

Colonisation and Late Period Faunal Assemblages from Ofu Island, American Samoa

Marshall I. Weisler,¹ Ariana B.J. Lambrides,¹ Seth Quintus,² Jeffrey Clark³ & Trevor H. Worthy⁴

¹ School of Social Science, University of Queensland, St Lucia, QLD 4072, Australia

² Department of Anthropology, University of Hawai‘i at Mānoa, Honolulu, Hawai‘i 96822, USA

³ Department of Sociology and Anthropology, North Dakota State University, Fargo, North Dakota 58108, USA

⁴ School of Biological Sciences, Flinders University, GPO 2100, Adelaide 5001, SA, Australia

Corresponding author. m.weisler@uq.edu.au

Abstract: The identification and analysis of 1583 bones from colonisation (~2700 cal BP) to late period (post-800 cal BP) cultural layers from archaeological site AS-13–41 on Ofu Island, American Samoa are reported. The assemblage is dominated by fish (~91 per cent; NISP = 1435, MNI = 162) with bones of human, Green Sea Turtle, sea birds (shearwaters and petrels) and a terrestrial bird (Buff-Banded Rail), as well as the commensals Pacific Rat, chicken (Red Junglefowl) and pig. We report here the first prehistoric records of Pacific Flying Fox (*Pteropus tonganus*) and the endemic Tooth-Billed Pigeon (Manumea, *Didunculus strigirostris*) from colonisation layers and two pelagic fish species only recorded from late pre-historic deposits: Mahi-mahi (*Coryphaena hippurus*) and flying fish (Exocoetidae). These and numerous genus-level fish identifications of surgeonfish (Acanthuridae), squirrelfish and soldierfish (Holocentridae), snapper (Lutjanidae) and parrotfish (Scaridae) are additional new fish records for Samoan prehistory reflecting the breadth of the fish reference collection as well as the practice of using all fish bones for identification; ~37 per cent of bones were assigned to family. Colonisation period deposits are characterised by greater quantities of fish, turtle and bird bones, declining towards later prehistory signalling the likely effects of human predation and an increasing emphasis towards agricultural production.

Keywords: Samoa, faunal analysis, *Pteropus tonganus*, *Didunculus strigirostris*, *Katsuwonus pelamis*, ubiquity analysis

Introduction

It is only during the past few decades that there was wide-spread recognition that island landscapes, habitats, flora and fauna have undergone centuries to millennia of human-caused disturbance following colonisation (Fosberg 1963a; Kirch 1982; Olson & James 1984). These modifications have included deforestation, habitat degradation, the introduction of new plants and animals that competed with endemic species, and over-hunting, all contributing to faunal depletion and extinctions (Green & Weisler 2004; Lepofsky et al. 1996; Whistler 1991; Worthy 1999). For example, it is now common to identify the bones of extinct species of birds, or at least new records, from cultural layers dating from the colonisation and early settlement periods of most archaeological sites (e.g., Steadman 1989; Worthy et al. 2015). Remains of fish are invariably the most common bones in Pacific archaeological sites and a wealth of information on prehistoric diet and subsistence, capture strategies and sustainability of marine resources are common research themes (recently reviewed in Lambrides & Weisler 2016). Here, we report on an archaeofaunal assemblage from site AS-13–41, Ofu Island, Manu‘a Group, American Samoa that represents ~2700 years of occupation. Predictably, the assemblage contains primarily fish bones, but smaller amounts of mammal (rat, human, pig and flying fox), bird and sea turtle were also recovered, allowing examination of the effects of human founding groups on a small, volcanic island. Comparisons with regional patterns of faunal exploitation, in the context of a now fairly well-documented cultural sequence for Ofu Island (Clark et al. 2016), provide insights on the human-animal-environment interactions in West Polynesia over nearly three millennia.

Socioecological Context

Ofu is part of the Manu‘a Group of the Samoan Archipelago along with Ta‘u and Olosega. The Manu‘a Group forms the eastern extent of the main Samoan Archipelago and is located 110 km east of Tutuila and Anu‘u, the other islands of American Samoa. All islands of Manu‘a are in close proximity; Ofu (7.3 km²) and Olosega (5 km²) are separated by a 100 m wide channel and Ta‘u (45 km²) is located roughly 10 km to the southeast (Figure 1).

Ofu Island was formed between 250 and 400 kya (McDougall 2010) and continues to feature high topographic relief with relatively limited incision where streams run intermittently after heavy rainfalls. The highest elevation, Tumu Peak, rises 495 m above sea level and is the convergence point of the two major ridges that form the backbone of the island. Much of the interior vegetation is anthropogenic and includes economic tree crops (e.g., *Cocos nucifera*)

and secondary vegetation (e.g., *Hibiscus* sp.) (Liu et al. 2011), reflecting past land use practices (Quintus 2015).

The modern population lives along the coastal flats that are widest on the southern and western coasts. The coast consists primarily of calcareous sand, though a mixture of terrigenous and calcareous sediments are present in the back beach. A fringing reef surrounds the entire island (Craig et al. 2001) but is widest on the western and southern coasts. It is well documented that the inland portions of these coastal flats were buried by colluvium when shorelines prograded (Kirch 1993a; Quintus et al. 2015), likely the result of sea-level fluctuation and local tectonic activity during the past two millennia.

The reef ecosystem supports a diverse coral assemblage (Craig et al. 2001). On the south coast, a reef crest protects a 2.5 m deep lagoon. The Ofu reef supports 90 species of coral with a 6–30 per cent coral cover (Hunter et al. 1993: 8). Reefs in American Samoa support more than 930 fish species (Craig 2009: 38), while limited surveys on Ofu have reported 288 species representing 47 families, most of which inhabit the shallow back reef and lagoon (Hunter et al. 1993: 22).

The island was colonised ~2700 years ago and forms the eastern extent of first millennium BC migrations in Oceania (Clark et al. 2016). Not surprisingly, the south and west coasts have the earliest occupations, at Ofu Village, To‘aga and Va‘oto Plain (Figure 1; Clark et al. 2016). Settlement was largely coastal from ~2700 to 1000 cal BP, and while prior use of the interior of the island cannot be ruled out, permanent habitation there does not occur until cal AD 1000, as evidenced by the construction of terraces and ditches (Quintus et al. 2015). The commensal animals chicken, dog, pig and rat were present during the prehistoric period and several species of flying fox have been recorded from modern surveys (Helgen et al. 2009: 83). Whether the commensals arrived at the same time with the initial colonists has been open to debate (Addison and Matisoo-Smith 2010).

The Ofu Village Site

The data reported here were obtained from archaeological site AS-13–41, at Ofu Village situated along the western coastal flat that is 200–250 m wide, with the adjacent fringing reef extending 600 m at its maximum (Figure 2). Archaeological excavations were undertaken across 9 ha with 16 m² excavated in four controlled excavation units and three backhoe trenches. The fauna discussed here came from two controlled excavation units, XU-3 and XU-4, located near the centre of the village and about 50 m apart (Figure 3).

XU-3 is ~125 m from the shoreline (Figure 3) and 12 stratigraphic layers were defined during excavation (Figure 4). Prehistoric artefacts were recovered from Layers X, XI and XII. The lowest layer, XII, is the sterile beach onto which prehistoric cultural deposits accumulated (Quintus 2015: 122). Layers X and XI contain more terrigenous sediments relative to Layer XII, a pattern that continues into Layer IX. No prehistoric or historic artefacts were identified in Layer IX. All prehistoric artefacts recovered from the unit were basalt flakes ($n = 27$). A single radiocarbon date from the base of Layer XI (Beta-372699, 2σ cal AD 1261–1387) dates the beginning of land use in the area. This late date, along with geoarchaeological evidence, suggests that the area was not used until a stable land surface formed from coastal progradation about 1000 cal BP.

XU-4 was the most inland unit excavated in Ofu Village and seven stratigraphic layers were documented (Figure 5). Prehistoric artefacts and faunal remains were recovered from Layers IV through VII. Layer VII represents a sterile beach surface on which initial human occupation began. All cultural materials within the sterile beach layer were found near the top. Terrigenous sediments increase towards Layer IV. The artefact assemblage was more diverse relative to XU-3 and artefacts from Layer VI were similar to assemblages documented in early deposits at To‘aga (Kirch 1993b). Ceramic sherds, basalt flakes, formal basalt tools, shell beads and Turbo sp. shell fishhooks were documented. The fishhooks were rotating forms less than 20 mm in length. Two charcoal samples of coconut endocarp were accelerator mass spectrometer (AMS) dated from Layer VI in sublayer VIc. While they were 70 cm apart in depth, the dates are statistically indistinguishable, suggesting fairly rapid sediment aggradation from ~2700 to 2500 cal BP (Beta-354137 and Beta-383081, 2σ 2781–2511 cal BP). A date from XU-2, approximately 25 m inland from XU-3 (Figure 3), at the interface between Layers V and sub-layer VIa, provides a date for the same stratigraphic position in XU-4 at cal AD 895–1021 (Beta-380263). Another determination, on a carbonised tree root from Layer IV, dated to about cal AD 1400 or later (Beta-372700).

Methods

Field Methods

All stratigraphic layers were defined by texture and Munsell colour. Sublayer designations were based on subtle changes in sediment compaction and matrix texture. Vertical control was maintained by excavation of 10 cm arbitrary levels within larger stratigraphic layers. The uppermost historic layers consisted predominately of compact clay which was excavated with

pick and shovel. Twenty-five per cent of these sediments were dry-screened through 1/4" (6.4 mm) mesh. After prehistoric artefacts were encountered in lower layers, trowels were used for controlled excavation and all sediment was dry-screened through 1/4" mesh. Features were screened separately and water-sieved through 1/16" (1.6 mm) mesh. All bone was bagged separately from artefacts and shell. No further sorting of bone was undertaken in the field.

Lab Methods

Bones were first sorted into the classes of rat, pig/human/unidentified vertebrate, turtle, fish and bird before identification to more specific taxonomic levels. Mammal bones were identified and compared to reference specimens including the Pacific Rat (*Rattus exulans*), pig (*Sus scrofa*), dog (*Canis familiaris*) and human. Turtle elements were compared to a juvenile Green Sea Turtle (*Chelonia mydas*) specimen. Fish were identified using the reference collection at the University of Queensland, which contains 45 families, 94 genera and 169 species. We were able to make several genus-level identifications of the archaeological fish bones because the reference collection has most genera from common families such as the surgeonfish (Acanthuridae; the reference collection has 4 out of 5 genera), parrotfish (Scaridae; 5 of 6 genera), soldierfish and squirrelfish (Holocentridae; 3 of 5 genera), snapper (Lutjanidae; 5 of 7 genera) and tuna (Scombridae; 6 of 7 genera). In the case of the jacks (Carangidae; 7 of 14 genera) and groupers (Serranidae; 5 of 16 genera), we only assigned identifications to genus-level if the archaeological specimen matched all defining attributes, and in these cases we prefaced the attribution with 'cf'; that is, compares favourably. We considered all fish bones for identification and recorded those we could assign to element but not to a more specific taxon other than fish (Weisler 2001: 144); this provides an indication of the quality of the fish bone reference collection we used. Individual fish bones were examined for weathering (e.g., root etching) and evidence of dissolution. The completeness of recovered fish bone was broadly assessed using a fragmentation index. Each bone identified to taxon and/or element was assigned to one of four categories – 0 to 25 per cent, >25 to 50 per cent, >50 to 75 per cent and >75 to 100 per cent. Bird bones, and the one mammalian bone positively identified as Pacific Flying Fox (*Pteropus tonganus*), were compared to photos or actual specimens. A taphonomic study of the bird bone was completed using established protocols outlined in Weisler (2001: 104-7). Each element was examined for the presence of burning and resulting colour, cut marks, spiral or straight fractures, rat gnawing and midden staining. Obvious breaks that occurred during excavation were noted but not considered further in the taphonomic analysis. We provide photographs of selected bird and turtle bones to document species identification,

to illustrate the general preservation of the bones and to show the range of fracture patterns. All bone measurements were taken with digital callipers and rounded to one decimal place. Quantification of bone elements was made by the number of identified specimens (NISP), minimum number of individuals (MNI) and weight. While previous Samoan faunal studies report at least NISP (e.g., Nagaoka 1993), we used all three quantification measures to make our data comparable across all Samoan assemblages and to facilitate broader regional comparisons.

