MesoRAD: A New Radiocarbon Data Set for Archaeological Research in Mesoamerica

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ABSTRACT

The Mesoamerican Radiocarbon Database (MesoRAD) compiles radiocarbon dates from the archaeological literature of Mesoamerica. The inaugural data set, ‘Lowland Maya Dates’, includes 1846 radiocarbon dates from 132 sites in 21 distinct environmental zones in the Maya lowlands. These data span the Paleoindian to Colonial Periods (11,670 to 190 uncal BP, 13,740 cal BP to modern) across southern Mexico, Belize, Guatemala, El Salvador, and Honduras. Here, we describe the methods used to compile and organize these dates, including the spatial, chronological, and environmental coverage of the data set.

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(1) OVERVIEW

CONTEXT

Regional radiocarbon databases and datasets compiling published 14C dates with their associated contextual information have flourished with an expanding number of dates-as-data (sensu) [1] studies. Such approaches are common in many areas of the world, especially in Europe [2, 3, 4], South America [5, 6, 7], and North America [8, 9, 10]. Mesoamerica’s absence in this corpus of research is poignant, given that this region was home to several complex prehistoric societies including the Olmec at San Lorenzo (Veracruz, Mexico), Teotihuacan (Valley of Mexico), the Aztec at Tenochtitlan (D.F. Mexico), the Zapotec at Monte Albán (Oaxaca, Mexico), and Classic Maya city-states, among others. To date, few dates-as-data studies have been published in Mesoamerica, with those that have concentrated in the Maya lowlands [11, 12, 14, 15]. Some of the reticence towards radiocarbon-based approaches in Mesoamerican archaeology stems from widespread reliance on ceramic-based chronologies, including those that were originally tied to historic calendar systems such as in the Maya lowlands. We have argued elsewhere that epigraphic and radiocarbon-based approaches complement each other well and often show similar patterns [12]. As global-approaches to radiocarbon-based demographic reconstructions continue into the future [16], filling in the spatial gaps in the coverage of radiocarbon data sets will be required for comparative regional and global analysis. Here, we report on the inaugural data set of the Mesoamerican Radiocarbon Database (MesoRAD), focused on identifying radiocarbon dates from the Maya lowlands.

The initial data collection was part of two related studies focused on identifying climatic impacts related the rise and fall of lowland Maya polities. In the first, Hoggarth and colleagues [12] identified the timing of the end of political systems across the northern Maya lowlands at the end of the Classic period. That study, while regional in nature, also contributed to understanding the timing of the end of monumental construction at Chichén Itzá in the context of regional drought in the ninth and eleventh centuries. In the second study, Ebert and colleagues [11] documented regional trends in polity growth across the central Maya lowlands from the Middle Formative to Early Classic period, with special attention to the impacts of a multi-decadal drought that spanned 150 to 250 cal CE. That study identified declines in activity in some regions of the lowlands (e.g., Northern Belize), while other region (e.g., Western Belize) remained stable. These two studies studies recorded some of the initial attributes of radiocarbon dates in the Maya lowlands, but it was not until later when the authors combined their data, added an additional 500 dates, and formally created MesoRAD. These activities standardized the data collection process and filled in both chronological and spatial gaps in the Maya lowlands dataset. Given that these previous papers were temporally and spatially restricted in their scope, they did not focus on the processes associated with compiling radiocarbon data sets. This paper introduces the larger, more complete radiocarbon compilation (n = 1846) and to fully describe dates and their attributes for use in future dates-as-data studies.

Spatial coverage

While MesoRAD was established as a repository for published radiocarbon dates from across Mesoamerica, the inaugural data set focuses within the Maya lowlands. This area spans from southern Mexico (including Tabasco and Chiapas), including the Yucatan peninsula, Belize, Guatemala, and parts of Honduras and El Salvador. The current data set covers this entire area, although only a few dates recorded for Honduras and El Salvador (Figure 1). The Maya lowlands have been further subdivided into 27 distinct environmental zones [17].

