Bayes *versus* pragmatism: a debate about dating Hawaiian temples

This important discussion about the use of radiocarbon to set up a narrative of temple construction on Hawai'i arises from a recent paper published in Antiquity *(2011: 927–41). It compares Bayesian and non-Bayesian solutions, and has implications that reach far beyond the Pacific.*

Keywords: Pacific, Hawai'i, radiocarbon, Bayesian analysis

Hawaiian temples and Bayesian chronology

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> [T]he chronological development of the Kohala, Kona, Waimea, Kahikinui, and Kalaupapa field systems, spanning three islands, is remarkably congruent. While there was some low intensity land use in Kohala and Kona prior to AD 1400, in all cases the onset of major dryland cultivation began around AD 1400. Following about two centuries of development, a final phase of intensification, typically marked by highly formalized garden plots and territorial boundaries, commenced about AD 1600 to 1650, and continued until the early post-contact period. Unlike the irrigation systems, many of which have continued in use throughout the nineteenth and twentieth centuries, the dryland field systems were all rapidly abandoned within a few decades following European contact (Kirch 2010: 153).

This chronology is adopted in a recent paper by McCoy *et al.* (2011: 939) as a 'ruling theory' (Chamberlin 1965), part of a larger argument that links field system development with the rise of elite authority, leading to what the authors refer to as the political elite "completely subsuming religious authority". The chronology the authors derive from their material stretches back to the late fifteenth century, which puts it in broad conformity with the ruling theory.

The centerpiece of their paper is a seriation of religious temples in the Leeward Kohala Field System (LKFS) that purports to arrange their construction dates in time. Hawaiian religious temples are famously variable and more than one attempt to order them formally has come to nothing (Bennett 1930; Stokes 1991). One reason for the formal variability was discovered when Kane'aki Heiau on O'ahu was excavated and shown to have been remodelled, often substantially, several times during its history (Ladd 1973). Hawaiian tradition is clear that remodelling temples was a common practice (Malo 1996: 82, 241). Features that the authors used to seriate the LKFS temples, and that presumably inform on

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the construction date, were shown at Kane'aki Heiau to be architectural components that might be added during a later remodelling stage. Because the seriation method for single objects dates "the time at which the attributes came together to make up the object" (Dunnell 1970: 307), the seriation proposed by the authors might track a history of remodelling events, rather than a history of construction.

This potential decoupling of the seriation from construction events is important because the authors use the seriation results to accept radiocarbon dates from beneath seven temples and to reject dates from beneath four others. This step is unfortunate because the radiocarbon dates were collected in a way that established their stratigraphic relationship beneath the basal stones of structures, a practice frequently ignored in Hawaiian archaeology. Care was taken to date short-lived woods selected from confidently identified charcoal to control for the effects of old wood. This careful procedure establishes the stratigraphic boundaries of two periods, one under the structure that pre-dates construction and another above the basal stones that post-dates construction. If the start and end dates of these periods are designated α and β, respectively, then the dating model can be expressed as $\alpha_{pre} > \beta_{pre} = \alpha_{post} > \beta_{post} =$ AD 1819, where the symbol $>$ is taken to mean 'is older than.' In plain English, this model says that the pre-construction period began at some unknown point in the past and ended when the post-construction period began, and that the post-construction period lasted until the overthrow of the traditional religion in AD 1819.

This model makes clear that the best estimate of the construction date, α_{post}, is the end of the pre-construction period, or β_{pre}. The authors instead use an approximation of α_{pre} as the *terminus post quem* for the construction date. There is nothing inherently wrong with this—α_{pre} is very likely to be older than the construction date—but it does throw away potentially useful information and it almost certainly leaves the impression of a construction date too far in the past.

The use of α_{pre} to estimate construction becomes problematic when the authors construct 'brackets' for the ages of the construction events. In this bracketing procedure the α_{pre} for the subsequent group in the seriation is used as the upper bound for the age bracket. There is no stratigraphic warrant for this procedure because the dated structures are independent of one another. Its sole basis appears to be the seriation, and an assumption that one temple form is abruptly replaced by the next.

