PAIRED DATING OF PITH AND OUTER EDGE (TERMINUS) SAMPLES FROM PRE-HISPANIC CARIBBEAN WOODEN SCULPTURES

Fiona Brock[1,2] • Joanna Ostapkowicz[3] • Christopher Bronk Ramsey[1] • Alex Wiedenhoeft[4] • Caroline Cartwright[5]

ABSTRACT. Radiocarbon dating of historical and archaeological wood can be complicated, sometimes involving issues of "inbuilt" age in slow-growing woods, and/or the possibility of reuse or long delays between felling and use of the wood. Terminus dates can be provided by dating the sapwood, or the outermost edge of heartwood, while a date from the pith can give an indication of the first years of growth. A sequence of samples from specific points within the bole can be used to determine the growth rate of the tree. Such a combined dating strategy is particularly useful in cross-referencing dates from a single piece, better placing it in its chronological context. This paper reports paired or multiple dates from 11 wooden sculptures dated as part of the *Pre-Hispanic Caribbean Sculptural Arts in Wood* project, which studied 66 wooden artifacts attributed to the pre-colonial Taíno, the indigenous peoples of the Caribbean's Greater Antilles. The calibrated ages of the pieces published here range from ~AD 700–1500, indicating that the Taíno were producing elaborate sculptures much earlier than previously thought. The paired or multiple dates from these carvings confirmed the accuracy of the results, and were also used to construct a growth rate model of what was expected to be a slow-growing species (*Guaiacum* sp.). This model demonstrates that the boles used to create the sculptures grew on average 1 cm every 6–13 yr.

INTRODUCTION

The Taíno inhabited Hispaniola (Haiti and the Dominican Republic), Puerto Rico, Jamaica, Cuba, the Bahamas, and the Turks and Caicos Islands at the time of first European contact in the late 15th century. Culturally complex and diverse, they spoke different languages and varied in artistic expression, but were linked broadly across this chain of islands through a shared ancestry and deep, far-reaching webs of social connection (Wilson 2007; Oliver 2009). Their ancestors had arrived from mainland South America via the Lesser Antilles, settling in Puerto Rico and Hispaniola by ~AD 400, and interacting with the local inhabitants who had occupied the Greater Antilles for millennia (Wilson 2007). Populations flourished and expanded into Cuba, Jamaica, and the Bahamas by ~AD 600 (Wilson 2007). From about this period, complex, stratified societies began to emerge (Oliver 2009:25), inspiring, among other things, an artistic florescence.

The Taíno created visually striking wood sculptures made of single boles and decorated with inlays of *guanin* (a gold-copper alloy) or shell: there are no extant examples featuring multiple wood components. By the time of Columbus' arrival in 1492, wooden sculpture is documented as being central to Taíno religious and social practices (Colón 1992:151; de Oviedo y Valdés 1959:I:112; Pané in Arrom 1999:25). The carvings took a wide variety of forms including *cohoba* stands used to hold hallucinogenic snuffs during ceremonies (e.g. Figure 1a); *cemís* that depicted spirits, deities, and ancestors; reliquaries (e.g. Figure 1b); and *duhos* (seats used by chiefs and other dignitaries during rituals and important sociopolitical occasions, e.g. Figure 1c).

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[1] Oxford Radiocarbon Accelerator Unit, Research Laboratory for Archaeology & the History of Art, University of Oxford, Dyson Perrins Building, South Parks Road, Oxford OX1 3QY, United Kingdom.
[2] Corresponding author. Email: Fiona.brock@rlaha.ox.ac.uk.
[3] World Museum Liverpool, William Brown Street, Liverpool L3 8EN, United Kingdom.
[4] Center for Wood Anatomy Research, Forest Products Laboratory, USDA Forest Services, One Gifford Pinchot Drive, Madison, Wisconsin 53726-2398, USA.
[5] Scientific Research Laboratory, British Museum, London WC1B 3DG, United Kingdom.

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Figure 1 Left to right: a) Pelican cohoba stand, *Guaiacum* sp., AD 978–1021 (modeled date for outer edge), Aboukir, Jamaica, H: 633 mm; W: 215 mm; D: 205 mm. Courtesy of the National Gallery of Jamaica, Kingston. b) Musée Barrois reliquary, *Guaiacum* sp., AD 1054–1181 (modeled dates), Dominican Republic/Haiti (?), H: 460 mm; W: 249 mm (max); D: 250 mm. Courtesy of the Musée Barrois, Bar-le-Duc, France, 850.20.38. c) Robsjohn-Gibbings duho, *Guaiacum* sp., AD 1451–1517 (modeled dates), L: 412 mm; H: 65 mm (max); W: 232 mm (max). Courtesy of the Division of Anthropology, American Museum of Natural History, New York, 25.0/3812.

