

The fire history of south-west Western Australia prior to European settlement in 1826-1829

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Abstract

Charcoal in sedimentary deposits is common in late Tertiary and Quaternary deposits in Australia well before Aboriginal people entered the continent. A Pliocene lake deposit 200 km north of Perth contains charcoal indicating wildfire was present in south-west Western Australia (WA) by that time and that climate is a controlling factor in providing conditions under which fire can establish. Superimposed on the 'natural' fire regime, anthropogenic fire was imposed after Aboriginal people entered the continent in the late Pleistocene, and in areas of south-west WA that Aborigines habitually occupied, had a controlling effect on the vegetation composition and structure. In areas fully occupied by Aborigines, fire intervals appeared to have been much shorter than in those areas not generally occupied or used as a food source, and many intervals in occupied areas were in the range of one to 10 yrs. In contrast, offshore islands and southern forest regions of south-west WA little used by Aborigines had major fires at much longer intervals. Similarly, analysis of core charcoal from a south coast estuary in semi-arid Fitzgerald River National Park, most of which was not occupied by Aborigines in historic times, indicates intervals between major fires were in the range of 30 to 100+ yrs. It is possible Aboriginal population numbers increased in the Holocene during climate amelioration following the Last Glacial Maximum which would have increased the area subject to short fire intervals. If this is so, the amount of Aboriginal burning at the time of contact with Europeans would have been at its maximum.

Introduction

Evidence of past fires in the form of charcoal in sediments has been found from Devonian times when plants first invaded the land (Martin 1996, Bond & van Wilgen 1996). In Australia fossil charcoal is common in Tertiary sediments, well before Aboriginal occupation of Australia (Truswell 1993, Martin 1996). Charcoal in sediments in the eastern Murray Basin in Victoria indicates fire was present there at least periodically throughout the whole of the Tertiary, but increased markedly in the late Tertiary (10 Ma-2 Ma BP) when it was associated with reduced rainfall and increased seasonality of precipitation (Kershaw *et al.* 1994). No complete Cainozoic sedimentary sequences are known from south-west WA (Fig. 1), equivalent to the deposits of the Murray Basin, but Eocene sediments in the far south, a meteorite crater north of Perth

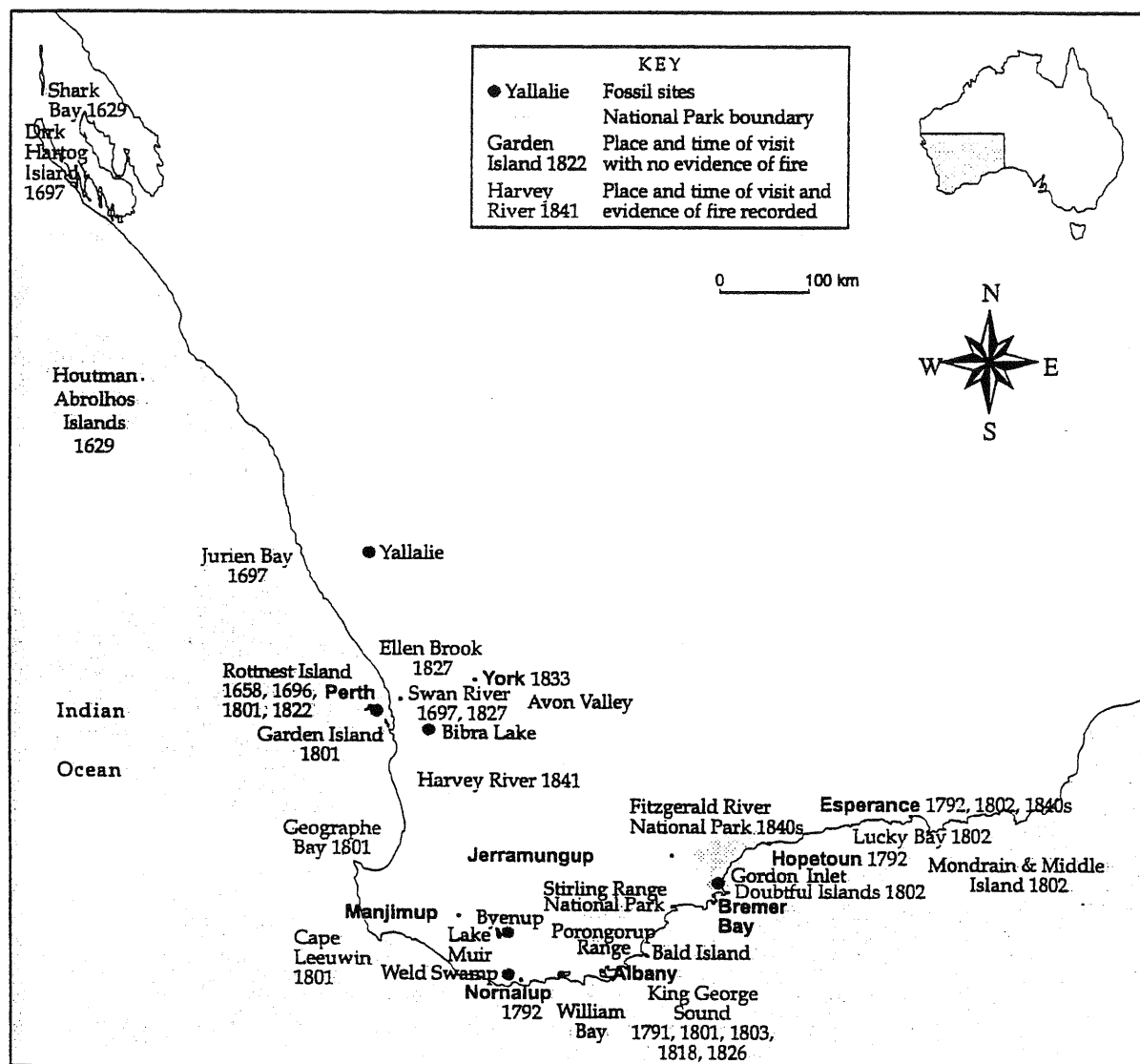


Figure 1. Map with locations of pre-settlement records in this paper and in Abbott (this volume).