In any event, the brackets created by the procedure are unlikely to be correct, given the radiocarbon dates from beneath the structures. The posterior distributions of the 11 estimates of β_{pre} are shown in Figure 1, which was created with output from the BCal software package (Buck *et al.* 1999). On present evidence, and given the dating model, most of the structures are likely to have been built in the eighteenth century. Late construction dates are also possible for the few structures that might have been built earlier than this.

The radiocarbon dates under the structures indicate that they were constructed late in traditional Hawaiian times, much later than the chronology proposed by the authors. The probability that β_{pre} is older than the late bound of its bracket is shown in the column labelled 'Probability' in Table 1, which was calculated by the BCal software package using the probability query indicated in the column labelled 'Query', where the symbol $>$ is taken to mean 'is older than' and the symbol $<$ means 'is younger than.' There is a 4 per cent probability that structures KAL-26 and KAL-27 in seriation group A are older than AD

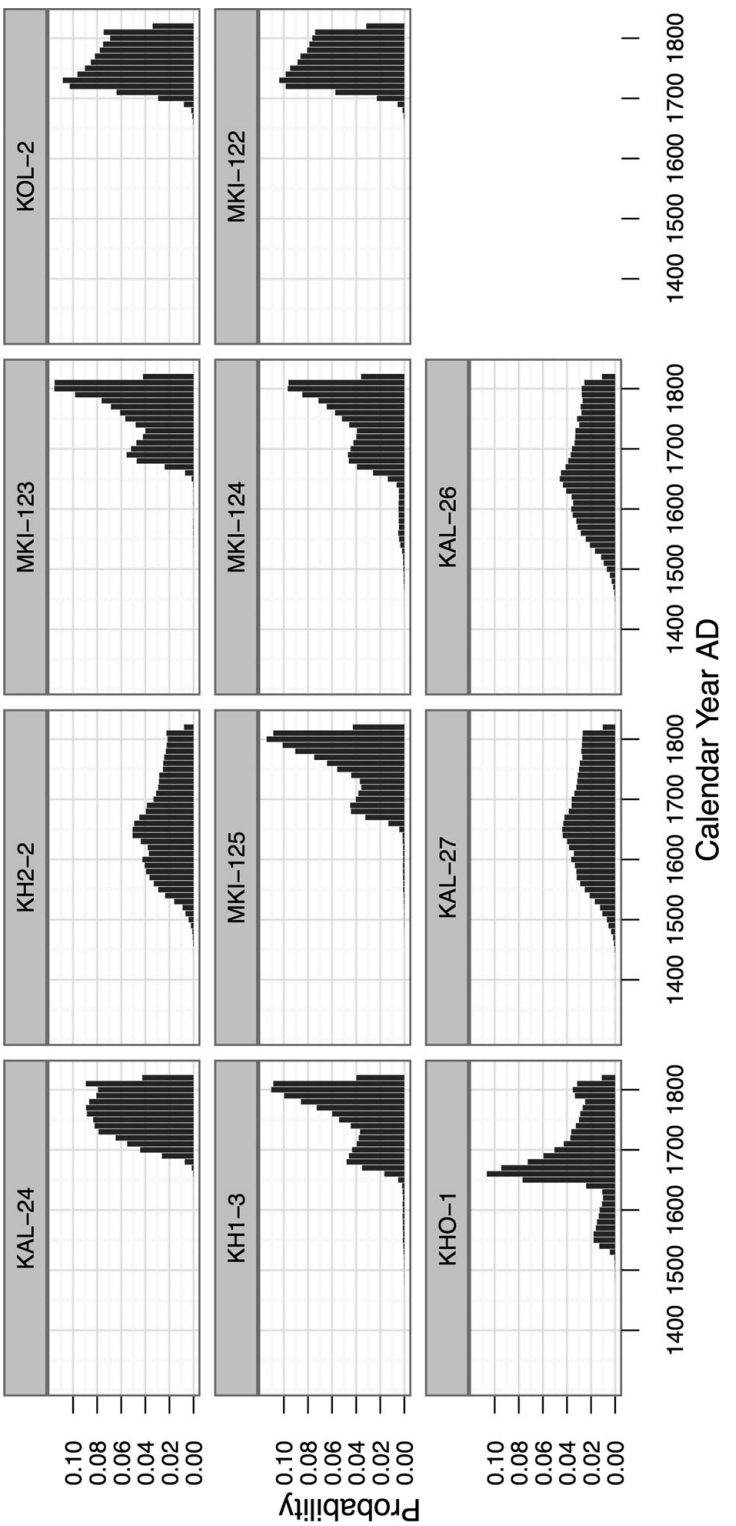

Figure 1. Posterior probabilities of temple construction events.

