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Assessing foraging variability on small islands in Manu‘a (American Samoa) during the first millennium BC

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ABSTRACT:

Small islands are important model systems for examining the role of people in shaping novel environments and modifying resources through time. Here we report on the vertebrate faunal assemblages recovered from two sites on Ofu and Olosega islands (American Samoa), which were occupied only a few centuries after the initial settlement of the islands. We assess forager decision-making both locally and regionally as well as changing subsistence regimes. Our results suggest foraging efforts were focused on the marine environment, particularly fish, but with concomitant evidence for interactions with terrestrial habitats (e.g. seabirds) including the introduction of commensal species (i.e. red junglefowl and Pacific rat). Notably we documented a high degree of similarity between the fish species reported archaeologically and those targeted by modern subsistence fishers in the region, which is despite the occurrence of wide scale coastal landscape changes over the past several thousand years. These preliminary outcomes may suggest fish resources have remained stable through initial occupation to the present-day, but future zooarchaeological research is required to comprehensively evaluate the sustainability of the marine fishery over the past several millennia.

Keywords: archaeofauna, island archaeology, Pacific Islands, Samoa, fishing

RÉSUMÉ:

Les petites îles sont des systèmes modèles importants pour l'étude du rôle de l'homme dans le façonnement de nouveaux environnements et la modification des ressources au fil du temps. Nous présentons ici les assemblages de la faune vertébrée récupérés sur deux sites des îles Ofu et Olosega (Samoa américaines), qui n'ont été occupés que quelques siècles après la colonisation initiale des îles. Nous évaluons la prise de décision des fourrageurs à l'échelle locale et régionale, ainsi que l'évolution des régimes de subsistance. Nos résultats suggèrent que les efforts de recherche de nourriture étaient concentrés sur l'environnement marin, en particulier sur le poisson, mais avec des preuves concomitantes d'interactions avec les habitats terrestres (par exemple les oiseaux de mer), y compris l'introduction d'espèces commensales (par exemple la sauvagine rouge et le rat du Pacifique). Nous avons notamment documenté un haut degré de similitude entre les espèces de poissons rapportées par les archéologues et celles ciblées par les pêcheurs de subsistance modernes dans la région, et ce malgré les changements à grande échelle du paysage côtier au cours des derniers milliers d'années. Ces résultats préliminaires peuvent suggérer que les ressources en poissons sont restées stables depuis l'occupation initiale jusqu'à aujourd'hui, mais des recherches zooarchéologiques futures sont nécessaires pour évaluer de manière exhaustive la durabilité de la pêche marine au cours des derniers millénaires.

Mots-clés: archéofaune, archéologie insulaire, Îles du Pacifique, Samoa, pêche

INTRODUCTION

Conceptualising islands as model systems provides the opportunity to explore the role of people in shaping novel environments and their long-term influence on resource availability, such as through species introductions, managing faunal populations or resource enhancement (DiNapoli & Leppard 2018; Fitzpatrick & Erlandson 2018; Kirch 2007; Vitousek 2002). It is within this context that small islands have increasingly become the focus of archaeological enquiry, informing our understanding of the complex and dynamic interrelationship between human settlement histories, palaeogeography, sociality, and subsistence regimes (e.g. Fitzpatrick *et al.* 2016; Giovas 2016; Keegan *et al.* 2008; Lambrides *et al.* 2020; McNiven 2016; O'Connor *et al.* 2019; Quintus & Clark 2017; Rick *et al.* 2020; Shaw *et al.* 2020; Weisler 2001). Importantly for faunal studies, the broader range of micro- and macro-environments that can be evaluated because of the small size of these islands can bring into focus drivers of both variability and long-term stability.

Ofu and Olosega are two of the smaller islands in the Samoan Archipelago that support permanent human populations. This paper reports on the vertebrate remains recovered from Va‘oto on the southwest tip of Ofu, and Vaiopi on the south coast of Olosega. These sites were occupied for a comparable and relatively short period of time, which appears to post-date the initial settlement of the islands of Manu‘a by ~200 years (~2700 calBP) (Clark *et al.* 2016; Petchey & Kirch 2019), but still represents an early phase of habitation in the region. The assemblages are dominated by fish remains, with low abundances of mammal (rat and human), bird, and sea turtle bones. Currently available archaeological faunal records dating to the period of initial and early human occupation of Samoa and western Polynesia are limited (e.g. Cannon *et al.* 2019; Rieth & Morrison 2017; Weisler *et al.* 2016). To understand variation in forager decision-making during this early phase of island use in the region, particularly Manu‘a, further datasets are required, as are methods for assessing faunal assemblage similarity and taxonomic heterogeneity. Here, we examine whether variability in foraging practices can be identified at the previously undocumented sites of Va‘oto and Vaiopi and consider subsistence regimes in the broader context of previously published archaeological and modern faunal records from the region. The new faunal records from Manu‘a reported in this study contribute to our understanding of forager-decision making both locally and regionally and enhance our understanding of potential connections between subsistence practices and proposed coastal landscape change over the past several millennia.

ECOLOGICAL CONTEXT AND ARCHAEOLOGICAL BACKGROUND

The Samoan Archipelago situated in the Central Pacific is comprised of nine main islands oriented east-west in a roughly linear formation distributed across a ~3,000 km^2 area (Figure 1). To the west are the islands of ‘Upolu (1,125 km^2), Savai‘i (1,694 km^2), Manono, and Apolima, the former two being the largest in the group. To the east are medium-sized Tutuila (142 km^2) and tiny Aunu‘u islands and, on the eastern extreme, 110 km from Tutuila, is a group of three small islands – Ofu, Olosega, and Ta‘u – that collectively are referred to as the Manu‘a Group (Figures 2 and 3). The western cluster of islands are today known as the Independent State of Samoa while the central islands together with Manu‘a constitute the U.S. Territory of American Samoa.

The islands of Manu‘a are relatively small compared to those in the western extent of the archipelago: Ofu (7.3 km^2), Olosega (5 km^2), and Ta‘u (45 km^2). This paper focuses on the twin islands of Ofu and Olosega. Each island is triangular in outline, with the eastern apex of Ofu separated from the western apex of Olosega by the Asaga Strait, a narrow channel of 100 m. Proximity and similarities in size and shape mean that these two islands have comparable terrestrial and marine environments. The islands constitute two coalescing shield volcanoes that formed 250-400 kya (McDougall 2010). The topographic relief is steep and rugged, with the highest point on Ofu, Tumu Peak, rising 495 m above sea level and Mount Piumafua on Olosega at 629 m. The islands’ vegetation is at least partly anthropogenic, including economic tree crops (e.g. *Cocos nucifera*) and secondary vegetation (e.g. *Hibiscu*s sp.) (Liu *et al.* 2011), reflecting past human intervention on the landscape (Quintus 2015).

Ofu and Olosega are surrounded by a continuous fringing coral reef (Craig *et al.* 2008) (Figure 3), 3.6 km^2 in area (Williams *et al.* 2011). On the south coast today, the reef crest generally lies about 100-250+ m from the shoreline, although it is farthest offshore (up to 500 m) on the west coast of Ofu.. The associated lagoon depths are up to 2.5 m, but beyond the reef edge, depth increases sharply, reaching over 200 m within 2.5 km of land in most places around the islands. The reef flat, reef crest, fore reef and bank/shelf on the south coast of Ofu and Olosega and west coast of Ofu—in proximity to archaeological sites mentioned in the text—are broadly characterised by expansive pavements colonised by macroalgae, coralline algae and coral, sand cover, reef rubble and coral cobbles, aggregated patch reef, and wave cut spur and groove formations hosting diverse coral communities (e.g. *Porites* and *Millepora* colonies) (Green 2002) (Figure 2).

The reef, with its diverse coral growth, supports abundant marine life (~2,705 species) that would have provided a rich resource base for people in the past (Fenner *et al.* 2008). Today sea turtles (Cheloniidae and Dermochelyidae) are considered endangered and occur in low numbers (Tuato'o-Bartley *et al.* 1993), but occasionally hawksbill turtles (*Eretmochelys imbricata*) nest on the beaches of Ofu and Olosega. Marine mammals such as whales (Balaenopteridae, Delphinidae, Kogiidae, Physeteridae, and Ziphiidae) and dolphins (Delphinidae) are seasonally present, but some Spinner dolphins (*Stenella longirostris*) and Rough-toothed dolphins (*Steno bredanensis*) are present year-round (Craig 2009; Johnston *et al.* 2008).

Reef studies in American Samoa report over 930 fish and 700 mollusc species (Craig 2009: 38; Fenner *et al.* 2008; Madrigal 1999); data specific to Manuʻa are more limited, but for Ofu, 288 species from 47 families of reef fish have been reported, mostly from the shallow back reef and lagoon (Hunter *et al.* 1993: 22). Lawrence and Sudek (2016) documented distinctions in fish biomass across Ofu and Olosega, noting that reef habitats in proximity to the Vaiopi (Olosega south coast) and Ofu Village sites (Ofu west coast) were populated by an equal or higher proportion of lower (trophic level) carnivores relative to herbivores. In contrast, population composition adjacent to the Vaʻoto and Toʻaga sites (Ofu south coast) were dominated by herbivorous fish (Lawrence & Sudek 2016). In the recent past, fishing efforts have been primarily shore-based (i.e. back-reef moats, reef flats, and upper reef slopes) in proximity to the modern village sites, with offshore fishing using boats undertaken less regularly, with an estimated 1400 kg of fish and invertebrates exploited per kilometre of shoreline each year (Craig *et al.* 2008). Furthermore, four gear types/capture strategies are predominantly utilised today: rod and reels (e.g. serranids, carangids [*Selar crumenophthalmus*], and holocentrids), spears (e.g. scarids, serranids, acanthurids, and holocentrids), weirs (*Selar crumenophthalmus*), and gleaning or handpicking (e.g. *Tridacna* spp. and *Turbo* spp.) (Craig *et al.* 2008).

