Ross, Anne, and Helene Tomkins, 2011. Changing perspectives in Australian archaeology, part IX. Fishing for data—the value of fine-mesh screening for fish-bone recovery: a case study from Peel Island, Moreton Bay, Queensland. *Technical Reports of the Australian Museum, Online* 23(9): 133–151.

doi:10.3853/j.1835-4211.23.2011.1574

ISSN 1835-4211 (online)

Published online by the Australian Museum, Sydney

Changing Perspectives in Australian Archaeology

edited by

Jim Specht and Robin Torrence

Papers in Honour of Val Attenbrow

Technical Reports of the Australian Museum, Online 23 (2011)

ISSN 1835-4211

nature culture **discover**

Changing Perspectives in Australian Archaeology

edited by

Jim Specht and Robin Torrence

nature culture **discover**

Australian Museum science is freely accessible online at
www.australianmuseum.net.au/journalfinder
6 College Street, Sydney NSW 2010, Australia

Australian museum

Technical Reports of the Australian Museum, Online (2011) No. 23: 133–145. ISSN 1835-4211
doi:10.3853/j.1835-4211.23.2011.1574

Changing Perspectives in Australian Archaeology, Part IX

Fishing for Data—The Value of Fine-mesh Screening for Fish-bone Recovery: A Case Study from Peel Island, Moreton Bay, Queensland

ANNE ROSS[1]* AND HELENE TOMKINS[2]

[1] School of Social Science & School of Geography, Planning and Environmental Management,
University of Queensland, St Lucia Queensland 4072, Australia
annie.ross@uq.edu.au

[2] School of Social Science,
University of Queensland, St Lucia Queensland 4072, Australia
htomkins@gmail.com

ABSTRACT. The age and extent of the Aboriginal fishery in Moreton Bay have been debated ever since excavations revealed low numbers of fish bones in coastal sites in southeast Queensland. Aboriginal people recall fishing as a major subsistence activity, yet archaeological evidence of low rates of fish bone discard have questioned this memory. In an effort to address these contrasting perceptions, excavation of the Lazaret Midden on Peel Island employed a 1 mm mesh sieve to maximize fish bone recovery. Our results suggest that fish remains are indeed numerous in this site, although the extreme fragmentation of the bone recovered from the fine sieve makes identification of fish taxa largely impossible. We discuss the implications of these findings for reconstructing Aboriginal subsistence patterns in Moreton Bay.

ROSS, ANNE, AND HELENE TOMKINS, 2011. Changing perspectives in Australian archaeology, part IX. Fishing for data—the value of fine-mesh screening for fish-bone recovery: a case study from Peel Island, Moreton Bay, Queensland. *Technical Reports of the Australian Museum, Online* 23(9): 133–145.

According to Aboriginal knowledge, people have been living in the region now known as Moreton Bay since the beginning of time (Ross & Coghill, 2000) (Fig. 1). Even at the height of the last glacial, when sea levels were as much as 170 m lower than present levels (Lambeck & Chappell, 2001) and Moreton Bay was an expansive plain, the high dunes that were to become Moreton Island and Stradbroke Island were never far from the sea (Neal & Stock, 1986: 618). Aboriginal knowledge is that occupants of this landscape practised a marine economy, in accordance with traditional Aboriginal law, as provided by the original creator beings (Denis Moreton, senior Gorenpul elder, pers. comm.). Therefore, Aboriginal people believe that the management and exploitation of marine resources, as part of the overall management of the landscape and seascape, has been a significant component of Aboriginal life forever.

Archaeological evidence supports the Aboriginal version of occupation history at a general level. It demonstrates that Aboriginal people have lived in southeast Queensland for at least 20,000 years (Neal & Stock, 1986). Neal argues, on the basis of the excavation results from Wallen Wallen Creek on the west coast of North Stradbroke Island, that marine exploitation was likely to have been the dominant subsistence activity throughout the site's occupation (Neal

* author for correspondence

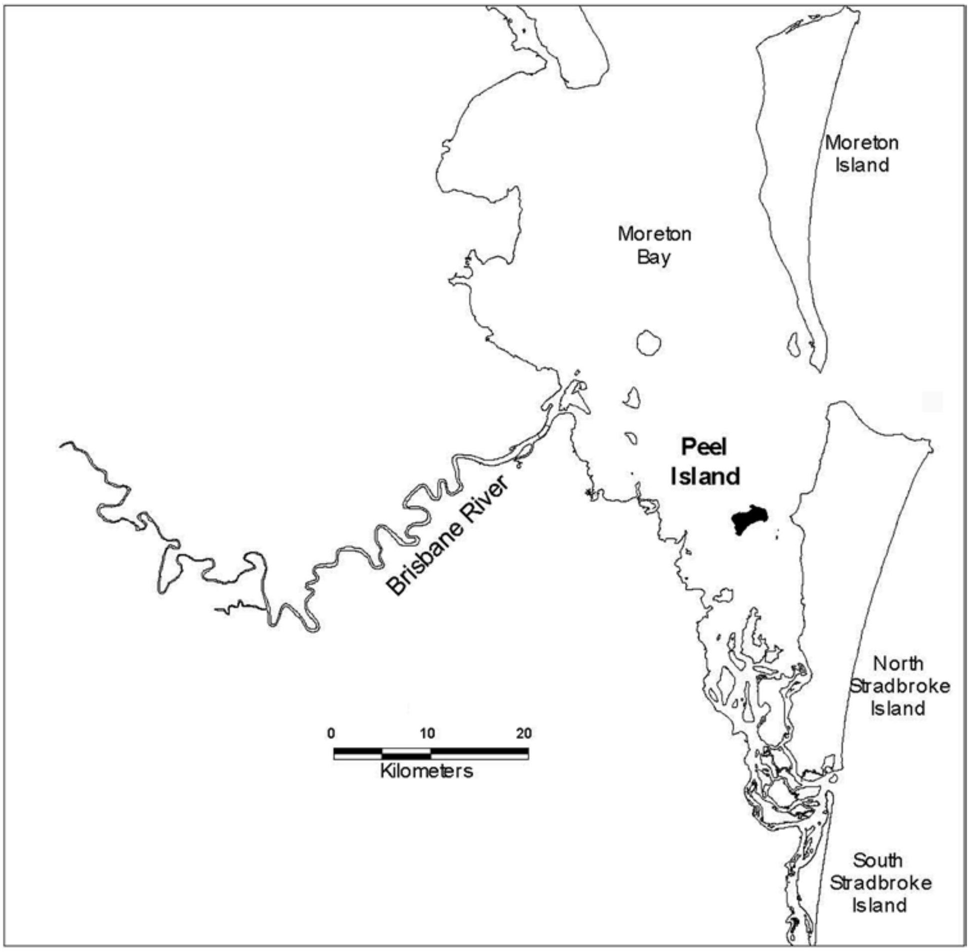

Figure 1. Location of Peel Island in Moreton Bay.

& Stock, 1986). Evidence from other archaeological sites on North Stradbroke Island and elsewhere in Moreton Bay indicates that the Aboriginal subsistence economy in this coastal region was based principally on marine resource harvesting (Hall & Robins, 1984; Ulm, 1995, 2002; Walters, 1986, 1989, 1992).

Historical accounts verify that a reliance on marine resources continued during the contact period (cf. Hall, 1984b). Oral history accounts state that many Aboriginal people living on North Stradbroke Island today continue to rely on marine resources as a significant component of their diet (Ross & Coghill, 2000; Ross & Quandamooka, 1996a, 1996b). Many of the traditional laws and responsibilities regarding the management of marine resources are still remembered and followed. According to the Aboriginal people of Moreton Bay, this reliance on marine foods is based on their inherited rights and responsibilities to the land and sea, and has persisted with little change or interruption since earliest times.

There are two main differences between archaeological evidence and Aboriginal knowledge. The first relates to the timing of marine exploitation. Walters (1989, 1992), for example, has argued that a significant fishery was not developed in Moreton Bay prior to c. 2000 cal. BP, based on an absence of fish remains in sites dating to earlier than this time. In fact, according to Walters and others (e.g., Ulm, 1995, 2002), fish remains are rare in most sites in Moreton Bay, including in sites dating to the last 2000 years (Table 1). Fewer than 50% of excavated coastal sites in Moreton Bay contain any fish remains at all (Ulm, 2002). The data summarized in Table 1 demonstrate that, apart from the middens on St Helena Island, on Sandstone Point (on the northern shores of Deception Bay) and at Toulkerrie (southwest Moreton Island), none of the excavated sites in Moreton Bay which have evidence of fishing contains more than a few small fragments of fish bone per square metre of excavated area. On this basis, Ulm (1995) has challenged Walters' interpretation of the absence of fish remains, arguing that such an absence may be due to taphonomic processes and/or to recovery techniques used in the region, rather than any real reflection of the minimal contribution of fish to the Aboriginal diet in Moreton Bay. Ross and Duffy (2000) have supported Ulm's criticisms, demonstrating that the common use of 3 mm sieves in excavations in Moreton Bay could mean that much of the highly fragmented fish bones are not being retrieved from excavated sites. It is interesting to note that, apart from St Helena Island where a 2 mm mesh sieve was used for artefact recovery, all other excavated sites in Moreton Bay used sieves with mesh sizes of 3 mm or larger. Only the Sandstone Point and Toulkerrie middens recovered very large numbers of fish bone, reinforcing the notion that recovery techniques may indeed play some role in explaining the low fish bone quantities from excavated sites in Moreton Bay (Table 1).

