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Reconstructing Aboriginal impacts on Australian forests: Archaeological studies from south-western Australia

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ABSTRACT: This paper presents archaeological perspectives on pre-European human impacts on Australian forests. Major questions, of interest to conservation and forestry also, are (i) how were forests used by hunting and gathering people? and (ii) to what extent did they manage forests by fire? Ethnographic and historic records attest to the Aboriginal use of fire in forests to control understoreys and manage food plants and animals. Opinions vary widely, however, on the ecological significance of past hunter-gatherer fire management and the cultural significance of evidence for past fires such as charcoal counts in pollen cores. This paper explores the potential clues to anthropogenic ecological changes to be found in the stratified archaeological and palaeontological records from limestone cave and rock shelter floor deposits in the Leeuwin-Naturaliste Region of south-western Australia. Comparison of this evidence with regional evidence for climatic change helps show whether local changes in flora and fauna were the result of changes in human activity or climate. Other clues derive from the distribution of artefacts as identified in area survey across vegetation zones. The various lines of evidence involve different geographic and temporal scales. Understanding and accounting for differences in scale will be critical in the future development of these methods in archaeology and palaeo-ecology.

1 INTRODUCTION

This paper discusses archaeological views on Aboriginal use of forests before European arrival in Australia. The questions addressed are:
(i) how did Aboriginal people occupy forests,
(ii) to what extent did they manage forests with fire?

There are two major motivations for this discussion.

Firstly, from an anthropological perspective, we know relatively little about how people used such densely vegetated areas where most biological production is not readily usable or accessible. On one hand, various researchers have claimed that forests presented challenges requiring specialized technologies or economies only developed in the last 5,000 years, a small fraction of the timespan of anatomically modern humans (Bailey et al. 1989; Cosgrove 1995, 1996; Headland 1987; McBrearty and Brooks 2002). On the other, there is evidence that modern humans were present in dense forests in the Late Pleistocene, or at least from 40,000 years ago, yet there is no forest toolkit or other material culture to archaeologically distinguish the forest mode of life from any other (Endicott and Bellwood 1991, Mercadar 2002). Evidence has accumulated in the last decade or so, showing that Pleistocene hunter-gatherers occupied closed forest (rain-forest); relatively little work has been done on the issue of how people used more seasonal forests, such as the Australian open-forests and tall open-forests (also known as dry and wet sclerophyll; Groves 1994). Some researchers suggest that Australian tall open-forests excluded hunter-gatherers (Cosgrove 1995, Ferguson 1985, Hallam 1975, Jones 1971); others speculate that humans could have controlled tall open-forest to some degree (J. Dortch 2004a, b; Hope et al. 1999; Hopkins et al. 1996; Lourandos 1983; MacPhail 1984). The uncertainty is due in large part due to the limited historical data concerning Aboriginal activity in forests, the limitations of archaeological data, and the nature of Aboriginal occupation of forests itself.

The second motivation for this discussion is that widely-held views of Aboriginal interaction with forest environments may be used to justify conservation practices. In particular the ecological significance of Aboriginal use of fire to manage plants and animals is a major issue in conservation and management aimed at maintaining both biodiversity and economic potential of forests (Bowman 1998, 2000). However, there is a danger in too readily accepting ideas that are still being refined and are based on arguably problematic sources (Bowman 2001; Horton 1982, 2000, 2002). These potential problems are as follows:

Ethnography and anthropology provide explicit and detailed descriptions of Aboriginal fire management for the tropical savannahs and the arid zone, but these sources may not be so relevant culturally or ecologically to southern Australian temperate forests. Unfortunately, due to the way southern Australia experienced massive cultural dislocation well before the refinement of ecological and anthropological techniques, equivalent sources of ethnographic information for southern Australian forests have not been exploited in the same way. It has been argued that there is potential for much more research into ethnographic knowledge of fire regimes in south-western Australia (Kelly 2002).

Charcoal estimations in pollen cores have been used to document rises and falls in human activity (e.g. Kershaw et al. 2003) yet considerable uncertainty exists as to their significance for fire regimes (Clark 1983, Horton 2000). Does a high charcoal concentration in sedimentary profiles indicate more frequent burning or more wild-fires? Clark (1983) notes that rises in charcoal concentration in pollen cores have been taken variously to mean both human arrivals and human departures.

Historical sources are somewhat limited by observer biases, notably lack of expertise in modern fields such as anthropology or ecology, and geographical location of the more sophisticated observers at major centres and on the coast (J. Dortch 2004b, Hallam 1987, Horton 2002). A more serious limitation is the applicability of 19^{th} and 20^{th} century records to the more distant past where plant associations and human activity may have differed in many ways from the recent past as well as the present (MacPhail 1984).

In a similar way, silvicultural experiments and dendrochronological research suggest various forest responses to different fire regimes (cf. Burrows et al. 1995, Rayner 1992, Ward and van Didden 1997), but not for the very long-term periods giving maximal perspective on the significance of present-day changes. Dendrochronological approaches to past fire regimes are furthermore based on assumptions about the significance of fire scarring in tree-rings, an indicator of fire severity that has been contested (Horton 2002).

