Assessing the potential to calendar date Māori waka (canoes) using dendrochronology

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Abstract

The short (c. 750 year) span of human occupation in Aotearoa New Zealand and imprecision of archaeological dating techniques available, presents particular challenges when investigating societal and technological change and continuity during the pre-European and early historic periods. Currently, radiocarbon (^{14}C) dating is used to determine the age of archaeological artefacts and/or sites but variations in atmospheric radiocarbon can affect the precision of calibrated dates resulting in broad age ranges for artefacts. This paper assesses the potential of dendrochronology to accurately and precisely date Māori artefacts, which would securely place them in a temporal context, enhancing understanding of manufacturing, provenance, and changes in style. Two kauri *(Agathis australis)* canoes (*waka*) recovered from waterlogged deposits in the Waikato River Delta and at Muriwai Beach, west Auckland, and currently undergoing conservation, were sampled for tree-ring dating. The ring width series were too short (<40 rings) for crossdating, however, the work described here has been valuable to informing processes regarding sampling and in highlighting the potential of tree-ring analysis to contribute meaningfully to understanding of these culturally and spiritually significant taonga.

Keywords: Agathis australis; dendroarchaeology; dugout canoe; kauri; log boat; Māori, waka.

1 Introduction

Aotearoa New Zealand was the last large landmass to be occupied by humans when Polynesian settlement occurred in the late 13th or early 14th century AD (Jacomb, et al., 2014). Sustained European contact began from 1769 AD and by 1840 AD New Zealand (NZ) was annexed as a British colony. The short (c. 750 year) span of human occupation in Aotearoa New Zealand and imprecision of archaeological dating techniques available, presents particular challenges when investigating societal and technological change and continuity during the prehistoric and early historic periods. Currently, radiocarbon (^{14}C) dating is used to determine the age of prehistoric artefacts and/or sites but variations in atmospheric radiocarbon can affect the precision of calibrated dates resulting in broad age ranges for artefacts, limiting understanding of manufacturing, provenance, and changes in style.

New advances in dating methods are now raising the possibility of developing a refined chronology for New Zealand, such as recent research by Hogg, et al. (2017) who used ^{14}C wiggle-matching to accurately and precisely date palisade posts from a swamp pā (fortified village) to within ±2 years. Dendrochronology can also provide absolute dates, but with no statistical error, and recently an opportunity arose to test whether calendar ages for Māori artefacts, specifically canoes (waka), could be obtained using tree-ring analysis. Waka are a particular focus of attention because the archaeological remains of canoes have been recently recovered from several New Zealand locations, with the oldest craft dating to the fourteenth century and youngest canoe potentially from the early 20th century (Irwin, et al., 2017). Investigations of these waka demonstrate use of different tree species including matai (*Prumnopitys taxifolia*), totara (*Podocarpus totara*) and kauri (*Agathis australis*), and changes in canoe manufacture, sailing technology and maritime communication through the pre- and post-contact periods, (Irwin, et al., 2017, Johns, et al., in review 2017, Johns, et al., 2014). However, one of the issues faced in these studies is the imprecision of dates for most of the canoes. Tree-ring analysis could establish exact calendar dates for surviving wood, providing a *terminus post quem* for manufacture of the craft. Here, we present the results of the first ever attempt at tree-ring dating Māori canoes and discuss how dendrochronology can contribute meaningfully to understanding these taonga (treasures).

1.1 Dendroarchaeology in New Zealand

Māori used a range of different tree species to build structures such as palisades, buildings (whare) and basic shelters and to make portable items including household goods, tools, hunting equipment and weapons, canoes (waka), and carvings (Wallace and Irwin, 2004). Such objects have been preserved in waterlogged environments and recovered during excavations or as a consequence of being exposed through human action or natural processes. The use of dendrochronology for archaeological dating of such artefacts was raised by archaeologist Jack Golson (1955) at the first annual conference of the NZ Archaeological Association, and subsequently discussed by researchers such as Bell (1958), Bell and Bell (1958), Cameron (1960), Dunwiddie (1979) and Norton and Ogden (1987). An early attempt at tree-ring dating archaeological wood (palisade posts) was unsuccessful (Scott, 1964) but in the decades following that work, the suitability of particular native species for dendrochronology has become better understood and a network of modern tree-ring chronologies had been established for several species, including NZ kauri (*Agathis australis*).