In this paper we present the results of an analysis of a random sample of bone recovered from the excavation of a large shell midden on Peel Island in Moreton Bay (Fig. 1). We demonstrate that a significant quantity of bone passes through the 3 mm mesh sieve and that collection of fragmented bone from the 1 mm sieve can provide a significant increase in bone retrieval from excavations. Some of this bone *can* be identified, and fish are amongst the taxa recovered. The results of this analysis demonstrate a stronger linkage between the archaeological data and Aboriginal oral

Table 1. Summary data for the introduction of fishing and quantity of fish remains from excavated sites in Moreton Bay, Queensland.

site	date first fishing (cal. BP)	area excavated (m^2)	sieve sizes used (mm)	quantity of fish remains	NISPs and g/m^2	references
St Helena Island	1834	0.5	2	576 fish NISPs total bone recovered (mostly fruit bat) weighed 290 g	1152/m^2 (<300 g/m^2 is fish)	Alfredson, 1983
Minner Dint	510	4	3	190 NISPs 23.55 g	47.5/m^2 (6 g/m^2)	Hall, 1980
Wallen Wallen Creek	3000	4	4	296 NISPs	74	
NRS7	Modern	0.75	3	126 NISPs	168/m^2	
NRS8	Modern	6.75	3	61 NISPs	9/m^2	
NRS10	Modern	0.25	3	87 NISPs	348/m^2	
Toulkerrie	2224	7.75	8, 6, 3	40,050 NISPs ranging from 69–236 g per 50×50 cm pit.	5168/m^2 (range 276–944 g/m^2)	Hall, 1984a; Hall & Bowen, 1989
Sandstone Point	2224	16	3	37 754 NISPs weight not reported	2360/m^2	Walters, 1986
First Ridge 19B	680	0.25	6, 3	1 NISP	4/m^2	
Little Sandhills	Modern	90	6, 3	18 NISPs	0.2/m^2	
New Brisbane Airport	5000	1.25	6, 3	"few elements"	—	
Saint-Smith Midden	1000	0.75	6, 3	40.5 g	54 g/m^2	
White Patch Site 3	640	4.5	3	"minimal"	—	
Bribie Island 9	200	0.75	6, 3	"fish and other vertebrate bone"	—	

history relating to marine resource exploitation in Moreton Bay than has resulted from the interpretation of remains recovered from other excavated sites where only 6 mm and 3 mm mesh screens were used.

Moreton Bay and Peel Island

At European contact the Moreton Bay region was home to three clans or family groups: the Nughi, Noonuccal and Dandrubin-Gorenpul. Today these three groups are known collectively as the Aboriginal people of Quandamooka. Each of the clans of Quandamooka is responsible for the management of a different part of the bay. Peel Island is the traditional country of Dandrubin-Gorenpul people (Denis Moreton, pers. comm.).

Following European occupation of the Moreton Bay region, Aboriginal use of Peel Island ceased because it was set aside for the incarceration of people deemed unfit for mainstream society. From 1874 to the 1890s it was a Quarantine Station, from 1910 to 1916 it was an Inebriates Asylum, and from 1907 to 1959 it was a lazaret for the incarceration of sufferers of Hansen's Disease, more widely known as leprosy (Prangnell, 1999). Since the island's abandonment by Europeans in 1959 it has been managed as a national park, and visitors to the island have been kept to a minimum (Blake, 1993).

Prior to the arrival of Europeans, the Aboriginal people of Quandamooka made use of a wide range of resources located throughout Moreton Bay, including Peel Island. Shell middens were once a common site type throughout the bay, but sand mining activities since the 1960s and the expansion of European settlement on many of these islands have seen the destruction or disturbance of a large number of middens and other sites (Ponosov, 1965; Durbridge, 1984; Durbridge & Covacevich, 1981). The large shell midden on the north coast of Peel Island, however, has remained largely intact, due in no small part to the nature of use of the island since 1874.

Quandamooka marine resource management today

Fishing, shellfishing, and marine mammal hunting activities occupy an important place in contemporary Quandamooka society. Most of the members of the Quandamooka community today practice fishing and shellfishing as part of their livelihood. Fishing and shellfishing activities are conducted within the context of the holistic management of land and sea resources (Quandamooka, 1997; QFMA, 1997: 120).

Mullet (*Mugil cephalus*) is one of the most important fish species taken. The people of Quandamooka have fished for mullet, known as *andaccal* or *nandaccal*, for many generations. The deep-sea mullet are available in winter, while the bay mullet are available all year round. There are important rules for the taking of mullet and these are followed in order to ensure the sustainability of the mullet catch. They are based on the social structure of the mullet population and the need for these fish to enter the bay before being taken in large numbers (Barker & Ross, 2003). Other fish targeted include tailor, which are caught in spring, and whiting, flathead, bream and trevally, which can usually be caught all year round (Dandrubin-Gorenpul elders, pers. comm., 1995).

According to their tradition, the people of Quandamooka cook fish whole, placing scaled but ungutted fish directly into the fire. Flesh is then removed from the skeleton, with the bones discarded into or close to the fire. Dogs will scavenge any bones thrown away from the fire (Dandrubin-Gorenpul elders, pers. comm., 1999). This practice of bone discard explains the highly fragmented, burnt and even calcined nature of much of the bone from the Lazaret Midden (see below).

The people of Quandamooka also gather a variety of shellfish resources. Eugaries (pipis—*Donax deltoides*) are taken from the active sandy coasts, while oysters (*Saccostrea commercialis*), whelks (*Pyrazus ebeninus*), quampies (pearl oyster—*Pinctada maculata*) and mussels (*Trichomya hirsuta*) are taken from the calmer waters of the muddy coasts. As with the mullet, there are rules for the taking of shellfish species that must be followed to ensure a sustainable harvest (Ross & Quandamooka, 1996a).

Archaeological evidence for marine resource use in Moreton Bay

Considerable archaeological evidence supports the existence of a maritime subsistence tradition in Moreton Bay dating over 5000 years (Table 1; Ulm, 1995: 46–50). The following represent the earliest dates for coastal sites in the bay:

- Wallen Wallen Creek (20,560±250 SUA-2341; Neal & Stock, 1986);
- New Brisbane Airport (4830±110 Beta-33342; Hall, pers. comm., in Ulm, 1995);
- Hope Island (4350±220 Beta-20799; Walters *et al.*, 1987).

However, while there is evidence for *shellfish* gathering at these and other more recent sites, evidence for *fishing* is much more limited. Walters (1986, 1989, 1992, 2001) has argued that, for Moreton Bay, "the story of fishing is a relatively recent one, belonging to the past 2000 years" (Walters, 2001: 62). Certainly, the majority of sites dating to earlier than 2000 BP have very few fish remains (Ulm, 1995: 68–69). The earliest dated evidence for fish bone is from New Brisbane Airport, where "a few elements" were recorded at 5000 cal. BP (Ulm, 1995: 88). However, even sites dating to the last 1000 years have few fish bones, as reported from the archaeological data. In fact, of the 62 excavated sites in southeast Queensland, only 27 have yielded any fish bones at all (Ulm, 2002: 79), and even then the quantities are mostly minimal, including sites dating within the last 2000 years (Table 1). It is only at Toulkerrie and Sandstone Point that very large numbers of fish bones were excavated: some 40,000 NISPs at each site (c. 400 g per m^2 of excavated area) and dating from 2224 cal. BP, compared to fewer than 1200 NISPs (ca 50 g per m^2) at all other sites (Table 1; Ulm, 1995: 88, 2002: 85–87). The large quantities of fish remains at Toulkerrie and Sandstone Point are difficult to explain. Large amounts of bone were found in even the 6 mm sieves (Hall, 1984a), which suggests that recovery methods alone are insufficient to explain the unusual quantities of bone discovered from these sites. Nevertheless, it is clear that the results of excavations from these sites are unusual in the overall Moreton Bay data, where very low amounts of fish bone (both in terms of NISP counts and bone weight) have even been recovered from sites dating to the very recent past. Why should the archaeological evidence from Moreton Bay differ so markedly from Aboriginal memory?

The Peel Island Lazaret Midden Excavation

Between 1995–1999 Ross and the Quandamooka Cultural Resources Management Team conducted an excavation programme at the Peel Island Lazaret Midden. One key aim of this excavation, addressed in this paper, was to review the evidence for a late onset of fishing in Moreton Bay, in the light of Aboriginal knowledge regarding the importance of fishing in the long-term economy of the bay.

The Peel Island Lazaret Midden is a large midden on the northern coast of Peel Island (Fig. 2), immediately adjacent to the Peel Island Lazaret complex. The midden is over 400 m long and at least 50 m wide. It extends from the western side of the lazaret to at least 200 m east of the most easterly building on the settlement. Those parts of the midden in close proximity to the lazaret settlement have been disturbed by a variety of post-contact activities. The eastern portion of the midden, however, shows no visible signs of damage and includes intact mounds with shell, stone and bone material exposed through the leaf litter on the surface.

