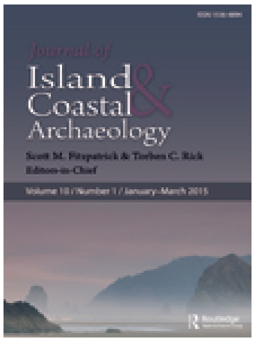

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Late Holocene Human Expansion into Near and Remote Oceania: A Bayesian Model of the Chronologies of the Mariana Islands and Bismarck Archipelago

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ABSTRACT

Since the investigations of Spoehr in the 1950s, most researchers have accepted a date of ~3500 BP/1500 BC for the initial human settlement of the Mariana Islands in the western Pacific. The relationship of this early expansion beyond Island Southeast Asia, characterized by Lapita-like pottery, to the appearance of Lapita in Near Oceania, generally was either given little thought or largely ignored. The Lapita settlement of Near Oceania is almost universally regarded as the initial expansion of Austronesian speakers into the Pacific, followed a few centuries later by a rapid migration to the east into Remote Oceania. More recently, however, radiocarbon evidence from several sites suggests that initial late Holocene expansion into the Pacific occurred in the Mariana Islands. This hypothesis needs critical evaluation. To this end, we created site- and region-level Bayesian calibration models. Results estimate that initial Lapita occupation of the Mussau Islands in the Bismarck Archipelago occurred between 3535 and 3234 cal BP (95% probability), which is 50–385 years (95% probability) earlier than the initial settlement of the Mariana Islands, dated to 3230–3085 cal BP (95% probability). Additionally, settlement of the Mariana Islands was either coeval or later (−66 to 254 years [95% probability]) than Lapita expansion out of Mussau into the greater Bismarck archipelago between 3397 and 3115 cal BP (95% probability). Radiocarbon datasets from these regions are hampered by problematic samples, and we anticipate that additional reliable radiocarbon dates will refine these estimates.

Keywords Bayesian calibration, Bismarck Archipelago, chronology, Lapita, Mariana Islands

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Color versions of one or more figures in this article are available online at www.tandfonline.com/uica.

INTRODUCTION

Settlement of the Mariana Islands ~3500 cal BP has been posited as the first expansion of Austronesian speakers beyond Island Southeast Asia (ISEA) during the late Holocene (Carson 2014; Carson and Kurashina 2012; Hung et al. 2011). The Pre-Latte Period, as this earliest archaeological manifestation is called in the Mariana Islands, is recognized by its distinctive pottery tradition of red-slipped, impressed, lime-infilled wares (Spoehr 1957:117–124), a tradition generally associated with the well-known Lapita ware of Melanesia (Bellwood 1975:13; Carson et al. 2013). Spoehr's (1957:66) original date on a large oyster shell from the Chalan Piao site on Saipan for the Pre-Latte Period was 1527 ± 200 BC. Marine shell was also used to date the Pre-Latte component of the Tarague site on Guam, producing a roughly similar determination of 3435 ± 70 BP (Kurashina and Clayshulte 1983). While these dates have been long-recognized as problematic due to the metabolism of ocean reservoir ^{14}C-depleted carbon in variable quantities (Athens 1986:116; also Petchey 2009), two subsequent determinations on unidentified charcoal from reworked shoreline sediments at the Achugao site on Saipan (Butler 1994:22–23) seem to have enshrined the 3500 BP/1500 BC age as the approximate date for the onset of the Pre-Latte Period and the settlement of the Mariana Islands (e.g., Butler 1994; Russell 1998). Recent investigations carried out by Carson and colleagues, noted above, purportedly solidifies this early chronology of initial Mariana Island settlement, but with the added wrinkle of suggesting that the initial migratory thrust of Austronesians out of ISEA was to the Mariana Islands and not to Near Oceania (see also Rainbird 2004:85). This position has been challenged based on analyses of ceramic attributes and chronological data (Clark et al. 2010; Clark and Winter n.d.; Petchey et al. 2016; Winter et al. 2012), as well as computer simulation modeling of voyaging (Fitzpatrick and Callaghan 2013; Montenegro et al. 2016).

Previously, the Bismarck Archipelago held priority as the initial area of settlement in Oceania by migrants associated with the Lapita Cultural Complex (Kirch 2000:88–93, 2010), which is materially identified by finely dentate-stamped pottery and an associated suite of lithic and shell tools and shell ornaments (see Specht et al. 2014 for an argument that material and cultural changes occurred variably across time and space in the archipelago and not as a single Lapita "package").