Taíno sculptures entered Europe with the first shipments of native wealth from the Indies (Las Casas in Parry and Keith 1984:66; Martyr D'Anghera 1970:125), acquired through gift exchanges, trading, or plunder. Over the following centuries, as the Caribbean islands were explored and settled by Old World immigrants, other examples emerged, many found in caves. There are over 300 pieces now held in museums and private collections around the world (Ostapkowicz 1998), and recent work on waterlogged sites such as Los Buchillones, Cuba, and La Aleta, Dominican Republic, has the potential to greatly expand this number (Calvera et al. 1996, 2006; Conrad et al. 2001). Many of the pieces deposited in museums in the 18th and 19th centuries, usually recovered as chance finds or circulating in private collections for decades, if not centuries, have lost their associated information. Hence, little is known about them—for example, how, when, and where they were made, whether their iconography reflects regional and temporal stylistic variations, or what their roles may have been within the context of Taíno culture.

The multidisciplinary *Pre-Hispanic Caribbean Sculptural Arts in Wood* project was established to provide a chronological framework for a corpus of 66 Taíno sculptures, selected on the basis of their historical significance and wide-ranging provenance. The aims were to build an understanding of the materials used, how they were carved and finished, and the stylistic variations between carvings, the latter potentially based either on their chronological placement or their provenance (with stable isotope studies aiding to confirm their source). Although 7 species of wood were identified as part of the project, *Guaiacum* spp. overwhelmingly dominated the results, being used for nearly three quarters of the pieces. Two species of *Guaiacum*, *G. sanctum* and *G. officinale*, are of particular interest to this study, with similar growth characteristics and wood structure. Their native range is along a western arc in the wider Caribbean, including the Greater Antilles, Bahamas, and the Turks and Caicos Islands, as well as in Central America, from Mexico to Costa Rica, and also Florida.

Dating sculptures such as these, and wood in general, can be problematic for a variety of reasons, including the "old wood effect"—the time between felling and use (in this instance, carving) and the potential for reuse of wood. Slow-growing or long-lived woods could also demonstrate an "inbuilt" age with potentially up to several centuries difference between the pith (the first years of tree growth) and the sapwood, which, as the youngest wood in the original bole, provides a terminus date (i.e. the date of felling). Both *G. sanctum* and *G. officinale* are generally considered slow-growing (e.g. Francis 1993; Dertian and Duvall 2009; López-Toledo et al. 2008; López-Toledo 2009; CITES 2011). However, it should be noted that "slow growth" has no precise definition when referring to woods, and such classifications are typically based on individual observation or experience (Wood 2010), details of which are only just beginning to emerge for *Guaiacum* (López-Toledo et al. 2008; López-Toledo 2009). Prior to this, the perception of *Guaiacum*'s "slow growth" appears to have been influenced—perhaps unduly—by the oft-cited Wilson and Eisner (1968) reference that suggested that some *Guaiacum* trees in Florida were more than 1000 yr old, although the accuracy of these estimates have since been debated (Tomlinson 1980).

The suitability of dendrochronology for dating tropical woods is still controversial due to the frequent lack of distinct growth rings (e.g. Worbes 2002), although occurrences of tropical trees that do form distinct growth rings on a stable, periodic basis have been recorded, including West Indian pine in the Dominican Republic (Speer et al. 2004) and several species in Bolivian rain forests (Brienen and Zuidema 2005). *Guaiacum* itself has indistinct or absent growth rings boundaries (Figure 2) (Inside Wood Database 2011). However, regardless of whether or not distinct growth rings are present in the wood used in Taíno sculptures, the application of traditional dendrochronological techniques is clearly not possible, as the pieces cannot be sectioned, polished, etc. as required without causing permanent damage to these unique carvings. Non-invasive techniques such as X-ray CT scans of the growth rings (e.g. Grabner et al. 2009) are only feasible if one can be confident in the growth rates of the species in question, normally not possible with such tropical hardwoods as *Guaiacum*, which lack distinct growth ring boundaries. For this very reason, there is an absence of reference chronologies for tropical hardwoods in the Greater Antilles, and so any dendrochronological data, even were they available, could not be tied into an established sequence. As recently as 2010, it has been suggested that radiocarbon dating is still the only accurate method for dating tropical woods without distinct growth rings (Patrut et al. 2010).

