# COLONIZATION AND PREHISTORY ON THE ISLAND OF MAUI: A RADIOCARBON SYNTHESIS OF MAUI ISLAND

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**ABSTRACT**

A long standing debate on the chronology of the colonization of the Hawaiian Islands has driven archaeological investigations and critical re-considerations in the use of radiocarbon dating (Dye, 2000; Wilmshurst et. al.; 2011a; Rieth et. al.; 2011). Understanding the potential effect of in-built age of unidentified wood charcoal reveals uncertainty in establishing the age of early arrival of Polynesians in Hawai`i.

Poor criteria for radiocarbon selection have contributed to both long and short chronologies. In the case of long chronologies, a majority of the evidence of an early colonization are from dates derived from unidentified charcoal, accepting large amounts of error in the process. Short chronologies have relied on dates from paleo-environmental context. These results provide poor association to actual anthropogenic events, which entertain a degree of doubt when used to discuss island settlement.

The highest precision of radiometric dating is provided by a conscious selection of short-lived plant taxa and parts, which contain a small degree of error in the dating of a target event, and are ideal in tracing the Polynesian migration to Hawai`i. Dates of the highest precision, assessed through a systematic classification of radiometric dates, have been used to re-construct a 13$^{th}$ century colonization of Hawai`i (Wilmshurst et al. 2011a; Rieth et al. 2011). This project analyzes the results of 831 radiocarbon dates from Maui Island and uses a classification system to assess dates with the highest precision and accuracy for dating initial Polynesian colonization. From the earliest dates

of identified short-lived plant taxa and parts, the AD 1214—1255 settlement of Maui is the most reliable date of colonization.

# CHAPTER 1. INTRODUCTION

Dating the events and materials of the past has been a primary goal of archaeology since the early 1900's. Juxtaposed to the technology of dating has been the refinement of methods and interpretations, resulting in the explanation of the archaeological record. Early chronological efforts by archaeologists studying ceramics in the Southwest of the United States established classes of artifacts, describing one set as being an older predecessor to another. In compensation to the lack of artifact seriations in East Polynesia and Hawai`i, the appeal of dating organic material from anthropogenic events in the stratigraphy drew the attention of many archaeologists.

One of the landmark samples was from the excavation of Kuliou`ou rock shelter (Emory and Sinoto, 1961). Not only was this date the first of thousands of samples submitted for the Hawaiian archipelago but it was the first date submitted from the Pacific. Since the Kuliou`ou rock shelter excavation, development and application of radiocarbon dating has become the critical method for chronology building. Yet the interpretation of the temporal data has seen a number of shifts over the years.

The selection of dates for building chronologies has varied between investigators. In the specific case of Hawaiian chronology, it has become a long standing discussion on the reliability of established chronologies. By the mid-80's through the early 90's radiocarbon chronology for the Hawaiian archipelago was a divided field of those supporting long chronology of occupation and those who observed a short chronology. The application of these chronologies aids their commentary on the temporal aspects of pre-historic colonization, settlement, land use, social and political organization, consumption, and economic systems.

Over the last 25 years, a majority of Hawaiian archaeological work has come from “grey literature” or technical reports of (CRM) cultural resource management. Methods for recent analyses of radiocarbon dates use a general chronometric hygiene protocol for the rejection or acceptance of dates, establishing initial settlement no later than AD 800 (Carson, 2005; McCoy, 2007). The organization and grouping of dates according to their precision, accuracy and reliability has been conducted to produce high-precision dating for both East Polynesia (Wilmshurst et. al., 2011) and Hawai`i Island (Rieth et. al., 2011) pre-Western contact settlement. Through the classification of radiocarbon dates from Maui Island, a systematic process of identifying dates with the highest reliability will generate the clearest age of initial settlement.

As the rise of radiocarbon dates promotes studies to reassess Polynesian colonization of East Polynesia and the Hawaiian archipelago, a systematic classification of radiometric data (Wilmshurst et. al, 2011) provides a chronology supported by high precision dates. Under the highest form of class acceptance date, the arrival of Polynesians to remote islands occurs at AD 1200-1290. Further application of radiocarbon classification has been conducted for Hawai`i Island, confirms the late settlement of Hawaiian archipelago by Polynesians from AD 1220-1261 (Rieth et. al., 2011). The implications of a short chronology and later initial settlement are a rapid settlement pattern and the extensive impact of humans on pristine island ecosystems.

Serving as a test to confirm settlement of Hawai`i (Rieth et. al., 2011) an analysis of 831 radiocarbon dates from both academic and CRM literature will provide a reliable rage for the colonization of Maui by Polynesians.  Application of chronometric hygiene protocol to the data will establish a classification of dates according to the accuracy and precision of the samples.

# CHAPTER 2. LITERATURE REVIEW

Previous approaches to answer questions on the pre-historic settlement were conducted through various methods. For some, the establishment of a chronology was formed through oral histories and genealogical reckoning (Fornander 1969), while others applied historical linguistic approach to origins (Emory 1946). However, genealogical reckoning and historical linguistics lack a scientific testability to deny or confirm their results. Scientific archaeology presents results within a systematic framework, focused on testing the correctness of hypothesis through measurable empirical evidence. Volcanic glass hydrology, coral dating and other methods have all made their way into archaeology, but none as prevalent as radiocarbon dating.

## $^{14}$C PROCESS

A brief summary of carbon-14 dating will be sufficient. The most common isotopes of carbon are $^{12}$C and $^{13}$C, both of which occur in the natural world. Carbon-14 is a naturally occurring, yet unstable, radioactive isotope that develops as cosmic rays enter the Earth's upper atmosphere and breakdown atmospheric Nitrogen (N-14). As $^{14}$C reacts identically to $^{12}$C and $^{13}$C, it becomes attached to organic molecules through photosynthesis. Plants which have absorbed $^{14}$C are then ingested by animals, taking in both stable and unstable carbon isotopes, a cycle that continues for the rest of the life of plants and animals. In 1949, J. R. Arnold and W. F. Libby detected the decay of unstable $^{14}$C in organisms (Taylor 1987). By identifying the $^{14}$C decay or release of extra neutrons to become stable carbon isotopes, the event of death is detected. This element is traced through AMS and BETA processing. Arnold and Libby's discovery of the measurable aspect of decaying organic material unlocked a means of dating past events in archaeological contexts.

**HALF-LIFE**

Once the organism dies, it stops accumulating $^{14}C$ and begins to lose the radioactive isotope by a rate of 1% every 83 years, and will reach a knowable half-life in 5730±40 years. Plants do not take in the same amount of $^{14}C$ as other organic tissues. Photosynthesis lowers the Carbon-14 intake of plants by 3-4%, which translates to an age range of 240—320 years (Aitken 1990).