While the broad outline of this expansion out of ISEA is not in dispute, the idea that the Mariana Islands were settled before the Lapita settlement in the Bismarck Archipelago is a hypothesis that needs to be tested. We developed a series of Bayesian calibration models using archaeological data[1] to clarify temporal trends of late Holocene expansion and settlement in these islands, and address the question: does initial human occupation of the Mariana Islands precede Lapita settlement of the Bismarck Archipelago? The robustness and reliability of chronologies are then evaluated, and we consider the use of various plant materials and marine invertebrates for radiocarbon dating in this region (Allen and Huebert 2014; Petchey 2009; Rieth and Athens 2013). Methodological issues in macro-scale chronological analyses such as this are also evaluated.

METHODS

For the Mariana Islands, conventional radiocarbon ages (CRA) were collected from the academic and cultural resource management (CRM) literature (Supplemental Material: Table 1; supplemental material available online). Measured radiocarbon ages lacking correction for isotopic fractionation were excluded, as were shell-derived ages unless locality-specific deltaR (ΔR) values had been calculated. Research by Petchey et al. (2016) shows that an archipelago-wide ΔR value, even if taxon-specific, cannot be developed for the Mariana Islands, due in part to a geographical variation in hardwater effect. Our analysis uses locality- and taxon-specific ΔR values for *Anadara antiquata* (218 ± 57

^{14}C years; pooled value) and marine invertebrate taxa that inhabit reef or open marine environments (23 ± 37 ^{14}C years) for Unai Bapot, Saipan (Petchey et al. 2016), and *A. antiquata* (−44 ± 41 ^{14}C years; pooled value) for Ritidian, Guam (Carson 2010).

For the Bismarcks, we relied on syntheses published by Specht and Gosden (1997), Spriggs (2003), Specht (2007), and Denham et al. (2012), although in limited cases the primary references were reviewed. Radiocarbon determinations were obtained from unidentified and identified plant charcoal, wood, and marine shell (Supplemental Material: Table 2). Denham et al. (2012) had excluded marine shell dates because of questionable ΔR values for the region; however, Petchey and Ulm (2012) have since published values for six tentative ΔR subregions for the Bismarcks along with a new value for Mussau. Using their ΔR values we have included calibrated shell-derived dates.

Oxcal 4.2 was used for Bayesian model calibration (Bronk Ramsey 2009, 2013). Bayesian calibration allows estimates of the start, end, and duration of events, which visual inspection of calibrated dates and summed probabilities cannot provide with the same statistical rigor and certainty (Bayliss et al. 2007). The Intcal13 calibration curve was used for terrestrial samples with the Marine13 curve used for marine samples (Reimer et al. 2013). The Northern Hemisphere curve (Intcal13) was used for the Bismarck samples, following McCormac et al. (2004:1088) since this region falls within the Intertropical Convergence Zone (ITCZ).

Analysis was iterative. Single or multiphase calibration models (see Bronk Ramsey 2009) were created for the Mariana sites, with single phase models created for the Mussau Islands and the Bismarck Archipelago excluding Mussau. The individual models for the Mariana Islands, Mussau, and greater Bismarcks were then combined in an overlapping, multi-sequence model to allow estimation of the differences in settlement dates. The models used Oxcal's Sequence, Phase, Boundary, and Difference commands (code provided as Supplemental Material). All individual models have agreement indices above 60 (equivalent to the 5% level of a χ^2 test) and show good agreement between the radiocarbon dates and phasing. Individual dates with low agreement values were excluded if they caused a model's agreement value to fall below 60. The combined multi-sequence model has an agreement index below 60. However, the settlement estimates for each region remain unchanged from the individual modeled results, and therefore the multi-sequence model estimates are considered valid. Modeled results are italicized to distinguish them from unmodeled dates.

SETTLEMENT OF THE MARIANA ISLANDS

The Mariana Islands are approximately 2,400 km due east of the northern Philippines and roughly 1,700 km north-northwest of the Bismarck Archipelago. Eight deposits in the archipelago have produced early assemblages and have associated radiocarbon determinations (Figure 1). The number of determinations per site used in our calibration models ranges from 1 (Ritidian, Guam) to 33 (Unai Bapot, Saipan).