Guaiacum wood is extremely hard and heavy, making it very difficult to carve, even with modern steel tools (Ostapkowicz 1998). These characteristics can override some of the concerns for ^{14}C dating discussed above for several reasons: i) the extreme hardness of the seasoned wood makes it likely that pieces were carved while still "green"—or freshly felled—and so easier to work, and this is suggested by the twisting and checking observed in some of the finished pieces (Ostapkowicz et al. 2011); ii) given its natural hardness after drying, the wood was unlikely to have been reused; and iii) to efficiently work the wood, carvers selected the material with an eye to the finished form of the carving, where much of the bole was retained and conservatively reduced to save labor (not only in cutting away extraneous material but also in resharpening stone tools). The other woods under consideration here are *Cordia* sp. and *Carapa* sp., neither of which are considered to be as slow growing as *Guaiacum*, and so do not have the same issues of potentially "inbuilt" age.

The ^{14}C component was of central importance to the *Pre-Hispanic Caribbean Sculptural Arts in Wood* project (see also Ostapkowicz et al. 2011, 2012), and it is clear from the issues discussed

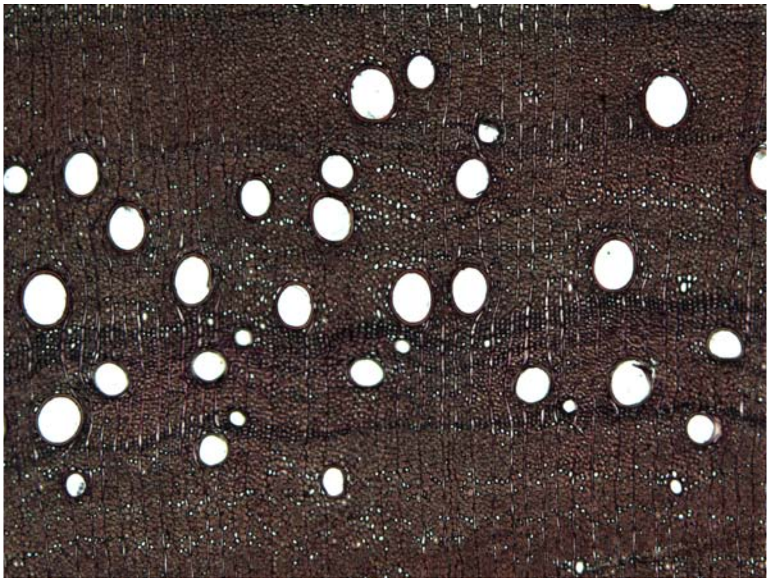

Figure 2 Transverse section of *Guaiacum officinale* showing a lack of distinct growth rings (image size: 2059 µm wide by 1544 µm tall). Photo: A Wiedenhoeft.

above that careful sampling was paramount. Our methodology was carefully tailored to the objects under investigation. To establish a reliable chronological framework for the sculptures, it was critical to identify when the selected woods were felled, and likely carved, and hence all pieces dated were sampled at, or close to, the outermost edge, ideally in sapwood where possible, to give a terminus date. As part of our sampling strategy, samples were also taken at the pith (or central heartwood) from 10 of the 11 pieces presented here, to date the first years of growth. Additional dates were measured at specific points within the bole for 3 of the sculptures, and samples were taken from the outer and inner edges of 1 hollow carving. The dates from the 8 pieces carved from *Guaiacum* were used in the construction of a growth rate model for the species, presented below.

METHODS

Sampling Strategy

Samples were collected from 2 or more locations from a total of 11 Taíno sculptures, listed in Table 1. Sampling of the sculptures was often a challenge, requiring sufficient material for a reliable date to be removed from specific locations (namely the pith and outermost rings) without the sampling being too apparent or damaging to the integrity of the objects (many samples were taken in already present cracks or damaged areas to minimize disturbance). Each piece was initially orientated relative to its position within the original bole, and then a small sliver of wood (usually between 30–90 mg, but some samples were as small as 6 mg where little material was available) was carefully removed with a scalpel. The MMA cohoba stand was the only piece from which samples were removed using a drill by in-house conservators, as per institutional requirements. Ten artifacts were sampled at the outermost heartwood edge; sapwood in sufficient quantity to sample was present in 1 piece, the Capt. Wheeler duho (Table 1). Ten of the 11 sculptures provided pith dates (Table 1).