Archaeological and palaeo-ecological records, despite certain pitfalls, discussed below, are potentially a major source of information about long-term human-environment interaction in Australian forests. These pitfalls relate to precision, scale, and taphonomy (the study of post-mortem and post-depositional processes that lead to highly restricted fossil samples). The following discussion will review these problems in the context of three archaeological sites in south-western Australia, a region that included some 40,000 km^2 of woodland, open-forest and tall-open forest at the time of European arrival (Dell et al. 1989).

Two cave sites in the Leeuwin-Naturaliste Region, an area noted for its numerous limestone caves and rock shelters and its variety of plant associations, provide long and detailed fossil records featuring artefacts and biotic remains. Tunnel Cave is a rock shelter located on the edge of a stand of Karri (*E. diversicolor*) tall open-forest in the Leeuwin-Naturaliste Region (Figures 1, 2; J. Dortch 1996, 2004a, b). Devil's Lair is a cave located within a stand of Karri forest some 20 km south of

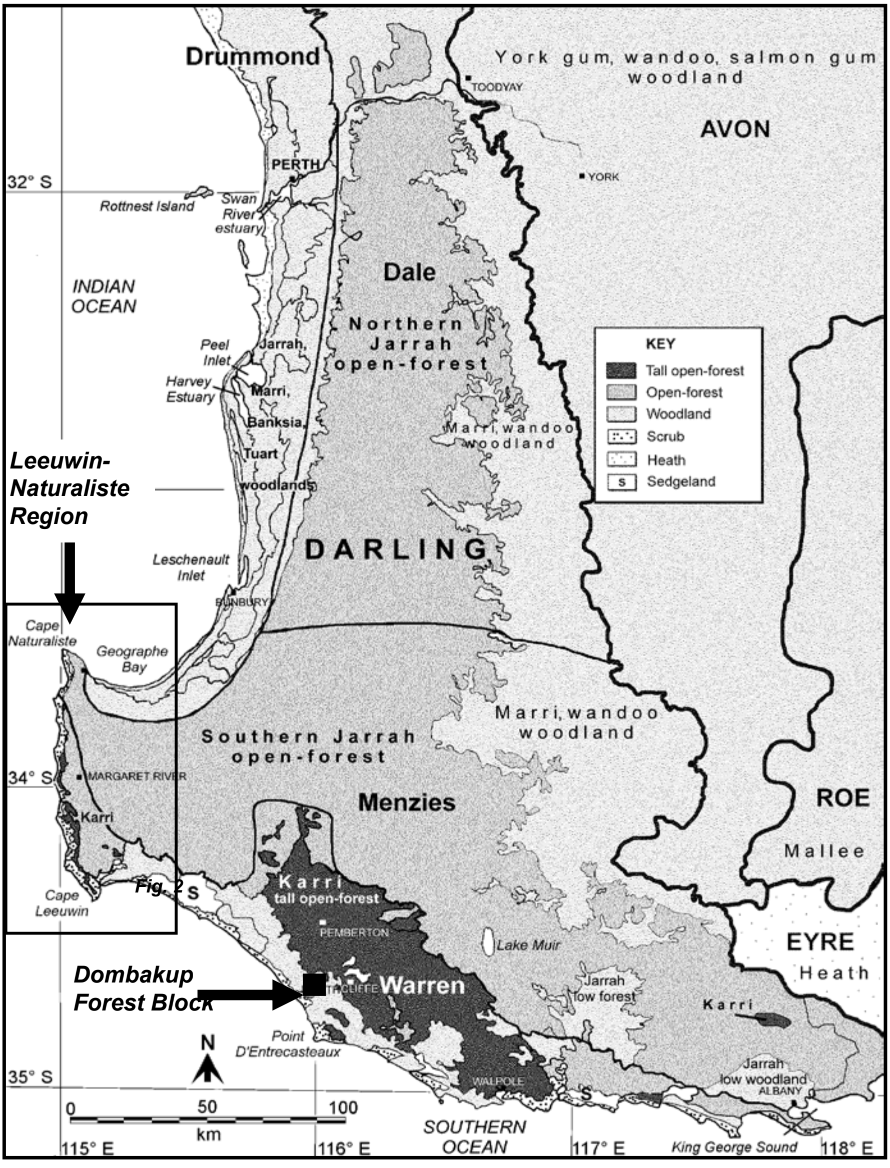

Figure 1. Map of south-western Australia, showing major vegetation formations, botanical districts (Darling, Avon, etc) and sub-districts (Dale, Menzies, etc) and locations mentioned in the text. After Beard (1981).

Tunnel Cave (Balme *et al.* 1978, C.E. Dortch 1979). These two sites together provide a detailed stratified record of human visits and activity against a background of local vegetation change for c.50,000 years (Turney *et al.* 2001).

The third site, a former State Forest block located near Northcliffe, a town in the main belt of Karri tall open-forest. Dombakup 24, now part of the D'Entrecasteaux National Park, features stone artefacts scattered throughout a large stand of Karri forest (J. Dortch *et al.* 1998). This stand is located close to outcrops of silcrete that were first quarried more than 7,000 years ago (C.E. Dortch and Gardner 1976).