Table 1. The fit of data to chronological model.

Temple	Seriation	Query	Probability
KAL-27	A	$\beta_{pre} > 1522$	0.04
KAL-26	A	$\beta_{pre} > 1522$	0.04
MKI-125	B	$\beta_{pre} > 1647$	0.01
MKI-124	B	$\beta_{pre} > 1647$	0.06
MKI-122	B	$\beta_{pre} > 1647$	<0.01
KHO-1	B	$\beta_{pre} > 1647$	0.17
KH2-2	C	$\beta_{pre} > 1680$	0.60
MKI-123	C	$\beta_{pre} > 1680$	0.03
KOL-2	C	$\beta_{pre} > 1680$	<0.01
KH1-3	C	$\beta_{pre} > 1680$	0.07
KAL-24	D	$\beta_{pre} < 1680$	0.99

1522, a nil to 17 per cent probability that the four structures in seriation group B are older than AD 1647, and a nil to 60 per cent probability that the four structures in seriation group C are older than AD 1680. Only seriation group D, whose bracket ends with the overthrow of traditional religion in AD 1819, seems a reasonable fit with the data. The high probability that structure KAL-24 was constructed after AD 1680 is an artefact of the authors' use of α_{pre}, rather than β_{pre}, as the construction date estimate. In fact, given the stratigraphic model and the evidence of the young radiocarbon date beneath the structure, it is likely that the temple was built well after AD 1680 (see Figure 1).

The conclusion that the radiocarbon dates are too young to support the ruling theory seems inescapable. If the functional attributes that the authors speculate for the various temple classes have any basis, then both the emergence of a "cross-polity sect of priests dedicated to Lono" and "a shift to an emphasis on authority derived from monumentality" (McCoy *et al.* 2011: 939) are eighteenth-century phenomena, rather than the seventeenth-century trends suggested by the authors under the influence of the ruling theory.

The sophisticated dating program carried out in the LKFS has produced a large corpus of stratigraphically secure and reliable age determinations. Model-based calibrations of these dates yield results that consistently contradict the ruling theory. The young dates beneath the foundation stones of the LKFS temples support the idea, based on a Bayesian calibration of radiocarbon dates on short-lived materials collected from beneath agricultural walls and trails, that imposition of elite authority in the LKFS was a late phenomenon, possibly contingent on events of the historic period (Dye 2011).

It is time to break free of the ruling theory and generate alternative working hypotheses consistent with the facts on the ground.

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The value of an "eclectic and pragmatic" approach to chronology building

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We are in complete agreement with Dye that multiple working hypotheses are valuable to advancing science and his alternative chronological model in which "most of the [temple] structures are likely to have been built in the eighteenth century" does offer a second reading of our primary data. But, while we welcome new scholarship, we reject the notion that our interpretations derive from a slavish adherence to a "ruling theory." The real issue here is the appropriateness of different statistical methodologies.

Archaeology has been held up as a field where "[t]he sense of a holy war between the Bayesians and their classical enemies, so prevalent in the philosophy of science literature, is almost entirely absent" (Steel 2001: S162–63). Instead, we exemplify the willingness of modern scientists to be "eclectic and pragmatic" in the application of statistics (Steel 2001: S163). In other words, we use particular statistical models on a case by case basis given the evidence at hand. This is true of our own work, and indeed we have chosen to use Bayesian statistical models when appropriate (Field *et al*. 2011a), but it is untenable to believe Bayesian methods are the right fit for every case.