Table 1 List of sculptures from which multiple samples were taken for dating, including their museum and accession number and sampling location. Calibrations are based on IntCal09 (Reimer et al. 2009) and are quoted at 95% probability (with subdivisions ignored). Artifacts were identified to *Guaiacum* spp. (G), *Cordia* sp. (Cd), or *Carapa* sp. (Cp). Only artifacts identified to *Guaiacum* spp. are included in the growth rate model. Modeled age ranges are based on a model average with self-consistent growth rates based on all pieces (see text). The agreement index (Bronk Ramsey 2009) indicates the degree of overlap between the calibrated and modeled dates and where <60 (*) indicates poor agreement. The Carpenter's Mountain anthropomorph is the only piece to show really poor agreement; this piece is from a more minor branch and may have a higher growth rate.

Sample	Sampling location	Species	^{14}C age (BP)	Lab nr	Calibrated age (cal AD)	Modeled age (AD)	Agreement index
MMA cohoba stand. *Hispaniola (?). Metropolitan Museum of Art, New York, USA (1979.206.380)*	Pith	G	1107 ± 26	OxA-20675	886–978	835–924	65
			1144 ± 27	OxA-20676			
	Left: 89.8 mm from pith, 7.5 mm from outer edge		1165 ± 28	OxA-20626	887–978	954–991	60
			1093 ± 24	OxA-21855			
	Right: 115.4 mm from pith, 4.1 mm from outer edge		1031 ± 27	OxA-20627	902–1034	975–1017	103
Musée Barrois reliquary. *Hispaniola (?). Musée Barrois, Bar-le-Duc, France (850.20.38)*	Inner edge ~25 mm from outer edge	G	904 ± 28	OxA-19398	1039–1208	1032–1158	107
	Outer edge		927 ± 28	OxA-19399	1026–1169	1054–1181	102
Aboukir pelican cohoba stand. *Aboukir, Jamaica. National Gallery of Jamaica, Kingston*	Pith	G	886 ± 26	OxA-21054	1044–1217	1156–1215	115
	23.94 mm from outer edge, 89.04 mm from pith sample		820 ± 40	Beta-153379	1057–1277	1257–1281	46*
	Outer edge: 112.9 mm from pith sample		646 ± 22	OxA-23004	1284–1391	1280–1303	79
Haitian duho. *Peabody Museum of Natural History, New Haven, USA (237501)*	4.1 mm from center of pith	G	491 ± 27	OxA-19178	1408–1447	1404–1448	95
	Outer edge, 130 mm from pith sample		369 ± 28	OxA-19176	1448–1633	1499–1603	59
Carpenter's Mountain canopy cemí. *British Museum, London (AM 1977, Q.1)*	Pith	G	981 ± 26	OxA-21145	995–1153	991–1057	128
	Outer edge: ~100 mm from pith sample		943 ± 26	OxA-21113	1027–1155	1084–1158	107
Small anthropomorph. *British Museum, London (AM 1977, Q793)*	Pith	G	869 ± 25	OxA-21152	1047–1224	1179–1250	77
	Outer edge: ~50 mm from pith sample		757 ± 25	OxA-21153	1227–1296	1224–1286	65
Carpenter's Mountain anthropomorph. *British Museum, London (AM 1977, Q.3)*	Pith	G	737 ± 25	OxA-21144	1226–1291	1218–1247	10*
	Outer edge (L): ~100 mm from pith sample		718 ± 26	OxA-21142	1257–1381	1256–1381	100
	Right side: ~40 mm from pith sample		779 ± 26	OxA-21141	1217–1277	1252–1280	100
Robsjohn-Gibbings duho. *American Museum of Natural History, New York (25.0/3812)*	Pith	G	657 ± 27	OxA-20845	1280–1391	1351–1394	106
	Outer edge (R): 118.0 mm from pith sample		356 ± 27	OxA-20844	1453–1634	1451–1517	100
Capt. Wheeler duho. *Cat Island (historically "San Salvador"), Bahamas. Bryn Mawr College, Pennsylvania, USA (97-1-65)*	Pith	Cd	506 ± 22	OxA-23003	1406–1442	n/a	n/a
	Sapwood: ~30 mm from heartwood sample		409 ± 25	OxA-20839	1435–1618		
Juaco duho. Baracoa. *Guantanamo, Cuba. National Museum of the American Indian, New York (042390)*	Pith	Cp	1371 ± 25	OxA-19057	619–682	n/a	n/a
	Outer wood: ~35 mm from pith sample		1316 ± 27	OxA-18799	665–771		
Bird & Turtle canopied cemí. *Hispaniola (?). British Museum, London (MI 168)*	Pith	Cp	805 ± 24	OxA-21148	1186–1273	n/a	n/a
	Outer wood: 125 mm from pith sample		801 ± 24	OxA-21149	1189–1274		