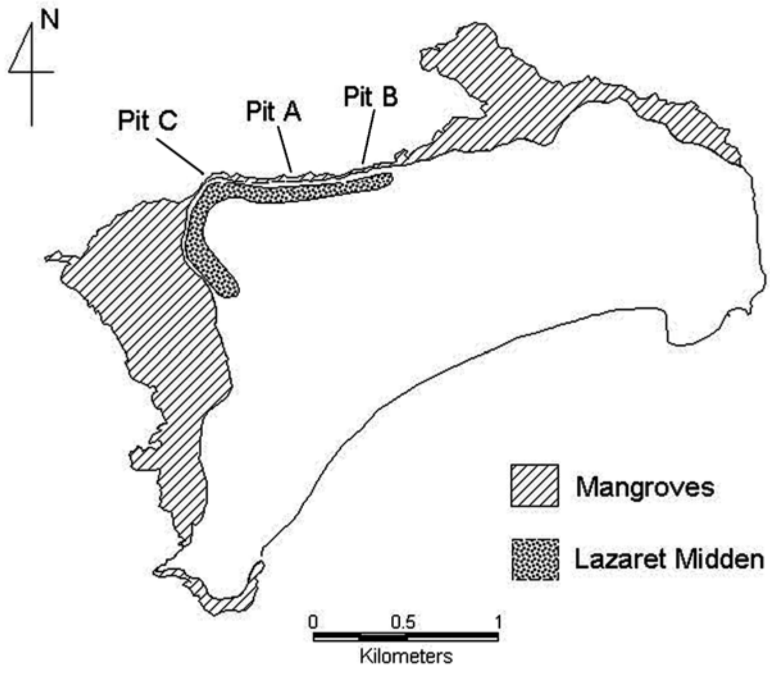

Figure 2. Location of Peel Island Lazaret Midden and excavated pits.

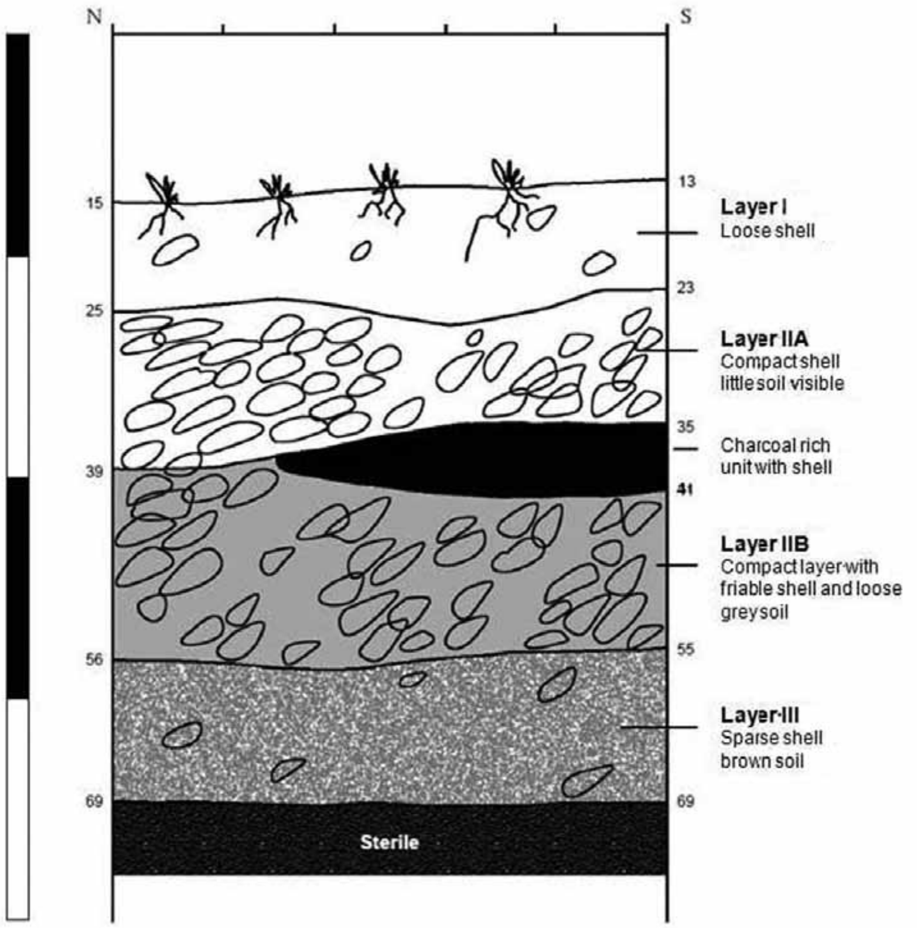

Figure 3. Section diagram, Pit A (east wall) of the Peel Island Lazaret Midden. Scale marked in 20 cm units.

Four 500 mm × 500 mm pits were excavated in the Lazaret Midden by Ross and the Quandamooka CRM Team over several seasons (Fig. 2). Three of the pits (labelled A, B1 and B4) were in the undisturbed eastern part of the site. Pit C was excavated in the open area in front of the lazaret as part of a community information day. The material excavated from this pit has not been analysed. Only the evidence from Pits A, B1 and B4 are discussed in this paper.

The excavation proceeded in arbitrary spits or "excavation units" (XUs), with each XU comprising one bucket (9.5 kg) of deposit or approximately 20—25 mm depth, within stratigraphic context (cf. Johnson, 1979). The shell midden deposit comprises three major stratigraphic divisions. The top 50—60 mm, stratigraphic Layer I, is a loose shell midden dominated by oyster and whelk. Layer II ranges from 150—300 mm. It is a compact and dense shell layer. The density of the shell in these compact sediments is indicative of the relative integrity of the cultural materials recovered from this part of the midden. There is no evidence for bioturbation of deposits, nor of any significant vertical or horizontal movement of cultural material. The existence of *in situ* hearths in this stratum is further evidence that the compact deposits that make up the bulk of the midden material in Layer II provide a relatively stable depositional environment at the site (for further discussion, see Ulm *et al.*, 2009). In Pit A the upper part of this layer (Layer IIA) is dominated by oyster, whelk and mussel shells. The lower part of Layer II in Pit A (Layer IIB) is comprised of increasingly less dense shell, with more soil content. Below Layer II, in both Pits A and B, Layer III (150—300 mm) has a sparse amount of shell in a progressively denser soil matrix, grading to sterile deposits 500—650 mm below ground surface (Figs 3 and 4). In Pit A, a dense charcoal lens probably represents a fireplace or hearth. A paired charcoal/shell sample was collected from this lens and submitted for dating (see below).

All excavated material was retained at the request of the Quandamooka community. Material was sieved through a 6 mm and 3 mm sieve in the field and the material retained in the sieves was bagged. The material that passed through the 3 mm sieve was also bagged, and samples of the residue passing through the 3 mm sieve were sieved through a 1 mm sieve in the laboratory. Members of the Quandamooka community were involved in all stages of the project, including laboratory sorting.

Radiocarbon dates. Nine radiocarbon dates were obtained from the site. Four were taken from Pit A and five from Pit B. Table 2 summarizes the results. Radiocarbon ages were calibrated by Sean Ulm using OxCal 4.1 (Bronk Ramsey, 2009) and the SHCal04 calibration curve for atmospheric samples (McCormac *et al.*, 2004) and the Marine09 calibration curve for marine samples (Reimer *et al.*, 2009) with a local ΔR value of 9±19 ^{14}C years, as recommended by Ulm *et al.* (2009). The median calibrated age is a central best-point estimate for the probability distribution of each date (following Telford *et al.*, 2004). There are two sets of paired charcoal and shell dates (Table 3). The pair from Pit B1 has produced comparable ages, but there is a difference between the charcoal and shell dates from the paired sample in Pit A. Nevertheless, Ulm *et al.* (2009) argue that both sets of pairs are likely to be coeval in age, with the shell date being the more reliable of the two. The only outlier date is Beta-98031, which is the charcoal date from Pit A. The most parsimonious explanation for the single outlier is that