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To address the research presented in our original paper, we first note that Dye accepts our radiocarbon dates on the charcoal of short-lived plant taxa. The main difference is that he would have us treat each of the temples dated as constructions that occurred "independent of one another." While construction events were independent in the strictest sense of the word, we should not assume that they were built without regard to pre-existing and contemporary religious structures. There is an abundance of anthropological and religious studies literature that point to the importance of creating and manipulating symbols through religious architecture, in addition to specific ethnohistoric data from nineteenth-century Hawai'i that describes a formal priestly class whose domain included designing the architectural layout of temples before European contact. Once the first temple was constructed in the study area, subsequent religious structures were not independent. Rather their form and location reflects a host of historically contingent factors and it would be a mistake to ignore the roles of social structure, tradition and agency. As a correlate to Dye's assumption of independence, he proposes that temple rebuilding was so great that it completely obliterated all possibility of the survival of stylistic groupings. We recognise that reconstruction over the lifetime of a structure is inherently problematic and explicitly make room for this in our interpretations to help explain dates that are true outliers (McCoy *et al.* 2011: 932). But, we also note that an extensive search of relevant documented cases of rebuilding of Hawaiian temples would likely show that large, complex sites were more commonly subject to renovation than a set of small temples found in upland agricultural fields. More importantly, if rebuilding is such a large issue, we find it a remarkable coincidence that the relative order of the groups derived from architectural elements fits so well with the completely independent evidence provided by the analysis of territorial boundaries (Ladefoged & Graves 2006).

We understand the appeal of the apparent security in dating afforded by Dye's particular model but in this case it comes at a cost, specifically the failure to recognise the most likely time period for the construction of architecture.

To demonstrate how bias is introduced in his Bayesian model consider the site KAL-24. In our original paper, we use a radiocarbon date to bracket the absolute range of possible construction dates for the site to between AD 1680 and 1819, the latter marking the year that traditional Hawaiian religion was ended by royal decree. Dye would place the construction "well after AD 1680," and presents a posterior probability curve sharply peaked leading up to AD 1819.

To expose how sensitive his proposed chronological model is to his choice of cut-off date, we compared three models created in BCal: (A) one that constrains the latest construction to AD 1778, the time of European contact; (B) one representing Dye's model that uses AD 1819 as a cut-off; and (C) one that does not constrain the date of construction (e.g. uses a cut-off of just before radiocarbon present, 1949). Figure 1 shows that each model yields quite different, and largely incongruent, posterior probabilities. In model A, on the left, there is a multi-peaked area of highest probability in the 50 years leading up to AD 1778. In the centre we see Dye's model (model B), where an unusual spike in probability is created primarily because AD 1819 just happens to fall on the beginning of the later of the two radiocarbon intercepts. In model C, the late intercept again has greatest sway and we find a relatively uniform area of high probability in the 150 years before radiocarbon

