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Late Quaternary Aboriginal hunter-gatherer occupation of the Greater Swan Region, south-western Australia

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ABSTRACT

The Greater Swan Region is an archaeological study area on the Indian Ocean coast in south-western Australia. It covers the central Swan Coastal Plain and the adjacent part of the formerly emergent Rottnest Shelf. Assessment of Aboriginal hunter-gatherer activity throughout this late Quaternary coastal landscape is based on dated records of open-air sites within their environmental settings, informed by historical accounts of mainland subsistence activities. Artefacts flaked from Eocene fossiliferous chert and other stone, identified, in situ, in dated dune soils on the mainland and in palaeosols and Tamala Limestone successions on Rottnest Island, show that during regressive sea levels human groups were distributed across a sand plain reaching from the Darling Scarp 70 km westward across the emergent Rottnest Shelf. On the mainland, open-air site settings near freshwater sources and terrestrial and estuarine habitats give insight into adaptive strategies of Aboriginal occupiers. A similar occupation pattern is proposed for the emergent shelf. Early Holocene records of terrestrial plant species and freshwater microfauna from Barker Swamp on Rottnest Island imply that freshwater sources and terrestrial habitats were comparable to those of the mainland. Further archaeological investigations on the Rottnest Shelf should include extant and former freshwater swamps on Rottnest Island.

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Aboriginal occupation; aeolianite; palaeosols; late quaternary; Greater swan region

Introduction

This paper assesses late Quaternary Aboriginal hunter-gatherer occupation patterns throughout the 'Greater Swan Region' (GSR) – an archaeological study area on the Indian Ocean coast of south-western Australia covering the central Swan Coastal Plain and the adjacent part of the formerly emergent Rottnest Shelf (Figure 1). The assessment is based on dated occupation sites within their environmental settings, informed by historic European and Aboriginal accounts of mainland Aboriginal coastal economies. The study takes in the range of physical settings historically occupied by coastal Aboriginal groups and evaluates previous settings in areas now offshore. The GSR covers a 60 km wide front from the Darling Escarpment 70 km westward to the continental shelf edge (Figure 1; Dortch and Dortch 2012). Its mainland portion – now part of the Perth Metropolitan Region – largely overlaps Hallam's original survey transect (Hallam 1987). During regressive sea levels, Aboriginal populations had access across a coastal sandplain more than twice its 30 km width today. Dated evidence for this access consists of flaked stone artefacts identified in situ in dune soils on the mainland and palaeosols on Rottnest Island and is supported by undated finds of artefacts on the mainland and on Rottnest and Garden Islands.

Late Quaternary physical setting

The mainland portion of the study area is a representative sector of the Swan Coastal Plain of which its exceptional feature is the Swan River Estuary (Figure 1). Three dune systems are defined across this sand plain, marked from west to east by an increase in biologically diverse terrestrial habitats (McArthur 1991). The youngest of these systems – the Quindalup Dunes – consists of white shelly sands of late Holocene to modern age, formed directly on the sea coast. Next is the Spearwood Dune System, developed during the late Quaternary, and featuring flaked stone artefacts, in situ, in dune soils overlying Tamala Limestone, a major Upper Pleistocene lithostratigraphic unit developed along the littoral and submerged continental shelves on the Indian and Southern Ocean coasts of south-western Australia (Playford et al. 1976, 2013). The third and oldest set of dune soils is the Bassendean Dune System, where many of the study area's

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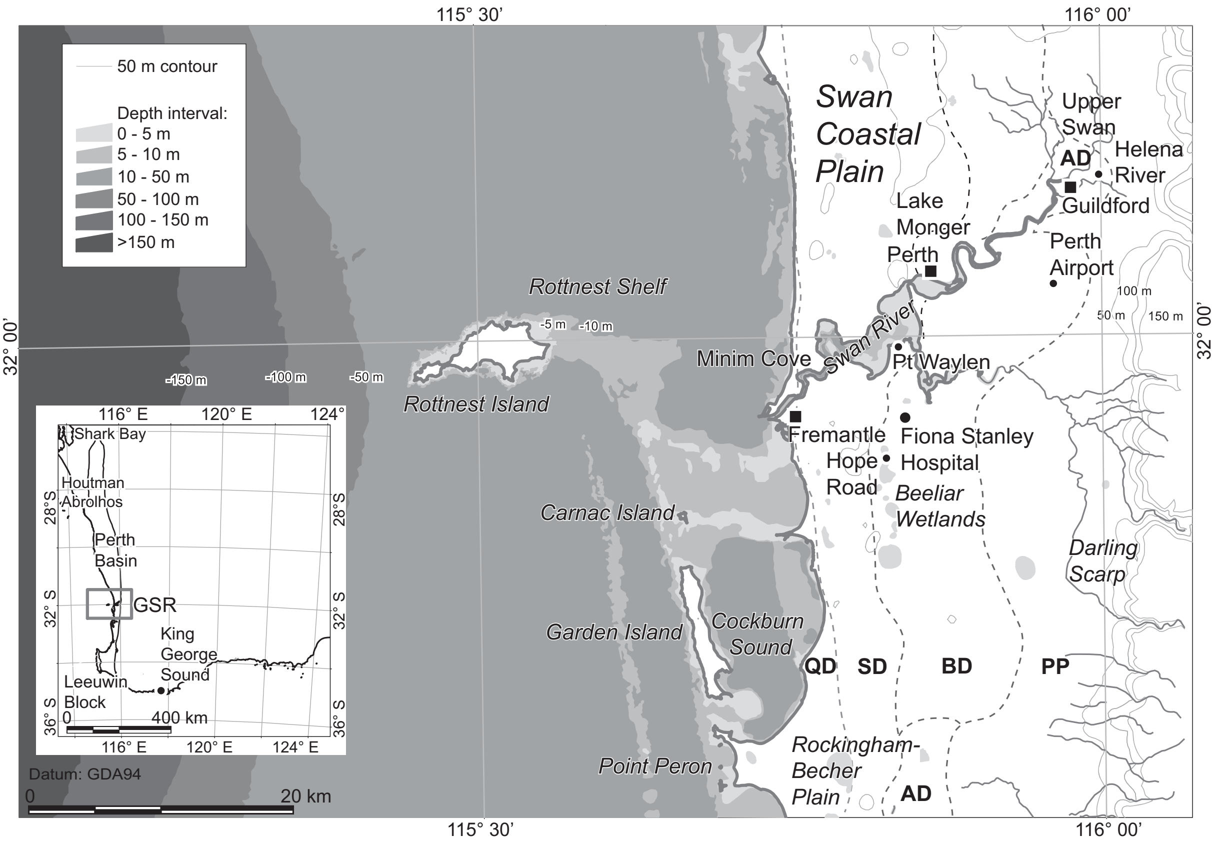

Figure 1. Greater Swan Region, showing localities and sites. Inset: South-western Australia. QD: Quindalup Dunes; SD: Spearwood Dunes; BD: Bassendean Dunes; PP: Pinjarra Plain; AD: Alluvial Deposits.

pre-European, former occupation sites are recorded (Hallam 1987). The soils in the Bassendean system are deeply weathered quartz sands in which the carbonate component has been leached away. Between the Bassendean sands and the Darling Scarp are alluvial and colluvial deposits, the latter termed the Pinjarra Plain (McArthur 1991). The Swan River Estuary, passing through all these land divisions, is estuarine upstream to the foot of the Darling Scarp.

