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Mid-Holocene Aboriginal Occupation of Offshore Islands in Northern Australia? A Reassessment of Wurdukanhan, Mornington Island, Southern Gulf of Carpentaria, Australia

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Abstract

Claims for mid-Holocene Aboriginal occupation at the shell matrix site of Wurdukanhan, Mornington Island, Gulf of Carpentaria, Australia, are reassessed through an analysis of the excavated assemblage coupled with new surveys and an extensive dating program. Memmott et al. (2006, pp. 38, 39) reported basal ages of c.5000-5500 years from Wurdukanhan as ‘the oldest date yet obtained for any archaeological site on the coast of the southern Gulf of Carpentaria’ and used these dates to argue for ‘a relatively lengthy occupation since at least the mid-Holocene’. If substantiated, with the exception of western Torres Strait, these claims make Mornington Island the only offshore island used across northern Australia in the mid-Holocene where it is conventionally thought that Aboriginal people only (re)colonised islands after sea-level maximum was achieved after the mid-Holocene. Our analysis of Wurdukanhan demonstrate high shellfish taxa diversity, high rates of natural shell predation and high densities of foraminifera throughout the deposit demonstrating a natural origin for the assemblage. Results are considered in the context of other dated shell matrix sites in the area and a geomorphological model for landscape development of the Sandalwood River catchment.

1. Introduction

For several decades the nature and antiquity of settlement and use of Australian offshore islands has been a focus of archaeological research (Figure 1) (e.g. Barker, 2004; Bowdler, 1995; McNiven et al., 2014; O'Connor, 1992; Rosendahl et al., 2014a; Rowland, 1987, 1989, 2002, 2008; Sim and Wallis, 2008; Veth et al., 2007). Studies have focused on questions concerning the nature and timing of use of islands, such as when were islands first used and/or permanently occupied? Why did people start using them? How did people travel to them? Why (and when) were some abandoned? Yet, despite numerous hypotheses developed from the available archaeological record, 'a convincing holistic explanation has yet to be achieved' (Rowland, 2008, p. 89).

As research into island use has expanded, several attempts have been made to explain regional variation in island use at a continental scale (Bowdler, 1995; O'Connor, 1992). Islands situated along the temperate southeast coast of Australia exhibit strong evidence for seasonal occupation (McNiven, 2000; Sullivan, 1982; Vanderwal, 1978), whereas islands in northern Australia have variable signatures in the timing and nature of use throughout the Holocene (Barker, 1991, 2004; David et al., 2004; Sim and Wallis, 2008; Wright, 2011). In the Whitsundays and western Torres Strait there is evidence for use of some islands during the Holocene marine transgression (Barker, 1991; David et al., 2004; Lamb and Barker, 2001; Wright, 2011). Vanderlin Island (Sim and Wallis, 2008) and islands off the northwest Kimberley coast (O'Connor, 1999) exhibit short occupation hiatuses during initial islandisation phases with re-occupation post-marine transgression. Other areas such as the northern, central and eastern Torres Strait and the Keppel Islands show evidence only for a post-marine transgression occupation. Some larger islands exhibit evidence for permanent occupation with a seasonal/episodic pattern of use of smaller satellite islands for focused activities (Border, 1999; McNiven, 2000). While there are numerous explanations offered for the variation in use of tropical and temperate islands, such as land area, resource availability, distance from shore, and technology, their occupation and use needs to be considered in the context of the archaeology of adjacent areas (David et al., 2004).

Sim and Wallis (2008) presented a model for Holocene coastal and island abandonment for the southern Gulf of Carpentaria. They proposed that as sea-levels rose in the early Holocene populations retreated to the elevated mainland strip. Subsequent island occupation attempts failed owing to inclement weather and changing environments. It was not until landscape and sea-level stabilisation and climate amelioration after 2500 years ago that permanent island settlement became possible. This hypothesis was developed using data from Vanderlin Island in the Sir Edward Pellew group and extrapolated across north Australia (Figure 1).

For the Wellesley Islands 250 km to the southeast of the Sir Edward Pellew group, Memmott et al. (2006, p. 38) reported a mid-Holocene shell deposit on Mornington Island:

Samples of oyster shell [*Striostrea mytiloides*] from a small midden at Wurdukanhan on the northwest side of Mornington Island have provided a basal date of 5284 to 5660 calBP. This is the oldest date yet obtained for any archaeological site on the coast of the southern Gulf of Carpentaria.

On the basis of this date, Memmott et al. (2006) proposed permanent occupation of Mornington Island from c.5500 years ago. This finding is not only at odds with the widely accepted timing of initial permanent use of Australian islands (Bowdler 1995) but also with Sim and Wallis's (2008) model for northern Australian island abandonment during initial islandisation.

Despite its key status in debates about island colonisation (e.g. Bowdler, 1995; Sim and Wallis, 2008), no further details about Wurdukanhan have been reported. This paper presents a re-analysis of the excavated assemblage from Wurdukanhan in the context of recent (2007-2010) survey results and topographic mapping.