at Yallalie with Pliocene lake sediments, and scattered late Tertiary and Quaternary lacustrine deposits of small extent provide glimpses into the conditions operating in some areas at those times. Most wildfires in past periods were probably started by lightning strikes, but after Aboriginal occupation, Aboriginals provided an ever-present source of ignition. The period of occupation of Australia by Aboriginal people has been estimated by dating archaeological deposits, and the earliest generally accepted dates are c. 60 ka BP in northern Australia (Roberts *et al.* 1994) and for south-west WA 50 ka BP at Devil's Lair (Turney *et al.* 2001). Discussion of the period of time Australia has had Aboriginal occupation is extensive and includes Singh *et al.* (1981), Singh & Geissler (1985), Bowman (1998) Kershaw (1986, 1994), Roberts *et al.* (1994) and Mulvaney & Kamminga (1999). Conventional ^{14}C dates indicate widespread occupation in Australia by at least 40 ka BP. For south-west WA, Hallam envisaged most of the south-west, east and west of the main forest belt, occupied by 30 ka BP (Hallam 1975, 1987), before the Last Glacial Maximum (LGM) at 20-15 ka BP (Hope 1994). The period of the LGM of 20-15 ka BP probably caused population shifts and fluctuation of population levels, as the period was cooler, windier and drier, and dune formation was active (Mulvaney & Kamminga 1999). The sea level during much of the period before the LGM was considerably lower than at present, and fell

even lower during the LGM, providing greatly widened coastal plains for Aboriginal occupation. After the LGM, climatic conditions ameliorated and sea level rose to and beyond its present level, reaching a peak in south-west WA at c. 5 ka BP (Williams *et al.* 1998). The present river estuaries formed about this time, providing fish for Aboriginal populations, and raised ground water tables may have increased coastal plain soaks, lakes and swamps, much favoured for Aboriginal food items.

The change in sea level and flooding of previously exposed areas of the coastal plain after 12-10 ka BP forced Aboriginal populations onto the present narrower coastal plains. Increased archaeological remains in many areas of Australia, including the south-west, during the Holocene indicate increased Aboriginal populations and a development of cultural and economic complexity termed 'intensification' (Mulvaney & Kamminga 1999). How much of this is due to flooding of previously occupied sites which are now not apparent or available for study, and how much is due to actual increase in population is hard to assess, but in either case the existing coastal plains show evidence of increased usage with its accompanying increased level of burning (Hallam 1975). At Lake George NSW, well inland, Singh & Geissler (1985) found the maximum core charcoal levels occurred over the last 10 ka. It is possible then that the extent of Aboriginal burning in the south-west witnessed by the first Europeans had existed for only the last 5-7 ka.

The overall picture for the south-west is therefore an increasing incidence of lightning-induced fire in the Tertiary as the climate dried and became more seasonal, followed by climatic fluctuation in the Pleistocene. In the late Pleistocene, from c. 60 ka BP, Aboriginal people entered the continent and comparatively rapidly spread to more favoured areas. For the south-west these were the well watered coastal zone and adjacent forest margins, and inland from the forest belt, the drier more open areas which carry woodland and shrublands. The impact of the LGM was probably mainly the effects of lower rainfall and increased continentality due to lower sea levels, but may have been severe enough to reduce population levels and force population shifts. In the Holocene, it is possible population levels increased and the existing coastal plains were subject to increasingly intense firing, with larger areas subject to reduced fire intervals, as the Aboriginal population sought to increase production of both vegetable and animal food items.

This paper will examine the evidence available for pre-settlement fire intervals from the lake deposits at Yallalie c. 2.5-3.6 Ma BP, from vegetation and charcoal changes at Byenup Lagoon from 4.8 ka BP and from variations in core charcoal in the sediments of a south coast estuary 4.6-2.7 ka BP. It will then touch on the information recorded by pre-settlement explorers and navigators on Aboriginal fire practices, and other research findings on areas and vegetation types in south-west WA.

Yallalie Pliocene lake deposits

A central ecological theme in Australia has been the role of fire in shaping the nature of the vegetation. One school of thought has it that Aboriginal people introduced a sustained fire regime that fostered the spread of sclerophyll vegetation across large areas of the continent (Singh & Geissler 1985, Kershaw 1986, Kershaw *et al.* 1993). Others argue the fire regime has been much more variable through time, and when Aboriginal burning regimes began, they were relatively unimportant in shaping broad vegetation patterns (Horton 1982, 2000, Bowman 1998, 2000). Flannery (1994) proposed faunal

and vegetational change driving increased burning, and observations in the south-west suggest Aboriginal firing modified the structure and composition of the vegetation in many areas (Hallam 1975). This debate can be significantly advanced if high quality vegetation and burning records can be obtained from sites that greatly pre-date human occupation of Australia.