The portion of Mesoamerica examined here covers approximately 50,000 sq.km:

- Description: Southern Mexico, Guatemala, Belize, and portions of western Honduras and El Salvador.
- Geographic Coordinate system: World Geodetic System (WGS) 1984.
- Datum: World Geodetic System (WGS) 1984.

Figure 1 shows the study area where published radiocarbon dates in the Maya lowlands have been compiled. Coordinates (WGS84) of the bounding box of this area are as follows:

- Northern boundary: 21.563417 (decimal degrees).
- Southern boundary: 13.827524.
- Eastern boundary: 86.766776.
- Western boundary: 92.440518.

Figure 2 shows the spatial clustering of dates, relative to total dates per period. Kernel Density maps, which calculate the magnitude-per-unit area from point features, were created for major time periods. Density analyses were weighted by the percent of dates represented by a site during a specific period (i.e., weighted by the count of dates at a site divided by total number of dates at all sites for the period). This allows us to identify areas that exhibit strong evidence of activity dating based on time period, but also demonstrates biases in archaeological research such as an emphasis on the Classic period or sites/regions that have been more intensively dated. For example, the large sample of dates from the Upper Belize River Valley (n = 303) is apparent from the Archaic through Terminal Classic periods, and these dates compose approximately 20% of the entire lowland Maya data set. Likewise, the large-scale radiocarbon dating programs at Ceibal [18] and the broader Pasión region (n = 164) can be identified as especially high for the Early/Middle Formative period, making up approximately 10% of the dataset. Though most sites with Postclassic...
Figure 1 Map of MesoRAD study area showing current extent of data coverage.

Figure 2 Kernel density function maps showing clusters of $^{14}$C dates (which passed chronometric hygiene) from each time period.
and Historic dates have between 1–3 dates, higher numbers of dates are also recorded at Mayapan ($n = 28$) [19]. While ‘dates as data’ studies suggest these trends show occupational intensity, spatial patterning also indicated localized trends archaeological research designs. Biases in contextual coverage are also apparent. Most dates derived from monumental site cores (defined as the ceremonial epicenters which contain public and monumental architecture), followed by settlement/residential contexts, caves, and rock shelters (Figure 3), demonstrating that radiocarbon-based chronology building has largely centered on monumental contexts at site cores.

**Temporal coverage**
Radiocarbon dates were identified from the central, southern, and northern Maya lowlands and show that these regions were intensely settled from the Formative to Terminal Classic periods. Figure 4 shows trends in $^{14}$C data across six time periods in the Maya lowlands. While some might expect that long-term research in the region would reveal a bias towards Classic $^{14}$C dates, we find that earlier time periods are not underestimated in the sample. Many published Formative period dates have emerged from recent projects, in addition to the long span of this interval in these figures. These trends show low-level occupation in the central lowlands during the Paleoindian and Archaic period (>1200 cal BC). Sedentism and the origins of village life ~1000 cal BC can be identified for the Formative period. ‘Hot spots’ are present in the Pasión region, such as at Ceibal (Inomata et al. 2013), in the Upper Belize River Valley [11], and in northern Belize (Hammond et al. 2009), though there is evidence of occupation across the entire lowlands. We identify intense occupational activity in southern Belize during the Early Classic [15] and nearly ubiquitous occupation across the region during the Late Classic.

![Figure 3](image3.jpg) Percent of dates that passed the chronometric hygiene criteria, by context.

![Figure 4](image4.jpg) Percent of dates associated with time periods across the Paleoindian to Historic Maya Lowlands.
Environmental Coverage

