RE-EXAMINING THE EVIDENCE FOR LATE COLONIZATION ON EASTER ISLAND

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ABSTRACT

One of the recent discussions to emerge among archaeologists regarding Rapa Nui (Easter Island) prehistory contrasts "early" and "late" estimates for initial human colonization of the island. These differing estimates, in turn, offer significantly different messages for the timing and rate of cultural evolution on the island. A recent study of eleven charcoal samples concluded that Rapa Nui was first colonized around 1200 CE. A new analysis of the same eleven charcoal samples suggests that the data are consistent with an earlier colonization date, around 900 CE. The three hundred year difference between the two estimates could mean the difference between a "short chronology" and "long chronology" to archaeologists and environmentalists alike.

INTRODUCTION

In their recent article in *Science*[1], Hunt and Lipo propose a late colonization date of 1200 CE for Rapa Nui (Easter Island) based on statistical analysis of ^{14}C dates for eleven charcoal samples. This date is later than prior estimates by as much as 800 years,[2] and falls 200 years later than the upper limit of plausible colonization dates according to a review of 120 ^{14}C dates by Martinsson-Wallin and Crockford[3] who conclude: "When evaluating the radiocarbon and obsidian hydration dates associated with prehistoric sites on Rapa Nui, the initial settlement on this island may be set between c. A.D. 600 and 1000".

Rapa Nui, as a result of the work of Jared Diamond[4] and others,[5,6] has become an alarming parable for our own impending global resource crisis, and the prehistoric poster-child for non-sustainable cultural extravagance. Doomsday scenarios, made even more urgent with the late colonization date offered by Hunt and Lipo, create an alluring but unsubstantiated interpretation of Rapa Nui prehistory. Hunt and Lipo propose that, "...colonists arrived around AD 1200. The founding Polynesian population then grew rapidly, had immediate, major, and visible impacts on the island's biota and physical landscape, and began investing in monumental architecture and statuary within the first century or two of settlement". The later date espoused by Hunt and Lipo implies a shorter prehistoric period for the island (approximately 500 years between Polynesian colonization and contact with Europeans) and lends credence to hypotheses that describe rapid cultural/ ecological change over smaller intervals of time.

Hunt and Lipo's analysis is based on two principles: chronometric hygiene and statistical analysis. However, their application of chronometric hygiene was selective and their statistical analysis was not justified in their presentation. Accepting Hunt and Lipo's application of chronometric hygiene, an alternative statistical analysis of the same eleven ^{14}C samples results in a date of approximately 900 CE instead of the 1200 CE date surmised by Hunt and Lipo. Because of the limited sample size and the problems inherent in radiocarbon dating, we caution readers *not* to cite this result as the authors' best estimate for colonization. Our intent is only to expose the questionable methodology in Hunt and Lipo's analysis, the analysis that sparked a new line of questioning regarding Rapa Nui's cultural chronology.

CHRONOMETRIC HYGIENE

Prehistoric colonization dates for human expansion into eastern Polynesia have been proposed, debated, and revised partly according to standards for "chronometric hygiene" in ^{14}C dating procedures.[7-12] Proponents of chronometric hygiene have identified common sources of error in archaeological age estimates based on ^{14}C dates and have proposed several criteria that can be employed to select reliable ^{14}C dates.[10,12,13] Hunt and Lipo begin by considering a corpus of 47 ^{14}C dates, all of which are older than 750 BP (uncalibrated). Applying three of the ten chronometric hygiene criteria for rejecting ^{14}C dates set forth by Spriggs and Anderson,[10] Hunt and Lipo eliminate 36 dates. In doing so, Hunt and Lipo rejected all seven dates older than 1170 BP, and 17 of 18 dates older than 900 BP. Incongruously, three of the radiocarbon dates rejected by Hunt and Lipo (M-710 dated to 1,100 BP, UA-618 dated to 1,040 BP, and Gak-2864 dated to 1,010 BP) were deemed "questionable" but *not* rejected by Spriggs and Anderson. One date (WSU-1146 dated to 1,180 BP) was rejected by Hunt and Lipo but *accepted* by Spriggs and Anderson using their full range of seventeen criteria (ten criteria to reject samples, three for determining a sample to be questionable, and four more for accepting a sample).

Hunt and Lipo (1:1605) state regarding their own analysis, "We used fewer criteria than Spriggs and Anderson,[10] making our sample of dates more inclusive but more vulnerable to the acceptance of dates that are erroneously old". However, Hunt and Lipo (hereafter H&L) chose to ignore or violate those principles of chronometric hygiene that may have otherwise included at least four relatively "old" samples from the island. Thus, the selective application of principles of chronometric hygiene may not be as "inclusive" as they argue, and may actually *predispose* their analysis to a "late" colonization conclusion.