At Yallalie, 200 km north of Perth (Fig. 1), a 110 m lacustrine mud sequence underlies 67 m of Quaternary sands. Magnetic stratigraphy shows the lake sequence has an estimated age between 3.6 and 2.5 Ma BP (Dodson & Ramrath 2001). A pollen and charcoal analysis (Fig. 2) of the upper 24 m of sediment reveals data from an estimated age range between 2.7 and 2.5 Ma BP. There is a general similarity to Quaternary pollen assemblages from sclerophyll vegetation in south-west WA (e.g. Pickett 1997) but in addition small numbers of gymnosperms and specialized angiosperms are present. These species include *Araucaria*, *Nothofagus brassispora*, *N. fusca* type, *Phyllocladus*, and *Dacrycarpus*, which along with several fern spore taxa suggest that pockets of rainforest existed in the region.

Charcoal values were relatively high in some sections of the sediment (Fig. 2), and were present in every sample examined. Many of the charcoal fragments were well preserved charred xylem and other plant material, and clearly had not been transported long distances to the deposit. The charcoal record seems continuous, although it is more abundant in the sclerophyll phases and reduced during phases with more open vegetation cover. Indeed, the Pliocene charcoal record is remarkably similar to that seen in the Holocene of south-west WA (e.g. Dodson & Lu 2000). It could follow that modification of the natural variability of the fire regime by Aboriginal people at these kinds of sites in the late Quaternary was minor, and certainly people could not be responsible for the great spread of sclerophyll vegetation dominated by *Eucalyptus* in Australia. The data therefore support the hypothesis that there is a long history of fire in the Australian environment (including the south-west), it precedes occupation of the continent by people by millions of years. A fossil charcoal record cannot be used alone as evidence of human impact. The fire regime for south-west WA over most of the Quaternary was controlled by climate and vegetation factors. It also seems likely that many rainforest elements have co-existed with fire since at least the Pliocene.

Byenup Holocene lake deposit

Byenup is a freshwater lagoon region near Lake Muir, east of Manjimup (Fig. 1). It is therefore an inland site. There is little known of any prehistory for the area which falls into the category of *Banksia* woodlands little frequented by Aboriginal people (Hallam 1975, Beard 1981). The pollen record (Dodson & Lu 2000) shows in the early Holocene a mix of *Casuarina* and eucalypts with an understorey of heath and some open herbaceous vegetation, including chenopods, occurred (Fig. 3). Fire was not an important factor at this time. The main record begins from c. 4.8 ka BP, and shows a vegetation mix of tree species *Eucalyptus marginata* and *Corymbia calophylla*, with the former becoming dominant by c. 3.5 ka BP. *C. calophylla* again becomes prominent in the last few centuries. A heathy understorey is present throughout the last 4.8 ka, but was apparently less dense during phases when *C. calophylla* was more prominent. *Melaleuca* woodland has been the main vegetation type around the wetland areas since the mid-Holocene.

In fluvial environments it is known that wood and charcoal may be incorporated into sediment after significant storage time in the flood plain (Blong & Gillespie