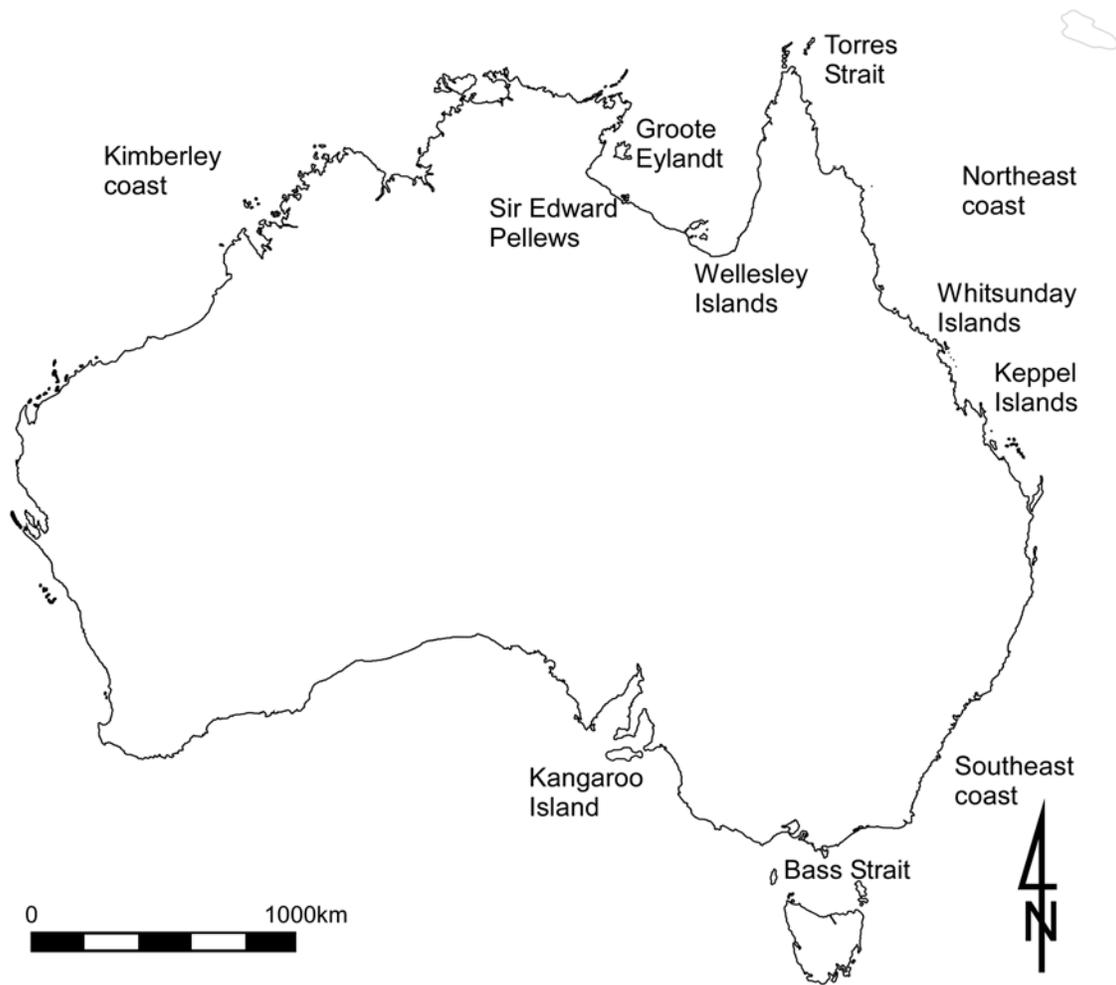


Figure 1. Australia highlighting islands where research has been carried out.

2. Wurdukanhan Site Description and Environment

Wurdukanhan is situated on the northwest Sandalwood River saltpan and takes its name from the Lardil indigenous country within which it is situated and that of the adjacent estuary (Figure 2). It is characterised by a series of shell deposits dominated by articulated black-lipped oyster valves (*Striostrea mytiloides*) interconnected by a compact surface pavement of highly fragmented shell (Figure 3). The site extends some 350 m trending southeast-northwest, from a northern vegetated sand platform across the saltpan to intersect with Wurdukanhan Creek (Figure 4). The most prominent exposure of shell rises c.70 cm above the immediate surrounding saltpan.

Post-depositional disturbance of the deposits is indicated by high fragmentation of surface shell of robust taxa. Vehicular disturbance relates to a 4WD track that truncates the site and bioturbation is evident from crab burrowing (from mud, mangrove and ghost crabs). Being situated only 240 m north of the estuary, Wurdukanhan is completely inundated by seasonal king tides, as witnessed in May 2009 (Figure 5). Other agents of disturbance may include cattle which were briefly grazed on the island during the twentieth century and the movement of other fauna (including kangaroos and pigs) over the area.

With the exception of one mangrove shrub c.50 cm high, vegetation is restricted to the fringing sand ridge platform located c.50 m north of the shell exposures in the form of mangroves up to 3 m in height, swamp ti-trees (*Melaleuca acacioides*) 2-3 m in height, and Guttapercha trees (*Excoecaria parvifolia*) 2-3 m in height. The surrounding hypersaline mudflats feature patches of Pigweed (*Portulaca oleracea*).

3. Excavation

Wurdukanhan was targeted for excavation by one of us (RR) in 1996 on the basis of visual inspection highlighting its discreteness from the surrounding environment, the mono-specific nature of the visible surface shell assemblage, and the apparent size-selection towards larger size classes of the dominant taxa, black-lipped oyster.

A 25 x 25 cm square, Wurdukanhan Pit 1, was excavated to a maximum depth of 32 cm in 10 excavation units (XU) that ranged from <1 cm to c.7 cm thick. Excavation of the upper units was difficult owing to the abundance of large shells and the wet-clayey nature of the sediment matrix. XUs 1-9 were dominated by black-lipped oyster, presumed to be cultural in origin at the time of excavation. The lowest unit, XU10, was characterised by an abundance of shell taxa described in the excavation notes as 'shell hash', analogous to deposition along nearby contemporary beaches. Although a site plan was not drawn during the 1996 investigation, the excavation square was relocated in 2007 using photographs and the presence of a small square depression in one of the smaller shell exposures.

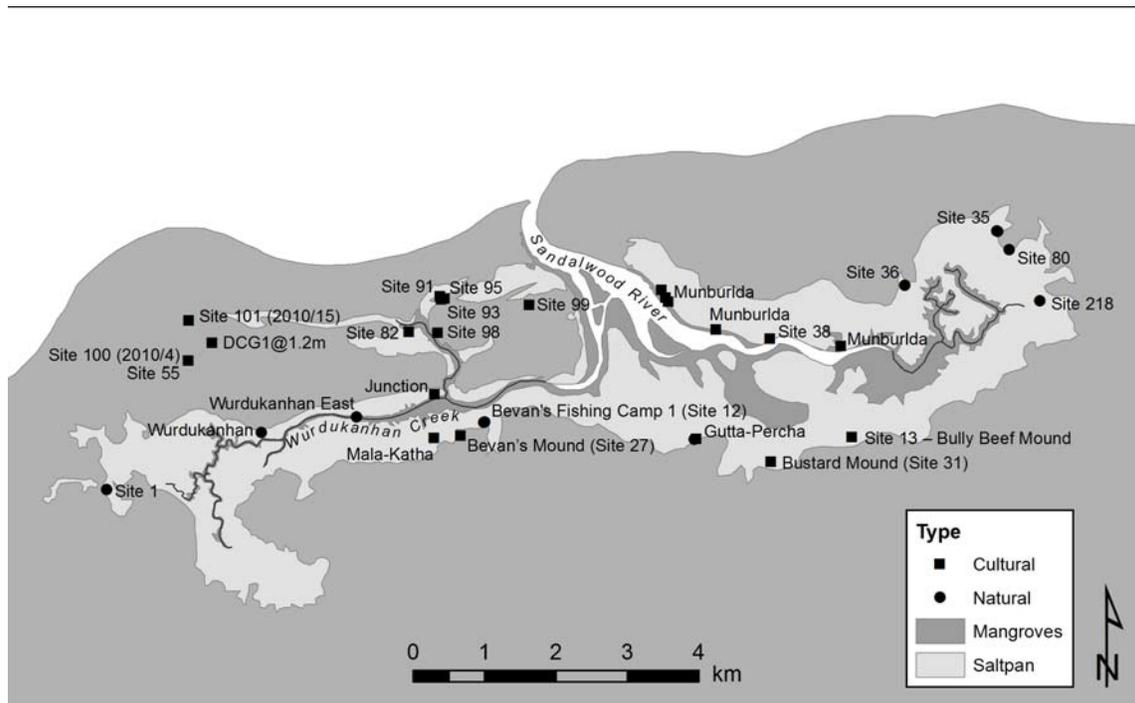


Figure 2. Yiinkan Embayment showing location of Wurdukanhan shell matrix site, dated BLO bioherm clusters and cultural sites. Scale of map does not enable effective illustration of individual exposures.



Figure 3. Fragmented shell pavement interconnecting black-lipped oyster exposures. Small increments on scale = 1cm.