Kauri dendrochronology is well established and a comprehensive network of modern, archaeological and sub-fossil kauri chronologies has been built for the upper North Island (Boswijk, et al., 2014) providing reference curves for dating material of unknown age. Analysis of kauri timber from 19th and early 20th century archaeological contexts has shown that the method can be usefully applied to dating material from historic era structures, contributing to understanding of the sites (Boswijk and Jones, 2012, Boswijk, et al., 2016). Because two of the recently recovered canoes – one found in the Waikato River Delta, Waikato and one at Muriwai Beach, Auckland (Figure 1) – were manufactured from kauri (Irwin, et al., 2017, Johns, 2015), they were considered to be suitable candidates to test whether tree-ring analysis could contribute usefully to understanding of these craft.

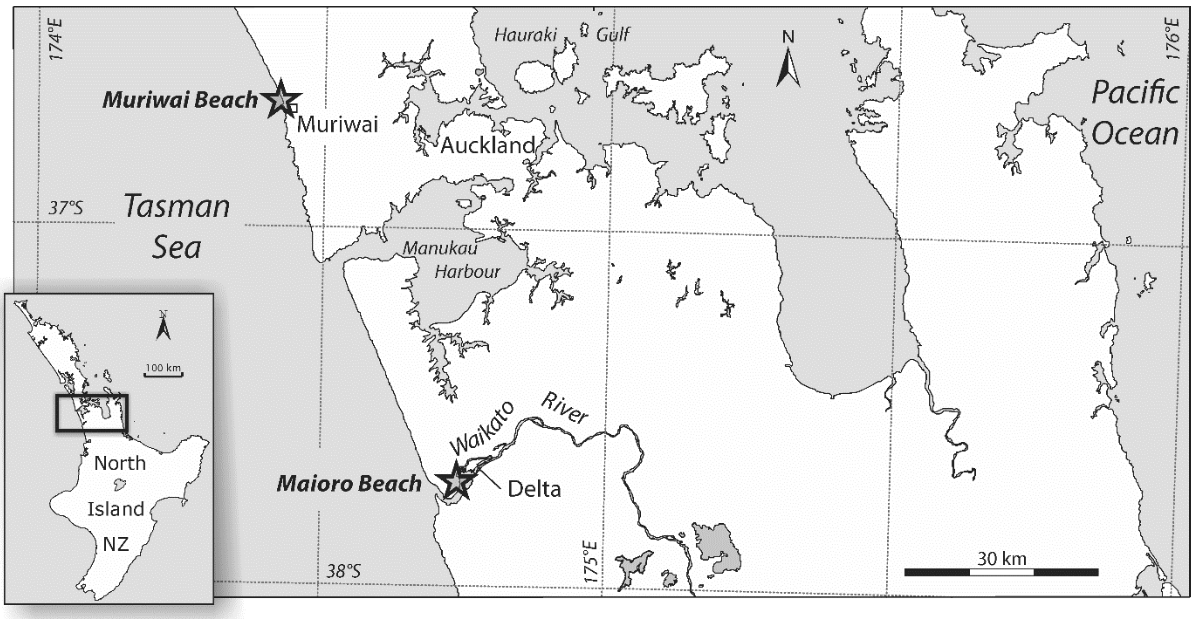

Figure 1: Location map of recovery sites for Waikato River Delta and Muriwai Beach waka

Both canoes had been radiocarbon dated but because of the influence of plateaux in the calibration curve, it is not possible to determine from the radiocarbon dates if the craft belong to the pre-historic or historic periods (Table 1). All that can be said is that the canoes are younger than the trees they were made from. We hoped to identify calendar dates for the wood through crossdating ring width patterns, but recognised that there was a risk of failure in being able to achieve this. As Baillie (1982) points out log boats and dug-outs present challenges for tree-ring dating as they tend to be hollow with thin walls that may contain relatively few rings, and the removal of outer rings (sapwood) during manufacture would also reduce the precision of a tree-ring date with regard to tree felling and construction of the craft. Additionally, heritage values may restrict sampling to preserve the integrity of the craft for conservation and display. In spite of these constraints, examples from Britain (Marsden, 1989, Whitewright, 2010), Europe (Rogers, 2010) and North America (Pickard, et al., 2011) demonstrate that tree-ring dates can be established for dug-out canoes and that the data are of value for interpretation of these craft. Permission was sought from, and granted by, the respective iwi (tribe) who have guardianship of the waka – Ngati Te Ata (Waikato River delta waka) and Ngati Whatua o Kaipara and Te Kawerau a Maki (Muriwai waka) – to obtain wood samples from each craft for dendrochronological dating.