Two site deposits were considered for Guam.[2] One determination obtained from an *A. antiquata* shell was included for the Ritidian site at the northern end of the island. As a single age, it was simply calibrated rather than calibrated in a Bayesian model structure. At 95% probability, occupation is estimated to have occurred 3501–3196 cal BP with a 68% probability range of 3435–3292 cal BP and 3283–3274 cal BP. Six determinations from unidentified charcoal from Mangilao were included in a multi-phase calibration model based on site stratigraphy (Levels 10–13 of Layer IIIg, the basal cultural deposit). The oldest and youngest determinations for level 12 were flagged during the initial model iteration as having low agreement values and were removed, thus leaving the six determinations.

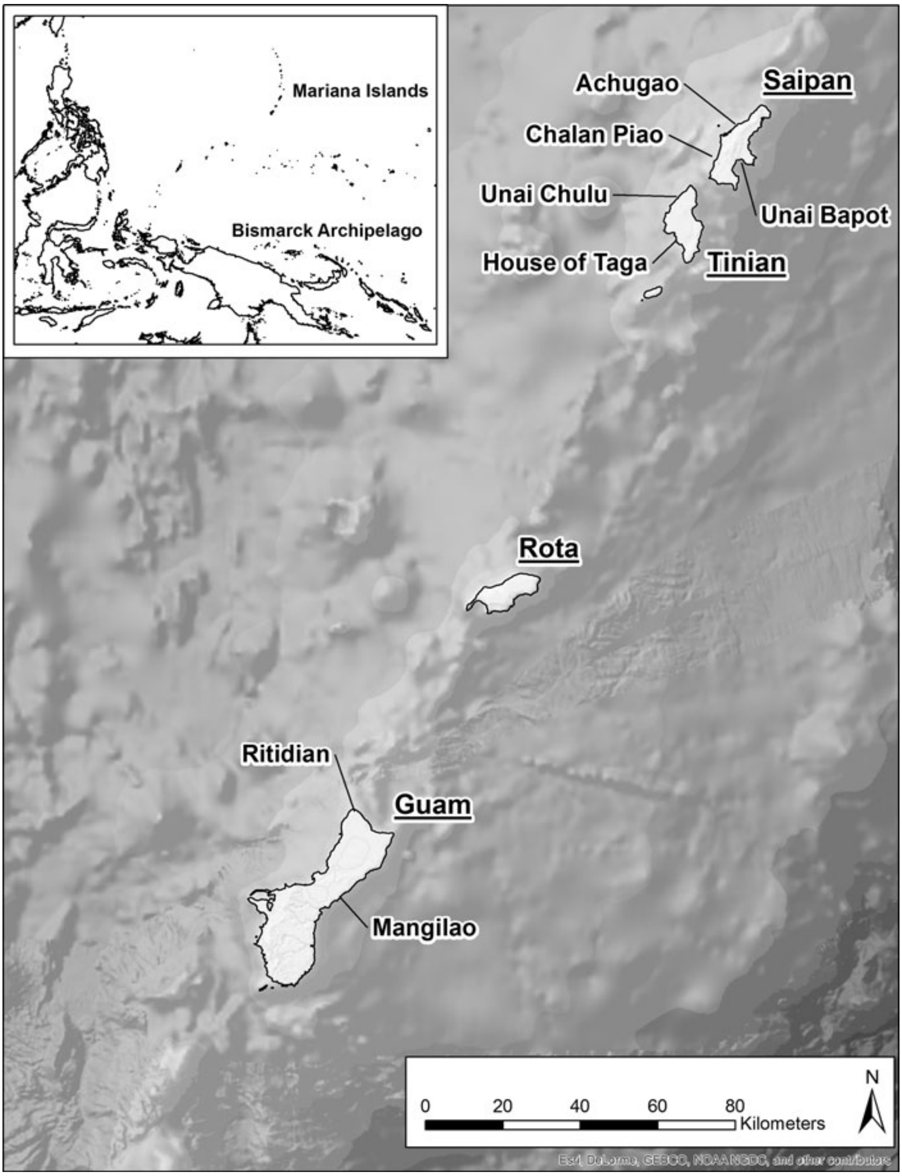

Figure 1. *Locations of early archaeological deposits in the Mariana Islands included in this study.*

Initial occupation at Mangilao occurred some time during *3631–3148 cal BP (95% probability)* or more likely *3410–3207 cal BP (68% probability)*.