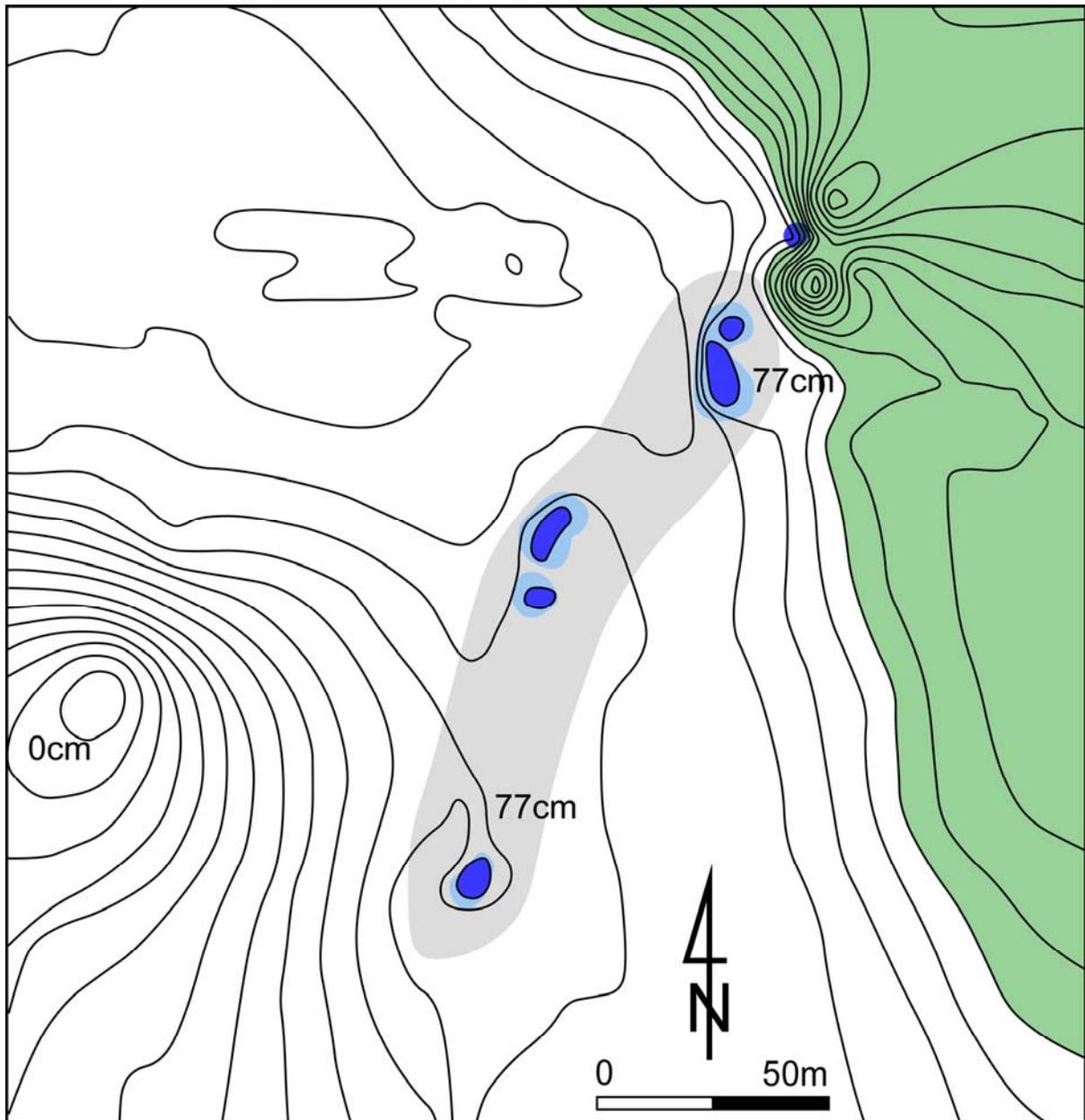


Figure 4. Wurdukanhan site map showing extent of raised shell exposures in blue and shell pavement in grey shading. Area in green denotes the adjacent vegetation zone and sand ridge system. Contours are in 7 cm intervals with topography established from >600 data points (base map drafted by Kelsey Lowe). Elevation is set on an arbitrary benchmark of 0 cm.



Figure 5. Image showing the partial inundation (during a mid-high tide) of Wurdukanhan during seasonal high tide (9 May 2009). The water margin is abutting the southern boundary of each exposure indicating a common elevation for each deposit. Note shell exposures extending east in the background of image

Owing to time constraints, limited information was recorded during the excavation. pH was only recorded for three excavation units (XUs 1, 8 and 10). No sediment samples were retained and while some XUs were weighed, no volumes were recorded for excavated material. No documentation exists for XUs 5 and 6. Wet sieving through 4 mm mesh was undertaken using a garden hose, prior to transport to the Queensland Museum for laboratory analysis and storage.

Two stratigraphic units (SU) were identified using field notes. SUI, comprising XUs 1-9 inclusive, was characterised as a well-consolidated moist clayey/mud dominated by large black-lipped oyster. Based on the mono-specific nature of the assemblage and apparent size selection of *S. mytiloides*, this SU was interpreted as a cultural shell unit. SUII comprised XU10 and was characterised by high shellfish diversity and an abundance of dense fragmented shell within a sandy sediment matrix. These features led Robins to interpret SUII as a natural beach shell assemblage. Robins obtained two radiocarbon ages: XU1 (Beta-100241, CRA 5100±90) and XU9 (Beta-100242, CRA 5180±80) (Table 1), but no other analyses were completed on the assemblage.

Table 1. Radiocarbon dates obtained for Wurdukanhan natural bioherm sites in the Yiinkan Embayment (na = $\delta^{13}\text{C}$ not reported by the laboratory). * = Date may extend out of range (i.e. modern).

Site Name	Site Type	Sample	Weight (g)	Lab. No.	Depth (cm)	$\delta^{13}\text{C}$	CRA	Calibrated Age BP (95.4%)	Calibrated Age BP Median
Bustard Mound	Cultural	<i>Anadara antiquata</i>	44.4	Wk-26683	0	-1.9±0.2	425±35	0*-297	131
Gutta-Percha	Cultural	<i>Anadara antiquata</i>	30.2	Wk-30543	22.5	-1.5±0.2	1959±39	1325-1822	1575
Munburlda – Site 47	Cultural	<i>Anadara antiquata</i>	21.19	OZL-932	0	-0.6±0.1	725±45	146-610	398
Munburlda – Site 83	Cultural	<i>Anadara antiquata</i>	26.64	OZL-934	0	-1.9±0.2	395±35	0*-273	115
Munburlda – Site 50	Cultural	<i>Anadara antiquata</i>	58.37	OZL-933	0	-2.2±0.1	365±30	0*-256	102
Munburlda – Site 43	Cultural	<i>Anadara antiquata</i>	39.55	OZL-931	0	-2.9±0.1	385±40	0*-270	112
Site 100	Cultural	<i>Anadara antiquata</i>	42.3	Wk-30551	0	-1.8±0.2	442±35	0*-317	140
Site 101	Cultural	<i>Anadara antiquata</i>	43	Wk-30549	0	-1.1±0.2	3187±40	2786-3325	3059
Site 55	Cultural	<i>Anadara antiquata</i>	61.5	Wk-30552	0	-1.7±0.2	426±35	0*-298	131
Site 82	Cultural	<i>Anadara antiquata</i>	34.8	Wk-30550	0	-1.3±0.2	2176±38	1556-2096	1826
Site 93	Cultural	<i>Anadara antiquata</i>	58.3	Wk-30545	0	-0.9±0.2	2076±37	1440-1965	1708
Site 95	Cultural	<i>Anadara antiquata</i>	38.1	Wk-30546	0	-2.8±0.2	1950±38	1320-1814	1564
Site 98	Cultural	<i>Anadara antiquata</i>	29.9	Wk-30547	0	-0.8±0.2	2351±40	1789-2310	2039
Site 99	Cultural	<i>Anadara antiquata</i>	92.8	Wk-30548	0	-0.4±0.2	455±35	0*-350	149
Gutta-Percha	Cultural	<i>Anadara antiquata</i>	18.0516	Wk-23122	2.9	-1.5±0.2	2015±38	1376-1885	1638