The offshore portion of the GSR is part of the Rottnest Shelf, centred on Rottnest Island (Collins 1988; Nicholas et al. 2013). Remote survey and physical sampling indicate that during Pleistocene low sea levels the shelf was carbonate sand plain featuring on its seaward edge a dune barrier, and eastward a succession of dune ridges aligned along former shorelines. Today's limestone reefs and islands are relicts of the coastal dune barrier (Brooke et al. 2010, 2014; Nicholas et al. 2013, 2014; Playford 1997). A few kilometres north of the Rottnest pre-island locality, the ancestral Swan River Estuary traversed the emergent shelf before entering the Perth Canyon incised into the shelf edge (Playford 1983:14). Rottnest, Carnac and Garden Islands were isolated with rising sea level reaching present height about 6.5 ka (Churchill 1959; Playford 1983, 1988, 1997). There is no evidence that Rottnest Island was occupied by mainland Aboriginal groups following its formation about 6.5 ka (see below). Rottnest Island is known to Nyoongar Aboriginal people today as *Wadjemup* – a name transcribed in the first decade of European colonisation (Lyon 1833:64). A Nyoongar traditional story related to colonist George Fletcher Moore in this same decade tells how the offshore islands became separated from the mainland (Moore 1978 [1884]).

Fresh water and other resources

Some 10 km inland from the coast, the onshore sand plain is marked by freshwater lakes and wetlands, rich in aquatic foods (Hallam 1987). Taking into account periodic east-west shifts in the positions of different plant associations, mainly in response to changes in precipitation, pollen sequences covering the past 40 ka in the central Swan Coastal Plain indicate that eucalypt, banksia and casuarina woodlands and melaleuca-fringed wetlands were present during the late Quaternary similar to those of today (Newsome and Pickett 1993; Pickett 1997). The emergent Rottnest Shelf was presumably vegetated and interspersed with wetlands and freshwater lakes, a probable example being the terminal Pleistocene–early Holocene lagoon delineated by the 10 m contour in the centre of Cockburn Sound

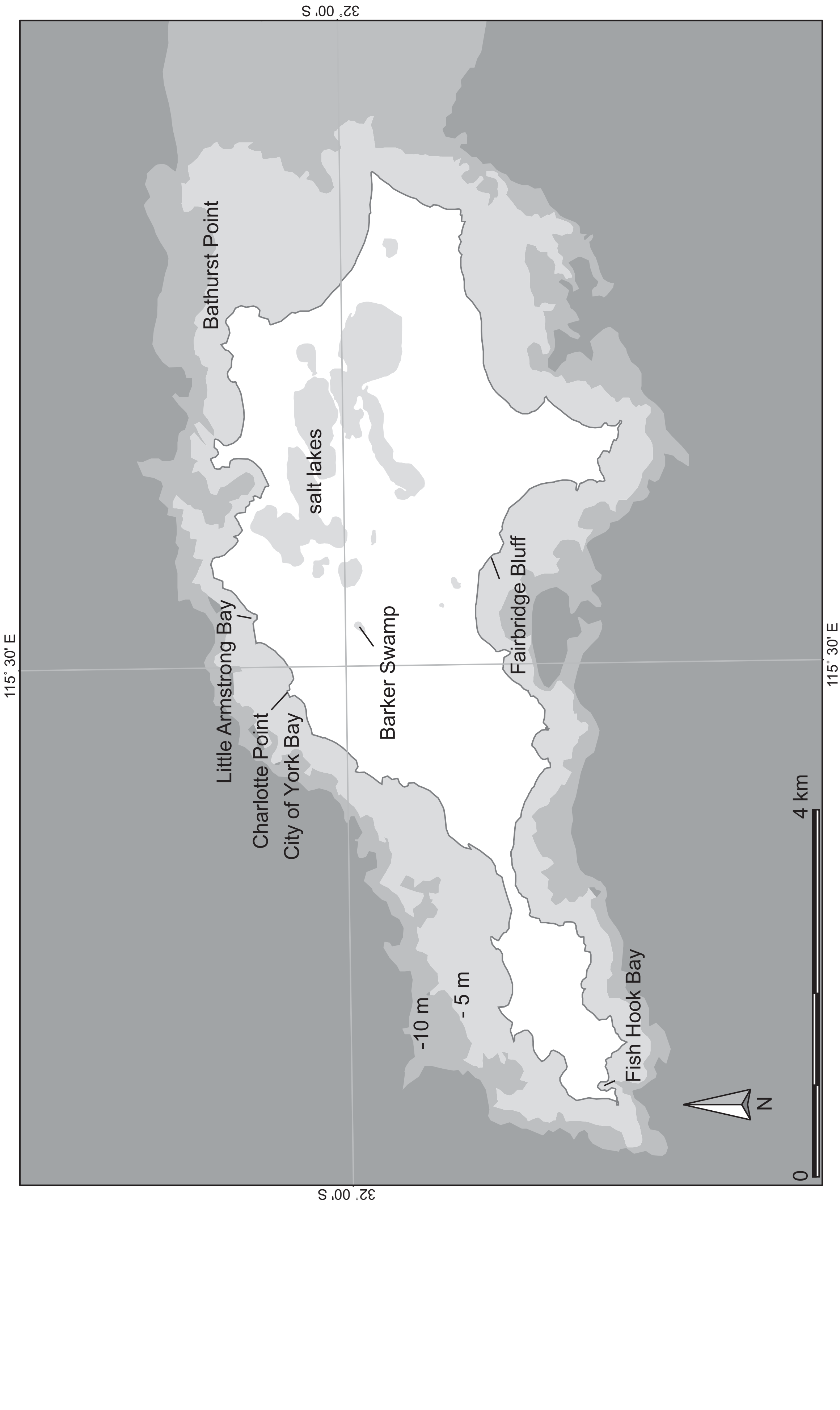

Figure 2. Rottnest Island with artefact find sites and other places mentioned in the text.

(Figure 1; Churchill 1959: Figure 2). In its 'pre-island' stage and as a newly formed island, Rottnest offered fresh water in woodland and shrubland settings, as shown by pollen and freshwater microfauna identified in dated cores of Holocene age at Barker Swamp (Figure 2; Backhouse 1993; Gouramanis et al. 2012). The island's present-day salt lakes are karst features that during glacio-eustatic low sea levels were probably freshwater sources (Dortch and Hesp 1994:31; Playford 1997:786, 1983:10).

