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Bark as fuel in a moderate intensity jarrah forest fire

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SUMMARY

Firefighters have long recognized that flammable bark on the boles of jarrah (*Eucalyptus marginata*) and marri (*Corymbia calophylla*) trees contributes to the intensity and suppression difficulty of forest fires burning under dry conditions. We surveyed trees in mature jarrah forest soon after a moderate intensity fire under dry summer conditions and found that mean tree bark thickness (measured at breast height) was about two thirds that of the bark thickness on trees in an adjacent forest that was burnt by low intensity fire seven years earlier. In addition, we calculated that bark on the boles of living trees contributed about 5 t ha^{-1} of fuel to the flaming zone of a moderate intensity fire. Firefighters need to be aware of the additional hazard posed by accumulations of flammable bark on marri and jarrah trees in forests that have not been burnt under dry conditions for long periods.

INTRODUCTION

Fuel reduction burning is the cornerstone of wildfire control in sclerophyll forests of south-west Australia. In jarrah (*Eucalyptus marginata*) forests, low intensity (<350 kW m^{-1}) fires are set at 6–10 year intervals to maintain surface litter fuel below about 8 t ha^{-1} in strategically important areas (McCaw and Burrows 1989). Normally, these fires burn under cool, moist conditions in spring or late autumn after the opening rains and do not burn the outer bark on standing trees above about 2 m. However, during moderate to high intensity wildfires and fires burning under very dry fuel and soil conditions, it is common for bark on standing jarrah and marri (*Corymbia calophylla*) trees to ignite along the entire length of the bole (Burrows 1997). This additional fuel source contributes to fire behaviour and to suppression difficulty by increasing fire intensity at the flaming zone and by providing material for long distance spotting (Luke and McArthur 1978). Spotting is the process of fire ignitions (spot fires) starting downwind of the main fire caused by burning pieces of bark (and other material) carried aloft in the convection column and deposited. In jarrah forests spot fires have been reported as far as 5–7 km from the main fire front. Short distance spot fires are often referred to by firefighters as hop-overs (embers which 'hop over' the fire break or control line). Long distance spotting and hop-overs can cause considerable control difficulties and can endanger the lives of firefighters in some circumstances. Recognizing this, bark characteristics form an important part of the fuel hazard rating system used in Victorian forests (Kellas 1992). As well as aggravating control difficulties, the combustion of bark on the bole and branches of jarrah and marri trees contributes to crown and bole damage (Burrows 1994).

The amount of flammable bark on the upper boles and limbs of standing trees accumulates despite low intensity fuel reduction burns and is usually only burnt during intense fires or fires burning under dry conditions. The aim of this survey was to estimate the amount (weight) of bark burnt from the boles of jarrah and marri trees during a moderate intensity summer fire.

METHOD

The survey was conducted in conjunction with fire behaviour studies carried out in the summer of 1983 in McCorkhill State forest some 25 km west of Nannup, Western Australia. The study site was typical of the mature Donnybrook Sunklands jarrah forest described by McCutcheon (1978). This forest had experienced a fire regime of low intensity fuel reduction burns on a 6–7 year rotation since the late 1960s, and prior to this study, was last burnt by low intensity prescribed fire in spring 1976. No recent wildfires have occurred in the area to our knowledge.

About two hundred jarrah and two hundred marri trees representing a range of bole sizes from 5 cm to 144 cm diameter at breast height over bark (d.b.h.o.b.) were selected in each of two adjacent 100 ha plots of mature forest. One plot was last burnt by low intensity fire in spring 1976 (the 'spring burnt plot') and the other was burnt by moderate intensity fire under dry fuel and soil conditions in summer 1983 as part of a fire behaviour experiment (the 'summer burnt plot'). Other than this, both sites had experienced the same management history and were very similar in all other respects, including stand structure and composition. The moderate intensity summer fire resulted in complete scorch to the overstorey and charring of the tree boles and lower limbs.

The weight of bark (t ha^{-1}) burnt from the tree boles during the 1983 moderate intensity summer fire was estimated by comparing the weight of bark on tree boles in the two burn treatments. This was done by measuring both bark thickness and stem diameter over bark at breast height (d.b.h.o.b.) on all sample trees, then calculating bark volume and weight. Bark volume was calculated by the following procedure.