**RADIOCARBON ERROR RANGES**

While radiation exposure has not been constant through time, reliability comes in the error range estimates added on to radiocarbon dates. These are called the sigma error. A one-sigma error can be interpreted as a 2/3 chance of the death of the sample occurring within the range specified. If a sample had a radiocarbon age of 1500, plus or minus 50, this would mean that it would be about 68% accurate to say the range of 1000—2000 years ago marked the material's death. For a higher degree of reliability achieving 95% chance, a broader range with a two-sigma error is conducted. 3 standard errors achieve 99% chance.

## EARLIEST USE

The adoption of tracing carbon from organic remains from archaeological excavations increased as time went on. Initial use of radiocarbon dating produced long chronologies with early settlement dates (Emory and Sinoto 1961; Kirch and Kelly 1975; Pearson et al. 1971; Kirch 1985; Cordy 1974; Hommon 1986). The first dated charcoal sample from the Pacific came from a field school operated by the University of Hawai`i at Manoa and the Bishop Museum (Emory and Sinoto 1961) and produced a date ~AD 1000 for the Kuliou`ou rock shelter. Work conducted on the Halawa dune (Kirch and Kelly 1975), the excavations at south point (Emory and Sinoto 1961), and the Bellows O18 site on O`ahu (Pearson et al. 1971) continued the incorporation of radiocarbon dating to discuss Hawaiian Island settlement. Age determinations recovered from these excavations represented the initial settlement of the archipelago around AD 600 (Pearson et al. 1971). Later, adjustments were made to accept all published radiometric dates, resulting in the interpretation of pre-Western contact settlement occurring about AD 300—400 (Kirch 1985).

## LONG CHRONOLOGIES

By the 80’s, archaeology in Hawai`i had established long chronologies that appeared on the influx of radiocarbon material (Cordy 1974; Hommon 1986; Kirch 1985). Settlement patterns were recognized through a multi-period framework, interpreting the use of island resources, land management, and socio-political movements through an archaeological scope. Within these discussions, two types of distinct agriculture are defined by their geographical context on Hawaiian Islands, leeward and windward (Cordy 1974; Kirch 1985). Archaeological investigations provided radiometric data for modified agriculture landscapes with two distinct temporal patterns emerged. Wetland agriculture, consisted of irrigated pond fields in highly predictable environments, were producing earlier dates (AD 600—1100), than dryland field systems (AD 1200-1600). Dryland systems, explained by Kirch (1985), represent a response to increasing population with the expansion of agriculture into the marginal leeward environment. Strict analysis of radiocarbon dates would soon challenge the reliability of long chronologies reliability.

## IN-BUILT AGE

The establishment of short chronology for the Hawaiian Islands has developed over the last twenty years. Collection of most of the early charcoal samples was not as selective as efforts (should be) today. Pieces of charcoal were not identified but were sent to labs to produce an "age" for the excavated event. In some cases, no record of sample provenience was kept, increasing difficulties with evaluating the accuracy of dates. Over 800 radiocarbon samples from the Pacific (McFadgen et al. 1994) were critically examined for effects of in-built ages. Results from the study exposed the risks of dates and chronologies built from unidentified samples. In Hawai`i, a revisiting of the earliest dated site on O`ahu (Dye 2000; Kirch and McCoy 2007; Tuggle and Spriggs 2001) found previous use and sampling of unidentified charcoal to create long tails in chronology. By eliminating questionable samples from unidentified charcoal, archaeologists observed a shift in the chronology of Hawai`i that favored a late settlement or short chronology, beginning around AD 800—1000 (Athens et al. 2002; Dye 2000; Dye and Pantaleo 2010; Kirch 2007); nearly a century later than previous long chronology models (Hommon 1986; Kirch 1985).

Some of these questionable samples included previously unidentified piece of driftwood, which could be a cedar or other long-lived piece of tree which traveled from the Pacific Northwest. Long-lived materials that were being used for foundational settlement dates could no longer hold as reliable evidence of settlement as researchers began to encounter selection of a preferred species over another because of accuracy. Short-lived material would provide a means of reducing the $^{12}C/^{13}C$ error of the identified plant taxa. Where long chronology entertained acceptance of dates from anthropogenic sites, the dangers of including dates from unidentified sampled material and those susceptible of containing in-built error (Dye 2000).

## SHORT CHRONOLOGY

Implications of a late Polynesian settlement were presented in Wilmshurst et al. (2011a), and corroborated in Rieth et al. (2011), ascribe to the rapid settlement of the Hawaiian Islands. Anticipation of human impact on delicate island ecosystems have been constructed from paleo-environmental data (Athens et al. 2002; Burney 2002), directing the extinctions of flightless birds and lowland forests to the presence of a human colonization by-product of the Polynesian rat (*rattus exulans*). In the analysis of radiocarbon dates of the `Ewa Plain on O`ahu (Athens et al. 2002), a date from a Polynesian rat bone, coupled with dates from Ordy Pond paleocores (Athens et al. 1999), indirectly represents human presence around AD 1000. The pre-historic extinction of bird species on Maui was also attributed to Polynesian introduction of rats (AA-760: 770 ±350 years BP), indicating initial settlement of the island as early as AD 872 or as late as AD 1616 (James et al. 1987). In both cases, the standard range of error is enormous and could hardly provide an accurate date of colonization on its own. In addition, the unknown amount of variation caused by marine influence in dating faunal specimen's remain to be further assessed, then offering credibility along the lines of identified short-lived plant taxa.

**CHRONOMETRIC HYGIENE**

With the increase of dates, mass reviews of radiocarbon data were conducted in the Pacific (Hunt and Holsen 1991; Spriggs and Anderson 1993). Chronometric hygiene analysis was established to exclude dates of sample material with high in-built age and correction for marine reservoir effects (Spriggs and Anderson 1993). Avoiding the error of incorporating all available dates to island chronologies, chronometric hygiene protocol is designed to increase the precision, accuracy and reliability of radiometric data through minimizes the distraction of unidentified samples in identifying the timing colonization.

Aspects of the initial chronometric hygiene protocol (Spriggs and Anderson 1993) has since been applied to the presentation of a wide range of syntheses in Polynesia—Rapa Nui (Hunt and Lipo 2006), Samoa (Rieth and Hunt 2008), and Aotearoa (Whilmshurst et al. 2008)—dramatically shortening the sequence of migrations and island settlement. The advent of CRM in Hawai'i has produced an abundance of radiometric data from "grey literature", adding to the discussion settlement chronology. Radiometric analyses sets in the Pacific (Hunt and Lipo 2006; Rieth and Hunt 2008; Whilmshurst et al. 2008), and Hawai`i as well (Athens et al. 2002) began to apply aspects of chronometric hygiene to support dates of colonization. The 194 radiocarbon dates from the `Ewa Plains (Athens et al. 2002) provided a basis for the initial settlement of O`ahu, with extension to include the archipelago. Evident from the declining populations of endemic *avaifauna* and flora, occurring contemporaneously with an increase in Polynesian rat (*rattus exulans*), confirms human activity and initial settlement no later than AD 1000 but as early as AD 800.