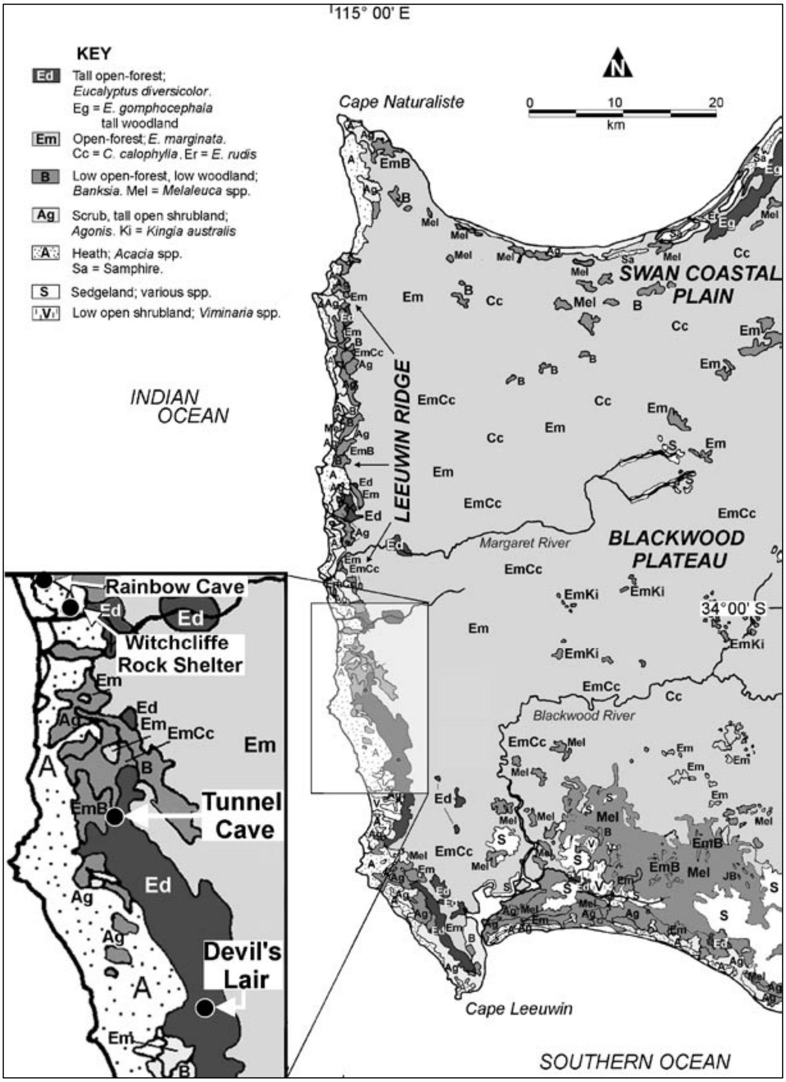

Figure 2. Map of the Leeuwin-Naturaliste Region, showing sites and vegetation formations.

The significance of Karri forest to Aboriginal occupation was first discussed by Sylvia Hallam in her ethnohistoric study *Fire and Hearth* (1975). The view that tall open-forest (*sensu* Groves 1994) challenges human occupation was based on the apparent difficulty of managing it by fire, the density of understorey vegetation impeding access, and the scarcity or inaccessibility of potential food plants and animals (Ferguson 1985, cf. Beard 1981, Groves 1994). Historic sources were uninformative on the extent or even the existence of human occupation in the wetter, denser southern forests. The theme of human exclusion from Karri forest regions was elaborated in the first major synthesis of south-western Australian prehistory (Ferguson 1985). This work identified a period of population decline coinciding with mid-Holocene expansions of Karri forest as then argued from pollen records (Churchill 1968, but cf. Newsome and Picket 1993).

A different picture is obtained from more recent archaeological studies in both south-eastern and south-western Australian forests. To summarise archaeological surveys and historical studies in south-eastern Australia, tall open-forest was as much used as open-forest, and was more often occupied than the interfingering stands of rain-forest, arguably a far more challenging forest formation (Bowdler 1983, Byrne 1983, Cosgrove 1995, McBryde 1978). Maximum activity by hunter-gatherers within these forests often seems to have been at convergence zones between different forest formations. Only in Tasmania is there much evidence for hunter-gatherer avoidance of tall-open forest, where it probably occupies a more extreme position on the continuum of difficult vegetation (Bowdler 1983a, Cosgrove 1995, Lourandos 1987), but even here, there is historical evidence for firing in diverse environments across the island (Bowman and Brown 1986, Thomas 1994). Caution is clearly required in extrapolating from these situations to human usage or avoidance of relatively benign and equally complex south-western Australian forest environments.

2.1 *Analysis of occupation deposits in cave and rock shelters*

Excavation of the Devil's Lair and Tunnel Cave deposits involved digging with small trowels and hand-shovels in 1-5 cm arbitrary depth units within sedimentary units distinguished in the field on the basis of colour, matrix composition or degree of compaction; *in situ* location and positioning of artefacts, hearths, bones and charcoal fragments; sieving of all sediment through 3 and 5 mm mesh screens; and collection of *in situ* and screened artifacts and biotic remains. Post-excavation analysis included identification of the rich faunal and charcoal assemblages, identification and measurement of all artefacts, radiocarbon dating, luminescence dating, geochemical analyses of hearth sediments, and weighing of material such as unidentified bone, total charcoal, and total sediment (Balme *et al.* 1978; Burke 1997; C.E. Dortch 1979; C.E. Dortch and J. Dortch 1996, 1997; J. Dortch 1996, 2004a, 2004b; Turney *et al.* 2001).