The underbark stem diameter (d.b.h.u.b.) and wood volume of the bole of each measured tree was determined by subtracting bark thickness from the d.b.h.o.b. measurement, and using jarrah stem volume tables (Harris 1965). The total volume of each bole, including bark, was determined the same way, but using a diameter measure made over bark. The underbark volume was subtracted from overbark volume to produce total calculated bark volume on the tree bole.

In order to estimate the weight of bark (in t ha^{-1}) it was necessary to determine the density of the bark of both species. Samples of bark from each species were oven dried and weighed. The volume of each sample was determined using the water displacement technique. Before immersion into water, bark samples were coated with a polyester varnish to reduce water absorption. Bark density was then calculated. The size class distribution and basal area of trees by species at each of the survey sites was determined by measuring the d.b.h.o.b. of all trees in a 500 m x 10 m belt quadrat and, as expected, was very similar. Knowing tree size, stocking (stems ha^{-1}), basal area, species, the total volume of bark in each bole size class (d.b.h.u.b.) by species and bark density, the difference in total bark quantity between the two sites could be estimated by subtracting the bark weight in the summer burnt plot from the bark weight in the spring burnt plot.

For the summer burnt plot, fuel measurements, weather and fire behaviour observations were made as part of the fire behaviour studies associated with Project Aquarius (Loane and Gould 1986). The quantity of litter fuel (dead leaves, twigs and bark < 6 mm in diameter) on the forest floor before and after burning was estimated by measuring litter depth on a 100 m x 100 m grid and using a pre-determined relationship between depth and quantity (Sneeuwjagt and Peet 1985). Litter fuel moisture content (as a percentage of oven-dry weight) was determined prior to burning from five to ten 40–50 g samples and the moisture content of the outer 5 mm of bark of jarrah and marri trees was determined by collecting about 30 g of bark (at breast height) from each of ten trees of each species. The summer burnt plot was burnt under warm dry conditions in February 1983. Multiple spot ignitions set on a 200 m grid pattern were used to ignite the plot and fire rates of spread were estimated from both ground observations and by examining imagery from an airborne infra-red scanner.

RESULTS

During the summer burn, the Soil Dryness Index (SDI) (Mount 1972; Burrows 1987) was about 1550 (or 155 – Mount 1972), average surface litter moisture content was about 7 per cent of oven-dry weight (o.d.w.), winds were from the south-east at about 13–18 km h^{-1} (28 m tower wind speed) and ambient temperature and relative humidity were in the range 30–33 °C and 35–40 per cent respectively. The quantity of fine dead (<6 mm diameter) surface litter fuel ranged from 3.5 t ha^{-1} to 11.5 t ha^{-1}, averaging 7.4 t ha^{-1} and under the dry conditions it was virtually all consumed by fire. The mean moisture content of the outer 5 mm of bark of marri and jarrah trees at the time of the fire was 9.3 per cent (o.d.w.) and burnt readily. Fire intensity ranged from 200 kW m^{-1} to 3000 kW m^{-1}, averaging about 1700 kW m^{-1}, and headfire flame heights ranged from about 0.3 m to 4.0 m. There were no records of the conditions under which the spring burn took place, but typically, such burns are implemented when the SDI is <750 (or 75 – Mount 1972).

Mean tree bark thickness (at breast height) was 34.7 per cent and 34.8 per cent lower in the summer burnt plot for jarrah and marri trees respectively (Tables 1 and 2). These differences are highly significant (at the 0.05 confidence level) and consistent across all diameter size classes. The relationships between tree diameter at breast height under bark (d.b.h.u.b.) and bark thickness for both species in the spring burnt and summer burnt plots are shown in Figures 1 and 2.

The tree basal area in the summer burnt plot was 25.9 m^2 and using the above technique, we calculated that bark on tree boles contributed about 5 t ha^{-1} to the fuel load. While not quantified, we observed numerous pieces of smouldering bark being carried aloft in the convection column and observed massive short distance (up to 200 m) spotting from burning pieces of bark (particularly marri) and partially burnt leaves. Most spot fires were ignited by smouldering pieces of bark rather than by leaves.