In contrast, terrestrial fauna is limited across American Samoa, while many of the exploited species present in the zooarchaeological record were introduced, such as pig (*Sus scrofa*), Pacific rat (*Rattus exulans*), and chicken (*Gallus gallus*). Native land mammals and birds include Pacific flying fox (*Pteropus tonganus*), Tooth-billed pigeon (*Didunculus strigirostris*), and Buff-banded rail (*Hypotaenidia philippensis*) (Nagaoka 1993; Weisler *et al.* 2016). Other terrestrial fauna available for exploitation included seabirds and land crabs (Craig 2009).

Prior research on Ofu has provided documentation of a dynamic coastline over the past 3,000 years. For To‘aga on the south coast, Kirch (1993) proposed a ‘morphodynamic model’ for the development of the coastal plain, which involved Holocene sea level rise to +1-2 m at 4000-2000 BP, island subsidence driven by point loading, and a changing biogenic sediment budget largely in response to these sea-level changes and local tectonic activity. Terrigenous sedimentation increased over time and while the To‘aga terrace was comparatively small at the time of initial settlement (ca. 2800-2700 BP) it expanded with progradation through to ca. 1000 BP (Kirch 1993). Quintus *et al.* (2015) concluded that coastline changes at Ofu Village on the west coast show a broadly similar sequence of coastal transfiguration but with sufficient differences to suggest that changes of coastal geomorphology did not progress at the same rate.

The data from the Va‘oto and Vaiopi sites reveal a comparable pattern of morphodynamics. The initial human habitation was by pottery-using groups on narrow zones of calcareous sand near the base of talus slopes. Habitation in some form continued for several centuries during which marine sands accumulated. Around 2000 BP, or a little later, there was increased terrigenous sedimentation. Eventually, the sites were capped by layers of colluvium derived from increased erosion of inland slopes and deposition on the coastal lowlands. The coastal flats prograded significantly as the relative sea level fell. Together, the data from these sites reinforce the interpretation of an ‘an island-wide process of shoreline progradation and marine regression’ (Quintus *et al.* 2015: 228) even though the specifics of those changes and their timing probably varied at different locations around the islands.

At both the Va‘oto coastal plain and Vaiopi, the coastal flats include small, freshwater marshes situated between the calcareous sand beaches and the cliffs, in contrast to the To‘aga and Ofu Village sites, which are not near freshwater marshes. Coring in both marshes revealed calcareous sand deposits underlying the marsh waters and sediments, indicating that those wetlands were once open to or bordering the ocean. As the relative sea level changed and calcareous progradation advanced, each area was transformed, probably to back-barrier lagoons, perhaps with an area of tidal flat. The precise timing of this landscape transformation is not known, but it may have coincided in part with human habitation. Those environments were undoubtedly attractive for initial inhabitants by providing a broader array of resources, especially potable water, than locations lacking nearby wetlands.

The first archaeological surveys of Ofu and Olosega islands (Clark 1980; Kikuchi 1963) predominantly documented surface sites that were dated primarily to the 20th century, but it was also postulated that earlier sites were probably buried under the modern coastal villages as well as located in the interior of the islands. While both of those postulations have proven to be correct, the coastal sites have provided the earliest evidence for occupation on the islands when compared to the interior uplands, and as such the coastal margins have been the focus of excavations. Those excavations have revealed a set of early, ceramic-bearing sites dating from the early centuries of the first millennium BC (~2700 years ago) through the first few centuries of the first millennium AD (Clark *et al.* 2016; Petchey & Kirch 2019). From west to east, those sites are at Ofu Village (AS-13-41) (Quintus *et al.* 2015; Weisler *et al.* 2016), Coconut Grove (AS-13-37) (Clark *et al.* 2016), Va'oto (AS-13-13) (Clark *et al.* 2016; Quintus & Clark 2017), To'aga (AS-13-1) (Kirch & Hunt 1993), and Vaiopi (AS-12-3), with the first four sites on Ofu and the last on Olosega. As measured between approximate site centres and following the coastline, the distances between the sites are small: Ofu Village to Coconut Grove 1.78 km; Coconut Grove to Va'oto, 0.37 km; Va'oto to To'aga, 2.0 km; and To'aga to Vaiopi, 3.18 km (Figure 2).

SITES AND SAMPLES

The faunal remains discussed here were recovered from two controlled excavation units at Va'oto (AS-13-13) and two units at Vaiopi (AS-12-3). Both sites reflect relatively intensive cultural deposition, either through permanent or recurrent occupation, over three to four centuries in the 1st millennium BC. As such, each assemblage is treated as a single temporal unit for comparison. Excavations at both sites reported here were directed by Clark and followed comparable procedures. All units were 1 m x 2 m and excavation proceeded by arbitrary 10 cm levels within cultural layers. Sediments from cultural layers were dry-sieved through 6.4 mm mesh, although one unit at each site was sieved though 3.2 mm mesh (i.e. Vaiopi, unit 12W/10N only). Features were wet-sieved separately through 1.6 mm mesh. Bone identified during excavation and sieving was bagged separately, and no further sorting was conducted in the field. Each site will be described separately below in terms of location, stratigraphy, and chronology. Only general stratigraphic summaries for each site are given here for context, with detailed stratigraphic descriptions for individual units across each site to be provided elsewhere. The focus of this study is the recovered vertebrate remains but we note that invertebrate remains were recovered from these sites and will be considered separately.

Va'oto Site (AS-13-13)

The Vaʻoto coastal plain is a small, low, predominantly sandy flat that constitutes the southwestern apex of Ofu Island. The Vaʻoto site is located in the large yard of the Vaʻoto Lodge (modern houses and rental cottages) (Figure 2). The site was first reported by Best (1992), who excavated two 1 m^2 units in the Lodge yard, and reported pottery sherds, which suggested early site occupation. Over successive years Clark (1997, 1999) and Clark and Quintus (2010-2013) conducted excavations at the site as part of a larger settlement system investigation on Ofu. The total site area is estimated to cover 3000-4000 m^2 with 52 m^2 excavated across 27 individual units. The northern and western portions of the site have been disturbed by the construction of the lodge buildings, but the core area of the buried site lying between the lodge and ocean is intact (Figure 4a). The seaward edge of the site is ~36 m from the modern beach crest and the inland boundary is near the talus edge of the steeply rising basalt cliffs.

Two excavation units were selected for detailed vertebrate faunal analysis (38E/9N in the south-central area of the site, and 22E/15N in the west-central area) as the stratigraphic variation in these units is representative of the variability documented across the site (Figure 4b). Unit 38E/9N was excavated to a depth of 170 cm below the surface (cmbs) and unit 22E/15N to 175 cmbs. Layer I is a clay-rich colluvium derived from talus slope erosion and redeposition over portions of the sandy coastal plain. Layer II is a sandy loam reflecting a significant admixture of sand with colluvium and further distinguished by the presence of scattered coral rubble, larger coral chunks, and basalt cobbles. Small amounts of pottery, lithics, and shell (some possibly midden) were recovered from this layer. However, historic artefacts and modern carbon are also present in Layer II that reflects modern bulldozer disturbance. The primary intact occupation layers are III, IV, and V, which contain abundant artefacts – including pottery, basaltic and volcanic glass tools and flakes, shell artefacts (fishhooks, ornaments, and scrapers), urchin-spine abraders, and more – as well as bone and mollusc remains. Layer IV is divided into sublayers based on variations in sediment colour, which was largely based on charcoal staining from combustion features. Layer VI is similar in appearance to modern beach sand. The few small ceramic sherds found in the upper centimetres of this layer are most likely the product of downward movement into otherwise culturally sterile sediments, or conceivably may reflect very earlier limited human presence.

Radiocarbon (AMS) and U-Th dates for the site have been reported (Clark *et al.* 2016) and additional radiocarbon dates on short-lived material refine this chronology (Figure 5;

Supplement 1). Initial human activity began at the site by 2500 calBP or slightly earlier (Layers V and VI in the eastern half of the site and Layer IV and V in the western half), based on a U-Th date from near the base of the deposit (Lab ID 2014-23: 2510-2496 cal BC, 2σ) and several radiocarbon dates on short-lived material (Wk-46269, WK-46271, ICA-17C/0882). Some radiocarbon date ranges do extend further back in time relative to the age on the coral, though this is common when comparing radiocarbon to U-series calibrations due to the typically low standard errors of the latter (e.g. Weisler *et al.* 2006b:Figure 8). Ceramic-depositing occupation at the site ended by 2100 BP or earlier (WK-46272, ICA-17C/0881), although some limited use of the area took place afterward until modern residences were established in the mid to late 20th century.

Vaiopi Site (AS-12-3)

Stretching along the southwest coast of Olosega is the elongated Olosega coastal flat. The modern village of Olosega is dispersed along the sandy flat, primarily between the ocean and the long, narrow Olosega freshwater marsh, the inland edge of which is bounded by high, steep, basaltic cliffs (Figure 6a). In 2013, archaeologists of the American Samoa Power Authority (ASPA) discovered the Vaiopi site when pottery sherds were found in the spoil from a small construction project. The site is toward the northwest end of the flat, with the beginning of the Olosega marsh roughly 320 m to the southeast (Figure 2). Today the site is ~45 m from the beach crest. Two channels through the reef (‘*ava*), which would have provided easy access to the ocean, lie ~80 and ~280 m to the southeast of the site. Excavations conducted by Clark in 2015 covered 20 m^2 in 10 controlled excavation units, eight 1 m x 2 m units in a 16 m^2 Cartesian block, with two additional 1 m x 2 m units several metres away.

One excavation unit from the block (12W/10N) and one of the isolated units (1E/21N) were selected for detailed vertebrate faunal analysis (Figure 6b). These selected units represented both geographic (coast to inland) and stratigraphic variation. Unit 12W/10N was excavated to a depth of 195 cmbs and unit 1E/21N to 220 cmbs. Stratigraphic observations were aided by a backhoe trench on the western edge of the site. Six stratigraphic layers were defined during excavation (I-VI) of the site. Layers I and II are thick deposits of clay-rich colluvium, which reflect major slumping or slide events from the steep ridge slopes that back the coastal flat. The colluvium caps Layer III, which is the upper extent of the cultural deposit. Layers IV, V and VI are sand deposits distinguished primarily by colour. Artefacts recovered parallel those found at Va‘oto, though not as numerous, and comparatively few features – primarily small combustion features – were encountered. Culturally sterile Layer VII consists of cross-bedded coarse sand indicative of a high-energy depositional environment, immediately proximal to the former coastline.