Samples were also taken for dating from selected points within the bole of 3 pieces. The MMA cohoba stand provided a total of 3 samples: 1 from the pith and 2 from within the bole (Figure 3). Two aliquots of the pith sample were dated, as part of ORAU's routine quality assurance procedures. The sample from the left of the pith was also pretreated and dated twice, as the initial date was slightly older than expected. An additional sample was taken from approximately midway between the pith and outermost wood samples of the Carpenter's Mountain anthropomorph (Table 1). The Musée Barrois reliquary is hollow (Figure 1b), so a pith sample could not be collected: instead, samples were taken from the outer and inner edges, ~25 mm apart. Pith and outer edge samples were taken from the Aboukir pelican cohoba stand (Figure 1a); however, an additional sample ~23 mm inwards from the outer edge had previously been dated by Beta Analytic (Manuels 2001), and this date was included in the growth rate model. In total, 21 measurements were used in the model.

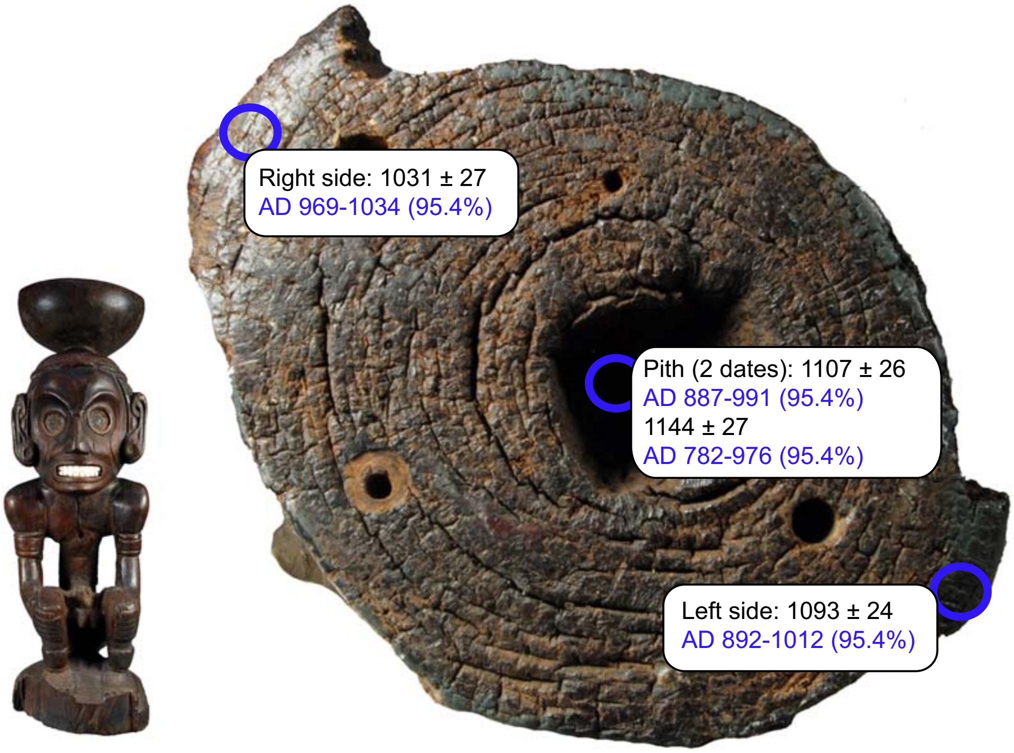

Figure 3 Sampling locations at the base of the MMA cohoba stand and results achieved (NB: the 4 large drill holes and central cavity are all from display mounts). Three ^{14}C samples were taken (circled), but 5 dates were run, as there was sufficient material to duplicate 2 dates. The distance between the pith sampling area and the left sampling site is 89.8 mm and 7.5 mm to the outer edge. The measurements for the right side are as follows: within 4.1 mm of the outer edge, and 115.4 mm from the pith. [Note that the terms "left" and "right" correspond to the artifact's sides when it is in its normal, upright position, and not to the sampling positions when viewing the base of the sculpture.] Cohoba stand, *Guaiacum* sp., shell, AD 975–1017 (modeled date), Dominican Republic/Haiti(?). H: 665 mm; W: 220 mm (max); D: 230 mm. The Metropolitan Museum of Art, The Michael C Rockefeller Memorial Collection, Bequest of Nelson A Rockefeller, 1979 (1979.206.380).