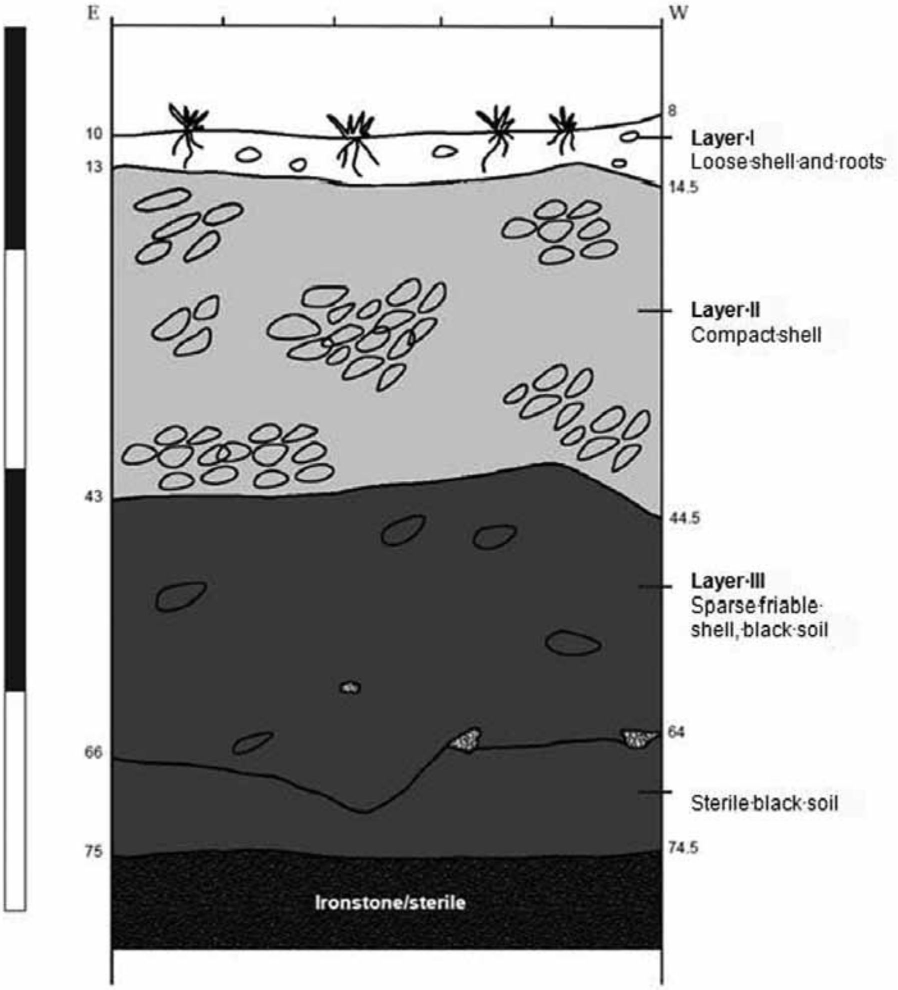

Figure 4. Section diagram, Pit B1 (south wall) of the Peel Island Lazaret Midden. Scale marked in 20 cm units.

it is unreliable (Ulm *et al.*, 2009). The following discussion is therefore based only on the shell dates.

The radiocarbon ages for the site indicate that the Lazaret Midden formed between 1200 cal. BP and the present. Values for pH (average 8.0) are high throughout the cultural levels of the site, even where shellfish remains (which often elevate pH as noted by Waselkov, 1987: 148–149) are few in number, are fragmented or are heavily weathered. Immediately below the cultural levels, pH values gradually decline and background pH across the island is highly acidic (average 4.0). These data suggest that faunal remains (both shellfish and animal bone) may have been initially discarded in soils with the background acidic pH, with much of the initial cultural material being dissolved by these acidic soils, causing the pH in these soils to be raised even though the cultural materials did not survive. The highly fragmented shellfish remains at the basal levels of the excavated pits (Layer III) may be the earliest surviving cultural materials in the more alkaline soils, with higher pH than the natural surrounding landscape being the result of the effects of the acidic soils on these earliest cultural deposits. It is possible, therefore, that the first occupation of the Lazaret Midden may date to older than 1200 cal. BP, having been deposited in levels below those containing the earliest (visible) archaeological materials, but that these earliest cultural remains were destroyed by acidic soils (cf. Waselkov, 1987: 149). Detailed pH analyses of soils and natural sediments near the Midden are required to test this hypothesis. Despite the possibility that the Lazaret Midden could date to earlier than 1200 cal. BP, it is unlikely that it is older than 2000 cal. BP.

The main point to come from the dates is that deposits at the Lazaret Midden accumulated relatively gradually and consistently over at least 1200 years, at a rate of approximately 50 mm every 100 years or one XU every 50–70 years. The Lazaret Midden, therefore, dates to the period when the Moreton Bay fishery should have been well established (Walters, 1986, 1989, 1992b, 2001).

Bone remains from the Peel Island Lazaret Midden

Bone was recovered from throughout the excavated deposit at the Lazaret Midden, including the lowest cultural levels (Table 4). Given the small size of the bone fragments recovered, and the length of time taken to sort even a small sample of the material from the 3 mm and 1 mm sieves, only 100 g samples of the materials retained in the 3 mm and 1 mm sieves were sorted from each XU (Ross & Duffy, 2000). Samples were chosen at random from the total volume of material retained in the 3 mm sieve and from material that passed through the 3 mm sieve to be retained in the 1 mm sieve. Consequently, the quantities of bone reported in the 3 mm and 1 mm columns of Table 4 make up only some 2–3% of the total bone that passed through the 6 mm sieve. Table 5 provides an extrapolated weight calculation for the likely weight of bone recovered (but not sorted) from Pits A and B1 (insufficient material from B4 has been sorted for inclusion in this analysis), based on an assumption that the 100 g samples are representative of the entire deposit

Table 2. Radiocarbon dates from the Lazaret Midden excavation on Peel Island.

Pit/XU	depth (mm)	lab #	material	conventional age BP	calibrated ^{14}C age	calibrated age BP (2σ)	calibrated age BP (median)
A/3	20	Beta-98030	shell	830±70	559 (474) 302	554–291	446
A/10	270	Beta–98032	shell	1090±60	765 (651) 537	753–530	643
A/10	270	Beta–98031	charcoal	970±60	966 (912,807) 730	954–728	839
A/16	530	Wk–8010	shell	1520±50	1221 (1063) 937	1190–930	1063
B4/1	surface	Wk–8012	shell	480±50	267 (95) 0	231–0	96
B4/12	300	Wk–8009	charcoal	500±50	618 (515) 465	557–332	507
B4/12	300	Wk–8013	shell	840±50	545 (480) 370	536–328	461
B4/17	470	Wk–8014	shell	1420±50	1100 (955) 871	1092–823	960
B1/25	480	Wk–8011	shell	1660±60	1334 (1233) 1063	1320–1058	1207

(and repeat experiments suggest that such an assumption is valid—see Ross & Duffy, 2000 for discussion). Table 4 indicates that the density of bone recovered from the Lazaret Midden is at least as high as that recovered from Toulkerrie and Sandstone Point (see below).

Until recently it has been impossible to draw any conclusions from the bone data recovered from the Lazaret Midden on Peel Island; the highly fragmented state of the bone, and the fact that many of these bones have been burnt and even calcined, has made morphological identification extremely difficult. Votjeck Hlinka attempted DNA extraction from a sample of this bone, but was unable to determine taxa because of problems with DNA survival in burnt bone (Hlinka, 2003). Recent advances in fish bone identification (Koon *et al.*, 2003; O'Connor, 2008) provided the catalyst for another attempt at morphological analysis of the bone excavated from the Peel Island Lazaret Midden and the consequent opportunity to address questions about the role of fish in Aboriginal subsistence in Moreton Bay.

Potential factors affecting the nature of fish bone remains

A random sample from the analysed midden material identified as "bone" was selected for further analysis by Tomkins, who has previously undertaken fish bone analysis from archaeological contexts. The random sample is representative of an assemblage that contains significant numbers of highly fragmented bone, much of which is not identifiable beyond Class (i.e. Osteichthyes fish). At the outset, it is important to consider potential factors affecting the nature of the bone material.

Controlled screening experiments have demonstrated the significant biases that screen mesh size can have in fish bone recovery (Casteel, 1972; Gordon, 1993; Nagaoka, 2005; Walters, 1979). Nagaoka (1994, 2005) demonstrates that use of ⅛ inch (3 mm) fine mesh screens will increase the number of taxa recorded when compared with using ¼ inch (6 mm) screens alone. This recovery bias is based on the size of fish taxa and the differential size and robustness of diagnostic skeletal elements (Colley, 1990; Gordon, 1993; Nagaoka, 2005; Weisler, 1993).

Vale and Gargett (2002) used 6 mm, 3 mm, and 1 mm screens for their Arrawarra I Project, which resulted in a well-recovered fish bone assemblage, except that the bones retained in the 3 mm and 1 mm mesh were highly fragmented and difficult to identify (cf. Ross & Duffy, 2000). Walters' (1979) study found that 80% of fish bone remains passed through 3 mm mesh and other research suggests that maximum representative recovery can only be achieved through use of sieve sizes between 0.5 mm and 2 mm (Casteel, 1971, 1972; Colley, 1990).

Walters (1986: 240) reports that high proportions of burnt bone have been recovered in the region. Burnt bone has been recovered from Pit A and Pit B1 of the Lazaret Midden, so it is possible that there could be significant bone losses due to burning. Post-depositional diagenesis is another factor that could affect survival of the fish remains. As discussed above, the Lazaret Midden is a fairly alkaline (pH = 8.0) environment in the upper XUs, while the lowest XUs are quite acidic (grading from pH = 6.0 to 4.0) and this would be responsible for bone destruction in the lower XUs.

Methods used for sub-sample analyses

All of the material in the sub-sample previously identified as "bone" was re-examined. The random sample selected for analysis comprised materials from eight XUs that had previously been sorted into "bone 6 mm", "bone 3 mm" and "bone 1 mm". The contents of each bag were counted and weighed to the nearest 0.1 g using an A&D EK 1200 electronic balance for samples above 10 g, while those below 10 g were weighed to the nearest 0.01 g on a Shimadzu AW120 electronic balance. Due to the minute size of most

Table 3. Analysis of paired radiocarbon dating samples from Pits A and B of the Lazaret Midden on Peel Island (Ulm *et al.*, 2009).