Site Name	Site Type	Sample	Weight (g)	Lab. No.	Depth (cm)	$\delta^{13}\text{C}$	CRA	Calibrated Age BP (95.4%)	Calibrated Age BP Median
Gutta-Percha	Cultural	<i>Anadara antiquata</i>	10.7938	Wk-23123	46.2	-0.2±0.2	2459±49	1875-2447	2166
Munburlda	Cultural	<i>Anadara antiquata</i>	40.4345	Wk-23127	0.92	-2.3±0.2	1337±34	708-1166	934
Munburlda	Cultural	<i>Anadara antiquata</i>	61.057	Wk-23128	23.1	4.2±0.2	1484±37	867-1299	1086
Site 22 – Junction	Cultural	<i>Anadara antiquata</i>	33.9812	Wk-23129	0	-0.3±0.2	2669±38	2163-2710	2446
Site 38	Cultural	<i>Anadara antiquata</i>	48.1023	Wk-23130	0	-1.3±0.2	1381±37	749-1220	983
Site 91	Cultural	<i>Polymesoda (Geloina) erosa</i>	63.3	Wk-30544	0	-5.3±0.2	516±35	0*-397	193
Bevan's Mound	Cultural	<i>Polymesoda (Geloina) erosa</i>	52.2	Wk-26682	0	-4.2±0.2	415±33	0*-286	125
Mala-Katha	Cultural	<i>Polymesoda (Geloina) erosa</i>	35.041	Wk-23125	4.77	-4±0.2	876±36	315-684	531
Mala-Katha	Cultural	<i>Polymesoda (Geloina) erosa</i>	19.2452	Wk-23126	20	-2.3±0.2	1266±37	653-1084	858
Site 13 – Bully Beef Mound	Cultural	<i>Polymesoda (Geloina) erosa</i>	34.3688	Wk-23131	0	-5.8±0.2	422±35	0*-294	129
Bevan's Fishing Camp 1	Natural	<i>Striostrea (Parastriostrea) mytiloides</i>	316.4	Wk-23135	0	0.4±0.2	5866±45	6093-6611	6337

Site Name	Site Type	Sample	Weight (g)	Lab. No.	Depth (cm)	$\delta^{13}\text{C}$	CRA	Calibrated Age BP (95.4%)	Calibrated Age BP Median
Gutta-Percha	Natural	<i>Striostrea</i> (<i>Parastriostrea</i>) <i>mytiloides</i>	342.4	Wk-23132	0	-0.6±0.2	4426±42	4370-4934	4652
Site 1	Natural	<i>Striostrea</i> (<i>Parastriostrea</i>) <i>mytiloides</i>	416.9	Wk-23134	0	-1.2±0.2	6238±47	6459-7023	6748
Site 1/A	Natural	<i>Striostrea</i> (<i>Parastriostrea</i>) <i>mytiloides</i>	2031.77	Wk-38401	0	-1.5±0.2	6146±37	6385-6900	6636
Site 1/B	Natural	<i>Striostrea</i> (<i>Parastriostrea</i>) <i>mytiloides</i>	741.86	Wk-38407	0	-1±0.2	6246±38	6475-7024	6756
Site 12	Natural	<i>Striostrea</i> (<i>Parastriostrea</i>) <i>mytiloides</i>	547.78	Wk-38404	0	-0.7±0.2	5576±34	5775-6264	6029
Site 218	Natural	<i>Striostrea</i> (<i>Parastriostrea</i>) <i>mytiloides</i>	471.1	Wk-38403	0	-0.9±0.2	6026±32	6276-6737	6503
Site 35	Natural	<i>Striostrea</i> (<i>Parastriostrea</i>) <i>mytiloides</i>	686.35	Wk-38406	0	-1±0.2	5913±41	6167-6641	6384

Site Name	Site Type	Sample	Weight (g)	Lab. No.	Depth (cm)	$\delta^{13}\text{C}$	CRA	Calibrated Age BP (95.4%)	Calibrated Age BP Median
Site 35	Natural	<i>Striostrea (Parastriostrea) mytiloides</i>	557.7	Wk-23136	0	-0.4±0.2	5961±45	6204-6680	6436
Site 36	Natural	<i>Striostrea (Parastriostrea) mytiloides</i>	145.2	Wk-38402	0	-1.7±0.2	4446±30	4402-4941	4674
Site 80	Natural	<i>Striostrea (Parastriostrea) mytiloides</i>	279.5	Wk-38405	0	-0.5±0.2	5899±35	6157-6631	6370
Wurdukanhan	Natural	<i>Striostrea (Parastriostrea) mytiloides</i>	294	Beta-100241	2	na	5100±90	5201-5861	5501
Wurdukanhan	Natural	<i>Striostrea (Parastriostrea) mytiloides</i>	196	Beta-100242	21.75	na	5180±80	5309-5876	5593
Wurdukanhan East	Natural	<i>Striostrea (Parastriostrea) mytiloides</i>	436.6	Wk-23133	0	-0.3±0.2	5142±43	5296-5810	5548
Gutta-Percha	Natural	<i>Tellina</i> sp.	1.1667	Wk-23124	52.8	-0.9±0.2	4124±30	3938-4526	4248

4. Re-Analysis Methods

Analyses were carried out on materials housed in the Queensland Museum (QM scientific collection #S685). Excavated material was re-sieved through 2.3 mm mesh to minimize additional material loss. However, as 4 mm mesh was originally used in the field, much of the <4 mm material will not be accurately represented in this analysis. The range of laboratory analyses that could be undertaken on the excavated assemblage from Wurdukanhan was therefore limited by the nature of the available samples (i.e. no sediment samples were collected). While analysis of the sieve residues (>4 mm) was able to be conducted, analyses of sediments (<4 mm) were restricted to foraminifera analysis, made possible through the recovery of small quantities of residual sediment extracted from individual shellfish. However, as the use of a high pressure hose for wet sieving at the time of the original excavation had removed sediments adhering to the surface of shells, sediment recovery was limited to the internal cavities of gastropods (as per McNiven, 1996).

