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– ARTICLE –

A Review of Archaeological Māori Canoes (*Waka*) Reveals Changes in Sailing Technology and Maritime Communications in Aotearoa/New Zealand, AD 1300–1800

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ABSTRACT

We compare ethnological views of Māori canoes (*waka*) of the first colonisation period with those of the European contact period, and then describe diverse archaeological *waka* from the interim period. The aim is to reconstruct basic design elements of whole canoes and to suggest their relative ages. Variations in form relate to differences in sailing ability and we refer to scientific performance testing of a range of model canoe hulls and sails. We find that through time technological change in *waka* correspond to other changes in New Zealand archaeology including demographic and social shifts, and the contraction of interaction spheres. The first canoe-builders in New Zealand adjusted to a new environment. The country became isolated within East Polynesia, but there were widespread communications and capable sailing canoes on the New Zealand coast. Through time, with a shift from multihulls to monohulls and changes in hull form, we see a general decline in the sailing performance of canoes and the development of new types more suited to paddling and downwind sailing. However, notwithstanding this trend, outrigger canoes which could sail well persisted into late pre-European times in both the north and south of the country.

Keywords: Canoes, boat technology, sailing performance, mobility, Māori

INTRODUCTION

Canoes were primary artefacts of seaborne migration and mobility, but scarcity of archaeological canoe remains has led to uncertainty and debate about the history of marine technology. New finds of the remains of Māori canoes (*waka*) in Aotearoa/New Zealand have improved the inventory in Polynesia. An on-going collaboration of archaeology, waterlogged wood conservation and the study of sailing performance aims to investigate the capability and cultural context of Pacific sailing canoes, both ancient and modern (Irwin and Flay 2015, Johns *et al.* 2014).

We begin with a summary of current views about Māori canoes of the first colonisation period derived mainly from comparative Polynesian ethnology, which we compare with those of the later European contact period described historically and ethnographically (Anderson *et al*. 2014, Finney 2006, Haddon and Hornell 1997, Irwin 2006, Pawley and Pawley 1994). We then describe archaeological *waka* from the interim period, aiming to reconstruct basic design elements of whole canoes from fragments, and to suggest their relative ages where possible. Variations in form relate to differences in sailing ability and we refer to performance testing of model canoes held to represent traditional and earlier forms. Finally, we relate changes in canoe technology, through time, to the changing context of Māori settlement, society and maritime communication.

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MĀORI *WAKA* (CANOES), EARLY AND LATE

The literature about Oceanic canoes is huge, but distinct canoe complexes can be identified (Doran 1981). The earlier forms of canoe in East Polynesia were the only ones to reach New Zealand (Haddon and Hornell 1997). Both double canoes and single outrigger canoes reached New Zealand and Māori traditions refer to both (Best 1925). Oceanic canoes were generally double-ended in under-

water shape (the same shape underwater at both ends), but above the waterline ancient Polynesian voyaging canoes had a distinct bow and stern (McGrail 2001: 322). They had a two-spar rig and sail, and they changed direction by tacking (turning the bow of the boat through the wind). Double canoes were well balanced with the wind coming from either side, but tacking single outrigger canoes had poor balance with the outrigger to leeward (on the side away from the wind). This is a reason East Polynesian voyaging canoes were often double, and they could carry more cargo as well.

By AD 1769 there had been a shift from multihulls to monohulls, and elaborate and sophisticated *waka taua* (war canoes) were conspicuous on the New Zealand coast. Only one double sailing canoe was reported in the North Island by Cook's first expedition although others were seen in the South Island, under sail or paddled. In 1642 Tasman had seen double canoes without sails in Taitapu, in the north of the South Island. Double canoes were giving way to single ones without outrigger by Cook's time, and single outrigger canoes were rare and at the point of disappearance. Haddon and Hornell (1997: 195) thought the change was '… probably coincident with a decline in the maritime enterprise of the people', but we will argue (below) that canoe technology adapted to the changing cultural and geographical context of communications. Polack, who lived for seven years in the north in the 1830s, wrote: 'Outriggers, invariably made use of by the South Sea Islanders, are unknown in New Zealand, and canoes are never or rarely lashed together; nor are platforms raised over the gunwales, and sheds erected on them, as is the usage of the above nations' (Polack 1838: 224). Haddon and Hornell (1997) assert that nowhere in New Zealand is there evidence for elaborate plank-built boats, such as the *pahi* of the Society and Tuamotu Islands. When Europeans arrived Māori canoes were beamy dugouts with deep planks attached and with no internal frames (Best 1925).

Haddon and Hornell explained the change in Māori canoe types as a rational response to a new environment:

> The reasons for abandoning the use of both double canoes and outrigger canoes in favour of the single form without outrigger were mainly two - the presence of timber of great girth in the virgin forests that covered much of the land, and the concurrent decline in overseas voyaging. For ordinary coastal journeys within sight of land open canoes of beam such as their Tahitian forefathers could never command required no longer the assistance of artificial stabilizing devices – the connection of two hulls or the use of a counterpoise float. (Haddon and Hornell 1997: 200)

We agree with this, as far as it goes, but will suggest additional reasons.

The linguist Bruce Biggs also related the decline of double canoes to the environment. He thought offshore voyaging by Māori in pre-European times was discouraged by New Zealand's isolation, unpredictable winds south of the tropics, and a large land area that produced no demographic pressure to migrate. He noted changes in language that accompanied the decline in voyaging and changes to canoes. The Polynesian word **katea* meaning the side of a canoe opposite the outrigger was lost with the outrigger itself; and the word **kiato* that refers to the booms that connect canoe to outrigger in island Polynesia refers to thwarts (seats) that also stabilized the top strakes of a Māori single canoe hull (Biggs 2006: 42). He also stated his belief (with which some others disagree) '… that all the old Polynesian techniques of celestial navigation were lost in New Zealand and the stars changed their meaning. To the Māori the stars were primarily harbingers of the seasons, not navigational beacons' (Biggs 2006: 60).