These investigations documented a complex and varying archaeological record of Aboriginal artefacts, fireplaces, and occupation surfaces. In addition to that record, the excavations provided thousands of fragments of animal bone and charcoal, sufficiently well-preserved for researchers using standard reference collections to identify genera and often species among a range of vertebrates and woody plants. Most of these biotic remains were argued to derive from organisms that lived or foraged within tens or hundreds of metres from the cave sites (Balme *et al.* 1978, Burke 1997, J. Dortch 2004a, b). Their identification, with due allowance for sampling bias and post-mortem (taphonomic) processes, gives insight into local environmental change, especially into change in local animal habitats and local canopy floristic composition, aspects influenced to some degree by fire regime.

2.1.1 *Devil's Lair*

Analysis of the Devil's Lair deposit, carried out by WA Museum researchers and collaborators from c. 1970 to the present day, provides a detailed dated stratigraphic record beginning more than 60,000 years ago (Turney et al. 2001). About 45,000 years ago the nature of this record changed dramatically when the cave's former entrance widened sufficiently to admit people and other large animals. This entrance then remained open, apart from relatively short episodes of flowstone formation suggesting intermittent blockages, up to some point in the period 6,000-12,000 years, when it collapsed completely, preventing build-up of more sediment and allowing the growth of a thick capping layer of flowstone (Balme et al. 1978). Deposition resumed again by 300 years ago after collapse of another part of the cave roof created the present entrance.

The result of many years intensive study of dating, sediments, and biotic remains gives a picture of environmental change in the Devil's Lair locality over a period of more than 40,000 years (Balme *et al.* 1978). The changes in fauna indicate a gradual reduction in area of closed habitats from c.30,000-22,000 BP, the dominance of open xeric habitats (22,000-13,000 BP), and a return to closed habitats from 13,000 BP. These findings were supported by a study on charcoal fragments carried out in 1997 showing changes in the proportions of tree taxa outside the cave from the last glacial maximum to the time the former cave entrance closed, and a further change by the time the new entrance formed (Burke 1997).

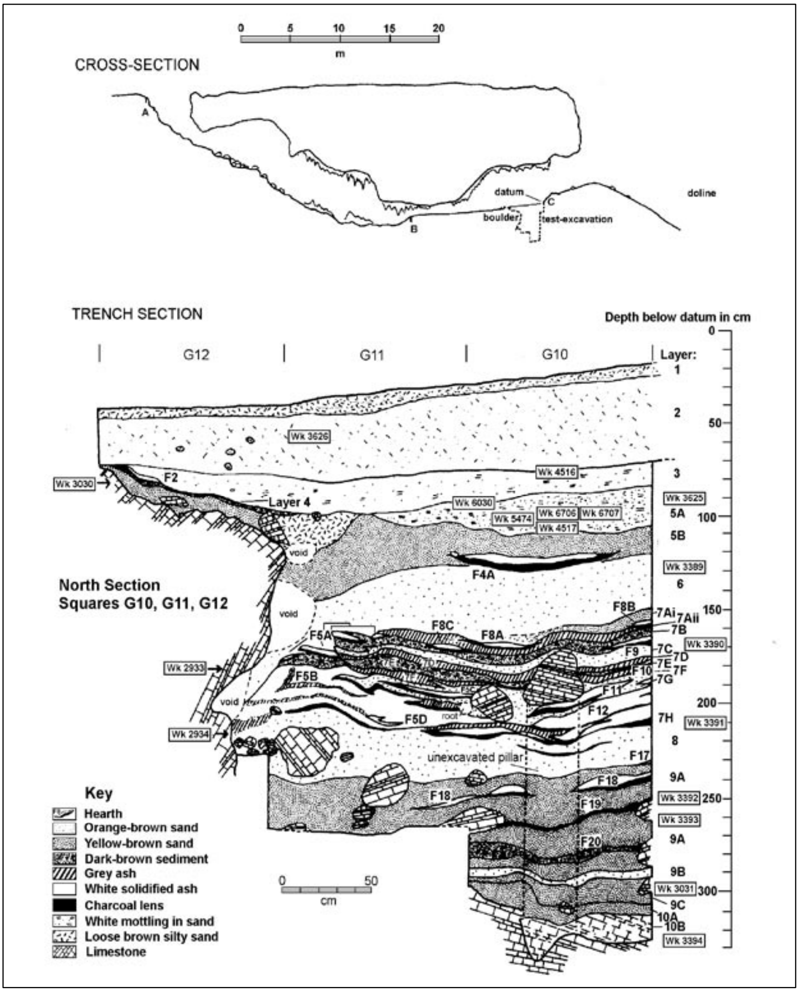

Figure 3. Cave section and trench section at Tunnel Cave, after J. Dortch (1996, 2004b).

2.1.2 *Tunnel Cave*

Tunnel Cave gives the terminal Pleistocene and Holocene record lacking from Devil's Lair (J. Dortch 1996, 2004b). Radiocarbon dating of discrete ash and charcoal beds identified as hearths (fireplaces) associated with most of the other archaeological material at Tunnel Cave (such as flaked stone and food remains) allows identification of episodes of human occupation in the cave (Figure 3, J. Dortch 1996). This evidence is crucial in identifying when the remains of human meals led to a high proportion of favoured prey species in the bone accumulation associated with the hearth. In stratigraphic units lacking hearths, artefacts and other traces of occupation are also scarce, so bone and charcoal fragments are presumed to derive largely from natural sources. In the case of bone fragments, as at Devil's Lair, a major natural source is likely to have been Tasmanian devils. For charcoal fragments, the major natural source would have been bush fires burning logs and debris around the caves.