Table 1: Radiocarbon dates for the waka from the Waikato River Delta, Waikato and Muriwai Beach, Auckland

Waka	Sample code	Waikato Lab number	CRA	Calibrated 95% prob. range (cal AD)
Waikato River Delta	C1985	WK 42098	258 ± 20 BP	1640 – 1800
Muriwai Beach	C1866	WK 44197	123 ± 20 BP	1690 – 1930

1.2 Māori canoes

Māori manufactured several different types of watercraft ranging from basic rafts (mokihi) made of raupō (*Typha orientalis*) or New Zealand flax (*Phormium tenax*) flower stalks to large and highly decorated *waka taua* (war canoe) capable of carrying up to 100 people on war expeditions and coastal voyaging (Bathgate, 1969, Best, 2005, Haddon and Hornell, 1997). These large craft were made from two or more logs and included top strakes, thwarts and seating, and are the most visible form of waka seen today as they are used for ceremonial purposes. Smaller, plainer versions of waka taua - *waka tete* – were used for coastal voyaging and sea fishing. The simplest mono-hull canoes were *waka tiwai*, made from a single dugout hull, which were used in harbours and rivers and for coastal fishing. Small craft known as *korea*, *kopapa* and *koku* would carry one to three people and were used on calm waters, harbours, lakes and rivers (Best, 2005). Māori also manufactured double canoes, made from two canoes either temporarily or permanently connected, and single canoes with outriggers (Best, 2005, Haddon and Hornell, 1997).

1.2.1 Waikato River Delta

The waka from the Waikato River delta (hereafter 'Waikato') had been washed onto Maioro Beach, where it was recovered by Dilys Johns and Ngati Te Ata in 2015 (Irwin, et al., 2017, Johns, 2015) (Figure 1). It is currently being conserved at a satellite facility at Waiuku Museum, south of Auckland city, where it is contained within a ~7 m x 1 m tank of water and biocide. The canoe is incomplete as it is missing its gunwhales but part of one end survives indicating that it was made from a single kauri tree and is possibly a waka tiwai (Figure 2). The surviving section of the hull is 5.40 m long and 0.68 m wide. The walls are thin (~60 mm) for its overall size, producing a light and easily driven waka. Particular features include two lugs (~120 mm thick) close to the shaped end that may have supported other fittings. At the time of sampling, the wood was degraded and soft and shakes or splits were evident. The grain was visible in the wet wood, suggesting that rings in the hull section were wide and that the surviving shaped end was carved from close to the centre of the tree.

Figure 2: The waka from Maioro Beach, Waikato River Delta.

1.2.2 Muriwai

The Muriwai waka was found in 2009 at the Okiritoto Stream, Muriwai Regional Park, Auckland and was recovered by Auckland Council archaeologist Rob Brassey, Dilys Johns and representatives of Ngati Whatua o Kaipara and Te Kawerau a Maki, the iwi associated with the waka (Brassey, 2010, Irwin, et al., 2017, Johns, 2010) (Figure 1). The waka was no longer complete, but the surviving section indicates that it was a dugout canoe and particular features including a mast step in the base of the hull suggests it may have been a coastal sailing craft, possibly with an outrigger (Figure 3). The surviving section is 6.95 m long and 0.62 m wide but it is thought to have been up to two meters longer when intact (Irwin, et al., 2017). Part of the hull was ~120 mm thick and visible grain indicated that the preserved growth rings were reasonably wide. The wood had splits and shakes and areas suffered from advanced deterioration. At the time of dendrochronological sampling (Figure 4), the waka was near the end of the bulking process, having been impregnated with a series of different molecular weights of Polyethylene glycol (PEG) to conserve the wood.