The House of Taga and Unai Chulu were included for Tinian. For the House of Taga, two unidentified charcoal samples included in a single phase model provide an estimate for initial occupation sometime between *3943 and 3225 cal BP (95% probability)* or more likely *3443–3246 cal BP (68% probability)*. Thirteen determinations from Unai Chulu were included in a multi-phase model based on excavation units and site stratigraphy. Initial occupation is estimated to have occurred sometime between *3522 and 3215 cal BP (95% probability)* or likely *3406–3246 cal BP (68% probability)*.

Achugao, Chalan Piao, and Unai Bapot were included for Saipan. For Achugao, five ages from unidentified charcoal were included in a single phase model, which estimates initial occupation sometime during *4894–3383 cal BP (95% probability)* or likely *4085–3513 cal BP (68% probability)*. Two unidentified charcoal dates for Chalan Piao result in an even broader occupation estimate of *5833–3175 cal BP (95% probability)* or likely *4117–3226 cal BP (68% probability)*.

Unai Bapot offers the best chronology for the archipelago. Thirty-four ages reported by Petchey et al. (2016) from unidentified charcoal, identified short-lived plant charcoal, an extirpated rail (*Gallirallus* cf. *philippensis*), *Anadara* sp. shell, and other marine invertebrates were organized in a two-phase model based on stratigraphy. Determinations obtained by other investigators were excluded because they could not be correlated with the site stratigraphy presented by Petchey et al. (2016).[3] Initial occupation is estimated to have occurred sometime between *3224 and 3083 cal BP (95% probability)* or likely *3208–3090 cal BP (68% probability)*. Our model structure follows Petchey et al. (2016) and, as expected, our results are indistinguishable from their estimate (*3200–3080 cal BP, 68% probability*).

With the exception of Unai Bapot, the initial settlement estimates for the Mariana Island sites (Figure 2) are problematic for at least three reasons. First, sample size is affecting the results. Simulation modeling conducted by one of us (TMR, along with D. Hamilton [Scottish Universities Environmental Research Centre]) indicates that for the portion of the calibration curve relevant to the settlement of the Mariana Islands and Bismarcks, ~40 radiocarbon determinations are required to obtain sub-century precision. Unai Bapot comes close to this sample size and has the most precise estimates: sometime within a ~150 year span at 95% probability or ~80 years at 68% probability. In contrast, Chalan Piao and Achugao are modeled on 2 and 5 dates, respectively, resulting in 95% probability estimates of 1,500–2,700 years. Second, potential inbuilt age for unidentified charcoal may be affecting results to varying degrees. Inbuilt age of decades to more than a century must be considered for all assemblages. However, a large enough sample size should allow detection of anomalously old ages (e.g., residual dating samples) as Petchey et al. (2016) demonstrate for Unai Bapot. Third, Achugao and Chalan Piao have other problems in the form of large error values and poorly provenienced (aggregated) dating samples, respectively.

LAPITA SETTLEMENT OF THE BISMARCK ARCHIPELAGO

The Bismarck Archipelago is off the northeast coast of New Guinea, consisting of large, volcanically active New Britain, New Ireland, the Mussau Islands, the Manus Islands, and hundreds of smaller islands and island groups. Humans initially occupied many areas of the archipelago during the Pleistocene (Torrence et al. 2004). Figure 3 displays the locations of 23 Lapita sites in the Bismarck Archipelago and Nissan Island (sites are listed by the National Museum and Art Gallery of Papua New Guinea three or four letter code).

The Mussau Group has been recognized as having the earliest Lapita sites in the Bismarcks, designated ECA and ECB on Eloaua (Kirch 2001). This assessment is supported by Denham et al.'s (2012) Bayesian analysis, which is based on charcoal and wood-derived radiocarbon determinations. We included charcoal and wood ages along with marine shell determinations from Kirch's (2001) excavations, as well as two determinations obtained more recently by Summerhayes et al. (2010) from Emirau. These ages ($n = 26$) were calibrated in a single-phase model for the island group.