Results

Vertebrate not identified further

This class includes primarily small fragmented mammal bones (likely pig and human) with lesser amounts of rat or possibly bird (shaft fragments), but no turtle. The 45 bones totalled 22.1 g with an average weight of 0.5 ± 1.9 g (Table 1). Some 26.7 per cent of all specimens were long bone fragments. One bone was burnt. Only 6 per cent of vertebrate fragments were from XU-3.

Mammals

Human

Two adult human bones were positively identified: a proximal phalange from the left foot and a proximal femur fragment. Both bones were recovered from XU-4, Layer IV and are clearly from redeposited contexts consistent with the interpretation of this layer (Quintus 2015: 128). Human remains from an apparent burial were also encountered at the base of the excavation, but those were left in place and therefore not included in this discussion. No human remains were reported from the To‘aga excavations (Nagaoka 1993), although they have been found at other sites on the island (unpublished data).

Pig

A greater reliance on gardening and terrestrial production in late prehistory is often indicated for island sequences, in part, by an increase in pig bone (Kirch & Yen 1982: 310). Three rib fragments were recovered from XU-4, Layer IV dated to cal AD 1400s (Quintus 2015: 128) and probably represent at least one adult and one juvenile due to the large size range. Only one pig tooth (unspecified) was recovered from the much larger excavations at To‘aga and no associated dates were reported (Nagaoka 1993: 196). From late prehistoric contexts (cal AD

1200s), 57 unspecified bones were recovered from only 3 m² of excavation at the Si'utu coastal midden on Savai'i while at least 11 of these bones are from the upper, likely historic layers (Ishimura & Inoue 2006: 45, Table 2).

Rat

Twenty bones of Pacific Rat (*Rattus cf. exulans*) weighing 1.46 g were recovered from all layers of the excavations (Table 1). We assigned these bones to *Rattus cf. exulans* due to the small size of the bones (two adult whole femora had maximum lengths of 22.5 and 25.0 mm) and by comparison with a *R. exulans* reference skeleton. Elements included: nine femora, five tibia, three innominates, two canines and one humerus. Eleven of these elements were whole and only one bone, a right femur, was burnt on the distal end. An equal number of adult (with fused epiphyses) and juvenile (missing epiphyses) individuals were represented.

Pacific Flying Fox

In Samoa, populations of flying fox (*Pteropus* spp.) have declined by 80 to 90 per cent in the past decade or so due to cyclones, land clearance and hunting (Mickleburgh et al. 2009). Buck mentions that the flying fox was occasionally captured using bow and arrow, but primarily by netting (1930: 532, 542). The first identified Pacific Flying Fox (*Pteropus tonganus*) bone from prehistoric contexts in Samoa was a left mandible (Figure 6: d and e) from XU-3, Layer XI dated to cal AD 1261–1387 (Beta-372699, Quintus 2015: 121). Since flying fox was not identified from paleontological deposits from a cave on Tutuila (Steadman & Pregill 2004), the flying fox could have been a human introduction to Samoa as it perhaps was on Rurutu (Weisler et al. 2006) and possibly Tubuai (Worthy & Bollt 2011), both in the Austral Islands. A humerus recovered from Ofu Village in Layer VI of XU-4 – the oldest cultural layer dating to the colonisation phase – has an odd fossa at the proximal end indicative of this taxon. Samoa formerly had four sympatric species of *Pteropus* (Helgen et al. 2009: 83) and the small size and lack of conclusive defining features of the Layer VI bone would require DNA analysis to determine the species.

Fish

There are only five archaeological studies in Samoa that report a substantial amount of fish bone (Figure 1), and these include a 9.5 hectare village along the Faga coastal flat on Ta'u (also in Manu'a), where test trenches and shovel testing documented the earliest layers to 1200 BP. No ceramics, bird, pig or dog bones were recovered, but fish remains were plentiful (Cleghorn

& Shapiro 2000: 82, 87). At To‘aga, along the southeast-facing shoreline of Ofu, a large coastal habitation, occupied continuously since about 2700 cal BP, contained abundant fauna exhibiting few changes in composition throughout the temporal sequence (Nagaoka 1993: 207). Two additional sites, with good bone preservation, are known from Tutuila. On a narrow shelf on the south coast near the centre of the island is a one hectare habitation, Fata-ma-futi. Dating to about 1600 BP, Morrison & Addison (2009) analysed abundant fish remains from 4 m² of excavation. Rieth & Cochrane (2012) described the faunal assemblage (predominantly fish) from a coastal site at Tula Village, south of Fagasa Point, that contained Polynesian Plainware dated to 2200 BP. On the southwest coast of Savai‘i at Si‘utu excavations into a small (~500 m²) late prehistoric sandy midden produced a diverse, well-preserved faunal assemblage consisting primarily of fish.

Precise comparisons between these five faunal assemblages and the current study are hindered because: (1) 1/4" (6.4 mm) or 1/8" (3.2 mm) screen sizes, used dry or with water, were used to sieve cultural deposits; (2) quantification was only by NISP, or both NISP and MNI, or just weights; (3) only Morrison and Addison (2009: 181–82) explicitly stated which fish elements were used for taxonomic identification; and (4) the use of reference collections with differing amounts of species constrains identifications. Differential bone preservation (Nagaoka 1993: 210) and the analyst’s skill are also issues to contend with when making regional comparisons. Numerous studies have demonstrated that screen size affects fish bone recovery with a bias towards large bodied taxa when only 6.4 mm sieves are used (Nagaoka 2005). Identification bias has also been shown only when the 5-paired cranial elements (premaxilla, maxilla, dentary, articular and quadrate) and ‘special’ bones unique to a family (such as dorsal, anal or dermal spines, scutes, caudal tangs and hypurals) are used for identification. This suite of elements was compared to an expanded set of paired cranial elements and also to all vertebrae, which demonstrated that as more elements are added, so too are taxonomic identifications (Lambrides & Weisler 2015a, b).

Considering the potential and documented biases when making regional comparisons of fish bone studies, we decided to use ‘ubiquity’ to measure the frequency of occurrence of individual taxa across all assemblages. Ubiquity measures the presence or absence of a taxon and for the Samoan assemblages we calculated the ubiquity of 28 fish families, one subclass (Elasmobranchii) and one super order (Batoidea) identified for all previous studies. A taxon can be considered ubiquitous if it is present in the majority of assemblages. As different fish families have varying amounts of identifiable elements – ranging from a high number with

Diodontidae and Scaridae to a lower occurrence with Scombridae – ubiquity is not subject to problems of over-representation of a taxon. Additionally, the aggregation effects of MNI or the interdependence problems with NISP are not issues (Grayson 1984). Table 2 lists the ubiquity of these taxa with nine reported for all Samoan assemblages: Acanthuridae (surgeonfish), Balistidae (triggerfish), Diodontidae (Porcupinefish), Elasmobranchii (sharks and rays), Holocentridae (squirrelfish, soldierfish), Lethrinidae (emperor, bream), Scaridae (parrotfish), Scombridae (mackerel, tuna, bonito) and Serranidae (groupers, sea bass). With the exception of Scombridae and Serranidae, these taxa were amongst the most ubiquitous taxa identified in 16 studies of archaeological fish bone assemblages representing all island classes from across the Pacific (Weisler & Green 2013: 84).

While ubiquity is useful for determining the number of taxa (richness) identified across assemblages, it does not inform on the relative abundance of individual taxa. Table 3 lists the rank-order of the seven most frequently identified fish families calculated by NISP. Diodontidae was not considered here as individual fish have more than 200 dermal spines that preserve well and are readily identified to family, thus NISP values are greatly inflated relative to other families. Likewise, shark and ray (Elasmobranchii or the group Selachii) vertebrae were not considered as these elements can number greater than 50 per individual and are readily identifiable by even a novice analyst. Only four families contribute the majority of bones to each assemblage, ranging from 38.4 to 73.4 per cent. The two highest families for most site assemblages are Acanthuridae and Scaridae, but top families also include Holocentridae, Labridae, Lethrinidae and Serranidae – all typically inshore taxa, especially if individuals are small to medium size. Scombridae was reported as identified from the Si‘utu site (Savai‘i Island), but no genus or species was listed in the table of identifications presented by trench and layer (Ishimura & Inoue 2006: Table 2), although *Katsuwonus pelamis* (Skipjack tuna) was listed in the list of taxa identified at the site (Ishimura & Inoue 2006: Table 1). This confused data presentation makes it impossible to determine the scombrid taxa identified and associated dates. When identifying fish bones using only the five-paired cranial bones and ‘special’ elements, these families are amongst the easiest to identify as they have distinctive mouth parts that generally preserve well; this is not the case for Acanthuridae (which generally have smaller fragile mouth parts), but members of the family have readily identifiable dorsal spines and caudal tangs. In Table 4 we also present the rank-order abundance of families from our study using all possible elements for identification contrasted with the five-paired cranial elements and specials. Both datasets are similar when determining the top families present in an

assemblage. However, only using the five-paired cranial elements and ‘specials’ captured less than 50 per cent of Acanthuridae, Carangidae, Cirrhitidae, Holocentridae, Scombridae and Serranidae and did not identify Bothidae, Coryphaenidae and Mugilidae in contrast to using all elements for identification (Table 4). As further detailed below, species richness increased substantially and new families and genera were added to the inventory for Samoa.

Considerations of data quality are integral when implementing faunal identification procedures and this ensures replicability by individual researchers and consistency across regional syntheses (Driver 1992; Lambrides & Weisler 2016; Wolverton 2013). As mentioned above, we considered all fish bones for identification, implemented strict guidelines for assigning genus-level identifications based on the completeness of the reference collection, and those bones that could be assigned to element but not family were recorded (NISP = 26: 31 per cent five-paired cranial bones and ‘specials’, 46 per cent expanded cranial elements and 23 per cent vertebrae).

A total of 1435 fish bones, weighing 307.9 g were recovered from the prehistoric levels of the Ofu Village site in XU-3 (n = 169) and XU-4 (n = 1266). A high portion – 37.1 per cent overall – of the archaeological fish bone assemblage was identified to taxon (mostly family and genus level identifications). Of the 533 fish bones identified to taxon and 26 to element only, 9.7 per cent had evidence of root etchings and 1.8 per cent were burnt. Less than one per cent of bones were affected by digestive processes; all noted cases were vertebrae and described as deformed after Butler and Schroeder (1998: 960). In general, bone completeness was high with 81.7 per cent of elements >50 per cent complete. Bone appeared to have a similar state of preservation throughout the sequence despite the increasing amount of terrigenous (perhaps more acidic) sediments in the later prehistoric deposits.