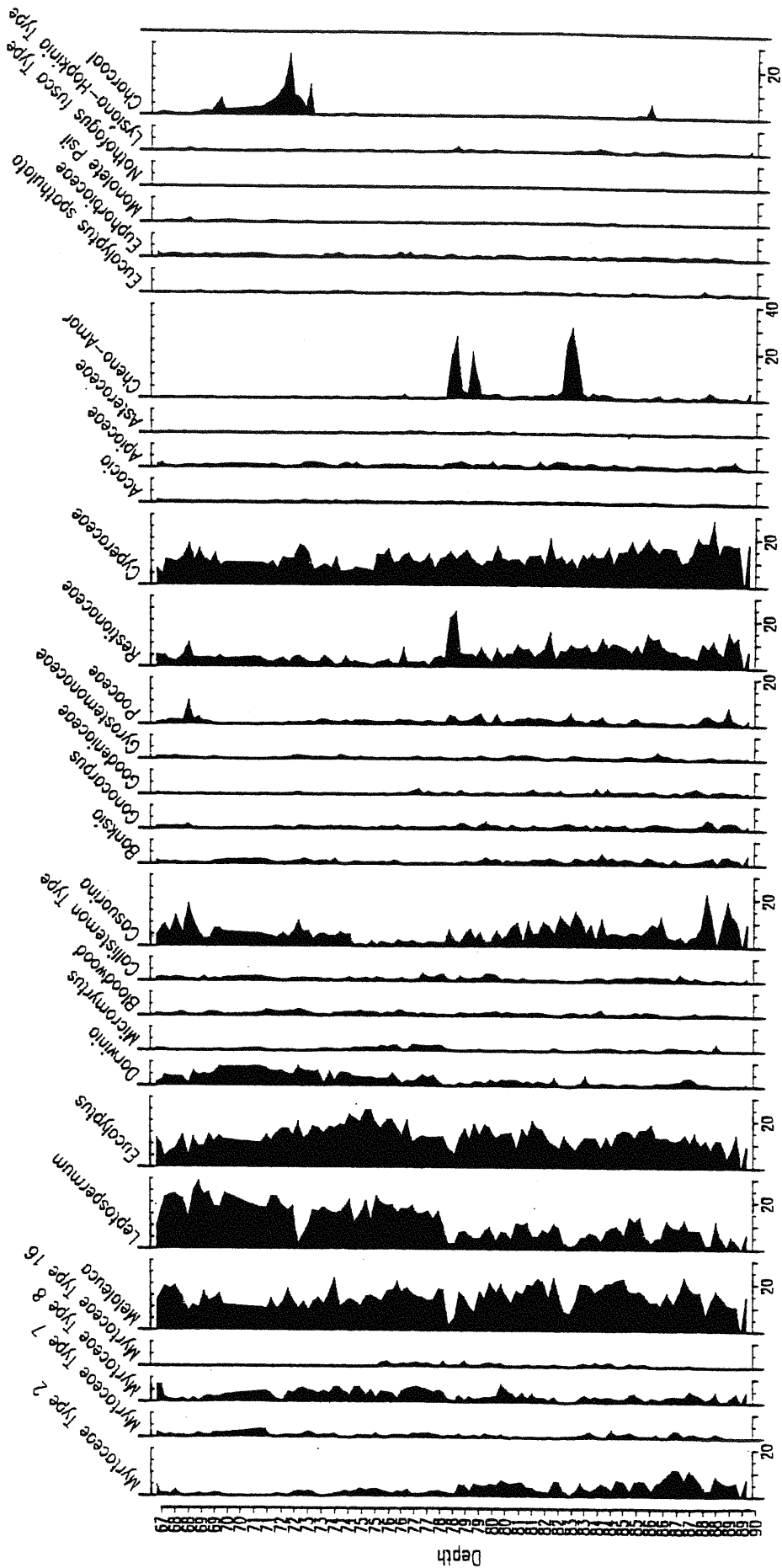


Figure 2. Pollen and charcoal diagram from upper section of Yallalie core, depth 67 to 90 m, covering period in Pliocene 2.7 to 2.5 Ma BP, from Dodson & Ramrath (2001).

1978). If it can be shown that pollen and charcoal are of the same age then vegetation and fire histories can be compared. Dodson & Zhou (2000) examined pairs of pollen residue and charcoal samples from equivalent levels in the Byenup samples. The 4 paired pollen residue and charcoal samples were consistent in age. This indicated that charcoal input at this site can be directly equated with vegetation dynamics revealed by pollen analysis. The possible role of fire in the vegetation changes can therefore be assessed by examining trends in charcoal and pollen abundance. Most of the charcoal values are relatively low and presumably are derived from bush-fires in the region, or small localized fires in the catchment. Two major peaks in charcoal, around 4.2 ka BP and from 2-3 ka BP probably reflect major local fires (Fig. 3). The higher values in heath taxa occurred between these 2 major charcoal occurrences. After the last major fire or series of fires there was an increase in *C. calophylla* and a decline in *E. marginata* pollen. These data may indicate that since the mid-Holocene fire has been a possible control on the mix between *E. marginata* and *C. calophylla*, with fire selecting against the latter and at the same time leading to a less dense understorey, although this hypothesis needs to be tested against other sedimentary deposits in the region.

Gordon Inlet estuarine sediment core, Fitzgerald River National Park

Recent work in Fitzgerald River National Park (FRNP) on the south coast of Western Australia (Fig. 1) using the abundance of charcoal in a sediment core compared to unburnt plant material (Relative Charcoal Abundance or RCA) has indicated the type of fire regime operating in the catchment of the Gairdner River 4.6-2.7 ka BP (Hassell 2000). The river catchment is within and adjacent to FRNP. The data come from a core of sediment extracted from Gordon Inlet, the barred estuary lagoon of the Gairdner River. By examining the whole core in 1 cm intervals, a record of charcoal brought down by the river from fires in the catchment and deposited in the estuary was obtained. The organic rich core sediments indicate comparatively long (more accurately 'intermediate') fire intervals between 30-100+ yrs operated over 4.6-2.7 ka BP. The climate of the area is now 'Mediterranean, semi-arid', with rainfall mostly 400-500 mm, falling predominantly in the winter period, but highly variable in timing and extent from year to year. Records left by Europeans who first traversed the area of FRNP show the vegetation was mature and dense, there was little permanent freshwater and little use by Aboriginals. The general lack of evidence of burning was consistent with little evidence of the normal signs of use by Aboriginals, although these signs were observed to both the west and east of the area, and Bird (1985) found Holocene stone artefacts immediately west of FRNP. The fact that freshwater is available only immediately after rain would not assist Aboriginal use of the area. The dry area of FRNP formed a natural boundary zone between the Goreng and Wudjari Aboriginal groups (Bird 1985). If the situation was the same back to 4.6 ka BP, then the type of fire regime indicated by the RCA results may be the 'natural' or 'non-Aboriginal' fire regime of that climate and vegetation type. The change in the fire regime over time may even indicate initial or increased Aboriginal burning in the headwaters of the Gairdner River from c. 3 ka BP.

Dating of intervals of the core (by ^{14}C) indicate each 1 cm sample of the lower section of the core represented and average of 8 yrs sedimentation, and for the upper section of the core, 14.5 yrs sedimentation. This level of resolution is sufficient to distinguish short fire intervals of 5-10 yrs from intermediate intervals of, say, 30-100 yrs.

Most charcoal from a fire reaches sites of terrestrial sediment deposition such as an estuary by riverine water transport from the first period of heavy rainfall and run-off after a fire (Clark 1983). The contribution of charcoal from air-borne smoke occurs only at the time of the fire, is dependent on wind conditions and direction, carries small particles, and is considered a minor sediment source. Most charcoal particles from a fire are left within the burnt area, are long lasting, and are available to be mobilized and transported by heavy rainfall events subsequent to the fire. A widespread fire in the catchment is thought to produce a marked initial pulse of charcoal in the sediment, followed by reducing amounts of charcoal over time from that fire. If no more fires occur in the catchment for 50-100 yrs, the amount of charcoal reaching the sediments will reduce to low levels (Clark 1983). Alternatively, if there are subsequent fires every 5-10 yrs within the catchment there will be a major pulse of charcoal every 5-10 yrs incorporated into the sediments. Thus the pattern of charcoal deposition over time (up the core) will be high peaks followed by a markedly reducing charcoal influx over a long time period for intense widespread fires after long intervals, or a relatively even influx from many lesser fires at short intervals.