Site interpretation

The material evidence for pre-European Aboriginal occupation in the GSR consists almost entirely of flaked stone artefacts, mainly chert, quartz, and other siliceous rocks. Other evidence includes isolated burials and stone manuports. The region's 674 recorded mainland archaeological sites include 609 concentrations of artefacts, both surface and subsurface (Department of Planning, Lands and Heritage 2018), which are interpreted as former open-air campsites (e.g. Hallam 1972). None of these sites has food remains or structures (e.g. hearths or fish traps) connected with past subsistence. Past Aboriginal subsistence patterns are inferred from site distributions relative to exploitable habitats, with reference to historic accounts of regional Nyoongar hunter-gatherer subsistence activities (Anderson 1984; Dortch 2002; Hallam 1972, 1975, 1987; Meagher 1974; Smith 1999). These accounts show that traditional Nyoongar economy was based on the systematic exploitation of largely seasonally available resources in coastal and adjacent inland districts, particularly in and around wetlands. These districts formed contiguous, permeable dialect group territories making up the Nyoongar language region or cultural bloc (Dortch 2002). Local biodiversity and the adaptability of the Nyoongar economy meant year-round availability of most foods, with seasonal abundances and occasional shortages. As noted above the environmental opportunities supporting this economy possibly held throughout much of the period of human occupation.

Eocene fossiliferous chert

For 20 ka or longer, Eocene fossiliferous chert was much used for artefacts along the Indian Ocean coast of south-western Australia, i.e. the Perth Basin and adjacent Leeuwin Block (Figure 1; Dortch 2004; Glover 1984: Figure 1; Playford et al. 1976). This distinctive chert, which features marine microfossils of Eocene age, has yet to be identified in any sources (Glover 1984). The stone ceased to be used 1–2 ka after sea level reached its present position c.6.5 ka (Ferguson 1980; Pearce 1978). Geochemical differences detected in fossiliferous chert artefacts sampled from 78 archaeological sites broadly dispersed along this 700 km littoral support the view that fossiliferous chert outcrops were once widely accessible (Glover and Lee 1984). This supposition is now questioned by claims that (1) the geochemical composition of some of the original 78 samples does not vary as claimed; (2) nowhere on the Indian Ocean coast were fossiliferous chert sources accessible to tool makers; and (3) the chert artefact assemblages on this coast probably derive from sources of very similar stone on the Nullarbor Plain c.1200 km to the east (O'Leary et al. 2017).

In the absence of conclusive evidence for any particular source, we judge localised sources as more likely. Collecting chert from outcrops formerly exposed a few kilometres offshore the present coast (or prior to dune formation on the littoral, Pearce 1978) is the simplest explanation for the presence of abundant assemblages at archaeological sites all along the western littoral. Irrespective of the source – whether <20 km to the west, 1200 km to the east, or both – artefacts flaked from fossiliferous chert are a distinctive feature of late Pleistocene and early Holocene sites on the Swan Coastal Plain (Clarke and Dortch 1977; Dortch and Dortch 2012; Ferguson 1980; Hallam 1987; Pearce 1978), in the Leeuwin-Naturaliste Region (Dortch 1979; 2004; Ferguson 1981) and along the Southern Ocean coast (Dortch and Gardner 1976; Dortch and Morse 1984; Smith 1993). The material is also represented by a single flake in the Houtman Abrolhos, last connected to the mainland during the late Pleistocene (Figure 1; Marwick 2002). The decreasing occurrence and then disappearance of fossiliferous chert artefacts in mainland sites dated from the middle to late Holocene supports the argument that this distinctive stone was regionally available only when the shelf was emergent.

Late Quaternary sites in mainland geomorphic zones

Here we review the oldest dated artefact find sites within the Spearwood and Bassendean Dune Systems and the Pinjarra Plain in the mainland portion of the GSR (Table 1, Figure 1). As a result of poor preservation and survey bias, the Quindalup Dune System generally lacks dated pre-European archaeological evidence (Hallam 1987: Table 1). All dates presented below are given as calibrated ages calculated using the OxCal SH13 curve (see Table 1 for the original uncalibrated ages).

Table 1. Dates for stone artefacts in situ in dune sands and palaeosols in the Greater Swan Region, south-western Australia (Figure 1).

Site	Stratigraphic setting	Laboratory code	Method	Nature of sample	Age (BP)	Calibrated age (ka)	Archaeological evidence	Environment	Reference
Mainland									
Minim Cove	Artefact-bearing Spearwood dune soil on eroded Tamala Limestone	SUA 454	^{14}C	Charcoal	9,930 ± 130	11.4 ± 0.5	Quartz and fossiliferous chert artefacts, including 16 in dated profile	Spearwood System dune overlooking Swan River	Clarke and Dortch 1977
Mandurah Road (Rockingham-Becher Plain)	Estuarine / marine shelly sand cut into artefact-bearing Spearwood dunes	GX 12906	^{14}C	Bivalve shell (*Katelysia* sp.)	8,365 ± 375 (C13 corrected)	9.3 ± 0.9	One quartz artefact and one fossiliferous chert artefact	Spearwood System dunes within 1 km of coastal plain lakes	Searle et al. 1988: Table 2, Figure 8
Fiona Stanley Hospital	Bassendean dune containing artefacts (lowermost same depth as Wk 24525)	Wk 24524 Wk 24894 Wk 24525	^{14}C ^{14}C - AMS ^{14}C - AMS	Charcoal Charcoal Charcoal	8,467 ± 284 13,826 ±60 31,201 ±385	9.4 ± 0.75 16.7 ±0.25 35.1 ±0.75	Quartz, fossiliferous chert, mylonite and granite artefacts, including two artefacts in dated profile	Bassendean System dunes within 1 km of Beeliar wetlands	Dortch et al. 2009; Dortch and Dortch 2012
Perth Airport: Adelaide St	Bassendean dune containing artefacts W4754-47755 from trench TPX02; remainder from trench TPX08	W4754 W4755 W4756 W4757 W4758 W4759	TL TL TL TL TL TL	Quartz sand	NA NA NA NA NA NA	12.0±1.4 19.6 ±2.6 24.4 ±2.9 22.4 ±2.6 35.0 ±2.8 28.4 ±2.8	Quartz, fossiliferous chert, and granite artefacts, including 1,247 artefacts in dated trenches	Bassendean System dunes within 1 km of wetlands	Mattner et al. 2014
Rottnest Island									
Charlotte Point	Artefact-bearing palaeosol intercalated with aeolianite	GU8.5 GU8.6 Wk 37948	SG OSL SG OSL ^{14}C	Calcareous sand Charcoal	NA NA Not reported	12.7±1.25 12.1±1.01 10.3±0.06	Fossiliferous chert artefact	Palaeosol in Tamala Limestone ridge overlooking coastal plain	Ward et al. 2016: Table 1
Little Armstrong Bay	Upper part of artefact-bearing palaeosol intercalated with aeolianite: GU8.4 same depth as chert tool	GU8.3 GU8.4	Single grain OSL Single grain OSL	Calcareous sand with quartz grains	NA NA	12.6±1.1 16.8±1.59	Fossiliferous chert artefact	Palaeosol in Tamala Limestone ridge overlooking coastal plain	Ward et al. 2016: Table 1
		CURL-16668	^{14}C - AMS	Emu eggshell	Not reported	28.2±0.18			
Bathurst Point	Surface of breccia calcrete cut block in which chert artefact is embedded	P 2.2	U-series	Calcium carbonate cement	NA	17.1±0.85	Fossiliferous chert artefact	Tamala Limestone ridge overlooking coastal plain	Ward et al. 2016: Table 1
	Base of breccia calcrete cut block in which chert artefact is embedded	R11/K0034	Single grain OSL	Breccia calcrete with quartz grains	NA	42.0±2.7			Ward et al. 2016: Table 1
City of York Bay	Palaeosol containing feldspar pebble (gastrolith or manuport)	R5/K0022	Single grain OSL	Sand	NA	49.1±3.3	Feldspar pebble (manuport)	Palaeosol in Tamala Limestone ridge overlooking coastal plain	Dortch and Hesp 1994:25–26; Ward et al. 2016: Table 1
Fish Hook Bay	Charcoal concentration in palaeosol in sea cave, associated with quartz pebble (gastrolith or manuport)	SUA 3030	^{14}C	Charcoal	18,660±250	22.5±0.6	Quartz pebble (manuport)	Palaeosol in Tamala Limestone ridge overlooking coastal plain	Dortch and Hesp 1994:27–28