DISCUSSION

Trees burnt by spring fire seven years previously had significantly thicker bark on their boles (at breast height) than trees burnt by a recent summer fire. This can be interpreted as being due to the combustion of dry outer bark during the more intense summer fire. The reduction in bark thickness was similar for all size classes and for both tree species (marri and jarrah). Kellas (1992) reported 25–40 per cent removal of bark off butts on regrowth and

TABLE 1

Mean bark thickness measured at breast height (1.3 m) for marri (*Corymbia calophylla*) in a forest (a) burnt in spring seven years previously and (b) burnt in summer three months previously. Tree bole diameter classes refer to measurements made at breast height and under bark (d.b.h.u.b.). Difference in mean bark thickness is highly significant for all size classes at the 0.05 significance level. Standard error in parentheses.

d.b.h.u.b. CLASS (cm)	NUMBER OF TREES MEASURED IN SPRING BURNT PLOT	MEAN BARK THICKNESS OF TREES IN SPRING BURNT PLOT (mm)	NUMBER OF TREES MEASURED IN SUMMER BURNT PLOT	MEAN BARK THICKNESS OF TREES IN SUMMER BURNT PLOT (mm)	DIFFERENCE IN MEAN BARK THICKNESS (%)
5–15	35	18.2 (0.7)	29	11.7 (0.6)	35.7
15.1–30	25	30.5 (1.3)	31	15.7 (0.4)	48.5
30.1–45	30	30.4 (1.1)	32	17.9 (0.7)	41.1
45.1–60	29	30.7 (0.9)	28	18.2 (0.7)	39.7
60.1–75	25	29.3 (1.0)	35	20.2 (0.6)	31.3
75.1–90	23	32.2 (0.7)	10	20.8 (0.7)	35.4
90.1+	20	31.3 (1.2)	13	20.1 (0.6)	35.7
Total	187	28.3 (0.5)	178	17.4 (0.3)	38.8