Overall, the assemblage is dominated by small-bodied inshore taxa, with Acanthuridae, Scaridae and Holocentridae accounting for 52.5 per cent of total MNI (Table 5). The marine environment adjacent to Ofu Village site is dominated by coral communities, encrusting coralline algae and other hard bottom substrates (Crossett et al. 2008). Acanthurids, scarids and holocentrids are found around most coral reef zones, from open pavement areas of shallow reef flats, shallow lagoon reefs and exposed outer seaward reef slopes, with some species inhabiting steep drop-offs and channels; these habitats are ideal for feeding on benthic encrusting algae or benthic invertebrates and small fish in the case of holocentrids (Froese & Pauly 2014).

When characterising change over time at the site, particularly between the early (~2700–1500 cal BP) and late (post-800 cal BP) assemblages, it is possible that there was a less intensive exploitation of the marine fishery in later prehistory (MNI: 106 vs. 46). While consistent with evidence of agricultural expansion (Quintus 2015), this trend is difficult to explore given the limited sample size and sole use of 6.4 mm screens. Acanthurids, holocentrids and scarids remained economically important throughout the prehistoric occupation of Ofu Village, but in later prehistory (post-800 cal BP) scombrids and serranids are within the top three ranked taxa (post-800 BP top ranked taxa: 1. Acanthuridae, 2. Scaridae and Scombridae, and 3. Holocentridae and Serranidae). The fish feeding behaviour data, useful here for inferring variations in patch choice and capture strategies over time, further supports this trend. The early assemblage is dominated by herbivorous taxa and, while there is a more even distribution of feeding behaviours in later prehistory, there is a higher proportion of piscivorous taxa – relative to herbivorous taxa – being exploited (e.g., scombrids, serranids, shark, etc; Figure 7). The distribution of omnivores/benthic carnivores remains relatively stable overtime. These trends may relate to changes in site use over time (Quintus 2015: 164–66), but a Spearman's correlation coefficient (r_s) was calculated to determine whether sample size was correlated with NTAXA through Layers IV to XI, and thus potentially influencing patterning in the data. As sample size was correlated with NTAXA ($r_s = 0.97$, $p = 0.03$) it is important to be mindful of the potential bias of sample size effects when interpreting the fish feeding behaviour data.

Despite the focused exploitation of the inshore fishery during prehistory, there is some evidence of offshore pelagic fishing. Here we document the first identification of, Mahi-mahi (*Coryphaena hippurus*) and flying fish (Exocoetidae) in the prehistoric archaeological record of the archipelago. Ishimura & Inoue also identified Mahi-mahi from the Si'utu coastal midden, but the context was considered 'likely to belong to recent time' (2006:45). We also identified an MNI of three Skipjack tuna (*Katsuwonus pelamis*) from the late prehistoric deposits (post-800 cal BP). Also dating from ~800 cal BP, Ishimura and Inoue (2006: Table 2) listed a NISP of 40 scombrids from Si'utu, which may represent an MNI of at least nine inferred from the distribution of bones across two trenches and nine stratigraphic layers. Unfortunately, they did not report the elements used for identification. While genus and species level identifications were not provided, Ono and Addison (2013) reported that Scombridae (MNI = 74) was ranked third after scarids and acanthurids across eight excavated units dating between 600–200 cal BP on Atafu Atoll, Tokelau (~700 km northwest). Two large Mahi-mahi were recovered from the earliest prehistoric deposits at our study site. For comparability, height (M1), width (M2) and

length (M3) of a caudal vertebra from each individual (#1 and #2) was measured using digital callipers after Lambrides and Weisler (2015b). Measurements are as follows, #1: M1 (22.3 mm), M2 (22.8 mm) and M3 (29.8 mm) and #2: M1 (18.4 mm), M2 (19.5 mm) and M3 (24.1 mm). When compared to the single Mahi-mahi reference specimen (1.3 m TL or total length) held in the comparative collection, average caudal vertebrae size (M1: 12.6 mm, M2: 12.8 mm and M3: 17.2 mm) is approximately 1.4 to 1.8 x larger than the reference specimen; this may suggest that the archaeological vertebrae represents individual fish up to about 2 m TL (maximum recorded size). Flying fish are often captured at night using dip nets and torches (Gillett & Ianelli 1993; Ono & Addison 2013) and interestingly, flying fish have also been reported in the literature as ideal bait for capturing Mahi-mahi (Osamu 2013).

Turtle

The Green Sea Turtle (*Chelonia mydas*) previously nested in 'fairly large numbers' in American Samoa during August and September (Hirth 1971:2: 6), and the sandy beach at Ofu was probably an ideal zone for such behaviour. Along the sandy east-facing shoreline of To'aga at site AS-13-1, only 56 turtle bones were recovered from ~30 m² of excavation – mostly from layer IIIB in unit 20 dated to 2900–2400 BP (Nagaoka 1993: 195) and roughly contemporaneous with XU-4 Layer VI at Ofu. The density of turtle bones at To'aga is far lower than from 4 m² excavated at Ofu. The oldest securely dated coastal habitation site on Tutuila, at 2400–2200 BP, has 40 turtle bones in one of the deepest layers and none in later deposits (Rieth & Cochrane 2012: 321, Table 55). At the late prehistoric Si'utu site, four unspecified turtle bones were inventoried from the bottom half of the cultural deposits in a 3 m² excavation (Ishimura & Inoue 2006: Table 2). At our study site, 26 of the 27 turtle (cf. *Chelonia mydas*) bone fragments from secure contexts were recovered from XU-4, Layer VI and suggests that, at these three sites, turtle was far more numerous in the early deposits than at any time afterwards pointing towards depletion of the resource during the earliest periods of human use for each specific settlement area. At Ofu site AS-13-41, Layer VI, 30 fragments (including three from the spoil dirt pile assigned to Layer VI in XU-4) weighed 65.9 g (mean 2.2 ± 2.3 g) representing a minimum number of three adult and juvenile individuals. All but two bones were fragments of typically flat plastron elements (mean size 4.8 cm²), with one scapula (42.6 mm long) and one phalange of a left front flipper. One plastron fragment was burnt and four others have ground edges. Naturally rectangular in plan, the plastron elements were ground along both parallel margins with one end bevelled or pointed. These were often hafted for use as digging tools in the Tuamotus (Chazine 1982: 297–303, 332–36; Emory 1975: 36, 38), and probably

Mangareva (Weisler 2004: 74, Figure 10), in association with horticultural pits or gardening areas. From the Vaito'otia site, Huahine, Society islands, Sinoto suggested in a museum display label that other turtle bone tools, with an asymmetrical bevel on one long end, were used as pandanus scrapers. Ranging in maximum length from 35.41–48.30 mm, the Ofu specimens are some of the first such artefacts reported for Samoa (Figure 8).

Bird

The spatial and temporal dimensions of bird bones in archaeological sites has been instrumental in gauging human impacts to pristine Pacific landscapes as there are now many records documenting species reductions after human colonisation of islands (Steadman 2006) linked to hunting and habitat destruction (Duncan et al. 2013). Archaeologists rarely question whether, for example, fish or turtle bones were deposited by people in habitation sites, yet many seabirds (especially, shearwaters and petrels – Procellariidae, terns – Sternidae, boobies – Sulidae, and tropic birds – Phaethontidae) nest in coastal locations, either burrowing in open sandy areas (Pratt et al. 1987) or nesting on cliffs, potentially introducing material to middens and rockshelters when unoccupied by people (MW, personal observations). Burrow collapse has been identified as the reason that at least some bird bones were recovered from cultural layers in rockshelters (Weisler & Gargett 1993: 90). Archaeologists need to use other evidence in addition to stratigraphic context and presence in a midden deposit to have higher confidence that bird bones recovered from archaeological sites were deposited by people (Anderson 1989: 190; Grayson 1991: 220). Species composition and element frequencies are necessary, but not sufficient, for inferring that bird bones were culturally-deposited. However, one of the most useful characteristics for determining human vs natural deposition of bird bones in archaeological sites is to examine breakage patterns. Fractures occurring when the bone is fresh or 'green' are typically jagged to spiral in form (Weisler & Gargett 1993: Figure 3) and likely the result of human butchering, whereas bones that broke when dry and chemically weathered, so removing proteins, often break straight and perpendicular to the long axis of the element.

The Ofu assemblage contained 46 bird bones (weighing 15.0 g; mean = 0.3 ± 0.4 g), 22 of which (47.8 per cent) were narrow, angular slivers resulting from butchering while the bone was fresh or green (Figure 6: k); none of these bones could be identified to a taxon other than bird. An additional 13 long bone shafts exhibited green fractures. Add to this the six jagged breaks, also formed on green bone, then 89 per cent of all bones were fractured while green suggesting human butchering. Additionally, four breaks were indeterminate and one fracture

was straight and broken while dry, presumably in a post-depositional context. There was no evidence of midden staining. Only two exhibited a dark brown colour suggestive of indirect heating such as exposure to a hearth, but not in direct contact with a flame. Some 37 (80.4 per cent) of all bones exhibited root etching and four were rat gnawed. An unidentified bird long bone mid shaft had a cut mark perpendicular to the long axis (Figure 6: g). When viewed in cross-section, the asymmetrical groove was likely made from a basalt flake.

Table 1 lists the bird bones identified from three cultural layers in excavation units XU-3 and 4. The number of identified specimens (NISP) was 46 and the minimum number of individuals (MNI) totalled nine. This latter number included three unidentified birds, two Red Junglefowl, one shearwater, one petrel, one Buff-Banded Rail and one Tooth-Billed Pigeon – all except the rail come from XU-4 Layer VI, which has been dated to 2730–2460 cal BP (Beta-354137 and -383081; Clark et al.2016: Table 1).

The Red Junglefowl (chicken), a human introduction, is represented by a left scapula, right and left tarsometatarsi (Figure 6: f, h), and a right humerus. Chicken is pre-sent in the earliest layer of the To‘aga site and continues in lesser quantities throughout the sequence (Steadman 1993: 225) and has also been identified in a primarily paleontological site on Tutuila where a juvenile femur was dated to 1505–1310 cal BP (Steadman & Pregill 2004: 617). Three chicken bones, representing at least two individuals, have also been identified in late prehistoric contexts at Si‘utu (Ishimura & Inoue 2007: Table 2).

Two seabirds were inventoried, both breed in colonies and nest in burrows where they would have been easy prey. A medium to small shearwater similar in size to *Puffinus assimilis* was represented by a completely burnt left ulna fragment with a jagged break characteristic of a green fracture (Figure 6: i). The other seabird was a petrel of gadfly petrel size (*Pterodroma* or *Pseudobulweria*), the latter genus is poorly known and today all species are critically endangered. Represented by a distal femur and left humerus, the latter exhibits classic spiral fractures at both ends (Figure 6: j). Today, all these seabirds are extirpated on Ofu (Steadman 1993: Table 14.1).

