 1959; Kirch 1985), the Society Islands (Emory 1979), and New Zealand (Duff 1956), very little was known at this time for such island groups as the Southern Cook Islands or the Austral Islands. Kirch (1986) had argued that these gaps in our sample of Eastern Polynesian material culture had implications for how prehistorians conceptualized cultural chronologies over this vast region. For example, Sinoto's claims for an "Archaic East Polynesian" culture (Sinoto 1970, 1979) were difficult to evaluate in the absence of well-documented artifact assemblages from key central Eastern Polynesian islands and archipelagoes (Kirch 1986). An additional objective of our Tangatatau excavations was therefore to develop a cultural chronology of artifact classes, which could form a basis for controlled comparison with other Eastern Polynesian sequences.

4. *Long-Distance Exchange and Eastern Polynesian Interaction Spheres.* Closely related to the questions of cultural chronology just discussed is the problem of long-distance interactions between Polynesian populations and communities on the various islands of Eastern (and Western) Polynesia. At the time we began our Mangaia Project, several archaeologists and geologists were beginning to apply methods of

geochemical analysis to the problem of characterizing and sourcing basalt artifacts from Polynesian sites, especially adzes (e.g., Weisler 1993). Given that the Tangatatau site contained substantial quantities of flaked basalt, as well as a full array of adze preforms, polished adze flakes, and finished adzes, we undertook geochemical analysis of this material using X-ray fluorescence (XRF), with Marshall Weisler in charge of this aspect of the work. As a part of this study, we relocated an ethnohistorically documented basalt quarry on Mangaia (Weisler et al. 1994) and determined that this source provided most of the lithic material worked in the rockshelter.

5. *Chrono-stratigraphic Objectives.* All four of the objectives discussed above depended on good stratigraphic controls and a program of "absolute" dating if they were to be successfully achieved. Thus, our fifth objective at Tangatatau Rockshelter was to excavate the site in a manner that would preserve as much stratigraphic context as possible and to link this context to a chronological framework provided by extensive radiocarbon dating. For absolute dating, we initially relied primarily on ^{14}C dating of charcoal and other carbonized plant remains from secure stratigraphic contexts; radiocarbon from site MAN-44, along with a Bayesian analysis of the rockshelter chronology, are the subject of Chapter 5.

Excavation Strategy and Procedures

The specific strategy and procedures applied to the excavation of Tangatatau in the 1989 and 1991 field seasons are described below. As the 1989 season was one of test excavation, with a smaller field crew, there were some differences—and particularly some refinement of methods—in the expanded 1991 season. Following the discussion of each field season, I turn to issues of sampling, recording systems, and databases.

Terminology

Given that basic excavation terms used by archaeologists vary from region to region, with the same term often having somewhat different meanings (e.g., Praetzelis 1993:71–72), it is important to define our terms. Following excavation methods that I had previously developed in my Mussau Islands Lapita research project (Kirch 2001:61), we used the following terminology:

Grid Unit (or simply, *unit*) is the 1-m x 1-m unit of excavation and hence of horizontal control (x and

y coordinates). In site MAN-44, each grid unit was labeled by the intersection of letters defining the E to W 1-m intervals along the X axis and numbers defining the S to N 1-m intervals along the Y axis.

Level: This is the vertical unit of control within a grid unit, defined by upper and lower depth boundaries (z coordinates) recorded at all four corners of the grid unit (depths were taken with a Leitz level and referenced to a single-site datum). Levels were numbered from top to bottom with Arabic numerals within each specific grid unit. These levels, however, are *not* arbitrarily defined slices of uniform depth. Levels did not intentionally cross stratigraphic boundaries, although sometimes thick strata were subdivided into two or more levels to provide finer vertical control. And, as is always the case when complex strata are being excavated, we did not in every instance catch indistinct or gradational transitions between deposits during the course of excavation, especially in some of the initial units when our understanding of the site's stratigraphic sequence was still tentative. However, for the most part, one or more levels in a unit typically correspond to the *beds* recorded in the stratigraphic sections (see below). Our use of the term *level* thus approximates what some users of the Harris Matrix recording system refer to as an "excavation context" (e.g., Spence 1993). Each level was recorded separately on a preprinted level form (during the 1991 season), with beginning and ending horizontal plans drawn of in situ features; all finds recovered in situ were piece-plotted and their x, y, and z coordinates recorded. Objects recovered in the screens were referenced to the grid unit and level (e.g., D30/4, the fourth level excavated in grid unit D30). All levels in the main excavation block are correlated with the stratigraphic *zones* (defined below) through a concordance provided here in the Appendix and also available online (www.dig.ucla.edu/tangatatau).

Feature: A feature is a subsurface, nonportable cultural artifact with three dimensions that was recognized during excavation and in most cases excavated separately (i.e., analogous to a level). Features are prefixed with F followed by a number (e.g., F31); they were numbered from 1 to 59 for the entire site. Features were integrated with a series of stratigraphic zones (see below) in a stratigraphic sequence matrix for the entire site.

Bed: This term refers to a natural sedimentary and depositional unit recognized by its lithology, structure, grain size, color, boundary contacts, and similar

geoarchaeological criteria. A bed is thus a "lithostratigraphic unit" (Stein 1992:76). Beds in site MAN-44 sometimes comprised sets of very thin *lenses* of ash, burned organic matter, and shell midden that could be difficult to follow or separate during excavation. Beds could only be clearly defined through close examination of excavation side walls after the completion of one or more adjacent excavation units; they were numbered and described for each section in a continuous sequence of Arabic numerals from top to bottom, the number sequence being unique to the particular stratigraphic profile being recorded.

Stratigraphic Zone: A sequence of stratigraphic zones (abbreviated SZ) was defined at the completion of the 1991 excavation season. A total of 19 zones were defined, numbered from bottom to top in order of stratigraphic deposition. A stratigraphic zone may consist of a single bed as described in the stratigraphic sections or, in some cases, combines several numbered beds in sequence. Throughout this monograph, we employ the stratigraphic zones (along with features) as the main analytical units for reporting and synthesizing the site's cultural content. In our archival databases, however, all recovered objects are referenced to a specific grid unit and level combination; a concordance (provided in the Appendix) links these grid unit/level proveniences to the stratigraphic zones (www.dig.ucla.edu/tangatatau).

The 1989 Season

Work at Tangatatau began on July 24, 1989, with a crew consisting of David Steadman, Melinda Allen (then a graduate student at the University of Washington), Ma'ara Ngu, Sonny Taomia, and the author. Excavation was done primarily by Kirch and Allen, with Steadman in charge of the sieving operations, assisted by Ngu and Taomia. We began by laying out a metric grid system over the rockshelter floor, with a baseline oriented 85° east of magnetic north. East-west grid lines were assigned letters beginning with A and progressing northward, while north-south gridlines were assigned numbers starting with 0 and progressing eastward. Each 1-m² grid unit is thus identified by the intersecting letter and number of the grid lines. This coordinate system was used throughout both field seasons. From our main east-west baseline extending the length of the rockshelter floor, the site was mapped with compass and tape at a scale of 1:100. A permanent datum was established on top of a large outcrop boulder in the

shelter floor (within unit F26); surface contours were determined using a Leitz level and stadia rod. Vertical profiles of the rockshelter were taken at the 10- and 30-grid lines. A version of this initial site map was published by Kirch et al. (1992:Figure 6, top).

Grid unit E30, dug by Allen over the course of three days, was selected as our first test sounding. Throughout this and all subsequent excavation work, the primary tools used were the Marshalltown trowel (both the pointed type and the rectangular blade type for cleaning profiles) along with whisk broom and paint brush. Excavated earth was placed into plastic buckets, which were carried to a nearby screening table built of sturdy *Hibiscus* branches. As always when one is “working blind” in an initial test without the benefit of prior stratigraphic knowledge of a site, we proceeded cautiously, changing levels whenever we encountered differences in sediment color or texture or other indications of a stratigraphic transition. In all, 15 levels were distinguished, with levels 1 through 12 consisting of beds of primarily grayish, ashy, charcoal-rich midden and levels 13 to 15 consisting of a distinctly contrasting yellowish-red sediment lacking shell midden but relatively rich in bird bones. Unit E30 had a total depth of 1.3 m.

For this initial test pit, all sediment was screened through nested mesh sets of ½-, ¼-, and ⅛-in. screen size. Preliminary field identifications of the recovered bird bones by Steadman indicated the presence of an extinct parrot (*Vini kuhlii*), two kinds of flightless rail, and a possible starling. The higher midden deposits had yielded bones of several seabird taxa (storm petrel and other petrel), a pigeon, Polynesian-introduced chicken, and pig (two incisors and some burned postcranial bone). Artifacts from unit E30 included two pearl shell fishhook fragments, two incomplete basalt adzes, three *Acropora* coral files, and basalt flakes and polished adze flakes. The initial test of E30 proved the great potential of Tangatatau with respect of our research objectives.

Following the completion of unit E30, we opened a second test, unit F10, 20 m to the west at the end of the long gallery formed by the rockshelter wall and two large roof-fall boulders. While this unit also yielded cultural materials, the stratification was not as fine-grained as in E30, seemingly due to a higher rate of sediment influx, originating from a natural chute at the end of the rockshelter. Thus, after completing F10 and recording its stratigraphy, we decided to focus our continued excavations in the central part of the rockshelter floor (Figure 4.4).

Grid unit F30, immediately north of E30, was the next square to be opened. With the profile of E30 now available as a stratigraphic guide, F30 was dug by natural stratigraphic beds, working inward from the north face of E30. Cultural materials continued to be richly represented, with nine fishhooks and the butt portion of a basalt adze. It was becoming evident that there were significant differences between the upper and lower cultural deposits, with the upper deposits consisting of a complex succession of often thin beds of ash and charcoal, along with similarly thin beds of shell midden alternating with lenses of silty clay. In contrast, the lower portion of the cultural deposit could be characterized as a thick, ashy-gray midden, richer in artifact density. Fieldnotes at this time include some tentative hypotheses that these stratigraphic differences might reflect changes in the nature of site function and activity. On July 29, I entered the following thoughts into my field notebook:

The differences between these two components [upper and lower] are very striking, and suggest some major changes in the source and mode of deposition, both geomorphological and cultural/behavioral. The lower component may reflect a ± continuous occupation at a time when the surrounding sedimentary basin/catchment was vegetated or stable. Thus the source of sediment is largely culturally-generated ash with some rockshelter rubble, etc. The upper component, however, includes numerous silty-clay lenses that appear to be inwash events. These suggest that the land surface outside the shelter had become unstable (eroded) and cleared of vegetation. The base level of the land surface N of the shelter may also have risen due to accumulation of clay sediments from up slope [Kirch 1989 “Excavations” Notebook, p. 19].

We next followed the same procedure of using the recorded stratigraphic profile of grid unit E30 as a guide, this time excavating adjacent unit D30 from the south face of unit E30, allowing us to correlate the levels defined in the initial, exploratory E30 excavation with the stratigraphic beds now clearly evident in the exposed stratigraphic sections. D30 proved to be particularly rich in fishhooks and other material culture.

Unit G30, dug from the exposed north profile of F30, extended the trench toward the dripline. G30



Figure 4.4. Excavations in progress at Tangatatau Rockshelter in 1989.

contained a large *makatea* roof-fall boulder that increasingly filled the unit as we descended, so that the lower deposits were mostly absent. Finally, we dug unit C30 at the southern end of the trench, working from the exposed south profile of unit D30. C30, which took the exploratory trench up against the rockshelter wall, again yielded a number of *Turbo* shell and pearl shell fishhooks, a basalt adze, and two tattoo needles of bone.

With the completion of unit C30, we had opened a continuous 1-m x 5-m trench extending from the rockshelter wall to within about 1.5 m of the dripline

(Figure 4.5). The north and south profiles of each unit had been recorded as each square was completed. We now recorded the continuous east and west profiles of the 5-m-long trench, allowing us to define a preliminary sequence of 10 stratigraphic zones, labeled A to J (Kirch et al. 1992:Figure 6, bottom). At the same time, a set of sediment samples was taken from the west face of the trench for laboratory analysis (see below).

Before leaving Tangatatau in 1989, we also excavated a 1-m x 1.5-m test trench in units R30 and S30, situated 20 m to the north of grid unit G30 and well beyond the shelter's dripline, to ascertain whether any



Figure 4.5. The completed initial test trench (units C30 to G30) at Tangatatau Rockshelter, 1989.

cultural deposits existed in the open space beyond the shelter. The surface at unit R30 was 50 cm lower than that at G30, with the ground sloping gently away as one progressed beyond the shelter's dripline. The upper 30 to 40 cm consisted of dark reddish-brown clay (Munsell 2.5 YR 3/4), which contained charcoal flecking throughout and appeared to have been repeatedly turned over due to gardening activities. A discontinuous band of concentrated charcoal flecks was encountered at 25 to 40 cm, and a sample was taken for radiocarbon dating. From 40 to 90 cm below the surface, the sediment consisted of a dark red clay (2.5 YR 3/6), much more compact and with very little charcoal flecking in the upper portion. Below this, from 90 to 150 cm (base of excavation), we encountered red (10 R 5/8), extremely compact, clay-silt lacking any charcoal. No bone, shell, or artifacts were found in any of the layers.

The 1991 Season

By the time we had completed the 1989 exploratory trench, it was clear that further work at Tangatatau was warranted. The rockshelter contained a well-stratified sequence rich in faunal materials, including avifauna, as well as a diverse assemblage of cultural materials. Both the zooarchaeological and artifact assemblages displayed notable changes over time, while the presence of extinct bird taxa at the base of the deposits suggested that the site spanned a period from near the beginning of human occupation on Mangaia up into late precontact times. In short, Tangatatau was an ideal site for meeting many of the key objectives laid out for our Mangaia Project. After applying for and receiving grant funding from the National Science Foundation, a second field season was launched in the summer of 1991.

The 1991 field team flew from Rarotonga to Mangaia on June 7; in addition to David Steadman and myself, the team included Berkeley geography graduate student Joanna Ellison (to continue the swamp coring and pollen work commenced by John Flenley in 1989) and anthropology graduate students Pia Anderson and Julie Endicott, who would assist in the archaeological excavations. Zooarchaeologist Butler joined the team on June 18, while archaeobotanist Hather arrived on July 13. The season ended on August 8.

Fieldwork at MAN-44 recommenced on June 10. We began by removing the backdirt from the 1989 C30–G30 trench and cleaning the sidewalls. While this work was proceeding, Kirch and Anderson made

a new, more detailed map of the rockshelter and its immediate environs using a Gurley telescopic alidade and plane table at a scale of 1:200.

Our first objective was to extend the C30–G30 trench to the north, out past the shelter's dripline. Excavation began in grid unit H30, most of which turned out to be taken up with a large boulder that had fallen from the shelter's ceiling. A small earth oven (feature F9) overlaid the boulder. As in 1989, Steadman took charge of the screening operations, assisted by Anderson, Endicott, Ngu, and Taomia. To avoid any confusion with sediment coming from more than one excavation unit at the same time, we used sets of different-colored plastic buckets.

After completing unit H30, excavation proceeded into grid units I30 and J30, the latter extending beyond the dripline. In these two units, the stratigraphy became progressively simpler, with fewer beds that could be lithologically discerned, presumably due to leaching from rain water; two earth oven features (F13 and F22) were encountered. Shell and bone content also decreased significantly, due to leaching and decomposition resulting from percolating rainwater. We thus terminated the trench with grid unit J30.

While work in units H30 to J30 proceeded, Kirch opened up grid unit G35, situated 5 m to the east of the main trench, to test the stratigraphic sequence in this central-eastern part of the rockshelter. A large earth oven (F15) appeared in level 5 of G35, with a small triangular adze recovered at the base of the feature. The F15 oven pit had been dug through early phase cultural deposits down to the precultural layer in the northern part of G35. However, the southern part of G35 contained an intact sequence of the earlier cultural deposits (Figure 4.6); from these, a large, bifacially retouched basalt tool and two fishhooks were found. After recording the stratigraphic sequence of the south face of G35, with nine stratigraphic beds, we opened adjacent grid unit F35, proceeding from the exposed south face of unit G35. Unit F35 exhibited intact stratification down to its base at 1.30 m below surface; the deeper beds yielded a number of shell fishhooks; a trapezoidal-sectioned, well-polished basalt adze; and numerous basalt flakes and adze preforms situated within several finely bedded ash lenses. As excavation approached the contact between the basal cultural layer (SZ-2) and the underlying SZ-1 deposit, numerous bird bones appeared, including some that Steadman tentatively identified as being of parrot, pigeon, and fruit-dove



Figure 4.6. Unit G35 after completion of excavation in 1991.

species, all extinct on Mangaia. After the completion of grid unit F35 on June 18, the stratigraphic section of the unit's south face was recorded so that excavation could commence in adjacent unit E35, which ended against the rockshelter's rear wall. Excavation of E35 was completed on June 19, completing a second north-south trench (E35–G35) that paralleled the C30–J30 trench 5 m to the north.

With the stratigraphic profiles exposed by the parallel C30–J30 and E35–G35 trenches, it was now evident that intact deposits dating to the earlier part of the MAN-44 occupation sequence were most likely to be found close to the rockshelter's wall. Away from the wall, these early deposits had been disturbed by large oven features dug down from later occupation surfaces (such as the large F15 oven feature in unit G35). We therefore decided that the best strategy would be to concentrate on the block of eight grid units between the two trenches and situated immediately north of the rockshelter wall (grid units

D31 to D34 and E31 to E34). Rather than excavate by single 1-m² grid units, as had been the case up until now, we decided to excavate sets of four grid units simultaneously, making it easier to discern and isolate features spanning more than a single grid unit (Figure 4.7). All sediment continued to be screened and provenienced according to the 1-m x 1-m grid units.

On June 20, we began digging the 4-m² block composed of grid units D31–D32 by E31–E32, work that continued until June 28. The upper half of the stratigraphic sequence here more or less reflected what we had initially encountered in the C30–G30 trench (SZ-5 to SZ-18), mostly consisting of ashy beds with considerable shell midden. The artifacts included several fishhooks of *Turbo* shell. Below these upper, ashy beds, we came upon a series of large pit features (e.g., F32, F34, and F37); some of these were earth ovens while others appear to have functioned as trash pits. These features had cut into but not entirely removed older, underlying



Figure 4.7. Commencing the block excavation joining the two initial test trenches at Tangatatau Rockshelter, in 1991

deposits that were best preserved close to the rockshelter wall. Indeed, at this point, we realized that the earliest occupation deposits in the site had been missing in our 1989 C30–G30 trench but were present here in the 4-m² block (these are zones SZ-2 and SZ-3 in our stratigraphic sequence). These earliest deposits proved to be rich in artifacts, including several whole basalt adzes of “archaic” Eastern Polynesian types, bone tattooing needles, and pearl shell fishhooks, along with large numbers

of basalt flakes and adze preforms indicating adze production within the rockshelter.

On June 28, the 4-m² block having been brought down into the precultural deposit (zone SZ-1), we recorded the stratigraphic profiles of the north faces of grid units E31 and E32 and the east faces of grid units E32 and D32 (Figure 4.8). Following this, there was a hiatus in our work at MAN-44 until August 9. During this interim period, Kirch made a three-day visit to

Rarotonga to obtain supplies and to meet photographer Thérèse Babineau, who was joining the field team. Steadman departed Mangaia on July 2 for scheduled work on Easter Island; thereafter, the screening operations at MAN-44 were supervised by Butler. From July 3 to 8, the team carried out brief test excavations at three other rockshelter sites in Keia district (MAN-81, MAN-82, MAN-84; see Chapter 13). None of these sites proved to have deeply stratified deposits; we therefore decided to return and continue the excavations at Tangatatau rockshelter.

On July 9, we recommenced excavations at MAN-44, beginning with deposits in grid units C31 and C32. Deposits in these two units had become exposed when adjacent grid units D31 and D32 were excavated, revealing that the rockshelter's wall was not vertical but sloped inward to the south. The C31 and C32 units thus preserved early phase deposits (zones SZ-2 and SZ-3), again with a number of important artifact finds. At this time, we also began to excavate the 4-m² block composed of grid units D33–D34 and E33–E34 to connect up with the E35–G35 trench. As with the



Figure 4.8. Completed four square meter block excavation consisting of units D31-D32 and E31-E32. Note the fine ash lenses and bedding characteristic of the upper stratigraphic deposits.

previous 4-m² block (D31–D32 and E31–E32), these four grid units were excavated together, with all finds provenienced to their 1-m grid units.

Archaeobotanist Jon Hather arrived on July 13 as we were proceeding with this final phase of excavation, allowing him to sample the early phase deposits for macrobotanical remains. Equally important, Hather and Kirch spent several days making an extensive reference collection of Mangaian woody plants, which was essential to Hather's subsequent identification of wood charcoal from MAN-44 (see Chapter 9).

July 15 to 16 were productive excavation days as we proceeded down into the deep deposits in grid units E34 and D34. These deposits contained significant quantities of charred plant remains that Hather bulk sampled for further identification and analysis in London. In addition, we exposed four basalt adzes of "archaic" types and several adze preforms along with much lithic debitage all arrayed around a small hearth feature (F48). With the completion of these grid units, we recorded the stratigraphic section of the north faces of E33 and E34 (thus joining those of E31–E32 previously recorded).

At this point, the work at MAN-44 was again halted as the team turned to test excavation and mapping of several sites in Tamarua district (see Chapter 13). On July 27, we returned to MAN-44 to excavate deposits in unit D35 that were preserved under the sloping rockshelter wall; these had been exposed by the excavation of adjacent unit E35 (Figure 4.9). Once again, these early phase deposits had been sealed in under the sloping rockshelter wall and yielded a number of basalt adze preforms along with a substantial quantity of carbonized plant remains. While Kirch excavated unit D35, Endicott excavated units A25 to C25 in a small "alcove" to the west of the main excavation area. In addition, Kirch excavated unit G40, to the east of the main block, to determine whether well-stratified deposits continued in that direction; in fact, the depth of cultural sediments proved to be thinning (Figure 4.10). After the completion of these final grid units and recording of their stratigraphic sections, the MAN-44 excavations were backfilled.

Screening and Sampling Considerations

In both the 1989 and 1991 field seasons, we used specially made sets of nested screens with descending mesh sizes of 1/2, 1/4, 1/8, and 1/16 in. A major objective from the outset was to obtain a nonbiased sample

of vertebrate faunal materials, including the smaller bones of land and seabirds; for this, prior work by Steadman had shown that sieving down to 1/16 in. was necessary. Throughout the project, *all* bone was collected from all four mesh sizes.

It quickly became apparent, however, that attempting to recover other kinds of materials from the smaller 1/8- and 1/16-in. mesh screens would be impractical in terms of time and effort. We therefore decided to retain flaked stone only from the 1/2- and 1/4-in. screens; we realize that this did bias the lithic sample against micro-debitage resulting from fine retouching.

The MAN-44 deposits contain large quantities of marine mollusk shells, far more than we could afford to ship back to the laboratory or even process, so again a sampling decision was necessary. In 1989, we retained all shell from the 1/2- and 1/4-in. mesh screens from grid unit E30 for later analysis in the laboratory. In 1991, shell from adjacent unit E31 was similarly retained. Toward the end of the 1991 season, when we realized that neither unit E30 nor E31 contained deposits representing the initial occupation of the rockshelter, we also collected the shell from the deeper levels (5, 6, and 7) of grid unit D35 (representing zones SZ-2 and SZ-3) as a sample of mollusks from these earliest deposits.

Recording Systems and Databases

As noted above, every 1-m² grid unit was assigned an identifier based on the intersection of east-west (0-n) and north-south (alpha) grid lines. Everything excavated from a particular grid unit was provenienced to the level from which it was recovered, either in situ or from the sifting screens, with levels being assigned Arabic numerals in the order they were dug. Within each level, "objects" (any recovered item) were numbered sequentially. Objects included bag lots of certain kinds of materials (such as basalt flakes, unsorted bone, charcoal, shell), sediment or other organic materials, and artifacts. Thus, any object from the MAN-44 excavation can be identified by a unique string of identifiers, such as the following: MAN-44-E30-3-4, which refers to the fourth object recovered from level 3 of grid unit E30, in this case a basalt flake. The MAN-44 general object database contains 5,795 entries in this format. For bag lots that were further analyzed and identified down to individual specimens in the laboratory, new numbers were assigned at the specimen level.



Figure 4.9. Completed excavations at Tangatatau Rockshelter, 1991.

During the 1989 field season, excavation notes were recorded in bound field notebooks, with sketch plans of each excavated level drawn on metric graph paper and stratigraphic sections similarly recorded at 1:10 scale. In 1991, we continued to use the bound field books for general notes and for stratigraphic profiles, but given the larger scale of the excavations, we used preprinted level recording forms, following a format developed by Kirch in prior work in the Mussau Islands and elsewhere. A sample of

this level recording form is shown in Figure 4.11. On these forms, the starting and ending depths of the level (as measured from the site datum using a Leitz level) were recorded for all four corners and the center point of the unit; these depths allow for an approximate calculation of excavated volume of the level. Sketches were drawn of any features exposed during the course of excavation and of the configuration of the grid unit floor at the closing of the level. In addition, the form provided for running notes on



Figure 4.10. Excavation unit G40, in the eastern part of the rockshelter floor, after completion of excavation, 1991.

features, nature of the deposit, remarks on significant finds, and a numeric list of recorded objects.

A photographic record of the excavations was maintained with 35-mm color slide film (Kodachrome 64) and in black and white with 35-mm and medium-format (2.5-in. roll film) film. A Pentax K1000 camera was used for the 35-mm photos and a Hasselblad 500CM camera for the medium-format photos.

The Mangaia Project was undertaken at a time when digital database software and computer hardware were rapidly evolving. During a major phase of laboratory work following the 1991 excavation season, all of the excavated materials were entered into a relational database system using Borland Paradox software. Several years later, Paradox was no longer supported by its defunct manufacturer and the databases were migrated to Microsoft Access and Excel. As a part of the digital archive for this project, these databases are available online (www.dig.ucla.edu/tangatatau).

Stratigraphy of the Tangatatau Rockshelter

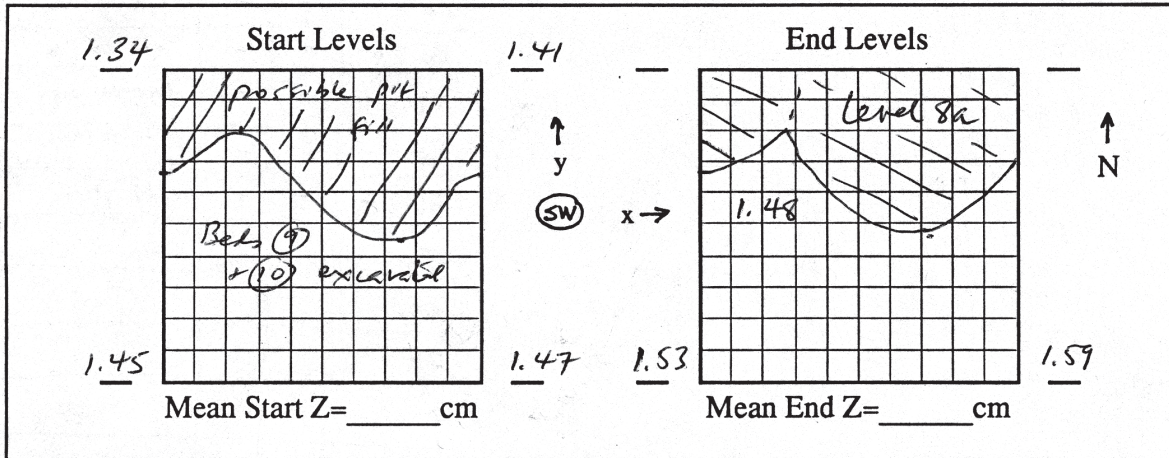
The main excavation block in MAN-44 reached depths of between 1.3 and 1.5 m below the surface, exposing a complex sequence of stratified beds, interspersed with a total of 59 cultural features such as pits and hearths. Stratigraphic profiles were drawn (at 1:10 scale) and recorded for almost every face of each grid unit; these records are retained in the archives of the Mangaia Project. For the purposes of this monograph, the stratigraphy is described along four main axes: the west face of grid units C30 to G30, the north face of units E30 to E35, the east face of units D32 and E32, and the west face of units E35 to G35.

The numbering of beds (using Arabic numerals, from top to bottom) is unique for each section being described; maintaining a single, integrated system of bed numbering throughout the site was simply too complicated. However, the beds in different sections are correlated through the sequence of SZs.

MANGAIA EXPEDITION 1991

Charcoal Saved
 Sieve Size: $\frac{1}{2} \rightarrow \frac{1}{8}$ mm
 Sieved: Dry Wet

Site MAN-44 Area _____
 Grid E33 Spit 9/82
 Stratum _____ Date 12.VII.91
 Depths: Surface Datum



COMMENTS (Note sediment characteristics, color; disturbances; samples taken; special problems):

S half corresponds to Beds 9 and 10 of the E face of E32, Notebook #I, p. 31.

Excavated midden beds 9 + 10 in S half of unit, attempting to isolate grey pit fill in the N half. Midden grey above, reddish brown below - loose by many outcrops. Taken down to compact grey surface.

Pit fill in N excavated as Level 8a - consists of compact, grey-brown sediment with much limestone rubble and scattered charcoal chunks.

Recorder: Pvk

obj	x	y	z	Description
1	2	18	1.55	p.s. fishhook tabs (partial) *
2	25	25	1.50	echinoid spine abrasion
3	-	-	-	fishhook bend fragment
4	-	-	-	drilled pearl shell tab
5	45	35	~1.54	complete p.s. fishhook tab (drilled) *
6	-	-	-	cut pearl shell
7	45	25	1.53	large piece cut pearl shell
8	53	30	"	cut pearl shell
9	48	20	"	p.s. fishhook - missing top only
10	52	32	"	cut pearl shell (chips)
11	54	31	"	cut p.s.
12	-	-	-	Adz flake
13	-	-	-	cut pearl shell
14	-	-	-	" " "
15	-	-	-	p.s. fishhook missing top only

* lying on Bed 10 surface

Figure 4.11. Example of the level form used during the excavation of MAN-44 during the 1991 field season.

West Face, Units C30 to G30

This stratigraphic section was recorded at the end of the 1989 field season, and a version of it was published by Kirch et al. (1992:Figure 6); in the published version, a tentative sequence of stratigraphic zones was labeled A through J. A series of 26 sediment samples was taken from this west face at the same time that the stratigraphy was described; laboratory analyses of these samples are reported in a separate section below.

The stratigraphic profile for the west face of units C30 to G30 is shown in Figure 4.12. Figure 4.13 is a photograph of the south face of unit D30 (which adjoins the C30–G30 section at a right angle), which gives a good visual impression of the differences between the thin, finely lensed alternating beds of white ash and charcoal that are characteristic of the upper half of the section and the massive gray, charcoal-flecked midden in the lower half. The stratigraphic section is described below, from top to bottom, according to the stratigraphic zones. Note that the SZs are numbered in chronological order of deposition, from bottom to top, while the individual beds are numbered from top to bottom, in the order that they were recorded in the field in 1989. Sediment colors are given in the Munsell system.

SZ-17 consists of a single bed, **Bed 1**, a dark reddish-brown (5 YR 3/2), silty textured sediment, loose and powdery in the southern units and becoming more compact to the north. Considerable organic matter (leaves, wood chips, etc.) was mixed in with the silt; historic period artifacts (glass, iron) were present.

SZ-15 consists of two distinct beds: **Bed 2** is a dark gray (5 YR 4/1), fairly compact deposit, with varying degrees of ash lensing. The deposit is characterized by a high frequency of charcoal, often in large chunks, along with pieces of burned limestone rubble, quite likely representing a phase of considerable earth oven activity. **Bed 6**, restricted to grid units E30 and F30, is a dark reddish-gray to reddish-brown (5 YR 4/2–3) midden with a thick band of charcoal and ash that appears to be an in situ combustion feature, possibly a hearth (this was not recognized as a hearth during excavation in 1989 and hence was not given a feature number). **Bed 6A** was defined as a deposit of grayish-white ash with charcoal chunks underlying the hearth.

SZ-14 is made up of **Bed 3**, a dark reddish-brown (5 YR 3/4) midden deposit with considerable limestone rubble and a fine, loose silty texture. This deposit contains much charcoal.

Feature F58 was originally labeled as **Beds 4 and 5**, which were later combined into F58 as they are the upper and lower fill of a large earth oven feature. A thick lens of charcoal separates the two beds.

SZ-13 consists of **Bed 7**, a dark reddish-brown (5 YR 3/2–3) gravelly midden deposit, fairly compact with a silty texture, primarily silt-clay mixed with ash. Some faint internal bands or lenses were evident in the section.

SZ-12 is a compact lens of grayish-white charcoal and ash, designated **Bed 8**, probably a rake-out deposit from a nearby hearth or earth oven. The deposit includes numerous 2- to 3-cm diameter burned limestone clasts.

SZ-11 is made up of three thin beds: **Bed 9** is a deposit of yellowish-red (5 YR 5/8) silty clay incorporating some shell midden and a few flecks of charcoal. This appears to be a single in-wash episode, probably deriving from the slope to the north of the rockshelter. **Bed 10** is a dark reddish-gray (5 YR 4/2) compact midden deposit, somewhat gravelly in texture with the matrix being a mixture of silt-clay and ash. **Bed 15** is a thin deposit of densely concentrated mollusk shells (*Cerithium*, *Strombus*, and *Turbo* were especially noted) and echinoderm tests and spines, in a matrix of fine, reddish-brown (5 YR 4/3) ashy silt.

SZ-8 is made up of **Beds 11 through 14**, along with **Bed 17**. **Bed 11** is a dark brown (7.5 YR 4/2) midden with considerable mollusk remains, in an ashy matrix. In unit E30, this bed becomes very finely lensed with fine bands of light and darker ash. **Bed 12** is a very pale brown (10 YR 7/3) deposit of compact ash, with bands of concentrated charcoal at top and bottom; this is probably an oven rake-out deposit. **Bed 13** is a dark reddish-brown (5 YR 3/4) compact midden deposit with a gravelly silty texture, containing considerable mollusk remains. The deposit is quite thick in unit C30 but could not be traced to the north of a burrow disturbance in unit E30. **Bed 14** consists of a complex series of fine lenses of charcoal, ash, oxidized silt-clay, and mollusk midden, with lenses ranging from 0.5 to 2.0 cm thick. The oxidized soil lenses are red (2.5 YR 4/6–8) to yellowish-red (5 YR 5/8) in color, while

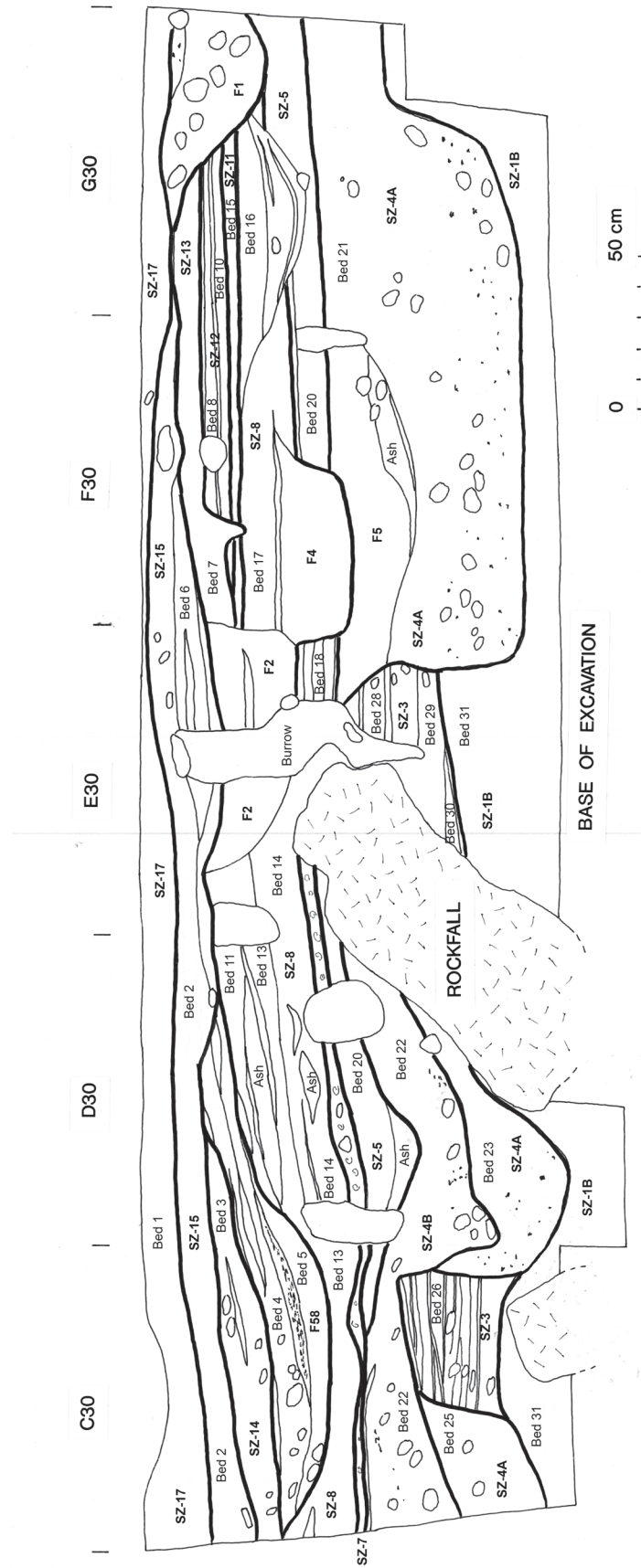


Figure 4.12. Stratigraphic section of the west face of the 1989 trench, units C30 to G30. Heavy lines indicate boundaries between stratigraphic zones.

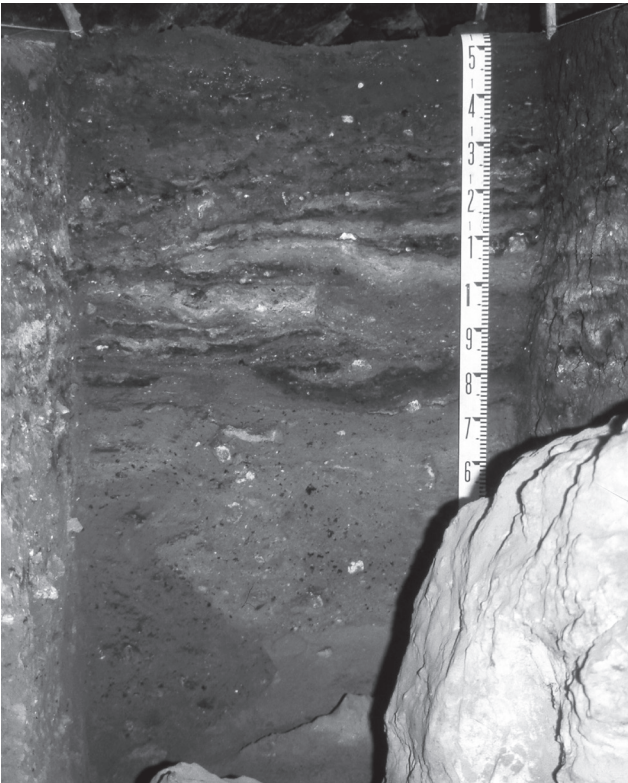


Figure 4.13. The south face of unit D30 after excavation, showing the fine, alternating charcoal and ash lenses of the upper portion which contrast with the massive midden deposit of the lower portion of the deposits.

the midden lenses are reddish brown (5 YR 4/3). **Bed 17** is very similar to **Bed 14** and is almost certainly an extension of the same deposit, although Beds 14 and 17 could not be directly linked in the section due to the intervening large oven feature **F2**. **Bed 17** consists of a reddish-brown (5 YR 4/3–4) silt-clay matrix “streaked” with 0.5- to 1.5-cm thick, discontinuous lenses of very dark gray (5 YR 3/1) to dark reddish-brown (5 YR 3/2) ash or oxidized silt-clay.

Feature F3, also labeled **Bed 16**, is a dense concentration of shell midden (much of it burned) with large charcoal chunks, in a gravelly silty, reddish-brown (5 YR 4/3) matrix. This deposit appears to be fill dumped into the upper part of the **F3** oven pit.

SZ-7 is made up of **Bed 19**, a dense concentration of mollusk remains traceable over much of the section, although interrupted by feature **F4** and a burrow disturbance in units **E30** and **F30**. This appears to represent a single event, with the mollusk remains deposited on a floor consisting of the top of **Bed 20**.

SZ-5 is made up of Beds 18 and 20. **Bed 18** is visible only

in a small part of the section, sandwiched between a deep, vertical burrow disturbance in unit **E30** and feature **F4** in unit **F30**, where it consists of a series of fine lenses of brown (2.5 YR 5/2) ashy silt, yellowish red (5 YR 5/6) silt-clay, and white ash. **Bed 20** is a yellowish red (5 YR 4–5/6) silt-clay incorporating a small amount of shellfish midden but otherwise largely devoid of cultural material. **Bed 20** could be clearly traced over most of the length of the trench. It appears to represent a fluvial in-wash event, possibly the result of a major storm event.

SZ-4B is the upper part of **SZ-4**, consisting of **Bed 22**, a dark reddish-gray (5 YR 4/2) to reddish-gray (5 YR 5/2) ashy midden with scattered large chunks of charcoal, containing many fist-sized pieces of limestone rubble.

SZ-4A/4B Interface. The interface between **SZ-4A** and **SZ-4B** is marked by **Bed 24**, a 0.25- to 1-cm thick band of whitish-gray ash, representing a discrete burning event on the surface of **Bed 25** and capped by **Bed 22**. **Bed 24** was evident only in unit **C30**.

SZ-4A, the lower part of **SZ-4**, is made up of Beds 21, 23, and 25. **Bed 21** is a brown (2.5 YR 5/2) to dark brown (7.5 YR 4/2) ashy silt midden deposit with large charcoal chunks scattered throughout, which also contains many fist-sized limestone clasts. The midden accumulated within a large pit that had been dug down into **Bed 31** (**SZ-1**), the preoccupation basal deposit in the shelter. **Bed 23** is a brown (2.5 YR 4/2) ashy midden with scattered large charcoal chunks. This appears to be the fill of a pit dug down through Beds 26 and 27 (**SZ-3**), although this was not recognized as a formal feature during excavation. **Bed 25** is a brown (7.5 YR 5/4) silty midden with large scattered charcoal chunks. The bed is thick in the southern part of unit **C30** but then becomes a thin lens sandwiched between Beds 24 and 26. Near the northern end of unit **C30**, **Bed 25** is truncated by **Bed 22**.

SZ-3 is represented in this section by Beds 26, 27, and 28, which are remnants of an originally much more extensive occupation deposit that had been truncated and disturbed by overlying **SZ-4**. **Bed 26** is a complex series of ash lenses (at least 17 discrete lenses could be counted within a vertical span of 20 cm), ranging in thickness from 0.25 to 3 cm. The thicker lenses were dominantly of grayish-white ash, with thinner bands of dark reddish-gray (5 YR 4/2) or very dark gray ash and oxidized soil separating

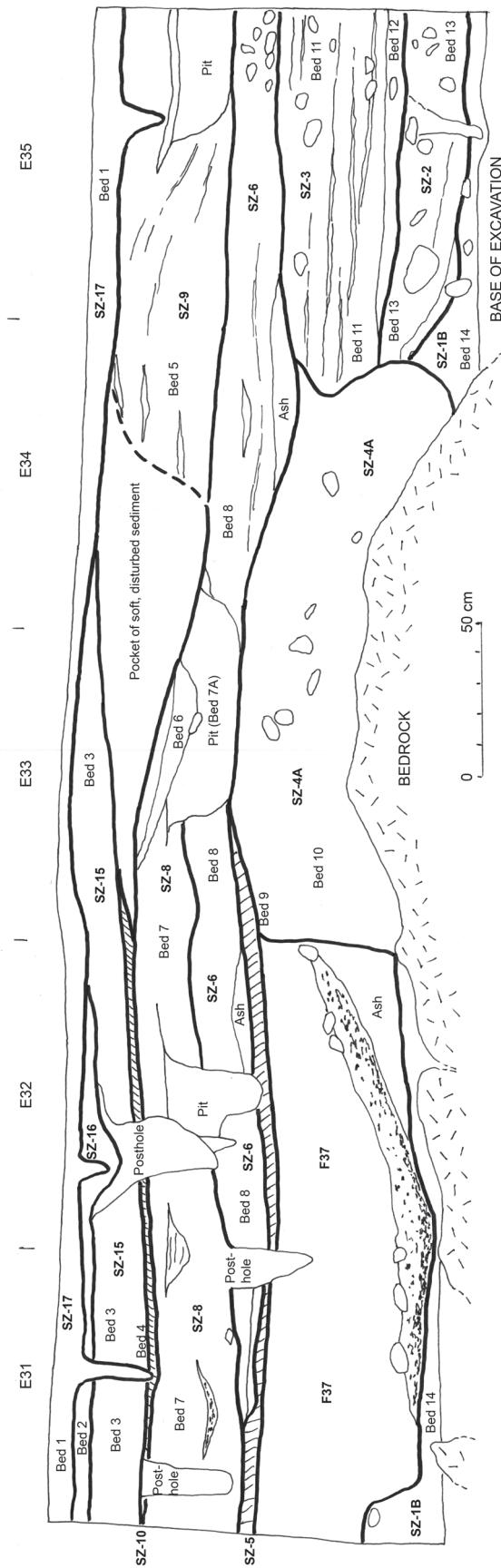


Figure 4.14. Stratigraphic section of the north face of units E31 to E35. Heavy lines indicate boundaries between stratigraphic zones.

them. Some burned limestone clasts are also incorporated into this deposit, which seems to represent the accumulation of a series of burning events on the rockshelter floor. This bed was observed only in unit C30 and is truncated by Beds 22 and 23 to the north and by Bed 25 to the south. **Bed 27** lies directly beneath Bed 26 and is similarly truncated on the south and north; Bed 27 is a dark reddish-brown (2.5 YR 2.5/4) oxidized soil. It is probably the oxidized upper part of Bed 31, resulting from a hot fire burning across the surface of Bed 31. Finally, **Bed 28** consists of alternating lenses of whitish-gray ash and grayish-brown ash, with some reddish-yellow oxidized silt-clay. This bed, seen only in a small sector of unit E30, is likely a continuation of Bed 26, although the intervening disturbances and large boulder make it impossible to be completely certain.

Feature F57, also labeled **Bed 29**, is a thick deposit of grayish-white ash incorporating some burned shell midden. This bed was not recognized as a discrete feature during excavation. **Bed 30** is a thick band of charcoal chunks in grayish-white ash at the base of feature F57.

SZ-1 is the basal stratigraphic zone, consisting of **Bed 31**, made up of fine, decomposed limestone with some fine silt-clay mixed in. In unit E30, under the large limestone boulder, Bed 31 was soft and powdery, was reddish yellow (5 YR 7/6–7) in color, and contained numerous shells of the indigenous terrestrial gastropods *Orobophana pacifica* and *Libera fratercula*. This upper part of the basal deposit was designated zone SZ-1B. As one progresses deeper in Bed 31, the sediment gradually becomes more compact and changes to a yellowish-red color (5 YR 5/8); this deeper part of the zone was designated SZ-1A.

In addition to the 31 beds described above, several features appear in the west face of units C30 to G30, some of which have already been described above. These include F1, F2, F3, and F58, all combustion features in the upper deposits. Features F4, F5, and F57 are situated within the deeper beds. All of the features are described in the MAN-44 features database, available online (www.dig.ucla.edu/tangatatau).

North Face, Units E31 to E35

This 5-m-long section runs east-west and connects the 1989 C30–G30 trench with the 1991 E35–G35 trench; the stratigraphic profile is shown in Figure 4.13. A

simplified version of this section was previously published in Kirch et al. (1995:Figure 4). Once again, the section is described from top to bottom, according to the stratigraphic zones; note that the bed numbering sequence in this section is independent of that in other sections.

SZ-17 consists of **Bed 1**, a dark gray to very dark gray (5 YR 3–4/1) compact, ashy deposit including much vegetal matter (coconut husk, wood chips, *Pandanus* drupes), and some historic period artifacts.

SZ-16 consists of **Bed 2**, a dark gray (5 YR 4/1) ashy deposit with some lenses of white ash, with some charcoal and burned limestone rubble inclusions.

SZ-15 is made up of **Bed 3**, a succession of thin ash and midden lenses ranging in thickness from 0.2 to 2.5 cm. The thinner lenses are black (10 R 2.5/1) and appear to be in situ floor burns. These alternate with the slightly thicker beds of ashy midden, generally red (10 R 5/6) in color.

SZ-10 consists of **Bed 4**, a yellowish-red (5 YR 4/6), thin but continuous bed of dense shell midden in a clayey matrix, easily traceable across the western half of the section.

SZ-9 is a thick deposit, designated **Bed 5**, consisting of multiple lenses of ash and oven rake-out material with heavy charcoal flecking throughout, interspersed with lenses of compact white ash. This deposit seems to be oven rake out material derived from the deep earth oven in unit G35 (feature F15). Bed 5 is truncated on its western edge by a pocket of very soft, loose, grayish-brown ashy midden, which overlies Bed 6 and is capped by Beds 3 and 1.

SZ-8 is made up of two beds: **Bed 6** consists of an upper lens of gray brown midden overlying a lower lens of reddish-gray midden with much shell. **Bed 7** is a dark reddish-gray (5 YR 4/2) midden and ash deposit incorporating some white and black ash lenses. Bed 7 is fairly compact, with numerous mollusk shells.

SZ-6 is a succession of compact, alternating white and black ash lenses, designated **Bed 8**. The thicker lenses, ranging from 1 to 3 cm are of white ash (5 YR 8/1–2) with some large charcoal chunks dispersed in them, while the thinner lenses (0.2–1 cm) are black (5 YR 2.5/1) or dark reddish brown (5 YR 3/2). This bed is continuous across much of the section.

SZ-5, made up of **Bed 9**, is a reddish-brown (5 YR 5/4) shell midden in a clayey matrix, very distinct within units E31 to E33. Bed 9 here correlates to Bed 20 in the C30–G30 section described earlier.

SZ-4A is made up of **Bed 10**, a massive deposit of brown (2.5 YR 5/2) to dark brown (7.5 YR 4/2) ashy silt midden with large charcoal chunks scattered throughout, along with many fist-sized limestone clasts. On the west, Bed 10 is truncated by a large pit feature (F37), while on the east, Bed 10 cut down through and removed earlier deposits (Beds 11, 12, and 13). The bottom of Bed 10 rests on limestone bedrock. Bed 10 in this section correlates to Bed 21 in the C30–G30 section previously described.

SZ-3 consists of Beds 11 and 12. **Bed 11** is a relatively thick complex set of alternating lenses of reddish-brown, white, and dark brown ash, interspersed with thin lenses of shell midden. Underlying this is **Bed 12**, a thick lens of compact white ash with some charcoal chunks.

SZ-2 is made up of **Bed 13**, an alternating lenses of yellowish-red midden, black (reduced) organic material (plant remains), and white ash. This deposit included much charcoal and a high frequency of fire-altered limestone rocks. A thick charcoal lens lies across the bottom of Bed 13, at the contact with Bed 14.

SZ-1, consisting of **Bed 14**, is a reddish-yellow (5 YR 6/8) deposit forming the base of the stratigraphic sequence. The upper 5 to 10 cm of Bed 14 (designated zone SZ-1B) is quite compact and has scattered charcoal chunks pressed down into it; this upper section appears to have been partly oxidized by burning. The deeper parts of Bed 14 (designated zone SZ-1A) are less compact, with a “floury” texture, containing numerous shells of indigenous land snails (*Orobophana pacifica* and *Libera fratercula*), crustacean fragments, and bird bones.

East Face, Units D32 and E32

This short, 2-m section running north-south connects the long north face of units E31 to E35, described above, with the rear wall of the rockshelter (Figure 4.15). The junction between the two sections is the northeast corner of grid unit E32. This section exhibits a relatively undisturbed sequence of the early deposits of SZ-2 and SZ-3. In the description below, Beds 1 through 4 are identical with 1 through 4 in the units E31–E35 north face section; below that, however, the bed numbering sequence diverges.

SZ-17, consisting of **Bed 1**, is a dark gray to very dark gray (5 YR 3–4/1) compact, ashy deposit including much vegetal matter (coconut husk, wood chips, *Pandanus* drupes) and some historic period artifacts. This runs across the entire top of the section.

SZ-16 is made up of Beds 2 and 2A. **Bed 2** is a dark gray (5 YR 4/1) ashy deposit with some lenses of white ash, with some charcoal and burned limestone rubble inclusions. This bed increases in thickness as it slopes slightly downward toward the rockshelter wall; in unit D32, its base has a pit-like contour. **Bed 2** overlies **Bed 2A** in unit D32, a pit-like depression with fill the same color as Bed 2 but containing a higher quantity of fist-sized limestone rubble (**Bed 2A** was also designated feature F56).

SZ-15 is made up of **Bed 3**, a succession of thin ash and midden lenses ranging in thickness from 0.2 to 2.5 cm. The thinner lenses are black (10 R 2.5/1) and appear to be in situ floor burns. These alternate with the slightly thicker beds of ashy midden, generally red (10 R 5/6) in color.

SZ-10 is a very thin zone consisting of **Bed 4**, a yellowish-red (5 YR 4/6), continuous bed of dense shell midden in a clayey matrix, traceable across nearly the section but truncated by **Bed 2a** in unit D32.

SZ-8 is made up of **Bed 5**, a dark reddish-gray (5 YR 4/2) midden and ash deposit incorporating some white and black ash lenses, and is fairly compact, with numerous mollusk shells. **Bed 5** is truncated by **Bed 2A** in unit D32. (This is the same as **Bed 7** in the E31–E35 north face section.) **Bed 5A** is a small intrusion, possibly a posthole, cut into **Bed 6** from **Bed 5** and incorporating **Bed 5** fill.

SZ-6 is a succession of compact, alternating white and black ash lenses, designated **Bed 6**. The thicker lenses, ranging from 1 to 3 cm, are of white ash (5 YR 8/1–2) with some large charcoal chunks dispersed in them, while the thinner lenses (0.2–1 cm) are black (5 YR 2.5/1) or dark reddish brown (5 YR 3/2). **Bed 6** is truncated by the bottom of **Bed 2A** in unit D32. (This is the same as **Bed 8** described in the E31–E35 north face section.)

SZ-5 consists of **Bed 7**, a reddish-brown (5 YR 5/4) shell midden in a clayey matrix, readily traceable across nearly the entire section. This is the same as **Bed 9** described in the E31–E35 north face section and as **Bed 20** in the C30–G30 west face section. **SZ-5** thus forms a clear stratigraphic marker throughout much of the rockshelter deposit.

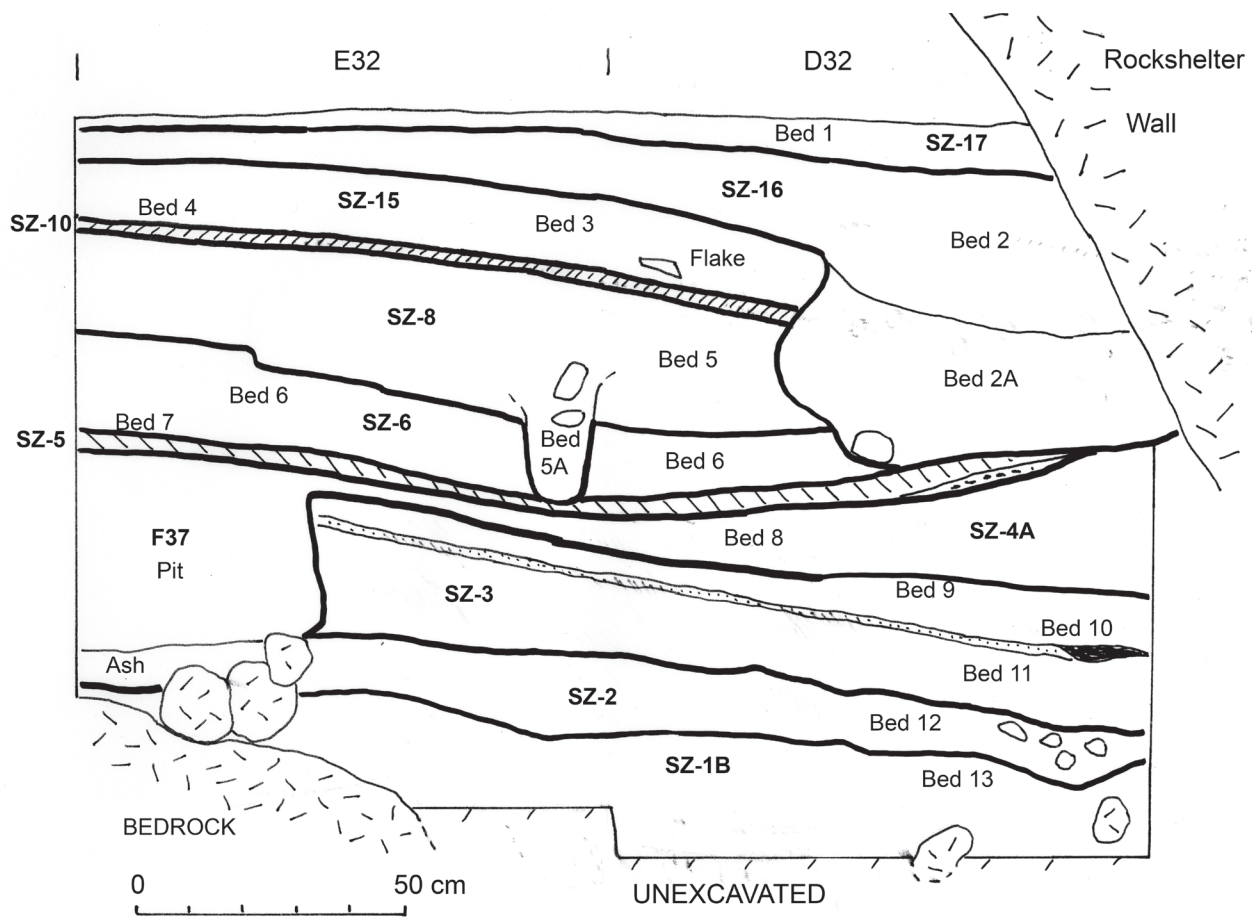


Figure 4.15. Stratigraphic section of the east face of units D32 and E32. Heavy lines indicate boundaries between stratigraphic zones.

SZ-4A consists of **Bed 8**, a reddish-gray (5 YR 5/2), fairly compact, ashy midden deposit, fairly thin in the north but increasing in thickness toward the rockshelter wall. The fill of a large pit, feature F37, consists of the same material. Feature F37 was dug from **Bed 8** down through underlying Beds 9 through 12. A thick deposit of white ash lies at the bottom of the F37 pit.

SZ-3 is made up of a succession of three beds: **Bed 9** is a reddish-brown (5 YR 4/3) compact midden deposit containing scattered charcoal chunks. **Bed 9** is separated from overlying **Bed 8** by a sharp, distinct contact marked by a discontinuous thin line of white ash about 1 mm thick, presumably marking a burn across a floor represented by the top of **Bed 9**. **Bed 9** is truncated in the northern part of unit E32 by the large F37 pit. **Bed 10** is a thin bed of dense shell midden in a reddish-brown matrix (5 YR 4/4), which is truncated in the northern part of unit E32

by the large F37 pit. **Bed 11** is a dark reddish-gray (5 YR 4/3) midden deposit containing much fire-altered limestone rock, with some white and black ash lenses interspersed. **Bed 11** is likely truncated in the northern part of unit E32 by the large F37 pit.

SZ-2 consists of **Bed 12**, alternating white and black ash lenses interspersed with some thin midden lenses. At the base of **Bed 12** as it contacts underlying **Bed 13**, the deposit is strongly oxidized with a dusky red (10 R 3/4) color indicative of an intense burning event at the time of initial occupation of the rockshelter.

SZ-1 consists of **Bed 13**, a reddish-yellow (5 YR 6/8) deposit, equivalent to **Bed 14** in the north face of E31–E35. The upper part of the deposit (SZ-1B) is strongly oxidized, whereas the deeper parts of **Bed 13** (SZ-1A) are less compact, with a “floury” texture, containing numerous land snail shells (*Orobophana pacifica* and *Libera fratercula*), crustacean fragments, and bird bones.

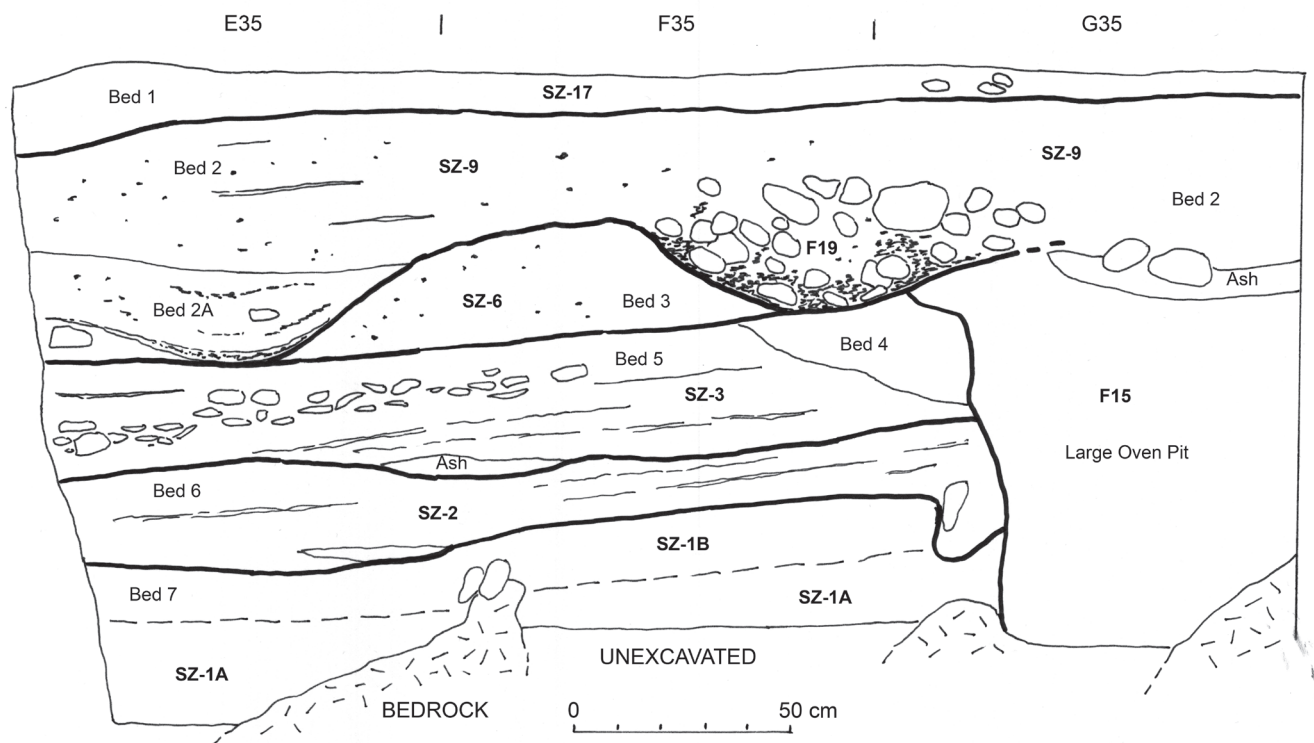


Figure 4.16. Stratigraphic section of the west face of units E35 to G35. Heavy lines indicate boundaries between stratigraphic zones.

West Face, Units E35 to G35

The final section described here is the west face of grid units E35 to G35, providing a north-south profile through the eastern portion of the main excavation block (Figure 4.16). Although this section exhibits disturbances in the upper deposits due to a large earth oven (feature F15), it also has a well-preserved series of earlier beds representing zones SZ-2 and SZ-3, in units E35 and F35.

SZ-17, running across the top of the entire section, consists of **Bed 1**, a dark reddish-brown (5 YR 3/2), compact, ashy deposit including much vegetal matter (coconut husk, wood chips, *Pandanus* drupes).

SZ-9 is made up of **Bed 2**, a dark gray to light gray (5 YR 4-6/1) deposit of ash with much charcoal included; some thinner lenses are evident in unit E35. The deposit consists primarily of oven rake-out material, presumably deriving from repeated use of the large oven (feature F15) exposed in unit G35. A smaller earth oven, feature F19, and a thick lens of white ash stratigraphically overlie the F15 oven. Feature F19 appears to have been cut down into Bed 2. **Bed 2A**, in unit E35, is a basin-like depression mostly filled

with white ash but also containing two distinct charcoal lenses; this was probably a small hearth or earth oven, although we did not formally recognize it as a feature during excavation.

SZ-6 consists of **Bed 3**, which was evident only in unit F35, as it is truncated on the north by the F19 feature and on the south by **Bed 2A**. It consists of compact, alternating fine ash lenses and is the same as **Bed 8** described in the north face of E31 to E35.

SZ-3 is made up of **Bed 5**, a thick deposit of thin, alternating lenses of black, red (7.5 YR 5/6), and gray midden, with some intervening lenses of pure white (5 YR 8/1) ash. In unit E35 and the southern part of F35, there was also a thick zone of cobbles, as seen in the section. **Bed 4** consists of a small area between units F35 and G35, truncated by the F15 oven, consisting of reddish-gray (5 YR 5/2) midden with much rubble. The precise chronological position of this small deposit was difficult to ascertain, and it was not assigned to a stratigraphic zone.

SZ-2 consists of **Bed 6**, which is similar in composition to overlying **Bed 5**, consisting of alternating lenses of burned midden. A thick lens of white ash (F53)

lying between units E35 and F35 was taken as the boundary between Beds 5 and 6.

SZ-1 is represented here by **Bed 7**, the preoccupation deposit consisting primarily of decomposed limestone. The upper 10 to 15 cm of Bed 7 (zone SZ-1B) is dusky red (10 R 3/2), apparently due to its being oxidized by one or more intense burn events; some charcoal is also incorporated into this upper part of the bed. Below 10 to 15 cm, the deposit becomes reddish yellow (5 YR 6/8) and is less compact and has been designated zone SZ-1A.

Laboratory Analysis of the MAN-44 Sediments

At the end of the 1989 field season, during the recording of the stratigraphy of the C30–G30 trench, a series of 30 sediment samples were taken from the trench's west face. Each sample was collected exclusively from a single bed in the described section and placed directly into a leak-proof heavy plastic bag for shipment to the lab. In addition, samples were also taken from features F2, F4, and F5, all exposed in the trench wall, from the R30–S30 test trench outside of the shelter and from grid unit F10 (five samples). The samples were subsequently analyzed in the geoarchaeology laboratory of the Archaeological Research Facility, Berkeley using a sedimentological (as opposed to pedological) approach. The sediment samples from the sampled beds were analyzed for physical and chemical characteristics to aid in determining the source, mode of transport and deposition, and subsequent postdepositional alteration of the bed's constituents (see Folk 1974; Stein 1985, 1987).

Analytical Methods

The laboratory methods used for the analysis of the MAN-44 sediment samples were identical to those reported by Kirch et al. (1993) for the To'aga site in Samoa. Laboratory work was carried out by then Berkeley graduate student Jim Allen under the supervision of Kirch.

After air drying, Munsell colors for each sample were recorded. The pH of each sample was determined using a Mettler automatic pH meter with a 20-g subsample prepared in a 1:1 solution with distilled water. Three readings were made for each sample, with the reported value being the mean of the three readings.

Grain size distribution was determined by mechanical sieving of a subsample through nested geological sieves with mesh sizes of -2ϕ (4 mm) to 4ϕ (0.0625 mm), representing the range from small pebbles down to

very fine sand on the Wentworth grade scale. Following sieving, weights of each fraction were determined on an Ohaus high-precision balance and the separate fractions bagged and retained for further study as necessary. The percentages and cumulative percentages of all ϕ size classes were then calculated.

Organic matter and carbonate content of the sediments was determined with a further subsample using the "loss-on-ignition" method of controlled heating in a Thermolyne muffle furnace. After initial weighing with an Ohaus precision balance, the sample was first heated to 550°C, at which temperate organic matter burns off completely. After cooling and weighing, the sample was then reheated to 1,000°C, at which point the calcium carbonates in the sample devolved to carbon dioxide gas; the sample was again cooled and weighed a final time, after which the percent organic and percent carbonate matter were calculated.

The final analysis involved examination of the 0 ϕ size fraction for its constituent components. For this, a slide preparation was made of the sieved 0 ϕ size fraction by fixing several hundred grains to the slide surface with glue. The slide was then examined under a low-power stereomicroscope and approximately 200 grains were individually categorized as follows: sea urchin fragments, charcoal particles, bone fragments, plant material, marine mollusk fragments (shell), land snails, rock, or crustacean fragments. After counting, percentages of each category were calculated.

Results

Complete analytical data for the 41 sediment samples collected in 1989 are provided in the online sediment database (www.dig.ucla.edu/tangatatau). Here we summarize the main trends from the C30–G30 stratigraphic section.

In terms of color, the MAN-44 sediments are strongly concentrated in the 7.5 YR hue (browns), although there is considerable range in both chroma and value. In some beds, however, the color shifts to a hue of 5 YR (reddish browns). This is the case, for example, with the upper 5 to 10 cm of Bed 31 (SZ-1), which has a color of 5 YR 4/4, presumably reflecting its oxidation due to burning of the floor prior to the onset of initial occupation.

The granulometry of the 16 samples from the west face of units C30–G30 is summarized graphically in Figure 4.17. Overall, there is a high degree of consistency throughout the stratigraphic column, with most of the sediments comprising fairly even mixtures of the

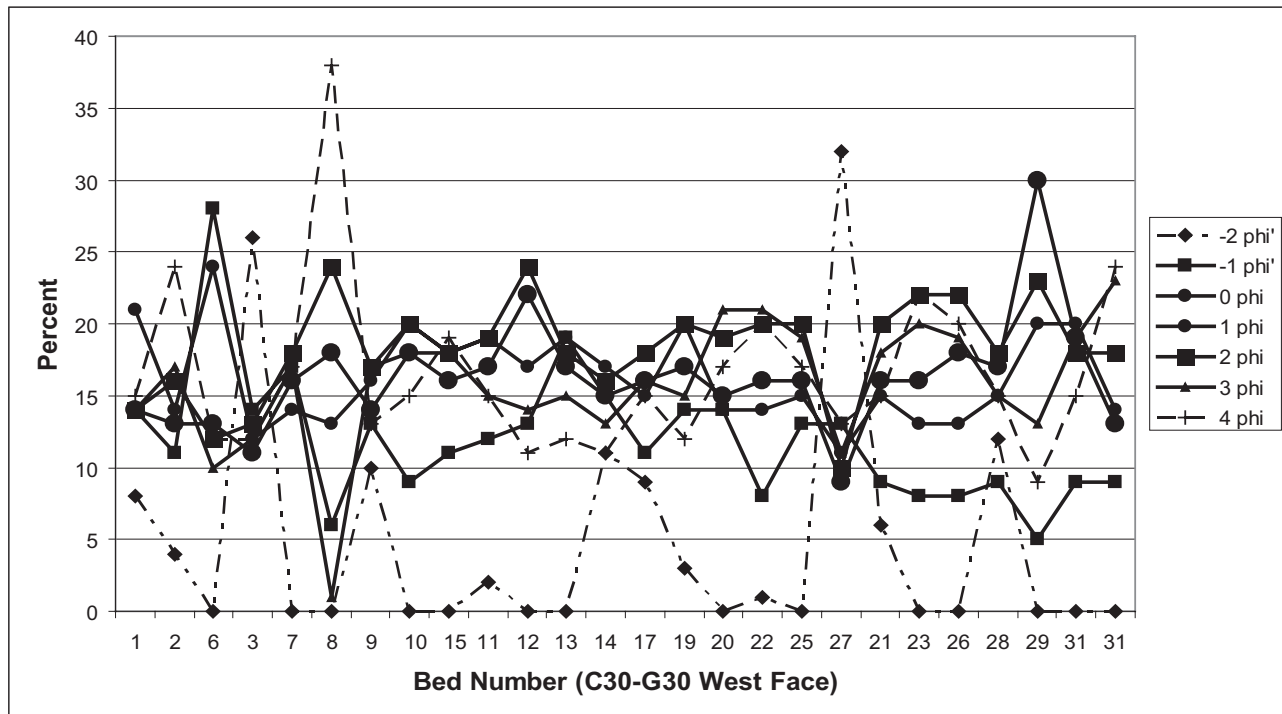


Figure 4.17. Granulometry of the C30-G30 trench sediment samples. The last two samples are from upper and lower parts of Bed 31, respectively

0 to 4 ϕ size classes (very coarse to very fine sands). The main differences are in the larger sized particles (-1 and -2ϕ), with the lowest beds (SZ-4a, -3, and -1) generally having lower percentages of these fine particles (although Bed 28 is an exception). A few of the higher beds, especially Beds 27, 14, 9, and 3, are also characterized by significant quantities of -2ϕ sized particles (small pebbles). Bed 8 also stands out for its high percentage of very fine-grained, sand-sized particles (4ϕ).

pH values for all of the samples ranged between 6.9 and 9.97, averaging 8.79, indicating that the deposits in MAN-44 are consistently in the moderately to strongly alkaline range. This clearly is the result of the high percentage of carbonates in the sediments (see below). Fortunately, such alkaline conditions are favorable to the preservation of bone and shell, accounting for the excellent faunal assemblage recovered from the site.

The organic and carbonate content of the sediments, as determined by loss-on-ignition, are summarized graphically in Figure 4.18. With the exception of a few beds, the carbonate content of the sediments is very high, averaging 47 percent by weight. The basal, preoccupation deposit (Bed 31) has a carbonate content of 46 percent, although this is strongly reduced

to only 29 percent in the upper few centimeters of this deposit, presumably due to intense burning that oxidized the sediment, turning it a dusky red. Beds 17, 19, and 20 are also relatively low in carbonates, as is Bed 9. Beds 9 and 20 both appear to represent fluvial in-wash events, which would explain their lower carbonate content; the same may also be true of Beds 17 and 19. Organic matter shows a more consistent profile through the site, with a mean of 13 percent. There is, however, a slight trend toward an increase in organic matter in the upper deposits, with the highest values attained in Beds 6 and 8.

The results of point-counting of the 0ϕ size fraction are graphically portrayed in Figure 4.19. Rock fragments (both of limestone and of basalt, the latter deriving from lithic production) dominate with a mean frequency of 45 percent, followed by shell fragments (mean 35 percent). Of particular note are the higher frequencies of crustacean fragments in the lower deposits and the higher frequencies of both sea urchin fragments and especially charcoal in the upper deposits. The higher quantities of charcoal grains in the upper beds correlate with the higher frequency of combustion features (earth ovens and hearths) in those beds.

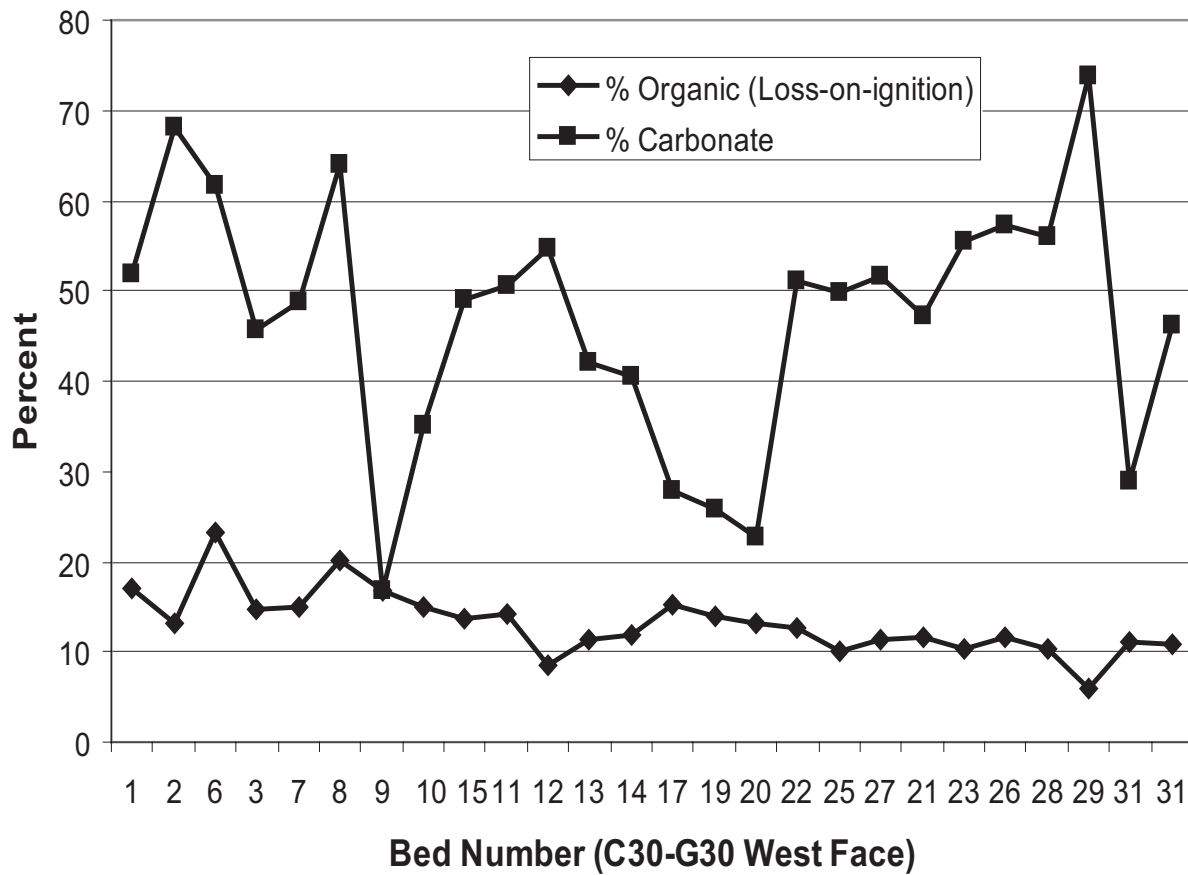


Figure 4.18. Organic matter and carbonate content of sediment samples from the C30-G30 trench. The last two samples are from upper and lower parts of Bed 31, respectively.

In sum, the sediments making up the Tangatatau Rockshelter deposits were derived primary from two sources: decomposition of the immediate limestone escarpment that forms the rockshelter walls and ceiling, combined with cultural materials such as mollusk shells, plant materials including wood for fuel (combusted to charcoal in the numerous earth ovens), and bone. The high carbonate input resulted in a strongly alkaline sedimentary environment. Analysis of the composition of sediment grains in the 0 φ fraction reveals that the particles are dominated by rock and shell fragments; there are also significant chronological trends in the decline of crustacean fragments and concomitant increase in sea urchin and charcoal fragments over time.

The Tangatatau Stratigraphic Sequence

By the time of our initial fieldwork in 1989, the application of a set of procedures for unambiguously expressing the stratigraphic relationships among the “units

of stratification” (beds, layers, features, and so forth) within a site was becoming widespread practice in archaeological excavation (Harris 1989; see also Harris et al. 1993). One goal of our excavations at MAN-44 was to apply these procedures to the complex stratigraphy within this rockshelter. To this end, throughout the 1989 and 1991 field seasons, we recorded the stratigraphic sections of nearly every face of all grid units and made systematic observations and notes regarding the correlation of beds and features between different units as the excavation progressed.

Based on the sections, notes, and correlations made during fieldwork, a finalized stratigraphic sequence for the main excavation block was compiled at the conclusion of the 1991 excavation. In preparing this final version of the stratigraphic sequence, we found it useful to compile a physical scale model of the excavation (at 1:10 scale) with photocopies of the stratigraphic sections pasted to stiff boards representing the various

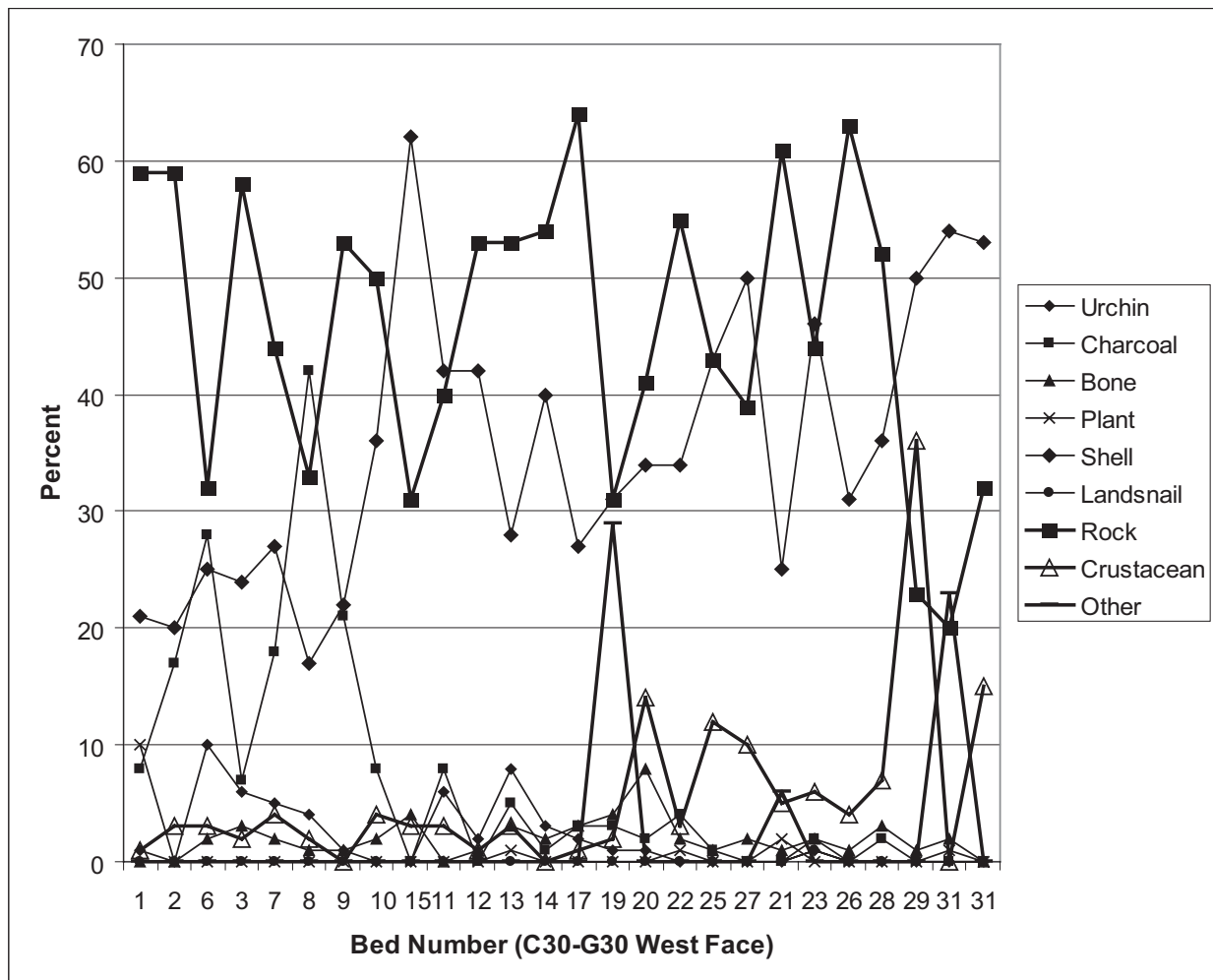


Figure 4.19. Results of point counting of the 0 φ size fraction of sediment samples from the C30-G30 trench. The last two samples are from upper and lower parts of Bed 31, respectively.

faces of the excavation grid units. (Xeroxing the sections onto clear acetate allowed us to reproduce them in mirror image as well, pasting them to the reverse sides of the boards.) Examining the physical model from various perspectives allowed us to cross-check the correlations made during excavation and to tie related beds into a final set of stratigraphic zones. The stratigraphic zones were then color-coded on the physical model. Unfortunately, the outlying test pits (units F10, A25–C25, and G40) could not be incorporated into this stratigraphic sequence, as the strata in those units were not directly linked to the main block and so could not be unambiguously correlated.

The outcome of this process was a stratigraphic sequence displaying the chronological relationships between the 19 SZs and 59 discrete features. Figure 4.20

presents a slightly simplified version of the stratigraphic sequence, omitting features that did not yield artifacts or faunal materials. Following Harris, a stratigraphic sequence such as that shown in Figure 4.20 is defined as “the order of deposition of the layers and the creation of feature interfaces through the course of time” (Harris 1989:34, emphasis added). The reader should keep in mind that Figure 4.20 does not display all of the superpositional relationships and stratigraphic contacts between the various beds and features; those relationships and contacts can be discerned from the stratigraphic sections presented earlier. Rather, Figure 4.20 displays the chronological relationships—the temporal order of deposition—between the stratigraphic zones and features. For this reason, as an example, zones SZ-4A and SZ-4B, along with features F37 and F38, are shown in

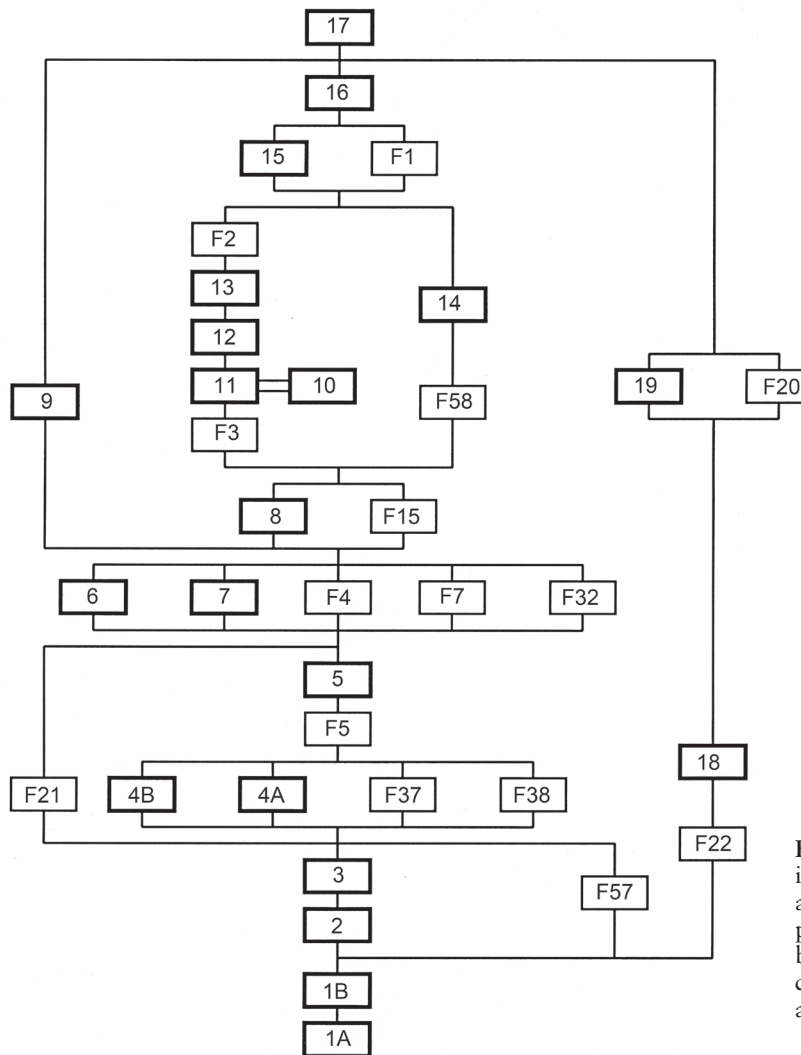


Figure 4.20. Stratigraphic sequence indicating the chronological relationships among the stratigraphic zones and principal features in the main excavation block at site MAN-44 (only those features containing analyzed faunal, floral, or artifact materials are depicted).

Figure 4.20 as higher than SZ-3 and lower than SZ-5, even though in places, SZ-4A directly contacts SZ-1B in the stratigraphic sections. This is because the physical contacts between SZ-4 and SZ-1B do not reflect the true chronological relationships between the two zones, since SZ-4 consists of pits that were dug through and obliterated intervening zones SZ-2 and SZ-3. The correct chronological position of SZ-4 is above SZ-3, as the contents of zone SZ-4 along with features F37 and F38 were deposited *after* SZ-3; this is what is indicated in the stratigraphic sequence in Figure 4.20.

Throughout this monograph, we use the stratigraphic zones and features whose chronological relationships are indicated in Figure 4.20 as our primary analytical units for presenting data on artifact, faunal, and floral materials recovered during the excavation. For the

benefit of future researchers, the correlations between excavated contexts (designated by grid unit and level) and zones and features are provided in the Appendix. These correlations are also provided in the online database and can be used to link any excavated object in the site catalog to its position in the stratigraphic sequence. Note, however, that this applies only to objects from the main excavation block, as the stratigraphic sections of the outlying test excavations could not be directly linked to the main stratigraphic sequence.

Subsurface Features

A total of 59 features were individually recognized, and the majority of these were excavated and their contents screened separately. Details of all of the features, including dimensions and description of their contents,

are provided in the MAN-44 Feature Database (www.dig.ucla.edu/tangatatau); the stratigraphic position of each feature relative to the stratigraphic zones is indicated in the site stratigraphic sequence matrix (Figure 4.20) and in the Feature Database.

The majority of features ($n = 40$) can be broadly classified as “combustion features,” meaning that they were loci of active burning. Most of these combustion features consist of relatively shallow, basin-shaped depressions, roughly circular in plan view and ranging in diameter from 0.3 to 1.1 m. Almost all of the combustion features contained some quantity of fire-altered (cracked and reddened or blackened) rock, usually limestone but occasionally volcanic. In function, these combustion features probably included two different types: (1) shallow “hearths” for roasting or broiling food as well as for light and (2) earth ovens, typically features with greater depth. Cooking in the earth oven, or *umu* in Mangaian, was “the standard method” for preparing food according to Hiroa (1934:136). This involved first heating the stones, then covering the food with leaves and a layer of earth, allowing the food to steam for a period of several hours.

Feature F15, only partly exposed in unit G35, was unusually large with a diameter somewhat greater than 0.7 m and a depth of 0.8 m. This oven was most likely an *umu ti*, used to cook large quantities of the roots of *Cordyline fruticosa* (*ti*). Hiroa (1934:137) describes such *umu ti*, which were important for cooking this “reserve food used in the dry season.” As he notes, “the cooked stems, rich in saccharine material, would keep for some time.”

Four features consist of ash lenses, which may represent material raked out from nearby combustion features. Another 12 features are pits, most of which are filled with ashy gray midden material. Several of these pits have ash or charcoal lenses at the base, indicating that they were first used as earth ovens but then later used as trash disposal pits. Five features consist of small postholes or stake holes.

The Depositional History of Tangatatau Rockshelter

As noted earlier, a total of 19 stratigraphic zones were defined at the end of the 1991 field season; their chronological relationships to each other and to the excavated features are graphically portrayed in the stratigraphic sequence shown in Figure 4.20. Here we discuss the salient characteristics of each zone,

beginning with the earliest and proceeding to the most recent, in the order of their depositional history.

Zone 1 is the basal deposit of primarily reddish-yellow sediment consisting of fine carbonates, largely derived from decomposition of the rockshelter wall and ceiling. The deposit yielded significant quantities of bird bones (of both land and seabirds, including several extinct or extirpated taxa), along with abundant shells of two species of native land snails (terrestrial gastropods): a globoid species of Helicinidae (*Orobophana pacifica*) and a distinctly keeled species of Endodontidae (*Libera fratercula*). As indicated by several accelerator mass spectrometry radiocarbon dates on bird bone, SZ-1 accumulated gradually during the mid to late Holocene (see Chapter 5), mostly prior to human arrival on Mangaia. The uppermost part of SZ-1, however, dates to the period after Polynesian colonization, since it contains bones of the human-introduced Pacific rat (*Rattus exulans*).

We subdivided zone 1 into two components. The lower portion (SZ-1A), which is less compact and often exhibited a “floury” texture, yielded a lower density of faunal materials. The upper portion (1B) was more compact and typically a “dusky red” in color due to oxidation, perhaps from burning vegetation and debris over the rockshelter floor prior to initial human occupation. SZ-1B also exhibits evidence of human disturbance in the form of oxidized lenses and small amounts of charcoal flecking pressed down into the deposit. Zone 1B has the highest concentration of bones of extinct land birds in the sequence, as well as bones of the human-introduced Pacific rat. While zone 1B does not represent an in situ habitation deposit, the presence of *R. exulans* bones indicates that it accumulated within the period of early Polynesian occupation on the island. Feature F23, a small pit with a fill of reddish oxidized material and some charcoal, is pene-contemporaneous with SZ-1B. Feature F46, a small basin-shaped combustion feature, lies stratigraphically between SZ-1B and SZ-2.

Zone 2 is the earliest in situ occupation deposit in the rockshelter, consisting of ashy midden with abundant mollusk and vertebrate faunal remains; the deposit exhibits extensive burning and oxidation. A plan view of zone 2 is shown in Figure 4.21, revealing how the large pits of SZ-4A truncate the SZ-2 deposits in units C31 and D31; in E32, SZ-2 is interrupted by a large pit (F37), and in units E33 and E34, it is again truncated by large pits of SZ-4A. Zone 2 has abundant evidence of lithic production, including basalt debitage

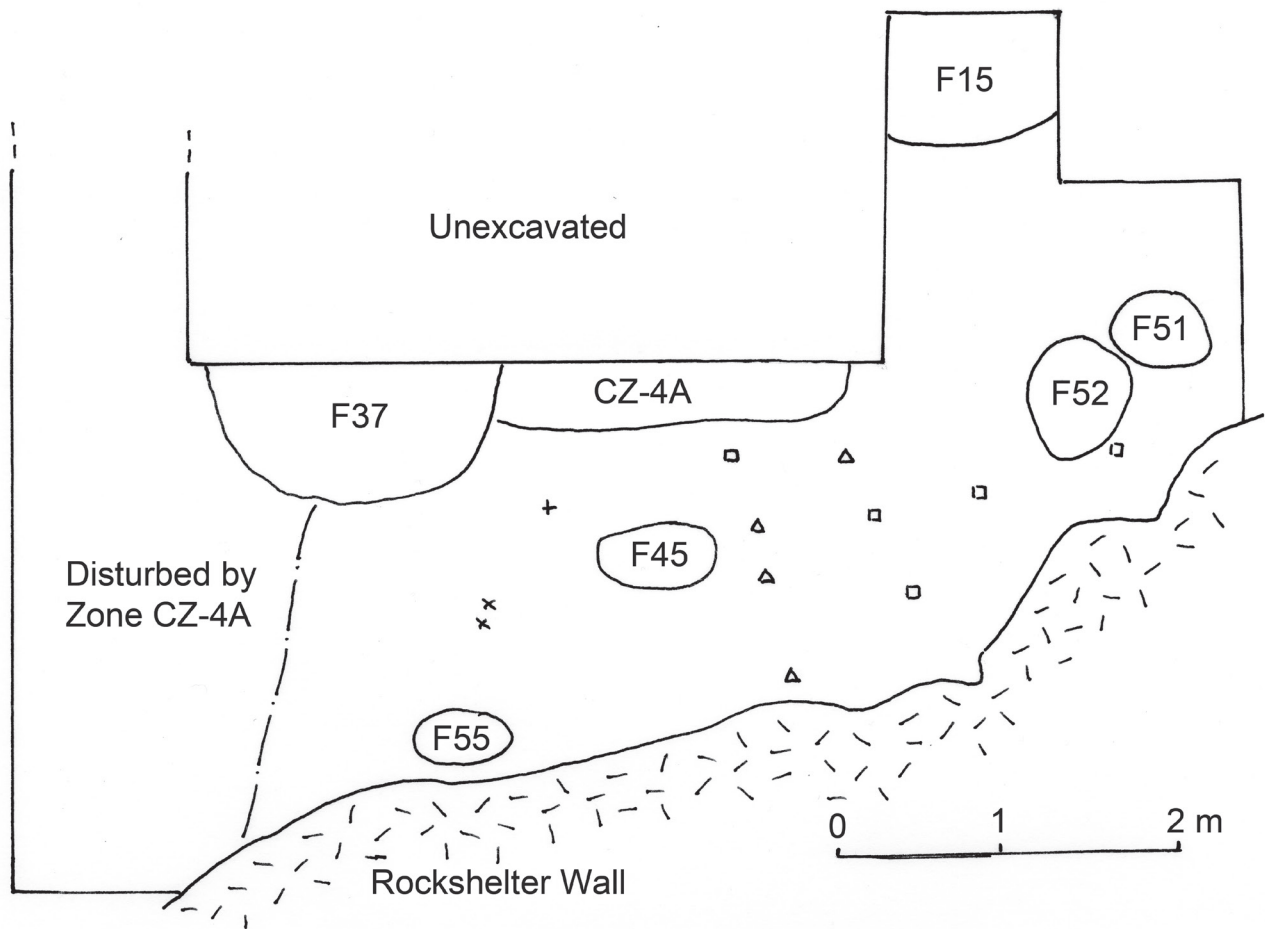


Figure 4.21. Plan of zone SZ-2, showing features and the location of piece-plotted artifacts (□, adze preform; Δ, adze or adze fragment; x, fishhook; +, coral sphere).

along with several adze preforms and finished adzes. A coral sphere, a hammerstone, and several fishhooks were also recorded in situ. Five features (F40, F41, F48, F52, and F55) are associated with SZ-2, all consisting of small combustion features; most likely these all functioned as hearths for light but possibly also for roasting foodstuffs.

Zone 3, deposited directly over SZ-2, continued the same depositional regime, with the difference that SZ-3 contained thin lenses of reduced (nonoxidized) material, including considerable quantities of carbonized plant remains (see Chapter 9). A plan of zone 3 is provided in Figure 4.22, showing the locations of artifacts plotted in situ as well as of features. As with SZ-2, zone 3 contained large numbers of basalt flakes, adze preforms, and hammerstones; many of the basalt flakes were concentrated in thin lenses, indicating in situ flaking floors. Zone 3 also yielded a broad array

of other artifact types, which, in combination with the midden materials, indicate use of the site as a primary habitation at this time, with a full range of domestic activities (see Chapter 10). Three features (F45, F47, and F51) are directly associated with SZ-3. These include two fairly large combustion features (probably earth ovens) and a thick concentration of black, reduced, carbonized plant material rich in macrobotanical specimens later identified by archaeobotanist Hather (see Chapter 9).

Zone 4 consists of a series of large, intercutting pits (features F36, F37, and F38) that destroyed and reworked earlier occupation deposits in the western and northern portions of the excavation. The functions of these pits are not evident from their form or contents; they are not oven features. A large pit (F5) filled with dark brown ashy silt lies stratigraphically between SZ-4 and SZ-5.

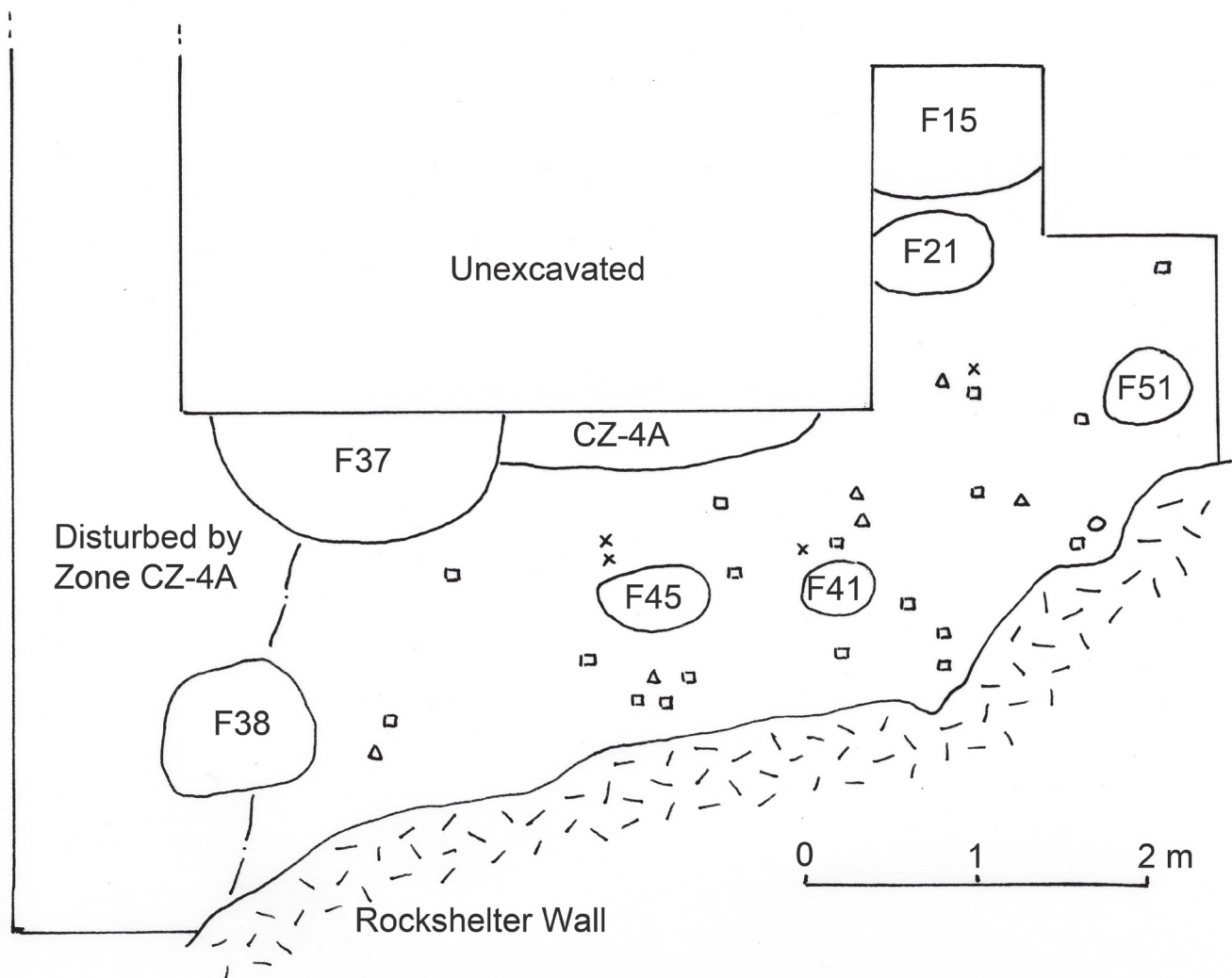


Figure 4.22. Plan of zone SZ-3, showing features and the location of piece-plotted artifacts (□, adze preform; Δ, adze or adze fragment; x, fishhook; o, hammerstone).

Zone 5 is a reddish-brown midden capping the SZ-4 pits; this zone forms a distinctive marker bed, typically not more than 5 to 10 cm thick, across much of the western and northern area of the main excavation block. The higher clay content of SZ-5 suggests that it may have resulted, at least in part, from a fluvial event such as a major storm or cyclone that brought alluvium into the shelter from the adjacent slopes. A single feature (F44) is associated with SZ-5, a basin-shaped combustion feature with very white ash.

Zone 6, a grayish-brown ashy midden deposit, directly overlies SZ-5 in the eastern half of the main excavation block. Zone 7 is pene-contemporaneous with SZ-6 but confined to the western part of the excavation; this consists of a thin but extensive deposit of

shellfish midden in a reddish-clay matrix (again possibly deriving from a fluvial in-wash event), somewhat disturbed by intrusive features. Zones 6 and 7 are associated with a group of eight features (F4, F7, F32, F33, F34, F43, F49, and F50), including three or possibly four combustion features, three midden-filled pits, and a small postmold.

Zone 8 is a thick, grayish-brown, ashy midden with many fine lenses extending over most of the western half of the excavated area. It is probably more or less contemporaneous with SZ-9, found in the eastern part of the site, but a series of disturbances in the vicinity of units E34, E35, and F35 (associated with a large earth oven and rake out in G35) make precise stratigraphic correlation impossible. SZ-8 is associated with no less

than 11 features (F15, F19, F25, F26, F27, F28, F29, F30, F31, F42, and F59), which include seven combustion features and four small postholes. Most of the combustion features are either hearths or earth ovens, but one large oven (F15) almost certainly functioned as an *umu ti* for cooking *Cordyline* root.

Zone 9 occurs in the eastern part of the excavated area and, as noted above, is largely contemporaneous with SZ-8. This zone consists of multiple lenses of ash and charcoal, much of it apparently deriving from oven rake out. Three combustion features (F13, F17, and F24) are associated with SZ-9.

Zones 10, 11, 12, and 13 consist of thin beds of alternating shellfish midden and ash, all probably deposited rapidly as discrete events and confined to the western part of the main excavation block. Contemporary with these is **zone 14**, a lens-shaped midden deposit largely confined to unit C30.

Capping SZ-10 to SZ-14 is **zone 15**, an extensive grayish, ashy, compacted midden containing much large charcoal. SZ-15 is associated with feature F1, a large earth oven combustion feature.

Zone 16 overlies SZ-15 over much of the western excavation and consists of a compact deposit of white ash resulting from intensive burning of vegetative material on the shelter floor. Features F6, a small basin-shaped combustion feature, and F54, a large pit filled with loose, ashy midden, are associated with SZ-16.

Zone 17, extending over the entire excavated area, is the uppermost deposit of loose, fine dusty soil containing noncarbonized plant remains along with historic period artifacts.

Zones 18 and 19 can only be roughly correlated with the sequence outlined above, as shown in the stratigraphic sequence (Figure 4.20), because these two superposed strata were evident only in the extension of the 30-trench beyond the drip-line into units H30 and J30. A large rockfall boulder extending completely across unit G30 prevented direct stratigraphic correlation, while leaching of the sediments in the outermost units also hindered stratigraphic interpretation. SZ-18 is roughly contemporary with SZ-2 through SZ-5, while SZ-19 spans the time represented

by SZ-6 through SZ-16. Four features (F10, F12, F16, and F20) are associated with SZ-19; these are all combustion features.

Before concluding, the question of whether the stratigraphic sequence in Tangatatau Rockshelter shows evidence of disturbance or mixing of deposits should be addressed. There is no question that at several times during their depositional history, some of the rockshelter's deposits were affected by the digging of pits, primarily for combustion features such as earth ovens or hearths. For the most part, however, such pits were small in both horizontal and vertical scale and did not extend deeply into underlying deposits. The amount of mixing that may have resulted from such activities was therefore likely to be minimal. There are, however, two exceptions that should be noted. The first was the digging of several large, intercutting pits (including features F37 and F38), which then became filled with zone SZ-4 deposits. These pits were dug following the deposition of zones SZ-2 and SZ-3 and cut into those early occupation deposits. The zone SZ-4 deposit therefore probably incorporates materials whose original depositional context was in SZ-2 or SZ-3. The second instance of a larger disturbance is in unit G35, where the deep oven pit F15 (contemporary with zone SZ-8) cut down through underlying deposits of zones SZ-3, SZ-2, and SZ-1. This could have led to the incorporation of some older material into parts of SZ-8 adjacent to the oven pit.

Although these disturbances probably resulted in the movement of some older materials upward, to be redeposited in later stratigraphic zones, all indications are that such disturbances were limited. As will be evident in subsequent chapters, consistent patterns of temporal change in artifact types, faunal assemblages, and archaeobotanical materials all testify to the site's basic stratigraphic integrity. Among others, these patterns include temporal shifts in fishhook manufacture from pearl shell to *Turbo* shell, changes in adze typology from untanged to tanged forms, and clear trends in the decline of wild faunal resources and shifts in charcoal from native to introduced woody species. The presence of such well-attested trends demonstrates that the site's deposits were not extensively mixed.

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5

Radiocarbon Dating and Bayesian Modeling of the Chronology of Tangatatau Rockshelter

Patrick Vinton Kirch

The two and a half decades since Tangatatau Rockshelter was first excavated in 1989 have witnessed significant debate over the timing of initial Polynesian discovery and settlement of the archipelagoes of Eastern Polynesia, resulting in major revisions in the accepted cultural chronology for the region (see, e.g., Allen 2004; Allen and Morrison 2013; Anderson et al. 1994; Conte and Molle 2014; Dye 2011; Kirch 1986; Kirch and Ellison 1994; Kirch et al. 2010; Spriggs and Anderson 1993; Wilmshurst et al. 2011). The debate over “long” and “short” chronologies for Eastern Polynesia, which unfolded throughout the 1990s and 2000s, was spurred along by major technical and methodological advances in the field of radiocarbon dating, most notably by (1) the development of the accelerator mass spectrometry (AMS) dating method and (2) advances in archaeobotanical identification of dated carbonized plant materials, allowing for the dating of identified, short-lived taxa. As a result of these developments, radiocarbon dating became not only more precise but also more accurate as such problems as dating unidentified “old wood” were eliminated.

An initial series of 30 ^{14}C dates from site MAN-44 (processed in 1989–1991) were obtained soon after the completion of excavations, but unfortunately just prior to the widespread application of these methodological advances. Subsequently, however, a second set of 16 ^{14}C dates from the lowest levels of the site (zones SZ-1A and

SZ-1B) were run in 1993 using the new AMS method in an effort to establish the age of the site’s basal deposits. Dating these early deposits was deemed critical in light of the emerging debate about Eastern Polynesian settlement. Most recently, as I reengaged with analysis of the MAN-44 materials in writing this monograph, it became apparent that additional AMS determinations on botanically identified, short-lived taxa would be essential to establish a firm chronology for the rockshelter; thus, another 25 samples were processed in 2011, 2015, and 2016, from strata throughout the sequence. In all, the radiocarbon corpus for site MAN-44 now includes 71 ^{14}C dates, certainly one of the largest sets of dates for a single stratified site anywhere in Eastern Polynesia.

In this chapter, I review the three sets of radiocarbon dates obtained at different times and the methods used for each set; the second and third sets are published here for the first time. I then apply a Bayesian calibration model to a subset of AMS dates from the main excavation block to define the most probable age ranges for the principal phases in the site’s stratigraphic sequence. Finally, I discuss the modeled radiocarbon dates by stratigraphic zone.

The Tangatatau Rockshelter Radiocarbon Corpus

Upon our return from the field in 1989, 15 samples recovered from the initial C30–G30 trench and from outlying test unit F10 were submitted to Beta Analytic,

Inc. for processing (lab numbers Beta-32816 to Beta-32830). All samples consisted of charcoal obtained from discrete hearths, earth ovens, or other combustion features, but following common practice at the time, these were not botanically sorted or identified. Some of the samples undoubtedly included—in addition to wood charcoal—carbonized seeds (such as those of *Aleurites moluccana*), drupes (such as *Pandanus*), or other carbonized plant materials. Beta Analytic reported that the samples “were pretreated by first examining for rootlets” and “then given a hot acid wash to eliminate carbonates” (M. Tamers, letter to D. W. Steadman, dated 21 Sept. 1989). Next, “they were repeatedly rinsed to neutrality and subsequently given a hot alkali soaking to take out humic acids. After rinsing to neutrality, another acid wash followed and another rinsing to neutrality.” The measured ^{14}C ages were determined through the liquid scintillation method of beta particle counting, which was then standard practice in radiocarbon dating. The final “conventional ^{14}C age” (see Stuiver and Polach 1977 for definition) was reported after correction for measured $\delta^{13}\text{C}$ values. The results of these analyses are reported in Table 5.1. These radiocarbon dates, along with dates from the sediment cores extracted from nearby Lake Tiriara, were published by Kirch et al. (1991).

In 1992, following the second excavation season, another set of 15 samples obtained primarily from the main excavation block but also including two samples from outlying excavation unit B25 were submitted to Beta Analytic for processing and dating (lab numbers Beta-52925 to Beta-52940). Once again, the samples consisted of unidentified charcoal obtained from discrete combustion features or burn lenses (bulk-collected charcoal from sieving was never submitted for dating from either of the field seasons). Beta Analytic applied the same pretreatment protocol and liquid scintillation counting method as was used for the 1989 samples; results are reported in Table 5.1. These radiocarbon dates, along with those previously obtained from the 1989 excavation season, were published by Kirch et al. (1995:Tables 1 and 2).

Figure 5.1 is an Oxcal plot of the calibrated age ranges for 24 radiocarbon dates, dated in 1989 and 1992, that are from the main excavation block and can be assigned to a stratigraphic zone or feature in the site’s stratigraphic sequence (see Figure 4.20). Calibrations were performed using the Southern Hemisphere SHCal13 calibration curve (Hogg et al. 2013). While a clear chronological

progression is evident, the relatively broad standard error ranges (resulting in elongated probability distributions) result in substantial overlap between stratigraphic zones. Moreover, several outliers are evident (especially Beta-32821, Beta-32825, Beta-32817, and Beta-32816). These outliers all appear to be of “Type T” as defined by Bronk Ramsey (2009a), in which the dated sample does not properly correspond to the event presumed to be dated. Most likely these outliers are the result of stratigraphic inversions or disturbances, in which materials were displaced through actions such as the digging of earth oven pits.

In addition, six radiocarbon dates were obtained on samples from units outside of the main excavation block (Table 5.1). Four samples from excavation unit F10 were dated in 1989 (all on unidentified wood charcoal), as plotted in Figure 5.2. Beta-32828 and Beta-32819 were both from level 8 at the base of the cultural deposit in F10 (and thus roughly equivalent to SZ-2 in the main excavation block). The four dates from unit F10, while overlapping considerably due to their large standard errors, nonetheless indicate that the sequence of deposits here parallels that in the main excavation block. Two samples of unidentified wood charcoal were also dated from unit B25, situated 4 m to the west of the main excavation block (see Table 5.1).

In 1993, the debate over the timing of human entry into the islands of Eastern Polynesia came to the fore with the publication of Spriggs and Anderson’s (1993) article calling for the application of “chronometric hygiene” in radiocarbon dating. At the same time, the new AMS radiocarbon method was becoming more widely available, particularly with the establishment of the Center for Accelerator Mass Spectrometry (CAMS) at the Lawrence Livermore National Laboratory (LLNL) in California. As LLNL was administered by the University of California, I agreed to take advantage of a program of subsidized dating offered by CAMS to U.C. Berkeley faculty. David Steadman and I agreed that the best use of the CAMS facility would be to obtain a series of dates on the bones of (1) extinct or extirpated birds and (2) Polynesian-introduced rats (*Rattus exulans*) from stratigraphic zones SZ-1A and 1B at the base of the stratigraphic sequence. The dating of the rat bones in particular was regarded as essential to establishing the arrival date for Polynesians on Mangaia Island. This commensal species was known to have been widely transported by humans across the Pacific, and its bones occur in virtually every early settlement context.

Table 5.1 Initial Non-AMS Radiocarbon Dates from Site MAN-44, on Unidentified Wood Charcoal

Lab No.	Unit	Level	Zone and/or Feature	Measured ¹⁴ C Age	±	δ ¹³ C	Conventional ¹⁴ C Age	±	Calibrated Age Range AD, 2σ ^a
Beta-32816	E30	13	1B	580	120	-27.3	550	120	1271–1645
Beta-32817	C30	10	4A	280	160	-28.1	230	160	1464–1950
Beta-32818	F30	10	F5	520	50	-26.6	490	50	1396–1510 (86.5%), 1576–1622 (8.9%)
Beta-32819	F10	8	Outlying unit	700	80	-26.9	740	80	1187–1408
Beta-32820	F10	2	Outlying unit	350	80	-26.0	330	80	1440–1700 (81.4%), 1722–1810 (13.0%), 1838–1845 (0.3%), 1867–1878 (0.5%), 1933–1938 (0.2%)
Beta-32821	G30	4	F3	230	60	-26.8	200	60	1650–1950
Beta-32822	E30	2	15	350	80	-26.7	330	80	1440–1700 (81.4%), 1722–1810 (13.0%), 1838–1845 (0.3%), 1867–1878 (0.5%), 1933–1938 (0.2%)
Beta-32823	F30	3	13	470	70	-26.6	450	70	1410–1634
Beta-32824	D30	6	7	610	80	-29.5	540	80	1294–1511 (88.7%), 1551–1558 (0.5%), 1575–1622 (6.3%)
Beta-32825	F30	9	F5	930	70	-27.0	900	70	1035–1275
Beta-32826	E30	13	1B	1010	70	-27.3	980	70	987–1229
Beta-32827	C30	11	2	750	80	-27.9	700	80	1223–1422
Beta-32828	F10	8	Outlying unit	840	80	-27.7	790	80	1054–1058 (0.2%), 1069–1077 (0.6%), 1148–1398 (94.6%)
Beta-32829	F10	3	Outlying unit	550	70	-27.2	520	70	1313–1359 (8.3%), 1380–1513 (77.0%), 1546–1624 (10.1%)
Beta-32830	F30	3	13	440	70	-26.4	420	70	1426–1646
Beta-52925	B25	2	Outlying unit	570	50	-25.1	570	50	1314–1358 (18.6%), 1380–1455 (76.8%)
Beta-52926	B25	5	Outlying unit	640	120	-24.5	650	120	1161–1505 (94.1%), 1590–1616 (1.3%)
Beta-52928	D31	13	4B	650	60	-26.6	620	60	1294–1438
Beta-52929	D32	3	8, F25	520	60	-27.4	480	60	1397–1518 (74.6%), 1539–1626 (20.8%)
Beta-52930	D32	5	8, F31	340	70	-26.3	320	70	1450–1695 (82.1%), 1726–1806 (13.3%)
Beta-52931	D34	8	2, F48	620	60	-28.9	560	60	1301–1365 (20.3%), 1375–1478 (75.1%)
Beta-52932	E31	10	F37	690	60	-26.3	670	60	1277–1417
Beta-52933	E32	12	1B/2	970	80	-27.0	930	80	1018–1276
Beta-52934	E32	12	1B/2	990	60	-26.9	960	60	1016–1229
Beta-52935	E32	13	2	680	60	-28.8	620	60	1294–1438
Beta-52936	E33	11	2	670	50	-26.4	640	50	1292–1421
Beta-52937	E35	2	9, F24	550	70	-26.7	520	70	1313–1359 (8.3%), 1380–1513 (77.0%), 1546–1624 (10.1%)
Beta-52938	E35	10	2, F38	750	60	-26.5	720	60	1229–1253 (4.8%), 1259–1400 (90.6%)
Beta-52939	E36	9	2, F52	780	50	-25.1	780	50	1206–1321 (83.0%), 1349–1387 (12.4%)
Beta-52940	G35	5	F15	420	50	-26.6	380	50	1456–1641

^aCalibrations based on Southern Hemisphere SHCal13 calibration curve, generated by Oxcal online radiocarbon calibration.