Figure 3: The waka from Muriwai Beach, west Auckland.

Figure 4: Boswijk (left) and Johns (right) sampling the Muriwai waka. Clumps of white PEG are visible on the surface of the canoe.

2. Methods

Waka are taonga and considered by iwi as ancestors, therefore their cultural and spiritual significance precludes the standard protocol of removing a slice or wedge from the canoe to obtain a section of wood for tree-ring analysis. During our consultations with iwi a representative inferred that to take a slice from the waka would be like cutting someone’s leg off. Elsewhere, a manual increment borer or a corer designed for waterlogged wood has been used on log boats to extract samples for tree ring analysis (Marsden, 1989, Martinelli and Cherkinsky, 2009, Pickard, et al., 2011, Whitewright, 2010). We tested a 5 mm manual tree borer and a 10 mm power corer on non-cultural waterlogged wood samples to ascertain what type of borer to use. Manual coring was not found to be suitable because the test samples split during coring raising concerns for the integrity of the waka. The 10 mm English made drywood borer driven by a battery-powered drill was more favourable. The borer leaves a 12 mm hole that could be blocked or left open as part of the korero (conversation) of the waka, and this was considered acceptable.

Permission was granted by the respective iwi to obtain two samples from each waka. These were taken on opposite sides of the watercraft to check for intra-tree replication of the ring pattern, and to potentially provide a longer sequence for crossdating against a millennial length kauri master chronology derived from modern trees and archaeological wood. Based on the median ring widths of modern (living) and archaeological kauri (1.402 mm and 1.258 mm respectively; Boswijk et al 2014) it might be anticipated that up to 100 rings could be present in areas of sufficient thickness, with caveat that these values are based on samples from mature trees that were several hundred years old at the time of dendrochronological sampling (modern) or felling for timber (archaeological). As indicated above, however, visible grain indicated wide growth rings and shorter ring width series were anticipated.

After sampling (discussed below in sections 3.1. and 3.2), the core samples were dried and glued to wooden plinths, and then sanded to a fine polish so that the growth rings could be seen clearly. Generally, kauri have well defined annual rings but they can also form false rings and have locally absent rings. Such anomalies can usually be identified and resolved through intra- and inter-tree/site crossmatching. Ring widths were measured using a low power binocular microscope and LINTAB measuring table linked to a computer, and the measurement function in TSAP-Win Scientific V4.69i (Rinn, 2002-2015). Crossdating followed standard procedures (English Heritage, 2004) using the statistical and visual crossdating functions in TSAP-Win.

3. Results

3.1 Waikato River delta waka

As indicated above (section 1.2), the Waikato waka is currently held in a tank where it is submerged in water and biocide. The condition of the wood – wet and impregnated with fine sediment – and location of the waka in the tank presented particular challenges to sampling. The tank was emptied on the day of fieldwork but, because of the weight and fragility of the waka, it could not be shifted from the tank or moved easily within the tank to facilitate access for coring. Consequently, sampling was carried out by leaning over the side of the tank and coring downwards into a side wall and one lug. Location details of the cores samples, WAK001 and WAK002, are provided in Table 2. Note, for the purpose of recording sample locations the surviving rounded end was treated as ‘north’ and sampling sites orientated to this.

Both cores fragmented during sampling (Figure 5a). The combination of downward pressure, wet wood, and the corer clogging probably caused the cores to twist and fracture, with breaks coinciding with small patches of soft, friable wood in an advanced state of degradation. In these sections rings were potentially lost due to the fibers becoming mashed or breaking away. The poor quality of the cores reduced their suitability for measurement and crossdating. WAK001 had between 50 and 60 rings but, because of multiple breaks, the measured ring width series was only 37 years long. WAK002 was so fragmented that it was not possible to obtain a reliable ring width series for intraseries comparison; 37 rings were counted on this sample (Table 3). It was noted that the characteristics of the cores were quite different as WAK001 had predominantly narrow rings and WAK002 had wide rings (Table 3), indicating that different parts of the parent tree's growth pattern were preserved in the waka hull and the lug. Kauri can have non-concentric growth and also have areas where the rings wedge out or become suppressed. The difference in the cores may hint at such phenomena or indicate changed conditions for the tree during its life.