Research of all-island radiocarbon dates shortly followed for the islands of Kaua`i, Moloka`i and Hawai`i Island (see Table 1). In the syntheses of both Kaua`i and Moloka`i, both academic and CRM radiometric data was collected and reviewed. Carson (2005) investigated a suite of 272 dates from Kaua`i. Using a general chronometric protocol, he observed an initial settlement of Polynesians on Kaua`i with few dates earlier than AD 1200, none of which were from short-lived plant materials. A similar synthesis of 175 dates from Moloka`i (McCoy 2007) built a chronology for this island from dates of unidentified charcoal. This inclusion of unidentified charcoal in estimating the arrival of humans provides little confidence of colonization occurring prior to AD 1200. These analyses were conducted with a general chronometric hygiene and both were unable to provide dated short-lived material prior to AD 1200.

| Island | Citation | Number of samples collected | Initial Settlement Dates | Notes on report |
|---|---|---|---|---|
| **Kaua'i** | Carson 2005 | 272 | ~AD 800—1000 | No pre-1200 AD dates from short-lived taxa |
| **Moloka'i** | McCoy 2007 | 175 | ~ AD 800 | No pre-1200 AD dates from short-lived taxa |
| **Hawai'i Island** | Rieth et al 2011 | 926 | AD 1220—1261 | Oldest date from high precision of short-lived taxa |
| **Maui** | this paper | 831 | AD 1214—1255 | Oldest date from high precision of short-lived taxa |

**Table 1.** Initial settlement dates from all-island radiocarbon syntheses

Recent applications of high precision dating have been conducted on 1,434 dates from East Polynesia (Whilmshurst et al. 2011a) and 926 dates from Hawai`i Island (Rieth et al. 2011). Where the designs of previous chronometric hygiene protocols were to reject dates derived from unfavorable dating material (Spriggs and Anderson 1993), Whilmshurst et al. (2011a) evaluated dates through a systematic classification method. The use of a highly conservative guideline is established to interpret initial settlement of the islands of East Polynesia through criteria which select the highest precision dates available. The patterns which emerge represent the most reliable dated material. The results from these syntheses found that the migration period of East Polynesia presented is substantially compressed when selection of the highest precision dates are used solely (Wilmshurst et al. 2011a). If the standards of the criteria for Class 1 are lowered (as suggested by Mulrooney et al. 2011) the timing of initial colonization will become earlier. As a consequence of reducing the conservative guidelines established, the confidence in this colonization date will become deflated as well.

The 926 radiocarbon dates from Hawai`i Island (Rieth et al. 2011) also provides initial settlement from dates with the highest application of chronometric hygiene. First, a general application of chronometric hygiene was conducted. Using a similar methodological approach for East Polynesia (Wilmshurst et al. 2011), ideal samples contain: i) a provenience linked to cultural activity; ii) a low amount of in-built error; and iii) provide calibration representing actual target event. The colonization of Hawai`i

Island around AD 1220—1261 is derived from short-lived plant material that obtain a standard error ≤10% of conventional radiocarbon age (CRA). The use in setting a high standard of error for the inclusion of dates of colonization results in a reliable model of estimation to be made. Adjusting the selection of dates less than 5% CRA would reduce sample size and be statistically problematic in application. A standard of error of ≤10% is common for most AMS dates produced since 1995 as well.

**MAUI ISLAND**

The island of Maui is the second largest (1,883 $km^2$) and second youngest island in the Hawaiian Islands. Its geographic location is central to the archipelago, with Moloka`i to the west, Lana`i and Kaho`olawe to the south, and Hawai`i Island to the east (see Figure 1). The presence of two degenerated shield volcanoes—the older eruption forming the West Maui mountains with Pu`u Kuku`i rising 1,764 *meters* above sea level and the youthful Haleakala to the east reaching 3,056 *meters* above sea level—create a dynamic ecological variation from dry lava fields of Keonio`io, to the tropical forest of Iao Valley. Maui's mountain systems create a rain shadow for the leeward areas of the island as well as the neighboring islands of Kaho`olawe and Lana`i. The effect of this widespread rain shadow has limited the development of perennial streams and rivers to the northeast sections of the Hana and Wailuku districts. Ethnographic observations of historic agricultural practices shows that of the larger islands (Hawai`i, Maui, O`ahu and Kaua`i) Maui had the least amount of wetland agriculture production and coastal fishponds (Handy and Handy 1972).

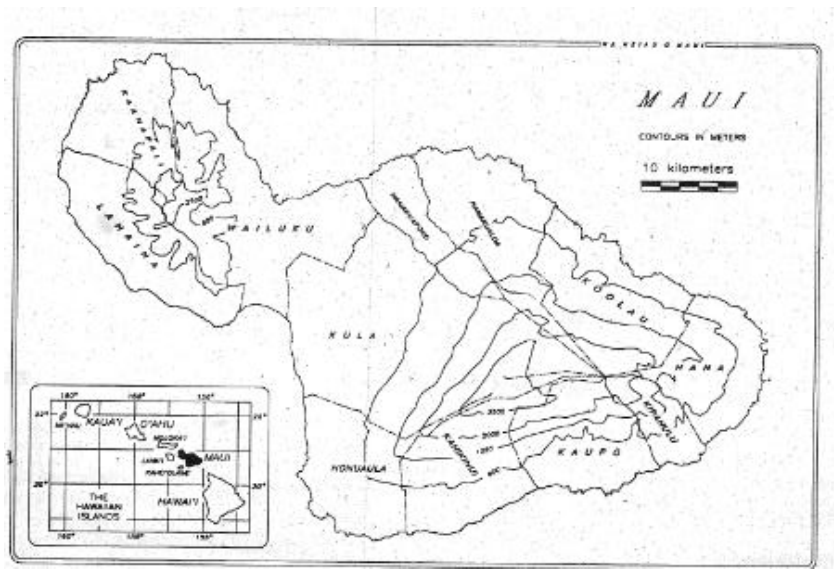



**Figure 1.** The Island of Maui (insert of the Hawaiian archipelago)

## LAND DIVISIONS

The division of land on Maui was traditionally arranged into *moku* (districts) and smaller divisions of *ahupua`a's* within these *moku*. Prior to the 1848 Mahele, there were 12 districts of Maui—East Maui: Hana, Kipahulu, Kaupo, Kahikinui, Honua`ula, Kula, Hamakuapoko, Hamakualoa, and Ko`olau; West Maui: Wailuku, Lahaina, and Ka`anapali (Sterling 1998; see Figure 2). Current cataloging of reports at the State Historic Preservation Office recognizes just 4 divisions—East Maui: Hana and Makawao; West Maui: Wailuku and Lahaina. The Lahaina district includes a portion of Lana`i—which was omitted from this analysis, limiting the data collection to the geographic boundary of Maui Island.