ARCHAEOLOGICAL REMAINS OF PRE-EUROPEAN WAKA

The pre-European remains of canoes are widespread in all three main islands of New Zealand (Figure 1), on exposed and sheltered coasts. It is obvious that coastal communication was widespread at times and canoe transport effective. We are interested in the technology represented by these finds; however, we note that the sample is still small and the finds are disparate, some without secure provenance or established age. Some came from archaeological sites and others from find spots with no associated cultural material, to which they may have drifted from elsewhere. Yet there is an opportunity to appraise the diversity of forms, to make tentative suggestions regarding trends of change, and to assess the hydrodynamic properties of the reconstructed canoes in order to compare their sailing performance with those of the ethnographic period. Our conclusions can be reviewed in light of future finds.

Anaweka

This find is a complete plank from the oldest directly-dated canoe in Polynesia and comes from a canoe of previously unknown form (Johns *et al.* 2014). It is 6.08 m long and was originally 0.95 m wide at the widest point (Figure 2) and comes from the back of the canoe, as shown by a carved sea turtle which faces forwards (Figure 3). Sea turtles featured prominently in Polynesian art and ritual dating back to early times (Rollett 1986). The wooden hull has been identified by R. Wallace as New Zealand matai (*Prumnopitys taxifolia*) with lashing holes caulked with the inner bark of New Zealand totara (*Podocarpus totara*). Radiocarbon dates of caulking indicate the canoe was last sailed in the period AD 1350-1400 (Table 1), but it had been previously damaged and repaired. There could be nearly 200 years of inbuilt age in the tree from which the hull was made (Johns *et al.* 2014).

The plank has a butt end like East Polynesian canoes

Figure 1. The locations of archaeological sites, find spots and canoe remains described in the text.

Figure 2. A photograph of the interior of the Anaweka plank showing one straight side (upper) and one curved side (lower); the pointed end is at the back of the canoe and the butt end formerly attached to another section of hull. There are four ribs and a longitudinal stringer.

of ethnographic times, but unlike the mortise and tenon joints of detachable end pieces (*haumi*) of historic Māori hulls. Lashing holes around the edges were for attachment of a missing dugout under-body and gunwale (Figure 2). Four carved ribs gave lightness and strength to the hull, and a longitudinal stringer held its parts together. The opposing sides of the canoe were evidently attached by cross-beams set into notches in the stringer and held together by

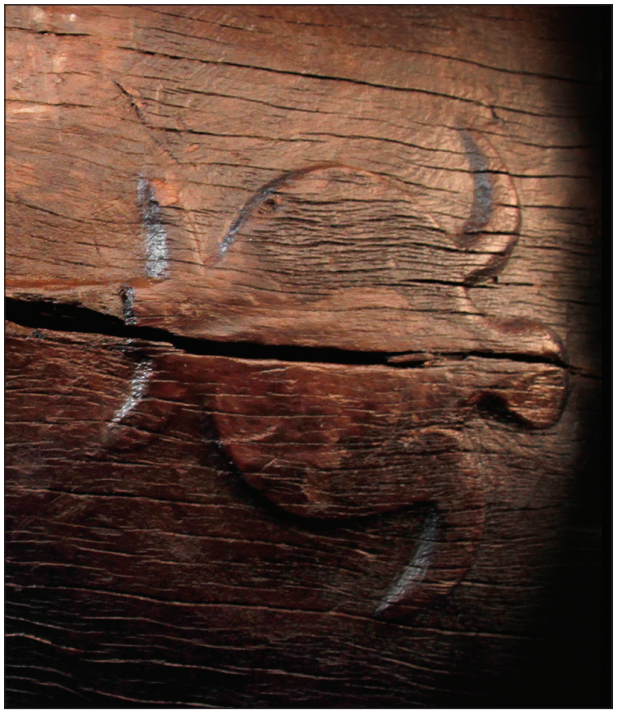


Figure 3. An image of the sea turtle carved near the waterline at the rear of the canoe, facing forward. Sea turtles were uncommon in Māori carving but of rich historical symbolism in tropical Polynesia.

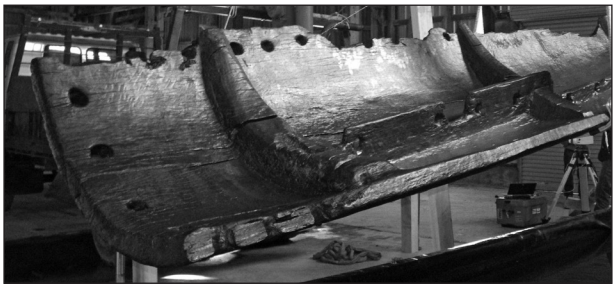
lashings (Figures 4a and 4b). This was a technology involving wooden elements held under compression by lashings under tension, which is also known archaeologically in Māori house construction (Wallace and Irwin 2004).

We used architectural software to digitally reconstruct the whole canoe. The possibilities were constrained (1) by the need for all parts of the complex plank to be orientated simultaneously, (2) for the underbody to be of a feasible form, and (3) for the stringer to be near horizontal for the tension-induced compression of the composite structure to be effective. Our solution is a *waka* hull not less than 1.50 m wide and cross-sections of the orientated plank are shown in Figure 5. The profile of the missing underbody can be estimated by extending the deepest part of the plank down to the keel. The lines of the whole hull are shown in Figure 6 and this solution shows a rounded V-shaped hull profile with a keel angle in the range of 100°–110°.

A reconstruction of the whole canoe with an Oceanic spritsail is shown in Figure 7. We regard it as an early adaptation of East Polynesian canoe technology to New Zealand with a hull of substantial hollowed-out parts and not readily classifiable as either a planked canoe or a dugout. Such a form could have been made from the very large trees that became readily available in New Zealand after settlement.