The core results are those from the deposition of sediment including charcoal from the whole of the river catchment. As such they indicate a 'catchment fire interval' from fires anywhere in the total catchment, not the fire interval of a small specific area. A fire indicated by a charcoal peak on a graph of RCA values over time may or may not have occurred in the same area (within the catchment) as the previous fire. The catchment fire interval will correspond to the fire interval of small specific areas only if the whole catchment is burnt in every fire. However, the catchment fire interval does provide a minimum fire interval for areas within the catchment.

The pattern of RCA results from the Gordon Inlet core indicate the core can be divided into 3 parts, called Fire Regimes 1, 2, and 3 (Fig. 4, Fig. 5, Fig. 6). Fire Regime 1 is the lowest section of the core, representing 4 676-4 250 yrs BP, which shows a pattern of high peaks followed by a reduction to low levels over a long period of time

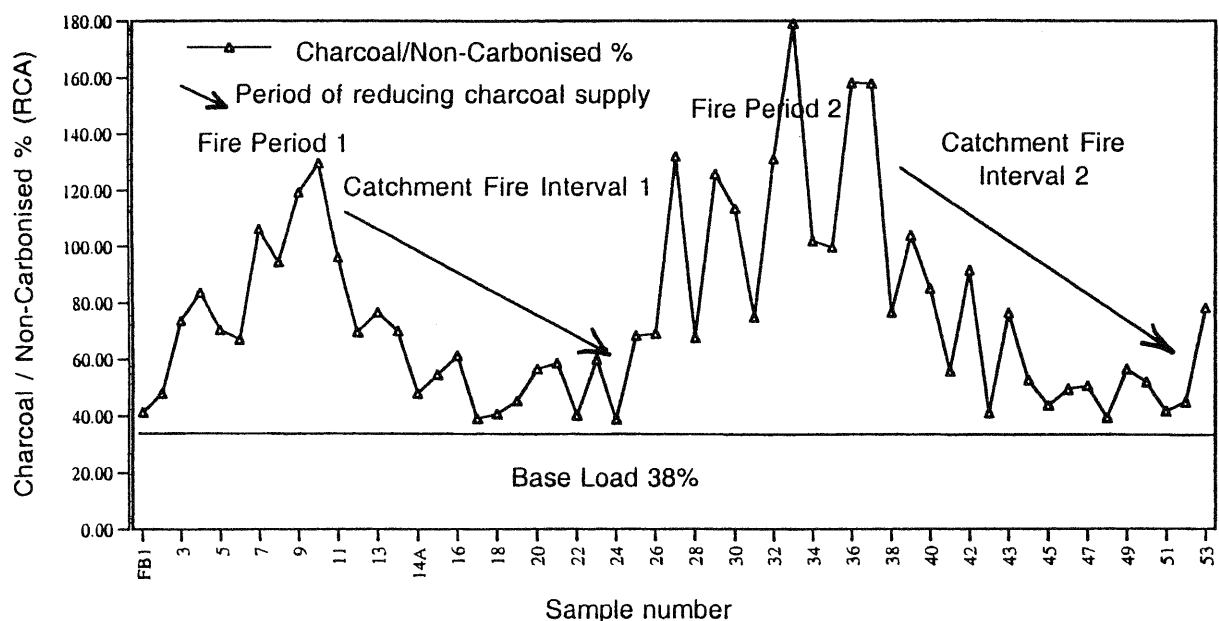


Figure 4. Lower section of Gordon Inlet core, plot of Relative Charcoal Abundance against sample number (=time). Fire Regime 1, 4 676 yrs BP (FB1) to 4 250 yrs BP (FB53). Major catchment fire periods of 50-80 yrs, major catchment fire intervals of c. 140 yrs (each sample represents 8 yrs).

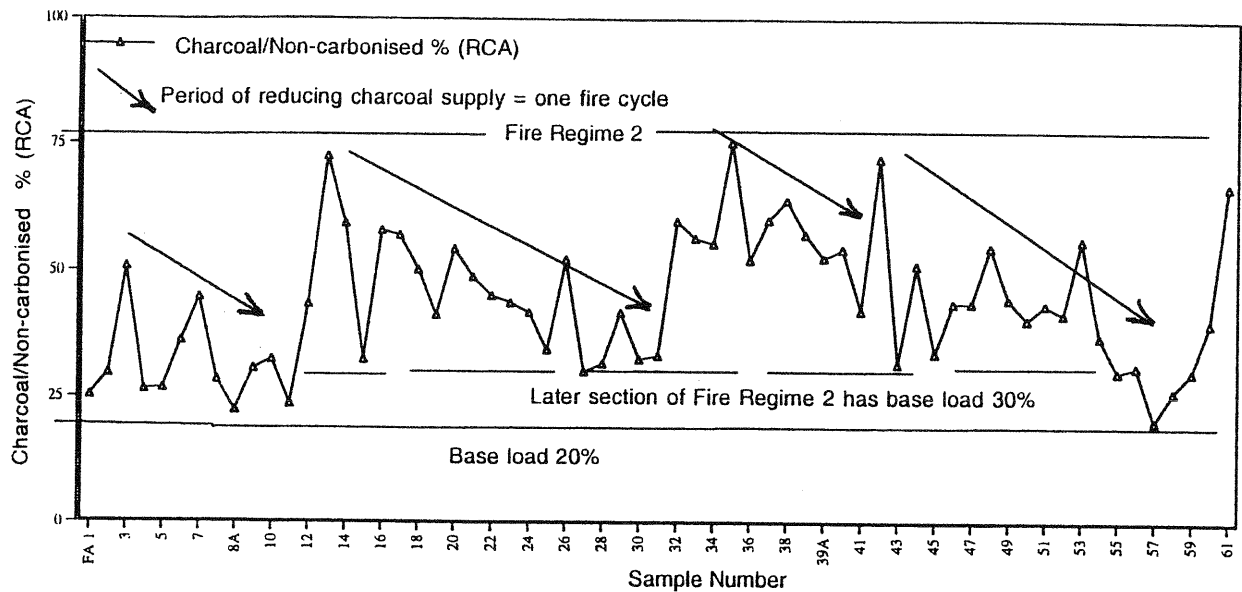


Figure 5. Central section of Gordon Inlet core, Relative Charcoal Abundance (RCA). Fire Regime 2, period 4 250 yrs BP (FA1) to 3 410 yrs BP (FA61). RCA peaks lower, major catchment fire intervals 160 – 260 yrs (each sample 14.5 yrs).