Statistical Analysis

Even if we accept H&L's application of chronometric hygiene, their statistical analysis raises additional questions. Each of the eleven ^{14}C dates accepted by H&L, after calibration, has an associated probability distribution function (PDF) (Figure 1). H&L create an "aggregate" PDF by averaging the eleven original PDFs, weighting each equally (Figure 2). H&L calculate the median of the aggregate PDF to be 1222 CE and conclude that this implies "colonists arrived around 1200 AD".

H&L provide no justification for aggregating in this manner. In fact, their procedure does not estimate the expected *earliest* date of all eleven PDFs; it estimates the expected date of a sample chosen at *random* from all eleven (see Appendix A). This statistical analysis would be more appropriate if each of the eleven PDFs were equally reliable as a correct PDF for the unique earliest date of colonization. However, the fact that the medians of the PDFs are spread over 365 years argues that the PDFs represent distinct depositional events, some of which are likely to be earlier than others. Consequently the PDFs of the earlier events are likely to more closely approximate the PDF of the earliest date of colonization.

From the eleven calibrated date PDFs we can calculate the likelihood (see Appendix B) of each charcoal sample being the earliest (Table 1). Sample T-6679 is by far the most likely of the eleven samples (with probability 0.86) to represent the earliest evidence of human occupation. The calibrated date of T-6679 has a median value of 906 CE, an expected value of 908 CE, and falls between 656 CE and 1166 CE at the 0.95 confidence level. The ^{14}C data for T-6679 indicate that this sample dates before 1200 CE with probability 0.99 (Table 2). This alone is enough to warrant skepticism about the claim that a dataset including T-6679 suggests a colonization date as late as 1200 CE. Given the discrepancy between the extremely early PDF for T-6679 and the other samples at hand, there may be some inclination to disregard T-6679 from the analysis, but this would only further undermine the integrity of H&L's application of chronometric hygiene. Regardless, H&L chose to retain T-6679 and it is their data that we are re-analyzing.

The true colonization date for Rapa Nui (which archaeologists will probably never know for sure) is likely to be earlier than any random, or even the earliest recovered, evidence of human occupation; and the median date for the single earliest of the eleven charcoal samples analyzed by H&L is necessarily (in mathematical terms) earlier than the median date of their aggregate PDF formed from all eleven samples. Furthermore, the median date of their aggregate PDF is heavily influenced by the latest dates that H&L chose to include in the analysis. If H&L had initially considered all dates older than 550 BP, instead of their selected cutoff of 750 BP, their median value (and implied colonization date) would have been much later than 1200 CE!

To review, H&L began with a group of 47 samples whose expected dates fall before the arbitrarily chosen cutoff of 750 BP. They proceeded to apply criteria of chronometric hygiene, although somewhat selectively, to refocus their analysis on 11 charcoal samples. And finally, they chose the misleading statistic of an unweighted average for an aggregate PDF of their focal group to arrive at an intriguingly novel colonization date for Easter Island.

An Alternative Analysis

Our alternative analysis outlined in Appendix B begins with two assumptions: (1) all eleven ^{14}C date PDFs are equally valid (each reasonably represents a date for human deposition, as H&L imply via chronometric hygiene); and (2) all eleven PDFs are statistically independent (roughly speaking, this means knowing the date of one sample for certain would not influence our estimate for the date of any of the other samples). The wide range of dates for the eleven samples accepted by chronometric hygiene (the median values of their PDFs span more than three centuries) supports the assumption of statistical independence. Thus, assuming that not all eleven samples are equally likely to be the earliest, we compute the probability distribution of the earliest date (see Appendix B) to have a median value of 906 CE, an expected value of 897 CE, and a 0.95 probability for the interval between 676 CE and 1136 CE (Figure 2). We emphasize that this earliest date is not simply the date of T-6679, which is most likely to be the earliest sample; it is the earliest date when information provided by all eleven samples is considered together (see Appendix B), including the unlikely possibilities that one or more of the samples are even earlier than T-6679.