Table 1. *AMS radiocarbon determinations of canoe (waka) hulls or associated materials. Samples of hull timber were collected from outer tree rings, but the dates contain unknown amounts of inbuilt age (see below).*

Provenance	Waikato Lab. No.	Material	CRA (BP)	δ13C‰	Cal range (68%) AD
Anaweka caulking	Wk 34276	fibre bark totara	605 ± 25	–25.6 ± 0.2	1326–1341 1390–1415
Anaweka caulking	Wk 35545	fibre bark totara	663 ± 25	–25.6 ± 0.2	1313–1357 1380–1392
Anaweka hull	Wk 36538	wood matai	834 ± 25	–25.5 ± 0.1	1226–1266
Doughboy caulking	Wk 37929	fibre bark totara	632 ± 212	–24.6 ± 0.2	1323–1346 1388–1399
Papanui processed fibre	Wk 40628	fibre	456 ± 24		1445–1479
Papanui cordage	Wk 40629	fibre harakeke	440 ± 21		1450–1488
Papanui cordage	Wk 40630	fibre harakeke	463 ± 21		1442–1464
Hutt River hull	Wk 44196	wood totara	491 ± 20		1430–1460
Henley hull	Wk 44686	wood matai	386 ± 24		1480–1512 1549–1560 1572–1623
Waikato delta hull	Wk 42098	wood kauri	258 ± 20		1640–1680 1740–1760 1780–1800
Muriwai hull	Wk 44197	wood kauri	123 ± 20		1710–1720 1810–1860 1880–1930



Figures 4a and 4b. Two views of carved ribs and the stringer. The stringer featured square notches and lashing holes between the ribs. At some early time when the canoe was in use, part of the stringer broke away along the lashing holes and it was repaired with lashing holes cut deeper in the wood and new smaller notches.

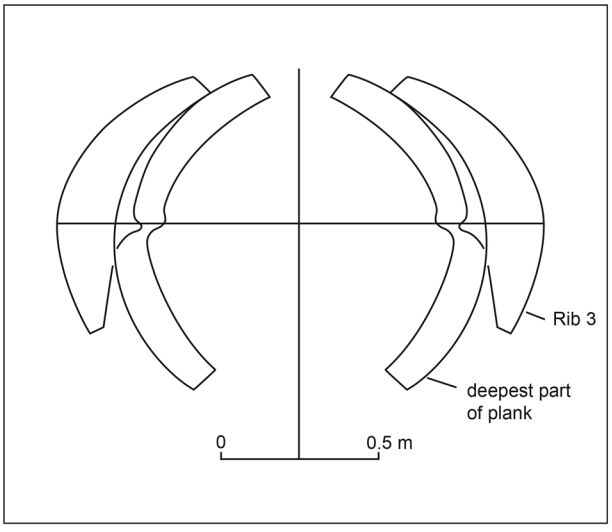


Figure 5. Two cross-sections of a canoe hull 1.50 m wide based on laser scanning. One section is at the deepest point of the plank, from which the under-body can best be reconstructed, and the second section is at Rib 3, which retains the profile of the plank. The tension-induced compression of the structure required the stringer to be near horizontal to be effective. The lower edge of the deeper section has been eroded by rot, but is re-created from the line of the plank.

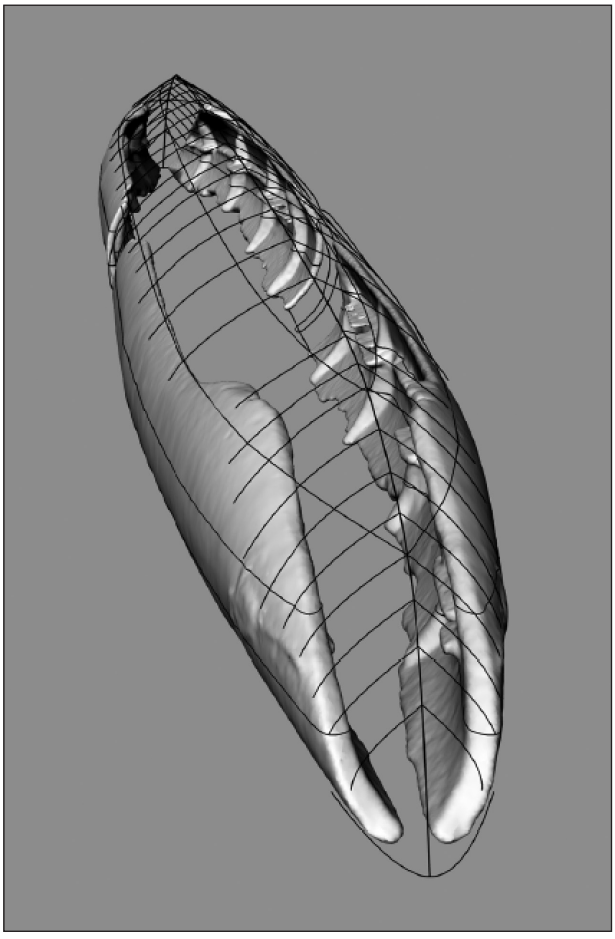


Figure 6. A digital reconstruction of the Anaweka canoe produces an underwater section with a rounded V-shape and a keel angle in the range of 100°–110°.

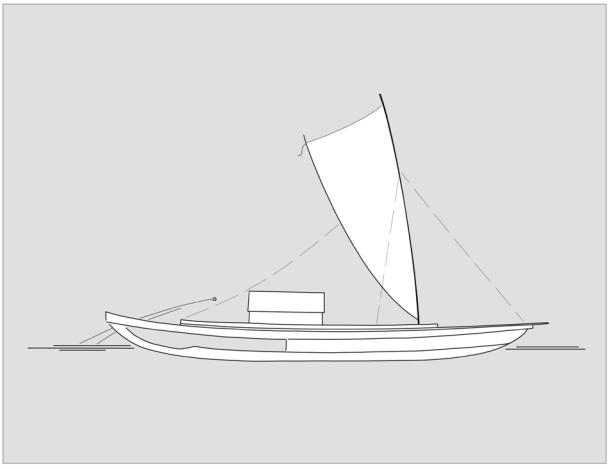


Figure 7. The Anaweka *waka* was a sophisticated canoe capable of ocean and long-distance coastal voyaging. We estimate the length to have been no less than 14.0 m, if the hull was in two sections.