Although short, the ring width series for WAK001 was tested against a kauri master chronology constructed from modern and archaeological data, and a statistically significant ($p=<0.0001$) match was identified in the early 16th century. At this point, however, we are very cautious in ascribing a calendar date to the canoe because of the risk of a spurious match due to the short series length and concerns about reliability of the ring sequence. On the basis of this finding, however, and the potential for obtaining a longer tree ring series (up to 60 years) for the canoe, we recommend resampling in the future.

3.2 Muriwai Beach waka

Sampling of the Muriwai waka was carried out when the canoe was lifted out of the impregnation tank onto a bespoke cradle which provided good access to the sides of the hull (Table 2). For the purposes of sampling, the most rounded end of the waka was treated as 'north' and sample sites oriented towards this.

Both cores fractured during sampling but the breaks were generally clean and either cut across a ring or followed the ring boundary, enabling the cores to be reassembled (Figure 5b). The growth rings were wide and complacent (showing little year-to-year variability) consequently the ring series were short (29 and 27 rings respectively). Crossmatching determined that the ring series covered the same time period and a 29-year average sequence was made (Figure 6). Unfortunately, the ring sequence was not of sufficient length for secure crossdating against the kauri master chronology.

Although unsuitable for dating, the wood samples provide some insight into the parent tree. The cores were taken from opposite sides and different ends of the canoe, ~3 meters apart, representing different heights in the parent tree. That they overlap in time suggests that the tree had a concentric growth pattern, and the wide rings indicate fast growth at least in the time period preserved in the hull. A *minimum* age estimate, calculated by dividing the radius (0.31 cm + an arbitrary value of 10 cm to account for loss of outer rings) by the average ring width (3.61 mm), suggests the parent tree may have been at least 110 years old when felled.

Table 2: Location of core samples from the Waikato and Muriwai waka

Sample	Location	Wall thickness	Comments
WAK001	West side of hull	~60 mm	Core spongy. 8 breaks, narrow rings.
WAK002	East lug	~120 mm	Fragmented, 7 breaks, and wood probably lost in breaks, wide rings.
MUR001	West side of hull, 1.5 m from south end.	~120 mm	Fragmented, 7 breaks, wide rings.
MUR002	East side of hull, 1.42 m from north end.	~120 mm	Fragmented, 6 breaks, wide rings, wood black.

Table 3: Summary details of tree ring series from the Waikato and Muriwai waka

Sample	No. Rings	Ring width			Relative	Comments
		min.	max	mean	date	
Waikato						
WAK001	37	0.10	0.77	0.37	1-37	50 – 60 rings present. 8 breaks.
WAK002	37	1.10	4.65	2.71	-	Series not reliable.
Muriwai						
MUR001	29 +3	1.46	5.53	3.58	1-29	From stern end. Wide rings. 7 breaks. End 3 rings not measured due to break
MUR002	27	2.08	5.47	3.61	2-28	From prow end. Wide rings. 6 breaks. All rings measured.