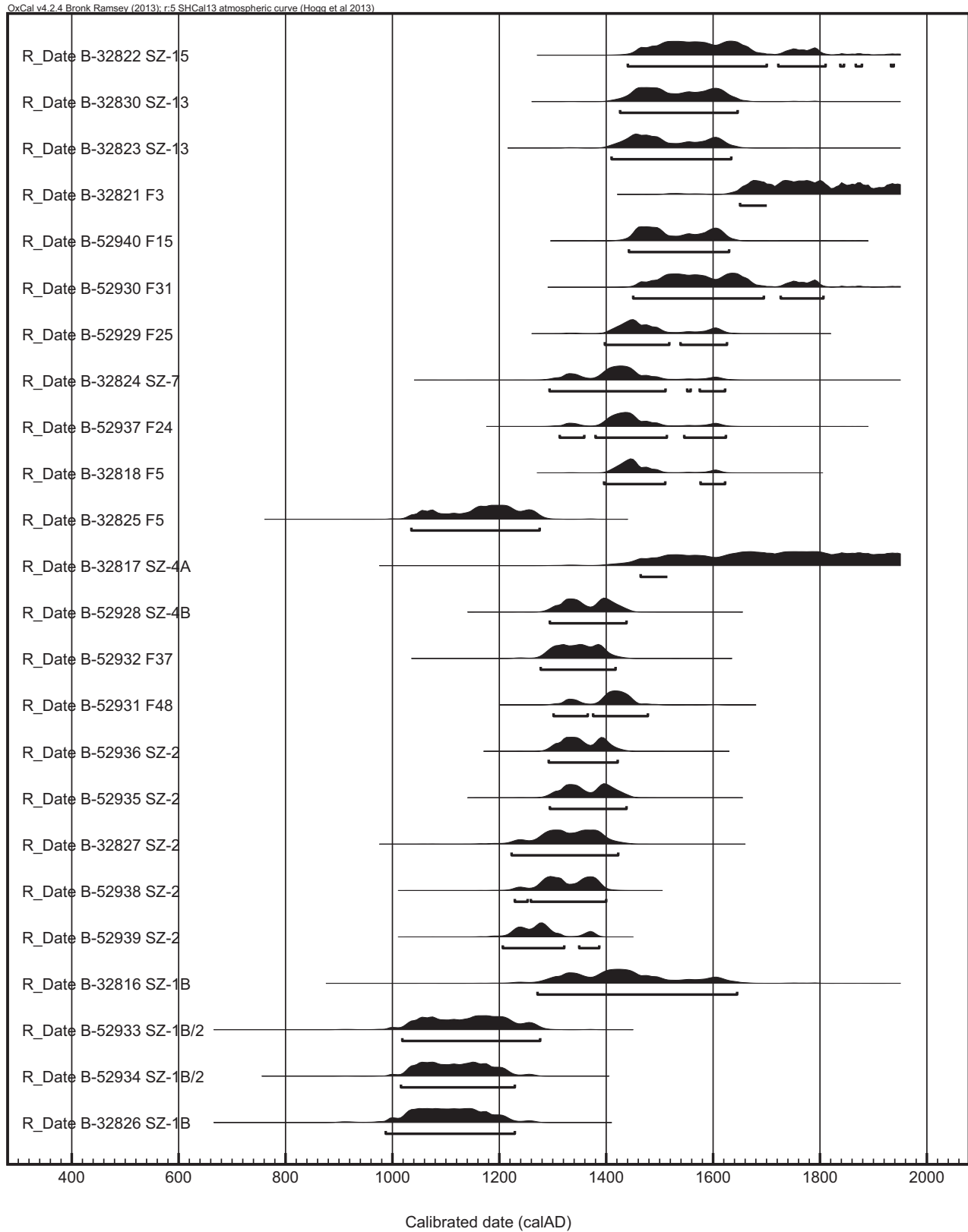


Figure 5.1. Oxcal plot of radiocarbon dates from site MAN-44 obtained in 1989-1991 on unidentified wood charcoal.

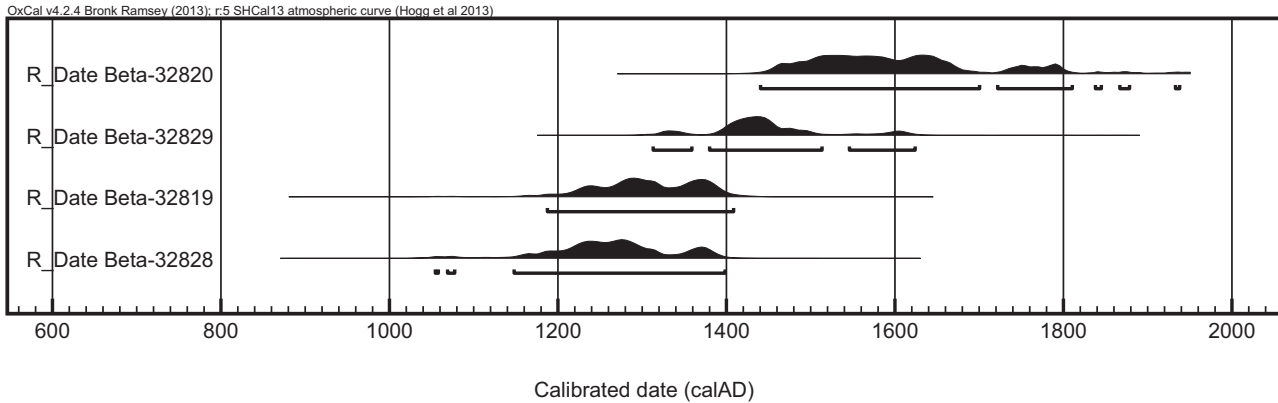


Figure 5.2. Oxcal plot of radiocarbon dates from outlying unit F10.

Sixteen bones of extinct or extirpated avifauna and of Pacific rats from SZ-1A and SZ-1B were sent to Thomas W. Safford at the Laboratory for Accelerator Radiocarbon Research at the University of Colorado, Boulder, who carried out the pretreatment and collagen extractions. The collagen fractions were AMS dated at CAMS/LLNL; results are reported in Table 5.2. These results have not been previously published. Figure 5.3 is an Oxcal plot of the calibrated age ranges for these bird and rat bone AMS dates from zones SZ-1B and SZ-1A. The wide dispersion of dates in zone SZ-1A makes it clear that this deposit, which accumulated prior to human arrival on the island, is a palimpsest that incorporated the bones of native birds over a several thousand year period. Zone SZ-1B, in stark contrast, accumulated very rapidly, as indicated by the tight distribution of dates for the Pacific rat.

In 2011, archaeobotanical collections from MAN-44, which had been analyzed by Jon Hather in 1991–1993 (see Chapter 9) and stored at the Institute of Archaeology, University College London, were returned to me at Berkeley and integrated with the other MAN-44 collections. This material, most of which had been identified to botanical taxon by Hather, provided an opportunity to obtain additional AMS dates on identified, short-lived taxa, thereby meeting the stringent criteria for “Class I” dates advocated by Wilmshurst et al. (2011). In March 2011, three samples of identified, short-lived botanical materials were sent to Beta Analytic for AMS dating (Beta-293377 to Beta-293379). Deriving from the base of zone SZ-2 and the contact between SZ-1B and SZ-2, these samples provided additional information on the age of initial

Polynesian occupation of the rockshelter (all previous dates from the site were regarded by Wilmshurst et al. [2011] as “Class II” or “Class III” and therefore not as reliable).

Most recently, a final series of AMS dates was obtained on the botanically identified materials previously identified by Jon Hather, from selected zones throughout the MAN-44 sequence. Twenty-two samples, on a range of identified, short-lived carbonized plant remains, were AMS dated by Dr. John Southon at the W. M. Keck Carbon Cycle Accelerator Mass Spectrometry Laboratory at the University of California, Irvine (UCIAMS-164888 to UCIAMS-164898 and UCIAMS-175448 to UCIAMS-175458). Many of the samples consisted of carbonized *Aleurites moluccana* (candlenut) endosperm, but other taxa were also dated, including the drupes of *Pandanus tectorius*, stem tissue of sugarcane (*Saccharum officinarum*), and the parenchyma of several tubers, including one of sweet potato (*Ipomoea batatas*). These are highest precision dates yet obtained for MAN-44, with standard errors of only ± 15 to 20 years. These dates are given in Table 5.3 and are published here for the first time.

Figure 5.4 is an Oxcal plot of the calibrated age ranges for the 25 new, high-precision AMS dates obtained on identified, short-lived carbonized plant materials; the dates are arrayed in stratigraphic order. When Figure 5.4 is compared with Figure 5.1, the advance gained in understanding of the site’s chronology through AMS dating of identified, short-lived plant materials is immediately apparent. Two outliers are evident in this set (samples UCIAMS-164892 and UCIAMS-164894), both again of “Type T” (Bronk

Table 5.2 AMS Radiocarbon Dates on Bone from Zones SZ-1A and SZ-1B, Site MAN-44

Lab No. ^a	Unit	Level	Zone	Dated Material	Conventional ¹⁴ C Age	±	Calibrated Age Range, 2σ (AD Unless Otherwise Noted) ^b
CAMS-10222	E35	10	1B	Bone, <i>Rattus exulans</i>	730	70	1218–1403
CAMS-10223	E35	11	1B	Bone, <i>Rattus exulans</i>	740	60	1224–1394
CAMS-10226	D32	13	1A	Bone, <i>Gallirallus ripleyi</i>	1440	60	543–766
CAMS-10227	D31	14	1B	Bone, <i>Rattus exulans</i>	620	80	1276–1455
CAMS-10348	C31	10	1B	Bone, <i>Rattus exulans</i>	800	60	1160–1320 (87.3%), 1351–1385 (8.1%)
CAMS-12818	D31	17	1A	Bone, <i>Ducula galeata</i>	3390	60	1871–1845 (1.8%), 1811–1804 (0.4%), 1776–1496 (92.4%), 1475–1461 (0.8%) BC
CAMS-12821	E35	12	1A	Bone, <i>Gallinolumba mui</i>	7570	80	6564–6547 (1.1%), 6528–6226 (94.3%) BC
CAMS-12822	E35	12	1A	Bone, <i>Gallirallus ripleyi</i>	5590	80	4581–4568 (0.5%), 4561–4235 (94.9%) BC
CAMS-12823	E35	12	1A	Bone, <i>Porzana rua</i>	6030	100	5210–4679 (94.6%), 4636–4619 (0.8%) BC
CAMS-14818	E35	12	1A	Bone, <i>Vini kuhlii</i>	2100	80	356–284 (7.9%) BC, 257 BC–114 AD (87.5%)
CAMS-8741	C31	11	1B	Bone, <i>Vini viduici</i>	1050	60	895–925 (5.9%), 957–1177 (89.5%)
CAMS-8742	E35	12	1B	Bone, <i>Rattus exulans</i>	710	70	1226–1408
CAMS-8743	D32	12	1B	Bone, <i>Rattus exulans</i>	700	70	1229–1253 (3.9%), 1259–1414 (91.5%)
CAMS-9187	E35	11	1B	Bone, <i>Rattus exulans</i>	650	70	1279–1435
CAMS-9188	E35	10	1B	Bone, <i>Rattus exulans</i>	1140	60	771–1041
CAMS-9409	E35	10	1B	Bone, <i>Rattus exulans</i>	1000	60	991–1208

^aAll dates processed by the Lawrence Livermore National Laboratory.

^bCalibrations based on Southern Hemisphere SHCal13 calibration curve, generated by Oxcal online radiocarbon calibration.

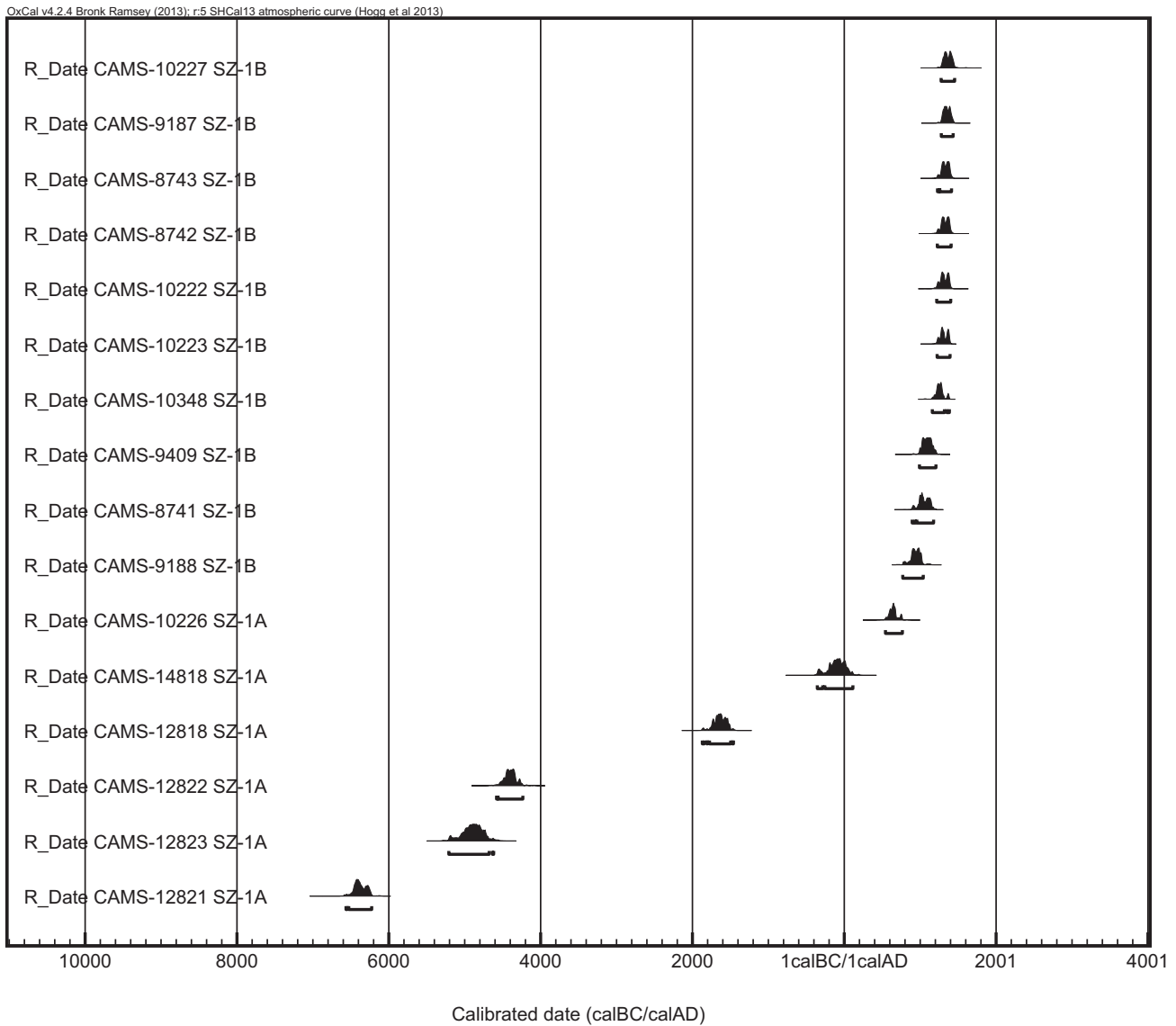


Figure 5.3. Oxcal plot of AMS radiocarbon dates on bird and rat bones from zones SZ-1A and -1B.

Ramsey 2009a) and presumably resulting from the incorporation of older materials into younger deposits through such disturbances as digging oven pits.

In all, 71 ¹⁴C dates are now available from site MAN-44. The initial set of 30 samples from 1989–1991 on unidentified wood charcoal analyzed using the liquid scintillation dating method then current (and with standard errors typically in the range of ± 60–80 years) provided a general indication of the site’s chronology but were inadequate for assigning tight temporal spans to the stratigraphic zones. Subsequent dating of the site’s basal deposits with AMS dates on bird and rat

bones, as well as on the sequence of cultural deposits with AMS dates on identified, short-lived carbonized plant remains, has now resulted in a more refined data set that can be used to assign temporal phases to the stratigraphic sequence.

Bayesian Modeling of the Tangatatau Sequence

A Bayesian approach to modeling and calibration of radiocarbon dates has increasingly come to the fore in Pacific archaeology (e.g., Allen and Morrison 2013; Athens et al. 2014; Denham et al. 2012; Dye 2011; Field et al. 2011). The principal advantage gained

Table 5.3 High-Precision AMS Dates on Taxonomically Identified Carbonized Macrobotanical Remains from Site MAN-44

Lab No.	Unit	Level	Zone	Dated Material	$\delta^{13}\text{C}$	Conventional ^{14}C Age	\pm	Calibrated Age Range AD, $2\sigma^a$
Beta-293377	E34	10	1B/2	<i>Morinda citrifolia</i> charcoal	-23.9	910	30	1048–1084 (8.5%), 1140–1230 (85.7%), 1250–1261 (1.2%)
Beta-293378	E34	11	2	<i>Hibiscus tiliaceus</i> charcoal	-25.2	660	30	1299–1399
Beta-293379	F36	8	2	<i>Aleurites moluccana</i> endosperm	-26.5	640	30	1301–1366 (64.6%), 1374–1410 (30.8%)
UCIAMS-164888	D34	8	2	<i>Aleurites moluccana</i> endosperm	-26.3	670	15	1301–1367 (73.1%), 1374–1394 (22.3%)
UCIAMS-164889	D34	9	2	<i>Aleurites moluccana</i> endosperm	-24.9	620	15	1320–1350 (45.9%), 1386–1410 (49.5%)
UCIAMS-164890	D34	6	3	<i>Aleurites moluccana</i> endosperm	-22.8	585	15	1394–1425
UCIAMS-164891	D34	7	3	<i>Aleurites moluccana</i> endosperm	-25.1	625	15	1320–1350 (54.3%), 1386–1406 (41.1%)
UCIAMS-164892	D35	3	6	<i>Aleurites moluccana</i> endosperm	-25.5	590	15	1391–1426
UCIAMS-164893	E31	6	7	<i>Aleurites moluccana</i> endosperm	-27.9	410	20	1452–1511 (61.9%), 1550–1557 (1.1%), 1575–1623 (32.4%)
UCIAMS-164894	D32	6	8	<i>Aleurites moluccana</i> endosperm	-26.7	635	15	1319–1352 (66.1%), 1385–1402 (29.3%)
UCIAMS-164895	F35	2	9	<i>Aleurites moluccana</i> endosperm	-24.8	380	20	1477–1628
UCIAMS-164896	E30	7	8	<i>Ipomoea batatas</i> parenchyma	-23.5	385	15	1463–1517 (32.7%), 1540–1625 (62.7%)
UCIAMS-164897	E36	8	2	<i>Pandanus tectorius</i> drupe	-23.3	660	15	1306–1362 (73.2%), 1377–1396 (22.2%)
UCIAMS-164898	E34	10	2	<i>Pandanus tectorius</i> charcoal	-23.2	720	15	1284–1316 (52.8%), 1356–1382 (42.6%)
UCIAMS-175448	D31	5	8	<i>Aleurites moluccana</i> endosperm	-26.9	390	15	1460–1515 (38.4%), 1540–1625 (57.0%)
UCIAMS-175449	D32	1	17	<i>Cordyline fruticosa</i> parenchyma	-24.2	240	15	1652–1675 (26.9%), 1737–1799 (68.5%)
UCIAMS-175450	D33	7	5	Tuber parenchyma	-25.3	410	15	1455–1509 (66.3%), 1584–1620 (29.1%)
UCIAMS-175451	D34	3	8	Tuber parenchyma	-30.4	365	15	1497–1631
UCIAMS-175452	D34	4	6	<i>Aleurites moluccana</i> endosperm	-27.2	425	15	1452–1502 (82.4%), 1595–1613 (13.0%)
UCIAMS-175453	D35	3	6	<i>Aleurites moluccana</i> endosperm	-25.3	425	15	1452–1502 (82.4%), 1595–1613 (13.0%)
UCIAMS-175454	E30	3	15	Tuber parenchyma	-25.4	355	15	1500–1597 (80.2%), 1611–1635 (15.2%)
UCIAMS-175455	E30	4	15	<i>Saccharum officinarum</i> stem	-24.3	315	15	1510–1577 (39.7%), 1621–1654 (55.7%)
UCIAMS-175456	E30	5	F2	<i>Saccharum officinarum</i> stem	-24.6	365	15	1497–1631
UCIAMS-175457	E32	4	8	Unidentified seed	-25.6	355	15	1500–1597 (80.2%), 1611–1635 (15.2%)
UCIAMS-175458	G35	2	9	Tuber parenchyma	-22.8	405	15	1456–1510 (59.9%), 1573–1623 (35.5%)

^aCalibrations based on Southern Hemisphere SHCal13 calibration curve, generated by Oxcal online radiocarbon calibration.

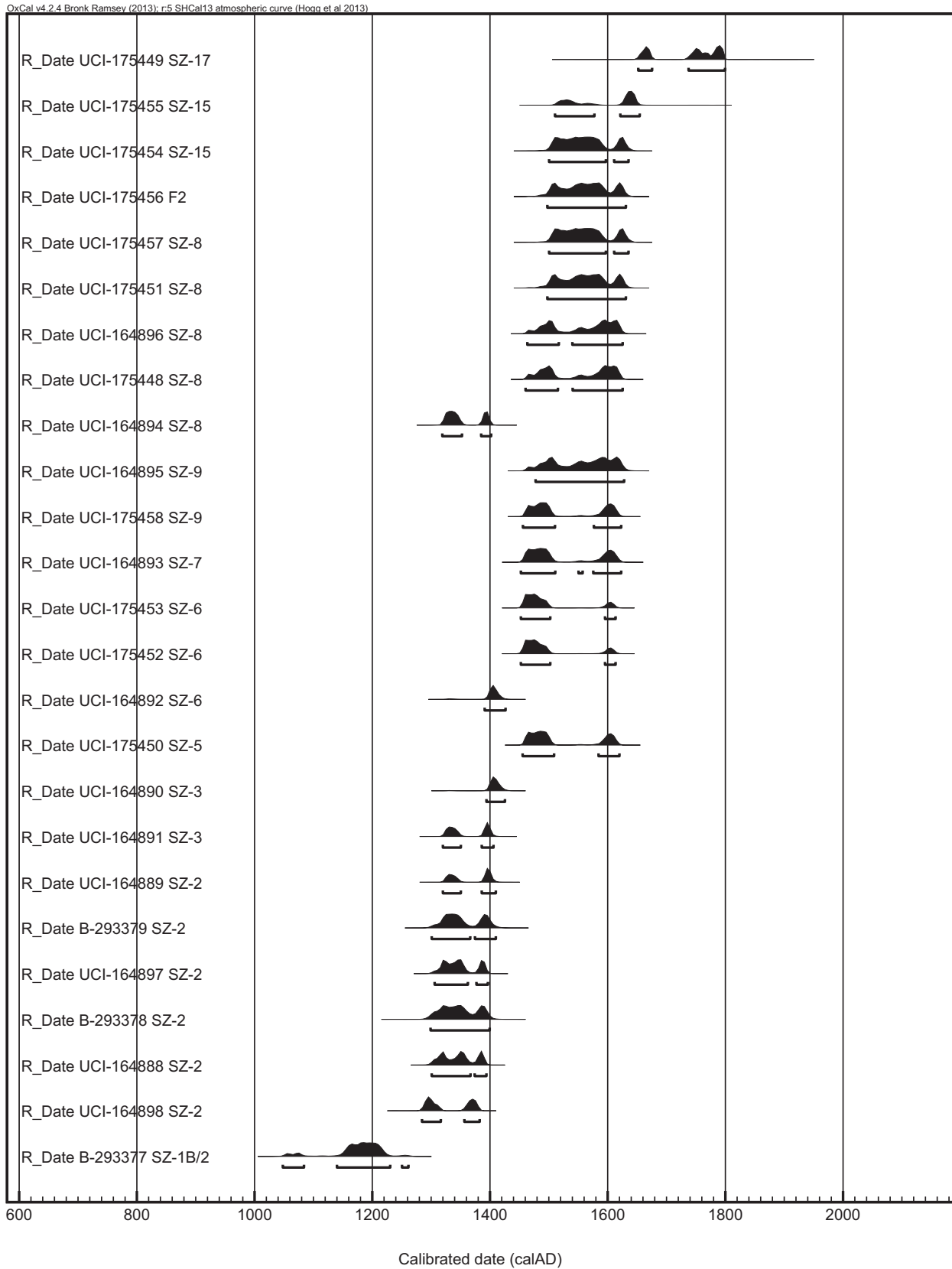


Figure 5.4. Oxcal plot of AMS radiocarbon dates on identified, short-lived plant remains from site MAN-44.

through the application of a Bayesian approach is that additional key information can be incorporated, especially stratigraphic relationships (such information is referred to as *prior* probabilities). Such prior information as the relative stratigraphic position of dated samples is combined in Bayesian modeling with the *likelihood* probabilities resulting from the actual ^{14}C measurements to produce *posterior* probabilities (referred to in Bayesian terminology as “highest posterior density [HPD] regions”; see Buck et al. 1991).

Some basic principles and terms need to be clarified before laying out the Bayesian model for site MAN-44. Given a stratum, k , within a depositional sequence such as at MAN-44, with one or more radiocarbon dates, the time period represented by stratum k can be stated mathematically as α_k minus β_k , where α (or the alpha parameter) is the early bounding temporal estimate for stratum k , and β (or the beta parameter) is the later bounding temporal estimate. Individual likelihood estimates are provided by the series of radiocarbon dates (the theta parameters) associated with stratum k , designated $\theta k_{(1)}, \theta k_{(2)} \dots \theta k_{(n)}$, with the relationship between all three kinds of parameters being: $\alpha_k > \theta_{k(1..n)} > \beta_k$. If stratum k directly overlies another stratum j , with abutting stratigraphic contacts and no indication of a hiatus in deposition, then the relationship between those two strata would be specified as

$$\alpha_j > \theta_{j(1..n)} > \beta_j = \alpha_k > \theta_{k(1..n)} > \beta_k.$$

Of course, other kinds of stratigraphic relationships can also be specified in a Bayesian model.

Bayesian modeling of the stratigraphic sequence in the main excavation block at site MAN-44 was conducted using the BCal online calibration tool hosted by the University of Sheffield (<http://bcal.shef.ac.uk/>; see Buck et al. 1999). Given the large standard errors associated with most of the initial radiocarbon dates obtained in 1991–1993 and the fact that they were run on unidentified wood charcoal (hence leaving the potential for old wood unresolved), I chose to base the Bayesian analysis exclusively on the suite of high-precision AMS dates (Tables 5.2 and 5.3). However, the two Type T outliers noted earlier (samples UCIAMS-164892 and UCIAMS-164894) were excluded from the Bayesian model. In all, a total of 38 AMS radiocarbon dates were incorporated into a Bayesian model for the site.

The Bayesian model constructed for the main excavation block at MAN-44 is represented schematically in Figure 5.5. The model was constructed on the basis

of the prior information provided by the stratigraphic sequence, as discussed in Chapter 4 (see Figure 4.20). Ten groups were defined, each group including one or more radiocarbon dates (the theta parameters). In most cases, a group is equivalent to a single stratigraphic zone, although zones SZ-6 and SZ-7 were combined in a single group as they are regarded as being contemporaneous in the stratigraphic sequence (see Figure 4.20). In most cases, the relationship between zones was defined as “abutting” because the strata lie conformably, one succeeding the other with no indication of a hiatus. However, where intervening strata were not dated (as between SZ-3 and SZ-5, SZ-8 and SZ-15, and SZ-15 and SZ-17), these relationships were specified simply as “earlier” and “later” rather than “abutting.” Zone SZ-9 was specified as having an abutting contact with underlying SZ-6 and SZ-7 and being earlier than SZ-17. The model was calibrated with a minimum sample size of 50,000 and a convergence checking sensitivity level of 4 (stringent).

Results of the calibrated model are presented in Table 5.4, where the HPD estimates (95 percent probability) for the “alpha” and “beta” parameters (lower and upper boundaries) for each group are provided. The probability distributions of selected alpha parameters are displayed graphically in Figure 5.6. Table 5.5 presents the posterior probability estimates (HPD regions) for each of the radiocarbon dates used in the model (the theta parameters). Finally, Table 5.6 presents estimated elapsed time ranges for each of the modeled groups.

Chronology of the Tangataau Rockshelter

Zone SZ-1A lies at the base of the MAN-44 stratigraphic sequence, underling the Polynesian occupation deposits. A floury-textured, calcareous sediment derived primarily from decomposition of the *makatea* limestone wall and roof of the rockshelter (see Chapter 4), zone SZ-1A contains the shells of native land snails, fragments of land crabs, and the bones of a number of taxa of extinct or extirpated landbirds and of several species of seabirds (see Chapter 6). The six AMS ^{14}C dates from SZ-1A, all on landbird bones, indicate that this deposit accumulated gradually over a period of more than 7,000 years, beginning in the early to mid-Holocene between 9138 and 6277 cal BC and ending between cal AD 850 and 1136 (parameters α_1 and β_1 , Table 5.4). Zone SZ-1A is thus a palimpsest representing a lengthy period during which land- and

MAN44 AMS Series 5

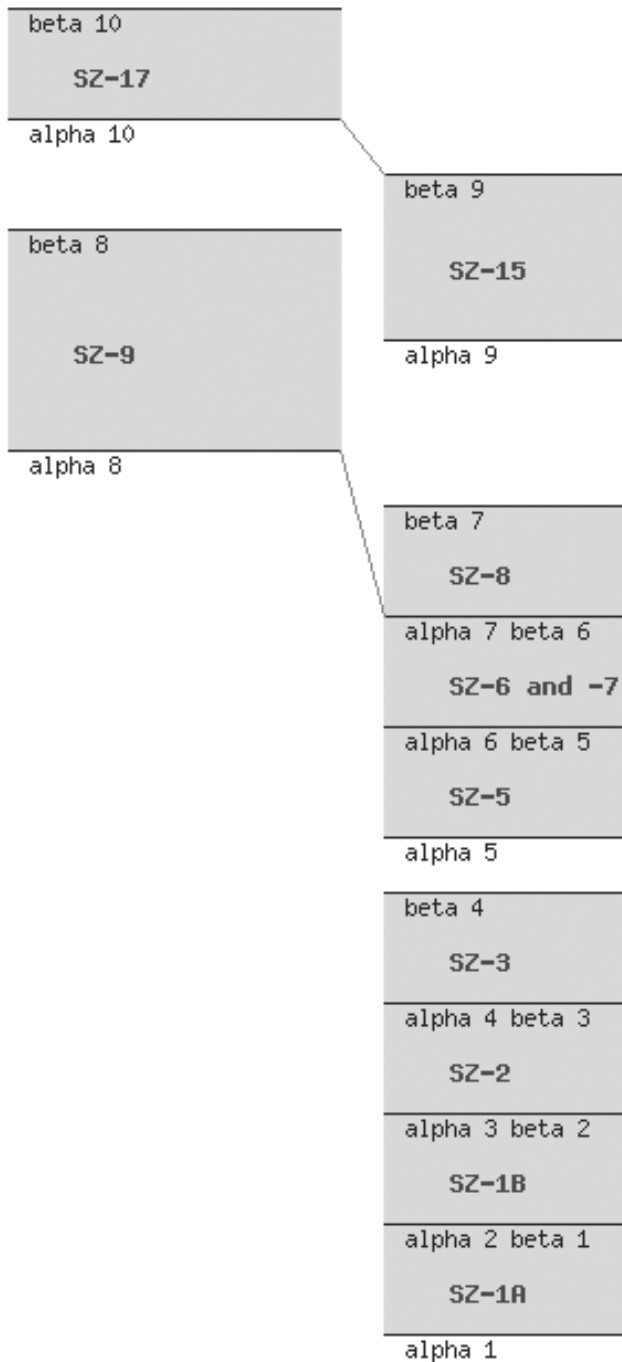


Figure 5.5. Schematic representation of the Bayesian calibration model for radiocarbon dates from the main excavation block of site MAN-44.

seabirds nesting or roosting on the *makatea* cliffs overhanging the rockshelter contributed their bones to the deposit through natural taphonomic processes.

The upper 5 to 15 cm of zone 1, designated SZ-1B, contrasts with the underlying SZ-1A in its distinct “dusky red” color (due to oxidation from burning) and unlike SZ-1A contains dispersed flecks and chunks of charcoal. Like SZ-1A, zone SZ-1B contains significant quantities of land- and seabird bones, but in addition, it also has numerous bones of the Polynesian-introduced Pacific rat (*Rattus exulans*). This commensal rat was dispersed by colonizing Polynesians to virtually every island group (Tate 1935); it is virtually ubiquitous in early occupation sites in Polynesia. *R. exulans* has a high reproduction rate, with a mature female producing several litters per year of anywhere from one to seven offspring each (Moller and Craig 1987; Tamarin and Malecha 1972). On an oceanic island such as Mangaia, which lacked natural predators for the rats, it is likely that the population of *R. exulans* exploded exponentially following human arrival. While the absence of artifacts signals that SZ-1B does not represent a permanent human occupation, the presence of both charcoal and rat bones leaves no doubt that Polynesians were present on Mangaia Island during the period that SZ-1B accumulated.

Ten AMS ¹⁴C dates were run by CAMS/LLNL on bone samples from SZ-1B, nine on *R. exulans* bones and one date on a bone of an extinct parrot (*Vini vidivici*). In addition, three dates on unidentified wood charcoal samples from SZ-1B were obtained from Beta Analytic in 1989–1991 (Table 5.1, Figure 5.1), while a fourth AMS date (Beta-293377) was recently obtained on identified charcoal of *Morinda citrifolia*, a short-lived shrub regarded as a Polynesian “canoe plant” (Whistler 2009:148–149). Bayesian calibration of the 11 AMS dates sets a lower boundary (α_2) of cal AD 850 to 1136 and an upper boundary (β_2) of cal AD 1315 to 1386 for this zone (Table 5.4). The two earliest dates on *R. exulans* bones from SZ-1B have Bayesian calibrated age ranges of cal AD 906 to 1050, 1079 to 1156, and 983 to 1180 (07 and 08, Table 5.5). Also notable from SZ-1B is the sample of *Morinda citrifolia* charcoal, which has an age range of cal AD 1051 to 1082 and 1141 to 1231 (010, Table 5.5). *M. citrifolia* is a medicinal plant (sometimes also used as a famine food) that was thought to have been transported by Polynesians to Eastern Polynesia on their voyages (Whistler 2009:148–149). The burning of *M. citrifolia*

Table 5.4 Highest Posterior Density (HPD) Estimates for Bayesian Calibration Model Parameters, in the Main Excavation Block of MAN-44

Model Groups	Parameter	95% HPD Intervals (cal BP)	95% HPD Intervals (cal BC/AD)
SZ-1A	α_1	11088–8227	9138–6277 BC
	β_1	1100–814	AD 850–1136
SZ-1B	α_2	1100–814	AD 850–1136
	β_2	635–564	AD 1315–1386
SZ-2	α_3	635–564	AD 1315–1386
	β_3	585–545	AD 1365–1405
SZ-3	α_4	585–545	AD 1365–1405
	β_4	555–504	AD 1395–1446
SZ-5	α_5	534–467	AD 1416–1483
	β_5	490–458	AD 1460–1492
SZ-6 and SZ-7	α_6	490–458	AD 1460–1492
	β_6	482–441	AD 1468–1509
SZ-8	α_7	482–441	AD 1468–1509
	β_7	450–339	AD 1500–1611
SZ-9	α_8	465–438, 435–340	AD 1485–1512, 1515–1610
	β_8	457–425, 380–230	AD 1493–1525, 1570–1720
SZ-15	α_9	438–371, 361–316	AD 1512–1579, 1589–1634
	β_9	423–340, 332–237	AD 1527–1610, 1618–1713
SZ-17	α_{10}	309–158	AD 1641–1792
	β_{10}	208–1	AD 1742–1949

wood in the rockshelter suggests that the plant was already established in the vicinity of the site prior to the beginning of permanent habitation.

The earliest rat bone dates from zone SZ-1B indicate that Polynesians had discovered Mangaia and introduced the Pacific rat prior to AD 1200. This is consistent with recent radiocarbon dates from other central Eastern Polynesian islands, all suggesting a rapid expansion of Polynesians throughout this region between roughly AD 900 and 1100. For Mo'orea Island in the Society Islands, for example, Kahn and Sinoto (in press) report early colonization period sites dating to the eleventh to thirteenth centuries, while palynological evidence for human presence on the island (in the form of *Colocasia* pollen) dates to cal AD 890 to 950 (Stevenson et al. in press). In the Cook Islands, Allen and Morrison (2013) place

initial human activities on Moturakau Islet at between the mid-eleventh and thirteenth centuries. Conte and Molle (2014:Table 1) report two calibrated radiocarbon dates from the deepest layer of the Hane site on Ua Huka Island in the Marquesas with age ranges of cal AD 891 to 1024 and 894 to 1014. And, for the early Onemea dune site on Taravai Island in the Mangareva (Gambier) group, Kirch et al. (2010) report a series of radiocarbon dates establishing the initial use of the site at between cal AD 950 and 1250.

Zones SZ-2 and SZ-3 represent the first permanent occupation of Tangatatau Rockshelter, marked by rapid accumulation of a dense deposit of charcoal and ash-rich sediment containing abundant lithic debitage along with finished adzes, fishhooks, tattooing combs, and other artifacts. Bayesian calibration of the eight AMS dates obtained on botanically identified,

Table 5.5 Bayesian Posterior Age Estimates for Radiocarbon Dates from Stratigraphic Zones SZ-1B to SZ-17, Site MAN-44

BCal Model Parameter	Lab No.	Zone/Feature	Bayesian Posterior Probability Age Estimate (cal AD)
07	CAMS-9188	SZ-1B	906–1050, 1079–1156
08	CAMS-8741	SZ-1B	983–1180
09	CAMS-9409	SZ-1B	1016–1209
010	Beta-293377	SZ-1B	1051–1082, 1141–1231
011	CAMS-10348	SZ-1B	1176–1318, 1360–1372
012	CAMS-10223	SZ-1B	1223–1335, 1345–1374
013	CAMS-10222	SZ-1B	1223–1376
014	CAMS-8742	SZ-1B	1228–1252, 1258–1375
015	CAMS-8743	SZ-1B	1230–1252, 1261–1375
016	CAMS-9187	SZ-1B	1273–1376
017	CAMS-10227	SZ-1B	1274–1377
018	UCIAMS-164898	SZ-2	1355–1388
019	UCIAMS-164888	SZ-2	1335–1394
020	Beta-293378	SZ-2	1332–1397
021	UCIAMS-164897	SZ-2	1329–1362, 1374–1395
022	Beta-293379	SZ-2	1325–1362, 1372–1399
023	UCIAMS-164889	SZ-2	1327–1350, 1383–1400
024	UCIAMS-164891	SZ-3	1390–1407
025	UCIAMS-164890	SZ-3	1394–1416
026	UCIAMS-175450	SZ-5	1456–1486
027	UCIAMS-175452	SZ-6	1465–1498
028	UCIAMS-175453	SZ-6	1466–1498
029	UCIAMS-164893	SZ-7	1466–1499
030	UCIAMS-175448	SZ-8	1479–1524, 1540–1563, 1575–1600
031	UCIAMS-164896	SZ-8	1481–1528, 1539–1567, 1577–1595
032	UCIAMS-175451	SZ-8	1489–1573
033	UCIAMS-175457	SZ-8	1493–1573
034	UCIAMS-175458	SZ-9	1487–1508, 1572–1622
035	UCIAMS-164895	SZ-9	1492–1513, 1540–1628
036	UCIAMS-175454	SZ-15	1522–1593, 1610–1642
037	UCIAMS-175455	SZ-15	1521–1554, 1556–1580, 1621–1650
038	UCIAMS-175449	SZ-17	1661–1671, 1737–1798

Table 5.6 Modeled Elapsed Time Estimates for Stratigraphic Zones, Main Excavation Block of Site MAN-44

Zone	Elapsed Time (years)
SZ-1A	7,252–10,364
SZ-1B	202–515
SZ-2	3–73
SZ-3	0–64
SZ-5	0–58
SZ-6 and SZ-7	0–37
SZ-8	0–118
SZ-9	0–166
SZ-15	0–141
SZ-17	0–226

short-lived taxa from these stratigraphically abutting zones gives a lower boundary of cal AD 1315 to 1386 and an upper boundary of cal AD 1395 to 1446 (α 3 and β 4, Table 5.4). Sample UCIAMS-164898 is of particular significance in pinning down a date for the onset of occupation in the rockshelter. This charcoal of *Pandanus tectorius* (a relatively short-lived monocot shrub) was recovered in unit E34, from ashy beds immediately above the contact between zones SZ-2 and SZ-1B. This sample yields a modeled age range of cal AD 1355 to 1388 (018, Table 5.5). The Bayesian model estimates that SZ-2 accumulated over a maximum elapsed time span of 73 years, while SZ-3 had a maximum elapsed time span of 64 years. It seems likely, however, that the entire SZ-2 and SZ-3 occupation lasted less than one century.

The SZ-3 deposit was truncated over parts of the main excavation block by the large pits of zones SZ-4A and SZ-4B and by feature F37. This was followed by the deposition of zones SZ-5, SZ-6, and SZ-7, which consist primarily of ashy midden deposits. The lower boundary of SZ-5 (α 5) is cal AD 1416 to 1483, while the upper boundary of SZ-7 (β 6) is cal AD 1468 to 1509, indicating that this sequence of deposits dates to the fifteenth century. The estimated elapsed time span for SZ-5 is a maximum of 58 years and that for SZ-6 and SZ-7 is a maximum of 37 years; again, the total span for all three zones is probably less than 100 years.

Zone SZ-8 is of particular interest as this represents another period of intensive occupation, being similar to SZ-2 and SZ-3 in the concentration of formal artifacts

such as fishhooks, adzes, abraders, and other tools (see Chapter 10). There are four high-precision AMS dates from SZ-8 (030 to 034, Table 5.5); the lower boundary for SZ-8 is cal AD 1468 to 1509 (α 7), and the upper boundary is cal AD 1500 to 1611 (β 7). The estimate of elapsed time for SZ-8 is somewhat longer than for the preceding zones, between 0 and 118 years. It would appear that the SZ-8 occupation may have spanned most of the sixteenth century.

As discussed in Chapter 4, the stratigraphic position of zone SZ-9 in the sequence is not entirely clear, as this deposit was present only in the eastern part of the main excavation block, with intervening disturbances that prevented direct stratigraphic correlation (see Figure 4.20). However, on the available stratigraphic evidence, zones CZ-8 and CZ-9 were thought to be largely contemporaneous. This is borne out by the Bayesian calibration of the two AMS dates from SZ-9 (034 and 035), which have age ranges putting them between the late fifteenth and early seventeenth centuries (Table 5.5).

Zone SZ-15 has two AMS dates, yielding a calibrated lower boundary of AD 1512 to 1579 and 1589 to 1634 (α 9) and an upper boundary of AD 1527 to 1610 and 1618 to 1713 (β 9, Table 5.4). Finally, zone SZ-17, which caps the stratigraphic sequence over the entire site and contains both indigenous artifacts and some items of postcontact Euro-American origin, was dated with just a single AMS date with age ranges of cal AD 1661 to 1671 and 1737 to 1798 (038, Table 5.5). This deposit probably began to accumulate in the mid-seventeenth century, prior to European contact, and has continued to be laid down through intermittent use in the postcontact period, as indicated by the presence of Euro-American artifacts.

To sum up, the stratigraphic sequence at the Tangatatau Rockshelter has been extensively dated with 71 radiocarbon dates, an initial 30 dates on unidentified wood charcoal, and a more recent series of 41 AMS dates on bird or rat bones and identified, short-lived plant remains. Bayesian modeling, relying exclusively on the AMS dates, provides a calibrated temporal sequence for 10 of the stratigraphic zones. The oldest, pre-Polynesian stratum accumulated very gradually over a period of more than 7,000 years. Polynesian arrival on Mangaia is indicated by the presence in zone SZ-1B of the introduced Pacific rat, dated to between the tenth and twelfth centuries. Initial occupation within the rockshelter, represented by zone SZ-2,

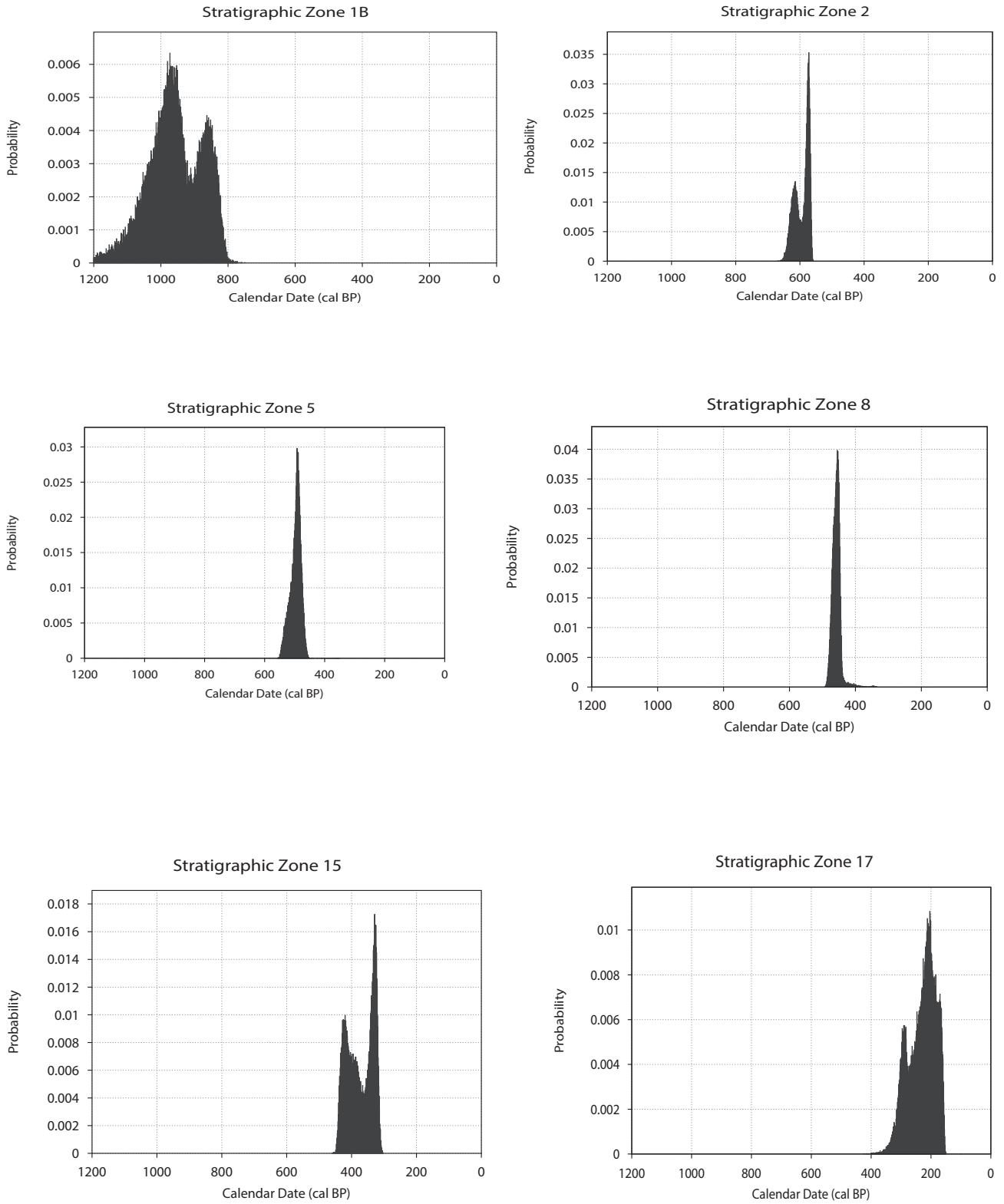


Figure 5.6. Probability distributions (HPD) for Alpha parameters for selected zones of the site MAN-44 sequence.

dates to the mid-fourteenth century. There appears to have been virtually continuous use of the rockshelter thereafter, with the higher stratigraphic deposits accumulating in the fifteenth to eighteenth centuries. Some intermittent use of the site continued into the post-European contact era.

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6

Vertebrate Fauna from Tangatatau Rockshelter: Mammals, Birds, and Reptiles

Patrick Vinton Kirch

The alkaline, carbonate-rich sediments of Tangatatau Rockshelter (see Chapter 4) provided an ideal depositional environment for bone preservation. In the course of our excavations 35,727 individual vertebrate faunal specimens were recovered from the main block of units. Eighty-nine percent of these vertebrate specimens consisted of fish bones, which are analyzed separately by Butler in Chapter 7. Here I summarize the 3,789 specimens of mammal, bird, and reptile bones from site MAN-44.

Methods

Vertebrate faunal remains were systematically recovered from all excavation units and levels by sieving of sediment through nested ½-, ¼-, and ⅛-in. mesh screens. Initial sorting of bone into major categories (fish, mammal, bird, etc.) was carried out by David Steadman, who sent the sorted fish bones to Butler and the mammal bones (except for rat and fruit bat) to Kirch for further analysis. Steadman retained the rat, fruit bat, and bird bones in his laboratory (these specimens are currently housed at the Florida State Museum, Gainesville). A digital database (originally prepared in Paradox and later converted to Excel) of the fruit bat and bird bones, listing each cataloged specimen separately with identification to species and skeletal element, was prepared by Steadman; this database provides the basis for the analysis of fruit bat and

bird remains from site MAN-44 in this chapter (the database is available at www.dig.ucla.edu/tangatatau). Steadman (2006:213–222, Tables 7-5 and 7-6) also published a summary analysis of the bird bones from site MAN-44.

The mammal bones (excluding rats and fruit bats) were analyzed in the Oceanic Archaeology Laboratory at U.C. Berkeley in 1992–1993 by Susan Antón and Pia Anderson, then graduate students in physical anthropology and archaeology, respectively. Identification of bones to skeletal element and taxon were made by comparison to a modern pig (*Sus scrofa*) skeleton collected on Mangaia and to two modern, small European dog (*Canis familiaris*) skeletons in the collection of the Museum of Vertebrate Zoology at Berkeley. A small number of skeletal elements initially identified as being human were further compared with human osteological reference collections in the Phoebe A. Hearst Museum of Anthropology at Berkeley. In addition to identifying the mammal bones to taxon and element, Anderson and Antón systematically observed patterns of fracturing, burning, and other modifications. These observations are included in the MAN-44 Mammal Fauna database, which, along with two unpublished manuscript reports (Anderson and Antón MS A, MS B), provided the data on which this summary of pig, dog, and human remains from MAN-44 is based.

In reporting the vertebrate faunal remains from MAN-44, we use number of identified specimens (NISP) as the primary means of quantification, rather than the minimum number of individuals (MNI). This is due to the high degree of fragmentation of many of the specimens, which renders determination of MNI highly problematic. However, as Grayson (1984) demonstrated, MNI and NISP are in general highly correlated, especially when sample sizes are large. In comparing faunal assemblages from different stratigraphic zones—especially when looking at overall temporal trends—we also use concentration indices (CIs) calculated as NISP per cubic meter of deposit, which provides a sample size correction for the different volumes of sediment excavated in each stratigraphic zone.

Mammals

A total of 2,872 mammal bones were recovered from the MAN-44 excavations, of which 2,360 were of the Pacific rat (*Rattus exulans*). Of the 512 nonrat bones,

485 could be assigned to a specific stratigraphic zone in the main excavation block (Table 6.1).

Medium Mammal

Aside from rat, the largest category of mammal bone (214 NISP) consists of fragments—primarily of long bones such as the femur, tibia, and humerus—of mammals in the size range of pig and dog. Given that no other quadruped vertebrates were present on Mangaia in precontact times, it is virtually certain that all of this material (excepting possibly a few specimens in postcontact zone SZ-17) represents either pig or dog. Furthermore, given that identified pig outnumbers identified dog bones by more than four to one, the majority of the medium mammal bone fragments most likely derived from pigs. Nonetheless, the fragments are too small to state with absolute certainty that they represent pigs. Fully 50 percent of the medium mammal bone shows signs of burning, with about 33 percent burned through. Eight percent were fractured

Table 6.1 Stratigraphic Distribution of Mammal Bones (NISP) from the Main Excavation Block at Site MAN-44

Zone or Feature	Medium Mammal	Pig	Dog	Rat	Fruit Bat	Human	Porpoise	Total
SZ-19	10	10	4	69				93
SZ-18	4	5		47				56
SZ-17	10	12		83		3	2	110
SZ-15	5	12		352		5		374
SZ-14				29				29
SZ-13				7				7
SZ-11				10				10
SZ-10	2	4	1	131				138
SZ-9		1		22				23
SZ-8	55	31	4	330		7		427
SZ-7	1	2	2	15				20
SZ-6	6	10		40		3	1	60
SZ-5	4	5		23			1	33
F37	3				7			10
SZ-4B	5	3		72	11			91
SZ-4A	4	8		123	3	1	1	140
SZ-3	73	30	8	438	4	5		558
SZ-2	30	13	13	506	21	2		585
SZ-1B	2			62	10			74
SZ-1A				1	6			7
Totals	214	146	32	2,360	62	26	5	2,845

while “green” while 4 percent show signs of gnawing, probably by rats.

Pig (*Sus scrofa*)

The domestic pig was one of several animals purposefully transferred into Remote Oceania by Austronesians and was present throughout most of the Polynesian islands. In several islands, including Mangaia, however, the pig became extirpated prior to European contact (Kirch 2001). The Rev. William W. Gill (1876:15) reported that “whilst pigs were found on Atiu and Rarotonga at the time of their discovery, on the neighbouring islands of Aitutaki and Mangaia the largest quadruped existing at that time was the rat” (see also Hiroa 1944:15; Williams 1837:244). Gill notes, however, that several place names incorporating the widespread Polynesian word for pig, *puaka*, provided evidence “that at one time they had at least a tradition of pigs.” The missionary Williams introduced a breeding pair of pigs to Mangaia in 1830; by 1852, their offspring had multiplied sufficiently that Gill (1876:91) reports a “grand feast” at which “upwards of a thousand hogs were killed and eaten.”

A total of 179 pig bones were excavated, of which 146 could be assigned to stratigraphic zones (Table 6.1). Pig bones are present throughout most of the MAN-44 stratigraphic sequence, including in the late prehistoric zone SZ-15, which is somewhat surprising in light of their absence on the island at the time of Williams’s visit in 1830; it would seem that the extirpation of pigs was a late event in the island’s precontact history. (The presence of pig bones in zone CZ-17 may be due to their reintroduction by the London Missionary Society missionaries.) Pig bones are quite abundant in SZ-2 and SZ-3 and indeed have their highest density (concentration index [CI] of 15.2 NISP/m³) in SZ-3. They are also, however, well represented in SZ-8 (CI of 11.6 NISP/m³).

Although the pig material is too fragmentary to attempt a detailed analysis of age, a significant number of specimens were from immature individuals, suggestive of regular culling of the herd. As with the medium mammal, a large number of the pig bones (43 percent) show signs of burning. Eight percent show signs of being fractured while the bone was still “green,” and 11 percent exhibit gnawing marks.

Dog (*Canis familiaris*)

Although also a widespread domestic animal in Polynesia, dogs like the pig were absent from Mangaia at the time of missionary contact (Hiroa 1944:15).

Thirty-two identifiable dog bones were recovered from MAN-44, and all of these could be assigned to a specific stratigraphic zone (Table 6.1). Dog bones have their highest densities in SZ-2 (CI of 8.2 NISP/m³) and SZ-3 (CI of 4.1 NISP/m³); they are absent from the higher parts of the section (above SZ-10). This suggests that dogs were extirpated from Mangaia some time prior to European contact and certainly prior to the elimination of pigs from the island.

In a pattern consistent with medium mammal and pig bone, the dog bones display a high degree of burning (78 percent), with 66 percent of the bones burned through. Nine percent exhibit signs of gnawing.

Pacific Rat (*Rattus exulans*)

The diminutive Pacific rat (*R. exulans*) has a wide distribution across the Pacific, having been transported by humans from an original homeland in Island Southeast Asia out into Remote Oceania, where the species is found on virtually every island (Tate 1951). Whether it was purposefully transferred as a food item has been a matter of some debate, but there is no doubt that in Mangaia, rats were a significant flesh food at the time of European contact. Williams, who visited the island in 1830, provides important ethnographic details on the consumption of rats on Mangaia:

In a meeting held with the Christians [i.e., those who had already converted], our advice was solicited upon several topics; among which was “rat-eating.” As Mangaia was not so abundantly supplied with fish as some other islands, and as there were no animals except rats, until I visited it, these formed a common article of food; and the natives said they were exceedingly “sweet and good;” indeed a common expression with them, when speaking of any thing delicious, was, “It is as sweet as a rat.” They find no difficulty in catching them in great numbers; which they do in many ways, but principally by digging a hole, and strewing in it a quantity of candle-nut (*aleurites*), and when a sufficient number of rats were in the hole, they drew a net over it, and secured them all. Having obtained as many as they wish, they singe the hair off on hot stones, wrap them up in leaves, and bake them. Saturday was their principal rat-catching day, as they were desirous of having “animal food” to eat with their cold vegetables on the Sabbath [Williams 1837:244–245].

Hiroa (1944:247) documents no less than five named methods of rat-catching on Mangaia. Although he claimed that the consumption of rats had stopped due to missionary influence, our Mangaian friends in 1991 told us that many people on the island still caught and enjoyed eating rats.

Rat bones were by far the most common mammal remains in site MAN-44, making up 82 percent of the mammal bone assemblage; their distribution by stratigraphic zone is shown in Table 6.1. There are a significant number of rat bones in SZ-1B, which is not strictly speaking a cultural deposit; this suggests that rats may already have spread over the island prior to the initial use of Tangatatau as an occupation site. They then reach high densities in the first two occupation deposits SZ-2 (320.2 NISP/m³) and SZ-3 (221.7 NISP/m³). Densities fluctuate somewhat in the higher stratigraphic zones but are again high in SZ-10 to SZ-11 (320.4 NISP/m³) and SZ-15 (268.7 NISP/m³).

Steadman (personal communication, 1993) examined a subsample of 1,053 rat bones from excavation units D31, D32, E31, and E32 for taphonomic patterns, finding that 64 percent consisted of axial skeletal elements and 36 percent of limb elements. Of the limb elements, 75 percent were broken, strong evidence of the animals being consumed. Furthermore, 53 percent of all bones were burned, again consistent with Williams's description of the rats being singed and baked.

Pacific Flying Fox (*Pteropus tonganus*)

The Pacific flying fox or fruit bat, also known as the insular flying fox (*Pteropus tonganus*), is a smallish, brown to black bat with a buff or cream-colored mantle (Hill 1979), fairly common on Mangaia at the time of our fieldwork in 1991. This nocturnal frugivore is known to be an important pollinator in some Pacific Islands (Cox and Elmqvist 2000). The Mangaians, who call this bat *moakirikiri*, prize its flesh, usually taking them with a shotgun at night while the bats are feeding on mangoes or other fruit around the villages.

P. tonganus has a geographic distribution from the Eastern Solomon Islands through the southwestern Pacific to Fiji, Tonga, Samoa, and the Cook Islands. Until recently, the Southern Cook Islands were thought to be the easternmost limit of the species' natural distribution, but the discovery of a few bones of *P. tonganus* on Rurutu Island in the Austral

archipelago in an archaeological context dated to between AD 1064 and 1155 indicates that it may have been carried by Polynesians into the Austral group (Weisler et al. 2006; see also Hawkins et al. 2015:7).

A total of 67 bones of *P. tonganus* were recovered from the MAN-44 excavations, 62 of them in the main block. As seen in Table 6.1, the stratigraphic distribution of these bones is striking, being restricted to SZ-1 through SZ-4 and F37; no bones were found in any stratigraphic zone higher than 4B or feature F37. The greatest concentration is in the earliest occupation deposit, SZ-2, which has a concentration index of 13.3 NISP/m³, higher than that for pig or dog in the same deposit. The presence of six bones in SZ-1A and another 10 bones in SZ-1B clearly establishes *P. tonganus* as having been naturally dispersed to Mangaia rather than a Polynesian introduction.

The complete absence of *P. tonganus* in the higher stratigraphic zones of MAN-44 raises the question of whether the species became extirpated in later prehistory, only to be reintroduced to the island by humans after European contact. The lack of flying fox bones in the higher strata does not appear to be the result of sample size effects, as the vertebrate bone samples from SZ-5, SZ-7, SZ-8, and SZ-15 are all quite substantial. Weisler et al. (2006:404) quote Captain Henry Martin to the effect that "flying foxes were taken to Tahiti in the mid-nineteenth century." We believe that the most likely explanation for the total absence of *P. tonganus* bones in the higher levels of MAN-44 is that the species became extirpated on Mangaia due to a combination of overexploitation and habitat destruction with extensive deforestation but later was reintroduced, probably in the late nineteenth century. The concurrent historic period introduction of a number of exotic fruit trees (including mangoes and papaya) was probably critical in providing a food source that has allowed the flying fox population to thrive on the island in recent times.

The Mangaian name for the flying fox, *moakirikiri* (literally "chicken with fur"), offers further circumstantial evidence that the flying fox was reintroduced historically, because the widespread Polynesian name for the flying fox is *peka* or *pe'a*. This older name was presumably lost when the flying fox was extirpated in precontact times. Having no name for the animal when it was reintroduced historically, the descriptive name "chicken with fur" was coined.

Human (*Homo sapiens*)

A total of 26 NISP were identified as human (Table 6.1). Of the seven specimens from the lower occupation deposits SZ-2 and SZ-3, four are teeth, one is rib fragment, one a radius fragment, and one a long bone fragment. Zone SZ-6 has three rib fragments. Zone 8 has seven specimens, all of them tibia or other long bone fragments, most exhibiting signs of burning and bashing, and one with a spiral fracture. SZ-15 has five specimens, one a tooth, one a maxillary fragment, and the others long bone fragments exhibiting burning and bashing. Finally, SZ-17 has three bones, two long bone fragments, and a rib fragment.

Although the sample size is small, the human bones from zones SZ-6, SZ-8, and SZ-15 consist primarily of long bone fragments (and some ribs and a maxilla) that were highly fractured and burnt. Given that Manganian mortuary practices typically involved burial of entire bodies in *makatea* caves, the treatment of the human bones in MAN-44 is unlikely to represent funerary behavior. Rather, such fracturing and burning of long bones is a pattern known to be associated with marrow extraction in human bone assemblages that have been cannibalized (White 1992). While we must be cautious in extrapolating from such a small sample, this would be consistent with the ethnohistoric evidence for warfare, violence, and possibly cannibalism in the later periods of Manganian history (Gill 1894; Hiroa 1934:6, 36–83, 157–161, 179–183). The relatively small number of such bones in MAN-44, however, suggests that the processing of human victims may have taken place elsewhere, such as at the Ana Manuku (MAN-84) site in nearby Keia Valley, where Steadman et al. (2000) documented the cooking in earth ovens and processing of at least 41 human individuals (see Chapter 13). The human bones at MAN-44 could thus represent body parts brought back to the rockshelter from events held elsewhere.

Porpoise (Delphinidae)

Five bones of an unidentified species of the family Delphinidae (oceanic dolphins) were recovered from SZ-4A, SZ-5, SZ-6, and SZ-17 (Table 6.1). The specimen from SZ-5 is a small tooth, the root of which had been drilled, presumably for suspension as an ornament (see Chapter 10). A rib from SZ-4A has been worked, probably for use as a thatching needle. It is impossible to say whether the porpoises represented by these bone fragments were hunted or were scavenged from animals that had beached themselves on the island's coast.

Introduced Mammals

Two specimens of mammals introduced to Mangaia in the historic period were recovered from MAN-44, both from SZ-17, which also contained glass, iron, and other foreign trade items. One specimen is the molar tooth of a goat (*Capra* sp.), while the other is a vertebra of a cat (*Felis catus*).

Birds

A total of 909 NISP bird bones were recovered from the MAN-44 excavations, of which 734 can be assigned to one of the stratigraphic zones in the main excavation block; the complete database of avifaunal remains (as prepared in 1993) is available in the online archive. Steadman and Kirch (1990) previously reported on the avifaunal assemblage recovered from the initial 1989 excavation at MAN-44, while Steadman (2006:219–223) also summarized the MAN-44 bird bones. The bone counts given in this chapter are based on the excavated avifaunal database compiled by Steadman in 1993 (see www.dig.ucla.edu/tangataua).

Seabirds

Fourteen species of seabirds (including migratory shorebirds) are represented in the faunal assemblage; the stratigraphic distribution of seabird bones is provided in Table 6.2. By far the most abundant species is the black-winged petrel (*Pterodroma nigripennis*), a small petrel “of open seas and offshore waters near its breeding grounds” (Pratt et al. 1987:63). Bones of both this petrel and of Audubon's shearwater (*Puffinus lherminieri*), which has similar habits (Pratt et al. 1987:57), were found only from SZ-8 and higher in the stratigraphic sequence. In contrast, the Polynesian storm petrel (*Nesofregetta fuliginosa*) is present in small numbers from SZ-1B through SZ-15. This large storm petrel “nests in burrows on mountaintops or atolls” (Pratt et al. 1987:73).

Two species of tropicbird are present. The white-tailed tropicbird (*Phaethon lepturus*) is well represented in the deeper deposits from SZ-1A to SZ-4 and only spottily in the higher zones. This species nests both in cliff faces and in trees; the *makatea* cliffs of Mangaia would have provided a suitable nesting habitat. Hiroa (1944:82–83) describes a decorative headband from Mangaia in the British Museum “incorporating long tail feathers of the tropic bird.” Only a single bone of the red-tailed tropicbird (*Phaethon rubricauda*) was found, from SZ-1B.

Table 6.2 Stratigraphic Distribution of Seabird Bones (NISP) from the Main Excavation Block at Site MAN-44

Zone or Feature	<i>Puffinus lherminieri</i>	<i>Pterodroma nigripennis</i>	<i>Nesofregatta fuliginosa</i>	<i>Phaethon lepturus</i>	<i>Phaethon rubricauda</i>	<i>Fregata ariel</i>	<i>Fregata minor</i>	<i>Sula sula</i>	<i>Anous stolidus</i>	<i>Procelsterna caerulea</i>	<i>Gygis alba</i>	<i>Gygis microhynchus</i>	<i>Pluvialis dominica</i>	<i>Numenius tahitiensis</i>	Total NISP	NTAXA
SZ-19		8													8	1
SZ-18				1											1	1
SZ-17	3	10							1						14	3
SZ-15	10	46	1	1		3			3				1		65	7
SZ-14	1	2		1					2						6	4
SZ-13	1	7													8	2
SZ-10		1	1						1						3	3
SZ-9		1													1	1
SZ-8	2	19				4	4		5						34	5
SZ-7			1												1	1
SZ-5			1						1						2	2
F37			1	3								1			5	3
SZ-4B				1				1			1				3	3
SZ-4A			1	6						1	1			2	11	5
SZ-3				5							1			1	7	3
SZ-2				14			1				3	6	1	1	26	6
SZ-1B			2	2	1				1		1	4			11	6
SZ-1A				4					1		2			3	10	4
Totals	17	94	8	38	1	7	5	1	15	1	9	11	1	8	216	

Both the great frigatebird (*Fregata minor*) and the lesser frigatebird (*Fregata ariel*) are present in small numbers, mostly in the higher stratigraphic zones. It is possible that these frigate birds nested in more remote parts of the *makatea*. However, Pratt et al. (1987:84) note that they also come to “fresh water ponds to drink by swooping down and skimming [the] bill on the surface,” which might have provided opportunities for the birds to be taken with nets. Only a single specimen of the red-footed booby (*Sula sula*) was recovered from SZ-4B.

Four species of terns (Sterninae) are present. The most abundant is the brown noddy (*Anous stolidus*), primarily in the higher stratigraphic zones (although also represented in SZ-1). The blue-gray noddy (*Procelsterna cerulea*) is represented by a single bone from SZ-4A. The common fairy-tern (*Gygis alba*, or *G. alba candida*) is present in SZ-1A through -4B but not higher in the site. The little fairy-tern (*G. micro-rhyncha*) occurs mostly in SZ-1B and SZ-2, with a single specimen also from pit feature F37. Both fairy-tern species nest or roost in trees (Pratt et al. 1987:186–187).

Two migratory shorebirds are also present and listed in Table 6.2. The lesser golden plover (*Pluvialis dominica*), represented by a single specimen from SZ-2, winters in the islands of the central Pacific. The bristle-thighed curlew (*Numenius tahitiensis*), which also winters on Pacific islands, is most frequent in the lower stratigraphic deposits.

Landbirds

Seventeen species of endemic or indigenous landbirds—many of them extinct or extirpated on Mangaia in modern times—are represented in the MAN-44 assemblage, along with the Polynesian-introduced jungle fowl or chicken (Table 6.3). The stratigraphic distribution of these landbirds (with the exception of chicken and ducks) is heavily weighted to the deeper zones, especially below SZ-4. Chicken is discussed separately below.

The gray duck (*Anas superciliosa*) is present throughout the sequence, although its bones are especially abundant in SZ-15. This species inhabits streams, ponds, marshes, and taro pondfields (Pratt et al. 1987:100). The increased frequency of duck bones in the higher stratigraphic zones at MAN-44 may therefore be a reflection of increased wetland habitat as the island's taro irrigation system was developed.

Five species of rail (Rallidae) are represented in the assemblage. *Gallirallus ripleyi* is an extinct, flightless species first described by Steadman (1987) based on surface material collected in Te Rua Rere cave on Mangaia. In MAN-44, bones of *G. ripleyi* are fairly abundant in deposits below SZ-5. The most common landbird in the entire MAN-44 assemblage is another extinct, flightless rail, *Porzana rua*, also originally described by Steadman (1987) from Te Rua Rere. As with *G. ripleyi*, *P. rua* occurs only below SZ-5. A second, still-undescribed extinct *Porzana* species is also represented by four specimens from these same deeper strata (see Steadman 2006:309). Also present is the spotless crake (*Porzana tabuensis*), a volant species fairly widespread in central and southeastern Polynesia (Pratt et al. 1987:126–127), usually inhabiting swamp vegetation around ponds and lakes (Mayr 1945:61). Although *P. tabuensis* is represented by only a few specimens, these include bones from SZ-15 and SZ-17, consistent with the persistence of the species on Mangaia today, albeit in low numbers. Finally, there is one specimen from SZ-1B of an extinct, undescribed species in the genus *Porphyrio*, of which Steadman (2006:314) writes, “The Mangaian swamphen was smaller than any other species of *Porphyrio*, living or extant.”

An as yet undescribed, extinct species of sandpiper in the genus *Prosobonia* is represented by a few specimens from zones SZ-1A, SZ-2, and SZ-4A (mentioned as *P.* undescribed species A in Steadman 2006:362).

Five species in three genera of the family Columbidae—pigeons and doves—are fairly well represented, again all in deeper stratigraphic contexts below SZ-5. Although extirpated on Mangaia, the Polynesian ground dove (*Gallicolumba erythroptera*) still survives in small populations on some of the Tuamotu atolls (Pratt et al. 1987:193–194; Steadman 2006:337–338). A much larger, universally extinct species, *Gallicolumba nui*, was formerly present in the Cook, Society, Tuamotu, and Marquesas archipelagoes (Steadman 2006:338). The Cook Islands fruit dove (*Ptilinopus rarotongensis*) survives in small numbers on Rarotonga and Atiu Islands (Pratt et al. 1987:198) but is extirpated on Mangaia; it is represented in all strata from SZ-4B downward. Finally, two species in the genus *Ducula*, both extirpated on Mangaia, are also fairly well represented in the lower strata of MAN-44. The Polynesian pigeon (*Ducula aurorae*) is today known only from the islands of Tahiti and Makatea

Table 6.3 Stratigraphic Distribution of Landbird Bones (NJSP) from the Main Excavation Block at Site MAN-44

Zone or Feature	<i>Gallus gallus</i>	<i>Anas superciliosa</i>	<i>Gallinallus ribleyi</i>	<i>Porzana tabuensis</i>	<i>Porzana rna</i>	<i>Porzana n. sp.</i>	<i>Porphyrio n. sp.</i>	<i>Prosobonia n. sp.</i>	<i>Gallincolimba erythroptera</i>	<i>Gallincolimba nui</i>	<i>Ptilinopus rarotongensis</i>	<i>Ducula aurorae</i>	<i>Ducula galeata</i>	<i>Vini kuhlii</i>	<i>Vini viduici</i>	<i>Vini sp.</i>	<i>Halcyon mangata</i>	<i>Acrocephalus kerarako</i>	NISP totals	NTAXA
SZ-19	6	7																	13	2
SZ-18		1			2												1		4	3
SZ-17	2	3		1															6	3
SZ-15	1	11		1						1									14	4
SZ-14	1																		1	1
SZ-11	1																		1	1
SZ-10	1																		1	1
SZ-8	17	2																	19	2
SZ-7	9	1																	10	2
SZ-6	3																		3	1
SZ-5	7	1			1														10	4
F37	7				3					1				8	2				22	6
SZ-4B	7			1	2					1	1	1	1	5	4				27	10
SZ-4A	9				14	1		1	4	1	1	1	1	10	8	5	1	2	69	14
SZ-3	19	2		2	6						1			4	2			1	38	9
SZ-2	3	1			37	1		1	3		3	1	5	9			2		76	12
SZ-1B					36	2	1		2	2	4	2	1	34	34	2	1	5	130	14
SZ-1A					16			2	5	3	1	1	3	19	5	2	1	6	75	13
Totals	93	29	43	5	117	4	1	4	14	8	12	5	11	89	55	9	6	14	519	

(Pratt et al. 1987:204), whereas the Nukuhiva pigeon (*Ducula galeata*) is restricted to Nuku Hiva Island in the Marquesas (where it was once thought to have been endemic). As Steadman (2006:335) observes, “Both species once were widespread in East Polynesia, and were sympatric in at least the Cook Islands and Society Islands.”

Two species of parrots in the genus *Vini* are well represented in deposits from SZ-4 and below. *Vini kuhlii*, Kuhl’s lorikeet, was thought to have been endemic to Rimatara Island in the Australs (Pratt et al. 1987:207), but archaeological and paleontological finds have shown that it in fact was originally widespread in the Cook Islands (Steadman 2006:344). A larger species, the conquered lorikeet, *Vini vidivici*, is universally extinct but was originally distributed throughout the Cook, Society, and Marquesas archipelagoes (Steadman 2006:Table 12-4). Several bones noted as *Vini* sp. in Table 6.3 could not be definitively assigned to either *V. kuhlii* or *V. vidivici*.

Still surviving on Mangaia although in small numbers is an endemic species of kingfisher, *Halcyon mangaia* (also known as *Halcyon ruficollaris*), which inhabits “woodland and scrub” and “nests in tree cavities” (Pratt et al. 1987:225). The Cook Islands reed warbler (*Acrocephalus kerearako*) is endemic to the Cook Islands; Pratt et al. (1987:257) state that the Mangaian population is a distinct subspecies. Despite the fact that it is still common on Mangaia, *A. kerearako* is represented in MAN-44 only by a few specimens in the lower deposits.

Jungle Fowl or Chicken (*Gallus gallus*)

Along with the pig and dog, the jungle fowl or chicken (*Gallus gallus*) was one of the domestic animals purposefully introduced by humans into Remote Oceania. The species has its origin in Island Southeast Asia (Ball 1933). *G. gallus* bones are present from zone SZ-2, the earliest cultural deposit, through SZ-17 but are especially abundant in SZ-3, SZ-8, and SZ-14, where they have concentration indices of 9.6, 6.3, and 10 NISP/m³, respectively. Curiously, Hiroa (1934) does not mention chickens in his discussion of Mangaian foods.

Reptiles

Lizard

No terrestrial reptiles are known to have been dispersed naturally as far east as the Southern Cook Islands, but Polynesians carried several species of

geckos and skinks with them as commensal animals, probably inadvertently (Zug 1991). The large oceanic gecko (*Gehyra oceanica*) and the mourning gecko (*Lepidodactylus lugubris*) are both quite common on Mangaia; we frequently observed individuals of *G. oceanica* basking on the limestone walls of Tangataua Rockshelter. Four bones of an unidentified species of Scincidae or Gekkonidae lizard were recovered from MAN-44, three from SZ-4 and one from SZ-15. Their presence may well be due to natural deposition rather than consumption by humans.

Turtle

Although common in archaeological contexts in some Pacific Islands, bones of the green sea turtle (*Chelonia mydas*) were rare in MAN-44. Only four specimens were recovered from the main excavation block, two from SZ-4A, one from SZ-8, and one from SZ-17. Given the narrow fringing reef and absence of extensive sand beaches around its coastline, Mangaia most likely did not offer an inviting nesting habitat for this species. Nonetheless, when they occasionally appeared in the waters off the island, turtles were taken for food. Hiroa (1934:117) mentions that the Shore High Priest (*ariki pa tai*) was entitled to “a special right over all turtles caught, and he received the special portion including the head and neck termed *te ua o te ‘onu*.”

Temporal Trends in the Exploitation of Vertebrate Fauna

A number of significant temporal trends are evident in the nonfish vertebrate faunal assemblage from Tangataua Rockshelter. To make valid comparisons between different stratigraphic zones, however, it is necessary to adjust the raw NISP bone counts to take into account the different volumes of sediment excavated in different strata. Concentration indices of bone densities were calculated as NISP per cubic meter of excavated sediment for each of the main stratigraphic zones, as shown in Table 6.4.

Figure 6.1 displays the temporal trends in the domestic animals—pig, dog, and chicken—with medium mammal also plotted, this latter primarily consisting of pig bone, although some dog is also no doubt included in the medium mammal category. Minor stratigraphic zones with limited sample sizes have been left out of this and subsequent plots. All three domestic animals are present from the earliest occupation deposit (SZ-2), with pig being the most abundant. Pig bones are

Table 6.4 Concentration Indices (NISP/m³ Sediment) of Vertebrate Fauna, Site MAN-44

Zone	Medium Mammal	Pig	Dog	Rat	Fruit Bat	Human	Chicken	Seabirds	Landbirds
SZ-17	6.4	7.7	0	53.5	0	1.9	1.3	9	3.9
SZ-15	3.8	9.2	0	268.7	0	4.6	0.7	49.6	10.7
SZ-14	0	0	0	290	0	0	10	60	10
SZ-13	0	0	0	29.2	0	0	0	33.3	0
SZ-10 and SZ-11	4.5	9	2.3	320.4	0	0	4.5	6.8	4.5
SZ-9	0	0.7		15.5	0	0	0	0.7	0
SZ-8	20.6	11.6	1.5	123.4	0	2.6	6.3	12.7	7.1
SZ-6 and SZ-7	5.2	8.9	1.5	40.9	0	2.2	8.9	0.7	9.6
SZ-5	5	6.2	0	28.7	0	0	8.7	2.5	12.5
SZ-4	2.8	3.4	0	60.9	4.4	0.3	5	4.4	30
SZ-3	37	15.2	4.1	221.7	2	2.5	9.6	3.5	19.2
SZ-2	19	8.2	8.2	320.2	13.3	1.3	1.9	16.4	48.1
SZ-1B	1.2	0	0	40	6.4	0	0	7.1	83.8
SZ-1A	0	0	0	0.8	5.2	0	0	8.7	65.2

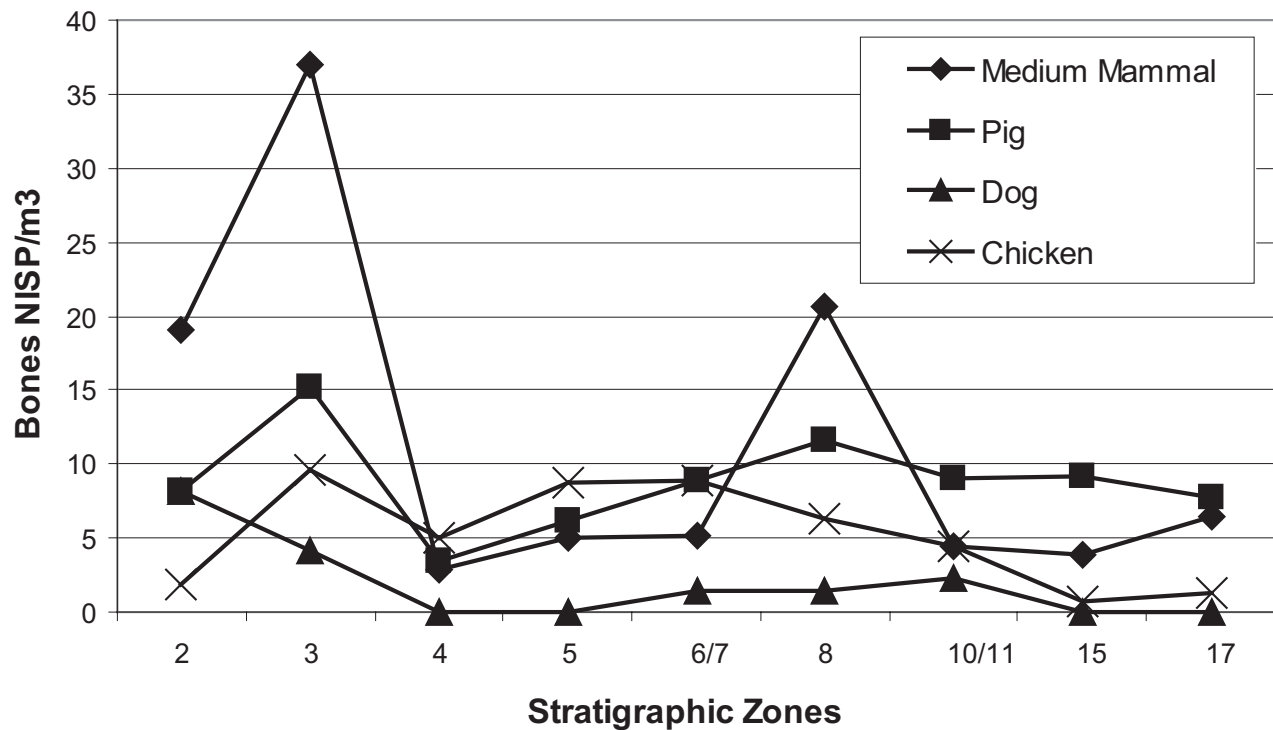


Figure 6.1. Temporal trends in domestic pig, dog, and chicken in site MAN-44.

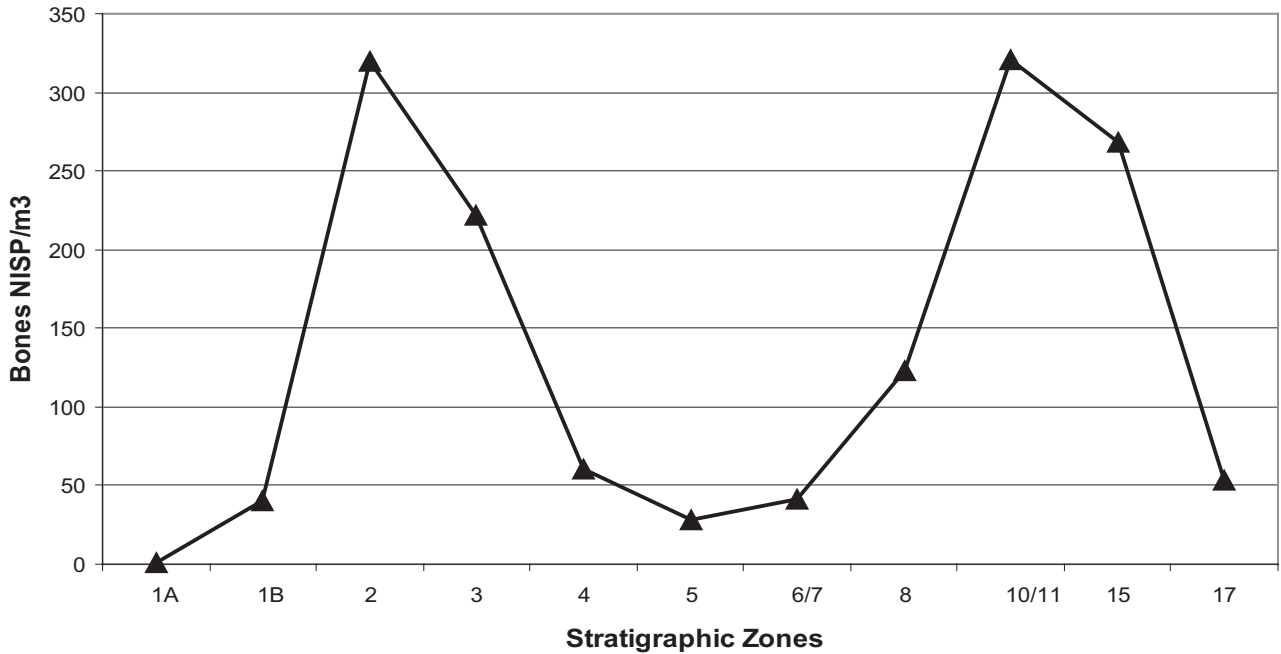


Figure 6.2. Temporal trends in the density of *Rattus exulans* bones in site MAN-44.

especially plentiful in SZ-3, whereas dog exhibits a decline in frequency; chicken rises in abundance in SZ-3. After SZ-4, dog remains a very minor component of the later assemblages, seemingly becoming extirpated by SZ-10/11. Pig retains a steady importance in the upper deposits, especially in SZ-8 (with most of the medium mammal in SZ-8 presumably coming from pigs). The fact that pig continues to be present as late as zone SZ-15 suggests that its extirpation on Mangaia occurred not long before the arrival of the missionaries, who found pigs to be absent.

The Pacific rat—whether or not it was originally introduced as a food item—certainly became an important component of the Manganian diet, as evidenced both by taphonomic patterns in the MAN-44 assemblage and by ethnohistoric accounts. Figure 6.2 shows the temporal trends in rat bone concentrations. The presence of *R. exulans* bones in SZ-1B indicates that this human-introduced animal was already present in the rockshelter environment prior to the initial occupation represented by zone SZ-2. Once people began to inhabit the rockshelter, however, rat bone density increased dramatically. Rat bone density declined somewhat in SZ-3, then fell to lower numbers in SZ-4, SZ-5, and SZ-6/7. However, rat bone density rises significantly again in the later occupations represented by

SZ-8, SZ-10/11, and SZ-15, when rats were most certainly a key part of the Manganian diet.

Turning to the indigenous vertebrate biota present on Mangaia prior to human arrival, the concentration indices for flying fox, seabirds, and landbirds are displayed in Figure 6.3. The most dramatic trend is without doubt the precipitous decline in the concentration of landbird bones from high levels in the preoccupation zones SZ-1A and SZ-1B down to very low densities after SZ-5. The high density in zone SZ-1A is a reflection of a long period of natural deposition of bird bones prior to human occupation (see Chapter 5 for details of chronology), while the density peak seen in zone SZ-1B likely derives from a combination of natural deposition along with the initial taking of birds by humans. The densities in zones SZ-2 and up through the sequence are the result of cultural practices, and the steep decline in bone concentration indices reflects a pattern of extirpation and extinction of most of the indigenous and endemic landbirds during the period of Polynesian occupation of Mangaia. Among the species that were eliminated from the Manganian biota during the later prehistoric period were five species of rails, five species of pigeons or fruit doves, and two species of parrots, leaving the historic period Manganian avifauna highly impoverished.

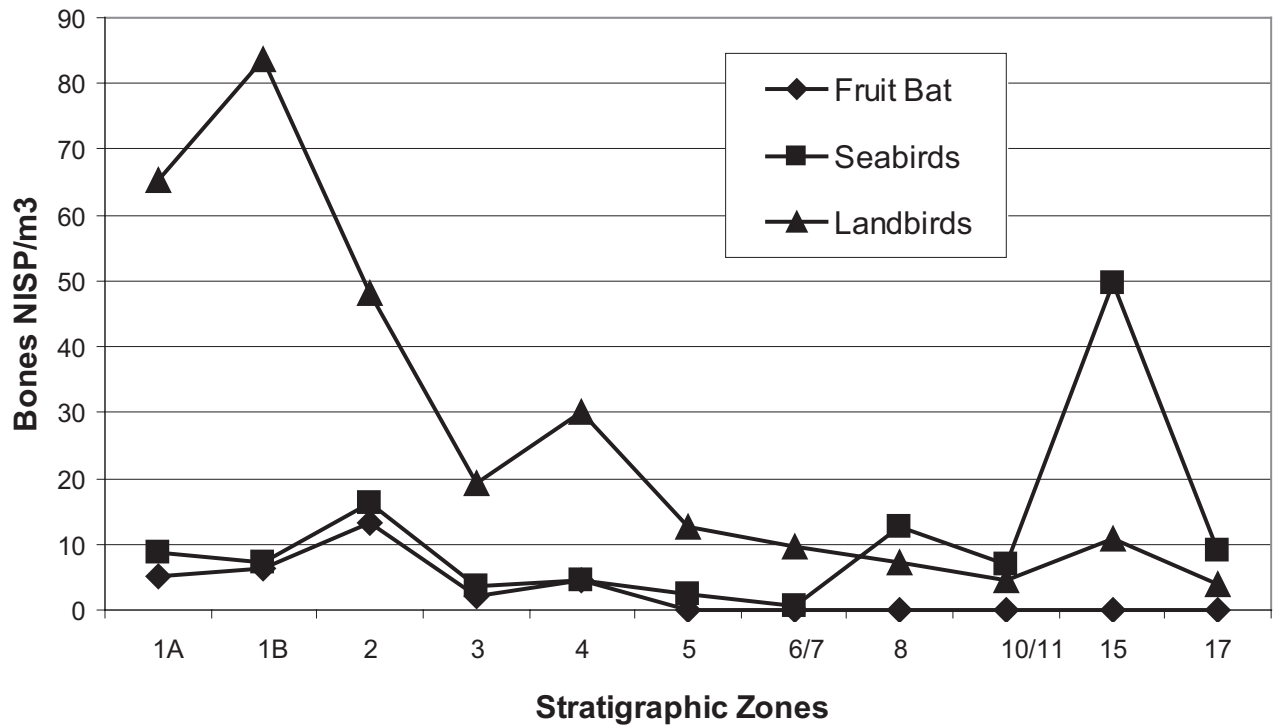


Figure 6.3. Temporal trends in the density of flying fox, seabird, and landbird bones in site MAN-44.

Bone concentration indices for the flying fox and for seabirds are very similar in the preoccupation deposit (SZ-1A and SZ-1B) and indeed closely track each other up through SZ-4. After that, however, the flying fox is absent and most likely had become extirpated on the island. It is noteworthy that the densities of seabird bones increase in SZ-8 and rise

dramatically in SZ-15. As indicated in Table 6.2, this late increase in seabird bones is due mainly to three species: *Puffinus lherminieri*, *Pterodroma nigripennis*, and *Anous stolidus*. This suggests a late phase strategy of taking these particular species, which may have been nesting or roosting in more remote parts of the *makatea* terrain.

7

Fish Remains from Tangatatau Rockshelter

Virginia L. Butler

Fish have been part of the fabric of human life in Oceania since earliest colonization. Besides a key source of protein and calories, fish were linked to ritual and social context—and contributed to people’s view of themselves and their place in the world. Te Rangi Hiroa’s (1944) *Arts and Crafts of the Cook Islands* highlights people’s depth of knowledge about the fish in local waters—the habitats fish preferred, the best time of day and tidal cycle in which to catch them, and the month of year when certain fish would be most abundant and rich in fat. Cook Islanders developed a wide variety of fish capture techniques using angling, traps, and nets, some involving large communal groups and protocols for distributing the catch. Fish were much more than food.

Excavation and recovery of a well-preserved fishbone assemblage from Tangatatau Rockshelter (MAN-44) provides an opportunity to study the deeper temporal context of Manganians’ relationship with fish. Detailed excavation of discrete deposits linked to high-resolution radiocarbon ages allows for the study of change in fisheries across 19 stratigraphic zones, from AD ~1000 up to the historic period. This chapter describes results from analysis of the fish remains from this important site. Questions to be addressed include the following: What fish were used and what habitats were exploited? How did fish use change through time? Were fish populations affected

by fishing pressure? How does the MAN-44 fishbone assemblage compare with those from other Eastern Polynesian sites? While the study generated many findings, perhaps the most noteworthy is the prominent and enduring use of a small freshwater fish from the Eleotridae family, which had not previously been documented in Oceanic faunal assemblages.

Methods and Materials

During the 1989 and 1991 field seasons at MAN-44, excavated matrix was dry screened to ⅛ in. (3.2 mm). Faunal remains were bagged in the field and returned to the lab, where fish remains were removed and counted. Fishbone represents over 90 percent of all the bone recovered from MAN-44; almost 32,000 specimens were identified as fish during preliminary sorting (Kirch et al. 1995). To sample this huge assemblage, I restricted analysis to remains found in the main excavation block, where stratigraphy and dating were best understood and focused on remains that could be assigned to one of the 19 stratigraphic zones, excluding remains found in features (see Chapter 4), which were less tightly linked to a time period.

Fish remains were further sampled by focusing on seven paired skeletal elements associated with the jaw and pectoral fin. For decades, Leach and colleagues (e.g., Leach 1986; Leach and Intoh 1984)

have promoted using five paired jaw elements (articular, dentary, quadrate, maxilla, and premaxilla) and a series of “special bones,” those elements that are diagnostic of one or a few fish taxa: pharyngeals diagnostic of Scaridae and Labridae; dorsal spines diagnostic of Balistidae and Acanthuridae; a variety of modified scales characteristic of Acanthuridae, Diodontidae, Carangidae, and Ostraciidae; and teeth diagnostic of elasmobranchs (sharks and rays). Lambrides and Weisler (2013; see also Butler 1988) have recommended that faunal analysts include a wider range of elements, including vertebrae, to address concerns that some taxa with less durable or distinctive jaw elements need to be documented with a different (or additional) set of elements. Clearly, some taxa, like elasmobranchs with cartilaginous jaws that do not preserve archaeologically, will not be identified using the standard jaw elements, and therefore including some “special bones” to document such fishes would be warranted. It is also clear that a commonly used measure of faunal abundance, Number of Identified Specimens (NISP) (Grayson 1984), would be greatly affected by a procedure that uses varying numbers of elements to identify different taxa (see also Weisler et al. 2010), which is why Leach (1986) promotes the use of Minimum Number of Individuals (MNI) to mitigate this problem.

For this study, I addressed some of these concerns by expanding the standard pairs of five jaw elements to include the hyomandibula and cleithrum (the main element of the pectoral fin) (see Figure 7.1 for skeletal elements included in study). Adding these relatively large and typically robust elements mitigates concerns that some taxa are underrepresented because of recovery bias or low preservation potential. Since with a few exceptions, bony fish taxa start with the same number of these elements (seven pairs or 14 total), NISP counts should be a robust measure of fish abundance if fragmentation is minimal or at least consistent across contexts. However, NISP counts for at least three taxonomic groups are reduced by focusing on this restricted group of elements. The marine and freshwater eels (order Anguilliformes) lack a pectoral fin and the associated cleithrum. As well, the eel’s premaxilla is extremely reduced in size and lacks distinctive features; none were identified from the site. Thus, eel NISP counts are lower than for other fishes with the full complement of seven paired elements. Since this bias is consistent, however, *change*

in relative abundance of fish taxa across stratigraphic zones is not affected. A lesser concern for eels is that the hyomandibula and quadrate are fused. To address this problem, each element in the fused set was counted separately.

Focusing strictly on the seven paired elements characteristic of bony fishes obviously creates problems for documenting cartilaginous fishes whose “hard parts” are altogether different: vertebrae, dorsal spines, teeth, and dermal denticles. To make up for this, I scanned fish remains for elasmobranch teeth and vertebrae during analysis. In the end, only eight shark teeth were identified, so remains of such fish are scarce, regardless of analytic decisions about element selection. In pulling the shark teeth, three teeth from a bony fish were identified, likely Sphyracidae (baracuda). These were noted but not incorporated into quantitative analysis.

Diodontidae (porcupine fishes) could also be underrepresented when relying on seven paired elements, given the taxon’s lightly built jaw and pectoral fin elements. Leach (1986) includes the distinctive porcupine quill-like modified scale (which gives the fish its common name) as a “special bone” probably to address this bias. Given that a single diodontid jaw element, a quadrate, was identified in the Tangatatau assemblage, I was concerned that this taxon was underrepresented because of the restricted set of elements used. To empirically assess this potential and particularly to see if *Diodon* abundance changed through time, I estimated the abundance of *Diodon* spines across stratigraphic zones through a simple grab sample and scanning process. From each stratigraphic zone, I chose three unit-level bags (or fewer if the stratigraphic zone lacked three) that appeared to have the most fish remains. I gently poured the remains onto a sheet of paper, then subdivided the pile into quarters, halves, or eighths, depending on the size of the original pile. In one arbitrarily selected subset from each unit-level bag, I counted the number of *Diodon* spines and the number of specimens (NSP, which includes all fish remains, including unidentified). I then used these counts to extrapolate to the whole bag, estimating the total number of spines and NSP in each bag if all the remains had been studied. Thus, if in one quarter of one bag, five spines and 40 NSP of fish were counted, 20 spines and 160 NSP were estimated for the entire bag. Remains from 36 bags were studied in this way.

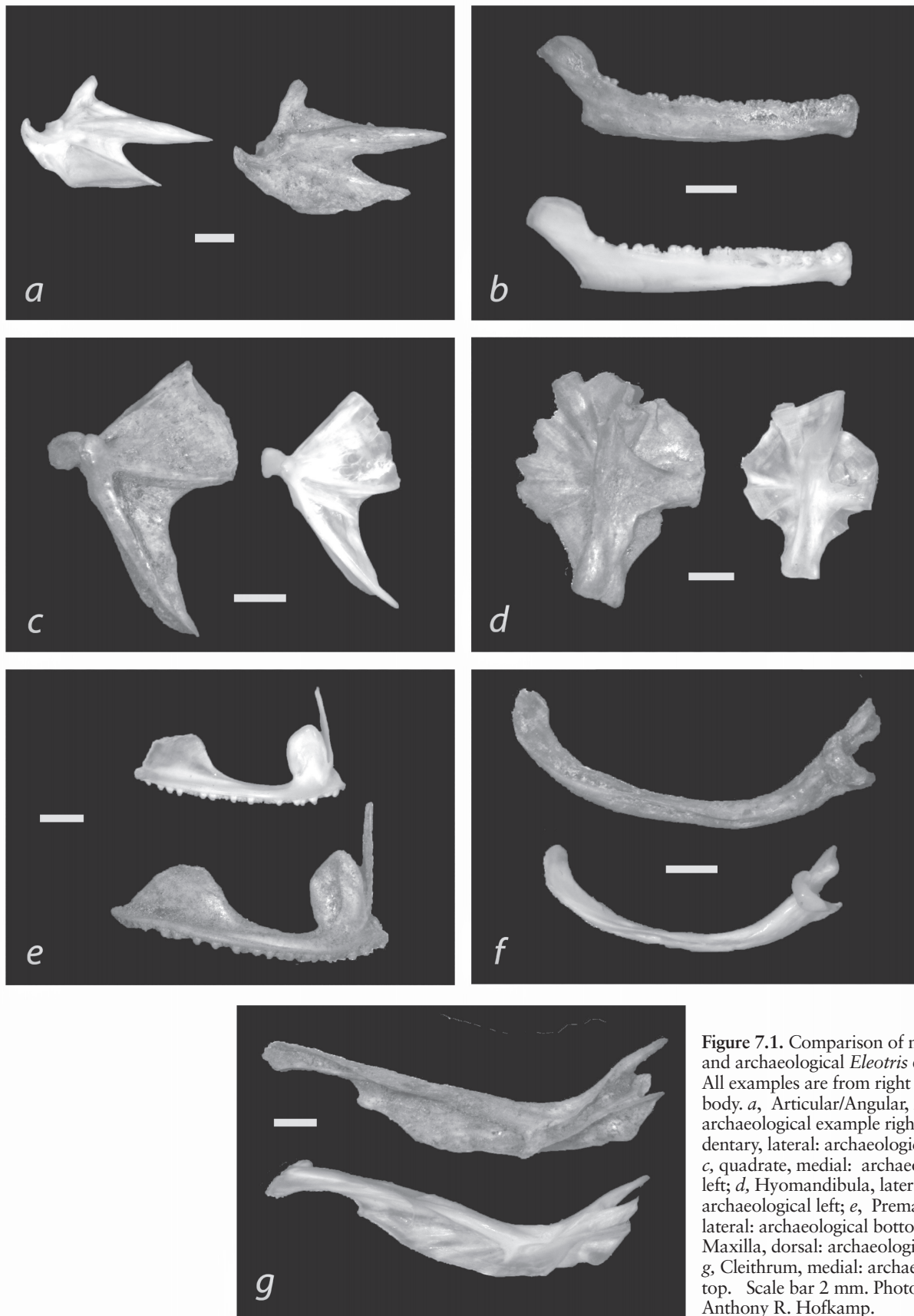


Figure 7.1. Comparison of modern and archaeological *Eleotris* elements. All examples are from right side of body. *a*, Articular/Angular, lateral: archaeological example right; *b*, dentary, lateral: archaeological top; *c*, quadrate, medial: archaeological left; *d*, Hyomandibula, lateral: archaeological left; *e*, Premaxilla, lateral: archaeological bottom; *f*, Maxilla, dorsal: archaeological top; *g*, Cleithrum, medial: archaeological top. Scale bar 2 mm. Photograph by Anthony R. Hofkamp.

One challenge to fish faunal analysis in Oceania is having access to large comparative skeletal collections that represent fishes in local project areas. Given the high level of species diversity and endemism, relying on reference collections made from one part of Oceania to identify fishes from another area is challenging. This has likely contributed to the generally coarse level of identification obtained, family level or higher.

For the Mangaia project, significant effort was made to address this concern, primarily through building a large skeleton collection from the island. In June to July 1991, I spent 11 days collecting fishes and making observations of species and habitat preferences through snorkeling. With help from several Mangaian (especially Ma'ara Ngu, Tuara George, Sonny Taomia, and Peter Ngatokorua), fish were speared, netted, and caught with hook and line. Whole fish were photographed in the field to record coloration that fades postmortem. Fish were frozen and returned to the United States, where more detailed taxonomic identifications were made, using species and generic keys. Photographs of fishes whose identification was ambiguous were sent to Arnold Suzumoto and Jack Randall at the Bernice P. Bishop Museum in Honolulu who confirmed identifications. Representatives of each taxon were skeletonized (using warm water maceration), which generated 117 skeletons, representing 92 species, 65 genera, and 37 families. Complete data on the Mangaia comparative collection is available in the online database.

With the aid of this relatively large reference collection, I identified the seven paired elements from MAN-44 to the finest taxon possible, often to the subfamily level. Mostly I relied on NISP for quantification but calculated a variation of MNI to evaluate whether counting method affected results. MAU (Minimum Animal Unit; Binford 1978) is like MNI in trying to estimate the number of individuals that contributed to a collection but does not take side into account. For a given site aggregate (e.g., a unit level, a stratigraphic zone, an entire site), one calculates the MAU for each taxon by summing the NISP, then dividing the total by the number of times the element occurs in the body. If 13 dentaries from a freshwater eel were documented in a given site aggregate, given two dentaries per individual, the MAU would be 6.5. If fragmentation is extensive or multiple parts of a given element can be identified, NISP is a poor estimate of the original number of elements present. A quantification unit controls for

this bias, the minimum number of elements (MNEs), wherein the best represented, nonoverlapping section of each element is included such that a single element can only be counted once. Most of the MAN-44 remains could only be identified to a given element and taxon if the nonrepetitive portion was present; thus, most NISP counts are actually MNEs.

One goal of this study was to determine whether fishing practices were extensive enough to cause resource depression (Butler 2001), which can be demonstrated from declines in prey body size (e.g., Beverton and Holt 1957). Casteel (1976) and others have shown that fishbone size and fish body size are strongly correlated. To estimate size of Serranidae, *Cirrhitus*, and *Eleotris* represented in Tangatatau, I measured dentary height (taken along the rostral border of the symphysis, perpendicular to the long axis of the element). To estimate *Anguilla* size also using dentaries, I measured the distance from the apex of the "V" found on the medial side, where the articular slips into the dentary, to the dorsal border. These measured distances were well defined. Using modern skeletal elements, I checked for replicability by measuring multiple times as well as lefts and rights from a single skeleton. Specimens were measured using digital calipers to the nearest 0.01 mm.

Specimens were also examined for evidence of burning. Only those specimens that were dark blue-black or calcined were recorded as burned.

Records were entered into an Excel database, and IBM SPSS Statistics version 23 was used for analysis.

Aquatic Habitats

Mangaia is a relatively small island with a central volcanic cone surrounded by a ring of upraised coral *makatea* (see Chapter 2). Freshwater streams flow in a radial pattern from the central volcanic core, forming swamps and lakes against the upraised *makatea*, the 1- to 2-km-wide and 10- to 60-m-high upraised limestone reef. Subterranean conduits through the *makatea* open onto the contemporary reef flat at or below sea level, connecting freshwater with the marine system. Just over 1 km west of Tangatatau Rockshelter is Lake Tiriara, the largest lake on the island. Two fish taxa were collected from it: *Anguilla* sp. (freshwater eel) and *Eleotris* sp. (sleeper). Both are catadromous, with phases of their life histories spent in fresh and marine habitats. *Eleotris* spawns in freshwater—its larvae float to sea, where fish mature and return as juveniles to freshwater to spawn. *Anguilla* spends its adult life

in freshwater and leaves the interior through the limestone conduits to spawn at sea. Juveniles return to freshwater, again through limestone channels to freshwater, where they mature.

A shallow fringing reef (~10 cm deep at low tide) encircles the island. It is widest on the leeward side (west and northwest), where the width is 120 to 130 m and narrowest on the windward side (northeast, east, southeast), where the width is only 30 to 50 m. This zone is characterized by tidal pools and surge channels that cut through the reef. My field observations suggest limited coral growth and overall low productivity of this zone. Relatively small fish dominate, including herbivores (Acanthuridae, Pomacentridae) and carnivores (Serranidae). The reef flat is bordered on its seaward edge by a well-defined ridge that is 20 to 40 m wide and 10 to 30 cm above the reef flat. The reef edge is fully exposed at low tide and can be accessed by walking out from shore. The edge slopes gently seaward. The bottom has much denser coral growth than the reef flat, and fish tend to be larger and of greater diversity. Bottom-dwelling solitary carnivores were common (cirrihitids, serranids), as well as mid-water fishes, such as larger acanthurids, balistids, labrids, and scarids. Beyond the seaward reef, water depth increases greatly. Deep, offshore waters support sharks, tunas (Scombridae), and other fast-swimming migratory fishes. Offshore habitats are accessed by canoes that can pass through narrow channels that cut through the fringing reef at several locations around the island.

Descriptive Summary

This section describes the criteria used for subfamily taxonomic assignment; nomenclature follows Myers (1989) and Randall et al. (Randall 1985; Randall et al. 1990). Habitat preferences are based on Myers (1989) and Randall et al. (1990) and my 1991 field observations.

Class Chondrichthyes—cartilaginous fishes

Family Carcharhinidae—requiem sharks

Materials: 8 isolated teeth

Remarks: G. Naylor (College of Charleston) examined photographs of representative specimens and suggested they were likely from the genus *Carcharhinus* (personal communication, November 2015; Naylor and Marcus 1994). Requiem sharks are one of the largest shark families. Ranging in length from 1 to 6 m, most

are pelagic but can move into inshore waters. They are fast-swimming, voracious carnivores.

Class Osteichthyes—bony fishes

Order Anguilliformes

Family Anguillidae—freshwater eels

Anguilla sp.

Materials: 16 articulars, 47 dentaries, 8 hyomandibulae, 16 maxillae, 5 quadrates: 92 specimens

Remarks: The anguillid family is represented by a single genus worldwide. Six species are known from the southwest Pacific region (Ege 1939). *Anguilla obscura* is the dominant species on Mitiaro (Jellyman 1991), another *makatea* island in the Cook Islands, although small populations of *Anguilla marmorata* and *Anguilla megastoma* may live there as well. The species present on Mangaia is unknown. *Anguilla* was most likely caught during its freshwater residence. Comparisons of archaeological and modern examples are shown in Figure 7.2.

Family Muraenidae—moray eels

Materials: 11 articulars, 32 dentaries, 5 hyomandibulae, 7 maxillae, 4 quadrates: 59 specimens

Remarks: Forty-eight species of moray eels have been recorded from French Polynesia (Randall 1985). Moray eels are carnivores; those species with long, sharp canine teeth feed on fishes and cephalopods, while those with rounded or conical teeth feed on crustaceans (Myers 1989). Unfortunately, teeth were not present on the MAN-44 muraenid jaw specimens, precluding taxonomic identification based on tooth morphology. Many species are more active at night than during the day; in general, moray eels tend to be secretive, dwelling in holes and crevices (Myers 1989).

Family Congridae—conger eels

cf. *Conger cinereus*

Materials: 6 articulars, 6 dentaries, 5 hyomandibulae, 12 maxillae, 2 quadrates: 31 specimens

Remarks: Four species of conger eels are reported from French Polynesia (Randall 1985). In Micronesia, the only large conger eel that occupies shallow coral reefs is *Conger cinereus*, which is a nocturnal predator of fishes and small crustaceans (Myers 1989). *C. cinereus* was the only species collected from Mangaia in July 1991. The MAN-44 conger eel specimens are extremely similar to those from *C. cinereus* and are most likely from this taxon.

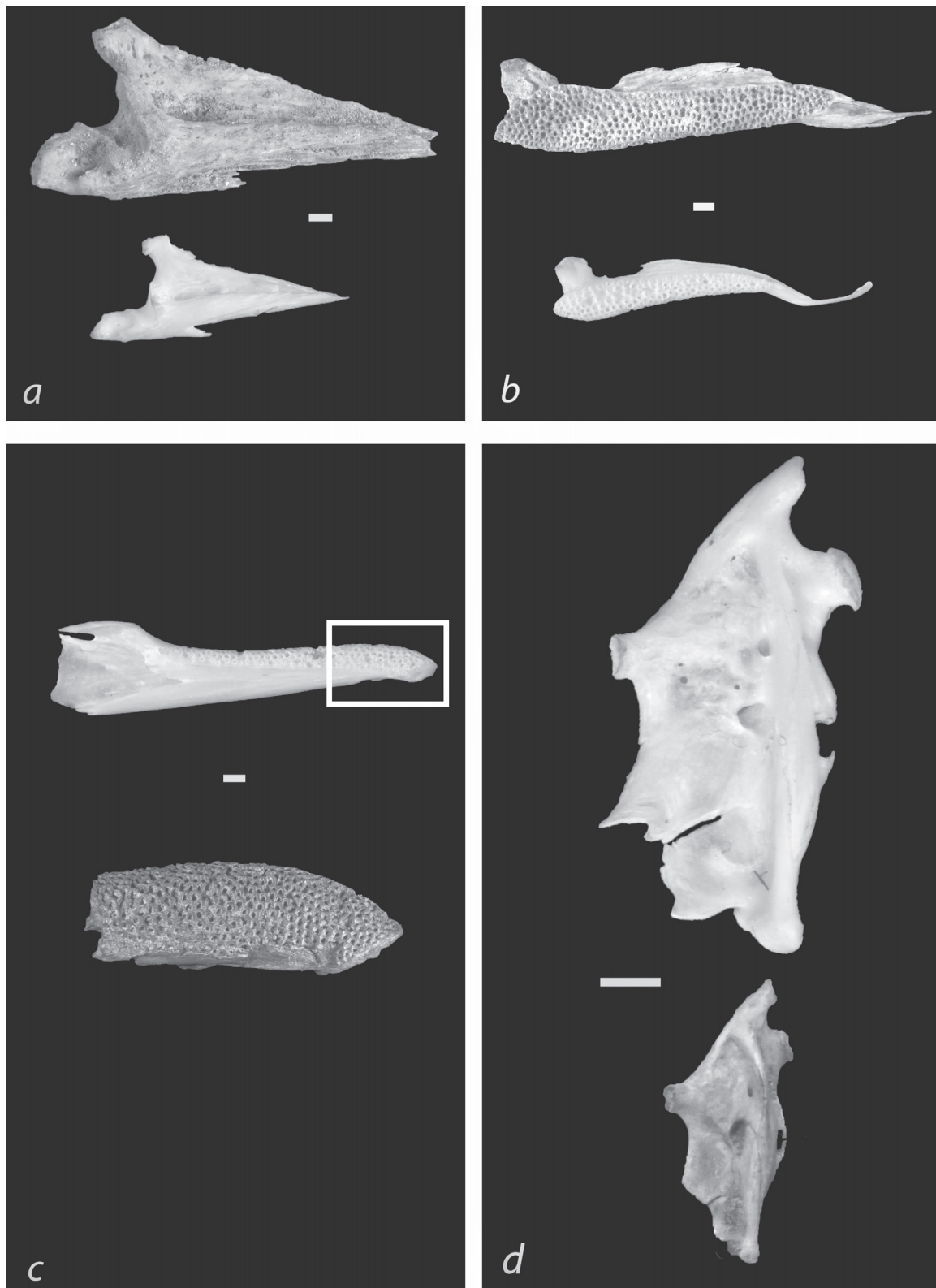


Figure 7.2. Comparison of modern and archaeological *Anguilla* elements. *a*, Articular/Angular, left medial: archaeological top; *b*, Maxilla, right medial: archaeological top; *c*, Dentary, left medial: archaeological bottom; *d*, Hyomandibula/quadrates, left lateral: archaeological bottom. Scale bar 2 mm. Highlighted box in *c*, dentary, defines the portion represented, archaeological specimen. Photograph by Anthony R. Hofkamp.

Order Aulopiformes**Family Synodontidae—lizardfishes**

Materials: 1 fragmentary dentary or premaxilla

Remarks: Three genera and eight species of synodontids are recorded from French Polynesia (Randall 1985). In descriptions of the Micronesian forms, Myers (1989) notes that lizardfishes are relatively small (130–300 mm maximum size), solitary bottom fishes that are ambush predators of small fishes. Those described occur only in shallow water. The single species collected from Mangaia, *Synodus dermatogenys*, was caught using hook and line from the wharf near Oneroa Landing.

Order Cyprinodontiformes**Family Belonidae—needlefishes**

Materials: 5 fragmentary dentaries or premaxillae

Remarks: Randall (1985) reports four species of needlefishes from French Polynesia. These fishes live at the surface, preying on small fishes (Myers 1989).

Order Beryciformes**Family Holocentridae**

Materials: 2 quadrates, 12 cleithra: 14 specimens

Subfamily Holocentrinae—squirrelfishes

Materials: 6 articulars, 12 dentaries, 6 hyomandibulae, 8 maxillae, 4 premaxillae, 5 quadrates, 3 cleithra: 44 specimens

Subfamily Myripristinae—soldierfishes

Materials: 1 articular, 2 dentaries, 2 hyomandibulae, 3 maxillae, 1 premaxilla, 1 quadrate, 1 cleithrum: 11 specimens

Remarks: The holocentrids are divided into two subfamilies; the skeletal morphology of these two groups is extremely distinctive, which allowed for subfamily identification of most of the MAN-44 elements. In general, holocentrids are most active at night. The two subfamilies differ, however, in their feeding habits. According to Myers (1989:74–81), the Myripristinae tend to forage in the water column above the reef, feeding on large zooplankton, including crustacean larvae. The Holocentrinae tend to stay closer to the reef bottom, where they consume worms, small fishes, and crustaceans. On Mangaia, three species were common in tide pools on the reef flat, hiding under ledges: *Myripristis woodsi*, *Myripristis kuntee* (Myripristinae), and *Sargocentron tiere* (Holocentrinae).

Order Syngnathiformes**Family Fistulariidae—cornetfishes**

Fistularia sp.

Materials: 4 fragmentary dentaries or premaxillae

Remarks: A single genus is known for the family. Randall (1985) reports one species for French Polynesia; Myers (1989) records a single but different species in Micronesia. The Micronesian form occupies all reef habitats to depths of 128 m. A carnivore that feeds on small fishes and crustaceans, *Fistularia* often schools with similarly sized individuals (Myers 1989).

Order Scorpaeniformes**Family Scorpaenidae—scorpionfishes**

Materials: 5 cleithra

Remarks: Nine genera and multiple species of scorpionfishes are recorded for French Polynesia (Randall 1985). Three species were collected on Mangaia (*Pterois antennata*, *Pterois radiata*, and *Synanceia verrucosa*); all were speared on the fringing reef flat. The cleithra identified were somewhat different from those on *Pterois* and *Synanceia* and must be from another genus in the family that was not collected.

Order Perciformes**Family Serranidae—sea basses and groupers**

Materials: 20 articulars, 30 dentaries, 15 hyomandibulae, 21 maxillae, 21 premaxillae, 12 quadrates, 17 cleithra: 136 specimens

Remarks: The serranid family is extremely large, with approximately 35 genera and 370 species worldwide (Nelson 1984). Randall (1985) reports 17 genera and 47 species in French Polynesia. Three genera and six species were collected on Mangaia in 1991. Unfortunately, morphological similarity across these taxa prevented subfamily taxonomic assignments of the MAN-44 remains. Most serranids are solitary, bottom-dwelling carnivores that eat fishes and crustaceans.

Family Kuhliidae—aholeholes

Kublia sp.

Materials: 2 maxillae, 1 premaxilla: 3 specimens

Remarks: One genus (*Kublia*) and two species, *Kublia marginata* and *Kublia mugil*, are found in Micronesia (Myers 1989) and French Polynesia (Randall 1985). Both species also were collected in Mangaia in 1991. The more common one on Mangaia, *K. mugil*, was

spear on the reef flat and caught in nets set on the fringing reef. Myers (1989:125) notes that *K. mugil* occurs in schools just beneath breaking surf along reef margins and then disperses at night to feed on free-swimming crustaceans. These are small fishes, reaching maximum sizes of only 200 mm.

Family Carangidae—jacks and pompanos

Materials: 5 articulars, 2 dentaries, 2 maxillae, 1 premaxilla, 2 quadrates: 12 specimens

cf. *Decapterus* sp.

Materials: 1 articular, 3 dentaries, 4 premaxillae: 8 specimens

cf. *Caranx* sp.

Materials: 1 cleithrum

Remarks: Randall (1985) documents 13 genera of carangids in French Polynesia with 18 species. Five genera and six species were collected from Mangaia. The fish were caught using spears or hook and line on the seaward side of the fringing reef. Carangids were not observed or ever captured on the reef flat in 1991. Significant morphological variation across genera permitted the tentative identification of the MAN-44 specimens. Carangids are typically strong-swimming open-water carnivores that consume fishes and crustaceans (Myers 1989).

Family Lutjanidae—snappers

cf. *Aphareus* sp.

Materials: 1 dentary

Remarks: Seven genera and 12 species are known for French Polynesia (Randall 1985). Only two genera, *Aphareus* and *Lutjanus*, were collected from Mangaia in 1991. *Aphareus furca* is the only species in the genus reported from Micronesia (Myers 1989) and French Polynesia (Randall 1985). According to Randall et al. (1990), jaws of *Aphareus* lack canines, which are common to most other snappers. The dentary from MAN-44 has the condition typical of *Aphareus* and therefore was tentatively assigned to this taxon. Throughout its range, *A. furca* is usually seen on outer reef slopes, between 6 and 70 m (Randall et al. 1990; see also 1- to 122-m depth [Myers 1989]). It is usually solitary and feeds on small fishes and crustaceans (Myers 1989). Maximum size reported for *A. furca* is 400 mm, but most adults reach only 300 mm in total length (Randall et al. 1990).