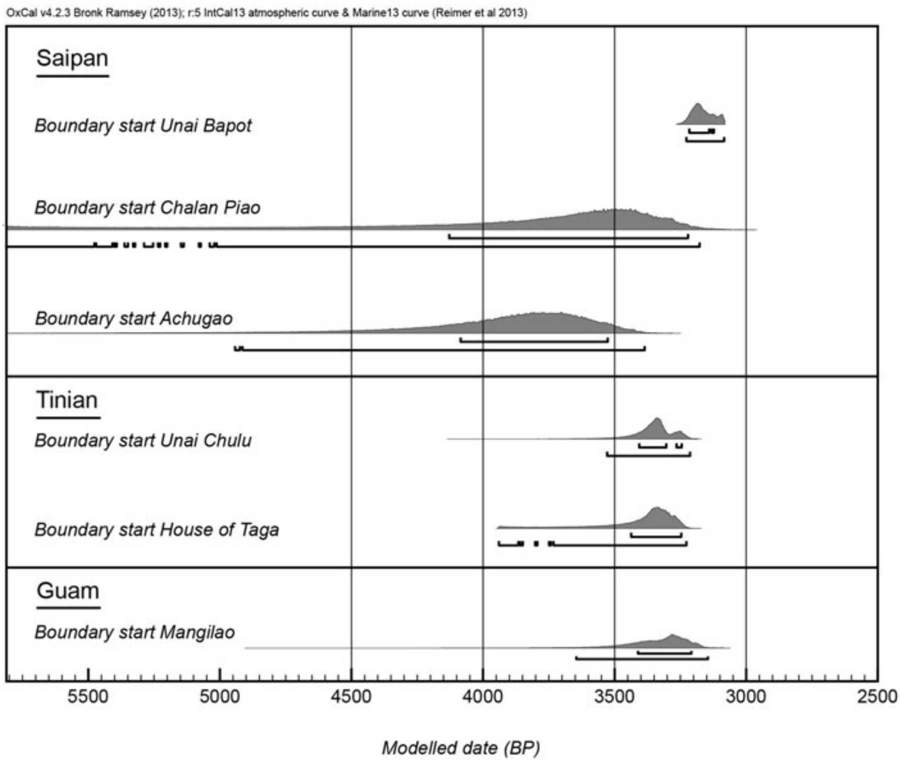

Figure 2. *Settlement estimates for Guam, Tinian, and Saipan.*

Shell dates were calibrated using Petchey and Ulm's (2012) ΔR of −293 ± 92. Our results indicate Lapita occupation began sometime during *3535–3234 (95% probability)* or likely *3453–3283 (68% probability)* (Figure 4). At 68%, our results are essentially the same as Denham et al.'s favored estimate (*3470–3250 cal BP, 68.2% probability*), while our 95% probability results remove over 100 years from their estimate (*3590–3110 cal BP, 95.4% probability*).

We initially ran a single phase model that included charcoal and marine shell dates for the remaining Lapita sites in the Bismarcks, but most of the shell-derived dates were identified as having low agreement values. Therefore, we separated the samples by material—charcoal or marine shell—and ran two single phase models. Marine shell determinations were calibrated using Petchey and Ulm's (2012) ΔR of 38 ± 14, 40 ± 19, 273 ± 216, and 314 ± 74, depending on the site locations. A cursory assessment of both models suggests that separate settlement events were dated: one which occurred sometime during *4018–3694 cal BP (95% probability)* based on charcoal-derived determinations and another, which post-dates the first by centuries, between *3510 and 3094 cal BP (95% probability)* based on shell-derived determinations. However, this certainly is not the case since this pattern is correlated with sample material. Rather, there are three primary factors that may be at work. One, charcoal determinations with large error values (170 or 190 years) are skewing the model results to the left (older side of the probability curve). Two, the charcoal model may be skewed by inbuilt age in some of the unidentified charcoal samples. Or, three, the ΔR values for the region