Radiocarbon dates were obtained from three samples of carbonised coconut endocarp (Figure 5; Supplement 1). From unit 11W/10N, adjacent to 12W/10N, Layer VI produced a date of 2409-2335 calBP (95.4%) (WK-45389). Some 20-25 cm of Layer VI deposit underlay this sample, but its depth (162-170 cmbs) suggests that it approximately represents the commencement of occupation at the site. From 1E/21N, Layer IV, at 110-120 cmbs, a date of 2670-2356 calBP (95.4%) (WK-45392) was reported. This date is just slightly earlier than the radiocarbon determination reported from 11W/10N, and is at least 30 cm above the proposed beginning of occupation, suggesting that the site was initially occupied sometime prior to 2400 BP. The third date was obtained from the backhoe trench, in a fireplace at the top of Layer III, therefore slightly pre-dating the colluvium event that covered the site and terminated the ceramic period occupation. The date of 2350-2181 calBP (95.4%) (WK-45386) is surprisingly early and suggests a very rapid build-up of sand from early in the occupation to termination. These dates suggest that deposition of these layers began before 2400 calBP and ended around or a little after 2300 calBP.

Unfortunately, there are also modern ages for radiocarbon determinations that derive from the ceramic-bearing layers indicating at least some intrusive material. Two of these dated samples are from the interface between Layer II and III and likely derive from the mixed colluvium layer. The other three are from within the primary cultural deposits and may have been introduced by crab activity. Based on the presence of ceramics throughout Layers III through VI at the site and the absence of historic artefacts from these ceramic-bearing deposits, we suggest that the pre-2000 calBP dates are a true reflection of the age of the material, though the incorporation of some intrusive faunal material cannot be ruled out.

METHODS

Identification and quantification protocols

Vertebrate faunal remains were sorted at the University of Queensland into the classes indeterminate vertebrate, human, rat, fish, turtle, and bird. Detailed analysis of the rat, turtle and fish remains were conducted at the University of Queensland (Weisler and Lambrides), the human remains at the University of Otago (Buckley) and bird remains at Flinders University (Worthy). All taxonomic identifications were conducted using comprehensive reference collections. Fish were identified using the reference collection at the University of Queensland, which contains 45 families, 94 genera and 169 species. All bone fragments were considered for taxonomic identification, and genus- and species-level identifications assigned conservatively to avoid over-identification (Driver 1992; Lambrides & Weisler 2016; Wolverton 2013). All vertebrate faunal remains were quantified using number of identified specimens (NISP) and minimum number of individuals (MNI).

Statistical analysis

Both sites were dominated by fish remains and only these assemblages provided an adequate sample size for more detailed consideration of assemblage similarity and taxonomic heterogeneity. Assemblage similarity was determined using methods developed by Giovas (2021) whereby a paired-index approach utilising the corrected Forbes and Morisita-Horn indices allows assemblages to be evaluated according to their dissimilarity, qualitative similarity, quantitative similarity, or substantive similarity. The Forbes index tracks the degree of taxonomic correspondence and is robust to sample size effects and species richness, which importantly for zooarchaeological assemblages is true when sampling is unequal (Alroy 2015; Giovas 2021). The Morisita-Horn index documents exploitation intensity and is not strongly influenced by species richness and sample size and rare species tend to have little effect, but critically, it is sensitive to the abundance of the most abundant species (Magurran 2004; Magurran & McGill 2010; see Giovas 2018 for a zooarchaeological application). For both indices, values of 1.0 indicate the assemblages or sites are similar. Taxonomic heterogeneity was measured using NTAXA, Shannon–Wiener index of diversity (H'), Shannon's evenness (E), Simpson's dominance ($1 - D$), and Fisher's α. Taxonomic richness was documented using NTAXA values. H' values fall below a theoretical value of 5, with high values suggesting greater taxonomic diversity and richness. E and $1 - D$ values are scaled from 0 – 1 with values closer to 1 indicating rich and even assemblages (Lyman 2008). Fisher's α tracks taxa represented by single individuals and provides an assessment of diversity that is independent of sample size (Faith 2013; Hayek & Buzas 2010). Coarse-grained feeding behaviour categories (e.g. Butler 1994; Lambrides *et al.* 2018) and habitat preferences (e.g. Giovas 2016; Newsom and Wing 2004) were assigned to fish taxa in order to examine broad scale distinctions in species selection and targeted fishing zones. This level of resolution was deemed suitable for this study, especially as comparisons between sites were by fish assigned to predominantly the family- and less so genus-level (also see discussions in Giovas *et al.* 2017; Weisler & Green 2013).

All analyses were calculated using NISP values to maximise available sample size and utilising non-overlapping taxonomic assignments (i.e. mutually exclusive categories) (Giovas 2021; Lyman 2008). All statistical analyses were completed using PAST, version 4.01 (Hammer *et al.* 2001) and Microsoft Excel functions.

RESULTS

Indeterminate Vertebrata

These are fragments that are likely from rat, bird, human or turtle, since no dog or pig bones were identified from the sites. A total of 118 bones weighed 22.9 g (average weight = 0.19 g). Using only morphological traits, it was not possible to separate small fragments of cortical bone which could be human or turtle. Very small mid shafts of long bones were equivocal for assigning to rat or bird.

Birds

There were 20 bird bones with an MNI of 13 divided almost evenly between chicken (*Gallus gallus*) and sea birds in the Procellariidae family consisting of shearwaters and petrels. All Procellariidae are those of adults. There are no obvious differences in bird species selection between the Va‘oto and Vaiopi sites. From the stratigraphic position of the chicken bones at both sites, these domesticates would have been introduced at the time of or shortly after initial occupation of the sites approximately 2500-2400 BP.

Mammals

Human

From the Va‘oto site, Feature 65B in unit 38E/9N (Layer V) was the partial skeleton of a human infant that was assessed using the macroscopic method of identification and age estimation. The remains consisted of a partial cranium, vertebral centra and postcranial skeletal elements from primarily the lower limbs. There was no dental material present. Most of the elements were fragmented to some degree but the left femur and left tibia diaphyses were near complete. Age was estimated as perinatal (specifically from 36-40 fetal weeks) from the femur and tibia diaphyseal lengths and degree of development of vertebral and cranial elements (Scheuer & Black 2000). No pathology was observed in the bony material. Feature 65B was just beneath the large oven of Feature 65 in the south half of the unit and was marked by a circular concentration of coral rubble and basalt pebbles that overlaid a concentration of bone, here identified as fetal, but not recognised as human by the excavator. A little over a metre to the north, cutting from the base of Layer V into Layer VI was a burial pit (Feature 69), although only the skull was present in this unit. The burial was subsequently revealed in the adjacent unit (39E/9N) and was female in a flexed position. Additionally from the Va‘oto site, scattered through Layer IV (in several spits between 79-134 cmbs) were 26 long bone fragments from the femur, tibia and humerus as well as one premolar fragment from Layer III. No human remains were recovered from the Vaiopi units examined, although human bone was encountered in other units.

Rat

Rat bones were by far the most numerous non-fish remains across all layers from both sites (Table 1). Some 121 bones (MNI = 15) of rat were recovered weighing a total of 3.7 g (average = 0.03 g). Nearly all elements of the skeleton were used for identification and included in rank-order: vertebrae (cervical, lumbar, and caudal), innominate, femur, tibia, incisor, humerus, mandible, maxilla, sacrum, phalange, and cranial. The bones were of a size that compared favourably with a Pacific rat *Rattus exulans* reference specimen. None of the bones were burnt and when it was possible to determine growth stage, all bones except one were adult (*n* = 7). It should be noted that ~28.5 g of rat bone from the Va‘oto site (unit 22E/15N, Layer IV and V) was sent for DNA extraction prior to this analysis and therefore was not included in the reported counts and weights. That effort, which was unsuccessful, accounts for much of the difference in rat bone relative abundance between the two sites (Table 1). While rat bone was found scattered throughout the cultural layers of both sites, there were also occasional pockets of densely concentrated rat bones, as was the case in unit 22E/15N. Sometimes bones in those concentrations were effectively cemented together as a mass, thus prohibiting accurate, detailed counts of specific bones.

Turtle

All recovered turtle bones were small fragments and assigned to the family-level (Cheloniidae). All but three of the 19 bones (mean weight = 0.1 g) were from Vaiopi (Table 1). Plastron fragments were used for identification aside from one proximal and one terminal digit from flippers belonging to juveniles. Individuals not of egg-laying age may have been taken at sea, possibly in the shallows.

Fish

A total of 764 (92.4 g) fish bones were recovered from Va‘oto and 3009 (267.9 g) from Vaiopi (Table 2). Overall, 1025 fish bones were identified to taxon (~27.2%), the majority of these were recovered from Vaiopi and mostly represented by family and genus identifications. No evidence of burning was recorded and less than one per cent of bones were affected by digestive processes, with all cases being vertebrae that were characterised as deformed (Butler & Schroeder 1998: 960).

Overall, diodontids (porcupinefish), acanthurids (surgeonfish), serranids (grouper), and muraenids (moray eel) were the most frequent across both sites, which accounted for 53.5% (Va‘oto) and 60.8% (Vaiopi) of total NISP (Table 2). There is some variability between taxonomic representation across sites when the top five highest ranked families are quantified using MNI values. For Va‘oto, acanthurids, scarids (parrotfish), serranids, muraenids, and labrids (wrasse) account for 52.9% of total MNI, compared to Vaiopi, with acanthurids, holocentrids (squirrelfish and soldierfish), scarids, carangids (jack), and serranids accounting for 51.2% of total MNI. Corrected Forbes and Morisita-Horn statistics were calculated to determine the degree of similarity between sites. High $S_{F'}$ (0.971) and $S_{M\text{-}H}$ (0.920) values were reported, which indicates an emphasis on a similar range of taxa and a comparable level of exploitation between sites. This was further supported by the measures of taxonomic heterogeneity, which suggest high taxonomic richness and low dominance at both Va‘oto (NTAXA = 21, H' = 2.599, E = 0.854, 1 – D = 0.905, Fisher’s α = 7.779) and Vaiopi (NTAXA = 25, H' = 2.437, E = 0.757, 1 – D = 0.879, Fisher’s α = 4.883).