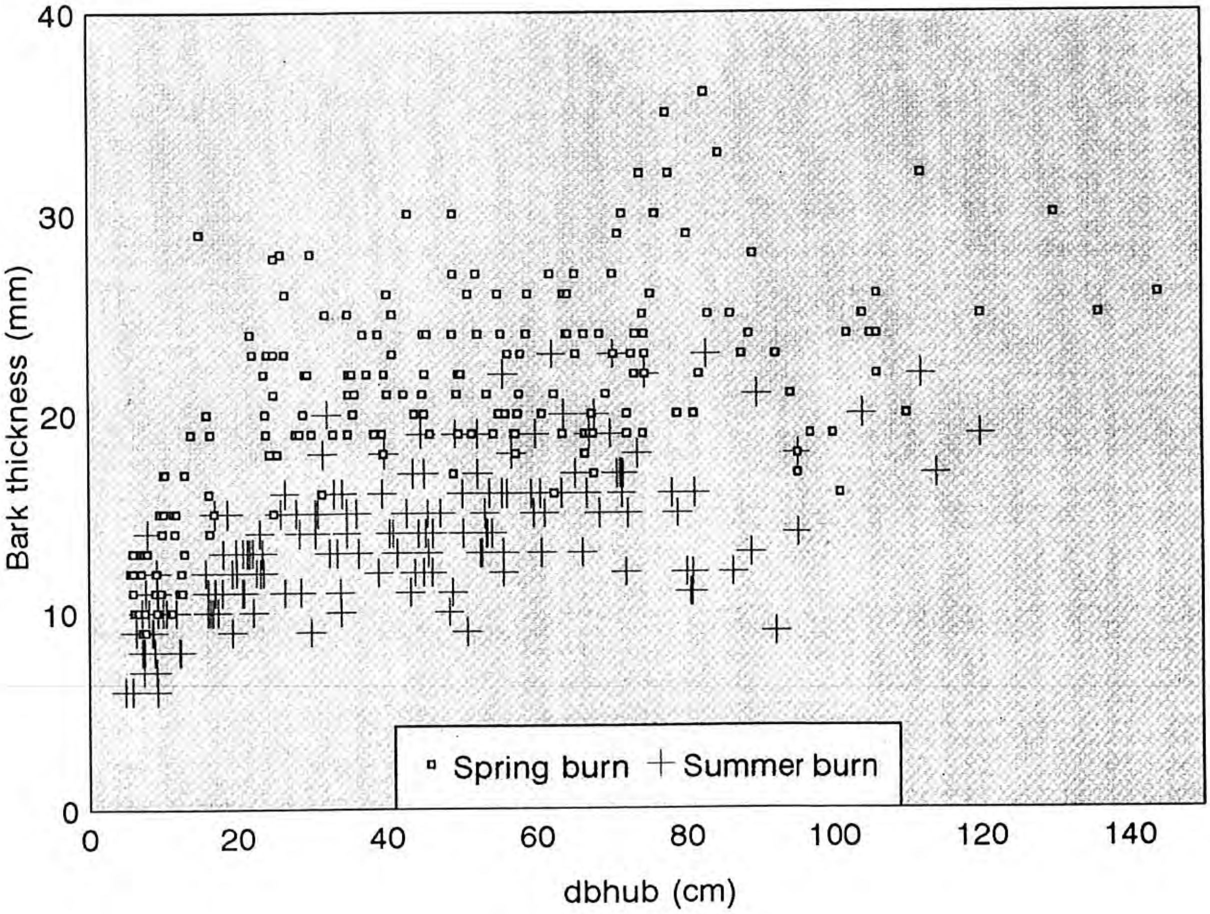

*Figure 1. The relationship between bark thickness and bole diameter measured at breast height (1.3 m) and under bark (d.b.h.u.b.) for marri (*Corymbia calophylla*) trees burnt (a) in spring seven years previously and (b) in summer three months previously.*

TABLE 2

Mean bark thickness measured at breast height (1.3 m) for jarrah (*Eucalyptus marginata*) in a forest (a) burnt in spring seven years previously and (b) burnt in summer three months previously. Tree bole diameter classes refer to measurements made at breast height and under bark (d.b.h.u.b.). Difference in mean bark thickness is highly significant for all size classes at the 0.05 significance level. Standard error in parentheses.

d.b.h.u.b. CLASS (cm)	NUMBER OF TREES MEASURED IN SPRING BURNT PLOT	MEAN BARK THICKNESS OF TREES IN SPRING BURNT PLOT (mm)	NUMBER OF TREES MEASURED IN SUMMER BURNT PLOT	MEAN BARK THICKNESS OF TREES IN SUMMER BURNT PLOT (mm)	DIFFERENCE IN MEAN BARK THICKNESS (%)
5–15	34	12.9 (0.4)	25	8.8 (0.3)	31.8
15.1–30	26	20.8 (0.8)	35	12.4 (0.3)	39.5
30.1–45	28	21.9 (0.6)	30	14.4 (0.5)	33.6
45.1–60	32	22.4 (0.5)	30	14.8 (0.5)	33.9
60.1–75	35	22.8 (0.7)	24	17.2 (0.6)	25.6
75.1–90	15	27.2 (1.4)	10	15.3 (1.3)	43.7
90.1+	20	23.6 (1.1)	6	16.8 (1.9)	28.8
Total	190	21.0 (0.6)	160	13.7 (0.5)	34.7