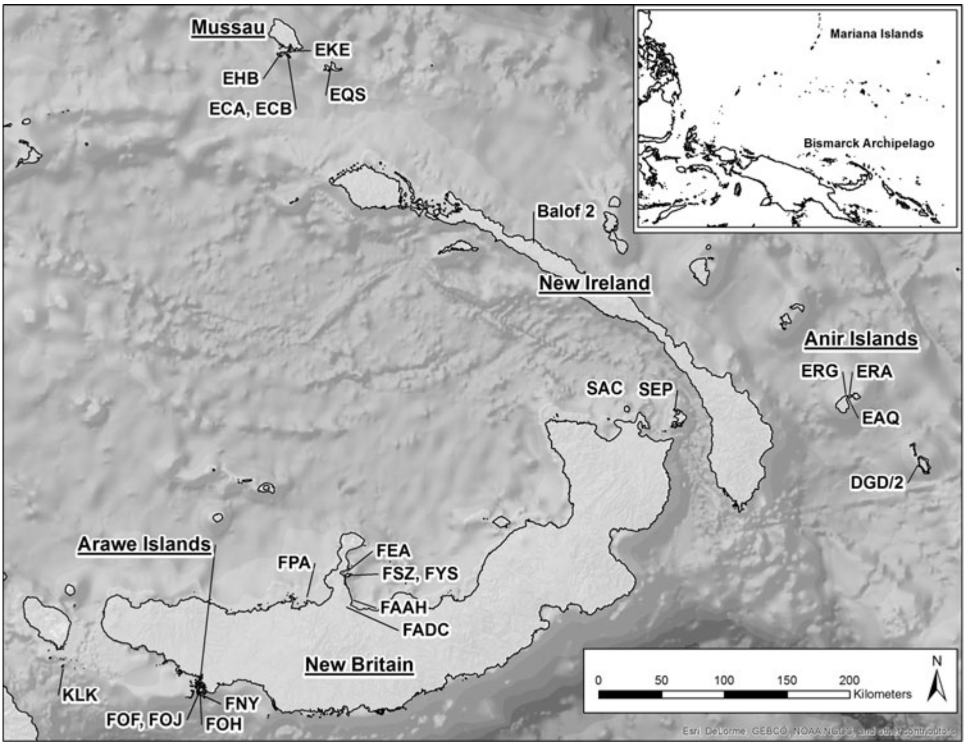

Figure 3. *Locations of early Lapita deposits in the Bismarck Archipelago.*

are incorrect and thus skew the results to the right (younger side of the probability curve).

To test factor one, we ran the charcoal model again after removing three determinations with error values of 170 or 190 years. The settlement date estimate remained statistically the same. To test factor two we ran the charcoal model with only dates from nutshells. The initial occupation estimate generated from the short-lived nutshell dates is statistically indistinguishable from the marine shell-derived estimate. When these datasets are combined, initial Lapita occupation is estimated to have occurred sometime between *3397 and 3115 (95% probability)* or likely *3304–3177 (68% probability)* (see Figure 4). With regards to factor three—errors in the ΔR values—we cannot evaluate this possibility directly now. However, the concordance between the nutshell and marine shell estimates supports the accuracy of Petchey and Ulm's (2012) ΔR values.

Our results indicate that Lapita settlement of Mussau probably preceded expansion into other parts of the Bismarck Archipelago, though contemporaneous settlement cannot be discounted (*−80 to 334 years [95% probability], or 29–234 years [68% probability]*). It is important to note that the Mussau estimate, unlike the greater-Bismarck estimate, includes a number of determinations obtained from unidentified charcoal. Based on our evaluation of the greater-Bismarck suite, it is likely that some of the Mussau charcoal dates include a degree of inbuilt age that is affecting the results. The sample size for each area is moderate ($n = 26$ for each model) though future reliable dates should improve the precision of the settlement estimates.

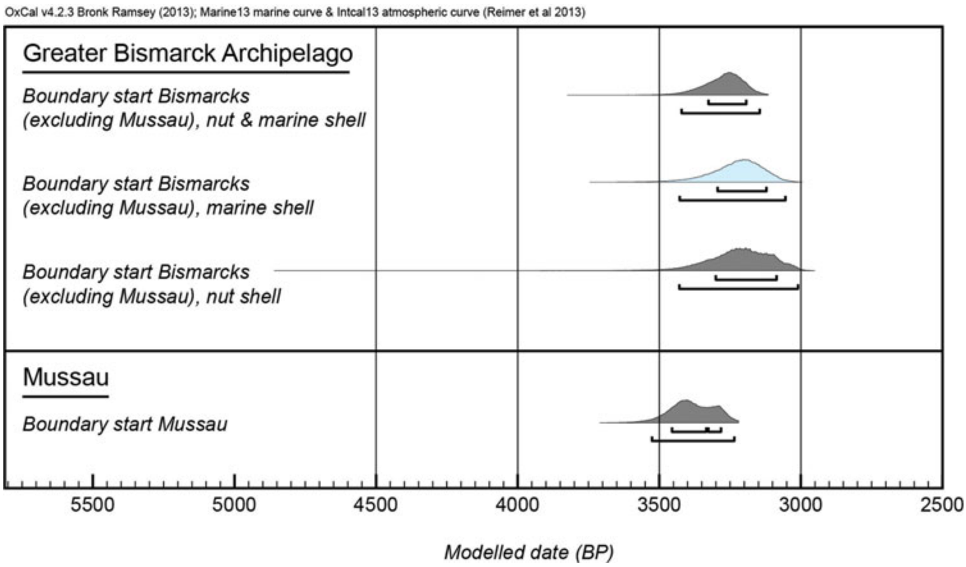

Figure 4. *Settlement estimates for the Mussau Islands and greater Bismarck Archipelago.*

DISCUSSION: SEQUENTIAL OR CONTEMPORANEOUS POPULATION EXPANSION IN THE WESTERN PACIFIC?