There was variability in the familial composition of each site identified in terms of rare or unique taxa. Coryphaenids (mahi-mahi) and elasmobranchs (sharks, skates, and rays) were only associated with the Va‘oto site, and belonids (needlefish), chaetodontids (butterflyfish), fistulariids (cornetfish), mugilids (mullet), pomacentrids (damselfish), and priacanthids (bigeye) with Vaiopi. At Vaiopi, there was a minimal increased emphasis on omnivores/benthic carnivores and piscivores, compared to Va‘oto where a higher relative proportion of herbivores were targeted, which was driven primarily by the exploitation of acanthurids and scarids (Figure 7a). At both sites, fishing efforts broadly targeted a similar range of habitat types with coral reef dwelling species (e.g. acanthurids, serranids, muraenids, holocentrids, labrids, and scarids) dominant and contributing ~75-88% (NISP and MNI) of the catch (Figure 7b). A slightly higher level of pelagic fishing (e.g. belonids, carangids, exocoetids [flying fish]) was inferred for Vaiopi, with an increased focus on inshore/shallow water species (e.g. elasmobranchs, mullids [goatfish], siganids [rabbitfish]) at Va‘oto. The Va‘oto and Vaiopi assemblages also contributed new fish taxonomic records for Samoa with the first archaeological reports of *Elagatis bipinnulata* (rainbow runner), Chaetodontidae, *Gnathodentex aureolineatus* (striped large-eye bream), *Mulloidichthys* sp. (goatfish), *Parupeneus* sp. (goatfish), Priacanthidae (bigeye), *Gymnosarda unicolor* (dogtooth tuna), and Siganidae.

DISCUSSION

Va‘oto (Ofu Island) and Vaiopi (Olosega Island), while located on different islands, are separated only by ~5 km and are situated in similar environmental settings: fronted by sandy beaches and narrow fringing reef, backed by steep cliffs, and near freshwater marshes. The archaeological deposits are deeply stratified (~170-220 cmbs), and both sites were occupied for a comparable and relatively short period of time (Va‘oto: ~2500-2100 BP and Vaiopi: pre-2400-2300 BP), which post-dates the earliest evidence for occupation of the islands of Manu‘a by ~200 years. The location of these sites is consistent with settlement patterns documented for the earliest occupation of these islands, with early sites predominately concentrated on the coastal flats adjacent to the expansive reef habitats (Clark *et al.* 2016; Petchey & Kirch 2019). Foraging efforts at the Va‘oto and Vaiopi sites were primarily focused on the marine environment, but with contemporaneous evidence for terrestrial resource exploitation (e.g. seabirds at nesting colonies) including the introduction of exotic species (i.e. red junglefowl and Pacific rat).

There is evidence for the exploitation of turtles (Cheloniidae) at both sites from initial occupation and through the successive centuries of site use. Furthermore, turtle bone abundance from Va‘oto (NISP = 3) and Vaiopi (NISP = 16) was comparative to the early period deposits from Ofu Village (XU4; NISP = 29) and To‘aga sites (1987 main excavation; NISP = 3) (Nagaoka 1993; Weisler *et al.* 2016). There has been some suggestion that foraging efforts or encroachment on nesting zones may have contributed to a reduction in turtle populations during the more recent past (Rieth & Cochrane 2012; Weisler *et al.* 2016). In the case of Ofu and Olosega Islands, potential declines in turtle exploitation may also relate to coastal beach erosion (and the removal of nesting habitat) exacerbated by sea level changes, which occurred from around 2000 BP at a time when terrestrial production was also expanding (e.g. Kirch & Hunt 1993; Quintus 2015). At any rate, these changes in turtle use have been documented at sites occupied well after the cessation of settlement at the Va‘oto and Vaiopi sites where the frequency of turtle remains was low. Indeed, the south coast of Ofu is a turtle nesting area today. It is apparent that further excavations, larger samples, and particularly additional records from the past ~1500 years are required to examine these post-colonisation changes in human-turtle interactions across the islands of Manu‘a.

A small number of seabird (shearwater and petrel; Procellariidae) remains were recovered from both sites, but no evidence of landbird exploitation (e.g. rails and pigeons) was documented, unlike at the Ofu Village (Weisler *et al.* 2016) and To‘aga sites (Steadman 1993). Shearwaters and petrels are medium-sized pelagic birds that burrow, especially in sandy deposits, to make nests in large colonies (Pratt *et al.* 1987). All targeted individuals were adults, which visit colonies at night, and were possibly captured when they returned to them. However, it should be noted that many individuals also visit colonies to seek mates (among other reasons), and all can be brought to ground by calling them in using a light source. In terms of exotic species, both red junglefowl (or chicken) and Pacific rat were introduced at the time of or shortly after initial occupation of Va‘oto and Vaiopi (approximately 2500-2400 BP), which is consistent with the identification of chicken and rat remains from the earliest layers of the Ofu Village and To‘aga sites (Weisler *et al.* 2016; Steadman 1993). There is no indication of pig, dog, or Pacific flying fox exploitation at either Va‘oto or Vaiopi. These sites add to the growing body of evidence that suggest pigs were not introduced with the earliest colonists, however, these outcomes could be a result of sampling error rather than true absence. The appearance of pig remains is often regarded as a proxy for increased gardening and terrestrial production (Kirch & Yen 1982), but there is limited evidence of pig bone archaeologically from Samoa and all recovered remains appear to date to the past ~800 years (e.g. Davidson 1969; Ishimura & Inoue 2006; Nagaoka 1993; Weisler *et al.* 2016). Pacific flying fox (*Pteropus tonganus*) has only been identified from one Samoan archaeological site (Ofu Village) and dated to ~690-570 calBP (Weisler *et al.* 2016). It has been proposed that this species may have been a human introduction as appears to have been the case for the Austral Islands (Weisler *et al.* 2006a; Worthy & Bollt 2011). The absence of Pacific flying fox from Vaʻoto, Vaiopi, and Toʻaga may further support the late introduction of this species to Samoa, assuming it is a human introduction, and/or its late incorporation into subsistence regimes.

Overall, the vertebrate faunal record is dominated by fish remains. Inshore and coral reef species, such as acanthurids, serranids, muraenids, holocentrids, labrids, and scarids were common and overall a high degree of similarity in foraging patterns was reported between sites. In terms of fishing technology, a number of fishhooks (Vaʻoto = 26 and Vaiopi = 24) were recovered, along with unfinished hooks, tabs, and probable core shells (*Turbo* sp.) from which tabs had been removed. There were also sea urchin (*Heterocentrotus* sp.) spine files (Vaʻoto = 53 and Vaiopi = 65) and coral and basalt abraders recorded, which were probably associated with the manufacturing of shell implements. Fishhook assemblages contained small hooks, mostly constructed from *Turbo* sp. with a few from *Pinctada* sp., in both rotating and jabbing forms, although rotating hooks predominate (Quintus & Clark 2020). It was concluded that the sizes and shapes of the hooks was most consistent with angling carried out in largely inshore environments and off the reef crest on the reef slope (Quintus & Clark 2020). This postulated harvesting strategy is consistent with fish bone evidence from Vaʻoto and Vaiopi and the documented focus on predominantly small-bodied inshore coral reef species, indicating that angling was probably not the dominant capture strategy exploited. This also is supported by documented taxonomic composition and related artefacts, such as the recovery of probable net weights (basalt, coral, and shell) from Vaʻoto.

This high degree of similarity in terms of species composition between fish assemblages from Vaʻoto and Vaiopi is notable given that Lawrence and Sudek (2016) reported modern distinctions in fish population structure across Ofu and Olosega. Reef habitats in proximity to the Vaiopi (Olosega south coast) today are associated with an equal or higher proportion of lower carnivores relative to herbivores, whereas faunal composition adjacent to the Vaʻoto site (Ofu south coast) are dominated by herbivorous fish. Archaeological results did indicate a minimally higher relative abundance of piscivores, and omnivores/benthic carnivores compared to herbivores for Vaiopi, with the opposite being reported for Vaʻoto, which is in accordance with modern reef fish surveys (Lawrence & Sudek 2016). Comparative analyses indicate an emphasis on a similar range of taxa and a comparable level of exploitation between sites (Table 3). These outcomes may suggest, (1) that benthic habitat structure and fish species composition of the reefs adjacent to these sites were more similar in the past than they are today (assuming people fished in relative proximity to the sites), and/or (2) the important role of cultural preference on species selection and size (e.g. Lambrides *et al.* 2019; Rogers & Weisler 2021; Weisler & McNiven 2016; Weisler & Rogers 2021), whereby a similar range of culturally preferred species were being selected for consumption across sites.