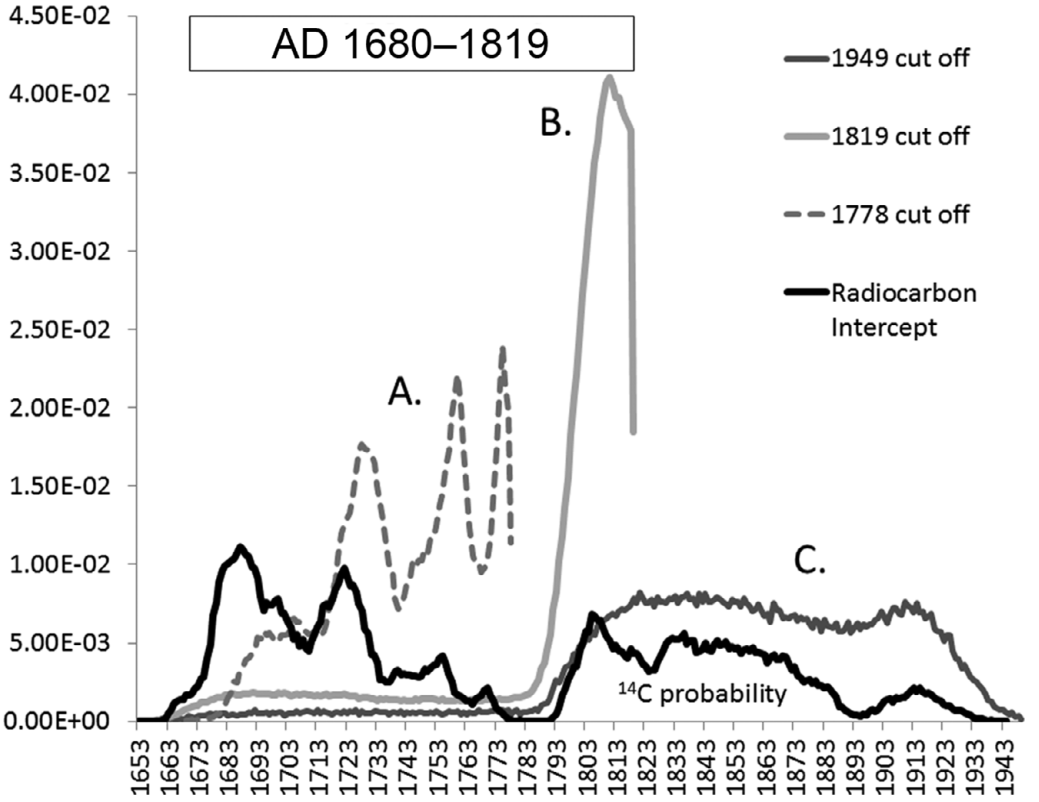

Figure 1. Various Bayesian models for site construction. In our original study, we bracketed temple construction based on the earliest end of a calibrated radiocarbon date on material from under foundation stones of KAL-24 as a TPQ, and AD 1819 as TAQ. Here we show alternative Bayesian models (BCal, Buck et al. *1999). Model A applies a cut-off date of AD 1778 (European contact), forcing an exaggeration of probability corresponding to the late end of the first radiocarbon intercept. In model B, a representation of Dye's model, the start of the second radiocarbon intercept forces a ramp up in the decade leading up to AD 1819. Model C, with a cut-off at radiocarbon present, simply pushes the curve to correspond to the entire second intercept. Each leads to the erroneous conclusion that construction must have occurred in the years immediately prior to the given cut-off date.*

present. In each of the three scenarios presented, the area of highest probability is an artefact of the decision regarding the cut-off date. Clearly, the apparent security and precision of the posterior probability is something we should not take at face value.

This is not an isolated case, indeed in another Bayesian re-analysis Dye (2011) has somewhat arbitrarily created late posterior probability for agricultural development for the same study area and then argued that "…the main thrust of field system intensification can be dated to the eighteenth and early nineteenth centuries. Much of it seems to be a post-[European] contact phenomenon" (Dye 2011: 29). He comes to this conclusion using a boundary for the last period of agricultural construction based on a "normal curve with a ten year standard deviation centered at AD 1850," a date meant to represent the historic era Mahele land redistribution act. However, there is no historic evidence that agricultural development occurred this late in the post-contact era, and the effect of choosing AD 1850

is the same as we see for KAL-24, it forces the posterior probability to ramp up, making it appear as if all activity in the field system occurred in the years immediately prior.

The construction of features in leeward Kohala occurred over an extended period of time and an entirely late chronology contradicts even the most conservative interpretation of radiocarbon dates from the area. Radiocarbon dates from temple excavations, which Dye does not dispute, likely represent 15 agricultural clearing events, with only 7 definitively post-dating AD 1650 (2σ) (i.e. 200 BP or later). This is consistent with other studies in which 16 out of 31 dates (Ladefoged & Graves 2008), and 23 out of 49 dates (Field *et al.* 2011b) were found to be 200 BP or later. Clearly there was a lot of activity in leeward Kohala after AD 1650, but there is very little archaeological or historical evidence that this occurred after *c.* AD 1820. Dye's models have led him to the incorrect conclusion that the leeward Kohala field system was abuzz with activity in the early nineteenth century; a proposition that if it were the case would be even more remarkable given the overall trend of post-contact rural depopulation due to introduced disease and migration to nineteenth-century port towns.

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