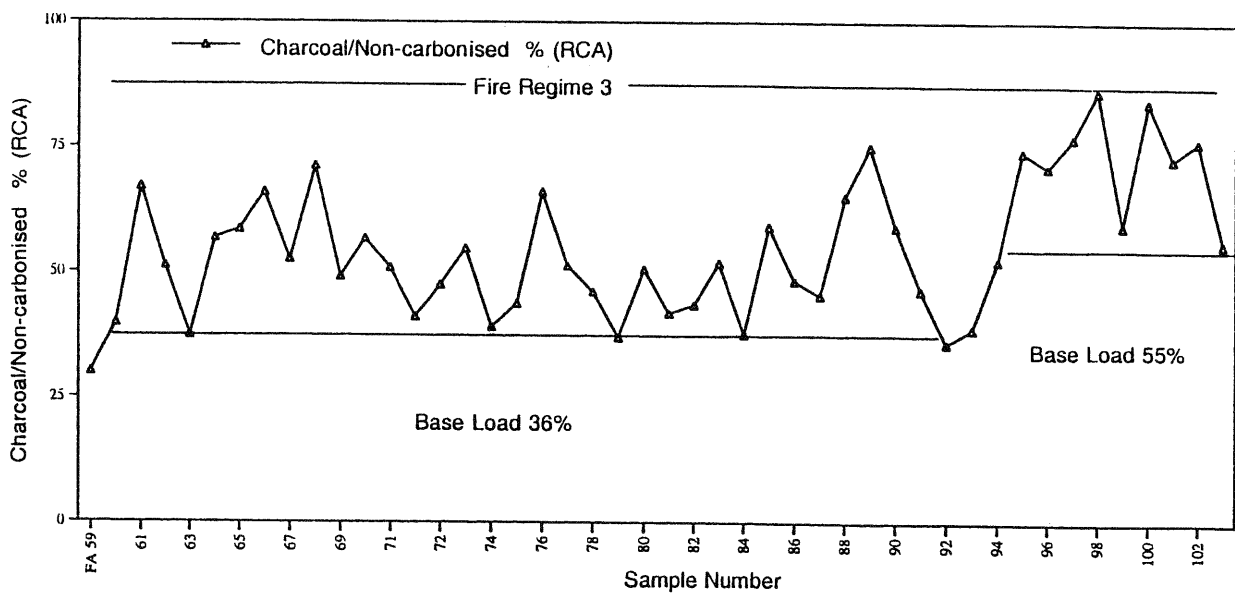


Figure 6. Upper section of Gordon Inlet core, Relative Charcoal Abundance (RCA). Fire Regime 3, period 3 410 yrs BP (FA60) to 2 756 yrs BP (FA103). No obvious fire cycles, minimum period between major peaks two periods, minimum catchment fire interval 29 yrs.

(100 + yrs). The fire regime indicated is widespread and almost certainly intense fires at intermediate intervals of up to 140 yrs. Fire Regime 2 is the central section of the core representing 4 250-3 410 yrs BP. It is similar to Fire Regime 1, but with reduced peaks and a lesser period between fires (range 29-87 yrs). Fire Regime 3 is the upper part of the core, 3 410-2 756 yrs BP, with most fires 29-58 yrs apart (assuming lesser peaks are due to separate fires and not an exceptionally heavy fall of rain). The more chaotic, but generally more even, pattern of Fire Regime 3 suggests even lesser and more variable catchment fire intervals. The minimum fire period is still 2 periods (samples) representing 29 yrs in time, at about the lower limit for 'intermediate' fire intervals.

As mentioned above, for a catchment fire interval of 29 yrs, the subsequent fire may or may not occur in the same location. For more smaller fires which burn only part of the catchment and provide a reduced sediment charcoal peak, a 29 yr catchment fire interval is likely to result in fire intervals for specific areas greater than the 29 yr minimum. The overall results suggest a trend towards smaller fires at lesser intervals but still not less than 29 yrs between fires in one location, and probably considerably longer.

Reports on Aboriginal burning from early navigators and explorers

For the historic period leading up to European settlement in Western Australia, early navigators noted the presence of smoke and fires on the mainland and assumed that this indicated the land was inhabited. Those visitors that landed on the coast confirmed the main source of fires they observed was the Aboriginal inhabitants. A full list of known references to native firing in south-west WA, covering the period 1658 to 1888, is given by Abbott (this volume) and he has classified the information under the headings season, frequency, scale and intensity of burning. However a discussion on some aspects of Aboriginal burning is relevant here. The first aspect is a consideration of islands as fire exclusion areas.