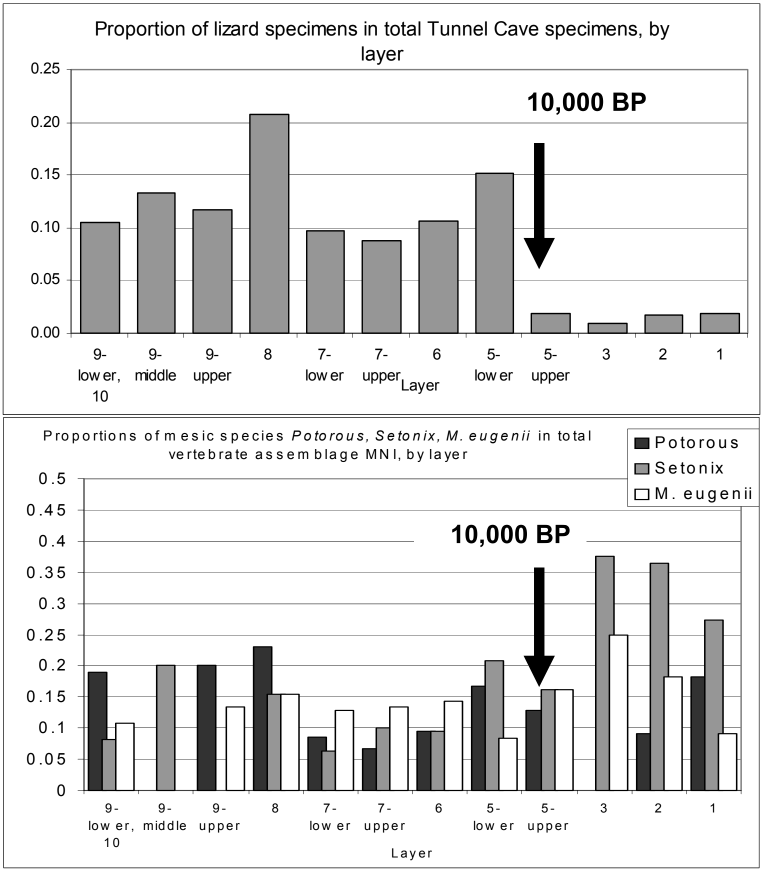

Figure 4. Faunal changes over time (from left to right on horizontal axis) at Tunnel Cave. MNI is the Minimum Number of Individuals as calculated from taxonomically-identified skeletal elements.

The Tunnel Cave faunal and charcoal records indicate major changes at 10,000 BP (Figure 4, Table 1). Changes in the vertebrate taxa strongly suggest changes in habitat, from more open vegetation to more closed vegetation, with a major change at the end of the Pleistocene, presumably related to the same events that influenced vegetation at Devil's Lair. A significant change is in the terminal-Pleistocene/early-Holocene increase in numbers of thicket-dwelling macropodids (*Setonix*, *Macropus eugenii*, *Potorous*) at the same time as a decline in macropodids that forage in open vegetation (*Bettongia lesueur*, *Petrogale lateralis*; not shown in Figure 4). Declines are also noticeable at both sites in the bandicoot *Perameles* (now found in arid regions) and in the representation of lizards (cf. *Scincidae*) which as a whole may have favoured dry conditions (reptile diversity and abundance in south-western Australia today correlates negatively with rainfall; How et al. 1987). At the same time as changes in identified vertebrate remains there are changes in charcoal species represented in the Tunnel Cave deposit. Late Pleistocene charcoal suggests associations typical of open-forest (dry sclerophyll) or woodland (*Eucalyptus marginata*-*Banksia*-*Agonis*-*Xanthorrhoea*). At 10,000 BP, this association probably gave way to a tall open-forest (wet sclerophyll) association dominated by *E. diversicolor*. Regional and global records indicate that the change is most likely due to post-glacial increases in rainfall (Harrison and Dodson 1993, Pickett 1997). Causes may include a more maritime influence after terminal Pleistocene marine transgression, global increases in temperature, an equatorward shift of rain-bearing westerlies, or a combination of these factors.

Table 1: Charcoal fragments identified at Tunnel Cave

Layer	Age estimated from grouped ^{14}C estimates[1]	Sample name	No. fragments sampled	No. fragments identified	*E. diversicolor*	*E. marginata*	*E. gomph.*	*Agonis*	*Banksia*	*Xanthorrhoea*	*Eucalyptus* sp.	Unidentified
1	modern to 1,400 BP	modern	30	30	23	5					2	
3	4,300-6,900BP	mid Holocene	20	20	17		3					
5-upper	6,900-8,300	early Holocene 2	25	25	17	6	2					
	9,800-9,900	early Holocene 1	65	58	27	13	5	1	12			7
5-lower	12,400-13,000	post-glacial	65	62		22	11	11	16	2		3
7-lower / 8	17,100-20,000	full glacial 2	39	32		19	3	1	7	1	1	7
9-upper	18,000-20,000	full glacial 1	30	30		21		2	7			
		Total	274	257	84	86	24	15	42	3	3	17