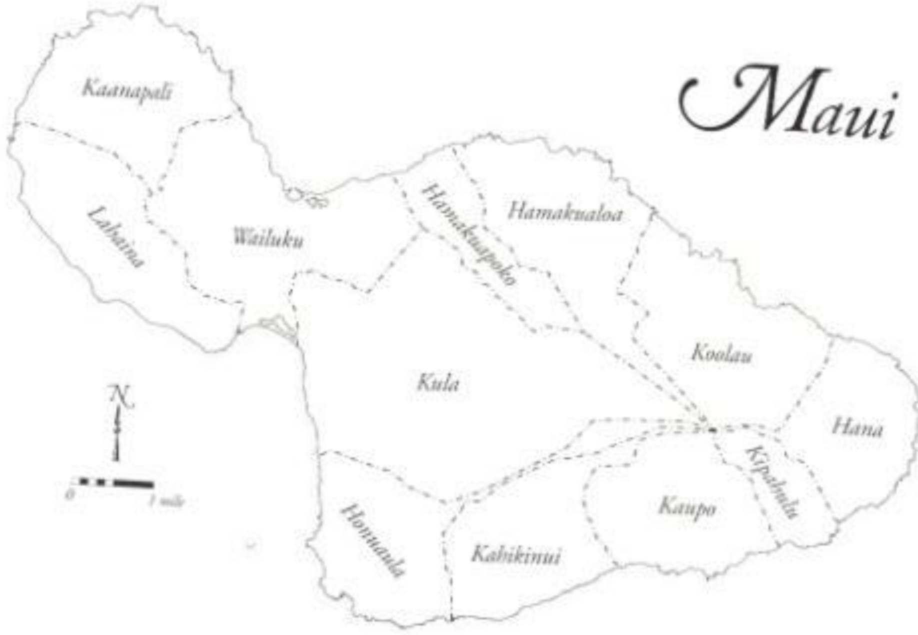



**Figure 2.** Traditional pre-1848 Mahele districts of Maui (Sterling 1988)

## MAUI ARCHAEOLOGY

This analysis of Maui radiocarbon dates has lead an investigation through more than 130 technical reports, articles, sections in edited volumes and other published works centered around the islands' sites. Over 40 years of archaeological investigation has been conducted on Maui, with contributions towards settlement patterns, agriculture, social-political structure, and environmental change interpreted by archaeologists (Athens 2002; Borthwick et al. 2002; Carson and Mintmier 2006; Donham 1989; Fredericksen 2000; Klieger et al. 1995; Rosendahl 1989). While these contributions have focused in explaining the various aspects of the prehistory of Maui, the discussion section will highlight 2 projects that provided an extensive amount of radiocarbon dates and engaged the discussion on the chronology of prehistoric Maui.

# CHAPTER 3. METHODS

The objective of this project is to examine the most credible radiocarbon dates to time the initial settlement of Maui. The classification serves to organize qualities of dated samples for entry or rejection into a class based on theoretical criteria. While the empirical data for each sample (i.e. radiocarbon year, error, $^{12}C/^{13}C$ ratio, etc.), are measurable units, classes and the standards for entry are, in contrast, built from a theoretical framework, previously established by Wilmshurst et al. (2011a) and utilized again in Rieth et al. (2011). The measurable aspects of the samples are empirical observations, while justification of grouping is explained through chronometric hygiene. The use of chronometric hygiene was conducted due to the unknown nature of in-built age of samples.

## DATA COLLECTION

An extensive review of published material, both academic and CRM, was undertaken for the creation of an all-island radiocarbon synthesis of Maui. A spreadsheet with an entry for each lab sample was created for filtering radiometric data tables and appendices of within published reports and research. A few known projects that produced dates that were not included to this analysis were due to the inaccessibility of radiometric data (Kirch 2010; see also Coil 2006; Holm 2008). The projects that did contribute data are represented in the collection of 831 dates from Maui; the largest collection of radiocarbon dates for the island. Radiocarbon dates that were omitted from the collection were based on:

1) Poor provenience—dates deriving from samples that meet this description lack direct cultural context. For the purposes of developing the highest precision date for initial colonization, these dates were excluded from analysis (i.e. extinct *avaifauna* bones, influx of marine shell species, geological deposits and paleoenvironmental cores).

2) Early Gakushuin Laboratory (pre-Gak4500) dates—Justification for excluding the dates from the Gakushuin Laboratory dates prior to Gak4500 were based on the unreliable nature of the dates provided from the laboratory. In comparison to results from other laboratories from the same site and layer (see Spriggs and Anderson 1993), the dates from this lab were found to be incorrect due to inadequate pretreatment efforts of samples.

**CLASSIFICATION**

Artifact classification has played an important role in the analytical practice of archaeology. With a few exceptions (Wilmshurst et al. 2011; Rieth et al. 2011) the active use of classifying radiocarbon dates is absent in Pacific and Hawaiian archaeology. This analysis uses a classification previously established for East Polynesia (Wilmshurst et al. 2011a) and further applied to Hawai`i Island (Rieth et al. 2011), to achieve the highest class of reliability for the colonization of Maui Island. This classification operates to order and rank the collection of dates from Maui. Focusing on the research question on the initial settlement of Maui, the classification of dates earlier than 400 BP was conducted. This is justified with an inferred consensus, which no arguments have surfaced to suggest archipelago was settled before AD 1400. Under this limit, dates later than 400 BP were not included in the classification.

Entries of individual lab samples were entered into a spreadsheet composed of general information given about the sample from the reports (i.e.: site number, provenience, sample material, calibrated $^{14}C$ age, error, etc.) and followed by rows for acceptance into theoretical classes—Class 1, Class 2 or Class 3.

1) sample was from an identified short-lived taxon or plant part, 2) sample was from an identified long-lived plant taxa, 3) sample was unidentified or unknown charcoal, 4) was samples of fully terrestrial (ultra-filtered or XAD-2 resin) bone, 5) bone with marine dietary influence, 6) marine shell and invertebrates, 7) coral, 8) bulk soil or ash and 9) mixed short-lived plants and unidentified charcoal (see Table 1).