Doughboy Bay

Another find with identical technology to the Anaweka canoe was recovered from Rakiura/Stewart Island in 1997, described initially by Roger Neich, then conserved (Johns 2000), and is now in Southland Museum. It is a broken piece of decking 1.62 m long and 0.62 m wide with lashing holes around the edges and with a butt end joint, like Anaweka (Figure 8). The upper outside surface is smooth and cambered, but underneath it has a transverse rib connected to a longitudinal stringer with lashing holes, like Anaweka. However, unlike Anaweka, the piece is bilaterally symmetrical with the stringer on the centreline, which supports the interpretation of it being a broken piece of decking. There are other similarities with Anaweka which collectively are remarkable. The Doughboy piece is also made of matai (*Prumnopitys taxifolia*) and caulked with totara bark (*Podocarpus totara*) which survived in 4 lashing holes. A radiocarbon date of caulking closely matches those from Anaweka (Table 1), and future analysis of tree rings could show if there is a further match.

Doughboy and Anaweka are uniquely similar in design and it is interesting that the form and size of the Doughboy deck would readily fit as decking on our reconstruction of the Anaweka canoe. It is possible that there were two similarly early canoes of this distinctive design made from the same materials. An alternative explanation is that both pieces were originally parts of the same canoe and became separated by drift after the canoe broke up, somewhere on the West Coast of the South Island. One piece ended up on the northwest coast and the other on the west coast of Rakiura, which is feasible in terms of winds and currents (Routeing Charts of the South Pacific Ocean 2005).

As an intriguing footnote we are informed that another piece was found several years later, also at Doughboy Bay (R. Beck pers. comm.); it was photographed at the time but has since been lost. It was a broken piece of a very similar plank with a pointed end rather than a butt end, and Russell Beck has plausibly suggested the existing Doughboy fragment and the newer discovery were ends of the same piece of decking.

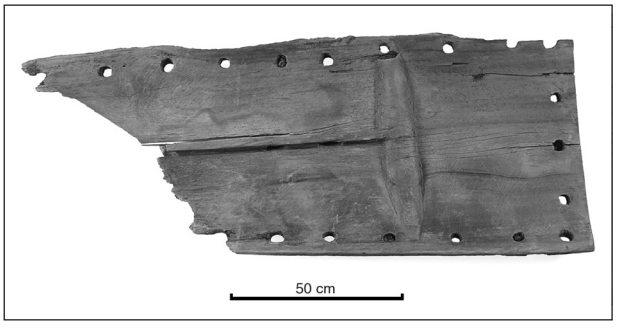


Figure 8. A view of the underside of the Doughboy deck piece from Stewart Island showing the transverse rib, longitudinal stringer with lashing holes, butt end for attachment to another deck section, and with lashing holes around the edges for attachment to the sides of a bilaterally-symmetrical canoe of exactly the kind we have reconstructed for Anaweka.

Several pieces of another canoe were recovered from a nearby archaeological site at Mason Bay (Gillies and Skerrett 1995). The primary find was a prow (or stern) piece, which was also made of matai (*Prumnopitys taxifolia*). It is not directly dated but displays carving of a style probably later than Doughboy. There is no reconstruction of the hull, so this interesting waka is not considered further here.

Waitore Swamp

Another significant piece of canoe decking was recovered during the 1970s excavation of an archaeological site in a stream channel leading from a small swamp to the seashore, between the mouths of the Patea and Whenuakura Rivers in Taranaki. A collection of wooden artefacts was recovered from within peaty clay layers radiocarbon dated to the 15th century, and many of the finds were from a single outrigger canoe of some structural complexity (Cassels 1979). The deck piece is famous because the decoration relates stylistically to a period of transition between early New Zealand East Polynesian to Classic Māori art forms (Cassels 1979).

For our purposes we note that the piece is bilaterally symmetrical like Doughboy and, significantly, there was also an outrigger float 2.21 m long (only part of its original length) and 16 cm wide, with holes for attachment to a cross beam that connected it to the *waka*. The deck acted as a cover for the bow or stern of a canoe and the outrigger provided stability when under sail, and together they tell us that Waitore was a sea-going canoe. It is interesting to note the widespread occurrence of pre-European outriggers elsewhere (Figure 1) at Te Horo (Adkin 1962), Monck's Cave (Skinner 1924), Papanui Inlet (below) and Foveaux Strait (Williams and Gillies n.d.).

Papanui Inlet

The substantial remains of a *waka* were excavated from an archaeological site in the Papanui Inlet of the Otago Peninsula (Johns *et al.* n.d.). The wood is totara (*Podocarpus totara*) and two associated pieces of flax cordage (*Phormium tenax*) and one hank of processed but unidentified fibre (Wallace 2015) have been radiocarbon dated to the mid-to-late 15th century (Table 1). Both sides of the hull have broken away and neither of the ends survive, so the original dimensions are unknown; however, the remaining piece is 6.33 m long and around 0.65 m wide. Clearly, it was the main body of a substantial dugout hull but it is uncertain whether the hull was carved in a single piece with integral ends, or in long sections with butt joints like

Anaweka, or whether it had shorter detachable ends (*haumi*) as found at the late lake village of Kohika (Irwin 2004) and known ethnographically (Best 1925).

One distinctive feature is a longitudinal ledge or step inside the hull running the full length of one side with a flat adzed surface approximately 4 cm wide (Figure 9). A remnant of a matching ledge survives on the other side of the hull which has broken away indicating the hull was bilaterally symmetrical. These ledges could be an unusual feature which relates to the early age of the canoe. They added longitudinal stiffness to the hull in the manner of a stringer or girder and also provided strength to allow the hull to be carved thinner and lighter above and below. The ledges could also have supported internal flooring, but there is no line of lashing holes to secure fittings, so this remains uncertain.

Figure 9. The broken end of the Papanui *waka* showing the ledge or girder on the right hand side of the image.