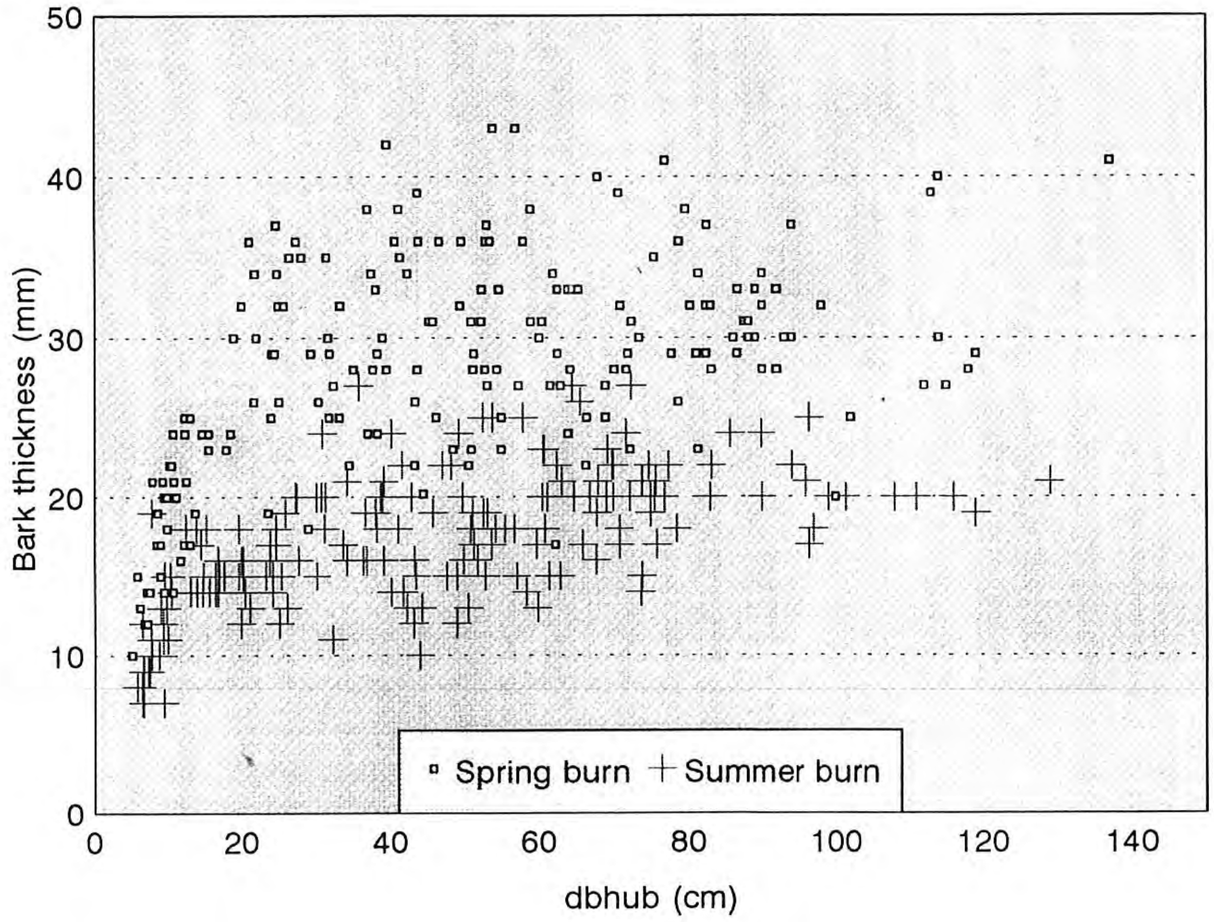

*Figure 2. The relationship between bark thickness and bole diameter measured at breast height (1.3 m) and under bark (d.b.h.u.b.) for jarrah (*Eucalyptus marginata*) trees burnt (a) in spring seven years previously and (b) in summer three months previously.*

overwood trees of messmate stringybark (*Eucalyptus obliqua*) respectively. He also reported an increase in bark loss with increasing SDI. Gill *et al.* (1986) reported a positive relationship between bark loss and fire intensity up to an intensity of about 1000 kW m^{-1} for two eastern Australian *Eucalyptus* species. They reported losses in bark thickness of up to 5 mm and 9 mm for gumbarked and stringybarked species respectively.

Under dry fuel and soil conditions, the quantity of bark on standing trees contributes substantially to the total fuel weight. At this study site, the mean quantity of fine surface litter fuel burnt during the summer fire was about 7.4 t ha^{-1} and we estimate that bark on the boles of standing trees contributed an additional 5 t ha^{-1} of fuel, assuming uniform bark loss along the tree bole. Peet and McCormick (1965) reported a figure of 9.7 t ha^{-1} of bark burnt in a high intensity experimental fire near Dwellingup. However, the stand they studied had a basal area of 44 m^2 ha^{-1}, which was 70 per cent higher than that of our study site.

The specific effect of bark fuel on the behaviour of forest fires, beyond increasing the spotting potential and contributing to the overall intensity of the fire, is not well understood and is not accounted for in existing fire behaviour models. Forest fire fighters need to be aware that while low intensity spring fires control the build-up of fine surface fuel, there is a steady and significant accumulation of flammable fuel and spotting material on tree boles and limbs.

The quantity of bark which burns will depend on the number of years since the last fire, the intensity of the last fire, the tree basal area, the dryness of the bark (which is probably related to the Soil Dryness Index (Mount 1972; Burrows 1987)), the dryness and amount of fine surface fuel and the weather conditions at the time of the fire. Kellas (1992) estimated that bark recovered to pre-burn thickness after a fire-free period of about 15 years. Moderate intensity prescribed fires under dry autumn conditions may be warranted from time to time to reduce the build-up of flammable bark on standing trees, thereby reducing spotting potential and suppression difficulties in the event of a wildfire.

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