At the Ofu Village site (Ofu west coast), where we have evidence for fish use over an extended time period, an increase in the relative abundance of piscivores compared to herbivores was reported between ~2700 BP and post-800 BP (Weisler *et al.* 2016). This increase in the exploitation of piscivores does correspond with modern surveys of the adjacent marine environment, where reefs today are populated by an equal or higher proportion of lower carnivores relative to herbivores (Lawrence & Sudek 2016). The fish records from Ofu Village offer potential evidence that the benthic habitat structure and fish species composition of reefs adjacent to Ofu and Olosega may have been more similar in the past than has been observed today, particularly in view of the high degree of similarity in targeted species between sites and cultural layers that represent some of the earliest occupation of these islands (e.g. Ofu Village, Va‘oto, To‘aga, and Vaiopi). Specifically, when the same paired-index approach is applied to all available early period fish assemblages from Manu‘a it is evident that these sites are substantively similar in terms of the targeted taxa and associated relative abundance (Table 3). The one exception is the Ofu Village and To‘aga site pair, where a high $S_{F'}$ (0.964) value, but a low $S_{M\text{-}H}$ (0.404) value was reported, which is below the 50% similarity threshold. This indicates many overlapping taxa between the two sites, but different proportional abundances. Further investigation indicates that this pattern is likely driven by the distinction between sites in the relative abundance of diodontid remains (NISP: Ofu Village = 28 and To‘aga = 285; also see rank-order abundance in Table 4). When diodontids are excluded from the analysis a high $S_{M\text{-}H}$ (0.845) value was reported. Diodontids are known to have more than 200 dermal spines per individual, which preserve well archaeologically and are readily identified to family. The MNI values are not available for the To‘aga site to further interrogate this trend, but given this analysis was completed in the 1990s using only the five-paired cranial and ‘special’ bones (Nagaoka 1993; see Lambrides and Weisler 2015 for a discussion of fish taxonomic identification procedures in the Pacific), it is likely the relative importance of this taxon was inflated.

There is still evidence for the exploitation of unique taxa at Va‘oto and Vaiopi, with belonids, chaetodontids, fistulariids, mugilids, pomacentrids and priacanthids only identified at Vaiopi, and coryphaenids and elasmobranchs only at Va‘oto. When considering the available records of fish exploitation for the Manu‘a Group, there is also evidence for the exploitation of taxa unique to each island, with tetraodontids (pufferfish) only recovered from Ta‘u, sphyraenids (barracuda), aulostomids (trumpetfish), kyphosids (sea chub), and coryphaenids from Ofu, and chaetodontids, pomacentrids, and priacanthids from Olosega (this study; Cleghorn & Shapiro 2000; Nagaoka 1993; Weisler *et al.* 2016). However, most archaeological fish records are from Ofu and data availability is regionally limited, so ultimately sampling is influencing our understanding of spatial variability in the selection of unique species across the Manu‘a Group. Whether the distribution of these unique taxa represents variability in foraging practices and species preferences between islands or is merely a measure of the exploitation or chance encounter of some species is unknown. Given the fish families identified archaeologically only comprise a small percentage of the total diversity of fish that theoretically would have been available for exploitation in the past, it is likely that stochastic effects of small sample size have influenced these reported outcomes. A Spearman’s correlation coefficient (r_s) was calculated to determine whether sample size was correlated with NTAXA at Va‘oto and Vaiopi and results indicated a strong correlation ($r_s = 0.70$, $p = <0.001$). However, it should be noted that the sample sizes reported here from Va‘oto and Vaiopi are relatively consistent with other published faunal datasets from Samoa in terms of the number of bones recovered, but with a higher percentage of the fish assemblage identified to taxon. This was due to the identification of all recovered fish bone elements (see Weisler *et al.* 2016 for Ofu Village), not just a limited range of cranial elements (e.g. dentary, premaxilla, maxilla, quadrate, and articular).

Recently collected fish catch data from Ofu and Olosega reveals that the range of species reported for the modern subsistence fishery (Craig *et al.* 2008), is similar to that targeted in the past, particularly those species that were and continue to be the dominant focus of subsistence regimes (e.g. scarids, acanthurids, serranids, holocentrids and carangids; see Table 4). Sabater and Carroll (2009) reported similar trends when evaluating the entire American Samoa coral reef fishery over the past three millennia. They suggested these marine resources were potentially utilised sustainably through time as supported by a correlation analysis of the proportional contribution of reef fish families represented archaeologically, in present reef surveys, present catch numbers, and fish species preference recorded during interviews (Sabater & Carroll 2009:323; see also Craig *et al.* 2008; Levine & Sauafea-Le‘au 2013).

However, only the archaeological fish bone evidence from the To‘aga site was available at that time (Nagaoka 1993), and the majority of comparative records (e.g. underwater visual census, catch history data etc.) used for the study documented post-1977 fishery dynamics. This study (Va‘oto and Vaiopi) and our earlier work (Ofu Village) has significantly increased the available early period faunal records from Ofu and Olosega. These outcomes are consistent with stability rather than change in resource availability, as hypothesised by Nagaoka (1993), although additional records are required for a more robust conclusion. While comparisons between archaeological, historic, and modern catch datasets can be limited in their precision, these historical approaches do enable the exploration of factors that drive long-term ecological change over millennia not just over the past ~50 years when underwater reef surveys and fish catch data were more systemically recorded globally (e.g. Kittinger *et al.* 2011; McClenachan & Kittinger 2013; McKechnie *et al.* 2014).

Available archaeological evidence from Ofu and Olosega does suggest that a wider range of families were exploited in the past, but this is potentially due to the time-averaged of fishing records and increased opportunity to record rare taxa. However, it is certainly possible that a wider range of families were targeted or available for exploitation in the past. Pelagic species were present in archaeological assemblages from the Manu‘a Group (e.g. belonids, coryphaenids, exocoetids, scombrids, sphyraenids), but are present in low numbers compared to inshore and coral reef species, which is consistent with modern observations where focused efforts on the inshore fishery have been reported (Craig *et al.* 2008). Modern fisheries research has also reported a recent decline in the abundance of sharks in nearshore waters, potentially linked to fishing pressure (Craig *et al.* 2008). There is evidence for the exploitation of sharks and rays (elasmobranchs) from all analysed sites on Ta‘u and Ofu (this study; Cleghorn & Shapiro 2000; Nagaoka 1993; Weisler *et al.* 2016), but not Olosega. The archaeological records suggest limited exploitation of elasmobranchs, which may indicate these modern observed declines occurred in the very recent past (but see Levine & Sauafea-Le‘au 2013). One notable distinction between the archaeological and modern catch data is the relative abundance of mullids (goatfish), which are represented in low numbers archaeologically, but were the second most commonly taken species in modern catches (Craig *et al.* 2008). These were predominantly juvenile yellowstripe goatfish (*Mulloidichthys flavolineatus*) caught in hand-woven baskets along the shorelines during a large 6-week recruitment event. The archaeological absence of these temporally constrained events may relate to modern shifts in juvenile yellowstripe goatfish recruitment patterns, issues of archaeological preservation and sampling, differences in fish bone discard behaviour following these events, or, less likely, this species may not have been targeted for exploitation in the past. Interestingly, goatfish (*Mulloidichthys vanicolensis*) were used as bait in the Marshall Islands to catch emperors, groupers and snappers (Weisler 2001: 108) and therefore would not be visible in archaeological sites.

CONCLUSION

The vertebrate faunal records from the Va‘oto (Ofu Island) and Vaiopi (Olosega Island) archaeological sites have enhanced our understanding of subsistence regimes on these small islands for some of the early colonists of the Samoan Archipelago by documenting interaction with the reef and terrestrial habitats including the introduction of commensal animals. Available evidence from these sites and from the region suggests marine resources were the primary foraging targets during the earlier, pottery-bearing phases of occupation. Over the past ~2000 years the relative contribution of marine resources to subsistence regimes declined due to enhanced terrestrial production, and expansion into the interior of these islands (Kirch & Hunt 1993; Quintus 2015; Quintus & Clark 2017; Quintus *et al.* 2015). With the exception of Pacific rat and human bone (burials and scattered) recovered from the Va‘oto and Vaiopi sites, non-fish vertebrate remains were not common and consisted primarily of avifauna and turtle. The relative abundance and taxonomic distribution of exploited bird species (i.e. Phasianidae and Procellariidae) and turtle (Cheloniidae) is broadly similar between early period faunal assemblages from Ofu (i.e Ofu Village, Va‘oto, and To‘aga) and Olosega (i.e.Vaiopi). The absence of definitively identified pig, dog, and Pacific flying fox at both Va‘oto or Vaiopi is consistent with early (ceramic) occupation layers elsewhere in Manu‘a and indeed across Samoa, Tonga and Fiji. It is conceivable that some of the very small, fragmented indeterminate vertebrate bones reported for some sites may in fact be pig, dog or flying fox, and further analyses such as ZooMS (e.g. Buckley *et al.* 2010) may provide an additional line of evidence to further explore whether these three species are post-first-millennium introductions (intentional or otherwise) in the archipelago.

For fish, our results suggest a high degree of similarity in foraging decisions across the islands of Ofu and Olosega during the early period of the cultural sequence; there is little evidence for site specialisation based on the targeted taxa and associated relative abundance. Furthermore, we documented a high degree of similarity between the fish species exploited in the past (i.e. early period records from Ofu Village, Va‘oto, To‘aga, and Vaiopi) to those harvested today by modern subsistence fishers in the region, which is despite the probable wide-scale coastal landscape evolution that has occurred over the past ~2700 years. While additional archaeological fish bone records are still required for the Manu‘a Group (but see Morrison & Addison 2009; Rieth & Morrison 2017 for Tutuila Island), particularly for the past ~1500 years due to low sample size, outcomes based on existing early period records are consistent with a continuation or degree of stability rather than a change in the range of species available for exploitation today as in the past. This suggests that there were no adverse impacts to the marine fishery through time as also supported by earlier studies in the region (Craig *et al.* 2008; Sabater & Carroll 2009), although we also note the insufficiency of available archaeologically derived faunal records for reaching firm conclusions about whether the fishery was sustainably exploited over the past ~2700 years.

This study has nearly doubled the number of sites from Manu‘a with published faunal records, particularly assemblages dating to the early period of island use, and while this has facilitated a more systematic comparison between sites, available marine and terrestrial faunal records are still limited when compared to other regions of the Pacific. Future zooarchaeological research in Samoa is required to extend the data available from which to consider the complex and dynamic role of social, cultural, and ecological factors in underwriting the observed regional changes in subsistence regimes, including potential variability in regional-level economic systems and settlement organisation.

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Table 1. Bird, rat, human and turtle remains recovered from Va‘oto and Vaiopi. Note that MNI values were calculated according to cultural layers, and only the site totals are presented here.