Two landbirds were identified: one left tibiotarsus fragment of a juvenile Buff-Banded Rail (*Gallirallus philippensis*) is the size of a small domestic chicken. Although ground nesting, extant populations are considered of ‘least concern’ by the International Union for Conservation of Nature. The first identification of the Tooth-Billed Pigeon (Columbidae *Didunculus strigirostris*) from a Samoan archaeological site was represented by a distal right

tibiotarsus coloured dark brown from exposure to heat and exhibiting a green facture (Figure 6: a). The tibiotarsus has the large nutrient foramen characteristic of this genus just proximal to the lateral condyle on the cranial facies (Worthy et al. 2015: 223). Known as *Manumea* and endemic to Samoa, it is the country's national bird which has been in sharp decline for decades due to human-caused habitat loss, severe cyclones destroying forest (preferred habitat) and the introduction of invasive species such as the Pacific Rat (*Rattus exulans*). Its distribution is linked to the fruit-bearing *Dysoxylum* family of trees and today it is only known from 'Upolu, Savai'i and Nu'utele (Beichle 1991: 83) with a combined population of less than 500 (Collar 2015: 192).

Discussion and Conclusions

It is now a common theme across the varied islands of Oceania that humans affected pristine insular landscapes by the direct or unintentional introduction of exotic animals, plants and even landsnails, modified ecosystems by fire and forest clearance, and altered habitats by terracing slopes and diverting streams for irrigation (Christensen and Weisler 2013; Kirch 1982; Lepofsky et al. 1996; Whistler 1991). Just considering here the fauna, even the small assemblage of 1583 bones (90.7 per cent fish) from 4 m² excavation on Ofu Island, the colonisation to late prehistoric layers evidence a varied inventory of marine and terrestrial resources exhibiting exploitation from a range of microenvironments as well as introduction of exotic species including chicken, pig and Pacific Rat – the latter of which has been implicated in the reduction or extirpation of land and sea birds throughout Polynesia and elsewhere (Steadman 2006). Human impact is further documented by the extirpation, or at least severe reduction, of the Green Sea Turtle, as all but one bone was found in the colonisation period layer – a similar temporal sequence to that on a Tutuila site (Reith and Cochrane 2012). In the Ofu example, it is likely that turtles were easily captured when females came ashore to lay their eggs in the sandy upper beach just seaward of the prehistoric village. People could also have displaced turtles from their preferred nesting locales so the depletion of turtles may have been brought about by human predation as well as human encroachment on nesting zones.

Although pig may have been introduced with the first colonists to Ofu, it does not appear in the archaeological deposits until late prehistory when pig is often associated with an increase in terrestrial food production. On small islands, however, is it sometimes absent at historic contact (Green and Weisler 2004; Kirch 2007: Table 3), and further archaeological excavations

on Ofu should address the changing frequency of pig bone in the sequence, especially in relation to expanded inland terrestrial production.

The 46 bird bones from a minimum of nine individuals included the Buff-Banded Rail and the introduced Red Junglefowl or chicken, the first identification for Samoa of the Tooth-Billed Pigeon, and shearwater and petrel seabirds – all from the colonisation period layer except the rail. Additional excavations with fine wet-sieving sediments using 3 mm mesh or smaller should greatly increase the inventory of avian taxa.

The first identified Pacific Flying Fox (*Pteropus tonganus*) bone from prehistoric contexts in Samoa was dated to cal AD 1261–1387 (Clark et al. 2016) and could have been a human introduction to Samoa as it appears to have been in the Australs (Weisler et al. 2006; Worthy & Bollt 2011). As there were four sympatric species in Samoa (Helgen et al. 2009: 83), archaeological investigations may help unravel whether one or more species were humanly introduced to the archipelago or endemic taxa developed through various evolutionary processes unique to islands.

The Ofu fish assemblage is dominated by small-bodied inshore species, with surgeonfish, parrotfish and squirrelfish/soldierfish accounting for more than half of all taxa. Members of these fish families inhabit shallow coral reefs, such as those adjacent to the Ofu Village site, where they are primarily captured with seine nets. These taxa, along with snappers, wrasses and groupers, account for most fish reported from archaeological assemblages across Samoa. In much smaller frequency, but equally ubiquitous, are triggerfish, tunas, shark and porcupinefish from typical Samoan assemblages. The fishhook assemblage from Ofu Island is the largest known from West Polynesia, with more than 50 hooks, the majority of which are small, rotating forms. We note that more than a dozen fishhooks were recovered from an early ceramic site on nearby Olosega, as well. Despite the large inventory of fishhooks, the faunal assemblage points to seine netting as the dominate capture strategy.

It is also interesting to note that the Ofu Village fish assemblage has 21 taxa from a sample of 1435 bones, while the To‘aga assemblage has only one additional taxon (Nagaoka 1993), but is 6.6 x as large. This suggests that identification protocols have improved in the last 20+ years and expanding reference collections have made it possible to identify a greater range of species. In this regard, we have reported the first identification of two pelagic species from prehistoric contexts for Samoa: Mahi-mahi and flying fish. Another pelagic species, Skipjack tuna, has been identified at Ofu Village and also the Si‘utu site (Savai‘i Island) and, similarly, was only

identified in the late prehistoric deposits (post-800 cal BP) at Ofu. Comparable trends were noted by Ono and Addison (2013) for Atafu Atoll, Tokelau where a high abundance of scombrids was noted for assemblages dating between 600–200 cal BP. This may suggest that the late prehistoric occurrence of Skipjack tuna/scombrids at Ofu and Savai'i islands as well as Atafu Atoll (~700 km apart) may be linked to changes in the regional availability of this resource, which could potentially be driven by climate variability, such as ENSO activity or sea surface temperatures; however, this model requires further testing. Scombrids are one of the top-ranked taxa in later prehistory and Skipjack tuna ('*atu*, *Katsuwonus pelamis*, NISP = 8, MNI = 3) were considered the 'chief's fish ... and there is much ceremonial connected with it'; there were prescribed ceremonial divisions of the fish with named portions assigned to specific ranking chiefs (Buck 1930: 124, Figure 73). The huge Mahi-mahi represents a maximum of two individuals and it may have been a prestigious fish; in the least, it was certainly a noteworthy catch. Nonetheless, pelagic fishing is a risky activity that was labour-intensive with uncertainty of results, and it was often associated with ritual (Buck 1930). While the early assemblage is dominated by herbivorous taxa, there is a higher proportion of piscivorous taxa – relative to herbivorous taxa – being exploited in later prehistory. Similar to what Nagaoka (1993) reported for To'aga, fish seems to contribute less to the overall diet in later prehistory, which may be related to increased terrestrial production and resource depression of the marine fishery. Bone preservation appears similar over time so taphonomic conditions do not seem to be influencing overall bone numbers. However, our sample sizes are small with a combined total of 152 individual fish.

These preliminary data offer an opportunity to evaluate changes in the human diet and subsistence practices over time through comparison with other datasets. Consistent with the rest of West Polynesia, previous researchers have argued that the original inhabitants of Ofu were largely reliant on the exploitation of wild, mostly marine resources (Kirch and Hunt 1993; Quintus 2015). The diversity and abundance of fish and other wild resources in the assemblages analysed here is consistent with this interpretation. The presence of domesticated fauna is limited to chickens based on present data, with pig appearing later and no evidence of dog from our assemblage. Only one dog bone was recovered from the Si'utu mid-den site, which the authors suggest may be from historic layers (Ishimura and Inoue 2006: 45, Table 2). Terrestrial production expanded, notably from 2000 cal BP onward (Quintus 2015). This sequence is consistent with a decrease in the diversity of fish exploited, declining evidence for sea turtle exploitation, as well as the limited presence of domesticated animals. In Figure 9, the dominant

food classes of fish, bird and turtle decline over time and pig appears only in the post-800 cal BP deposits. By cal AD 1000, limited stable isotope evidence suggests that much of the human diet was based on terrestrial plants (unpublished data in the authors' possession), which is also supported by the decline in wild foods leading up to this time. After cal AD 1000, much of the population relocated to the interior of the island (Quintus et al. 2015) but still continued to use the coastal Ofu Village site.

The diminutive but diverse faunal assemblage spanning nearly three millennia at Ofu Village has provided new insights into human-animal-environment interactions in the Samoan Archipelago. By introducing commensal animals, persistently exploiting the adjacent reef zone and modifying the terrestrial landscape, human colonists left unmistakable signatures that evidence their place in modifying island ecosystems – a topic that was just entering the conversation more than half a century ago (Fosberg 1963b).

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References

- Addison, D.J. & Matisoo-Smith, E. 2010. Rethinking Polynesian origins: A West-Polynesia Triple-I model. *Archaeology in Oceania*, 45(1): 1-12.
- Anderson, A. 1989. *Prodigious Birds, Moas and Moa-hunting in Prehistoric New Zealand*. Cambridge University Press.
- Belchle, U. 1991. Status and acoustical demarcation of pigeons of Western Samoa. *Notornis*, 38(1): 81-86.
- Buck, P.H. (Te Rangi Hiroa) 1930. *Samoan Material Culture*. Honolulu: Bernice P. Bishop Museum Bulletin 75.
- Butler, V.L. & Schroeder, R.A. 1998. Do digestive processes leave diagnostic traces on fish bones. *Journal of Archaeological Science*, 25(10): 957-71.
- Chazine, J-M. 1982. Archaeological research (preliminary). In Hatanaka, S. & Shibata, N. (eds.) *Reao Report: A Study of the Polynesian Migration to the Eastern Tuamotus*. Kanazawa, Japan: The University of Kanazawa, pp. 267-417.
- Clark, J.T., Quintus, S., Weisler, M., St Pierre, E., Nothdurft, L. & Feng, Y. 2016. Refining the chronology for west Polynesian colonization: New data from the Samoan archipelago. *Journal of Archaeological Science: Reports*, 6: 266-74.
- Christensen, C.C. & Weisler, M.I. 2013. Land snails from archaeological sites in the Marshall Islands, with remarks on prehistoric translocations in tropical Oceania. *Pacific Science*, 67(1): 81-104.
- Cleghorn, P.L. & Shapiro W. 2000. Archaeological data recovery report for the proposed Ta'u road reconstruction, at Faga and Fitiuta, Ta'u Island, Manu'a, American Samoa. Pago Pago, Tutuila, American Samoa: American Samoa Historic Preservation Office.
- Collar, N.J. 2015. Natural history and conservation biology of the tooth-billed pigeon (*Didunculus strigirostris*): a review. *Pacific Conservation Biology*, 21(3): 186-99.
- Craig, P., 2009. *Natural History Guide to American Samoa*. Pago Pago: National Park of American Samoa.
- Craig, P., Bireland, C., & Belliveau, S. 2001. High temperatures tolerated by a diverse assemblage of shallow-water corals in American Samoa. *Coral Reefs*, 20: 185-89.
- Crossett, K.M., Clement, C.G. & Rohmann, S.O. 2008. *Demographic Baseline Report of U.S. Territories and Counties Adjacent to Coral Reef Habitats*. Silver Spring, MD: NOAA, National Ocean Service, Special Projects.