[1] For radiocarbon ages and sample numbers, see J. Dortch (2004b). *E. gomph.* = *E. gomphocephala*

2.1.3 *Taphonomic considerations*

A large number of biases are inherent in these studies. The fossil remains are a heavily filtered record of the past flora and fauna in site environments, due to the varying potentials of different species to be located near the sites and to be preserved in cave floor deposits. In addition to this certain species are more likely than others to have been deposited by humans, Tasmanian devils (*Sarcophilus*), owls (*Tyto* spp, *Ninox* spp.), and carnivores visiting cave sites. The cave site investigators address these issues in some detail (Balme *et al.* 1978; Burke 1997; J. Dortch 2004b). Multi-variate analyses and statistical tests indicate that human hunters at Tunnel Cave may have favoured *Petrogale*, *Bettongia lesueur*, and *Perameles*, and the varying representation of these vertebrates therefore reflects changes in human activity as well as changes in environment. The same tests show that a large part of the total variation in the identified vertebrate assemblages of Tunnel Cave and

Devil's Lair is attributable to past environmental change. The species that most reliably indicate this environmental change are the smaller macropods and terrestrial marsupials, and among these, those most adapted to extremes of eucalypt forest or woodland, dry and open on one hand and wet and closed on the other. At both sites, moreover, any rise or fall in numbers of in a xeric (dry habitat) species is complemented by the opposite trend in a more mesic species. This observation provides further support for changes in habitat strongly influencing the particular species that were most often deposited in the cave sites.

Taphonomic concerns for charcoal can be limited to ones of preservation or attrition, rather than ones of addition caused by human contributions to natural accumulations. All the samples were selected from non-occupation layers adjacent to human occupation layers. Major considerations were the selection against species whose timber is most susceptible to biological decay (fallen logs of *Corymbia calophylla* decay faster than other major timbers, and would be less likely to have been burnt in bush-fires; Thorton et al. 1996) and the selection against taxa with a tendency to burn quickly to ash rather than charcoal (the 'ash test' for *E. diversicolor* is a known means of distinguishing its timber). Identification of a control population from the uppermost 10 cm of the Tunnel Cave deposit, including a few modern artefacts and therefore likely to have derived from the taxa growing at the site today, showed that certain woody taxa (shrubs, small trees, and the tall tree *Corymbia calophylla*), were not preserved at all. On the other hand, the high representation of *E. diversicolor* showed that a proportion of its timber would still be represented as charcoal despite any loss due to the 'ash test' effect. Preservation is also correlated with trunk size: small-sized species that are now very common near the site (notably *Agonis*, Dortch and Burke, pers. obs.) are poorly represented in the control sample.

The effects of poor preservation would have been most obvious in older layers, and would have worked against diversity in the fossil record. Small trees would not have been represented unless they were very common. The finding of greater diversity in fossil charcoal species in the Pleistocene including many small trees strongly indicates a change in the dominant tree taxa around Tunnel Cave and Devil's Lair.

The environmental changes at Devil's Lair and Tunnel Cave are localised and well-dated. The vertebrate fauna most strongly indicating environmental change typically have ranges of a few km (Strahan 1995). The modern taxa found to be well represented as charcoal were those growing within a few metres of the cave sites. At Tunnel Cave, episodes of human occupation can be identified precisely, because almost all archaeological material is stratigraphically associated with hearths, which are separated by thicker layers of sediment lacking hearths or many artefacts. Hearths are dated directly by radiocarbon on associated charcoal or charcoal lenses to within a few centuries accuracy (Devil's Lair on the other hand provides few hearths, almost all layers provide some artefacts, and adjacent layers tend to provide overlapping radiocarbon age estimates, so individual episodes of occupation are more difficult to discern).

The geographical precision for palaeo-environmental evidence, coupled with chronological precision for human occupation at Tunnel Cave, is important because it allows stronger inferences than were possible before, about the plant associations that people moved through when they occupied Tunnel Cave, and the plant associations that they appear to have used infrequently.

2.2 *Artefact scatters at Dombakup 24*

Dombakup 24 is a forest block featuring a range of plant associations and stone artefacts scattered across the ground surface and down to at least 50 cm below surface open sites (Dortch *et al.* 1998). These artefacts were located through intensive survey designed to overcome poor ground visibility, the major problem in searching for sites in forest. In heritage assessment work commissioned by the Department of Conservation and Land Management, test-pits were excavated at 50 m intervals along transect lines 50-100 m apart through ca. 300 ha of the forest block, which is covered by dense, never-logged tall open-forest. Thirty-two 50 x 50 cm test-pits were excavated in the main part of tall open-forest and in adjacent areas of open-forest and tea-tree thicket. For efficiency, test-pits were excavated with spades and minimal recording of features and artefacts. All sediment was sieved through 5 mm mesh sieves. Artefacts recovered in the sieves were identified and measured. Artefacts were also identified in survey of logging road cuttings.