Family Lethrinidae—emperors

Monotaxis grandoculis

Materials: 1 maxilla

Remarks: *Monotaxis grandoculis* skeletal remains are easily separated from other lethrinids in being much more robust and having distinctive molariform teeth. In Micronesia, Myers (1989:143) notes that this species is relatively common in water over lagoons and seaward reefs at depths between 1 and 100 m. He notes that adults form loose aggregations during the day and disperse to hunt at night for hard-shelled sand-dwelling invertebrates. None were observed during field study in 1991. The identification was made using a reference skeleton obtained by P. V. Kirch from the Mussau Islands, New Ireland, Papua New Guinea in 1986.

Family Mullidae—goatfishes

Materials: 3 dentaries, 3 hyomandibulae, 1 premaxilla, 1 cleithrum: 8 specimens

cf. *Mulloidis* sp.

Materials: 1 maxilla

cf. *Parupeneus* sp.

Materials: 1 dentary, 1 maxilla, 3 premaxillae: 5 specimens

Remarks: Randall (1985) reports three genera and 11 species for French Polynesia. Members of two of the genera (*Mulloidis* and *Parupeneus*) were commonly seen on the reef flat on Mangaia in 1991. All of the species are carnivores, feeding on benthic fishes, crustaceans, and other invertebrates.

Family Pempherididae—sweepers

cf. *Pempheris oualensis*

Materials: 1 dentary, 1 cleithrum: 2 specimens

Remarks: A single species of pempheridid is reported for French Polynesia (Randall 1985), *Pempheris oualensis*; this species and a second one (*Parapriacanthus ransonneti*) are the only members of the family found in Micronesia (Myers 1989). The MAN-44 specimens are extremely similar to those of *P. oualensis* and are probably from this taxon. According to Myers (1989), this species lives in shallow lagoons and seaward reef margins to at least 36-m depths. During the day, it forms aggregates under ledges of surge channels or in caves, whereas at night, it disperses over the reef to feed on benthic and planktonic invertebrates and

fishes (Myers 1989). *P. oualensis* is relatively small, reaching lengths of only 220 mm. *P. oualensis* was collected from Mangaia in 1991, speared on the seaward edge of the fringing reef.

Family Kyphosidae—sea chubs

Materials: 1 articular, 1 dentary, 1 hyomandibula, 2 maxillae, 3 premaxillae, 3 quadrates, 1 cleithrum: 12 specimens

Remarks: Two genera (*Kyphosus*, *Sectator*) and four species of sea chubs are reported for French Polynesia (Randall 1985). A single species, *Kyphosus bigibbus*, was collected from Mangaia in 1991, speared on the fringing reef flat. Myers (1989) notes that sea chubs are omnivores but feed primarily on benthic algae; most forms are common on exposed seaward reefs.

Family Pomacanthidae—angelfishes

Materials: 1 hyomandibula

Remarks: Randall (1985) reports four genera and 13 species for French Polynesia. A single species, *Pomacanthus imperator*, was collected from Mangaia, speared on the seaward side of the fringing reef. All of the angelfishes have relatively small jaws and teeth; food preferences include sponges, algae, benthic invertebrates, and fish eggs (Myers 1989). Species in the family feed on the coral reef at varying depths, ranging from 3 m to over 90 m.

Family Pomacentridae—damsel-fishes

Materials: 3 articulars, 1 dentary, 4 hyomandibulae, 1 premaxilla, 2 quadrates, 1 cleithrum: 12 specimens

cf. *Abudefduf* sp.

Materials: 4 premaxillae

Remarks: The pomacentrids are an extremely large family: nine genera and 39 species are known for French Polynesia (Randall 1985). At least 89 species in 16 genera are known for Micronesia (Myers 1989). Some species are schooling planktivores; most species are omnivorous, feeding on various benthic algae, small invertebrates, or zooplankton. A single species that was extremely common on the reef flat, *Abudefduf septemfasciatus*, was collected from Mangaia. The MAN-44 specimens were identical to those of *Abudefduf*. The assignment remains tentative given the lack of other comparative material. Species in the genus are small, with adults reaching maximum lengths of less than 200 mm.

Family Cirrhitidae—hawkfishes

Materials: 7 articulars, 6 dentaries, 14 hyomandibulae, 15 maxilla, 7 premaxillae, 27 cleithra: 76 specimens

cf. *Cirrhitus* sp.

Materials: 20 articulars, 43 dentaries, 13 hyomandibulae, 42 maxillae, 29 premaxillae, 14 quadrates, 13 cleithra: 174 specimens

Remarks: Eight genera and 13 species of hawkfishes are reported for French Polynesia (Randall 1985); 10 species occur in Micronesia (Myers 1989). Two species were collected from Mangaia: *Cirrhitus pinnulatus* and *Paracirrhites hemistictus*. The skeletal morphology of these two species is extremely distinctive, at least for the seven elements analyzed in this study, allowing for tentative assignments of relatively complete MAN-44 specimens to genus. All of the archaeological specimens that were sufficiently complete closely matched that of *Cirrhitus* and not *Paracirrhites*. *C. pinnulatus* is the only species of *Cirrhitus* that has been reported for French Polynesia, Micronesia, and the Great Barrier Reef (Randall et al. 1990); I assume that another species is not present in the Cook Islands. Given that the archaeological specimens closely match those from *C. pinnulatus*, this species probably is the source of the MAN-44 specimens. In Micronesia, *C. pinnulatus* is the largest member of the family but still only reaches lengths of 230 mm. It commonly lives on the bottom of reef fronts and rocky shorelines to depths of about 3 m, ambushing prey that includes crabs, crustaceans, and fishes (Myers 1989). On Mangaia, solitary individuals of *C. pinnulatus* and *P. hemistictus* were observed on the seaward reef, as they rested on the bottom.

Family Mugilidae—mulletts

Materials: 1 hyomandibula, 2 cleithra: 3 specimens
cf. *Mugil* sp.

Materials: 1 quadrate

Remarks: Six species within five genera are reported for French Polynesia (Randall 1985). Mulletts are small-mouthed fishes that mainly feed on fine algae and detritus from the surface of bottom sediments. Representatives of two genera were collected from Mangaia, *Mugil* spp. and *Chaenomugil leuciscus*, both caught in nets set on the fringing reef flat.

cf. Family Sphyracidae—barracudas

Materials: 3 isolated teeth

Remarks: These teeth are large, pointed, and blade-like and show close similarity to barracuda, based on comparison with a preserved example of *Sphyracina jello* (University of Washington fish collection, uncatalogued, collected in 1948 from Palawan, Philippines). Teeth were at first mistakenly thought to be from shark and set aside for close attention. Teeth of bony fish were otherwise not studied from Tangataua. Four species in the genus *Sphyracina* are known for French Polynesia (Randall 1985). Barracudas are carnivores mainly of fish, known for their large mouths and long, sharp-edged teeth. They are commonly seen on reefs—including on the edge of outer reef drop-offs (Randall et al. 1990).

Family Polynemidae—threadfins

cf. *Polydactylus sexfilis*

Materials: 1 articular, 3 hyomandibulae, 2 maxillae, 2 premaxillae: 8 specimens

Remarks: Two species of threadfins, *Polydactylus sexfilis* and *Polydactylus plebeius*, are recorded for French Polynesia (Randall 1985); *P. sexfilis* is the only common species in Micronesia (Myers 1989) and the Great Barrier Reef (Randall et al. 1990). On Mangaia, *P. sexfilis* was the only species in the family collected. Given the extremely close match between the MAN-44 specimens and *P. sexfilis*, the archaeological remains are probably from this species. According to Myers (1989), *P. sexfilis* occurs along sandy shorelines and over sandy lagoon bottoms. They eat shrimps, crabs, worms, and other benthic invertebrates and sometimes form schools (Randall et al. 1990). On Mangaia, the species was speared on the seaward reef during a night dive.

Family Labridae

Materials: 10 articulars, 5 dentaries, 1 dentary/premaxilla, 23 hyomandibulae, 5 maxilla, 32 premaxillae, 8 quadrates, 27 cleithra: 111 specimens

Gomphosus varius

Materials: 2 articulars, 4 dentaries: 6 specimens

cf. *Thalassoma* sp.

Materials: 1 articular, 8 dentaries, 1 maxilla, 54 premaxilla, 2 quadrates: 66 specimens

cf. *Thalassoma quinquevittatum/Thalassoma lutescens*

Materials: 2 dentaries

cf. *Thalassoma purpureum/Thalassoma trilobatum*

Materials: 16 dentary, 1 premaxilla: 17 specimens

cf. *Thalassoma/Halichoeres* sp.

Materials: 3 articular, 12 maxillae, 6 quadrates: 21 specimens

cf. *Anampses* sp.

Materials: 4 dentaries, 2 maxillae, 4 premaxillae: 10 specimens

cf. *Hemigymnus* sp.

Materials: 1 articular, 1 dentary, 1 maxilla, 1 premaxilla: 4 specimens

cf. *Halichoeres* sp.

Materials: 1 dentary, 2 premaxillae: 3 specimens

cf. *Cheilinus* sp.

Materials: 1 articular, 3 dentaries, 1 maxilla, 1 premaxilla, 3 quadrates: 9 specimens

Remarks: The huge labrid family is one of the most diverse in terms of shape, color, and size. Randall (1985) reports 67 species in 25 genera from French Polynesia. On Mangaia, 11 species in nine genera were collected. Great morphological distinctiveness across the represented genera in the reference collection permitted tentative generic assignments of some of the archaeological specimens (see Figure 7.3 for examples of labrid jaw elements from MAN-44).

Gomphosus is represented by a single species, *Gomphosus varius*, in French Polynesia, Micronesia (Myers 1989), and the Great Barrier Reef (Randall et al. 1990); the same species was collected from Mangaia, speared on the seaward side of the fringing reef. The species, commonly known as the bird wrasse, has an unusually long snout that is used to probe corals for small benthic invertebrates and sometimes fishes (Myers 1989:184; Randall et al. 1990:316).

Thalassoma contains numerous species; four were collected on Mangaia. Typically smaller species (*T. lutescens*, *T. quinquevittatum*) or juveniles of larger species were commonly observed on the fringing reef flat; larger species (*T. purpureum*, *T. trilobatum*) were only observed on the seaward edge of the fringing reef

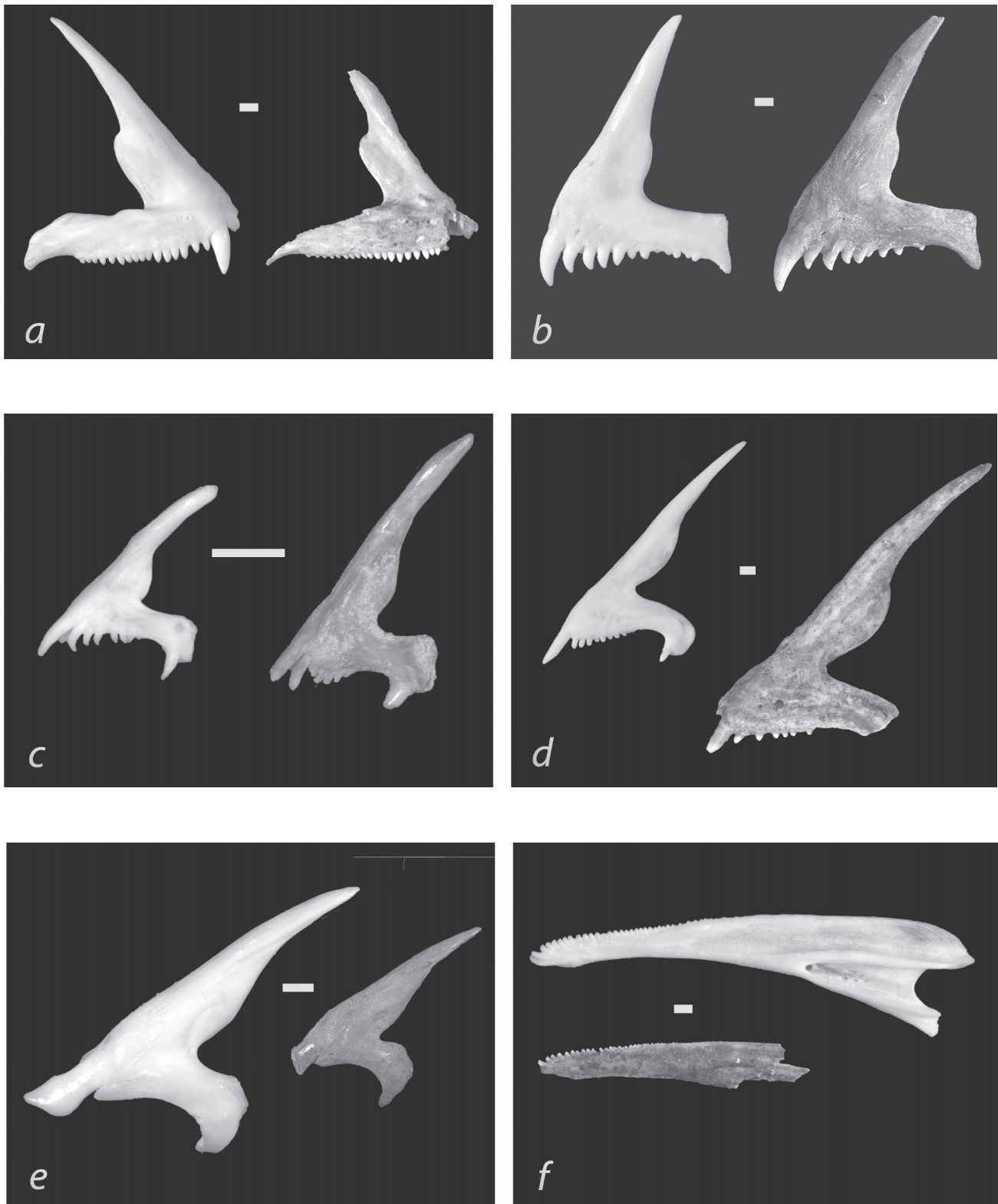


Figure 7.3. Comparison of modern and archaeological elements of labrid genera collected from Mangaia. *a to e*: premaxilla, archaeological example on right; *f* dentary, archaeological example on bottom; all show lateral aspect. *a*, *Cheilinus* sp., right; *b*, *Thalassoma* sp., left; *c*, *Halichoeres* sp., left; *d*, *Hemigymnus* sp., left; *e*, *Anampses* sp., left; *f*, *Gomphosus* sp., left. Scale bar 2 mm. Photograph by Anthony R. Hofkamp.

or in surge channels or deep tide pools on the reef flat. Based on Myers (1989:189–190), most species feed on benthic invertebrates or fish eggs, although some species do eat fishes.

Anampses includes five species in French Polynesia; only one species, *Anampses caeruleopunctatus*, was captured on Mangaia, speared on the seaward reef. All species of *Anampses* have distinctive teeth (on the dentaries and premaxillae) that have a pronounced anterior projection. Based on Myers's (1989:182–184) descriptions of feeding habits, species of *Anampses* are common on seaward reefs and feed mainly on various benthic invertebrates.

Hemigymnus is represented by two species in Micronesia and only one in French Polynesia, *Hemigymnus fasciatus*. Both species are commonly found on seaward reefs and lagoons; their diets are also similar, with a focus on various benthic invertebrates. *H. fasciatus* was the only species in the genus collected from Mangaia, speared on the seaward reef.

Halichores is the largest genus in the labrid family; six species are known from French Polynesia (Randall 1985). A single species was collected on Mangaia, *Halichores margaritaceus*, and was commonly observed on the fringing reef flat. Based on descriptions in Myers (1989), most species are quite small, reaching maximum lengths of less than 200 mm. Most species feed on benthic invertebrates and are found at depths between 1 and 60 m, mostly occurring in shallow waters.

Cheilinus is another speciose genus in the family with six species known from French Polynesia (Randall 1985). A single species was collected from Mangaia, *Cheilinus unifasciatus*, speared on the seaward reef. Most species in the genus feed on benthic invertebrates.

Family Scaridae—parrotfishes

Materials: 2 hyomandibulae, 1 premaxilla, 9 quadrates: 12 specimens

Subfamily Scarinae

Materials: 6 dentaries, 1 maxilla, 6 premaxillae: 13 specimens

Subfamily Sparisomatinae

Materials: 2 dentaries, 2 maxillae, 5 premaxillae, 1 fragmentary dentary or premaxilla: 10 specimens

Remarks: Twenty-one species in six genera are

reported for French Polynesia (Randall 1985). Two genera, *Calotomus* and *Scarus*, were collected from Mangaia; they were only observed on the seaward side of the fringing reef and only captured using a spear-gun. Genera representing the subfamilies (*Calotomus* sp.—Sparisomatinae; *Scarus* sp.—Scarinae) have very different jaw morphologies, which allowed for subfamily assignments of many of the MAN-44 specimens. Most species of parrotfish graze on algae on rock or consume live coral.

Family Eleotridae—sleepers

cf. *Eleotris* sp.

Materials: 54 articulars, 71 dentaries, 7 hyomandibulae, 40 maxillae, 22 premaxillae, 30 quadrates, 133 cleithra: 357 specimens

Remarks: The Eleotridae family consists of a large group of primarily fresh and brackish water fishes. A single, unknown species of *Eleotris* has been reported for French Polynesia (Randall 1985). A single species, *Eleotris fusca*, has been documented on Mitiaro (Jellyman 1991); this species has also been collected on Niue and New Caledonia and is probably the one present on Mangaia (R. M. McDowall, personal communication, March 12, 1993). Examples of the seven skeletal elements are shown in Figure 7.1. Little is known about the taxon's life history and ecology. In Hawai'i, *Eleotris sandwicensis* adults spawn in freshwater; their eggs or larvae wash downstream to sea, where individuals mature. Fish are still very small (15–20 mm) when they return to freshwater streams (R. A. Kinzie, personal communication, June 9, 1993). They have been found in a variety of freshwater habitats in Hawai'i, including mud-silt stream mouths and cobble-boulder pools (S. Hau, personal communication, March 8, 1993). *E. fusca* can reach total lengths of 260 mm (Hoese 1986).

Eleotris is probably the taxon Hiroa refers to as goby (family name Gobiidae) in his ethnography of the Cook Islands (Hiroa 1944:236, 244). Mangaian referred to a small freshwater fish as *kokopu* (Hiroa 1944). While true gobies may inhabit fresh and brackish water habitats on Mangaia today or did in the past, their remains were not identified at Tangatatau. Gobies tend to be very small (less than 100 mm in length), so it is possible that if their remains were present in site deposits, they slipped through the 1/8-in. mesh used. However, given the prominence of the fish in Te Rangi Hiroa's account (see below in Results)

and the abundance of *Eleotris* remains in the rockshelter, it is much more likely that that his “goby” is in fact an eleotrid.

**Family Acanthuridae—surgeonfishes and
Siganidae—rabbitfishes**

Materials: 151 cleithra

Family Acanthuridae—surgeonfishes

Materials: 20 hyomandibulae, 1 maxilla, 1 quadrate:
22 specimens

cf. *Acanthurus* sp.

Materials: 1 dentary, 32 hyomandibulae, 3 maxilla, 1 premaxillae, 3 quadrates: 40 specimens

cf. *Ctenochaetus* sp.

Materials: 1 quadrate

cf. *Naso* sp.

Materials: 1 dentary

Remarks: Acanthurids are represented by 30 species in five genera (including *Zanclus*) in French Polynesia (Randall 1985). On Mangaia, 13 species in five genera were collected. Except for the cleithrum, the skeletal morphology was distinctive across genera, and sufficiently complete archaeological specimens could be assigned to genus. The acanthurid cleithrum is similar to that of another family, the Siganidae, and so the aggregate category was used for this element. Given that siganid remains were not otherwise identified in the MAN-44 assemblage, the cleithra are probably from Acanthuridae, and in quantitative analyses, all remains are treated as acanthurids.

Acanthurids are small-mouthed herbivores. Species of *Acanthurus* feed on zooplankton and benthic algae; *Ctenochaetus* feeds mainly on detritus. Most species of *Naso* occupy the water column above the reef, feeding on large zooplankton. On Mangaia, small acanthurids (*Acanthurus triostegus*, *Acanthurus nigrofuscus*, *Ctenochaetus striatus*) were very common on the reef flat. Larger forms were common on the seaward side of the reef edge.

Order Pleuronectiformes

Family Bothidae—lefteye flounders

cf. *Bothus* sp.

Materials: 1 quadrate

Remarks: Three species in two genera (*Bothus*, *Engyprosopon*) are reported for French Polynesia (Randall 1985); a single species, *Bothus mancus*, also common in

French Polynesia, was collected from Mangaia, speared on the reef flat. Most bothids eat crustaceans and fishes (Randall et al. 1990:449). The two species of *Bothus* common in Polynesia and Micronesia occur in similar habitats, sandy bottoms from the inner reef flat to depths of 80 m or more (Myers 1989:255).

Order Tetraodontiformes

Family Balistidae—triggerfishes and

Monacanthidae—leatherjackets

Materials: 8 hyomandibulae, 5 quadrates, 11 cleithra:
24 specimens

cf. *Rhinecanthus* sp.

Materials: 9 hyomandibulae, 4 quadrates, 6 cleithra:
19 specimens

cf. *Xanichthys* sp.

Materials: 1 quadrate

Monacanthidae—leatherjackets

cf. *Cantherhines* sp.

Materials: 1 cleithrum

Remarks: Twenty-one species in 14 genera of the closely related triggerfishes and leatherjackets are reported for French Polynesia (Randall 1985). Seven species in five genera were collected from Mangaia. *Rhinecanthus* species are omnivores that consume algae, detritus, mollusks, worms, fishes, and foraminiferans, among other items. The two most common species in Micronesia (and the only species collected from Mangaia, *Rhinecanthus aculeatus* and *Rhinecanthus rectangulus*) are most common in shallow reef zones. All of the *Rhinecanthus* species are relatively small, reaching maximum sizes of about 250 mm.

Xanichthys careuleolineatus is the only species in the genus recorded for French Polynesia (Randall 1985); two other species are found in Micronesia. Habitat preferences of species of *Xanichthys* vary, but in general, they are uncommon in water less than 24 m deep and are usually found at much greater depths (Myers 1989; Randall et al. 1990). Myers (1989:260) notes that *X. careuleolineatus* is occasionally caught by bottom fishing; on Mangaia, this species was caught using hook and line on the seaward side of the fringing reef.

Three species of *Cantherhines* are known for French Polynesia; two were collected on Mangaia. *Cantherhines pardalis* was caught in a net set on the

reef flat, and *Cantherhines dumerilii* was speared. Species in this genus favor shallow reef areas occurring in water from 1 to 35 m (Myers 1989:262). Based on its large size, the MAN-44 cleithrum likely comes from *C. dumerilii*, the only very large species in this genus.

Family Diodontidae—porcupinefishes

Diodon sp.

Materials: 1 quadrat, 206 body spines (estimated)

Remarks: Three species in one genus, *Diodon*, are reported in French Polynesia (Randall 1985). Only *Diodon bystrix* was collected from Mangaia, speared in a tide pool on the fringing reef flat. Species in the family feed on hard-shelled invertebrates and live mainly in rocky coral reef areas where they can find shelter during the day; they are active at night (Myers 1989). A single quadrat was identified during the main phase of analysis; the body spines were tallied from a grab sample of fishbone bags from each stratigraphic zone (see Materials and Methods).

Results

A total of 1,649 fish remains representing 56 taxa from 31 families were identified from the main excavation block at Tangatatau (Table 7.1). The complete fish faunal database is available in the online database (www.dig.ucla.edu/tangatatau). While a huge variety of fish are present, as with many faunal assemblages, taxonomic abundance is highly uneven: based on NISP, eight of the 31 families represent 87 percent of the total assemblage, which, in descending order of abundance, include Eleotridae (sleepers), Cirrhitidae (hawkfishes), Labridae (wrasses), Acanthuridae (surgeonfishes), Serranidae (groupers), Anguillidae (freshwater eels), Holocentridae (squirrelfishes), and Muraenidae (moray eels) (Figure 7.4). The prominence of freshwater fishes, *Anguilla* and *Eleotris*, is especially noteworthy as these taxa are either rare or not noted at all in other Oceanic assemblages (Weisler et al. 2010; Weisler and Green 2013).

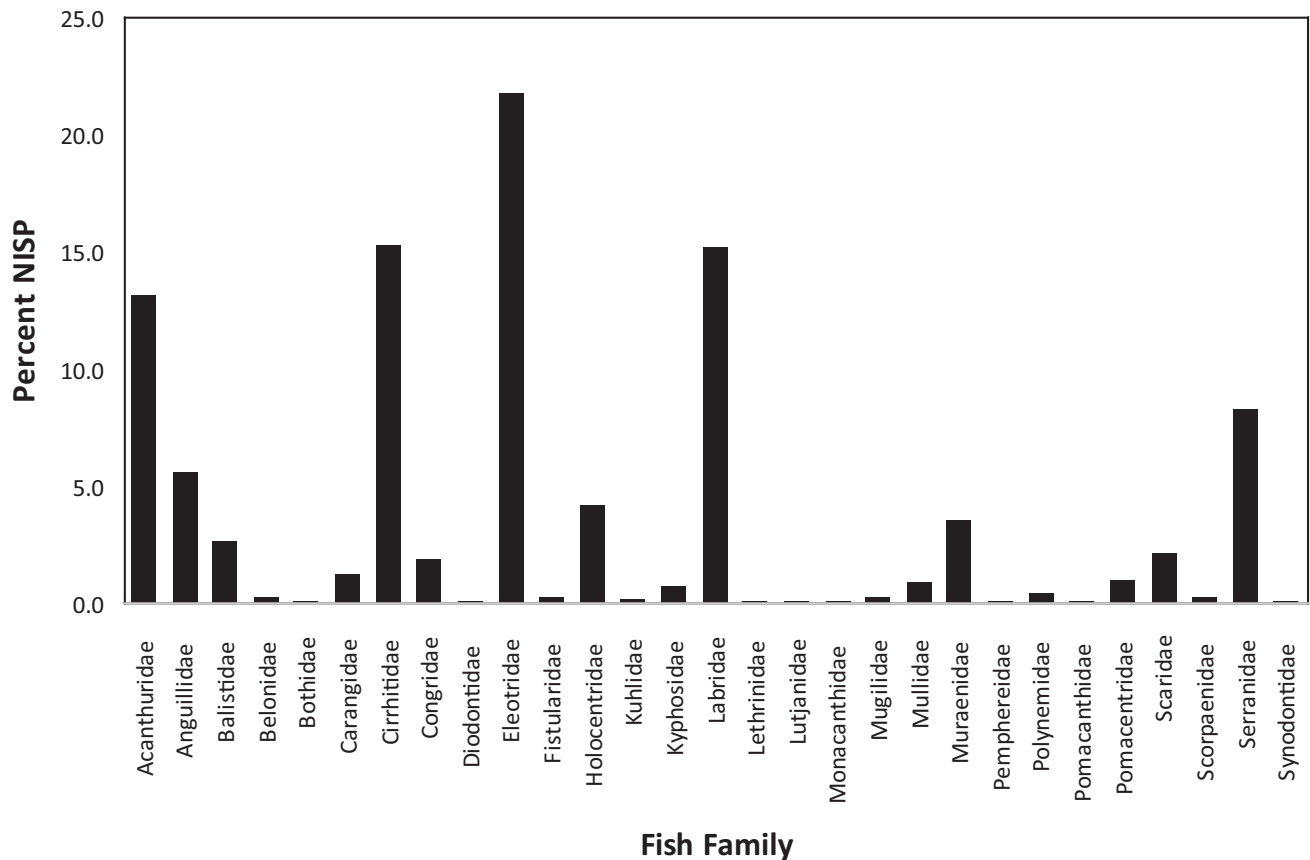


Figure 7.4. Barchart showing relative frequency (%NISP) of fish families, MAN-44.

According to Hiroa, Cook Island people did not place much importance on freshwater eels, except on Mitiaro, where they were caught “in large quantities from an inland lagoon” (Hiroa 1944:245). On the other hand, Hiroa provides a detailed description of *Eleotris* fishing on Mangaia:

Fresh-water gobies (*kokopu*) are found in the streams and in fresh-water lakes such as Lake Tiriara [~1 km east of MAN-44] in Mangaia. When the sea was too rough to permit of [*sic*] sea or lagoon fishing, the process of *rotu* or *rutu kokopu* for gobies was carried out in Lake Tiriara. In olden times, the shores of the lake were cleared of hibiscus trees (*‘au*) and weeded. A party of about 40 men took part in the operations, standing in water up to the breast, this depth being termed one *tukungā*. An old *nariki* net was set with a man holding each end pole. The other men formed an oval formation (*rau tangata*) and worked toward the net splashing the water with both hands to drive the fish before them into the net. When the net was lifted, as many as three coconut-leaf baskets were filled. The lake was worked over, and even the deeper parts near the exit under the makatea wall were explored. When operations ceased, the catch was distributed (*tu‘a*) among those who had taken part. . . . Angling for goby (*titomo kokopu*) was done with gorges and with the primitive hooks made with pandanus spines. The bait was fresh-water shrimp (*koura vai*) [1944:244].

Mangaians devoted considerable effort to the capture of this small nondescript fish. While Hiroa hints that *kokopu* was a backup resource—taken when rough waters made marine fishing difficult—the organization required for large-scale communal fishing, as well as the substantial harvests that such efforts generated, suggests *kokopu* was an important resource. Hiroa also notes that *kokopu* was angled by children, which would have provided a low-risk way for them to contribute to the subsistence quest. The prominence of *Eleotris* in almost every stratigraphic zone in the rockshelter highlights its enduring importance to site occupants.

Most marine fish taxa at MAN-44 represent inshore fishes that could have been caught on the reef flat or reef edge, with only a handful of remains from offshore, pelagic fishes (Table 7.2). While multiple taxa could be taken on *both the reef flat and the seaward edge* (e.g.,

marine eels [Muraenidae, Congridae], Serranidae, Holocentridae), 16 taxa noted in the rockshelter are almost exclusively found on the seaward side of the reef edge: Cirrhitidae, several labrids (*Anampses*, *Hemigymmus*, *Cheilinus*, *Gomphosus*), larger balistids (*Xanichthys*, *Cantherhines*), and carangids (*Aphareus*, *Caranx*). Marine fish and fishing receive the greatest attention by Hiroa (1944): dozens of approaches to fishing, especially related to nets and traps, are reviewed.

Effects of Quantification/Analytic Decisions on Results

What effect has the use of NISP had on fish abundance estimates? The short answer is, “not much”; faunal abundance based on NISP is very similar to that from MAU. One can base MAU values on various aggregates of site deposits (e.g., the whole site, excavation unit and level, or other entities). Given the detailed stratigraphic records and rich radiocarbon record for MAN-44, I reasoned the best discrete entity for calculating MAU would be by aggregated stratigraphic zones (the aggregates being SZ-2, SZ-3 to SZ-4B, SZ-5 to SZ-7, SZ-8 to SZ-9, and SZ-10 to SZ-17). Each aggregate of stratigraphic zones represents a block of time, making it unlikely that remains from a single fish are scattered across multiple aggregates of zones, which would inflate MAU estimates. I compared counting units for the family level, given small sample sizes associated with many of the subfamilies. In this way, MAUs were calculated for each family in each aggregate of stratigraphic zones, then tallied for the whole site. As shown in Table 7.3, the rank orders based on NISP and MAU are extremely similar; the correlation is high and significant ($r_s = 0.99$, $p < 0.01$). For both methods, the same 10 families are ranked the highest. The greatest difference is with Acanthuridae, which is highest ranked for MAU but ranks fourth with NISP. This taxon generates relatively lower NISP values because of the underrepresentation of jaw elements, which are lightly built and less likely to preserve.

To study the effects of quantification in more detail, I compared NISP and MAU values for two of the aggregates of stratigraphic zones (SZ-5 to SZ-7 and SZ-10 to SZ-17) (Figure 7.5), focusing on the top 10 families. In both cases, rank-order correlations are high and significant. NISP values place acanthurid at a lower rank than MAU in both comparisons (Figure 7.5), as noted for the whole site. On the other hand, the similarities far outweigh the differences, suggesting that both counting units are providing similar kinds of information about taxonomic representation. Given

Taxon	1A	1B	2	3	4A	4B	5	6	7	8	9	10	11	13	14	15	17	18	19	F32 ^a	No Zone	NISP
cf. <i>Mugil</i> sp.																1						1
cf. Sphyraenidae ^b										2							1					—
cf. <i>Polydactylus sexfilis</i>							1			2						5						8
Labridae	3	4	9	4	6	4	14	3	5	34	1	2	2	2	1	6	1	7	7			111
<i>Gomphosus varius</i>										3												6
cf. <i>Thalassoma</i> sp.		1	6	6	6	6	8	3	3	22	2		1	1	1	1	2	4				66
cf. <i>T. purpuraceum</i> or <i>trilobatum</i>				1	2		3		1	8			1							1		17
cf. <i>T. quinquevittatum</i> or <i>lutescens</i>				1		1																2
cf. <i>Thalassoma</i> or <i>Halichoeres</i> sp.					3	2	1	1	1	10	1	1	1	1	1					1		21
cf. <i>Anampses</i> sp.		3	3	2						1					1							10
cf. <i>Halichoeres</i> sp.					1	1				1												3
cf. <i>Hemigymnus</i> sp.					2					2												4
cf. <i>Cheilinus</i> sp.					6	2		1														9
Scaridae		2	7	1								1						1				12
Scarinae			9	2	2		1	1														13
Sparisomatinae					2	1	1			5			1									10
cf. <i>Eleotris</i> sp.	12	70	20	40	13	11	5	21	5	62	4	4		1		69	2	19	2	2		357
Acanthuridae or Siganidae	1	1	12	27	15	6	21	5	9	47	2	4	1	3		8	2	2	6	1		173
cf. <i>Acanthurus</i> sp.		2	5	9	3		4		1	14								1		1		40
cf. <i>Ctenochaetus</i> sp.								1														1
cf. <i>Naso</i> sp.			1																			1
Bothidae					1																	1
Balistidae or Monacanthidae				1	3	2	5	1	5	4	1	1	1									24
cf. <i>Rhinecanthus</i> sp.				2	1		2		1	12					1							19
cf. <i>Xanichthys</i> sp.										1												1
cf. <i>Cantherbines</i> sp.					1																	1
<i>Diodon</i> sp.			1																			1
Totals	1	46	168	198	178	67	140	56	80	377	22	27	11	12	1	135	16	62	37	14	1	1,649

^aFish remains were studied from F32, a large pit feature in CZ-6 and CZ-7; otherwise, fishbone in features was not studied.

^bDocumented from teeth only.

Table 7.2 List of Finest Fish Taxa by Aquatic Habitat

Taxon	Freshwater	Reef Flat	Reef Edge	Offshore
<i>Anguilla</i> sp.	x			
cf. <i>Eleotris</i> sp.	x			
<i>Kuhlia</i> sp.		x		
Mullidae		x		
Synodontidae		x		
Muraenidae		x	x	
cf. <i>Conger cinereus</i>		x	x	
Belonidae		x	x	
Holocentridae		x	x	
Holocentrinae		x	x	
Myripristinae		x	x	
<i>Fistularia</i> sp.		x	x	
Scorpaenidae		x	x	
Serranidae		x	x	
cf. <i>Pempheris oualensis</i>		x	x	
Kyphosidae		x	x	
Pomacanthidae		x	x	
Pomacentridae		x	x	
Mugilidae		x	x	
cf. <i>Thalassoma</i> sp.		x	x	
cf. <i>T. quinquevittatum</i> or <i>lutescens</i>		x	x	
cf. <i>Thalassoma</i> or <i>Halichoeres</i> sp.		x	x	
cf. <i>Halichoeres</i> sp.		x	x	
Acanthuridae or Siganidae		x	x	
cf. <i>Acanthurus</i> sp.		x	x	
cf. <i>Ctenochaetus</i> sp.		x	x	
Bothidae		x	x	
<i>Diodon</i> sp.		x	x	
Carangidae			x	
cf. <i>Decapterus</i> sp.			x	
cf. <i>Caranx</i> sp.			x	
cf. <i>Aphareus</i> sp.			x	
Cirrhitidae			x	
cf. <i>Polydactylus sexfilis</i>			x	
<i>Gomphosus varius</i>			x	
cf. <i>T. purpureum</i> or <i>trilobatum</i>			x	
cf. <i>Anampses</i> sp.			x	
cf. <i>Hemigymnus</i> sp.			x	
cf. <i>Cheilinus</i> sp.			x	
Scaridae			x	
cf. <i>Naso</i> sp.			x	
cf. <i>Rhinecanthus</i> sp.			x	
cf. <i>Xanichthys</i> sp.			x	
cf. <i>Cantherhines</i> sp.			x	
Carcharhinidae				x
cf. Sphyrnidae				x

Table 7.3 Comparison of Fish Family Frequency, NISP vs. MAU, Site MAN-44

Family	Total NISP	Rank	Total MAU	Rank	Rank Difference
Eleotridae	334	1	60.5	2	-1
Labridae	227	2.5	43.5	3	-0.5
Cirrhitidae	227	2.5	30.5	4	-1.5
Acanthuridae/Siganidae	204	4	72	1	3
Serranidae	121	5	15.5	6	-1
Anguillidae	89	6	25	5	1
Holocentridae	64	7	11	8	-1
Muraenidae	54	8	14	7	1
Balistidae	44	9	9.5	9	0
Scaridae	34	10	7.5	10	0
Congridae	29	11	6.5	11	0
Carangidae	19	12	4	12	0
Pomacentridae	15	13	3.5	13.5	-0.5
Mullidae	14	14	3.5	13.5	0.5
Kyphosidae	11	15	2.5	15.5	-0.5
Polynemidae	8	16	2	17.5	-1.5
Scorpaenidae	5	17.5	2.5	15.5	2
Belonidae	5	17.5	2	17.5	0
Mugilidae	4	19.5	1.5	19	0.5
Fistularidae	4	19.5	1	20.5	-1
Kuhliidae	3	21	1	20.5	0.5
Pemphreidae	2	22	0.5	25.5	-3.5
Bothidae	1	26	0.5	25.5	0.5
Diodontidae	1	26	0.5	25.5	0.5
Lethrinidae	1	26	0.5	25.5	0.5
Lutjanidae	1	26	0.5	25.5	0.5
Monacanthidae	1	26	0.5	25.5	0.5
Pomacanthidae	1	26	0.5	25.5	0.5
Synodontidae	1	26	0.5	25.5	0.5

its simplicity and additive property, NISP is used to quantify most results.

Representation of Diodontidae was greatly affected by the restricted set of elements used in analysis. While a single quadrat was documented (in zone SZ-2), providing a NISP of just one, diodontid spines were found in 9 of the 13 zones studied (Table 7.4), showing that the fish was used throughout most of the occupation. As extrapolated from subsamples, a total of 206

body spines was estimated for the 36 unit-level bags I scanned. Given that a single fish has over 400 individual spines (based on counts of comparative reference skeleton, VLB91-1-74), the frequency of spines is a poor estimate of fish abundance per se. On the other hand, including spines provides a simple way to document the presence of this taxon in site contexts, supporting Leach's (1986) call for use of this "special bone" in Oceania fish faunal analyses.

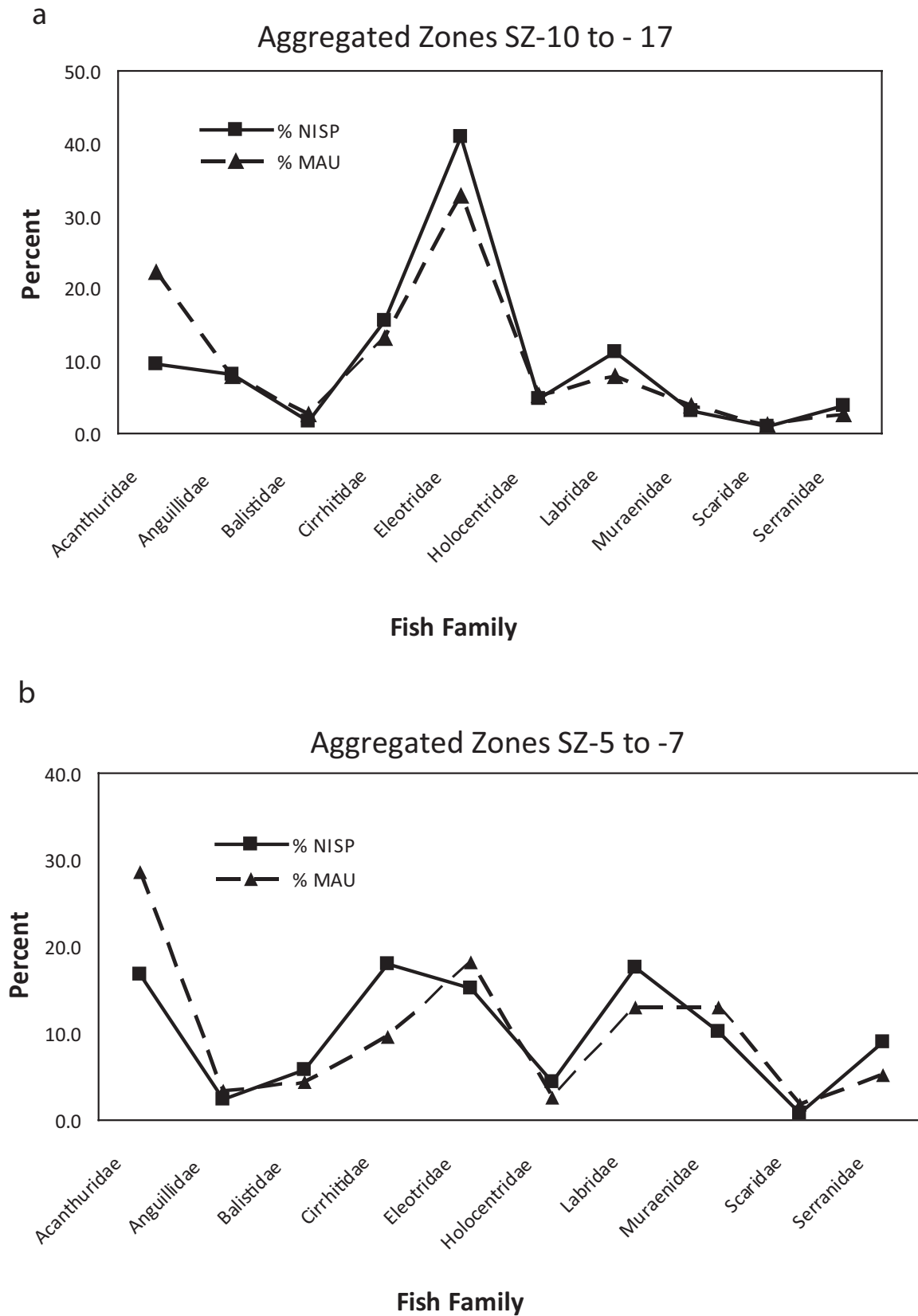


Figure 7.5. Comparison of %MAU vs. %NISP calculated for aggregates of stratigraphic zones: *a*, SZ-10 – SZ-17; *b*, SZ-5 –SZ-7.

Table 7.4 Estimated Abundance of Diodontidae Body Spines, Site MAN-44

Stratigraphic Zone (SZ)	No. of Unit-Level Bags Studied	Estimated NSP	Estimated No. of Spines	% Diodon Spines (No. of Spines/NSP)	Concentration Index (No. of Spines/Volume)
17	5	839	8	1.0	5.2
15	3	439	4	0.9	3.1
14	1	43	0	0.0	0.0
13	2	122	0	0.0	0.0
11	1	152	4	2.6	22.2
10	3	413	10	2.4	38.5
9	3	758	2	0.3	1.4
8	3	888	0	0.0	0.0
6	3	494	4	0.8	3.8
5	3	936	4	0.4	5.0
4A	3	912	0	0.0	0.0
3	3	1,108	160	14.4	81.0
2	3	622	10	1.6	6.3
Estimated total	36	7,726	206		

Taphonomic Considerations: Burning

Kirch et al. (Chapter 8) describe extensive burning and breakage of the invertebrate remains in site MAN-44. If fish remains and shellfish entered the site as part of the same activity chain of collection, processing, and deposition, we might expect consistency in burning and breakage across stratigraphic zones. While breakage/element completeness was not documented for fish remains, my impression is that the remains are relatively complete, which is inconsistent with the shellfish. As well, relatively little fishbone was burned. Out of 1,638 specimens, only 168 specimens or 10 percent are burned, whereas over 90 percent of the shellfish showed evidence for burning (see Chapter 8). The comparison in condition between fish and shellfish is not ideal, since fishbone represents all excavation units and stratigraphic zones at the site, whereas the shellfish included in the taphonomic study is from unit E31 alone, representing zone SZ-4A and younger stratigraphic zones. Since the fish remains show localized burning, the condition of the invertebrate remains from excavation unit E31 may not be representative of the whole site.

As a proportion of fish NISP in a given stratigraphic zone, burned fishbone is extremely common in SZ-2, with much lower proportions of burning in higher/younger stratigraphic zones (Figure 7.6); burning of freshwater fish remains, especially from *Eleotris*,

is especially common. Focusing on SZ-2 and the three families with the highest NISP (Anguillidae, Eleotridae, Cirrhitidae), chi-square analysis shows that the incidence of burning varies significantly across families (Table 7.5; $\chi^2 = 12.20$, $p = 0.002$). Examination of adjusted residuals (VanPool and Leonard 2011) shows which categories are most responsible for the significant chi-square. Adjusted residuals are interpreted as standard normal deviates (or z scores); significant values ($p = 0.05$) are those residuals that are less than -1.96 and greater than 1.96 . As shown in Table 7.5, significant residuals are associated with both freshwater taxa: eleotrid remains show higher incidence of burning than expected, whereas fewer anguillid remains are burned than expected. Patterning in burning of the marine fish, cirrhitid, is not significant.

Why so much burned bone in SZ-2 and why is it preferentially associated with *Eleotris*? If burning simply resulted from disposal of fish remains in fires as trash, we would expect consistent burning across taxa, which is not the case for the freshwater fish. Also, if it was a common practice to burn fish food residue, then we would expect more fishbone burned in higher stratigraphic zones, since combustion features such as hearths and earth ovens are common above SZ-2 (see Chapter 4). The causes for the isolated burning in SZ-2 and for *Eleotris* in particular are not known. Closer study of spatial context of remains may provide

Table 7.5 Frequency (NISP) of Burning in Zone SZ-2 for Three Most Abundant Families, Site MAN-44

Family	Burned		Not Burned		Total
	NISP	Expected/Adjusted Residuals	NISP	Expected/Adjusted Residuals	
Anguillidae	21	14.7/2.8	6	12.3/-2.8	27
Eleotridae	29	38.0/-3.4	41	32/3.4	70
Cirrhitidae	13	13/1.4	6	8.7/-1.4	19
Total	63		53		116

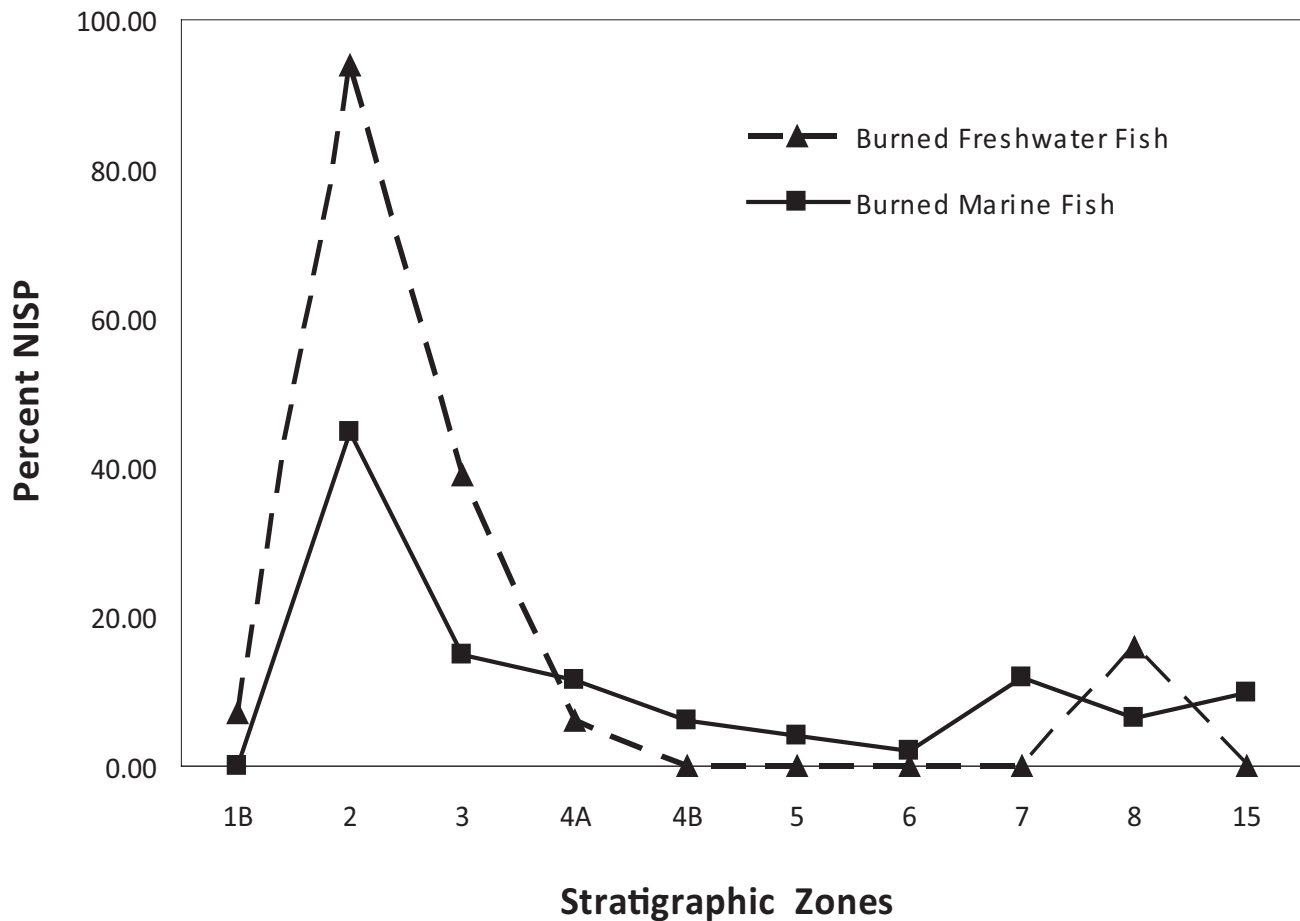


Figure 7.6. Frequency (%NISP) of burning for marine vs. freshwater fishes by stratigraphic zone (stratigraphic zones excluded if less than 30 NISP).

answers. For now, results show that during *most site occupation*, fish processing such as roasting did not result in burning of fishbone and that people disposed of fish away from fires.

Temporal Trends in the Fish Assemblage

This section highlights several temporal trends in (1) fishbone concentration index (CI) reflecting the scale of fishing, fish processing, and deposition of remains

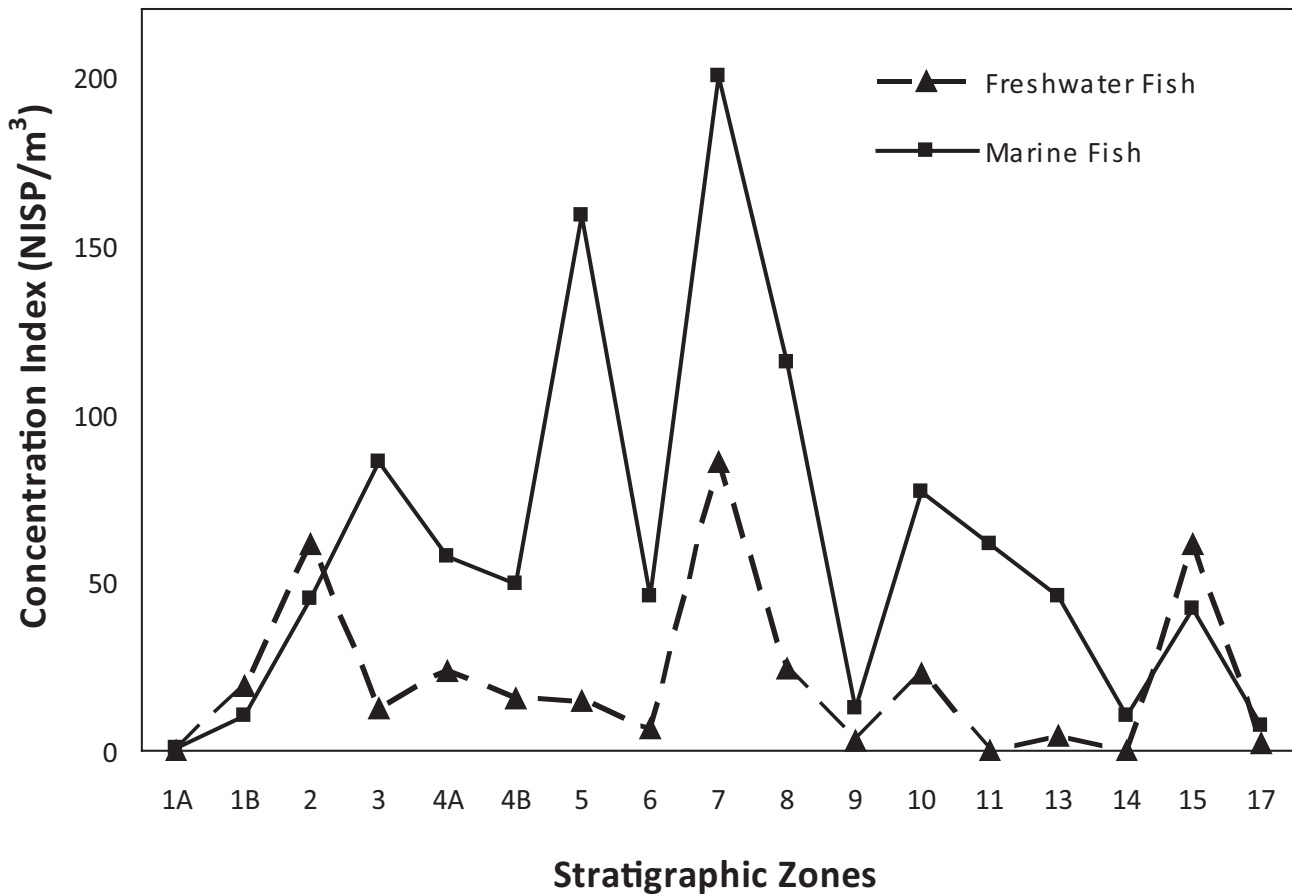


Figure 7.7. Concentration Index (CI) for freshwater and marine fish by stratigraphic zone.

at the rockshelter, which is also compared to trends in mollusk distribution; (2) proportional representation of the most abundant fish taxa as a measure of resource selection; (3) fish representation compared to the fish hook assemblage to track ways technology informs on resource selection; and (4) fish body size to better understand predation intensity and habitats exploited.

Changes in Intensity of Fish Exploitation

As shown in Figure 7.7, fish CI, calculated as NISP/m³ for each stratigraphic zone, is highly uneven. The deepest stratigraphic zones show relatively modest fish use, with major increase in use for SZ-5 and SZ-7, then a return to more moderate use after SZ-8. Freshwater fish dominate in early zones, SZ-1B and SZ-2, and then in SZ-15. Marine fish use rises sharply in SZ-3 and continues to dominate until after SZ-13. While the density of marine and freshwater fishbones clearly vary, rank orders of the CI for the two fish groups are moderately correlated ($r_s = 0.51, 0.05 > p > 0.02$). Fishers sought

out marine and freshwater fish (and returned their catch to the rockshelter) during all occupation periods.

The sharp increase in CI from SZ-1B to SZ-2 supports the interpretation that SZ-2 reflects the earliest in situ habitation (see Chapter 4), whereas SZ-1A and SZ-1B represent either natural formation or only sporadic human use. The prominence of land- and seabird remains in zones SZ-1A and SZ-1B (see Chapter 4) suggests that the fish remains found there may represent residue from bird exploitation. It is also plausible that the fish remains recovered in SZ-1B were originally deposited in SZ-2 and worked their way into deeper strata through human disturbance.

The CI for marine fish and marine mollusks (calculated as g/m³) across stratigraphic zones is extremely similar (Figure 7.8; for more information on invertebrates, see Chapter 8). Marine fish and shellfish use increases greatly after SZ-4B and sharply declines after SZ-8. Because the analyzed invertebrate sample did not include material from zones SZ-9 to SZ-13, it is not

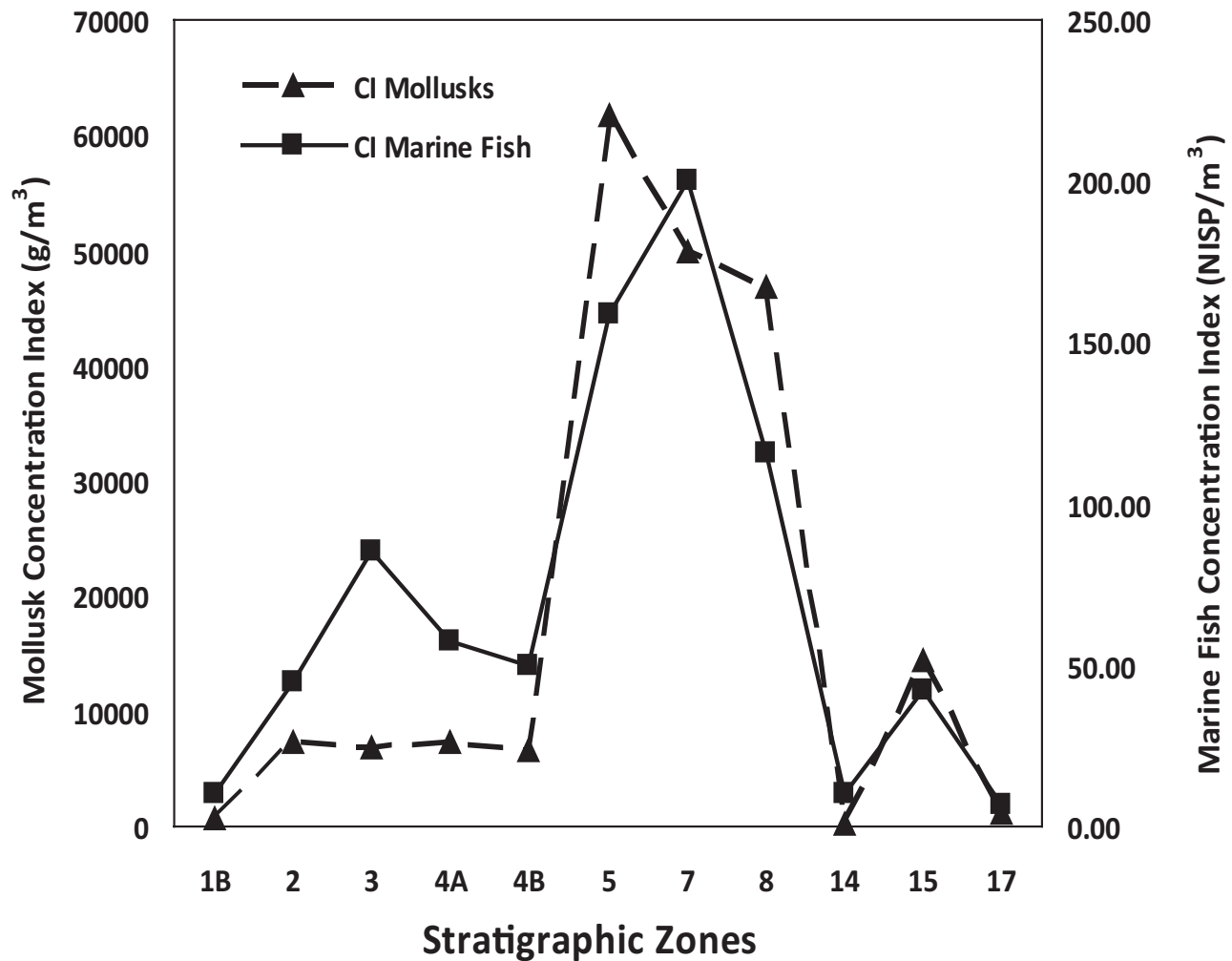


Figure 7.8. Concentration Index (CI) for marine fish and mollusks by stratigraphic zone.

possible to systematically compare fish and invertebrate use for these zones. Since marine fish continue to contribute to rockshelter deposits during these upper zones (Figure 7.7), it seems likely that invertebrates did as well.

Changes in Fish Taxa Selection

Looking closely at changes in abundance of particular fish taxa based on percent NISP for each zone shows that representation is highly dynamic (Figure 7.9a,b). Regarding freshwater fishes, except for SZ-1B, *Eleotris* is always more abundant than freshwater eel and in four zones (SZ-2, SZ-4A, SZ-7, and SZ-15), *Eleotris* is the most abundant fish taxon overall (Figure 7.9a,b). (Note: these comparisons include zones with sample size ≥ 30 NISP). For the four most abundant marine fish families (Figure 7.9b), Cirrhitidae is consistent in zones above SZ-2, while the relative frequency of

Acanthuridae, Labridae, and especially Serranidae is more variable.

The frequency of diodontid also varies greatly, based on two abundance estimates, a concentration index and spine frequency as a fraction of NSP (Figure 7.10). Zone SZ-3 shows especially high frequencies of spines, SZ-10 and SZ-11 contain a modest frequency, and spines are very uncommon otherwise (Figure 7.10). The sharp rise in diodontid in SZ-3 is consistent with the increase in the marine fish CI noted above (Figure 7.7), supporting the idea that SZ-3 marks an increase use of marine resources from SZ-2.

Fish Representation and Fishhooks

There is much interest in studying fishing in Oceania—using fishing-related artifacts like fishhooks, ethnographic records of fishing, and archaeo-fish remains to

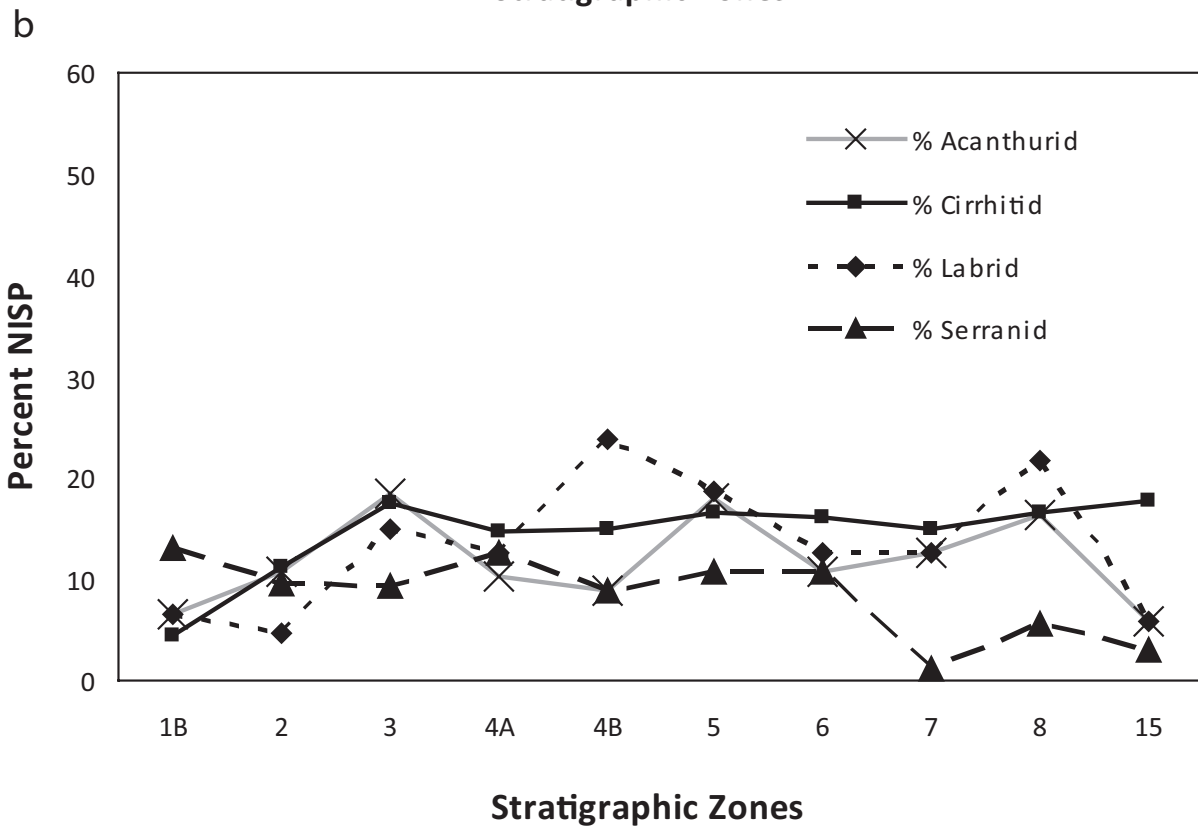
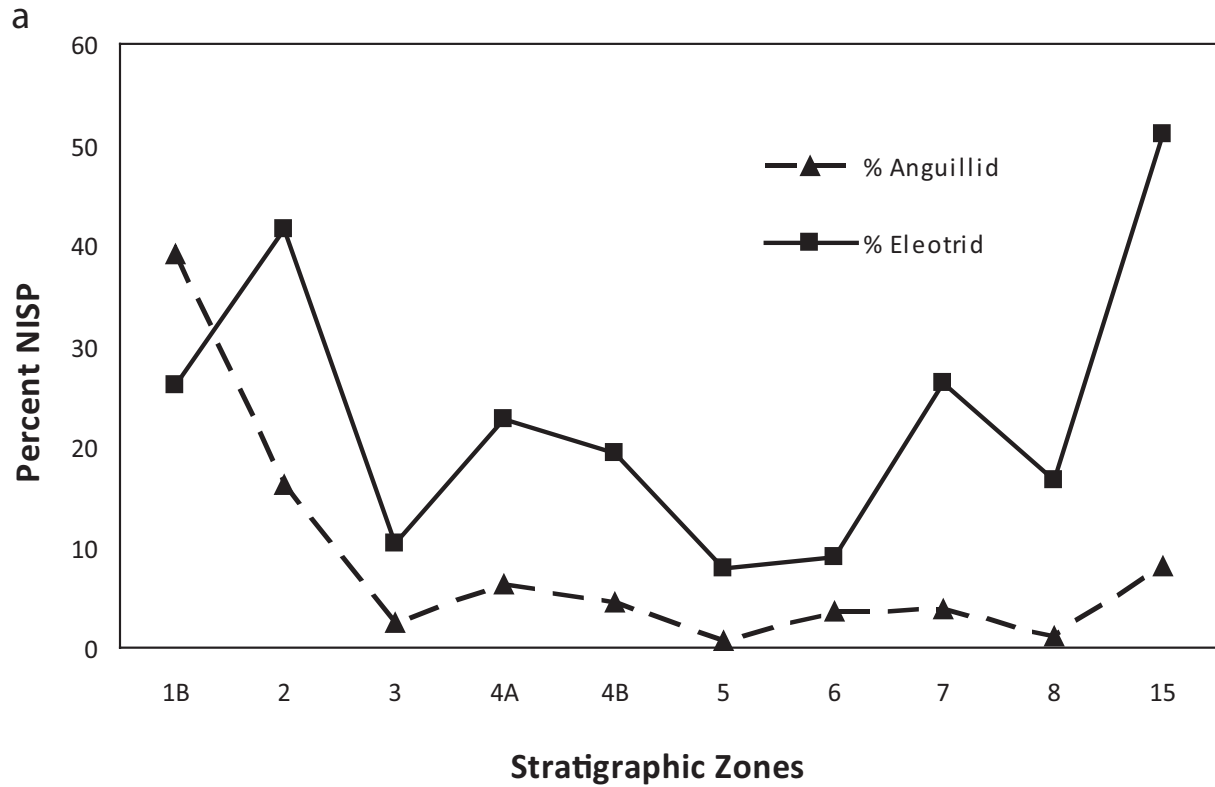


Figure 7.9. Frequency (%NISP) of fish by stratigraphic zone. *a*, freshwater fish; *b*, marine fish (stratigraphic zones excluded if less than 30 NISP).

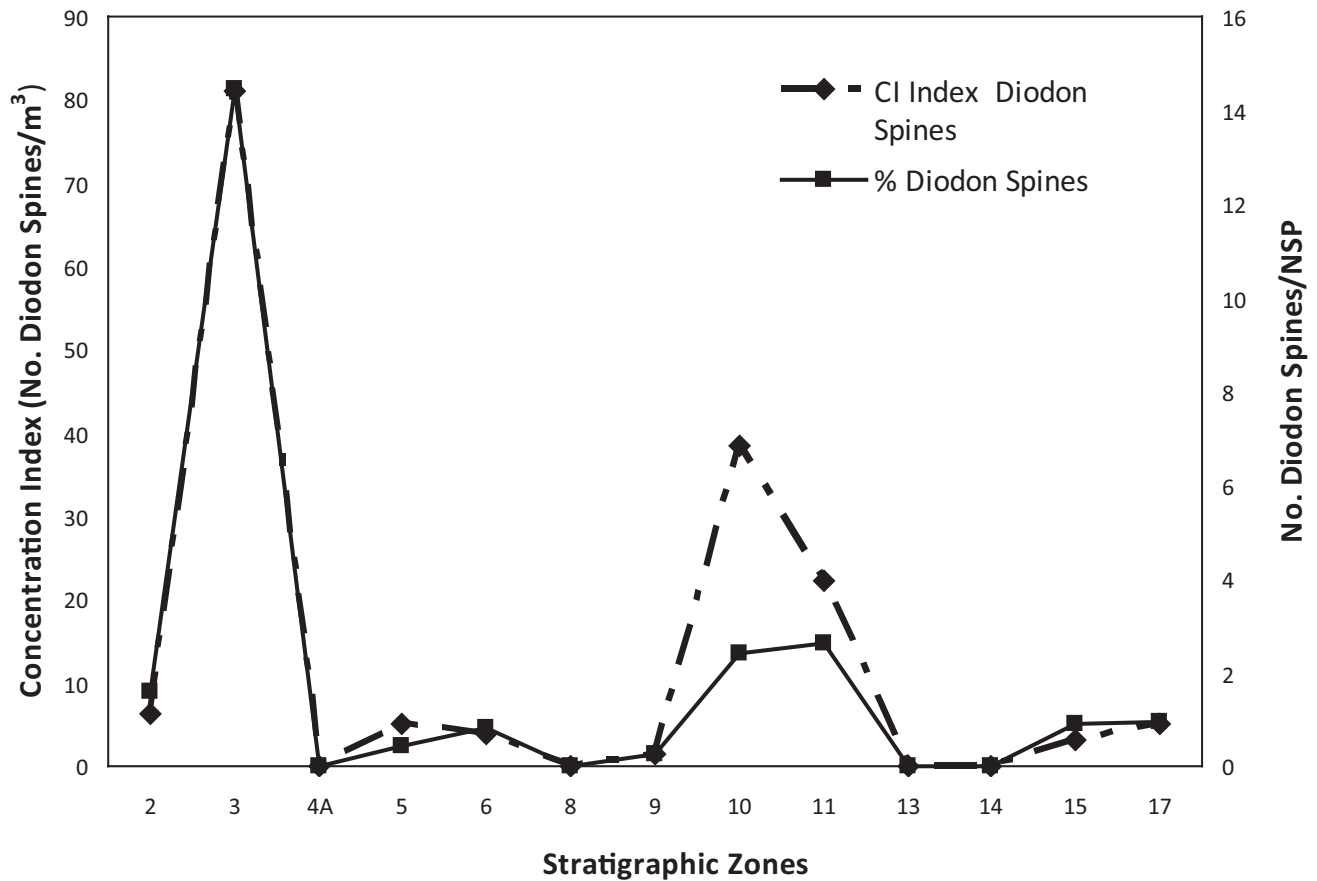


Figure 7.10. Concentration Index (CI) of Diodontidae spines and estimated number of spines/estimated number of specimens (NSP) by stratigraphic zone.

reconstruct fishing practices and to explore the social and environmental conditions that explain variation in fisheries seen over space and through time (e.g., Allen 1992a; Butler 1994; Kirch and Dye 1979; Weisler et al. 2010). Tangatatau Rockshelter—with abundant fishhooks (Chapters 10 and 11), a high-resolution stratigraphic context (see Chapter 5), and well-documented fish remains—provides an opportunity to explore temporal change in fisheries on Mangaia.

The shell fishhook assemblage includes 234 finished hooks (115 complete) (see Chapter 11, Table 11.4). While both straight shank (type I) and curved shank (type II) hooks are present, here I combine the types for comparison with the fish faunal record. The hooks vary in abundance across stratigraphic zones (Table 11.4); the most distinct trend is the near absence of hooks above SZ-8. Do changes in hook abundance correspond to the types of fish represented? Much previous research suggests that certain fish types—namely,

carnivores—are preferentially caught by angling versus netting or traps and spears (Butler 1994; Leach and Intoh 1984; Masse 1986). Carnivorous fish consume more active prey with large jaws designed to procure and handle prey, and they are more likely to strike a baited hook than herbivores/omnivores, which tend to have smaller mouths and focus on sessile or slow-moving prey (Butler 1994). Herbivores/omnivores are more likely to be captured with nets and traps.

Given this context, I posed two expectations for fish taxonomic representation across zones: (1) the frequency of carnivores should *decline* after SZ-8 and (2) the frequency of fishhooks should co-vary with the frequency of carnivores across zones. To test these expectations, I created a fishhook concentration index (N fishhooks/m³, including complete and fragmentary) for each zone. To assign fish families represented in the rockshelter to feeding type, I used Butler (1994), and for families not treated by Butler, I used Myers (1989).

I then created two concentration indices (NISP carnivores/m³), one exclusively for marine carnivores and one that included marine and freshwater fishes (both *Eleotris* and *Anguilla* are carnivorous).

There is some support for the expectations (Figure 7.11). Focusing on the direction of the CI trend lines (and less on magnitude), all three indices decline after SZ-8. Moreover, the overall trend in CIs from SZ-4B to SZ-8 are consistent. The CI for marine carnivores shows more consistency with the fishhook CI than the index that incorporates freshwater fishes. Arguably, the marine carnivore CI is the most appropriate one against which to compare the fishhook record. While

the dominant freshwater fish in the rockshelter, *Eleotris*, could be taken with hook and line, the net fishery was especially productive and was likely the main way in which the fish was caught (Hiroa 1944).

However, there are at least two limitations with these tests. First, carnivorous fishes are prominent in stratigraphic zones higher than SZ-8 (Figure 7.9b, see especially the high proportion of cirrhitids), when shell fishhooks are extremely scarce, so we know that at least some carnivorous fish were caught with technology that did not require shell fishhooks. Possibly fishhooks in these upper zones were made from perishable materials such as coconut shell—or perhaps these fish

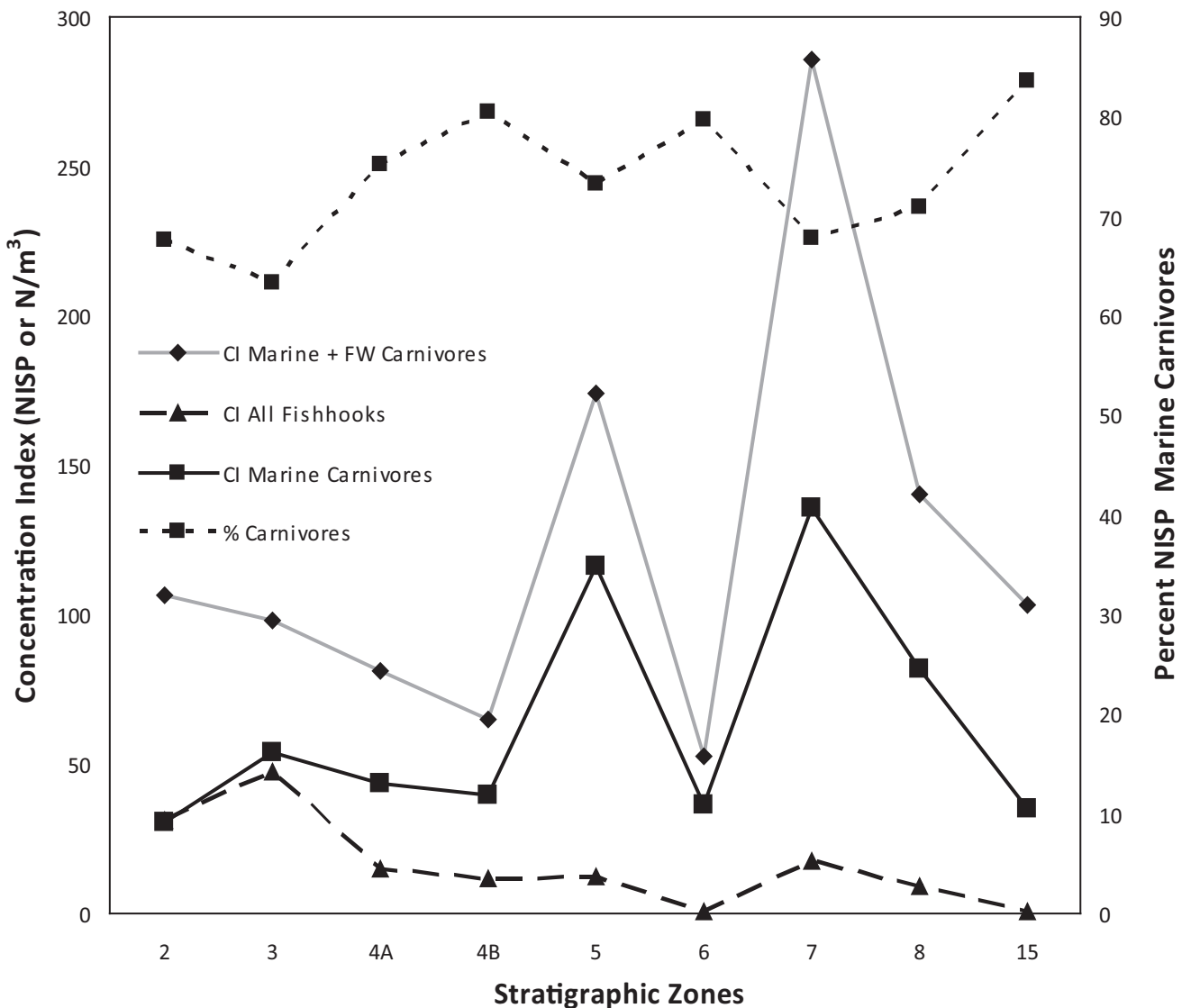


Figure 7.11. Concentration Index (CI) of marine carnivorous fish, marine and freshwater carnivorous fish, and fishhooks; and %NISP of marine carnivorous fish by stratigraphic zone.

were not caught by angling at all. Regardless of the reason (both may contribute), tight linkage between fishhook frequency and representation of fish feeding types is probably elusive. The other problem with the test as designed for MAN-44 relates to the concentration indices as measures of fish feeding type. Carnivorous fishes absolutely dominate *all* stratigraphic zones (Figure 7.11), representing between 60 percent and 85 percent of the fish remains in each zone. Variation in the CIs for carnivores is telling us about variation in fish use overall, rather than use of carnivorous fish per se.

In sum, while fishhook frequency obviously varies across stratigraphic zones, linking changing fishhook concentration to carnivore versus herbivore fish representation is problematic. At a general level, the dominant fishhooks present—the curved shank and straight shank forms—are consistent with the types of fish present and the habitats people fished. Following the reasoning of Reinman (1970) and Allen (1992a), which links fishhook form and function, the straight shank forms were probably mostly used in calmer waters of the reef flat. The curved forms would have been preferred for fishing in rougher waters at the seaward edge. As well, curved fishhooks would be less likely to snag on submerged rocks and coral, more common on the seaward edge. The presence of only two hook pieces from compound hooks (so-called bonito trolling lures, see Chapter 11) is consistent with the limited evidence for pelagic fish at Tangataau.

Fish Body Size—Link to Resource Depression?

In 2001, I used foraging theory as applied to studies of human-resource relationships in multiple archaeological contexts (e.g., Allen 2002, 2003; Broughton 1994; Nagaoka 2002) to test whether intensity of fishing practices caused resource depression of fish populations on Mangaia (Butler 2001). My results showed some evidence for resource depression of fishes, with an apparent increase in frequency in small-bodied taxa and declines in body size of two fish taxa. Expanding the study here to include measures of two additional taxa provides further hints that people overexploited some of the island's fishery resources.

I focused my study on four taxa, which provided the largest samples of the dentary, one of the most abundant elements identified at the site. Table 7.6 summarizes sample sizes and basic statistics for the 128 specimens measured. Three of the taxa probably each represent a single species (*Anguilla* sp., *Eleotris* sp., and *Cirrhitus*

pinnulatus), so trends in size over time reflect change in the body size of that species. The fourth taxon, Serranidae, represents a number of genera and species, which are characterized by great variation in size (Myers 1989). Thus, declines in size in serranid dentaries may represent a decline in age/size reflecting heavy predation on a given species or increased use of smaller-bodied species, or both factors could be involved.

As shown in Figure 7.12, freshwater taxa *Anguilla* and *Eleotris* do not change in size through time. The test for exploitation pressure on *Anguilla* is limited, given the very small sample sizes above SZ-4. The substantial *Eleotris* record, however, is sufficient to show that the taxon was sustainably used over the duration of the rockshelter occupation.

On the other hand, the size of *Cirrhitus*, one of the dominant marine taxa captured on the seaward side of the reef edge, declines in size in SZ-15 from SZ-8 (Figure 7.12), a change that is significant at the 0.10 level ($t = 1.736$, $p = 0.103$). As well, Serranidae size also declines (Figure 7.12), but as noted above, whether this reflects an actual decrease in size of individuals in the population or shifts to smaller species is not known. In foraging models, however, a shift to smaller-bodied taxa is expected if abundance of larger-bodied taxa were to decline. Thus, the ambiguity as to what variable is being measured with the decline in serranid size is not critical to the case that Mangaian fishers may have caused resource depression of some fish populations. More critical is the very small number of serranid dentaries used for the study ($n = 12$, across stratigraphic zones), limiting inferences regarding decline in size.

The fish represented in the rockshelter are quite small throughout the entire occupation sequence. While specific body size reconstructions are not possible, comparing archaeological bone size to modern reference materials (Table 7.6) indicates the diminutive nature of the Tangataau fish remains. Most of the *Eleotris* and *Cirrhitus* represented are less than 200 mm standard length, which is expected, as these are small-bodied fish. The archaeological *Anguilla*, however, is much smaller than the fish is capable of reaching. The modern *Anguilla* caught on Mangaia (specimen VLB 91-1-81), with a standard length of almost half a meter, has a dentary measure of 3.10 mm. The mean size of the archaeological *Anguilla* dentary is less than half this size, only 1.37 mm, and the largest dentary measures only 2.01 mm in height. *Anguilla* sampled on Mitiaro, another *makatea*

island in the Cook Islands (Jellyman 1991), are large as well, with mean sizes comparable to modern fish caught on Mangaia. Thus, freshwater systems on *makatea* islands can certainly support eels much larger than the largest fish recovered from the Tangatatau Rockshelter.

There are at least two hypotheses to account for the small size of eels at Tangatatau. One possibility is that prior to the earliest occupation of the rockshelter, human populations on the island had already depleted the eel population. The Vairorongo site—located on the narrow coastal plain on the northwest side of Mangaia near Avarua—shows evidence of human occupation between AD 1060 and 1302, prior to sustained human occupation of MAN-44 (see Chapter 3; Igarishi 1999). A second explanation is that hillside erosion caused by extensive forest clearing associated with agriculture would have reduced aquatic habitat, preventing freshwater eels from reaching large size. More work is needed to evaluate these possibilities.

Tangatatau Rockshelter in Regional Context

To place site MAN-44 in a wider regional context, I compared the site’s fish records to those from seven other sites in Eastern Polynesia (Table 7.7). This overview is hardly comprehensive (see Weisler et al. 2010 and Weisler and Green 2013 for more detailed comparative study) but rather was carried out only to suggest broad patterns. Such patterns are likely linked to local environmental setting, which in turn conditions fishing strategies and other components of social-cultural life (Allen 1992a; Butler 1994; Kirch and Dye 1979; Weisler et al. 2010; Weisler and Green 2013).

The eight sites compared here represent occupations that date to the past 1,000 years. Internal temporal components have been aggregated, as the goal is to show spatial rather than temporal trends. Recovery and analytic methods for most sites are reasonably similar (e.g., relatively fine mesh used, at least 1/8 in. [3.2 mm]), but differences in excavation volume, elements recorded, and size of comparative collections used likely affected fish identification and taxonomic abundance measures to some extent. I included the Ngaaitutaki Rockshelter (Igarishi 1999a; Leach et al. 1994) located on the northeast side of Mangaia even though the excavators apparently did not use screens (see Chapter 3), which clearly would affect fish faunal representation and bias comparisons. Of the three sites with reported remains (Leach et al. 1994), Ngaaitutaki represents the largest excavated volume and identified fish sample and, given its proximity to Tangatatau, I thought the benefits of including the site outweighed its liabilities.

Many features distinguish these sites, including site function (village vs. specialized use), proximity to and type of aquatic habitats (inland vs. coastal, deep lagoon vs. shallow reef flat), and taphonomic conditions (rockshelter vs. coastal dune). To differentiate these variables and control for them in a rigorous way is beyond my current study. My overview considers major environmental differences in comparisons. Four records are from *makatea* islands (Mangaia, Rurutu, and Henderson Island), characterized by inland freshwater wetlands and shallow, narrow reef flats; the rest are from sites adjacent to relatively deep water lagoons or bays associated with near-atolls (Aitutaki, Mangareva). Although Mangaia

Table 7.6 Summary Statistics on Dentary and Body Size (mm) of Fish Taxa in Body Size Study

Family	Archaeological Samples Dentary Height (mm)				Modern Reference Material			
	<i>n</i>	Range	Mean	SD	Taxon	Catalog Number	Standard Length ^a	Dentary Height
Anguillidae	23	0.74–2.01	1.37	0.35	<i>Anguilla</i> sp.	VLB91-1-81	560	3.1
Serranidae	13	2.31–10.56	5.35	2.58	<i>Epinephalus spilotoceps</i>	VLB91-1-11	122	2.49
Cirrhitidae	38	2.42–6.74	4.47	1.08	<i>Cirrhitus pinnulatus</i>	VLB 91-118	116	3.55
Eleotridae	54	1.11–2.61	1.99	0.32	<i>Eleotris</i> sp.	VLB91-1-82	110	1.73

^aStandard length: measured from tip of snout to caudal base (which marks the break between the last vertebra and the caudal fin).

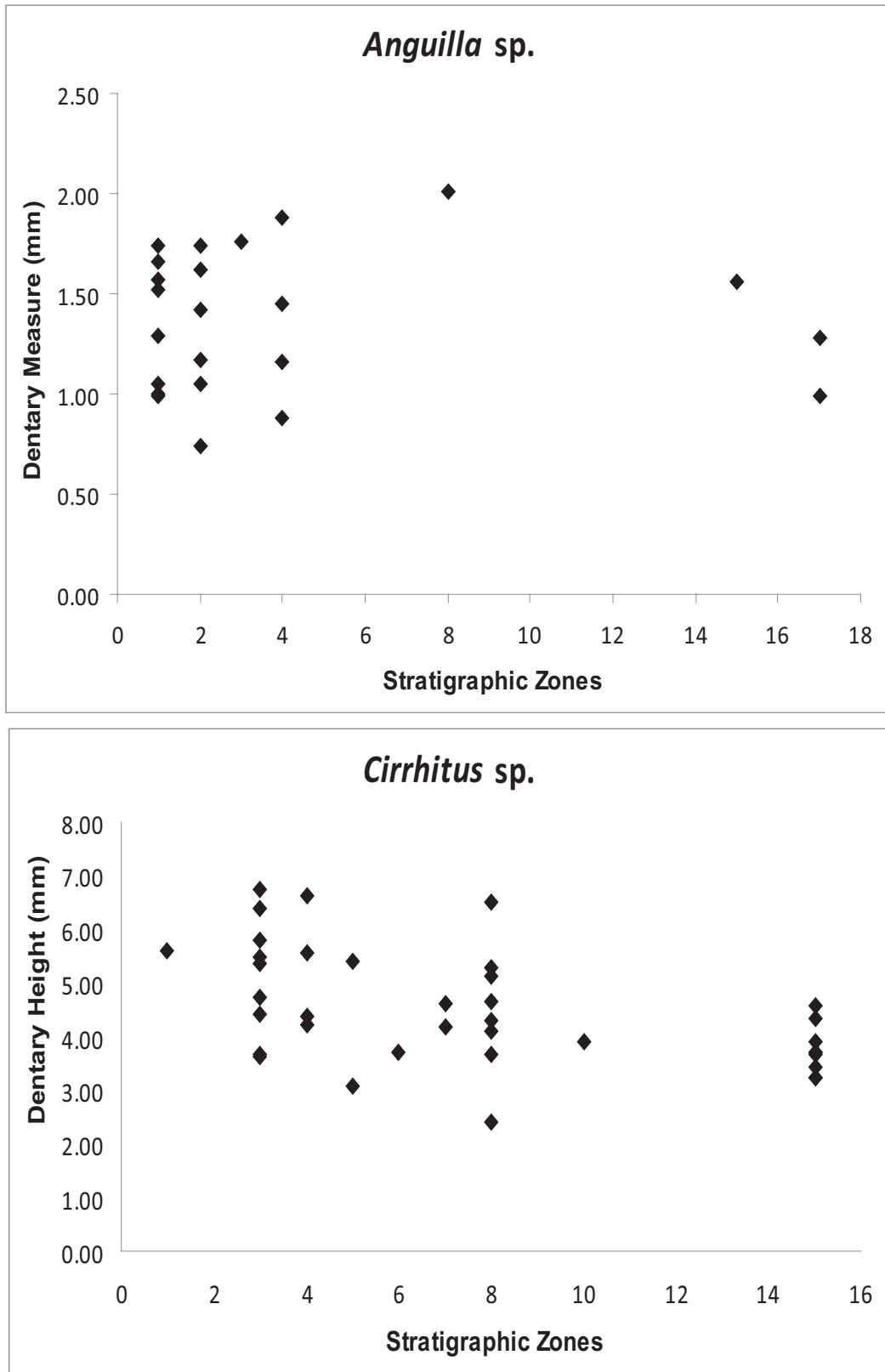


Figure 7.12. Scatterplots showing the distribution of bone measure (mm) by stratigraphic zone. See description of measures in text.

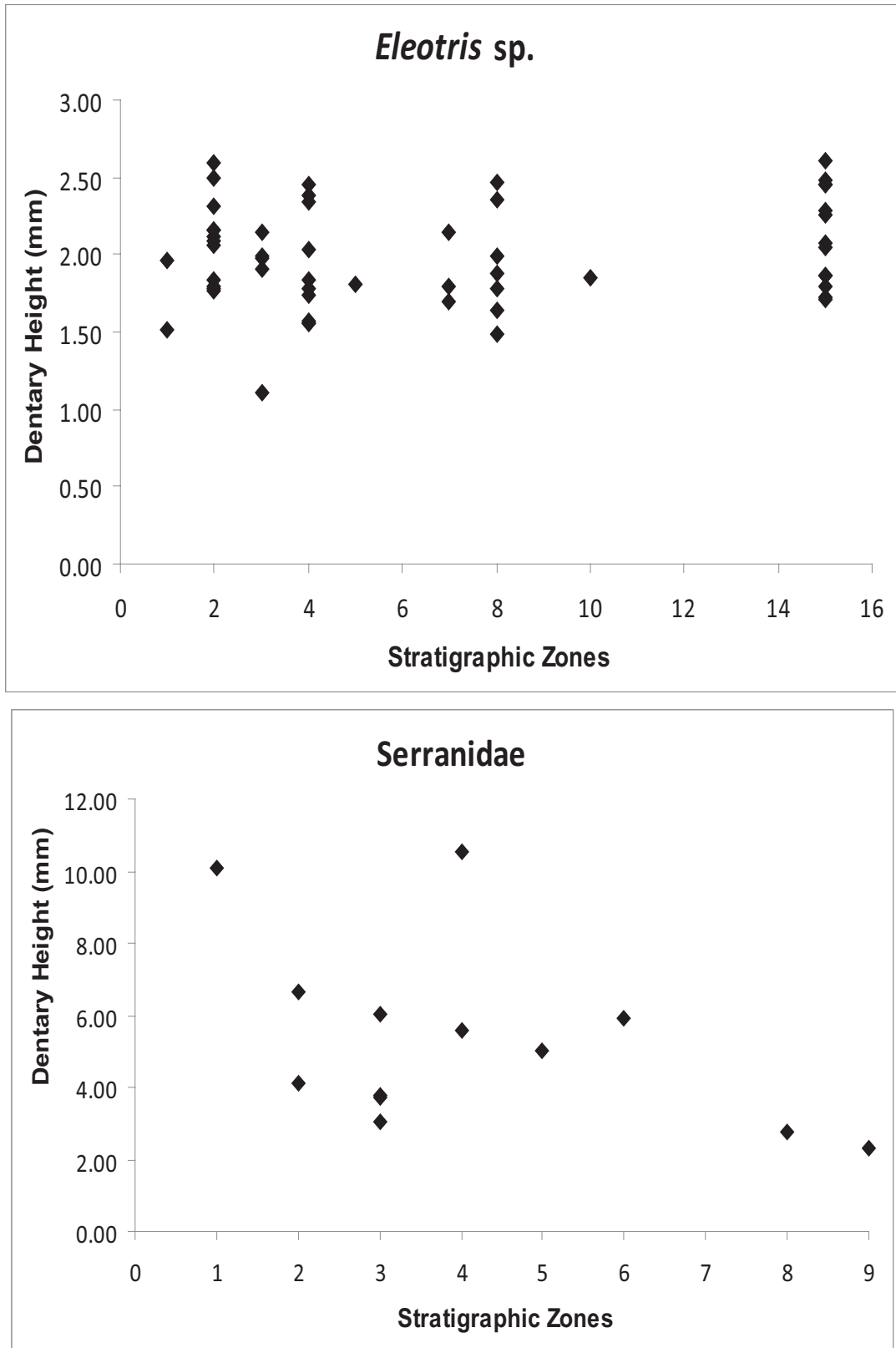


Figure 7.12. Scatterplots showing the distribution of bone measure (mm) by stratigraphic zone. See description of measures in text.

Table 7.7 Fish Family Frequency in Eastern Polynesian Archaeological Sites

Family	Makatea Islands							
	Mangaia				Rurutu		Henderson	
	MAN-44	Rank	Ngaaitutaki	Rank	Peva Dune	Rank	HEN-5	Rank
Acanthuridae	215	4	1		153	3	21.2	2
Albulidae								
Anguillidae	92	6						
Apogonidae								
Aulostomidae								
Balistidae	44	9	55	1	8	9	2.5	6
Belonidae	5		1		2		0.5	
Bothidae	1							
Carangidae	21		1		37	5	13.6	3
Cirrhitidae	250	2			13	7	3.7	5
Congridae	31							
Diodontidae	1		7	5	293 ^a		2.2	7
Eleotridae	357	1						
Exocoetidae					1			
Fistularidae	4				1			
Holocentridae	69	7	4	6	32	6	0.5	
Kuhliidae	3				1		1.7	8
Kyphosidae	12				4		0.5	
Labridae	249	3	15	3	37	5	6.5	4
Leptocephalidae ^b			3					
Lethrinidae	1		2	10	10	8	0.5	
Lutjanidae	1		3	8	3		0.5	
Monacanthidae	1							
Mugilidae	4							
Mullidae	14		3	8	3		1.2	9
Muraenidae	59	8	9	4				
Ostraciidae								
Pemphreidae	2						0.5	
Polynemidae	8							
Pomacanthidae	1							
Pomacentridae	16							
Scaridae	35	10	4	6	316	1	0.5	
Scombridae					5	10	0.5	
Scorpaenidae	5		1					
Serranidae	136	5	19	2	217	2	41.7	1
Siganidae								
Sparisomidae ^b			1					
cf. Sphyaenidae	3							
Syngnathiformes					2			
Synodontidae	1							
Tetraodontidae					3			
Elasmobranchs ^c	+				+		+	
Total	1,649		130		1,142		1,725	

Sources: MAN-44, this chapter; Ngaaitutaki, Leach et al. (1994); Aitutaki Islands, Allen (2002); Peva Dune, Weisler et al. (2010); HEN-5, Weisler and Green (2013); TAR-6, Kirch et al. (2010); AGA-3, Kirch et al. (2015).

Note: Ten most abundant families per site ranked (shaded). NISP is used except for Ngaaitutaki, which is MNI. Raw frequencies listed except for Henderson Island, which are percentages.

Near-Atoll Islands								No. of Sites/Family-Ranked Top 10
Aitutaki				Mangareva				
Moturakau	Rank	Urcia	Rank	TAR-6	Rank	AGA-3	Rank	
84		9	9	3	7	97	3	6
29		1						1
3								
43								
94	10	4	10			1		6
129	9	2				2		1
67		1						
172	7	21	7			6		4
89		1						3
4								
24		2				11	9	3
								1
155	8	32	4	9	5	38	5	7
								1
17								
354	3	27	6	24	3	57	4	8
55		10	8	5	6	28	6	5
351	4	30	5			13	8	4
7								
306	5	38	3			7	10	5
213	6	2				18	7	4
1		1		13	4	6		1
1								
21								
759	2	231	1	401	1	429	2	7
7								1
		1						
2097	1	206	2	149	2	450	1	8
6								
3								
86		3						
+		+		+				
5,177		622		604		1,163		

^aIncludes body spines; not used for rank order assignment, given large number per individual.

^bFamily name used by Leach et al. (1994) unknown reference; Leptocephalid may refer to eel, as Leptocephalus larvae is name for early life history phase of freshwater and marine eels. Taxon not included in rank order analysis.

^cNoted presence of sharks and rays remains.

is not exclusively a *makatea*-type island, given the central volcanic cone, its aquatic habitats are similar to true *makatea*-type islands, and therefore Mangaia is placed in this group for comparison.

Fish family abundances (NISP, except for Ngaaitutaki, which uses MNI) were used to determine rank orders of the 10 most abundant families (Table 7.7). To obtain a crude measure of ubiquity of “abundant family,” I summed the number of sites in which a given fish family ranked in the top 10. Lower values for a fish family suggest that family has more restricted importance, while higher values show a fish family’s importance is more widespread across sites. The use of shading provides a visual way to track ubiquity and rarity; the more cells shaded for a given family row, the more widespread that “abundant family” is across sites (Table 7.7).

Out of 40 possible fish families identified among the eight assemblages, almost half, 19, are ranked in the top 10 at least once (Table 7.7), which suggests a high degree of variability in the fish families on which people focused. On the other hand, five fish families are ranked in the top 10 for seven to eight of the eight assemblages, suggesting that these families were consistently important across the region: Acanthuridae, Holocentridae, Labridae, Scaridae, and Serranidae. Moreover, except for MAN-44 where the family is ranked fifth, serranids are ranked either first or second in a given site assemblage, highlighting the importance of this fish family in most locations.

At the other end of the spectrum are fishes with a much more restricted prominence, making it into the top 10 in only one site: Kuhliidae (flagtails)—on Henderson Island; Scombridae (tunas)—at the Peva site, Rurutu Island; and Belonidae (needlefish) in Moturakau Rockshelter on Aitutaki (Table 7.7). In these cases, the family still is only ranked ninth or tenth, suggesting that it was not a major contributor to subsistence in these restricted settings. By contrast, the two families only found at site MAN-44, Eleotridae and Anguillidae, are highly to moderately ranked (Eleotridae is first, Anguillidae is sixth), indicating an important local subsistence role for these rarely represented families.

The two assemblages from inland rockshelters on Mangaia, located adjacent to freshwater lakes and swamps and with access to similar marine environments, might be expected to show the greatest similarity of all sites in the comparison. This is not the case.

Ngaaitutaki lacks remains of eleotrids and cirrhitids entirely and acanthurids are extremely scarce, while all three taxa are highly ranked at MAN-44 (Table 7.7). As these fishes are small-bodied, the scarcity of their remains at Ngaaitutaki is most likely explained by the lack of screens used during excavation. Other differences related to large-bodied fishes are harder to account for. Balistids are the top-ranked fish at Ngaaitutaki and anguillids are absent. (Leach et al.’s [1994] taxon named Leptocephalidae may refer to anguillids.) Balistids are ranked ninth or tenth in most other assemblages (Table 7.7), so the prominence of this taxon at Ngaaitutaki is especially noteworthy. Serranids and labrids are prominent at both Mangaian sites, but these families are also common across all sites in the comparison, so the similarity does not reflect on Mangaia fisheries in particular.

The broad contrasts drawn by Weisler et al. (2010; Weisler and Green 2013) in fisheries between *makatea* and near-atoll environments are somewhat supported by this analysis. As they note, and this comparison illustrates, scarids tend to be relatively scarce on *makatea*-type islands (Mangaia, Henderson Islands), given the limited coral reef habitat preferred by this coral-eating fish. However, Weisler and Green (2013) suggest that serranids tend to rank highest on *makatea*-type islands, whereas my comparison suggests that serranids tend to rank high in all sites, regardless of environment. One striking contrast is the prominence of cirrhitids in the three *makatea* archaeological sites where fine mesh screens were employed and their absence or scarcity in the four near-atoll assemblages (Table 7.7). My field observations on Mangaia indicated that this carnivorous fish, which is caught by angling, is strictly associated with the seaward side of the reef flat edge, which can be accessed by foot during low tide. Such a fishery may be represented on all the *makatea* islands.

Most surprising in the multisite comparison is the singular presence and abundance of freshwater fishes at Tangatatau and their scarcity at other archaeological sites in Eastern Polynesia (and Oceania more generally). Limited freshwater habitat likely explains much of this absence across the Pacific. Perhaps the other *makatea* islands in this comparison simply lack extensive wetland habitats sufficient to support eleotrids and anguillids. Since the life cycle of these fishes requires passage to sea, perhaps the *makatea* lacks conduits through which fish could pass. Possibly wetlands supporting freshwater fish are too distant from occupation

sites to make such fishing worthwhile or even feasible due to territorial boundaries. MAN-44's close proximity to Lake Tiriara, which supports *Eleotris* and *Anguilla* today and which could be taken as part of agricultural field activities, would make the freshwater fishery especially valued. Finally, possibly part of the explanation is analytical, in that reference collections lack examples of these fishes. As has been noted previously, more work is needed to understand why the record for freshwater fish use at Tangatatau record is so distinctive.

Summary

The Tangatatau Rockshelter fish record provides tangible evidence that some of the fishing practices described by Te Rangi Hiroa (1944) extend back close to one millennium. An extremely wide range of fishes were captured in all easily accessible habitats: freshwater wetlands, the nearshore reef flat, and the outer reef edge. Offshore areas were rarely fished. Most of the fish represented are carnivorous; this, plus the large collection of fishhooks, supports the idea that angling was commonly used to procure fish, although nets and traps were used as well. Fishbone concentration indices are highest in the deepest parts of the rockshelter (zone SZ-8 and below), but even the highest zones contain fish remains (e.g., SZ-15, SZ-17), especially dominated by eleotrids and cirrhitids, indicating that the rockshelter was the locus of fish processing and consumption almost until the time of European contact. There is slight evidence for resource depression, but the main finding is that fish tend to be small-bodied throughout the rockshelter's occupation sequence and overall sustainable fish use. Comparison of fish family abundance across Eastern Polynesia indicates a number of common patterns—heavy reliance on serranids, labrids, holocentrids, and acanthurids, for example—but also

distinctions, namely the prominence of freshwater fishes, especially *Eleotris* on Mangaia. That Hiroa highlighted this fishery in his 1944 account suggests long-term continuity of resource use.

Acknowledgments

I thank Pat Kirch and Dave Steadman for inviting me to be part of the Mangaia project and Pat for his thoughtful leadership in bringing this monograph together. NSF Grant BNS-9020750, awarded to Kirch and Steadman, supported my field and lab work. Mangaiaans—Ma'ara Ngu, Tuara George, Sonny Taomia, and Peter Ngatokorua—guided me to the best and safest places to catch fish. Without their knowledge, generosity, and patience, I would have collected a tiny fraction of the fish that became my comparative skeleton collection. My study is richer by far because of their help. Many fishery biologists helped me along the way. Arnold Suzumoto and Jack Randall verified many of the taxonomic identifications of modern fishes caught on Mangaia. Gavin Naylor helped identify the Tangatatau shark teeth. Robert McDowell, Stuart Poss, and Robert Kinzie answered questions about eleotrids. Katherine Maslenikov (Burke Museum Fish Collection) assisted me with comparative study of barracuda (and other large carnivorous fish) teeth. Anthony Hofkamp photographed the fish remains. Much of this analysis took place in the early 1990s, when I was an adjunct faculty member at the University of Colorado Museum Paleontology program. Then curator Peter Robinson provided much support and kindness during my tenure there. I thank Melinda Allen for her friendship and collegiality and for helping me maintain a connection with Oceanic archaeology over the past 25 years. Finally, I thank Foss Leach for his pioneering work on fishbone archaeology in Oceania since the 1970s.

8

Invertebrate Faunal Remains from Tangatatau Rockshelter

Patrick Vinton Kirch, Mireille N. Gonzalez, and Aimée M. Plourde

The Manganian people—like all Polynesians—extensively exploited their inshore and marine environments, both for food and for materials with which to manufacture various kinds of artifacts. The stratified deposits at Tangatatau Rockshelter are rich in the remains of invertebrates, especially mollusks but also sea urchins and crustaceans. This chapter presents an analysis of the invertebrate faunal assemblages recovered from the MAN-44 excavations; the fishbone assemblage is dealt with separately in Chapter 7.

Materials and Methods

During the initial 1989 field season, it became apparent that the MAN-44 deposits contained a high density of invertebrate remains, requiring a sampling strategy. It was simply beyond our budget or labor force to recover all of the shell, sea urchin, and crustacean remains, ship these back to the laboratory, and sort and identify the material. (A back-of-the-envelope calculation indicates that the total weight of invertebrate remains from the 29-m² excavated would have been at least 900 kg.) During the 1989 excavation, we decided to retain all shell and other invertebrate remains in unit E30 from the ½-in. and ¼-in. mesh sieves but not from the ⅛-in. mesh. As the material in the ⅛-in. mesh sieves was highly fragmented, we felt it would be difficult to identify to genus or species. The invertebrate sample recovered from unit E30 totaled

19.52 kg. We also retained invertebrate remains from unit F10, totaling 1.58 kg.

During the 1991 excavation, we employed a slightly different excavation strategy. For unit E31, we again retained all of the invertebrate remains found in the ½-in. and ¼-in. mesh screens, but this time we also bagged the entire contents of the ⅛-in. mesh, after removing bone, charcoal, and as much of the obvious rock fragments as feasible. The total weight of invertebrate remains recovered from unit E31 totaled 39.87 kg; as both units E30 and E31 had roughly the same volume, the greater weight of invertebrate remains in E31 reflects the additional retention of the contents of ⅛-in. sieves. As the excavation expanded and it became clear that the earliest stratigraphic zones in the MAN-44 sequence were not represented in units E30 or E31, we also retained the invertebrate remains from unit D35, levels 6 (SZ-3) and 7 (SZ-2), totaling 0.85 kg.

Later comparison in the laboratory between the samples recovered from units E30 and E31 demonstrated that the lack of material from the ⅛-in. mesh in unit E30 did not significantly bias the sample in terms of taxonomic representation. All of the genera and species identified for unit E31 were also present in unit E30. The main difference was simply in the addition of a great deal more fragmentary material, which was exceedingly time-consuming to sort and

identify. In addition, while only 5 percent of the larger-sized unit E30 material could not be identified down to genus or species, 13 percent of the smaller-sized unit E31 material remained unidentifiable.

The laboratory work of identifying and quantifying the invertebrate remains from MAN-44 was carried out in two phases, by A. Plourde and M. Gonzalez, both as honors thesis research projects at U.C. Berkeley. Plourde analyzed the materials from units C30, D35, and E30 in 1992 (Plourde 1992), while Gonzalez analyzed those from unit E31 in 2014 (Gonzalez 2014). The text of this chapter was prepared by Kirch, based on the databases and unpublished theses of Plourde and Gonzalez.

In the laboratory, invertebrate remains were first sorted into general categories of mollusk, sea urchin, and crustaceans. Mollusk shells were then further sorted to the lowest taxonomic categories possible based on degree of fragmentation; most of the material could be identified at least to genus and much of it to species as well. The high degree of fragmentation of the shell, however, rendered a certain amount of the material unidentifiable beyond the general category “miscellaneous shell.” Assignment of taxonomic names follows Salvat and Rives (1975) in the first instance; Cernohorsky (1971, 1978), Kira (1962), and Habe (1964) were also used as reference guides. Initial taxonomic identifications were confirmed through physical comparison of the MAN-44 specimens with the conchology collection of the Museum of Paleontology at the University of California, Berkeley.

Zooarchaeologists have debated the most appropriate methods for quantifying mollusk assemblages (e.g., Claassen 1998:91–121; Reitz and Wing 1999; Szabó 2009:186–188). For Polynesian shell assemblages, shell weight has often been the preferred measure (e.g., Kirch 1979a; Kirch and Yen 1982; Rolett 1998), although this has its detractors (Szabó 2009). The standard alternatives to weight are Number of Identified Specimens (NISP) and Minimum Number of Individuals (MNI). While MNI might in theory be preferable to either NISP or weight, it is difficult to apply when there is a high degree of fragmentation of shell, as is the case with the MAN-44 assemblage. In the analysis of unit E30, Plourde used both weight and NISP, whereas in the quantification of unit E31, Gonzalez also determined MNI in addition to NISP and weight. The criteria used to determine MNI varied according to taxon depending on taphonomic considerations. For example, with the gastropods *Nerita* and *Drupa*, MNI was determined on the basis of intact apertures, while with *Turbo*, the high

degree of smashing of the apertures required the counting of intact shell apices.

In this chapter, we have opted to report and analyze the mollusk data by weight. Not only is this the most direct form of quantification, but in fact weight and NISP are highly correlated. Figure 8.1 is a scatterplot and regression of mollusk weight versus NISP for 25 principal taxa from site MAN-44. The very strong correlation between the two measures is confirmed by an R^2 value of 0.91. We recognize, of course, that taxa vary considerably in their average shell weights, so that, for example, a heavy *Turbo setosus* shell weighs considerably more than the two valves of a *Modiolus auriculatus*. Moreover, edible meat weight does not necessarily correspond to shell weight. This requires caution in making interpretations involving between-taxa comparisons. However, analysis of temporal trends within a site is not affected by these concerns. In any event, the full data set with NISP, MNI, and weight values for the MAN-44 mollusks is available in the online database (www.dig.ucla.edu/tangatatau).

In the analysis of the unit E31 mollusk assemblage, Gonzalez also recorded the number of whole or unbroken shells for each taxon and level, permitting the quantification of the degree of fragmentation, as discussed later in this chapter. In addition, burning was noted on a presence/absence basis.

The extremely high degree of fragmentation of the MAN-44 mollusk assemblage did not allow us to quantify shell size, except for the case of *T. setosus*, whose heavy opercula were more resistant to smashing. As operculum diameter is allometrically correlated with shell size, we measured the maximum diameters of all intact *T. setosus* opercula in an effort to determine whether there is evidence for temporal changes in the size of this important food species.

Sea urchin remains were sorted into spines, test fragments, and mouth parts, but only the spines of the distinctive *Heterocentrotus mammillatus* were identified to species. Similarly, crustacean remains (typically highly fragmented) were separated out as a single category; a representative sample of crustacean remains was examined by Gustav Paulay at the Florida Museum of Natural History.

The Tangatatau Mollusk Assemblage

In comparison with many other Pacific Island archaeological mollusk assemblages, that from site MAN-44 is relatively limited in species-level diversity, perhaps not surprising in light of Mangaia’s narrow fringing reef,

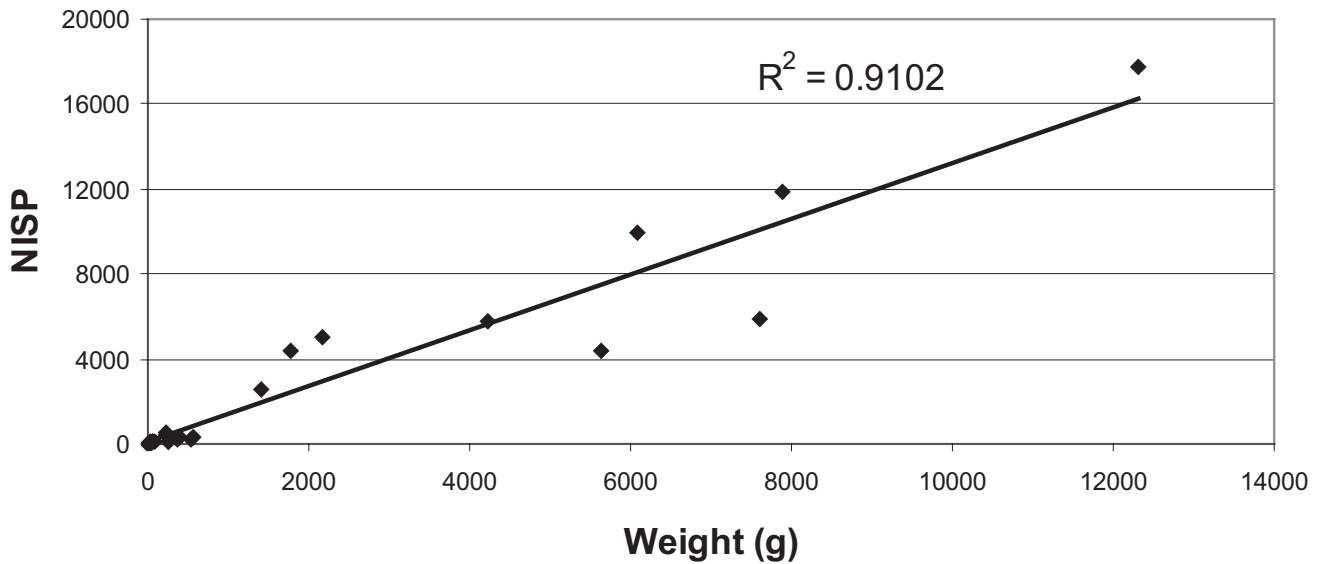


Figure 8.1. The strongly-correlated relationship between mollusk weight and NISP for 25 principal taxa in the MAN-44 site.

which lacks some microhabitats (such as a true lagoon). The island’s southerly latitude and colder water presumably also restrict its marine biodiversity in comparison with more tropical archipelagoes such as the Society Islands or Tuamotus. The MAN-44 assemblage includes 20 genera and 26 species of gastropods and eight genera and as many species of bivalves, along with a single species of chiton (Polyplacophora). Selected gastropods are illustrated in Figure 8.2 and three of the main bivalves in Figure 8.3. Table 8.1 provides weights of the main genera and species of mollusks by stratigraphic zone (the table combines data from units D35, E30, and E31); some minor taxa have been eliminated but can be found in the online database.

As can be seen in Figure 8.4, six genera make up 84 percent of the total mollusk assemblage from site MAN-44. The dominance of these taxa is further indicated in the rank-order plot of all mollusk genera shown in Figure 8.5. *Drupa* spp. (primarily *Drupa ricinus*) account for nearly twice as much as any other taxon, followed by the bivalve *M. auriculatus*, then by gastropods *Astraea rhodostoma*, *Conus* spp., *T. setosus*, and *Cerithium* spp. As we discuss later in this chapter, however, the rank order of taxa changed through time at site MAN-44.

Gastropods

Patellacea (Limpets)

Two species of limpet are represented in the assemblage: *Patelloida conoidalis* (Acmaeidae) and *Patella flexuosa*

(Patellidae). *P. flexuosa*, which can attain diameters up to about 38 mm, is typically abundant on wave-battered outer reef crests (Salvat and Rives 1975:255). *P. conoidalis* is slightly smaller in size (diameters up to 21 mm). Both species are relatively common throughout the MAN-44 stratigraphic sequence.

Turbinidae (Turban Shells)

Two genera and species of turban shells are present throughout the sequence. *A. rhodostoma* is slightly more abundant by weight than *T. setosus*. Both species tend to favor the “frontal zones” or outer slopes of the reef where there is abundant wave action (Salvat and Rives 1975:257–259). *A. rhodostoma* attains diameters up to about 30 mm, but *T. setosus* can grow much larger, up to 60 mm or more, and is prized on most islands for its abundant meat. As we discuss later in the chapter, *T. setosus* seems to have been a high-ranked taxon that was heavily exploited by the initial occupants of MAN-44; it consequently suffered considerable pressure, resulting in a classic case of “resource depression.” The shells of both taxa in MAN-44 are heavily fragmented and often burned.

Neritidae (Nerites)

A single species, *Nerita plicata*, is present in relatively low frequency in the MAN-44 deposits. This nerite inhabits the intertidal zone, where it clings to rocks or lodges in crevices (Cernohorsky 1978:42; Salvat and Rives 1975:92). Burning and fragmentation of *N. plicata* shells is common.