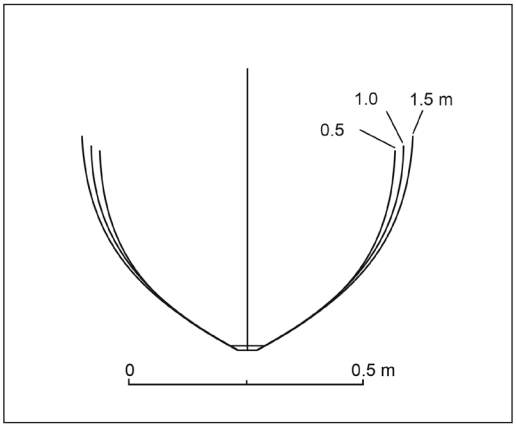


Figure 10. Cross sections of the Papanui *waka* derived from laser scanning taken at 0.5 m, 1.0 m and 1.5 m from the wider broken end.

The *waka* has been laser scanned and the derived cross-sections in Figure 10 show a moderately V-shaped hull with a narrow flat facet along the keel line (Figure 11), which would be useful when the canoe was landing. There is also a suggestion of a soft shoulder, representing a slight change of angle in the upper sides of the surviving hull. It is very likely that the freeboard of the hull was originally raised by planks or strakes but no finished edges or lashing holes survive.

It is of interest that part of a well-defined outrigger has been found in the same Papanui site, although not in stratigraphic association with the canoe, but it does indicate that a sailing canoe was present. Papanui Inlet is a sheltered location with good access to the sea, and the remains of this *waka* suggest a robust sailing canoe used for coastal transport. Some other fittings continue to come from the site and suggest the canoe was of a sophisticated form (Johns *et al.* n.d.).

Hutt River

One end of a large canoe came from a find spot in sediments four metres deep in a braided section of the Hutt River. It is made of totara wood (*Podocarpus totara*). A C14 date of the timber (Wk 44196) gives an age of 491±20 BP and a date range of calAD 1420–1460 at 95% probability (Table 1). We tentatively estimate the actual age of the canoe as falling into the interval between the canoes dated to the 15th century (above) and those from Kohika dated to the late 17th century (Irwin 2004). The calculation takes as

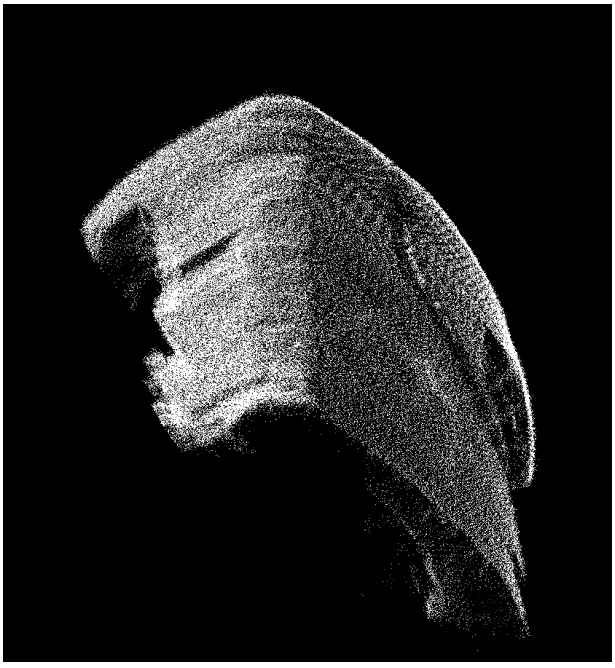


Figure 11. A scan of the narrower broken end of the Papanui *waka* showing a flat facet along the keel line.

a rough guide the difference between the inbuilt age of the timber and the age of the caulking of the Anaweka *waka*.

The piece comprises the dugout end section of a large canoe - probably the bow (Figures 12 and 13). It measures 3.47 m long and is no less than 1.35 m wide, and the main body of the canoe could have been slightly wider. A large part of one side has broken away from the butt end leaving only a small section of intact hull near the pointed end. Clearly it was part of a very substantial canoe and its low profile would certainly have needed to be raised with planking. The piece is more likely to be a rough-out under construction than a damaged piece under renovation because there are no lashing holes at the butt end for attachment to the main hull, and it lacks a finished edge for the attachment of planks. In addition, the very front of the hull appears to be unfinished rather than damaged and missing.

The canoe is bilaterally symmetrical and five scanned cross-sections of the hull are shown in Figure 14. There is a clearly-defined chine (abrupt change of angle) near the bow, which runs into a softer chine towards the butt end.

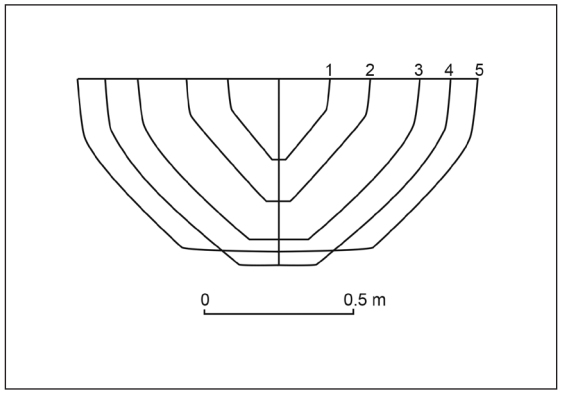


Figure 14. Transverse sections of the Hutt River bow at profiles 1–5 shown with the hull right-way-up. On the damaged side the 3rd, 4th and 5th profiles are incomplete because of the missing section; the 1st profile is missing its upper edge, and the 2nd profile from the front is the only complete one. The depth of the hull underbody is 0.65 m at profile 4, but the main body of the hull would have been deeper and the canoe would have needed more freeboard with the addition of side strakes.

Figure 12. The Hutt River bow section viewed upside-down from the butt end. The right-hand-side of the hull in the image (which would be the port or left-hand-side of the canoe right-way-up) has broken away for much of its length, so the butt end of the canoe is incomplete.