Pit/XU	depth (mm)	lab #	material	δ^{13}C (‰)	δ^{18}O (‰)	CRA (BP)	equivalent marine model age	△R (^{14}C yr)
B4/12	300	Wk-8009	charcoal	–27.2±0.2	—	500±50	905±35	–65±61
B4/12	300	Wk-8013	shell	0.7±0.2	–1.36±0.06	840±50	840±50	
A/10	270	Beta-98031	charcoal	–25e±2e	—	970±60	1306±72	–216±94
A/10	270	Beta-98032	shell	1e±2e	—	1090±60	1090±60	

Table 4. Bone remains sorted from Peel Island Lazaret Midden from the 6 mm, 3 mm and 1 mm sieves. All data recorded as bone weight in grams; *NS* = Not Sorted; * 35.8 g of this weight is a large dugong bone fragment that is not included in the totals.

	PIT A				PIT B1				PIT B4			
XU	6 mm	3 mm	1 mm	Total	6 mm	3 mm	1 mm	Total	6 mm	3 mm	1 mm	Total
1	0	0	0	0	1.0	1.8	0.7	3.5	6.2	1.4	1.1	8.7
2	0.3	0	0.5	0.8	1.0	0.8	0.9	2.7	39.5*	1.6	0.7	6.0
3	0	0.1	0.4	0.5	4.3	0.7	NS	5.0	17.9	1.1	0.7	19.7
4	0	0	0.3	0.3	0.4	NS	NS	0.4	7.1	0.9	0.8	8.8
5	0	0.1	0.2	0.3	0.2	0.3	NS	0.5	NS	NS	NS	—
6	0	0	0.1	0.1	0	0.1	0.3	0.4	11.4	0.4	0.5	12.3
7	0	0.1	0.1	0.2	1.9	0.1	0.1	2.1	0.1	0.3	0.3	0.7
8	0	0.1	0.1	0.2	0	0	0.3	0.3	19.4	NS	NS	19.4
9	0	0.1	0.2	0.3	1.1	0.3	0.1	1.5	0.3	NS	NS	0.3
10	0	0.3	0.3	0.6	0.8	0.2	0.2	1.2	0.5	1.2	0	1.7
11	0	0.2	0.3	0.5	0.4	0.1	0.1	0.6	NS	NS	NS	—
12	0	0.1	0.2	0.3	0.1	0.2	0.1	0.4	0.4	NS	NS	0.4
13	0	0.2	0.1	0.3	5.3	NS	<0.1	>5.3	1.6	NS	NS	1.6
14	0	0.6	0	0.6	0	0.3	0.3	0.6	37.7	NS	NS	37.7
15	0.8	0	0.3	1.1	0	0.1	0.2	0.3	2.8	NS	NS	2.8
16	0	0.1	<0.1	0.1	0	0.6	0.4	1.0	0.9	NS	NS	0.9
17	0	0	0	0	2.0	0.8	0.4	3.2	<0.1	NS	NS	<0.1
18	0	0	0	0	0	0.7	0.3	1.0	end of cultural material			
19	0	0	0	0	1.0	0.3	0.4	1.7				
20	end of cultural material				0.4	0.7	0.4	1.5				
21					0.7	0.8	0.3	1.8				
22					1.0	0.4	0.2	1.6				
23					1.0	0.5	0.1	1.6				
24					0.8	0.8	0.1	1.7				
25					0.9	0.4	0.1	1.4				
26					0.2	0.4	<0.1	>0.6				
27					0.2	0.9	<0.1	>1.1				
28					1.0	1.3	0.1	2.4				
29					—	0.1	0.1	0.2				
					end of cultural material							
total	1.1	2.0	3.1	6.2	25.7	13.7	6.4	52.2	110.0	6.9	4.1	121.0

bone fragments, the contents of each bag were examined under laboratory conditions using a microscope with a 4× lens and a 2× focal magnification.

Any bones that could be identified to taxa were removed from the general finds labelled "bone" and placed in a new bag and labelled accordingly. In order to have some certainty that there were indeed fish bones in the material collected from the 1 mm sieve, it was necessary to also review bones retained in the 3 mm and 6 mm sieves. In this way, bone from the 3 mm sieve that had previously been labelled "fish" was confirmed (or otherwise), and this also facilitated evaluation of the typical structure and colour of fish bone excavated from this site. The bone fragments retained in the 1 mm sieve were then compared to the 6 mm and 3 mm reference specimens to confirm identification as fish or non-fish.

Results

This analysed sub-sample represents approximately 10% of the sorted midden deposit. The total weight of bone material examined in the sub-sample was 22.8 g, comprising 1101 NISPs. The count and weight analysis of the bone in the selected sub-sample is shown in Table 6, and the taxonomic composition of the samples is shown in Table 7. Although the bones collected in the 3 mm and 1 mm mesh sieves are extremely fragmented, it is still possible to distinguish fish vertebrae, spines, and teeth.

The greater part of the total (56%) by weight (12.4 g) of the bone from the sub-sample of sorted material from the Peel Island Lazaret Midden was attributed to dugong (*Dugong dugon*) and/or turtle (Chelonia). Any bones that could not be assigned to a class, order or family were designated as "vertebrate".

Fish bones (n = 572) made up over half the count (52%) and 35% of the weight (7.92 g) of the bones analysed. Of the c. 8 g of bone identified as fish, c. 1 g (12%) is from the 1 mm sieve. It is important to note that NISPs can be a poor measure of abundances in cases such as this where the assemblages are highly fragmented and therefore, weight is often a more realistic measure for comparative purposes (Allen *et al*., 2001). There is a strong likelihood that fish bones actually make up a greater proportion of the sampled contents, but due to the highly fragmented condition of the bones, we err on the side of conservatism.

Only two fish bones from the sample could be identified to family: a left dentary and a right dentary from a wrasse (tuskfish—Labridae family). As these two bones are both the same size (40 mm in length), and were both collected from Pit B4 XU3, they are most probably representative of 1 MNI. Despite problems with identification, the small fraction of bone can still be identified to major animal groups, including fish. Since the mere recognition of fish bones satisfactorily addresses our major research question about the scale of the Moreton Bay fishery, important answers can be provided.

Table 5. Extrapolated total bone weights from excavated deposits in Pits A and B1 in the Lazaret Midden on Peel Island, calculated by assuming the sorted samples represent 2.5% of the total deposit. Data from Pit B4 are not included, as insufficient material from this excavated square has been sorted.

XU	6 mm weight (g)	3 mm weight (g)	1 mm weight (g)	total bone weight (g)
1	1.0	72.0	28.0	101.0
2	1.3	32.0	56.0	89.3
3	4.3	32.0	17.0	53.3
4	0.4	1.0	13.0	14.4
5	0.2	16.0	9.0	25.2
6	0	4.0	16.0	20.0
7	1.9	8.0	8.0	17.9
8	0	4.0	16.0	20.0
9	1.1	16.0	12.0	29.1
10	0.8	20.0	20.0	40.8
11	0.4	12.0	16.0	28.4
12	0.1	12.0	12.0	24.1
13	5.3	9.0	5.0	19.3
14	0	36.0	12.0	48.0
15	0.8	4.0	20.0	24.8
16	0	28.0	17.0	45.0
17	2.0	32.0	16.0	50.0
18	0	28.0	12.0	40.0
19	1.0	12.0	16.0	29.0
20	0.4	28.0	16.0	44.4
21	0.7	32.0	12.0	44.7
22	1.0	16.0	8.0	25.0
23	1.0	20.0	4.0	25.0
24	0.8	32.0	4.0	36.8
25	0.9	16.0	4.0	20.9
26	0.2	16.0	1.0	17.2
27	0.2	36.0	1.0	37.2
28	1.0	52.0	4.0	57.0
29	—	4.0	4.0	8.0
total	26.8	630.0	379.0	1035.8

Discussion

If nothing else, the Peel Island study supports the case for using at least a 3 mm mesh sieve for the collection of bone from archaeological sites. Furthermore, the results confirm that using a 1 mm mesh sieve can be an effective recovery technique in situations where archaeological bones are highly fragmented. Sea mullet (*Mugil cephalus*) and whiting (*Sillago* spp.) have particularly small and fragile bones (Hall, 1980: 105), and both these species are documented as being highly important marine resources for the people of Quandamooka. It could reasonably be expected, therefore, that these fragile bones would fragment and pass through 6 mm and even 3 mm mesh screens, ultimately being omitted from data tables unless a 2 mm or 1 mm mesh were to be used.

The question about the value (i.e. time/money versus results/identifications) of analysing bone collected in a 1 mm mesh sieve is still debatable. On the one hand, this detailed analysis of just a small sub-sample from the Peel Island Lazaret Midden has not contributed any taxonomic identification of fish bones beyond the Class level. On the other hand, Erlandson (1994: 16) argues that "minor changes in the weight of fish or mammal bone found in a midden sample can alter estimates of the dietary yield of various faunal classes dramatically." As at least 12% by weight of the fish bone from the Lazaret Midden passed through the

Table 6. Counts and weights of bone contents in sampled bags from the Lazaret Midden on Peel Island.