Table 1 shows the totals for the various sample types (1—9) that were present in the initial collection of data, which first included dates later than 400 BP. These totals would later be affected by the removal of dates later than 400 BP to answer the question on identifying the most confident date of Maui colonization.

| | Material Type (Counts) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | ***Short-lived plant*** | ***Long-lived plant*** | ***Unidentified charcoal*** | ***Ultra-filtered Rattus exulans bone*** | ***Marine shell*** | ***Coral*** | ***Mixed charcoal*** | ***Total*** |
| *Class 1* | 8 | 0 | 0 | 0 | 0 | 0 | 0 | *8* |
| *Class 2* | 24 | 2 | 0 | 1 | 0 | 1 | 0 | *28* |
| *Class 3* | 0 | 4 | 795 | 0 | 3 | 3 | 1 | *795* |
| *Total* | *32* | *6* | *795* | *1* | *3* | *4* | *1* | *831* |

**Table 1**: Counts of samples identified by material type and sample class.

The analytical approach in the investigation of early dates of Maui, was established by Wilmshurst et al. (2011) for East Polynesia, and Rieth et al. (2011) for Hawai`i Island, to investigate the highest quality of dated samples. To produce a high degree of precision, a standard was set to favor CRA dates with a standard error ≤10%. Rieth et al. (2011) recognizes the AMS dates that were submitted ~1995 were regularly returning dates with error's ≤10%. Removal of dates with large standard assists the goal of identifying the most reliable timing of initial settlement. Adjustment to lower the 10% standard will result in lower accuracy of dates and decrease credibility of Class.

Class 1 dates consist of identified, short-lived plant taxa and plant parts for which standard error of the CRA is ≤10% (see Table 2). Thus, if terrestrial bone that was processed with XAD-2 ultrafiltration and had a standard error of ≤10%, it would be included; however, no such samples were retrieved during the collection process. Identified short-lived plant samples are able to produce low measurement error and therefore serve as some of the best samples available for radiocarbon dating. Due to the high degree of accuracy, precision and reliability, these Class 1 dates represent the highest ranked samples of this critique.

| District | Ahupuaa | Site | Sample Category | $C^{14}$ Lab ID | CRA years BP | CRA error | Initial quality class | ≤10% Standard error | Measured Age not CRA | From Auwai | Overall reliability class | Citation for Source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Makawao | Haleakala | 50-50-11-2509 | 1 | Beta-209592 | 410 | 40 | 1 | 0 | 0 | 0 | 1 | Carson and Mintmier (2006) |
| Makawao | Haleakala | 50-50-11-3652 | 1 | Beta-209584 | 460 | 40 | 1 | 0 | 0 | 0 | 1 | Carson and Mintmier (2006) |
| Makawao | Haleakala | 50-50-11-2509 | 1 | Beta-209591 | 580 | 40 | 1 | 0 | 0 | 0 | 1 | Carson and Mintmier (2006) |
| Makawao | Haleakala | 50-50-11-3681 | 1 | Beta-209582 | 630 | 40 | 1 | 0 | 0 | 0 | 1 | Carson and Mintmier (2006) |
| Hana | Unclear | 5372 | 1 | Beta-171429 | 640 | 40 | 1 | 0 | 0 | 0 | 1 | Haun and Henry (2004) |
| Kipahulu | Alae 'Iki | 50-50-17-1088 | 1 | Beta-150615 | 730 | 50 | 1 | 0 | 0 | 0 | 1 | Dye et al. (2002) |
| Makawao | Kailua | 2498 | 1 | Beta-42172 | 800 | 80 | 1 | 0 | 0 | 0 | 1 | Kennedy (1991) |
| Kipahulu | Papauluana | 50-50-17-5620 | 1 | WK-15608 | 373 | 29 | 1 | 0 | 0 | 0 | 1 | Carson and Reeves (2005) |

**Table 2.** Class 1 radiocarbon samples

Class 2 samples consist of identified, long-lived plant taxa and obtained an error of less than 10%. It also includes dates from unidentified wood charcoal, mixed samples of identified and unidentified plant taxon, identified short-lived plant taxa or plant parts with a standard error <10%, terrestrial bone processed by XAD-2 ultrafiltration with a standard error <10%, marine shell, and coral, yet the unknown degree of in-built age for marine species challenges the reliability and accuracy of dates these samples explains its classification as Class 2.

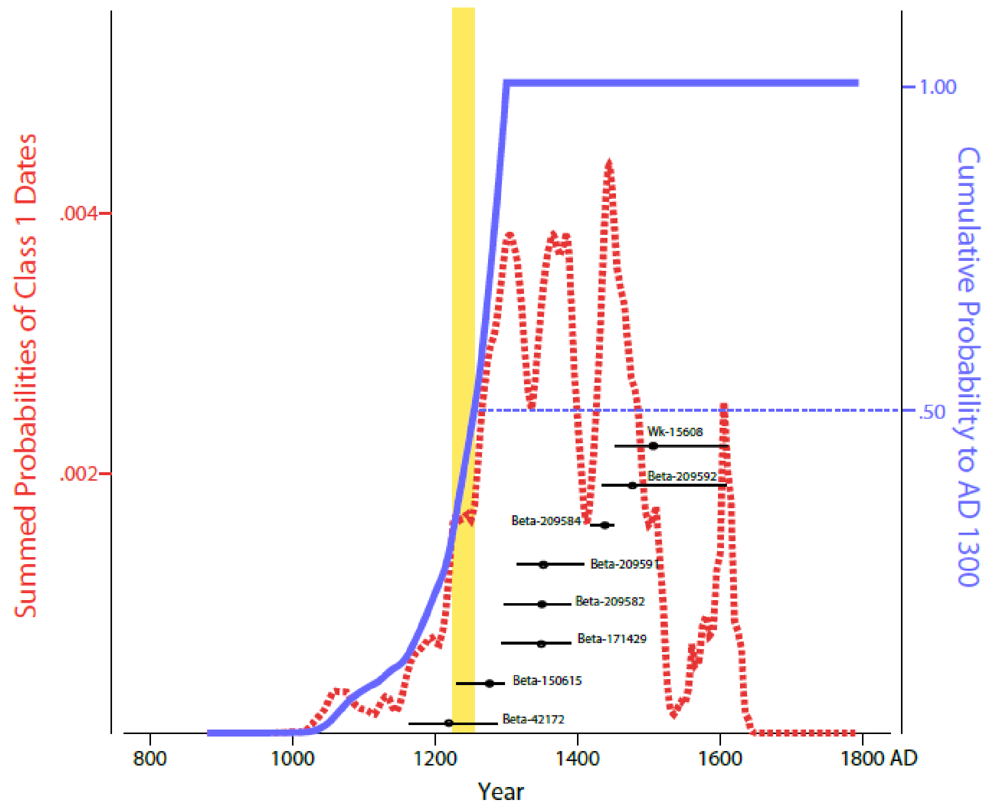
Class 3 consists of unknown samples or unidentified wood, charcoal, and shell samples for used for dating. It also includes report samples that provided the 'measured' radiocarbon ages without the adjusted CRA fall in this class. Samples that were obtained from *`auwai* or irrigation channels fall within this class, as it presents a date for an unknown event. In this classification, Class 3 contains dates with unknown in-built age and target event, representing the least reliable dating.