AMS: Accelerator Mass Spectrometry.
Samples in each site are listed in stratigraphic order from uppermost to lowermost. Radiocarbon ages were calibrated using the OxCal SH13 curve (Bronk Ramsey 2009); errors are at 2 sigma; radiocarbon years are not applicable (NA) for OSL, TL and U-series dates.

Spearwood Dune System

Minim Cove

A radiocarbon date implying a minimum age of 11.4 ka for fossiliferous chert artefacts in situ in the Spearwood Dunes comes from Minim Cove, Mosman Park (Clarke and Dortch 1977). In 1975, archaeologists from the Western Australian Museum (WAM) excavated a 1.5 m^2 test pit in a two-metre deep deposit of undisturbed, uniformly mottled, yellow quartz sand infilling an irregular calcarenite (aeolianite) surface of pinnacles and solution pipes. These limestone formations are covered by a thin veneer of secondarily cemented calcium carbonate, suggesting that the enveloping quartz sand unit in-filled a deflated Tamala Limestone exposure typically featuring pinnacles and solution pipes. Two fossiliferous chert chips cemented to vertical faces within this calcium carbonate veneer substantiate the excavators' view that the artefact-bearing dune soil accumulated on the calcarenite and is not a leached residual (Clarke and Dortch 1977:38). The charcoal sample dated 11.4 ka is 40 cm above 14 fossiliferous chert flakes and two quartz flakes, suggesting occupation began earlier than the reported date.

Mandurah road

Three fossiliferous chert artefacts were located *in situ* within Spearwood Dunes in road cuttings along the eastern shoulder of the north-south running Mandurah Road, east of Lakes Cooloongup and Walyungup (C. Dortch, unpublished field notes). A sample of marine molluscs (cockle shells: *Katelysia* sp.) in situ in shelly marine beach sands abutting this Spearwood dune soil – which rests on Tamala Limestone – indicates a calibrated age of 9.3 ka showing that post-glacial sea level rise had brought the marine shoreline to this position at that time (Searle et al. 1988: Table 2). This date suggests an early Holocene or terminal Pleistocene age for the chert artefacts buried within the older Spearwood Dune soil. Searches in the deflated dunes around the two lakes and in the prograded beach ridges covering c.5 km between the lakes and the present coast (i.e. the Rockingham-Becher Plain: Searle et al. 1988) revealed no stone artefacts.

Point Peron

Immediately west of the Rockingham-Becher Plain is the Tamala Limestone headland of Point Peron, where three fossiliferous chert artefacts lie within orange-brown soils of Spearwood type in-filling solution pipes and pinnacles exposed along the shoreline cliffs. A fourth fossiliferous chert artefact is embedded in a horizontal cemented carbonate unit in the Tamala Limestone at this site. Regrettably, this once datable find is now buried beneath a concrete slab poured sometime after its identification. No stratigraphic association can be established between the three fossiliferous chert artefacts mentioned above and a sand sample from the same site with a thermoluminescence (TL) date of c.78 ka (Price et al. 2001: Table 2). The four fossiliferous chert flakes from Point Peron, along with artefacts of this stone exposed in railway cuttings in Spearwood dunes overlooking the sea at Mosman Park (Clarke and Dortch 1977) are the sole finds on the mainland seacoast of the GSR.

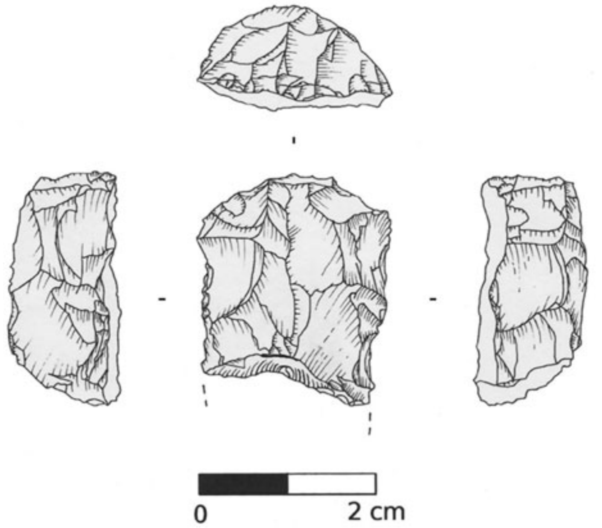

Figure 3. Four views of a mylonite adze flake, Bassendean Dunes (Fiona Stanley Hospital). The top view shows front of heavily used, adze working edge. Central lower view indicates that the truncated end consists of a single negative flake scar, with edge-damage consistent with subsequent use as a tool (Illus. François Mazieres).