Our results do not support the contention that the initial occupation of the Mariana Islands preceded Lapita settlement of the Bismarck Archipelago. Colonization of the Mariana Islands occurred approximately *50–385 years (95% probability)* after Lapita appearance in Mussau. However, this finding is based on Unai Bapot—which is well-dated, contains early ceramics and other artifacts, and extirpated avifauna—being representative of earliest settlement in the archipelago. Our results indicate that Lapita settlement of Mussau occurred sometime between *3535 and 3234 cal BP (95% probability)*, with contemporaneous or centuries-later (*−80 to 334 years [95% probability]*) expansion into the greater Bismarck area between *3397and 3115 cal BP (95% probability)* (Figure 5). Settlement of the Mariana Islands between *3230 and 3085 cal BP (95% probability)* may have been contemporaneous with this expansion into the greater Bismarck Archipelago, or it may have succeeded it by centuries (*−66 to 254 years [95% probability]*). However, colonization of the Mariana Islands does represent initial dispersal into Remote Oceania, as noted by previous researchers (Carson 2014; Hung et al. 2011; Petchey et al. 2016; see also Sheppard et al. 2015).

It is equivocal whether robust and reliable chronologies have been established for these regions. Unai Bapot is a well-dated site deposit, assuredly one of the best in the western Pacific. This only highlights the poor state of chronology building for the rest of the Mariana Islands. At a macro scale, the Mariana dataset has to contend with a majority of dates from unidentified charcoal, samples from problematic proveniences, potential residual dating samples, and the need for the development of localized ΔR values. Re-dating key sites may be possible using curated samples, which for certain sites such as Chalan Piao and Achugao may be the only option since the deposits have been largely destroyed by development.

The Mussau and greater Bismarck Archipelago datasets are somewhat better,

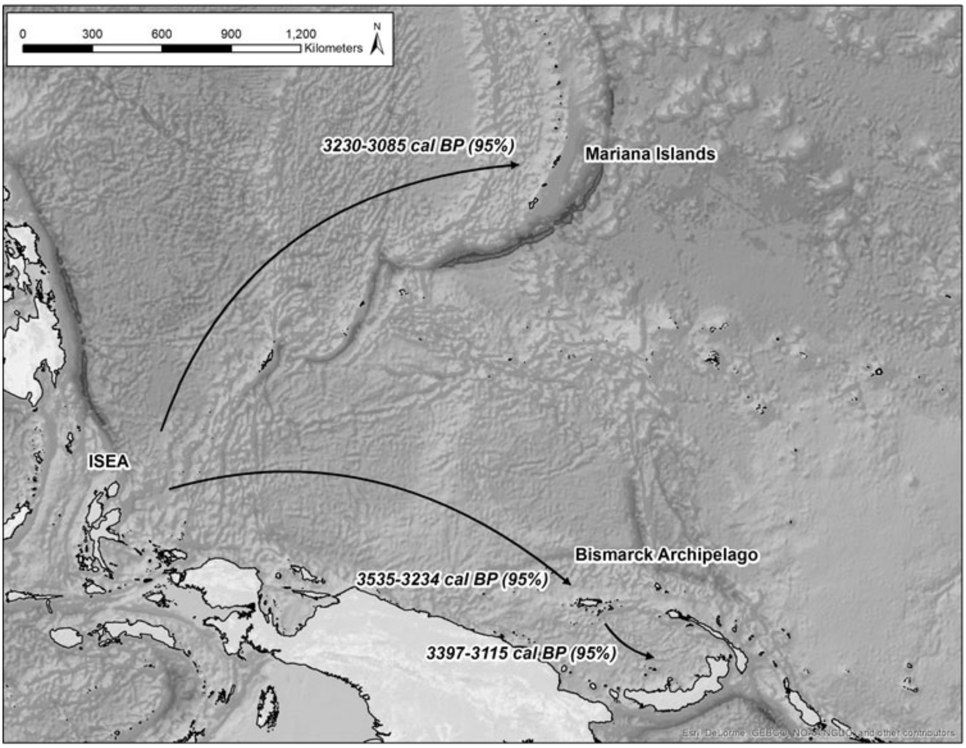

Figure 5. *Estimated settlement dates for the Bismarck Archipelago and Mariana Islands.*

particularly due to the suite of nutshell dates and improved ΔR estimates. The Mariana issues are just as pertinent for the Bismarcks. As with the Mariana Islands, an increased number of dates from short-lived materials reliably associated with human activity will improve the precision and accuracy of the colonization estimates.