**CALIBRATION**

Due to variable atmospheric $^{14}C$ for specific to the Northern and Southern hemisphere of the Earth, proper offsets and calibrations are made in producing the actual timing of the event dated. Terrestrial samples from the classification were calibrated using INTCAL09, while MARINE09 (Reimer et al. 2009) for the calibration of three coral samples (Beta-76260, Beta-76262 and Beta-78264) was used.

Early Age Estimation Models (EAEM) and Late Age Estimation Models (LAEM) were explained in previous use of high-precision dates for determining the initial settlement of East Polynesia (Wilmshurst et al. 2011a) and Hawai`i Island (Rieth et al. 2011). The LAEM is simply an application of statistical probability to analyze Class 1 dates, recognizing the point for initial settlement, followed by the likeliness of arrival occurring before the identified initial settlement event (see Figure 3). Statistically speaking, this is the point at which the event has breached the 50% confidence and is more likely to occur earlier rather than later.

While a small, non-zero probability the event took place on the early tail of individual samples, statistical reliability is achieved through probability overlap from a multiple individual dates, here referred to as EAEM. To create the EAEM, the sum of each Class 1 probability distribution is conducted to form a collective distribution line. In doing so, identification of the overlap of individual sample probability distribution will serve as evidence in the timing of colonization. The establishment of AD 1300 for occupation of Maui Island is derived from an agreeable consensus that Polynesians settled the archipelago prior to AD 1300. Further, results from previous research of initial settlement on Hawai`i Island (Rieth et. al. 2011) and island groups of East Polynesia (Wilmshurst et al. 2011a), provide evidence of initial colonization before AD 1300.




**Colonization Event: AD 1215—1255**

**Figure 3. Maui Island EAEM/LAEM**—Estimates for the timing of Maui Island based on 8 Class 1 dates. The one-sigma ranges for the Class 1 calibrated radiocarbon dates are shown as black horizontal lines; circles represent median of individual probability distribution (bottom axis). Red dashed line indicates sum of probability distributions (left axis). Solid blue line serves as the cumulative probability (right axis) provides reasoning for confidence that colonization occurred no later than AD 1300. The dashed light blue indicates the point on these curves where the area is more likely that the colonization event occurred before this point in time, a value based on the Late Age Estimation Model (LAEM). The yellow bar represents the range between the two statistical indicators of EAEM and LAEM. This area represents a statistically confident statement of the timing of colonization on Maui occurring sometime between AD 1215—1255.

# CHAPTER 4. RESULTS

Eight hundred and thirty-one (831) radiocarbon dates were collected from archaeological investigations on Maui. Of these 831 dates, 212 dates occur from a CRA ≥400 years, and are isolated to examine initial settlement. Seven Class 1 dates were obtained; with 3 additional Class 2 dates of identified sample material excluded due to error ranges slightly greater than 10%. A single Class 1 date (WK-15608) with a measured radiocarbon age of 373 ± 29, was also included in the model. While just outside of the 400 year CRA, the removal of (WK-15608) does not affect the EAEM currently projected by current Class 1 dates. Class 1 dates produced an estimated age of colonization at AD 1215(EAEM)—1255 (LAEM).

Six Class 2 dates appear earlier than 400 years BP. Materials that were dated include: 2 short-lived plants, 2 long-lived plants, a *rattus exulans* bone, and single coral sample. Inclusion of dated samples of identified short-lived plant and coral to the early age estimation model (EAEM) would support colonization occurring after AD 1215. While remains of introduced *rattus exulans* (AA-760) has been used for inferring human settlement at 770 years BP, the very large standard error ±350 years BP does not provide a precise range of dates. Instead of including materials that are assumed to be found in “colonization” assemblages (Dye 2011), the approach taken in this paper empirically classifies dates according solely on their precision and accuracy. Further, the inclusion of this sample into this discussion on the colonization of Maui lowers the confidence for initial settlement dating.

Unidentified charcoal remains the highest sampled material for dating events on Maui Island. The 199 dates ≥400 years BP, are classified as Class 3, the lowest precision and least reliable when included in the discussion of initial settlement. Chronologies built with Class 3 dates will hinder the precision and accuracy of estimations of colonization as outliers dates upward of 20,000 years BP (18,000 BC) distort the clarity of colonization recognition (see Figure 4). Upon the removal of the extremely early outlier (Beta-44165: with $^{14}C$ years BP of 19,550 170), acceptance of Class 3 dates from 3 unidentified charcoal samples would serve as evidence of an initial settlement before BC 3000. Dates lack cohesiveness in the range of Class 3 dates that proceed after BC 3,000 till AD 1000, where dates begin to overlap. In some approaches, overlapping of multiple dates from unidentified charcoal validates the chronology of events.