Islands off the coast of south-west WA were not occupied or visited by Aboriginals who had no watercraft and insufficient swimming skills to reach the islands. Vlamingh in the *Geelvinck* called at Rottneest Island in December 1696 (Robert 1972, Playford 1998) and found the island well wooded and unburnt, as had Volkersen in 1658. Freycinet and Fauré, sailing with Baudin, landed at Rottneest in June 1801 where they also found the woods thick and difficult to penetrate (Cornell 1974). King in 1822 found Rottneest Island was not inhabited or visited by the natives and the vegetation was dense. Garden Island nearby and much closer to the mainland was also unburnt in 1801 and covered by thick growth (Hallam 1975). A similar situation was found for the islands of the Recherche Archipelago by Flinders in 1802 (Hallam 1975, Weston 1985), Bald Island before and after settlement (Storr 1965), Michaelmas Island in King George Sound (Captain Barker in 1830 in Mulvaney & Green 1992). The structure of the vegetation on the islands was distinct from that on the mainland with species that were shrub-sized on the mainland where they were subject to Aboriginal burning, in some locations forming thickets and low forest on the islands where they were free from Aboriginal burning (Weston 1985). Weston found there had been no fires on Middle Island for 170 yrs. The situation was similar on Kangaroo Island off South Australia (Péron 1816, Tate 1883, Lange 1979, Singh *et al.* 1981). The early reports are necessarily confined to the coastal zones, and it was not until after settlement that Aboriginal burning practices inland were observed.

D'Entrecasteaux with the *Recherche* and *L'Espérance* anchored near Esperance in 1792. Riche the botanist and some companions visited the mainland in December 1792 and saw some fires were lighting up from place to place. Riche separated from the others and became lost, but was able to observe the natives at their fires over several days. He observed numbers of fires and the natives 'from morning till night, were busy poking their fires' (Duyker & Duyker 2001). Baudin anchored in King George Sound in February 1803. There was little contact with the natives, but on departure on 1st March, west of the Sound, they observed several columns of smoke. On the 3rd of March, further west, they saw a great number of fires and 'counted 17 of them all at a short distance from each other and none in any way resembling the great blazes that

we had often noticed. On the contrary, these appeared to be private fires which did not last long and which all disappeared before dark' (Cornell 1974). Phillip Parker King on the *Mermaid* visited King George Sound in January 1818. He noted smoke from native fires every evening. King considered the vegetation had recovered completely by 16 yrs after the previous fire. His crew inscribed a tree with the ship's name but when they called again 3 yrs later the inscription was barely legible due to the tree having been burnt (Sellick 1997).

Official settlement of King George Sound commenced in December 1826. Scott Nind as surgeon to the settlement reported that in the Albany area, summer was the fishing and burning season for the natives, that Christmas was when they commenced firing the country, and that burning was carried out in consecutive portions (Hallam 1975). Further east from Albany exploration did not occur until the 1840s and although post 1826-29, these later reports are considered to represent the situation there before settlement. Eyre in 1841 found numerous signs of natives from the western edge of the Great Australian Bight to the eastern margin of FRNP, but in the area of the Park there were no signs of native occupation and the vegetation was dense, mature, largely unburnt and very difficult to move through (Eyre 1845). Roe found a similar situation during his epic journey to the Esperance area, and return (Roe 1849).

For the Aboriginals, fire was the universal tool. Its use pervaded all aspects of Aboriginal life. It was used for cooking, comfort, light, hunting, in ritual, signalling, to drive out intruders, for protection against evil spirits, to clear travelling ways, prepare foods for harvest, and, in the words of Vancouver, for the production of 'a sweeter growth of herbage' (Lamb 1984), which, in due course, would attract food species. Hallam (1975) considers fire was the tool used 'to modify and exploit their terrain as to continue to extract sufficient resources for increasing populations'. The areas of the coastal plains although reduced with rising sea levels after the LGM still had the potential (with the newly formed estuaries) to support denser population numbers with greater use of the firestick. In contrast, inland areas may have reached their carrying capacity earlier and did not support increasing populations late in the Holocene (Hallam 1975). On the coastal plain, pre-settlement burning habits were maintained for some time after settlement and Bunbury, quoted in Hallam (1975), indicated that large areas were burnt at fire intervals of 2-3 yrs. However not all areas are thought to have been burnt at these short intervals. The evidence is that much of the west coastal plain was occupied, exploited and burnt regularly. River valleys and well watered areas on the edge of the forest country on the Darling Scarp were used at least seasonally. The drier country east of the northern Jarrah forest, such as the Avon Valley and Victoria Plains, and that east and north-east of the Jarrah-Karri forest in the south (such as the Porongurup and Stirling Range area), was also occupied by resident groups, but the central section of the Jarrah forest south of Perth to the wetter south coast was little used and little burnt (Hallam 1975) except along some of the watercourses (Pearce 1989). Grey in 1841 searched for a Mr Elliott who had set off westwards from Williams to reach Leschenault, and found the forest dense on the elevated tableland, the understorey a prickly scrub, the ground encumbered with fallen trunks and very little wildlife, and.....'we had in vain looked for natives' (Hallam 1975). As Grey emerged from the forest near the Harvey River, he found the trees more scattered, and there were grassy areas and signs of natives. Bannister in 1833 passed through '90 miles of luxuriant pasture ground' south of the York area along the eastern margin of the Jarrah forest but found dense forest with thick undergrowth north-west and west of Albany in which he met no people (Hallam 1975).