All shell taxa were identified to the lowest taxonomic level possible based on surviving diagnostic features using reference texts (Abbott and Dance, 1998; Lamprell and Healy, 1998; Lamprell and Whitehead, 1992; Wilson, 2002) and the Tropical Archaeological Research Laboratory (TARL) malacology reference collection developed for this project. All taxonomic listings obtained from reference books were checked using the online WoRMS and Atlas of Living Australia Databases to ensure consistency in nomenclature and to obtain the current senior listing. The relative abundance of shellfish in the deposit was calculated using both weight (to the nearest 0.01 g) and Minimum Number of Individuals (MNI) (based on non-repetitive elements for each taxon). Number of Identified Specimens (NISIP) was not used owing to high levels of fragmentation in the shell assemblage (see Grayson, 1984; Mowat, 1995).

Morphometric analysis was carried out on oyster *Striostrea (Parastriostrea) mytiloides* using digital calipers (to the nearest 0.01 mm) to characterize size distribution in the assemblage. *S. mytiloides* is a elongate-ovate benthic oyster growing to 175 mm on dead corals or mangrove roots (Lamprell and Healy, 1998, p. 136). Two measurements were recorded on whole oyster lids (after Kent, 1992, p. 25) – maximum length, and maximum height perpendicular to the length at the centre point. Surface area was calculated using the formula for an oval [(length x width) x 0.8] (after Kent, 1992)].

Foraminiferal analysis was carried out on sediments from each excavation unit to assess the depositional context of deposits, with the exception of XU10 where no sediments were recovered (see Rosendahl et al., 2007, 2014b). A sub-sample of the <2.3mm sediment sample was wet-sieved with freshwater through nested Endecotts sieves. Each taxon of foraminifera was quantified by establishing minimum number of individuals (MNI). Identification of foraminifera and their habitats was assisted with several reference texts (Albani, 1979; Militante-Matias, 1990; Murray, 1991; Palmieri, 1976; Sen Gupta, 1999) and online World Modern Foraminifera Database.

Detailed pedestrian transect site surveys were conducted across the Sandalwood River embayment that covers 21 km², spanning 14 km east-west and varying in width from a few hundred meters to over 3 km. The survey area was characterized by multiple land units, ranging from parallel beach ridges (some densely vegetated) to hyper-saline saltpans. Dense vegetation cover restricted survey in some areas while 100% of the saltpan was covered due to unimpeded visibility.

Radiocarbon ages for all sites were calibrated using OxCal 4.1.3 (Bronk Ramsey, 2009) and the Marine13 dataset (Reimer et al., 2013), with a ΔR of -49 ± 102 for marine samples (Ulm et al., in press). All calibrated ages are reported at the 95.4% age range (Table 1). Samples were processed at Waikato Radiocarbon Dating Laboratory and Australian Nuclear Science and Technology Organisation identified by the laboratory code prefixes WK and OZL respectively. Radiocarbon ages of *Polymesoda (Geloina) erosa* may appear too young given the unknown terrestrial carbon intake of each individual (see Petchey et al., 2013). The inclusion of these dates (Wk-30544, Wk-26682, Wk-23125, Wk-23126, Wk-23131) does not alter the model and presenting them at the 95.4% age range should capture this uncertainty.

5. Re-Analysis Results

The Wurdukanhan invertebrate assemblage comprised 30 mollusc taxa and several fragments of crustacea (*Scylla* spp.). *Striostrea mytiloides* dominated the assemblage, comprising 94% (13,095 g) of the total shell weight and 81% (n=2003) of shell MNI (Tables 2 and 3). The remaining 29 taxa represent just 6% (776 g) of the total shell assemblage mass. As an indication of the large size of *S. mytiloides*, just four valves make up 14% of the total assemblage weight while an articulated *S. mytiloides* weighing 1051.9 g in XU4 comprises 53% of the XU shell weight. Five fragments of crustacea were recorded in XUs 4, 5, 6 and 8 with a total weight of 3.8 g. The fragments were well-preserved with no evidence of charring.

Morphometric analysis of 379 whole oyster lids was carried out. This analysis demonstrates that while large oysters dominate the assemblage by weight, they only represent a small portion of the total oyster MNI. Overall, with the exception of the four large valves, the oysters in the deposit are small with an average size of 4.3 cm² with 68% (n=261) of the assemblage measuring less than 5 cm² (Figure 7). Less than 2% (n=8) of the measured assemblage is greater than 10 cm² (one each in XUs 1 and 3, two in XU5, and four in XU9).

Articulated *S. mytiloides* valves were recorded in XU4 and XU9, with conjoining pairs identified in XU4 and XU5. A conjoined *Lutraria* sp. was identified in XU9. Species diversity decreases towards the surface, as suggested in Robins' field notes, from > 20 taxa in the lower wave deposited shelly-clastic beach ridge unit in XU9 and XU10 (all fragments are heavily bleached), to fewer than 10 taxa in XUs 1-8 (with high levels of preservation indicated by pigment retention). Pre-depositional natural shellfish predation (boring on oyster valves) was observed throughout the sequence. This predation was evident on 22% (2315.2 g) of the oyster assemblage by weight, indicating these animals were already dead upon deposition/burial. Predation is evident in all XUs except XU1 and XU3, with percentages by weight as follows: XU2 (32%), XU4 (12%), XU5 (35%), XU6 (39%), XU7 (22%), XU8 (18%), XU9 (17%), and XU10 (10%). Vertebrates were represented by a single, well-preserved shark tooth weighing 0.13 g in XU3. Two fragments of non-artefactual stone weighing 2.90 g were recorded in XUs 8 and 9. No artefactual stone was recovered.

A total of 8 g of sediment was extracted from gastropod shells in the sieve residues of XUs 1-9 for foraminiferal analysis. While this is not an ideal sample size for testing archaeological sediments (Rosendahl et al., 2007, p. 1586), 1 g is considered suitable for testing geological sediments or samples to have a known foraminiferal content (Gill et al., 1991).

Wurdukanhan sediments reveal an average foraminiferal density of 4372 per 100 g of sediment, with all XUs exceeding 1000 foraminifera per 100 g (Figure 6). This density is well within the parameters described for a naturally deposited assemblage, viz. >1000 foraminifera per 100 g of sediment (see Rosendahl et al., 2007, 2014b). Five foraminifera taxa were identified, dominated by *Elphidium* sp. and *Ammonia beccarii*, with lower concentrations of *Triloculina* sp. and *Textularia* sp.. These species occur in shallow, intertidal ecosystems (Sen Gupta, 1999). The dominance of *Elphidium* sp. and *A. beccarii* with *Triloculina* sp. indicates the possible presence of sea-grass in the local environment, while *Textularia* sp. is not tolerant to high salinity levels. The overall assemblage is indicative of an estuarine/intertidal zone not that of a supra-tidal zone which would be dominated by *Quinqueloculina seminula* and *Elphidium hughesi* (Wang and Chappell, 2001) or a supra-tidal mudflat that would exhibit an assemblage characteristic of the entire estuarine system (Berkeley et al., 2009).