- Duncan, R.P., Boyer, A.G. & Blackburn, T.M. 2013. Magnitude and variation of prehistoric bird extinctions in the Pacific. *Proceedings of the National Academy of Sciences USA*, 110(16): 6436-441.
- Driver, J.C. 1992. Identification, classification, and zooarchaeology. *Circaea*, 9: 35-47.
- Emory, K.P. 1975. *Material Culture of the Tuamotu Archipelago*. Honolulu: Department of Anthropology, Bernice P. Bishop Museum. Pacific Anthropological Records 22.
- Fosberg, F.R. 1963a. Disturbance in island ecosystems. In Gressitt, J.L. (ed.) *Pacific Basin Biogeography*. Honolulu, Hawai'i: Bishop Museum Press, pp. 557-61.
- Fosberg, F.R. (ed.) 1963b. *Man's Place in the Island Ecosystem: a Symposium*. Honolulu: Bishop Museum Press.
- Froese, R. & Pauly, D. 2014. FishBase. World Wide Web electronic publication. www.fishbase.org, version (October, 2015).
- Gillett, R. & Ianelli, J. 1993. Flying fish. In Wright, A. & Hill, L. (eds.) *Nearshore Marine Resources of the South Pacific*. Suva: Institute of Pacific Studies, Forum Fisheries Agency and International Centre for Ocean Development, pp. 177-201.
- Grayson, D.K. 1984. *Quantitative Zooarchaeology, Topics in the Analysis of Archaeological Faunas*. New York: Academic Press.
- Grayson, D.K. 1991. Late Pleistocene mammalian extinctions in North America: taxonomy, chronology, and explanations. *Journal of World Prehistory*, 5(3): 193-231.
- Green, R.C. & Weisler, M.I. 2004. Prehistoric transfer and extinction of animals in Mangareva, southeast Polynesia. *Archaeology in Oceania*, 39(1): 34-41.
- Helgen, K.M., Helgen, L.E. & Wilson, D.E. 2009. Pacific flying foxes (Mammalia: Chiroptera): two new species of *Pteropus* from Samoa, probably extinct. *American Museum Novitates*, 3646: 1-37.
- Hirth, H.F. 1971. *Synopsis of Biological Data on the Green Turtle Chelonia mydas (Linnaeus) 1758*. Rome: Food and Agriculture Organization of the United Nations. FAO Fisheries Synopsis No. 85.
- Hunter, C.L., Magruder, W.H., Friedlander, A.M., & Meier, K.Z. 1993. *Ofu Reef Survey: Baseline Assessment and Recommendations for Long-Term Monitoring of the Proposed National Park, Ofu, American Samoa*. Pago Pago, Tutuila, American Samoa: the National Park Service.
- Ishimura, T. & Inoue, T. 2006. Archaeological excavations at the Si'utu midden site, Savai'i Island. *Journal of Sāmoan Studies*, 2: 43-56.

- Kirch, P.V. 1982. The impact of prehistoric Polynesians on the Hawaiian ecosystem. *Pacific Science*, 36(1): 1-14.
- Kirch, P.V. 1993a. The To'aga site: modeling morphodynamics of the land-sea interface. In Kirch, P.V. & Hunt, T.L. (eds.) *The To'aga Site: Three Millennia of Polynesian Occupation in the Manu'a Islands, American Samoa*. Berkeley: Contributions of the University of California Archaeological Research Facility No. 51, pp. 31-42.
- Kirch, P.V. 1993b. Non-ceramic portable artifacts from the To'aga site. In Kirch, P.V. & Hunt, T.L. (eds.) *The To'aga Site: Three Millennia of Polynesian Occupation in the Manu'a Islands, American Samoa*. Berkeley: Contributions of the University of California Archaeological Research Facility No. 51, pp.157-66.
- Kirch, P.V. 2007. Three islands and an archipelago: reciprocal interactions between humans and island ecosystems in Polynesia. *Earth and Environmental Science Transactions of the Royal Society of Edinburgh*, 98(1): 85-99.
- Kirch, P.V. & Hunt, T.L. 1993. *The To'aga Site: Three Millennia of Polynesian Occupation in the Manu'a Islands, American Samoa*. Berkeley: Contributions of the University of California Archaeological Research Facility No. 51.
- Kirch, P.V. & Yen, D.E. 1982. *Tikopia, the Prehistory and Ecology of a Polynesian Outlier*. Honolulu: Bernice P. Bishop Museum Bulletin 238.
- Lambrides, A.B.J. & Weisler, M.I. 2015a. Assessing protocols for identifying Pacific Island archaeological fish remains: the contribution of vertebrae. *International Journal of Osteoarchaeology*, 25(6): 838-48.
- Lambrides, A.B.J. & Weisler, M.I. 2015b. Applications of vertebral morphometrics in Pacific Island archaeological fishing studies. *Archaeology in Oceania*, 50(2): 53-70.
- Lambrides, A.B.J. & Weisler, M.I. 2016. Pacific Islands ichthyoarchaeology: implications for the development of prehistoric fishing studies and global sustainability. *Journal of Archaeological Research*, DOI: 10.1007/s10814-016-9090-y.
- Lepofsky, D., Kirch, P.V & Lertzman, K.P. 1996. Stratigraphic and paleobotanical evidence for prehistoric human-induced environmental disturbance on Mo'orea, French Polynesia. *Pacific Science*, 50(3): 253-73.
- Liu, Z., Gurr, N.E., Schmaedick, M.A., Whistler W.A., & Fischer, L. 2011. *Vegetation Mapping of American Samoa*. Vallejo, CA: U. S. Department of Agriculture, Forest Service, Pacific Southwest Region. General Technical Report (R5-TP-033).
- McDougall, I., 2010. Age of volcanism and its migration in the Samoa Islands. *Geological Magazine*, 147(5): 705-17.

- Mickleburgh, S., Waylen, K. & Racey, P. 2009. Bats as bushmeat: a global review. *Oryx*, 43(2): 217-234.
- Morrison, A. E. & Addison, D. J. 2009. Examining causes and trends in marine trophic level change: 1500 years of fish exploitation at Fatu-ma-Futi, Tutuila Island, American Sāmoa. *Journal of Island and Coastal Archaeology*, 4(2): 177-94.
- Nagaoka, L. 1993. Faunal assemblages from the To'aga site. In Kirch, P.V. & Hunt, T.L. (eds.) *The To'aga Site, Three Millennia of Polynesian Occupation in the Manu'a Islands, American Samoa*. Contributions of the University of California Archaeological Research Facility, No. 51. Berkeley, pp. 189-216.
- Nagaoka, L. 2005. Differential recovery of Pacific Island fish remains. *Journal of Archaeological Science*, 32(6): 941-55.
- Olson, S. & James, H. 1984. The role of Polynesians in the extinction of the avifauna of the Hawaiian Islands. In Martin, P. & Klein, R. (eds.) *Quaternary Extinctions: A Prehistoric Revolution*. Tucson, Arizona: University of Arizona Press, pp. 768-80.
- Ono, R. & Addison, D. 2013. Historical ecology and 600 years of fish use on Atafu Atoll, Tokelau. In Ono, R., Morrison, A. & Addison, A. (eds.) *Prehistoric Marine Resource Use in the Indo-Pacific Regions*. Canberra: ANU E Press, pp. 59-83.
- Osamu, H. 2013. The history and culture of dolphinfish (*Coryphaena hippurus*) exploitation in Japan, East Asia, and the Pacific. In Ono, R., Morrison, A. & Addison, D. (eds.) *Prehistoric Marine Resource Use in the Indo-Pacific Regions*. Canberra: ANU E Press, pp. 141-51.
- Pratt, H.D., Bruner, P.L. & Berrett, D.G. 1987. *A Field Guide to the Birds of Hawaii and the Tropical Pacific*. Princeton, New Jersey: Princeton University Press.
- Quintus, S., 2015. Dynamics of Agricultural Development in Prehistoric Samoa: The Case of Ofu Island. PhD thesis, Anthropology, University of Auckland.
- Quintus, S., Clark, J.T., Day, S.S., & Scwert, D.P. 2015. Landscape evolution and human settlement patterns on Ofu Island, American Samoa. *Asian Perspectives*, 54(2): 208-37.
- Rieth, T. & Cochrane, E.E. 2012. *Final: Archaeological Monitoring and Data Recovery in Support of the Federal Emergency Management Agency Permanent Housing Construction Program, Tutuila Island, American Sāmoa*. Honolulu: International Archaeological Research Institute, Inc.
- Steadman, D.W. 1989. Extinction of birds in eastern Polynesia: a review of the record, and comparisons with other Pacific Island groups. *Journal of Archaeological Science*, 16(2): 177-205.

- Steadman, D.W. 1993. Bird bones from the To'aga site: prehistoric loss of seabirds and magapods. In Kirch, P.V. & Hunt, T.L. (eds.) *The To'aga Site, Three Millennia of Polynesian Occupation in the Manu'a Islands, American Samoa*. Contributions of the University of California Archaeological Research Facility, No. 51. Berkeley, pp. 217-28.
- Steadman, D.W. 2006. *Extinction and Biogeography of Tropical Pacific Birds*. Chicago: University of Chicago Press.
- Steadman, D.W. & Pregill, G.K. 2004. A prehistoric, non-cultural vertebrate assemblage from Tutuila, American Samoa. *Pacific Science*, 58(4): 615-24.
- Weisler, M.I. 2001. *On the Margins of Sustainability: Prehistoric Settlement of Utrök Atoll, Northern Marshall Islands*. Oxford: British Archaeological Reports International Series 967.
- Weisler, M.I. 2004. Contraction of the southeast Polynesian interaction sphere and resource depression on Temoe Atoll. *New Zealand Journal of Archaeology*, 25 (2003): 57-88
- Weisler, M.I., Bollt, R., & Findlater, A. 2006. A new eastern limit of the Pacific Flying Fox (Pteropodidae *Pteropus tonganus*) in prehistoric Polynesia: a case of possible human transport and extirpation. *Pacific Science*, 60(3): 403-11.
- Weisler, M.I. & Gargett, R. 1993. Pacific Island avian extinctions: the taphonomy of human predation. *Archaeology in Oceania*, 28(2): 85-93.
- Weisler, M.I. & Green, R.C. 2013. Mangareva fishing strategies in regional context: an analysis of fish bones from five sites excavated in 1959. *Journal of Pacific Archaeology*, 4(1):73-89.
- Whistler, W.A. 1991. Polynesian plant introductions. In Cox, P.A. & Banack, S.A. (eds.) *Islands, Plants, and Polynesians: An Introduction to Polynesian Ethnobotany*. Portland, Oregon: Dioscorides Press, pp. 41-66.
- Wolverton, S. 2013. Data quality in zooarchaeological faunal identification. *Journal of Archaeological Method and Theory*, 20(3): 381-96.
- Worthy, T.H. 1999. What was on the menu? Avian extinction in New Zealand. *New Zealand Journal of Archaeology*, 19(1997): 125-60.
- Worthy, T.H. & Bollt, R. 2011. Prehistoric birds and bats from the Atiahara site, Tubuai, Austral Islands, East Polynesia. *Pacific Science*, 65(1): 69-85.
- Worthy, T.H., Hawkins, S., Bedford, S., & Spriggs, M. 2015. Avifauna from the Teouma Lapita site, Efate Island, Vanuatu, including a new genus and species of megapode. *Pacific Science*, 69(2): 205-54.