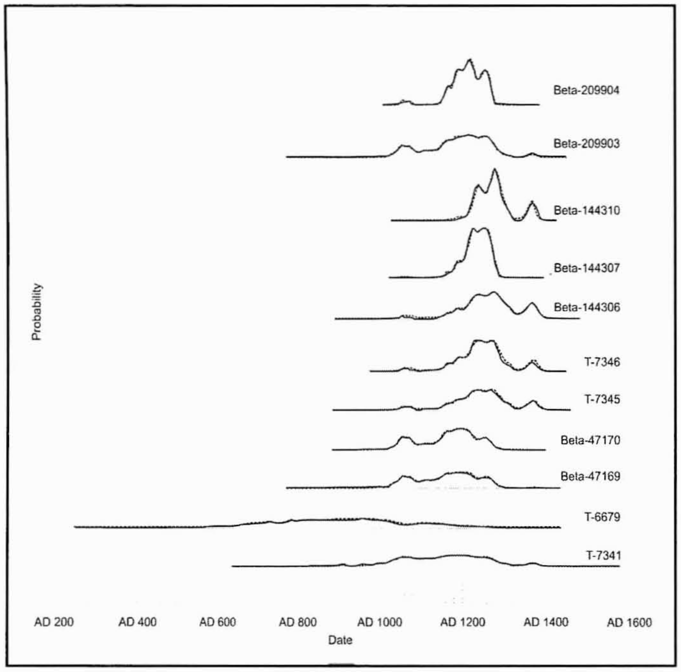

Figure 1. Comparison of PDFs reported by Hunt and Lipo (solid lines) with PDFs calculated by OxCal 4.0[14,15] beta software (dotted lines) and the southern hemisphere calibration curve SHCal04.[16]

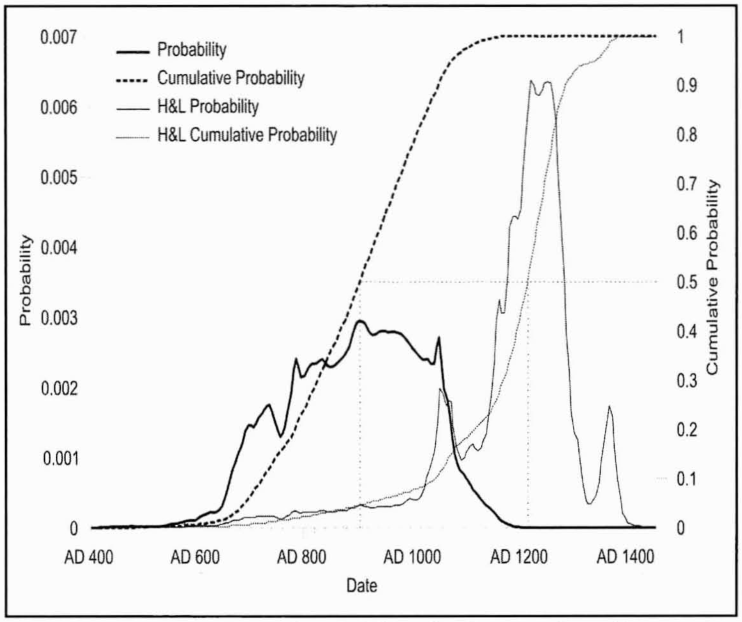

Figure 2. Comparison of probability distributions from Hunt and Lipo's analysis (light lines) and our analysis (heavy lines). Mean or expected date according to Hunt and Lipo is 1187.8 CE; median, 1220.5 CE; standard deviation, 63.1 years. Mean or expected date from our analysis (see Appendix) is 896.5 CE; median, 905.5 CE; standard deviation, 125.3 years. Both analyses examined the same 11 radiocarbon dates.

Table 1. Calculations based on conditional probabilities that each sample is the earliest of the eleven samples.

charcoal sample	*radiocarbon*	*calibrated date*	*probability*	*expected date if earliest*
T-6679	1,170 BP ± 140	908 CE	0.860	874 CE
T-7341	900 BP ± 120	1157 CE	0.060	999 CE
Beta-47169	900 BP ± 80	1164 CE	0.031	1057 CE
Beta-47170	900 BP ± 60	1169 CE	0.023	1070 CE
Beta-209903	870 BP ± 80	1189 CE	0.020	1062 CE
Beta-209904	870 BP ± 40	1212 CE	0.004	1079 CE
T-7345	810 BP ± 80	1244 CE	0.006	1067 CE
T-7346	810 BP ± 70	1248 CE	0.004	1071 CE
Beta-144306	790 BP ± 80	1264 CE	0.003	1068 CE
Beta-144307	840 BP ± 40	1235 CE	0.001	1088 CE
Beta-144310	780 BP ± 50	1277 CE	< 0.001	1089 CE

Table 2. Likelihood estimates of possible earliest dates of the eleven samples.

Distribution Considered	**Probability that Date is On or Before**				
	800 CE	900 CE	1000 CE	1100 CE	1200 CE
Hunt & Lipo Aggregate	0.022	0.045	0.075	0.182	0.416
Sample T-6679	0.245	0.484	0.753	0.898	0.985
Earliest Date, All Samples	0.247	0.491	0.771	0.971	> 0.999

By offering 1222 CE as a median date for the initial occupation of Rapa Nui, H&L determine that the likelihood of colonization taking place *after* 1222 CE is just as probable as the likelihood of colonization taking place before 1222 CE! Our analysis of the same charcoal samples and the same PDFs for these charcoal samples suggests that the likelihood of colonization after 1222 CE is less than one in one hundred thousand.