6. Survey Results

Nine *S. mytiloides* (black-lipped oyster) bioherm clusters, each with several discrete exposures, were documented within the supra-tidal mudflats of the Sandalwood River (Figure 2). They are characterised by extensive pavements of heavily weathered and fragmented *S. mytiloides* with interconnecting mono-specific clusters that exhibit excellent valve preservation and an abundance of articulated valves ranging up to 1.2 kg each. No cultural materials were observed in association with these exposures. Fifteen radiocarbon determinations were obtained from 10 discrete exposures, bracketing the formation of these deposits between c.4500 and 7000 cal BP (Table 1).

7. Discussion

While the Wurdukanhan deposit was initially speculated to be a cultural deposit, consideration of the site utilising multiple analytical proxies presented here, including a broader geomorphic context, clearly defines it as a natural bioherm.

Black-lipped oysters do not grow in the Sandalwood River today. While Lardil Aboriginal people still collect these shellfish from other places, like the Elizabeth River in the northeast of Mornington Island, this may not be *S. mytiloides* as the common-name 'Black-lipped oyster' applies to several species of oyster such as *Saccostrea echinata* and *Pinctada margaritifera*.

The dates obtained on all other *S. mytiloides* (natural) deposits span 4108-6622 years ago (clustering between 5400 and 6600 years ago) during a period when sea-levels were higher than present (up to +2 m) before falling to present levels over the past 2500 years (Reeves et al., 2008; Woodroffe, 2009; Sloss et al., 2011; Lewis et al., 2013). Sea-levels dropped to present levels after 5300 years ago. The position of the dated natural deposits towards the margins of the saltpan is consistent with a growth position for these shell assemblages at a time when these areas were regularly inundated (i.e. they were in the lower intertidal zone). These areas are now hypersaline flats only inundated during king tides, storm surges and wet season rains.

Table 2. Wurdukanhan Pit 1 invertebrate assemblage, showing weight (g).

Family	Genus	Species	Excavation Unit										
			1	2	3	4	5	6	7	8	9	10	Total
Marine Bivalvia													
Arcidae	<i>Anadara</i>	<i>antiquata</i>					0.89	13.3				1.41	15.59
Cardiidae	<i>Lunulicardia</i>	<i>hemicardium</i>							0.8	1.72	6.2	22.7	31.42
	<i>Beguina</i>	<i>semiorbiculata</i>									0.5	4.3	4.8
Corbulidae	<i>Corbula</i>	<i>fortisulcata</i>		0.52	0.08	0.627	2.5	2.7	2.1	7.2	9	24.8	49.52
Isognomonidae	<i>Isognomon</i>	sp.		1.65		0.45	3.26	7.33	13.9	4.53	11.7	25.1	67.91
Lucinidae	<i>Codakia</i>	<i>tigerina</i>									6.3		6.3
Mactridae	<i>Mactra</i>	sp.								0.45	0.7	1.18	2.33
	<i>Spisula</i>	<i>(Notospisula) trigonella</i>									5	7.12	12.12
	<i>Lutraria</i>	sp.			0.84		1.28		6.4	7.9	52.3		68.72
Mytilidae	<i>Brachidontes</i>	<i>maritimus</i>		0.24		0.40	1.8	1.59	2.7	6.5	6.3	25.2	44.73
Ostreidae	<i>Striostrea</i>	<i>mytiloides</i>	1711.3	1096.2	776.8	1984.4	923.5	1523.9	715.3	1486.7	1590.9	1286.1	13095.1
Pteriidae	<i>Pinctada</i>	sp.	0.50		0.85			0.30			0.4	0.3	2.35
Tellinidae	<i>Tellina</i>	<i>staurella</i>			1.72				0.1		2.6	12.8	17.22
Veneridae	<i>Circe</i>	<i>scripta</i>									3.9	1.26	5.16
	<i>Dosinia</i>	<i>scalaris</i>										3.95	3.95

	<i>Dosinia</i>	sp.								1.47			1.47
	<i>Gafrarium</i>	spp.	2.12	3.17	5.39	2.74	8.97	17.1	13.5	51.5	57.2	80	241.69
	<i>Marcia</i>	<i>hiantina</i>		0.54									0.54
	<i>Placamen</i>	<i>placidum</i>									0.2	3.53	3.73
Marine Gastropoda													
Buccinidae	<i>Peristernia</i>	<i>australiensis</i>										0.52	0.52
	<i>Pollia</i>	<i>undosus</i>									1.6	2.98	4.58
Potamididae	<i>Terebralia</i>	spp.							0.1		6.1	2.77	8.97
		<i>sulcata</i>								1.07	8.9	41.1	51.07
Strombidae	<i>Stromb</i>	<i>shell</i>										0.33	0.33
Trochidae	<i>Trochus</i>	sp.		0.1				0.18	0.4	1.38	3	9.3	14.36
Turbinidae	<i>Angaria</i>	<i>delphinus</i>										2.55	2.55
	<i>Turbo</i>	sp.	0.24						0.3	0.56	1.6	8.2	10.9
OTHER													
Echinoidea	Echinarachnius	(sand dollar)										0.67	0.67
Patelloidea	Limpit						0.4					0.25	0.65
Serpulidae	serpulid	(tube worm)					0.60				1.3	0.17	2.07
Crustacea						1.17	0.7	1.69		0.30			3.86

Table 3. Wurdukanhan Pit 1 invertebrate assemblage, showing MNI.

Family	Genus	Species	Excavation Unit										
			1	2	3	4	5	6	7	8	9	10	Total
Marine Bivalvia													
Arcidae	<i>Anadara</i>	<i>antiquata</i>					1	1				1	3
Cardiidae	<i>Lunulicardia</i>	<i>hemicardium</i>							1	1	7	24	33
	<i>Beguina</i>	<i>semiorbiculata</i>									1	5	6
Corbulidae	<i>Corbula</i>	<i>fortisulcata</i>		1	1	1	6	6	5	16	12	35	83
Isognomonidae	<i>Isognomon</i>	sp.		1		2	2	5	2	5	6	6	29
Lucinidae	<i>Codakia</i>	<i>tigerina</i>									1		1
Mactridae	<i>Mactra</i>	sp.								1	2	5	8
	<i>Spisula</i>	<i>(Notospisula) trigonella</i>									6	10	16
	<i>Lutraria</i>	sp.			1		1		1	1	2		6
Mytilidae	<i>Brachidontes</i>	<i>maritimus</i>		1		1	3	5	3	7	7	25	52
Ostreidae	<i>Striostrea</i>	<i>mytiloides</i>	59	138	187	147	171	144	142	256	232	527	2003
Pteriidae	<i>Pinctada</i>	sp.	1		1			1			1	1	5
Tellinidae	<i>Tellina</i>	<i>staurella</i>			3				1		5	12	21
Veneridae	<i>Circe</i>	<i>scripta</i>									6	2	8
	<i>Dosinia</i>	<i>scalaris</i>										6	6
		sp.								4			4