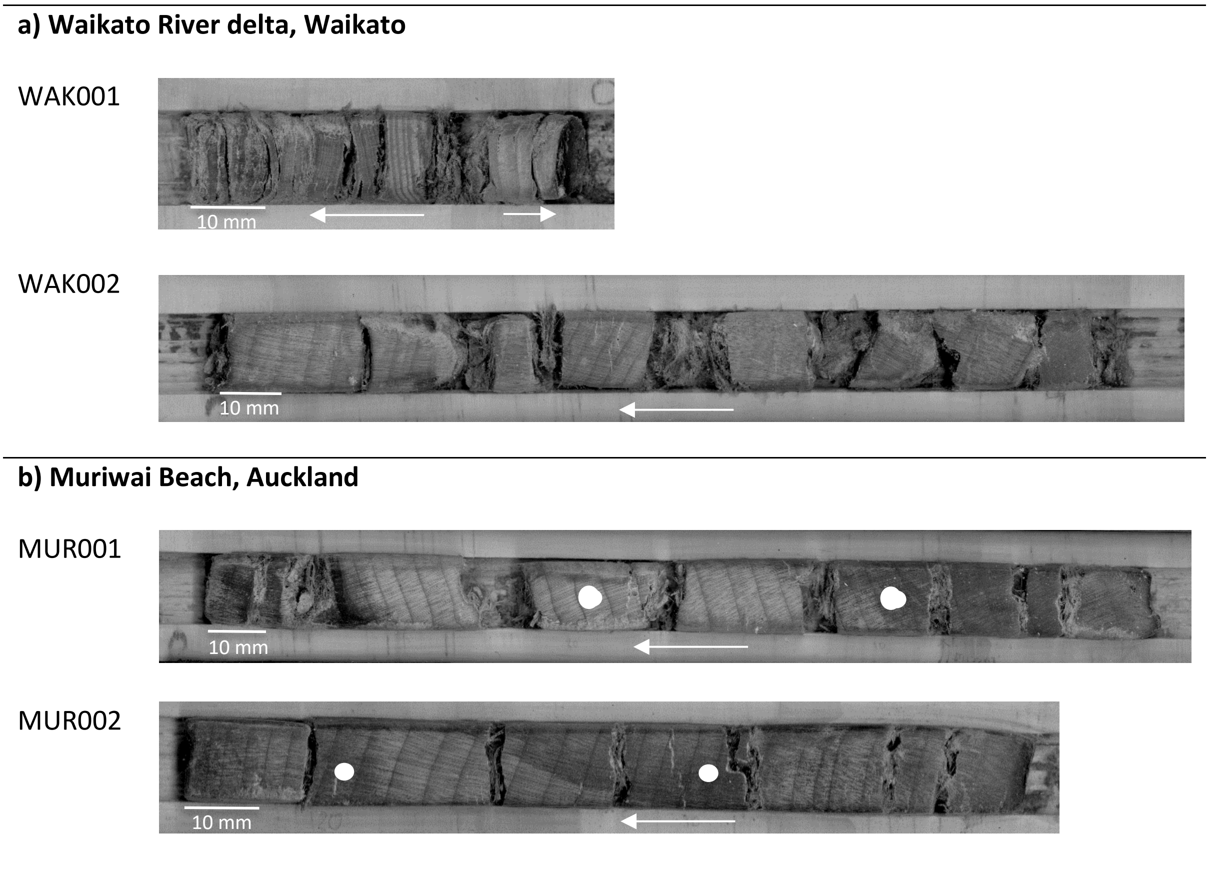

Figure 5: Core samples from Maioro Beach and Muriwai Beach waka. Arrows indicate direction of growth. On WAK001 one section was misplaced. Dots mark years 10 and 20 on the Muriwai Beach cores.