Our results are consistent with conclusions drawn by earlier proponents of a more thorough chronometric hygiene methodology[10] and indicate a greater than 0.75 likelihood that the earliest of the eleven samples dates to between 600 CE and 1000 CE, the range reported by Martinsson-Wallin and Crockford[3]. The charcoal samples evaluated by H&L actually indicate that Rapa Nui was likely colonized by 900 CE; although with only these eleven samples, the range of uncertainty is rather large (± 230 years at the 0.95 confidence level).

It is important to note that our analysis is not a comprehensive review of early radiocarbon dates for Rapa Nui, but rather a comment on the analytical methodology which led to the "late" colonization conclusion recently formed by H&L. As H&L warn, future research, including analysis of a larger and more reliable body of evidence, may call for revision of the most likely date range for initial colonization of Easter Island. However, we urge archaeologists in the Pacific and elsewhere to consider the statistical analysis described in Appendix B instead of H&L's "aggregate probability" approach. The analysis we present in Appendix B is generally applicable for finding the earliest date (or, analogously, latest date) associated with a set of independent samples for which reliable PDFs are known, and could be used to estimate colonization events (or terminal events) for other populations and regions for which similar data are available.

Appendix A

The Hunt and Lipo aggregate PDF is an unweighted average of 11 individual PDFs:

$$p(t) = \frac{1}{11}\sum_{i=1}^{11} p_i(t).$$

Sampling a date from the Hunt and Lipo aggregate PDF is equivalent to the following procedure: randomly choose one of the eleven individual PDFs, and then sample a date t from the selected individual PDF. In this procedure, the probability of obtaining a date t is the probability of selecting the first individual PDF multiplied by the probability of selecting date t as a random sample from the first PDF, plus the probability of selecting the second PDF multiplied by the probability of selecting date t as a random sample from the second PDF, and so on. Since the probability of randomly choosing each individual PDF is 1/11, the probability of obtaining a date t through this procedure is

$$p(t) = \frac{1}{11}p_1(t) + \frac{1}{11}p_2(t) + \ldots \frac{1}{11}p_{11}(t) = \frac{1}{11}\sum_{i=1}^{11} p_i(t),$$

identical to the Hunt and Lipo aggregate PDF.

Appendix B

The PDF of the sum of random variables is not given by the normalized sum of the PDFs of the random variables; a more complicated calculation (convolution) is required. Similarly, the minimum of a set of random variables is not calculated from the normalized sum of the PDFs of the random variables (weighted or unweighted).

From the OxCal calibration program we have discrete PDFs for the dates of the eleven charcoal samples i, $i = 1, 2, \ldots, 11$ (Figure 1). Let x_i be a random variable representing the date of charcoal sample i, let x be a random variable representing the earliest date from the collection of samples, and let A_i be the event that sample i is the earliest sample. Assuming the random variables x_i are independent, the cumulative probability that the earliest date x falls on or before time t can be expressed as:

$$\Pr[x \le t] = 1 - \Pr[x > t] = 1 - \prod_{i=1}^{11} \Pr[x_i > t].$$

and the PDF for the earliest date is:

$$\Pr[x = t] = \Pr[x \le t] - \Pr[x \le t-1].$$

These functions are graphed in Figure 2.

The probability $\Pr[A_i]$ that sample i is the earliest (or one of the earliest in the case of ties) is calculated by conditioning on the date of sample i:

$$\Pr[A_i] = \sum_t \left(\Pr[A_i | x_i = t]\Pr[x_i = t]\right),$$

where $\Pr[A_i|x_i=t]$ is the conditional probability that sample i is the earliest sample given that its date is t. Assuming all the random variables x_i are independent,

$$\Pr[A_i | x_i = t] = \Pr[x_j \ge x_i, \forall j \ne i | x_i = t] = \prod_{j \ne i} \Pr[x_j \ge t]$$

and we have

$$\Pr[A_i] = \sum_t \left\{ \left(\prod_{j \ne i} \Pr[x_j \ge t] \right) \Pr[x_i = t] \right\}.$$

We can also compute the conditional PDF $\Pr[x_i \mid A_i]$ for the random variable x_i, given that charcoal sample i is the earliest sample:

$$\Pr[x_i = t \mid A_i] = \frac{\Pr[A_i \mid x_i = t]\Pr[x_i = t]}{\Pr[A_i]}.$$

The probabilities $\Pr[A_i]$ are given in Table 1 (as "Probability Earliest") along with expected dates calculated from $\Pr[x_i \mid A_i]$.

NOTES / REFERENCES

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> **"Guardians of earth and rock."**
> — **Edward Tregear**