Bassendean Sands

Fiona Stanley Hospital

The two younger of three radiocarbon dates on charcoal samples collected from a 1 m^2 test-pit in the Bassendean Dune System provide a minimum age for a single stone tool (Figure 3) found in situ, depth c.150 cm below the original ground surface, in a well-sorted quartz sand dune overlooking wetlands (Dortch et al. 2009). The retouched tool is made of mylonite, a chert type outcropping in the Darling Scarp minimally 17 km east of the find site. The youngest date, c.9.4 ka, is from 40 cm higher up in the deposit; the second date, c.16.7 ka, is 20 cm higher than the tool's find position, and the third date, c.35.1 ka, is the same depth and position as the tool and suggests its true age. A large fossiliferous chert flake (length 8 cm – the largest recorded on the Swan Coastal Plain) and 48 other fossiliferous chert and quartz flakes and cores were identified in grader cuttings in this dune and at lower elevations within 100 m of the test excavation. The nearby presence of undated fossiliferous chert artefacts implies a late Quaternary age for this dune soil; like the mylonite tool, they indicate group movements or interaction within the GSR.

The mylonite retouched tool is interpreted as an adze flake (i.e. a hafted tool), based on morphology and use-flaking. It has been truncated by a single blow against its bulbar face. Its lower right-hand corner shows edge-wear consistent with its having been used as a tool after this event (Figure 3). This specimen could conceivably contribute to the continental record of considerable antiquity for the hafting of stone tools (e.g. Hamm et al. 2016; McDonald et al. 2018; Mulvaney and Kamminga 1999).

Perth Airport

Some of the most prolific mainland sites recorded are in Bassendean Sands near wetlands in the Perth Airport estate, covering c.3,000 ha in the eastern part of the study area (Figure 1). Some 50 sites have been identified since surveys began in the 1970s (Anderson 1984). The artefact assemblages include fossiliferous chert artefacts, late Holocene tool types (e.g. microliths) and flaked historic glass, indicating continuity in site use (Anderson 1984:19, 24). At one site, 'Adelaide Street', 1,247 stone artefacts were recovered from 100 cubic metres of excavated sediment (Mattner et al. 2014). Artefacts were concentrated in several locations, suggesting former activity areas. Similar concentrations have been reported from other excavations in the airport grounds, though no other dates are yet available. Finding no charcoal, the excavators at Adelaide Street undertook TL dating of six bulk sand samples, inferring an age range for occupation from c.35 to 12 ka (Table 1). A dating reversal between the lowermost two samples in trench TPX08 is possibly explained by variations in background dosage at lower depths. The sequence of remaining TL dates in broad stratigraphic order suggests the preservation of a chronostratigraphic sequence, among the oldest recorded in the GSR.

Pinjarra plain

This innermost geomorphic zone in the study area consists of alluvial clay-rich soils (Hallam 1987:19–20; McArthur 1991:26). Bowdler et al. (1991:24) label this geomorphic zone 'Alluvial Deposits', and affirm its archaeological research potential. Dated charcoal associated with artefacts at the Helena River site (Schwede 1983) could be as old as 29 ka, while the Upper Swan site – 15 km north of the GSR study area – has produced a date of 38 ka (Pearce and Barbetti 1981). Despite justifiable concerns about the reliability of the associations of artefacts and dated charcoal at Upper Swan (Bowdler et al. 1991:24; Mulvaney and Kamminga 1999:138), the dates from this site are in broad stratigraphic order, and some of the flaked quartz, quartzite and chert artefacts from the same depositional units can be re-fitted, indicating some degree of stratigraphic integrity.

Mainland summary

The mainland distribution of dated open-air, artefact find spots relative to wetlands and other exploitable habitats offers insight into the adaptive strategies of hunter-gatherer groups from late Quaternary times to the historic era (Table 1). Except possibly for Minim Cove, all the sites reviewed above were occupied repeatedly during this prolonged time period.

Late Quaternary stone artefact find sites on the Rottnest Shelf

The archaeological evidence recorded on the Rottnest Shelf consists of isolated fossiliferous chert and calcrete artefacts on Rottnest and Garden Islands, and one quartz flake identified on the latter (Figure 1; Dortch 1991; Dortch and Dortch 2012; Dortch and Hesp 1994; Dortch and Morse 1984).

Rottnest Island

Upper Pleistocene geochronology

The absolute chronology for Rottnest Island's constituent Tamala Limestone (c.140 to 10 ka) is based on about 40 mostly optically stimulated luminescence (OSL) dates from several widely-distributed localities along the island littoral (Brooke et al. 2014; Ward et al. 2016), which accord with earlier TL and other datings (Price et al. 2001). The oldest OSL date (c.140 ka, for aeolianite at Fairbridge Bluff) is consistent with isotopic and TL dates giving a last interglacial age for the Rottnest Limestone (Price et al. 2001; Stirling et al. 1995, 1998; Szabo 1979), which is a fossil coral reef intercalated with Tamala Limestone at this site (Playford 1988, 1997). During the early to middle Holocene, transgressive seas cut cliffs and headlands into the newly forming island's limestone hills and ridges.

All the late Pleistocene luminescence and isotopic dates in Table 1, and most of those in Ward et al. 2016: Table 1 are significantly younger than the nearly 100 age estimates produced by whole-rock amino acid racemisation (AAR) assay of the same

Figure 4. Charlotte Point, Rottnest Island: artefact-bearing palaeosol intercalated within aeolianite units. Chert artefact find spot is behind person's lower legs. Photo Ron Priemus, Rottnest Island Authority (RIA).

Figure 5. Sea-cut Tamala Limestone cliff face at artefact find site at Little Armstrong Bay, Rottnest Island (cf. Ward et al. 2016:Figure 2C). The person at the cliff base is pointing at the artefact-bearing palaeosol (Figure 6). The palaeosol is bounded top and bottom by aeolianite units. Mainland coast is visible on the horizon. Photo Mark Ward, RIA.

Figure 6. Eocene fossiliferous chert tool in situ in palaeosol section at Little Armstrong Bay (Figure 5). Modern graffiti is incised in the section face. Photo Reg Yarran, RIA.

units within the island's Tamala Limestone successions (Hearty 2003). Acceptance of the whole-rock AAR chronology for these successions, including the two oldest of the three sites noted below in which chert artefacts are in situ within intercalated palaeosols (Charlotte Point, Little Armstrong Bay and Bathurst Point), would connote absolute ages for human presence on Rottnest Island far earlier than the oldest dated Australian archaeological sites (e.g. O'Connell and Allen 2015). Brooke et al. (2014:120) critically review discrepancies between whole-rock AAR and luminescence (mainly OSL) chronologies for the Tamala Limestone on Rottnest Island and the adjacent mainland, as do Playford et al. (2013:102–103) for similarly contrasting chronologies at Shark Bay c.700 km to the north.

