

## Supplement 4:

### Expanded materials and methods section for "Polynesian settlement of the Marquesas Islands: The chronology of Hanamiai in comparative context."

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#### 2.1. The Hanamiai radiocarbon samples in stratigraphic and cultural context

##### 2.1.1. Hanamiai North

The original series of age estimates for Hanamiai North is based on analyses conducted in the 1980s. Because the dated material consisted of unidentified wood charcoal, we set out to refine the Hanamiai chronology with new dates that minimize the potential for in-built age. However, because no short-lived plant material was found among archived samples from the Hanamiai North excavations, we selected samples of worked pearl shell (*Pinctada margaritifera*).

Pearl shell, which occurs naturally in sheltered Marquesan bays, was used to manufacture ancient fishhooks and it is well represented in most coastal Marquesan archaeological sites. The Hanamiai excavations yielded abundant pearl shell debitage. Pearl shell is fragile and there is no evidence suggesting it was curated in ancient times. This, together with its short life span and the fact that *P. margaritifera* is a filter feeder, minimizes the potential for in-built age in archaeological specimens.

In addition to the pearl shell samples, we dated four wood charcoal specimens from Hanamiai North, with taxonomic identifications made by J. M. Huebert using the International Archaeological Research Institute (Honolulu) wood reference collection and methods described by Huebert and Allen (2016). Our objective in dating taxonomically-identified wood charcoal is to tackle head-on the "old wood" problem, and to understand its potential influence on the original Hanamiai settlement chronology.

Three of the wood charcoal samples ( $\theta_1$ ,  $\theta_2$  and  $\theta_4$ ) consist of *Calophyllum inophyllum* (*temanua*) and *Cordia subcordata* (*tou*) (Table 2, main text). These are native, long-lived (more than 100 years) trees with the potential for in-built age (Allen and Huebert 2014). Studies of wood charcoal assemblages from Marquesan sites on Nuku Hiva suggest that these species comprise elements of the Polynesian settlement era coastal strand vegetation (Huebert and Allen 2016). The fourth identified wood charcoal sample ( $\theta_{67}$ ) consists of coconut (*Cocos nucifera*). Coconut may have been present from the time of initial Polynesian colonization (Huebert and Allen 2016), and it too has the potential for in-built age (Allen and Huebert 2014).

Also important is the potential for the displacement of dating samples from their original stratigraphic contexts, as a result of natural and human activities. For example, tunnelling by crabs can cause extensive disturbance at some Marquesan

coastal sites, including Teavau'ua (Allen 2004: 150, 154, 157) and Ha'atuatua (Supplement 1: 39) on Nuku Hiva, although the evidence for crab burrows at Hanamiai is minimal. Ten of the eighteen Hanamiai North age estimates date specimens collected *in situ* from burnt surfaces, hearths and earth ovens; their contexts are considered to be secure. For the isolated pieces of wood charcoal and pearl shell, the potential for stratigraphic displacement by taphonomic factors can be assessed through the fortuitous discovery of a tool made from the mandible of a medium-sized whale, likely pilot whale (*Globicephala macrorhynchus*). The finished tool, which may have been used as a scraper, was discovered together with eighty-nine chipped fragments of the same material (Rolett 1998:77). The fragments are mostly in the 1 - 3 cm size range and they apparently derive from manufacture of the finished tool – no other comparable bone fragments were found at Hanamiai. The finished tool was collected *in situ* at 246 cmbd (cm below datum) in Layer H and depths for the fragments range from 210 – 265 cmbd (Figure 7). The range of vertical distribution suggests that other remains of similar size, including the isolated pieces of charcoal and shell for dating the earliest Hanamiai North deposits, may have moved up to 35 cm from their original depths.

Evidence for the Hanamiai North founder settlement is from Layers G, H and GH. The deepest cultural deposit is either H or GH (Fig. Grid), with the difference between these determined by the presence of a culturally-sterile stream bed deposit beneath Layer H. Silt from the alluvial deposit lends a dark color and firm texture to H while GH is an extension of the same deposit but with less silt, as it

lies beyond the limits of the stream bed. Together, Layers H, GH and G comprise Phases I and II of the Hanamiai North cultural sequence. Their combined thickness in the areal excavation is about 50 cm.

In addition to bones of a previously unknown flightless rail (*Gallirallus roletti*) (Kirchman and Steadman 2006) and other extinct birds (Rolett and Steadman 1996) (Figure 8, main text), Layers H and GH yielded a rich array of artifacts. Stone adzes were found together with fishhooks and quantities of worked pearl shell. Figure 9 (main text) shows a view of the excavation in progress. Nine age estimates (including four new ones) date the contexts from which these artifacts and bones of the extinct birds were collected (Table 2, main text). Overall, the Layer GH and H artifact and faunal assemblages are notably similar.

Layer G is notable for a well-preserved living floor associated with a massive stone pavement (Figure 4, main text). Although the fishhooks and adzes discovered here represent Archaic forms, a sharp decline in the number and concentration of bird bones justifies the distinction of Layer G as a separate analytic unit, Hanamiai Phase II of the founder settlement. There are three age estimates for an occupation about 15 cm below the Layer G stone pavement and its associated living floor.