From Albany northwards and east to Bremer Bay the country was used and burnt by Aboriginals. Even in the Albany to Bremer area there were areas 'shunned' by the Aboriginals where the scrub remained thick and difficult to penetrate (Roe 1849). However the south coast population was not as dense as that on the coastal plain west of the Darling Scarp (Le Soeuf 1993). Pre-settlement population densities have direct implications for the extent and intensity of Aboriginal burning. For the Esperance area east of FRNP, Smith (1993) estimated the likely population did not exceed 300-400 people. The people in this area occupied the coastal area to the headwaters of the south-flowing rivers, and did not appear to mix with the inland groups (Smith 1993, Hassell 1975). Roe (1849) found indications of much lesser numbers inland from the headwaters of the southern rivers. Estimates for the Swan Coastal Plain by Dortch (2000) were from 10 to 18 per 100 km², for the King George Sound (Albany) region from 4 to 10 per 100 km², with inland densities half the latter figure. The early European observations were thus in the denser populated coastal areas where the degree of Aboriginal burning was probably at its maximum. No real evidence of the 'intensification' postulated for eastern Australia (Mulvaney & Kamminga 1999) was found by Dortch (2000) for far south-west WA. His evidence suggests changes there were gradual, and changes in 'economic strategies' were the result of changing emphases. However the large areas in Western Australia with a wide range of food items and locally high relative abundance of resources made assessment difficult.

Published research on south-west WA fire intervals

Research on pre-settlement fire regimes other than the above has been carried out on timber and grasstree stem fire scars, and from charcoal levels in lake and swamp deposits. The incidence of fire in the southern Karri forest was investigated by examining fire scars on Karri (*Eucalyptus diversicolor*) logs at sawmills, and stand age of growing Karri, which needs fire for good germination (Christensen & Annels 1985). Few fire scars were seen on timber at sawmills, and uneven stands (age cohorts) of Karri which lives to 300 yrs suggest low to moderate intensity fires at comparatively frequent intervals. Intense fires were infrequent.

The sediments in Weld Swamp in the southern forests were examined by Churchill (1968). He found charcoal was common in the peat over the last 5 ka and that some fires had burnt and truncated the peat deposit. Fires in the swamp early in the period were infrequent and intense, whereas later fires were more frequent. Charcoal from William Bay, also west of Albany is dated c. 7 ka BP (Birmingham *et al.* 1971). For the more northerly forest areas, stem analysis of the fire scars on Jarrah which lives 300-400 yrs, indicated an average pre-settlement intense fire interval of 81 yrs which reduced after settlement to c. 17 yrs (Burrows *et al.* 1995). Jarrah is resistant to low to medium intensity fires but intense fires leave a permanent scar on the trunk. The pre-European fire regime in the drier areas of the Jarrah forest and forest margins was probably one of frequent, low intensity Aboriginal fires set mainly in summer and autumn, with occasional long intervals between fires ending in high intensity fires that scarred the tree trunks. The wetter zone of the Jarrah forest and the Karri forest was burnt less frequently (Burrows *et al.* 1995).

'Blackboys' or grasstrees (*Xanthorrhoea*) are relatively long-lived and the stem provides a fire history of that plant (Ward *et al.* 2001). They are widespread in south-west WA including the dry eucalypt forest and if sufficient individuals are examined,

may provide a record of the fire history of the immediate area. Aboriginals were known to set fire to number of individual grasstrees as signal fires so examination of large numbers of plants is needed to infer a wide ranging fire rather than lines of individual grasstrees ignited by passing Aboriginals. For the 80 yrs prior to European contact and the following 40 yrs (to 1870), Ward *et al.* (2001) recorded 2-4 fires per decade (say fire intervals of 3-5 yrs). European influence has increased the fire intervals progressively to 5-7 yrs, 10 yrs and for the last 20 yrs fires were 15-16 yrs apart. Of the areas they sampled, a number are in the northern Jarrah forest, others are close to the forest margin, areas known to have been subject to Aboriginal use (Hallam 1975). The applicability of the above results on fire intervals to the whole of the forest region, including those not much used or traversed by Aboriginals, is, however, open to question.

A pollen study on cores from 3 near-coastal lakes on the Swan Coastal Plain included notes on charcoal occurrence (Pickett 1997). She found carbon dates on the sediments extended as far back as 34 ka BP. There were indications of 2 periods between 34 ka BP and 11 ka BP, corresponding to the LGM, when fires were more frequent and intense. This period is thought to have been drier and more fire prone. After 11 ka BP charcoal increased in conjunction with eucalypt pollen, but reduced in the mid-Holocene when rainfall may have been higher. After 4 ka BP, charcoal levels rose again. Aboriginals lived in the Perth environs over the whole of the period, but Pickett found Aboriginal impacts were more pronounced in the mid- to late-Holocene when the population density is thought to have increased substantially. A low even level of charcoal after 4 ka BP correlated with evidence of Aboriginal occupation of the lakeside since 5 ka BP.

Conclusions

Fire conditions in the south-west are primarily dependent on climatic factors, particularly the level and seasonal spread of rainfall. As in eastern Australia, fire was present in the south-west by the end of the Tertiary as evidenced by charcoal in the Yallalie Pliocene sediments. However, for the Quaternary, the actual fire regime in various areas was probably strongly dependent on the presence or absence of Aboriginals, and where present, on the population density. Areas that did not provide fresh water and food species were shunned or visited rarely by Aboriginals. In these areas, such as the central southern forest regions and FRNP area, much longer fire intervals operated, at least for major fires. Similarly, Aboriginal-free offshore islands had long fire intervals, some well over 100 yrs. Areas that were regularly used by the Aboriginal people were burnt on a regular basis, the frequency of which depended on the density of the population and the capacity of the land to provide a range of Aboriginal food. The west coastal plain from Busselton to Swan River appears to have had the densest population, with lesser numbers beyond the forest to the east, down to the south coast. From evidence available to date it would appear population levels increased in near-coastal areas in the Holocene as the climate warmed after the Last Glacial Maximum, and sea-level rose to and beyond its present level. The area of country subject to Aboriginal burning, and the frequency with which it was burnt, would have increased accordingly. The amount of Aboriginal burning observed at contact time is therefore likely to have been at its maximum.

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