While it is possible that the initial settlers of the Mariana Islands could have come from the Bismarck region, pottery differences with Lapita suggest it is more likely they came directly from ISEA (Clark and Winter n.d.). An origination point(s) in the Bismarcks, coastal New Guinea, or the Maluku Islands is supported by seafaring simulation models (Fitzpatrick and Callaghan 2013; Montenegro et al. 2016; also Winter et al. 2012). Interestingly, these models provide no support for either downwind (drift) or directed (planned) voyages to the Mariana Islands from the Philippines, but show that between the months of July and October there was a modest probability for successful voyages originating from the south (Halmahera, New Guinea, and the Bismarck Archipelago). Montenegro et al. (2016), using several other modeling parameters (ENSO events, shortest-hop trajectories), show that successful downwind and directed voyages can occur to western Micronesia via Palau and Yap from the southern Philippines and Maluku Islands during ENSO conditions, and from New Guinea and the Bismarcks during La Niña conditions.

These studies, of course, do not address the issue of chronology that is the subject of this paper, but they do concur that an origin for initial Mariana Islands settlement from the northern Philippines is unlikely as posited by Hung et al. (2011). Further, contra Hung et al. (2011) and Carson et al. (2013), even the best candidate site for demonstrating a Philippine connection through its pottery, Nagsabaran, located in the northern Philippines, shows considerable significant differences with early Pre-Latte Period pottery (Clark and Winter in press; Winter et al. 2012). Similarly, the pottery evidence does not support a dispersal of early Austronesians from the Mariana Islands to either Near or Remote Oceania.

It is apparent that the period ~3500–3000 cal BP was one of dynamic population movement in the western Pacific (Kirch 2010), with continued expansion into Remote Oceania in the following centuries (Sheppard et al. 2015). Movement by multiple human groups from numerous locations within a relatively short time period, and across the large ISEA/western Pacific region, may be explicable through a general population-level mechanism, such as the agriculturally fueled demographic expansion argued by Bellwood (2011), or selection associated with changes in climate and maritime technology as argued by Cochrane (in press). A reliable chronology is essential for distinguishing between these and other possibilities.

Chronological modeling for the western Pacific needs to be improved with additional quality dating samples. We suggest that archaeologists exercise greater care in sample selection, choosing short-lived samples confidently associated with human activity, while controlling for residual samples, and date more high-quality samples from individual sites. Further research is also needed to accurately determine localized ΔR values throughout regions of interest. This work has been ongoing in Hawai'i and central Polynesia for the last several decades, with the result that settlement dates are often determined to be later than previously thought (e.g., Athens et al. 2014; Dye 2015; Rieth and Cochrane 2017; Wilmshurst et al. 2008). A similar reevaluation is already underway in the Mariana Islands and Near Oceania, and we anticipate a slightly later chronology for Lapita expansion to the Bismarck Archipelago when probability estimates for dating in these regions are narrowed.

ACKNOWLEDGEMENTS

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END NOTES

1. We do not consider paleoenvironmental evidence for initial Mariana Islands colonization at or slightly prior to 3500 BP (Athens et al. 2004; Athens and Ward 1995, 2004) due to the qualitatively different kind of data used in such studies. They suggest a human presence going back to the mid- or late fourth millennium BP; however, experience in Hawai'i has shown the need for caution when making fine-resolution dating inferences based on bulk sediment samples obtained from coastal brackish or saltwater environments as in the Mariana Islands (Athens et al. 2014:152).
2. The single determination on "marine shells, primarily limpets" (Kurashina and Clayshulte 1983:118) from Tarague was not considered due to uncertainties about the proper ΔR value for this location.
3. Inclusion of Carson's (2008) *A. antiquata*-derived ages from his basal cultural stratum (Layer IV-A) in our Layer VII model phase did not produce a significantly different settlement estimate. Carson's oldest determination (Beta-216616, 3710 ± 50 BP) had a poor agreement value.

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