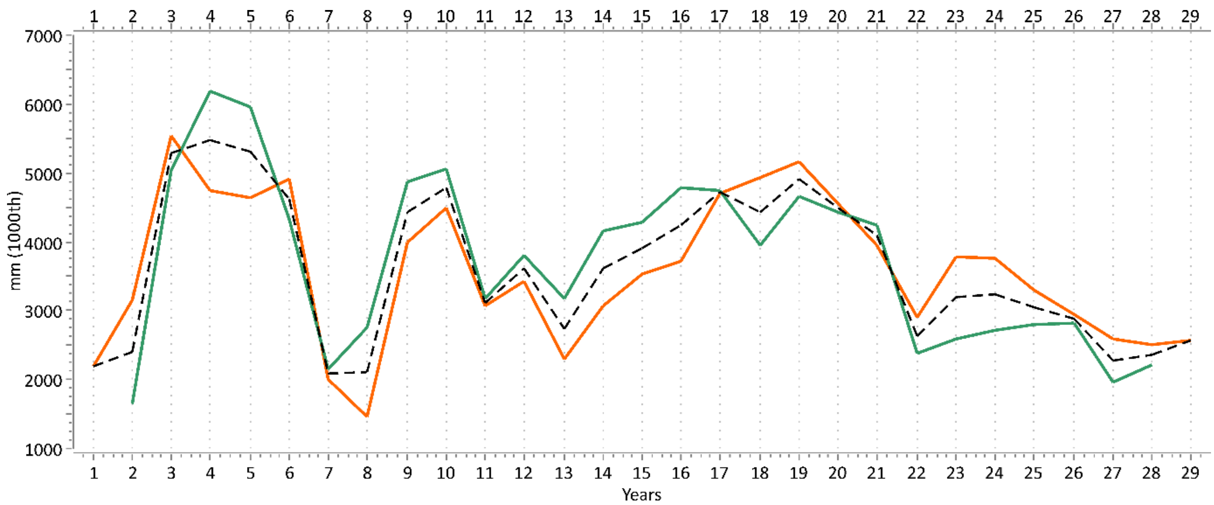

Figure 6: Alignment of ring width series for MUR001 (orange) and MUR002 (green) (TVBP=3.9, r = 0.75, overlap = 27 years). The dashed line is the averaged sequence MURW.

4. Discussion

Current investigation of archaeological waka is focused on species used, construction and form because they indicate changes in technology and sailing performance through time, which in turn reflects shifts in transportation and communication within New Zealand in the pre-European period (Irwin, et al., 2017). Accurate and precise dating of canoes is therefore critical to enable development of a chronological framework for such craft, and to establish temporal relationships between different canoes. The Waikato and Muriwai waka are the first canoes where tree-ring analysis has been applied with the intention of refining the age of the wood and providing a *terminus post quem* date for construction of the craft. Unfortunately, as discussed above, no tree-ring dates were forthcoming for either waka because of poor quality cores and short sequence length. Whilst this is disappointing, the research described here has been valuable to informing processes regarding methodology, informing understanding of suitability of such craft for tree-ring dating, and highlighting the limitations and potential of tree-ring analysis to contribute meaningfully to understanding of these culturally and spiritually significant taonga. Each of these points is discussed in turn below.

4.1 Sampling methodology

Currently coring is considered to be the best method for obtaining a tree-ring sample as it causes minimal damage to the waka, but the approach requires further refinement to improve outcomes. As indicated above (section 2), we used an English produced borer typically used on dry wood (oak) which was known to also work well on dry kauri. Whilst testing indicated this type of corer was more favorable than an increment borer, we still encountered issues with breakage. These were probably a result of the tube clogging with wet sawdust causing the core to stick, twist and snap. For the Waikato waka, breakage was probably exacerbated by downward pressure on the corer. In contrast, although the Muriwai cores also broke, the wood sections were solid and the breaks were relatively clean. This is most likely because access to the craft was better for sampling and the wood had been stabilized with PEG. For this type of research to proceed, alternative types of borers suitable for coring waterlogged wood need to be investigated (on non-cultural wood) and further examination of waka should include sampling of dry, conserved canoes to ascertain if these produce better outcomes, i.e. intact cores.

4.2 Limitations

Successful extraction of samples aside, there are three key limitations to tree-ring dating Māori artefacts such as dugout canoes: series length, reliability of the ring width series, and species used to manufacture the craft. Core sampling can also provide an opportunity to apply alternative dating techniques, such as high-resolution wiggle-match radiocarbon dating. Awareness of manufacturing techniques is also critical to interpretation of any dates obtained from canoes.

Series length: The number of rings contained in an object is a product of the age and size of the parent tree when it was felled, its growth characteristics (fast or slow growth), manufacturing processes involving removal of wood, and the form of the watercraft. Potential series length can be estimated by a preliminary assessment of the grain, informing whether core sampling will proceed, and sampling location determined by thickness of surviving wood. As demonstrated here however, we cannot automatically assume that the thicker sections will necessarily contain more rings than thinner sections of the canoe. The lug on the Waikato waka was made from part of the tree where the rings were wide in contrast to the hull, and the presence of 50-60 narrow rings in the hull of the Waikato waka was not apparent from initial observation of the canoe. Therefore, based on our experience, sampling of waka may be worthwhile even if an initial visual assessment of the grain suggests insufficient rings (<50) present in the craft. Locations for coring should consider thickness, but also take into account other aspects such as wood quality.