Considerable scholarship has focused on the cultural changes that occurred during the Classic to Postclassic period transition. Shifts in settlement from interior locations to coastlines, lakes/lagoons, and rivers is often hypothesized based on archaeological data [20]. Dates from the Maya lowlands permit us to help understand these patterns. We organized sites into resource zones based on water/resource availability and used $^{14}$C dates to look at temporal shifts between zones. These zones include interior sites, which are those that lack rivers or lakes/lagoons within 2 km of the ceremonial center, those with bodies of water (lakes, lagoons, rivers) within 2 km of the ceremonial center, those with cenotes within 2 km of the ceremonial center, and those located within 2 km of the coastline. The identification of water features came from published maps and articles, although it is possible that smaller water features that are not reported in the literature may be present at some sites. The distance of 2 km was used as a buffer since that is the distance which epicentral settlement mound density drops off at known medium-sized settlements [21]. Results indicate (Figure 5) approximately 66% of Late Classic $^{14}$C dates are associated with interior sites, with 31% with sites near freshwater bodies. Few dated sites were located along the coast or by cenotes (although sites do exist that fit these criteria, we simply lack $^{14}$C dates). These trends minimally shifted during the Terminal Classic, both in terms of location of sites and frequencies of dates.

Settlement trends shift during the Postclassic and Historic periods, when interior sites decrease and sites near freshwater bodies of water, cenotes, and the coastline become more frequent. Sizable reductions (~39%) in $^{14}$C dates from interior areas are also noted from the Late Classic to Postclassic period (Figure 5). While dates associated with cenotes increased primarily because of the large sample of dates from Mayapan, dates from zones with adjacent freshwater bodies of water also increase into the Postclassic period (Table 1). These analyses demonstrate potential to assess regional scale questions, such as settlement shifts related to environmental resources, across Mesoamerica using $^{14}$C data.

(2) METHODS

This database was created by scouring the published literature for radiocarbon dates, searching journal articles, books, and unpublished grey literature (field reports, dissertations). Publications in both English and Spanish were explored so that we did not miss entire sites due to language barriers. While this data set is likely not completely exhaustive, it represents the first and largest systematic compilation of radiocarbon dates from Mesoamerica.

STEPS

The data set was assembled using Microsoft Excel for ease of organizing data. This also allows other researchers, especially those based outside the US, to download the full dataset in .csv formats for convenient use. Column were organized using several categories, including:

Context and provenience

Site: Name of the archaeological site in which $^{14}$C dates were recovered.
Adaptive Region: Environmental zone (if identified).
See [17] for adaptive regions of the Maya lowlands.
Provenience: Specific contextual information about the provenience of the dated sample, including structure number, feature information (e.g. “under Floor 4”), and other relevant associated archaeological information.
Context: Categories of specific contexts types where sample was recovered. Included examples are: Site Core, Settlement, Cave, Rockshelter.

Sample specifics

Material: Material dated (e.g. charcoal, bone, shell, etc.). When species are reported, they are also listed here.
Lab number: Reported lab number. In the case that conflicting lab numbers are reported, we referred back to the original publication to decide which to use in the database.
Conventional $^{14}$C Age (BP): Uncalibrated radiocarbon age (BP)
Error: Attached uncalibrated error.
Dating Method: Conventional radiometric or AMS dating when reported
Duplicate/Replicate: Here we note whether dates are duplicates or replicates. Duplicate dates are dates on the same sample by multiple labs or using multiple protocols.
Chronometric hygiene/Issues with date: Notes about quality control, including whether a date fits with other archaeological data, has large attached errors, or a date was identified as an outlier in a sequence in
Figure 5 Percent sites and dates associated with aquatic resources.
a Bayesian chronological model.
Citation: Original reference(s) where date was reported.

**SAMPLING STRATEGY**
We did not institute a sampling strategy for inclusion into the spreadsheet. Rather, all dates that were identified were included in the radiocarbon data set irrespective of quality control attributes (see next section) or temporal period. This allows future researchers to critically evaluate whether to utilize dates or not, with concerns noted in the "Chronometric hygiene" notes.

**QUALITY CONTROL**
Dates were evaluated in relation to chronometric hygiene criteria [12] to identify questionable dates. While all dates were compiled for storage within the radiocarbon database, details were added about questionable dates, which include those that did not align with other archaeological data (such as those that dated earlier or later than would be accepted archaeologically), those with measurement precisions >100 years, or dates rejected by the original researchers for other specific reasons. Since radiocarbon chronologies, coupled with chronometric hygiene standards, are largely lacking across the Maya Lowlands, these steps create standardized criteria that may be used for comparative studies. Of the compiled data, 82.8% ($n = 1529$) passed the chronometric hygiene criteria, while 317 dates have been identified that might be questionable or critically assessed for use in 'dates as data' studies in future studies.