Table 8.1 Distribution of Mollusk Taxa by Stratigraphic Zones, Site MAN-44 (Weight in Grams)

Taxon	SZ-1B	SZ-2	SZ-3	SZ-4A	SZ-4B	SZ-5	SZ-7	SZ-8	SZ-15	SZ-17	Totals
Gastropods											
<i>Astraea rhodostoma</i>	30.8	17.8	35.3	594.1	90.6	2,462.4	468.6	1617	357.8	4.8	5,679.2
<i>Cantharus undosus</i>	0.6	0	0	9.7	4.5	149.6	23.3	127.2	22.7	0	337.6
<i>Cerithium</i> spp.	0	0	1	49.9	6.96	441.4	334.4	2,320.2	456.6	0	3,610.46
<i>Conus</i> spp.	1.6	0	16.3	63.6	65.8	2,103.9	635.7	1,955.8	258.4	6.5	5,107.6
<i>Cymatium nicobaricum</i>	0	0	0	0.9	0.7	25.1	21.4	97.4	60.3	0	205.8
<i>Cypraea</i> spp.	0	0	0	2.2	2.5	67.8	27.4	106.4	20.7	0.2	227.2
<i>Drupa</i> spp.	3.1	3.0	3.3	356.5	136.6	3,640.0	1,214.2	4,259.9	1,157.2	13.5	10,787.3
<i>Hipponyx conicus</i>	0.3	0	0.6	0.5	0	7.2	1.3	16.8	2.7	0.4	29.8
<i>Morula</i> spp.	0	0	0	1.1	2.6	18.5	7.4	26.3	1.16	0	57.06
<i>Nerita plicata</i>	0.4	0	4.4	7.0	2.3	38.6	23.8	90.2	21.9	2.0	190.6
<i>Patella flexuosa</i>	1.0	12.6	0.6	35.1	12.0	339.2	131.7	472.1	179.4	1.1	1,184.8
<i>Patelloida conoidalis</i>	0.3	0.5	5.7	50.5	15.5	521.8	140.2	563.8	181.2	0.7	1,480.2
<i>Pterygia nucea</i>	0	0	0	0	0	0	0	4.4	0	1.0	5.4
<i>Strombus</i> spp.	0.7	0	1.0	39.5	9.0	410.3	194.7	934.1	243.7	6.6	1,839.6
<i>Tectarius grandinatus</i>	0.3	22.4	12.2	76.2	18.1	3.4	0	1.9	0	0	134.5
<i>Thais intermedia</i>	0	0	0	0	0	137.3	51.1	156.9	123.2	0	468.5
<i>Turbo setosus</i>	52.8	291.0	37.0	861.1	142.4	1,200.8	281.4	1,200.0	104.32	14.7	4,185.52
Bivalves											
<i>Asaphis violascens</i>	0	48.4	14.7	50.2	1.84	43.9	1.4	25.9	0	0	186.34
<i>Chama pacifica</i>	0	0	0	18.2	0	8.4	0	1.56	0	0	28.16
<i>Codakia divergens</i>	0	0	0	4.7	1.02	2.2	1.8	5.0	3.4	0	18.12
<i>Modiolus auriculatus</i>	7.3	0.9	5.7	223.5	36.5	1,089.6	817.4	2,699.9	917.78	5.3	5,803.88
<i>Periphyta reticulata</i>	0	0	0	7.5	0	20.3	13.8	21.4	1.1	0	64.1
<i>Pinctada</i> sp.	0	0	0	0	0	7.6	4.4	18.3	2.7	0	33
<i>Scutarcopagia scobinata</i>	0	0	0	0	0.5	0	0.1	4.6	0	1.0	6.2
<i>Tridacna maxima</i>	0	0	0	0.9	0	30.4	41.4	224.5	116.6	8.5	422.3
Polyplacophora: Chiton	0	0	0	0	0	0.7	0	0	0.1	0	0.8
Unidentified fragments	2.8	37.9	34.9	118.7	40.7	2,348.1	1,026.1	1,698.0	114.1	7.6	5,428.9
Totals	102	434.5	172.7	2,571.6	590.12	15,118.5	5,463	18,649.56	4,347.06	73.9	47,522.94

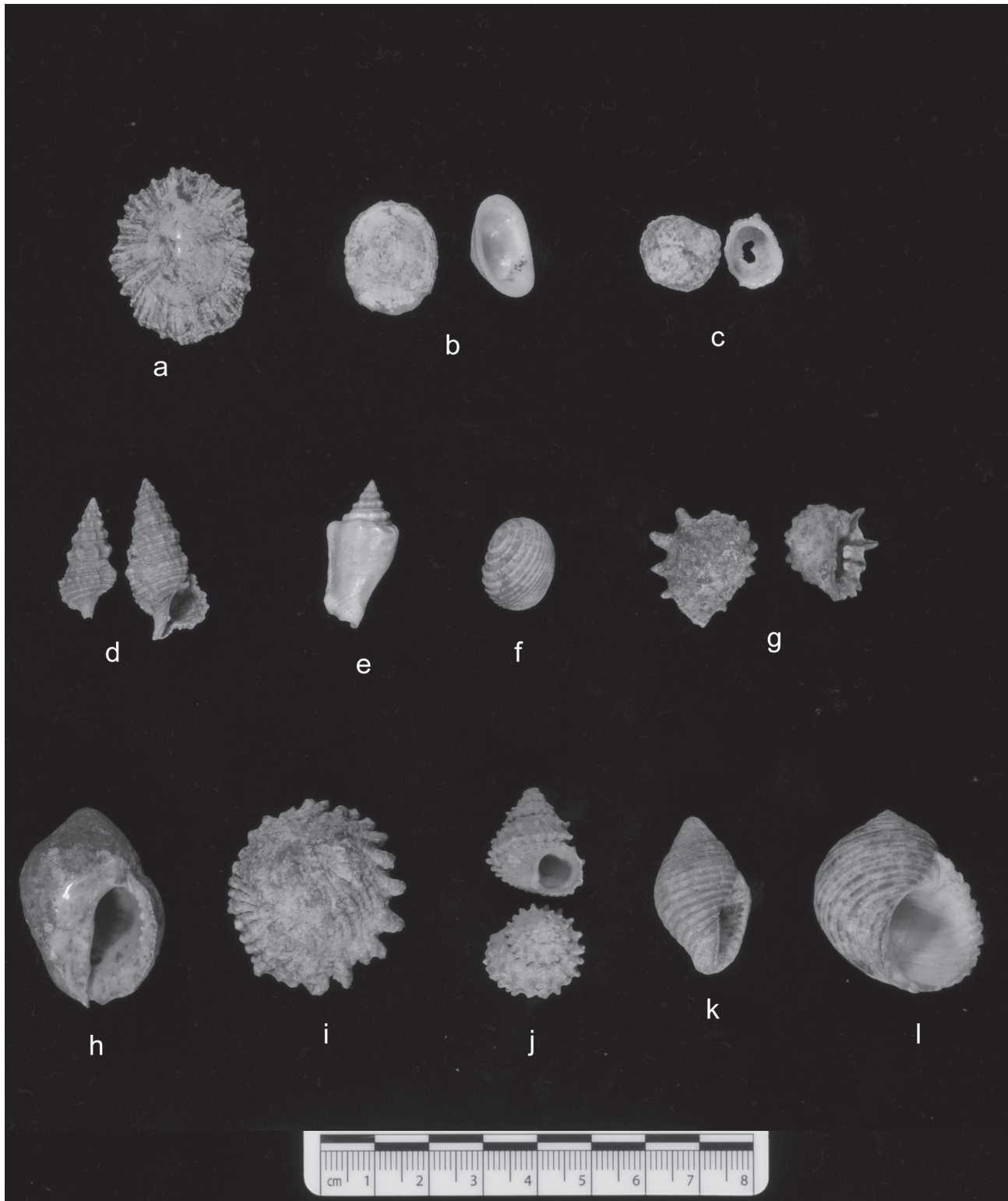


Figure 8.2. Gastropods from site MAN-44: a, *Patella flexuosa*; b, *Patelloida conoidalis*; c, *Hipponyx conicus*; d, *Cerithium columna*; e, *Strombus mutabilis*; f, *Nerita plicata*; g, *Drupa ricinus*; h, *Thais intermedia*; i, *Astraea rhodostoma*; j, *Tectarius grandinatus*; k, *Cantharus undosus*; l, *Turbo setosus*.



Figure 8.3. Bivalves from site MAN-44: top, *Asaphis violasceus*; middle, *Periglypta rectiulata*; bottom, *Tridacna maxima*.

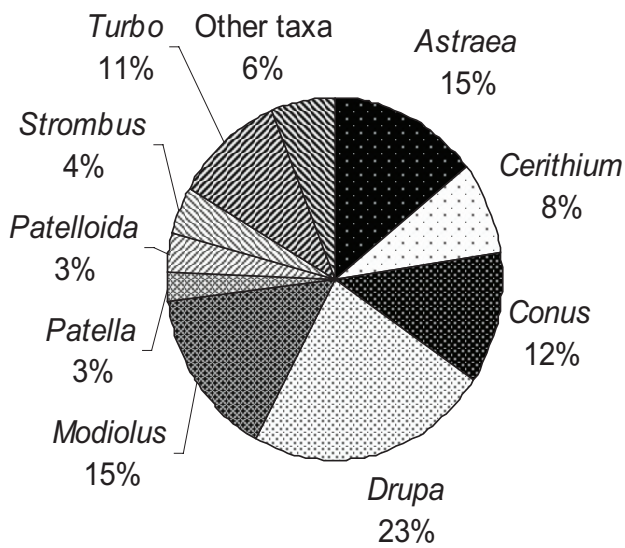


Figure 8.4. Percent composition by mollusk genera of the site MAN-44 assemblage.

Littorinidae (Periwinkles)

Tectarius grandinatus is a relatively large species of periwinkle (up to 30 mm in length) with a distinctive spiny surface. It occupies the supra-tidal zone (higher than the habitat of *N. plicata*), where it adheres to hard surfaces such as reef limestone. This exposed habitat no doubt made *T. grandinatus* highly susceptible to collecting, which likely explains why it is abundant only in stratigraphic zones SZ-2 through SZ-4B, as its population was presumably largely decimated in later prehistory.

Cerithiidae (Ceriths)

Two species of ceriths, *Cerithium columna* and *Cerithium tuberculiferum*, are present in the MAN-44 assemblage, but the latter is represented by just a few specimens in unit E30. *C. columna* inhabits sandy sediments (Cernohorsky 1978:50–51; Salvat and Rives

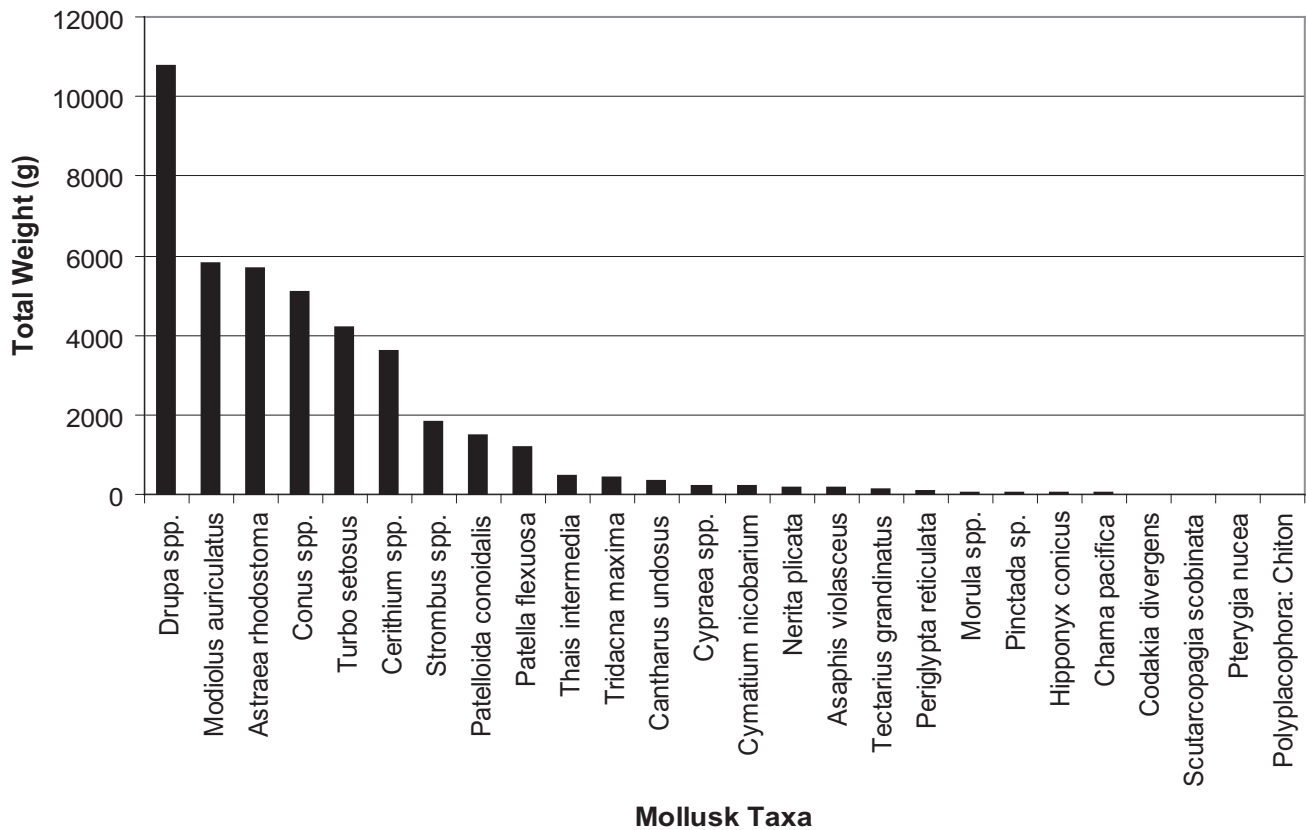


Figure 8.5. Rank order plot of taxa comprising the MAN-44 mollusk assemblage.

1975:268), making it a more difficult search target for human gatherers. Thus, it is not surprising that the species is present in low frequency in the earlier deposits but becomes more abundant in SZ-8, when populations of other high-value or readily available taxa such as *T. setosus* and *T. grandinatus* had declined due to resource depression.

Strombidae (True Conchs)

The majority of conchs in the MAN-44 assemblage were identified as *Strombus mutabilis*, but some of the shells from unit E31 were also identified as *Strombus maculatus*. *S. mutabilis* has a slightly more pronounced spire and the body whorl is less globose than in *S. maculatus*, but discriminating between the two can be difficult, especially when dealing with fragmentary specimens. Both species inhabit coral sands or detritus (Salvat and Rives 1975:275). The *Strombus* shells in MAN-44 exhibit a high degree of fragmentation and burning.

Hipponicidae (Hoof Snails)

Hipponyx conicus, a small (9–12 mm diameter), limpet-like species of hoof snail, is present in small numbers (total NISP 79). This gastropod attaches itself to the shells of a larger host snail, one of the most common of which is *T. setosus* (Salvat and Rives 1975:115). Most likely the specimens of *H. conicus* in site MAN-44 were not collected as food but rather entered the site adhering to shells of *T. setosus*.

Cypraeidae (Cowries)

The cowrie shells in MAN-44 are heavily broken and burnt, making species-level identification difficult. The only species that could be definitively identified is the snake's head cowrie, *Erosaria caputserpentis* (variously assigned by some taxonomists to the genera *Cypraea* or *Monetaria*). This smallish cowrie, which in our assemblage rarely exceeds about 20 mm in length, inhabits a number of microhabitats, including fissures of the algal reef crest, coral heads, and the undersides of coral cobbles. It was never especially abundant in the MAN-44 assemblage but becomes more common in the higher strata.

Cymatiidae (Tritons)

Present in relatively small numbers, mostly in the higher strata, *Cymatium nicobaricum* is a smallish triton (maximum length about 60 mm) typically found under coral blocks or rubble. Specimens in the MAN-44 assemblage were frequently burnt and smashed.

Muricidae (Rock Snails)

Within this large gastropod family, species of the genera *Drupa*, *Morula*, and *Thais* are all represented in the MAN-44 assemblage. *Drupa* shells are in fact the most abundant of any mollusk in the site (Figures 8.4 and 8.5). Due to the high degree of fragmentation and burning, many of the *Drupa* specimens could not be identified to species, but *D. ricinus*, *Drupa morum*, and *Drupa speciosa* are all present, with *D. ricinus* the most abundant. All three species prefer wave-swept reef crest or fore reef habitats.

Two species of *Morula*, *Morula granulata* and *Morula uva*, are present in relatively small numbers. Like *Drupa*, they frequent the outer reef crest where there is considerable wave action. The third muricid genus, *Thais*, is represented by the species *Thais intermedia*, which is present in low frequency only in the upper stratigraphic deposits.

Buccinidae (True Whelks)

A single species of true whelk, *Cantharus undosus*, is present in relatively small numbers. It inhabits coral colonies (Salvat and Rives 1975:318).

Columbellidae (Dove Snails)

Five specimens of a small dove snail, *Pyrene tururina*, were recovered from SZ-5 in unit E30.

Nassariidae (Dog Whelks)

Only two specimens of *Nassarius gaudiosus* were recovered, one each from SZ-8 and SZ-14.

Mitridae (Mitre Shells)

Two specimens of an unidentified species of *Mitra* were recovered from SZ-5 and SZ-8. A very few specimens of *Pterygia nucea* were also found in SZ-8 and SZ-17; this species frequents coral sand substrates.

Conidae (Cones)

Cone shells are the fourth most abundant taxon in the MAN-44 assemblage, as measured by weight (Figure 8.5). The high degree of smashing and burning of the cone shells made identification to the species level problematic, but three species are definitely present: *Conus chaldeus*, *Conus ebraeus*, and *Conus rattus*. These are among the smaller sized species of cones. Their habitats include the reef platform and reef crest.

Bivalves

Mytilidae (Sea Mussels)

The only species of bivalve that is truly abundant in the MAN-44 assemblage, *M. auriculatus*, is the second most common mollusk in the site by weight (Table 8.1 and Figure 8.4). Given that the valves of *M. auriculatus* are quite lightweight, a substantial number of individuals are represented (more than 11,850 NISP in the sample analyzed). Salvat and Rives (1975:367) indicate that this mussel is common on fringing reefs where it adheres to algal growth. As discussed further below, *M. auriculatus* became dominant only in the later phases of site occupation (especially zones SZ-7 and SZ-8). This may have been correlated with ecological changes on Mangaia's fringing reef, as living coral substrate was transformed to dead coral platform (a likely consequence of continual human exploitation of and traversing the reef platform), a habitat conducive to algal growth.

Pteriidae (Pearl Oysters)

Small quantities of invariably fragmentary valves of a small *Pinctada* sp. were recovered from the upper stratigraphic units of the site. The fragmentary nature of the specimens made specific level identification impossible, although it is clear that the material is not from the large pearl oyster *Pinctada margaritifera*, which does not occur on Mangaia. (Shells of *P. margaritifera* were imported to Mangaia in the early phase for the manufacture of fishhooks; see Chapter 11.) The *Pinctada* shells represented in the upper midden deposits may be *Pinctada maculata*, although further analysis would be necessary to verify this.

Lucinidae (Saltwater Clams)

Small quantities of *Codakia divergens* were found in several stratigraphic zones, but the species was never important. These clams, whose valves attain maximum lengths of about 26 mm, live in sandy sediments.

Chamidae (Jewel-Box Clams)

Only five NISP of the species *Chama pacifica* were recovered from the MAN-44 assemblage.

Tridacnidae (Giant Clams)

Specimens of *Tridacna maxima* occur primarily throughout the higher strata. These sessile clams, which adhere to corals or in fissures in the reef platform, are prized throughout Polynesia for food; in some islands,

their thick, hard shells were also used to manufacture adzes, but we have no evidence for this use in Mangaia.

Veneridae (Venus Clams)

A small number of the valves of *Periglypta reticulata*, invariably broken, were recovered, primarily from the upper stratigraphic units. This clam reaches lengths of 7 to 8 cm and inhabits sandy substrates.

Tellinidae (Tellin Clams)

Only 13 NISP of the species *Scutarcopagia scobinata* were recovered, primarily in upper-level strata.

Psammobiidae (Sunset Clams)

Small quantities of *Asaphis violasceus* are distributed throughout the site MAN-44 deposits. This clam attains lengths of up to 65 mm and inhabits sandy sediments (Salvat and Rives 1975:204).

Taphonomic Considerations: Breakage and Burning

An unusual aspect of the MAN-44 mollusk assemblage is the high degree of breakage and burning exhibited by the specimens. In the senior author's experience of analyzing a number of mollusk assemblages from Oceanic archaeological sites, he has never encountered an assemblage with this extent of taphonomic modification. To quantify these modifications, the assemblage of unit E31 was analyzed for both degree of breakage (by counting the numbers of whole shells) and for burning (by presence/absence of obvious blackening, charring, or calcining of the shell). Table 8.2 presents data on the percentage of whole shells for the six most common mollusk taxa by stratigraphic zones for unit E31 (calculated by dividing the number of whole shells by the NISP count). The numbers document the high degree of breakage. With the heavy-shelled *Drupa* and *Turbo*, there is also a trend toward increased breakage over time.

For a thin-shelled mollusk such as *M. auriculatus*, it could be hypothesized that fragmentation of the shell was, at least in part, a consequence of trampling underfoot within the confines of the rockshelter. The other five taxa, however, all have dense, sturdy shells that require force to be crushed. The high degree of fragmentation must therefore be a consequence of purposeful smashing of the shells, presumably to obtain the bits of soft parts that are difficult to extract from the shells simply by pulling on the animal.

Table 8.2 Percent Whole Shells for Five Most Common Mollusk Taxa by Stratigraphic Zones (Unit E31), Site MAN-44

Taxon/Zone	4A	4B	5	7	8	15
<i>Drupa</i> sp.	8.3	6.1	2.4	4.6	2.2	1.2
<i>Modiolus auriculatus</i>	1.8	11.1	5.6	7.9	11.6	0.9
<i>Astraea rhodostoma</i>	0	0	1.9	1.7	0.8	0.9
<i>Conus</i> spp.	0	0	0	1.9	0.8	0.5
<i>Turbo setosus</i>	15.4	0	4.6	3.9	1.7	0
<i>Cerithium columna</i>	0	0	2.4	2.9	7.1	3.2

Burning was noted on a presence/absence basis for each individual lot of specimens by taxon and unit/level provenience. For 392 such lots within unit E31, fully 90.1 percent exhibit signs of burning. Given that Polynesians often consume mollusks raw, this is an unusually high degree of burning. It should be noted, however, that at least some of the burning may have resulted from tossing the shells into a fire after consuming the meat, rather than by roasting or cooking them prior to eating.

Freshwater and Terrestrial Mollusks

While the vast majority of mollusk specimens from MAN-44 are of marine taxa that were gathered and brought to the rockshelter by Polynesians foraging for food, four species of terrestrial and freshwater snails were also recovered during the excavations. Specimens of these taxa were examined by malacologist Carl C. Christensen of the Bernice P. Bishop Museum (Honolulu); representative voucher specimens have been deposited in the Bishop Museum collections. Two taxa are indigenous species that were present prior to Polynesian colonization, but two are synanthropic taxa introduced to Mangaia by Polynesians.

The basal deposits of stratigraphic zones SZ-1A and SZ-1B contain abundant shells of *Orobophana pacifica* (Helicinidae) and *Libera fratercula* (Endodontidae). *O. pacifica* (Figure 8.6c) is an indigenous helicinid widespread throughout southeastern Polynesia, including the Southern Cook Islands, the Australs, and the Society Islands (Brook 2010:178). *L. fratercula* is a native endodontid endemic to the Southern Cook Islands, including Mangaia (Solem 1976:423). The abundance of these taxa in the basal deposits of the rockshelter indicates that they were a component of the native biota in the vicinity of the rockshelter prior to human occupation.

Of greater relevance to the history of human land use on Mangaia is the presence of a freshwater snail of the family Thiaridae, *Melanoides tuberculata* (Figure 8.6b). Two specimens were recovered from stratigraphic zone SZ-2, and the snail continues to be present throughout the stratigraphic sequence (SZ-3, 3 specimens; SZ-5, 17 specimens; SZ-7, 11 specimens; SZ-8, 22 specimens; SZ-11, 1 specimen; SZ-13, 2 specimens; SZ-15, 19 specimens; SZ-17, 1 specimen). *M. tuberculata* is thought to have had an origin in Africa, although its natural range evidently extended throughout most of the Old World tropics (including Island Southeast Asia) in premodern times (Pilsbry and Bequaert 1927:253, map 2). The species is highly invasive and recently has become pan-tropical in its distribution (Facon et al. 2003; Peso et al. 2011; Vogler et al. 2012). While *M. tuberculata* has been reported from such Polynesian islands as Samoa and the Society Islands (Cowie 1998; Pointier and Marquet 1990; Starmuhlner 1976, 1993), there has been some question as to whether it was dispersed by Polynesians or arrived in the islands later, as a result of European commerce. The presence of numerous specimens of *M. tuberculata* throughout the MAN-44 sequence leaves little doubt that it was carried to Mangaia by the initial Polynesian colonists to reach the island. It is doubtful that this was a purposive introduction; rather, the snails—which thrive in irrigated pondfields—were most likely inadvertently transferred with planting stocks of taro (*Colocasia esculenta*).

Finally, three specimens of the arboreal tree snail *Partula hyalina* were recovered from stratigraphic zone SZ-15 (Figure 8.6a). The unique, white shells of this snail were prized by Polynesians for making necklaces (*lei*). *P. hyalina* has an unusual geographic distribution that includes the island of Tahiti, where it is apparently native, and certain of the Austral and Cook Islands, including Mangaia. Lee et al. (2007) have convincingly argued that the aesthetic value of these shells prompted Polynesians to transfer populations of *P. hyalina* from Tahiti to the Southern Cooks and Australs in precontact times. The presence of *P. hyalina* specimens in the upper layers of MAN-44 adds support to this hypothesis.

Sea Urchins

Sea urchin remains (Echinoidea) were present throughout the MAN-44 deposit, in the form of test fragments, spines, and mouth parts, and were sorted into those morphological categories. The only species that could

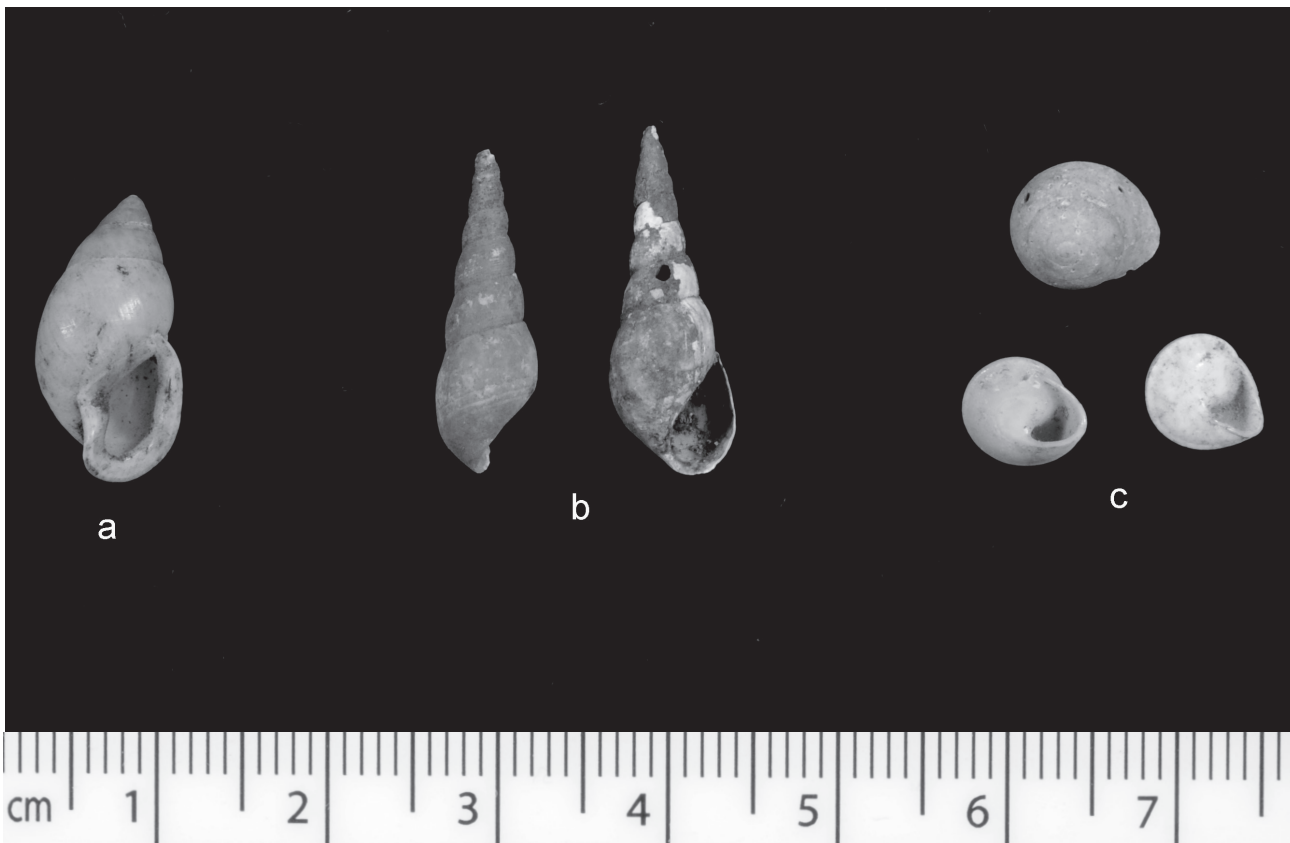


Figure 8.6. Land and freshwater mollusks from site MAN-44: a, *Partula hyalina*; b, *Melanoides tuberculata*; c, *Orobophana pacifica*.

readily be distinguished, due to its distinctive large spines, was the slate-pencil urchin *Heterocentrotus trigonarius*, the spines of which were sometimes used as abraders in the manufacture of shell fishhooks and possibly other artifacts (see Chapter 10). *H. trigonarius* spines were identified from stratigraphic zones SZ-4A, SZ-5, SZ-8, SZ-15, and SZ-17. Other genera of sea urchins that appear to be represented in this material include *Diadema*, *Echinothrix*, and *Echinometra*. All of these, including the *Heterocentrotus*, were undoubtedly consumed, probably raw.

Figure 8.7 shows the stratigraphic distribution of all sea urchin remains as concentration indices (grams per cubic meter). While sea urchins are present throughout the sequence, their concentration increases dramatically in zones SZ-5 through SZ-8, a pattern that is paralleled with the mollusk remains (see discussion below). This suggests that the gathering of invertebrates for food became more intensive in the later phases of occupation at the Tangatatau Rockshelter.

Crustaceans

Crustacean remains were encountered throughout the MAN-44 sequence, including zones SZ-1A and SZ-1B, where land crabs appear to have been part of the naturally deposited fauna, together with terrestrial gastropods and bird bones. The concentration index for crustaceans in SZ-1A is 78.6 g/m^3 , but this rises to 238.9 g/m^3 in SZ-1B with the additional input of human-obtained marine crabs. The concentration index (CI) values for crustaceans remain very consistent throughout the subsequent cultural deposits, ranging from 228.7 g/m^3 in SZ-4B to 251.9 g/m^3 in SZ-5 and 230.4 g/m^3 in SZ-8. Crustaceans drop to their lowest CI of 65.5 g/m^3 in SZ-15.

Identification of fragmentary crustacean remains is challenging. Several representative samples were sent to marine biologist Dr. Gustav Paulay at the Florida State Museum, who has collected crustaceans in the Cook Islands. Paulay (personal communication, February 2016) reports that the remains from MAN-44 represent a diverse assemblage, mostly of medium-sized

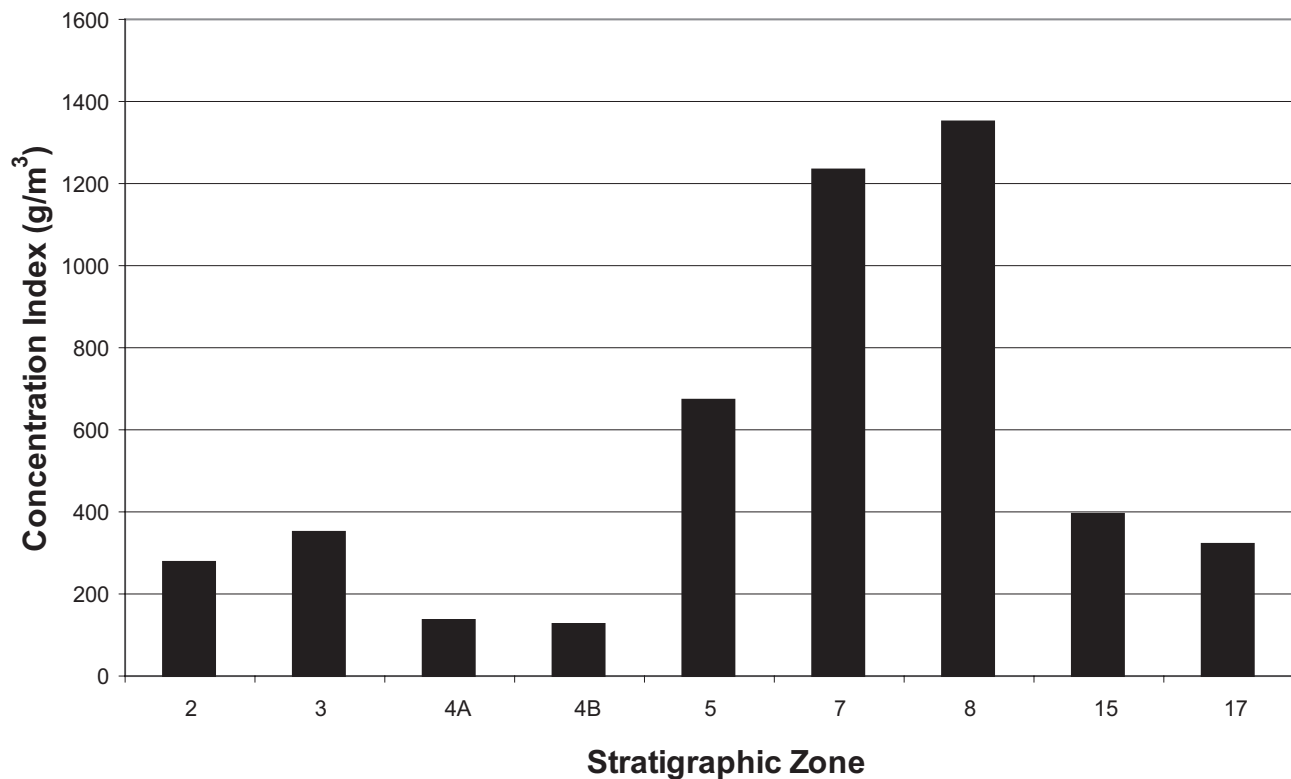


Figure 8.7. Concentration indices (grams per cubic meter) of sea urchin remains by stratigraphic zone in site MAN-44.

marine decapods but also some coenobitids (*Coenbita* certainly and potentially also *Birgus*). There are several species of xanthids, portunids, and diogenid hermit crabs, including *Zosimus aeneus* (quite common), *Charybdis* (probably *Charybdis obtusifrons*), *Aniculus* (probably *Aniculus ursus*). These identified species are classic reef flat/reef crest taxa that could readily be collected on Mangaia by gleaning. The presence of *Z. aeneus* is somewhat surprising, as it is a renowned poison crab, and it is not eaten on many islands. A more detailed taxonomic analysis of the crustacean remains from site MAN-44 is planned for the future.

Temporal Trends in the Tangatatau Invertebrate Assemblage

Having reviewed the various taxonomic categories of invertebrates present in the MAN-44 assemblage, we turn now to temporal trends within the site's sequence. Three major kinds of changes are evident: (1) changes in the intensity of mollusk and other invertebrate exploitation over time; (2) size changes in the large marine gastropod *T. setosus*, indicative of resource depression; and (3) changes in the relative frequency

or abundance of particular mollusks over time. We discuss these trends in turn.

Changes in Intensity of Mollusk Exploitation

The first major trend is one that we have already noted for the sea urchins (see Figure 8.7)—namely, a dramatic increase in the concentrations or density of invertebrate remains, beginning with stratigraphic zone SZ-5. The same situation obtains for the mollusks, as is evident in Table 8.3 and Figure 8.8. The CI values for zones SZ-2 through 4B all remain in the range of 6 to 7 kg/m³, whereas in SZ-5, this rises dramatically to 61.8 kg/m³. Zones SZ-7 and SZ-8 have CIs of 49.8 and 46.8 kg/m³, respectively. SZ-14, a thin bed without much horizontal extent (see Chapter 4), has an extremely low density. SZ-15 then has a CI of 14.5 kg/m³, and the final SZ-17 has a value of 1.2 kg/m³. In sum, while the exploitation of mollusks occurred throughout the MAN-44 occupation sequence, the much higher CI values in zones SZ-5, SZ-7, and SZ-8 suggest that mollusks were more intensely exploited (resulting in a higher rate of deposition) during the time period represented by those strata.

Table 8.3 Concentration Indices (g/m³) for Principal Mollusk Taxa from Selected Stratigraphic Zones, Site MAN-44

Taxon	SZ-2	SZ-3	SZ-4A	SZ-4B	SZ-5	SZ-7	SZ-8	SZ-15	Totals
<i>Astraea rhodostoma</i>	297	28	850	962	13,783	4,260	4,255	1,752	26,187
<i>Cerithium</i> spp.	0	40	34	76	1,969	3,040	5,577	1,723	12,459
<i>Conus</i> spp.	0	652	85	715	10,811	5,779	5,449	1,060	24,551
<i>Drupa ricinus</i>	50	132	593	1,413	19,514	11,038	12,576	6,190	51,506
<i>Modiolus auriculatus</i>	15	228	186	368	2,408	7,431	6,798	699	18,133
<i>Patella flexuosa</i>	0	24	17	99	1,617	1,197	1,344	279	4,577
<i>Patelloida conoidalis</i>	8	228	61	182	2,857	1,274	1,597	398	6,605
<i>Strombus</i> spp.	0	40	39	87	1,705	1,732	2,529	1,097	7,229
<i>Tectarius grandinatus</i>	373	488	186	175	28	0	6	0	1,256
<i>Turbo setosus</i>	4,850	1,480	1,138	1,590	5,021	2,558	3,102	414	20,153
Totals	5,593	3,340	3,189	5,667	59,713	38,309	43,233	13,612	172,656

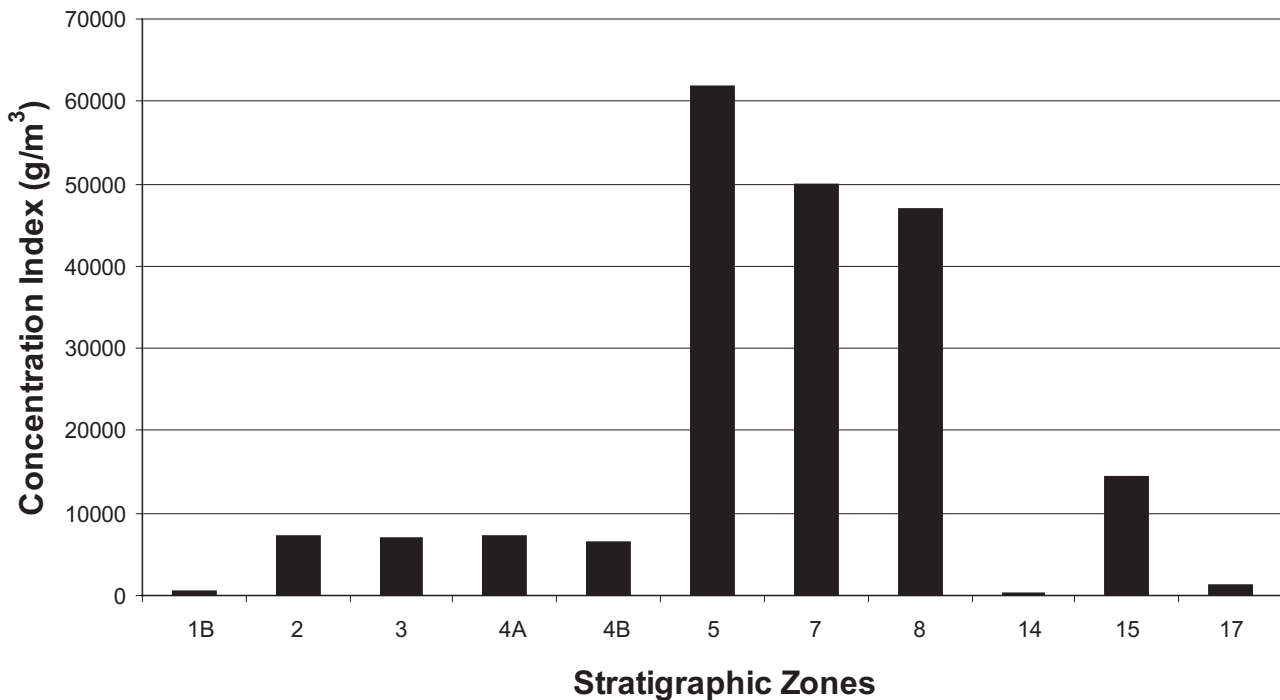


Figure 8.8. Concentration indices (grams per cubic meter) of mollusk shells by stratigraphic zone in site MAN-44.

Size Changes in *Turbo setosus*

Constant collecting pressure on an animal population, such that individuals are culled before they can reach maturity and hence full size, results in the phenomenon referred to as “resource depression” (Broughton 1999; Grayson 2001). Resource depression can be zooarchaeologically indicated by elimination of top-ranked prey taxa from an assemblage and/or by reductions in

the average sizes of individuals being taken over time. Unfortunately, in the MAN-44 mollusk assemblage, the unusually high degree of fragmentation of the shells does not leave an adequate sample of whole shells available for measurement. However, in the case of one gastropod species, *T. setosus*, the dense opercula are mostly intact, and sample sizes are large throughout the MAN-44 sequence. Since the opercula diameters

increase allometrically in proportion to the size of the *Turbo* shell and its aperture, we were able to measure the diameters of these opercula and use these data as an index of the degree of resource depression across the MAN-44 stratigraphic sequence.

As is evident in Figure 8.9, the mean sizes as well as the overall size ranges of *T. setosus* opercula decrease dramatically over time in the MAN-44 sequence. In early stratigraphic zones SZ-2 and SZ-3, the median diameters are 31.2 mm in both samples, and there are no individuals with diameters less than 20.5 mm. Zone SZ-4A continues to have some large individuals, but the median has dropped to 26.9 mm. In succeeding SZ-5 (when mollusk gathering intensity spikes, as previously noted), the median diameter has declined to 11.1 mm. Zones SZ-7 and SZ-8 continue to have a few large individuals, but the median values remain low, at 11.8 and 11.5 mm diameters, respectively. Finally, in the higher stratigraphic zones SZ-11 and SZ-15, there are no individuals with operculum diameters greater than 20 mm.

These data are interpreted as a classic case of resource depression. *T. setosus* is a large gastropod with a substantial amount of meat and thus prized for its food value. As we demonstrate below, it was the most preferred mollusk gathered during the initial phase of site occupation (in zones SZ-2 and SZ-3). Clearly, during this early period, only large individuals were targeted, but by the time of zone SZ-4A, a full spectrum of large to small shells were being collected. The numbers of large individuals began to rapidly decline, becoming increasingly rare, and by the time of zones SZ-11 and SZ-15, no large individuals were present at all.

Changes in Taxon Rank Order

The final temporal trends that we discern in the invertebrate faunal sequence at MAN-44 are changes in the relative frequency or abundance of particular mollusk taxa, changes that once again are most likely related to resource depression but in some cases may also reflect changing ecological conditions on Mangaia's narrow

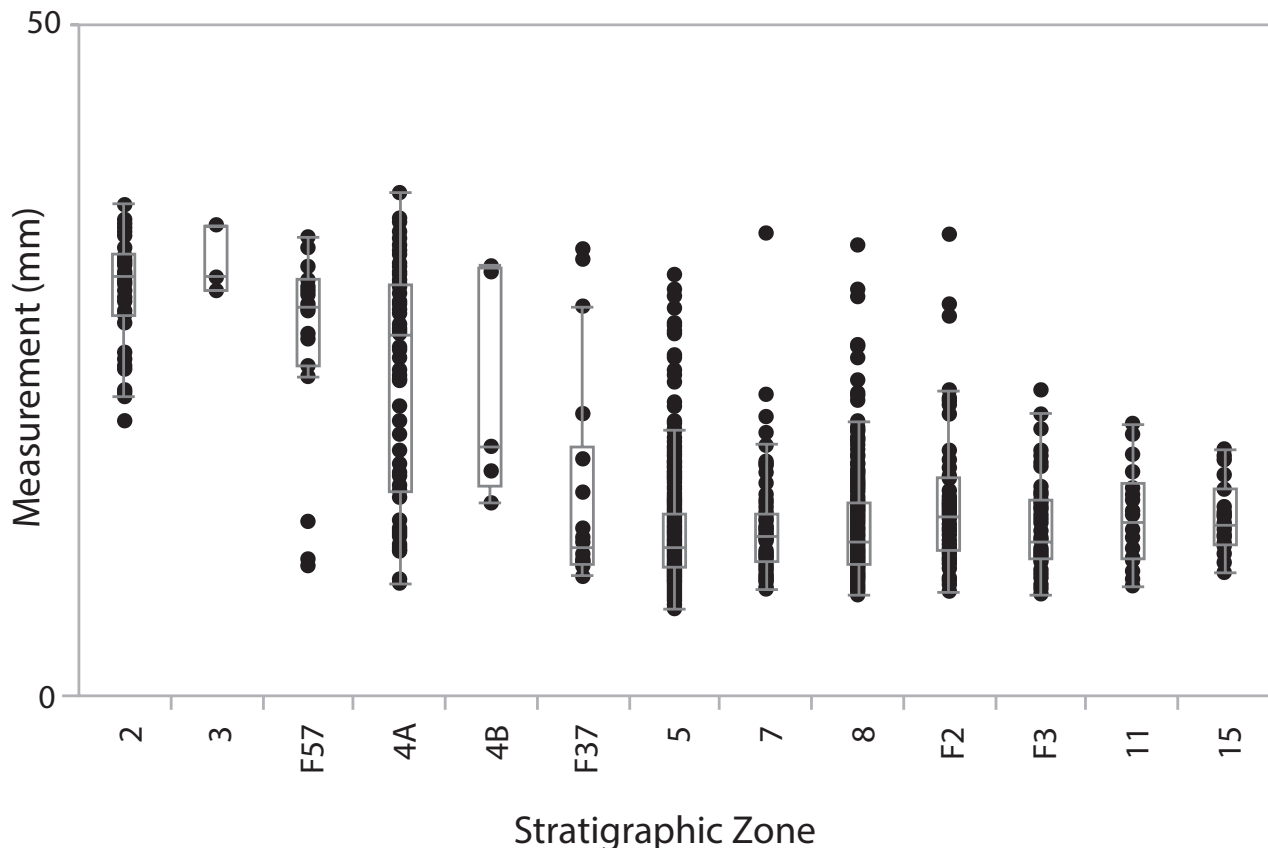


Figure 8.9. Box-and-whisker plot of *Turbo setosus* opercula diameters from stratigraphic zones of site MAN-44.

fringing reef. These trends also are indicative of changing patterns of mollusk gathering as certain preferred species became less available and people were constrained to shift to other, initially less highly valued taxa.

These temporal differences can be illustrated by comparing the rank order abundances (by weight) of mollusk taxa in later zone SZ-8 (when mollusk collecting was at a high level of intensity) with those of earlier zone SZ-4A, as shown in Figure 8.10. Whereas in the early levels the highly valued, large-bodied turban shell species *T. setosus* and *A. rhodostoma* were the first and second ranked taxa, in SZ-8, these had declined to sixth and fifth place in rank order. *Drupa* sp. and *M. auriculatus*, which were third and fourth ranked in SZ-4A, had become the first and second ranked taxa

by SZ-8. *T. grandinatus*, a very easily collected littoral gastropod, was completely absent by SZ-8.

We can further tease out temporal trends in individual mollusk taxa by examining their CI values over time, as in Figure 8.11. Due to the large differences in CI values, we have separated the 10 taxa into two groups to make the trends more graphically evident. In the initial occupation zones SZ-2 and SZ-3, we can see that *T. setosus* and *T. grandinatus* were both preferred taxa, the former undoubtedly due to its large size and meat value and the latter presumably because it was readily gathered along the intertidal littoral fringe. The limited habitat of *T. grandinatus* would have made it highly susceptible to resource depression, and indeed this taxon is virtually absent after SZ-8. *T. setosus*,

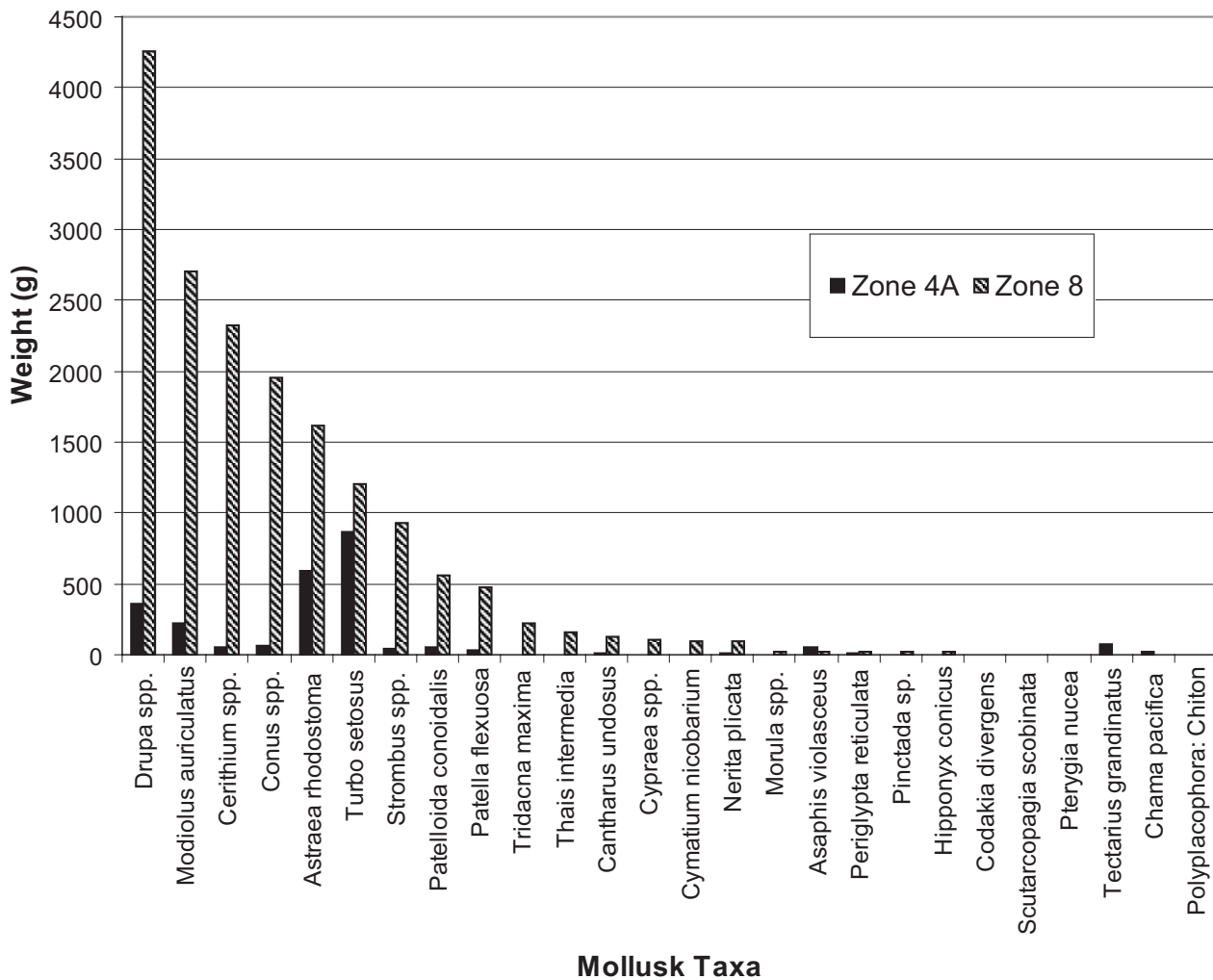


Figure 8.10. Rank order abundance (by weight in grams) of mollusk taxa in early stratigraphic zone SZ-4A compared with later zone SZ-8.

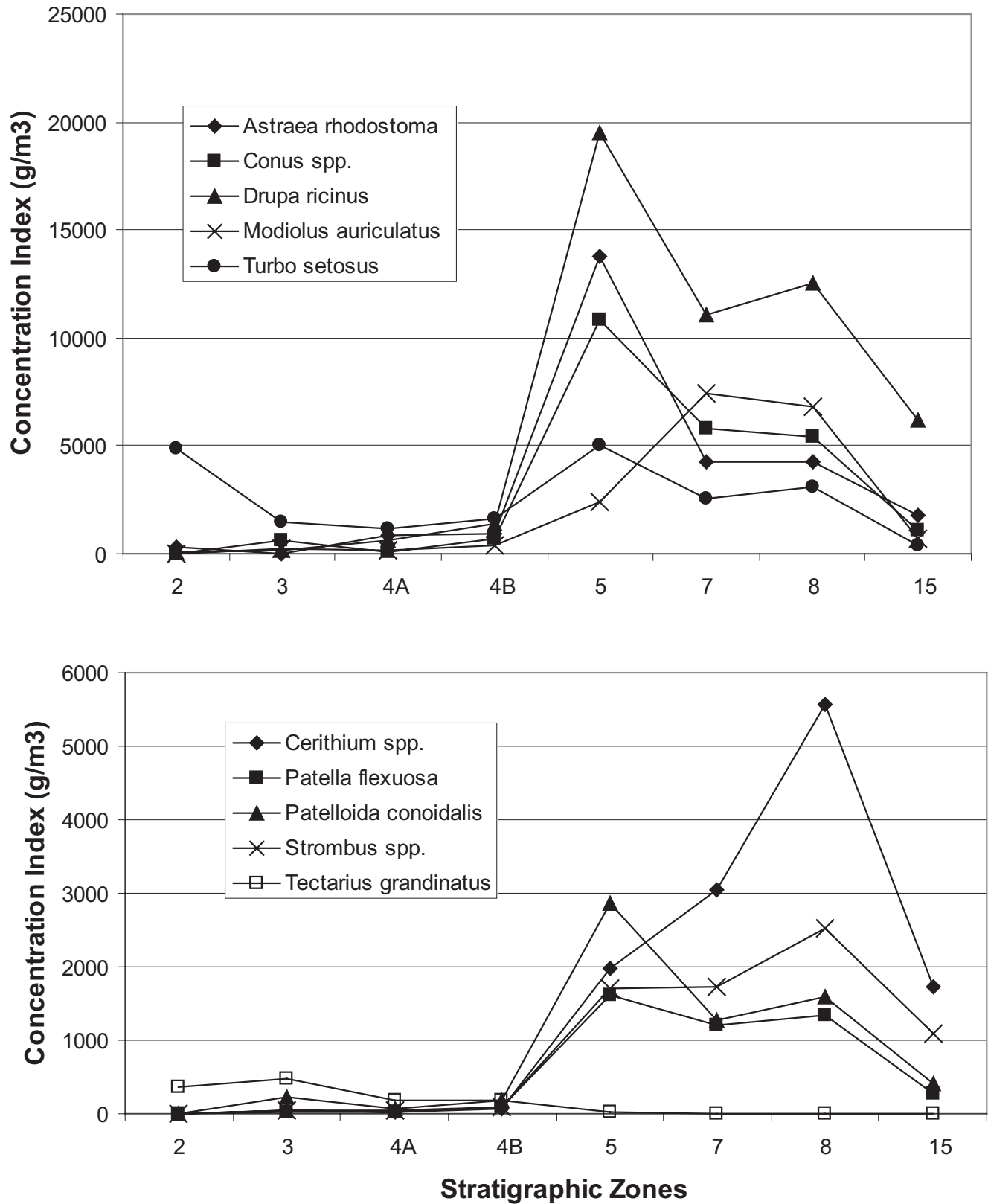


Figure 8.11. Concentration indices (grams per cubic meter) of selected mollusk taxa by stratigraphic zones in site MAN-44.

whose habitat on the outer surge zone of the reef made it more resilient to collecting pressure, nonetheless exhibits major size decreases as documented above.

In zone SZ-5, several taxa that had been relatively unimportant in the earlier strata now become more abundant, including *D. ricinus*, *A. rhodostoma*, *Conus* spp., *P. conoidalis*, and *Strombus* sp. Interestingly, the mussel *M. auriculatus*, although gathered from early on in the occupation sequence, only becomes significant after SZ-5 and reaches its peak densities in SZ-7 and SZ-8. This mussel's habitat consists of seagrass (algae) beds, which may have been increasing in area and replacing zones dominated by corals in the earlier time periods. We hypothesize that human trampling on Mangaia's narrow fringing reef over time transformed areas of former coral gardens into zones of coral rubble and bare limestone platform, readily colonized by algae. Such habitats would not only have

avored an increase in the population of *M. auriculatus* but also of *Cerithium* and *Strombus*, which prefer to hide under coral rubble; notably, these taxa also increase in zone SZ-8.

In sum, the exploitation of mollusks over the several centuries that the Tangatatau Rockshelter was occupied was quite dynamic. It seems likely that early targeting of preferred taxa led to resource depression in those species (clearly demonstrated in the case of *T. setosus*), leading to a shift to other mollusk species that may not have been so highly valued. Some of these shifts in relative mollusk abundance could also have been a consequence of ecological changes on the reef itself, such as a decline in areas of living coral and concomitant increases in zones of rubble and seagrass, changes that would have been a likely consequence of constant human activity on an especially narrow and fragile fringing reef.

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9

Archaeobotanical Assemblages from Tangatatau Rockshelter¹

Patrick Vinton Kirch, Jon G. Hather, and Mark Horrocks

The excavations at Tangatatau Rockshelter yielded a rich assemblage of plant remains, including some delicate tissues not often recovered from Polynesian archaeological contexts. These assemblages have allowed a rare opportunity to examine the plant resources—indigenous and introduced, wild, managed, and cultivated—that formed the vegetative environment of this island community. This chapter deals with macrobotanical remains, including wood charcoal, recovered from the MAN-44 excavations, as well as plant microfossils (pollen, phytoliths, and starch grains) extracted from selected sediment samples.

Macrobotanical Remains: Materials and Methods

Recovery of macrobotanical remains from MAN-44 was achieved by three methods: (1) individual carbonized specimens were handpicked during excavation or while screening and separately bagged for later identification, (2) bulk samples were taken in the field from what appeared to be particularly rich deposits of

carbonized plant materials, and (3) wood charcoal was systematically collected from selected excavation units during sieving. All archaeobotanical materials were sent to Hather at the Institute of Archaeology, London, for detailed laboratory study.

Preliminary examination of all classes of plant remains was carried out under low-power incident light microscopy; identifications based on morphological characters were achieved by the unaided eye or by this method of microscopy. Plant remains requiring examination by higher magnification—potentially identifiable using anatomical characters—were then examined by scanning electron microscopy (SEM) using methods developed by Hather (1991, 1993, 1994).

Wood charcoal from four excavation units (A25, D35, E33, and E34) was identified using epi-illuminated microscopy by comparing archaeological fragments of wood charcoal with modern stained, thin-sectioned, and experimentally charred reference material. Forty woody plant species were collected by Hather

¹ The identification and analysis of macrobotanical remains from MAN-44 was carried out by Jon Hather between 1991 and 1994. Hather did not write up a complete report on this material but did author a short paper for presentation at a meeting of the Society for American Archaeology. Hather subsequently retired from the Institute of Archaeology and was not available to assist in preparing this chapter but did read and approve the final chapter draft. The collection of macrobotanical remains from MAN-44 was, however, returned to the Oceanic Archaeology Laboratory at Berkeley in 2012 and is now curated as part of the MAN-44 collection. A database of the identified materials prepared by Hather, along with photographs of selected specimens, and the unpublished manuscript have formed the basis for this chapter, which was prepared by Kirch. The analysis of plant microfossils extracted from MAN-44 sediment samples was carried out by Horrocks.

Table 9.1 Macrobotanical Remains (NIISP) from the Main Excavation Block, Site MAN-44

Taxon	Plant Part	SZ-2	SZ-3	SZ-4A	SZ-5	SZ-6	SZ-7	SZ-8	SZ-9	SZ-10	SZ-15	SZ-17	Totals
Food plants													
<i>Cocos nucifera</i>	Endocarp	2	6			2							10
<i>Cocos nucifera</i>	Husk		1			1							2
<i>Cocos nucifera</i>	Leaf		1										1
<i>Cocos nucifera</i>	Bracts		1										1
<i>Pandanus tectorius</i>	Drupe	2	8	1	1			1	1	1			15
<i>Cordyline fruticosa</i>	Root		1									1	2
<i>Cordyline fruticosa</i>	Leaf		1			1							2
<i>Saccharum officinarum</i>	Stem		1										1
<i>Musa</i> sp.	Leaf			1									1
<i>Ipomoea batatas</i>	Tuber (parenchyma)			3				3			1		7
<i>Colocasia esculenta</i>	Corm		1										1
<i>Cyrtosperma chammissonis</i>	Tuber (parenchyma)	1	1										2
Nonfood plants													
<i>Aleurites moluccana</i>	Endocarp		4										4
<i>Aleurites moluccana</i>	Endosperm	12	36	2	2	7	5	5	2		1	1	73
<i>Hernandia</i> sp.	Seed	2	5	1	1	1							10
<i>Caesalpinia major</i>	Seed	1						1					2
<i>Schizostachyum glaucophyllum</i>	Stem		1										1
Indeterminate	Parenchyma		4						1			1	6
Indeterminate	Leaf		4			1							5
Totals		20	76	8	4	13	5	10	4	1	2	3	146

and Kirch on Mangaia as the basis for this reference material (see Archaeobotanical Database). For each excavated level within the study units, 50 charcoal specimens were examined and identified (except in cases where fewer than 50 specimens were present in a level).

Nonwood Carbonized Remains

Eleven plant taxa were identified from a total of 146 specimens of nonwood, carbonized plant remains recovered from the main excavation block; the distribution of these remains by stratigraphic zone is shown in Table 9.1. Although we have presented counts of individual specimens, we caution that the data presented in Table 9.1 should be treated more qualitatively rather than quantitatively; this is because the higher numbers in certain zones (such as SZ-3) reflect targeted bulk sampling, which was not conducted systematically across all contexts.

Food Plants

Coconut (*Cocos nucifera*) is present from the earliest occupation deposit, SZ-2, and is especially well represented in zone SZ-3, where in addition to carbonized endocarp (shell), we recovered mesocarp (husk), leaf parts, and proximal bracts (Figure 9.1). A small fruited, wild form of coconut was apparently naturally dispersed through central Polynesia prior to Polynesian arrival (Kahn et al. 2015; Parkes 1997), but the remains from MAN-44 appear to be from the larger fruited cultivars introduced by Polynesian colonists. Whistler (1990:383–384) lists the varied uses of this important plant, which, in addition to the water and meat offered by its nut, included twine, rope, and netting from husk fibers; containers from the cleaned shells; mats and baskets from the woven leaves; and house posts from the timber. Merlin (1991:138) observes that *C. nucifera* is an important component of the “mixed disturbed forest” on Mangaia and is cultivated in a number of places throughout the *makatea*.

The most ubiquitous of the food plant remains in the MAN-44 assemblage is the drupe of the screwpine, *Pandanus tectorius*. This distinctive, shrubby tree is indigenous throughout southeastern Polynesia but provided both food and industrial materials to Polynesian communities (Whistler 1990:357–358). The carbonized materials from MAN-44 are all drupes or “keys” (individual polydrupes of a syncarpous fruit), preserved as the hard, woody bases with holes caused by

the degradation of the individual locules (Figure 9.2). As Whistler (1990:358) notes, “The sweet, colored, basal portion of the phalange [drupe] can be eaten raw or cooked.” Hiroa (1934:136) writes that *Pandanus* drupes, along with the bitter fruits of the *nono* (*Morinda citrifolia*), were foods of the “fugitives” who inhabited the *makatea* regions. In addition to the fruits, however, the *Pandanus* also provided tough leaves used for thatching houses as well as for plaiting mats and baskets (Hiroa 1944). *P. tectorius* is quite abundant on Mangaia today, both in the mixed and disturbed native forest zones, as well as dominant in its own “*Pandanus* scrub” vegetative zone (Merlin 1991:Table 1).

Cordyline fruticosa (also known as *Cordyline terminalis*), known by the Polynesian name of *ti* or *rau ti*, is a Polynesian introduction cultivated in Eastern Polynesia exclusively by vegetative reproduction, as the cultivar is sterile (Hinkle 2004). In MAN-44, it is represented by carbonized root tissue in zones SZ-3 and SZ-17 and by partially charred and uncharred leaf tissue in SZ-3 and SZ-6 (Figure 9.3). *C. fruticosa* was also a plant with multiple uses: the enlarged root is sugar laden and was cooked in special, large earth ovens. Hiroa (1934:137) writes that the cooking of these roots—“a reserve food of the dry season”—was a community effort. “The cooked stems, rich in saccharine materials, would keep for some time.” The glabrous leaves, however, were also very important as wrappers for fish or other flesh foods to be cooked in the earth oven (Whistler 1990:397).

Stem tissue of the sugarcane (*Saccharum officinarum*), another Polynesian introduction, was identified from zone SZ-3 (Figure 9.4). The plant is common in house gardens, and the sugar-filled stem is chewed as a snack (Whistler 1990:405).

Several different cultivars of *Musa* hybrids, bananas, were introduced by the Polynesians. Hiroa (1934:136) says they are called *koka* on Mangaia, a lexical innovation. The soft tissue of the fruit typically does not preserve in archaeological contexts, but *Musa* leaf tissue was recovered in a charred state from zone SZ-4A. Banana leaves were an important material for wrapping foods and for covering earth ovens.

Of particular note was the recovery of a number of carbonized tuber fragments (parenchyma) of the sweet potato (*Ipomoea batatas*) during the 1989 excavation season. These were found in unit E30 (from zones SZ-4A, SZ-8, and SZ-15) in the main excavation block and from three levels in outlying unit F10

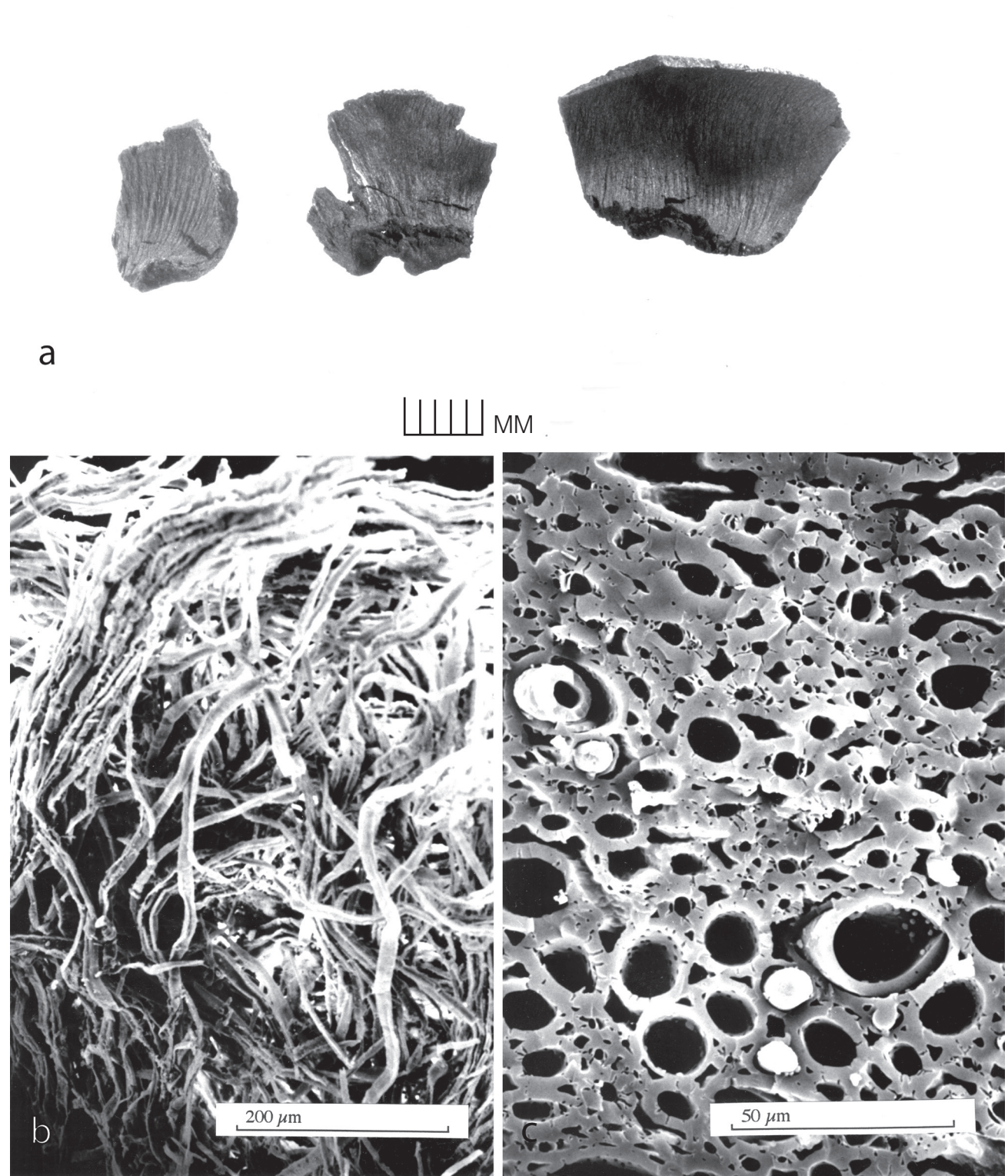


Figure 9.1. Carbonized coconut (*Cocos nucifera*): a, husk fragments (D34-6-18); b, SEM photo of coconut fiber (D35-5-11); c, SEM photo of endocarp (A25-4-1). Photograph by Jon G. Hather.

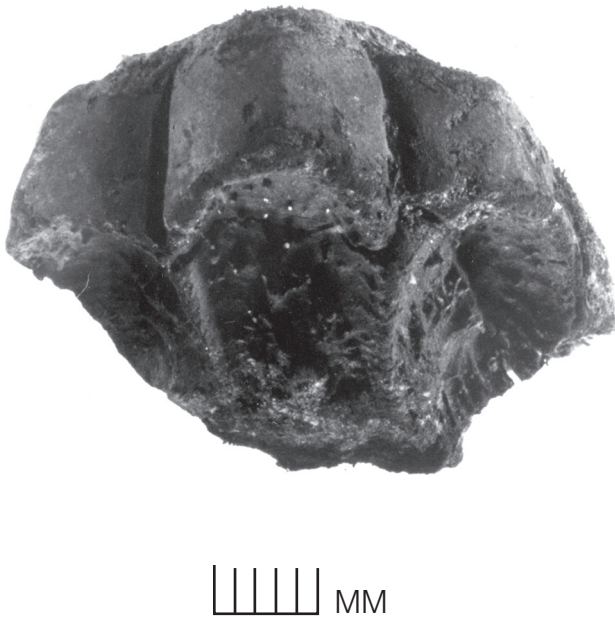


Figure 9.2. Carbonized drupe of *Pandanus tectorius* (D32-3-10). Photograph by Jon G. Hather.

(these latter are not reported in Table 9.1 because they cannot be assigned to a stratigraphic zone). These remains, with descriptions of the tuber anatomy, were previously published by Hather and Kirch (1991), and the details need not be repeated here. They provide crucial evidence for the introduction of sweet potato—a plant of South American origin—into central Eastern Polynesia in pre-European times. The remains from MAN-44 provided direct, archaeobotanical support for the hypothesis advanced by Yen (1974) that *I. batatas* had been transferred from South America into Polynesia well before European contact, most likely by Polynesians making a return voyage. According to Hiroa (1934:136), on Mangaia, “the sweet potato . . . was the chief food of the conquered in peace times, for it grew in the dry soil of the makatea and the uplands.”

One specimen of *I. batatas* parenchyma, identified by Hather and returned to the Oceanic Archaeology Laboratory at Berkeley, was submitted in 2015 to the radiocarbon laboratory at the University of California,

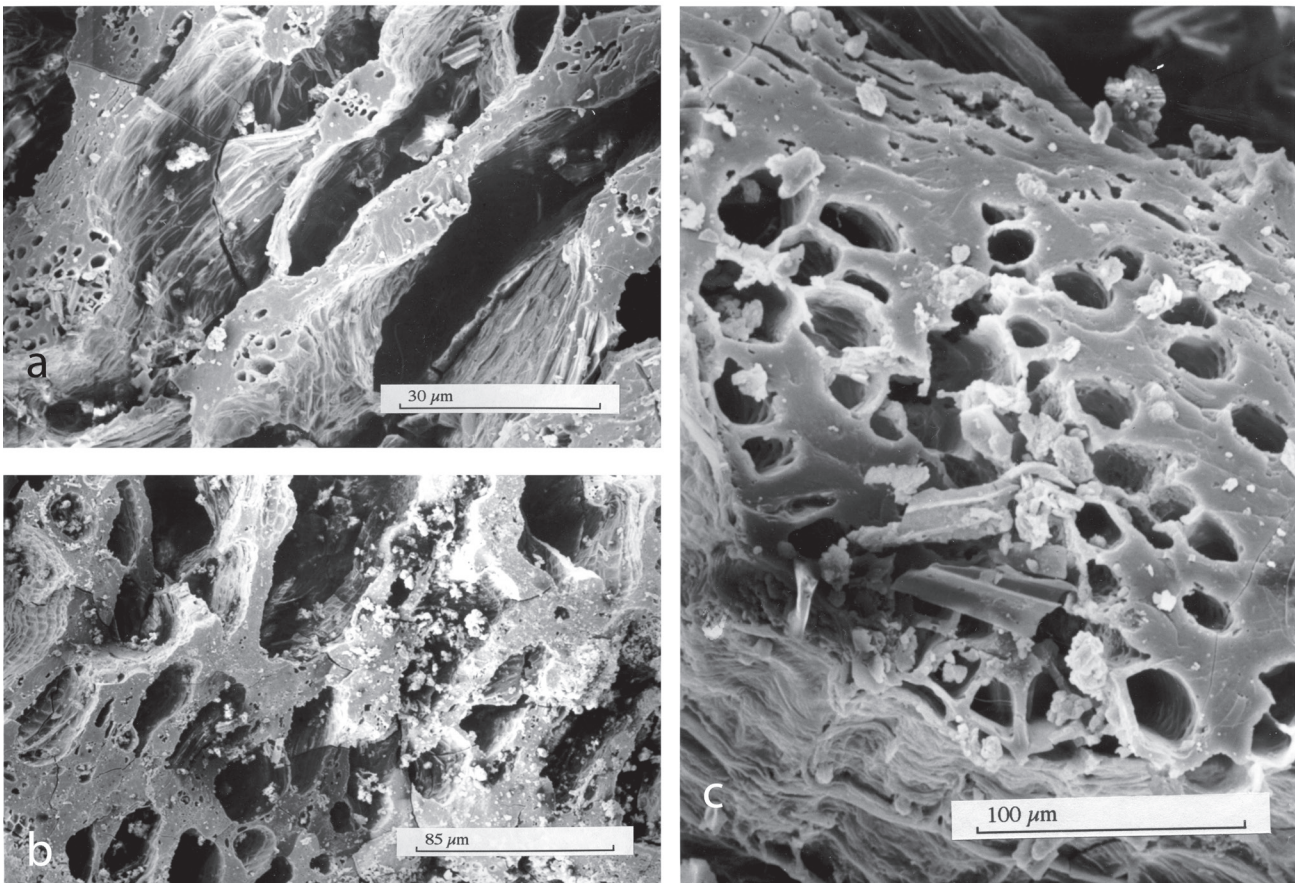


Figure 9.3. SEM photos of carbonized *Cordyline fruticosa* (D32-1-12) at different scales of magnification. Photograph by Jon G. Hather.

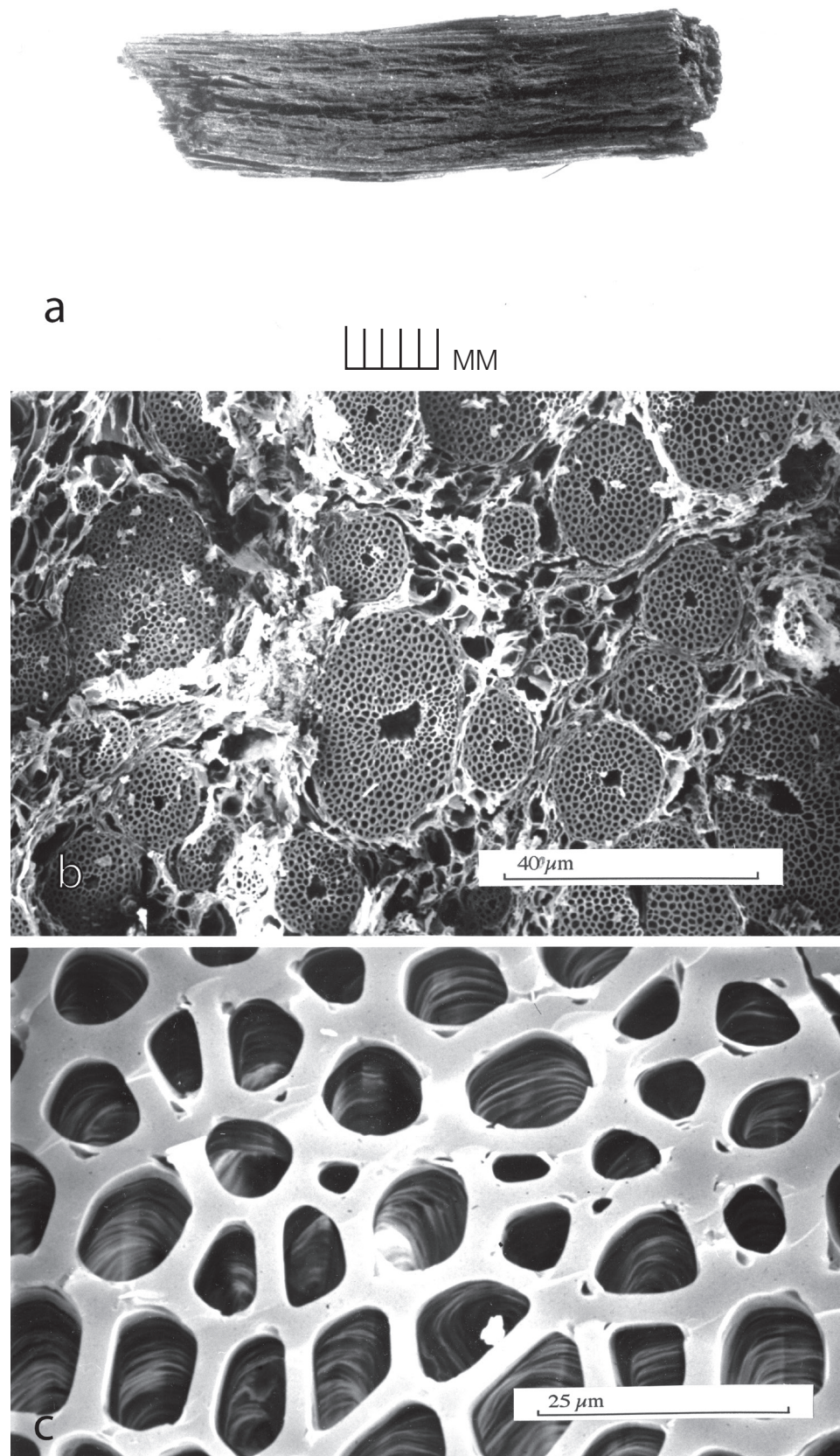


Figure 9.4. Carbonized sugarcane (*Saccharum officinarum*) (D34-6-18).
Photograph by Jon G. Hather.

Irvine, for direct accelerator mass spectrometry (AMS) dating. The specimen was excavated from level 7 of unit E30 and comes from zone SZ-8 (see Table 5.3). The resulting ^{14}C age of 385 ± 15 BP (UCIAMS-164896) has a calibrated age range of AD 1448 to 1616 at two standard deviations.

Carbonized soft tissue (parenchyma) from the corm or tuber of two important aroid species, *Colocasia esculenta* (or taro) and *Cyrtosperma chammisonis* (or giant swamp taro), were also identified, the former from zone SZ-3 and the latter from both SZ-2 and SZ-3 (Table 9.1). Taro, grown in irrigated pondfields, was the “staple food of the Mangaiaans” (Hiroa 1934:136) and a key Polynesian introduction throughout the region. Wilder (1931:26–27) reports the presence of numerous named cultivars on nearby Rarotonga Island. The presence of *C. chammisonis* was more surprising, as it is not known to be present on Mangaia today, although this large aroid is important in the atolls of the Northern Cook Islands (Whistler 1990:395) and is also present on Rarotonga (Wilder 1931:27). The tuber of this aroid, also a Polynesian introduction, is much larger but also considerably coarser and more fibrous than that of the true taro. Hiroa (1934) does not mention it in his brief account of Mangaian foods; it is likely that the plant did not persist on Mangaia into postcontact times.

Nonfood Plants

In addition to the food plants, four nonfood species are represented in the MAN-44 macrobotanical assemblage (Table 9.1). By far the most abundant taxon represented in the site is the candlenut, *Aleurites moluccana* (Figure 9.5), with carbonized remains of both the endosperm (kernel) and endocarp (nut shell) present. (In addition to the remains itemized in Table 9.1, numerous smaller fragments of carbonized candlenut endocarp were commonly present throughout the site’s deposits.) The candlenut tree is a Polynesian introduction, with the oily kernels formerly used to make torches (Whistler 1990:408, Figure 13). The kernel can also be ingested, but eating any quantity of the nuts results in diarrhea. Merlin (1991:139, Table 1) indicates that *A. moluccana* is a common tree in the “mixed disturbed native forest” of Mangaia.

Ten carbonized seeds of a *Hernandia* species (Figure 9.6) were recovered from zones SZ-2 through SZ-6 (Table 9.1). Two species are present on Mangaia, *Hernandia moerenhoutiana* which is common in the

“mixed native forest” and “mixed disturbed native forest,” and *Hernandia nymphaeifolia*, which appears to have a more restricted distribution (Merlin 1991:Table 1). Neither species has edible seeds, although polished seeds of *H. nymphaeifolia* are strung together in necklaces (Whistler 1990:394). The timber of *H. moerenhoutiana* was used to make canoes.

Two seeds of *Caesalpinia major* were recovered from zones SZ-2 and SZ-8 (Table 9.1). Of this indigenous tree, Whistler (1990:401) writes that “the hard, round seeds, called tataraka on Mangaia, are sometimes used as marbles by children.” According to Merlin’s survey (1991:Table 1), the tree is fairly rare on the island. The two recovered seeds were smaller than most mature *C. major* seeds and therefore possibly green (unripe and soft) when originally gathered.

A Polynesian-introduced species of bamboo, *Schizostachyum glaucophyllum*, is represented by a single specimen from zone SZ-3 (Figure 9.7). Split pieces of bamboo were formerly used as cutting instruments, while whole stems were used for house walls, nose flutes, and fishing poles (Whistler 1990:370).

Wood Charcoal

As noted earlier, samples of wood charcoal recovered through sieving were analyzed from four excavation units: A25, D35, E33, and E34. Unit E34 had the most complete representation with 30 taxa from all of the major stratigraphic zones, so we discuss the charcoal from this unit most extensively, followed by additional notes on charcoal from the other three analyzed units.

Unit E34 Charcoal Sequence

The results of wood charcoal identification for unit E34 are provided in Table 9.2; 50 specimens from each level were identified, and the cell values given in Table 9.2 are percentages for each taxon. Note that because the charcoal was analyzed by excavation level, for some stratigraphic zones, there is more than one level. For all levels except level 11, there was sufficient charcoal to randomly choose 50 specimens for identification (all identified specimens were selected from the >4-mm fraction). A total of 511 charcoal fragments were identified.

The potential for either cultural or ecological interpretation of wood charcoal from archaeological contexts is a matter of some debate. If we assume a certain amount of human selection in the taxa used for fuel, construction, and the manufacture of artifacts, all of

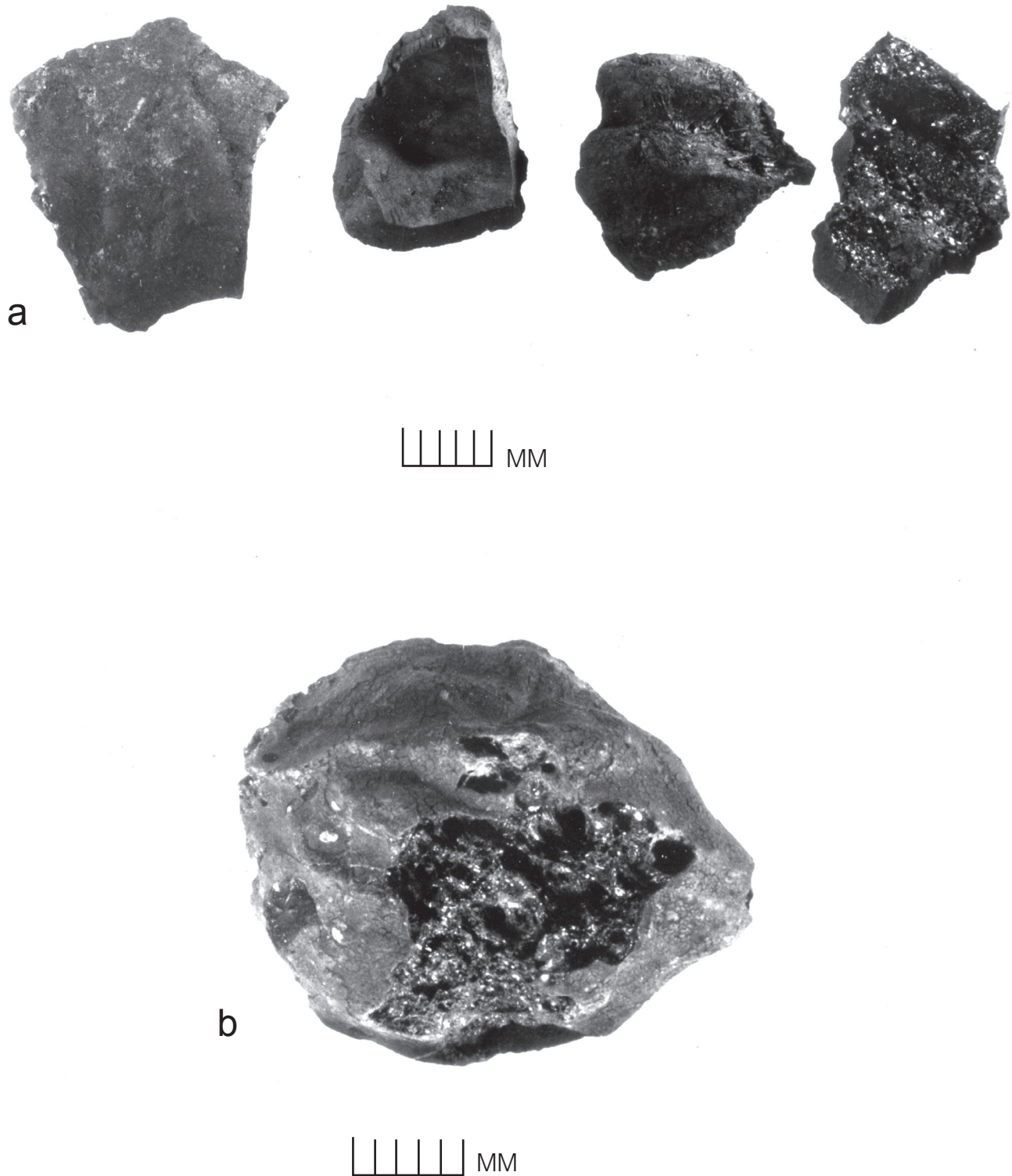


Figure 9.5. Carbonized candlenut (*Aleurites moluccana*): a, endocarp fragments (D34-6-23); b, endosperm (D31-2-2). Photograph by Jon G. Hather.



Figure 9.6. Carbonized seed of *Hernandia* sp. (D35-3-11).

which could potentially contribute to the wood charcoal record, then the results of an analysis such as this cannot directly reflect the natural environment in the same way that, for example, a pollen record may do. What is reflected, however, is a picture of the availability and use of certain resources in the surrounding environment of the site. As such, the wood charcoal from unit E34 displays marked variation in the selection of wood from different ecological zones through time.

The earliest evidence of wood charcoal in unit E34 comes from zone SZ-1B, the top of the preoccupation deposit, which also displayed evidence for intense burning immediately prior to the initial human use of the rockshelter. The sample here consisted of just 11 fragments and was restricted to three taxa. *Hibiscus* sp. (most likely *Hibiscus tiliaceous* in this case) is a littoral to lowland shrub or small tree while *Homalium accuminatum* is a tree that occurs today primarily in mixed disturbed native forest (Merlin 1991:Table 1). The third taxon present in SZ-1B is *Pemphis acidula*,

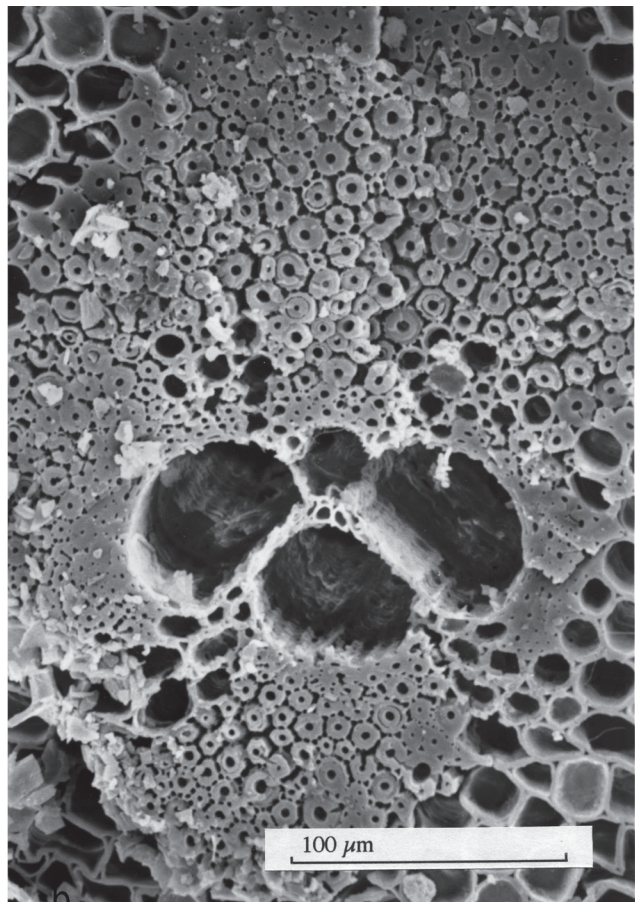
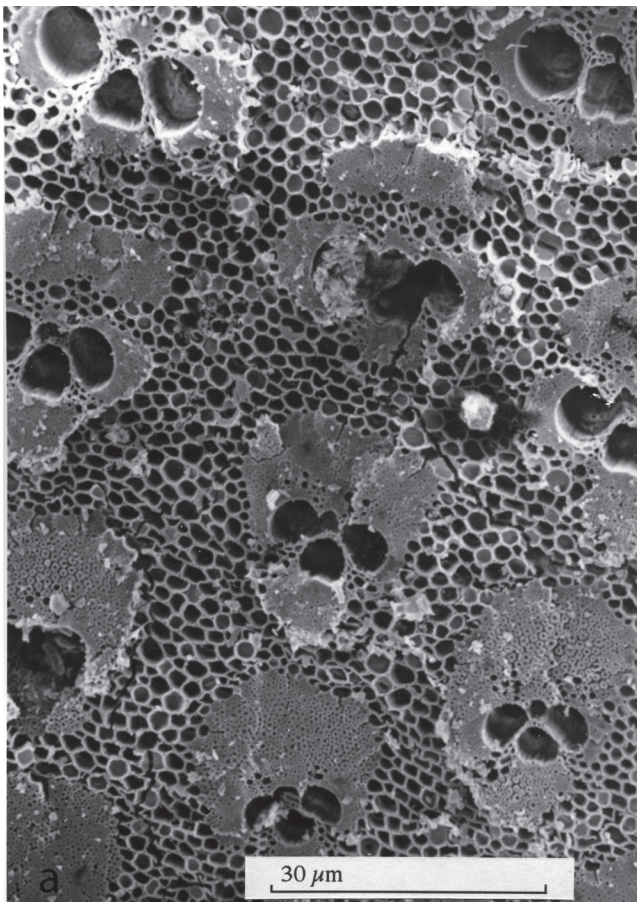


Figure 9.7. SEM photos of carbonized bamboo (*Schizostachyum glaucophyllum*) (E34-6-14). Photograph by Jon G. Hather.

Table 9.2 Charcoal from Unit E34, Enumerated by Excavation Level, Site MAN-44

Taxon	Status	L-11	L-10	L-9	L-8	L-7	L-6	L-5	L-4	L-3	L-2	L-1
Stratigraphic Zone		1B										
<i>Aleurites moluccana</i>	Polynesian introduction	2	2	10	2	3	3	4A	6	8	15	17
<i>Artocarpus altilis</i>	Polynesian introduction						6		10		12	54
<i>Barringtonia asiatica</i>	Indigenous				8		4		8	2		
<i>Caesalpinia major</i>	Indigenous					18	2					
<i>Calophyllum inophyllum</i>	Indigenous						4	2		4		
<i>Canthium barbatim</i>	Indigenous						2					
<i>Casuarina equisetifolia</i>	Indigenous	2						6			2	
<i>Cocos nucifera</i>	Polynesian introduction							2	2	4	4	
<i>Cordia subcordata</i>	Indigenous										2	
<i>Cordyline fruticosa</i>	Polynesian introduction					14						
<i>Elaeocarpus tonganus</i>	Indigenous	14	4	16	8	8	22	26	40	36	20	
<i>Erythrina subumbrans</i>	Indigenous			2			2		6		2	4
<i>Fagraea berteroa</i>	Indigenous			2			2					
<i>Ficus tinctoria</i>	Indigenous										2	
<i>Genistoma sykesii</i>	Indigenous				26			14				
<i>Glochidion ramiflorum</i>	Indigenous							2			4	6
<i>Guettarda speciosa</i>	Indigenous							2				2
<i>Hernandia</i> spp.	Indigenous	12			2		6	28	20	44	12	
<i>Hibiscus</i> spp.	Indigenous	45.5	18	18	4	12						8
<i>Homalium acuminatum</i>	Indigenous	45.5	12	44	12	15	14					
<i>Inocarpus fagifer</i>	Polynesian introduction			2	2	2	4	4	10	8	16	18
<i>Morinda citrifolia</i>	Polynesian introduction	10	8	10	10	2	2				2	
<i>Myoporum sandwicense</i>	Indigenous				6							
<i>Pandanus tectorius</i>	Indigenous		6		2				2			2
<i>Pemphis acidula</i>	Indigenous	9	22									
<i>Scaevola scricea</i>	Indigenous								2			
<i>Sophora tomentosa</i>	Indigenous		4	10		2						
<i>Syzygium malaccense</i>	Polynesian introduction					2						
<i>Terminalia catappa</i>	Polynesian introduction						2					
<i>Tournefortia argentea</i>	Indigenous				10	6		8		2	12	
Total number of fragments		11	50	50	50	50	50	50	50	50	50	50
NTAXA		3	9	9	12	11	14	10	9	7	12	7

Note: All values are percentages, based on 50 identified specimens from each level.

a tough, salt-tolerant wiry shrub normally restricted to rocky shorelines but also highly regarded as firewood (Whistler 1990:361). It is entirely likely that the highly combustible *Pemphis* wood—which would not naturally have occurred in the vicinity of the rockshelter—was brought to the site to ignite a fire to burn off vegetation growing in and around the rockshelter prior to its first use. The *Hibiscus* and *Homalium* were probably components of the natural vegetation growing at the site.

With zone SZ-2, represented by three excavation levels, we see the presence of three Polynesian introductions: the shrub *M. citrifolia*, which bears a bitter fruit used medicinally and also as a famine food; the fruit tree *Inocarpus fagifer* (Tahitian chestnut) with its large edible seed; and the candlenut tree, *A. moluccana*. Presumably these important economic species were all cultivated components of the environment within the vicinity of the rockshelter. Of indigenous taxa being brought to the site for fuel, the most important now appear to have been *Hibiscus* sp., *H. acumdatum*, and *Elaeocarpus tonganus*, all taxa that are likely to have been present either on the *makatea* or lowland slopes near the rockshelter. Merlin (1991:Table 1) indicates that *E. tonganus* is a dominant tree in both the “mixed disturbed” and “mixed” native forest communities. Also present in SZ-2 are *Barringtonia asiatica*, a large littoral tree whose fruit are used for fish poison and whose wood is sometimes used for carving, and *Casuarina equisetifolia*, the ironwood tree used for spears and other purposes.

With zone SZ-3, we see the first appearances of three other Polynesian introductions: the breadfruit tree (*Artocarpus altilis*), the Malay apple (*Syzygium malaccense*), and the tropical almond (*Terminalia catappa*). Along with continued representation of *I. fagifer*, these tree crops all indicate the establishment of arboriculture on the island. The *ti* plant, *C. fruticosa*, also appears in the wood charcoal assemblage of SZ-3. The most commonly burned wood species in this zone are *A. moluccana*, *E. tonganus*, *C. major*, *Hibiscus* sp., and *H. acumdatum*. Several other indigenous forest taxa also appear in lesser quantities in SZ-3, including *Canthium barbatum*, *Fagraea berteriana*, *Genistoma sykesii*, *Guettarda speciosa*, and *Sophora tomentosa*.

Zone SZ-4A continue to show heavy use of *E. tonganus* along with *Hernandia* and *G. sykesii* wood for fuel. The *H. acumdatum*, which was so plentiful

in earlier levels, now disappears completely from the charcoal record, as does *Hibiscus*. Of tree crops, coconut is present for the first time, along with *I. fagifer*. Candlenut wood continues to be well represented. Two littoral taxa, the large *Calophyllum inophyllum* tree whose wood is prized for carving and the shrubby *Tournefortia argentea*, are also present.

In zone SZ-6, fully 40 percent of the charcoal consists of *E. tonganus*, with *Hernandia* sp. also important. The Polynesian-introduced trees *A. moluccana*, *I. fagifer*, and *C. nucifera* in aggregate make up another 22 percent of the charcoal.

By zone SZ-7, the number of taxa has been reduced to just seven, and between them, *E. tonganus* and *Hernandia* sp. make up fully 80 percent of the charcoal. Tree crops are again represented by *I. fagifer* and coconut. Small quantities of the littoral trees *B. asiatica* and *C. inophyllum* are also represented, along with the hot-burning *P. acidula* undoubtedly gathered along the coastline as fuel.

Zone SZ-15 displays a slight increase in diversity, but *E. tonganus* and *Hernandia* sp. continue to be the main indigenous woods represented. The increase in *I. fagifer* charcoal to 16 percent, along with considerable quantities of candlenut, speaks to the importance of arboriculture by this late period. Finally, zone SZ-17 is heavily dominated by candlenut (54 percent) and by *I. fagifer*, again indicating the substantial importance of Polynesian-introduced trees.

Overall, the gradual transformation of the island’s vegetation from one completely dominated by indigenous taxa to a strongly anthropogenic, managed landscape in which Polynesian-introduced trees played a dominant role is indicated by temporal trends in charcoal from unit E34, summarized graphically in Figure 9.8.

Unit E33 Charcoal Sequence

Charcoal frequency data for unit E33 may be found in the MAN-44 Archaeobotany Database (available online at www.dig.ucla.edu/tangatatau). Twenty-three taxa are present in the assemblage. *E. tonganus* and *H. acumdatum* are again major fuel woods in the earlier zones but are mostly absent above zone SZ-8. The transformation from indigenous to Polynesian-introduced dominants is very striking in the E33 sequence, with the combination of coconut, candlenut, and *I. fagifer* making up 22 percent of SZ-8, 74 percent of SZ-10, and finally 84 percent of SZ-15 charcoal.

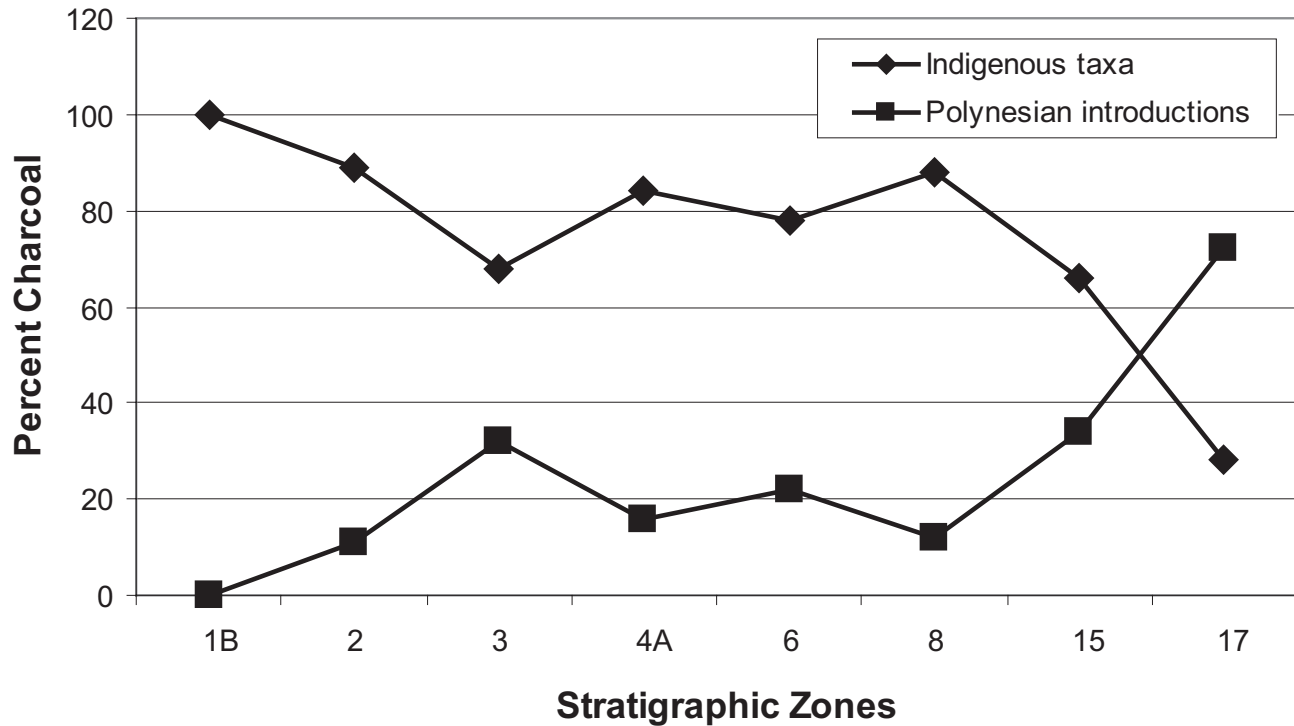


Figure 9.8. Temporal changes in indigenous versus Polynesian-introduced species as indicated by the unit E34 charcoal sequence.

Unit D35 Charcoal Sequence

The charcoal assemblage from unit D35 (see MAN-44 Archaeobotany Database for frequency data [www.dig.ucla.edu/tangatatau]) has 17 taxa represented, from zones SZ-1B to SZ-9. *E. tonganus* is again dominant in the earlier deposits but absent after SZ-3, whereas *Hibiscus* sp. continues to be heavily used up through zone SZ-9. Coconut wood is present throughout and reaches 24 to 26 percent in zones SZ-6 and SZ-9. As in the other analyzed units, the dramatic shift from indigenous to Polynesian-introduced taxa is clear, with the latter reaching 80 percent in SZ-6 and 75 percent in SZ-9. The three trees driving this shift are once again coconut, candlenut, and the Tahitian chestnut (*I. fagifer*).

Unit A25 Charcoal Sequence

The charcoal assemblage from unit A25 is the least diverse of those analyzed, with just 14 taxa present. The levels of A25, which lies outside of the main excavation block, cannot be directly correlated with our stratigraphic zone sequence. However, the general trends are similar, with the four deepest levels again

showing heavy use of *E. tonganus* and *Hibiscus* sp. but with those taxa absent in the two upper levels. The three uppermost levels are dominated by coconut, candlenut, and Tahitian chestnut, as in the other analyzed units.

**Plant Microfossils
Materials and Methods**

Seven sediment samples collected from the west face of the 1989 C30–G30 trench at site MAN-44 were analyzed for pollen, phytoliths, and starch to provide a record of past vegetation, environments, and human activity. The sediment samples, with their corresponding stratigraphic zones, are as follows:

Sample No.	SZ
1	17
6	15
13	8
20	5
23	4A
27	3
29	1

The samples were prepared for pollen analysis by the standard acetolysis method (Moore et al. 1991). Except for sample 6, which contained insufficient pollen for meaningful interpretation, at least 110 pollen grains and spores were counted for each sample, and slides were scanned for types not found during the counts. Microscopic fragments of charcoal were extracted along with pollen during preparation, providing evidence for fire. The samples were prepared for phytolith analysis by density separation (Horrocks 2005). Except for samples 6 and 13, which contained insufficient intact phytoliths for meaningful interpretation, at least 150 phytoliths were counted for each sample, and slides were scanned for types not found during the counts.

Plant microfossil analysis also included starch (Reichert 1913; Seidemann 1966; Torrence and Barton 2006). Starch is the main substance of food storage for plants and is mostly found in high concentrations of microscopic grains in underground stems (e.g., tubers and corms) and roots and seeds. The grains are synthesized and stored in amyloplasts, subcellular units specialized for this function.

Microfossil Analysis Results

All seven sediment samples contained microscopic fragments of charcoal, reflecting human fire activity at the site, although the lowermost sample (29, from SZ-1) contained noticeably much less than the overlying samples. All samples except sample 6 contained sufficient pollen for meaningful interpretation. Spores of ground ferns dominated the lowermost four samples (from zones SZ-1 to SZ-5), with pollen of *P. tectorius* dominating the higher pollen-bearing samples (Figures 9.9 and 9.10). The widespread species *P. tectorius* was almost certainly indigenous to the Cook Islands, but cultivars of this genus, particularly those used in mat making, were introduced to Polynesia (Whistler 2009). Coconut (*C. nucifera*) pollen was found in all of the samples except for the lowermost from zone SZ-1. Coconut pollen was found by Parkes (1997) in pre-Polynesian levels on Aitu Island in the Southern Cooks, and Kahn et al. (2014) have demonstrated the presence of a small-cavitated, “wild” form of coconut in pre-Polynesian deposits on Mo‘orea Island in the Society Islands. Thus, a type of coconut could have been naturally present on Mangaia, although Polynesians likely introduced the drinking-nut cultivars (Whistler 2009).

Pollen of several Polynesian-introduced taxa—namely, cf. banana (*Musa* sp.), *C. equisetifolia*, candlenut (*A. moluccana*), cf. *M. citrifolia*, *ti* (*C. fruticosa*) and cf. sweet potato (*I. batatas*)—occurred intermittently throughout the stratigraphic profile at MAN-44 (Figure 9.9). Sweet potato pollen, which was found in samples from zones SZ-8 and SZ-17, can be differentiated from two common indigenous species of the genus, *Ipomoea pes-caprae* and *Ipomoea macrantha*. Moraceae/Urticaceae pollen are also featured. Pollen of the Moraceae and Urticaceae is difficult to differentiate. Two other Polynesian introductions, paper mulberry (*Broussonetia papyrifera*) and breadfruit (*A. altilis*), however, are of the Moraceae. Pollen of another subsistence plant, the fish-poison tree (*B. asiatica*), which is indigenous to most of Polynesia, including the Cooks, was found in the uppermost sample. Pollen of *C. major*, an indigenous vine-like shrub, was also found in several samples.

Pollen of an invasive herbaceous weed, *Sonchus*, was found in the uppermost sample. Although some *Sonchus* species could have been introduced to parts of the Pacific Island region by Polynesians (Leach 2005), some other species are thought to have been introduced after European contact (Arthur Whistler, personal communication to M. Horrocks, 2016).

Phytolith preservation was highly variable in the MAN-44 sediment samples. No phytoliths were found in the lowermost sample, while sample 20 (from zone SZ-5) had insufficient phytoliths for meaningful interpretation. Sample 6 had a large amount of phytoliths, but these were too fragmented and otherwise degraded for identification. The phytolith assemblages in the remaining samples were dominated by grasses, with palms showing peaks in samples 1 and 13, from zones SZ-17 and SZ-8 respectively (Figure 9.11). Both these taxa have high phytolith production compared with other types of plants and therefore tend to be overrepresented in phytolith spectra. Very large amounts of grass phytoliths (around 75 to 90 percent) in this case, however, strongly suggest the utilization of grass species by people using the rockshelter. Leaf phytoliths of banana were each found in the lowermost two samples.

One type of starch was identified in the rockshelter sediments, in the lowermost sample. This type was present as individual starch grains and amyloplasts, ranging in degree of preservation from well preserved to highly degraded. This starch could be from several

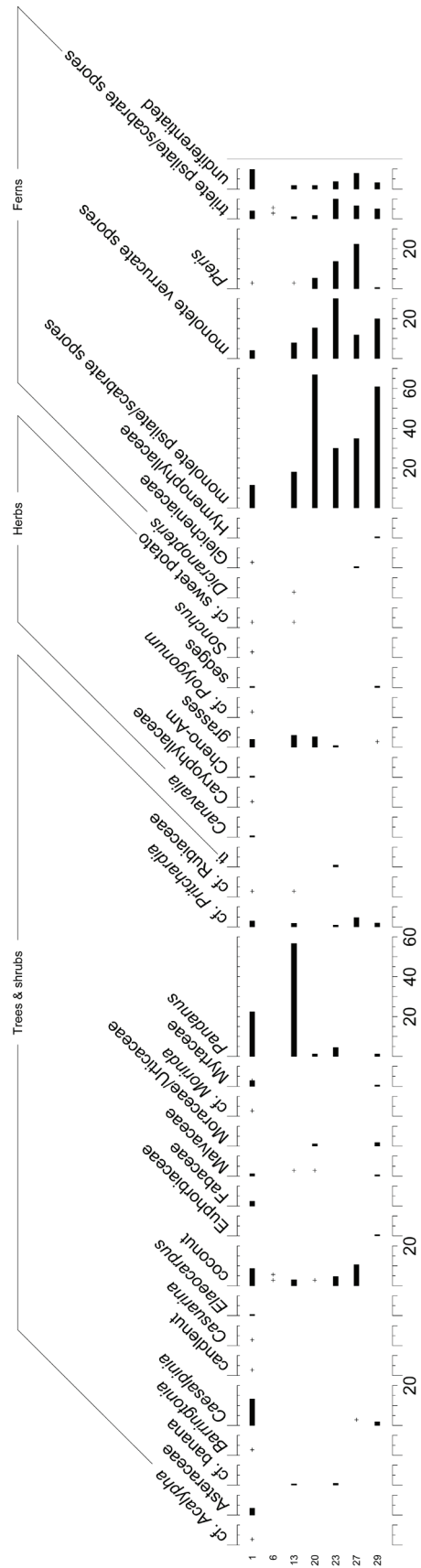


Figure 9.9. Pollen percentage diagram for sediment samples from site MAN-44 (+ = found after count, ++ = present in very small amount).

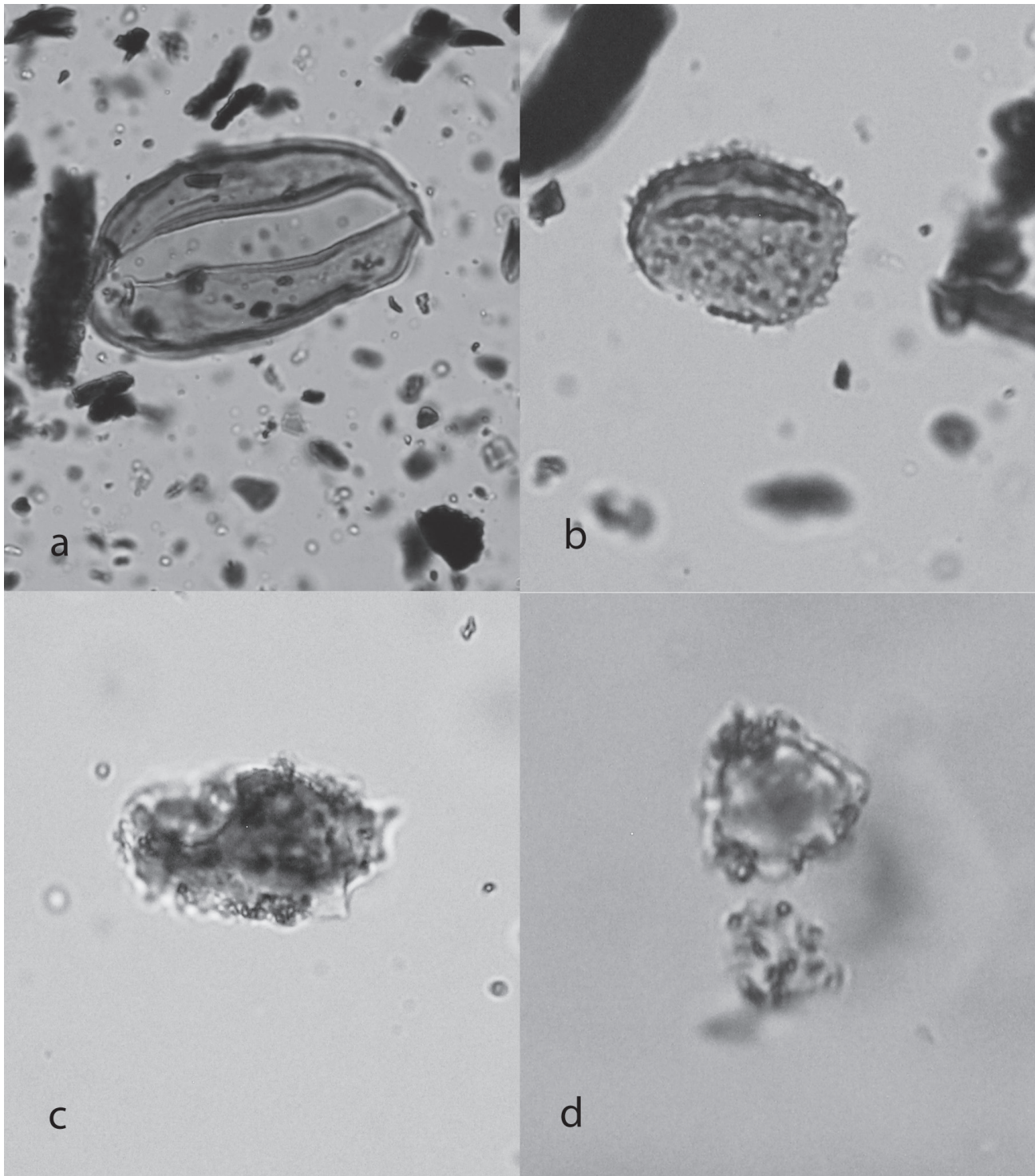


Figure 9.10. Plant microfossils from site MAN-44. Brackets = micron measurements, taken at the widest diameter. a, *Cocos nucifera* pollen grain (74); b, *Pandanus tectorius* pollen grain (25); c, *Musa* sp. leaf phytolith, showing characteristic raised crater (23); d, Arecaceae leaf phytolith, showing characteristic spherical spinulose morphology (13). Photograph by Mark Horrocks.

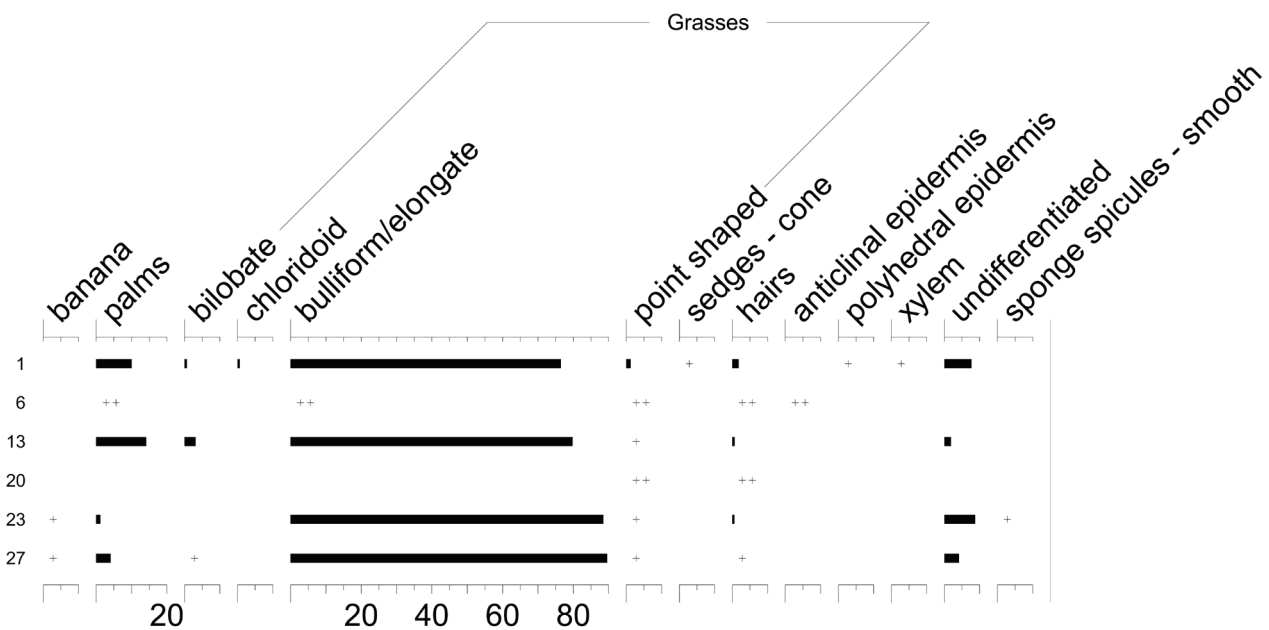


Figure 9.11. Phytolith percentage diagram for sediment samples from site MAN-44 (+ = found after count, ++ = present in very small amount).

crop species—namely, the root of sweet potato, the corms of giant taro (*Alocasia macrorrhizos*) and giant swamp taro (*Cyrtosperma merkusii*), or the tuber of Polynesian arrowroot (*Tacca leontopetaloides*). These species have starch grains that can be difficult to differentiate.

Summary

The recovery and identification of both macrobotanical remains (carbonized plant parts and charcoal) and plant microfossils (phytoliths and pollen grains) from Tangatatau Rockshelter provides important insights into the use of plants at the site over time. Immediately prior to human occupation, the vegetation in the vicinity of the rockshelter included such indigenous taxa as *H. tiliaceous*, *H. acuminatum*, *P. tectorius*, and a species of *Pritchardia* palm, as well as a variety of ferns.

The first occupants of the rockshelter possessed a diverse suite of Polynesian cultigens, or what are sometimes referred to as “canoe plants,” given that they were not native and had to be introduced to the Polynesian archipelagoes (Whistler 2009). Five species of trees bearing edible fruits or nuts are well attested: breadfruit (*A. altilis*), coconut (*C. nucifera*), Tahitian chestnut (*I. fagifer*), the Malay apple (*S. malaccense*),

and the beach almond (*T. catappa*). In addition to these, the candlenut tree (*A. moluccana*) is well represented in the zone SZ-2 and SZ-3 deposits. Both the true taro (*C. esculenta*) and the giant swamp taro (*C. chammisonis*) were present, and other field crops included bananas (*Musa* sp.), sugar cane (*S. officinarum*), and the *ti* plant (*C. fruticosa*). A species of bamboo (*S. glaucophyllum*) and the medicinal plant *M. citrifolia* were also cultivated. This roster of 13 Polynesian introductions leaves little doubt that the initial colonizers of Mangaia brought with them virtually the full range of cultigens necessary to establish a thriving horticultural subsistence system on the island.