Flaked stone artefacts

Six fossiliferous chert artefacts and four calcrete artefacts are recorded from the island. Three of the fossiliferous chert artefacts were identified in situ in dated, late Quaternary palaeosols intercalated within Tamala Limestone successions at Charlotte Point, Little Armstrong Bay and Bathurst Point (Table 1). Ward et al. (2016: Table 1; Figure 2) provide stratigraphic sections for these three sites, showing provenances of the artefact finds and the sand, calcrete and other samples mostly dated by OSL measurements, both single-grain (SG) and single aliquot (SA) assay.

Charlotte Point and Little Armstrong Bay

OSL dates for two artefact-bearing palaeosol units at Charlotte Point and Little Armstrong Bay (Figures 4 and 5) range from 16.8 to 12.1 ka (Table 1). A radiocarbon date 10.3 ka for charcoal in the palaeosol at Charlotte Point may represent plant growth or roots burning within the sediment before cementation.

The artefact-bearing palaeosol at Little Armstrong Bay has two OSL dates – 12.6 and 16.8 ka – the younger for a sample from just above, and the older from the same depth as, the chert tool shown in situ in Figure 6. This palaeosol yielded the first vertebrate fossil find identified on Rottnest Island: a fragment of emu eggshell (*Dromaius novaehollandiae*) in situ at the same depth as the chert tool. Radiocarbon dated to c.28.2 ka, this eggshell

Figure 7. Bathurst Point East section (Eocene fossiliferous chert artefact find site), Rottnest Island, photographed from offshore (Ward et al. 2016: Figure 2(B)). Person is standing on breccia calcrete pavement 50 cm behind the find position of the Eocene fossiliferous chert artefact shown in Figure 9. Photo Ron Priemus, RIA. Numbered units in reverse stratigraphic order, as follows: (1) 'Older aeolianite' (continuing below sea level). (2) Breccia calcrete capped by carbonate lens. An OSL date for the breccia calcrete is c.42 ka; as sample position is immediately below the artefact, this date cannot be related to it, though it provides an absolute age for the top of the 'older aeolianite'. (3) Rhizolithic palaeosol (seen as a 50 cm high bench behind person's legs): sediment sample from the top of this bench is OSL dated c. 32.9 ka (see text). (4) Unconsolidated calcareous palaeosol (estimated age more than 6.5 ka). This unit, featuring numerous, weakly cemented *Leptopius* sp. weevil pupal cases and in which two calcrete flakes have been recorded in situ, is the partly vegetated white unit at the person's shoulder level. (5) Disturbed, vegetated dune.

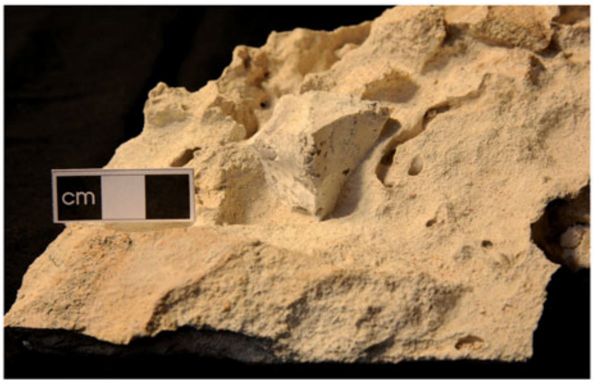

Figure 8. Eocene fossiliferous chert flaked piece in situ in surface of block cut from breccia calcrete (unit 2 in Figure 7), Bathurst Point, East Section. The surface of this block has a U-series age estimate of c.17.1 ka. Photo Alice Beale, Western Australian Museum (WAM).

fragment may be redeposited from an older deposit (Ward et al. 2016:23; Table 1). In 2016, fine sieving c.0.8 m^3 of undisturbed sediment dug from the palaeosol during construction of a beach access stairway revealed no artefacts or macrofaunal remains.

Bathurst Point

The Tamala Limestone succession exposed in the sea cliff at Bathurst Point has two dated stratigraphic sections: East and West, 60 m apart (Ward et al. 2016: Figure 2(B); Table 1). The basal unit in each is the older aeolianite, which in the West section has a TL date c.67 ka and an OSL date c.77 ka (Brooke et al. 2014: Figures 3F, 4F; Price et al. 2001: Table 2). At the top of the older aeolianite in each section is a massive breccia calcrete pavement that in the East section is OSL dated c.42 ka (Figure 7). In this section, this unit is capped by a 0.5–1 cm lens of carbonate cement, which has a U-series date of c.17.1 ka, based on a weighted average age of six sub-samples from its surface. These samples are from the top of an artefact-bearing, 8 × 8 cm block cut from the uppermost part of the brecciated calcrete unit (Ward et al. 2016: Figure 3;18, 21). Provisionally classifiable as a small flake core (Figure 8), the lower part (presumed striking platform) of this artefact is marginally within the dated thin carbonate lens, and is c.2 cm above the base of the block, a sample from which yielded the above-noted c.42 ka OSL date. As the artefact cannot confidently be associated with this date, its absolute age is that of the U-series date. Ward et al. (2016:21–23) regard the c. 32.9 ka OSL date for the rhyzolithic palaeosol (Figure 7: unit 3) as anomalously old. However, given the ubiquitous evidence for erosion, re-deposition and re-cementation at this site (Ward et al. 2016:25), this date is not necessarily discrepant with the c.17.1 ka U-series date for the carbonate lens overlapping the base of the Eocene fossiliferous chert artefact in Figure 8. This date and the c.16.8 ka OSL date for the chert tool from Little Armstrong Bay provide a minimum c.17 ka age for the earliest recorded human presence on Rottnest Island.

The upper part of the Tamala Limestone succession in both East and West sections – in which no cultural material has been identified – has relatively minor dating anomalies (Ward et al. 2016). Apart from the fossiliferous chert flaked piece (Figure 8), the only other 'pre-island' artefact finds from Bathurst Point are two calcrete flakes in situ in the undated, unconsolidated, calcareous palaeosol (stratigraphic unit 4) overlying the limestone succession in the East section (Figure 7).