Pit/XU	>3 mm count	1 mm count	>3 mm weight (g)	1 mm weight (g)	total bone count	total bone weight (g)
PIT A XU2	22	80	0.27	0.49	102	0.76
PIT A XU3	14	200	0.08	0.34	214	0.42
PIT A XU8	2	17	0.05	0.10	19	0.15
PIT B1 XU8	15	150	0.0	0.29	165	0.29
PIT B1 XU11	32	14	0.49	0.08	46	0.57
PIT B4 XU3	242	300	18.91	0.70	542	19.61
PIT B4 XU7	1	3	0.39	0.23	4	0.62
PIT B4 XU12	9	0	0.38	0.0	9	0.38
totals	337	764	20.57	2.23	1101	22.80

Table 7. Taxonomic division of bone in sub-samples from the Lazaret Midden on Peel Island.

pit	sieve size	taxon	count NISP	weight (g)	comments
PIT A	>3 mm	Vertebrate	1	0.01	tiny bone fragment
PIT B4	>3 mm	Vertebrate	101	1.10	tiny bone fragments, 1 triangular flat fragment
PIT A	1–3 mm	Vertebrate	148	0.46	tiny bone fragments, most likely fish
PIT B1	1–3 mm	Vertebrate	97	0.18	tiny bone fragments, could be fish
PIT B4	1–3 mm	Vertebrate	150	0.46	tiny bone fragments
PIT A	>3 mm	Osteichthyes [a]	30	0.23	vertebrae and spine fragments, some burnt
PIT B1	>3 mm	Osteichthyes	43	0.47	1 vertebra, 2 spines, 1 dentary, other bone fragments, some burnt
PIT B4	>3 mm	Osteichthyes	123	2.40	mostly fish vertebrae and spines, a few fish teeth, some translucent rays from fish fins, 1 pharyngeal plate frag, 1 palatine frag.
PIT A	1–3 mm	Osteichthyes [b]	149	0.47	1 fish tooth, vertebrae and spine fragments, some burnt
PIT B1	1–3 mm	Osteichthyes [b]	75	0.18	vertebrae, spine and teeth fragments, translucent rays from fish fins
PIT B4	1–3 mm	Osteichthyes [b]	150	0.46	mostly fish spines, a few fish teeth, some translucent rays from fish fins, other bone fragments
PIT B4	>3 mm	Labridae	2	3.71	1L and 1R dentary from wrasse (tuskfish); same size probably represents 1MNI
PIT A	>3 mm	Mammal	3	0.12	1 mammal tooth, 1 phalange, fragment of flat bone (hard cortical layer covering spongy bone) possibly from dugong or even Reptilia (turtle)
PIT B4	>3 mm	Mammal	26	12.47	some phalanges, fragments of flat bones (hard cortical layer covering spongy bone)
PIT A	>3 mm	Rodent	3	0.03	2 long bones, 1 possible rib
PIT A	>3 mm	Unknown	1	0.01	chalky substance
PIT B1	>3 mm	Unknown	4	0.02	could be seed pods, also chalky substance
PIT B1	1–3 mm	Unknown	2	0.01	could be tree bark
PIT B4	1–3 mm	Unknown	3	0.01	could be piece of bark

[a] Boney fish.
[b] In these cases 50% of bone is assigned to Osteichthyes and the remainder to Subphylum Vertebrata.

3 mm sieve, and without the analysis of the 1 mm fraction would otherwise not have been included in the final figures for this site, the contribution of bone provided by the 1 mm mesh sieve is demonstrably important.

The results of the analysis of the sub-sample, along with the more general analysis of all the bone from Pits A and B1 (Table 5), if extrapolated across the entire Lazaret Midden site, have implications for the debate regarding the importance of fish as a resource for the people of Quandamooka who camped at Peel Island. The calculations presented in Table 5 indicate that the total amount of bone excavated from the Lazaret Midden may be significantly higher than that recovered from most other excavated sites in the Moreton Bay region, although a direct comparison is not possible because total bone weight is not reported for many sites (Table 1) and NISPs were not calculated for Peel Island. At Toulkerrie, where fish bone weight has been provided (Hall, 1984a; Hall & Bowen, 1989), the amounts are less than the extrapolated total bone weights from the Lazaret Midden: c. 100–200 g per 500 mm × 500 mm pit at Toulkerrie (Table 1) compared to approximately 500 g for the same size excavated pit from Peel Island (1036 g for two pits of analysed bone, Table 5). However, if only 35% (conservatively) of the total extrapolated bone weight from Peel Island is fish, this equates to approximately 175 g per 500 mm × 500 mm excavated pit (500 g × 35%). This quantity of fish bone in the Lazaret Midden on Peel Island is similar to that recovered from Toulkerrie and Sandstone Point, based on the similarity in NISP counts from these two sites.

The results of the Peel Island research, and those from Toulkerrie and Sandstone Point, show that a well-developed fishery operated across Moreton Bay over at least the last 2000 years, and perhaps over a longer time-frame. Given that at least 35% (conservatively) of the bone recovered from the Lazaret Midden is fish, this translates to a total of approximately 175 g of fish bone by weight from the two fully analysed 500 mm × 500 mm pits (Pits A and B1), or 350 g of fish bone per m^2. Assuming these pits are representative of the entire shell midden, and the similarity of results from pits over 200 m apart suggests representativeness (see Ross & Duffy, 2000 for discussion), these results correspond to approximately 7,000 kg of fish bone throughout the site (350 g × the total area of the site: 2000 m^2). This equates to around 5.8 kg of fish bone discarded annually over the life of the site (7,000 kg over 1200 years). What does this quantity of bone mean for total fish consumption at the site?

The calculation of fish meat from fish bone remains is complex because of the difficulty in controlling for seasonal variation in fish body mass (Erlandson, 1994; Rick & Erlandson, 2000), for differences afforded by fish size, age and sex, and because different fish species have different ratios of skeletal to edible flesh weights (Barrett, 2005; Rick *et al*., 2002: 112). Elasmobranchs (sharks, skates and rays), for example, have very variable meat to bone weight ratios, ranging from 28:1 to 203:1 (Rick *et al.*, 2002: 116). More common bony fish have very much lower ratios. Teleosts—the most common bony fish, including many coral reef species—have meat-to-bone ratios that range from 18:1 to 4.4:1 (Rick *et al.*, 2002: 118). It is preferable, therefore, to use species-specific meat-to-bone ratios when calculating dietary value of archaeological bone remains (Barrett, 2005; Rick *et al.*, 2002: 118).

With the fragmentation of the bone in our study, and the inability to determine fish species, a specific analysis of bone weight to meat weight conversion is not possible. Even where such data are available, dietary conversions based on bone weight are never accurate (see Barrett, 2005 for a detailed review). Nevertheless, there have been a number of recent studies that indicate the potential of the "weight method" in generating a general view of meat weight from archaeological bone data, especially with respect to fish. Barrett (2005: 10) argues that use of raw bone data to calculate meat quantities, especially with respect to fish, "will underestimate the potential dietary contribution of fish." According to Barrett, fish bones in teleosts constitute 2.2—3.7% of total body weight of the fish. A conservative conversion factor for fish bone to fish meat would therefore be 25:1 (4% bone weight to total fish weight). Rick and Erlandson (2000) suggest an even more conservative ratio of 6:1 for teleosts. Using these two estimates as the potential range for fish meat based on known fish bone weight provides an opportunity to estimate the likely quantity of fish meat consumed at the Lazaret Midden per annum. Using the range of between 25:1 and 6:1, the total fish consumption from the Peel Island Lazaret Midden would be in the order of 35–145 kg per annum (5.8 kg per annum of bone × conversion factor 6 = 34.8 kg; 5.8 kg per annum of bone × conversion factor 25 = 145 kg). Given that the Peel Island Lazaret Midden is just one of many midden sites in this part of Moreton Bay, and that similar quantities of fish bone have been found (Toulkerrie and Sandstone Point) or may be found with better recovery techniques, this is not an inconsequential fishery.

Could this well developed fishery on Peel Island have existed before 2000 cal. BP? As the Lazaret Midden is younger than this, the site cannot be used to answer this question. But there are several relevant sites with reasonable quantities of fish remains in Moreton Bay and the surrounding coastal region. Wallen Wallen Creek is the oldest of these (Neal & Stock, 1986), and here Neal has documented that marine exploitation was likely to have been an important subsistence activity from 3000 BP (Rob Neal, pers. comm. to Sean Ulm, 1995). There are other sites that date to earlier than 2000 BP, and at least some of these also contain fish bones (Ulm, 1995: 45–46). Our analysis indicates that if more effective recovery techniques had been used, fish bone may have been more prevalent in sites throughout Moreton Bay, including sites older than 2000 cal. BP.