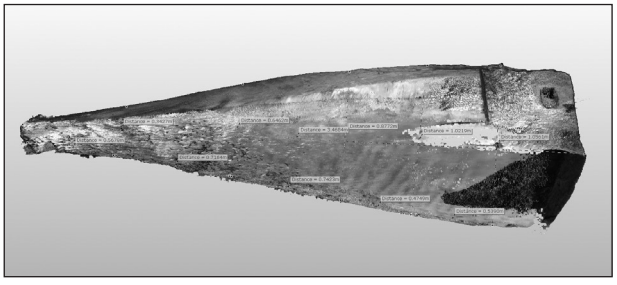


Figure 13. A laser scan of the Hutt River *waka* showing the flat facet along the keel line and a reduced step at the butt end.

Along the keel line a flat horizontal surface or facet begins at a point near the bow and widens evenly towards the butt end. The sides of the hull from the flattened keel line are generally V-shaped in profile.

The back end of the bow section is unusual, and possibly transitional. It is flat across the back like a butt joint, but there is a wide and distinct step in the keel line (Figure 12). If the timber in the step had been completely removed it would have created a typical mortice and tenon joint as found at Kohika and known ethnographically. Instead, there was a different arrangement, very possibly with an extension of the main hull section (acting as a tenon) fitting into the step in the bow section. More of the canoe would be needed to tell.

On the centreline of the step is a square hole 10 cm wide (Figure 12) with traces of bore holes in the corners. The hole would have been covered from below in the complete canoe, and it is located in a very likely place for a mast-step - on the centreline as viewed from inside and outside the hull. If the hole was for a mast there could have been a hole into the timber of the main hull below, in which case the mast would have functioned as a peg through the joint as well. This mast would have been further forward than depicted in early historic drawings of canoes, but rigs of this kind can sail satisfactorily, and the mast step would not be unusually far forward for a canoe with two sails.

Our interpretation is that the Hutt River *waka* was a large and powerful coastal sailing canoe, in the making, but for some reason unfinished.

Paekakariki and Kohika

A *waka* from a find spot on a west coast beach near Paekakariki is a large detachable end-piece (*haumi*), probably a bow, with lashing holes along its edges for the attachment of strakes and a carved prow (*tauihu*), and it has a conventional late mortice and tenon joint (Figures 15 and 16). It measures 1.90 m long and 0.75 m wide. The piece has been scanned and has a V-shaped underwater profile. We would not expect the V-profile to have continued into the main body of the hull on the basis of several similar *waka* end-pieces found at the archaeological site of Kohika, along with many other hull parts plus fittings, balers, paddles, a steering paddle, cordage and plaited matting that could be sailcloth. Currently the Paekakariki *waka* is undated, but we would expect it to be similar in age to Kohika, which is late 17th century AD.

Waikato River Delta

This large kauri (*Agathis australis*) *waka* was from another find spot in the delta of the Waikato River. It is missing its gunwales, but part of one end survives indicating the canoe was carved from a tree in one piece. The surviving piece measures 5.40 m long and 0.68 m wide. The hull wall is thin for its overall size, so the canoe would have been light and easily driven. The underwater section presents a rounder profile than earlier canoes in the sample which added buoyancy and load-carrying capacity, but reduced the ability to sail across the wind (see below). We are tempted to interpret it as a large river canoe. As such, it would usually have been paddled, but could have carried a small sail when travelling along stretches of the river with the wind behind. A radiocarbon date on the timber suggests a late pre-European age for the *waka* (Table 1).

During early decades of Auckland's European settlement much of its food was grown by Māori, carried down the Waikato River, across the portage to the Manukau Harbour and thence to the early Port of Onehunga. The recent archaeological discovery of extensive Māori kumara horticulture along the river around Horotiu, north of Hamilton by Gumbley and Hoffmann (2013) suggests a pre-European antecedent, with which the Waikato River *waka* could have been associated.

Figure15. The Paekakariki bow piece with lashing holes around the edges for the attachment of strakes and a prow, and with a mortice and tenon joint for attachment to the main hull.

Figure 16. An end-on view of the Paekakariki *waka*

Henley

The Henley canoe was a small one-piece *waka* found around 1895 in the Taieri Plain south of Dunedin. It was carved from matai (*Prumnopitys taxifolia*), and caulking material extracted from lashing holes was initially thought to be raupo and grass (Best 1925: 44), but this early identification is unreliable. It has a deep and narrow hull 6.95 m long and 0.50 m deep. The scanned cross-section in Figure 17 shows a sharp V-bottom with a flat facet 5 cm wide along the keel line, similar to the keel line of the Papanui *waka*. The hull is approximately 0.50 m wide at sharply-defined chines, and above these the sides slope in to a narrow opening at the gunwale. This canoe was not properly conserved and, if it has been distorted in shape (Best 1976: 42), it could have been above the chine. This narrow canoe would have been unstable in the water and it is no surprise that there are holes in the gunwale suitable for

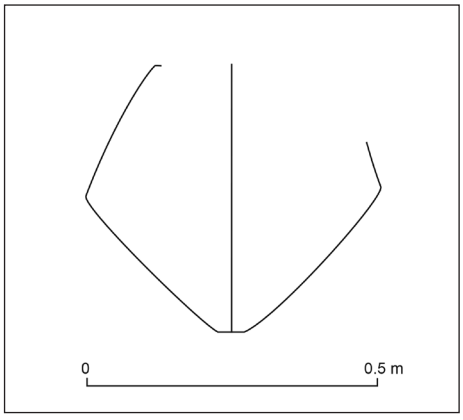


Figure 17. The hull profile of the Henley *waka* in mid-section showing a V-shaped hull with chines (abrupt changes of angle in the hull profile), and inward-sloping sides above the chines.

attaching an outrigger. With its deep-V hull it is likely to have been sailed. A radiocarbon date on the timber of the canoe suggests it is late but pre-European (Table 1).