Other stone artefact finds

Undated fossiliferous chert artefacts from Rottnest Island include two retouched flakes (Figure 9(B,D)) from an eroding palaeosol at the summit of the cliff overlooking Fish Hook Bay at the island's West End, and a notched flake (Figure 9(A)), which

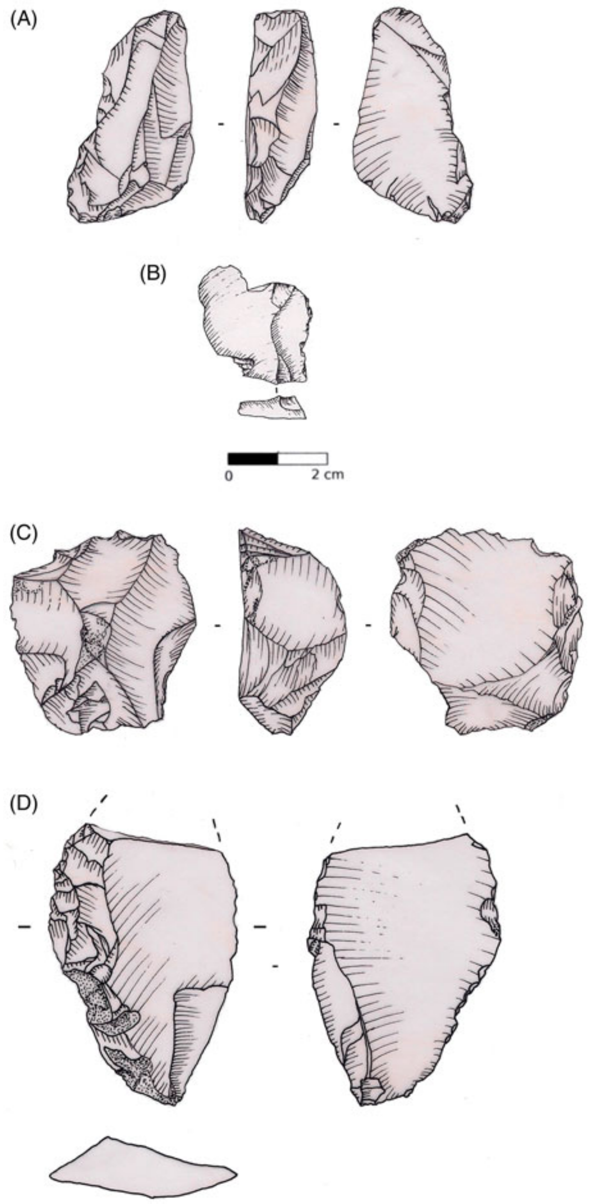

Figure 9. Eocene fossiliferous chert tools from Rottnest Island find sites, giving year of find. (A) Notched flake, Little Armstrong Bay, 1992. (B) Retouched flake, Fish Hook Bay, 1984. (C) Retouched flake, Little Armstrong Bay, 2010 (see also Figure 6). (D) Retouched flake, Fish Hook Bay, 1992 (Illus. François Mazieres).

almost certainly had fallen from the artefact-bearing palaeosol at Little Armstrong Bay (Dortch and Hesp 1994: Figure 3). These three fossiliferous chert tools and four calcrete flakes (including the two from Bathurst Point, mentioned above) pre-date 6.5 ka, the estimated time of the island's separation from the mainland (Playford 1988, 1997). The two calcrete flakes from Bathurst Point East (Figure 7: stratigraphic unit 4) and a third calcrete flake from a deflated dune overlying Tamala Limestone near Fish Hook Bay (Dortch and Hesp 1994: Figure 2:2) indicate human presence of the pre-island *Wadjemup* locality during the early Holocene. Lastly, Dortch and Hesp (1994) reported a feldspar pebble, identified as a gastrolith or manuport, from the City of York Bay palaeosol, now dated 49 ka (Table 1).

Garden and Carnac Islands

The pre-island cultural record for Garden Island, 20 km south of Rottnest, consists of three fossiliferous chert flakes, five calcrete flakes and a single quartz flake, all found on wind-eroded, Tamala Limestone cliff summits on the island's western shore. The quartz flake was cemented by secondary carbonate to a limestone exposure (Dortch and Morse 1984:39). It is the sole cultural item from the Rottnest Shelf showing a connection to the Darling Escarpment or districts further east, the nearest sources of naturally occurring quartz (Glover 1984). The southern end of Garden Island is 2.5 km from the mainland. Despite this relatively short distance, there is as yet no evidence that Aboriginal people visited the island following its formation as such. In several searches, no stone artefacts have been identified on Carnac Island, a 19 ha nature reserve 4 km north of Garden Island.

Shelf summary

The Rottnest Shelf cultural record tallies 19 flaked stone artefacts on two islands. The late to terminal Pleistocene age range of the three dated fossiliferous chert artefact contexts on Rottnest Island and the 20 km distance between it and Garden Island implies human presence over much of the emergent shelf before 17 ka, and as recently as 6.5 ka – the estimated age for the islands' formation and the shelf's submergence.

Discussion

The archaeological potential of the GSR lies in mainland and offshore localities where excavation could disclose associated cultural and biotic material implying subsistence activities or past environmental conditions, or yield information about occupation patterns relative to resources (Table 1). Here we assess the relative potential of the various geomorphic zones in the GSR.

Central Swan Coastal Plain

The largest and most prolific middle to late Holocene stone artefact sites in the central Swan Coastal Plain are the Perth Airport estate, and undated fossiliferous chert and quartz artefact assemblages at Lake Monger and the Beeliar wetlands (Figure 1), all located near abundant freshwater resources 7–20 km inland, with relatively few sites recorded closer to the present seacoast. As an example of the archaeological value of this region, a site at Hope Road, in the Beeliar Wetlands, contains fossiliferous chert artefacts underlying artefacts made from quartz, and at the surface, flaked bottle glass and other European materials (Dortch and Hook 2017). This undated succession implies repeated wetland occupation from mid-Holocene times until the historic period. However, open-air sites in these heavily leached sands are unlikely to yield vertebrate or other faunal remains. There are no published reports of excavations yielding artefacts in locations more than 1 km from water sources, suggesting the significance of water in any predictive model for the region.

Test pits in caves or overhangs in the Tamala Limestone cliffs bordering the Swan River Estuary would offer some chance for identifying biotic remains in association with stone artefacts. The central Swan Coastal Plain seems to lack limestone caves with deep floor deposits as in nearby coastal regions (Dortch 2004; Monks et al. 2016). No artefacts have been recorded *in situ* in palaeosols exposed in Tamala Limestone successions along the Swan River Estuary or on the mainland coast within the GSR. Twelve of the youngest OSL dates for these successions exceed 100 ka (Brooke et al. 2014: Tables 2, 4) and five TL dates range c.72–83 ka (Price et al. 2001: Table 2).

Midden deposits may be an unlikely site type in the region. Dortch et al. (1984) note the abundance of marine bivalves in mid-Holocene shell beds at several locations along the course of the Swan River Estuary but identified no midden deposits here.

Rottnest shelf

The archaeological record of the Rottnest Shelf is most accessible on Rottnest Island, which has archaeological potential beyond that of rare finds of artefacts in situ within limestone successions. 'Pre-island' subsistence opportunities are indicated by the eight formerly freshwater swamps, which suggest that the Rottnest 'pre-island' locality offered attractive conditions for human occupiers (Backhouse 1993; Gouramanis et al. 2012). The sediments revealed in cores around these former swamps are peat and calcilutite indicating fresh water conditions by 7.5 ka giving way to brackish water at 6.6 ka (Backhouse 1993). Despite more arid conditions during full glacial periods, the presence of fresh water at the Rottnest locality during the late Quaternary is also implied by calcrete units in the Tamala Limestone cliffs at many island locations, e.g. Bathurst Point (Playford 1997:794; Semeniuk 1986; Ward et al. 2016:23).