		Va‘oto (2500-2100 BP)				**Vaiopi (pre-2400-2300 BP)**			
Taxon	**Common name**	**NISP**	**%NISP**	**MNI**	**%MNI**	**NISP**	**%NISP**	**MNI**	**%MNI**
Aves									
(Domesticates)									
Phasianidae									
Gallus sp.	Red junglefowl	4	1.24	2	15.38	3	1.38	3	13.04
cf. *Gallus* sp.		2	0.62	1	7.69				
(Seabirds)									
Procellariidae	Shearwaters and petrels					2	0.92	2	8.70
Pterodroma sp. (large)	Petrel	2	0.62	2	15.38				
Puffinus sp.	Shearwater	2	0.62	1	7.69				
Puffinus sp. magn *P. pacificus*						1	0.46	1	4.35
Puffinus pacificus	Wedge-tailed shearwater					4	1.83	1	4.35
Mammalia									
Hominidae									
Homo sapiens	Human	262	81.37	3	23.08				
Muridae									
Rattus cf. *exulans*	Pacific rat	8	2.48	2	15.38	113	51.83	13	56.52
Reptilia									
Cheloniidae	Sea turtle	3	0.93	2	15.38	16	7.34	3	13.04
Indeterminate Vertebrata	Rat, bird, turtle	39	12.11			79	36.24		
Total identified		**322**		**13**		**218**		**23**	

Table 2. Fish remains recovered from Vaʻoto and Vaiopi. Note that MNI values were calculated according to cultural layers, and only the site totals are presented here. Feeding behaviour and habitat preference data was obtained from FishBase (Froese & Pauly 2021) and Randall (2005).

		Feeding Behaviour	**Habitat**	**Vaʻoto (2500-2100 BP)**				**Vaiopi (pre-2400-2300 BP)**			
Taxon	**Common name**			**NISP**	**%NISP**	**MNI**	**%MNI**	**NISP**	**%NISP**	**MNI**	**%MNI**
Chondrichthyes											
Elasmobranchii	sharks, skates, and rays	P	Insh	5	2.35	4	4.71				
Actinopterygii											
Indeterminate (element only)		N/A		14				25			
Acanthuridae	surgeonfish	H	Cor	26	12.21	9	10.59	76	9.36	15	8.52
Acanthurus sp.		H	Cor	1	0.47	1	1.18	3	0.37	2	1.14
Ctenochaetus sp.		H	Cor					1	0.12	1	0.57
Naso sp.		H	Cor	5	2.35	4	4.71	3	0.37	3	1.70
Balistidae	triggerfish	O/BC	Cor	5	2.35	1	1.18	27	3.33	7	3.98
Belonidae	needlefish	P	Pel					3	0.37	3	1.70
Bothidae	lefteye flounder	O/BC	Insh	1	0.47	1	1.18	2	0.25	1	0.57
Carangidae	jack and trevally	P	Insh/Pel	2	0.94	2	2.35	7	0.86	4	2.27
Carangoides sp.		P	Insh	2	0.94	1	1.18	1	0.12	1	0.57
Caranx sp.		P	Insh					8	0.99	6	3.41
Elagatis bipinnulata	rainbow runner	P	Pel					2	0.25	1	0.57
Selar sp.		P	Pel					3	0.37	3	1.70
Chaetodontidae	butterflyfish	O/BC	Cor					4	0.49	3	1.70
Cirrhitidae	hawkfish	O/BC	Cor	9	4.23	3	3.53	15	1.85	6	3.41
Congridae	conger and garden eels	P	Cor	3	1.41	2	2.35	18	2.22	5	2.84
Coryphaenidae											
Coryphaena hippurus	mahi-mahi	P	Pel	1	0.47	1	1.18				
Diodontidae	porcupine										
Diodon sp.		O/BC	Cor	35	16.43	5	5.88	193	23.77	6	3.41
Exocoetidae	flying fish	O/BC	Pel	13	6.10	3	3.53	53	6.53	7	3.98
Fistulariidae	cornetfish										
Fistularia sp.		P	Cor					2	0.25	2	1.14
Holocentridae	squirrelfish and soldierfish	O/BC	Cor	6	2.82	1	1.18	18	2.22	8	4.55
Myripristis sp.		O/BC	Cor	1	0.47	1	1.18	20	2.46	7	3.98
Sargocentron sp.		O/BC	Cor	2	0.94	2	2.35	20	2.46	5	2.84
Labridae	wrasse	O/BC	Cor	12	5.63	6	7.06	6	0.74	3	1.70

Lethrinidae	emperor and bream	O/BC	Cor	2	0.94	1	1.18	6	0.74	5	2.84
Gnathodentex aureolineatus	striped large-eye bream	O/BC	Cor					1	0.12	1	0.57
Lethrinus sp.		O/BC	Cor	1	0.47	1	1.18	7	0.86	3	1.70
Lutjanidae	snapper	P	Cor	3	1.41	2	2.35	19	2.34	5	2.84
Lutjanus cf. *kasmira*	bluestripe snapper	P	Cor					1	0.12	1	0.57
Lutjanus sp.		P	Cor					15	1.85	6	3.41
Mugilidae	mullet	O/BC	Insh					2	0.25	2	1.14
Mullidae	goatfish	O/BC	Insh	4	1.88	2	2.35				
Mulloidichthys sp.		O/BC	Insh	1	0.47	1	1.18	1	0.12	1	0.57
Parupeneus sp.		O/BC	Insh	3	1.41	2	2.35	1	0.12	1	0.57
Muraenidae	moray eel	P	Cor	22	10.33	7	8.24	92	11.33	9	5.11
Ostraciidae	boxfish	O/BC	Insh	1	0.47	1	1.18	9	1.11	4	2.27
Pomacentridae	damselfish	O/BC	Cor					3	0.37	2	1.14
Priacanthidae	bigeye	P	Cor					1	0.12	1	0.57
Scaridae	parrotfish	H	Cor	11	5.16	5	5.88	18	2.22	7	3.98
Calotomus sp.		H	Cor	3	1.41	2	2.35	3	0.37	2	1.14
Chlorurus sp.		H	Cor	1	0.47	1	1.18	14	1.72	6	3.41
Hipposcarus longiceps	Pacific longnose parrotfish	H	Cor	1	0.47	1	1.18	1	0.12	1	0.57
Scarus sp.		H	Cor	1	0.47	1	1.18	5	0.62	4	2.27
Scombridae	mackerel, tuna, and bonito	P	Pel	1	0.47	1	1.18				
Gymnosarda unicolor	dogtooth tuna	P	Pel					1	0.12	1	0.57
Serranidae	grouper	P	Cor	25	11.74	8	9.41	126	15.52	14	7.95
Siganidae	rabbitfish										
Siganus sp.		H	Insh	4	1.88	2	2.35	1	0.12	1	0.57
Total identified (excl. indeterminate fish to element)				**213**		**85**		**812**		**176**	
Total bones				**764**				**3009**			
Total weight (g)				**92.4**				**267.9**			
% identified				**27.9**				**30.0**			

H = herbivore, O/BC = omnivore/benthic carnivore, P = piscivore, Cor = coral, Insh = inshore, Pel = pelagic

Table 3. Early period fish assemblages from the islands of Manu‘a, corrected Forbes and Morisita-Horn similarity statistics, and similarity classifications for the Ofu Village, Va‘oto, To‘aga and Vaiopi sites (following Giovas 2021).

Site pair	Site A NISP	Site B NISP	Site A *NTAXA*	Site B *NTAXA*	*NTAXA* in common	$S_{F'}$	$S_{M\text{-}H}$	Similarity classification
Ofu Village[a]–Va‘oto[b]	423	213	20	21	17	0.965	0.743	Substantive
Ofu Village–To‘aga[c]	423	550	20	17	15	0.964	0.404	Qualitative
Ofu Village–Vaiopi[d]	423	812	20	25	18	0.965	0.647	Substantive
To‘aga–Va‘oto	550	213	17	21	14	0.928	0.609	Substantive
To‘aga–Vaiopi	550	812	17	25	14	0.915	0.760	Substantive
Va‘oto–Vaiopi	213	812	21	25	19	0.971	0.920	Substantive

[a] Weisler *et al.* (2016), XU4, 2700-1500 BP.

[b] This paper, all layers, 2500-2100 BP.

[c] Nagaoka (1993) and Petchey & Kirch (2019), 1987 main excavation, IIA-C, ~2700-2200 BP.

[d] This paper, all layers, pre-2400-2300 BP.

Table 4. Rank-order abundance by NISP and percentage of total NISP (included in brackets) for the top five fish families recovered from early period Manu‘a sites, compared with available modern subsistence fishing data ordered by catch weight for the year 2002 to 2003 only.

	Early Manu‘a archaeological records				**Modern catch composition**
Taxon	**Ofu Village[a]**	**Va‘oto[b]**	**To‘aga[c]**	**Vaiopi[d]**	**Ofu and Olosega[e]**
Acanthuridae	2 (20.6)	2 (15.0)	3 (8.2)	4 (10.2)	4 (9.0)
Carangidae					3 (12.2)
Holocentridae	3 (13.5)		2 (11.1)	5 (7.1)	5 (8.2)
Lutjanidae					3 (12.2)
Mullidae					1 (13.6)
Muraenidae		4 (10.3)		3 (11.3)	
Scaridae	1 (22.2)	5 (8.0)	5 (4.2)		2 (13.3)
Serranidae	4 (9.9)	3 (11.7)	4 (7.6)	2 (15.5)	3 (12.2)
Diodontidae	5 (6.6)	1 (16.4)	1 (51.8)	1 (23.8)	
% of top 5 taxa	72.8	61.5	83.0	68.0	80.7
Total identified	423	213	550	812	N/A
Total bones	1148	764	2552	3009	21,386 kg[f]

[a] Weisler *et al.* (2016), XU4, 2700-1500 BP.

[b] This paper, all layers, 2500-2100 BP.

[c] Nagaoka (1993) and Petchey & Kirch (2019), 1987 main excavation, IIA-C, ~2700-2200 BP.

[d] This paper, all layers, pre-2400-2300 BP.

[e] Craig *et al.* (2008), annual fish catch excluding bigeye scad, 2002-2003.

[f] Annual fish catch.