	<i>Gafrarium</i>	spp.	1	1	1	1	1	3	2	6	7	15	38
	<i>Marcia</i>	<i>hiantina</i>		1									1
	<i>Placamen</i>	<i>placidum</i>									1	15	16
Marine Gastropoda													
Buccinidae	<i>Peristernia</i>	<i>australiensis</i>										1	1
	<i>Pollia</i>	<i>undosus</i>									3	5	8
Potamididae	<i>Terebralia</i>	spp.							1		1	1	3
		<i>sulcata</i>								1	8	44	53
Strombidae	<i>Strombus</i>	sp.										2	2
Trochidae	<i>Trochus</i>	sp.		1				1	2	2	9	27	42
Turbinidae	<i>Angaria</i>	<i>delphinus</i>										1	1
	<i>Turbo</i>	sp.	1						1	1	3	17	23
OTHER													
Echinoidea	Echinarachnius	(sand dollar)										1	1
Patelloidea	Limpit						1					1	2
Serpulidae	Serpulid	(marine tube worm)					1				1	1	3
Crustacea						1	1	1		1			4

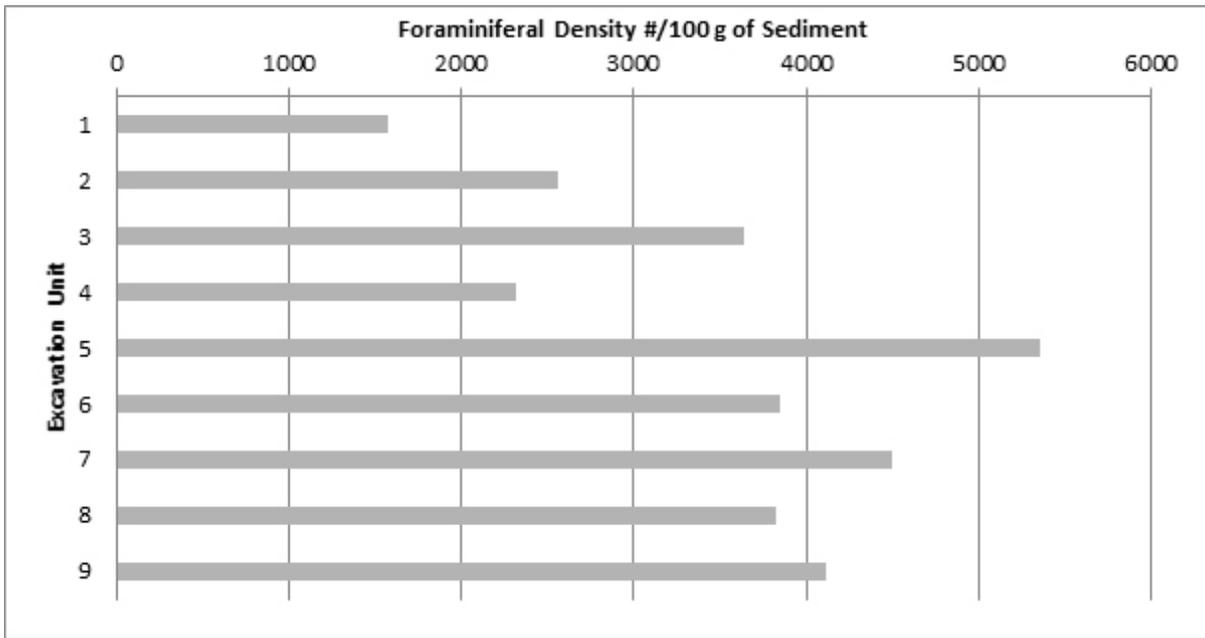


Figure 6. Wurdukanhan foraminiferal density (#/100 g).

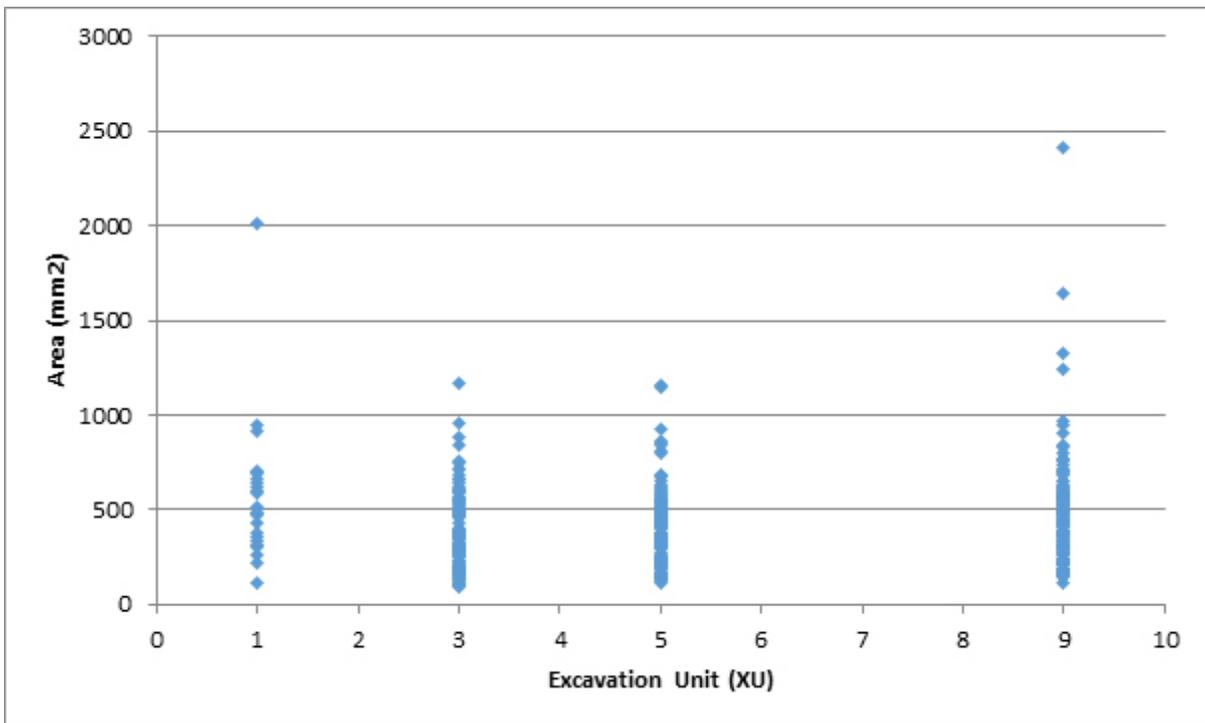


Figure 7. Scatter plot of oyster lid area (mm2) illustrating high proportion <1000 mm2.

The base valves of *S. mytiloides* with alternate attachment scars (mangrove and bedrock) also demonstrate that marine resources and mangrove communities were in place in the embayment c.7000-4500 cal BP (see also Rosendahl et al., 2014a). The chronology of the bioherms likely indicate a period when the embayment became intertidal coupled with coastal progradation, resulting in the stranding of the deposits. The archaeological (cultural) evidence is dominated by shell matrix deposits and is restricted to the mid-to-late Holocene. The earliest definitive date for human activity on the saltflat comes from surface of Site 101 c.3059 years ago, indicating that that base of this mound may be slightly older yet much younger than the proposed occupation at Wurdukanhan of c.5000 years ago (Table 1, Figure 8). Significantly, there is a clear chronological gap (of at least 1000 years) between the natural deposits and the cultural deposits.