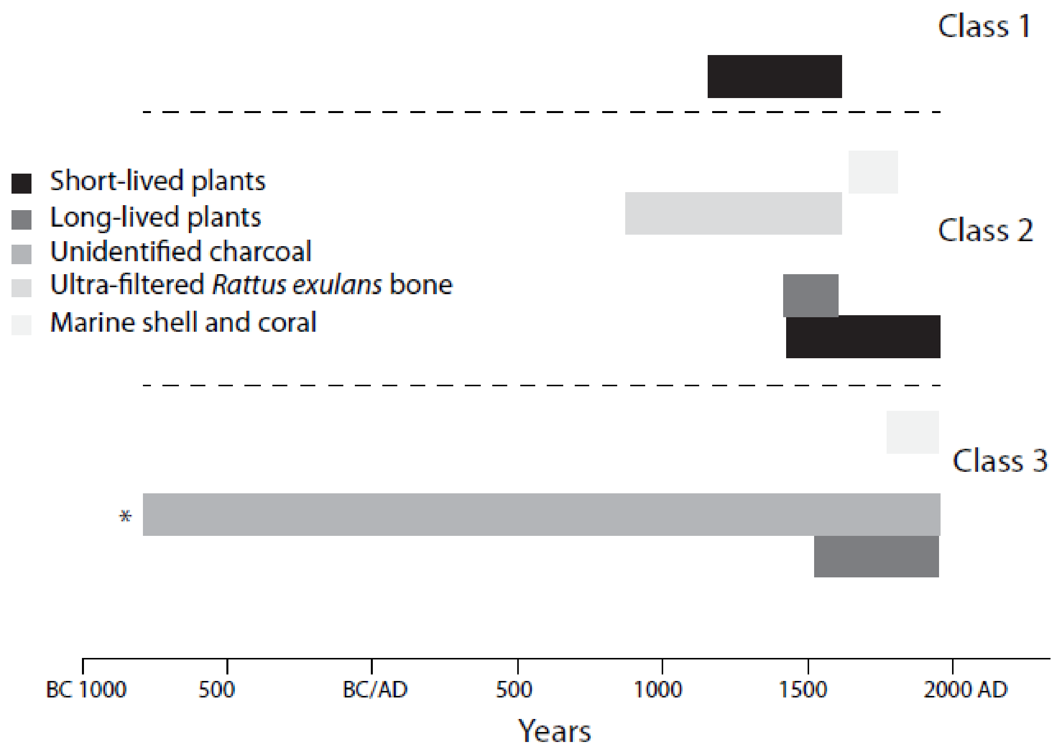



**Figure 4.** Minimum and maximum ages for each sample category according to class.

* Unidentified charcoal early dates extend to 18,000 BC

All of the 7 Class 1 dates geographically come from East Maui, 5 from the district of Makawao, and the remaining 2 from Hana. The 5 dates from Makawao come from locations higher than 457 *meters* above sea level and could infer a rapid settlement of the entire island of Maui, as a clear indicator of long term coastal establishment prior to upland expansion is not represented in the results. The corpus of all dates weighs towards the districts of Makawao (n=71) and Wailuku (n=65), consisting of 64% of dates ≥400 BP. The remaining districts of, Hana (n=19), Honua`ula (n=2), Ka`anapali (n=7), Kahikinui (n=7), Kipahulu (n=3), Lahaina (n=12),Kula (n=14), Kaupo (n=1), Makena and Kihei (n=11), represent the limited amounts of CRM and academic research that has been conducted at these locations. The *ahupua`a* of Wailuku has the highest number of radiocarbon dates, being the commercial center of the island today, and has seen the most CRM work due to development.

This dispersal of Class 1 dates, across leeward and windward districts as well as the coastal and alpine zones, does not support a substantial expansion period as previous chronologies have suggested (Kirch 1985, 2010; Hommon 1986; Cordy 1974). Instead, a rapid and expansive use of the land is evident as the spanning locations of Class 1 dates for Maui is not limited to a specific district or a distinct geo-climatic environment.

# CHAPTER 5. DISCUSSION

The results from the analysis of Maui Island radiocarbon dates have implications on multiple aspects. First, the discussion of the impact of the analysis results in regards to the previous systematic approaches for Hawai`i Island (Rieth et al. 2011) and East Polynesia (Wilmshurst et al. 2011a). Second, implications of late colonization on Maui shall be discussed in light of this papers' two largest data contributing research projects. Lastly, other lines of evidence that support the results from this analysis will be presented.

The results of three classifications focused on the colonization of the Hawaiian archipelago are strikingly consistent in its dates (see Table 4). Table 4 compares the EAEM/LAEM results from Wilmshurst et al (2011a), Rieth et al. (2011) and this paper. The consistency speaks to the efficiency of the use of classification and truncated probability distributions for analyzing radiocarbon dates. Through the conservative criteria for selection of samples and the use of summed radiocarbon probability distributions, these results provide the best confidence on earliest date of settlement for the Hawaiian Islands.

The analysis results of the earliest colonization of Maui (in this paper) and Hawai`i Island (Rieth et al. 2011) demonstrate the late settlement of the Hawaiian archipelago. Hawai`i Island colonization appears from AD 1220—1261 fitting just within the predictive model for the island chain by Wilmshurst et al. (2011a). Compared with Wilmshurst et al. (2011a) AD 1219—1266 interpretation of the colonization of the archipelago, Maui Island EAEM predicts settlement 5 years earlier (AD 1214—1255).

The EAEM and LAEM for Class 1 date consistency of Hawai`i Island and Maui offer that this re-occurring visibility is supported by samples that achieve the highest degree of confidence. All other earlier dates are provided through samples of lesser confidence. Until Class 1 date or dates are discovered to test the results of this paper, the earliest date of AD 1214—1255 will serve as the date of Maui colonization.

Collectively, the syntheses by Wilmshurst et al. (2011), Rieth et al. (2011), and this paper represent an analysis of over 2000 radiocarbon dates. Under the same classification procedures, 44 Class 1 dates return an averaged range of colonization from AD 1217—1260. These 3 individual reports for the Hawaiian Islands all produce specific overlaps of Class 1's earliest dates and represent the most reliable date of colonization.

| **Research** | **Island(s)** | **Number of dates assessed** | **Number of Class 1 Dates** | **Date of Colonization** |
|---|---|---|---|---|
| **Wilmshurst et al. 2011a** | Hawaiian Island Chain | 305 | 21 | AD 1219—1266 |
| **Rieth et al. 2011** | Hawai`i Island | 926 | 16 | AD 1220—1261 |
| **This paper** | Maui Island | 831 | 7 | AD 1214—1255 |

**Table 4**. EAEM/ LAEM conducted for Hawaiian Islands using class 1 dates

The effect of the late AD 1214—1255 colonization date on Maui gains support from findings of two larger works on Maui. These two projects contributed the most radiocarbon dates and interpreted the chronology of Maui. Kolb's work with *heiau* of Maui and Kirch's Kahikinui project produced a substantial amount of publications on Maui archaeology and are well suited in light of the results of this paper.

Michael J. Kolb spent nearly two decades investigating and interpreting the construction of Hawaiian monumental temple sites, or *heiau* (Kolb 1991, 1994, 1999, 2006; Kolb and Radewagen, 2007). In his dissertation (Kolb 1991), Kolb surveyed 108 remaining *heiau* on Maui and recorded excavations conducted on 8 of them. From dated samples from 7 *heiau* sites, radiometric dates suggested initial *heiau* construction occurring within the range of AD 1235—1374 with stylistic additions of core-filled walls and platform design around AD 1650 (Kolb 1992: 25). Surprisingly, these results are complimented by the results of Class 1 dates, AD 1214—1255. Although a majority of his samples were unidentified charcoal—Class 3 dates, a degree of consideration can be given to his interpretation of the chronology of the construction and expansion of monumental architecture on Maui. The rapid settlement of Maui is further supported by the dispersed locations of these dated sites across both leeward and windward districts.