Figures

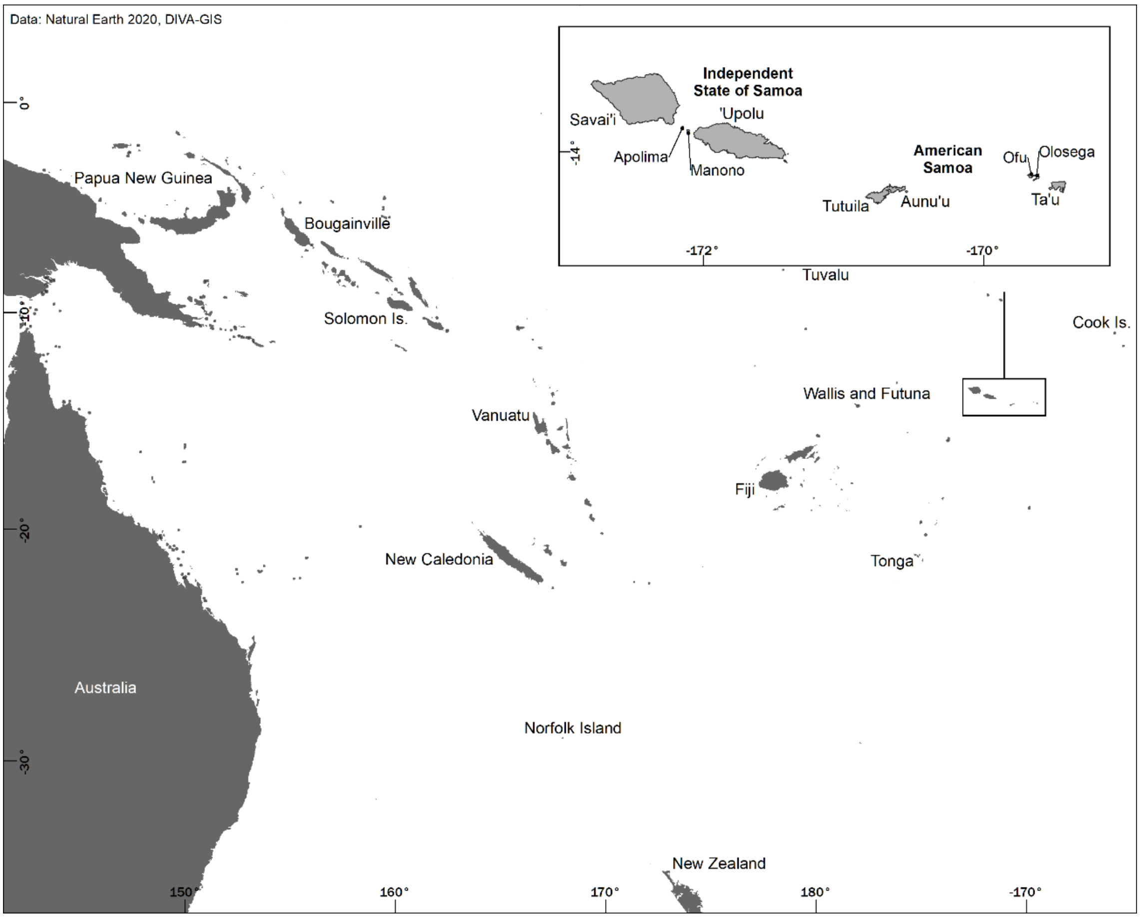

Figure 1. The location of the Independent State of Samoa and American Samoa.

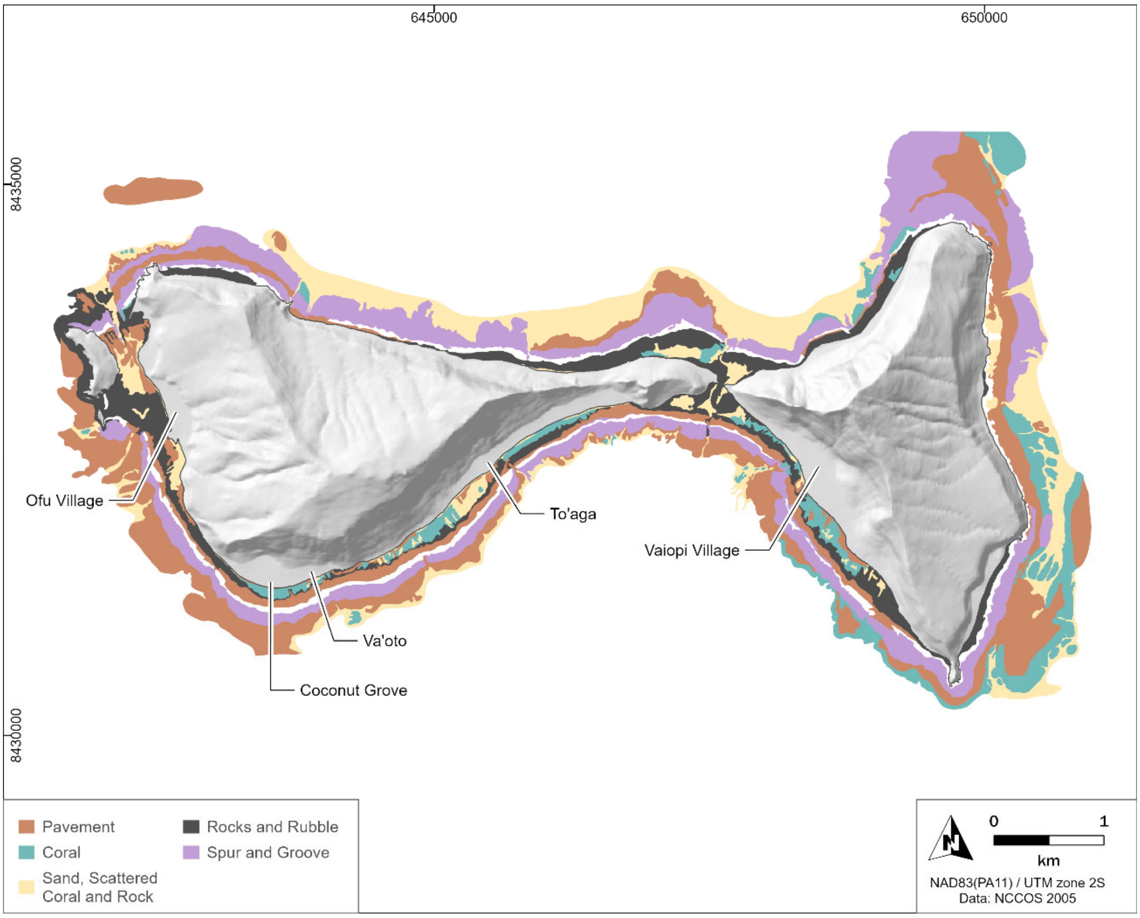

Figure 2. Map of Ofu and Olosega (American Samoa) showing the location of archaeological sites mentioned in text, and the modern distribution of inshore benthic habitat types (after Battista & Christensen 2005).

Figure 3. Ofu (left) and Olosega (central), looking across the fringing coral reef towards Ta‘u in the background, facing east-southeast. Site of To‘aga is adjacent to the coast below this vantage point, and Vaiopi is on the Olosega coast, on the left of the first strip of houses (Photograph: Jeffrey Clark, 2013).

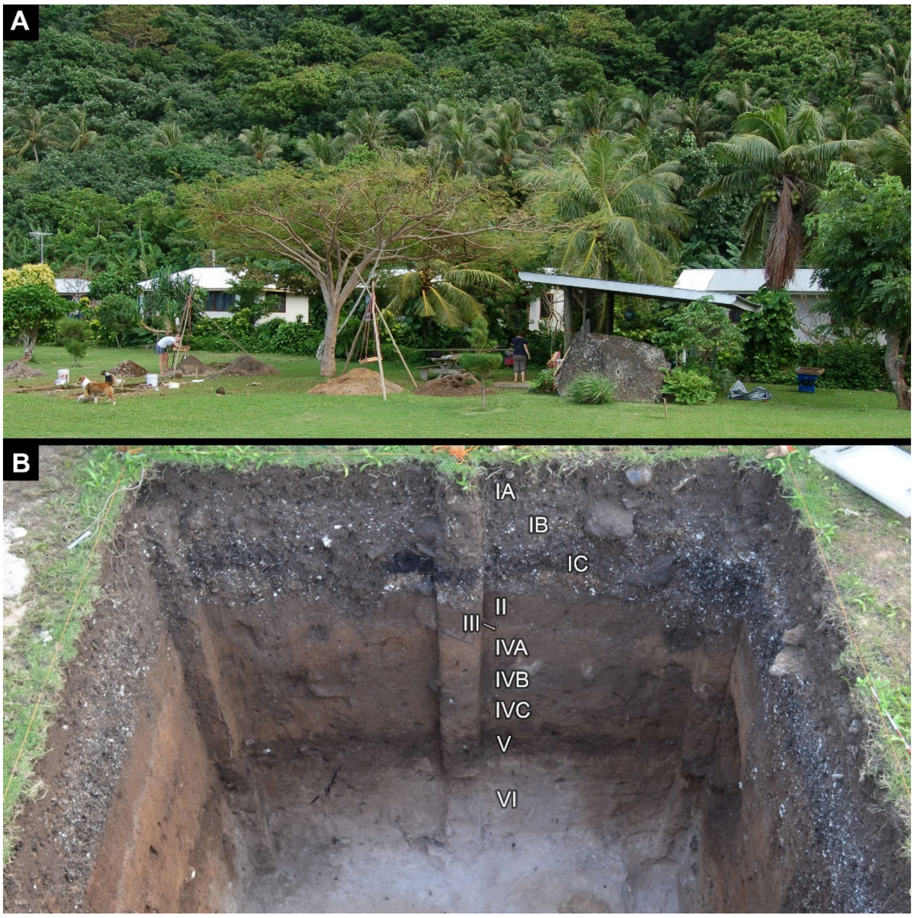

Figure 4. Va‘oto site (AS-13-13) (a) showing excavation in progress, facing northwest (Photograph: Jeffrey Clark, 2010), and (b) representative stratigraphic cross-section of unit 22E/15N (right) facing north, divided into six stratigraphic layers (Photograph: Jeffrey Clark, 2013).