Reliability of the ring width series: A second limitation for New Zealand species such as kauri, is the potential for a series to have locally absent or false rings which can affect cross dating by disrupting the growth pattern. Usually, these can be resolved by intra- and inter-tree replication. Analysis of the Muriwai waka demonstrates that it is possible to produce replicable ring width series from samples taken from opposite sides of the canoe. This shows the potential to obtain a reliable average sequence that can be used for tree-ring dating and validates taking two samples from the craft.

Species: The third limitation to tree-ring dating waka relates to species. The canoes discussed here were selected as the first test cases for tree-ring dating because they were manufactured from kauri, a species with a well-established network of tree-ring chronologies. As indicated above (Section 1) recent finds have included the archaeological remains of canoes manufactured from other species including matai and totara. Although the dendrochronological potential of these species was investigated in the 1970s, and matai has been used for ecological research, the value of these species for tree ring dating is not well understood. Both species are found throughout New Zealand and further research into site chronology development and the presence of regional signals is required before crossdating of archaeological wood can be attempted.

Radiocarbon dating: In some cases is may be possible to combine dendrochronology and high-resolution radiocarbon dating to refine the age of the wood, as per Hogg, et al. (2017). This would be applicable where a ≥60 ring sequence is established, but perhaps not able to be crossdated due to series length, or where the canoe is manufactured from species for which, currently, there are no reference tree-ring chronologies.

Interpretation of dates: The purpose of tree-ring dating is to refine the age of the waka, however the temporal proximity of a date (tree-ring or radiocarbon) to the time of tree felling and waka manufacture will be affected by the amount of wood lost from the outer part of the tree during shaping of the hull. Therefore, interpretation of tree-ring (or wiggle-matched radiocarbon dates) requires understanding of manufacturing processes, in particular whether only sapwood or sapwood and heartwood was removed, and investigation of the average number of sapwood rings that kauri (or other species) are likely to have to generate sapwood estimates that can be applied to interpretation of calendar dates.

4.3 The parent trees

Regardless of dating potential, the core samples provide some insight into the parent trees which would add a new dimension to archaeological investigations of canoes and may confirm or challenge preconceived ideas regarding the types of trees that were being selected for different types of canoe. Oral histories and ethnographic literature, such as Best (2005), tend to place emphasis on waka taua and both the ritual surrounding selection and felling large trees and the processes of making the large war canoes, rather than 'inferior' craft. Best (2005:55) justified this by saying that "A description of the waka tiwai, or plain dugout, would afford no illustration of a built-up craft, or of methods of ornamentation", yet it means that selection practises and rituals associated with 'everyday' craft may not be thoroughly documented. The *impression* gained of the Muriwai waka from the ring width series, combined with the waka dimensions, is that it was made from a fast-growing tree that was at least 110 years old and probably ≤ 1 m in diameter and > 9 m tall. The estimated size and age *suggests* a young kauri that has not yet attained the fully mature form of a canopy emergent with a thick trunk and spreading crown. This may be different to the large trees selected for waka taua, and perhaps implies selection of trees fit for purpose.

5. Conclusion

This paper summarises the first attempt to use dendrochronology to date archaeological Māori cultural artefacts since the 1960s, and the first analyses of tree-ring samples from waka. Accordingly it serves as a baseline for further research on precision dating for cultural artefacts, highlighting both difficulties and potentialities, and informing the future development of tree-ring based methodologies. Even though tree-ring dates could not be obtained for these particular kauri waka, the findings demonstrate that there is great potential to derive useful information from tree-ring analysis of the wood and we consider that further research on the dendroarchaeology of waka from archaeological contexts and museum collections is warranted.

Future work should focus initially on waka manufactured from kauri with a view to expanding to canoes made from other species such as matai and totara, in conjunction with development of tree-ring reference chronologies for these species. Only by sampling a higher number of craft and wider range of canoe types, will it be possible to: (a) refine a methodology for sampling canoes; (b) establish whether calendar dating waka is achievable using dendrochronology; (c) combine tree ring analysis with radiocarbon wiggle matching for accurate dating; and (d) develop greater understanding of the parent trees used to make the craft. This research has the potential to herald a new technique to establish a chronological framework for material culture in New Zealand by adding a fresh dimension to ongoing studies of archaeological waka in Aotearoa.

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