Unlike Hane and Ha'atuatua, where there are gaps in the archaeological sequence after the founder settlement, the Hanamiai North sequence is fairly continuous

from the founder settlement occupation until sustained contact with the Western world. Layer F, which follows the Hanamiai founder settlement, stands out for evidence of activities involving the manufacture and reworking of adzes. Dense concentrations of lithic debitage were found close to a low stone platform (*paepae*) (Rolett 1998:79, 206-207) but temporally-sensitive artifacts are comparatively scarce. There are 3 age estimates for Layer F. The Hanamiai North dune area was flooded during the Layer F occupation, capping Layer F with a thin, silty deposit designated Layer E (Rolett 1998:71, 79-81). Dark-colored and hardened, Layer E provides an ideal stratigraphic marker extending across most of the areal excavation (Figure 4, main text). As evidence for flooding, Layer E is consistent with an emerging record of Pacific-wide paleotsunami events, including ones believed to have impacted the Marquesas (Allen et al. 2021, Goff et al. 2022). We have three age determinations for the previously undated Layers D and C. Among these,  $\theta_{122}$  is from 5 cm above the interface between Layers E and D, while samples  $\theta_{119}$  and  $\theta_{121}$  date Layer C. Together, the age estimates for Layers C, D and F are useful for dating the possible paleotsunami event represented by Layer E. Finally, there is a single radiocarbon date for Layer B. Historic-era artifacts from Layer B indicate that it was occupied during the 19th century.

### *2.1.2. Hanamiai South*

The Hanamiai South founder settlement deposits were excavated across 30 m<sup>2</sup> between 2012 and 2014 (Rolett 2021), following their discovery 28 years after the excavations at Hanamiai North. These deposits contain diagnostically Archaic

artifacts like the ones found at Hanamiai North. The fishhooks, in particular, are highly similar. Excavation methods employed at Hanamiai South proceeded by 10 cm (and sometimes greater) arbitrary levels within stratigraphic layers. The excavation grid was based on north and east coordinates (e.g. N80 E70) rather than the alphanumeric system used at Hanamiai North.

The deepest cultural deposit in the Hanamiai South stratigraphic sequence, Layer F, is a light-colored marine sand deposit dated by three samples of coconut endocarp charcoal. Layer F is around 100 cm thick and the upper levels contain comparatively little cultural material. By contrast, the lower levels yield abundant artifact assemblages, including an adze polishing stone made from columnar basalt and a debitage concentration associated with the manufacture of adzes. Fishhooks from the lower levels consist of angular and curved shank forms like those typical of other Marquesan founder settlement sites. Two of the SLM age determinations for Layer F ( $\theta_{12}$  and  $\theta_{13}$ ) are associated with the lower levels. Another age determination ( $\theta_{14}$ ) is for a hearth situated 30-50 cm above the lower levels, in a context with fewer artifacts and lower densities of bone and shell.

## **2.2. Model-based chronologies**

The application of Bayesian statistics offers an effective approach for building model-based chronologies. Designing good Bayesian models involves merging scientific data such as age determinations with expert knowledge relating to stratigraphy and other chronological relationships (Buck and Meson 2015). For

instance, in designing the Hanamiai model, we took into consideration data that quantifies the potential displacement of dating samples from their original stratigraphic contexts. In addition, Bayesian models like those developed here should be tested and revised through experiments measuring reproducibility and sensitivity (Buck and Meson 2015). Reproducibility is the ability to achieve replicable results during multiple runs of the model. By contrast, sensitivity analysis tests the role of an independent variable to determine its contribution to uncertainty in the model. In our models, we use sensitivity analysis to quantify uncertainty associated with the application of three different values for the marine reservoir effect ( $\Delta R$ ). Tests we performed for reproducibility and sensitivity were achieved by running each of the site chronology models five times in OxCal (Ramsey 1995).

We compared the Hanamiai site chronology with the chronologies for seven other Marquesan sites (Table 3, main text). As might be expected for a range of projects conducted over a span of more than 50 years, the research goals and field methods vary significantly. The number of age determinations for each site, as well as the choice of material dated (SLM or unidentified charcoal), also varies widely although the most recent research emphasizes SLM dates. Basic background and contextual information for the seven sites are presented in Supplement 1, 2 and 3.

Supplement 1 describes our modeling methods. In the case of Hanamiai, based on the demonstrated potential for residuality and intrusion (Figure 7, main text), we decided to treat Hanamiai Phases I and II (Layers H, GH and G) as a single entity,

Hanamiai I/II. This led to a model for the Hanamiai sequence that consists of Hanamiai Phase I/II (the founder settlement with Archaic artifacts), Hanamiai Phase III (Layers F and E, a transitional early/late occupation), Hanamiai Phase IV (Layers D and C, Classic era occupations) and Hanamiai Phase V (Layers B and A, Historic phase occupations).

Our Bayesian chronological models for the seven other sites largely follow established stratigraphic sequences: 1) The Hane model follows Anderson and Sinoto (2002) in dividing the sequence into Lower and Upper phases; 2) The Hakaea and Teavau'ua models follow sequences proposed by the excavators; 3) The Ha'atuatua model is confined to the main dune – it does not include the excavations in Area B; and 4) The Ho'oumi model, which correlates stratigraphy across discontinuous excavation units, is based on a modified interpretation of the sequence proposed by Allen et al. (2021).

For all of the site chronologies, we conducted a series of systematic tests using the various  $\Delta R$  estimates proposed for the Marquesas. The purpose of these tests was to identify outlier dates. Often it is not clear why specific dates present as outliers, but possibilities include in-built age and stratigraphic displacement of the dated sample by natural processes or human activities, as well as field and laboratory errors. We removed the outliers and calibrated each model five times to ensure replicability. We refer to the replicable calibrations as chronology solutions.

After establishing the site chronology solutions, we used the R statistical software package ArchaeoPhases (Philippe and Vibet 2019) to estimate the rate at which settlements were established during the early Polynesian colonization of the Marquesas. Finally, using the Chronomodel software (Lanos et al. 2015), we experimented with a model based on the site chronology solutions to estimate dates for the transition in Marquesan material culture from the Archaic to the Classic phase.

## **References**

See the main text for references cited