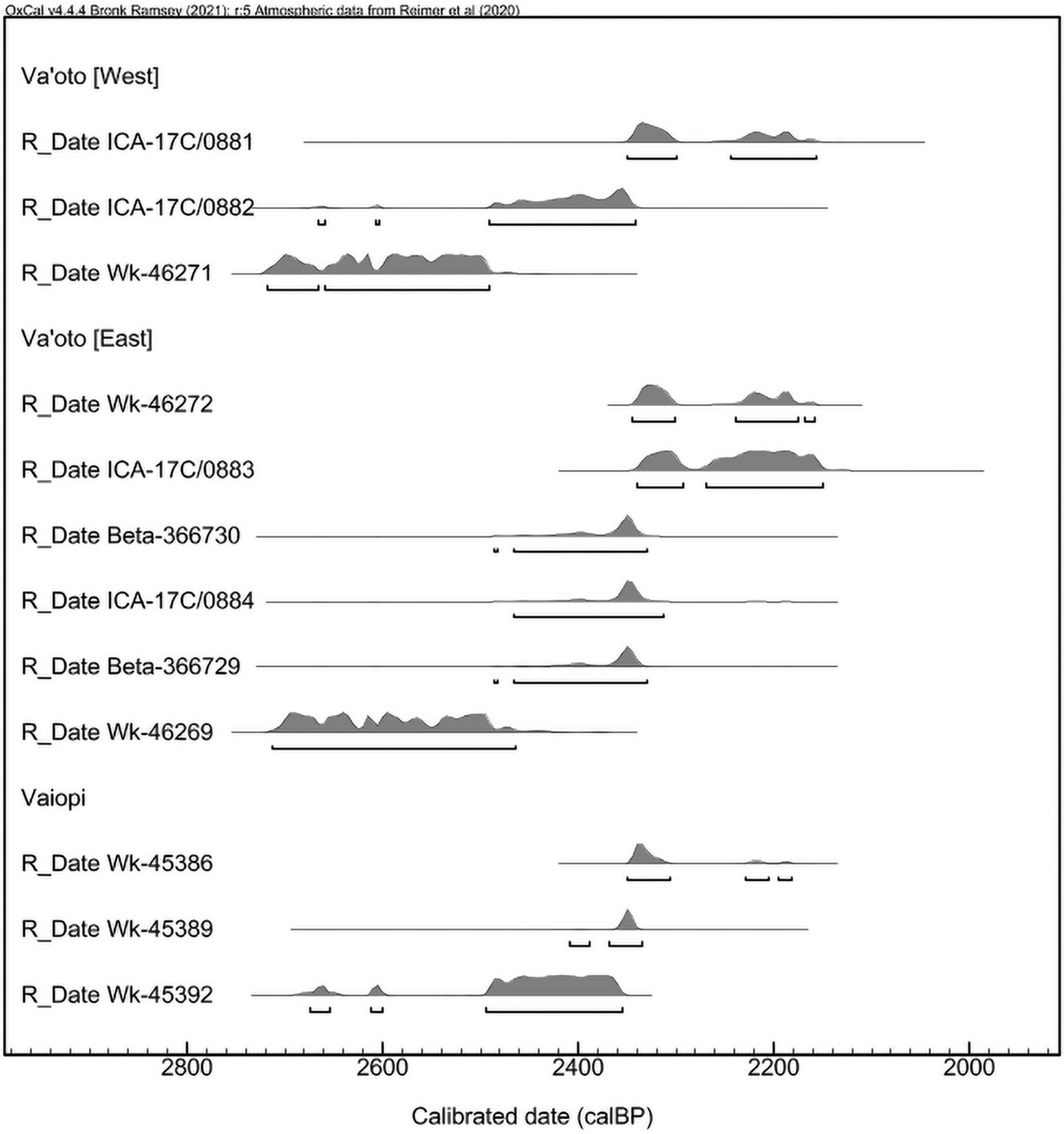

Figure 5. Radiocarbon dates based on short-lived wood charcoal samples from Va'oto and Vaiopi and include previously and newly reported dates (see also Supplement 1). Dates were calibrated in OxCal 4.4. (Bronk Ramsey 2009) using the IntCal20 calibration dataset (Reimer *et al.* 2020). Additional U-Th dates are reported and discussed in Clark *et al.* (2016).

Figure 6. Vaiopi site (AS-12-3) (a) showing location in close proximity to steep, basaltic cliffs (Photograph: Jeffrey Clark, 2009), and (b) representative stratigraphic cross-section of unit 1E/21N facing north, divided into six stratigraphic layers (Photograph: Jeffrey Clark, 2015)

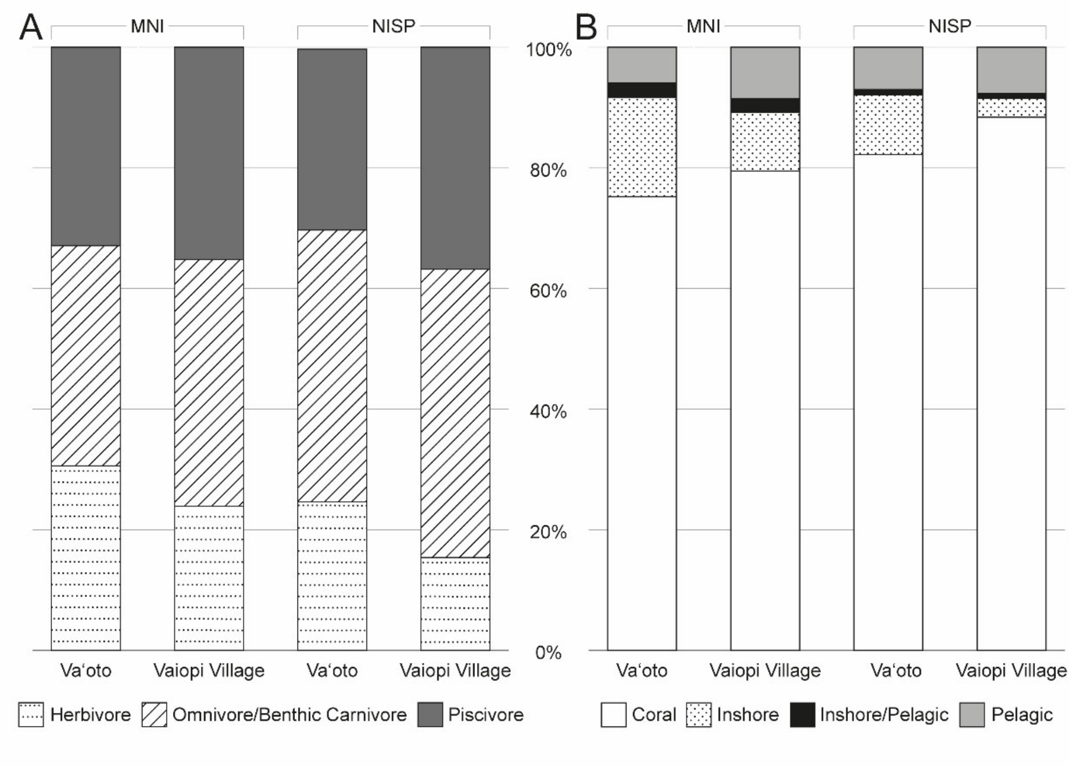

Figure 7. Comparison of fish (a) feeding behaviour, and (b) habitat exploitation at Va‘oto and Vaiopi as calculated by per cent MNI and NISP contribution.

Supplementary Material

Supplement 1. Radiocarbon determinations on short-lived wood charcoal samples from the analysed deposits of the Va‘oto and Vaiopi sites. Dates were calibrated in OxCal 4.4. (Bronk Ramsey 2009) using the IntCal20 calibration dataset (Reimer *et al.* 2020). All samples dated were *Cocos nucifera* endocarp, except for Beta-366730, which was *Cordyline* sp. stem.

Lab. No.	**Site**	**Unit**	**Layer**	**13c/12c**	**^{14}C Age (years BP)**	**Calibrated Age BP (95.4% Prob.)**
ICA-17C/0881	Va‘oto	21W/11S	IV	-24.3	2280±30	2350-2300 (51.8%), 2245-2157 (43.7%)
Wk-46271	Va‘oto	21E/15N	IV (Feat. 92)	-	2489±19	2719-2666 (19.0%), 2659-2491 (76.4%)
ICA-17C/0882	Va‘oto	21E/15N	IV	-24.7	2380±30	2666-2660 (0.9%), 2608-2604 (0.7%), 2491-2342 (93.9%)
Wk-46272	Va‘oto	45E/12N	III	-	2266±19	2344-2301 (50.3%), 2238-2176 (43.2%), 2169-2159 (2.0%)
ICA-17C/0883	Va‘oto	35E/12N	IV	-26.6	2240±30	2339-2292 (26.1%), 2269-2151 (69.4%)
Beta-366730	Va‘oto	39E/9N	V (Feat.74)	-28	2350±30	2486-2483 (0.4%), 2466-2330 (95.0%)
Beta-366729	Va‘oto	40E/9N	V	-25.3	2350±30	2486-2483 (0.4%), 2466-2330 (95.0%)
Wk-46269	Va‘oto	38E/9N	V (Feat. 65)	-	2476±19	2714-2465 (95.4%)
ICA-17C/0884	Va‘oto	39E/9N	VI-V (Fea. 77)	-24.5	2340±30	2465-2313 (95.4%)
WK-45386	Vaiopi	Trench	III	-	2292±19	2350-2306 (80.6%), 2228-2205 (9.2%), 2196-2181 (5.6%)
WK-45389	Vaiopi	11W/10N	VI	-	2348±19	2409-2389 (3.8%), 2369-2335 (91.6%)
WK-45392	Vaiopi	1E/21N	IV	-	2419±17	2670-2656 (3.4%), 2612-2601 (2.6%), 2494-2356 (89.4%)