While all of the cultigens listed above have their ultimate origins in the western Indo-Pacific region and were transferred to Oceania as a part of the expansion of Austronesian-speaking peoples, one additional crop plant appearing in the Tangatatau archaeobotanical assemblage has a South American origin: the sweet potato (*I. batatas*). The earliest carbonized fragments of sweet potato at site MAN-44 come from zone SZ-4A (dating to the late fourteenth to early fifteenth centuries), with additional specimens from zones SZ-8 and SZ-15. The addition of sweet potato to the Mangaian crop roster was significant, given the plant’s tolerance

for relatively dry and poorer quality soils, which permitted sweet potato to be cultivated in the *makatea* regions. As Hiroa (1934:136) observed, sweet potatoes were the principal food of the conquered tribes who were deprived of prime irrigated taro fields.

The archaeobotanical assemblage from Tangatatau also provides evidence for the gradual transformation of the island's vegetation, complementing the palynological evidence for significant deforestation of the

central volcanic cone, obtained from the swamp sediment cores (see Chapter 2). The charcoal data, in particular, document the increased dominance in the late precontact era of Polynesian-introduced plants, eventually accounting for roughly 70 percent of the charcoal in zone CZ-17. By the time of European contact, the Mangaian environment had been transformed through cumulative generations of human activity into a thoroughly anthropogenic and highly managed landscape.

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10

Material Culture and Technological Change at Tangatatau Rockshelter

Patrick Vinton Kirch

The excavations at Tangatatau Rockshelter yielded one of the largest assemblages of portable artifacts from a stratified context anywhere in central Eastern Polynesia. The assemblage is rich in stone adzes and shell fishhooks, two artifact classes that have long played important roles in interpretations of Polynesian prehistory, as well as in other kinds of tools, implements, and ornaments. The stratigraphic distribution of the major categories of portable artifacts in the main excavation block is provided in Table 10.1. The lower two occupation horizons, zones SZ-2 and SZ-3, were especially rich in portable artifacts, but some higher zones such as SZ-5 and SZ-8 also yielded substantial numbers of objects. Many of the artifact classes exhibit significant changes in morphology or in the technology of manufacture between the lower and upper deposits, providing important evidence for the local evolution of technology on Mangaia.

This chapter provides a descriptive account of the MAN-44 artifact assemblage, with an emphasis on morphological and technological changes. This is followed, in Chapter 11, with a more detailed typological analysis of the shell fishhooks and in Chapter 12 with an analysis of flaked stone debitage.

Basalt Adzes

Polynesian Adze Classification

In Eastern Polynesia, where ceramics are mostly lacking, stone adzes and shell fishhooks are the two major

artifact classes upon which archaeologists have long focused their typological and comparative studies. During the pre-World War II period prior to the advent of stratigraphic excavations in Polynesia, adzes were frequently found during the surface surveys conducted by the Bishop Museum and other institutions. Early interest in adze variation led several scholars to define a standard set of terms for describing adzes (Buck et al. 1930). Key terms include the *front* and *back* of the adze (defined in relation to how the adze is hafted on its wooden handle, with the bevel on the back, facing the person grasping the handle), the *tang* or reduction of the butt portion for ease in hafting, and the *poll* or end opposite the bevel.

One of the first attempts at systematic classification was Stokes's (1930) study of 96 adzes collected on Tubuai Island in the Austral group. Stokes divided the considerable range of morphological variation in this assemblage by means of an "analytical key" (a form of taxonomic classification, in the sense of Dunnell [1971]), with four major "series" encompassing numerous subtypes. Hiroa's (1930:333–356) analysis of 162 adzes from the Samoan archipelago was perhaps the first to draw attention to the typological significance of adze cross sections. The most basic distinction was between adzes with a "quadrangular" cross section and those with a "triangular" cross section. Within these broad categories, Hiroa defined eight "types"

Table 10.1 Stratigraphic Distribution of Major Categories of Portable Artifacts in the Main Excavation Block, Site MAN-44

Zone or Feature	Adzes	Adze Preforms	Adze Flakes	Hammer-stones	Branch Coral Abraders	Porites Coral Abraders	Sea Urchin Spine Abraders	Bone Awls	Scrapers	Fishhooks	Tattooing Combs	Totals
SZ-18	1		1				1			1		4
SZ-17			2			2		1				5
SZ-15			4		2	1	1			1		9
F58	1											1
SZ-10	1	1	3	1		3			2			11
SZ-9	1											1
F2, F3	1				1	1				3		6
F15										2		2
F20	1											1
SZ-8	3	6	31	1	12	5	7		3	24		92
F4, F7, F32					4		1			7		12
SZ-7		2	12		8	1	2			5		30
SZ-6		3	4	3	4	1	1			1	1	18
SZ-5	5	2	12		4	2				10		35
F5	1									9		10
F37, F38	1				1	1				8		11
SZ-4A/B	2	3	21			3	5	1	1	44	4	84
SZ-3	6	21	32	13	2	15	13		4	94	3	203
SZ-2	6	10	20	1	3	4	1		1	49		95
SZ-1B									3	5		8
Totals	30	48	142	19	41	39	32	2	14	263	8	638

and several subtypes. In his monumental study of Cook Islands “arts and crafts,” Hiroa (1944:133–157) studied a collection of 120 adzes in museum collections, continuing to emphasize the importance of cross-section shape in classifying adze variation, subdividing his sample in the first instance into “inverted triangular” and “quadrangular” categories. Various subtypes were then defined on the basis of shape (in plan view) and elaboration of the tang.

Roger Duff was responsible for the next major advance in Polynesian adze classification, first with his study of a large assemblage of 207 adzes excavated at the early “Moa hunter” site of Wairau Bar in New Zealand (Duff 1956), followed by a more geographically wide-ranging classificatory scheme for Eastern Polynesian adzes (Duff 1959). Duff’s classification

continued the emphasis on cross section, with six major types defined as follows:

- Type 1: Tanged quadrangular adzes
- Type 2: Quadrangular adzes without tang
- Type 3: Adzes of triangular section, apex downward
- Type 4: Adzes of reversed triangular section
- Type 5: Side hafted adzes
- Type 6: Circular sectioned adzes

Several varieties were also defined within the major types. Duff’s typology thus combines elements of a “paradigmatic” classification (the intersection of cross-section form and presence/absence of a tang) with “grouping” (ad hoc groups based on similarity or likeness), in the terms used by Dunnell (1971) for different

approaches to archaeological systematics. Although stratigraphic excavations had by now commenced throughout parts of Polynesia, Duff did not draw upon distributional data from stratigraphic contexts in testing his hypotheses for the historical development of adzes. Rather, Duff relied upon the classic “age-area” theory of artifact development and diffusion, in which the most widely spread forms were regarded as the oldest types. Nonetheless, Duff’s typology has been widely applied, and it is convenient for us to continue to use it as a descriptive device for classifying the adzes from site MAN-44.

Before turning to the MAN-44 adze assemblage, several other contributions to Polynesian adze classification should be mentioned. Robert Suggs, one of the pioneers of stratigraphic excavation in Eastern Polynesia, explicitly rejected the Duff typology in his analysis of a collection of 222 adzes recovered during the course of his 1956 to 1957 excavations on Nuku Hiva Island in the Marquesas (Suggs 1961:105–114). Although noting that the Duff typology was “logical” (a recognition of its “paradigmatic” features), Suggs (1961:106) proposed a new typology based on “chronologically significant features” unique to the Marquesas. In Dunnell’s (1971) terms, however, Suggs’s typology uses the method of “grouping,” resulting in ad hoc types (groups) defined by features unique to that particular assemblage. Unfortunately, this makes it virtually impossible to apply Suggs’s typology beyond his particular collection.

Green and Davidson (1969, 1974) proposed a classification for Samoan adzes that built upon the older typology of Hiroa (1930) but with the criteria for distinguishing types more clearly defined in a “taxonomic” manner (*sensu* Dunnell 1971). More important, Green and Davidson (1974:Figure 92; see also Green 1971) integrated emerging stratigraphic distributional data from key excavations in Western and Eastern Polynesia to demonstrate how the Polynesian “adze kit” developed over time. These data showed that early Western Polynesian adze assemblages were dominated by forms with ovoid, plano-convex, or quadrangular to trapezoidal cross sections, usually lacking tangs. Adzes with triangular cross sections first appear in later Samoan contexts associated with Polynesian Plain Ware ceramics (ca. AD 100–300), and both quadrangular and triangular forms are evident in early Eastern Polynesian assemblages such as Hane in the Marquesas (ca. AD 900–1200).

Emory (1968) drew upon a large collection of Polynesian adzes in the Bishop Museum (mostly surface collected but also incorporating some excavated specimens) to effect a broad comparative study, again emphasizing cross section as a basic criterion. Among Emory’s (1968:166) key conclusions were the following: “The adzes of West Polynesia are derivative of early adzes of adjacent Melanesia and Micronesia. The early adzes of Tahiti and the Marquesas, although derived from those of West Polynesia, departed from the norm of a trapezoidal cross section by varying its form and by developing a tang. The tanging of adzes in East Polynesia can be observed as an independent development in East Polynesia itself.” This was an important conclusion as it laid to rest arguments that Eastern Polynesian tanged adzes evidenced direct culture-historical connections with Southeast Asia, where tanged adzes also occur (as argued, for example, by Duff 1959).

In recent decades, adze classification has been less of a priority of archaeologists, as attention has turned instead to issues of adze production and function and to the geochemical sourcing of adzes and evidence for their movement between islands and archipelagoes (e.g., Best et al. 1992; Kirch et al. 2012; Rolett 1998; Weisler 1993, 1997; Weisler et al. 2016). However, in an important thesis dealing with adze production on Tubuai Island, the French archaeologist Aymeric Hermann (2013:Table 11) has applied the French *chaîne opératoire* approach to understanding the sequence of production of adzes, resulting also in a “*techno-typologie*” of four major groups.

Adze Preforms

It is instructive to begin not with the finished adzes from Tangatatau but with a consideration of adze preforms, as these unfinished objects yield insights into the stages of manufacture that resulted in the finished adzes, which have been the object of the classificatory schemes reviewed above. Production of adzes was a major activity of the occupants of Tangatatau Rockshelter, especially in the lowest habitation zones SZ-2 and SZ-3 but also continuing into the later phases of site use. Fifty-four adze preforms were recovered during the excavations, along with a large quantity of flake debitage (debitage analysis is the subject of Chapter 12).

The preforms can be readily divided into two major categories based on whether the preform consists of a *core* or a *flake*, following standard lithic terminology.

Core-type preforms ($n = 29$) have been extensively worked from a larger block, while the flake type preforms ($n = 25$) have been made by first selecting an appropriately shaped flake (almost always quadrangular, or parallel sided in cross section) and then modifying the flake with either unifacial or bifacial trimming. About half ($n = 15$) of the core-type preforms exhibit triangular cross sections, resulting from bifacial trimming along two or three edges; slightly fewer ($n = 11$) display quadrangular (or slightly trapezoidal) cross sections. Three preforms of core type have distinctive biconvex cross sections resulting from bifacial trimming along two parallel sides. In contrast, flake-type preforms are mostly quadrangular in cross section ($n = 23$), with just two specimens exhibiting a triangular cross section.

Statistically, there are significant size differences between the core and flake preform types, as illustrated in Figures 10.1 and 10.2. Flake-type preforms are thinner, with a mean thickness of 19.05 mm, while core types have a mean thickness of 25.35 mm.

Although there is overlap, core-type adze preforms tend to be not only thicker but longer as well. In short, the method of producing a preform by selecting a conveniently shaped flake and trimming it was applied when a relatively smaller adze with quadrangular cross section was the desired outcome. When a larger, thicker adze was the goal, the core method was used.

The stratigraphic distribution of core- and flake-type preforms, subdivided by their respective cross sections, is given in Table 10.2. While both core and flake types of preform are present in the early zones, the core type is more prevalent, becoming rare in the upper stratigraphic zones. Flake preforms with quadrangular cross sections are the most common, represented throughout virtually the entire stratigraphic sequence.

Five examples of adze preforms are illustrated in Figures 10.3 and 10.4. Figure 10.3a is a typical flake-type preform (from feature F7) for a relatively small adze of triangular shape, in which the back consists almost entirely of the original ventral flake

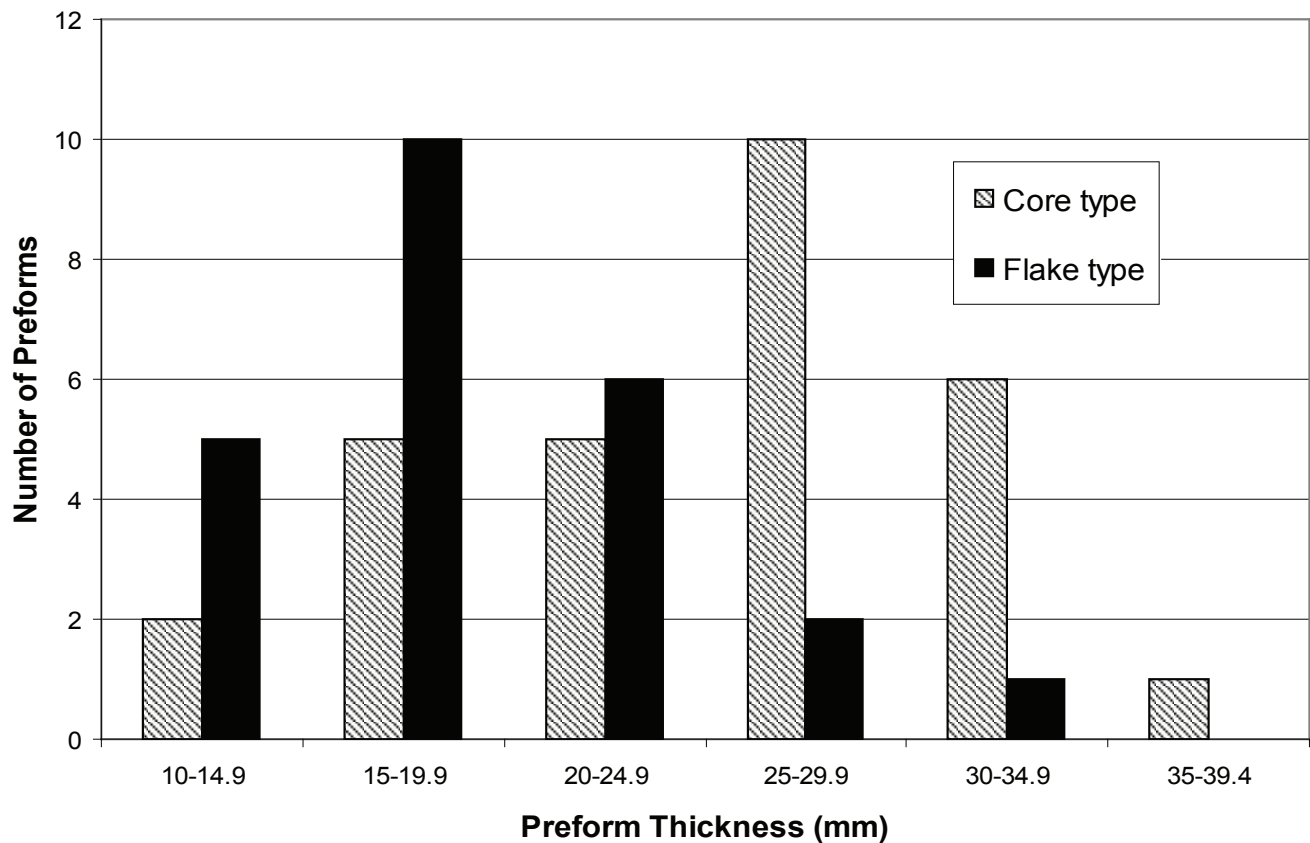


Figure 10.1. Histogram of adze preform thickness by core and flake types.

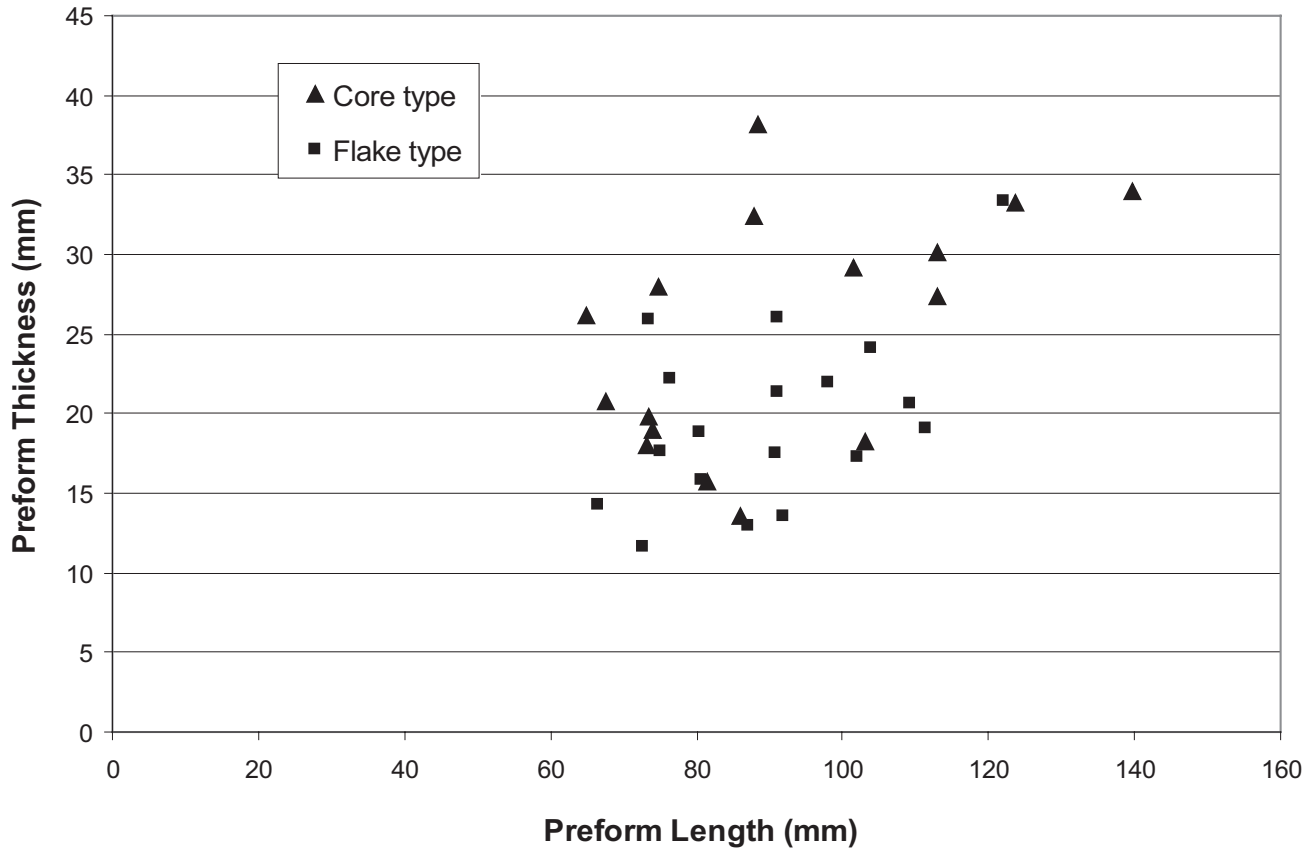


Figure 10.2. Scatterplot of adze preform length and thickness, by core and flake types.

Table 10.2 Stratigraphic Distribution of Adze Preforms in the Main Excavation Block, Site MAN-44

Zone or Feature	Core-Type Preforms			Flake-Type Preforms		Totals
	Biconvex	Triangular	Quadrangular	Triangular	Quadrangular	
SZ-19		1				1
SZ-15					1	1
SZ-10					1	1
SZ-9					1	1
F15					1	1
SZ-8		1	1	1	4	7
F7					2	2
SZ-6	1				1	2
SZ-5			1			1
F21					1	1
4A		1			2	3
SZ-3	1	6	6		9	22
SZ-2		7	3	1		11
Totals	2	16	11	2	23	54

surface, with unifacial trimming. In contrast, Figure 10.3b shows a similarly shaped triangular adze preform (from zone SZ-3) made using the core method with extensive bifacial trimming. The preform shown in Figure 10.3c is a larger core type with a triangular cross section (from zone SZ-2), in this case also exhibiting substantial reduction of the butt along both sides, resulting in a distinct tang. The preform in Figure 10.4a (from SZ-4A), like that shown in Figure 10.3c, also has a distinct tang but has been made using the flake technique with bifacial trimming and has a quadrangular cross section. Finally, Figure 10.4b shows a very thick, quadrangular preform (from SZ- 3) made with the core method.

Basalt Lithic Debitage

In addition to the 54 adze preforms discussed above, the site MAN-44 deposits contained a large quantity of basalt flakes, the result of on-site adze production and maintenance. A total of 6,582 non-retouched basalt flakes were recovered, 6,560 of these from the main excavation block and 292 from the outlying excavation units. In addition, 14 cores (other than obvious adze preforms) were recovered. A detailed analysis of a sample of this basalt lithic debitage obtained from four of the 1991 excavation units is provided in Chapter 12.

Finished Adzes

Eleven whole adzes and 21 partial sections of broken adzes were recovered from the MAN-44 excavations. For reasons described above, it is convenient to use the classic Duff (1956, 1959) typology to categorize these specimens. The stratigraphic distribution of the 30 specimens from the main excavation block is given in Table 10.3, using Duff’s type designations. Types 1 and 2 are mostly confined to the lower stratigraphic zones, with type 2A being particularly well represented. Adzes of types 3 and 3A, while also occurring in the deeper zones, are more frequent in the upper stratigraphic zones, from SZ-5 to SZ-18. These differences in the stratigraphic distribution of types indicate significant shifts in adze technology over time, a finding that reinforces the evidence from the adze preforms.

Metric data on 10 complete adzes that can be assigned to a Duff type are displayed in Figure 10.5 (one aberrant, unclassified adze is not included). Type 2 adzes tend to be thinner but have a significant range of variation in their bevel widths, as well as in the width/thickness index. Type 3 adzes are very uniform in length, tend to be thick, and display considerable range in bevel width. Type 1 adzes, with just two highly similar examples, are fairly long, are intermediate in thickness, and have wide bevels.

Table 10.3 Stratigraphic Distribution of Adzes and Adze Sections from the Main Excavation Block, Site MAN-44

Zone or Feature	Type 1	Type 1A	Type 2	Type 2A	Type 3	Type 3A	Type 3D	Unclassified	Totals
SZ-18					1				1
SZ-10					1				1
SZ-9						1			1
F58						1			1
F3					1				1
F20						1			1
SZ-8		1					1	1	3
SZ-5					2	2	1		5
F5			1						1
F37								1	1
SZ-4A/4B								2	2
SZ-3	1	1		3	1				6
SZ-2		1		3	1	1			6
Totals	1	3	1	6	7	6	2	4	30

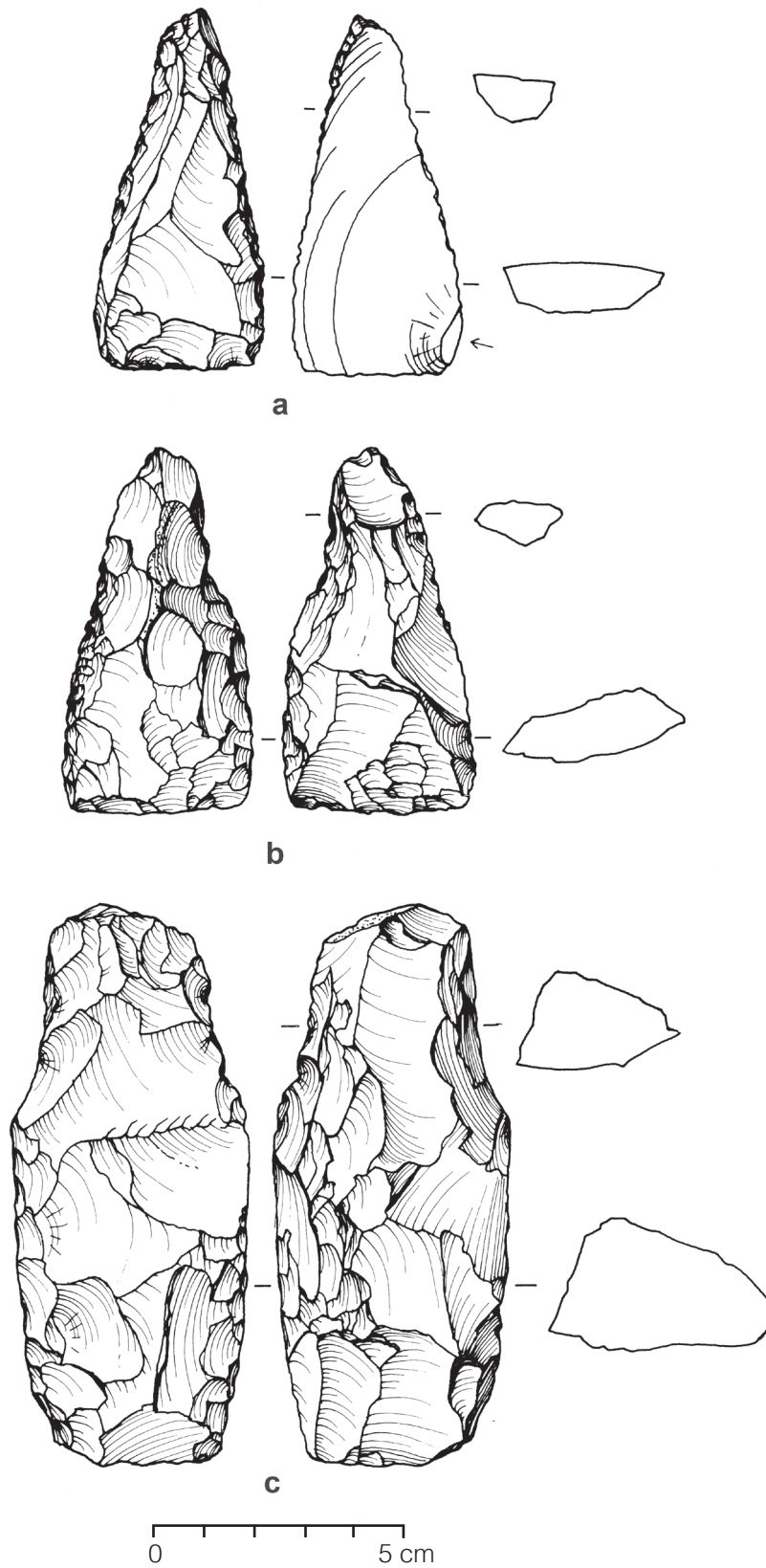
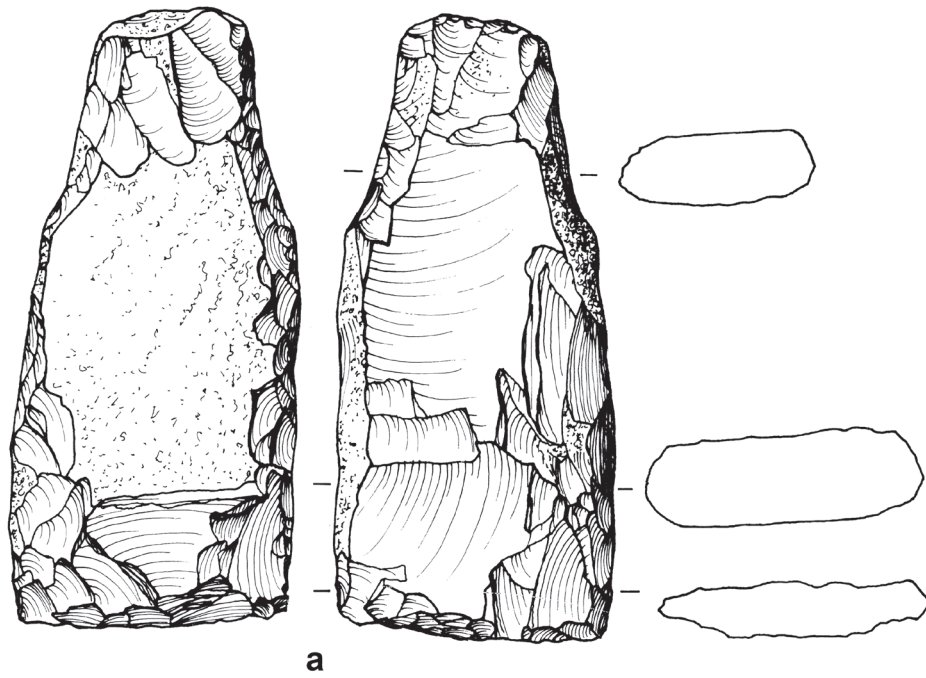
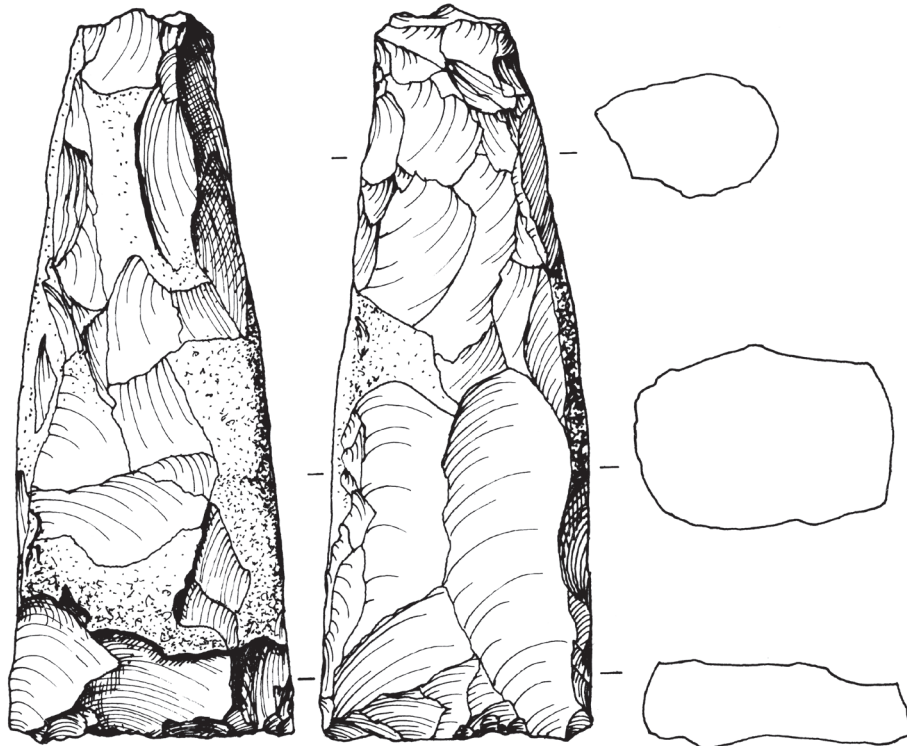


Figure 10.3. Adze preforms from site MAN-44: a, flake type preform (E31-7-1); b, core type preform (E34-6-3); c, core type preform with reduction of tang (D34-8-12).



a

0 5 cm



b

Figure 10.4. Adze preforms from site MAN-44: a, flake type preform with reduced tang (C31-7-2); b, massive core type preform with quadrangular cross-section (E34-7-11).

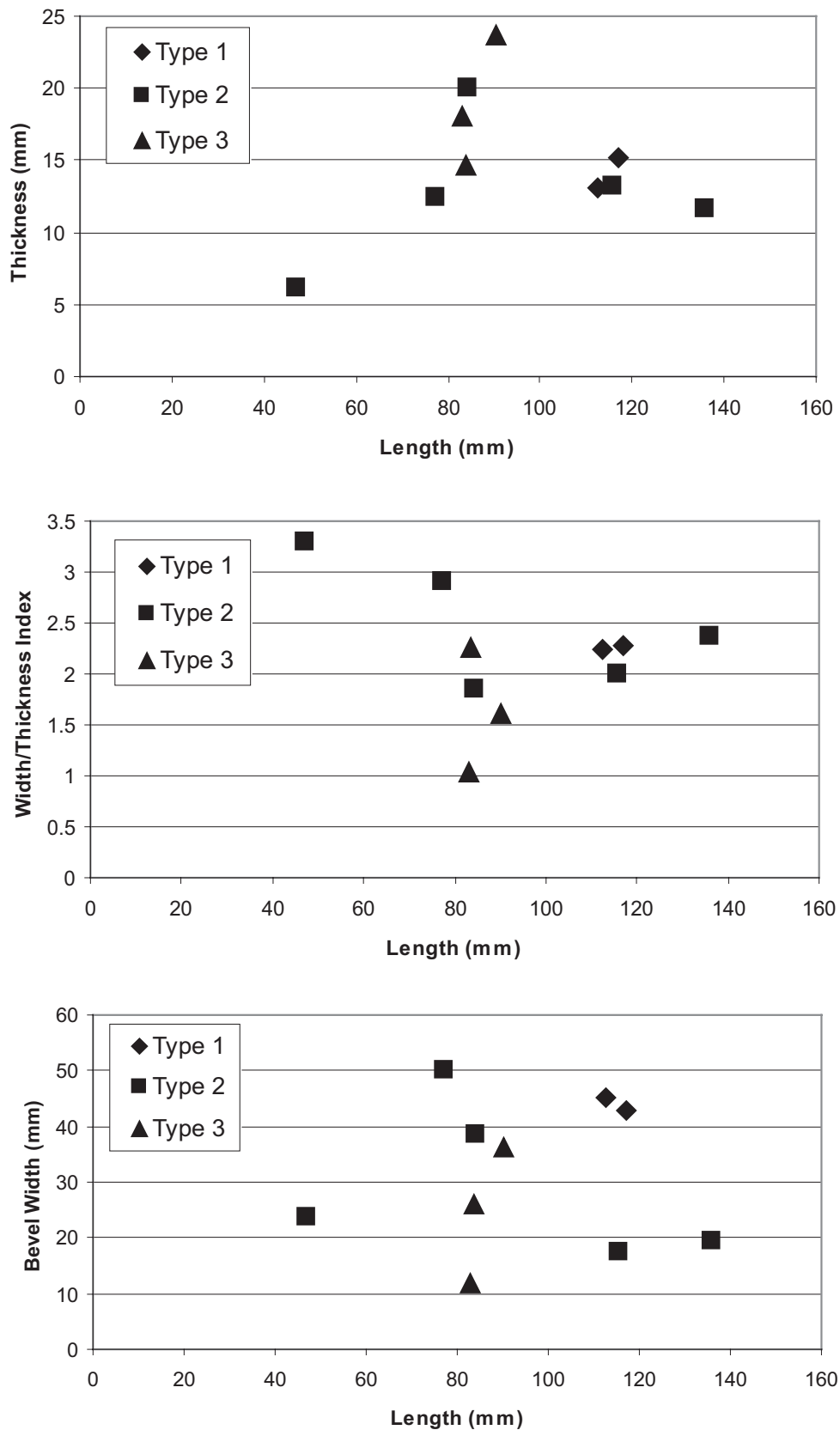


Figure 10.5. Metric variables for complete, classifiable adzes from site MAN-44.

Figure 10.6 illustrates two complete adzes of Duff's type 1A, tanged quadrangular adzes. The first specimen (Figure 10.6a), from zone SZ-2, is beautifully ground and polished. The tang consists of the rear 30 mm of the front face, which has been roughed by pecking; in addition, there are two small nipples or lugs on the corners of the poll. The adze is quadrangular in cross section, although much thinner than most of the type 1A adzes figured by Duff (1959:Figure 2). With this thinner cross section, the adze in Figure 10.6a closely resembles a Duff type 2A adze, but the clear presence of the tang with lugs necessitates its classification as type 1A. The second specimen (Figure 10.6b) is similar to the first in size, shape, and cross section; indeed, it might have been made by the same craftsman, although it comes from zone SZ-3. The adze tapers substantially from bevel to butt; although present, the tang is not pronounced, again formed by pecking of the butt region. This specimen lacks the lugs seen in Figure 10.6a, but the poll has been chipped, which might have removed the lugs if they were originally present. The bevel is slightly curved, with extensive use-wear damage. The adze is well ground and polished except for the tang, which retains original flake scars. As with the first specimen (Figure 10.6a), this adze has a cross section more typical of a Duff type 2A adze, but again the presence of a distinct tang puts it in the Duff 1A category.

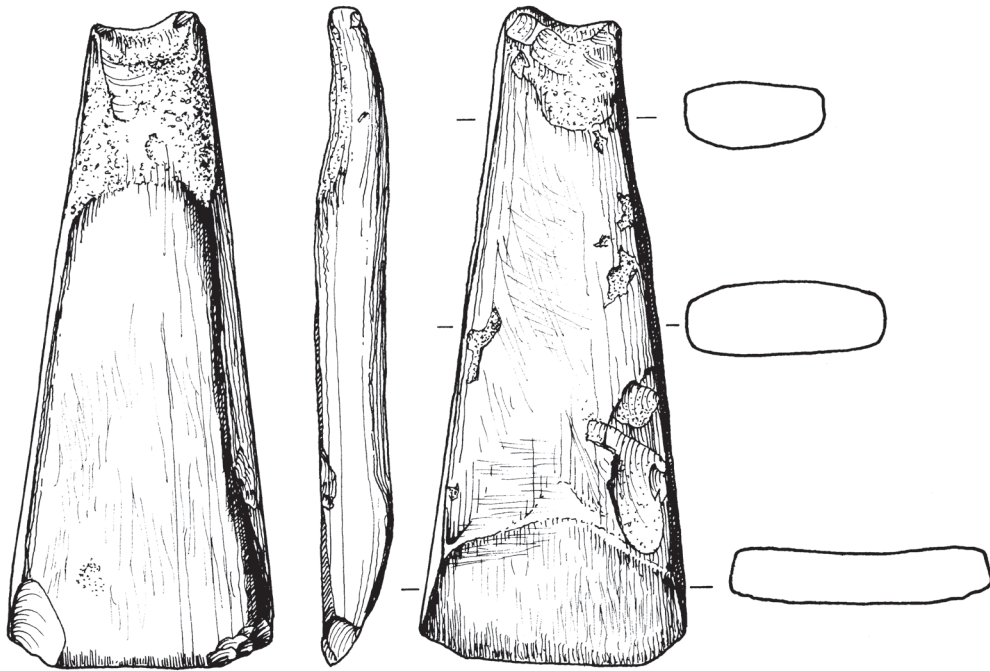
Two partial adze sections of type 1 are illustrated in Figure 10.7. The specimen shown in Figure 10.7a, from zone SZ-3, is the mid-section of an adze with a slightly trapezoidal cross section, which is missing the tang and most of the bevel. It is fairly well ground and polished overall but displays some flake scars. This was most likely a classic Duff type 1A adze, but as the tang is missing, classification remains uncertain. The second specimen (Figure 10.7b), from zone SZ-8, consists of the tang and part of the mid-section of a type 1A adze with pronounced tang augmented with nipples or lugs; unfortunately, the section is split down the middle, so the second lug has been lost and the cross section is more difficult to discern, although it was certainly quadrangular. This kind of adze with a well-developed tang and lugs is very typical of later Cook Islands adzes (Hiroa 1944); hence, its presence in zone SZ-8 is important as it indicates that this distinctive form had been developed by the late fifteenth century (see Chapter 5).

Figure 10.8 shows two highly similar adzes, both from zone SZ-3; their similarity again suggests that they might have been made by the same craftsman. Both are

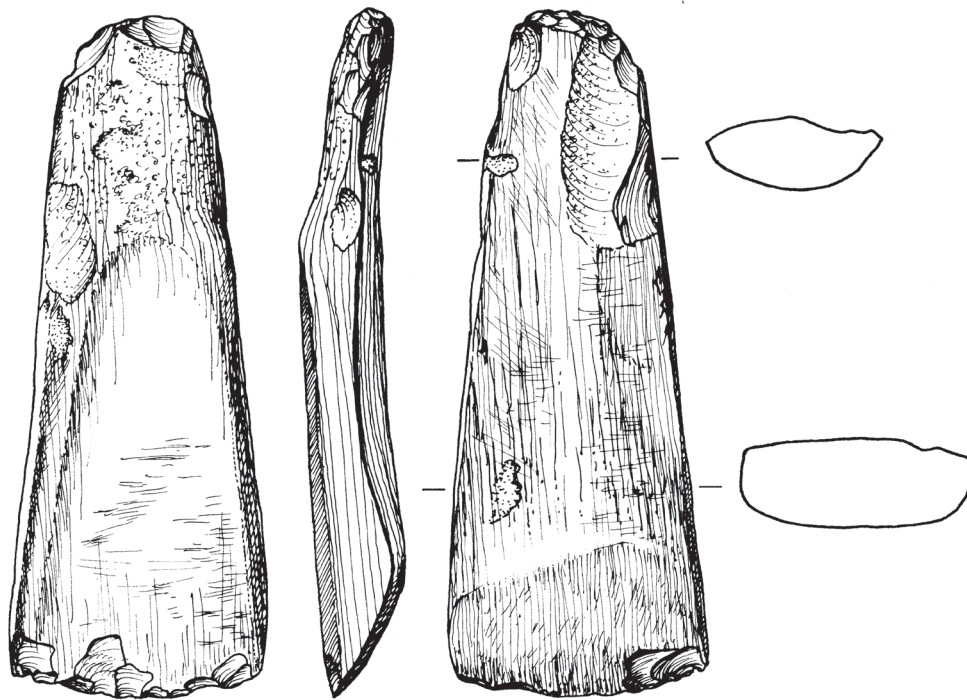
of a long, narrow variant of Duff type 2A, quadrangular adzes lacking a tang. The first specimen (Figure 10.8a) exemplifies adze manufacture from a flake, evident by the long, continuous flake scar that forms most of the back of this adze. The adze is well polished except in the butt region, where flake scars have been left on the front face, presumably to facilitate hafting (the rough scars would grip the sennit used to lash the adze blade to the wooden handle). The second specimen (Figure 10.8b) is complete except for part of the bevel, which was removed with a large flake, probably during use. Although the cross section is quadrangular, there is a slight "keel" along the back, which indicates that the original preform was of the core type, with a triangular section. The butt is not fully ground, leaving traces of flake scars.

Figure 10.9 illustrates five further examples of type 2A adzes, both complete and partial. The adze shown in Figure 10.9a, from zone SZ-2, is extremely well ground and polished overall, with a pronounced triangular shape in plan view. Only a few traces remain of original flake scars. The cross section varies from biconvex to quadrangular/trapezoidal with sharp edges on the front and rounded edges on the back. The bevel is nearly straight but has a slight concavity. Figure 10.9b shows a small, whole adze from zone SZ-2. This adze was made on a thin flake; it has been extensively ground but still shows traces of flake scars. From zone SZ-3 we recovered the bevel section (Figure 10.9c) of a well-ground and extensively polished adze. Enough is present to assign it to type 2A; it may have been a slightly larger version of the form represented by the whole adze in Figure 10.9a. Shown in Figure 10.9d is the butt and poll of a thin, quadrangular adze, most probably of type 2A, from feature 5. This adze appears to have been made on a flake and is partially ground and polished with some flake scars remaining. The final specimen in Figure 10.9e, from zone SZ-2, is a nearly complete type 2A adze, well ground and polished on the front, minimally ground on the sides and back. The bevel of this adze appears to have been in the process of rejuvenation through trimming but had not yet been reground.

We turn now to adzes with triangular cross sections, type 3 in the Duff classification. Figure 10.10 illustrates two adzes of type 3A. That shown in Figure 10.10a, from zone SZ-5, is rather crudely made, minimally ground, and polished primarily on the front; the bevel has been damaged through use and probably was awaiting regrinding when it was discarded. The adze



a



b

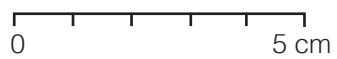


Figure 10.6. Type 1A tanged adzes: a, D32-11-25; b, D33-9-6.

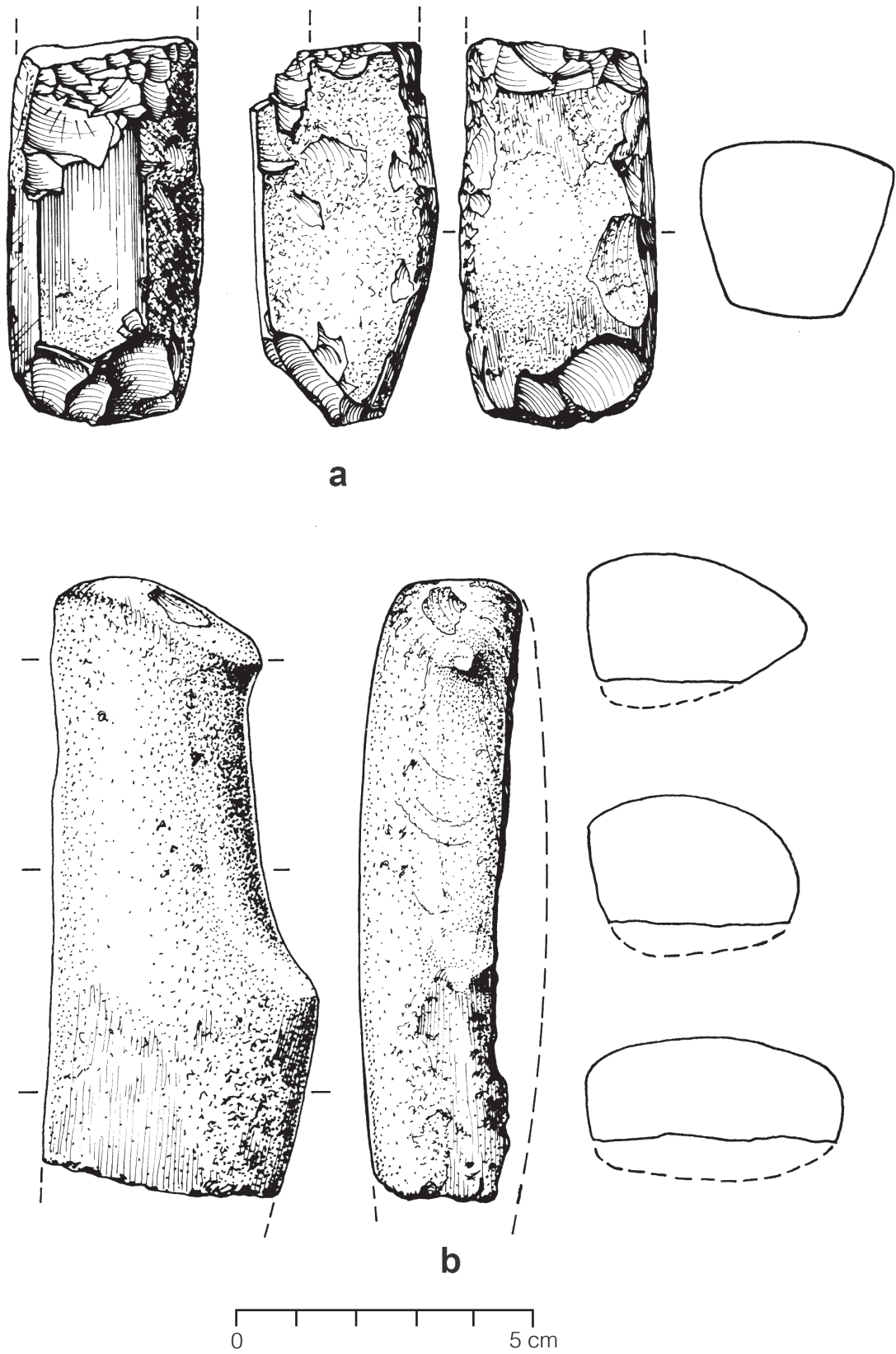


Figure 10.7. Partial adzes of Type 1: a, F35-7-5; b, D32-5-9.

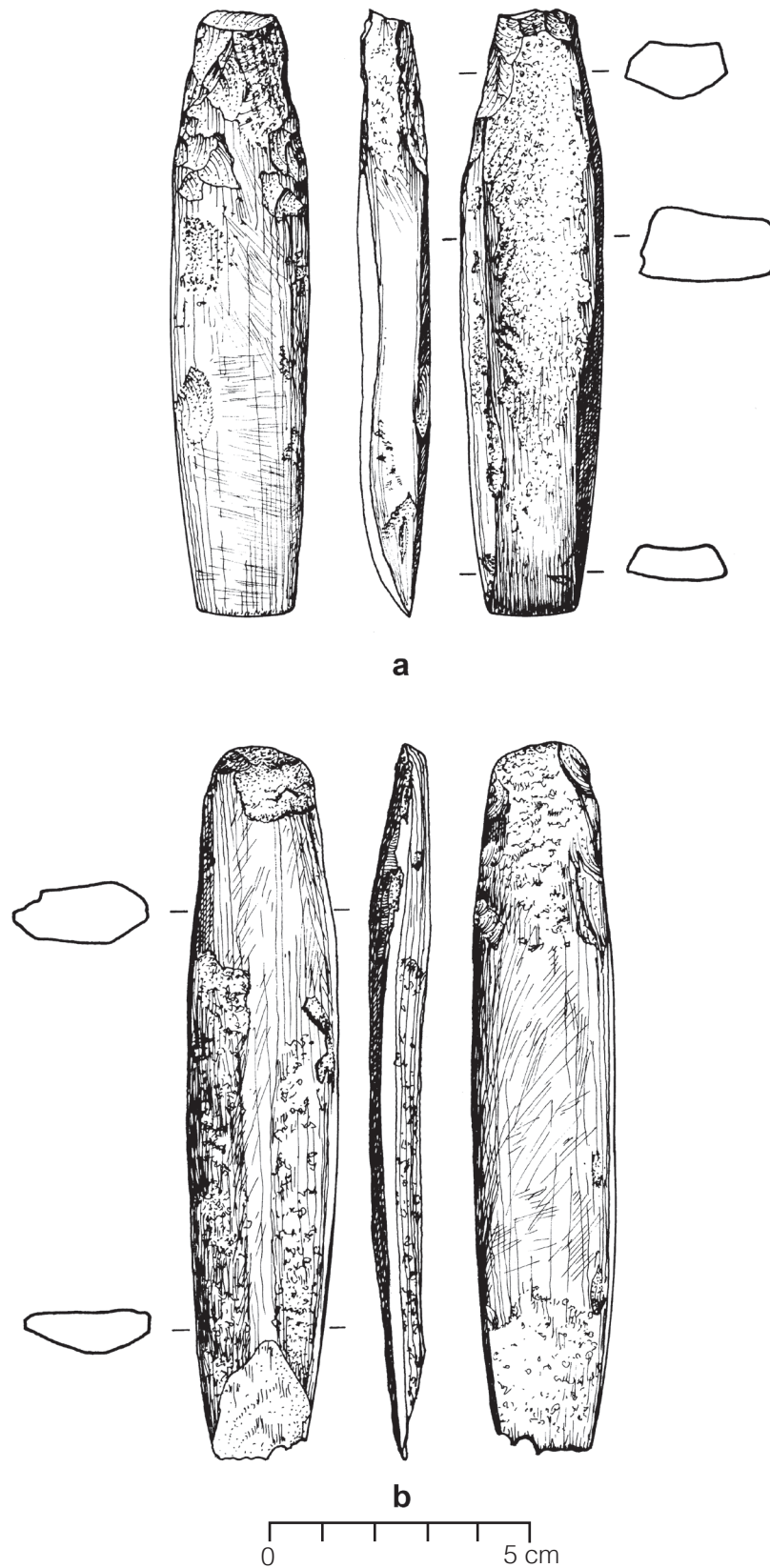


Figure 10.8. Type 2A adzes, narrow variant: a, D32-10-3; b, E34-7-10.

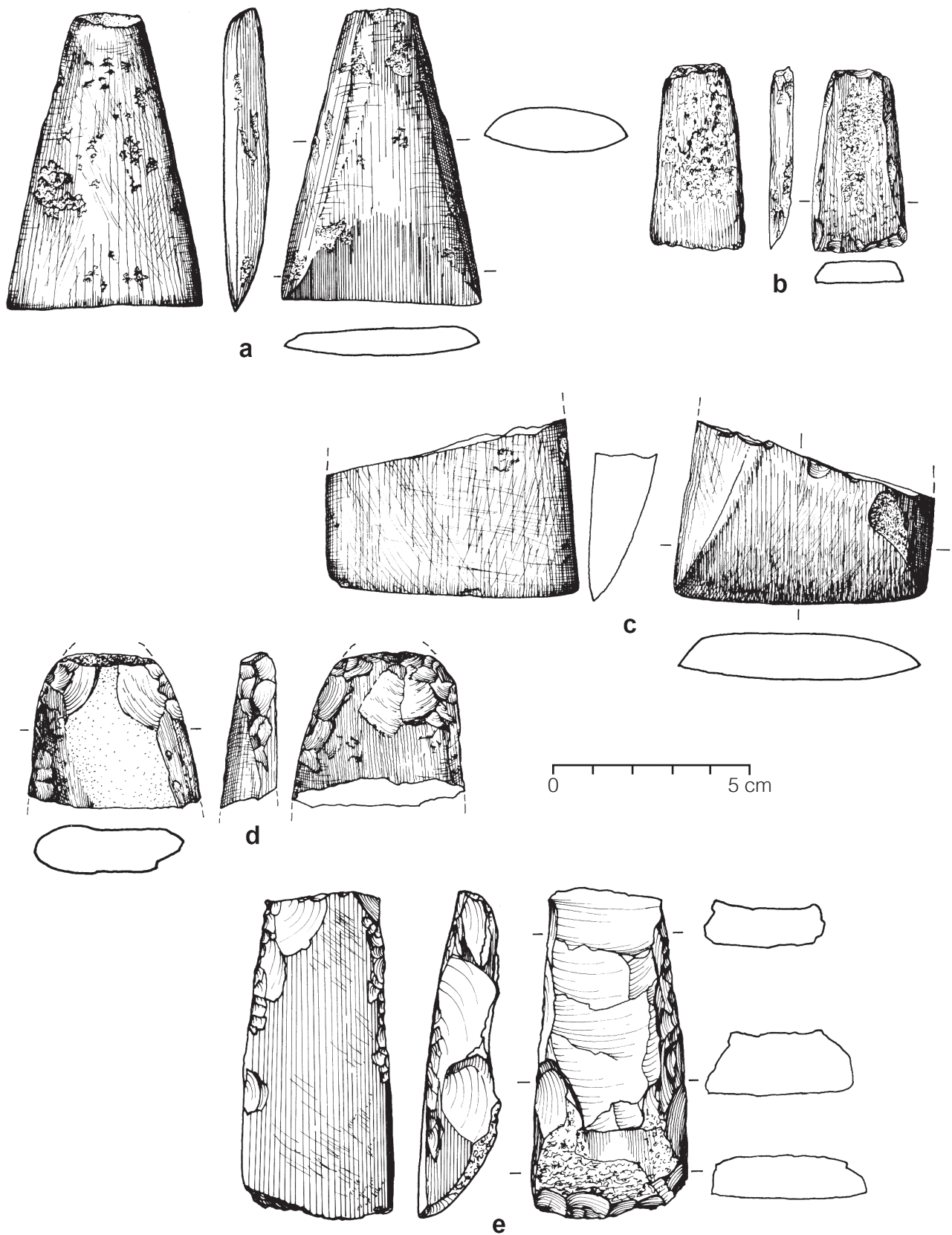


Figure 10.9. Type 2A adzes: a, E34-8-1; b, D34-9-1; c, E34-7-8; d, F30-10-4; e, E34-9-1.

has been reduced on both sides toward the butt to produce a tang. A more carefully crafted adze is shown in Figure 10.10b, from zone SZ-2. This specimen is well ground and polished, except for the tang where original flake scars still dominate, again probably to facilitate hafting. The bevel is slightly curved. This adze was made with the core technique, but its original triangular cross section has been greatly smoothed through extensive grinding.

Figure 10.11 illustrates three additional adzes with triangular cross sections. The complete adze shown in Figure 10.11a, from zone SZ-8, is of type 3D, what Duff (1959:137) referred to as a “triangular chisel.” This narrow adze with a curved, convex bevel is well ground and polished on much of the front, less so on the back. The triangular cross section is pronounced; it was manufactured from a core-type preform. The other two specimens illustrated in Figure 10.11 are of Duff (1959:135) type 3A, triangular adzes with the apex down (i.e., on the back of the adze) and with significant tangs, the cross sections of which approach circular. The specimen shown in Figure 10.11b comes from zone SZ-9 and consists of the tang and mid-section of a classic-type 3A adze, well ground on the front, much less so on the sides and tang. The tang is pronounced and strongly reduced along the front of the adze. The specimen in Figure 10.11c, from feature F58, is also a tang and partial mid-section, extensively ground and polished except on the tang, which retains some flake scars. The tang is strongly reduced laterally and on the front. The fact that both of these two specimens come from higher stratigraphic zones is significant, putting the development of pronounced tanged forms of adzes into temporal contexts after the mid-fifteenth century.

Two additional adze sections of Duff type 3A are illustrated in Figure 10.12. That shown in Figure 10.12a, from feature F20, consists of a mid-section, most of the bevel, and a small part of the tang of a classic-type 3A adze, well ground and polished overall but with a few traces of flake scars. Enough of the tang remains to show that it was strongly reduced and had a nearly ovoid cross section. The second specimen (Figure 10.12b), from zone SZ-5, is the mid-section of a triangular adze, well ground and polished overall but missing the end of the bevel and virtually all of the tang. However, a sharp reduction from the shoulder to a narrow tang is evident, making assignment to type 3A certain. These specimens come from

stratigraphic contexts in the middle of the MAN-44 sequence, roughly the late fourteenth to fifteenth centuries, again providing evidence for the development of triangular adzes with pronounced tangs by this period.

Four partial adze sections of Duff type 3 are illustrated in Figure 10.13. The first (Figure 10.13a) is the butt of a triangular adze from zone SZ-2. The adze has a triangular section and is fairly well ground and polished. It seems not to have had a reduced tang, but the subtype cannot readily be identified on this incomplete specimen. Another adze butt is shown in Figure 10.13b, from zone SZ-5. This was a heavy adze with a triangular cross section, so extensively ground that the cross section appears subrounded. This appears to be the reduced tang of a type 3A adze. A small butt fragment is shown in Figure 10.13c, from outlying excavation unit B25. This tang section of a triangular adze has some grinding, but most of the surface consists of original flake scars; it was made from a core rather than a flake. Finally, the bevel of a triangular adze from zone SZ-10 is shown in Figure 10.13d. The specimen is extensively ground and polished. Although the tang is missing, the pronounced triangular cross section and extensive grinding suggest that it came from a type 3A adze.

The final adze to be described, illustrated in Figure 10.14, is an aberrant specimen that does not fit into the Duff classification scheme. This consists of a small flake with trapezoidal cross section that has had only minimal grinding along the curved edge to create a bevel, as well as along the flake scar ridges of the back to smooth them off slightly. It has an expedient look and clearly represents only a minimum of effort.

To sum up, the assemblage of complete and partial adzes from Tangatatau Rockshelter displays an evolution of adze forms over time. The earlier stratigraphic contexts contain primarily quadrangular adzes of Duff type 2A, or type 1A adzes with tangs that are minimally reduced. Beginning in the middle stratigraphic contexts (with zone SZ-5) and continuing into the later levels, the adzes are mostly of triangular types 3 or 3A, typically with pronounced tangs.

Geochemical Sourcing of Adze Rock

Archaeologists working in Eastern Polynesia traditionally relied upon stylistic similarities between fishhooks, adzes, and architecture to infer interisland contacts. Over the past 25 years or so, however,

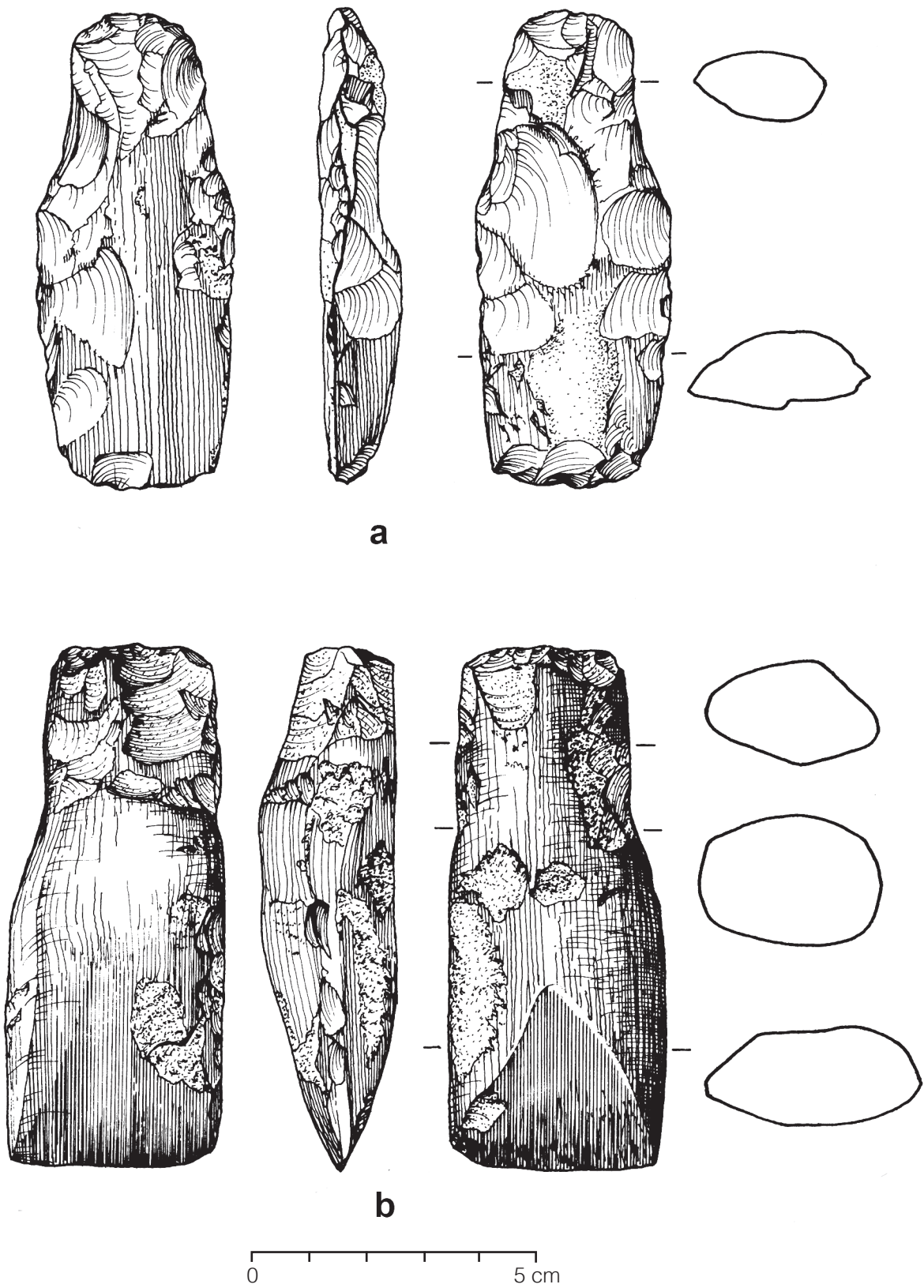


Figure 10.10. Type 3A adzes: a, E31-8-2 (refitted to E31-12-1); b, D34-8-3.

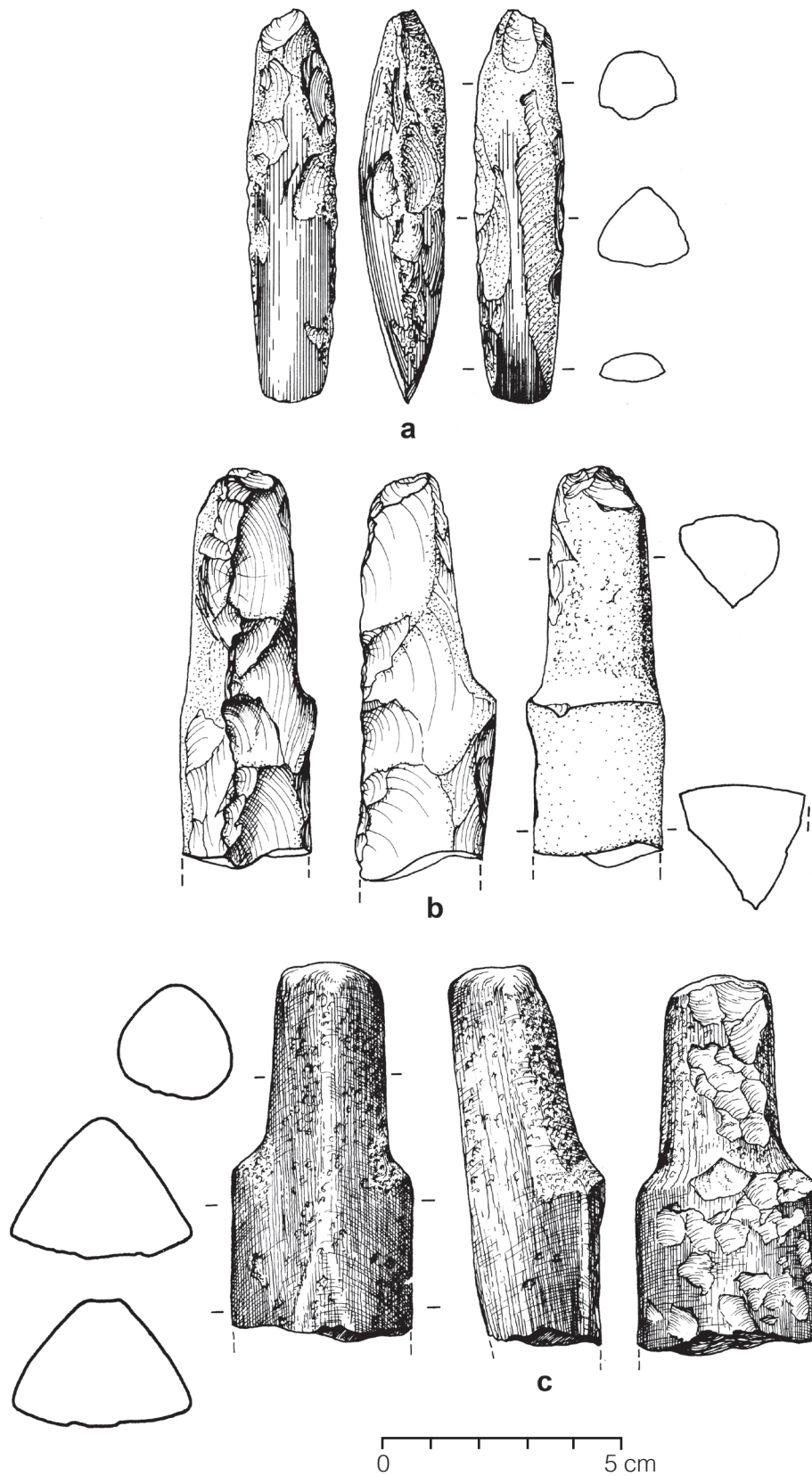


Figure 10.11. Type 3D and 3A adzes: a, E34-3-1; b, F35-3-1; c, C30-4-2.

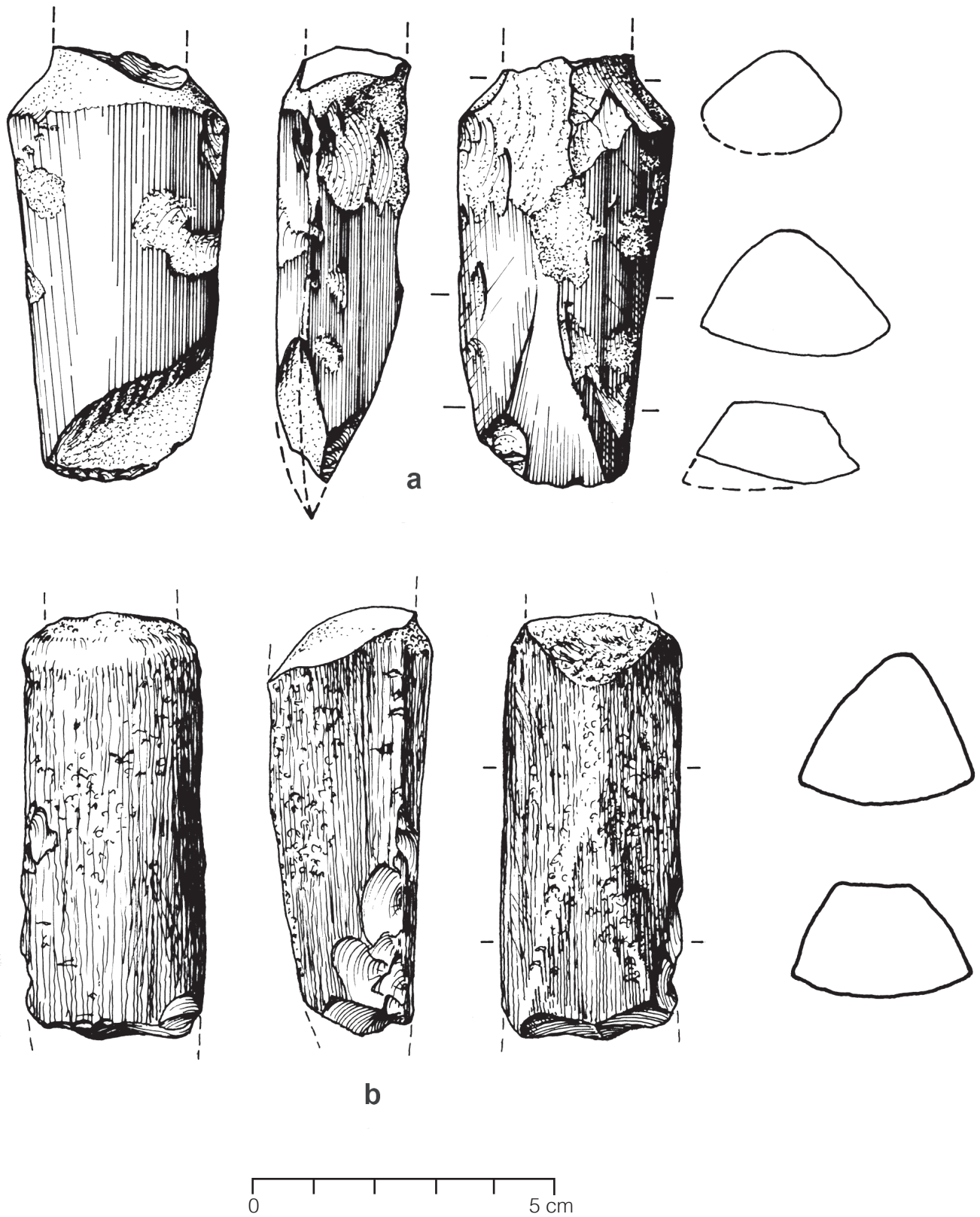


Figure 10.12. Partial adze sections of Type 3A: a, J30-4-1; b, D30-8-5.

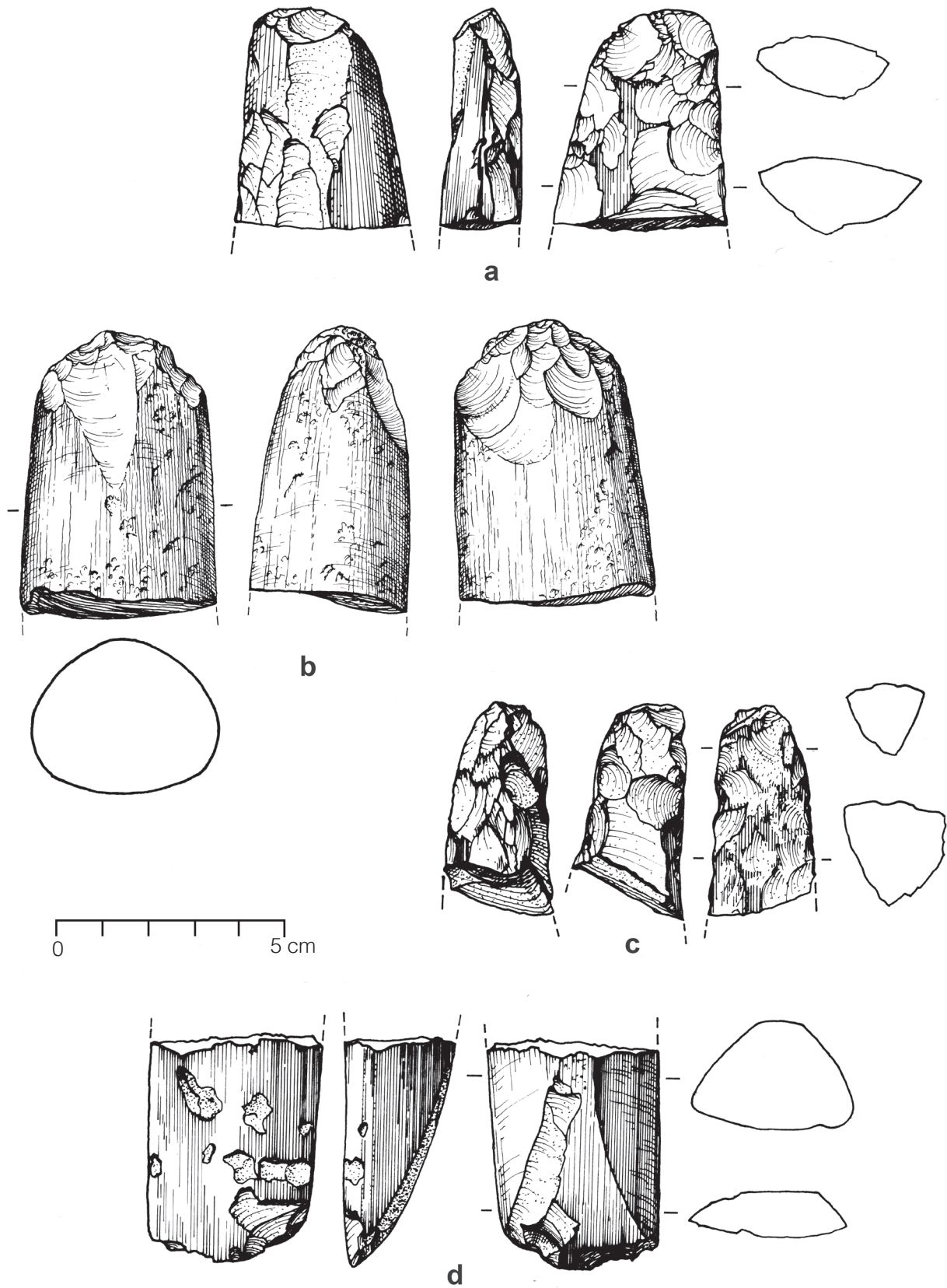


Figure 10.13. Partial adzes of Type 3: a, D34-9-2; b, E30-8-2; c, B25-3-1; d, D33-3-5.

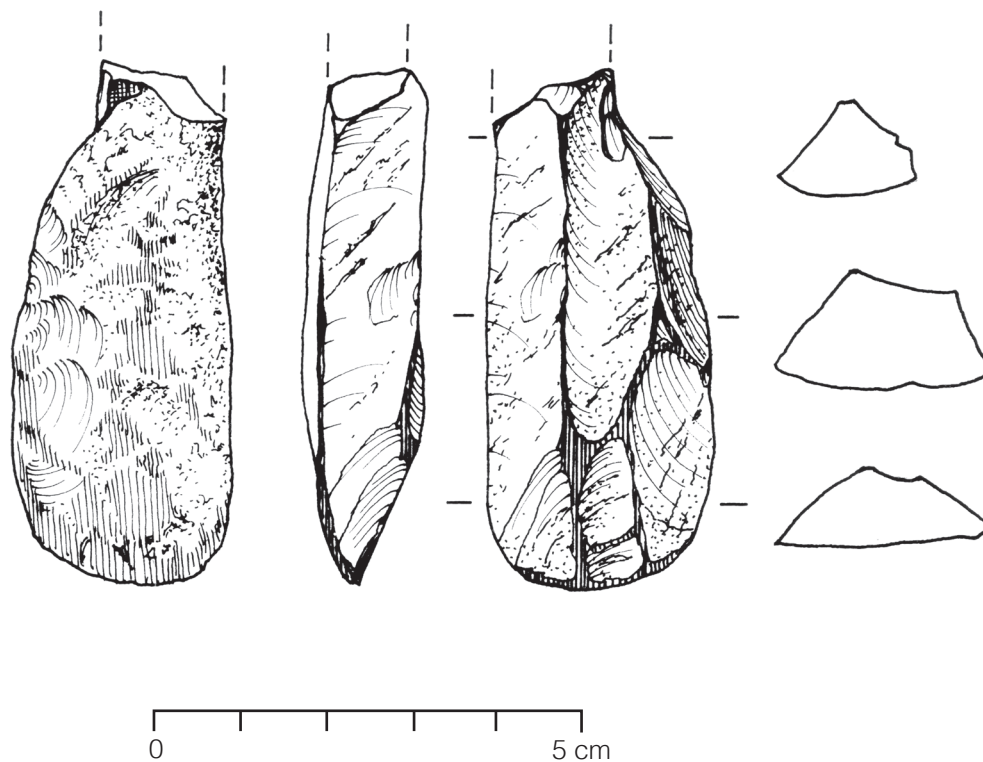


Figure 10.14. Small adze of aberrant type (D31-13-12).

numerous studies have demonstrated the efficacy of using geochemical analysis of basalt adze material for tracking interisland communication within this region (e.g., Rolett 1998; Rolett et al. 2015; Sinton and Sinoto 1997; Weisler 1993, 1998; Weisler and Kirch 1996).

Because Mangaia's volcanic rocks are so extremely weathered, fresh basalt is found only as limited dike exposures in stream valleys (Marshall 1927:36). However, Gill (1876) mentioned the existence of an adze quarry at a place called Mata'are. With assistance from Mangaian informants, we were able to relocate the Mata'are dike source, obtaining samples for geochemical analysis (Weisler et al. 1994). We also obtained dike stone from a streambed in Veitatei Valley, this presumably having been eroded out of an exposure higher in the drainage basin.

A first attempt to determine the source(s) of adze rock represented at Tangatatau was undertaken by Weisler (1993). All whole adzes and large adze fragments, as well as a sample of adze preforms, adze flakes, and unmodified flakes from MAN-44, were selected for analysis using the nondestructive, energy-dispersive X-ray fluorescence technique (EDXRF). The analysis

was undertaken at the Department of Geology and Geophysics, University of California, Berkeley using a Spectrace 440 energy-dispersive X-ray fluorescence spectrometer and a Tracor X-ray (Spectrace) TX 6100 X-ray analyzer. Additional analytical details are provided in Weisler (1993).

Elemental abundances of elements in the mid-Z range were analyzed as these are easily detected by the EDXRF technique and occur in sufficient quantities in oceanic basalt. The results suggested that most of the adze material excavated from site MAN-44 probably originated from the local Mata'are source. Significantly, however, four polished basalt adze flakes from MAN-44 (from zones SZ-2, SZ-4A, and SZ-8) appeared to match the major Tatagamatau quarry source on Tutuila Island, American Samoa. These initial results were published by Weisler and Kirch (1996:1384), who pointed to the 1,600-km distance between Tutuila and Mangaia, noting that this discovery provided "considerable support to the view that regular long-distance voyaging between distant archipelagoes was common throughout much of Polynesia, at least during the earlier phases of its settlement."

As subsequent work on geochemical sourcing of adze rock in various Polynesian localities has demonstrated, however, nondestructive EDXRF is limited in its ability to discriminate among similar volcanic sources, which frequently overlap in their elemental compositions (e.g., Weisler et al. 2013, 2016). To refine the geochemical sourcing of adze material from site MAN-44, Weisler and colleagues at the University of Queensland resampled 36 adze specimens (seven whole or partial adzes, one preform, and 28 adze flakes) for destructive analysis of both trace elements and isotopes. A small quantity of powder (between 0.15 and 0.39 g) was obtained from each specimen by milling, using a diamond-coated barrel-shaped drill bit. Trace element concentrations were determined using Thermo X-series quadrupole inductively coupled plasma mass spectrometry (ICPMS) at the University of Queensland, with detection limits for most elements in the range of parts per trillion. Following ICPMS analysis, a second aliquot retained for isotope analysis was subjected to Sr, Nd, and Pb chemical separation. Sr isotopes were measured by thermal ionization mass spectrometry (TIMS) on a VG Sector 54 system at the Radiogenic Isotope Facility in Queensland. Nd and Pb isotopes were analyzed in static mode by multicollector inductively coupled plasma mass spectrometry (MC-ICP-MS) using a Nu Plasma system. Full methodological and analytical details of these analyses, along with all relevant data sets, are presented in Weisler et al. (2016).

The results of this second phase of geochemical analysis and sourcing of adze material from MAN-44, published in full by Weisler et al. (2016), reveal a more complex picture than that suggested by the original EDXRF study. Here I briefly summarize the main results reported by Weisler et al. (2016). As shown in Figure 10.15, two local Mangaia sources and five nonlocal rock sources are indicated by the trace element data; these source assignments were further confirmed by the isotopic data. Nineteen of the 36 sampled artifacts were assigned to local basalt sources on Mangaia. Seven artifacts are compositionally almost identical to a rock sample from the Mata'are source (Figure 10.15A). Thirteen artifacts closely match a source rock from Veitatei, also on Mangaia (Figure 10.15B). Two artifacts are compositionally and isotopically similar to volcanics found on the island of Rarotonga, Southern Cook Islands (Figure 10.15C). An additional artifact (D33-3-7) is assigned to Rarotonga based on the isotope data. Two other artifacts (F35-7-5 and F36-6-1), not plotted in Figure

10.15, fall within the general geochemical range for the Cook Islands but cannot be matched to an individual island or source.

Seven artifacts are similar to the basaltic source rock found at the major ceremonial and quarry complex at Vitaria, on Rurutu in the Austral Islands (Figure 10.15D). Three complete adzes (D33-3-5, E34-7-8, and J30-4-1) originated from 'Upolu Island, Samoa, suggested by the match in trace element data to published compositions for two Samoan basaltic volcanics (Figure 10.15E), an assignment that is confirmed by matching Nd and Sr isotopic data. One artifact from MAN-44 (D32-3-5) matches two source flakes from the major quarry complex at Tangamatau, Tutuila Island, Samoa (Figure 10.15F). Finally, specimen D34-9-8 is exceptional as the only artifact that can be linked to the Marquesas archipelago; the closest similarity with trace elements is with a source rock from Eiao Island, which is notable for its major quarry complex (Figure 10.15G).

To summarize, slightly more than half of the sampled basalt adzes or adze flakes from site MAN-44 can be assigned to three sources within the Cook Islands: the Veitatei ($n = 13$) and Mata'are ($n = 7$) sources on Mangaia and one source on nearby Rarotonga Island ($n = 3$). Two other artifacts most likely come from unidentified sources within the Cook Islands. Seven artifacts are linked to the Vitaria quarry complex on Rurutu, in the Austral Islands. Four artifacts originated from the Samoan archipelago, from the island of 'Upolu and from the well-documented Tangamatau quarry complex on Tutuila Island. Finally, one artifact can be traced to Eiao Island, Marquesas, with its extensive quarry complex.

The stratigraphic distribution of the 35 geochemically analyzed adzes and adze flakes from the main excavation block is given in Table 10.4. As can be seen, local Mangaia rock sources were used throughout the rockshelter's occupation sequence. Interestingly, however, only the Veitatei source appears in the earliest zones SZ-2 and SZ-3, with the first use of the Mata'are source appearing in zone SZ-5. The single specimen from Eiao in the Marquesas occurs in the earliest occupation deposit, zone SZ-2. The specimens deriving from Rurutu, in the Australs, are concentrated in the deeper strata (SZ-2 to SZ-5), although one artifact also appears in SZ-8. In contrast, artifacts sourced to Rarotonga occur only in the upper strata. Of particular interest are the four artifacts from the Samoan sources, one of which occurs in SZ-2, but the other three are from higher strata.

Table 10.4 Stratigraphic Distribution of Geochemically Analyzed Adzes and Adze Flakes from the Main Excavation Block, Site MAN-44

Zone or Feature	Mangaia (Veitaitai)	Mangaia (Mata'are)	Samoa	Marquesas (Eiao)	Australs (Rurutu)	Cook Islands (Rarotonga)	Other Cook Islands	Totals
SZ-19/F20	1		1					2
SZ-17						1		1
SZ-10	1	1	1			1		4
SZ-8	1	4	1		1			7
SZ-7	1							1
F32/F37		1				1		2
SZ-6		1						1
SZ-5		2			1			3
SZ-4B					1			1
SZ-3	4		1		2		2	9
SZ-2	1			1	2			4
Totals	9	9	4	1	7	3	2	35

Other Tools and Implements

Basalt and Chert Awls or Borers

Four retouched lithic objects, three of basalt and one of chert, can be classified as awls or borers; these are illustrated in Figure 10.16. The first three (Figure 10.16a–c) are all made on flakes, with bifacial trimming to produce a narrow point. One specimen (Figure 10.16c) exhibits considerable use-wear polish on two sides, presumably deriving from prolonged gripping by the hand while using the implement. The fourth specimen (Figure 10.16d) was made from a chert core and has a pronounced, tapering point. Chert occurs in nodule form in several parts of Mangaia, having originally formed in the limestone *makatea* (Marshall 1927).

Basalt Coconut Grater

Throughout tropical Polynesia, an essential food preparation implement was the coconut grater, typically consisting of a wooden stool or tripod with a projection upon which was mounted the grater head, often a piece of pearl shell with a serrated edge (Kirch and Green 2001:152, Figure 6.2). Hiroa (1930:111) mentions that in Samoa, the grater head was sometimes made of stone, with a “chipped convex cutting edge.” A carefully retouched basalt flake recovered from zone SZ-7 appears to be just such a coconut grater head (Figure 10.17b). It consists of a large, rectangular flake, one end

of which has been unifacially retouched to form a nicely rounded and slightly serrated edge. In addition, the two sides have been trimmed to produce slightly concave indentations that would facilitate hafting of the grater head to the wooden stool. To our knowledge, this is the first such basalt coconut grater head recovered from an Eastern Polynesian archaeological context.

Retouched Basalt Flakes

A number of basalt flakes from site MAN-44 exhibit purposeful retouching so as to render them useful as expedient tools. We did not make a formal study of these flakes, but a few examples are illustrated in Figures 10.17 and 10.18. Figure 10.17a shows a heavy flake that has been unifacially trimmed to form a convex edge, probably for use as a scraper. A similarly heavy flake depicted in Figure 10.17c has also had extensive unifacial trimming to produce a curved edge; the most likely function was again as a scraper. The elongated, triangular flake in Figure 10.18a has had its point retouched, possibly for use as a graver or perforator. The eccentric flake in Figure 10.18b has bifacial trimming that results in a concave indentation; it might have been used to shape a wooden shaft. The long, rectangular flake in Figure 10.18c has fine, bifacial nibbling along one edge; this could have been used as a cutting tool. The heavy flake in Figure 10.18d has

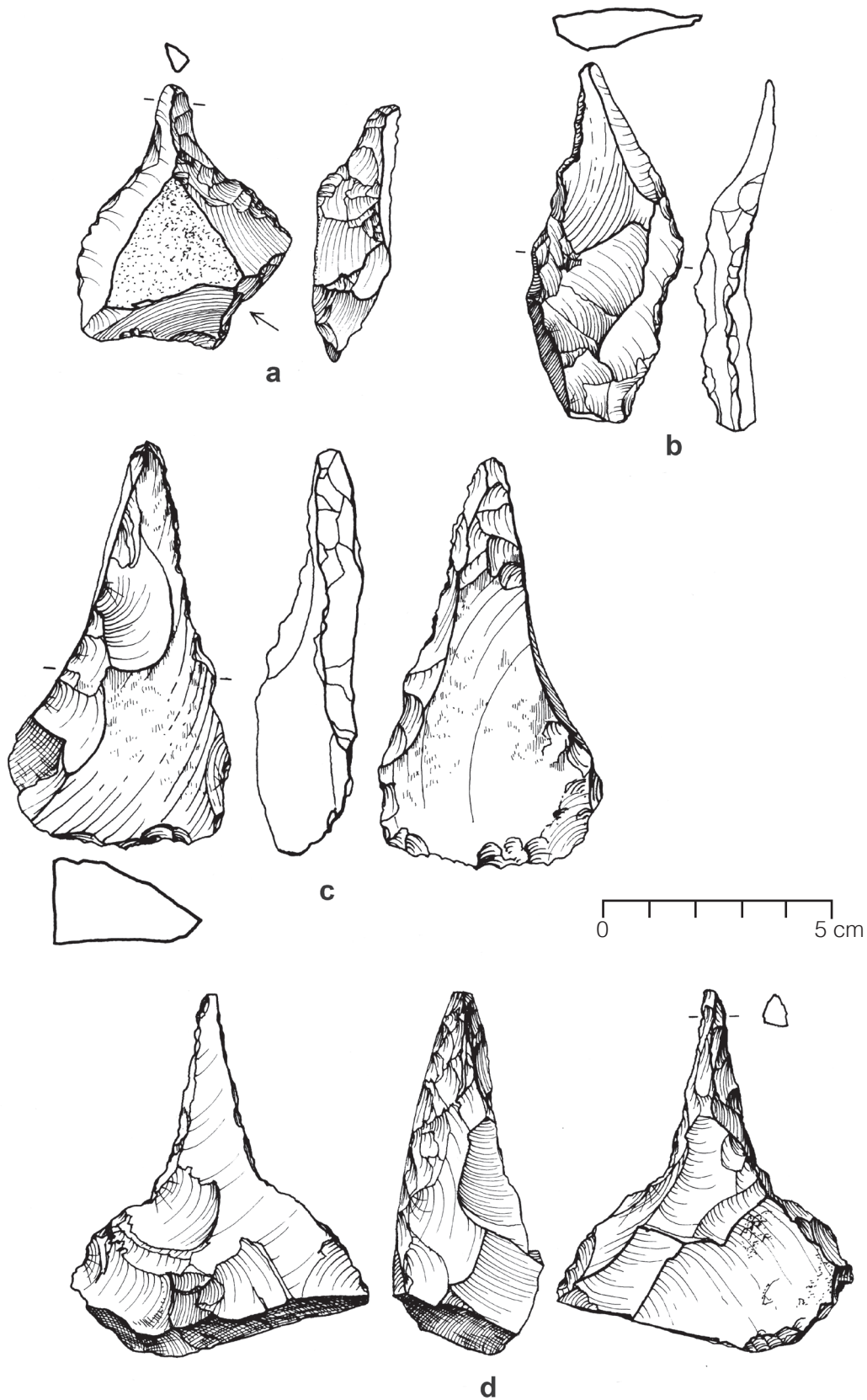


Figure 10.16. Awls or borers of basalt and chert: a, C31-2-7; b, C30-6-58; d, D30-3-12; e, E36-3-4.

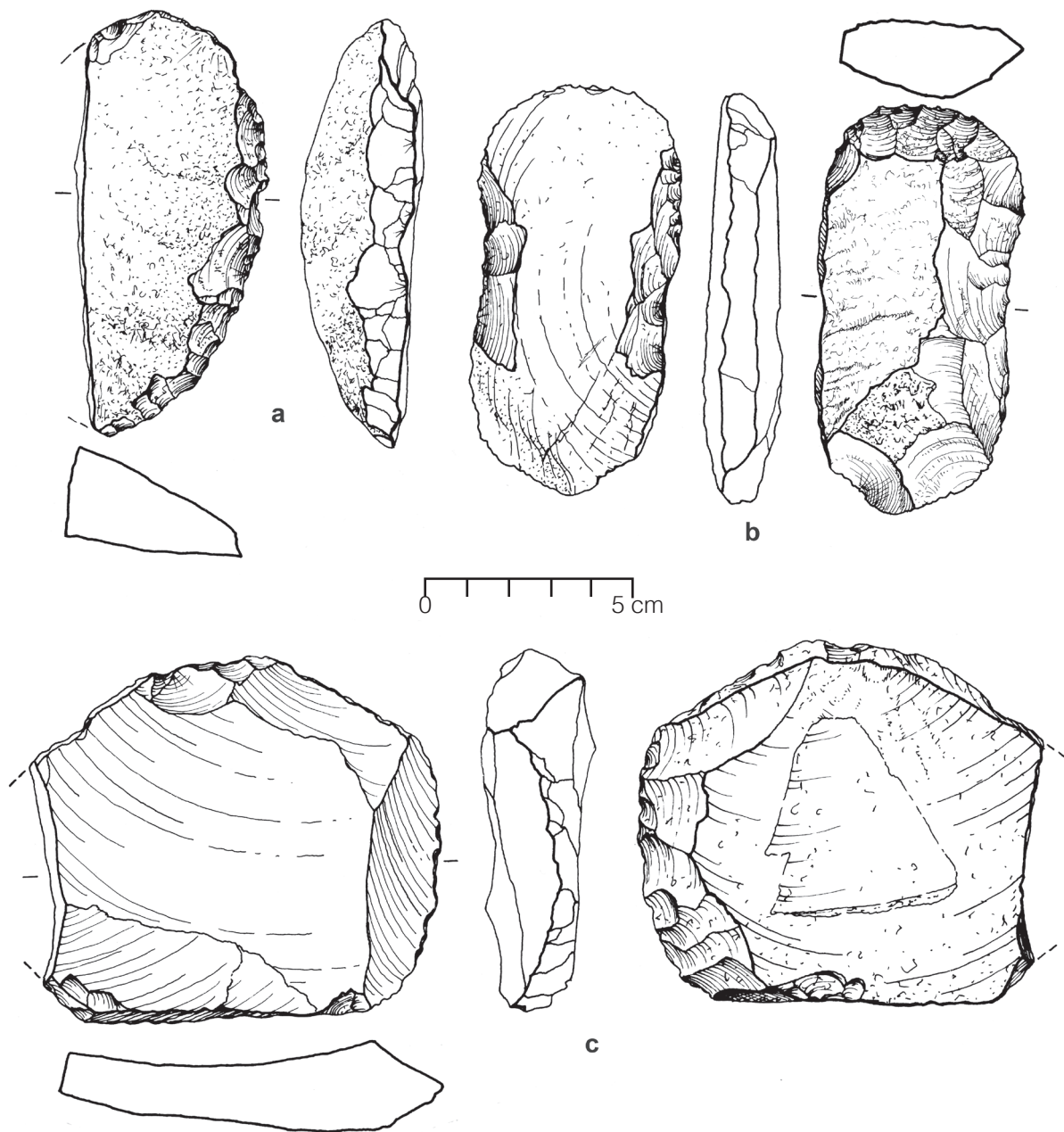


Figure 10.17. Retouched basalt lithic artifacts from site MAN-44: a, scraper, E30-6-1; b, coconut grater, C30-6-15; c, scraper, D33-7-3.

bifacial trimming to produce a curved edge; the most likely function was as a scraper. Finally, the thin flake in Figure 10.18e displays limited unifacial trimming and may have been used as a cutting tool.

Hammerstones

Twenty-one objects were classified as hammerstones. All are roughly spherical to elongated stones exhibiting evidence of crushing or battering on one or more

ends or facets (Figure 10.19). The majority ($n = 15$) are of limestone obtained from the *makatea*. As this limestone is softer than basalt, it was probably well suited as a “soft” hammer for flaking and trimming the basalt used in adze production. Five of the hammerstones are of basalt, and one is of a kind of scoria. In weight, these range from 75 to 342 g. Most have diameters in the range from about 50 to 70 mm, but the largest has a diameter of 122 mm.

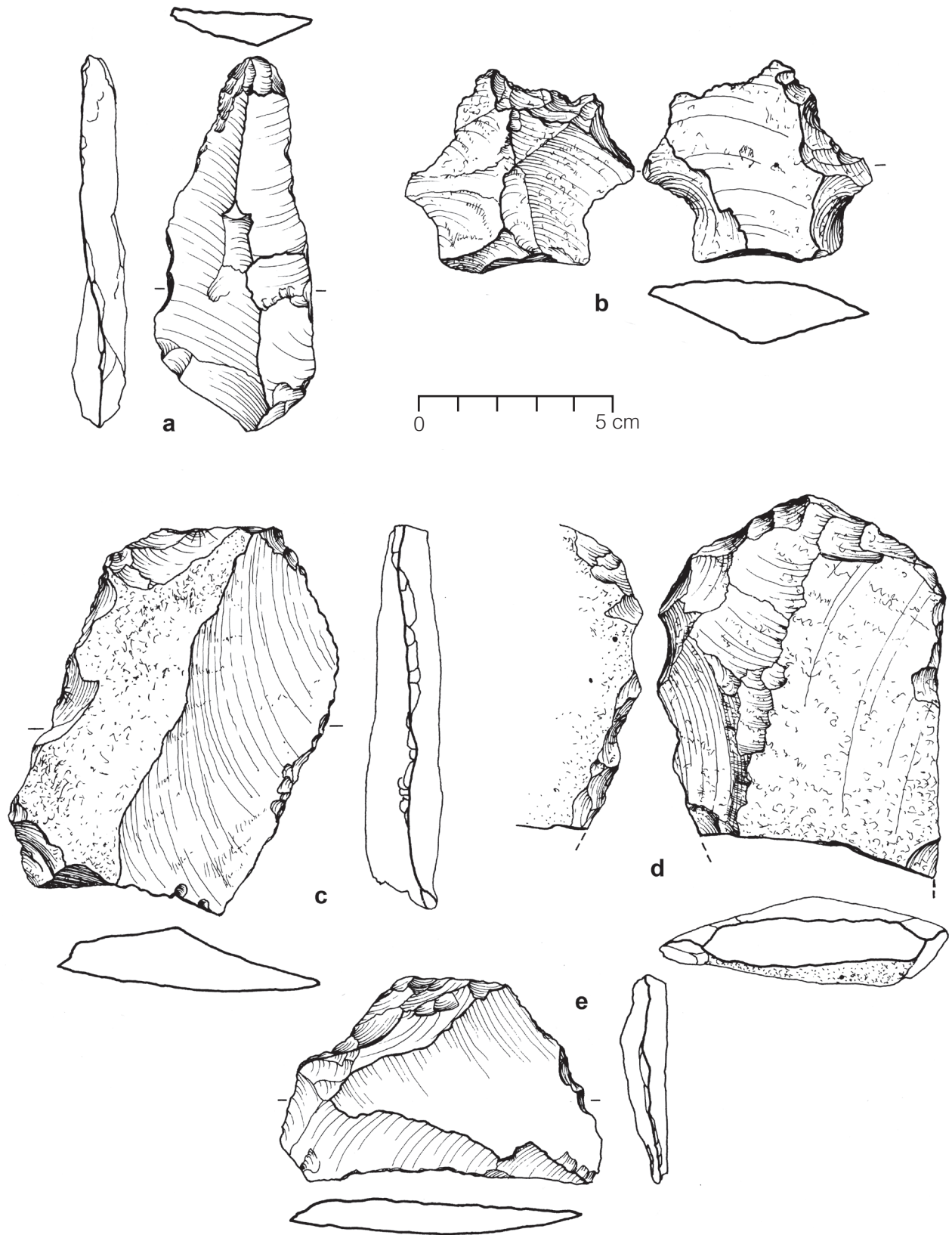


Figure 10.18. Retouched basalt flakes: a, C30-6-71; b, F30-9-13; c, C30-4-6; d, E34-2-1; e, E33-4-1.

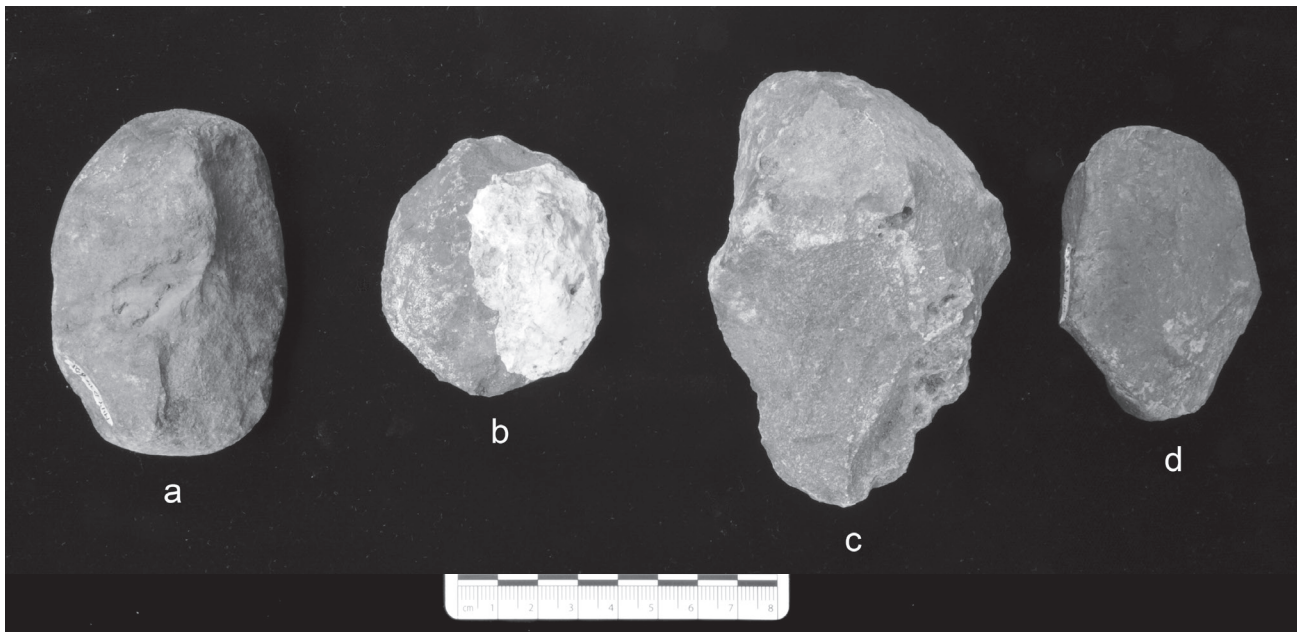


Figure 10.19. Selected hammerstones from site MAN-44: a, D34-6-21; b, D35-3-15; c, E34-6-16; d, E35-5-3.

Bone Awls

Two awls made from modified bones were found during the MAN-44 excavations. That illustrated in Figure 10.20a comes from zone SZ-17 and is made from the mid to distal end of a human femur. There are natural fracture breaks at both ends, with one area filed down to a sharp point. Filing grooves are visible on this worked end (probably from a coral abrader), along with considerable use polish or sheen. A second bone awl, shown in Figure 10.20b, from feature F58, is made from an ulna, probably of a pig (it is definitely not human).

Branch Coral Abraders

The narrow branches of *Acropora* spp. corals (“branch corals”), which are covered in small sharp verrucae or corallite cells that provide a naturally abrasive or rasp-like material, were widely used in Polynesia as abraders, especially for the manufacture of shell fishhooks but probably other shell or bone objects as well. Abraders can readily be distinguished from unworked *Acropora* coral branches by their worn, smoothed tips (Figure 10.20d–g). A selection of branch coral abraders is illustrated in Figure 10.21.

A total of 41 *Acropora* coral abraders were recovered from site MAN-44. Although they occur throughout the stratigraphic sequence, they are most heavily concentrated in zones SZ-7 and SZ-8, where

the greatest numbers of *Turbo* shell fishhooks occur. In virtually all cases, the abraded tips exhibit circular cross sections, indicating that the abraders were used in a circular, rotating fashion, which would have been especially suited to producing the round holes evident on some fishhook preforms. The abraded portions of the branch corals range in length from 10 to 40 mm, while the diameters of the abraded tips range between 6.5 and 13.5 mm.

Porites Coral Abraders

Porites coral abraders were made from one or more species of stony coral (such as *Porites lobata*) whose corallite cells are closely packed, with fused cell walls, providing a dense but porous structure that is naturally abrasive when rubbed against materials such as shell, bone, or wood. Like branch coral abraders, *Porites* coral abraders were widely used in Polynesia for the manufacture of fishhooks and other artifacts. In MAN-44, they are almost as common as branch coral abraders, with 39 specimens distributed throughout the stratigraphic sequence (Table 10.1). However, unlike the branch coral abraders, which are most frequent in the higher zones, the greatest concentration of *Porites* coral abraders is in zone SZ-3. This suggests that *Porites* coral abraders may have been preferred tools for the manufacture of pearl shell fishhooks, which are more abundant in the lower stratigraphic deposits.

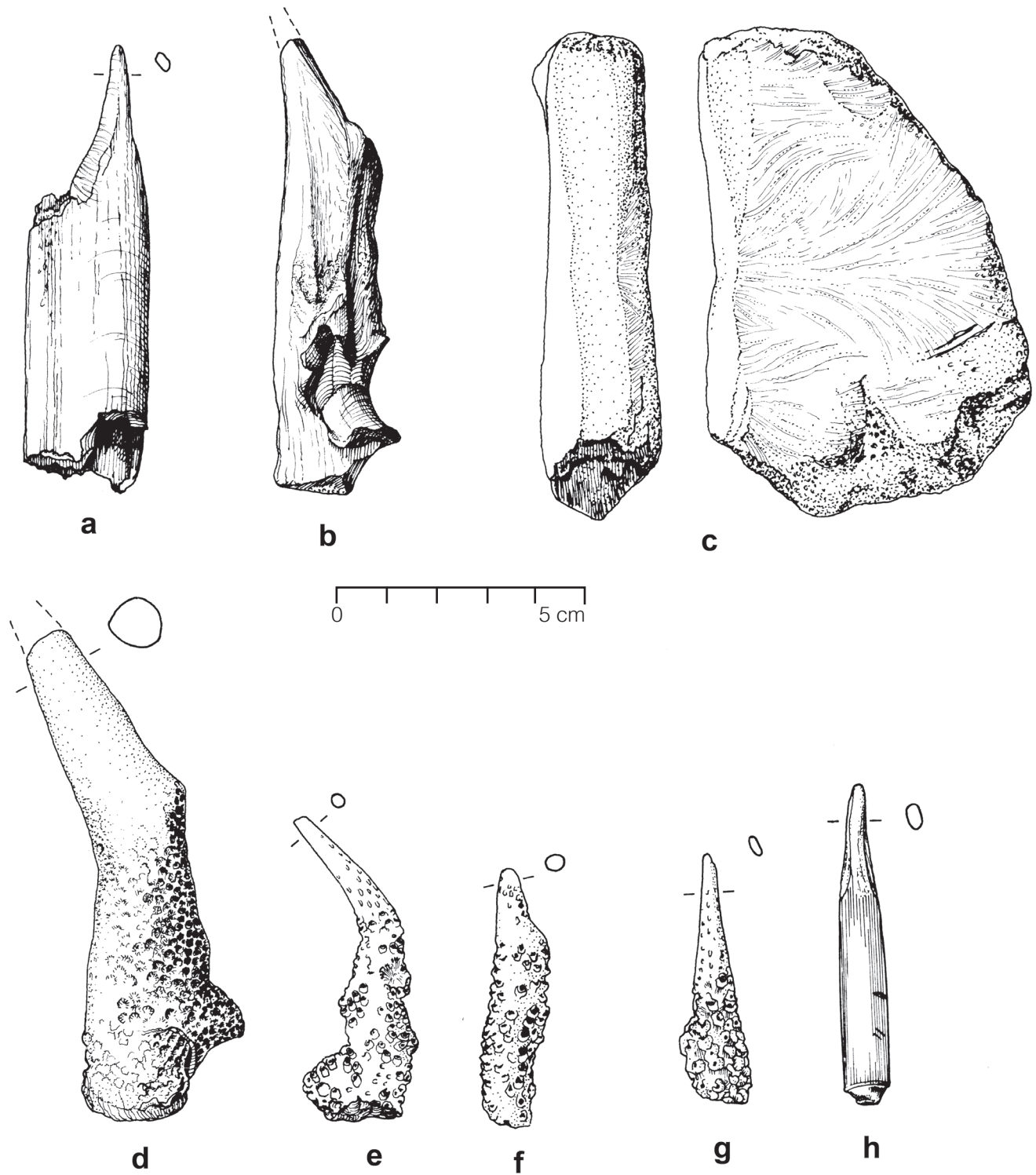


Figure 10.20. Bone awls, coral abraders, and sea-urchin spine abradar: a, bone awl, C30-1-4; b, bone awl, C30-4-1; c, block coral abradar, D30-6-3; d-g, branch coral abraders, d, D30-6-2; e, E30-8-3; f, E30-8-3, g, E31-6-3, h, sea-urchin spine abradar, D30-5-6.



Figure 10.21. Selected examples of branch coral (*Acropora*) abraders (worn tips all at the upper ends of the abraders): a, D30-6-2; b, D30-6-5; c, D31-7-10; d, D31-6-1; e, E31-6-3; f, E31-7-5; g, E31-10-1.

The *Porites* coral abraders from site MAN-44 can be divided into two subtypes: (1) smaller, narrow abraders typically well worn on all sides and having a tapering shape with a distinctly triangular or sometimes quadrangular cross section and (2) larger blocks of coral with one or more flat, abraded facets. Examples of the first subtype are illustrated in Figure 10.22 and those of the second subtype in Figures 10.20c and 10.23. The smaller, tapering abraders were most likely used

for fishhook manufacture, particularly for shaping and polishing pearl shell hooks. The larger, block abraders may have been used in other kinds of manufacturing activities, on wood as well as on shell or bone. One particularly well-shaped block abraded (Figure 10.22c) has a quadrangular section and has been abraded smooth on all surfaces. Another example (Figure 10.22b) is coated in a reddish material suggesting that it might have used to grind hematite or ochre.



Figure 10.22. Selected *Porites* coral abraders of the smaller, tapering variety: a, C31-6-1; b, D33-3-1; c, D35-4-12; d, E31-10-3; e, E34-6-17.

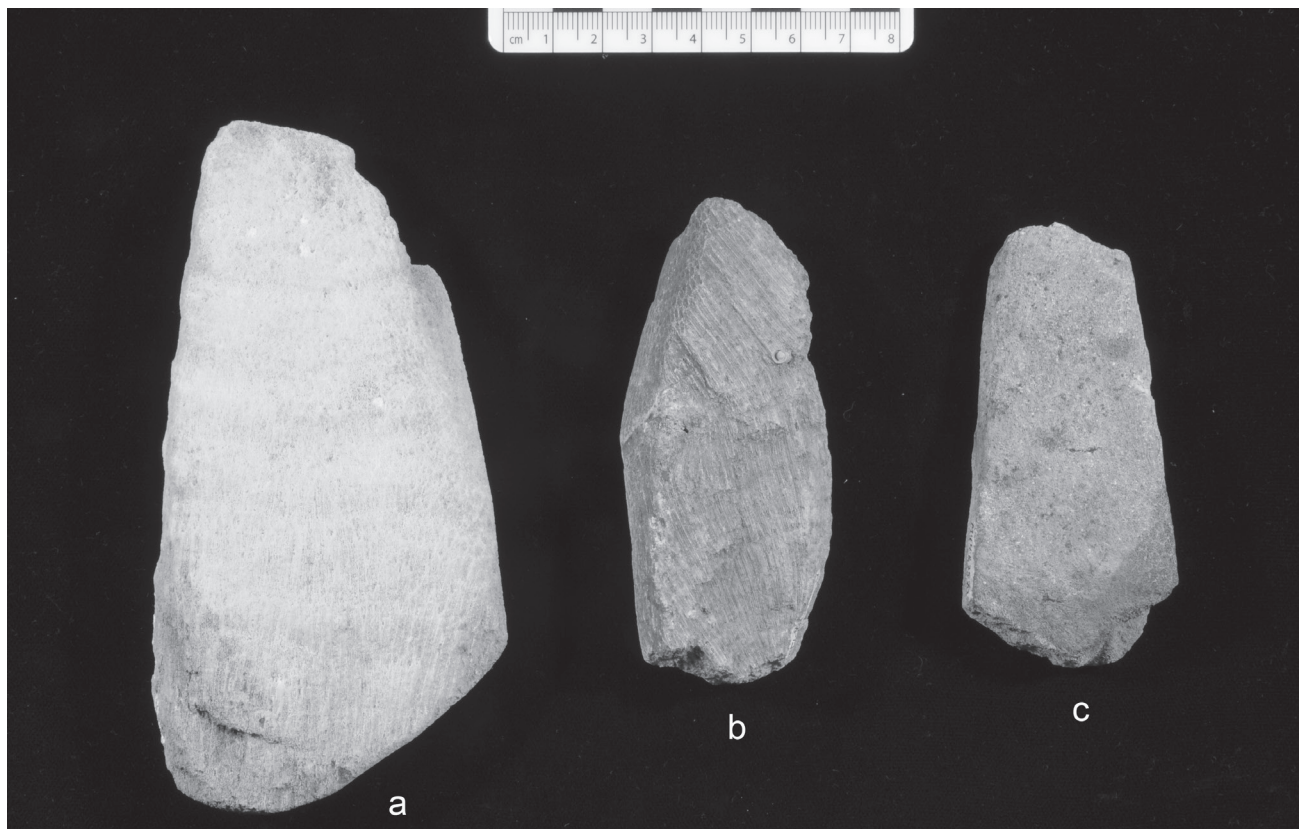


Figure 10.23. Selected *Porites* coral abraders of the larger, block variety: a, D30, surface; b, D34-6-12; c, E35-7-2.

Sea Urchin Spine Abraders

The spines of large slate-pencil sea urchins (*Heterocentrotus mammillatus*), which range up to 10 cm in length, have a naturally abrasive quality, making them well suited to fine finishing work in the manufacture of fishhooks or other shell objects; they were widely used for this purpose in Polynesia. Thirty-three spines from MAN-44 exhibit abraded surfaces (Figure 10.24). Most spines were abraded only on their distal ends, sometimes on a single facet and at other times with two facets creating a sharp angle between them. In one case (Figure 10.24b), the proximal part of the spine was abraded.

Stratigraphically, sea urchin spine abraders are found throughout the MAN-44 sequence (Table 10.1). However, they are most common in SZ-3 and SZ-8, zones in which there is also abundant evidence of fishhook production, confirming that these tools were used mainly for that purpose. They were probably equally important for finishing both pearl shell and *Turbo* shell hooks.

Shell Scrapers

Twenty examples of whole valves of the large bivalve *Periglypta reticulata* exhibit extensive chipping and/or rounding of the ventral edge of the valve, consistent with the use of these shells as scrapers. They could have been used for scraping fibrous materials, such as *Pandanus* leaves in preparation for mat making, or for fine finishing of wooden objects. During fieldwork in Niutopotapu Island in 1976, I observed a traditional woodworking craftsman using similar bivalve shells to smooth the surfaces of his wooden bowls.

Fishing Gear

The MAN-44 excavations produced a large assemblage of fishing gear, with 262 complete or fragmentary hooks and an additional 78 pieces, including hook preforms, unfinished hooks, and worked shell. This assemblage is the largest collection of fishhooks from any site in the Cook Islands, indeed one of the largest anywhere



Figure 10.24. Selected sea urchin spine abraders: a, C30-5-5; b, D31-7-13; c, D32-5-11; d, D34-8-7; e, I30-6-1.

in central Eastern Polynesia. Fishhooks, along with adzes, have been the focus of much typological study in Eastern Polynesia, taking on the role played by ceramics in other parts of the world (e.g., Emory et al. 1959; Sinoto 1962, 1967, 1970). A detailed typological analysis of the MAN-44 fishhook assemblage is the subject of Chapter 11; here I summarize a few key aspects of the hooks.

The Tangatatau fishhooks were manufactured from two species of marine shell, whose different physical properties and size ranges significantly influenced the morphology of the hooks. The majority of the hooks (82 percent) were manufactured from the valves of the large pearl oyster, *Pinctada margaritifera*, a species that does not occur in Mangaia, which lacks the oyster's lagoon habitat. The pearl shells were therefore imported to Mangaia, probably from other islands within the Cook archipelago where the species does occur; however, we cannot rule out importation from more distant sources, such as the Society Islands. The large size of the *P. margaritifera* shells (up to 130 mm; Salvat and Rives 1975:368) allowed for the manufacture of larger fishhooks (with shank lengths up to 34 mm). In addition, the cross-laminated microstructure of pearl shell conferred substantial strength to a fishhook, while the shell's high luster also helped to attract fish.

Hooks were also manufactured from the reef gastropod *Turbo setosus*, which was locally available on Mangaia. The hooks were prepared from the main body whorl of this shell, but with a maximum height of about 61 mm (Salvat and Rives 1975:257), only smaller hooks could be made from *Turbo* shell (the maximum shank height of *Turbo* hooks is 24 mm). Moreover, intense pressure on the Mangaian population of *T. setosus* from constant gathering of the mollusk for food (see Chapter 8) made it difficult to obtain larger shells during late prehistory. Not surprisingly, most of the *Turbo* shell hooks in MAN-44 are relatively small.

While both pearl shell and *Turbo* shell fishhooks are found throughout the stratigraphic sequence in MAN-44, pearl shell hooks dominate in the lower zones SZ-2 to SZ-4A/B and are absent above zone SZ-8. This probably relates to a gradual cessation of external exchange relations and hence lack of available pearl shell. In contrast, *Turbo* shell hooks are rare in the deeper zones but become dominant in the upper deposits, especially in zone SZ-8.

Pearl Shell Fishhooks

Almost all of the pearl shell fishhooks are of the "one-piece" or angling type (Emory et al. 1959:7, Figure 3), but there are two fragments of "composite" type trolling-lure shanks. These fragmentary lure shanks come from zones SZ-3 and SZ-4A. No trolling-lure points were found at MAN-44, although one complete point was found at site MAN-84 (see Chapter 13).

A selection of 32 complete or larger fragments of pearl shell one-piece fishhooks is illustrated in Figure 10.25, demonstrating the range of variation in hook morphology. Following the terminology of Emory et al. (1959), both "jabbing" and "rotating" varieties are present. The shanks range from straight to curved, with some of the curved shanks exhibiting distinctly angular contours. The bends are mostly O- or U-shaped, with V-shaped bends lacking. There are several instances where the point has a recurved tip. Several variations of head (or line-lashing device) are present, the most common being a protruding knob on the exterior side of the shank. These morphological variations are more fully explored by Carlier in Chapter 11.

Turbo Shell Fishhooks

A representative selection of 13 *Turbo* shell fishhooks is illustrated in Figure 10.26. Almost all of the hooks are of the rotating type, and the bends often have a distinctive ovoid shape. The shanks are either straight or have a slight curvature, but no distinctly angular shanks are present, in contrast with the pearl shell hooks. In a number of *Turbo* shell hooks, the height of the point is equal to that of the head. There are several instances of points with recurved tips. An exterior knob is again the most common line-lashing device, but at least two heads (Figure 10.26) have an interior, downward-pointing knob not evidenced on any of the pearl shell hooks.