Interest in the site was stimulated by its proximity to the Northcliffe Silcrete Quarry, an area of quarried and chipped silcrete boulders outcropping on the eastern boundary of the forest block first identified in regional survey in the 1970s (C.E. Dortch and Gardner 1976). Radiocarbon dates on charcoal associated with silcrete artefacts excavated in the quartz sands covering the site indicate quarrying began by 7,000 BP and continued well after 3,000 BP (C.E. Dortch and Gardner 1976). Artefacts in the forest block were mostly silcrete, and probably derived from quarrying. The variety of artefact types and re-use suggested that these artefacts had been modified and used beyond the initial quarrying or "reduction" stages of production, perhaps during occupation of campsites in the area of the current forest block. One test-pit with artefacts provided charcoal dated to c.500 BP. Given root perturbation (throwing associations of charcoal and artefacts into some doubt) more definitive dating will have to await the discovery of hearths or other occupation features that can be dated directly.

While dense vegetation limited the surveyors' ability to document the precise extent or location of these sites, sufficient artefacts were located to infer patterns of artefact distribution (Table 2). Chi-squared tests and Fisher tests indicated that the only significant factor governing artefact distribution was distance from the quarry area (p H0 < 0.05). More surprisingly, soil type, plant associations, distance to drainage lines, and local vegetation structure and floristic composition were not found to be significant factors. Although these are preliminary findings requiring testing by further survey, the conclusion from this survey was that hunter-gatherers' choice of site location in Dombakup 24 was not governed by forest type or other environmental factors. Considering the present day understorey structure, which is presently extremely difficult for people to move through, the area may have previously featured an open understorey in a tall open-forest, or a more open structure overall (e.g. open-forest or woodland). Changes in climatic conditions may have caused such vegetation change, although little evidence for Holocene vegetation change is evident in regional pollen cores (Newsome and Pickett 1993). Given the indications for quarry use in the late Holocene and the presence of artefacts close to the ground surface, people may have been visiting the Dombakup 24 area in the last one or two millennia. If so, they may have travelled under the same *E. diversicolor* canopy as exists today, and the climatic conditions are likely to have been conducive to closed understoreys.

In these circumstances, human groups must have exercised some control over vegetation in the area of Dombakup 24, creating either an open understorey or a network of paths and campsites within dense forest sufficiently complex over time to produce the pattern of discarded artefacts identified in the test-pit survey. The other alternative is simply that the density of Karri forest understoreys and consequent accessibility of Karri forests has varied considerably in the past.

Table 2: Artefact distribution in Dombakup 24, a 300 hectare area dominated by tall open-forest.

Formation	Tall open-forest	Open-forest	Low open woodland
Dominant taxa	*Eucalyptus diversicolor* or *E. diversicolor-Corymbia calophylla*	*E. marginata-C . calophylla*	*E. marginata* (*Melaleuca preissii* thicket understorey)
Number of shovel-pits with artefacts	12	3	0
Number of shovel-pits without artefacts	12	1	4
Total test-pits	24	4	4
Road survey: numbers of artefacts seen in or near road sections	10	16	5

3 DISCUSSION

Historical evidence is meagre when it comes to the Aboriginal presence in south-western Australian forests. Early European explorers of south-west Australia were struck by the absence of people in the areas of "southern forest" they traversed (Hallam 1985 and refs therein, but cf. Mulvaney and Green 1992, Wilson 1835, on Aboriginal activity in the vicinity of tall forest). Since absence of evidence is not evidence of absence, the distribution of people in different forest formations needs to be understood in the context of how people used forests. Fortunately there is considerably more historical and archaeological evidence for other forest types, giving some insight into use of the more difficult forest types.

Several studies point to the organization of Aboriginal groups of far south-western Australia around coastal landforms, with relatively less use of forested hinterlands (Anderson 1984, C.E. Dortch 2002). For groups of the far south-west, with access to the coast, numerous sources attest to large annual gatherings lasting weeks or months and sustained by enormous quantities of anadromous fish trapped or caught in estuaries and inlets (C.E. Dortch 2002, Hallam 1987, and references therein). Other sources indicate that coastal plains, with wetlands and small lakes, provided quantities of food in the form of waterfowl, eggs, amphibians, and sedges. These foods were supplemented with terrestrial plants and animals, including yams, arboreal marsupials, and macropods, all found in abundance on the coastal plains and woodlands.

Moving inland, the first historical observers found fewer obvious food sources, and fewer people. Modern-day zoological and botanical surveys confirm the lower numbers of edible plants and animals in open-forest and tall open-forest. A further factor limiting occupation of forested hinterlands is the distribution of permanent water, especially in the northern forests. Mediterranean climatic conditions mean that streams dry up through summer. If all these streams flow, as can only happen in winter, no location in forest is much more than 2 km from water (Ward and van Didden 1997). In the coastal regions water is more reliable year around, due to aquifer-fed lakes and ponds and year-round coastal rain showers. Since coastal subsistence strategies were most effective in summer, there was a natural division between large summertime gatherings on the coast and winter-time foraging by small family-based groups in the forested hinterland (Anderson 1984). Comparison of historically recorded Aboriginal food plants and animals (103 recorded plant species, 65 recorded terrestrial or freshwater animal species) in woodland, open-forest and tall open-forest indicates that the majority of food species were found in all plant formations, but few or none were endemic to tall open-forest, and this formation offered the least variety of food resources (J. Dortch 2004b).