Table 1. Non-fish bones identified from Ofu site AS-13-41.

		post 800 BP						2700-1500 BP		Total	
		XU3		XU3		XU4		XU4			
		Layer X		Layer XI		Layer IV		Layer VI			
Taxon	Common name	NISP	MNI	NISP	MNI	NISP	MNI	NISP	MNI	NISP	MNI
Aves (unidentified bird)		1	1	5	1			31	1	37	3
Domesticates											
Phasianidae <i>Gallus gallus</i>	Red Junglefowl							4	2	4	2
Seabirds											
Procellariidae cf. <i>Puffinus</i>	Shearwater							1	1	1	1
Procellariidae <i>Pterodroma</i> or <i>Pseudobulweria</i> sp.	Petrel							2	1	2	1
Landbirds											
Rallidae <i>Gallirallus philippensis</i>	Buff-banded Rail			1	1					1	1
Columbidae <i>Didunculus strigirostris</i>	Tooth-billed Pigeon							1	1	1	1
Total bird		1	1	6	2			39	6	46	9
Vertebrate											
	Pig, dog, rat, bird			6	1	17	1	22	1	45	3
<i>Rattus</i> cf. <i>exulans</i>	Pacific Rat	2	1	4	2			14	5	20	8
<i>Sus scrofa</i>	Pig					3	2			3	2
<i>Homo sapiens</i>	Human					2	1			2	1
<i>Pteropus tonganus</i>	Pacific Flying Fox			1	1					1	1
cf. <i>Pteropus tonganus</i>	Pacific Flying Fox			1	1					1	1
cf. <i>Chelonia mydas</i>	Green Sea Turtle			1	1			29	2	30	3
Totals		3	2	19	8	22	4	104	14	148	28

Table 2. Fish taxa identified from Samoan archaeological sites.

Taxon	this study	Cleghorn & Shapiro (2000)	Ishimura & Inoue (2006)	Morrison & Addison (2009)	Nagaoka (1993)	Rieth & Cochrane (2012)	Ubiquity %
Acanthuridae	x	x	x	x	x	x	100.0
Balistidae	x	x	x	x	x	x	100.0
Diodontidae	x	x	x	x	x	x	100.0
Elasmobranchii including shark	x	x	x	x	x	x	100.0
Holocentridae	x	x	x	x	x	x	100.0
Lethrinidae	x	x	x	x	x	x	100.0
Scaridae	x	x	x	x	x	x	100.0
Scombridae	x	x	x	x	x	x	100.0
Serranidae	x	x	x	x	x	x	100.0
Carangidae	x	x	x	x	x		83.3
Labridae	x		x	x	x	x	83.3
Lutjanidae	x		x	x	x	x	83.3
Muraenidae	x	x		x	x	x	83.3
Mullidae		x	x		x	x	66.7
Belonidae	x			x	x		50.0
Scorpanidae			x	x		x	50.0
Bothidae	x				x		33.3
Cirrhitidae		x		x			33.3
Congridae	x				x		33.3
Mugilidae	x			x			33.3
Ostraciidae	x				x		33.3
Sphyraenidae					x	x	33.3
Aulostomidae					x		16.7
Batoidea					x		16.7
Coryphaenidae	x						16.7
Exocoetidae	x						16.7
Fistulariidae	x						20.0
Kphosidae					x		20.0
Pomacentridae				x			20.0
Tetraodontidae		x					20.0
Total taxa	21	13	14	17	22	14	
Total bones	1435	NR	172	6231	9524	7455	

NR= not reported. Only weight given in report.

Cleghorn & Shapiro (2000) site AS-11-1, Ta'u Island.

Ishimura & Inoue (2006) Si'utu site, Savai'i Island.

Morrison & Addison (2009) site Fatu-ma-Futi, Tutuila Island.

Nagaoka (1993) site AS-13-1, Ofu Island.

Rieth & Cochrane (2012) site PHC XZ11, Tutuila Island.

Table 3. Rank-order of the top four fish families by NISP.

Taxon	this report (all elements)	this report (5-paired cranial & specials)	Ishimura & Inoue (2006)	Morrison & Addison (2009)	Nagaoka (1993)	Rieth & Cochrane (2012)
Acanthuridae	1	2		1	1	2
Holocentridae	3	3			3	
Labridae			4	4		4
Lethrinidae						3
Scaridae	2	1	3	2	4	1
Scombridae			1			
Serranidae	4	4	2	3	2	
% of top 4 taxa	63.0	52.3	38.4	68.6	60.8	73.4
# of all fish bones	1435	1435	172	6231	9524	7455

Ishimura & Inoue (2006) Si'utu site, Savai'i Island.

Morrison & Addison (2009) site Fatu-ma-Futi, Tutuila Island.

Nagaoka (1993) site AS-13-1, Ofu Island.

Rieth & Cochrane (2012) site PHC XZ11, Tutuila Island.

Table 4. Fish rank-order abundance of families from Ofu site AS-13-41 using all elements for identification vs the five-paired cranial elements and specials.

Family	Five-paired cranial elements + 'specials'				All elements				5 paired vs all
	NISP	MNI	Rank-order		NISP	MNI	Rank-order		% Difference
	NISP	MNI	MNI	NISP	NISP	MNI	MNI	NISP	NISP
Acanthuridae	45	24	1	2	104	32	1	2	43.3
Balistidae	15	5	6	7	19	5	7	8	78.9
Belonidae	3	1	9	13	3	1	10	13	100.0
Bothidae					1	1	10	14	0.0
Carangidae	7	5	6	11	16	9	5	9	43.8
Carcharhinidae	1	1	9	15	1	1	10	14	100.0
Cirrhitidae	3	1	9	13	10	2	9	11	30.0
Congridae	3	1	9	13	4	1	10	12	75.0
Coryphaenidae					3	2	9	13	0.0
Diodontidae	38	5	6	3	39	5	7	5	97.4
Exocoetidae					4	2	9	12	0.0
Fistulariidae	2	1	9	14	3	1	10	13	66.7
Holocentridae	31	21	3	4	65	25	3	3	47.7
Labridae	9	5	6	10	10	5	7	11	90.0
Lethrinidae	16	8	4	6	20	9	5	7	80.0
Lutjanidae	13	3	8	8	25	7	6	6	52.0
Mugilidae					3	1	10	13	0.0
Muraenidae	9	4	7	10	10	4	8	11	90.0
Ostraciidae	4	1	9	12	4	1	10	12	100.0
Scaridae	69	22	2	1	114	28	2	1	60.5
Scombridae	1	1	9	15	10	5	7	11	10.0
Selachii	12	5	6	9	12	5	7	10	100.0
Serranidae	19	7	5	5	53	10	4	4	35.8
Total Identified	300	121			533	162			56.3

Table 5. Fish identified from Ofu site AS-13-4.

Taxon	Common name	Feeding Behaviour	post-800 BP						1200–1000 BP		2700–1500 BP		Total		Total by Family		Total by Family		% change NISP to MNI		
			XU3		XU3		XU4		XU4		XU4		NISP	MNI	NISP	MNI	%NISP	%MNI			
			Layer X	Layer XI	Layer XI	Layer XI	Layer IV	Layer IV	Layer V	Layer V	Layer VI	Layer VI									
			NISP	MNI	NISP	MNI	NISP	MNI	NISP	MNI	NISP	MNI	NISP	MNI	NISP	MNI	%NISP	%MNI			
Osteichthyes (unidentified fish to element)		N/A			4	1	1	1			20		26								
Selachii	Modern sharks	P	3	1	2	1	5	1	1	1	1	1	12	5	12	5	2.3	3.1	>0.8		
Carcharhinidae	<i>Carcharhinus cf. leucas</i>	P			1	1							1	1	1	1	0.2	0.6	>0.4		
Acanthuridae	Surgeonfish, unicornfish, and tang	H	1	1	6	2	2	2	3	1	48	16	60	22	104	32	19.5	19.8	>0.2		
Acanthuridae	<i>Acanthurus</i> spp.	H			2	1							11	2	13	3					
Acanthuridae	<i>Ctenochaetus</i> spp.	H			2	1							13	2	15	3					
Acanthuridae	<i>Miso</i> spp.	H			1	1							14	2	15	3					
Acanthuridae	<i>Zebriasoma</i> sp.	H											1	1	1	1					
Balistidae	Triggerfish	O/BC			2	1							17	4	19	5	19	5	3.6	3.1	<0.5
Belontiidae	Needlefish	P											3	1	3	1	3	1	0.6	0.6	>0.1
Bothidae	Lefteye flounder	O/BC					1	1					1	1	1	1	0.2	0.6	>0.4		
Carangidae	Jack, trevally, pompano, and scad	P							1	1	3	2	4	3	16	9	3.0	5.6	>2.6		
Carangidae	<i>cf. Carangoides</i> sp.	P											2	1	2	1					
Carangidae	<i>cf. Caranx</i> sp.	P											5	1	5	1					
Carangidae	<i>cf. Decapterus</i> sp.	P					1	1					1	1							
Carangidae	<i>cf. Selar</i> sp.	P			1	1	1	1					2	1	4	3					
Cirritidae	Hawkfish	O/BC			3	1							7	1	10	2	10	2	1.9	1.2	<0.7
Congridae	Conger and garden eels	P											4	1	4	1	4	1	0.8	0.6	<0.1
Coryphaenidae	<i>Coryphaena hippurus</i>	P											3	2	3	2	3	2	0.6	1.2	>0.7
Diodontidae	<i>Diodon</i> spp.	O/BC	4	1	3	1	3	1	1	1	28	1	39	5	39	5	7.3	3.1	<4.2		
Exocoetidae	Flying fish	O/BC			1	1							3	1	4	2	4	2	0.8	1.2	>0.5
Fistulariidae	<i>Fistularia commersonii</i>	P											3	1	3	1	3	1	0.6	0.6	>0.1
Holocentridae	Squirrelfish and soldierfish	O/BC					1	1					16	14	17	15	65	25	12.2	15.4	>3.2
Holocentridae	<i>Myripristis</i> spp.	O/BC	1	1									12	3	13	4					
Holocentridae	<i>Sargocentron</i> spp.	O/BC			4	1	2	1					29	4	35	6					
Labridae	Wrasse	O/BC	1	1	1	1	1	1					7	2	10	5	10	5	1.9	3.1	>1.2
Lethrinidae	Emperor and Bream	O/BC											1	1	1	1	20	9	3.8	5.6	>1.8
Lethrinidae	<i>Lethrinus</i> spp.	O/BC			1	1			1	1	10	3	12	5							
Lethrinidae	<i>Monotaxis grandoculis</i>	O/BC							1	1	6	2	7	3							
Lutjanidae	Snapper	P			1	1							3	1	4	2	25	7	4.7	4.3	<0.4
Lutjanidae	<i>Aphareus</i> sp.	P											1	1	1	1					
Lutjanidae	<i>Aprion</i> sp.	P											1	1	1	1					
Lutjanidae	<i>Lutjanus</i> spp.	P			3	1							16	2	19	3					
Mugilidae	Mullet	O/BC											3	1	3	1	3	1	0.6	0.6	>0.1
Muraenidae	Moray Eel	P											10	4	10	4	10	4	1.9	2.5	>0.6
Ostraciidae	Boxfish	O/BC											4	1	4	1	4	1	0.8	0.6	<0.1
Scaridae	Parrotfish	H			1	1	8	1	6	2	42	4	57	8	114	28	21.4	17.3	<4.1		
Scaridae	<i>Calotomus</i> spp.	H											1	1	10	3	11	4			
Scaridae	<i>Chlorurus</i> spp.	H							1	1	24	4	25	5							
Scaridae	<i>Hippocampus longiceps</i>	H			1	1							4	2	5	3					
Scaridae	<i>Scarus</i> spp.	H	1	1	1	1							14	6	16	8					
Scombridae	Mackerel, tuna, and bonito	P			1	1	1	1						2	2	10	5	1.9	3.1	>1.2	
Scombridae	<i>Katsuwonus pelamis</i>	P	2	1	5	1	1	1					8	3							
Serranidae	Sea bass, grouper, and fairy basslet	P			9	2	1	1					33	3	43	6	53	10	9.9	6.2	<3.8
Serranidae	<i>cf. Epinephelus</i> spp.	P			1	1							7	2	8	3					
Serranidae	<i>cf. Variola</i> sp.	P											2	1	2	1					
Total Identified (excl. unidentified fish to element)			13	7	53	25	28	14	16	10	423	106	533	162							
Total bones			31		138		80		38		1148		1435								
Total weight (g)			5.7		16.4		15.7		11.6		258.4		307.9								
% Identified			41.9		38.4		35.0		42.1		36.8		37.1								

All date ranges are calibrated ages. Percentages rounded to one decimal place.