Conclusions

Part of Walters' argument for the late development of a fishery in Moreton Bay is that the "wallum" coastal margins of southeast Queensland are economically marginal and that permanent occupation of the coast could not have occurred until fishing had intensified. Evidence for the depauperate nature of the wallum and other coastal areas of Australia, however, has been challenged. Ulm (1995: 38–39) points out that the wallum itself is a very narrow ecological zone, unlikely to have provided a significant barrier to human occupation of the coastal lowlands generally. Citing the work of ecologists such as Dwyer *et al.* (1979), Ulm (1995: 38) argues that it is likely that terrestrial resources were more abundant in the coastal environments of the bay prior to European land use degradation at a time when Aboriginal burning regimes were operating. This accords well with evidence from members of the Quandamooka community, who describe the importance of fire in the management of both floral and terrestrial faunal resources (Coghill & Coghill, 1998), and with ethnohistorical evidence for well-developed exploitation of hinterland resources (macropods, emus, birds, ducks and reptiles) (Hall, 1982; Petrie, 1904). These species were abundant in pre-contact times (Ulm, 1995: 39). Consequently, neither the archaeological nor the ethnohistorical evidence from Moreton Bay contradicts Quandamooka claims for a long tradition of fishing and coastal resource exploitation. Furthermore, Beaton (1995) argues that "procumbent" coastlines (those having a shallow continental shelf, like those in and off Moreton Bay) may have experienced dynamic changes as sea level rose, but that these changes were a substitution of one type of marine fauna (coral dwelling species) by another (mud dwelling species). These changes, Beaton argues, would not have precluded continuing coastal use. These ideas are supported by other researchers, such as Barker (1999), Cotter (1996, cited in Hall, 1999), Morse (1999), and Veitch (1999).

This evidence, along with the data from the Peel Island Lazaret Midden excavation analysed here, demonstrates that a rethink of Walters' model is required. There are two factors of importance here. The first is the use of a 1 mm sieve to maximize the recovery of fish bone data. The second is that the issues of subsistence in Moreton Bay are far more complex than allowed for by Walters' model. Fishing has been a vitally important part of Moreton Bay subsistence, both today and in the past, but evidence from the archaeological record is not always a direct reflection of past reality (Bailey, 1999; Barker, 1999; Smith, 1999).

The interpretation of the archaeological evidence for the Lazaret Midden on Peel Island indicates the value of understanding Aboriginal resource laws within a landscape and seascape context. The fish bone from the Peel Island Lazaret Midden site is supportive of Aboriginal claims for the long-term importance of a Moreton Bay fishery.

ACKNOWLEDGMENTS. For assistance in planning the excavation, participation in excavation and laboratory work, and/or general discussion, we particularly thank community members Uncle Bob Anderson, Auntie Joanie Moreton, Uncle Cliff Campbell, Auntie Thelma Campbell, Auntie Shirley Moreton, Uncle Keith Borey, Auntie Eileen O'Laughlin, Uncle Denis Moreton, Brian Coghill, Denise Coghill, Shane Coghill, Mark Jones, Warren (Nikko) Nixon, Troy Coolwell, Aaron McIvor, Mandy Blivet, Suzanne Blivet, Grant N Martin, Grant W Martin, Leigh Myers, Josh Perry, Alan Perry, John Tapp, Lee Tippo and Dale Ruska. University of Queensland archaeology staff and students who participated on the project were Paddy Waterson, Jon Prangnell, Jill Reid, Melissa Carter, Vanessa Krueger and Toni Kriewaldt. Sean Ulm provided many hours of discussion about dates and other aspects of the Moreton Bay fishery. The analysis undertaken by Helene Tomkins would not have been possible without the training provided by Marshall Weisler, who imparted some of his vast knowledge and skill in the field of fish bone identification. Two anonymous referees provided some very useful comments on an earlier version of the manuscript, and the paper is much improved for their input. Linda Thompson and Jess Holland drafted the figures. Funding for the research came from a University of Queensland New Staff Grant and from the Australian Institute of Aboriginal and Torres Strait Islander Studies.

References

Alfredson, G., 1983. St Helena Island—a changing pattern of exploitation? *Australian Archaeology* 17: 79–86.

Allen, M.S., T. Ladefoged & J. Wall, 2001. Traditional Rotuman fishing in temporal and regional context. *International Journal of Osteoarchaeology* 11: 56–71.
doi:10.1002/oa.546

Bailey, G., 1999. Shell mounds and coastal archaeology in northern Queensland. In *Australian Coastal Archaeology*, ed. J. Hall & I. McNiven, pp. 105–112. Canberra: ANH Publications, Department of Archaeology and Natural History, Australian National University.

Barker, B., 1999. Coastal occupation in the Holocene: Environment, resource use and resource continuity. In *Australian Coastal Archaeology*, ed. J. Hall & I. McNiven, pp. 119–127. Canberra: ANH Publications, Department of Archaeology and Natural History, Australian National University.

Barker, T., & A. Ross, 2003. Exploring cultural constructs: the case of sea mullet management in Moreton Bay, south east Queensland, Australia. In *Putting Fishers' Knowledge to Work,* ed. N. Haggan, C. Brignall & L. Wood, pp. 290–305. *Fisheries Centre Research Reports* 11(1), University of British Columbia.

Barrett, J., 2005. Bone weight, meat yield estimates and cod (*Gadus morhua*): a preliminary study of the weight method. *International Journal of Osteoarchaeology* 3: 1–18.
doi:10.1002/oa.1390030102

Beaton, J., 1995. The transition on the coastal fringe of Greater Australia. *Antiquity* 69: 298–806. *Special number* 265.

Blake, T., 1993. *The leper shall dwell alone. Peel Island Lazaret Conservation Plan: A report for the Department of Environment and Heritage*. Brisbane: Department of Environment.

Bronk Ramsey, C., 2009. Bayesian analysis of radiocarbon dates. *Radiocarbon* 51(1): 337–360.

Casteel, R., 1971. Differential bone destruction: Some comments. *American Antiquity* 36(4): 466–469.
doi:10.2307/278467

Casteel, R., 1972. Some biases in the recovery of archaeological faunal remains. *Proceedings of the Prehistoric Society* 38: 382–388.

Coghill, S., & B. Coghill, 1998. Aboriginal use of fire on North Stradbroke Island. In video titled *Fire Management Today*, ed. A. Ross. St Lucia (Qld): VideoVision, University of Queensland.

Colley, S.M., 1990. The analysis and interpretation of archaeological fish remains. In *Archaeological Method and Theory 2*, ed. M.B. Schiffer, pp. 207–253. Tucson: The University of Arizona Press.

Durbridge, E., 1984. Aboriginal Middens, North Stradbroke Island. In *Focus on Stradbroke: New information on North Stradbroke Island and surrounding areas 1974–1984*, ed. R. Coleman, J. Covacevich & P. Davie, pp. 9–15. Brisbane: Boolarong Publications.

Durbridge, E., & J. Covacevich, 1981. *The Social Environment: North Stradbroke Island*. Amity Point (Qld): Stradbroke Island Management Organisation.

Edmonds, V.J., 1986, *Subtropical Rainforest: Archaeological evidence for Aboriginal use in the Border Ranges, southeast Queensland*. M.Litt. thesis, University of New England, Armidale.

Erlandson, J.M., 1994. *Early hunter-gatherers of the California coast*. New York: Plenum Press.

Frankland, K., 1990. *Booral: A preliminary investigation of an archaeological site in the Great Sandy Strait Region, southeast Queensland*. B.A. (Hons) thesis, University of Queensland, Brisbane.

Gordon, E., 1993. Screen size and differential recovery: a Hawaiian example. *Journal of Field Archaeology* 20(4): 453–460.
doi:10.2307/530074

Hall, J., 1980. Minner Dint: a recent Aboriginal midden on Moreton Island. *Occasional Papers in Anthropology* 10: 94–112.

Hall, J., 1982. Sitting on the crop of the bay: An historical and archaeological sketch of Aboriginal settlement and subsistence in Moreton Bay, southeast Queensland. In *Coastal Archaeology in Eastern Australia. Proceedings of the 1980 Valla Conference on Australian Prehistory*, ed. S. Bowdler, pp. 79–95. Canberra: Department of Prehistory, Australian National University. *Occasional Papers in Prehistory* 11.

Hall, J., 1984a. Exploratory excavation at Toulkerrie midden (LB:B75) Moreton Island, S.E. Queensland. *Queensland Archaeological Research* 1: 61–84.

Hall, J., 1984b. Fishing with Dolphins? Affirming a traditional Aboriginal fishing story in Moreton Bay, SE Queensland. In *Focus on Stradbroke: New Information on North Stradbroke Island and Surrounding Areas, 1974–1984*, ed. R.J. Coleman, J. Covacevich & P. Davie, pp. 16–22. Brisbane: Boolarong Press.

Hall, J., 1999. The impact of seal level rise on the archaeological record of the Moreton Region, southeast Queensland. In *Australian Coastal Archaeology*, ed. J. Hall & I.J. McNiven, pp. 169–184. Canberra: ANH Publications, Department of Archaeology and Natural History, Australian National University.

Hall, J., & G. Bowen, 1989. An excavation of a midden complex at the Toulkerrie Oystermens Lease, Moreton Island, S.E. Queensland. *Queensland Archaeological Research* 6: 3–17.

Hall, J., & R. Robins, 1984. A working model of Moreton Island prehistory: MRAP Stage 1. *Queensland Archaeological Research* 1: 85–94.

Hlinka, V., 2003. *Genetic Speciation of Archaeological Fish Bones*. Ph.D. thesis, University of Queensland, Brisbane.

Johnson, I., 1979. *The Getting of Data: A Case Study from the Recent industries of Australia*. Ph.D. thesis, Australian National University, Canberra.