Radiocarbon Dating

Although there are no records that any of the artifacts had been subjected to conservation treatments, this is always a concern with older museum collections, and so all the pieces were initially subjected to a solvent wash comprising of sequential hour-long washes with acetone (45 °C), methanol (45 °C), and chloroform (room temperature) to remove any unknown contaminants and potentially also some natural oils and resins from within the wood itself and which may have been mobile across some or all of the bole. The samples were left to air-dry thoroughly before being subjected to a routine acid-base-acid (ABA) treatment consisting of sequential washes with 1M HCl (80 °C, 20 min), 0.2M NaOH (80 °C, 20 min), and 1M HCl (80 °C, 1 hr) with thorough rinsing with ultra-pure Milli-Q™ water after each step. The samples were then bleached with 5% w/v sodium chlorite solution at pH 3 for up to 30 min at 70 °C before being washed with water and freeze-dried. They were then combusted to CO_2 that was cryogenically distilled and reduced to graphite at 560 °C in the presence of an iron catalyst, as described by Brock et al. (2010), prior to accelerator mass spectrometry (AMS) dating.

Growth Model

When dating wood from temperate regions, it is often possible to use tree rings to determine the age difference between different samples taken from the same piece of wood. This improves the precision of the calibrated ages through "wiggle-matching" (Bronk Ramsey et al. 2001). This approach is not possible with tropical woods such as *Guaiacum* because there are no tree rings as such, and although information on the growth rates of this species is beginning to emerge (López-Toledo et al. 2008; López-Toledo 2009), it is not yet clear how widely applicable these estimates are and whether they can be used to estimate the expected age difference between samples in pieces such as these.

To overcome this limitation, we have combined the information from the 8 *Guaiacum* carvings for which we have multiple ^{14}C dates (a total of 21 dates). The approach taken is essentially a model averaging approach. We have evaluated the growth rate by building a self-consistent Bayesian model, which assumes that the growth rate of all of the trees from which the pieces are drawn is the same. This is clearly not strictly the case, as the radial growth rate of wood in trees depends on a range of factors, in particular climatic and environmental conditions, and individual trees of the same species can vary in their speed of growth, especially when comparing 2 trees from different geographical locations. Because wood is a water-conducting tissue, conductive area (wood area) must keep pace with the transpirational demands of additional foliage. As trees mature and the diameter increases, the total area of each successive growth ring of a given width increases, and at some point the tree can form a narrower ring (e.g. Zamudio et al. 2002). Thus, tree age (diameter) can be an important determinant of the radial growth rate of wood. However, assuming that the growth rate is the same for all trees from which pieces were taken for this model allows us to find a realistic range of growth rates.

The Bayesian model applied in this case uses a single parameter (`cm_period`), which gives the time period for the radial growth of 1 cm of wood, with a uniform prior, U(0,30). The distances between samples are defined from measurements made on the pieces, and for the most part are accurate to the nearest mm—although certain exigencies, such as sampling locations in damaged areas or surrounded by uneven contours resulted in measurements that were taken within 5-mm accuracies. The model is implemented in OxCal (Bronk Ramsey 2009) with code given in the Appendix.

The model assumes linear radial growth independent of age and derives an estimate for the range of possible growth rates consistent with the ^{14}C dates. This range, which is quite broad (6–13 yr for 1 cm of growth), is then applied to all pieces and the results of the modeling averaged over this range of possibilities. The model is equivalent to using an *a priori* assumption of growth rate in this range, but has the benefit that the growth rate is directly determined from the specimens.

It would in principle be possible to generate much more complex models of growth, dependent on the distance of the wood from the pith and taking into account non-linear growth. Such an exercise might show that the younger trees usually have faster growth within this range and older trees slower growth. However, all of the pieces come from different parts of the trees and so in any case are likely to see variability in growth rate, something which ^{14}C lacks the resolution to pick up with this kind of data set. In practice, the growth rates in these different circumstances are still likely to remain within the growth rates estimated under the simple model we have applied and, therefore, the results of the modeling should be robust.