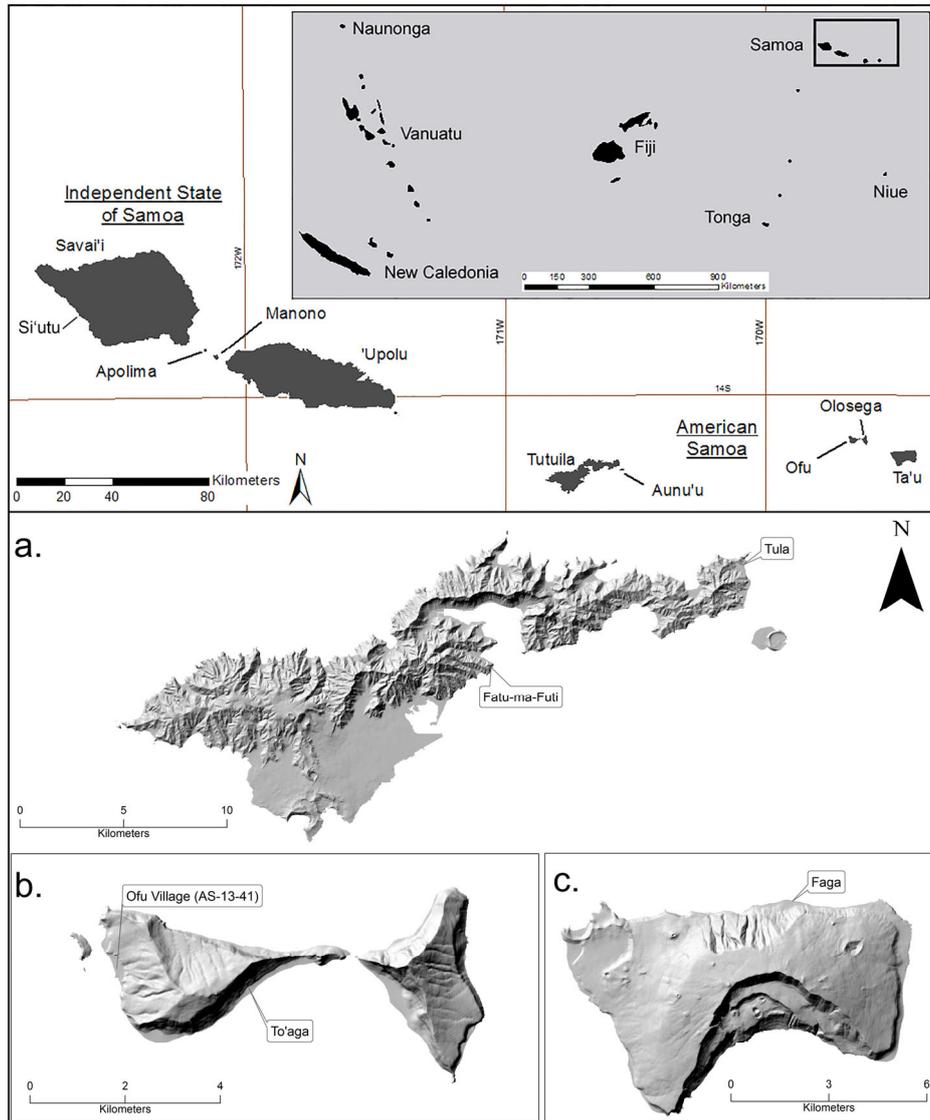


Figure 1. Map of the central Pacific showing the location of the Samoan Archipelago, the Independent State of Samoa and American Samoa, and sites discussed in the text: a) Tula Village, Fagasa Point and Fatu-ma Futi (Tutuila Island), b) To'aga and the Ofu Village study site (Ofu Island) and c) Faga (Ta'u Island). The Si'utu midden site is situated at the southwest coast of Savai'i Island.

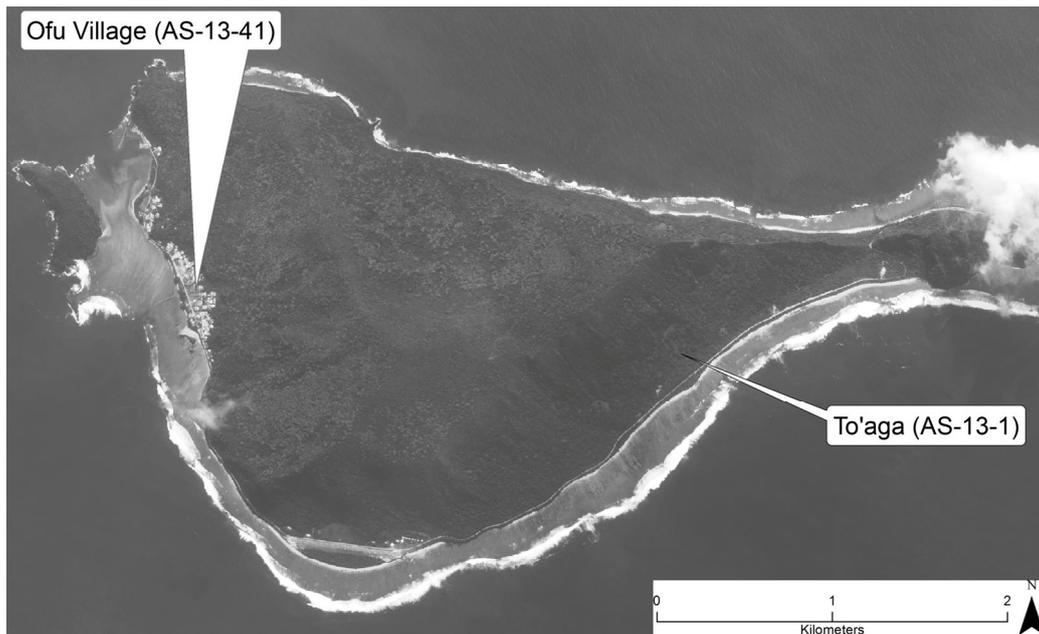


Figure 2. Ofu Island showing the broadest reef on the west coast adjacent to the Ofu Village study site AS-13-41 and the To'aga site. Note the two paths beginning at the shoreline at Ofu Village that cross the reef meeting at the reef edge.



Figure 3. Aerial photo of the modern Ofu Village (Ofu Island) showing the locations of XU-3 and 4; faunal assemblages from these units are reported here. The reef path immediately seaward of T3 is clearly visible.

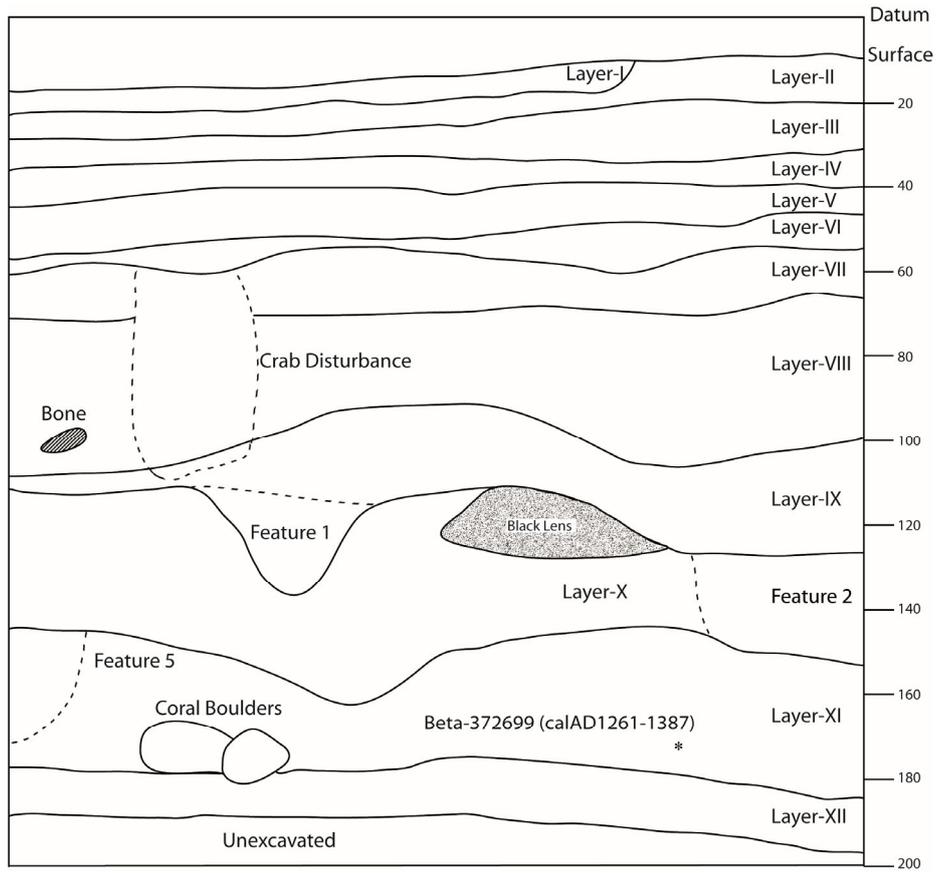


Figure 4. Stratigraphic profile of XU-3 with location of radiocarbon date in Layer XI. Depth is in centimetres.

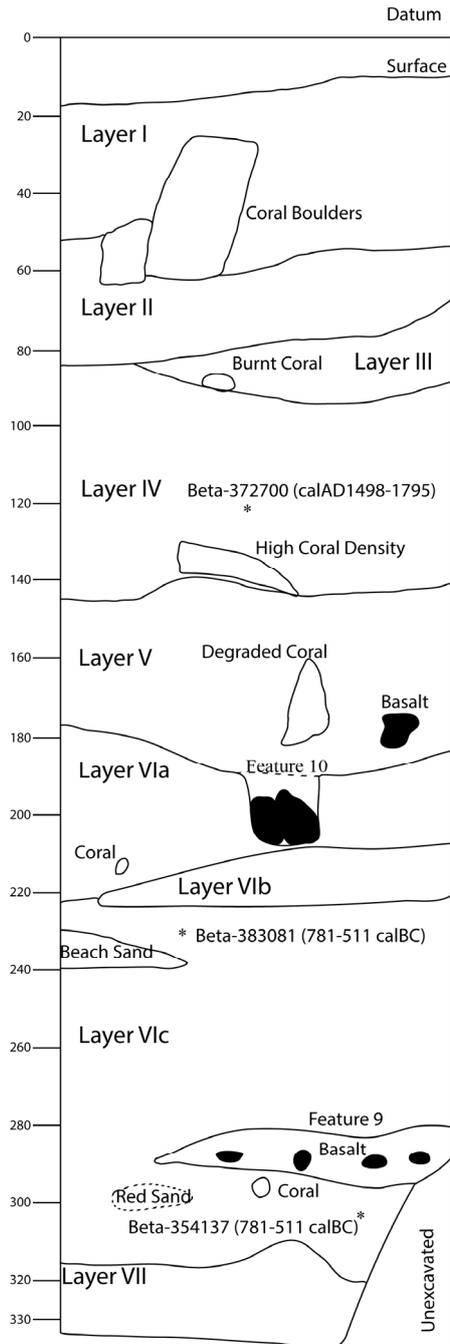


Figure 5. Stratigraphic profile of XU-4 showing the location of the radiocarbon dates in Layer VIc and IV. Depth is in centimetres.