Other potential excavation sites on Rottnest Island are sea caves in which unconsolidated weathered quartz sands and palaeosols are exposed, e.g. a 3.5 m high, brown palaeosol present in a sea cave at Fish Hook Bay, featuring two charcoal lenses in its vertical section, one of which is radiocarbon dated 22.6 ka. The lower right-hand portion of the Charlotte Point stratigraphical section (Figure 4) shows, several metres below the artefact-bearing unit, two palaeosols intercalated with aeolianite units. This image clearly evokes the multiplicity of palaeosols in Tamala Limestone successions on Rottnest Island.

Artefact rarity

Dortch and Hesp (1994:29–30) review three factors that seem significant in accounting for the scarcity of 'pre-island' cultural finds on Rottnest Island. Firstly, the locality's elevated position near the edge of the emergent continental shelf may have been less suitable for human occupation than more low-lying and well-watered areas. Secondly, sites on the Rottnest coast would have been destroyed as the newly formed island was reduced 40% in area through continued middle Holocene sea level rise (Dortch and Hesp 1994; Playford 1997). Site loss has probably continued, given that nearly all of the recorded artefacts noted above are from actively eroding sea cliffs. Thirdly, the island's dense scrub and dune cover restrict archaeological visibility. These two factors may help explain the similarly sparse artefact record on Garden Island.

Sea floor appraisal

In the 1990s, dive searches on parts of the submerged shelf failed to identify any cultural evidence. However, systematic recording of former landscape features on the sea floor has the potential to reveal past terrestrial settings, e.g. calcrete root or solution pipes ('pinnacles') and other Tamala Limestone landscape features are identifiable at varying depths (Dortch and Dortch 2012: Figure 8; Dortch and Hesp 1994: Figure 7). Searches of carbonate shell and sand tailings dredged from the floor of Cockburn Sound in industrial operations revealed lumps of reddish cemented soil and pieces of preserved wood indicative of former terrestrial settings buried beneath marine shelly sand (Dortch 1991).

Estuary histories

In the earlier stages of its inundation through late Quaternary sea level rise, the Rottnest Shelf should have been a viable living space for successive Aboriginal populations. Little can be said about the range of terrestrial and aquatic habitats present there during this long transition, though one seemingly exploitable habitat continuing to exist was the ancestral Swan River Estuary, however much altered by shifts in its hydrology and configuration, and in the reordering of its biota. Although nothing is established about this ancestral estuary as the shelf was progressively submerged, palaeontological investigations give insight into the estuary's hydrological and biological development since the middle Holocene (Kendrick 1977; Yassini and Kendrick 1988). Two marine shell beds, one at Guilford radiocarbon-dated 7.1 ka and a similar one associated with marine microfauna dated 6.4 ka at Point Waylen, are matched by undated, similar shell beds at localities upstream and downstream from Point Waylen. The Guildford molluscan assemblage indicates that during the early to middle Holocene the Swan River Estuary experienced less winter flooding than today, and was more open to the sea (Kendrick 1977:97). The estuary then had a greater diversity of marine invertebrate fauna than it has had since. At Point Waylen, molluscan and microfaunal suites suggest a change post-4 ka towards higher rainfall, reduced faunal diversity and regression of 1 m (Yassini and Kendrick 1988:112). The estuary in this post-4 ka phase still offered a wide variety of crustaceans, fish, and waterfowl, though its complement of edible molluscs was greatly diminished. These studies of marine shell beds from the Swan River Estuary, and ones of similar age at Peel Inlet 60 km south, along with marine faunal records from estuaries on the Indian and Southern Ocean coasts of south-western Australia, support the view that resource-rich estuaries were present on the outer parts of the continental shelves throughout late Quaternary phases of sea level rise (Dortch 1999:30–32; Dortch et al. 1984:93). In considering these regional estuarine histories, Hodgkin and Kendrick (1984:91) state: 'the estuaries and their biota … had a degree of continuity [throughout] … many rises and falls of Pleistocene sea level'.

Lack of faunal remains

Throughout the GSR, the only macrofaunal specimen having even provisional cultural associations is the emu eggshell fragment from the chert artefact-bearing palaeosol at Little Armstrong Bay (Figures 2 and 6). The absence of specific archaeological indications for subsistence activities in the GSR is not surprising. At present, nearly the whole of the present archaeological record for estuarine fishing on both coasts in south-western Australia – confirmed by oral traditions and diverse historic accounts to have been a crucially important economic activity – is limited to a 130 km reach of the Southern Ocean coast. Even here, with some 30 stone structures interpreted as tidal weirs on the shores of Broke and Wilson Inlets, Oyster Harbour (King George Sound) and several smaller estuaries, the sole faunal record for estuarine fishing is from Katelysia Rock Shelter at Wilson Inlet (Dortch 1999). Throughout south-western Australia, the exceptional records of faunal remains are those excavated from Tamala Limestone cave and rock shelter occupation deposits (Dortch 2004; Monks et al. 2016). In the GSR this absence of direct evidence for past subsistence is even more noticeable today than was observed in the first field surveys in the region a half-century ago (Hallam 1972).

Conclusion

The Greater Swan Region is at the heart of a distinct linguistic and cultural block that provides invaluable information about past Aboriginal subsistence and traditional land usage. Rottnest Island, in particular, has provided 10 artefacts, including three dated c.13–17 ka, representing Pleistocene use of the former Greater Swan Region during marine regression. Together with pollen cores from Barker Swamp, the Rottnest record indicates potential for reconstruction of occupation patterns at this time. The totality of Pleistocene finds across the GSR indicates occupation patterns centred on persistent wetlands, supporting the view that former wetland areas will be the most archaeologically prospective locations on the submerged parts of the coastal plain. As yet, no sites on the Greater Swan Region provide abundant biotic remains that would give direct insight into Aboriginal land usage, largely because of post-depositional effects of erosion and poor preservation of biotic remains in sands.

Appraisal of late Quaternary human adaptation throughout the Greater Swan Region study area will depend upon understanding the territorially and seasonally adaptive arrangements of mainland Aboriginal occupation, with reference to occupational records – both archaeological data and historical accounts – from here and other coastal parts of south-western Australia and elsewhere along the continental littoral. The record of stone artefacts identified on offshore islands broadens the perspective of Late Quaternary Aboriginal activities in this region. Further archaeological study of these activities on Rottnest Island should include survey of palaeosols along the littoral and residual dunes overlying aeolianite successions, and test excavation around extant and former fresh-water swamps.

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Disclosure statement

The authors report no potential conflict of interest.

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