RESULTS AND DISCUSSION

The dates from the 11 pieces sampled are presented in Table 1. The outermost wood dates are all younger than the corresponding pith dates as expected, with the exception of the Musée Barrois reliquary and the Bird and Turtle canopied cemí, where their respective paired dates overlapped. In the case of the reliquary, this is because the samples were taken only 25 mm apart, suggesting that, at least in this *Guaiacum* bole, the growth rate was subsumed within the date's margin of error of ±28 yr. The Bird and Turtle canopied cemí is carved from *Carapa*, which is a faster growing species than *Guaiacum* (Lieberman and Lieberman 1987). The paired dates demonstrate the inbuilt age of the wood in some carvings and the importance of a consistent sampling protocol throughout the project, and provide confidence in both the pretreatment and dating processes, as well as our sampling strategy.

The growth rate model demonstrates that the time required for the growth of 1 cm of *Guaiacum* wood lies between 6 and 13 yr (see Figure 4a), further refining the 4–14 yr results previously proposed by Ostapkowicz et al. (2011). Although it is recognized that the growth rate of trees can vary due to the age of the tree both physiologically (as younger trees grow faster than older ones) and architecturally (as the diameter of the stem increases, the same amount of added biomass results in narrower rings), the pieces included in the model were likely all carved from different parts of the tree, and hence these factors would have automatically been incorporated into the model. This is supported by the good agreement of our growth rate with the estimates of López-Toledo et al. (2008) that are equivalent to a period of 8–14 yr for smaller trees or 10–13 yr for larger ones (diameter >60 cm). Growth rates of this range are consistent with most of the pieces concerned, except for the Carpenter's Mountain anthropomorph whose dates suggest a faster growth rate, and (only marginally) the Aboukir pelican cohoba stand, where the growth rate would appear to be more variable. It is not surprising that growth rates varied between the different sculptures, as the wood used for each would have been subjected to slightly different environmental and climatic conditions during its growth. However, this estimate seems fairly robust to the inclusion/exclusion of individual pieces; for example, if we exclude the most extreme Carpenter's Mountain anthropomorph date, the growth period for 1 cm is still estimated to be a similar 6 to 15 yr (see Figure 4b). Using the estimate for the possible growth rates (6–13 yr) for all pieces, we can then average over all of these possibilities to generate modeled dates for each of the samples, and refine the calibrated ranges for the individual pieces. These are shown in Table 1, along with the OxCal agreement index (Bronk Ramsey 2009) for each of the measurements.

The calibrated ages of the samples from the outermost edges (i.e. those representative of the likely time of carving) of the Taíno pieces presented here (Table 1) range from ~AD 700 to the time of the first European contact, but generally cluster between AD 900 and 1500, as do the majority of the pieces in the wider study. The "mature" or "classic" period of Taíno art is not considered to begin until about AD 1200, and complex Taíno wooden sculptures are often thought to have been produced within the last few centuries prior to European contact (Rouse 1992:123; Curet 1996:126). These dates show that the Taíno were actually producing elaborate sculptures several centuries earlier than previously thought. However, as the Taíno population expanded and diversified, and different chiefdoms began to emerge from ~AD 600, it is perhaps not surprising that the caliber of large-scale sculpture production also escalated from around the same time.