Ornaments and Personal Adornment

Tattooing Combs

Eleven whole or fragmentary tattooing combs (sometimes called "needles") were recovered from MAN-44, primarily from the lower stratigraphic zones (Table 10.1). The largest whole comb (31.7 mm long), which was found in two conjoining pieces, was made from a robust, flat piece of bone (2.4 mm thick), mostly certainly turtle (Figure 10.27a). The comb is 22.8 mm wide with 11 tines (three of which appear to have broken off during use) and tapers to 9 mm wide at the



Figure 10.25. Selected pearl shell fishhooks from site MAN-44: top row (l to r), C30-9-6, C10-10-1, C30-10-2, C31-3-2, C31-7-4, C32-3-2, D30-6-4; second row, D30-10-4, D30-10-8, D30-10-11, D30-11-8, D32-10-8, D32-10-12, D33-9-2; third row, D33-9-3, D33-9-16, D33-9-18, D33-11-5, D34-6-11, D35 from collapsed face; fourth row, E32-9-5, E32-10-2, E32-11-3, E32-11-4, E34-4-2, E34-5-5; fifth row, E34-6-11, E34-7-18, E34-9-4, E34-10-1, F30-10-6, F35-8-2.

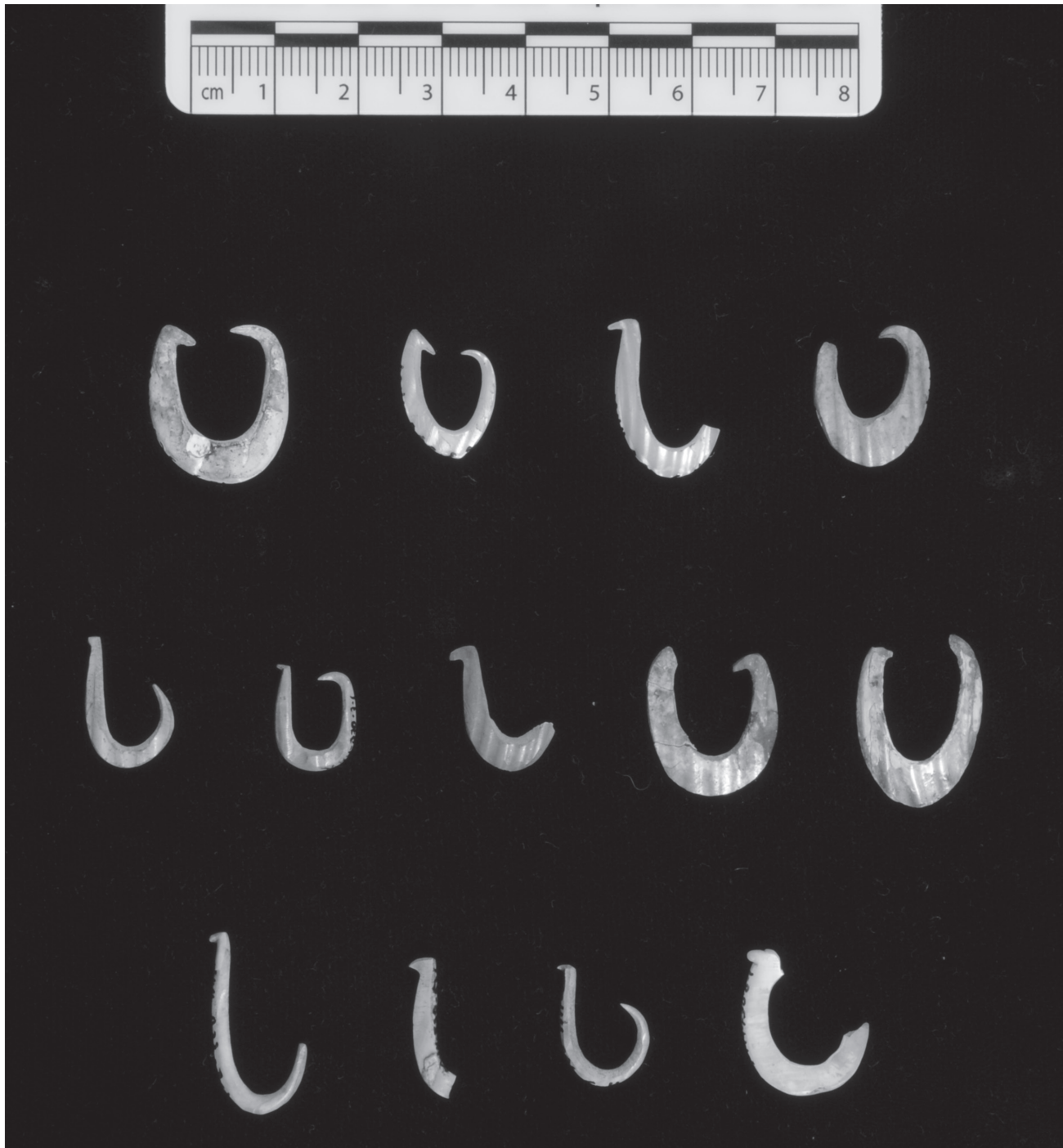


Figure 10.26. Selected *Turbo* shell fishhooks from site MAN-44: top row (l to r), A25-6-1, A25-6-3, A25-6-4, C30-3-1; second row, C30-4-5, D30-3-1, D30-4-2, D30-4-3, D32-5-3; bottom row, D33-7-1, E30-5-1, E31-6-4, F30-8-1.

butt. A single hole near the butt end (4 mm in diameter) facilitated hafting.

Six other complete tattooing combs are similar in being made from long bone shafts, possibly of a large bird such as a *Fregata* sp. (Figure 10.27b; Figure

10.28). The longest is 31.5 mm in length and the shortest is 25.5 mm; thickness ranges from 1 to 2.9 mm. One has six sharp, needle-like tines; three have five tines (although some were broken during use); one has four tines; and one has two tines. All have

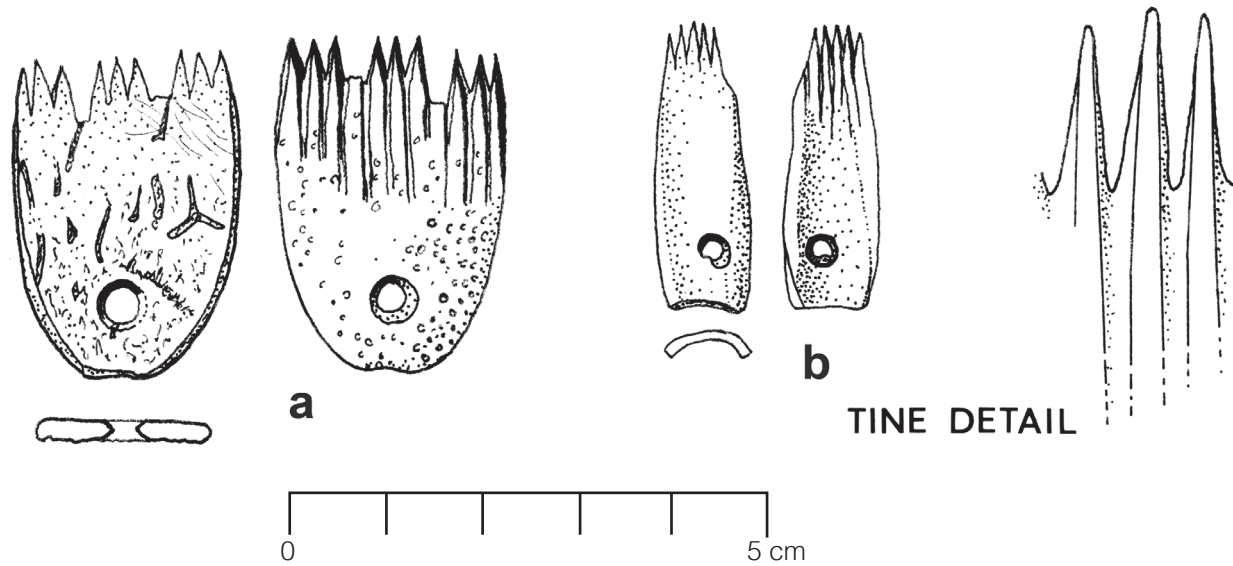


Figure 10.27. Tattooing combs: a, C30-9-1; b C30-9-5.

a single drilled hole, 3 to 4 mm in diameter, near the butt end to facilitate lashing to a handle. In all cases, the butt end is also slightly concave; in one case, the sides opposite the hole are also concave, features probably intended to facilitate lashing a fine cord to the comb. There are two other fragments of this type of comb, one of a butt end with perforation and the other of a tip with five tines.

One specimen cannot be described as a “comb” because it has only a single point (Figure 10.28g); this also lacks a perforation for hafting. It is really just a sliver of long bone, and it might not be identifiable as a tattooing instrument except for the fact that the distal portion is covered with a dark black ink stain. Several other tattooing combs also show traces of black ink.

Early European accounts (quoted in Hiroa 1944:127) make it clear that the early nineteenth-century Manganians practiced tattooing, an art that was widespread throughout Polynesia. Hiroa (1944:128), however, who made an exhaustive study of Cook Islands material culture in museum collections worldwide, reported that “so far as I know, no old [tattooing] instrument from the Cook Islands has been preserved.” This statement renders the collection of tattooing combs from Tangatatau Rockshelter of particular importance in providing a material record of this important art form.

Pendants and Beads

A necklace segment from zone SZ-15 consists of a rectangular plaque of shell, measuring 33.2 mm long by 17.5 mm high, with two perforated lugs extending another 5 mm above the top of the plaque (Figures 10.29, 10.33i). The shell is a large species of *Conus*. This object is clearly identical in form to what Hiroa (1944:111–114, Figures 58, 59) calls “ivory necklaces,” which were unique to Mangaia Island and incorporated several kinds of elements all lashed to a cord of braided sennit. The piece from MAN-44 matches closely the “four-sided plates” described and illustrated by Hiroa, including the suspension lugs. The only difference between the ethnographic museum pieces described by Hiroa and our archaeological specimen is that the object from MAN-44 is made from shell, whereas the museum pieces are all of whale ivory or bone. It may well be that, prior to European contact, these ornaments were made of shell, but following contact with whaling ships, the necklace elements began to be manufactured with whale tooth ivory obtained from visiting ships.

A small porpoise (*Delphinidae*) tooth (G35-5-5) from feature F15 has been drilled through the root for suspension, probably as a pendant (Figure 10.30); the root had broken off through the perforation. A fragment of a bone bead (D33-2-3), 24.3 mm long, came from zone SZ-15. The bead has a grooved lip at either end and is well polished. It may be from the phalanx of a pig.

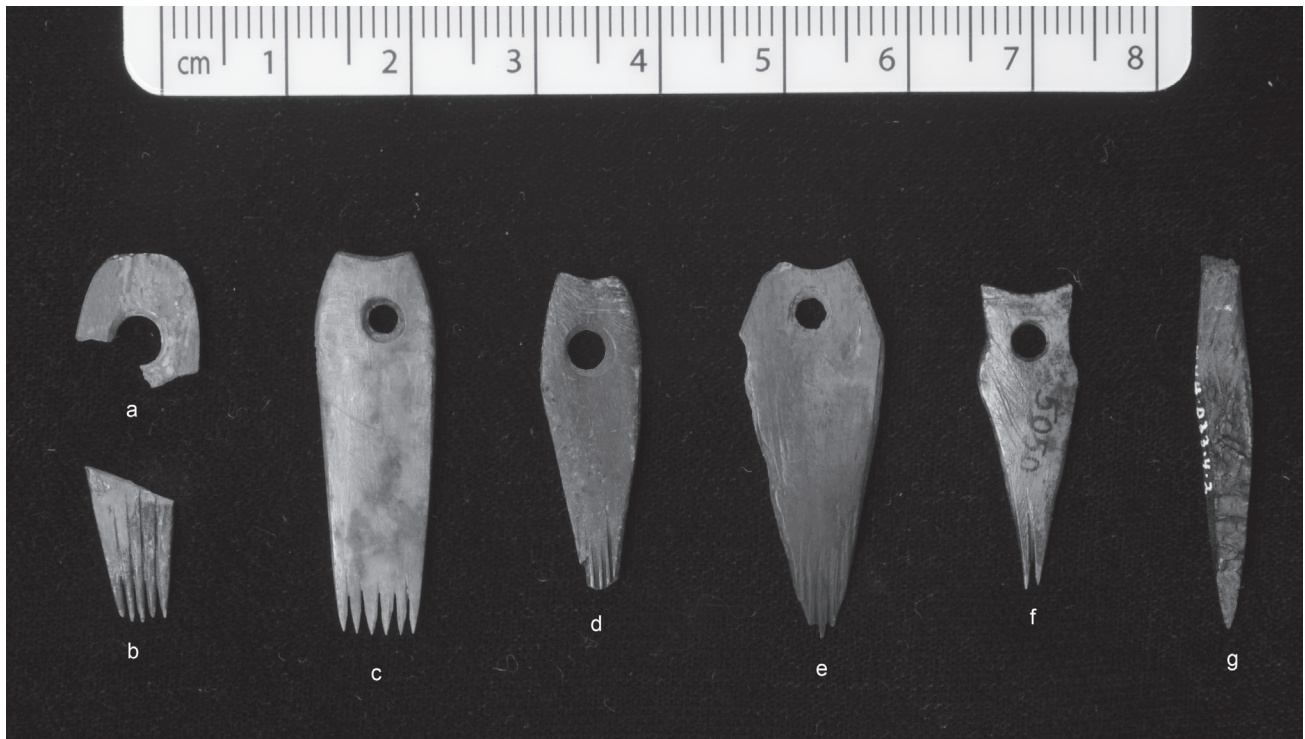


Figure 10.28. Tattooing combs: a, D32-10-11; b, C31-4-2; c, D31-7-5; d, D31-13-4; e, E33-9-19; f, D33-9-36; g, D33-4-6.

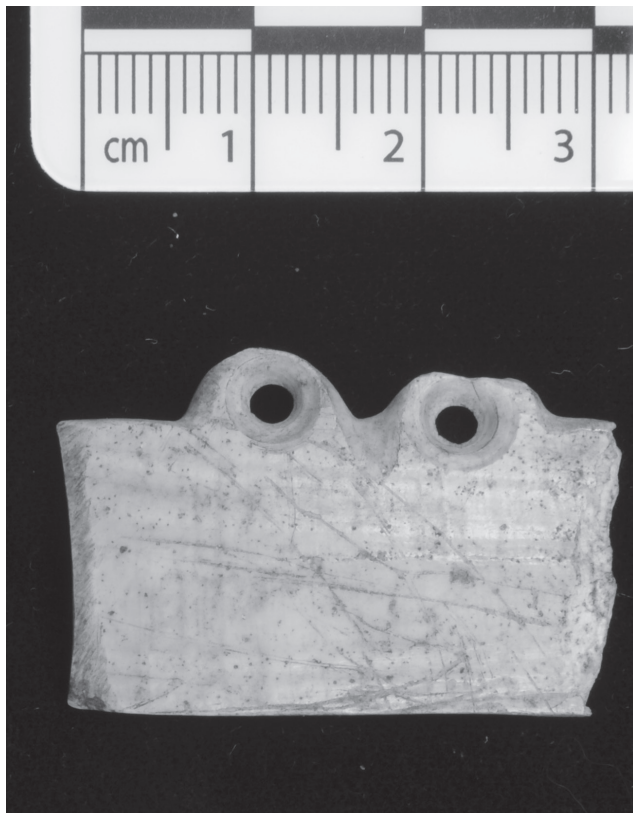


Figure 10.29. Shell necklace segment (E32-2-1).

An unusual artifact, which may have functioned as a pendant or ornament of some kind, is the sternum of a chicken (*Gallus gallus*). As seen in Figure 10.31, the bone has two drilled holes, presumably for suspension.

Miscellaneous Artifacts

Tupe Gaming Stone

From zone SZ-15 we recovered a nearly perfectly round disc (79 mm diameter) of *Porites* coral, well ground and smoothed (Figure 10.32). The two sides have slightly convex, curved surfaces, with thicknesses at the rim of 17.4 mm and at the center of 26.7 mm. Our Mangaian workmen immediately identified this object as a pitching disk for the game of *tupe*. Hiroa (1944:254–256) describes *tupe* as a pitching game “somewhat resembling the modern ship game of shuffle board” in which discs were “pitched onto plaited coconut-leaf mats. . . . The game was played as a four-some, two opponents seating themselves behind each mat.” Hiroa (1944:Figure 158) describes *tupe* pitching discs from Mangaia as being made of wood, with a flat bottom and conical top, and does not mention discs of coral. Our informants, however, had no hesitation in identifying this coral disc as a *tupe* gaming piece.

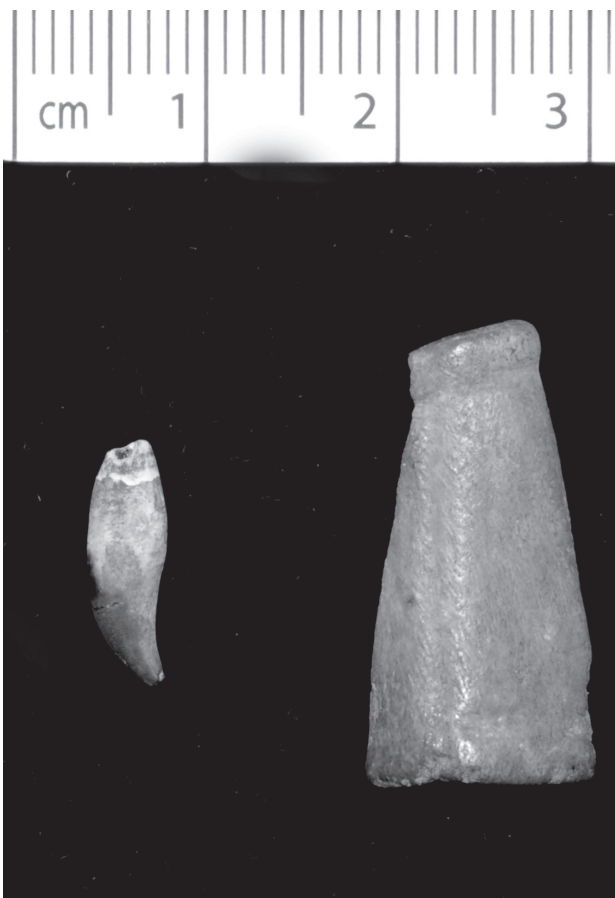


Figure 10.30. Drilled porpoise tooth (G35-5-5) and fragment of a bone bead (D33-2-3) from site MAN-44.

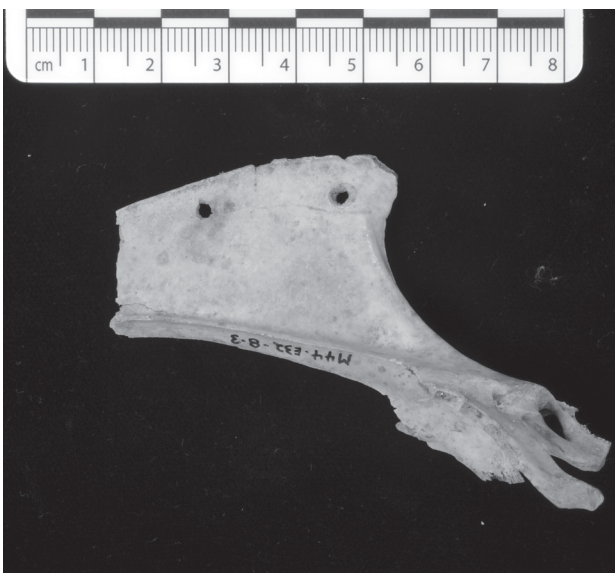


Figure 10.31. Chicken sternum with holes drilled for suspension (E32-8-3).

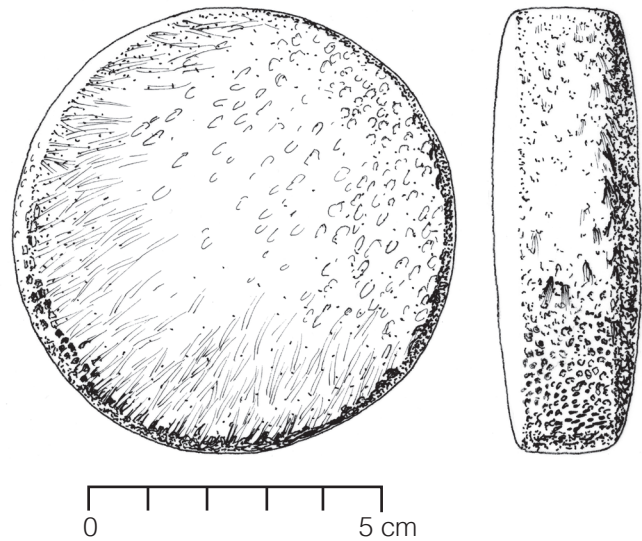


Figure 10.32. Tupe gaming disc (C30-2-1).

Worked Bone and Shell

A number of worked bone and shell objects were found during the MAN-44 excavations, mostly representing artifacts either abandoned during manufacturing or the detritus from artifact production. A selection of these objects is illustrated in Figure 10.33. Figure 10.33a shows a section of pig tibia from zone SZ-8, which appears to have been discarded while in the process of removing a series of bone bead blanks (see also Figure 10.32). In Figure 10.33b, the end of a pig humerus that has been cut and discarded is illustrated (see also Figure 10.34). A small rectangular bone plaque is shown in Figure 10.33c, while a larger rectangular piece of cut bone is seen in Figure 10.33d. The function of such bone plaques is not known, although they might possibly have served as net gauges. The four objects illustrated in Figure 10.33e–h are all cut pieces of pearl shell, probably early stages of preforms for small fishhooks. Objects shown in Figure 10.33j–m are likewise small fishhook blanks that have been drilled with either one or two perforations. The process of fishhook manufacture is described in greater detail in Chapter 11.

Basalt Sphere

A piece of basalt, shaped into an almost perfect sphere by pecking, was recovered from zone SZ-3. The sphere, with a diameter of 42.5 mm, may have functioned as a slingstone (Figure 10.35). Hiroa (1944:302–303, Figure 189) mentions spherical slingstones made of basalt from the Cook Islands.

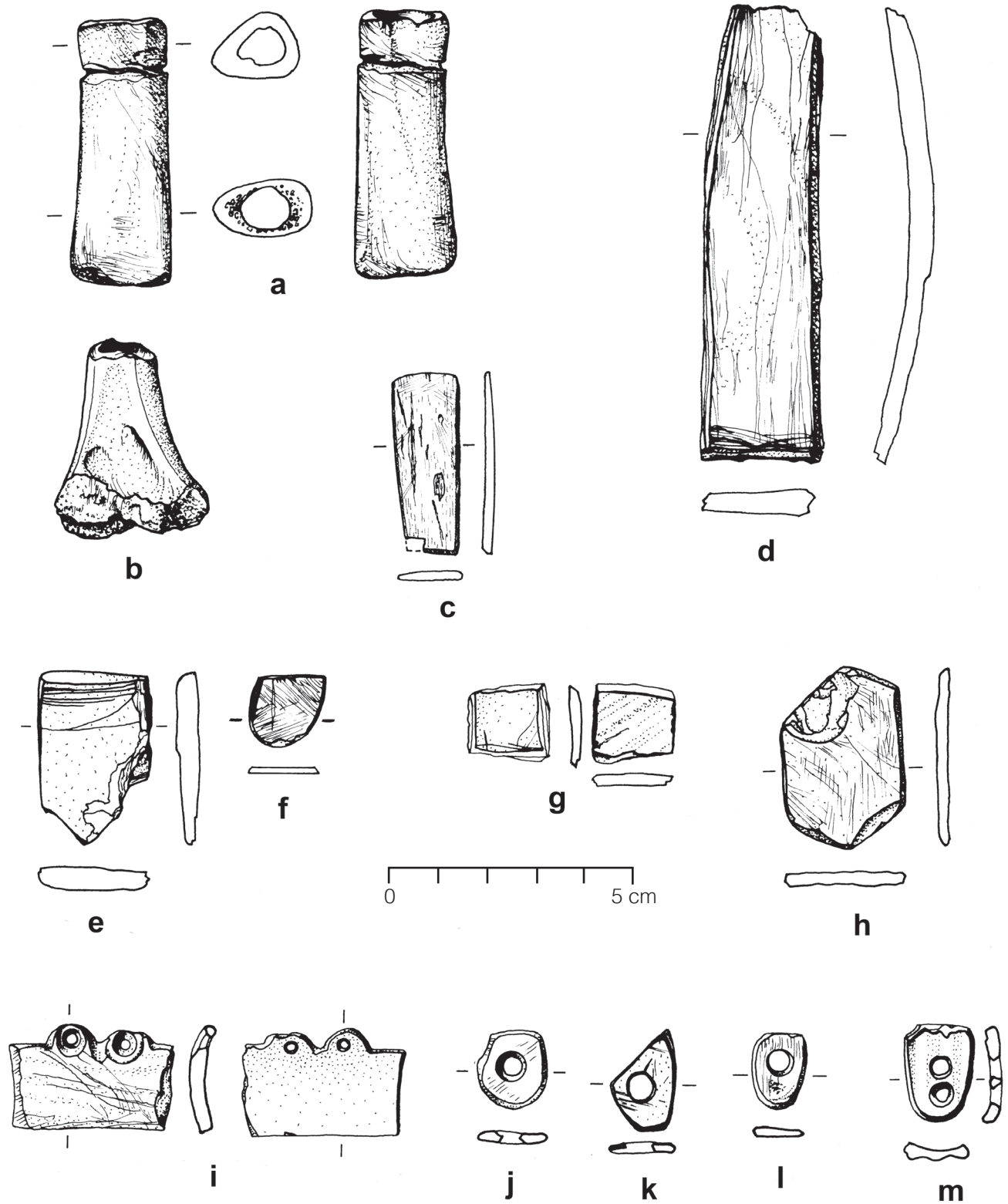


Figure 10.33. Worked bone and shell objects: a, D32-3-8; b, D35-1-1; c, I30-7-2; d, E34-6-40; e, E36-6-10; f, F30-11-2; g, F30-9-1; h, D34-9-7; i, E32-2-1; j, E35-7-4; k, D31-7-7; l, D30-5-2; m, A25-6-2.

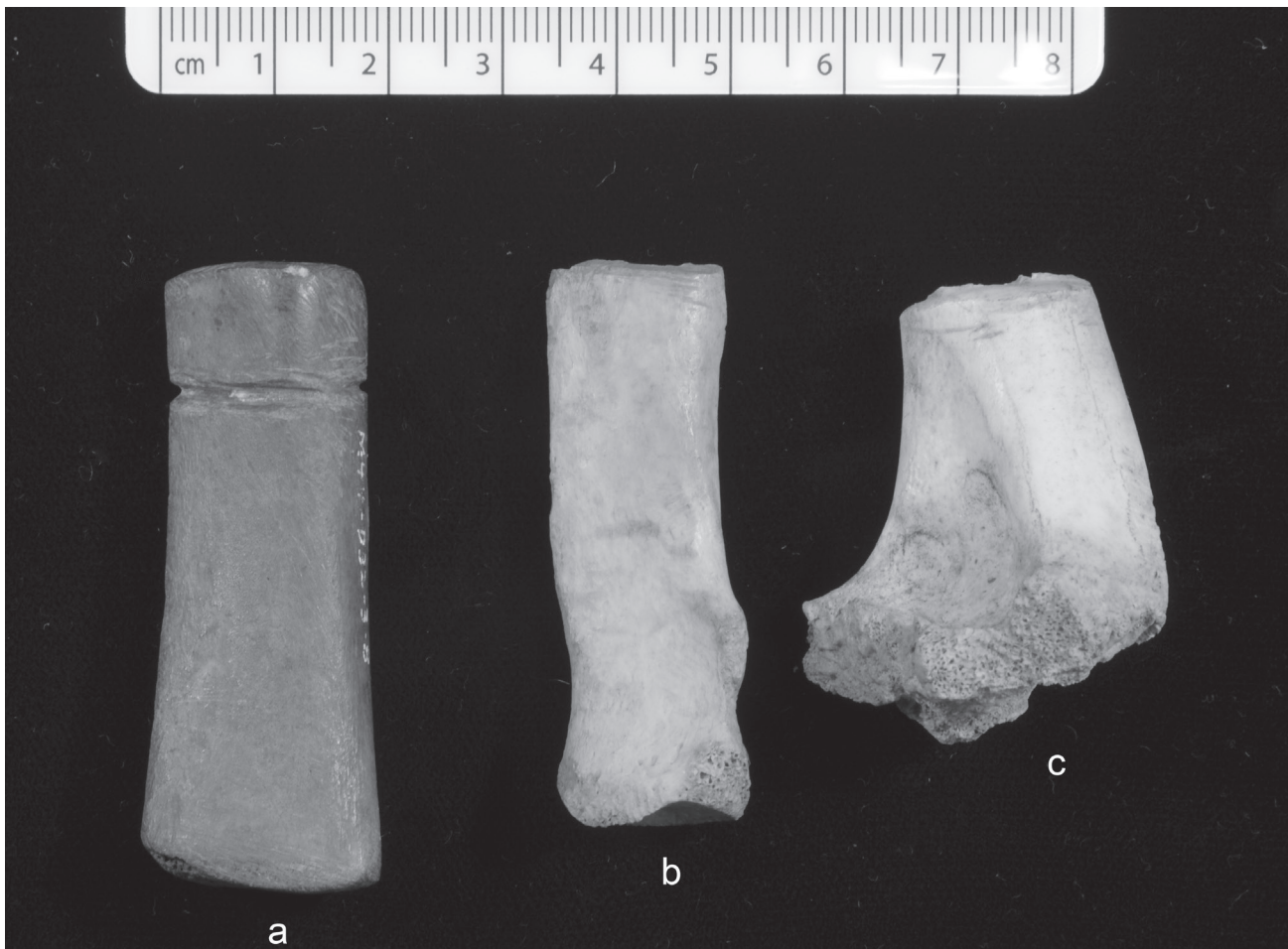


Figure 10.34. Selected specimens of worked bone from site MAN-44: a, section of pig tibia with bead segment partly defined by sawing (D32-3-8); b, pig radius with cut end (E34-6-6); c, pig humerus with cut end (D35-1-1).

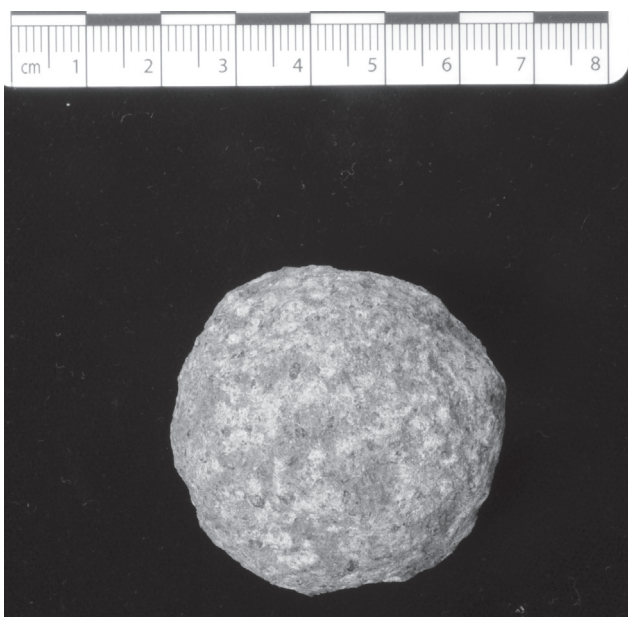


Figure 10.35. Basalt sphere, possible slingstone (C31-9-3).

Calcite Spheres

Twelve spherical (or, in two cases, more discoid) objects made of pecked calcite (derived from stalactites or stalagmites obtained in the *makatea* caverns) were found during excavation (Figure 10.36). The smallest has a diameter of 24.5 mm and the largest 65.4 mm. The calcite would seem too fragile to have served as hammerstones, and these objects do not appear to be fragments of calcite pounders (see below). It is quite likely that some of them might have served as slingstones, following Hiroa's (1944:302–303, Figure 189) description of spherical slingstones in the Cook Islands. One sphere came from zone SZ-2, four each from SZ-3 and SZ-4A, and one each from zones SZ-5, SZ-6, and SZ-8.

Calcite Pounder Fragments

Food pounders of various conical forms are typical Eastern Polynesian artifacts; in most islands, they were made of basalt. In Mangaia, however, calcite derived

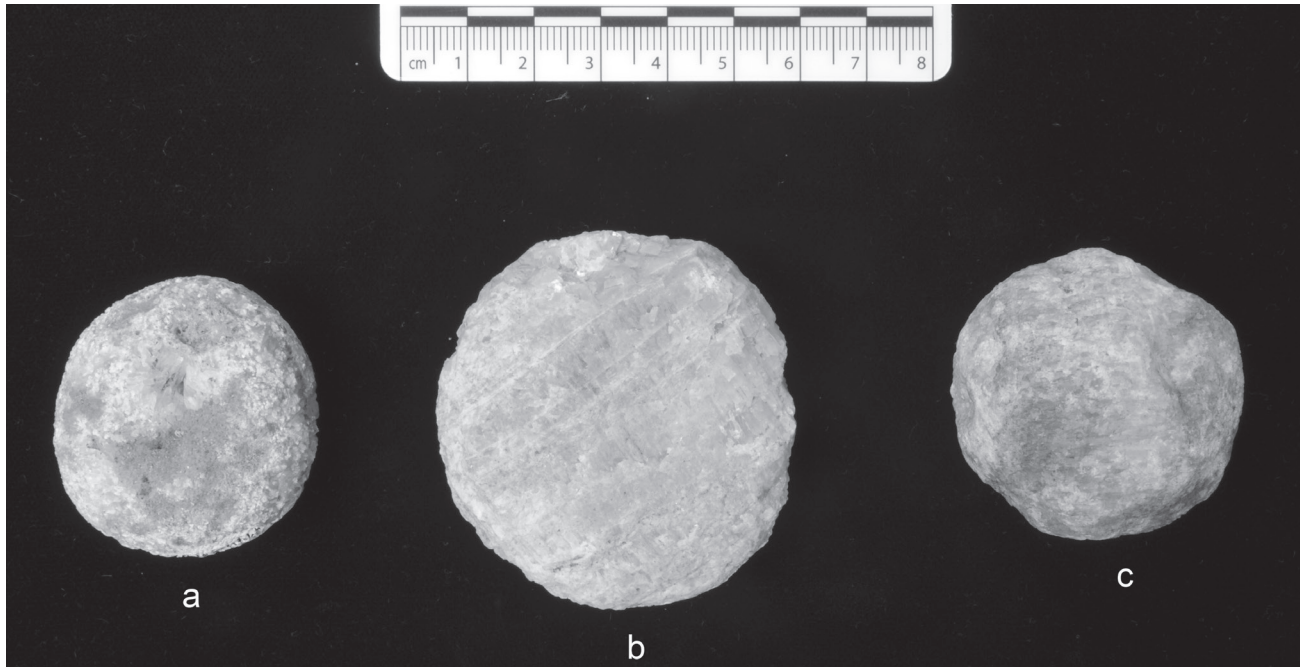


Figure 10.36. Selected examples of calcite spheres from MAN-44: a, C31-6-6; b, D33-6-1; c, E35-6-8. Specimens a and c are spherical, while b is more discoid in shape.

from stalactites and stalagmites in the *makatea* caverns was extensively used to produce pounders, usually with a distinctive T-shaped head (Hiroa 1944:32–33, Figure 9). Three fragments of calcite pounders were recovered at MAN-44. One specimen (D32-3-4) from zone SZ-8 is a well-shaped lug from a T-handle type of pounder (Figure 10.37, left). Another specimen (D33-7-6) from zone SZ-5 also appears to be such a lug but from a larger and heavier pounder (Figure 10.37, center). A third specimen (E32-8-2), also from zone SZ-5, appears to be the end of a lug or perhaps the head of a cylindrical pounder (Figure 10.37, right).

Euro-American Artifacts

A small number of historic artifacts of Euro-American origin were recovered from zone SZ-17. The base of a heavy, three-piece mold-made bottle of black glass bears the lettering “C. W. & Co.” (Figure 10.38a); this kind of bottle ceased to be manufactured after about 1880. A second bottle base, of olive green glass, was manufactured in a two-piece mold; this is characteristic of whiskey bottles manufactured between about 1845 and 1920. A clay pipe stem and partial bowl (Figure 10.38b) was obviously curated for some time, as the broken, short stem shows evident teeth marks. A copper alloy on iron pants button has wording that reads, in part,

“Non-tarnish . . .” (Figure 10.38d). Finally, a Prosser-type ceramic button (Figure 10.38c) dates to post-1840. All of these objects are consistent with a date in the second half of the nineteenth century, suggesting some use of the rockshelter into that time period.

Discussion and Conclusions

Material Culture and Site Function

The range of artifact classes represented in the various stratigraphic zones at site MAN-44 provides an important line of evidence bearing on the site’s function at different points in time and on the specific kinds of activities carried out within the rockshelter. The distribution of artifact classes by stratigraphic zone, summarized in Table 10.1, makes it clear that the greatest concentration and diversity of portable artifacts is found from zones SZ-2 to SZ-8, with fewer artifacts in zones SZ-9 and higher. It is also clear that the heaviest concentration of artifacts, and greatest range of functional classes, occurs in zones SZ-2, SZ-3, and SZ-8. These three zones were clearly all deposited as a result of intensive occupations, during which a significant range of activities took place, including basalt lithic working, adze production and maintenance, the manufacture and repair of shell fishhooks, and food processing and consumption. The presence of tattooing

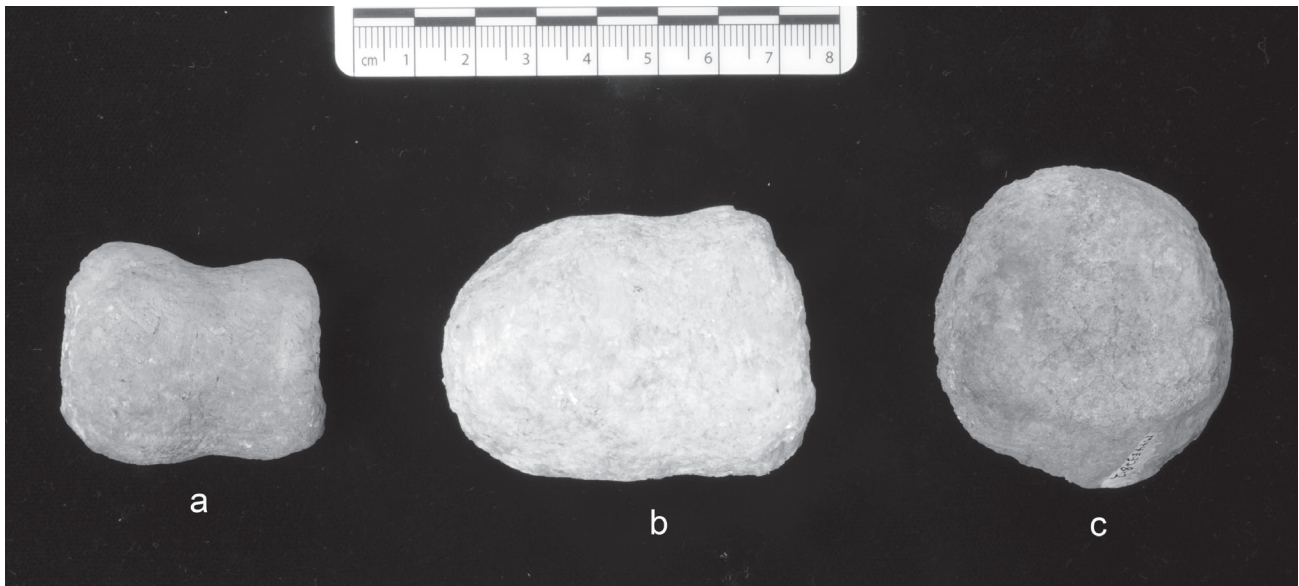


Figure 10.37. Fragments of calcite food pounders: a, D32-3-4; b, D33-7-6; c, E32-8-2.

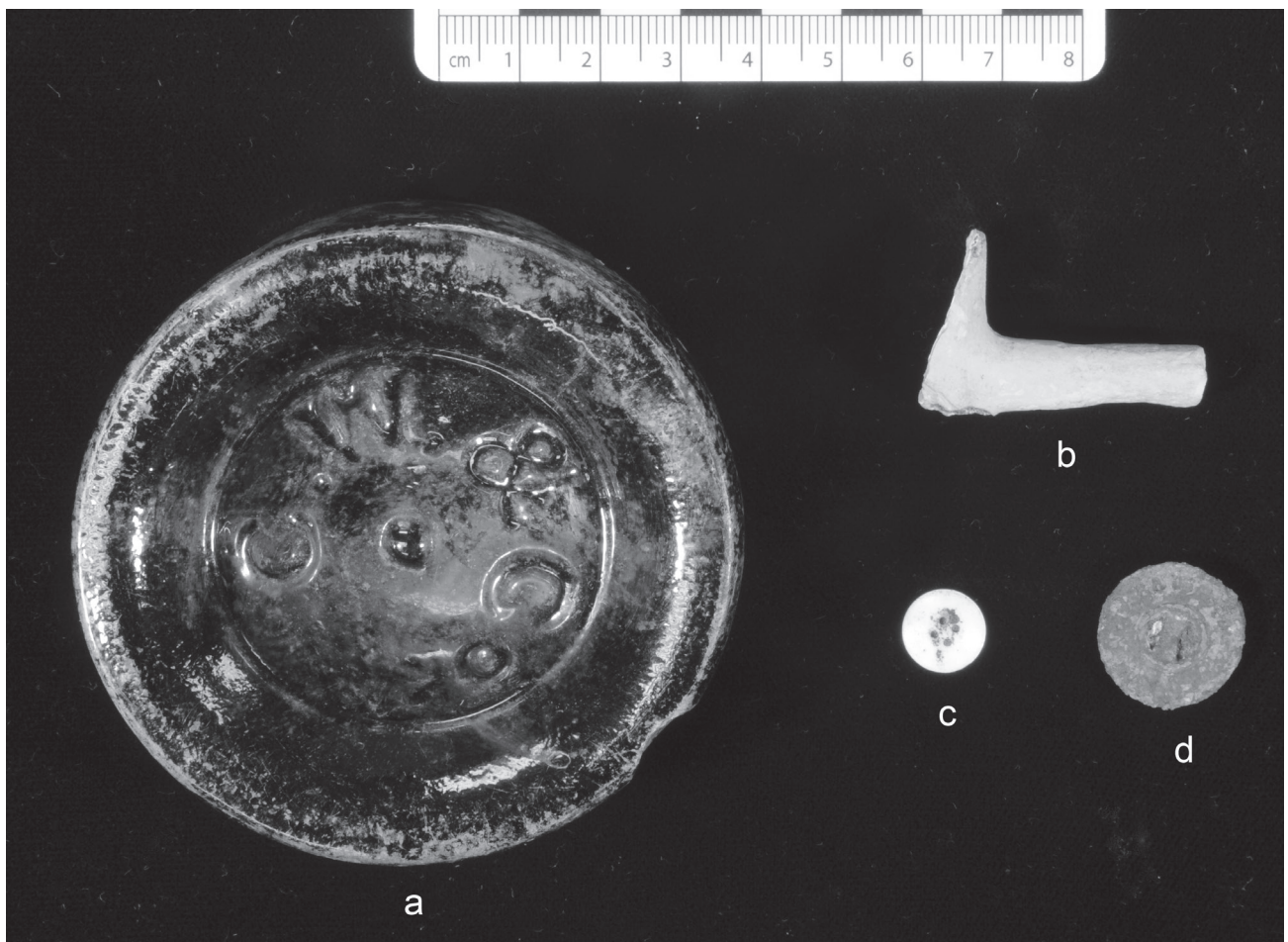


Figure 10.38. Artifacts of Euro-American origin: a, glass bottle base, A25-1-1; b, clay pipe stem, C30-1-2; c, milk glass button, D30-2-2; d, copper button, C30-1-1.

combs in zones SZ-3 and SZ-4A/B (the latter probably incorporating materials redeposited from SZ-3) further indicates that tattooing was practiced within the confines of the rockshelter during the early occupation phase. Such a range of activities would be consistent with the rockshelter serving as a primary habitation site, with both genders present, quite likely the abode of an extended family or household.

The frequency and density of basalt lithic debitage within the rockshelter provides further clues as to changing intensity of adze and other stone tool production over time. Figure 10.39 displays data on non-retouched basalt flakes from the major stratigraphic zones in the main excavation block. The upper diagram is a plot of total numbers of flakes per stratigraphic zone, while the lower diagram shows flake density as a concentration index (flakes/m³ of excavated deposit). In terms of sheer numbers of basalt flakes, zones SZ-3 and SZ-8 clearly stand out, indicating that these were periods of intensive basalt knapping. When we consider flake density, however, it is also apparent that all of the lower zones from SZ-2 to SZ-10 (with the exception of SZ-9) have densities of 300 flakes per cubic meter or greater. Thus, although zones SZ-3 and SZ-8 do stand out for their particularly high frequency of flakes, it is apparent that lithic reduction was an important activity throughout much of the time that Tangatatau Rockshelter was used. In the higher zones (SZ-11 through SZ-17), the relatively low numbers and densities of basalt flakes suggest that adze production or other lithic working was not very significant.

Long-Distance Interaction in Eastern Polynesia

Over the past two decades of archaeological research in Eastern Polynesia, it has become increasingly evident that once discovered and colonized by early Polynesians, the newly established communities on the islands and archipelagoes scattered over this vast expanse of the eastern Pacific did not immediately become isolated from each other. Having the sailing technology and navigational skills to discover these remote islands, the early Eastern Polynesians were also capable of maintaining interisland and intercommunity contacts and interaction networks. Most of the evidence to support an interpretation of extensive inter-archipelago contact has been the result of increasing technical sophistication in the geochemical characterization of stone adzes, permitting these artifacts to be sourced to specific islands and in some cases individual

quarries (see, e.g., Allen 1996b; Rolett 1998; Rolett et al. 2015; Walter 1998; Weisler 1993, 1998; Weisler et al. 2016).

The material culture record from Tangatatau Rockshelter adds considerably to this emerging picture of widespread long-distance interaction in Eastern Polynesia. The best evidence, once again, comes from the adze assemblage, where geochemical analysis shows that although the majority of adzes produced or used in the rockshelter were made with local rocks (the Mata'are and Veitatei sources), a not inconsequential number of adzes derived from external sources. In the earliest two occupation deposits (SZ-2 and SZ-3), we have evidence of adzes or adze stone being imported from Rurutu in the Austral Islands and Eiao in the Marquesas, as well as from Samoa in Western Polynesia. While the Eiao source soon dropped out, importing of adzes from Rurutu continued as late as zone SZ-8. What is especially noteworthy, however, is the later importation of adzes from Rarotonga (the nearest island to Mangaia) but also from Samoa. Among other implications, it seems that the cultural "boundary" between Eastern and Western Polynesia was to some degree "porous."

The implications from the adze geochemical data that Mangaia was—at least for the first few centuries after its settlement—connected to a wider interaction network are reinforced by the evidence of pearl shell artifact distribution in site MAN-44. The pearl oyster, *P. margaritifera*, does not occur naturally on Mangaia due to the absence of a lagoon, the oyster's habitat. Yet pearl shell artifacts, especially fishhooks, are common in zones SZ-2 to SZ-4 and present up through zone SZ-8. The pearl shells from which these hooks and other objects were made must have been imported from other islands possessing the lagoonal habitat of the pearl oyster. Aitutaki Island would have been a likely source of pearl shell, although by no means the only one. *T. setosus* shell was used to make fishhooks from the beginning of the Tangatatau sequence, which is not surprising given that *Turbo* shell has a deeper history of use for fishhooks going back to the Ancestral Polynesian period in Western Polynesia (see, e.g., the *Turbo* shell hooks from the To'aga site in Samoa, described by Kirch [1993]). Clearly, however, pearl shell was the preferred material for making fishhooks at Tangatatau up until about zone SZ-5, when *Turbo* shell hooks begin to become more frequent. It seems unlikely that this shift was due to a sudden preference

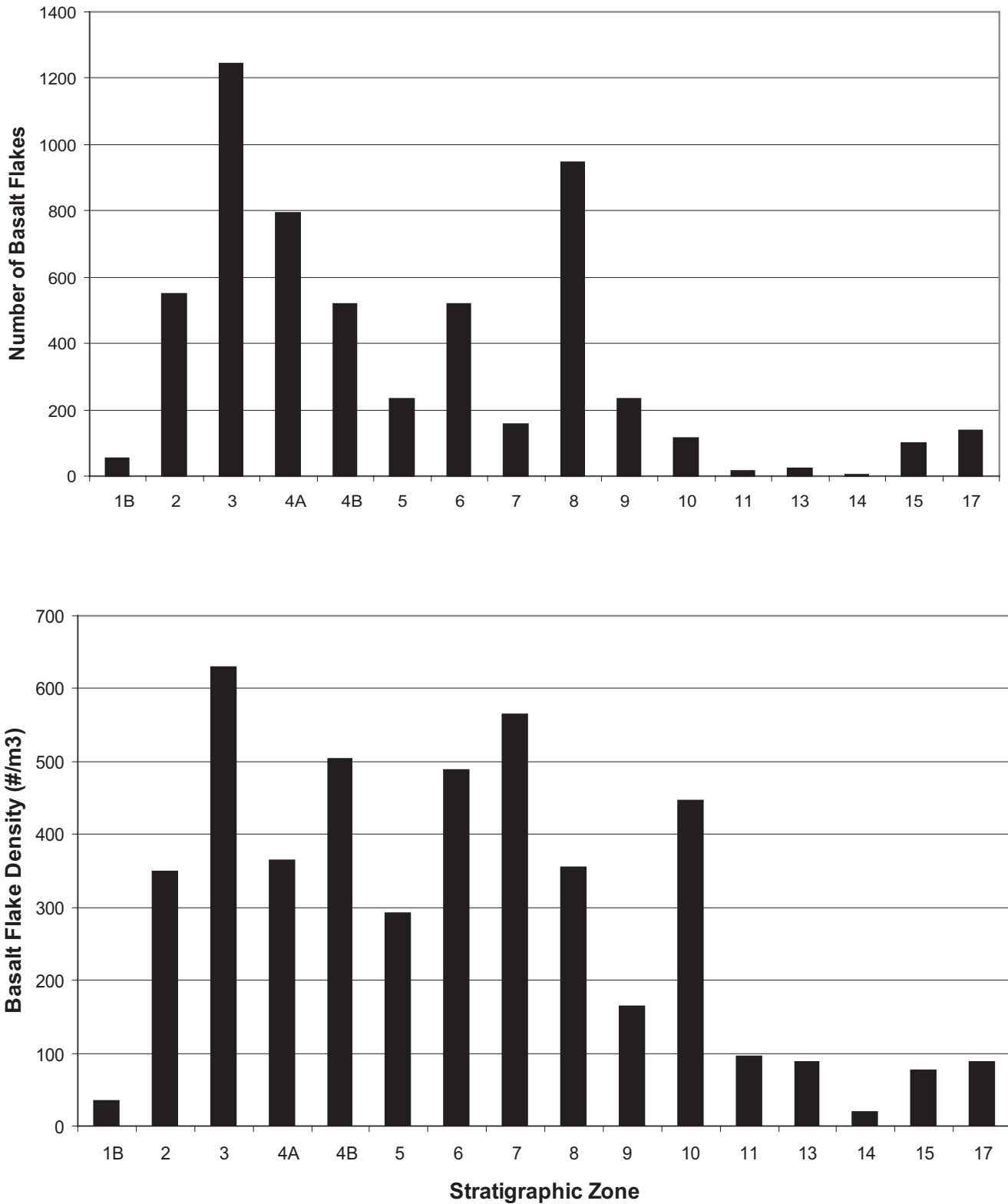


Figure 10.39. Flaked basalt debitage by stratigraphic zone in site MAN-44. Upper histogram: numbers of basalt flakes by stratigraphic zone. Lower histogram: density of basalt flakes (#/m³) by stratigraphic zone.

for the smaller, harder-to-work, and weaker *Turbo* shell, which is definitely inferior to pearl shell. Rather, the likely explanation was that pearl shell had become more difficult to obtain, probably as a result of the contraction of the formerly more extensive interaction network, severing ties with sources of the pearl oyster.

Technological Change

Finally, the record of material culture within Tangatatau Rockshelter provides us with several insights regarding the processes of technological change on Mangaia over a span of about five centuries. Technological changes are especially evident in the stone adzes and shell fishhooks, both of which are represented by large sample sizes.

The early adze kit, represented by 12 specimens from zones SZ-2 and SZ-3, is consistent with adze assemblages from other early Eastern Polynesian sites in being dominated by forms with quadrangular cross sections and lacking a developed tang (that is, Duff types 1, 1A, and 2A). That some experimentation with triangular-sectioned forms was already under way,

however, is indicated by the presence of two adzes of Duff type 3 (see Table 10.3). From zones SZ-5 and higher up in the stratigraphic sequence, adzes with triangular cross sections dominate (Duff types 3, 3A, and 3D). Moreover, considerable effort was now devoted to producing pronounced tangs, which are highly characteristic of ethnographically documented Cook Islands adzes (Hiroa 1944).

With the shell fishhooks, there were significant changes both in the materials used and in fishhook form (see Chapter 11). As noted above, a shift from pearl shell dominating in the early assemblages to *T. setosus* shell in the later assemblages was almost certainly a consequence of declining external interaction and lack of access to the pearl oyster shell. This shift in material may partly be responsible for the decline in type II (curved shank) hooks, which are quite frequent in the early deposits but rare or absent in the higher strata. The changes in fishhook morphology, however, may also have been driven by other factors, whether functional or stylistic (Allen 1992a, 1996a).

11

The Tangatatau Fishhook Assemblage: A Typological Analysis

Christelle Carlier

The fishhook assemblage from Tangatatau Rockshelter is one of the largest recovered from a Cook Islands site with a well-informed stratigraphic context. A large part of the material culture of this site consists of fishing gear, including fishhooks (complete or partial), as well as blanks or cut and worked shells, demonstrating in situ fishhook manufacturing. The fishhook corpus from MAN-44 is composed of a total of 340 pieces. Among these, we focus first on the well-defined pieces, especially the finished hooks (260 pieces) and the worked shells and blanks (59 pieces for these two categories). To

these are added three indeterminate pieces and 16 indeterminate significant worked shells (Table 11.1).

One-piece fishhooks are the most frequent at MAN-44, representing 76.4 percent of the total assemblage and 99.2 percent of the determinate pieces. Only two specimens are two-piece fishhooks (bonito-lure shanks), illustrated in Figure 11.1. The Tangatatau hooks were manufactured from two species of shell, pearl shell (*Pinctada margaritifera*), which dominates in the deeper zones, and *Turbo setosus* shell, which is more common in the higher zones.

Table 11.1. The Fishhook Assemblage, Site MAN-44.

Category	Finished Fishhooks	Unfinished Fishhooks
One-piece fishhooks:	260	
<i>Complete</i>	13	
<i>Incomplete</i>	50	
<i>Fragments</i>	197	
Two-pieces fishhooks	2	
Blanks		31
Worked shell		28
Total of the determinate pieces	262	59
Indeterminate pieces		3
Worked shell detritus		16
Total		340



Figure 11.1. Troling lure shank fragments of pearl shell from MAN-44: a, D34-5-9; b, D34-7-15.

In this chapter, the morphology of the complete and incomplete pieces will first be examined in terms of fishhook typology. The many fragments, representing 75.7 percent of finished one-piece fishhooks, are then analyzed, followed by a consideration of spatial and stratigraphic distribution in the rockshelter. Finally, we will analyze the blanks and worked shells (59 pieces) to shed light on the manufacturing process.

Complete and Incomplete One-Piece Fishhooks

A total of 63 specimens (13 complete and 50 incomplete fishhooks) were analyzed to establish a typology. It is necessary to clarify the designations “complete” and “incomplete” as these affect the number of attributes that can be examined methodically. Complete hooks have all the attributes to be identified and therefore are classified typologically. Incomplete hooks lack either their point (or a part of it) but retain an entire shank length, from the head to the bend, so that the shape and the type of fishhook can still be identified. Fragments are pieces providing the least information, being only isolated parts of a hook, such as a bend, point, or shank.

The classification method applied here follows Carlier and Conte (2009) and is based on an invariable principle: the shape of the shank, straight or curved in this assemblage. This gives the general shape of the hook. Other attributes then qualify the various typological ramifications (shape of the point, its length, ratio between the point and the shank, shape of the bend). For the 63 studied one-piece fishhooks from MAN-44, we can distinguish two major morphological groups: the jabbing and rotating fishhooks.

Type I: Straight Shank Fishhooks

Type I consists of fishhooks with a straight shank (Figure 11.2). This group is poorly represented at MAN-44, with only 13 pieces (4 complete and 9 incomplete). From the four complete hooks of type I, three different forms of point are evident, yielding three subtypes:

Type IA: one fishhook with a straight point (Figure 11.2a)

Type IB: two fishhooks with a curved point (Figure 11.2b)

Type IC: one fishhook with a straight point and a curved tip (Figure 11.2c). The point length (Lp) is equal to the shank length (Lsb): $Lp = Lsb$.

One must be cautious when interpreting the data from such a small sample of complete type I fishhooks. In addition to the four complete hooks of type I, all made of *Turbo setosus* shell, we can include the nine incomplete straight shank fishhooks, four of which are in pearl shell. This demonstrates that type I hooks are not only made of *T. setosus* shell, contrary to what might be inferred from the complete pieces alone. These straight shank incomplete fishhooks have an elongated shape closer to subtypes IA and IB than to subtype IC (as well in pearl shell than in *T. setosus* shell). The material for type I does not seem to be related to the shape.

Two of the nine incomplete fishhooks of type I are particular with specific proportions. One is very elongated, the ratio between the length of the shank (32 mm) and its width (2.5 mm) being small, in contrast with the other hook, which looks more “robust.” The width of the shank is almost higher than the bend with a high ratio between the length of the shank (16 mm) and its width (3.5 mm).

We can see that raw material seems to be related to hook shape, including the detail of the line lashing (the head). The fishhooks in *T. setosus* shell include one with a top outer knob (C-form, with a top perpendicular to the axis of the shank or outward inclined).

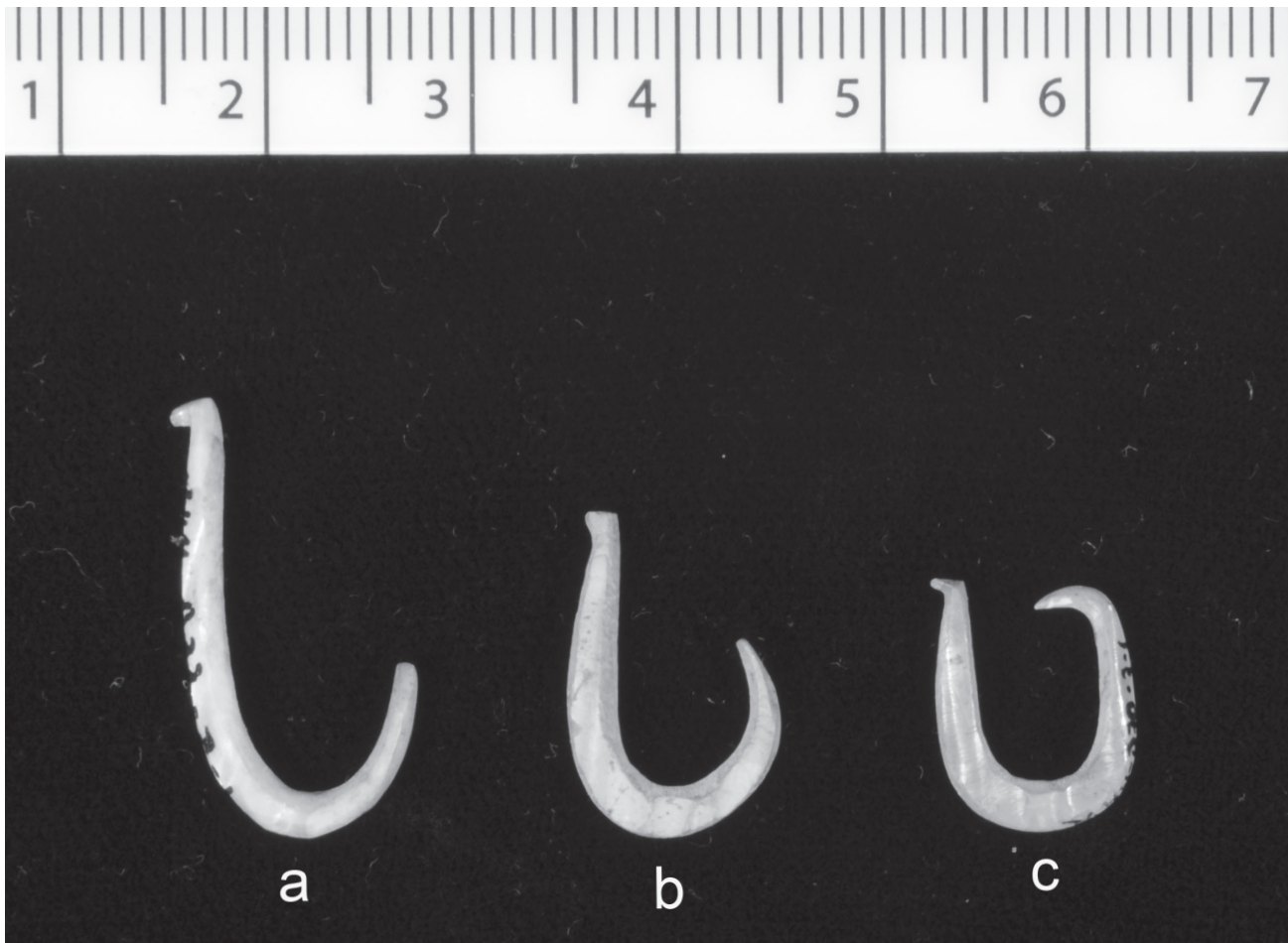


Figure 11.2. Type I fishhooks: a, D33-7-1; b, C30-4-5; c, D30-3-1.

Except for one specimen, the fishhooks in pearl shell have different head shapes: an inside notch with an outer knob (B-form) and also top outer knob (C-form) but strongly concave top.

Type II: Curved Shank Fishhooks

These fishhooks present an obvious feature: a curved shank with a curved point, showing a generally circular shape. This group of fishhooks is more widely represented in the site, with 50 specimens (9 complete and 41 incomplete). Several subtypes were determined from their general shape (shank, bend, and point) and characteristic details (shape of the head and proportions). On 46 pieces, three subtypes II are distinguished:

Type IIA includes seven hooks, all made of *T. setosus* shell, only three of which are complete (Figure 11.3). These pieces have a specific shape: a head with a top inner knob (F-form with an inner inclined top) and a strongly

curved end. This general shape gives the fishhook a symmetrical shape. We also note that the bend consists of two shapes: “U” and “V.” We note, however, variations on the height of the point: it is slightly higher than the height of the shank [$Lp > Lsb$] or equal [$Lp = Lsb$] or slightly lower [$Lp < Lsb$]. These three cases are illustrated by each of the three complete fishhooks. Their overall size does not vary much; they measure between 15 and 20 mm. This subtype is mainly made of *T. setosus* shell.

Type IIB is a typical example of circular hook with a highly curved shank and a generally circular shape [$Lsb = Lb$]. There are only one complete and eight incomplete fishhooks of this type (Figure 11.4). There is uniformity in shape, as well as in material and size. They are all made in pearl shell, and their dimensions do not vary greatly (Lsb is between 14 and 17 mm).

Type IIC is the most frequent, with 30 pieces, of which four are complete (Figure 11.5). These hooks also have



Figure 11.3. Type IIA fishhooks: a, D32-5-5; b, A25-6-1; c, A25-6-3.

a circular shape, but we set them apart from subtype IIB due to their different proportions: $Lsb > Lb$. They are all in pearl shell. Except a small (8 mm) and two large fishhooks (28 and 30 mm), their size does not vary greatly; they are between 13.5 and 21 mm. Their heads have an outer knob (C- or D-form), except two pieces whose head is shaped in C-form, but with a top concave, and in B-form, the top inclined outside.

Most of these hooks have a general U-shape, and the point is almost as high as the shank [$Lp \approx Lsb$]. However, it should be noted that one of the complete hooks is different, with a curved point (Figure 11.5d).

There are four fishhooks whose morphology is associated with type II, due to their curved shank, but for which it would be unwise to define a subtype, because of their low numbers and incomplete aspect. Two similar fishhooks (Figure 11.6) have a curved shank that is associated with a straight point, unlike the hooks discussed above. They are both in *T. setosus* shell and have similar sizes and characteristics: a head with a long top outer knob (D-form), with a domed top. With a curved shank, these fishhooks can be classified as type II, despite the fact that they are not circular, because of their straight points and the higher ratio Lsb / Lb . They might represent a possible fourth subtype of

type II, if the analysis of the fragments shows the same characteristics.

Another incomplete fishhook (in pearl shell) also stands out from the type II group with different proportions. The ratio between shank height and bend length is high, unlike the circular hooks observed above (circular fishhooks have an Lsb / Lb ratio close to 1). The bend has a long and narrow shape (Figure 11.7a). It is the largest piece of the complete and incomplete samples, with a shank height of 34 mm high.

The fourth piece showing a particular type II shape, also in pearl shell, has a point whose axis deviates from the shank (Figure 11.7b), giving the bend a very “open” shape. This incomplete hook is particular and the shape of his head also with a B-form (only five pieces, on the whole assemblage, have such a head shape).

To sum up, we have defined two major morphological types: type I fishhooks with a straight shank, comprising 20.5 percent of the complete and incomplete hooks, and type II, fishhooks with a curved shank, which are more numerous (79.5 percent of the assemblage). Both types encompass three subtypes each and three particular shapes associated with type II. We now turn from morphology to fishhook size, as this may also inform us regarding the function and use of the hooks.

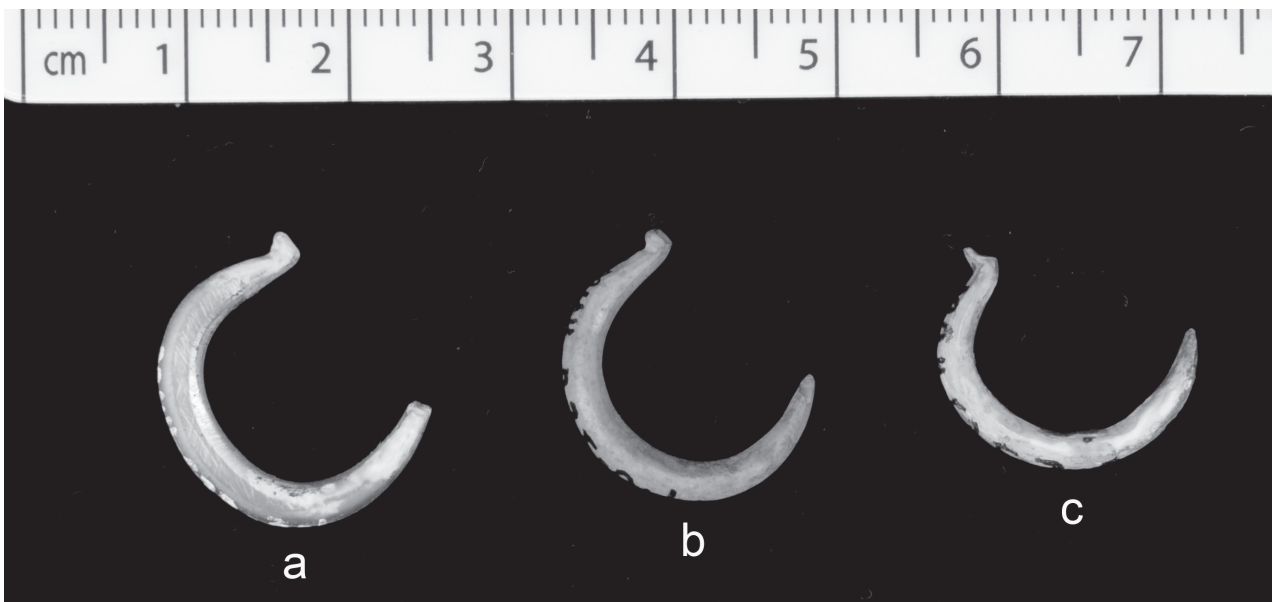


Figure 11.4. Type IIB fishhooks: a, C32-3-1; b, D35-0-1; c, E35-7-6.

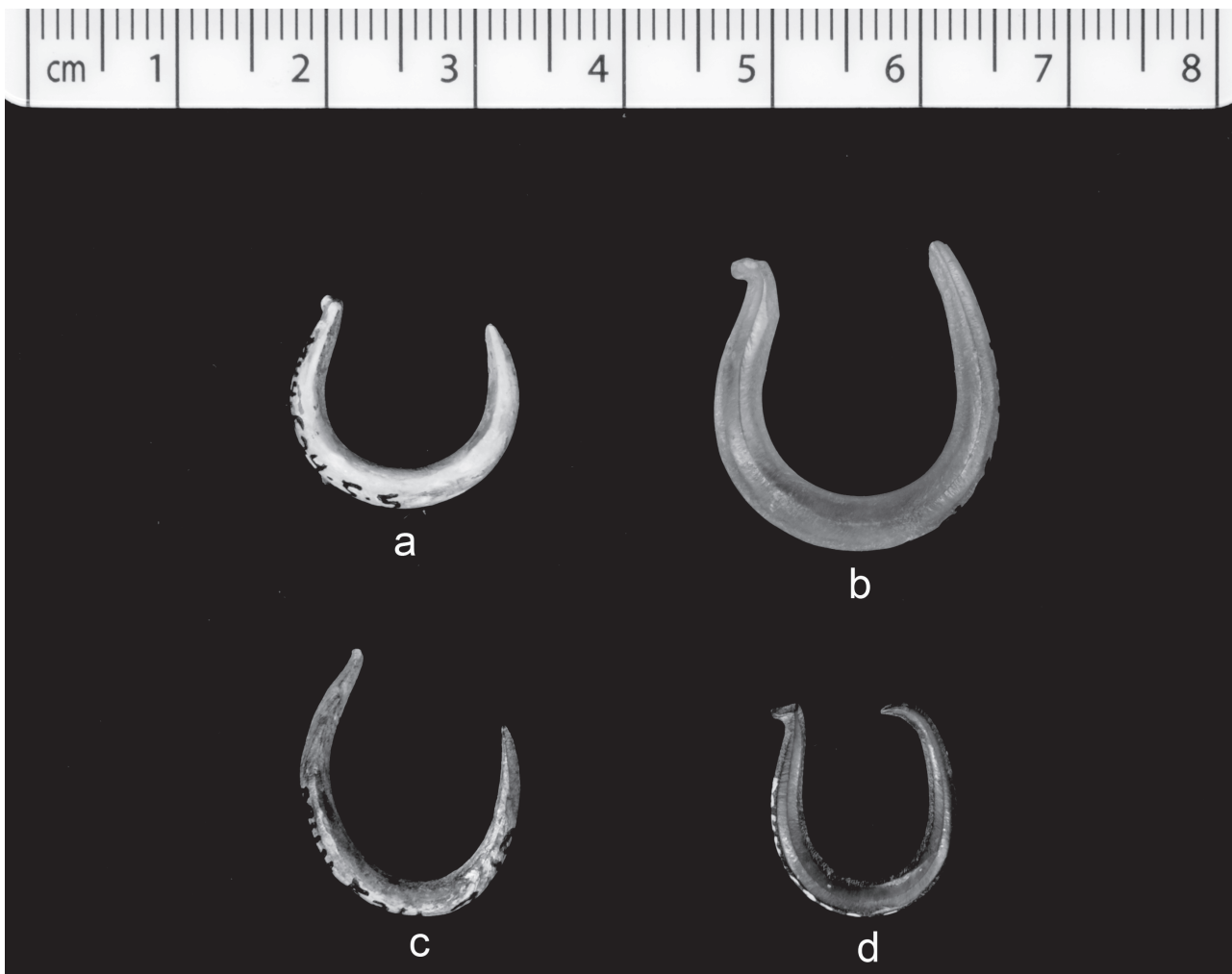


Figure 11.5. Type IIC fishhooks: a, E34-5-5; b, D30-10-4; c, E34-7-18; d, C32-3-2.

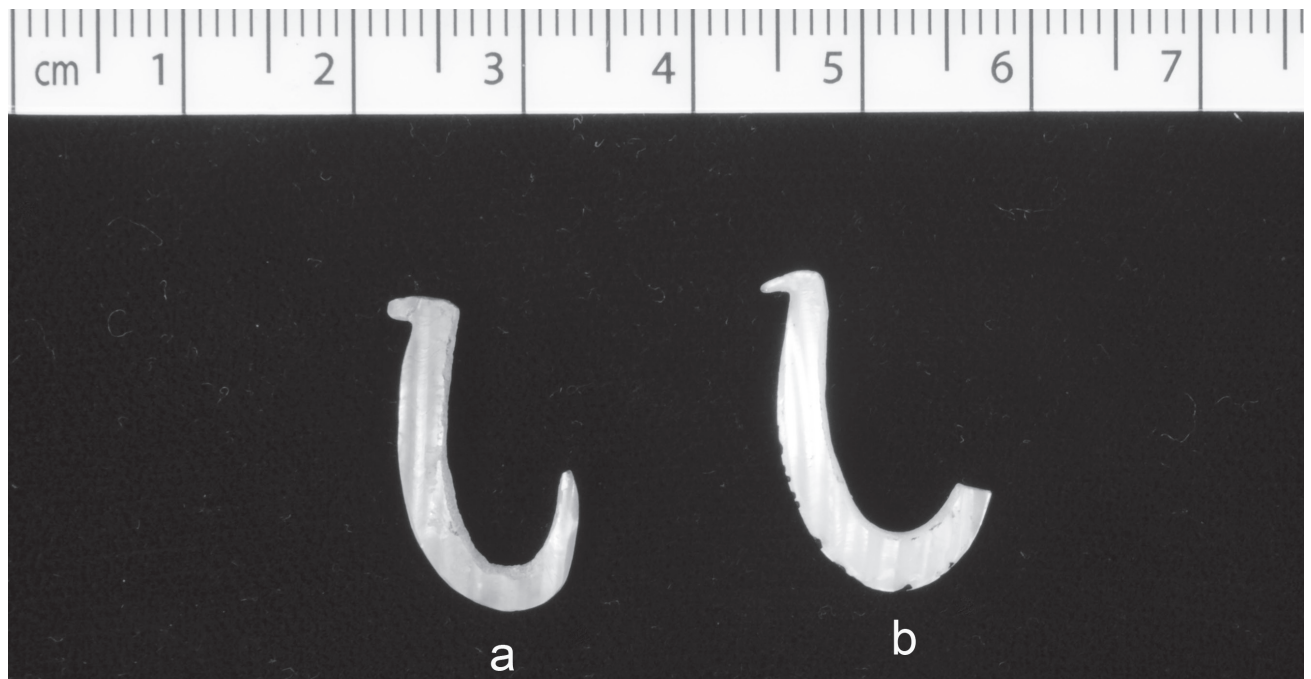


Figure 11.6. Type II fishhooks of *Turbo* shell: a, D32-5-6, b, A25-6-4.



Figure 11.7. Type II hooks of pearl shell: a, F30-10-6; b, E34-10-1.

Fishhook Size

The 63 fishhooks already analyzed for their morphology are available for examination of their sizes. The length of the shank (*Lsh*), representative of the overall height of the hook, is the most important measurement and can be applied to incomplete hooks with intact shanks as well as to complete hooks. Figure 11.8 shows the distribution of shank length for the 63 complete and incomplete hooks. Shank length is concentrated between 13 and 21 mm, with peaks at 15 mm (11 hooks) and 20 mm (8 hooks). Only seven fishhooks have shank lengths falling outside of this range: one very small hook with a shank length of 8 mm and six others with shank lengths between 23 mm and 34 mm.

When we analyze fishhook size by the shape of the shank, whether straight (type I) or curved (type II), as in Figure 11.9, despite the smaller sample size for type I hooks, there is no appreciable difference in the size distributions of the two types (although most of the largest hooks are of type II).

The MAN-44 fishhook assemblage was manufactured from two species: the pearl oyster, which had to be imported from other islands of the Cook archipelago (*P. margaritifera*), and the locally available Turban shell (*T. setosus*). Considering the entire assemblage

(complete, incomplete, and fragments of one-piece fishhooks, two-piece fishhooks, blanks shell, and cut and worked shell; i.e., 321 pieces), 66 are in *T. setosus* shell (20.6 percent) and 255 in *P. margaritifera* shell (79.4 percent). The majority of type I hooks are of *T. setosus* shell, with 9 pieces out of 13. In contrast, the 50 hooks of type II are predominantly made of pearl shell. As can be seen in Figure 11.10, the shank lengths of hooks in *T. setosus* shell, nine pieces, does not exceed 20 mm (with one outlier at 24 mm). All of the largest hooks, with shank lengths from 28 to 34 mm, are made of pearl shell. This difference is presumably due to limitations in the size of available *Turbo* shell.

Fishhook Fragments

The initial typological analysis was based on 63 complete and incomplete fishhooks. However, in addition, the MAN-44 assemblage includes 197 fishhook fragments, with 98 pieces of shank (with or without a head) and 2 fragments of head, 64 fragments of bend, and 33 pieces of point. Since these fragments constitute some 75.7 percent of the entire fishhook assemblage, it is essential to include them in the analysis. It is possible to determine the general shape (types I or II) of 70 fragments, mostly shanks (60 specimens) and some bends (10 specimens).

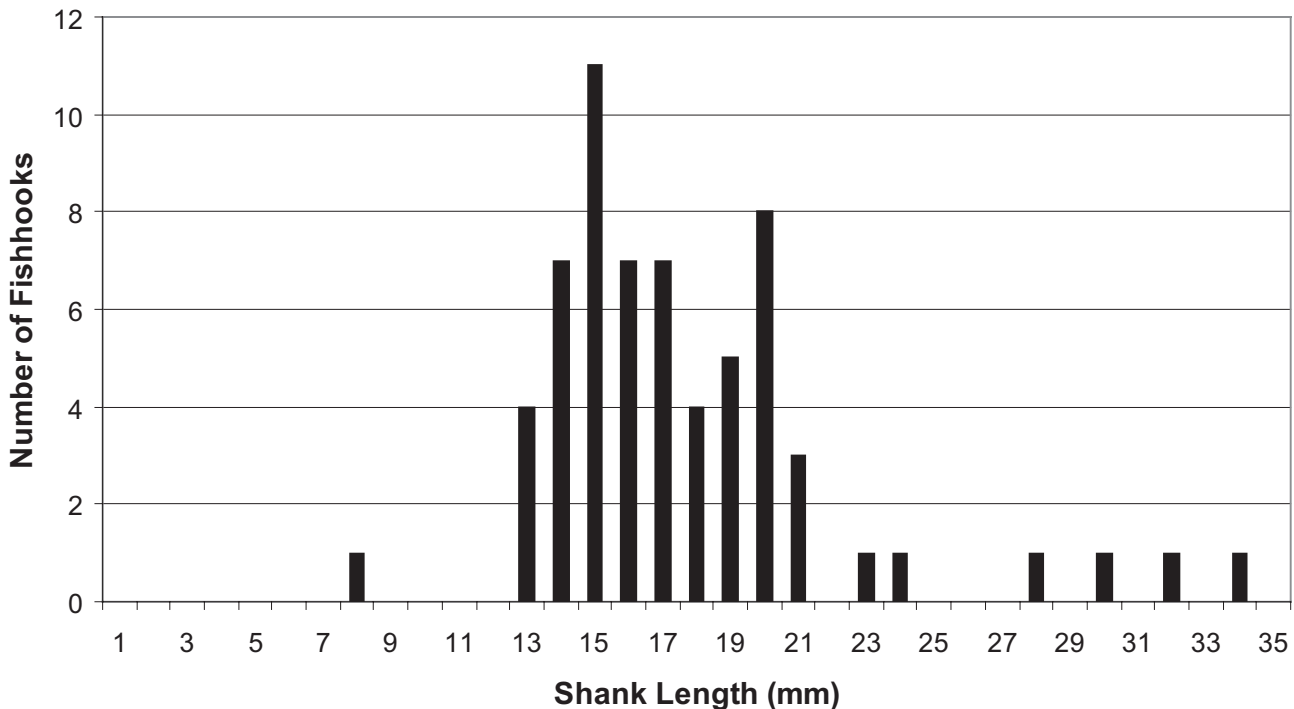


Figure 11.8. Histogram of MAN-44 fishhook shank length (N=63).

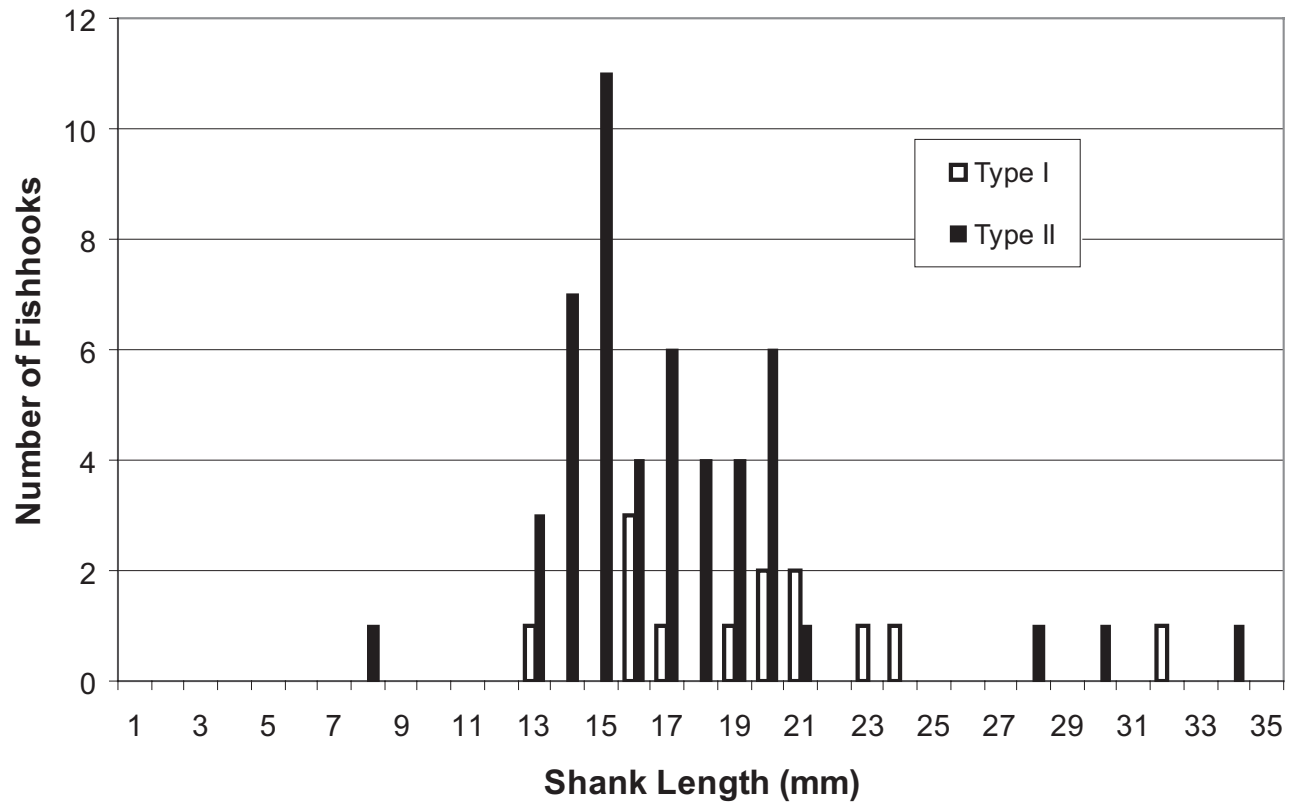


Figure 11.9. Histogram of MAN-44 fishhooks (N=63) subdivided by morphological type (straight versus curved shank).

Type I Fragments

We have 29 pieces whose shank is straight and therefore associated with type I. Most of these (22) are of pearl shell, while only 7 are of *T. setosus* shell. It is more problematic to assign these fragments to subtypes, as few retain a part of the bend. However, we can identify the subtype of four specimens: one has a shape similar to subtype IA (with a straight point), where the width of the bend is equal to the shank [$lc = lb$]. Another has a very long shank compared with its width and is closer to one of the isolated subtypes of type I. The last two have a characteristic not found in the typological analysis of the complete and incomplete hooks, with a slightly V-shaped bend. This morphological attribute would suggest a further subtype among type I or a variant of subtype IB (Figure 11.11).

The remaining 25 fragments provide some information regarding the shape of the shank and its width. Most are greater than 4 to 6 mm in width, with a single fragment made in *T. setosus* shell exhibiting the smallest width (2 mm). Considering the complete and partial type I sample, they all have shank widths of

less than 3.5 mm. All have shank heights of between 13 and 32 mm, for which we observe three recurrent widths: (1) for a shank width of 2 mm, the heights range from 13 to 21.5 mm; (2) for a shank width of 2.5 mm, the heights range from 16 to 23 mm; and (3) for a shank width of 3.5 mm, the heights range from 16 to 24 mm.

Twelve fragments have a head whose shape shows a top outer knob (C-form) or long top outer knob (D-form). Eight of these pieces are made of pearl oyster shell. Except for one, all have a head with a C- or D-form. Their width does not exceed 4 mm.

Four hook fragments of pearl oyster shell present part of their bend but not enough to identify the subtype. The shank widths do not exceed 3.5 mm.

Type II Fragments

Among the 197 fishhook fragments, 41 can be assigned to type II. Of these, 36 are of pearl oyster shell and five are of *T. setosus* shell. Five of these type II fragments are of the bend, 35 are fragments of shank, and one is a head fragment.

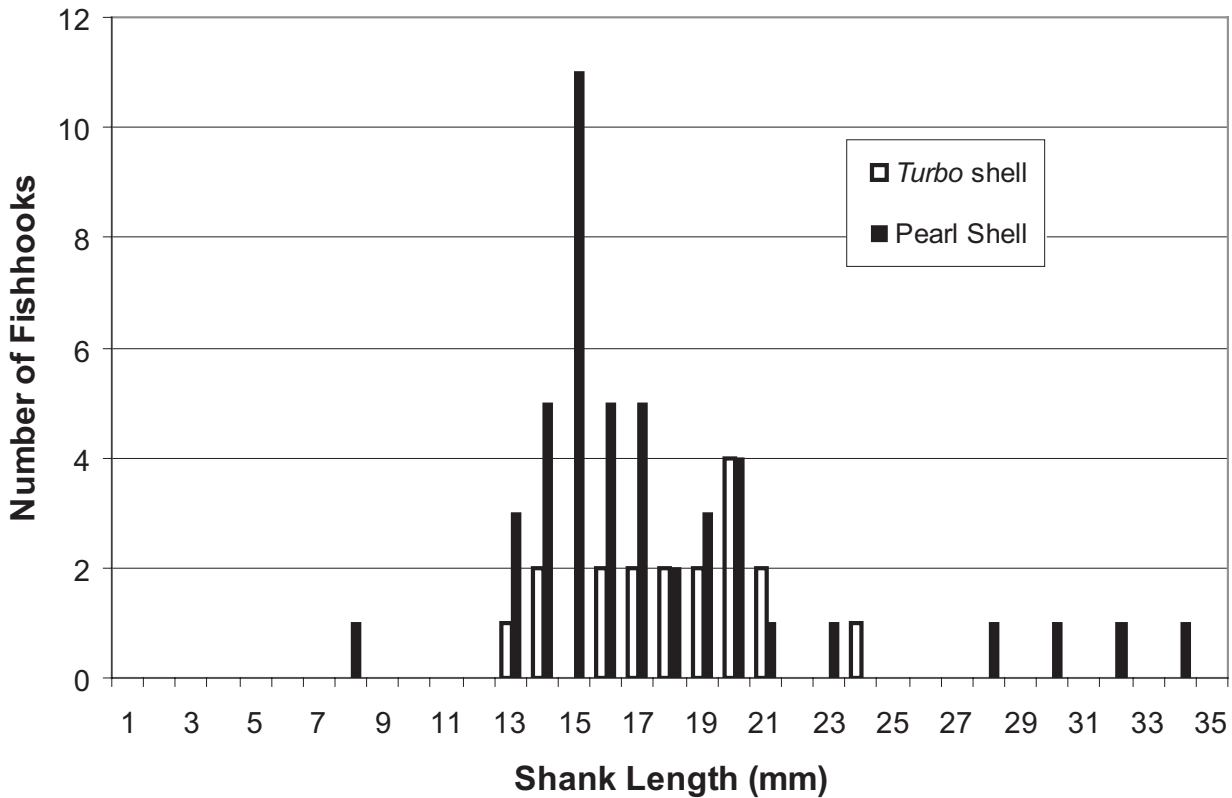


Figure 11.10. Histogram of MAN-44 fishhooks subdivided by material.

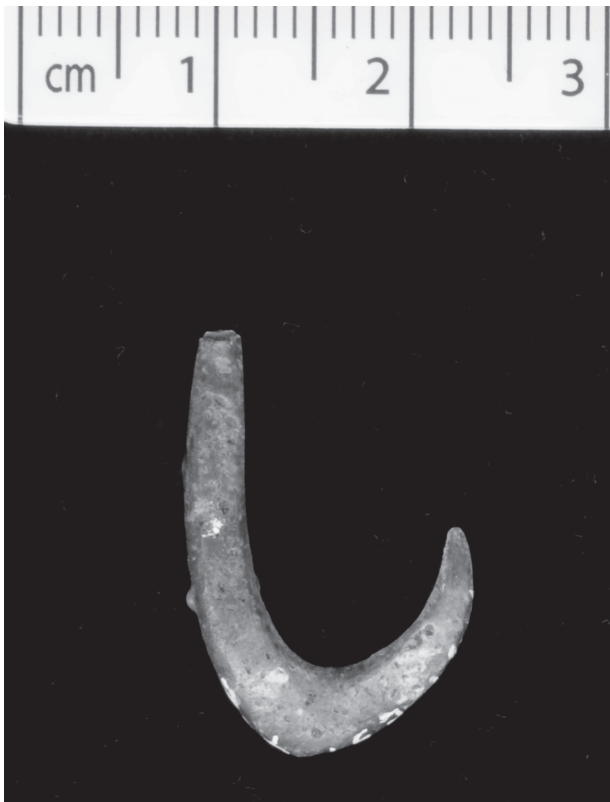


Figure 11.11. Fragment of subtype IB fishhook: E34-4-2.

Three of the four bend fragments retaining a part of the point are of *T. setosus* shell. Both have a particular V-shape of bend, with a divergent point (Figure 11.12). From the shape and the raw material, we can assign them to subtype IIA. The third is close to subtype IIA, with the characteristic shape of the point and a curved tip. The fourth bend fragment in pearl oyster shell could be identified as type II.

The fifth bend fragment (E34-6-11), in pearl oyster shell, retains its complete point (Figure 11.13); the shank is incomplete and curved. The bend is U-shaped and the point straight with a sharply curved tip. This is a large hook, with unusual dimensions: point length is 35 mm and appears to have been longer than the shank. This particular shape, which seems clearly associated with type II due to its shank shape, is not like other type II pieces in that the point length is greater than that of the shank and the point is straight with a curved tip. In shape, it is similar to subtype IIA hooks, but subtype IIA hooks are all in *T. setosus* shell and the dimensions of this specimen exceed the average dimensions of this group (where the average height is between 15 and 20 mm). These observations imply a probable additional subtype within type II.



Figure 11.12. Fragment of type IIA fishhook in *Turbo* shell: C30-5-2.

We also have 35 pieces of shank that are too small to identify typologically, as they do not have sufficient attributes preserved. Only their width can be analyzed. Most of these fragments have a shank width of less than 3 mm (32 pieces). Based on the analysis of shank widths from type II complete and partial fishhooks, we can see that the majority, whose width is less than 3 mm, would have had shank lengths of less than 20 mm. More specifically, we can divide these shank fragments into three groups based on shank width: (1) for shank widths of 2 mm, shank heights ranged from 13 to 15 mm; (2) for shank widths between 2 and 3.5 mm, shank heights ranged from 14 to 20 mm; and (3) for shank widths greater than 3.5 mm, shank heights ranged from 17 to 34 mm. A correlation between raw material and fishhook dimensions is not evident. Both small and large shank widths are associated with pearl oyster shell and *T. setosus* shell; however, the four fragments with a large shank width (greater than 3.5 mm) are all in pearl oyster shell.



Figure 11.13. Atypical Type II hook in pearl shell: E34-6-11.

Those fragments retaining their head exhibit a C-form (top outer knob), except for two fragments in pearl oyster shell whose heads are B-form (inside notch with an outer knob) and D-form (long top outer knob).

To sum up this analysis of fishhook fragments, we were able to typologically identify 70 specimens among the 197 fragments of one-piece fishhooks, an identification rate of 35.5 percent. The addition of these fragments more than doubles the corpus analyzed typologically. Unfortunately, the 127 remaining fragments, which cannot be typologically determined, were mostly burned and therefore weakened, making them difficult to classify.

One-Piece Fishhook Head Morphology

The attributes of the head (or line-lashing device) of one-piece fishhooks have long been recognized as being of typological importance in Polynesian archaeology (e.g., Allen 1992a; Ayres 1979; Carlier 2002; Emory et al. 1959; Ottino 1992). We begin, first, with the head shapes observed among the complete and partial hooks and then turn to the fragments whose head is preserved. The following is a list of the head shapes most commonly observed in archaeological fishhook assemblages from other Eastern Polynesian sites (illustrated in Figure 11.14):

- A-form: inside notch
- B-form: inside notch with an outer knob
- C-form: top outer knob
- D-form: long top outer knob
- E-form: apparent outer knob, with a frequent inside notch
- F-form: top inner knob
- G-form: notches

Note that Figure 11.14 illustrates only head shapes with flat tops; however, they can also be concave, convex, or pointed.

Among the 63 complete and partial hooks from site MAN-44, four head shapes are present (B, C, D, and F). The C-form head predominates, with 40 examples, followed by the D-form (12 examples), while the F- and B-forms are the least represented and the A-, E-, and G-forms are totally absent. We can further observe that (1) C-form heads dominate strongly, among type I hooks (69.2 percent) as well as among those of type II (62 percent); (2) F-form heads are only associated with type II hooks; (3) D-form heads are primarily

associated with type II hooks (10 out of 12 pieces); and (4) B-form heads are associated with both types of hooks (two in each type).

Adding the 41 identified fragments with intact heads to the complete and partial hooks increases the sample to 104 pieces (see Table 11.2). In this larger sample, the C-form continues to dominate (72 percent), while the other forms do not include more than 15 specimens each. In addition, the rare G-form now appears on a single specimen, while A-form is definitely absent from the assemblage.

The correlations among fishhook head shape, hook type, and raw material are summarized in Table 11.2. From this it is evident that type I hooks having a C- or D-form head are primarily associated with *T. setosus* shell (12 of 19 specimens), while type II hooks having a head of these same forms are mainly made from pearl oyster shell (67 of 71 pieces). Fishhooks with a B-form head are exclusively made of pearl oyster shell. Conversely, fishhooks with an F-form head are exclusively made from *T. setosus* shell.

Table 11.2. Fishhook Head Types at Site MAN-44.

Head Form	Type I		Type II		Total
	Pearl Shell	Turbo Shell	Pearl Shell	Turbo Shell	
B-form	2		3		5
C-form	6	9	58	2	75
D-form	1	3	9	2	15
F-form				8	8
G-form			1		1
Total	9	12	71	12	104

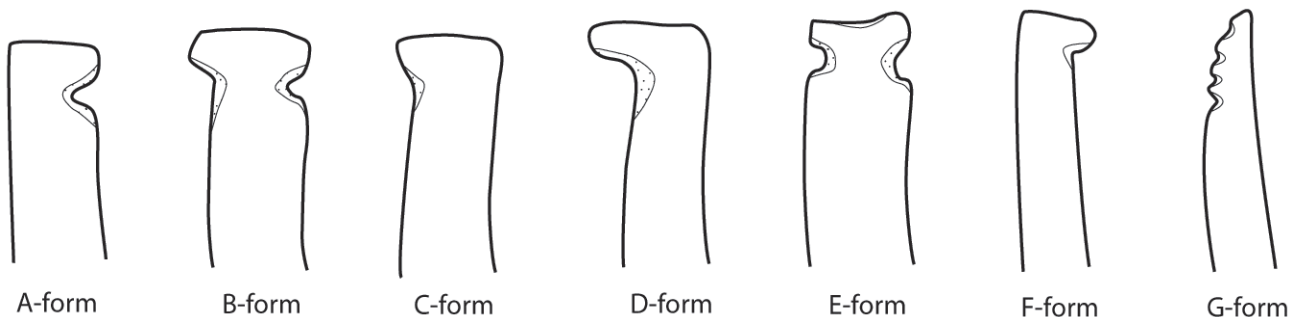


Figure 11.14. Fishhook head types.

Unfinished Fishhooks: The Manufacturing Process

Important clues as to the process of manufacturing fishhooks at site MAN-44 can be derived from careful study of the morphology of shell blanks and from traces of tool marks. The available sample includes 75 specimens: 31 blanks, 28 pieces of worked shell, and other detritus of worked shell possibly related to fishhook manufacturing. Sixteen of these waste pieces were studied in detail. The number of worked shell pieces is almost equivalent to that of blanks. Not every piece exhibits tool traces, with only two pieces showing some traces of grooving. It is difficult to interpret the origin of the waste shells: did they derive from manufacturing or a natural break? Three of these pieces come from the central part of a valve of pearl oyster, the part of the valve that is removed to make a one-piece fishhook (Figure 11.15). The remaining pieces are too highly broken up to allow any secure interpretation.

Of the 31 hook blanks, we observed several tool marks and stages of manufacture. From these, three stages are evident in the manufacturing process: (1) cutting the shell to prepare the blank, (2) shaping of the blank, (3) and detailed finishing.

Three pieces represent the first stage of the manufacture process, the cutting of a blank from a natural shell, two in *T. setosus* and one in *P. margaritifera* (although this latter was found on the surface). All three are relatively similar, with a rounded overall shape (at least three-fourths of their edges) and similar dimensions (between 10 and 21 mm high) (Figure 11.16). However, traces of basic cutting cannot be clearly identified, probably because initial filing or abrasion on their edges has softened the contours. Two other pieces of worked pearl shell exhibit signs of grooving (Figure 11.17) that suggest that initial cutting of the shell was by grooving. Similarly, a large piece of *T. setosus* shell



Figure 11.15. Large piece of pearl shell, probably the initial stage in fishhook manufacture.

has straight edges, as if it had been first cut; unfortunately, the piece is eroded, erasing traces of tool use.

The blanks associated with the second stage of the manufacturing process are mainly in *T. setosus* shell (5 pieces). The single pearl shell blank has different characteristics from those in *Turbo*. With a rounded shape, the inner zone of the blank is excavated out (Figure 11.18d). Few traces remain of the tool, but the appearance suggests a central digging with a fine file. The piece is cleaved, however, affecting the study of the tool traces. We can still identify that this blank was intended for a type II fishhook. With one exception, the blanks in *T. setosus* shell all have one or more holes in the center. Unfortunately, they are all fragmentary, but two have a shaped head (Figure 11.18a,b), and one has two holes (Figure 11.18c). It thus seems clear that the fishhooks in *T. setosus* shell were made by perforating the inner area and that the head was already shaped at this stage. The tools used to perforate the shell blanks were most likely abraders of *Acropora* branch coral (see Chapter 10).

The third stage of fishhook manufacture is the best represented, with eight pieces, including three in pearl shell and five in *T. setosus* shell. The three pearl shell

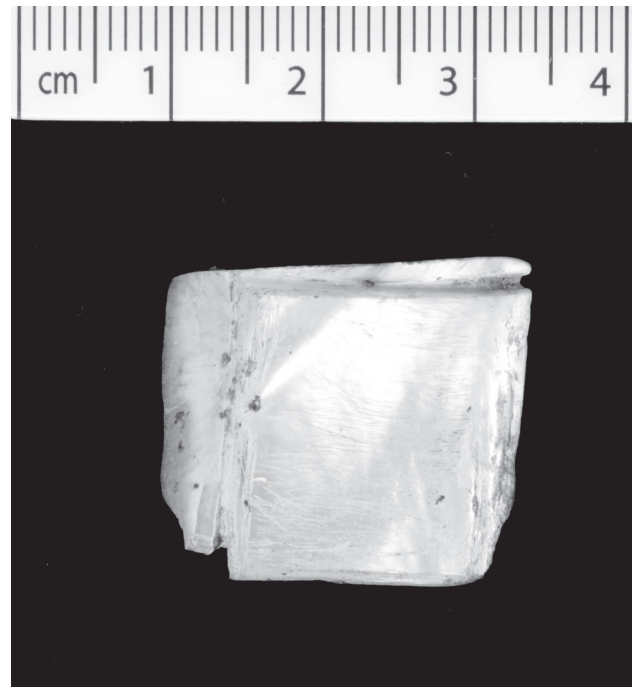


Figure 11.17. Pearl shell fishhook blank showing cut marks: F30-9-1.

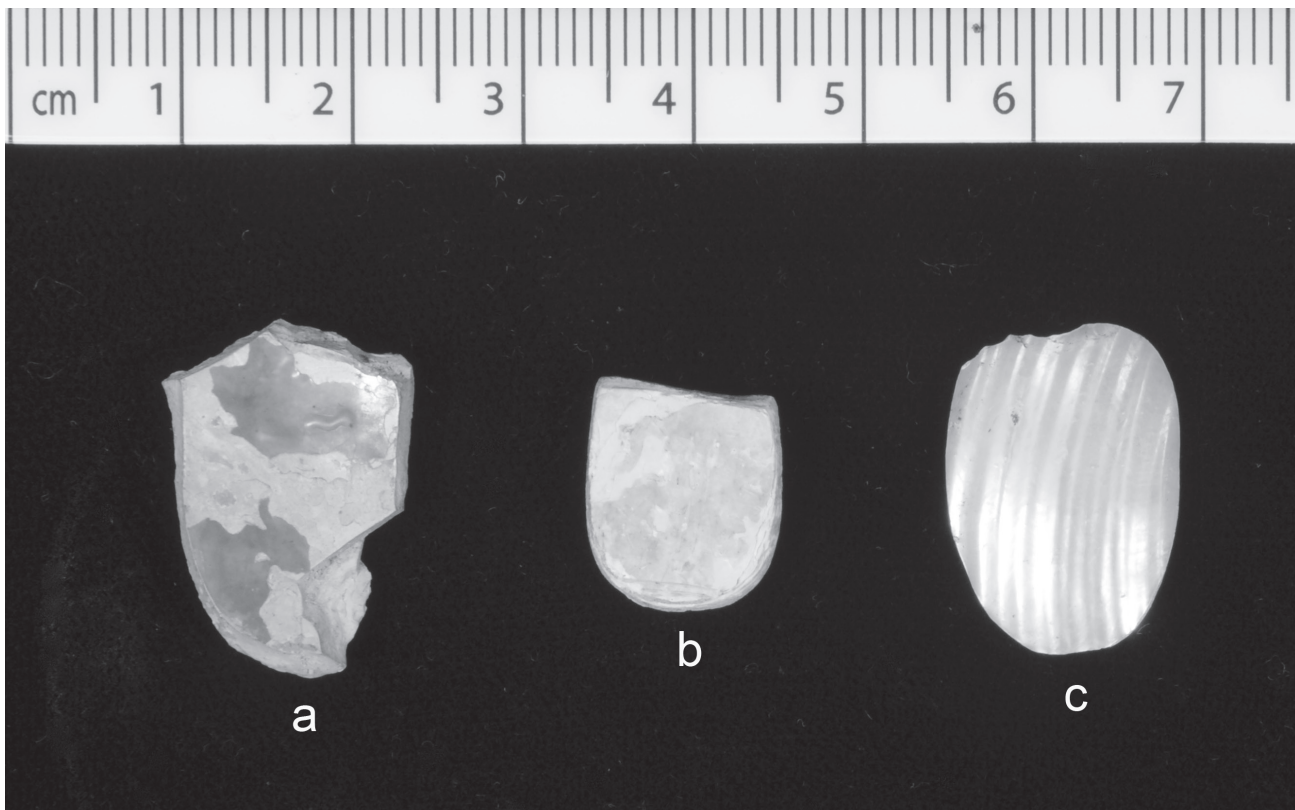


Figure 11.16. Fishhook blanks: a, C30-12-1; b, F30-11-2; c, 0-0-1.

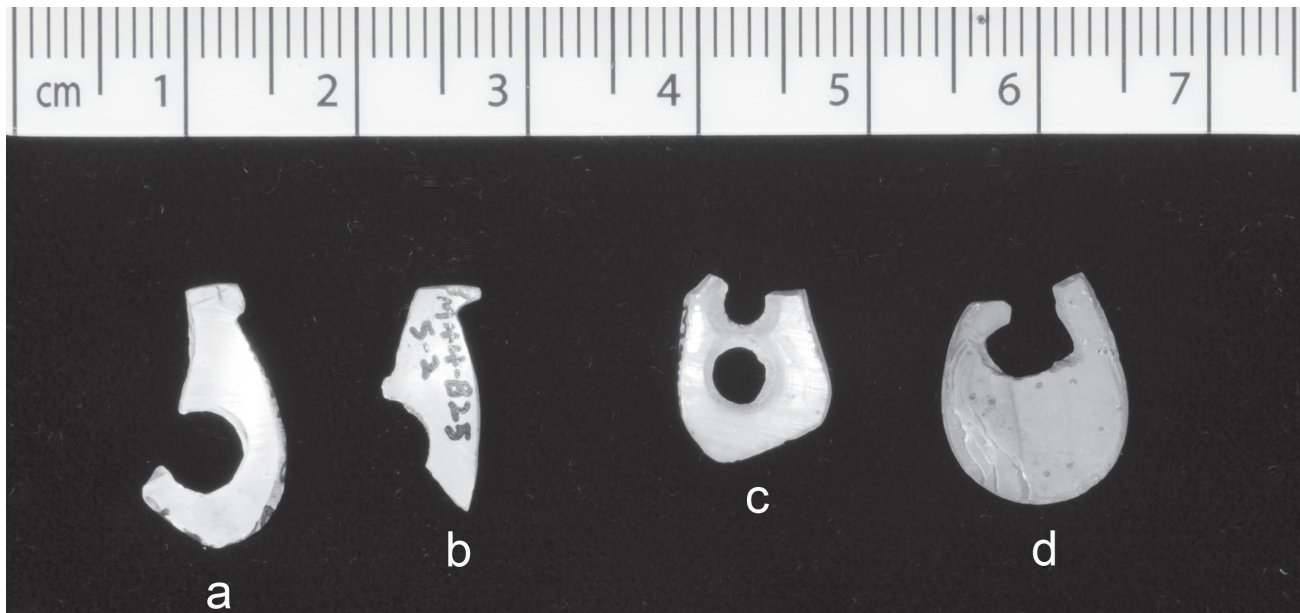


Figure 11.18. Unfinished fishhooks abandoned during second stage manufacture: a, D30-6-9; b, B25-5-2; c, G30-4-5; d, C30-9-4.

blanks are very fragmentary or damaged. Two are of type I, with their contours defined but still rough (Figure 11.19a,b). It is difficult to identify traces of tool use, but one seems to have traces of percussion or drilling.

Of the five *T. setosus* shell blanks, two are associated with type I and three with type II. The two type I pieces have a C-form head (top outer knob) but are fragmented and the point is not retained (Figure 11.19c,d). The three blanks showing type II attributes have an inner zone drilling (Figure 11.19e). They are associated with the subtype IIA or IIB, which is interesting because, among the finished pieces present, only fishhooks in *P. margaritifera* were related to these two subtypes. Their heads are of C-form. The two blanks are clearly associated subtype IIA; one retains the head, the other its incurved tip (Figure 11.19f,g). They have the same dimensions as the finished hooks from this same subtype (between 15 and 20 mm) and are almost finished; only a little refinement and polishing are necessary on the edge to obtain a completely finished hook. They were probably abandoned at this stage due to a break at the tip or head.

Stratigraphic Distribution of the Site MAN-44 Fishhooks

A total of 234 finished one-piece hooks (complete, partial, and fragments) can be attributed to either a stratigraphic zone or a feature in the main excavation block (thus excluding seven hooks from outlying units

A25, B25, and F10). Most of the hooks come from the lower stratigraphic deposits, especially SZ-2 and SZ-3, although SZ-8 also has a significant number of hooks.

The stratigraphic distribution of fishhooks made from either pearl shell or *Turbo* shell is provided in Table 11.3. Hooks of *P. margaritifera* shell are found mainly in the oldest zones, in SZ-1B to SZ-5, but especially in SZ-2, SZ-3, SZ-4A, and SZ-4B. The number of pearl shell hooks decreases sharply after SZ-5, and these are absent in the uppermost zones. Hooks made from *T. setosus* shell, while present in small numbers in the lower deposits, are concentrated in the upper zones, with SZ-8 having the highest concentration with 19 specimens. *P. margaritifera* does not naturally occur on Mangaia (which lacks the lagoon habitat necessary for pearl oysters) so the shells used to manufacture pearl shell hooks must have been imported from other islands. The predominance of pearl shell in the earlier layers suggests that it was the preferred material for fishhook manufacture. The shift from pearl shell to locally available *Turbo* shell is thus likely due to the cessation of external exchange links between Mangaia and other islands where pearl shell was available.

Of the total of 234 finished hooks, 115 from the main excavation block could be classified typologically; their stratigraphic distribution by zone and feature is provided in Table 11.4. As can be seen, both type I and type II hooks are found throughout the stratigraphic sequence, although type II hooks are



Figure 11.19. Unfinished fishhooks abandoned at stage three of manufacture: a, C30-10-3; b, D34-9-12; c, D30-4-2; d, G30-5-1; e, F30-8-1; f, D30-4-3; g, C30-3-1.

much more common in the earlier zones. Type II hooks are especially concentrated in zones SZ-2 and SZ-3, with 10 and 48 specimens, respectively.

A further trend is evident if we look at the type II hooks in greater detail: in the lower zones, hooks of subtype IIB are frequent, dominating in SZ-3, with 34 pieces. This same subtype is found also in zones SZ-5 (1 of 2 parts), SZ-4A (6 of 7 pieces), SZ-4B (3 of 4 pieces), SZ-3 (34 of 48 pieces), and SZ-2 (6 of 10 pieces). Subtype IIC, with a shank more elongated than the hooks of subtype IIB, is also present in the same stratigraphic zones.

Turning to fishhooks with intact heads, we have a total of 104 pieces, complete, partial, or fragments,

but five specimens are from outlying excavation units (units A-25 and F-10); thus, 99 specimens are available for stratigraphic analysis. The stratigraphic distribution of fishhook head forms by stratigraphic zone and feature is provided in Table 11.5. Hooks with heads of C-form dominate the assemblage, occurring throughout the sequence, from early to late. Hooks with heads of D-form are much less common but also occur throughout the sequence. In contrast, hooks with B-form heads occur only in the lowest zones (SZ-1B to SZ-4A/4B). Hooks with F-form heads, of which there are just four examples, are limited to upper zone SZ-8 and feature F32. There is only a single G-form head, from an early context.

Table 11.3. Stratigraphic Distribution of Fishhooks by Material Type, Site MAN-44 (Including Blanks and Unfinished Hooks).

Zone (SZ) or Feature (F)	Pearl Shell Fishhooks	Turbo Shell Fishhooks	Totals
SZ-18		1	1
SZ-15		1	1
F2, F3		3	3
F15	2		2
SZ-8	5	19	24
F4, F7, F32	1	6	7
SZ-7		5	5
SZ-6		1	1
SZ-5	6	4	10
F5	6	3	9
F37, F38	8		8
SZ-4A	32		32
SZ-4B	12		12
SZ-3	92	2	94
SZ-2	48	1	49
SZ-1B	4	1	5
Totals	216	47	263

Table 11.4. Stratigraphic Distribution of Finished Fishhooks, Site MAN-44.

Zone (SZ)	Type I Fishhooks	Type II Fishhooks	Fishhooks of Unclassified Type	Totals
18	1			1
15			1	1
8	7	6	11	24
7	4		1	5
6	1			1
5	2	2	6	10
4A	5	7	20	32
4B	1	4	7	12
3	5	48	41	94
2	9	10	30	49
1B	2		3	5
Total	37	77	120	234

Discussion and Conclusions

The fishhook assemblage uncovered at the Tangatatau Rockshelter is exceptional, both in its size (340 pieces) and for its context: an assemblage associated with the exploitation of marine resources found in conjunction with a complex stratigraphy, abundant fish faunal remains, and associated paleoenvironmental data. The MAN-44 assemblage joins two other collections of hooks from the Cook Islands, from excavations on Ma'uke (the Anai'o site; Walter 1989) and on Aitutaki (the Moturakau Rockshelter; Allen 1992a; Allen and Schubel 1990). Unfortunately, many of the pieces from Tangatatau are broken and fragmented, with more than 125 specimens having signs of burning, which degrades and weakens the shell. Despite these factors, considerable information was obtained regarding the types of fishhooks and their manufacture throughout the occupation of the shelter.

One trend is immediately evident: the assemblage is dominated by one-piece hooks, with only two pieces from compound hooks (two fragments of bonito trolling lure). This suggests that fishing practices were largely focused on inshore environments, either on the fringing reef or in the immediate benthic environment just beyond the reef. The presence of the two compound hooks—used for taking pelagic fishes, often carnivorous—does indicate infrequent pelagic trolling.

Several shapes of one-piece hooks were distinguished. Two large groups emerge: hooks with a straight shank (type I) and hooks with a curved shank (type II). There are subgroups within these two types, sometimes not well represented or with few complete hooks. However, the assignment of 70 of the 197 fragments to hook type enlarges the sample. The majority of hooks are of type II, with 68.4 percent of the pieces identified. The dominance of this type combined with their relatively small size (84 percent have a shank height of less than 20 mm) suggests that most of these hooks were designed to catch small- to medium-sized fishes, again indicating a near shore fishing focus.

It is commonly accepted that the shape of a hook affects its mechanical action: the movement produced will be different if the shank is straight or curved. A hook with a straight shank goes vertically into the mouth of the fish, while a curved shank turns on its own axis, sticking the hook in the mouth of the fish and reducing the chances that it will release (Garanger 1965:133; Nordhoff 1930:156). Curved-shank hooks are associated with either fishing in deep sea areas (Ayres

Table 11.5. Stratigraphic Distribution of Fishhook Head Forms, Site MAN-44.

Stratigraphic Zone (SZ) or Feature (F)	Fishhook Head Form					Totals
	B-form	C-form	D-form	F-form	G-form	
SZ-18			1			1
F2		1				1
F58		1				1
F15		1				1
SZ-8		4	3	2		9
F32				2		2
SZ-7		2	1			3
SZ-5		2				2
F5		2				2
F21			2			2
F37, F38		2			1	3
SZ-4A/4B	1	11				12
SZ-3	1	38	8			47
SZ-2	2	8	1			11
SZ-1B	1	1				2
Totals	5	73	16	4	1	99

1979: 68; Garanger 1965:134; Métraux 1940:172–173) or fishing in shallow areas, with some current or with the presence of reef or abundant submerged rocks (Johannes 1981:116). The second possibility seems more likely, given the environment of Mangaia, with a narrow fringing reef. These criteria (inshore, small fishes, small hooks) suggest daily fishing with limited gear needed and ease of access to fishing spots.

The integration of stratigraphic data, however, moderates these initial interpretations. Indeed, hooks associated with subtype IIB (“circular”) and subtype IIC predominate at the base of the sequence, especially in zone SZ-3. In the early occupation zones, both types I and II coexist, with a greater preference for curved shank hooks whose number decreases after SZ-3, while the number of straight shank hooks, although somewhat fewer, remains essentially constant.

Zooarchaeological analysis of fish remains from MAN-44 (see Chapter 7) reveals a trend toward reduction in size of fish taxa over time. Indeed, the earliest zones yield larger species that decrease in number in the later layers, unlike the small species more abundant in time (Butler 2001:93). This change can be compared

with the above interpretations regarding the hooks.

This could also mean a decrease of the practice of angling, especially fishing in deeper water for the benefit of fishing gear leaving no archaeological traces, including net fishing, poisoning, or trapping fish (a similar interpretation is advanced for Aitutaki by Allen [1992a:197]). Carnivorous fish are captured more readily with techniques using a hook while herbivorous and omnivorous fishes require techniques of “mass capture.” The analysis of fish remains from MAN-44, however, shows a certain stability of herbivorous and omnivorous taxa, which suggests relative continuity of the techniques used (Butler 2001:95). On the other hand, a second correlation between the fishbones and the fishing gear is observed: the number of taxa decreased from zone SZ-8, which corresponds to the decrease in the number of hooks found (Butler 2001:91).

Analysis of head shape reveals some temporal patterns. The C-form dominates the assemblage, from zones SZ-1B to SZ-8. The presence of the D-form, less common, is more or less constant throughout the occupation of the shelter. The other three head shapes

appear in more restricted distributions: the B-form is confined to the oldest zones, the F-form to more recent zones, while the G-form is present on a single piece in feature F38, contemporary with zone SZ-4A/4B. The A-form and E-form are absent from the corpus.

The analysis of 58 blanks and worked shells attests to the in situ production and manufacturing of hooks in the rockshelter. The manufacturing process is divided into three stages: initial cutting of the blank, shaping of the blank, and finishing of the hook. The pieces are mostly from *P. margaritifera* shell (68.9 percent) in the deeper zones, while those in *T. setosus*, less represented, are in the upper zones.

This evolution of hook shape over the occupation of the site is paralleled by another phenomenon: the use of raw material. The hooks were manufactured from two species: *P. margaritifera*, a large majority, and *T. setosus*. Their use varies with time: pearl shell dominates in the older zones (especially between SZ-2 and SZ-4A/4B), while *T. setosus* shell dominates in the upper zones (SZ-5 to SZ-8). *P. margaritifera* was probably imported from other islands of the archipelago, whose lagoons would provide suitable habitat for pearl shell (Weisler 1993:126–130). In contrast, *T. setosus* shell was locally

abundant and easily accessible (Allen 1992a:194). The abandonment of pearl shell fishhook manufacture is probably related to the cessation of importation.

The same phenomenon was observed in the MR-1 rockshelter, on Moturakau islet in Aitutaki, where, in the older layers, most of the hooks were made from pearl shell, with a constant presence of hooks of *T. setosus* shell. From AD 1450 to 1550, *Turbo* became more numerous while hooks in pearl shell, although still remaining the majority, decreased in number until they disappeared around 1650 AD (Allen 2002:198–199).

Several hypotheses have been advanced regarding the decrease of pearl shell hooks and the increase of those in *T. setosus*. From this period, the interisland contacts and trade dynamics change, possibly in relation to a retrenchment of the Mangaia population on itself and a break in pearl shell imports (Allen 1996a; Hiroa 1934; Weisler 1993). Other interpretations involve alterations of the environment, for natural or anthropogenic reasons, which may have disrupted the habitat of the pearl oysters (as is suggested in case of Aitutaki; Allen 1992a:193–194) or that there was a possible overexploitation of the shell (Allen 1996a:105).