Koon, H.E.C., R.A. Nicholson & M.J. Collins, 2003. A practical approach to the identification of low temperature heated bone using TEM. *Journal of Archaeological Science* 30(11): 1393–1399.
doi:10.1016/S0305-4403(03)00034-7

Lambeck, K., & J. Chappell, 2001. Sea level change through the Last Glacial cycle. *Science* 292(5517): 679–686.
doi:10.1126/science.1059549

McCormac, F.G., A.G. Hogg, P.G. Blackwell, C.E. Buck, T.F.G. Higham & P.J. Reimer, 2004. SHCAL04 southern hemisphere calibration, 0–11.0 cal. kyr bp. *Radiocarbon* 46: 1087–1092.

McNiven, I.J., 1990. *Prehistoric Aboriginal settlement and Subsistence in the Cooloola Region, coastal Southern Queensland*. Ph.D. thesis, University of Queensland, Brisbane.

McNiven, I.J., 1992. Sandblow sites in the Great Sandy Region, coastal southeast Queensland: Implications for models of late Holocene rainforest exploitation and settlement restructuring. *Queensland Archaeological Research* 9: 1–16.

Morse, K., 1999. Coastwatch: Pleistocene resource use on the Cape Range Peninsula. In *Australian Coastal Archaeology*, ed. J. Hall & I. McNiven, pp. 73–78. Canberra: ANH Publications, Department of Archaeology and Natural History, Australian National University.

Nagaoka, L., 1994. Differential recovery of Pacific Island fish remains: evidence from the Moturakau Rockshelter, Aitutaki, Cook Islands. *Asian Perspectives* 33: 1–17.

Nagaoka, L., 2005. Differential recovery of Pacific island fish remains. *Journal of Archaeological Science* 32: 941–55.
doi:10.1016/j.jas.2004.12.011

Neal, R., & E. Stock, 1986. Pleistocene occupation in the south-east Queensland coastal region. *Nature* 323: 618–621.
doi:10.1038/323618a0

O'Connor, T., 2008. *The Archaeology of Animal Bones.* College Station: Texas A & M University Press.

O'Neil, D.H., 1993. Excavation sample size: A cautionary tale. *American Antiquity* 58(3): 523–529.
doi:10.2307/282111

Petrie, C.C., 1904. *Tom Petrie's Reminiscences of Early Queensland*. Brisbane: Watson, Ferguson and Co.

Ponosov, V.V., 1965. *Results of an Archaeological survey of the southern region of Moreton Bay and Moreton Island (1963–1964)*. Report to Department of Psychology, University of Queensland, Brisbane.

Prangnell, J. M., 1999. *'Intended solely for their greater comfort and happiness': historical archaeology, paternalism and the Peel Island Lazaret.* Ph.D. thesis, University of Queensland, Brisbane.

Quandamooka, 1997. Quandamooka Submission to the Moreton Bay Task Force. Appendix 1. In *Queensland Fisheries Management Authority Moreton Bay Fishery Discussion Paper No. 6*, pp. 127–133. Brisbane: Moreton Bay Task Force and Queensland Department of Primary Industries.

QFMA, 1997. *Queensland Fisheries Management Authority Moreton Bay Fishery Discussion Paper No. 6*, pp. 127–133. Brisbane: Moreton Bay Task Force and Queensland Department of Primary Industries.

Reimer, P. J., M.G.L. Baillie, E. Bard, A. Bayliss, J.W. Beck, P.G. Blackwell, C. Bronk Ramsey, C.E. Buck, G.S. Burr, R.L. Edwards, M. Friedrich, P.M. Grootes, T.P. Guilderson, I. Hajdas, T.J. Heaton, A.G. Hogg, K.A. Hughen, K.F. Kaiser, B. Kromer, F.G. McCormac, S.W. Manning, R.W. Reimer, D.A. Richards, J.R. Southon, S. Talamo, C.S.M. Turney, J. van der Plicht, & C.E. Weyhenmeyer, 2009. IntCal09 and Marine09 radiocarbon age calibration curves, 0–50,000 years cal. bp. *Radiocarbon* 51(4): 1111–1150.

Rick, T.C., & J.M. Erlandson, 2000. Early Holocene fishing strategies of the California Coast: evidence from CA-SBA-2057. *Journal of Archaeological Science* 27: 621–633.
doi:10.1006/jasc.1999.0493

Rick, T.C., J.M. Erlandson M.A. Glassow, & M.L. Moss, 2002. Evaluating the economic significance of sharks, skates, and rays (Elasmobranchs) in prehistoric economies *Journal of Archaeological Science* 29: 111–122.
doi:10.1006/jasc.2000.0637

Ross, A., & S. Coghill, 2000. Conducting a community-based archaeological project: an archaeologist's and a Koenpul man's perspective. *Australian Aboriginal Studies* 2000/1&2: 76–83.

Ross, A., & R. Duffy, 2000. Fine mesh screening of midden material and the recovery of fish bone: The development of flotation and deflocculation techniques for an efficient and effective procedure. *Geoarchaeology* 15(1): 21–41.
doi:10.1002/(SICI)1520-6548(200001)15:1<21::AID-GEA2>3.0.CO;2-L

Ross, A., & Quandamooka Land Council, 1996a. Aboriginal approaches to cultural heritage management: a Quandamooka case study. In *Australian Archaeology '95: Proceedings of 1995 Australian Archaeological Association Conference*, ed. S. Ulm, I. Lilley & A. Ross. *Tempus*. 6: 107–112.

Ross, A., & Quandamooka Land Council, 1996b. Quandamooka perspectives on cultural heritage. *In Place* 2: 1,5–6.

Shaffer, B.S., & J.L.J. Sanchez, 1994. ¼"-mesh recovery of controlled samples of small- to medium-sized mammals. *American Antiquity* 59(3): 525–530.
doi:10.2307/282464

Smith, M., 1999. Southwest Australian coastal economies: A new review. In *Australian Coastal Archaeology*, ed. J. Hall & I. McNiven, pp. 15–24. Canberra: ANH Publications, Department of Archaeology and Natural History, Australian National University.

Stuiver, M., & T.F. Braziunas, 1993. Modeling atmospheric ^{14}C influences and ^{14}C ages of marine samples to 10,000 BC. *Radiocarbon* 35(1): 137–189.

Stuiver M., & P.J. Reimer, 1993. Extended ^{14}C data base and revised CALIB 3.0 ^{14}C age calibration program. *Radiocarbon* 35(1): 215–230.

Stuiver, M., P.J. Reimer & T.F. Braziunas, 1998. High-precision radiocarbon age calibration for terrestrial and marine samples. *Radiocarbon* 40: 1127–1151.

Telford, R.J., E. Heegaard & H.J.B. Birks, 2004. The intercept is a poor estimate of a calibrated radiocarbon age. *The Holocene* 14(2): 296–298.
doi:10.1191/0959683604hl707fa

Ulm, S., 1995. Fishers, Gatherers and Hunters on the Moreton Fringe: Reconsidering the Prehistoric Aboriginal marine fishery in southeast Queensland, Australia. B.A. (Hons) thesis, University of Queensland, Brisbane.

Ulm, S., 2002. Reassessing marine fishery intensification in Southeast Queensland. *Queensland Archaeological Research* 13: 79–96.

Ulm, S., F. Petchey & A. Ross, 2009. Marine reservoir corrections for Moreton Bay, Australia. *Archaeology in Oceania* 44(3): 160–166.

Vale, D., & R.H. Gargett, 2002. Size matters: 3-mm sieves do not increase richness in a fishbone assemblage from Arrawarra I, an Aboriginal Australian shell midden on the mid-north coast of New South Wales, Australia. *Journal of Archaeological Science* 29(1): 57–63.
doi:10.1006/jasc.2001.0704

Veitch, B., 1999. Shell middens on the Mitchell Plateau: A reflection of a wider phenomenon? In *Australian Coastal Archaeology*, ed. J. Hall & I. McNiven, pp. 51–64. Canberra: ANH Publications, Department of Archaeology and Natural History, Australian National University.

Walters, I., 1979. *Information Loss in Zooarchaeology: A study of vertebrate remains from two middens, Moreton Island, Queensland*. B.A. (Hons) thesis, University of Queensland, Brisbane.

Walters, I., 1986. *Another Kettle of Fish: the prehistoric Moreton Bay fishery*. Ph.D. thesis, University of Queensland, Brisbane.

Walters, I., 1989. Intensified fishery production at Moreton Bay, southeast Queensland, in the late Holocene. *Antiquity* 63: 215–224.

Walters, I., 1992a. Seasonality of marine fishing in south-east Queensland. *Queensland Archaeological Research* 9: 29–34.

Walters, I., 1992b. Antiquity of marine fishing in south-east Queensland. *Queensland Archaeological Research* 9: 35–37.

Walters, I., 2001. The Aboriginal Moreton Bay fishery: Two things I still know—A response to Ross and Coghill. *Australian Aboriginal Studies* 2: 61–62.

Walters, I., P. Lauer, A. Nolan, G. Dillon & M. Aird, 1987. Hope Island: salvage excavation of a Kombumerri Site. *Queensland Archaeological Research* 4: 80–95.

Waselkov, G.A., 1984. Shellfish Gathering and Shell Midden Archaeology. *Advances in Archaeological Method and Theory* 10: 93–210.

Weisler, M.I., 1993. The importance of fish otoliths in Pacific Island archaeofaunal analysis. *New Zealand Journal of Archaeology* 15: 131–159.