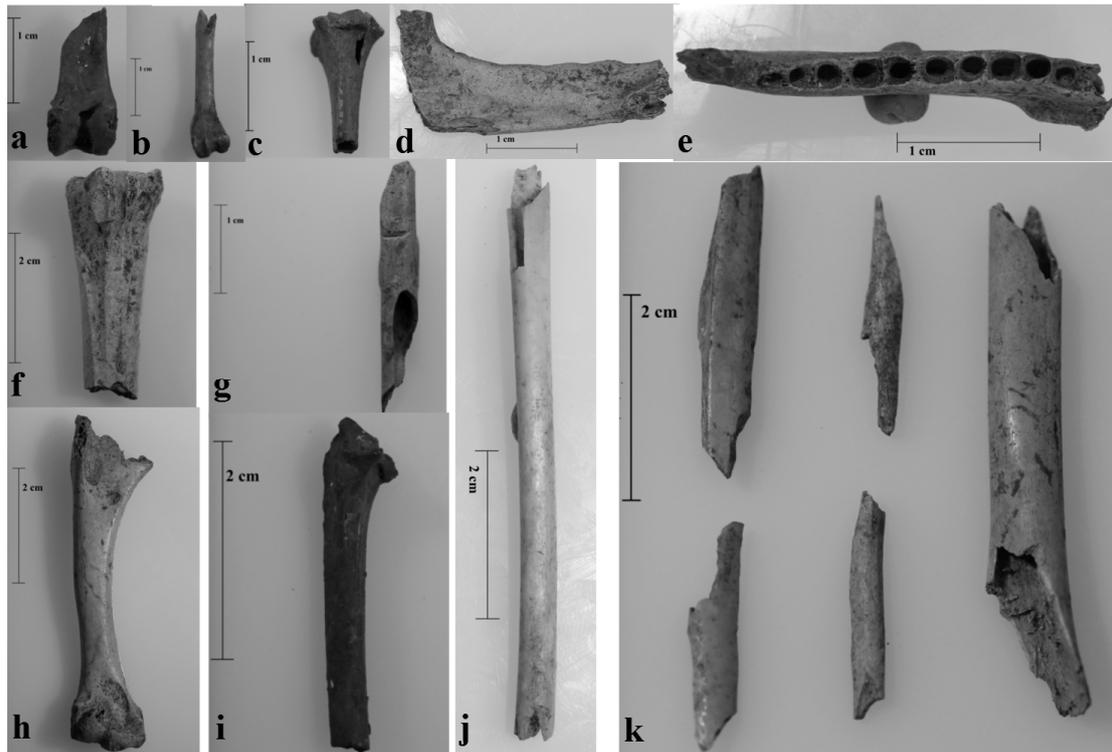


Figure 6. Examples of species and breakage patterns of archaeological bird and mammal bones. a) distal right tibiotarsus of the Tooth-Billed Pigeon (*Didunculus strigirostris*) with green fracture, b) distal left femur of a shearwater (*Procellariidae Puffinus* sp.), c) proximal left tibiotarsus of the Buff-Banded Rail (*Gallirallus philippensis*), d and e) left mandible of Pacific Flying Fox (*Pteropus tonganus*) in occlusal and medial views, f) proximal left tarsometatarsus of Red Junglefowl (chicken, *Gallus gallus*), g) cut mark on unidentified mid shaft, h) right humerus of chicken with chewed proximal end, i) proximal left ulna of shearwater (*Procellariidae*), j) green fractures on a shaft of a *Procellariidae* ulna, and k) depicts five bones of fractured angular mid shafts including a left humerus with spiral fractures. (Photos, M. Weisler.)

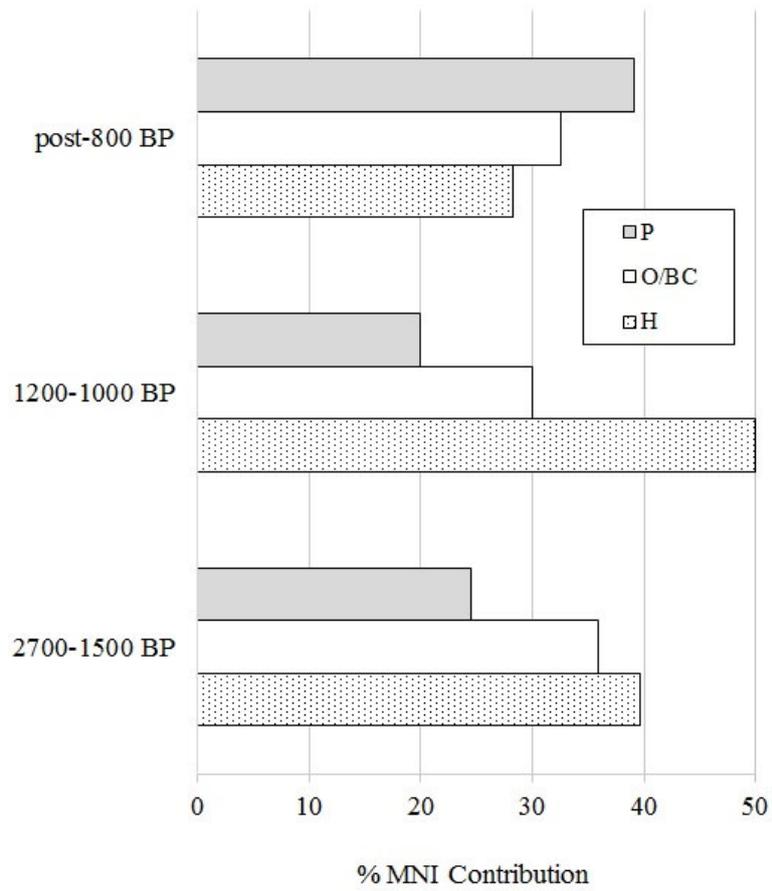


Figure 7. Fish feeding behaviour by temporal period as calculated by per cent MNI contribution. P = piscivore, O = omnivore, BC = benthic carnivore and H = herbivore.

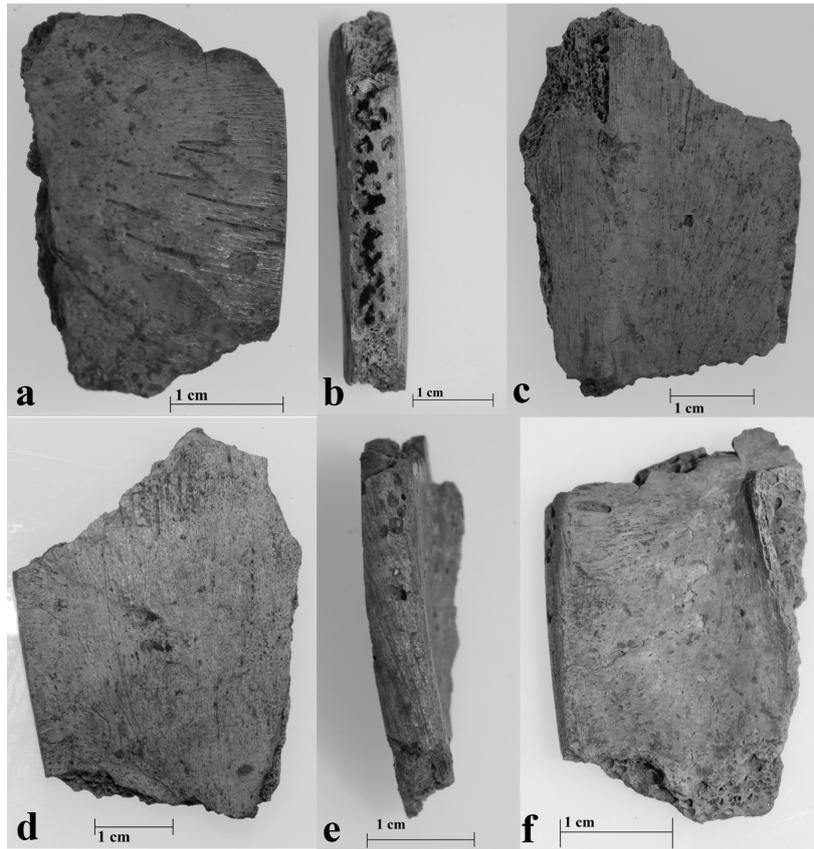


Figure 8. Two examples of ground turtle plastron fragments from XU-4, Layer VI. Views a (ground on right) and d (ground edge on left) exterior, b and e showing ground edge, c (ground edge on right) and f (ground edge on left) interior views. (Photos, M. Weisler).

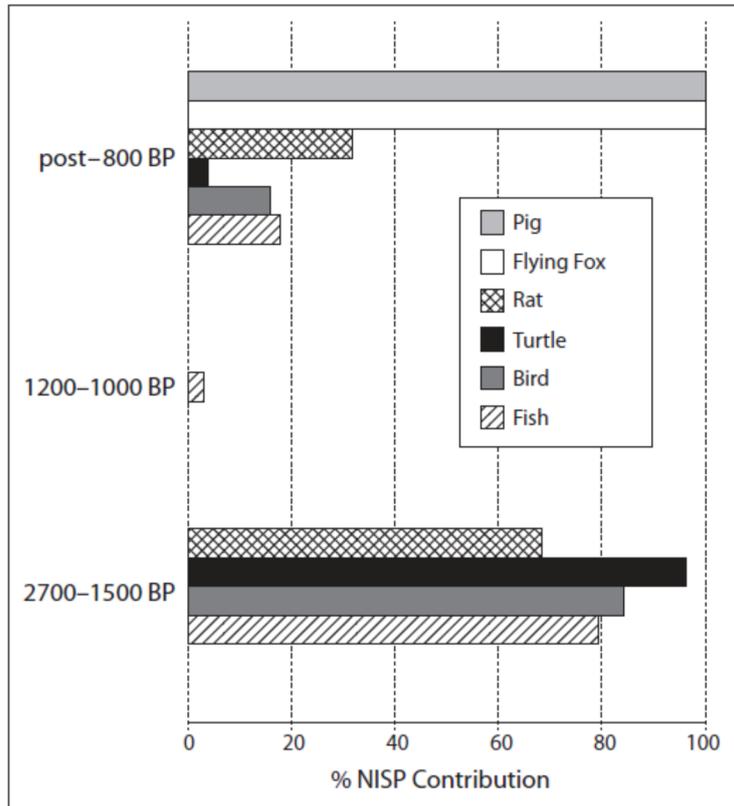


Figure 9. Per cent faunal class by temporal period as calculated by NISP.