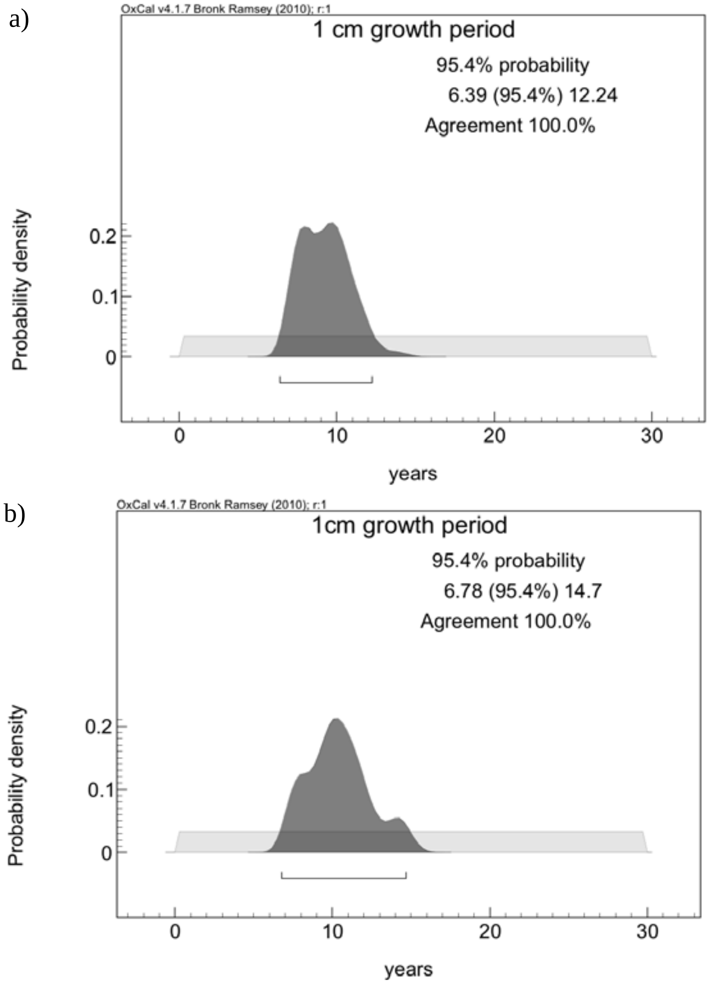

Figure 4 Estimates of the period required for 1 cm of radial wood growth a) on all pieces, and b) without the Carpenter's Mountain anthropomorph (which shows poor agreement with the model). The Bayesian model on which these estimates are based assumes a linear radial growth rate, which is consistent between all pieces.

CONCLUSION

^{14}C dating of wood can be problematic due to the potential reuse of wood and differences in age across a tree from the pith to the sapwood's outer rings. The nature of Taíno wooden sculpture—carved of dense tropical hardwoods that are still poorly known—makes it even more challenging to sample and date. We have demonstrated that dating pairs of samples from the pith and the sapwood or outermost heartwood rings can give confidence in both the sampling and dating procedures implemented. The results can also be used to generate a growth rate model for species that do not have distinct growth rings, and the models can be used to refine the calibrated ages of pieces. With specific regard to *Guaiacum*, the model has demonstrated that the selected boles used to carve the sculptures grew on average 1 cm every 6–13 yr, and this helps to contextualize and inform on the ^{14}C dates achieved in this study.

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APPENDIX – OxCal MODEL CODE

```
Options()
{
 Resolution=1;
};
Plot()
{
 cm_period=U(0,30);
 Label("MET cohoba stand");
 Pith=R_Combine()
 {
  OxA20675=R_Date(1107,26);
  OxA20676=R_Date(1144,27);
 };
 Mid_L=Pith+N(8.98,0.05)*cm_period;
 Mid_L&=R_Combine()
 {
  OxA20626=R_Date(1165,28);
  OxA21855=R_Date(1093,24);
 };
 OxA20627=Pith+N(11.54,0.05)*cm_period;
 OxA20627&=R_Date(1031,27);
 Label("Musee Barrois reliquary");
 OxA19398=R_Date(904,28);
 OxA19399=OxA19398+N(2.5,0.05)*cm_period;
 OxA19399&=R_Date(927,28);
 Label("Aboukir Pelican cohoba stand");
```

```
  OxA21054=R_Date(886,26);
  Beta153379=OxA21054+N(8.9,0.05)*cm_period;
  Beta153379&=R_Date(820,40);
  OxA23004=Beta153379+N(2.39,0.05)*cm_period;
  OxA23004&=R_Date(646,22);
  Label("Haitian duho");
  OxA19178=R_Date(491,27);
  OxA19176=OxA19178+N(13,0.5)*cm_period;
  OxA19176&=R_Date(369,28);
  Label("Carpenter's Mountain Canopy Cemi");
  OxA21145=R_Date(981,26);
  OxA21113=OxA21145+N(10,0.5)*cm_period;
  OxA21113&=R_Date(943,26);
  Label("Small anthropomorph");
  OxA21152=R_Date(869,25);
  OxA21153=OxA21152+N(5,0.5)*cm_period;
  OxA21153&=R_Date(727,25);
  Label("Carpenter's Mountain Anthropomorph");
  OxA21144=R_Date(737,25);
  OxA22142=OxA21144+N(10,0.5)*cm_period;
  OxA21142&=R_Date(718,26);
  OxA22141=OxA21144+N(4,0.5)*cm_period;
  OxA22141&=R_Date(779,26);
  Label("Robsjohn-Gibbings Duho");
  OxA20845=R_Date(657,27);
  OxA20844=OxA20845+N(11.8,0.05)*cm_period;
  OxA20844&=R_Date(356,27);
  MCMC_Sample()
  {
   Number("=cm_period");
  };
 };
```