12

Lithic Assemblages of Tangatatau Rockshelter: Reduction Strategies and the Organization of Lithic Technology

Jennifer G. Kahn

The MAN-44 rockshelter yielded abundant and diverse lithic remains, including basalt adzes and preforms, waste flake debris, retouched flakes, and utilized flakes. This chapter presents an analysis of the debitage and flake tools recovered in the 1991 excavations. A detailed record of the manufacture and use of stone tools at MAN-44 necessitates that the tools as well as debris be studied in detail (Andrefsky 1998; Kahn 1996; Shott 1994).

A primary goal of the debitage analysis was to determine the nature of lithic procurement, production, and use at the site and how this changed over time. The analysis was structured to establish whether all stages of adze manufacture and use were represented in the rockshelter's cultural deposits—that is, if there is evidence for both early stage preform shaping and later stage preform finishing, as well as adze rejuvenation. X-ray fluorescence analysis has confirmed that the majority of MAN-44 adzes were produced from two local sources, the Mata'are basalt and a source in Veitatei (see Chapter 10). An ethnohistoric account suggested that there was unrestricted use of the Mata'are basalt source, no reduction at the source itself, and full reduction by “the artisan,” presumably adze craft specialists (Weisler et al. 1994). The

question remains, where did adze manufacture and reduction take place on Mangaia? An archaeological survey of the Mata'are source tentatively confirmed the supposition that reduction did not take place at this quarry, because flake debris, cores, and adzes were not found at the site of the eroding boulders (Weisler et al. 1994).

A detailed reduction stage analysis was conducted to determine whether the lithic assemblage at site MAN-44 evidenced a full range of adze reduction or manufacture or whether the organization of lithic technology at the rockshelter conforms to sequential production system patterns observed at other Polynesian habitation sites, where typically only later stage finishing of adze blanks and adze polishing are represented in addition to imported finished adzes (Clark and Herdrich 1993; Dixon et al. 1994; Kahn 1996, 2005, 2007; Mills et al. 2011; Withrow 1991:221–237). A second objective was to identify whether the nature of lithic technology at Tangatatau Rockshelter changed over time. In particular, was the shift over time in adze morphology, from early, mostly untanged forms to late classic tanged forms, as documented in Chapter 10, associated with a change in the organization of adze production?

A third research goal was to establish the range and nature of the raw material exploited for stone tool production at the site. Various sources of raw material have been documented as potentially available for use at the site (Weisler et al. 1994; Weisler and Green 2013), including local sources in Veitatei Valley and at Mata‘are (Weisler et al. 1994). Other sources of basalt on Mangaia include coarse-grained basalt dyke stone, limited to a few outcrops and stream drainages, and waterworn basalt cobbles found in streambeds (Weisler et al. 1994). Boulders of chert are found on the slopes of Ivirua on the northeast side of the island. A second chert source has been identified at Niirimoku on the western side of the island (Marshall 1927). The reduction stage analysis was conducted with this knowledge of the island’s geology in mind to establish the nature of the original form of the lithic raw materials worked at the site.

An additional goal was documenting the range of variability in lithic production at MAN-44, particularly with reference to flake tool production and use. Many lithic analyses in Polynesia have been limited in scope, overlooking the presence of flake tools. New research has demonstrated the utility for in-depth analyses of Polynesian and Oceanic lithic assemblages for documenting the extent, nature, and use of flake tools (Bollt 2008; Clark et al. 1998; Haslam and Liston 2008; Ishimura and Addison 2007; Kahn 1996; McCoy et al. 2015; Weisler and Haslam 2005; Winterhoff 2007). The MAN-44 assemblage is well suited to such an analysis because a number of simple flake tools were recovered in the excavations.

Methods

The large quantity of lithic materials recovered during the 1991 MAN-44 excavations necessitated a sampling strategy. Data for the total lithic assemblage recovered from the 1991 horizontal excavations in the main excavation block are presented here only briefly. Lithics from four excavation units (E35, E36, F35, and F36) were selected for detailed and time-consuming reduction stage analysis of the full range of lithic debitage. These units were chosen because they had large numbers of lithic artifacts from stratigraphic zones SZ-2 and SZ-3, deposits with the highest density of basalt flakes, adze preforms, and hammerstones, which during excavation were interpreted as *in situ* flaking floors (Kirch et al. 1995:50–53). This sample was judged to be representative of the range of variability in the lithic assemblage at the site.

All 1991 lithic artifact lot bags were given lot numbers and entered into an Excel database. Artifact counts, weights, and raw material types were recorded for each bag. For the detailed reduction stage analysis, each artifact was washed and assigned an individual catalog number. Debitage and stone tools recovered from units E35, E36, F35, and F36 were first divided into broad raw material type categories: basalt, chert, limestone, and unidentified.

The MAN-44 analysis presented here follows an individual flake analysis approach or attribute-based approach (see Andrefsky 1998:110–111; Shott 1994). A series of metric and nonmetric traits were recorded for the range of debitage types (shatter, flake fragments, complete flakes). Other reduction stage analyses studies in Polynesia have demonstrated the need to look at the full range of debitage to understand the range of reduction activities carried out at any one site (Clarkson et al. 2015; Dixon et al. 1994; Kahn 1996, 2005; Smith et al. 1996; Turner and Bonica 1994).

I recorded attributes that had the highest utility in documenting lithic assemblage variation, based on my previous research (Kahn 1996). The choice of recorded variables also allowed the present analysis to be broadly comparable to previous research in the region. Table 12.1 lists the attributes used in the debitage and tool analysis.

Each artifact was classified according to a broad morphological type (core, complete flake, flake fragment, shatter, retouched flake, used flake, adze flake) based on the presence or absence of flake characteristics. Each morphological type was then analyzed for a series of type-specific attributes (Table 12.1). For example, the percentage of each debitage type within an assemblage (complete flake, shatter, or flake fragment) can be useful for determining how flakes were removed, variability in techniques between knappers, and the type of reduction that occurred at particular sites (core vs. tool production; see Andrefsky 1998; Carr and Bradbury 2001; Kahn 1996; Prentiss 2001; Williams and Andrefsky 2011; Williams et al. 2013), as well as the degree of postdepositional fragmentation (Holdaway and Stern 2004). Minimally, the following attributes were recorded for all samples within the MAN-44 analysis: length, width, weight, dorsal scar count, cortex cover, cortex type, and raw material type.

Recorded metric attributes included length and width (measured with digital calipers to the nearest tenth) and weight (measured to the nearest 0.01 g with

Table 12.1. Attributes and Codes Used in the Technological Analysis of Lithics, Site MAN-44.

Attribute	Code/Comments
Weight	To the nearest 0.1 g
Raw material	Stone unspecified, basalt, chert, calcite, limestone
Lithic class	Complete flake, proximal flake fragment, distal/medial flake fragment, shatter, retouched flake, utilized flake, core, hammerstone, adze, adze blank, adze preform, adze flake, adze flake fragment, adze shatter, grinding stone fragment
Dorsal cortex	0%, 1%–24%, 25%–49%, 50%–74%, 75%–99%, 100%, missing data
Dorsal scars	0, 1, 2, 3, 4, 4+, missing data
Platform completeness	Complete, absent, incomplete, missing data
Platform cortex	0%, 1%–24%, 25%–49%, 50%–74%, 75%–99%, 100%, missing data
Length	To the nearest .01 mm
Width	To the nearest .01 mm
Retouch area or use area	Proximal, distal, right lateral, left lateral, missing data
Retouch or use surface	Dorsal, ventral, dorsal and ventral, missing data
Length of retouch or use	To the nearest .01 mm
Retouch or use character	Continuous, discontinuous, missing data
Retouch or use invasiveness	Fine, extensive, missing data
Edge angle at area of retouch or use	Measured with goniometer to the nearest degree
Number of surfaces with polish (adze flakes and debitage)	1, 2, 3, missing data
Surface and location of polish	Dorsal, distal termination, striking platform, dorsal and striking platform, dorsal and distal, dorsal and distal and platform, missing data
Flake shape	Parallel, subparallel, irregular, divergent, convergent, missing data
Type	Nonedge, indeterminate edge, side edge, bevel edge, indeterminate corner, bevel corner, bevel corner and back, two sides, missing data
Bevel angle or edge angle	Measured with goniometer to the nearest degree

an electronic scale). Most Polynesian lithic studies have recorded size attributes (Cleghorn 1982; McCoy 1986; Withrow 1991) following the premise that debitage size decreases as the production of an adze proceeds. More recent studies have used the mass analysis approach (MA) or other size/weight grouping approaches to provide general size classes for debitage (Bayman and Nakamura 2001; Clarkson et al. 2015; Hermann 2013; Johnson 2013; Kahn 1996; Kahn et al. 2009; Mills et al. 2011; Mintmier 2007; Winterhoff 2007).

The recorded morphological attributes include percentage of dorsal cortex, percentage of platform cortex, and number of dorsal scars. The percentage of dorsal cortex and dorsal cortex type (waterworn, tabular dyke stone, vesicular) can be useful for sorting out early stage reduction debitage from later stage

debitage (Bayman and Nakamura 2001; Clarkson et al. 2015; Cleghorn 1982; Dibble et al. 2005; Dixon et al. 1994; McCoy 1986; Mintmier 2007; Turner and Bonica 1994; Withrow 1991) and for identifying the original form of the parent material (Anderson et al. 1994; Cleghorn 1982; Smith et al. 1996). Dorsal scar counts (recorded as 0, 1, 2, 3, 4, and 4+) have been used extensively for identifying reduction stage (Magne 1985) and for differentiating core versus tool reduction (Bradbury and Carr 1999). Dorsal scar counts have been recorded in various formats by Pacific archaeologists (Clarkson et al. 2015; Cleghorn 1982; Hermann 2013; Turner and Bonica 1994). The percentage of platform cortex is generally assumed to be a more reliable indicator for identifying primary reduction than dorsal cortex counts (Magne 1985; Tomka 1989).

Adze flakes were analyzed in detail to understand the nature of on-site adze rejuvenation such as bevel resharping. In several instances, the MAN-44 lithics were partially patinated, which hindered the recording of certain variables such as the presence of dorsal flake scars or the presence of cortex. In such instances, these fields were recorded as “missing data.”

Results

A total of 3,071 lithic artifacts were recovered from the 1991 main excavation block in MAN-44. I analyzed 1,831 lithic artifacts in detail, which comprised the full range of debitage from excavation units E35, E36, F35, and F36. This constitutes a 60 percent sample of the debitage recovered from the 1991 excavations. Here, I discuss all of the lithic artifacts recovered from these units, except for the adzes and preforms, which are described in Chapter 10.

The quantity of lithic materials varied greatly by stratigraphic zone in the four units analyzed. Figure 12.1 shows the density of lithic materials in the four analyzed units by zone, calculated as concentration indices (lithics per cubic meter). The preoccupation basal deposit (zone SZ-1A) has just two lithic artifacts, which are presumably intrusions from the overlying cultural deposits. Nineteen lithic artifacts were recovered from zone SZ-1B; these may represent intermittent use of or visits to the rockshelter prior to permanent habitation, which began with zone SZ-2. The paucity of stone artifacts in zone SZ-1B supports the interpretation of the limited use of the site during this time period, based on evidence of human disturbance, lenses, charcoal, and rat bones (Kirch et al. 1995; see also Chapter 4).

The majority of lithic artifacts were recovered from stratigraphic zones SZ-2 (541 lithics or 29.5 percent of the total sample) and SZ-3 (1,164 lithics or 63.6 percent). These zones represent in situ occupations with a rich diversity of faunal and plant remains (see Chapters 5 to 9). The density of lithic remains in these deposits (SZ-2 concentration index of 751 lithics/m³; SZ-3 concentration index of 1,252 lithics/m³) in association with a range of other tools and food remains supports the interpretation that Tangatatau Rockshelter was used as a habitation site with a broad range of activities during this period. The later prehistoric deposits, zones SZ-6 and SZ-9, and the postcontact deposit, zone SZ-17, have greatly reduced densities of lithics (Figure 12.1). It should be noted, however, that the

four analyzed units had rather limited representation of the later stratigraphic zones; zone SZ-8, for example, was not represented in the analyzed sample.

The majority of the lithic artifacts are of basalt (1,739 artifacts or 95 percent), while chert artifacts are in much lower frequency (87 artifacts or 4.7 percent). Two limestone flakes that may represent spalls from the rockshelter wall, but appear to be artificially modified, were recovered, both from zone SZ-1B. Four pieces of debitage (0.2 percent of the sample) of uncertain raw material type (all from zone SZ-3) are characterized by a “salt-and-pepper” matrix; they may derive from an unidentified late volcanic extrusive.

Overall, there is little variability in raw material use at the rockshelter over time (Figure 12.2). Basalt dominates in all of the deposits. Chert has a limited but generally constant frequency throughout the sequence, suggesting opportunistic use of local chert sources from the initial occupation of the rockshelter up to the later prehistoric period.

Tools

Recognizing the importance of flake tool manufacture and use within Polynesian lithic industries (see Clark et al. 1998; Kahn 1996), all debitage was scanned macroscopically for retouch and edge damage scars. Tools were classified according to broad categories, including polished adze flakes, utilized and retouched flakes, and cores (Table 12.2). Miscellaneous formal tools were defined as well-worked artifacts with substantial retouch. Informal tools include utilized flakes (used in an unmodified form) and minimally retouched flakes. Overall, tools make up 2.4 percent of the total analyzed 1991 lithic assemblage.

Polished Adze Flakes and Shatter

Zones SZ-2 and SZ-3 have the highest counts for polished adze flakes and shatter. In general, the adze flakes and shatter are small, although there is some range in length, width, and weight from the mean in these assemblages (Table 12.3). Adze flakes and shatter with polish on just a single surface dominate (11 in SZ-2 and 17 in SZ-3). Zone SZ-2 has a higher frequency of polished adze debitage with two polished surfaces (eight examples or 40 percent) than SZ-3 (seven examples or 29 percent). Most debitage with polished surfaces have polish on the dorsal surface, followed in frequency by debitage with polish on the striking platform or the dorsal surface and striking platform (Table 12.4).

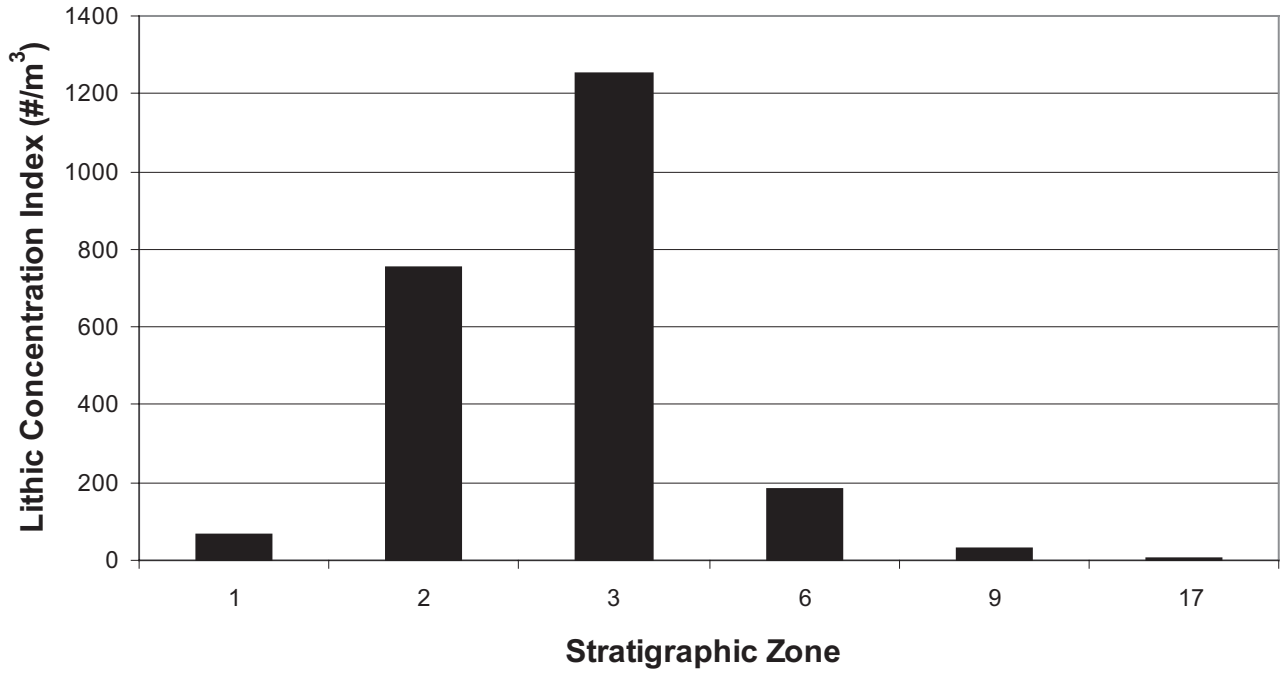


Figure 12.1. Concentration indices for lithic material by stratigraphic zones (from analyzed units E35, E36, F35, and F36).

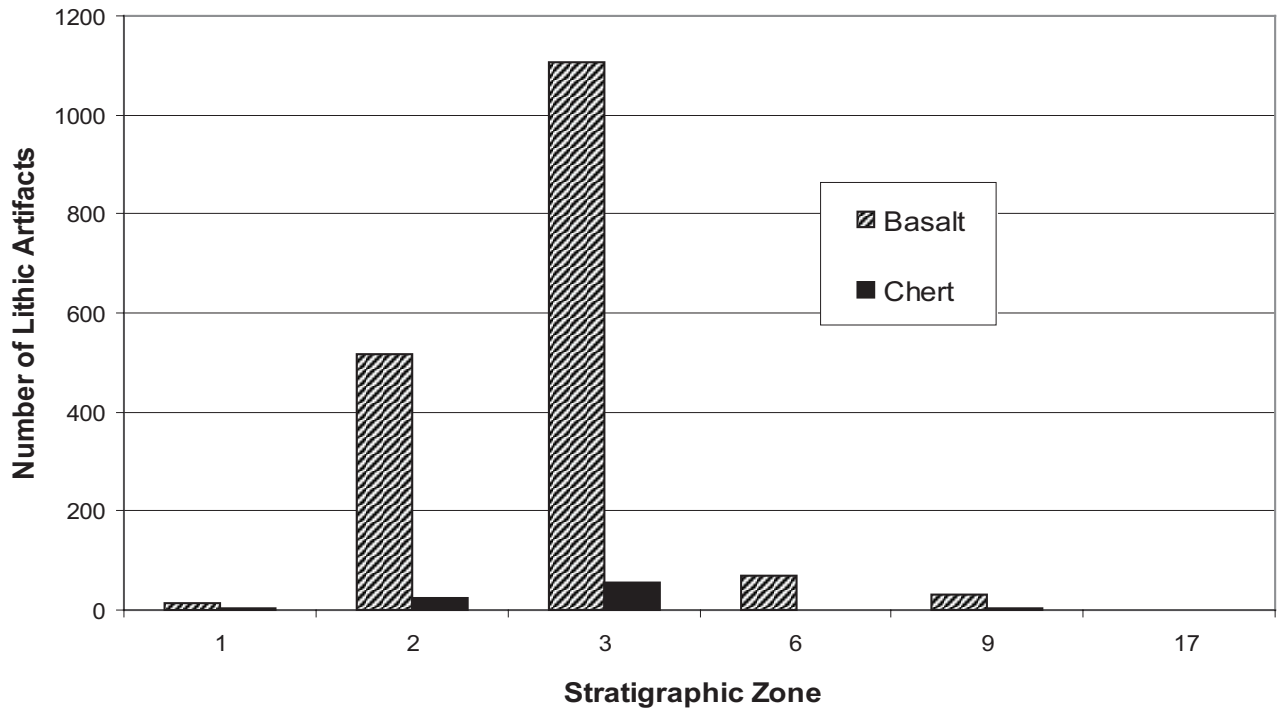


Figure 12.2. Distribution of basalt versus chert lithics by stratigraphic zone.

Table 12.2. Lithic Tool Frequency by Stratigraphic Zone, Site MAN-44.

Tool Type	SZ-1	SZ-2	SZ-3	SZ-6	SZ-9	SZ-17
Adze flake	0	17	11	0	0	1
Adze flake fragment	0	3	9	0	1	0
Adze shatter	1	0	4	1	0	0
Utilized flakes	0	2	3	0	0	0
Retouched flakes	0	0	2	0	0	0
Core, core fragments	0	1	4	0	0	0

Table 12.3. Frequency and Size Statistics for Adze Flakes and Shatter, Site MAN-44.

Zone (SZ)	Count	Average Length	Range	Average Width	Range	Average Weight	Range
17	1	18.7	—	22.4	—	4.3	—
9	1	20.8	—	27.5	—	3.9	—
6	1	10.3	—	17.2	—	2.7	—
5	1	35.3	—	19.8	—	6.7	—
3	24	20.1	8.1–40.5	7.7	7.7–28.2	2.5	.20–10.0
2	20	20.3	6.4–48.6	11.2	11.2–63.0	6.4	.4–32.0
1	1	28.2	—	30.8	—	13.4	—

Table 12.4. Location of Polished Surfaces on Lithics, Site MAN-44.

Attribute	SZ-2		SZ-3	
	<i>n</i>	%	<i>n</i>	%
Dorsal	8	40.0	16	66.7
Striking platform	3	15.0	1	4.2
Dorsal and striking platform	4	20.0	5	20.8
Dorsal and distal	3	15.0	1	4.2
Dorsal, distal, platform	1	5.0	0	0
Two adjacent surfaces (adze shatter only)	0	0	1	4.2
Missing data	1	5	1	4.2

Table 12.5. Adze Debitage Edge Types, Site MAN-44.

Edge Type	SZ-2		SZ-3	
	<i>n</i>	%	<i>n</i>	%
Nonedge	8	50.0	16	66.7
Indeterminate edge	3	15.0	3	12.5
Side edge	3	15.0	2	8.3
Bevel edge	1	5.0	2	8.3
Indeterminate corner	2	10.0	1	4.2
Missing data	1	5.0	1	4.2

High amounts of zone SZ-2 and SZ-3 polished adze debitage do not contain a ground or polished edge (50 percent and 66.7 percent, respectively) (Table 12.5). Side edges, bevel edges, and indeterminate edges and corners are all represented in low numbers.

Most of the adze shatter is of moderate size, in the 1- to 4-cm range, although zone SZ-3 has a somewhat higher percentage of adze debitage <1 cm in length (8.3 percent) that may be linked to deliberate adze resharpening (Table 12.6). The majority of shatter pieces with polished surfaces in both zones are <5 g in weight (Table 12.7). Zone SZ-2 has a higher percentage of polished debitage, >5 g, in agreement with the size distribution data indicating that zone SZ-3 has higher frequencies of smaller adze debitage than does SZ-2.

Withrow (1991) has described three processes that produce adze flakes and shatter at habitation sites: accidental breakage during use, accidental breakage during resharpening and maintenance, and deliberate removal in adze resharpening and maintenance. She argued that deliberate adze resharpening would result in assemblages with small flakes (<1 cm in length and <5 g in weight) with a high incidence of polish. In particular, most flakes would exhibit polish on the striking platform and bevel (representing removals from the bevel during resharpening) or would represent bevel corners. In a similar manner,

Table 12.6. Length Distribution Patterns for Polished Adze Flakes and Shatter, Site MAN-44.

Zone	<1-cm Length		1–1.99 cm		2–2.99 cm		3–3.99 cm	
	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%
SZ-2	2	1.0	10	50.0	4	20.0	4	20.0
SZ-3	4	8.3	10	41.7	5	20.8	5	20.8

Table 12.7. Weight Class Distribution for Adze Debitage, Site MAN-44.

Zone	<5 g		>5 g	
	<i>n</i>	%	<i>n</i>	%
SZ-2	13	65.0	7	35.0
SZ-3	20	83.3	4	16.7

Olszewski (2007) has argued that sites emphasizing adze recycling and resharpening should have high quantities of polished flakes, especially those with polish on the platform and those in smaller size ranges. The moderate, rather than small, size of the polished adze debitage at MAN-44, as well as the low frequency of bevel edges (represented as flakes with polish on the striking platform) and only moderate frequency of flakes with two polished surfaces, does not support an interpretation of deliberate adze repair, such as bevel resharpening, being emphasized in either zone SZ-2 or SZ-3. However, two adze flakes were recovered that had two opposing edges and were removed from the full width of an adze. Flakes of this type typically indicate an effort to repair broken cutting edges during adze maintenance (Withrow 1991:203, 210), suggesting some limited efforts at adze maintenance at the rockshelter.

Three pieces of polished adze debitage were used as simple flake tools after they had been detached from the adze, either by use or intentional reworking. Most had a single region of use. One example had bifacial use-wear scars, suggesting a longitudinal use-motion. Another had unifacial wear, suggesting a scraping use-motion. A third had use-wear on the left lateral pointed edge, where the surface was dulled as if used as an awl. This adze flake also had use-wear on a separate area of the left lateral margin with unifacial wear suggestive of a scraping activity. These data follow trends in other Eastern Polynesian lithic assemblages, where adze flakes with sharp edges were typically used to a larger extent as expedient tools rather than nonpolished flakes (Kahn 1996).

Cores

Cores occur in low frequency in the MAN-44 assemblage. Five cores or core fragments were recovered in the 1991 excavations, four fashioned from basalt and one from chert. In all cases, the cores were unprepared, lacking standardized shapes and having flakes removed in multiple directions (after Andrefsky 1998:15; Kahn 1996). The basalt cores had multiple platforms where reduction was initiated. The chert core had a single platform for flake removal but lacked a standardized shape or standardized direction of flake removals. The MAN-44 cores are amorphous, in that they lack prepared shapes. These types of cores are typically associated with core reduction for removal of flakes for later use, either in a retouched or unretouched state.

With the exception of specimen E36-5-17, the basalt cores are medium sized (see Kahn 1996), ranging from 53 to 69 mm in length and 29 to 92 mm in width (Table 12.8). The cores do not appear to be exhausted and could have been reduced further. Their size, as well as their amorphous form, is consistent with the production of flakes for simple flake tool manufacture. The presence of utilized flakes and retouched flakes at the site supports an interpretation of flake tool production and use at the rockshelter. This practice has been identified at other habitation sites in Eastern Polynesia (Dixon 1994; Sinoto and McCoy 1975; Smith et al. 1996), although this activity has often been overlooked.

The E36-5-17 core is in the size range expected for flake blanks used in adze manufacture (see Withrow 1991:97, 1087; Table 4.3). This specimen is a piece of fine-grained dykestone that has been minimally reduced from three platform areas to remove the cortical surface. It resembles an early stage adze blank. It was likely rejected at an early stage because in removing the cortical surface, a number of flake removal failures ended in hinge or step fractures that led to platforms that could no longer be reduced. It is recorded here as a core because the piece is reduced too minimally to be formally called an adze blank.

Table 12.8. Descriptive Metric and Nonmetric Data for Cores, Site MAN-44.

Zone	Raw Material	Condition	Cortex	Remnant Platforms	Length (mm)	Width (mm)	Weight (g)
SZ-2	Basalt	Whole	Absent	2	53.20	29.00	28.50
SZ-3	Basalt	Fragment	Absent	2	66.30	39.10	67.60
SZ-3	Basalt	Fragment	Absent	3	69.80	92.50	251.80
SZ-3	Basalt	Whole	75%–99%	3	114.60	55.70	555.50
SZ-3	Chert	Whole	Absent	1	21.90	19.30	12.30

The chert core is small in size and appears close to exhaustion. Its small size and the small size range of the chert debitage (see below) indicate that the original form of this material was in small nodules. This may represent use of chert nodules isolated in the local *makatea* or use of the source at Niirimoku but does not appear to represent chert from the Ivirua source, which has large cobble- and boulder-sized nodules.

No prepared cores—that is, cores with single platforms and flakes removed in one direction—or bipolar cores were found. Again, the amorphous nature of the analyzed cores indicates that they represent core reduction for flake tools.

Debitage Analysis
Unknown Raw Material

Four artifacts of unknown raw material were found in the later prehistoric deposits, zones Z-6 and SZ-9. Two complete flakes and two pieces of shatter were recovered, all with small size dimensions (average length 23.8, average width 34.1 mm). One flake had 1 to 24 percent dorsal cortex cover, and all debitage had dorsal scar counts of 2 or 3. Flake platforms were crushed and, in one case, had evidence for platform preparation and unsuccessful flake removals. The small quantity of debitage of this “unknown” raw material, its small size (Table 12.9), and the presence of cortex on one flake all suggest that a small nodule of this raw material was opportunistically reduced at the site.

Chert: Unretouched Debitage

The chert assemblage makes up just 4.7 percent of the overall 1991 MAN-44 lithic assemblage. There was considerable variability in the color of the chert debitage, ranging from the most common, a light brown matrix with a gray pitted cortical surface, to pieces with a deep red, dark brown, or gray matrix. Not enough

Table 12.9. Mean Length, Thickness, and Weight for Debitage by Raw Material, Site MAN-44.

Material	Mean Length (mm)	Mean Width (mm)	Mean Weight (g)
Unknown	23.8	34.2	7.5
Basalt	28.1	28.5	12.4
Chert	21.8	21.6	4.0
Limestone	30.8	24.6	5.8

is known about chert sources on Mangaia to pinpoint the artifacts’ specific provenance, but the range in color tentatively suggests that either more than one source was used or there is intrasource variation in color.

The majority of the chert artifacts were recovered in stratigraphic zones SZ-2 and SZ-3 (28.7 percent and 62.1 percent, respectively). Low frequencies of chert debitage were recovered in zones SZ-1, SZ-6, and SZ-9. The low amount of chert in these zones follows the overall low frequencies of all types of debitage basalt from these strata, rather than representing decreasing availability of chert at any time. Due to the small sample size, I will only discuss the general characteristics of the chert assemblage.

Overall, the size and weight data for the chert debitage indicate opportunistic reduction of small nodules (Table 12.9). The majority of chert artifacts are medial or distal flake fragments (42.5 percent), followed in frequency by shatter (21.8 percent), complete flakes (23.0 percent), and proximal flake fragments (11.5 percent). The low number of complete flakes suggests that the debitage results from general core reduction (after Prentiss and Romanski 1989:91), as does the recovery of the chert core. Based on experimental data contrasting debitage from biface manufacture from that of expedient core reduction (see Baumler and

Downum 1989; Prentiss and Romanski 1989), the frequency of chert shatter is lower than expected if the assemblage resulted from generalized core reduction. However, it is closer to expected frequencies of shatter in experimental expedient core reduction than to experimental frequencies from formal tool production. This suggests that chert was reduced for both simple and formal flake tools. The frequency of utilized and retouched chert flakes in the assemblage is low, as is the frequency of formal tools. Chert flakes and tools may have been removed from the site, used, and deposited at other locales.

Within the Cook Islands, chert is known to occur locally only on Mangaia (Weisler et al. 1994:205–206). The majority of the chert debitage recovered in the 1991 excavations is small. While the sample size is small, the data suggest that the chert reduced at the site was restricted to smaller sized nodules, rather than the “huge boulders of chert” that were reported by Marshall (1927:37) in the Ivirua area. Most likely, local *makatea* chert nodules were being opportunistically gathered and reduced at the site.

Overall, the frequency of dorsal cortex for the chert assemblage is relatively low, with only about 22 percent of the debitage bearing cortex. Platforms bearing cortex are rare, making up just 10 percent of the assemblage. Overall, cortex-bearing chert debitage is found with low frequency; 78 percent of the assemblage lacked cortex, while 5 percent had 1 to 25 percent cortex coverage, 7 percent had 26 to 50 percent coverage, 3 percent had 51 to 75 percent coverage, 6 percent had 76 to 99 percent coverage, and 1 percent had full cortex cover. Chert was being reduced first off-site, or cortical flakes were underrepresented in the small sample that was studied. Local sources appear to have been cobbles or smaller nodules with an outer cortex layer, so a higher percentage of cortical flakes would be expected if all stages of reduction were present. Some early to late-stage reduction of nodules with cortex is represented in the low frequency of flakes with a range of cortex coverage. A single flake with 100 percent cortex cover supports an interpretation of at least some of the chert nodules being reduced from their original form on-site, with the cortex not fully removed from all of the chert nodules before they entered the site.

Sixty-nine percent of the chert debitage had two or fewer dorsal scars, while just 30 percent of the debitage had complexly scarred dorsal surfaces (three or more dorsal scars). The only moderate level of complexly

scarred chert debitage recovered implies that simple flake tool and formal tools were being produced. The low amount of cortical-bearing chert debitage tentatively suggests that nodules were being reduced off-site before being reduced in the rockshelter.

Basalt: Unretouched Debitage

Few lithic studies in the Pacific have systematically recorded frequency data for distal flake fragments and shatter (e.g., Turner and Bonica 1994; Williams 1989). However, data from adze quarry sites suggest that adze debitage assemblages should have a high percentage of platform remnant bearing flakes and low frequencies of shatter (McCoy et al. 1993).

Frequency distribution patterns for debitage types in zones SZ-2 and SZ-3 conform to this pattern, with high percentages of complete flakes (47 and 50 percent, respectively), high percentages for flake fragments (44.3 and 40.5 percent, respectively), and low frequencies of shatter (8.4 and 9.4 percent, respectively) (Table 12.10). Overall, zone SZ-2 has 59.3 percent of debitage with remnant platforms, while zone SZ-3 has 63.7 percent, both high frequencies similar to those documented at quarry locales where adzes were manufactured. While the sample size is small, debitage distribution patterns in zone SZ-6 diverge from this pattern. In zone SZ-6, 42 percent of the assemblage is made up of complete flakes, with 50 percent of the overall assemblage-bearing platforms. Shatter frequency is higher than in any other assemblage, at 21 percent. Generalized core reduction produces higher frequencies of shatter than tool production. The higher frequency of shatter in zone SZ-6 may correlate to an increasing emphasis on generalized core tool reduction at the rockshelter.

Dorsal cortex cover is perhaps the most widely used variable for inferring reduction stage, particularly for distinguishing the extremes of the reduction sequence from one another (early from late) (Clarkson et al. 2015; Magne 1985; Odell 1989; Tomka 1989). Overall, the amount of dorsal cortex frequency in the MAN-44 assemblages is low, at 13.5 percent of the zone SZ-3 debitage and 5.8 percent of SZ-2 debitage (Table 12.11). This is well below ranges for early stage adze reduction experiments (i.e., Turner and Bonica [1994] report 64.6 to 78.1 percent cortical flakes; Clarkson et al. [2015] report c. 36 percent cortical flakes) and below expected ranges for quarry assemblages with the full range of adze reduction present (50 to 90 percent after Dixon [1995];

Table 12.10. Frequency of Basalt Debitage by Stratigraphic Zone, Site MAN-44.

Zone (SZ)		Complete Flakes	Proximal Flake Fragments	Medial/Distal Flake Fragments	Shatter	Totals
1	<i>n</i>	3	1	4	5	13
	%	23.1	7.7	30.8	38.5	100
2	<i>n</i>	230	60	158	41	489
	%	47.0	12.3	32.3	8.4	100
3	<i>n</i>	537	146	288	101	1,072
	%	50.1	13.6	26.9	9.4	100
6	<i>n</i>	28	4	21	14	67
	%	41.8	6.0	31.3	20.9	100
9	<i>n</i>	7	1	12	6	26
	%	26.9	3.8	46.2	23.1	100

26.2 to 48.4 percent after Turner and Bonica [1994]). It is also below expected frequencies for assemblages related to mid-stage adze preform manufacture (Dixon et al. 1994). It is, however, within ranges reported for workshop sites and residential locales with final finishing of adzes (Clarkson et al. [2015] report c. 6 percent; Dixon et al. [1994] report less than 10 percent; Turner and Bonica [1994] report 12.6 to 21.4 percent; Kahn [1996:232] reports 2 to 10 percent).

The low frequency of cortex is unexpected, given that the original form of the majority of the parent material appears to be either dykestone or eroded waterworn cobbles from the Mata'are source. The low frequencies ofdebitage with cortex cover, particularly the low numbers of flakes with both dorsal and platform cortex, suggest that the majority of on-site adze reduction was associated with the reduction of quarried flake blanks rather than tabular blocks of dykestone. There is little evidence to suggest that much unmodified stone or blanks were removed from the quarry and transported to the site.

In addition, the low frequency of corticaldebitage indicates that the assemblages were derived mainly from middle to later stage adze manufacture, where a significant portion of the early stage reduction appears to have occurred off-site. For example, 5 percent of the SZ-3debitage and just 3 percent of the SZ-2debitage have 50 percent or more dorsal cortex cover, representing early stage adze reductiondebitage. The low frequency ofdebitage with 100 percent dorsal cortex in SZ-2 and SZ-3 supports an interpretation that the assemblages relate primarily to later stage reduction,

similar to frequencies reported by Turner and Bonica (1994) and by Clarkson et al. (2015) in their late-stage adze reduction experiments (1 to 6.1 percent and 0 percent flakes with full dorsal cortex coverage, respectively). It is below the frequencies expected for quarry site assemblages (2.3 to 23 percent reported by Turner and Bonica [1994]). Thus, some early stage adze reduction was taking place on-site, but overall, the data support that the majority of initial stage adze reduction was initiated off-site, perhaps at as yet undiscovered workshop areas. This is similar to patterns commonly found at habitation sites elsewhere in Polynesia (Dixon et al. 1994; Kahn 2005:369, 372, 419; Kahn and Kirch 2013; Mills et al. 2011; Orliac et al. 1989:136), excluding those unique cases where high-status households had attached lithic specialists or where specialized house sites were associated with particular ritual activities involving stone tool production and use (Kahn 2005, 2007; Kahn and Kirch 2013; Kirch et al. 2010; Taomia 2001; Walter 1998; Weisler and Kirch 1985).

Several researchers have argued that platform cortex is a more reliable indicator of reduction stage than dorsal cortex (Magne 1985; Tomka 1989), but this attribute is rarely recorded in Polynesian lithic analyses. Low amounts of flakes and proximal flake fragments with cortex-bearing platforms were recorded, just 5.2 percent and 3.3 percent of zones SZ-3 and SZ-2debitage, respectively (Table 12.12). The paucity of platform cortex conforms to the pattern already discussed for dorsal cortex frequency, further supporting that the original basalt reduced at MAN-44 either lacked large amounts of cortex (i.e., flake blanks) or were reduced to some extent

Table 12.11. Frequency of Dorsal Cortex Cover for Basalt Debitage (Includes Flakes, Flake Fragments, and Shatter), Site MAN-44.

Zone (SZ)		0	1%–24%	25%–49%	50%–74%	75%–99%	100%	Missing Data ^a
1	<i>n</i>	11	1	1	0	0	0	0
	%	84.6	7.7	7.7	0	0	0	0
2	<i>n</i>	443	4	10	8	7	0	17
	%	90.6	.8	2.0	1.6	1.4	0	3.5
3	<i>n</i>	905	53	41	25	24	2	22
	%	84.4	5.0	3.8	2.3	2.2	.2	2.1
6	<i>n</i>	63	1	3	0	0	0	0
	%	94.0	1.5	4.5	0	0	0	0
9	<i>n</i>	24	1	0	0	0	0	1
	%	92.3	3.8	0	0	0	0	3.8

^aMissing data refers to instances where certain attributes could not be recorded because of artifact patination.

prior to their arrival at the site. The low frequency of flakes with both striking platform and dorsal cortex conforms to patterns found for flake blank reduction rather than tabular dykestone reduction (Cleghorn 1982).

Dorsal scar counts can be used to differentiate early stage adze production (preform and blank roughing out) from late-stage adze production (preform finishing, trimming, side straightening). Early adze reduction (early blank/preform roughing out) produces high amounts of debitage with two or fewer dorsal scars (89.5 to 90.0 percent in Turner and Bonica [1994]) and low amounts of debitage with three or more scars (10 to 30 percent). Later reduction (final trimming) produces higher frequencies of flakes with three or more dorsal scars (35 to 76 percent).

Zones SZ-2 and SZ-3 have moderately high frequencies of early stage debitage with two or fewer dorsal scars, at 63 percent and 65 percent, respectively (Table 12.13). These percentages are lower than expected for assemblages resulting from just early stage reduction of adzes, yet definitively higher than expected for assemblages resulting solely from late-stage adze trimming. The percentages conform most closely to amounts recorded by Turner and Bonica (1994) for replicative experiments that included the full range of adze manufacture, where around 72 to 82 percent of the debitage has two or fewer dorsal scars. These data indicate that a range of adze manufacturing stages were practiced at MAN-44 during the SZ-2 and SZ-3 occupations. The somewhat lower percentages for early stage debitage in the MAN-44 assemblages support an interpretation that some initial reduction of basalt (i.e., initial adze/

blank roughing out, where cortex would be removed) occurred prior to the importation of this raw material to the site, in agreement with debitage assemblage cortex frequencies. Furthermore, the moderate percentages of late-stage debitage with three or more dorsal scars, at 34 percent and 33 percent of the SZ-2 and SZ-3 assemblages, respectively, indicate that while a full range of adze manufacture was practiced at the site, there was a greater emphasis on late-stage trimming activities than early stage reduction, indicating again that basalt entered the site in a partially reduced state (see also Williams 1989:79–81). The presence of polished adze flakes and shatter demonstrates that reworking of adzes after their manufacture and use was carried out (i.e., bevel resharpening), which may have elevated the counts for late-stage debitage.

Based on metric data alone, the MAN-44 basalt debitage assemblages are smaller than expected if the full range of adze reduction were present (Table 12.14; see Clarkson et al. 2015). Moderately small flakes dominate all assemblages. All zones have overall low average length and width frequencies (ranging from 24.5 to 32.4 mm) and low average weights (from 9.1 to 16.1 g). These values fall into frequencies for final preform trimming and final edge straightening, based on Turner and Bonica’s (1994) replicative experiments, although small size flakes are produced in all stages of adze manufacture. Overall, the debitage size frequency indicates that reduction activities at the rockshelter focused on middle- to late-stage adze manufacture and finishing rather than the initial stages of blank and preform manufacture.

Table 12.12. Frequency of Platform Cortex Cover for Basalt Flakes and Proximal Flake Fragments, Site MAN-44.

Zone (SZ)		0%	1%–24%	25%–49%	50%–74%	75%–99%	100%	Missing Data ^a
1	<i>n</i>	4	0	0	0	0	0	0
	%	100	0	0	0	0	0	0
2	<i>n</i>	235	5	1	1	3	0	45
	%	81.0	1.7	.3	.3	1.0	0	15.5
3	<i>n</i>	593	7	8	1	15	5	54
	%	86.8	1.0	1.2	.1	2.2	.7	7.9
6	<i>n</i>	30	0	1	0	0	0	1
	%	93.8	0	3.1	0	0	0	3.1
9	<i>n</i>	8	0	0	0	0	0	0
	%	100	0	0	0	0	0	0

^aMissing data refers to instances where certain attributes could not be recorded because of artifact patination.

Table 12.13. Frequency of Dorsal Scars for Basalt Debitage, Site MAN-44.

Zone (SZ)	0 Scars		1 Scar		2 Scars		3 Scars		4 Scars		4+ Scars		Missing Data ^a	
	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%
1	0	0	5	45.4	6	54.5	0	0	0	0	0	0	0	0
2	0	0	110	22.5	195	39.9	95	19.4	56	11.5	13	2.7	20	4.1
3	2	.2	240	22.4	455	42.4	246	23.0	73	6.8	37	3.5	19	1.8
6	0	0	14	20.9	35	52.2	13	19.4	4	6.0	1	1.5	0	0
9	0	0	12	46.2	8	30.8	2	7.7	2	7.7	1	3.8	1	3.8

^aMissing data refers to instances where certain attributes could not be recorded because of artifact patination.

Table 12.14. Metric Data for Basalt Debitage by Stratigraphic Zone, Site MAN-44.

Zone (SZ)	Average Length (mm)	Length Range	Average Width (mm)	Width Range	Average Weight (g)	Weight Range
1	28.8	6.2–62.8	24.5	9.6–54.5	12.5	0.20–66.0
2	25.4	6.9–166.9	26.0	5.1–82.2	9.1	0.10–193.0
3	28.9	4.0–96.5	29.4	3.3–333.9	12.5	0.10–237.4
6	28.5	11.3–93.9	31.3	8.00–103.0	14.6	0.70–167.9
9	32.4	12.8–93.5	27.1	10.1–83.5	16.1	0.5–130.7

A number of researchers have used general length distributions to infer adze reduction stages in archaeological assemblages. Most agree that flakes >50 mm in length are produced in early stage adze reduction, and those <50 mm in length are produced in later stage adze reduction (Leach 1981), although small flakes are produced with the highest frequency in all stages of production (Cleghorn 1982; Turner and

Bonica 1994). The MAN-44 data (Table 12.15) indicate that later stage reduction activities rather than early adze reduction activities were emphasized at the site. There was little change in this pattern over time.

Turner and Bonica (1994:7–8) applied mass analysis techniques in their adze reduction experiments and found that weight size classes could distinguish between early stage preform roughing out (size classes

Table 12.15. Length Size Class Data for Basalt Debitage, Site MAN-44.

Zone (SZ)	<50 mm		>50 mm	
	<i>n</i>	%	<i>n</i>	%
6	60	89.6	7	10.4
3	967	90.2	105	9.8
2	460	94.1	29	5.9

>300 g, 201–300 g, 101–200 g, 51–100 g) and later stage adze trimming (size classes 21–50 g, 3–20 g). The weight distribution data for the MAN-44 basalt debitage (Table 12.16) confirm the reduction stage patterns discussed above. All zones have high numbers of small flakes and are dominated by flakes in the 3- to 20-g weight class. The high percentages of 3- to 20-g flakes (71.9 to 80 percent) correspond to patterns found in late-stage experimental adze replication, which emphasized final trimming and/or reworking of adzes (Turner and Bonica 1994:16–17). The lack of debitage in the heaviest weight categories (just 0.6 percent of the SZ-3 assemblage) supports an interpretation of little early stage reduction at the rockshelter. In Turner and Bonica’s (1994) experiments, flakes of this weight were associated with preform and adze roughing out. The weight distribution patterns indicate that late-stage adze reduction (trimming) was emphasized at MAN-44, as well as adze reworking.

Discussion

The reduction stage analysis of the MAN-44 basalt debitage demonstrates the following points with respect to adze manufacturing stages and the Mangaia stone tool economy. First, preforms recovered at the rockshelter appear to have been produced off-site and imported in an already worked, although rough form (Figure 12.3). Following from this, there must be workshops near the

quarries or working floors where preforms were fashioned that have as yet not been recorded on Mangaia. Adze reduction on Mangaia appears to have followed a sequential production system pattern, where different stages in the process (early quarrying, preform manufacture, later trimming) were spatially segregated across the landscape.

Second, the low frequencies of cortex-bearing debitage support an interpretation that flake blanks were being reduced at the site or already worked dykestone tabs or waterworn cobbles that lacked full cortex coverage. Adze production emphasizing the reduction of flake blanks has been documented at other central Eastern Polynesian sites (Anderson et al. 1994).

Third, while some early stage preform reduction occurred at the site, the emphasis was on middle-stage preform shaping, later stage edge straightening, and adze finishing. While some reworking of adzes is represented, the numbers of polished adze flakes in the MAN-44 assemblage are not high, unlike sites where high numbers of polished flakes were inferred to represent an emphasis on adze resharpening (Allen and Steadman 1990; Olszewski 2007; Withrow 1991).

Throughout the site’s occupation history, later stage adze reduction was emphasized. There appears to have been little change in the organization of adze production over time. However, zone SZ-2 consistently exhibits slightly higher frequencies of late-stage debitage than SZ-3 or SZ-6, implying that final adze trimming was emphasized to a slightly greater degree in the earlier occupation of the site.

Extra-Areal Comparisons

It is of some interest to compare the MAN-44 lithic analysis data to other Archaic Eastern Polynesian sites. At the Archaic period house site at Peva, Austral Islands, Bollt (2008) recovered 33 adzes and broken preforms in addition to moderately dense frequencies of debitage

Table 12.16. Basalt Debitage Weight Size Class Data, Site MAN-44.

Zone (SZ)	3–20 g		21–50 g		51–100 g		101–200 g		201–300 g		>300 g		All
	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	
6	32	80.0	3	4.5	2	5.0	3	7.5	0	0	0	0	40
3	473	71.9	131	20.0	41	6.2	9	1.4	4	.6	0	0	658
2	189	80.8	26	11.1	15	6.4	4	1.7	0	0	0	0	234

Note: Excludes flakes in the smallest weight class, <3 g, after Turner and Bonica (1994).

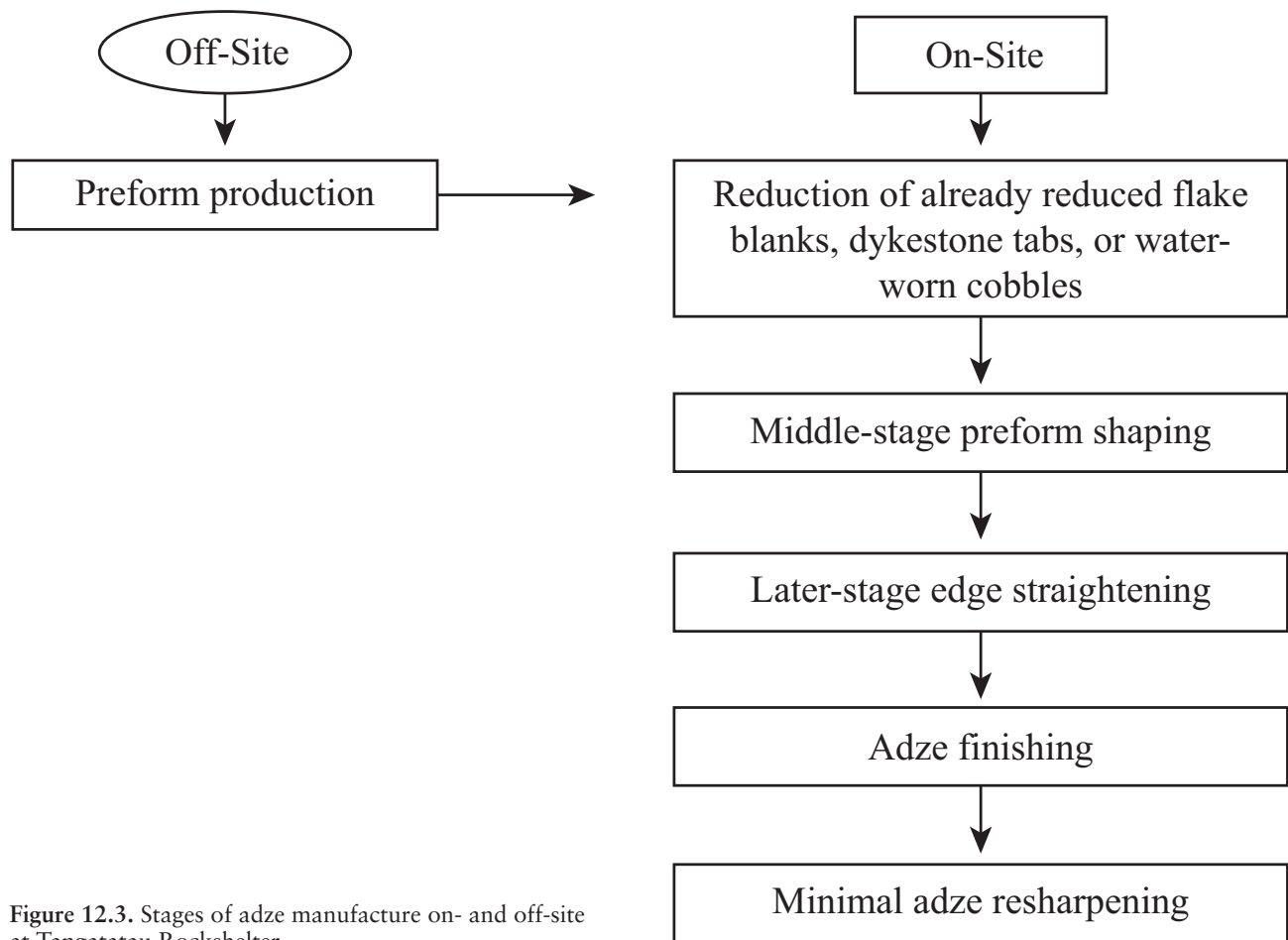


Figure 12.3. Stages of adze manufacture on- and off-site at Tangatatau Rockshelter.

and flake tools. While detailed analysis of the debitage was not carried out, Bollt (2008:193) argued that the small size of the flakes (predominately smaller than 4.5 cm) indicated late-stage finishing of preforms that had been brought into the site from quarries elsewhere on the island, comparable to my findings at the MAN-44 rockshelter. Similarly, at the Atiahara site on Tubuai, the dominance of non-cortex-bearing flakes (85 percent of the total) and the low numbers of decortification flakes with 100 percent cortex cover (at 1 percent of the total) (see Hermann 2013) suggest that blanks and preforms from quarries and working floors elsewhere on the island were to some extent imported into the site and then used or further reduced (as a form of late-stage production or preform finishing).

Few Archaic period lithic assemblages in the Cook Islands have been subjected to detailed reduction stage analyses. However, the limited data indicate that there was spatial segregation of different stages in the

reduction process. Allen and Schubel (1990) reported high densities of basalt debitage from a 1-m test unit in the Moturaku Rockshelter. Based on the density of basalt artifacts, they argue that the shelter represents a specialized activity area where early stage quarrying and reduction of basalt took place, in addition to fish procurement. It seems likely that a specialized site of this nature focusing on the initial stages of adze production will be found within the vicinity of MAN-44 in the future. At the Ureia Site (Aitutaki Island), the oldest deposits had cooking and adze resharpening activities. The density of basalt debitage suggested a workshop area, and the high frequency of polished adze flakes (19 percent) indicated an emphasis on adze reworking and resharpening activities. The MAN-44 assemblages do not have a high frequency of polished adze debitage. It may be that because of the site's proximity to the abundant and high-quality basalt at the Mata'are quarry, economizing behavior such as adze resharpening was not stressed.

Walter's (1998) excavations at Anai'o, an Archaic period habitation site (Ma'uoke, Southern Cooks), recovered moderate densities of lithic debitage. A high percentage of the assemblage lacked cortex (90 percent); this, along with the small mean size (mean length 28.0 mm) and high percentage of polish debitage (14 percent), indicates that late-stage adze production and reworking were carried out at this habitation site. These data are consonant with findings from the MAN-44 rockshelter.

Overall, the Cook Islands data suggest that certain habitation sites stressed late-stage preform trimming and adze reworking, while early stage reduction was carried out at spatially segregated, restricted activity sites. Similar patterns stressing late-stage adze reduction or resharpening have been found at other Archaic period habitation sites in central Eastern Polynesia (Kahn 1996; Rolett 1998; Sinoto and McCoy 1975) and later prehistoric sites in New Zealand (Turner and Bonica 1994), Hawai'i (Dixon et al. 1994), and the Society Islands (Kahn 2005; Kahn and Kirch 2013). For example, in their analysis of southwest Moloka'i sites, Dixon et al. (1994) documented in situ production of blanks at quarry sites and blank finishing at workshop sites where cortex was removed. Preforms were then transported to smaller sites where final preparation and polishing took place.

Proximity to basalt sources appears to structure the organization of lithic technology in Polynesia to some degree. Variation in the degree of adze reworking carried

out at a site may be influenced by access to raw material. Sites such as MAN-44 that were near large sources of fine-grain basalt do not have high distributions of polished adze debitage suggestive of extensive reworking practices. In an example from the Marquesas, Kahn (1996) argued that adzes at the Ha'atuatua site on Nuku Hiva Island were imported from the off-island source at Eiao Island in an advanced stage of reduction but not as fully polished adzes. Late-stage trimming, as well as adze polishing and reworking, took place at the habitation site. However, adze rejuvenation was not emphasized at the site, as only 2.8 percent of the debitage recovered were polished. It appears that broken adzes were not intensely rejuvenated or economized, perhaps because adzes were also fashioned from local coarse-grained basalt sources.

Detailed reduction stage analysis of basalt debitage assemblages in Eastern Polynesia has been crucial for defining this spatial segregation of different segments of the adze reduction process. Evidence from the Tangatatau Rockshelter indicates that this organization of adze production was conservative and changed little through time. However, here we are dealing with a site that was in close proximity to two fine-grained basalt sources (Veitatei and Mata'are). Residents of sites farther away from this source, such as inhabitants of the Ure'ia and Anai'o sites, appear to have had a more restricted access to adzes, and it is in these sites where we find greater amounts of adze resharpening as an economizing behavior.

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13

Archaeological Investigations at Other Sites

Patrick Vinton Kirch and Julie M. E. Taomia

While the main thrust of our 1989 and 1991 field seasons on Mangaia was the excavation of Tangatatau Rockshelter, in both field seasons, we also carried out surface surveys and test excavations at a number of other sites to fill out aspects of the island's archaeological record. A brief overview of Mangaian archaeological sites and settlement patterns has already been presented in Chapter 3. Here we provide summaries of the test excavation or detailed mapping carried out at selected sites in Keia, Veitatei, and Tamarua districts. The locations of the sites discussed in this chapter are provided in Figure 3.1.

Keia District Sites

Rockshelter Site MAN-84 (Ana Manuku)

Ana Manuku, designated site MAN-84, is a spacious rockshelter formed by an overhang of the *makatea* escarpment, situated about 100 m south of the place where the Keia taro pondfields drain under the *makatea*. The shelter's floor is about 25 m long and varies from 2 to 4 m wide. As seen in the site plan (Figure 13.1), the floor area is defined on the east by a massive rockfall. East of the rockfall and beyond the shelter's dripline is a flat soil area where we noted a few basalt flakes and some large pieces of shell midden (*Tridacna*, *Turbo*). In 1991, the shelter was home to a herd of goats that had deposited a thick layer of dung soaked with goat urine, making excavation a rather unpleasant task.

This large, airy shelter seemed promising for excavation, and we initially hoped that it might contain a deeply stratified series of occupation deposits, as at MAN-44. To this end, we decided to test the site on July 3, 1991. The shelter floor was gridded out, and two test pits (units D31 and E18) were excavated. To our surprise and disappointment, the site proved to contain only a relatively shallow cultural deposit (beneath the thick layer of goat dung), 20 to 25 cm thick, containing very few artifacts (one adze preform butt was found in E18). In unit D31, however, the cultural deposit yielded 17 NISP of human bones, a number of which showed signs of burning and smashing. Beneath the cultural deposit was a natural deposit of "floury-textured" silty clay (similar to zone SZ-1A at MAN-44); this was relatively rich in bird bones. After the completion of the two test units, we discontinued work at MAN-84 and returned to the excavations at Tangatatau Rockshelter.

In 1997, David Steadman (accompanied by Susan Antón) returned to Mangaia to carry out expanded excavations at MAN-84. Steadman's primary aim was to expand the sample of avifaunal remains from the underlying precultural deposit. Steadman and Antón excavated nine 1-m² units in a block that incorporated the original D31 test dug in 1991. These expanded excavations were published in full by Steadman et al. (2000), and I merely summarize the key results here.

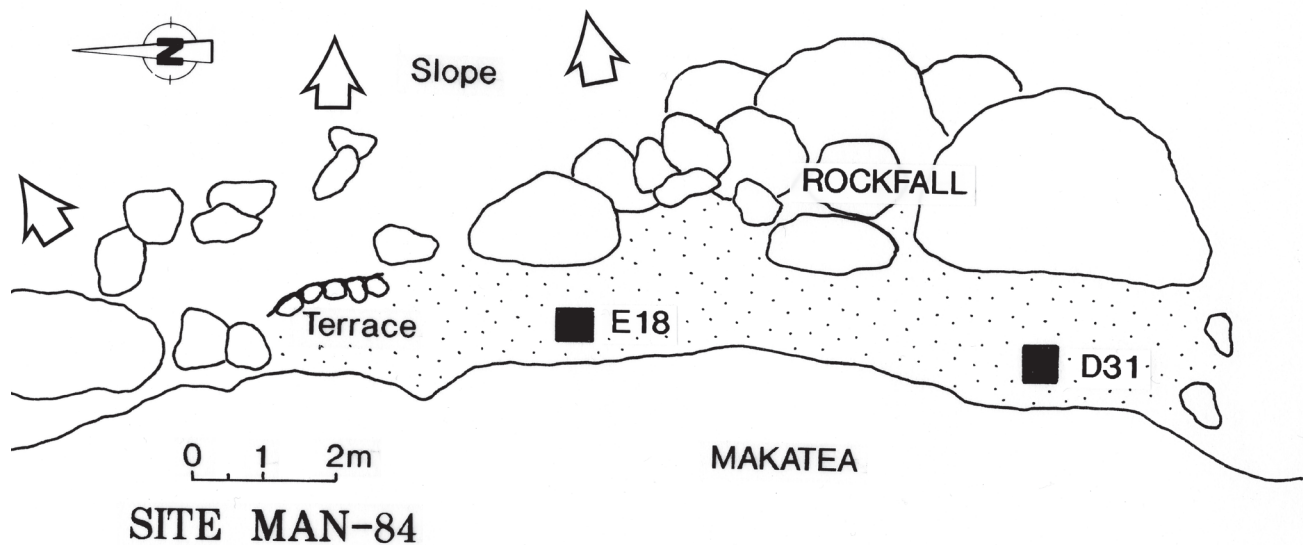


Figure 13.1. Plan of site MAN-84, Ana Manuku, showing two test pits excavated in 1991.

From the expanded excavation, it became clear that the cultural deposit recognized in 1991 actually consists of two discrete layers, designated Layer II and Layer III (Layer I being the deposit of goat dung). Seven earth ovens were exposed in Layer II and five earth ovens in Layer III. The stratigraphy can be summarized as follows:

Layer I (0–15 cm below surface) is the deposit of compacted goat feces.

Layer II (15–30 cm) is a very dark grayish brown (10 YR 3/2), fairly compact cultural deposit with distinct bedding planes.

Layer III (30–50 cm) is a yellowish-brown (10 YR 5/4) cultural deposit that appears to have some material mixed in from underlying Layer IV, as result of the digging of earth ovens into the shelter floor.

Layer IV (50 cm to base of excavation at 85 cm) is a strong brown (7.5 YR 5/6) sediment lacking in charcoal or other cultural material but containing considerable quantities of naturally deposited bird bones.

The expanded 1997 excavations again resulted in only seven artifacts, four of which are items of personal adornment (see “Portable Artifacts from Other Investigated Sites,” below). And as in the 1991 test excavation, the faunal remains from the cultural deposits (Layers II and III) included an extraordinary 1,856 NISP of human bone (along with 1,850 fish, 1,595 rat, 2 fruit bat, and 1 dog), a faunal assemblage entirely different from that at

MAN-44. As Steadman et al. (2000:878) note, “Human bones are abundant in Layer II and especially in Layer III, both inside and outside the ovens. All clearly in a midden rather than burial context.” Detailed analysis of human bone component of the assemblage by Antón revealed that at least 41 individuals are represented, “ranging in age from foetal/newborn to adults probably of both sexes” (Steadman et al. 2000:879). Layer II contains 4 MNI (Minimum Number of Individuals) adults and 7 MNI subadults, and Layer III contains 10 MNI adults and 20 MNI subadults. The assemblage also displays unmistakable signs of heating and burning, including 84 percent at least “lightly browned” and 20 percent “heavily heated or burnt.” All of the adult and older juvenile bones are highly fragmented and exhibit signs of fracturing while the bone was fresh.

Steadman et al. (2000:Table 1, Figure 5) obtained nine accelerator mass spectrometry (AMS) radiocarbon dates on human bones from MAN-84, all overlapping at two standard deviations (Figure 13.2). Bayesian modeling of this suite of dates, using BCal, yields a lower bounding parameter (α_1) of cal AD 1393 to 1449 and an upper bounding parameter (β_1) of cal AD 1437 to 1503. The estimated elapsed time between α_1 and β_1 is 0 to 99 years; most likely, however, the human skeletal remains in MAN-84 were deposited over a shorter period of time, perhaps just over the course of two to three decades. The multiple ovens suggest a series of repeated events in which one or more human bodies were butchered and cooked at some time during the fifteenth century.

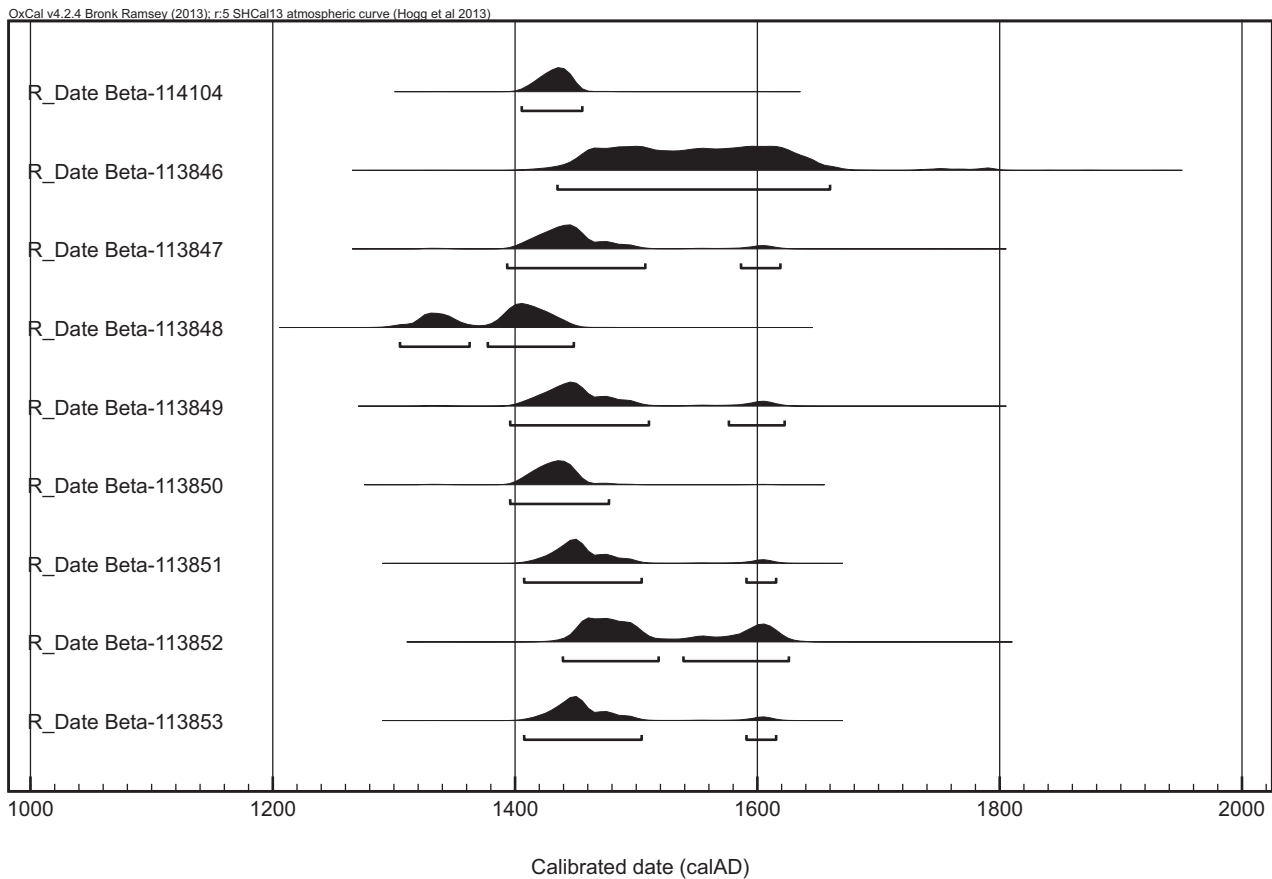


Figure 13.2. Oxcal plot of AMS dates on human bone from site MAN-82.

As Steadman et al. (2000:800–882) argue at some length, the human remains at MAN-84, associated with a series of earth ovens and deposited in a midden context, do not represent cremations, nor are they consistent with any ethnohistorically or ethnographically documented Manganian burial rituals. They are, however, consistent with a substantial body of ethnohistoric evidence regarding human sacrifice, ritual taking of victims during times of war, and cannibalism (Gill 1894; Hiroa 1934:51, 66, 73). Steadman et al. (2000:882) conclude that “substantial body parts of at least 41 persons of all age classes were cooked at MAN-84 in what seems to be one event or two closely timed events at *c.* AD 1400–1450. That these body parts were eaten is suggested by the remains of other animal foods (fish, rats, birds) in the identical midden context.”

Rockshelter Site MAN-81

This site is a rockshelter formed by an overhang along the southern part of a large block of limestone about 25 m away from the main *makatea* escarpment in Keia.

The main floor area under the dripline is about 18 m long and from 2 to 3 m wide. The floor consisted of a dark gray ashy deposit that looked promising for excavation; one test pit (unit D19) was excavated on July 4, 1991 (Figure 13.3).

The stratigraphy in unit D19 consisted of three discrete layers, as follows:

Layer I (0–13 cm) is a compact, dark reddish gray (10 R 3/1) with much fire-altered limestone rubble and abundant endocarps of the candlenut (*A. moluccana*). The candlenut shells are mostly unburned and may have accumulated naturally following abandonment of the shelter. Two pieces of European bottle glass were found in Layer I.

Layer II (13–23 cm) is a reddish-brown (5 YR 4/3) midden deposit with some fine ash lenses, containing a substantial quantity (25.4 kg) of shell. The northern half of the unit had a small combustion feature (feature 1) about 35 cm deep filled with white ash and fire-cracked rock with some scattered charcoal.

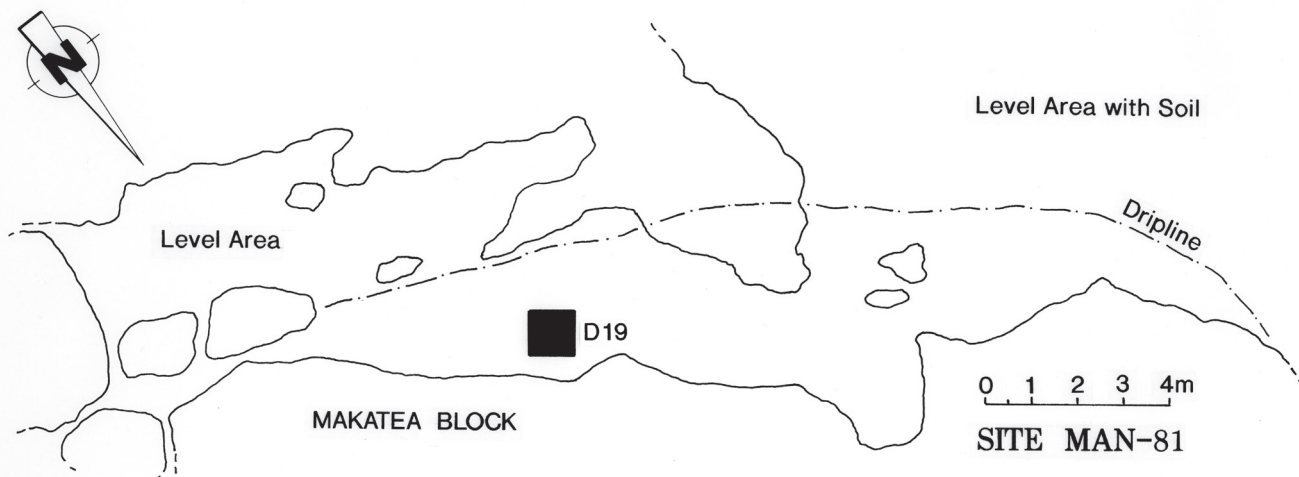


Figure 13.3. Plan of site MAN-81 showing location of the 1991 test excavation.

Layer III (23–80 cm) is a reddish-yellow (5 YR 6/6) precultural deposit with much small limestone rubble and land snail shells (similar in texture to CZ-1A at MAN-44).

The only formal artifacts recovered in the test excavation were the two pieces of bottle glass from Layer I. A sample of unidentified wood charcoal from feature 1 was submitted to Beta Analytic for radiocarbon dating, returning a conventional age of 300 ± 60 BP (Beta-48347), which has a calibrated 2σ age range of cal AD 1459 to 1807. Layer II most likely accumulated during the later period of Mangaian prehistory (i.e., post-AD 1500) while the bottle glass in Layer I indicates some continued use into the postcontact period.

Rockshelter and Refuge Cave Site MAN-82

Site MAN-82 consists of a combined rockshelter and refuge cave situated along the inner *makatea* escarpment of Keia district. The rockshelter is at ground level, with an overhang sheltering an area about 16 m long and 2 to 4 m wide. Immediately above the rockshelter (and about 7.5 m higher than the shelter floor) is the entrance to the refuge cave, a solution cavern running into the *makatea*. Both the shelter and the refuge cave were mapped and test excavated from July 5 to 8, 1991.

The entrance to the refuge cave, which lies directly above the rockshelter, is about 5 to 6 m wide but is partly blocked by two stalagmite/stalactite columns. (We gained entrance by constructing a ladder of *Hibiscus* logs; presumably some kind of ladder was

also used when the cavern was occupied.) When the surrounding area was clear of trees, a fine view would have been had out over Keia Valley. The cavern would have been readily defensible. The main chamber has a ceiling height of about 6 m. The floor area nearer to the entrance is covered in reddish soil; dripping water from the ceiling has exposed shell and sea urchin midden in this deposit. Thick bottle glass shards were noted in a few places near the entrance, suggesting use of the cave into postcontact times. Between 20 and 30 m back into the cavern (in semi-darkness) we noted areas of dense midden and black ash lying directly on the cave floor (as at site MAN-54). At the rear of the cavern is a pool of fresh water up to 30 cm deep, providing a source of drinking water.

We excavated four 50-cm x 50-cm test pits in the refuge cavern. TP-1 in the entryway area revealed a deposit of reddish-brown sediment 5 to 10 cm thick overlying the limestone floor. Within the deposit were several thin lenses (ca. 1.5 cm thick) of dark gray and white ash. TP-2, in the slope running down from the entryway into the back chamber, had a deposit of clayey, reddish-brown sediment up to 10 cm thick, including sea urchin spines and bone midden. TP-3 was situated under a ledge about 1 m high and around 50 cm from the cavern wall, where there was much shell and sea urchin midden visible on the surface. Here the reddish-brown clayey deposit was only 3 to 5 cm thick, overlying the limestone bedrock. Finally, TP-4 was located in the darker part of the cavern, revealing a thin (3–5 cm thick) greasy deposit of dark gray midden containing much charcoal and ash.

A single 1-m test unit (G22) was excavated in the floor of the rockshelter, just in front of the entrance to the refuge cave. This excavation revealed a single cultural deposit of ashy sediment with charcoal flecks extending down to 40 to 60 cm below surface. Some lenses of white, gray, and red ash were noted within this deposit. The only formal artifact recovered was part of a possible calcite pounder, but there was substantial shell midden (40.8 kg).

A charcoal sample was taken from the base of the cultural deposit, just above the contact with the underlying sterile subsoil. Submitted to Beta Analytic, this small sample was forwarded by Beta to Zurich, where it was dated by the then novel AMS method (Beta-48348 and ETH-8868), yielding a 2σ age range of cal AD 1290 to 1425. As this date is from the very base of the deposit, most of the midden presumably accumulated in the later part of the Mangaia sequence.

Veitatei Valley Sites

Rockshelter Site MAN-63 (by J. M. E. Taomia)

MAN-63 is a small rockshelter with shallow cultural deposits. The vegetation surrounding the rockshelter consisted largely of *Hibiscus* and low brush, which covered the rockshelter area; *Aleurites* endocarps and leaves of other plants covered the ground surface. This site was tested to provide a further example of rockshelter occupation in the Veitatei district; the excavations were under the direction of Julie M. E. Taomia.

MAN-63 consists of four components: the rockshelter area of which two 1-m units were excavated and three nearby stone constructions. Structure 1 was built out from the limestone wall southeast of the excavation units. The main area of this structure is raised about 30 to 40 cm above the surrounding ground surface; it is bounded on the east and west by low stone walls. A large limestone rock was used as the northeast corner. The west wall is about 80 cm high. Structure 2 is a freestanding enclosure with an area of 3 x 4 m and an entrance to the northeast. The third structure, also a walled enclosure, lies about 20 m northeast of the main excavation area.

Five test units were excavated at MAN-63: two adjacent units (D15 and D16) within the prehistoric midden deposits of the rockshelter, one unit (N19) against the south wall of Structure 2, and two units (D23 and E21) within Structure 1. Units D15 and D16 in the prehistoric midden were located within the slightly raised area indicative of subsurface midden

deposits. Excavations followed the natural stratigraphy. Unit D15 was excavated to a depth of about 70 cm, while unit D16 was substantially more shallow (40 cm). Layer I was a compact, black clayey deposit containing many roots, rootlets, and earthworms. Small limestone pebbles and some shell were present. Layer II was a brown-red clayey deposit with white ash mixed in as well as charcoal. Layer III, a loose dark reddish-brown silty loam with a large quantity of roots and charcoal, was only present in unit D15. Layer IV was a very compact yellowish clay with charcoal pressed 2 to 3 cm into the deposit. A sample of this charcoal returned a date of 830 ± 80 BP (Beta-48345), which has a calibrated 2σ age range of cal AD 1045 to 1386.

Feature 1 was a combustion feature excavated into Layer IV from Layer III, present in both units. The upper portion was a dark brown with burned limestone cobbles; this was underlain by a loose pinkish white ashy deposit. Feature 2 was a shallow basin-shaped fire pit containing some rocks. Feature 3 was a deep (42 cm) pit with reddish-brown fill. Feature 1 appeared to have been dug into the top of this pit.

Very few artifacts were found, and all were recovered from units D15 and D16. A *Turbo* shell fishhook point and six basalt flakes were found in Layer I. Layer II contained an adze preform, a broken adze, a *Turbo* fishhook missing its point, 13 basalt flakes, and a coral abrader. Layer III contained six basalt flakes, while one adze flake, eight basalt flakes, and a piece of cut pearl shell (*Pinctada*) were found in Layer IV.

Two 1-m test pits were excavated adjacent to the walls of Structures 1 and 2 to establish the depth of the stone structures and to elucidate their possible use. Unit N19, excavated against the southern wall of Structure 2, yielded no associated cultural remains. Small flecks of charcoal were found throughout the top 20 cm of the red clay soil. Below this was sterile red clay. There were also no stone courses or foundation stones belonging to the structure below the course lying on the surface. Our Mangaian informants suggested that the structure was probably a pig pen dating to historic times.

Unit E21 was excavated against the eastern stone wall of Structure 1. Again no foundation stones were found below the lowest course of surface stones. Four pieces of very weathered indeterminate bone were found in the otherwise sterile top 20 cm of rocky red clay soil. The function of this structure is unknown.

Veitatei Habitation Terraces and Probable *Marae* (MAN-39, 92-96)

As noted in Chapter 3, the majority of archaeological sites on Mangaia are open sites situated on ridge spurs and the lower slopes of the valleys just above the irrigated pondfield complexes that cover the valley floors (see Figure 3.1). While dozens of such open sites were noted during a reconnaissance survey, our test excavations were focused on rockshelter sites that had the greatest potential for good stratification and preservation of faunal and floral remains. In Veitatei Valley, however, we spent several days mapping and investigating a complex of earthen terraces situated on the low ridge spur that divides the Veitatei swamp into two sections (see Figure 3.1 where the sites are indicated directly below the label “Terrace Complex”). A dirt road running inland just above the adjacent taro pondfields provided ready access to this complex of seven terraces, which were mapped with plane table and alidade as shown in Figure 13.4. The terraces had all been artificially constructed by cutting back into the gentle hill slope and depositing the fill to build up the front part of each terrace. The terraces, which are generally longer than they are wide, are presumed to have provided the foundations for pole-and-thatch houses.

The dirt road ran directly over a small terrace about 7 m long and 4 m wide (MAN-39), exposing a heavy

concentration of coral pebbles (*kirikiri*) that presumably had been laid down as a paving. Along the north-eastern edge of the terrace, the road also exposed an alignment of coral slabs that probably demarcated the edge of a former structure. Near the front of the terrace, a basalt slab running perpendicular to the coral slab alignment may likewise have demarcated another side of the structure. In the southwestern corner of the terrace, we observed a partially buried stalactite that had been brought to the site from a *makatea* cave; as noted in Chapter 3, such stalactite uprights were a distinctive feature of Mangaia *marae*. A small adze of triangular cross section with a well-formed tang was found about 2 m from the stalactite (see “Portable Artifacts from Other Investigated Sites,” below).

We excavated a 1-m x 4-m trench across the south-east part of the MAN-39 terrace, revealing two distinct layers of coral pebble or *kirikiri* paving. The upper layer of clay mixed with pebbles, which had been exposed by the dirt road, extended to a depth of 10 to 15 cm, below which was a mixed orange-brown, stiff clay that extended to about 30 cm below surface. At this depth, a distinct second *kirikiri* lens appeared, 2 to 8 cm in thickness. A charcoal sample associated with this earlier pebble pavement was radiocarbon dated (Beta-48342) with a calibrated age range (2σ) of cal AD 1210 to 1420. We also excavated a 1-m x 3-m trench

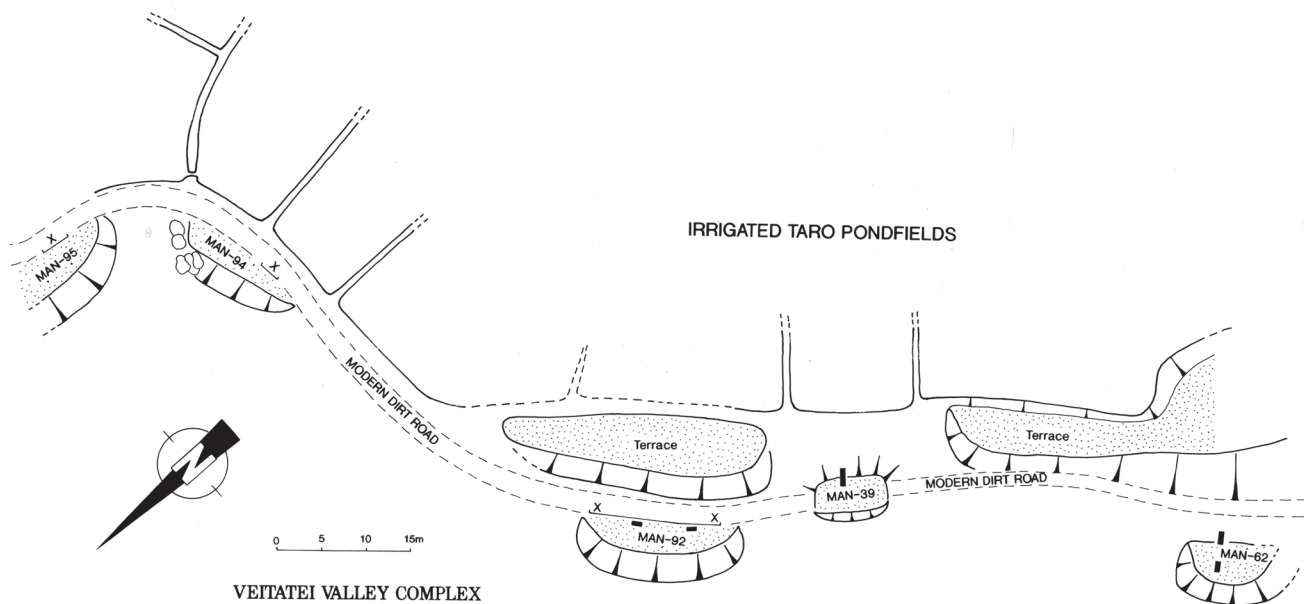


Figure 13.4. Plan map of earthen terraces in Veitatei.

across the front face of MAN-68, a small earthen terrace to the south of MAN-39 (Figure 13.5), revealing a large limestone slab that had originally formed part of a retaining wall for the terrace.

Just a few meters inland of MAN-39, the tractor that cut the dirt road had sliced about 40 cm into the downslope face of another terrace, which we designated MAN-92. The tractor cut afforded an opportunity to examine a stratigraphic section through the length of the terrace. The cut was cleaned off and straightened with trowels, and a 30-m stratigraphic section was recorded and drawn at a scale of 1:10. A 1-m x 2-m test excavation was also opened up immediately inland of the straightened road cut (Figure 13.6). An upper occupation deposit of brown loam (10 YR 4/3) overlay a strong brown (7.5 YR 5/6) more clayey loam; some *kirikiri* paving was present



Figure 13.5. View of the trench excavated across the MAN-68 terrace; note the large limestone slab which formed part of the front facing of the terrace.

as lenses in the upper deposit. Twenty-nine discrete features were recognized in the profile, primarily postholes and combustion features (hearths and earth ovens), many cutting down from the upper into the lower deposit. The lower deposit, however, also contained discrete features such as charcoal lenses and fire pits. The multiple features suggest that the terrace had a complex history of occupation.

Three charcoal samples obtained from features in site MAN-92 were radiocarbon dated. Feature 19, a charcoal lens at the base of the exposed profile and deep within the lower deposit, yielded an age of 800 ± 80 BP (Beta-48358) with age ranges (2σ) of cal AD 1035 to 1300 and 1369 to 1381. This date is quite early in relation to the MAN-44 radiocarbon sequence (see Chapter 5) and probably relates to initial forest clearance and perhaps agricultural activity in the Veitatei Valley. Feature 25, a small fire pit with fire-cracked rock situated within the lower deposit, yielded a date of 610 ± 70 BP (Beta-48359) with an age range of cal AD 1290 to 1448. The upper occupation phase is dated by charcoal from feature 4, a charcoal lens at the interface between the upper and lower deposits, with an age of 150 ± 50 BP (Beta-48356) and an age range of cal AD 1670–1950; since no European artifacts were present in MAN-92, we would put the age of the upper deposit at between AD 1670 and roughly 1830.

Tamarua District Sites

Rockshelter Site MAN-83 (Te Ana o Ka) (by J. M. E. Taomia)

Te Ana o Ka (MAN-83) Rockshelter in Tamarua district is located behind an area of pig wallows. The rockshelter measures about 39 m² in area, of which 11 m² was excavated, under the direction of Julie M. E. Taomia. In most places, the shelter's ceiling was less than 3 m above the ground surface. The large block of limestone that forms the shelter probably broke off of the *makatea* south of the site prior to human occupation. Rocks of 1 to 4 m x 1 to 2 m are found along the western portion of the shelter. The overhang extended about 2 m over the cultural deposits. The shelter is surrounded by *Hibiscus tiliaceus* and candlenut (*A. moluccana*) trees; the shelter floor was littered with candlenut endocarps. Coconut (*Cocos nucifera*) trees also grow in the area.

Nine 1-m x 1-m units were excavated in the main area under the rock overhang, and two additional units were excavated at the western end of the shelter. In most of the excavated area, the cultural deposits were



Figure 13.6. Straightened road cut through Veitatei terrace site MAN-92, with 1 x 2 m test excavation. Three shallow post holes can be seen in the side wall of the test excavation.

about 40 to 50 cm deep, with pits extending to greater depths in some places. Some of the excavation units were not full meter units because of intrusive rocks (e.g., unit C10) or because they were located against the wall of the rock shelter (e.g., unit B15).

The cultural deposits were evident on the surface by a slight mounding under the limestone overhang of the shelter. Excavations revealed that the cultural remains consisted of extensive pits and combustion feature activity. The cultural deposits were deepest in the eastern portion of the rockshelter; the deposits in the two western units were shallower. Excavations followed natural stratigraphy except where the natural layers were thick, in which case arbitrary breaks were made and new levels were begun for better control of the provenience of remains. Shell was retained from the screens for units C17 and D10. Radiocarbon samples were collected where possible, but much of the charcoal was small, particularly that from the lower levels.

The eastern portion of the site contained three stratigraphic layers, within which there were a number of features:

Layer I was a dark brown (7.5YR 3/2) compact silty clay containing a large quantity of rootlets and candle-nut (*A. moluccana*) endocarps, with some larger roots running through the deposit.

Layer II was a dark reddish-brown (5 YR 3/3) looser silty clay that generally had a high shell midden content. Particularly noteworthy was the large amount of small urchin spines found in this layer.

Layer III was a strong brown (7.5 YR 4/6) loose clay that contained no cultural materials.

The stratigraphy in the western part of the site differed somewhat from the main trench. Layer I was underlain in the western part of the site by a gray ashy feature fill, and this was underlain by Layer III described above.

The eastern portion of the main excavation area contained a high density of features, mostly fire pits or hearths. These features varied greatly in terms of size. Two fire pits within the matrix of Layer I were located at the northern end of the excavation units and may represent changing use patterns as the deposition

of material made use of the shelter itself difficult for adults. All other features at the site were part of Layer II. There were four small shallow fire pits in Layer II; none had been excavated into the underlying deposits. The other features were large, deep fire pits and pits that contained burned limestone and charcoal and often had an ash layer at their base. Several of these extended into Layer III.

Layer I contained glass, metal, *Turbo* shell artifacts (fishhook tabs, a fishhook bend and a point), an adze flake, coral files, shell scrapers, and 20 basalt flakes. Layer II contained pearl shell, coral files, adze flakes, worked *Turbo* shell pieces, urchin spine abraders, two shell scrapers, 184 basalt flakes, and four chert flakes. Fishhook production apparently took place at the site during the deposition of both layers. Very little stone working was conducted at the site during Layer I deposition. The bulk of the flaking activity during Layer II deposition took place in the central part of the main excavation area, and the densest concentration of basalt flakes were outside of the features.

Three pig bones (scapula and mandible fragments and a tibia) and one pig tooth were recovered from Layer II, as were two unidentifiable long bones. A human phalange with a notch in it and a human premolar were both found in Layer I.

Two radiocarbon dates were obtained from MAN-83. The first sample, from unit D16 (level 1), yielded a date of 480 ± 80 BP (Beta-48349) and an age range (2σ) of cal AD 1428 to 1476. The second sample, also from unit D16 (level 3), returned a date of 200 ± 120 BP (Beta-48351) with an age range of cal AD 1501 to 1950. The dates are stratigraphically inverted, which suggests some disturbance or reworking of the deposits, probably as a result of repeated digging of combustion features. The dates, however, suggest the occupation of MAN-83 occurred during the latter half of Mangaian prehistory, which is consistent with the dominance of *Turbo* shell fishhooks in the site (see “Portable Artifacts from Other Investigated Sites,” below).

Rockshelter Site MAN-87 (Te Kaeru) (by J. M. E. Taomia)

Te Kaeru (MAN-87) is a late prehistoric to early historic rockshelter site located in Tamarua district. The site was originally observed by Kirch, who noticed the dark midden sediment and found an adze flake on the surface. A total of eight units were excavated under the direction of P. Anderson.

The area sheltered by the rock face is large and divided into three main “chambers,” covering an area of about 17 m². Excavation proceeded in the largest of these three chambers, which extended 7 m and was around 7.5 m deep (Figure 13.7). The drip line of the rock shelter began around 7.5 m from the deepest part of the rock face.

Three main layers were excavated stratigraphically. In most parts of the site, the layers are quite distinct, although in some cases, a thin “contact” layer was present where one layer graded into the next.

Layer I consists of a rich dark brown soil containing burnt candlenut (*Aleurites* sp.) and burnt coconut shell remains. At the bottom of this layer, the candlenut becomes less common, but the layer is otherwise homogeneous throughout.

Layer II is quite distinct in that the sediment is a light orange brown color, with a sandy texture.

Layer III is extremely distinct and consists of a bright yellow very fine sandy material that is sterile. Within the sediment are chunks of decaying limestone rock that are compacted versions of the same sandy material.

Layer I became thicker as it proceeded toward the dripline, away from the rock face, while Layer II was thicker toward the rock face.

Layer I yielded both postcontact and traditional artifacts. Unit H26 contained a *Turbo* shell fishhook tab and an adult pig premolar. In unit H27, the neck of a glass bottle with the cork still intact was found, and from unit H30 came a possible coral abrader. A piece of cut *Turbo* shell in a “V” shape came from unit I27, as did a subadult human first metatarsal and a juvenile pig molar. At the bottom of a pit feature, we found a cut piece of *Turbo* shell. Another adult pig molar and pig bone fragment were found in J27, as was a fragment of a basioccipital bone from an adult human. A human maxilla, probably from another adult individual due to its size, was also found in unit J27, as was an adze flake. An indeterminate bone fragment was found at the same level in unit I26. Layer II did not contain any artifacts but often contained chunks of charcoal. Layer III was sterile.

Numerous features were recorded at the site, including six postholes, four combustion features, and seven pits. Four of the pits contained ash but no other signs of burning.



Figure 13.7. View of rockshelter site MAN-87 during excavation in 1991.

Two radiocarbon dates were obtained from MAN-87, both from unit H27. A sample from Level 2 in Layer II (Beta-48354) yielded a date of 80 ± 60 BP, with an age range (2σ) of cal AD 1675 to 1950 and 1799 to 1942. The second sample, from Level 3 (Beta-48355), at the base of Layer II, gave a date of 110 ± 70 BP, with an age range of cal AD 1670 to 1950. Both dates indicate that the MAN-87 rockshelter was used from very late prehistory (after ca. AD 1670) and into the historic postcontact period.

Tautua Refuge Cave (Site MAN-54)

Tautua, designated site MAN-54, is a large limestone cavern in the *makatea* rampart overlooking Tamarua Valley. According to our informant Noka Tumarama, the hereditary owner of the cavern, Tautua was used as a refuge by the Tamarua people in times of war. Reilly (2009:252) says that Tautua was the refuge cave of the Tonga'iti lineage, referencing a song recorded by Mamae that tells of the killing at Tautua of Ngutuku, a Tonga'iti warrior, whose body was then sacrificed to Rongo (see also Reilly 2003:76).

Noka Tumarama initially guided us to the site in 1989, when a quick reconnaissance revealed that the cavern contained a complex array of stone structures, midden deposits, and other features. On June 22, 1991, we were able to spend an entire day in the cavern, again guided by Noka Tumarama, during which time the main chambers and features were mapped with plane table and alidade at 1:200 scale, photographs taken, and surface collections made. The site plan is shown in Figure 13.8.

Tautua is accessed from a large main solution cavern formed by water flowing from Tamarua Valley (Figure 13.9). The refuge cave itself sits some 7 to 10 m above the level of the main cavern floor and was presumably eroded by flowing water at an earlier phase in the tectonic uplift of the *makatea* escarpment (see Chapter 2). Entering the muddy floor of the main cavern at the base of the Tamarua Valley taro pondfields, one first ascends a talus of limestone boulders that have fallen from the cavern's roof. There are several small terraces constructed into the talus with accumulations of midden. A small basalt chisel, two adze preforms, and a coral abrader

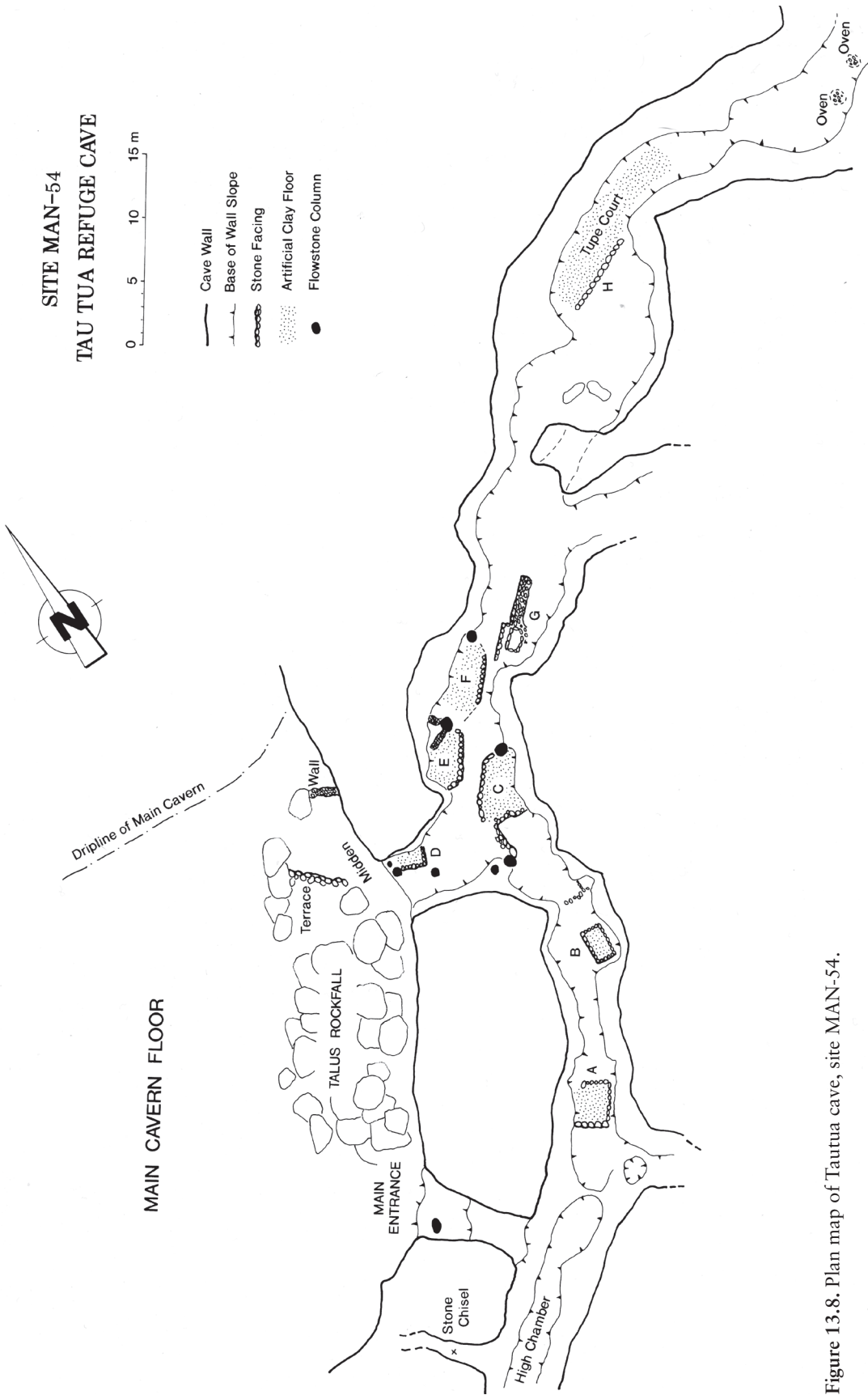


Figure 13.8. Plan map of Tautua cave, site MAN-54.



Figure 13.9. View of the *makatea* escarpment from the floor of Tamarua Valley, with taro pondfield in the foreground. The entrance to Tautua cave (site MAN-54) lies within the large cavern visible on the extreme right of the photo.

were found on these terraces (see “Portable Artifacts from Other Investigated Sites,” below).

The entrance to the refuge cave is on the eastern side of the main cavern, consisting of a solution tube about 3 m wide perched about 7 m above the level of the main cavern floor (Figure 13.10). Noka Tumarama showed us how to scale the 7-m-high cliff leading up to the narrow entrance, which required removing boots so that one’s toes could grip the small pockets in the slippery limestone (for our later descent, we made use of ropes and a crude ladder of *Hibiscus* logs).

After passing through the 5-m-long entrance passageway (the floor of which exhibited some midden), one enters a long main chamber running perpendicular to the entrance passageway (or roughly north-south);

this main chamber contains most of the structural features within the refuge cave. The ceiling of this main chamber is in places as high as 10 m, allowing one to walk unobstructed along its length. At places there are columns formed by stalactites and stalagmites that have merged together.

In the area where one first enters the main chamber (to the south of feature A, shown in Figure 13.8), the floor was covered in a rubbly midden deposit with considerable quantities of fire-cracked oven stone, test fragments and spines of sea urchins (especially *Heterocentrotus mammillatus*), and the shells of *Turbo* and *Modiolus* along with candlenut endocarps. A nearby depression in the floor was likewise filled with midden, including rat bone, candlenut, sea urchin, and



Figure 13.10. The entrance to Tautua cave (site MAN-54) lies directly above the figure in white, at an elevation of about 7 m above the main cavern floor.

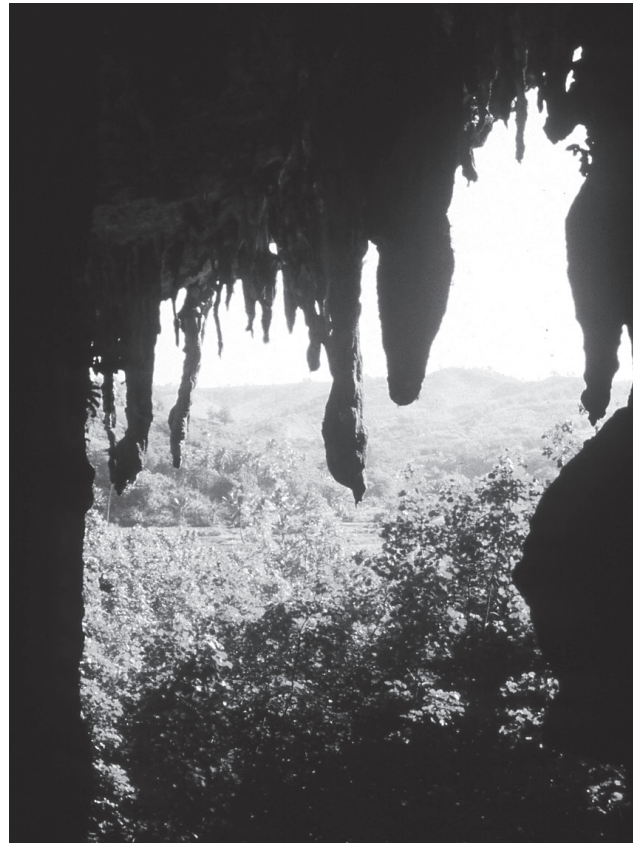


Figure 13.11. The view of Tamarua Valley from the seating place of the warrior guard within Tautua cave.

a basalt adze preform. Another small cavity in the floor was filled entirely with the spines of *Diodon hystrix*, the spiny pufferfish.

Moving roughly northeast along the main chamber, the first structure encountered is a rectangular platform (feature A), the southwestern side of which is well faced with six large stalactite slabs (facing ca. 30 cm high); the other facings are of rubble, about 10 cm high. The rubble fill has been surfaced with a veneer of red clay. A possible slingstone was noted on the platform corner. The chamber floor beyond the platform was again covered in shell and sea urchin midden.

Feature B is another rectangular platform with faces 20 to 30 cm high constructed of one to two courses of limestone slabs. As with feature A, the surface of this platform had been surfaced with red clay. About 3 m past feature B, a small alcove in the chamber wall was described by Noka Tumarama as a cooking area and exhibited charcoal, shell, and sea urchin midden. A broad level floor area extending almost to feature

C was covered in midden scatter, including fish and bird bones, sea urchin, and *Turbo* and *Tridacna* shell. Feature C is a large rectangular platform, the northwestern face of which is constructed with 10 large stalactite slabs laid in a single course about 20 cm high. As with the other platforms, the rubble fill had been surfaced with a layer of red clay.

At this point, a second passageway extends perpendicularly from the main chamber for about 8 to 9 m, leading to another opening to the main Tamarua Valley cavern. Here, however, the drop to the main cavern floor is more or less vertical and about 10 m high, making it impossible to scale without ropes or a ladder. A small platform, feature D, was constructed near the edge of the drop-off, against two stalagmite columns. Noka Tumarama told us that this platform was the seating place for a guard or lookout who could take advantage of the view afforded across Tamarua Valley to keep a watch out for enemy warriors (Figure 13.11). Black midden covers the cave floor between features D and C.



Figure 13.12. View of Feature E platform in Tautua cave (site MAN-54).

Opposite feature C is another roughly rectangular platform, feature E, with a facing ranging from 50 to 100 cm high formed of two to three courses of limestone boulders and cobbles (Figure 13.12). There is a low wall at the rear of the platform, built up to a stalagmite column. Once again the platform surface has been covered in red clay.

Continuing on into the main chamber, just beyond feature E is a less distinctly defined platform, feature F,

with a rubble facing up to 75 cm high (Figure 13.13). On a ledge in the cave wall above the platform is a badly disturbed human burial (cranium, femur, and vertebrae noted). An adze fragment was found on the platform.

Immediately beyond feature F is feature G, which, unlike the previous platforms, does not have a clay-covered surface but rather contains a cist constructed with stalactite slabs 30 to 40 cm in diameter (Figure 13.14). Noka Tumarama described this as a burial crypt, and

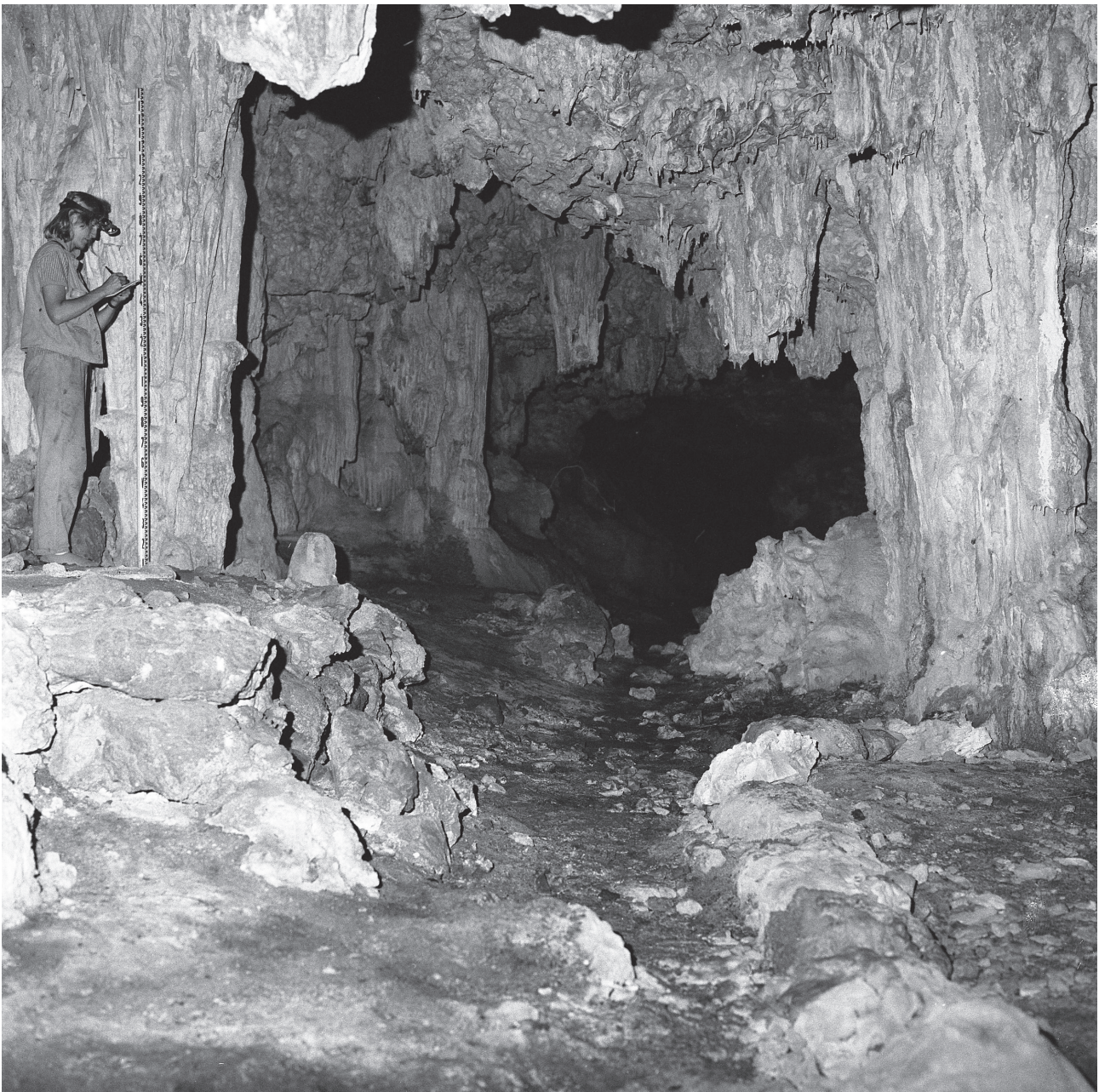


Figure 13.13. View of the main chamber in Tautua cave (site MAN-54) with the low facing of Feature C on the right and part of the facing of Feature E on the left, with Feature F in the distance.

one femur was seen within the feature (the other bones may have been removed previously). The level cave floor beyond feature G is covered in midden, and one basalt adze preform was collected here. At this point, the main chamber narrows somewhat, then widens again, with midden again continuing along with quantities of fire-cracked oven stones indicative of cooking activity. At this point, natural light from the two perpendicular entrance passages is essentially nonexistent.

The last formal structure, feature H, was described by Noka Tumarama as a court for playing the game of *tupe*. Hiroa (1944:254–256) describes the *tupe* game “as somewhat resembling the modern ship game of shuffle board,” being played with circular pitching discs of *miro* wood. This feature is defined on its southern end by a 30-cm-high facing of stalactite slabs, followed by a 15-m-long area with a well-packed clay surface.



Figure 13.14. View of Feature G, platform containing a cist made of stalactite slabs.

Beyond feature H, the chamber floor exhibited evidence of cooking activity in the form of two small fire pits with charcoal and fire-cracked rock and two large oven features (*umu*), each about 80 cm in diameter and filled with fire-cracked rock. Noka Tumarama described this as a cooking area for the people who took refuge in the cave during times of war. Another

38 m beyond the oven features is a pool of freshwater, which would have provided a source of drinking water for the cave's occupants.

Given the substantial quantities of midden material observed on the cave floor, there is little doubt that Tautua served as a dwelling place for a small group of people for some period of time or for a

series of repeated visits. Most of the activity seems to have been concentrated in the area between features B and F, where there is some natural light from the two entrance passageways. Features A, B, C, E, and F all most likely functioned as sleeping platforms, the clay surfaces probably covered in *Pandanus* mats when in use. The small platform feature D evidently served as the seating area for a lookout. Features G and H evidently had specialized functions, the former as a burial crypt and the latter as a *tupe* court, as described by our informant. That the occupants would have taken the time to prepare a court for playing the *tupe* game suggests that they may have anticipated long stays within the cave. It is curious, however, that this feature is beyond the zone with natural light, as is the cooking area with the earth ovens.

Two radiocarbon dates were obtained from MAN-54. One (Beta-48344) consisted of charcoal collected from one of the earth oven features in the rear of the

cavern; this yielded a date of 60 ± 60 BP, with age ranges of cal AD 1680 to 1950. The second sample is of a *Tridacna* shell collected from the cavern floor (Beta-48343) with a date of 420 ± 60 BP; due to the ocean reservoir effect, this has age ranges of cal AD 1724 to 1950. Both dates confirm a very late precontact use of the cavern, which may have overlapped into the early contact period, although the absence of European artifacts in the site suggests that it was not used after missionization.

Portable Artifacts from Other Investigated Sites

Not including unmodified basalt flakes, 100 portable artifacts were recovered from the excavations described above, with the largest assemblage coming from site MAN-83 (Table 13.1). Catalog data on these artifacts, including proveniences, are available in the online database (www.dig.ucla.edu/tangatatau).

Table 13.1 Portable Artifacts from Mangaia Sites Other Than MAN-44.

Artifact Categories	Sites (MAN)									Totals
	54	63	81	82	83	84	87	95	96	
Basalt chisel	1									1
Adze section	1			1						2
Adze preform	3	2				1		1		7
Adze flake	1	1			4		2			8
Basalt coconut grater	1									1
Branch coral abrader		1			13		1			15
<i>Porites</i> coral abrader	2									2
Sea urchin spine abrader					1					1
Hammerstone									1	1
Pounder fragment				1						1
One-piece fishhook fragment		2			17		1			20
Unfinished fishhook					1		1			2
Fishhook tab					3					3
Two-piece trolling lure point						1				1
Bivalve scraper					4					4
Bone ornament						3				3
Worked bone					2					2
Worked shell					6		1			7
Metal					9					9
Glass			2		7		1			10
Totals	9	6	2	2	67	5	7	1	1	100

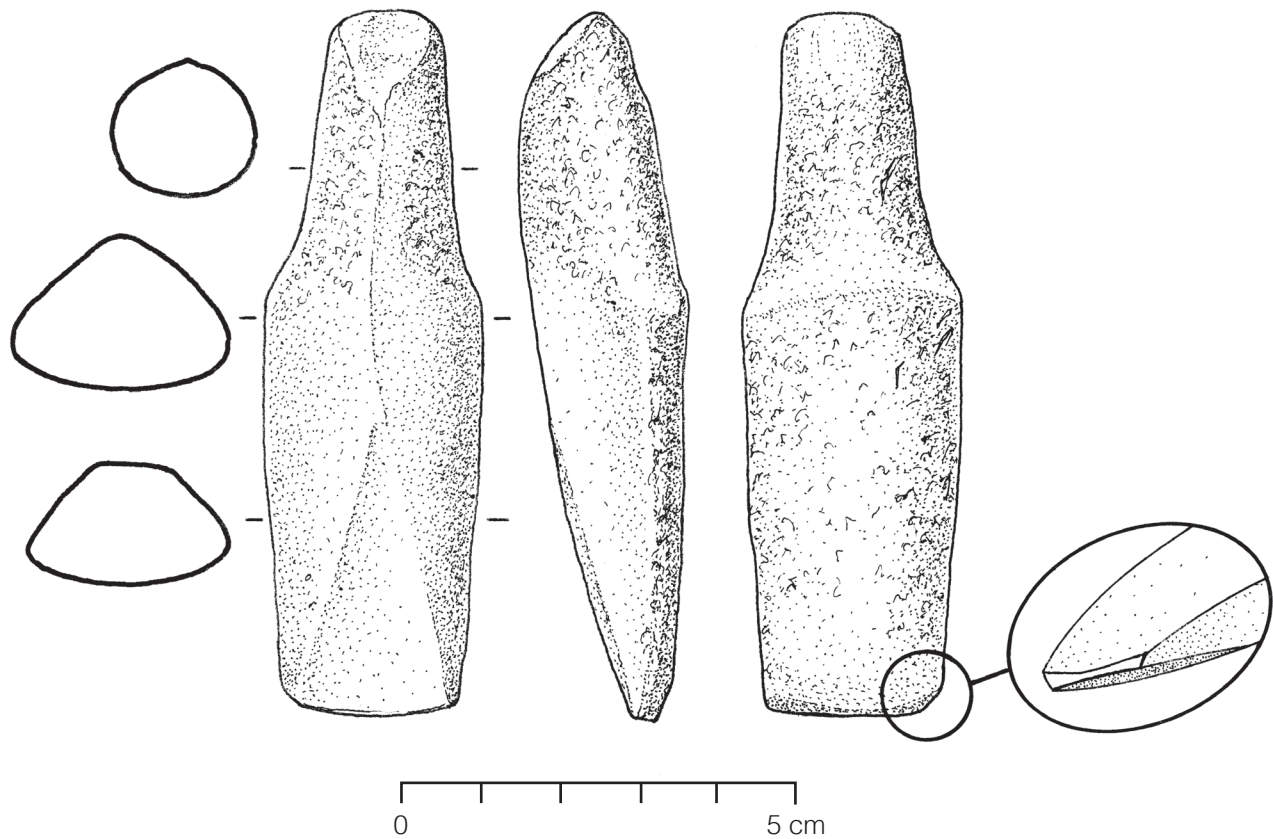


Figure 13.15. Small triangular, tanged adze found on site MAN-39. Detail shows how the bevel of the adze has been ground flat.

Adzes

A small, well-made and polished, tanged adze with a triangular section (Duff type 3) was found on site MAN-39, a small terrace in Veitatei, which likely was the foundation terrace of a *marae*. A unique feature of this adze, shown in Figure 13.15, is that the bevel has been purposefully ground flat, making the adze ineffective as an actual woodworking implement. Given that the adze was found in a probable *marae* context, it may well be the blade for one of the distinctive “ceremonial adzes” unique to Mangaia Island. These adzes, well described by Hiroa (1944:379–391, Figures 244–246), had elaborately carved wooden pedestals with designs representing particular deities; their intricate sennit lashings were also considered divine. It would be interesting to note whether such ceremonial adzes in museum collections have had their bevels ground flat as in the case of the specimen from MAN-39.

A finely ground and polished basalt chisel (Figure 13.16) was found on the surface at MAN-54; the chisel is 58.9 mm long, 9.5 mm wide, and 10.9 mm thick and is untanged.

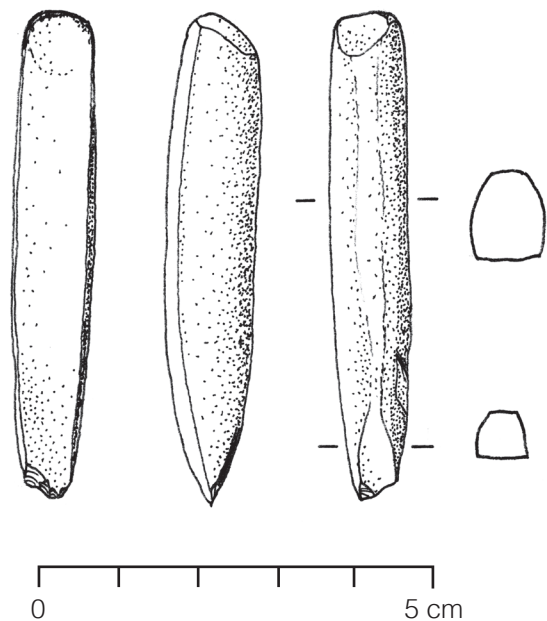


Figure 13.16. Small, untanged basalt adze or chisel from site MAN-54.

On the surface of site MAN-82, we recovered the midsection and butt end of a classic, late period Cook Islands tanged adze, finely pecked and ground; the cross section at the midpoint is subquadrangular. The butt end rises is a slight lug to facilitate hafting (Figure 13.17). This specimen closely resembles the “type 3” Cook Islands adze illustrated by Hiroa (1944:155, Figure 98), but given its quadrangular cross section would be classified as a Duff type 1 (Duff 1959:Figure 2). A surface specimen from MAN-54 is the butt end of an adze (or possibly adze preform, as it has not been ground) with a roughly lenticular cross section. Seven adze preforms were also recovered, as enumerated in Table 13.1.

As noted earlier, J. Endicott Taomia returned to the Veitatei terrace site MAN-95 to conduct more extensive excavations for her Berkeley doctoral dissertation (Endicott 2000). In the course of these excavations, she recovered a number of adze preforms and complete adzes. In Figures 13.18 and 13.19, we

illustrate four of these adzes from site MAN-95, as they are all classic examples of later precontact Cook Islands adzes. These adzes are all variants of Duff’s type 3 (Duff 1959).

During the course of our reconnaissance surveys on Mangaia in both 1989 and 1991, we also found a number of whole or partial adzes in surface contexts. Figure 13.20 illustrates a surface find from Keia district. This adze has a lenticular cross section, with a highly reduced tang with a circular cross section. Another surface find is shown in Figure 13.21; this adze also has a sharply reduced tang, but in this case, the cross section is distinctly triangular. Both of these adzes are again variants of Duff’s type 3 (Duff 1959).