Muriwai

This canoe was from a find spot at the side of a stream flowing into the sea (Brassey 2010). It is similar in several ways to Henley and has a one-piece dugout hull with integral ends. It now measures 6.95 m long and 0.62 m wide, but would have been a metre or two longer when intact. It was made from kauri (*Agathis australis*) which only grew north of the Bay of Plenty. A radiocarbon date shows the wood to be recent or modern (Table 1), but we believe the canoe to be traditional if not pre-European. The hull has been laser scanned and its lines are shown in Figure 18. It has a fine V-shaped underwater profile with definite chines, and approximately vertical sides above the chines. The top edges of the hull are missing, and added planks were likely. Inside the hull on the centreline there is a raised rectangular socket in an area of thicker timber which gave strength to support a mast and sail (Figure 19). A mast-step in the bottom of a hull implies an outrigger canoe, because in a double canoe the mast can be stepped on beams between the hulls. Outrigger canoes, (*waka ama*) were extremely rare by the time of European arrival in New Zealand (Best 1976). Thus, we interpret the Muriwai find as a late, sophisticated and lightly-built sailing canoe, ideal for coastal travel in moderate weather.

Mokomoko Inlet

Two broken pieces of a *waka* found on different occasions in Mokomoko Inlet, Foveaux Strait were later fitted together. The find is a section of canoe 3.80 m long and 0.38 m wide made of rimu (*Dacrydium cupressinum*). This find

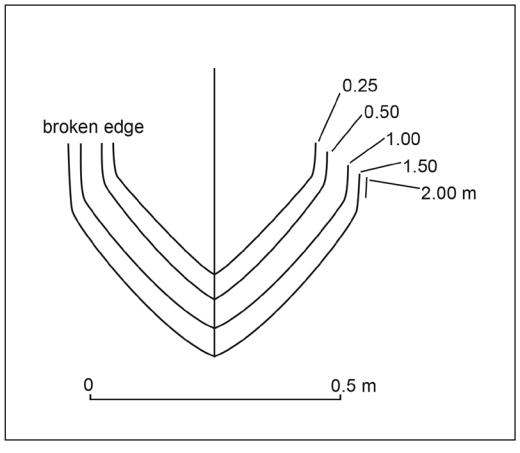


Figure 18. Cross sections of the scanned Muriwai *waka* at measured distances from the broken end of the hull (0.25 m, 0.50 m, 1.00 m, 1.50 m and 2.00 m).

Figure 19. A square mast step was carved into an area of thicker timber in the interior base of the Muriwai *waka*.

came from one side of a canoe that was probably unfinished. Part of the outside was finished, but the inside of the hull is only roughed out. What is clear is that it was part of a dugout underbody with an edge for attachment of a plank and with lashing holes at one end. What is more significant is that the hull has a chine like the Henley and Muriwai canoes and a V-shaped profile. The find is undated.

DISCUSSION AND CONCLUSIONS

The sample of archaeological canoe remains reveals considerable diversity of form but it is inadequately dated and too small to establish a typology. However, we can note some trends of change in canoe construction and design which would influence sailing performance, and we relate these to the wider context of New Zealand archaeology.

Diversity and change in canoe construction and design

Firstly, with regard to wood, there are four species in the sample. The oldest canoe parts Anaweka and Doughboy plus two younger canoes, Henley and Mason Bay, were

all made of matai (*Prumnopitys taxifolia*), and found in the south. The Mokomoko *waka*, also from the south, was made of rimu (*Dacrydium cupressinum*). Matai is reputed to become waterlogged and heavy and was perhaps not an ideal choice for underwater parts, so the use of this wood could suggest canoes were routinely stored out of the water in New Zealand as they were elsewhere in the Pacific. Other canoes were of more suitable straight-grained totara (*Podocarpus totara*). In the north, both the Waikato and Muriwai canoes were built of lighter kauri (*Agathis australis*), which only grew north of the Bay of Plenty.

In terms of size, we estimate no sailing canoe in the sample as much longer than 15 m and none much shorter than 10 m, but there were great differences in displacement and cargo capacity and, consequently, in sea-keeping ability and range. With regard to construction the sample is too small to establish a pattern except that the early Anaweka *waka* was the only canoe built in long sections with integral ends. Two small canoes (Henley and Muriwai) and one large one (Waikato) were carved in single pieces, and several others had hulls with detachable ends.

In terms of archaeological dating, the canoes of the 14th and 15th centuries are securely dated (Anaweka, Doughboy, Waitore and Papanui). However, of the later ones, only the Kohika site is well dated - to the late 17th century. Four *waka* are dated only from their timber (Hutt River, Henley, Waikato and Muriwai) and, while care was taken to sample outer tree rings, there is an unknown amount of inbuilt age. Of those dated by timber, only the Hutt River canoe can be ascribed to the 16th or 17th centuries (pre-Kohika). However, for the other three the situation is compounded by the vagaries of the radiocarbon calibration curve, and all that can be said is that they are generally late and probably pre-European, except possibly Muriwai which is certainly traditional.

In terms of design and age, the oldest canoes tell us something of the voyaging technology introduced to New Zealand, and of experiments with new materials. Thus, in the 14th century, Anaweka and Doughboy had ribs and a stringer, plus decking, and the hull was built in large sections with butt ends. Interestingly, it shared aspects of technology with planks from the Fa'ahia site on Huahine (Sinoto 1979) and in some ways was the equivalent of a planked canoe of the tropics but built of larger New Zealand timbers. The carved sea turtle that accompanied it at sea invoked the rich symbolism of Polynesia.

New Zealand soon became isolated in East Polynesia, but there was widespread early transport of industrial stone around the country. The 15th century *waka* found in Papanui Inlet was well suited to coastal sailing, and perhaps for bringing North Island obsidian to early sites on the Otago coast nearby (McCoy and Robles 2016). At much the same time on the Taranaki coast Waitore was a sophisticated outrigger sailing canoe with a deck decoration illuminating a transformation in indigenous art (Cassels 1979).