The past decade has seen a rise in research in the Gulf of Carpentaria addressing regional gaps in understandings of the antiquity and nature of island use (Sim and Wallis, 2008) and human responses to mid-to-late Holocene patterns of local- and broad-scale climatic and environmental change (Faulkner, 2008, 2009; Hiscock and Faulkner, 2006; Sim and Wallis, 2008). However, as the dataset increases so too does the evidence for continuity of island and landscape use throughout the marine transgression (Barker, 2004; David et al., 2004; O'Connor, 1999; Wright, 2011). While there is evidence for mid-Holocene hiatuses in island use (Sim and Wallis, 2008), the overall patterns of population-environment interaction are becoming more nuanced when interpreted within broad and local-scale environmental change (Ulm, 2013). The pattern in island use fits into the broader-scale trend that is prevalent in the mid-to-late Holocene archaeological record in other mainland and island regions throughout Australia, demonstrating a gradual increase in new sites, resource intensification and increasing-to-permanent use of marginal environments. This pattern has been argued to be a 'risk' minimisation response to increased climatic instability with subsequent increased group mobility following known abundant resources (Hiscock 2008), or alternatively an increase in regional population densities with continued group fissioning and an overall decrease in territory size and increase in site densities (Collard et al., 2011; McNiven, 1999).

The Wellesley Islands dataset does not address the question pertaining to initial island use, however it does address questions on the nature of occupation and the late Holocene pattern of people-environment interactions. The Yiinkan Embayment was an ideal region to address these issues and to test models for human-environment interaction given the potential it provided to construct a secure local chronology of land formation processes and environmental conditions in which to contextualise the archaeological record (Rosendahl et al., 2014a, 2014b). Numerous fixed biological indicators in the form of black-lipped oyster (*S. mytiloides*) bioherms enabled local sea-level and palaeoenvironmental proxies to be studied. The series of parallel transgressive beach ridges, with a secure understanding of regional deposition, further refined the timing of local mid-to-late Holocene landform evolution of the embayment.

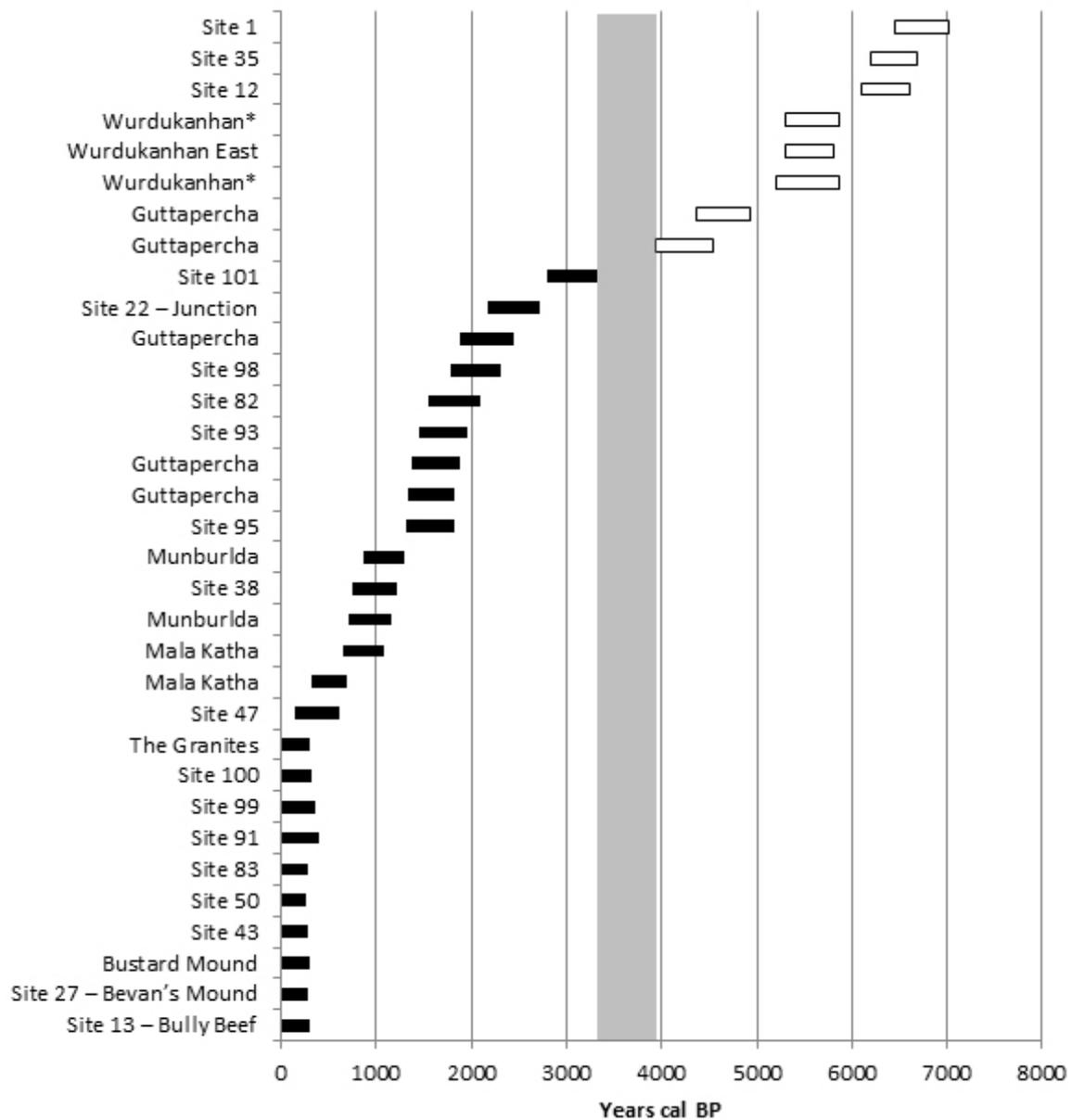


Figure 8. Distribution of radiocarbon dates available for the Yiinkan Embayment: bioherms are shown in white; cultural deposits are shown in black (after Rosendahl et al. 2014a). Grey bar indicates period of landform stabilisation during sea-level stabilisation.

8. Conclusion

We can now conclude firmly that the mid-Holocene dates originally reported for Wurdukanhan are not associated with human activity. Instead the mid-Holocene geomorphological and archaeological record shows that the Sandalwood River area experienced major landscape change associated with sea-level change and sedimentation regimes, reflected in the *in situ* death assemblages of *Striostrea mytiloides* stranded above regular inundation levels. The first archaeological evidence for human use of the area dates to shortly before 3000 years ago. This evidence dispels claims of mid-Holocene island use in the southern Gulf of Carpentaria made by Memmott et al. (2006).

The presence of mangrove habitats and shellfish communities at c.7000 cal BP, inferred from the oyster bioherms, demonstrates that absence of island use during initial islandisation was not a result of resource availability (cf. Beaton 1985). As demonstrated for the Wellesley Islands and other areas of northern Australia, resources established rapidly after initial coastal and/or island formation. Use of Mornington Island falls into patterns observed in other regions, with populations expanding into new areas, intensifying their use of the resource base with localised increases in new site establishment and a signature that demonstrates a complex knowledge of their environment. However, as the land surface investigated is unable to shed light on earlier occupation, further investigation of older land surfaces may alter this understanding.

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