Other Tools

A basalt flake with a unifacially retouched, slightly curved end (Figure 13.22) found on the surface of site MAN-54 is almost certainly a coconut grater. It has a length of 72.2 mm, width of 45.2 mm, and

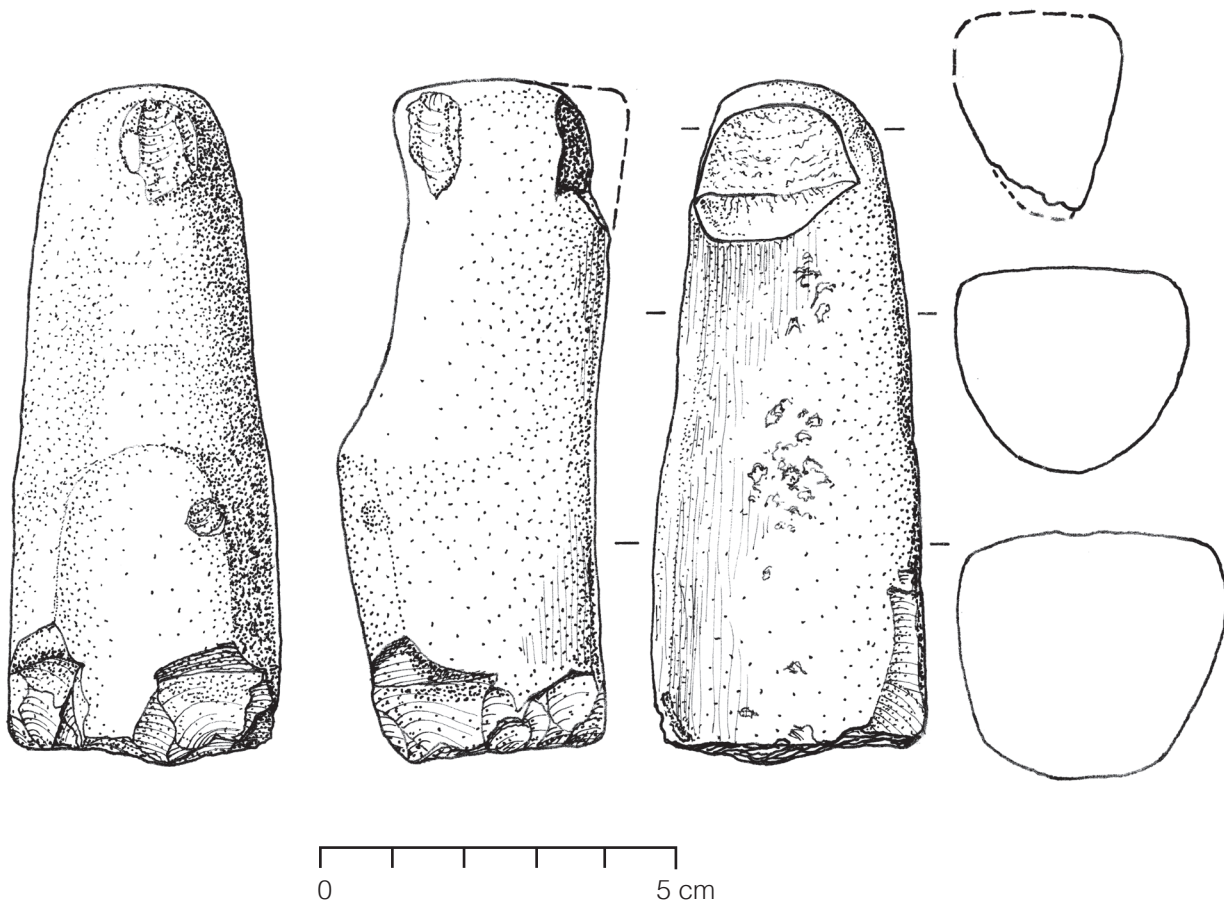


Figure 13.17. Butt end of a quadrangular, tanged adze from site MAN-82.

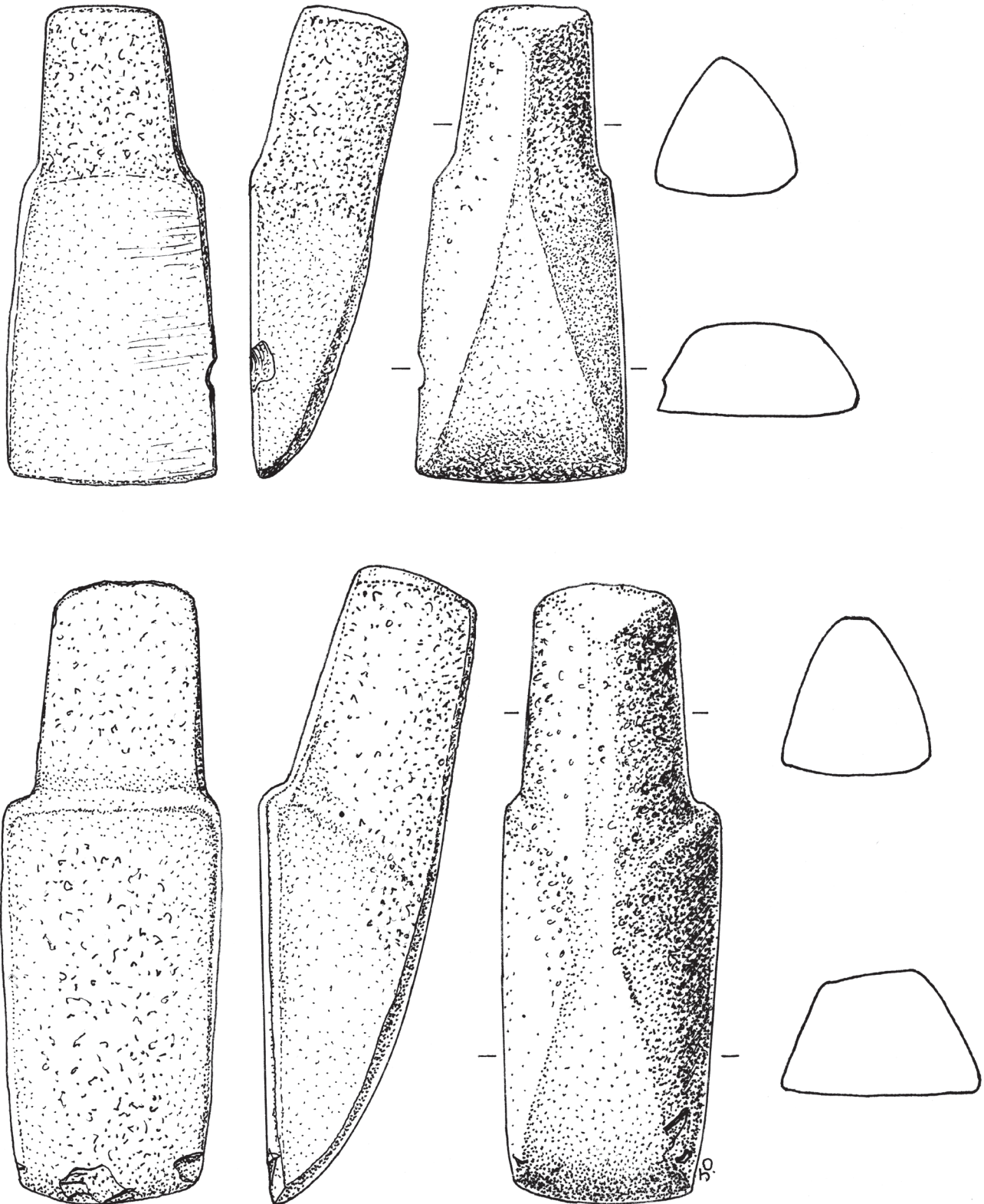


Figure 13.18. Triangular sectioned, tanged adzes from site MAN-95.

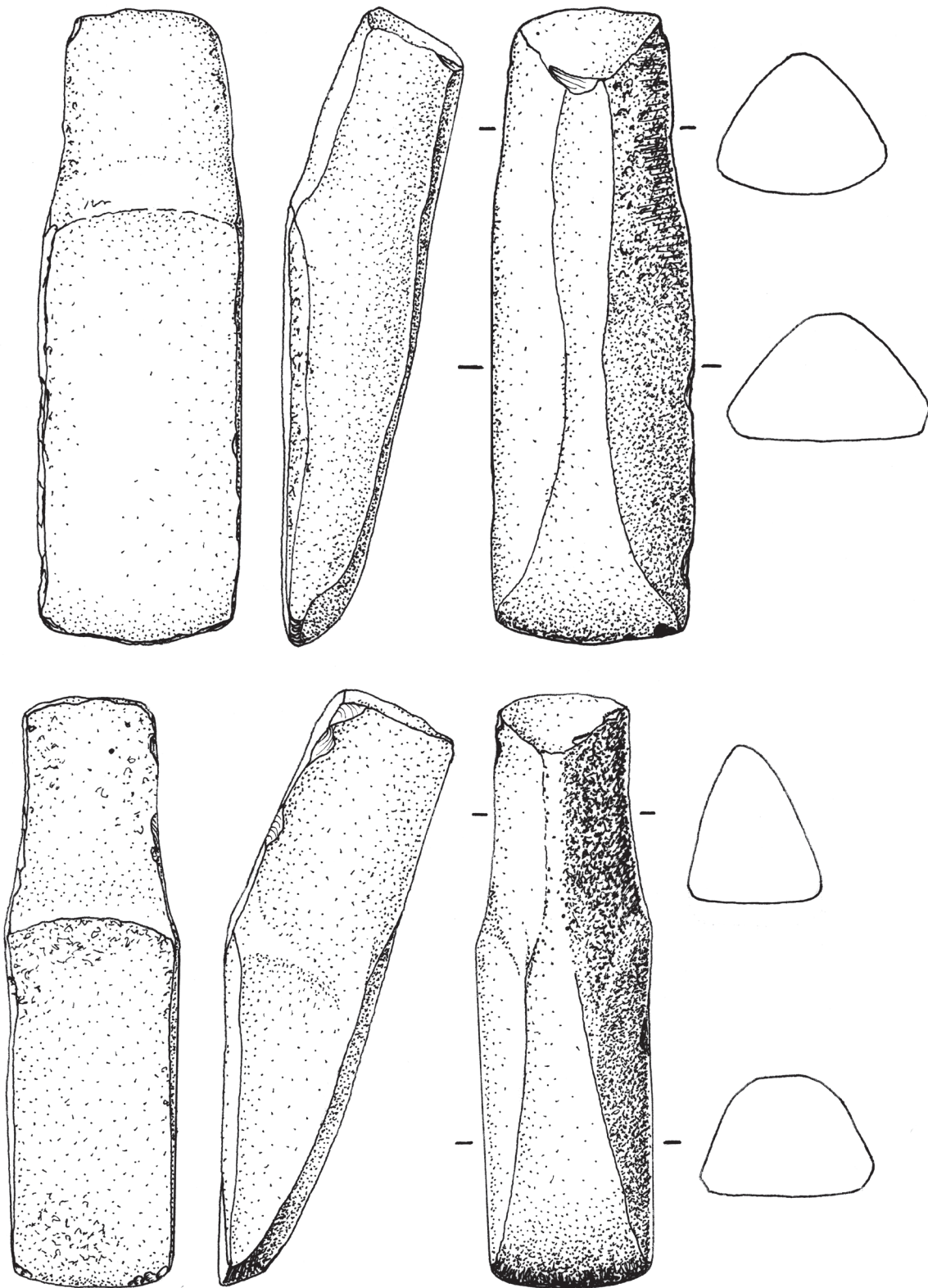


Figure 13.19. Triangular sectioned, tanged adzes from site MAN-95.

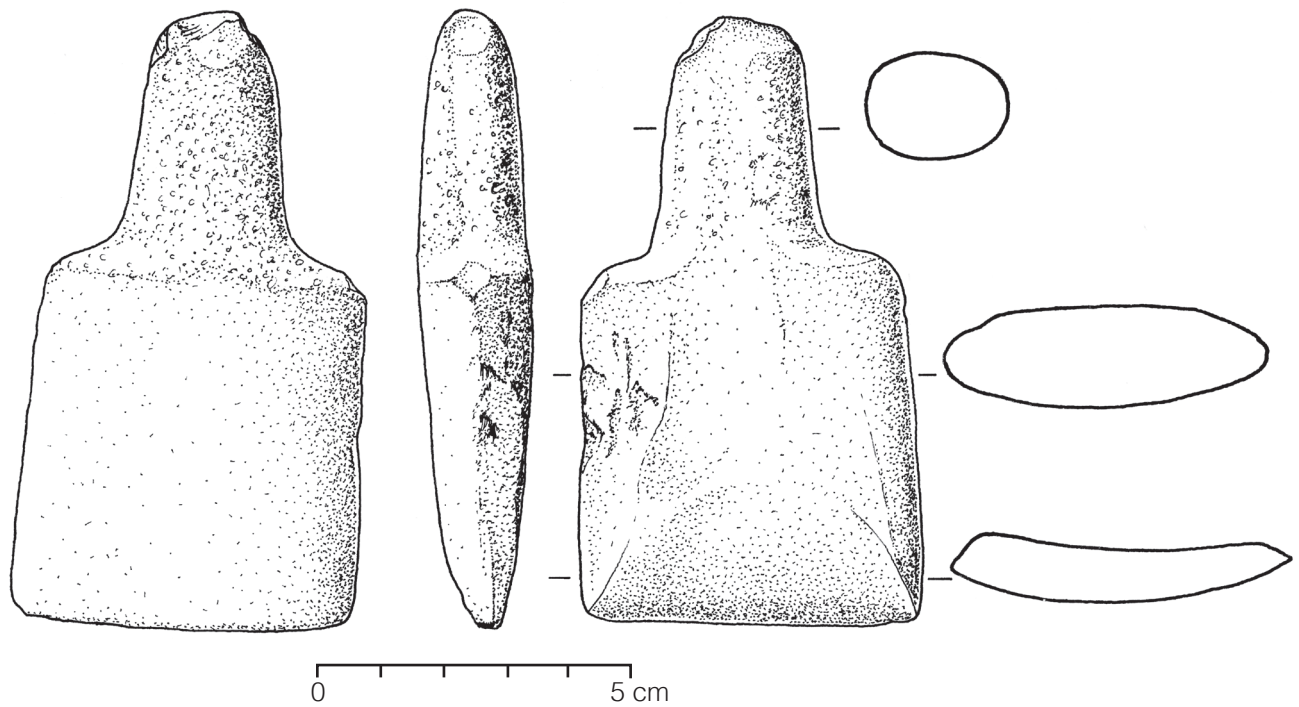


Figure 13.20. Adze with strongly reduced tang, surface find from the Keia area.

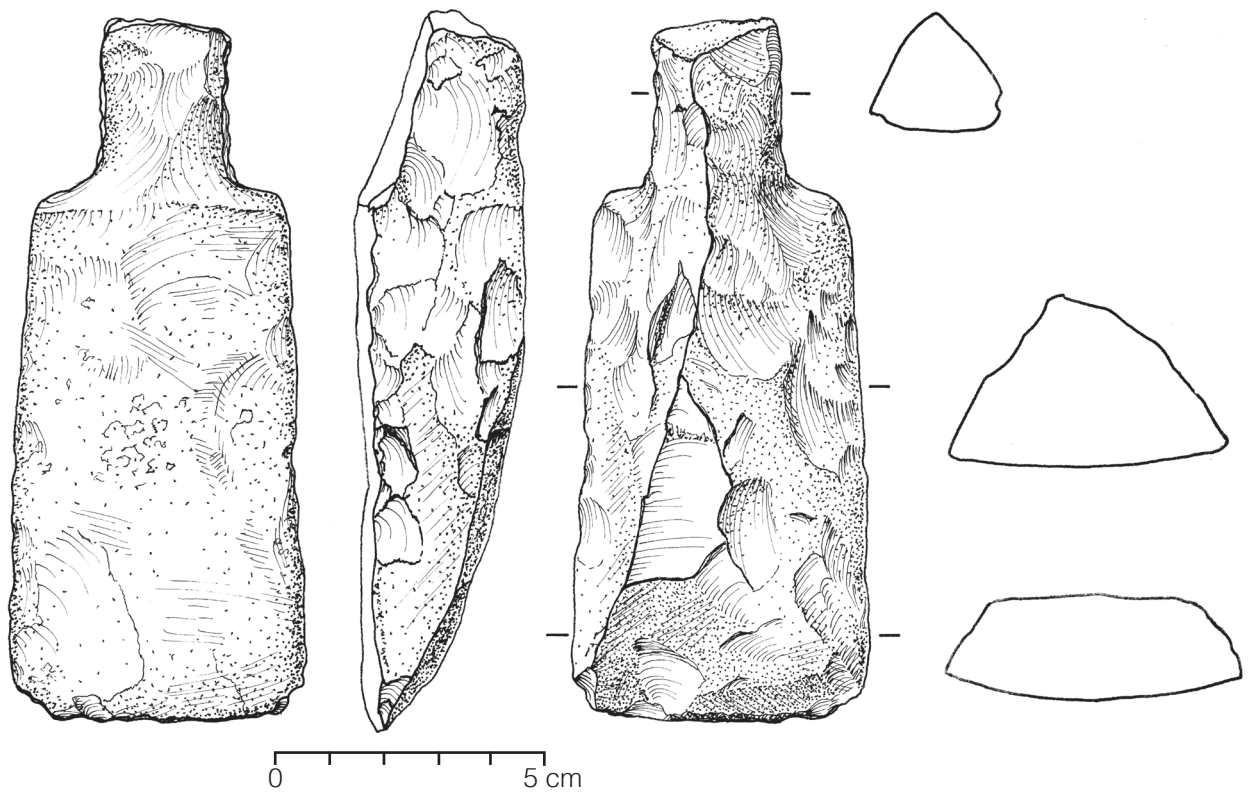


Figure 13.21. Partially ground adze with triangular cross-section, with strongly reduced tang.



Figure 13.22. Basalt coconut grater head from a surface context in site MAN-54.

thickness of 11.3 mm. When in use, it would have been lashed to a wooden coconut grating stool (see Hiroa 1944:24, Figure 3b).

Fifteen abraders made from branch coral (*Acropora* sp.) were recovered, 13 of them from site MAN-83; a selection of these is illustrated in Figure 13.23, along with a single sea urchin spine abradar, also from MAN-83. The branch coral abraders all have worn tips that are circular in cross section; these were presumably used to perforate and work pearl shell and *Turbo* shell for fishhook manufacture. Two abraders of block coral (*Porites* sp.) were found on the surface of site MAN-54. One is thin and well ground on both slightly convex surfaces, while the other is more massive and has a single slightly convex grinding surface. These block coral abraders were probably used to polish wooden artifacts.

A rounded cobble of limestone from MAN-96 may be a small hammerstone or possibly a slingstone.

A calcite object from site MAN-82 appears to be a “lateral projection” from the head of a food pounder, similar to those described and illustrated by Hiroa (1944:32–33, Figure 9).

Fishing Gear

Twenty incomplete one-piece fishhook fragments were found, of which 17 are from site MAN-83. Six are of pearl shell (*Pinctada margaritifera*) with the others all of *Turbo setosus* shell. The *Turbo* shell hooks all have circular bends. Four specimens with complete shanks from MAN-83 have shank lengths of 15.5, 18.2, 18.4, 20.9, and 21.8 mm. One pearl shell shank had a length originally >35 mm. All of the *Turbo* shell hooks retaining their heads have line attachment type D (see Chapter 11). The larger shank of pearl shell (Figure 13.24h) has a line attachment type F. A selection of fishhook fragments with diagnostic attributes is illustrated in Figure 13.24.

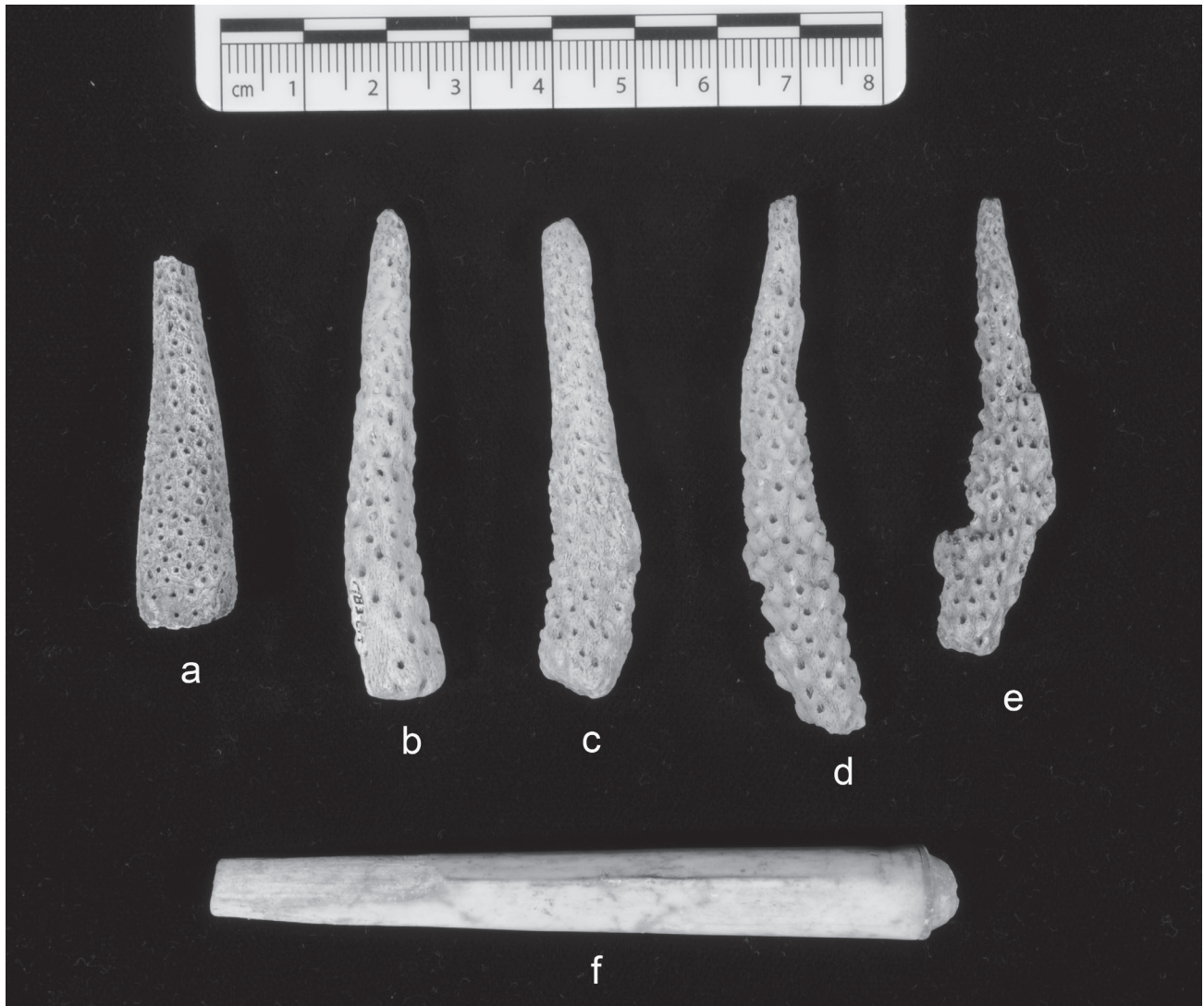


Figure 13.23. Branch coral (*Acropora*) abraders (a-e) and a sea urchin spine abraded (f) from site MAN-83: a, C14-1-5; b, C14-2-2; c, C14-2-3; d, C17-4-4; e, D17-2-2; f, C17-2-2.

From site MAN-84, we recovered a complete two-piece trolling lure point of pearl shell (Figure 13.25a). The base has two holes for attachment to a lure shank. This point was likely to have been worn as a neck ornament rather than actually being used as fishing gear; it may have belonged to one of the individuals whose bodies were cooked at the rockshelter.

Scrapers

Four large valves of *Periglypta reticulata*, all from site MAN-83, exhibit extensive wear along their ventral margins; these were presumably used as scrapers, possibly for preparing tubers such as taro or sweet potato for cooking.

Bone Ornaments

Three bone ornaments were recovered from site MAN-84 (Figure 13.25b,c). A complete, finely carved bone bead (of indeterminate mammal bone, possibly pig) has a length of 12.4 mm and maximum width of 16.5 mm. The second specimen is a fragment of a bead with a carved lip, also of mammal bone. A smaller, grooved bone bead has a diameter of 10.3 mm. All of these objects were likely to have been worn by individuals whose bodies were processed and cooked in the MAN-84 earth ovens.

Other Artifacts

In addition to the formal artifacts described above, several pieces of worked bone and shell were recovered



Figure 13.24. Selected fishhooks from site MAN-83 (a-g are *Turbo* shell; h is pearl shell): a, D17-2-4; b, C14-2-1; c, C16-2-4; d, C17-4-5; e, D17-3-1; f, D16-3-2; g, D16-3-4; h, C16-2-7.

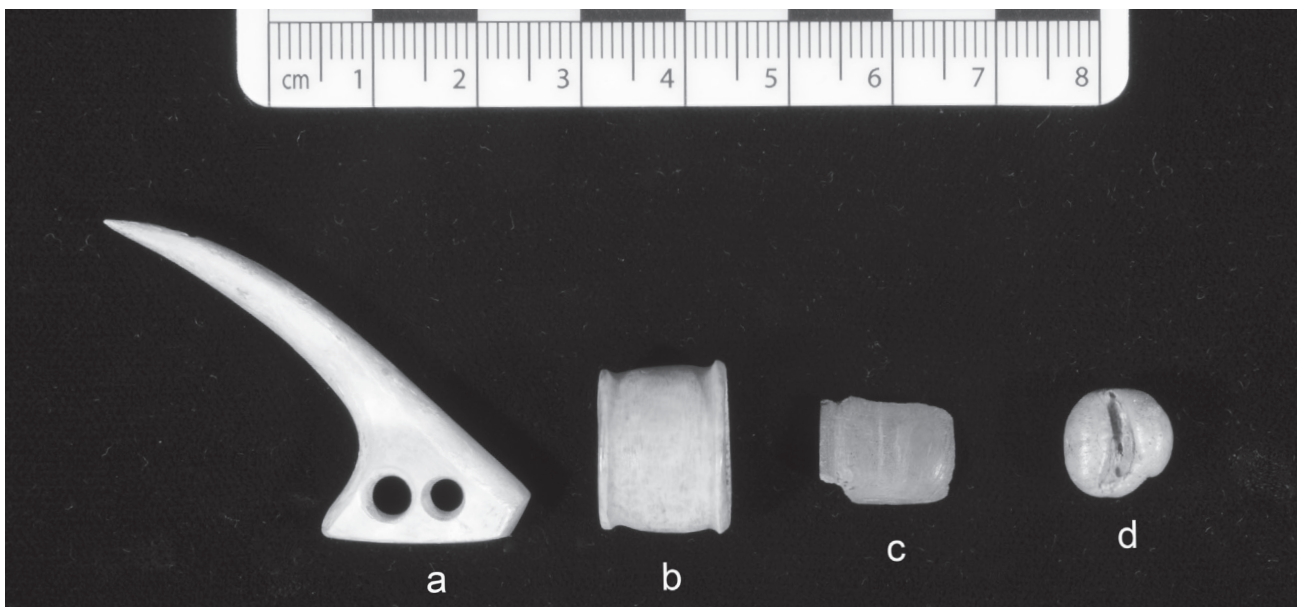


Figure 13.25. Artifacts from site MAN-84: a, trolling lure point; b, bone bead; c, bone bead fragment; d, grooved bone bead.

(Table 13.1). Some fragments of glass, mostly bottle glass (including the neck of a mold-blown bottle from MAN-87), and scraps of metal indicate the continued use of sites MAN-81, MAN-83, and MAN-87 into the postcontact period.

Radiocarbon Dates from Other Investigated Sites

Sixteen radiocarbon dates were obtained from the sites described in this chapter. Details of all radiocarbon dates are provided in Table 13.2; the dates have already been discussed in their specific site contexts. In all but one instance, the dates were run on unidentified wood charcoal, and thus some possibility of in-built age on old wood should be recognized with these dates. The two earliest dates, from MAN-63 and MAN-92, overlap in age with the oldest deposits (zone SZ-1B) at rockshelter site MAN-44, indicating inland activities in Veitatei Valley between around cal AD 1030 and 1300. Most sites, however, postdate AD 1300 and thus appear to have been occupied during the latter half of Manganian prehistory.

Conclusions

The sites described in this chapter extend our understanding of the Manganian archaeological record, helping to place the Tangatatau Rockshelter (MAN-44) in a broader context. Of several other rockshelters tested in Keia, Veitatei, and Tamarua districts, only site MAN-83 showed evidence of fairly intensive occupation similar to that at MAN-44. The radiocarbon dates and dominance of *Turbo* shell fishhooks at MAN-83 indicate that the occupation of that shelter took place during the last few centuries prior to European contact. Other rockshelters show only ephemeral use or, in the case of MAN-84, highly specialized use for the processing and cooking of human bodies. Sites MAN-54 and MAN-82 are of particular note in documenting the use of caverns in the limestone *makatea* as places of refuge in times of war. The open terrace sites of the Veitatei Valley complex (MAN-39, 92-96) illustrate residential sites situated adjacent to the taro pondfields; such residential terrace complexes were typical of the proto-historic Mangaia settlement pattern.

Table 13.2. Radiocarbon Dates from Other Mangaia Sites (All Dates Are Non-AMS Except for Beta-48348).

Lab No.	Site	Unit/Level	Material	Measured ¹⁴ C Age	±	δ ¹³ C	Conventional ¹⁴ C Age	±	Calibrated Age Range, 2σ ^a
Beta-48341	MAN-35		Charcoal	720	60	-25.9	700	60	1234–1410
Beta-48342	MAN-39	H11/1	Charcoal	740	80	-26.1	720	80	1210–1420
Beta-48343	MAN-54		Shell	100.4 ± 0.8% modern		+2.4	420	60	1724–1950
Beta-48344	MAN-54		Charcoal	90	60	-26.9	60	60	1680–1950
Beta-48345	MAN-63	D15/5	Charcoal	840	80	-25.7	830	80	1045–1386
Beta-48347	MAN-81	D19/2 (Fe 1)	Charcoal	310	60	-25.7	300	60	1459–1807
Beta-48348 ETH-8868	MAN-82	G22/4	Charcoal				640	55	1290–1425
Beta-48349	MAN-83	D16/1	Charcoal	480	80	-24.8	480	80	1428–1476
Beta-48351	MAN-83	D16/3	Charcoal	220	120	-25.8	200	120	1501–1950
Beta-48352	MAN-84	D31/3	Charcoal	810	90	-27.8	770	90	1054–1411
Beta-48354	MAN-87	H27/2	Charcoal	130	60	-28.0	80	60	1675–1950
Beta-48355	MAN-87	H27/3	Charcoal	150	70	-27.4	110	70	1670–1950
Beta-48356	MAN-92	Fe 4 charcoal lens	Charcoal	150	50	-25.2	150	50	1670–1950
Beta-48358	MAN-92	Fe 19 charcoal lens	Charcoal	800	70	-25.2	800	80	1051–1395
Beta-48359	MAN-92	Fe 25 fire pit	Charcoal	620	70	-25.2	610	70	1290–1448
Beta-48360	MAN-94		Charcoal	340	90	-25.7	330	90	1438–1950

^aCalibrations based on Southern Hemisphere SHCal13 calibration curve (except for Beta-48343).

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14

Synthesis: The Evolution of the Mangaia Socio-Ecosystem

Patrick Vinton Kirch

This concluding chapter, which aims at a synthesis of the varied strands of evidence presented throughout this volume, takes as its starting point the contention of Barton et al. (2004:254) that each human society is “constantly reshaping the intertwined cultural and natural components of the socio-ecological landscape on which its members and their descendants must operate.” This approach emphasizes that “interactions among people are as much a critical aspect of socioecosystems as are interactions between people and the natural world” (Barton et al. 2004:289). I begin with a succinct overview of the Mangaian sequence, synthesized into four cultural phases, providing a temporal scaffolding on which to hang several lines of argument that will be advanced regarding the evolution of production and landscape transformation, demographic trends, the history of resource exploitation, and the evolution of technology.

The Mangaia Cultural Sequence

In preceding chapters, the multiple data sets from Tangatatau Rockshelter have been analyzed and presented in terms of the site’s stratigraphic zones (see Chapter 4), the radiocarbon chronology for which is summarized in Chapter 5. For purposes of a broader synthesis, however, it is necessary to collapse the fine-grained rockshelter sequence comprising 19 stratigraphic zones into a cultural sequence of phases, into

which evidence from other sites can also be incorporated. Following the practice I developed in earlier studies of Tikopia and Niuatoputapu Islands (Kirch 1988; Kirch and Yen 1982), I have applied the names of key archaeological sites to the phases of the Mangaia cultural sequence. Using such site names avoids the inevitable interpretative baggage that comes with descriptive labels such as “developmental” or “expansion” phases (as applied, for example, by Suggs [1961] for the Marquesas). The following paragraphs briefly describe each of the four precontact phases recognized for Mangaia, correlating these with the stratigraphic zones at Tangatatau Rockshelter and with other relevant sites. This sequence is somewhat finer-grained and more nuanced than that proposed by Walter and Reilly (2010), which was partly based on published data from site MAN-44.

Vairorongo Phase (AD 1000–1300)

The Vairorongo Phase takes its name from the Vairorongo site, situated on the coast slightly north of Oneroa Village and excavated by Igarashi (1999a), as described in Chapter 3. This phase represents the initial Polynesian settlement of Mangaia, a period concerning which we admittedly still know far too little. The Vairorongo Phase is represented at Tangatatau Rockshelter only by the ephemeral traces of human presence in zone SZ-1B. The main archaeological manifestation of this phase is

therefore the Vairorongo site, especially the lower sector (Layers 6, 7, and 8) at Area A.

There are three reasons to believe that the Vairorongo area was the first to be settled by the Polynesian discoverers of Mangaia: (1) the area is adjacent to the best of the few natural passes through the fringing reef and canoe landings on the island, (2) it is the location of a major freshwater spring that issues from the limestone rock, and (3) it was the location of the island's most sacred *marae*, Orongo. Throughout Eastern Polynesia, important *marae* are often regarded as having been constructed on the sites of founding settlements (Kirch 2000a).

Fixing a starting date for the Vairorongo Phase is difficult, as it is by no means certain that the limited Area A excavations at Vairorongo uncovered the earliest traces of human occupation. In fact, the two oldest secure dates for the Polynesian presence on Mangaia come from bones of the Polynesian-introduced rats (*Rattus exulans*) recovered from zone SZ-1B at Tangatatau Rockshelter; as reported in Chapter 5, these give a range of cal AD 906 to 1050, 1079 to 1156, and 983 to 1180, respectively (95 percent confidence). A date on carbonized *Morinda citrifolia*, a Polynesian “canoe plant,” from rockshelter zone SZ-1B also gave calibrated age ranges

of cal AD 1051 to 1082 and 1141 to 1231. It seems reasonable to assign a starting date for the Vairorongo Phase of approximately AD 1000, recognizing that there is still an uncertainty of approximately one century before or after this date.

Oda et al. (1999) reported seven radiocarbon dates from the lowest three strata at the Vairorongo site, all on botanically unidentified wood charcoal. Figure 14.1 is an Oxcal plot of those ¹⁴C dates, calibrated with the SHInt13 curve. Bayesian modeling of this set of seven dates, treating them all as a single group, yields a lower bounding age estimate (α_1) of cal AD 1156 to 1277 and an upper bounding age estimate (β_1) of cal AD 1231 to 1359 (highest posterior probability region, 95 percent probability). The single earliest date (sample A9, 07) has a calibrated age of AD 1203 to 1288. Based on these dates, the Area A occupation at Vairorongo dates to the thirteenth century and overlaps with the zone SZ-1B deposit in Tangatatau Rockshelter. Note that this age range precedes our Bayesian estimate for the oldest radiocarbon date from zone SZ-2 at Tangatatau Rockshelter, which is cal AD 1355 to 1388 (see Chapter 5). I have therefore set the ending date for the Vairorongo Phase as AD 1300.

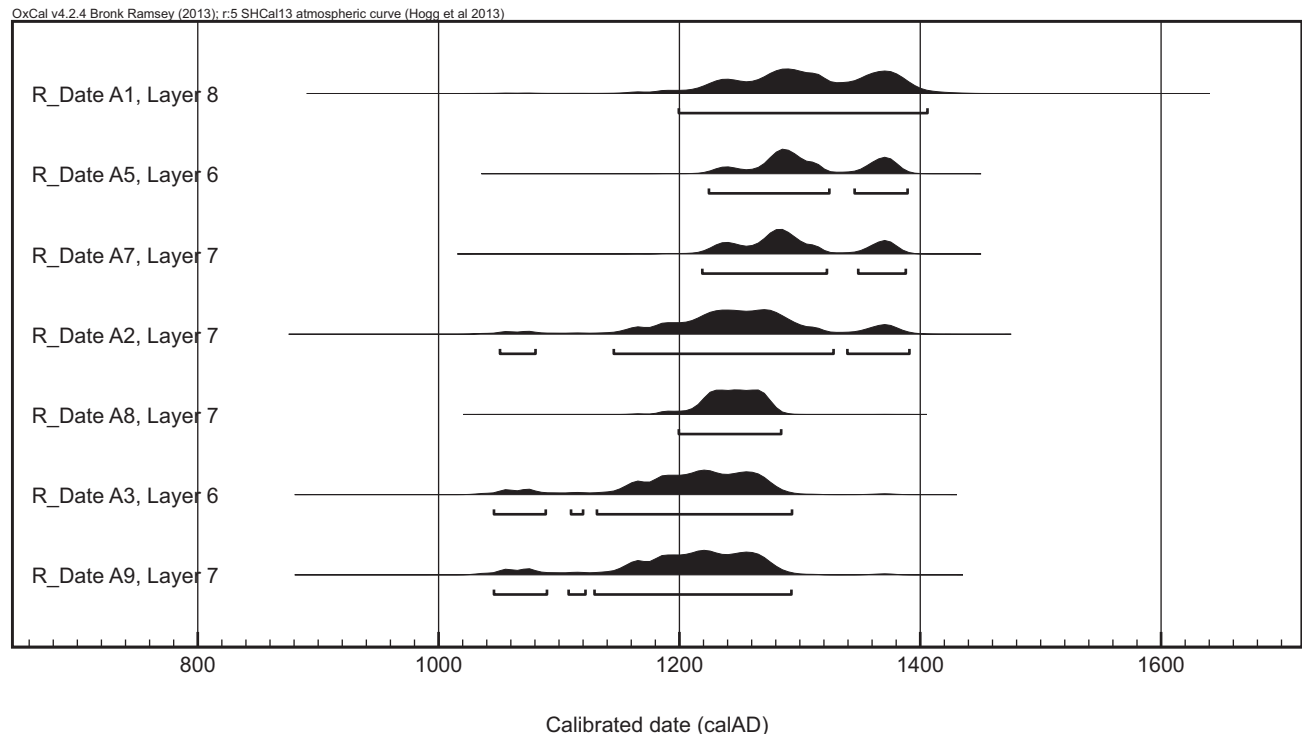


Figure 14.1. Oxcal plot of radiocarbon dates from the lower strata at Vairorongo, Area A.

As reported by Igarashi (1999a, 1999b), the lower layers at Area A of Vairorongo yielded a limited assemblage of artifacts, including two basalt adzes (types not indicated or illustrated), a tooth ornament, a tattooing comb, a slate-pencil sea urchin spine abrader, and 12 complete or broken fishhooks (Igarashi 1999b:Table 2, nos. 23–34). The fishhooks are mostly of pearl shell and include two large hooks (one complete, of curved shank, rotating type) with head types similar to hooks from other early Eastern Polynesian contexts (Sinoto 1967, 1970, 1996). Most of the faunal remains from the site, reported by Oyama (1999), come from the upper strata and hence postdate the Vairorongo Phase, but a few bones of pig and a number of *R. exulans* bones are attributed to the lower strata. In sum, the limited information available from the Vairorongo Area A excavations is consistent with initial Polynesians colonizing Mangaia sometime in the first two centuries AD, bringing with them pigs and rats and importing a material culture assemblage that included classic early Eastern Polynesian fishhooks, tattooing implements, and basalt adzes of unspecified type.

Before turning to the succeeding Tangatatau Phase, a caveat should be advanced: the Vairorongo Phase need not have commenced with permanent occupation of the island. It is entirely plausible that the phase started with a period of initial exploration and intermittent, temporary, or repeated occupation by a group based on another nearby island, such as Rarotonga. Mangaia would have been a challenging island to settle, given the formidable *makatea* zone ringing the more agriculturally productive interior. A reasonable colonizing strategy would have been to stage repeated short-term visits to the island, establishing tree crops and making gradual forays into the interior, prior to commencing permanent habitation. There can be little doubt, however, that permanent settlement was achieved no later than the beginning of the thirteenth century.

Tangatatau Phase (AD 1300–1400)

The Tangatatau Phase, named after the rockshelter that is the focus of this monograph, corresponds to the lower occupation strata at MAN-44, specifically zones SZ-2 to SZ-4B. Bayesian calibration establishes the onset of occupation at Tangatatau at cal AD 1315 to 1386, based on the radiocarbon dates from zone SZ-2 (see Chapter 5).

With the onset of the Tangatatau Phase, we see permanent habitation of the island's interior; this may have commenced even earlier in the Vairorongo Phase, but there is no question that by the Tangatatau Phase, people

were living around the swampy wetlands such as Lake Tiriara (an important source of freshwater fish and eels) and beginning to establish the island's horticultural production system. From the archaeobotanical evidence, we know that they possessed a nearly complete suite of Polynesian cultigens, including *Colocasia* taro, giant swamp taro (*Cyrtosperma chamissonis*), bananas, sugarcane, and tree crops such as coconut, Tahitian chestnut, and breadfruit.

The people residing at Tangatatau raised substantial numbers of pigs and also had dogs as well as chickens. They hunted the indigenous flying fox along with many species of landbirds and seabirds. Although living in the island's interior, they regularly crossed the *makatea* to gather shellfish on the fringing reef, targeting such prized mollusks as the large *Turbo setosus*. They fished on the reef and immediately offshore, using several kinds of hooks made primarily from pearl shell, but probably also used nets, traps, spears, and plant poisons, techniques widespread throughout Polynesia (Kirch and Green 2001).

The material culture of the Tangatatau Phase, richly evidenced at site MAN-44, displays numerous similarities with artifact assemblages of similar age from other central Eastern Polynesian islands, including Aitutaki and Ma'uke in the Southern Cook Islands (Allen and Schubel 1990; Walter 1998), the Marquesas (Rolett 1993, 1998; Sinoto 1966, 1970; Suggs 1961), the Society Islands (Sinoto and McCoy 1975), Rurutu and Tubuai in the Austral Islands (Bollt 2008; Hermann et al. 2015), and Mangareva (Conte and Kirch 2004; Kirch et al. 2010). Basalt adzes, which were made primarily from local stone obtained at the Mata'are source or from a source in Veitatei district, included untanged quadrangular adzes of Duff type 2A but also quadrangular tanged adzes (type 1) and adzes with triangular cross sections (type 3). The fishhooks were made mostly from pearl shell, which does not occur locally on Mangaia and therefore had to be imported, most likely from other islands in the Southern Cooks, especially Aitutaki, which has a huge lagoon. Fishhooks with curved shanks (type II) predominated, although straight shank forms (type I) were also present. The importation of pearl shell, as well as adzes from Samoa and from other localities in central Eastern Polynesia (including Rurutu in the Austral Islands and Eiao in the Marquesas), indicates that the small founding community on Mangaia continued to be connected to a wider network via regular interisland and even inter-archipelago voyaging.

Ngaaitutaki Phase (AD 1400–1600)

I have chosen the name of the large rockshelter in Ivirua district, excavated by Kyoto University in 1989 (Oshima et al. 1999), for the third phase of the Mangaia sequence. This phase is evidenced by materials from several sites in different parts of the island. At Tangataau Rockshelter in Veitatei district, the Ngaaitutaki Phase is represented by stratigraphic zones SZ-5 through SZ-8. According to our Bayesian model for the MAN-44 site, the lower temporal boundary of SZ-5 ($\alpha 5$) is cal AD 1416 to 1483, while the upper boundary of SZ-8 ($\beta 7$) is cal AD 1500 to 1611 (Chapter 5). Unfortunately, there is only a single ^{14}C date from the Ngaaitutaki site itself, from uncertain context at the base of the deposits (see Chapter 3). However, the majority of the fishhooks from the Ngaaitutaki site were manufactured from *Turbo* shell (Igarashi 1999b:Table 2), while the finished adzes and adze preforms illustrated by Oshima et al. (1999:Figures 12, 13) are largely tanged, with triangular cross sections. These artifact types are consistent with those from zones SZ-5 to SZ-9 at Tangataau. In Keia district, the Ana Manuku rockshelter (site MAN-84) has a series of dates on the human remains centered on the fifteenth century (see Chapter 13), placing the site within the earlier part of the Ngaaitutaki Phase. The deposits at site MAN-83, Te Ana o Ka rockshelter in Tamarua district, can also be assigned to the Ngaaitutaki Phase (see Chapter 13). As with Ngaaitutaki Rockshelter, the artifact assemblage at MAN-83 is dominated by fishhooks of *Turbo* shell.

The fact that the Ngaaitutaki Phase is represented by sites in four of the island's districts attests to the expansion of settlement by this time; indeed, there are theoretical reasons to believe that the island may have achieved a population peak by the beginning of the phase (see discussion further below). The island's agricultural system, based in large part on the intensive irrigated complexes in the valley bottoms, was presumably well established by this time. Certainly, the evidence from stratigraphic coring in the swampy basins and associated pollen analysis (see Chapter 2) indicates that the volcanic hillsides had been largely deforested with the indigenous mesic forest replaced by fire-resistant fernlands and scrub *Pandanus*. Changes in the subsistence system included significant reductions in the quantities of pigs raised but—at Tangataau at least—offset somewhat by increases in the intensity of marine mollusk and fish exploitation. The indigenous

flying fox had become extirpated, along with a number of endemic landbirds. Dog became extirpated on the island by the end of the Ngaaitutaki Phase. The bones of rats are abundant in the MAN-44 faunal records for this phase, with taphonomic indications that they had become a regular part of the diet.

The material culture of the Ngaaitutaki Phase exhibits significant differences from the preceding Tangataau Phase, indicating considerable local evolution of technology. Fishhooks were now manufactured almost entirely from the locally available *T. setosus* shell, rather than the preferred pearl shell (*Pinctada margaritifera*), which does not occur on Mangaia. The probable cause for this shift from pearl shell to *Turbo* shell is a decline in external contacts with other islands, hinting that Mangaia was beginning to close in on itself socially. The basalt adze complex also exhibits major changes, with the untanged quadrangular adzes (Duff type 2) that were so prevalent in the preceding phase being replaced by the highly distinctive tanged adzes with either quadrangular or, more often, triangular cross sections (Duff types 1 and 3).

The Ngaaitutaki Phase may have been a time of heightened interpersonal violence, warfare, and possible cannibalism. The strongest evidence for this comes from the Ana Manuku Rockshelter (MAN-84), where at least 41 human bodies, including both sexes and ranging from newborns to adults, were cooked in earth ovens and processed in a manner similar to that of pigs or dogs at Tangataau, being disposed of in a midden context (Steadman et al. 2000). Radiocarbon dates on the human remains from MAN-84 indicate that the bodies were processed during a relatively short time span, during the earlier part of the Ngaaitutaki Phase. A small number of human bones from zones SZ-6 and SZ-8 at Tangataau Rockshelter are also suggestive of cooking and processing. I will return to the question of violence and possible cannibalism later in this chapter, when the archaeological evidence is viewed in the context of probable demographic scenarios.

Tautua Phase (AD 1600–1830)

The fourth and final phase of the proposed Mangaia sequence—which I have named after the Tautua refuge cave in Tamarua district—consists of the last two centuries immediately preceding first contact with Europeans (Cook's fleeting visit in 1777) and later missionization (beginning in 1824). This phase is the least well evidenced at Tangataau Rockshelter, correlating

to upper zones SZ-10 to SZ-17, dating to the late sixteenth to eighteenth centuries (see Chapter 5); by this time, the rockshelter was being used less intensively and perhaps only intermittently. However, additional evidence for the Tautua Phase comes not only from the site MAN-54 refuge cave but also from several large open terrace habitation sites (MAN-92, MAN-95, and MAN-97 in Veitatei district and MAN-100 in Keia district) excavated and radiocarbon dated by Endicott (2000:167, 178, 188).

By this final period, the settlement pattern evidenced in the ethnohistoric record was fully developed, with the valley bottoms extensively converted to taro pondfield irrigation systems. Surrounding the irrigated fields on the lower valley slopes were clusters of habitation terraces (such as the sites excavated by Endicott [2000]) and adjacent tribal *marae* or temples. Rockshelters continued to be used as residential sites, but more important was the use of caves such as Tautua and MAN-82 in Keia district (see Chapter 13) as refuges in times of conflict and war. *Makatea* caverns were also regularly used as burial places.

Changes continued to take place in the island's subsistence system, most notably the complete extirpation of pigs by the end of the Tautua Phase. With dogs and flying foxes having been eliminated in earlier times, this left the diminutive Pacific rat as the only mammal (other than, potentially, humans) available as a protein source; as we know from the ethnohistoric records, rats had indeed become a major food item. Most landbirds had also been extirpated, but interestingly, the faunal record at Tangatatau exhibits a spike in the taking of seabirds in zone SZ-15, seemingly a late-phase strategy of targeting nesting or roosting seabirds in remote parts of the *makatea*. At the same time, there is also an increase in duck bones in SZ-15, perhaps indicative of an increase in that species due to the extent of wetland habitat provided by the taro pondfields. The exploitation of marine shellfish and fish declines in intensity during this phase, with evidence for resource depression both in the marine mollusk *T. setosus* and in the reef fish *Cirrhitus* (and possibly also in serranid fish).

The material culture record for the Tautua Phase is only sparsely represented in Tangatatau Rockshelter, but additional evidence—especially for the adze complex—comes from the open habitation terraces excavated by Endicott (2000) in Veitatei district. Eight whole adzes recovered from the MAN-95 excavation (Endicott 2000:Figure 5.15) are all of classic

late prehistoric Cook Islands type, with pronounced tangs and triangular cross sections (see Chapter 13, Figures 13.18 and 13.19). Endicott's excavations also revealed evidence of extensive flaking of chert nodules, as an alternative to basalt, at several of the Veitatei terrace sites.

Dynamic Coevolution of Landscape and Horticultural Production

Having outlined the four phases of a Mangaian cultural sequence, I turn now to a more detailed consideration of how the island's production system and economy coevolved with its environment and landscape over the roughly eight centuries between initial Polynesian colonization and the arrival of Europeans. Mangaia possesses unusual geological circumstances that in certain ways rendered the island particularly vulnerable to disturbance and rapid ecological change following the arrival of humans. As Fosberg (1963a, 1963b) long ago pointed out, vulnerability to disturbance is a hallmark of islands—especially *oceanic* islands—but Mangaia lies at one extreme along the spectrum of such vulnerability.

For one thing, Mangaia is remarkably old for an oceanic (or mid-Pacific Plate) volcanic island, most of which subside after about 5 to 6 million years, becoming atolls. Mangaia's roughly 20-million-year-old volcanic cone had subsided beneath Pacific seas and was enshrouded in a wide ring of coral reef some 110,000 years ago, when the rapid emergence of Rarotonga—a new “hot spot” volcanic island—warped the thin oceanic crust and sent Mangaia jolting 70 m above its former sea level. The deeply weathered volcanic cone, now elevated 169 m above sea level, became entrapped behind the *makatea* rampart of uplifted coral limestone. During the Pleistocene, rainwater draining off the central volcanic cone incised a radial stream pattern, with drainage channels evolving into solution caverns penetrating the limestone ring and eventually emptying into the ocean. With post-Pleistocene sea level rise, these caverns became submerged and partly blocked, and depositional basins formed at the interface of a volcanic hill and limestone ring in each of the main drainage systems.

The research of Vitousek (2004; Vitousek et al. 2004) on nutrient cycling and availability on oceanic islands has shown how, as volcanic islands age and undergo subaerial weathering, the nutrient content of their soils declines precipitously. On a 20-million-year-old surface

such as Mangaia's, rock-derived phosphorus in particular would have been almost wholly lacking. Nonetheless, we know from the extensive coring work carried out by our project (see Chapter 2), revealing deep stratigraphic records for all the major drainage basins, that throughout most of the Holocene, the volcanic cone was cloaked in a mesic forest dominated by arboreal taxa (including *Weinmannia* sp., *Erythrina* sp., and *Palmae* sp.) (Ellison 1994a; Kirch et al. 1992). During this prehuman period, rates of erosion on the volcanic cone were low, with only occasional deposition of clay bands, probably following periodic cyclone devastation of the forest canopy. As Kirch et al. (2010, 2015) have argued for the 5- to 6-million-year-old islets of Mangareva, it was most likely the continual input of marine-derived nutrients transferred by large populations of nesting and roosting seabirds, deposited on Mangaia with the birds' guano, that sustained this forest cover.

Polynesians arriving on Mangaia between AD 900 and 1100 undoubtedly brought with them a full suite of tropical cultigens with the intention of establishing a horticultural economy on the island. This was part and parcel of the strategy of "transported landscapes" that proved so successful in the Polynesian colonization of oceanic islands that otherwise lacked much in the way of naturally occurring edible plant resources (Kirch 1979b:296). Although no archaeobotanical work was conducted at the Vairorongo site, the extensive macrobotanical remains from zones SZ-2 and SZ-3 at Tangatatau Rockshelter document the presence of taro (*Colocasia esculenta*) and giant swamp taro (*Cyrtosperma chamissonis*), along with bananas (*Musa* hybrids), *ti* (*Cordyline fruticosa*), and sugarcane (*Saccharum officinarum*), all important Polynesian garden cultigens. In addition, there were several important tree crops, including coconut (*Cocos nucifera*), breadfruit (*Artocarpus altilis*), Tahitian chestnut (*Inocarpus fagifer*), the Malay apple (*Syzygium malacense*), and the tropical almond (*Terminalia catappa*). Nonfood plant introductions also included candlenut (*Aleurites moluccana*), bamboo (*Schizostachyum glaucophyllum*), and the *nonu* shrub (*Morinda citrifolia*). Although the island's first few generations of gardeners may have taken advantage of the marshy areas bordering the inland swamps to plant taro and especially giant swamp taro, the initial stages of horticultural development and expansion were most likely in the form of shifting cultivations on the interior slopes and hill. The practice of shifting cultivation, or "slash-and-burn" gardening as it is sometimes called, is widespread and ancient in Oceania

(Kirch 1994), with many of the linguistic terms for this gardening method documented for Proto-Polynesian and even Proto-Oceanic vocabularies (Kirch and Green 2001:126–130; Kirch and Lepofsky 1993). There can be little doubt that Mangaia's colonizers were intimately familiar with the practices of shifting cultivation.

The effects of this initial phase of shifting cultivation on the geologically old, nutrient-depleted, and vulnerable interior landscape of Mangaia are amply documented in the stratigraphic and pollen archives obtained from the swamp cores (see Chapter 2). Microscopic charcoal particles, previously absent in the deeper levels of the cores, suddenly shoot up to densities of 300,000 grains per cubic centimeter, indicating the regular use of fire, a clear signal of shifting cultivation. Geochemical analyses likewise register sharp increases in the deposition of free iron, silicon dioxide (SiO_2), and aluminum trioxide (Al_2O_3), as well as a decrease in phosphorous (in the form of P_2O_5) in the upper portions of the TIR-1 core from Veitatei Valley (Kirch 1996; Kirch et al. 1992). These are all proxy measures of the stripping of a thin, nutrient-rich organic soil layer from the surface of the volcanic cone, exposing the ancient, deeply weathered, nutrient-poor laterite. The deforestation of approximately 25 percent of the island's landscape that resulted from these human-induced activities is recorded in the pollen spectra, which show dramatic reductions in arboreal taxa coupled with a marked increase in the fire-adapted *Dicranopteris linearis* fern and scrub *Pandanus tectorius*. This dramatic deforestation—and in particular the inability of the indigenous forest that originally cloaked the volcanic hills to recover—was most likely a consequence not only of the extreme geological age of the central volcanic cone (and lack of inherent soil nutrients) but also of the rapid decimation of the island's seabird populations, which, as noted earlier, had acted as keystone species in maintaining the ecosystem's nutrient supply.

Deforestation of the central volcanic cone and exposure of the hillslopes to erosion led to significant deposition of clay in the narrow valley bottoms and swampy basins where the streams pond against the inner *makeatea* escarpment. In Veitatei Valley, as much as 6 m of clay now overlies peat deposits that formed during the mid to late Holocene; in other valleys, such clay in-fills range from 1 to 4 m deep (Ellison 1994a). From the perspective of the Mangaian cultivators, this newly deposited alluvium provided ideal terrain on which to construct irrigated pond-fields, separated by low earthen embankments, in which

taro could be intensively cropped. Thus, as the upper volcanic ridges and steeper slopes became progressively denuded and stripped of their thin soil mantle, rendering them useless for continued shifting cultivation, the deposition of alluvium allowed for the expansion of the irrigated component of Mangaian horticulture. The time frame over which this shift in emphasis from extensive, dryland cultivation to intensive, wetland cultivation took place remains to be precisely determined, but it is likely that the irrigation systems already dominated Mangaian production by the Ngaaitutaki Phase, and undoubtedly this was the case in the Tautua Phase.

This sequence of geomorphic transformation, initially precipitated by the practices of shifting cultivation on an unusually old and vulnerable landscape, and the intimately linked changes in the island's horticultural production system are diagrammatically summarized in Figure 14.2. The increasing importance of wetland, irrigated cultivation of taro—in what the Mangaians came to call the *puna* lands—had major implications for the evolution of Mangaian society and political organization (see Chapter 2). Control over the intensively cultivated valley bottoms became a central goal of competing tribal groups, as Mangaian oral traditions amply attest (Hiroa 1934; Reilly 2003, 2009). The repercussions spilled over into the realm of religion and ritual, with Rongo—elsewhere in Eastern Polynesia the god of horticulture—here becoming a dual deity of gardening and of war.

One more aspect of Mangaian horticulture deserves our attention: the introduction to the island of the sweet potato (*Ipomoea batatas*). As Yen (1974) famously argued and recent research has confirmed (Roullier et al. 2013), the sweet potato was domesticated in South America, its transfer into the islands of Eastern Polynesia occurring in pre-Columbian times, almost certainly by Polynesian voyagers who reached the coast of South America and returned with a cargo of dormant tubers. One of the striking archaeobotanical finds at Tangatatau Rockshelter in 1989 was several fragments of carbonized sweet potato parenchyma (see Chapter 9), first reported by Hather and Kirch (1991). The earliest of these was recovered from zone SZ-4A, with other specimens from SZ-8 and SZ-15. It is likely that the sweet potato entered the Mangaian cultivation system around the end of the Tangatatau Phase. Direct accelerator mass spectrometry (AMS) dating on one carbonized specimen from SZ-8 yielded a calibrated age of AD 1448 to 1616.

The introduction of sweet potato to Mangaia—as indeed elsewhere in Polynesia—arguably had a significant impact on the island's production system. Not only does the plant produce relatively high yields, but it is more tolerant of drier and nutrient-poor soils than the *Dioscorea* yams or dryland taro varieties transported by Polynesians from their western homeland islands (Ballard et al. 2005). While irrigated taro (*mamio*) was the culturally preferred food of Mangaia, the sweet potato (*kuara*) also held a place of considerable importance in Mangaian subsistence. As Hiroa (1934:136) writes, sweet potato “was the chief food of the conquered in peace times, for it grew in the dry soil of the makatea and the uplands.” In short, the introduction of the sweet potato may have helped to partially counteract the deleterious effects of early shifting cultivation on the volcanic interior, allowing some cultivation to continue on the lower slopes as well as in the *makatea* lands.

Throughout the majority of Oceanic societies, pig husbandry was intimately integrated into island production systems (Oliver 1989:221–229). Pig meat is typically the most prestigious feasting food, and even pig tusks are often items of exchange or value. Pig bone is present in the Vairorongo site, and the animals certainly were introduced to Mangaia with the initial colonizers. Yet the ethnohistoric record is clear on the fact that when the London Missionary Society missionaries first arrived in the 1820s, pigs were not present on Mangaia. Gill (1876) relates that there was a tradition of Mangaians having kept pigs at some time in the past. When the missionary Williams introduced a breeding pair to Mangaia, they were eagerly accepted and indeed consecrated on the *marae*; not long afterward—given porcine breeding proclivities—the Mangaians possessed large pig herds.

What transpired on Mangaia to cause the most valued of Oceanic domestic animals to be extirpated prior to European contact? Mangaia is not the only relatively small Pacific island on which this scenario has been archaeologically attested. A particularly well-documented case is Tikopia, where pigs were husbanded throughout most of that island's prehistory, yet had been purposefully eliminated in late prehistory (Kirch and Yen 1982). Mangareva in Eastern Polynesia provides another example (Green and Weisler 2004; Hiroa 1938a; Kirch et al. 2015), as do some atolls in Micronesia (Intoh 1986). On Aitutaki Island in the Southern Cooks, the frequency of pigs in the archaeological record declines significantly over time (Allen in press; Allen and Craig 2009), although it is unclear whether pigs were completely extirpated by the time of European contact.

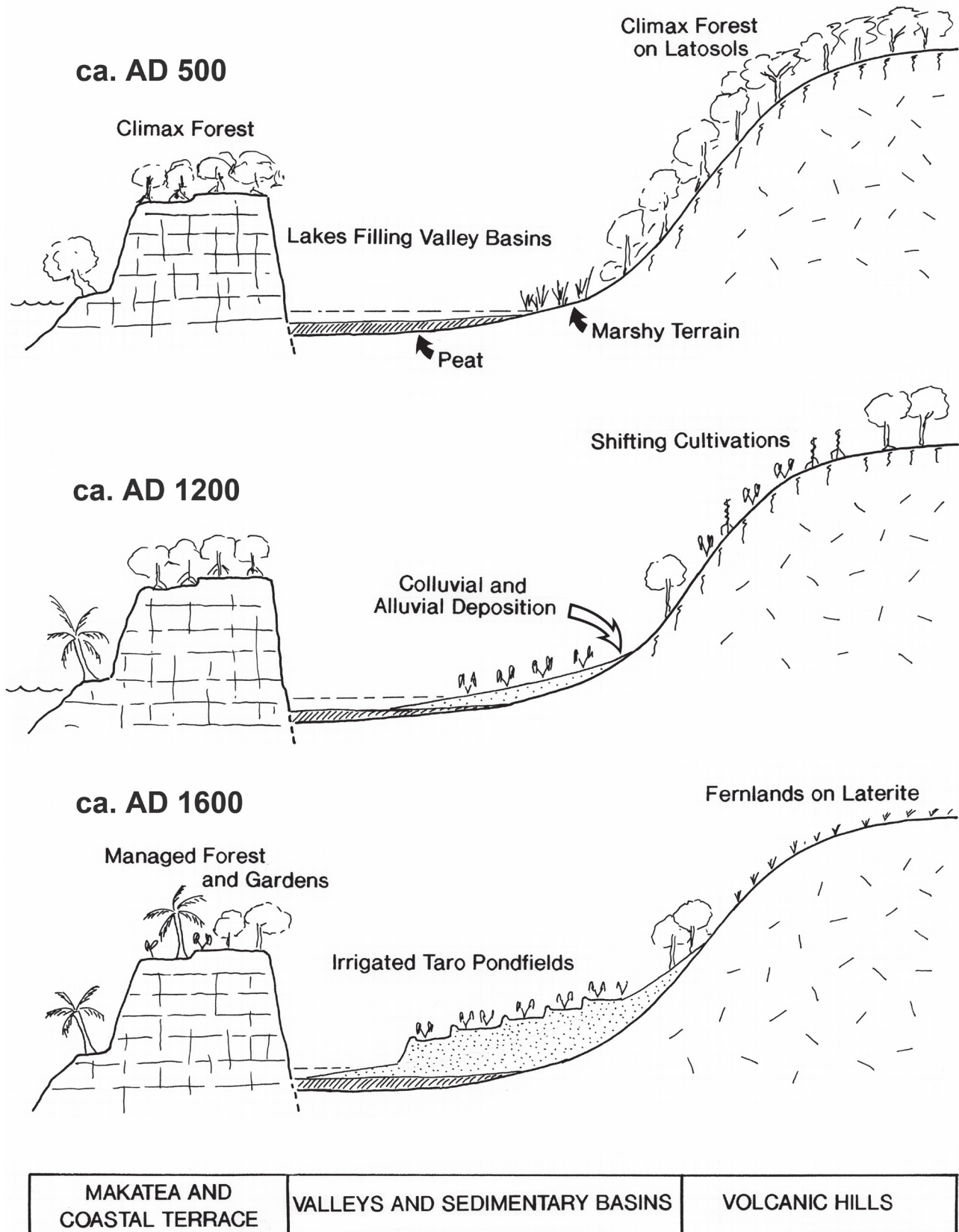


Figure 14.2. Diagrammatic summary of the geomorphic transformation of the Mangaian landscape and consequent changes in the island's horticultural system.

Seeking an underlying explanation for these parallel histories of the elimination of pigs from island economies, I turned some years ago to the ecological principle of *trophic competition* (Kirch 2001). On small islands, pigs cannot be left to forage at will, for they will readily enter gardens where they uproot and devastate the crops with alacrity. Pigs need to be penned or at least separated from garden areas (as in Futuna, see Kirch 1994); as a consequence, they must be fed by their human wards, typically with food scraps, substandard tubers, coconut meat, and even human feces (of which they are notoriously fond). But in situations where food is scarce and the human population itself comes to rely increasingly on marginal food stuffs, the populations of pigs and humans can come into direct competition for calories. Pig flesh is delicious and highly prized socially, but the basic law of trophic conversion means that 10 kilos of carbohydrate foods are required to produce 1 kg of pig meat. Under conditions of food shortage, the human population is much better off to directly consume those 10 kilos of carbohydrates than to feed them to the pig

herds, in the process losing 90 percent of the food value in the trophic conversion of carbohydrates to pig flesh. Based on this fundamental ecological principle, I argued that the elimination of pigs on such islands as Tikopia, Mangareva, and Mangaia reflected situations in which acute food shortages (at least *periodic* shortage, in times of drought or cyclone-inflicted damage to the production systems) had arisen.

Figure 14.3 plots the concentration indices of pig bone plus “medium mammal” bone in the deposits at Tangatatau Rockshelter. As discussed in Chapter 6, the vast majority of medium mammal bone in the site is almost certainly of pig, even though the high degree of fragmentation does not permit definitive identification. Combining the pig and medium mammal categories, however, yields an arguably more accurate representation of the frequency of pigs over time in the rockshelter deposits. The pattern seen in Figure 14.3 is quite striking, with two peaks: one toward the end of the Tangatatau Phase and the second, somewhat less pronounced, in the succeeding Ngaaitutaki Phase.

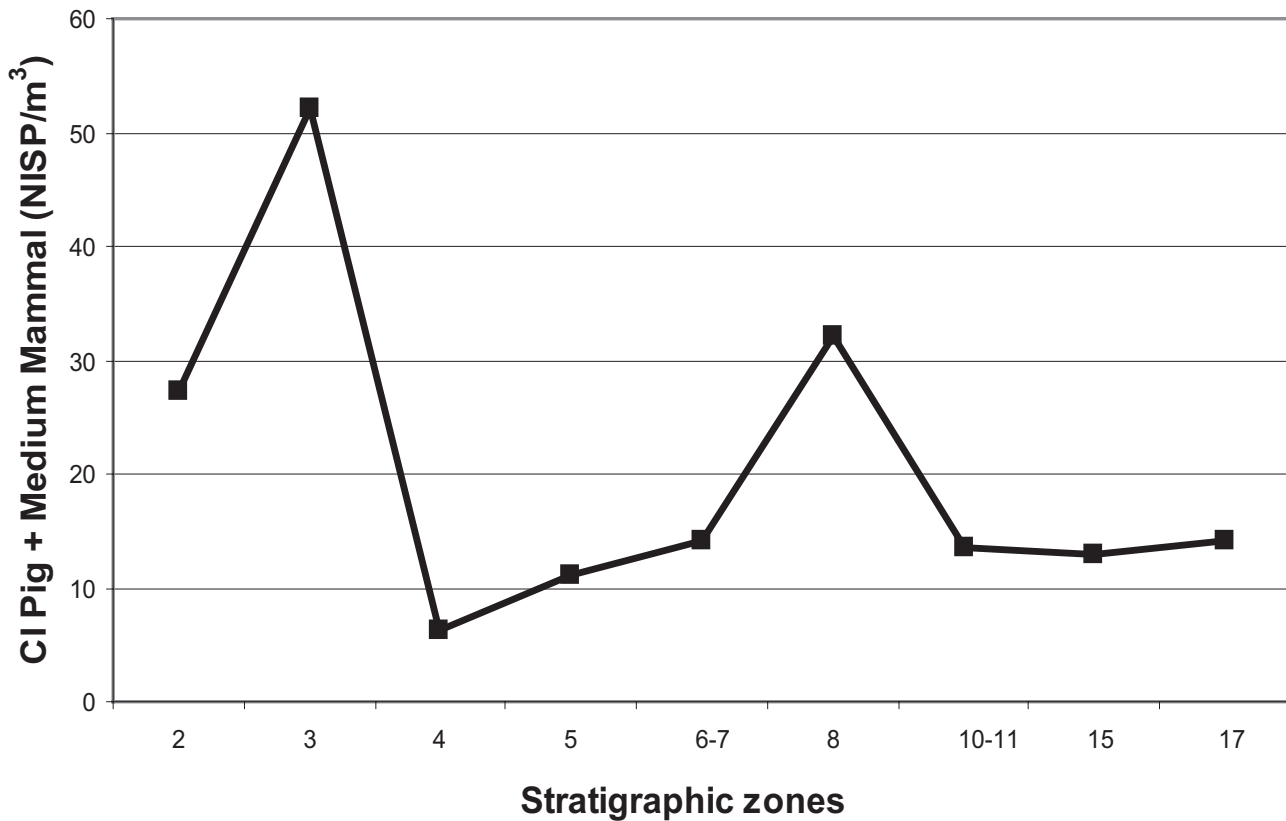


Figure 14.3. Concentration indices of pig plus medium mammal bone in the Tangatatau Rockshelter sequence.

It would seem that the history of pig husbandry on Mangaia (at least insofar as the record from the Tangatatau Rockshelter may be taken as representative) was fairly complex. The highest frequency of pigs occurred during the Tangatatau Phase, when the human population was likely still rapidly growing and the horticultural sector expanding. The decline in the concentration index of pig bones from zones SZ-3 to SZ-4, however, is truly precipitous, arguably a signal of stress in the horticultural sector, significant food shortage, and trophic competition. This raises the question of whether the end of the Tangatatau Phase witnessed a population peak and consequent food shortage, a hypothesis I will return to below.

The faunal record further suggests a gradual rebuilding of the pig husbandry sector in the succeeding Ngaaitutaki Phase, with another peak (only about half as pronounced as the first) in zone SZ-8 of the Tangatatau stratigraphic sequence. It is tempting to attribute this to a “rebalancing” of the horticultural system after the collapse of shifting cultivation on the interior volcanic cone and subsequent intensification of the wetland pondfield sector made possible by the newly deposited alluvial lands in the valley bottoms. The addition of sweet potato to the crop roster may also have been a positive factor, as noted above. Such transformations could have reduced the trophic competition between pigs and humans, allowing for the husbanding of sizable pig herds once again. After SZ-8, however, the concentration indices of pig bone decline one more time, indicating that during the final Tautua Phase, only modest numbers of pigs were being kept and consumed. And, as we know from the ethnohistoric record, pigs were eventually completely eliminated, although this must have taken place not too long prior to European contact, as pig bone is present up through zone SZ-15 of the rockshelter deposits. (The pig bone in SZ-17 presumably derives from the missionary reintroduction of pigs.)

Population and Food Availability: A Theoretical Digression

I have alluded above to demographic implications of the trends discernible in the archaeological record of food production on Mangaia and wish to now explore these further through a brief digression that draws upon recent developments in demographic theory. Of course, we have no direct, empirical data on the absolute size, density, or other parameters of Mangaian population

in prehistory; indeed, the ethnohistoric record provides only a rough estimate of the number of people inhabiting the island at the time of missionization, between 2,000 and 3,000 (see Chapter 2). But recent theoretical models of the linkages between population growth and food availability for populations expanding in a spatially limited environment, developed by the Hawai'i Biocomplexity Project (Kirch 2010c; Kirch et al. 2012), permit us to make some informed hypotheses regarding Mangaian demographic history. Ultimately, these models bear on the longstanding Malthus-Boserup debate (Boserup 1965; Malthus 1798; Spooner 1972; Wood 1998).

It is not necessary here to go into detail regarding the theoretical models linking population and food availability; these have been published fully elsewhere (Lee and Tuljapurkar 2008; Puleston and Tuljapurkar 2008). In brief, in a space-limited small island such as Mangaia with a circumscribed area amenable to cultivation, the area cultivated is a function of available labor. When the population is small, the cultivated area expands in proportion to the labor supply; as population increases, the cultivated area eventually reaches its limits, at which point land, not labor, becomes the limiting factor. Until such time as land availability becomes limiting, the rate of population increase can be quite high, especially in situations such as Remote Oceania, which lacked most Old World diseases. However, demographic rates respond sensitively to food supply, or what Puleston and Tuljapurkar (2008) call the *food ratio* (E), a measure of food availability. When E is significantly greater than 1, the population is able to grow rapidly, but when E approaches or drops below 1, negative feedback effects impinge on mortality and fertility, causing the population growth rate to decline. The dynamics, moreover, are nonlinear.

[F]or any real population the food yield $Y(t)$ and the food ratio $E(t)$ is a time-varying random function. The food ratio $E(t)$ responds to variability in yield (from climate, crops, and soil), and also to variability in population structure (from growth or decline in response to past shortages or surpluses, and sharing behavior). As a result the population dynamics are actually stochastic: variable climate interacts with the plant-soil dynamics and affects yield, and the population responds to changing yields via changing mortality and fertility. The analytical

strategy for such models focuses on the probability distribution of food yield and of population structure and number. These can be studied using simulations and analytical methods [Kirch et al. 2012:25].

Figure 14.4 displays simulations of population growth and food availability (E) for scenarios involving different spatial areas and levels of agricultural productivity, developed by the Hawai'i Biocomplexity Project during its investigation of agricultural intensification and population dynamics in the leeward dryland field systems of Hawai'i Island. These simulations are directly relevant to the Mangaian case. Note that regardless of the size of the territory occupied by these simulated populations or of the different inherent levels of productivity (determined by differential soil nutrient levels and represented as different levels of yield in tons/hectare), the overall shape of the simulated population growth curves and the trends in the food availability ratio (E) remain essentially identical. The population growth curves all exhibit an early phase of exponential growth followed by a rapid transition to a stochastic equilibrium as E approaches a value of 1. The food ratio, for its part, exhibits a mirror image of the population curve, with at first gradual but then rapid decline to a stochastic equilibrium value of $E < 1$. As Puleston and Tuljapurkar (2008:149) observe, "When $E < 1$ the population experiences some degree of food deprivation and so we call E the hunger level." Also note that the elapsed time between initial colonization and the achievement of a stochastic equilibrium is in all scenarios roughly 250 years, again regardless of differences in territory size or productivity. This is highly relevant to the Mangaia case.

Applying the insights from these simulations, we can predict that a similar demographic scenario would have played out on Mangaia during the early phase of population growth and expansion of the island's horticultural system. Specifically, we hypothesize that on this small island with limited arable land, initial population growth was exponential or nearly so, fueled by abundant food ($E > 1$). Labor—the numbers of able-bodied individuals available to clear and work the land—was the limiting factor. As population increased and the limits to arable land were approached, the food ratio would have started to decline rapidly, in turn depressing the rate of population growth as periodic food shortages began to affect mortality and fertility.

The rate at which food availability declined could have been heightened significantly by the deforestation and erosion of the vulnerable central volcanic cone, as described earlier, as this would have reduced the total area amenable to shifting cultivation. The time frame for this transition from a labor-limiting to a land- and food-limiting situation—as predicted by the simulations in Figure 14.4—would most likely have been on the order of 250 years.

Depending on when the first Polynesians arrived on the island and established permanent settlements, the island's population would have approached its first demographic crunch sometime between about AD 1250 and AD 1450, toward the end of the Tangatatau Phase. It seems more than a coincidence, then, that this is the same time frame when the density of pig bones in Tangatatau Rockshelter exhibits a precipitous decline (Figure 14.3). As noted earlier, maintaining a large pig herd would have necessitated a substantial food surplus, with a food ratio E significantly greater than 1. The steep drop in density of pig bones from SZ-3 to SZ-4 is as clear a signal of stress in food availability as we are likely to get from the archaeological record. It strongly suggests that toward the end of the Tangatatau Phase, food had become scarce in relation to the population size ($E \leq 1$).

There is yet another indication that Mangaia had entered a period of substantial stress around the end of the Tangatatau Phase and beginning of the Ngaaitutaki Phase: the evidence for interpersonal violence represented by the 41 or more individuals who were dismembered and baked in the earth ovens at Ana Manuku Rockshelter (site MAN-84) in Keia district. These events are radiocarbon dated to a relatively short period between cal AD 1390 and 1470 (see Chapter 13), which spans the transition from the Tangatatau to Ngaaitutaki Phases. The evidence from Ana Manuku speaks to a period of severe hostility and violence between social groups, one that is echoed as well in Mangaian oral history. Hiroa (1934:46–48; see also Reilly 2003, 2009) relates the traditions of a series of conflicts between the Ngati-Tane and Ngariki tribes, involving two incidents in which members of the former group were killed and reputedly cooked in large earth ovens. These conflicts occurred relatively early in the historical sequence of Mangaian traditions; it conceivable that the traditions echo a period of demographic stress and competition that took place around the transition from the Tangatatau and Ngaaitutaki Phases.

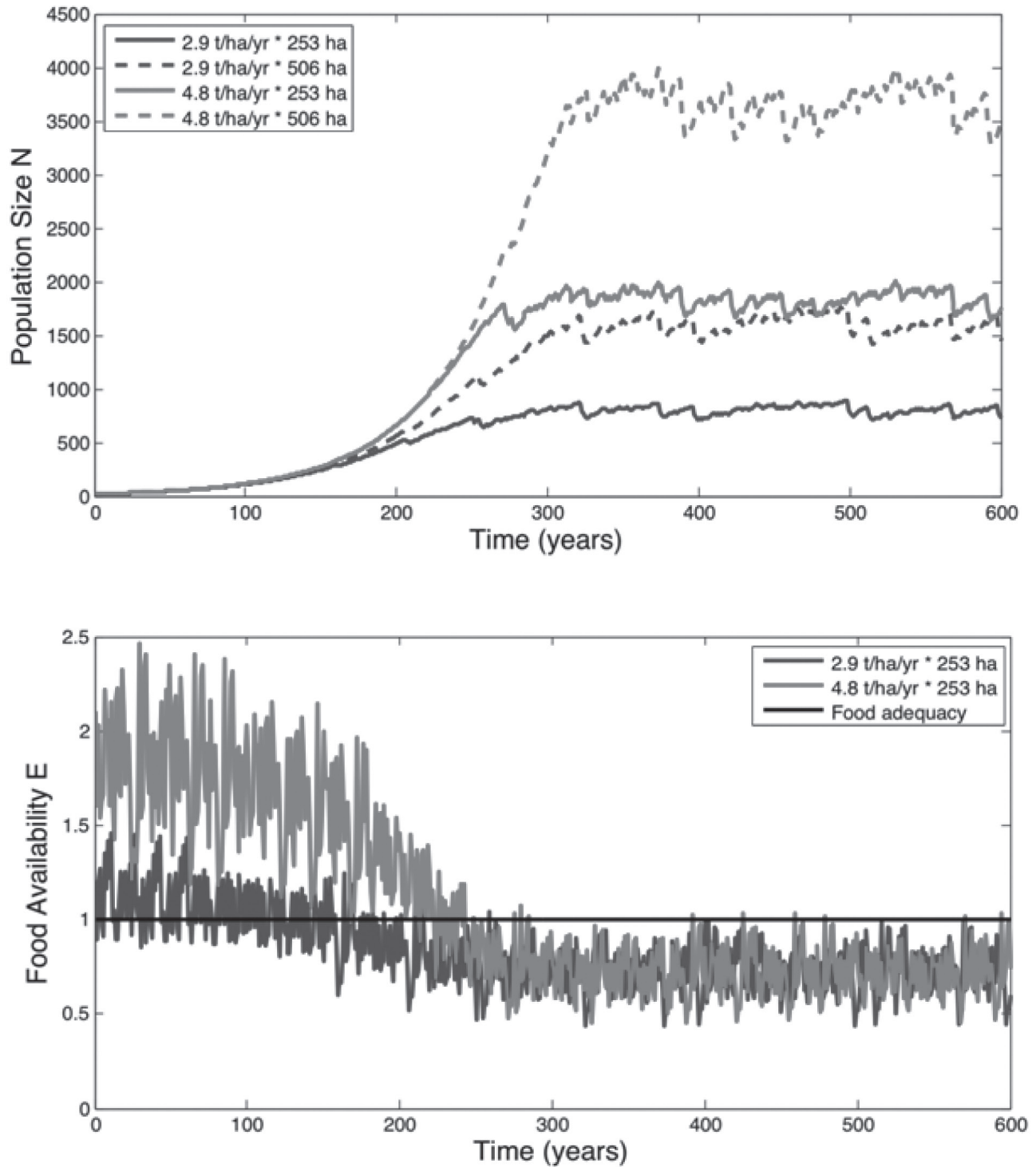


Figure 14.4. Simulations of population growth (top) and food availability (bottom) for agricultural populations in circumscribed areas of differential size and levels of productivity, over a 600-year time scale. Note that differences in scale and productivity do not affect the overall trends, and that the elapsed time from initial colonization to a stochastic equilibrium state is approximately 250 years (adapted from Kirch et al. 2012, figs. 7 and 8).

Remarkably, however, Mangaia did not remain trapped in a state of Malthusian stochastic equilibrium, with limited surplus and constant hunger. The gradual increase in pig bone density in the faunal record, which builds up to another peak later in the Ngaaitutaki Phase (in zone SZ-8 of the rockshelter sequence), suggests that the balance between population and food production gradually improved, with food availability such that a surplus adequate to feed pig herds was once again achieved. Quite likely such an improvement in food availability was aided by two innovations (to invoke Boserup's theory): first, expansion and intensification of the valley irrigation systems, made possible by the extensive deposition of alluvium, and, second, by the introduction of the sweet potato, which allowed gardening to expand into the *makatea* regions, as well as onto the poorer lateritic soils of the lower volcanic slopes. Significantly, the intensity of interpersonal violence witnessed at Ana Manuku seems not to have been repeated later, even if intertribal competition and warfare continued and indeed became institutionalized in Mangaian society.

Resource Exploitation and the Question of Sustainability

While horticultural production was undoubtedly the most important component of Mangaia's subsistence system—and the one most closely entwined with food availability and population—the exploitation of natural or “wild” resources also played a significant role throughout prehistory. Indeed, despite the importance of pig husbandry at various times, fishing and shellfish gathering were always key sources of protein and on a daily basis certainly contributed more to Mangaian diet than domesticated animals. Hence, I turn now to the history of resource exploitation as well as to the question of whether such exploitation was sustainable over the long run of Mangaian history.

The sector of natural resources that suffered the most severe impact from Polynesian colonization and subsequent exploitation was the island's avifauna, and although they are mammals, not birds, we can include here the Pacific flying fox (*Pteropus tonganus*) as well. Thanks to the rich avifaunal record in Tangatatau Rockshelter, augmented by Steadman's work at other Mangaia sites, including Te Rua Rere Cave and Ana Manuku (Steadman 2006:218–229), the record of prehistoric birds on Mangaia is one of the best

documented for any Oceanic island. Twelve species of seabirds and 16 species of native landbirds are in evidence in the rockshelter deposits (see Chapter 6; also, Steadman 2006:Table 7-2). Shockingly, of the native landbirds, only five species survived into the historic period: the reef heron (*Egretta sacra*), the duck (*Anas superciliosa*), one species of rail (*Porzana tabuensis*), the Mangaia kingfisher (*Halcyon mangaia*), and a warbler (*Acrocephalus kerearako*). Among the species that were extirpated or went entirely extinct were several species of rails (including *Gallirallus ripleyi* and *Porzana rua*), five species of pigeons or doves (*Ptilinopus rarotongensis*, two species of *Ducula*, and two species of *Gallicolumba*), three parrot species (*Vini* spp.), and a swift (*Collocalia manuoi*).

As the stratigraphic distribution of bird bones in Tangatatau Rockshelter indicates (see Table 6.3), the greatest exploitation of landbirds occurred during the Tangatatau Phase (zones SZ-2 to SZ-4). The decrease in the number of landbird taxa beginning with zone SZ-5 is quite shocking (see Figure 6.4). This decimation in the biodiversity of landbirds almost certainly was due to several converging factors. Direct hunting of birds, both for food and for feathers (especially in the case of the parrots, for example), was certainly a contributing factor. However, habitat disturbance and alteration were likely to have been even more important, in particular the deforestation of the central volcanic cone, removing a substantial area of potential bird habitat. A third factor leading to the extirpation of some of the ground-dwelling taxa such as the rails may well have been predation by the Polynesian-introduced Pacific rat.

The record for seabirds is quite different from that of landbirds, with 8 of the 13 species known from Tangatatau and other Mangaia sites surviving into modern times (although six of these are today represented only by small, frequently endangered, populations). Species not surviving on Mangaia into the historic period include a *Puffinus* sp., *Pterodroma nigripennis*, the storm petrel (*Nesofregatta fuliginosa*), and a booby (*Sula sula*). The faunal record from Tangatatau Rockshelter (see Figure 6.3) shows that while seabirds were exploited throughout the sequence, the greatest densities of seabird bones occur late in time, during the Tautua Phase (particularly in zone SZ-15). This late peak in seabird exploitation suggests intense hunting of birds that nested or roosted in difficult to access parts of the *makatea*.

The causes of seabird decline were doubtless similar to those that affected the landbird populations: hunting, habitat disturbance, and, for some ground-nesting species, predation by rats. In addition to the deforestation of the central volcanic cone, the planting of coconut palms around the island's coastal plain and on parts of the *makatea* could also have negatively affected populations of tree-nesting seabirds; research on Palmyra Atoll has shown that when indigenous forest dominated by *Pisonia* and *Tournefortia* was replaced by coconut palms, the density of breeding birds declined significantly (Young et al. 2010).

Whatever the mix of causes of seabird population decline, the broader implications for ecosystem functioning on Mangaia were probably severe, given the role of seabirds as transferors of marine-derived nutrients from the ocean to land, via guano deposition. Considerable research documents the significant inputs of seabird guano fertilization to higher nitrogen (N) availability and $\delta^{15}\text{N}$ values in island ecosystems (Anderson and Polis 1999; Briggs et al. 2012; Mizota and Naikatini 2007; Szpak et al. 2012). As noted earlier, the very old geological age of Mangaia and consequent impoverishment of its soils in N would have made reduction and eventual removal of guano inputs to the island a serious restraint on forest regrowth, lowering baseline $\delta^{15}\text{N}$ values. Observed $\delta^{15}\text{N}$ values between primary producers fertilized with seabird guano differ by up to +11% higher than those without seabird input (Wainwright et al. 1998). Removal of guano inputs from the Mangaia ecosystem would therefore have lowered $\delta^{15}\text{N}$ values across primary producers, an effect that would have cascaded through the entire island food web. Swift et al. (2016) have argued that precisely such a cascade effect was responsible for a similar lack of reforestation on the small islands of the Mangareva group.

Mangaia's other flighted indigenous animal, the flying fox or fruit bat, also saw its population decimated during the course of the Tangatatau Phase; bones of *Pteropus* do not occur higher than zone SZ-4B and feature F37 in the MAN-44 stratigraphic sequence. This discovery was initially surprising given that the flying fox inhabits Mangaia today, but it appears that this resulted from an undocumented nineteenth-century reintroduction of the animal (as also took place in Tahiti). The fact that the flying fox was reintroduced after having been extirpated from the island for several centuries explains why the Mangaian name for the

animal is a compound descriptive term, *moakirikiri* ("chicken with fur"), rather than a variant of the widespread and ancient Polynesian word *peka* or *pe'a*, as found on other islands where flying fox populations have persisted.

As noted in Chapter 2, Mangaia is encircled by an especially narrow fringing reef and lacks a true lagoon. The total area of reef is roughly 2.25 km², a much smaller surface area than the 52 km² of land and hence potentially highly susceptible to the continual pressure of human fishing and resource gathering. Indeed, the faunal records of both marine invertebrates and marine fishing from Tangatatau Rockshelter provide abundant evidence for effects on the marine fauna and biodiversity, including some clear cases of resource depression.

The assemblage of marine mollusks from Tangatatau exhibits temporal patterns suggestive of an early emphasis on high-valued or easily gathered taxa, these being replaced over time by other species that were harder to obtain, were less desirable, or in some cases whose abundance may have increased due to changes in the reef's ecology. In the Tangatatau Phase (zones SZ-2 to SZ-4B), the highest ranked taxa were the large-bodied turban shells, *Turbo setosus* and *Astraea rhodostoma*. By the later Ngaaitutaki Phase, these early preferences dropped substantially in rank, being replaced by *Drupa* spp., *Modiolus auriculatus*, *Cerithium* spp., and *Conus* spp. as the highest-ranked taxa. All of these yield much less meat and are more time-consuming to gather. *Tectarius grandinatus*, although never one of the most highly ranked mollusks, was nonetheless easy to obtain as it frequents the intertidal rock platforms; it is completely absent from the higher stratigraphic zones, having been effectively extirpated through overharvesting. The increased importance of the *Modiolus* mussel in the Ngaaitutaki and Tautua Phases may well be a consequence of a shift in fringing reef habitats from those dominated by corals to zones covered in algal beds. Coral is highly susceptible to trampling, whereas zones of broken and dead coral are readily colonized by seagrasses, the preferred habitat of *Modiolus*.

Despite these shifts in the relative ranking of mollusks taken in earlier versus later time periods, the exploitation of mollusks continued throughout the use of the rockshelter. Moreover, the *density* of shellfish remains in site MAN-44 increases several fold from the Tangatatau to Ngaaitutaki Phases, a trend mirrored in the marine fish bone density patterns (see Figures

7.8 and 7.11), as well as in the density of sea urchin remains (see Figure 8.7). One possible explanation for this higher intensity of marine exploitation of both reef fish and mollusks in the Ngaaitutaki Phase lies in the significant decline in pig husbandry at the end of the Tangatatau Phase, as discussed earlier. With stress in the horticultural sector and a lack of suitable carbohydrate surplus to sustain the pig herds—exacerbated by decimation of bird and flying fox populations—the human inhabitants of Mangaia may well have turned to more intensive exploitation of the reef to meet their protein needs.

The final, Tautua Phase exhibits a drop back to levels of mollusk and marine fish density that are as low as the earlier Tangatatau Phase. By this late phase, the highly prized *T. setosus* gastropod was undoubtedly under intense pressure, with only smaller-sized individuals in evidence, a classic case of resource depression (see Figure 8.9). The most commonly gathered mollusk was the small *Drupa ricinus*, whose thick shells had to be thoroughly smashed to extract the few grams of meat contained within. Sea urchin concentration indices in the rockshelter also exhibit a significant drop from the preceding Ngaaitutaki Phase. It is in the Tautua Phase as well that resource depression in the reef fish *Cirrhitus* sp. is evidenced, with reductions in average body size. Size reductions in serranid fish also occur during this phase, although these may be the result of a shift to smaller-bodied species of serranids rather than to size reductions in specific taxa (see Chapter 7). In consort, the evidence from the mollusks, sea urchins, and marine fish all points to substantial pressure on the limited fringing reef of Mangaia during the island's final two centuries prior to European contact. When we recall that by this time pigs were in short supply and soon to be extirpated, that most of the landbirds were gone along with the flying foxes, and that seabirds nesting in the remote *makatea* were being targeted intensely, a picture of considerable pressure on the island's natural food resources cannot be avoided.

Was there, then, any component of Mangaian resource exploitation that was sustainable? The answer appears to lie in the realm of the freshwater fishery, focused on the taking of *Anguilla* eels and *Eleotris* fish. Both taxa exhibit increases in their concentration indices in the final Tautua Phase, and neither displays any signs of resource depression (i.e., no decreases in body size). The continued abundance of these freshwater fishes, which finally surpassed marine fish in their

densities in zone SZ-15, is no doubt due to the careful management of the valley bottom taro pondfields and adjacent freshwater ponds or small lakes (such as Lake Tiriara). As I personally observed on Futuna Island (Kirch 1994:154–155), *Anguilla* eels thrive in taro pondfields; the expanded area of irrigation on Mangaia in the late period would have provided the maximum habitat for these eels. The same may well be true of the *Eleotris* fish, which certainly inhabit both the lakes and streams but may also thrive in the taro fields. In this regard, it is noteworthy that the one landbird species relatively common in the Tautua Phase deposits at MAN-44 is the duck (*Anas superciliosa*), whose preferred habitat on the island is again the taro pondfields. All of this indicates that the one component of the late precontact Mangaian economy that was truly sustainable was the irrigated sector—not only for its central role in providing the *mamio* or wet taro that was the core of the Mangaian diet but also for these supplementary protein sources of eels, freshwater fish, and ducks. Little wonder that the *puna* lands were so prized and so fiercely fought over!

Finally, in addressing the sustainability of Mangaian resources, we must return to the subject of the diminutive Pacific rat (*R. exulans*), not an indigenous component of the Mangaian ecosystem but one that had been introduced to the island by the initial Polynesian colonizers. Whether this introduction was purposeful or not we shall probably never know. This aspect of rat translocation to the islands of the Pacific has been debated, for while the Pacific rat could have been carried purposefully as a food resource, its status as a commensal species also made it highly amenable to being transported inadvertently, as a stowaway on voyaging canoes. Regardless of how it came to be part of the cargo of the first Polynesians to settle Mangaia, the rat population expanded very fast, probably exponentially. Its bones are common even in zone SZ-1B (and, indeed, provide the radiocarbon evidence for initial colonization); they are in high concentrations in the Tangatatau Phase deposits (SZ-2 and SZ-3 especially). Rat bone concentration falls somewhat during the Ngaaitutaki Phase (zone SZ-8) but reaches high densities again in the Tautua Phase (especially in zones SZ-10/11, SZ-14, and SZ-15).

The ethnohistoric record for Mangaia offers abundant testimony that rats provided a major source of protein, possibly even greater than that of reef fish or mollusks, to judge from Williams's (1837:244)

remarks: “As Mangaia was not so abundantly supplied with fish as some other islands, and as there were no animals except rats, until I visited it, these formed a common article of food; and the natives said they were exceedingly ‘sweet and good’; indeed a common expression with them, when speaking of any thing delicious, was, ‘It is as sweet as a rat.’” Hiroa (1944:247) also documented the importance of rats as a food item. Being effectively omnivorous and with a high reproductive rate, the rats provided one more sustainable component to the late precontact Mangaian socio-ecosystem.

The Evolution of Technology

The evolution of the Mangaian socio-ecosystem encompassed more than the dramatic transformations of landscape and natural resources, accompanied by major shifts in horticultural production or animal husbandry, as discussed above. There was as well substantial change in technology, only some of which is directly evidenced in the archaeological record. We have, for example, no direct evidence of the changes that must have taken place in the technological aspects of horticulture, as the island’s population shifted its emphasis from forest clearance and shifting cultivation to permanent, wet field irrigation. One hint of innovation in agronomic technology is provided by the ethnographic witness of a unique wooden implement used by Mangaian cultivators to prepare their taro beds for planting (see Figure 2.11). Perhaps future archaeological investigations in the irrigated field systems will yield additional clues regarding this sector of agricultural innovation.

We also must be cautious in our expectations regarding the extent to which the archaeological record is likely to represent the full spectrum of ancient Polynesian material culture, the larger part of which was manufactured from perishable materials—wood, fiber, bark, leaves, bamboo, feathers, and so forth—which preserve only under unusually favorable circumstances. Hiroa’s (1944) definitive monograph on the *Arts and Crafts of the Cook Islands* describes 147 different kinds of artifacts preserved in museum collections. Of these, a mere 27 types (18 percent) were manufactured from durable materials that can be expected to survive in most archaeological contexts. Despite these caveats, the record of material culture from Tangatatau Rockshelter, augmented by smaller assemblages from other excavated sites, demonstrates significant technological evolution.

The first settlers to arrive at Mangaia may have come directly from a Western Polynesian source (given the presence of adze flakes of Samoan geochemical origin in the basal deposits at Tangatatau), but even if their immediate homeland was another central Eastern Polynesian island such as Tahiti, they were at most no more than two or three generations removed from a Western Polynesian ancestry. Their material culture would have derived directly from the artifact assemblage of the Ancestral Polynesian homeland in the first millennium AD. Kirch and Green (2001:163–200) described this assemblage, drawing upon both direct archaeological objects and linguistic reconstructions for categories of material objects. Pottery had virtually disappeared from Western Polynesia by the late first millennium AD, replaced by functional equivalents in wooden bowls and other containers. The adze kit had evolved from an earlier Lapita complex making extensive use of *Tridacna* shell to one based on basalt, with plano-convex, quadrangular, and triangular cross-sectioned forms. The Western Polynesian adze kit of the late first millennium, however, generally lacked an emphasis on development of a distinct tang (Kirch and Green 2001:Figure 7.3). A variety of other tools are in evidence, including coral, stone, and sea urchin spine abraders. One-piece fishhooks made from *T. setosus* shell are especially well documented from the To’aga site in Samoa, including rotating and “bent shank” forms (Kirch 1993:Figure 11.2).

The Vairorongo and Tangatatau Phases on Mangaia evidence a material culture not far removed from this Ancestral Polynesian predecessor. The adze kit of these early phases continued to be dominated by quadrangular, untanged forms, especially those of Duff’s type 2A. Considerable experimentation with triangular sectioned forms was already under way, however, and these would gain in popularity as time passed. Moreover, an interest in producing adzes with a distinct tang, by reducing the butt portion of the adze, or by leaving this unpolished, or even by creating distinct “nipples” near the poll (as in Figure 10.6a), is already in evidence in the Tangatatau Phase. These traits would be increasingly emphasized in later phases. Although Mangaian adze makers faced considerable limitation in the lack of extensive basalt sources on this geologically old, deeply weathered island, they discovered and extensively exploited at least two local sources, one in Veitatei district and the other at Mata’are. Finished adzes were also imported from other islands: in addition to Samoa,

Tangatatau Phase adzes were imported from Rurutu (in the Austral Islands) and from Eiao (in the Marquesas).

The fishhooks of the Vairorongo and Tangatatau Phases continue some of the forms seen in Ancestral Polynesia (such as the curved or “bent shank” hooks of the To‘aga site) but also evidence experimentation with new shapes. Although some hooks continued to be made of *Turbo* shell as in the ancestral homeland, the majority were now manufactured from pearl shell (*P. margaritifera*), a major innovation in that the pearl oyster shell is stronger and permitted larger hooks to be made. For the Mangaian craftsmen, however, this necessitated access to an external source of pearl shell, as the oyster—whose habitat is a lagoon—does not grow on the island.

Other aspects of early Mangaian technology continued directly from the Ancestral Polynesian tradition. These included the use of both branch coral (*Acropora*) and *Porites* coral, as well as sea urchin spines, as abrading tools. The tattooing combs from Tangatatau also follow directly from an earlier tradition of bone implements best evidenced by Poulsen’s finds at the To.1 site in Tonga (Poulsen 1987:208, Plate 68).

In contrast, the later Ngaaitutaki and Tautua Phases exhibit significant changes in material culture, some necessitated by changes in the availability of materials (especially imported pearl shell), others apparently more stylistic in nature. The later Mangaian adzes are largely dominated by triangular-sectioned forms, although some quadrangular types continue. Most notable, however, is the emphasis now placed on making the tang highly pronounced, often by lateral reduction of the poll. While these developments no doubt facilitated hafting, they obviously were not strictly necessary from a functional standpoint and must therefore be interpreted as largely stylistic in nature.

By the late Ngaaitutaki Phase, pearl shell seems to have become a rare commodity, to judge by the nearly complete shift from pearl shell to *Turbo* shell for fishhook manufacture. Presumably this reflects a breakdown or cessation in external, long-distance exchange relationships with other communities where pearl shell was naturally abundant. The shift to *Turbo* shell had practical consequences, as hooks of *Turbo* cannot be made as large as those from the pearl oyster, nor can the trolling lure shanks for pelagic fishing be crafted out of *Turbo*. Another adaptation to the loss of access to pearl shell is seen with the adaptation of coconut grater heads to basalt (as in Figures 10.17b and 13.22).

Finally, we should note the distinctive adaptation to *makatea* conditions reflected in the use of calcite obtained from stalagmites and stalactites taken from the island’s limestone caverns. In the absence of abundant basalt or other volcanic rock, the dense calcite was used to manufacture several kinds of artifacts, including slingstones and food pounders. Chert nodules, remnants of older, largely dissolved *makatea* found in Ivirua district, were also knapped as an alternative to basalt, as shown by the presence of considerable numbers of chert lithics at the Tautua Phase terrace sites excavated by Endicott (2000) in Veitatei.

Mangaia in Eastern Polynesian Perspective

In concluding this synthesis of the Mangaian archaeological record, I will briefly draw attention to two ways in which the evidence from Tangatatau Rockshelter and other sites on the island has helped to address larger issues in Eastern Polynesian prehistory. Specifically, these concern the timing of initial Polynesian entry in the region and the issue of long-distance voyaging and interaction between islands and archipelagoes.

For nearly two decades, a substantial debate ensued among Polynesian archaeologists over the timing of initial Polynesian intrusion into the archipelagoes of central Eastern Polynesia as well as beyond to the marginal apices of the Polynesian Triangle. One school of thought held that settlement had occurred early in the first millennium AD, if not indeed at the end of the first millennium BC. This position was based in part on early radiocarbon dates from the Marquesas Islands (Sinoto 1966, 1979; Suggs 1961) and the fact that the Western Polynesian homeland was already well settled by 800 to 700 BC (Irwin 1981; Kirch 1986), making it probable that there was only a “short pause” in the expansion of Lapita voyagers and their Polynesian descendants across the Pacific. The other camp, inspired by Spriggs and Anderson’s (1993) application of “chronometric hygiene” to radiocarbon dating, argued for a much later dating of the settlement of Eastern Polynesia and, by implication, a “long pause” in the settlement of the Pacific. Most recently, Wilmshurst et al. (2011) took such chronometric hygiene to its extreme (rejecting any dates that were not made on botanically identified, short-lived plant remains), arguing that with the exception of the Society Islands (which they took to have been colonized ca. AD 1025–1121), the Eastern Polynesian archipelagoes were not peopled until AD 1200 to 1290 (but see the issues raised by Mulrooney et al. 2011).

It is not necessary to rehearse here the full history of this debate. Little support now remains for a long chronology of Eastern Polynesian settlement extending back into the early first millennium AD. Extensive redating of key sites such as Hane in the Marquesas (Conte and Molle 2014) and a number of putative early sites in the Hawaiian Islands (see Kirch 2011 for a review) using AMS methods on botanically identified short-lived taxa have failed to replicate the older dates obtained by pioneering excavators in the 1950s and 1960s. At the same time, the ultra-short chronology advocated by Wilmshurst et al. (2011) is not supported by the most recent, high-precision AMS dating from several localities in central Eastern Polynesia, including Mangaia. As we have demonstrated in this monograph, Mangaia had a human presence by approximately AD 1000, based on the calibrated dates for Polynesian-introduced rat bones in SZ-1B at Tangatatau (Chapter 5). Similarly, in the Mangareva Islands, the Onemea site on Taravai has multiple AMS dates indicating settlement by AD 950 to 1050 (Kirch et al. 2010). In the Marquesas, Conte and Molle (2014) assigned the earliest occupation phase at the Hane dune site to AD 900 to 1000, based on several new AMS dates. And for Hawai'i, which is believed to have been settled from the Marquesas, the best recent assessment of the date of initial colonization is AD 940 to 1130 (Athens et al. 2014). In short, the new evidence from Tangatatau Rockshelter, when combined with recent AMS dating or redating of key sites in Mangareva, the Marquesas, and Hawai'i, leaves little room for doubt that initial Polynesian expansion out of the Western Polynesian homeland and into the archipelagoes of central Eastern Polynesia was well under way between AD 900 and 1100. By the beginning of the thirteenth century, numerous communities were already well established throughout virtually every major island and archipelago of Eastern Polynesia.

The emerging consensus that there was an extremely rapid diaspora out of Western Polynesia with the subsequent emplacement of new colonies on islands throughout the central Eastern Polynesian region between AD 900 and 1100 testifies to the remarkable long-distance voyaging and navigational skills achieved by these seafarers. In this regard, it is sobering to contemplate how anthropologists have gone full-circle in their views regarding Polynesian voyaging, from Te Rangi Hiroa's (1938b:12) *Vikings of the Sunrise*, in which he regarded the Polynesians as the "supreme navigators

of history," to the 1950s stance that Polynesians had arrived in their island homes not by purposeful voyaging but simply by the accumulation of random "drift" voyages (Sharp 1956), and in recent times back to a recognition that the early Polynesians were indeed capable of astounding long-distance way-finding, even to the coast of South America (Finney 1996). The discovery of carbonized sweet potato tuber fragments in Tangatatau Rockshelter contributed one bit of evidence confirming these remarkable voyages.

The archaeological record from Tangatatau likewise helps attest to the network of long-distance contacts maintained by these early Eastern Polynesian communities, for at least two to three centuries following the initial colonization of the region. Far from becoming rapidly isolated, the early Mangaiaans remained part of an extensive central Eastern Polynesian exchange network, evidenced both by their continued importation of valuable pearl shell—essential for fishhook manufacture—and by the record of imported adzes from both the Austral and Marquesan archipelagoes. The empirical evidence for this early Eastern Polynesian exchange network has gradually emerged, primarily due to advances in the geochemical sourcing of basalt adzes (Allen 1996b; Rolett 1998; Rolett et al. 2015; Walter 1998; Weisler 1993, 1998).

The fact that the fledgling societies emplaced throughout the islands of central Eastern Polynesia in the first few centuries of the second millennium AD maintained contact with each other goes a long way toward explaining why the Eastern Polynesian cultures share a considerable number of innovations in common. As Burrows (1939:88–90) long ago recognized, several dozen traits, ranging from the use of stone food pounders, the watermarking of barkcloth, and tanged stone adzes in the realm of material culture, to simplification of kinship terminology (the true "Hawaiian" classificatory system), to naming of the nights of the moon, all mark Eastern Polynesian cultures as distinct from those in the Western Polynesian homeland. For these innovations to be widely shared, as they are, required some period when they were spread and adopted by the ancestral Eastern Polynesians. Clearly, this was the time period between roughly AD 1000 and 1400 when there were continued long-distance voyages and contacts between the Eastern Polynesian archipelagoes, even those as distant as Hawai'i and Aotearoa.

If I may be permitted a further speculation regarding this early period in the history of Eastern Polynesia,

it is to pick up on a long-forgotten suggestion of Te Rangi Hiroa (1939:6) that the major gods of Eastern Polynesia—specifically Tane, Tu, and Rongo—had their origins in deified ancestors, specifically “navigating ancestors who guided their voyaging ships” to the islands of the central eastern Pacific. These three gods are uniquely shared among the cultures of Eastern Polynesia. Given the Polynesian practice of deifying ancestors, it is entirely plausible that these gods were indeed originally master way-finders responsible for discovering the islands where their descendants later worshipped them. And in the same way, such famed culture heroes as Tahaki and Rata, likewise noted in Polynesian myth for their voyaging feats (Luomala

1955), may also have once been famed voyagers who traveled among the archipelagoes of Eastern Polynesia.

It is in some measure gratifying to know that the mundane fragments of pearl shell and basalt adzes recovered from the ashy layers of Tangatatau Rockshelter and other Eastern Polynesian sites have helped to bring us to this new understanding of the region’s early history. Te Rangi Hiroa himself held archaeology in low esteem; he thought it a “dry subject” with little potential to contribute knowledge regarding the deep past of his Polynesian people (see Kirch 2000b:329, fn19). But in the end, it has been archaeology that has helped to restore Hiroa’s vision of the greatest navigators of history.

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Glossary of Mangaian Words

anu'e. A fern (*Dicranopteris linearis*) that dominates the interior hills.

aravai. An irrigation channel.

ariki i te ua i te tapora kai. Priest known as the Ruler of Food in pre-Christian Mangaia.

ariki pa tai. The Shore High Priest of pre-Christian Mangaia.

ariki pa uta. The Inland High Priest of pre-Christian Mangaia.

kairanga-nuku. A subdistrict chief.

kopu. A descent group, sometimes referred to as a “tribe.”

kuara. The sweet potato (*Ipomoea batatas*).

makatea. The zone of upraised coral reef limestone that forms a ring around the central volcanic cone of Mangaia Island.

mamio. Taro (*Colocasia esculenta*), the most important Mangaian food crop.

mangaia. The paramount chief or war leader of Mangaia in precontact times.

marae. Traditional (pre-Christian) temple or place of worship.

moakirikiri. The Pacific flying fox or fruit bat (*Pteropus tonganus*).

mokora'a. A wild duck (*Anas superciliosa*), which frequents swampy areas.

noni. A Polynesian introduced shrub (*Morinda citrifolia*), the fruit of which were used medicinally and as a famine food.

'orometua. A pastor of the London Missionary Society church.

pao. A wooden implement plunged into the mud of a taro planting bed in order to make a cylindrical hole for planting taro slips.

pava. Chief in charge of a district (*puna*).

pi'a atua. A lesser priest or spirit medium.

puna. The irrigated taro lands; also the term for a traditional district.

rau-tuanu'e. The degraded interior volcanic hills, dominated by the *anu'e* fern (*Dicranopteris linearis*) and scrub *Pandanus*.

rau-tuitui. Forested parts of the *makatea*, dominated by *tuitui* (candlenut, *Aleurites moluccana*) trees.

repo taro. An irrigated taro pondfield.

tapere. A traditional land unit smaller than a district.

taro pa'i. A raised bed within an irrigated taro pondfield.

tupe. A traditional Mangaian pitching game.

umu. The traditional earth oven.

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Appendix

Grid Unit, Level, and Stratigraphic Zone Concordance (Main Excavation Block, Site MAN-44)

Grid Unit	Level	Zone/Feature	Grid Unit	Level	Zone/Feature
C30	1	17	D30	5	8
C30	2	15	D30	6	7
C30	3	14	D30	7	5
C30	4	F58	D30	8	4B
C30	5	8	D30	9	4B
C30	6	7	D30	10	4A
C30	7	5	D30	11	1B
C30	8	4B	D30	12	1A
C30	9	4B	D31	1	17
C30	10	4A	D31	2	15
C30	11	1B	D31	3	8
C30	12	1A	D31	4	8
C31	1	15	D31	5	8
C31	2	8	D31	6	8
C31	3	4A	D31	7	F32
C31	4	4A	D31	8	5
C31	5	F38	D31	9	4B
C31	6	4A	D31	10	4B
C31	7	4A	D31	11	4B
C31	8	3	D31	12	4B
C31	9	3	D31	13	4B
C31	10	1B	D31	14	1B
C31	11	1A	D31	15	1A
C32	1	4A	D31	16	1A
C32	2	3	D31	17	1A
C32	3	2	D32	1	17
C32	4	1B	D32	2	15
D30	1	17	D32	3	8
D30	2	15	D32	4	8
D30	3	8	D32	5	8
D30	4	8	D32	6	8

Grid Unit	Level	Zone/Feature	Grid Unit	Level	Zone/Feature
D32	7	6	E30	12	F57
D32	8	5	E30	13	1B
D32	9	4A	E30	14	1A
D32	10	3	E30	15	1A
D32	11	2	E31	1	17
D32	12	1B	E31	2	15
D32	13	1A	E31	3	8
D32	14	1A	E31	4	8
D32	15	1A	E31	5	8
D32	16	1A	E31	6	7
D33	1	17	E31	7	F7
D33	2	15	E31	8	5
D33	3	10	E31	9	4B
D33	4	8	E31	10	F37
D33	5	8	E31	11	4B
D33	6	6	E31	12	4A
D33	7	5	E31	13	F37
D33	8	4A	E31	14	1B
D33	9	3	E32	1	17
D33	10	3	E32	2	15
D33	11	2	E32	3	8
D33	12	1B	E32	4	8
D34	1	17	E32	5	8
D34	2	15	E32	6	6
D34	3	8	E32	8	5
D34	4	6	E32	9	F37
D34	5	4A	E32	10	F37
D34	6	3	E32	11	3
D34	7	3	E32	12	2
D34	8	2	E32	13	1B
D34	9	2	E32	14	1A
D34	10	2	E33	1	17
D34	11	1B	E33	2	15
D35	1	9	E33	3	10
D35	2	9	E33	4	8
D35	3	6	E33	5	8
D35	4	3	E33	6	6
D35	5	3	E33	7	5
D35	6	3	E33	8	4A
D35	7	2	E33	9	3
E30	1	17	E33	10	3
E30	2	15	E33	11	2
E30	3	15	E33	12	1B
E30	4	15	E34	1	17
E30	5	F2	E34	2	15
E30	6	F2	E34	3	8
E30	7	8	E34	4	6
E30	8	5	E34	5	4A
E30	9	5	E34	6	3
E30	10	4A	E34	7	3
E30	11	4A	E34	8	2

Grid Unit	Level	Zone/Feature	Grid Unit	Level	Zone/Feature
E34	9	2	F36	3	6
E34	10	2	F36	4	3
E34	11	1B	F36	5	3
E35	1	17	F36	6	3
E35	2	9	F36	7	3
E35	3	9	F36	8	2
E35	4	6	F36	9	2
E35	5	3	G30	1	17
E35	6	3	G30	2	13
E35	7	3	G30	3	11
E35	8	2	G30	4	F3
E35	9	2	G30	5	5
E35	10	2	G30	6	4A
E35	11	1B	G30	7	4A
E35	12	1A	G30	8	4A
E36	1	17	G30	9	4A
E36	2	9	G30	10	1B
E36	3	6	G35	1	17
E36	4	3	G35	2	9
E36	5	3	G35	3	9
E36	6	3	G35	4	F15
E36	7	3	G35	5	F15
E36	8	2	G35	6	3
E36	9	2	G35	7	3
F30	1	17	G35	8	2
F30	2	15	G35	9	1B
F30	3	13	H30	1	F1
F30	4	11	H30	2	19
F30	5	8	H30	3	19
F30	6	8	H30	4	19
F30	7	5	H30	5	18
F30	8	F4	H30	6	18
F30	9	F5	H30	7	18
F30	10	F5	H30	8	1B
F30	11	4A	I30	1	17
F30	12	4A	I30	2	19
F30	13	1B	I30	3	19
F35	1	17	I30	4	19
F35	2	9	I30	5	19
F35	3	9	I30	6	18
F35	4	6	I30	7	18
F35	5	6	I30	8	18
F35	6	F21	I30	9	1B
F35	7	3	J30	1	17
F35	8	3	J30	2	19
F35	9	3	J30	3	19
F35	10	2	J30	4	F20
F35	11	2	J30	5	18
F35	12	1B	J30	6	18
F36	1	17	J30	7	F22
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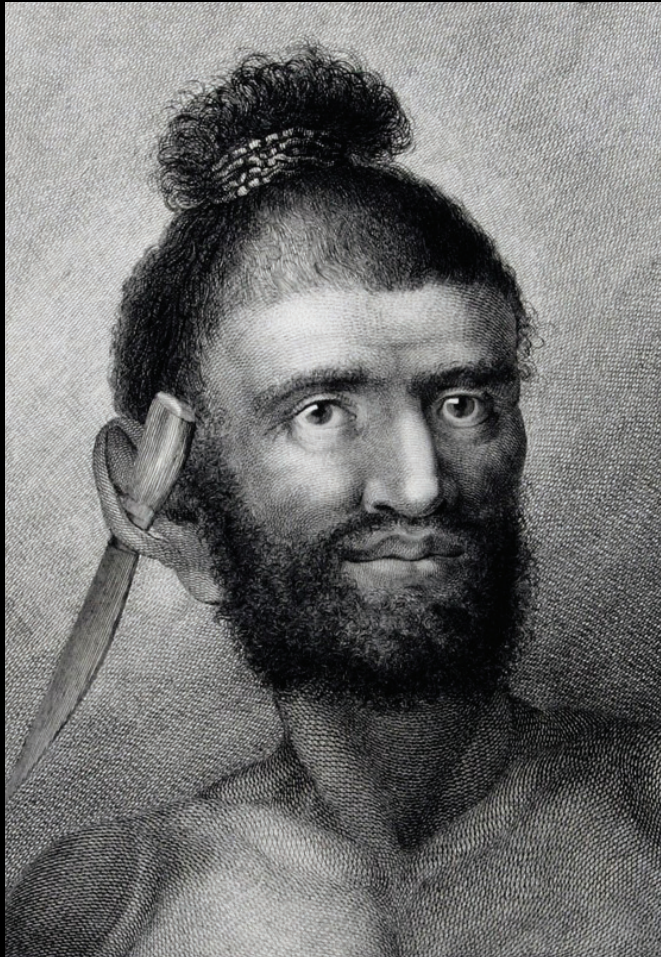
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Tangatatau Rockshelter

The Evolution of an Eastern Polynesian Socio-Ecosystem



Tangatatau Rockshelter on Mangaia Island (Southern Cook Islands), excavated by a multi-disciplinary team in 1989–1991, produced one of the richest stratigraphic sequences of artifacts, faunal assemblages, and archaeobotanical materials in Eastern Polynesia. More than 70 radiocarbon dates provide a tight chronology from AD 1000 to European contact circa 1800. The faunal assemblage provides compelling evidence for dramatic reductions in indigenous bird life following Polynesian colonization, one of the best documented cases for human-induced impacts on island biota.

Tangatatau is unique among Polynesian archaeological sites in the extent to which fishing was dominated by freshwater fishes and eels. The site also yielded an extensive suite of carbonized plant materials, including sweet potato tubers, demonstrating that this South American domesticate had reached Eastern Polynesia by AD 1400. Mangaia illustrates the often far-reaching consequences of human land use and resource exploitation on small and vulnerable islands.

A remarkable fusion of dirt archaeology and lab science focused on a tropical island at the gateway to Eastern Polynesia. Ancient Polynesia comes alive in *Tangatatau*.

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