By around AD 1500 the scale of interaction around the New Zealand coast had changed as seen in contracting distributions of significant rock types for flaked adzes including basalt from Tahanga and argillite from Nelson and the southern South Island, although trade in *pounamu* (nephrite) was later to increase (Turner 2000, Walter *et al*. 2010). Canoe design operated in a context of changing patterns of mobility. If the Hutt River canoe can be attributed to the 16th or early 17th century, it had a mast step, and detachable ends that were neither early butt joints nor later mortice and tenon ones, but ones possibly transitional between. By the late 17th century Kohika canoes were similar to ethnographic dugouts with detachable ends, mortice and tenon joints, and more rounded hull sections (Irwin 2004) and Paekakariki was likely the same. It is interesting that Haddon and Hornell (1997) long ago correctly hypothesised on the basis of comparative ethnology that mortise and tenon became more common in New Zealand. The Waikato River Delta *waka* is late and large, and has a light and rounded hull suitable for rivers. However, in contrast, Henley was a probably a small outrigger sailing canoe with a V-shaped hull with chines and Muriwai, which had a mast-step, is similar.

A change in sailing performance

Diversity and change in canoe forms involved differences in sailing performance. There is an established science of sailing (Garrett 1996) and a range of Polynesian hulls and sails have been tested in the Yacht Research Unit at the University of Auckland (Irwin and Flay 2015).

The capacity of canoes to sail across the wind, as well as simply run before it, affected the routes and choices available to sailors, and we conclude that sailing performance changed together with patterns of connectivity on the New Zealand coast. By the time of Cook the major shift from multihulls to monohulls involved a fundamental change in sailing practice. Polynesian canoe hulls were long and narrow with no keels, and stability was provided by outriggers (or a second hull) which provide a *righting moment* that offsets a *rolling* or *overturning moment* generated by the sail. Roll stability is fundamental because it allows a canoe to sail with the wind coming from the side without capsizing (Irwin 2006). But most of the canoes seen by Cook's expedition in 1769 were single ones and Joseph Banks reported that '…we very seldom see them make use of Sails, and indeed never unless they were to go right before the wind' (Morell 1958:139).

We notice that some archaeological canoes had more V-shaped underwater hull profiles than those described ethnographically by Best (1976:43) which were more U-shaped. Towing tank tests by Flay (2013) and computational fluid dynamics (CFD) by Boeck *et al*. (2012) compared three hulls with U-shaped or V-shaped keel angles (U-1, V-1 and V-2). V-shaped hulls generated more hydrodynamic lift (a side force to windward) than U-shaped ones

and could sail at higher angles across the wind (Irwin and Flay 2015). In the archaeological sample the tendency was for earlier canoes to be more V-shaped than later ones, but there were two exceptions. If the dates on hull timber are confirmed (Table 1), both Muriwai and Henley canoes had deep-V hulls in late pre-European times. Both also had outriggers and hulls with chines (Figures 17 and 18). There may have been an innovative development of chines in New Zealand where large trees allowed the construction of strong and rigid one-piece hulls. Below the chines such hulls generated hydrodynamic lift, and the width of the hull at the chine created buoyancy for the canoe under sail.

The Oceanic spritsail was widespread in East Polynesia including New Zealand when Europeans first arrived (Irwin and Flay 2015), which indicates shared ancestry among sails which later varied in isolation among the islands of marginal East Polynesia. These sails were suited to *reaching* across the wind and *running* with the wind. Typically they had a V-shape with two spars, one stepped on the canoe like a mast, and a trailing spar attached to the bottom of the leading one, trimmed as the canoe sailed at different angles. However, Anderson has suggested that a 1769 drawing of a Māori double canoe by Spöring, has the two spars attached separately to the canoe, unlike an Oceanic spritsail, and that could have been the normal type (Anderson *et al.* 2014, Anderson and Boon 2011).

A model of the Māori sail held by the British Museum (Oc, NZ. 147), believed to have been collected by Cook (Irwin and Flay 2015), has been tested in a wind tunnel. It was compared when set up as a conventional Oceanic spritsail with one mast with a trailing second spar, and as set up as a double-mast sail as in Anderson and Boon (2011, Figure 3). The driving force was found to be similar for both sails through the range of sailing wind angles, (as measured by the driving force coefficient, *Cdf* as a function of the apparent wind angle, *AWA*). Actually, because the two spars came together quite closely at the base, the sail shapes were not very different, even though they were set up differently as "single" and "double." However, the overturning moment was greater for the double-mast sail, (as measured by the rolling moment coefficient, *Crm* as a function of the *AWA*). The result suggested that there was more loading higher up the sail in the double-mast case and, certainly, it was harder to trim as both masts could move around more independently. We conclude that the Māori sail was generally set as an Oceanic spritsail in pre-European times, like sails elsewhere in East Polynesia, because it was easier to manage and less prone to capsize.

Canoes in the changing context of New Zealand archaeology

The first canoe-builders in New Zealand encountered and adjusted to a new environment. In the archaeological sample only the Anaweka *waka* stands out as a truly ocean-going canoe. New Zealand became isolated within East Polynesia, but there was widespread early settlement and continuing communication, and there were capable sailing canoes on the New Zealand coast. Through time the technology continued to change, perhaps with the contraction of interaction spheres and in the range of coastal passage making. Riverine activity increased with the expansion of horticulture and settlement in the interior North Island. Other general changes included population increase, the formation of social groups of larger scale and increasing competition between them. New Zealand is just one of several Pacific cases where emerging competitive polities used canoes for warfare.

It is possible on present evidence that small-to-medium sized outrigger sailing canoes like Henley and Muriwai, persisted into late pre-European times in both the south and the north of the country, and could sail efficiently and well in moderate weather. But we see a more general decline in the sailing performance of other canoes with a shift from multihulls to monohulls, a loss of roll stability, more paddling and downwind sailing. The archaeological canoes suggest a change in hull form involving a reduction in hydrodynamic lift required for sailing at higher wind angles. The large and elaborate *waka taua* (war canoes) so conspicuous in the late 18th and early 19th centuries, sometimes seen sailing downwind, were fabulous canoes in their own right, but they were remote from the sailing technology of early New Zealand settlement and operated in a different social context.

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