**CONSTRAINTS**
Locational data are sensitive, given the widespread looting in the region. However, in order to enhance the useability of the data set, the locational data has been scrubbed using code from [13] to hide the genuine site locations. This has the effect of offering locational data for future users while not comprising site integrity.

(3) **DATASET DESCRIPTION**
The ‘Lowland Maya Dates’ data set is archived as a .csv file updated as additional dates are identified (the current version is v.1.4, updated in November 2021). One worksheet of the excel file consists of $^{14}$C dates from archaeological contexts. A second worksheet includes radiocarbon dates identified from environmental contexts compiles dates from agricultural fields, lake core, and other environmental proxies. A third worksheet includes the bibliography for the citation column of the database.

**OBJECT NAME**
MesoRAD_v.1.4shiftedloc.csv

**DATA TYPE**
Secondary data

**FORMAT NAMES AND VERSIONS**
.csv

**CREATION DATES**
Dates from the Maya lowlands were initially compiled as part of two related projects. Hoggarth compiled the first dataset in 2014, with the (SPD) results from the Late Classic through Late Postclassic periods published in [12]. Ebert and colleagues [11] compiled dates from the central and southern Maya lowlands, of which the (SPD) results from the Formative to Early Classic periods were reported [11]. These initial dates were standardized into the formal data set, with the addition of a ~500 additional dates, in 2019. The inaugural data set was archived on tDAR in 2020 (Hoggarth and Ebert 2020), although until this paper we had not described the processes of how those data were compiled.

**DATASET CREATORS**
The scholars who have contributed to the compilation of radiocarbon dates in the Maya lowlands include the three authors (Hoggarth, Ebert, and Castelazo Calva).

**LANGUAGE**
English, Spanish

**LICENSE**
Creative Commons Attribution 4.0

**REPOSITORY LOCATION**
The data sets are permanently archived at and can be downloaded from tDAR [22]. The DOI for ‘Lowland Maya Dates’ is: doi: 10.48512/XCV8467840
https://core.tdar.org/dataset/467840/mesorad-v14

| PAL/ARCH | E-M FORM | L FORM | E CLASSIC | L CLASSIC | T CLASSIC | POSTCL/HIST | MOD | NO INFO |
|----------|----------|--------|-----------|-----------|-----------|-------------|-----|---------|
| Interior | 81       | 306    | 143       | 213       | 223       | 82          | 49  | 3       | 27     |
| Body of Water | 64   | 138    | 42        | 87        | 103       | 34          | 31  | 4       | 24     |
| Cenote   | 6        | 7      | 5         | 6         | 3         | 19          | 50  | 0       | 6      |
| Coast    | 22       | 6      | 22        | 6         | 8         | 7           | 16  | 0       | 1      |
| Unknown  | 0        | 0      | 6         | 1         | 0         | 1           | 0   | 0       | 1      |

Table 1 Number of radiocarbon dates per time period in each environmental zone.
MesoRAD is the largest and only compilation of 14C dates in Mesoamerica. The creation of the data set offers a new opportunity to apply dates-as-data research in specific sub-regions, such as in the Maya lowlands. Until recently, this region was completely absent from such studies. Future studies can explore more fine-grained questions on demographic trends, as well as human-environmental interactions, using information assembled. As additional areas in Mesoamerica are added, we expect that differing culture areas can be compared more easily. As dates-as-data studies expand to be more global in nature, the data from MesoRAD can be utilized to assess major questions in archaeology.

Researchers who work in Mesoamerica (or Central America) who have published radiocarbon data (primary data from their research or compiled secondary data from a region) who wish to archive that data with MesoRAD are welcome to contact Julie Hoggarth (Julie_Hoggarth@baylor.edu).

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COMPETING INTERESTS

The authors have no competing interests to declare.

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