The extensive archaeological project, hosted by the University of California, Berkley, in the *moku* of Kahikinui, produced multiple publications on the prehistoric environment, (Holm 2006; Kirch et al. 2005), agriculture (Coil 2004; Coil and Kirch 2005) and settlement (Kirch 1997, 2004, 2007; Kirch and Sharp 2005). A recent publication by

Kirch (2010) recognizes the colonization of the archipelago, between AD 800—1000 from other short-lived chronologies (Athens et al. 2002; Dye and Pantaleo 2010; McCoy 2005, 2007). While the AD 800—1000 date of colonization contains samples with large range of errors, the Class 1 results of this research provide a confident date of arrival 200—400 years later than previously assumed. A $^{230}$Th date from branch coral found on the surface of a temple wall returned a corrected age of 1580±10 (Kirch and Sharp 2005: 104). While the $^{230}$Th method of dating produces dates for the harvesting of fresh coral, the provenience upon which the materials were found (on top of walls) offers no support date the construction and obtain a trivial degree of confidence in dating the actual date of the site’s completion.

Dating the prehistoric events of the Hawaiian archipelago has a history of its own. A major shift from an early settlement for the islands has been re-adjusted by the re-investigation of early sites and avoiding dates from unidentified charcoal. The results of re-investigations early sites were found to be no older than AD 1300 (Dye 1992; Kirch and McCoy 2007; Tuggle and Spriggs 2001). Others still suggest that the colonization of the islands occurs around AD 1040—1219 (Dye and Pantaleo 2010; Dye 2011), based on a Bayesian model. While the Bayesian model is constructed from assumed timing of the colonization date, empirical radiocarbon evidence can provide a falsifiable test for questioning the arrival of Polynesians on Maui. Recent analyses produced for remote islands of East Polynesia (Wilmshurst et al. 2011a) and Hawai`i Island (Rieth et al. 2011) use a classification system to test the hypothesized timing of colonization. Class 1 dates present the most credible colonization for the Hawaiian Islands, an urgent need for a standardization protocol for the identification of samples and selection of short-lived plant taxa for dating remains to be developed in archaeology's academic and CRM disciplines.

As these independent lines of research merge on the 13th century arrival of Polynesians, assist in recognizing the effectiveness of the systematic approach taken in this paper and others (Wilmshurst et al. 2011a; Rieth et al. 2011). First, genealogical research traces the 23 generations of Hawai`i's chiefly lineage, to the arrival of the Hawaiian Islands about 1200 AD (Cachola-Abad 2000: 225). Cachola-Abad conducted research on the chiefly genealogies of the four largest islands of the Hawaiian archipelago. By establishing a classification system, she was able to give credibility on genealogical information provided through various sources, where more repetition reflects a higher credibility. The most credible conclusion portrayed 23 generations on Maui, occurring from Kamehameha to Paumakua (Cachola-Abad 2000: 176—177). With an estimated range of 25 years between each generation, the timing of colonization is predicted to be around 1200 AD. As multiple lines of supplemental evidence identify the arrival of Polynesians in the Hawaiian archipelago by 1200 AD, the results from the classification of the radiocarbon dataset is proven to be the most credible evidence.

The 13th century AD arrival of Polynesians on the Hawaiian Islands is not only supported by genealogical reckoning, but also from linguistic evidence and oral histories. Through an evaluation of these non-radiocarbon methods, Kirch (2011) identifies the work of Abraham Fornander, Peter Buck, and Kenneth Emory as unanimously concluding the late colonization of Hawai`i, around 1200 AD.  The impact of now having radiocarbon record that supports these statements, only under the “extreme” form of chronometric hygiene application, represents the effectiveness of the criteria.

The radiocarbon dating analysis presented in this paper, authenticates the systematic approach first created for East Polynesia (Wilmshurst et al. 2011a) and further applied to Hawai`i Island (Rieth et al. 2011).  When compared to other lines of evidence and investigation on the colonization of the archipelago, the results are consistent and complementary.  Future research conducting the reassessment of radiocarbon analyses for Moloka`i and Kaua`i (McCoy 2007; Carson 2005), as well as the unaddressed islands of Lana`i, Kaho`olawe, Necker and Nihoa, will conclusively exhibit the largest radiocarbon synthesis of an island chain.  Upon its completion, this concise review will have provided a cumulative answer to the falsifiable test presented to each island’s timing of colonization.  While the debate on Hawaiian chronology continues (Mulrooney et al. 2011; Wilmshurst et al. 2011b; Dye 2011, Rieth et al. 2011), the 13$^{th}$ century arrival of Polynesians continues to appear in confidence and clarity.

## CHAPTER 6. CONCLUSION

The review of 831 radiocarbon dates from Maui Island, serves as the most reliable source for the timing of initial Polynesian colonization at AD 1214—1255. With the selection of highest precision dates of East Polynesia (Wilmshurst et al. 2011a), Hawai`i Island (Rieth et. al. 2011) and now Maui Island, the 13th century arrival of Polynesians to the Hawaiian archipelago is marked. It has been over 20 years since the suspicions of early dates from unidentified charcoal have been investigated (Dye 2000), exposing the necessity of a higher standard of radiometric use in date acceptance.

Examination of Maui Island dates show that prevalent submission and use of unidentified charcoal has hindered the refinement of the chronology building process. This allows for large error from in-built age to affect the reliability of temporal statements. The use of classification in the process of including or excluding dates considered for the timing of colonization and using the summed distribution probability of the most credible class of dated samples is a preferable approach than to assuming colonization is recognized in assemblages, therefore selecting the early tails of probability distributions.

In the classification system of radiocarbon dates, dating unidentified charcoal represents the lowest credibility of dates as Class 3. While these dates have been used in the past to support claims of an early colonization, the re-examination of these sites pointed out the danger of their use in chronology building. Future efforts to promote the accuracy of radiocarbon dating, such as wood identification and dating of short-lived plant taxa or parts, will assist in the building of credible chronologies. The standardizing of submitted materials for dating is stressed to both the academic and CRM fields of archaeology.

As Hawaiian archaeology reflects on the history of the discourse, the now known errors should be carefully examined to prevent further confusion and produce confident statements on the prehistoric past. Especially in the case of dating the arrival of Polynesians in Hawai`i, the use of radiocarbon dating has assisted in telling the story across multiple disciplines. Many of which refer to archaeological sources to which the information was gathered. Methods in which archaeologists can achieve the highest reliability are vital to the success of the discipline, which future research may build off of. To entertain assumptions about assemblages or imply human presence through indirect evidence creates holes in the statements made. Thus the highest form of chronometric hygiene in this paper is founded on the credibility of the available radiocarbon data. From which, the AD 1214—1255 initial colonization of Maui is now established.

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