Archaeological support for this model is found in comparison of inland and coastal sites (Pearce 1982). As many sites were located per square kilometre in regional survey in Jarrah (*E. marginata*) forest inland of the Darling Scarp near Bunbury as in the coast plain west of the scarp, but sizes and total artefact assemblage of the forest sites were much smaller. Similarly, with exceptions like Dombakup 24, commercial heritage assessment surveys (a large body of data still requiring collation and synthesis) generally identify fewer artefacts or smaller sites in forested or previously forested areas (e.g., MacDonald Hales and Associates 1994).

The Ferguson (1985) model extends these observations to human occupation over time, but contrary to its claimed patterns of site occupation, there is not a strong relationship between changes over time in regional site density or artefact numbers and the putatively changes in extent of Karri forest (C.E. Dortch and Smith 2001, J. Dortch 2004b). This may in part be due to the limited evidence, since Ferguson's evidence consisted of 17 dated sites distributed across an area comparable to that of half of France or Texas. An additional factor is the high degree of ecological and botanical diversity across south-western Australia, which would have permitted the continuation of most hunter-gatherer strategies despite reconfigurations of plant associations and vegetation structures at a localised scale. For instance, Beard's (1981) continua of plant associations as determined by rainfall for given substrates suggest that rainfall would have had to drop by 70% in the last glacial period in order for vegetation endemic to south-western Australia to have disappeared and for new plant species to invade. There is no evidence from regional pollen cores, from continental evidence of climate change, or from offshore palaeo-records of sea-surface temperatures to support more than a 40% drop in precipitation at the height of the last ice age (Harrison and Dodson 1993, Pickett 1997).

Pollen cores in fact indicate limited changes in vegetation regionally (Newsome and Pickett 1993) and Pickett (1997) goes as far to suggest that such glacial-period changes as do occur on the coastal plains may have been due to marine regression and transgression, and consequent changes in the influence of coastal rainfall and the height of aquifers. Few records exist for inland south-western Australia, so it is currently impossible to compare coastal records with inland ones. But given the long-term stability of the region's climate and vegetation (Dell et al. 1989), it seems likely vegetation did not change on the scale required to have disrupted the hunter-gatherer subsistence strategies outlined above. If there had been human impacts on vegetation, pollen cores for south-western Australia may be too broad-scale to show therm. Detailed localised records over a large area are therefore required in the search for evidence of human impacts on vegetation.

The Dombakup 24 survey shows that human groups using the Northcliffe Silcrete Quarry in the last few millennia before present moved frequently through an area now covered by tall open-forest and very dense understorey thicket. People could have fired the understorey very frequently in order to maintain access to the quarry and various campsites around it. On the other hand, various tracks and campsites within dense forest might have been used at different times over a long period, creating a complex diachronic record. More intensive survey, dating, and identification of past vegetation within the survey area would help test these competing hypotheses. Nevertheless, the evidence as it stands suggests a human presence in unfavourable vegetation and hence an ability to control or limit the vegetation, even if only on tracks or paths.

Seemingly in contradiction to the Dombakup 24 record, the Leeuwin-Naturaliste Region cave sequences show that human occupation was sensitive to vegetation change. People abandoned camp-sites when tall open-forest encroached and used them intensively when the sites were surrounded by open-forest or woodland. They did not abandon sites completely, however, since at Tunnel Cave there are stone artefacts associated with *E. diversicolor* charcoal and a single hearth dated 1,400 BP, made during the period of tall open forest growth at the site. The apparent contradiction is probably largely due to the geographically restricted view of human occupation offered by test-excavations, no matter how intensively studied, and to the mosaic character of south-western Australian forest vegetation. Regional archaeological records indicate that people were using other sites a few kilometres from the cave sites throughout the Holocene. Even within a few hundred metres of Tunnel Cave there are today woodland and open-forest formations with greater opportunities for travel and access to resources. Given the choices available to regionally based hunter-gatherer groups it is likely that use and disuse of different locales reflects prioritisation of subsistence strategies around the most productive environments rather than a complete inability to control certain vegetation types.

4 CONCLUSIONS

Current evidence for human occupation of south-western Australian forests indicates that Aboriginal hunter-gatherers occupied every region and encountered every type of plant association. They prioritised their use of different associations, largely because their economy and population and the floristic and ecological diversity of the wider region enabled this choice. Vegetation change, such as the encroachment of tall open-forest over some localities, did not spell disaster for regional populations.

The corollary of these comments is that humans probably did not greatly alter the distribution of forest types, simply because this was largely unnecessary for the whole region frequently enough, especially in the wetter, southern parts of the region and in *E. diversicolor* tall open-forest. However, it does seem feasible that particular locations in unfavourable forest areas were visited regularly, implying that the forest there may have been controlled.

For conservation purposes, these findings suggest that a fire regime of minimal human intervention in least-used areas may be appropriate, but the geographically limited archaeological record as currently known indicates much caution is needed. Certain areas of woodland may have seen very frequent firing, reflecting the annual usage of coasts and wetlands. On the other hand even in coastal woodland regions hunter-gatherer populations may have left a few localities untouched by fire for years at a time. The detail required to precisely identify hunter-gatherer settlement patterns and firing impacts across the region continues to be beyond the reach of the archaeological record as currently known. Fine scale work around productive archaeological locations such as the cave sites and in areas that saw the greatest focus of Aboriginal activity has the most potential to identify human impacts on forests. At the same time greater effort should be made to locate sites in the large blank spots on the archaeological map of south-western Australia.

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