BUSHLAND FUEL QUANTITIES IN THE BLUE MOUNTAINS
Litter and Understorey

by A. P. Van Loon

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Bushland fuel quantities in the Blue Mountains Litter and Understorey - A. P. Van Loon

Corrigenda.

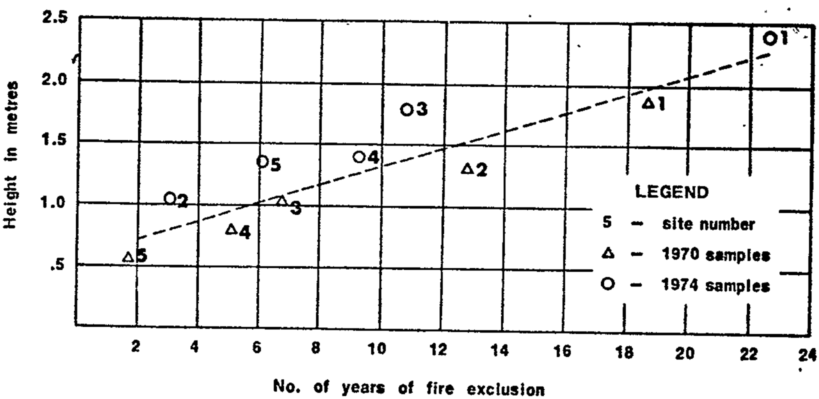
Page 9 - Figure 4.

Height of Understorey.

Site identification is provided in the reproduced graph below. The Forestry Commission of N.S.W. apologises for this omission.

FIGURE 4

Height (m) of understorey against years of fire exclusion



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SYDNEY

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INTRODUCTION

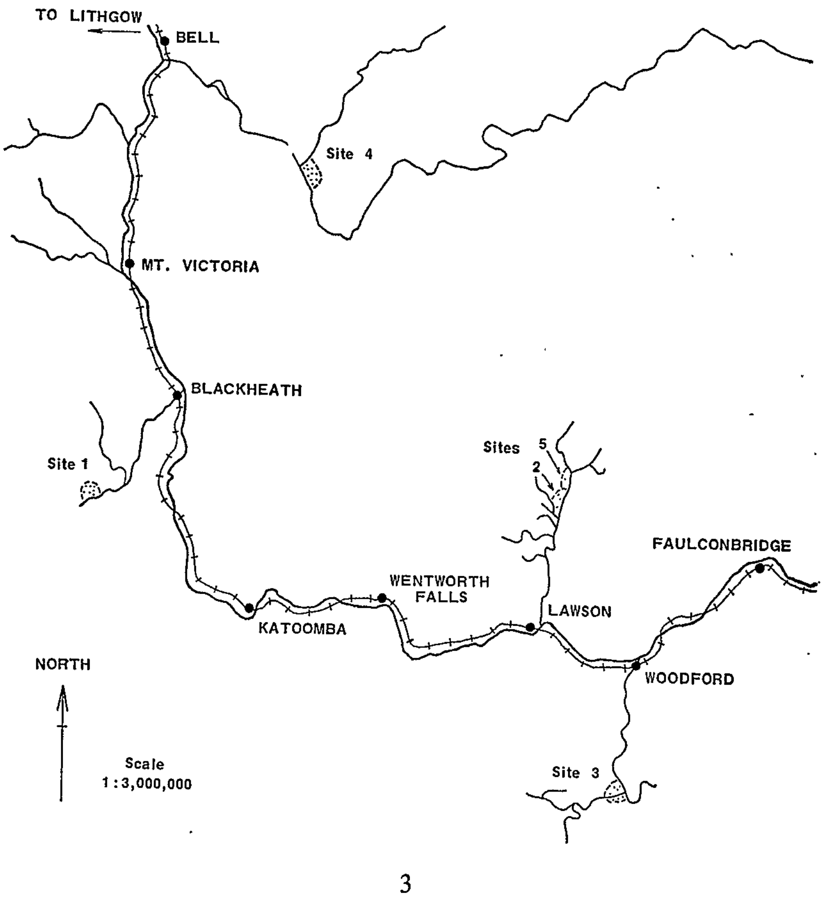
Because the Blue Mountains region of N.S.W. is one of the most bushfire prone areas of the State, fuel weights occurring there are of continuing interest.

On the one hand increased emphasis by fire control authorities on the use of prescribed burning, in efforts to minimize wildfire occurrence and damage, attracts steady criticism by sections of the conservation movement, while on the other hand, despite the increased use of prescribed burning, wildfires are not likely to be fully eliminated, although their frequency and extent may well be curtailed.

Fuel weight data presented here are based on two separate studies, and although the results of both are in close agreement, they are described separately because they differ not only in their objectives, but also in sampling techniques adopted.

FIGURE 1

SHOWING LOCATION OF FUEL SAMPLING SITES IN THE BLUE MOUNTAINS REGION OF N.S.W.



The first study was a survey of the fuel weights occurring on areas with different fire histories. The second was an experiment designed to examine the effects of repeated low intensity fire on the native vegetation.

SURVEY OF FUEL WEIGHTS

This study, carried out primarily at the request of the Bushfire Council of New South Wales, was designed to obtain an estimate of the rate of fuel accumulation against time following wildfire occurrence.

To this end 5 sites with documented fire histories were sampled in 1970 at which time the number of years that fire had been excluded from them ranged from 1.8 to 18.6 years. The same sites were sampled again in 1974, when due to the fact that one of the sites had been prescribed burnt in 1971, periods of fire exclusion on the sites varied between 3 and 22.8 years.

The location of the sample sites is shown in Figure 1, which shows their wide geographic distribution over an area exceeding 50 000 ha.

At both sampling periods weights of the litter-layer and the understorey vegetation were determined separately.

RESULTS I

A. Weight of the Litterlayer

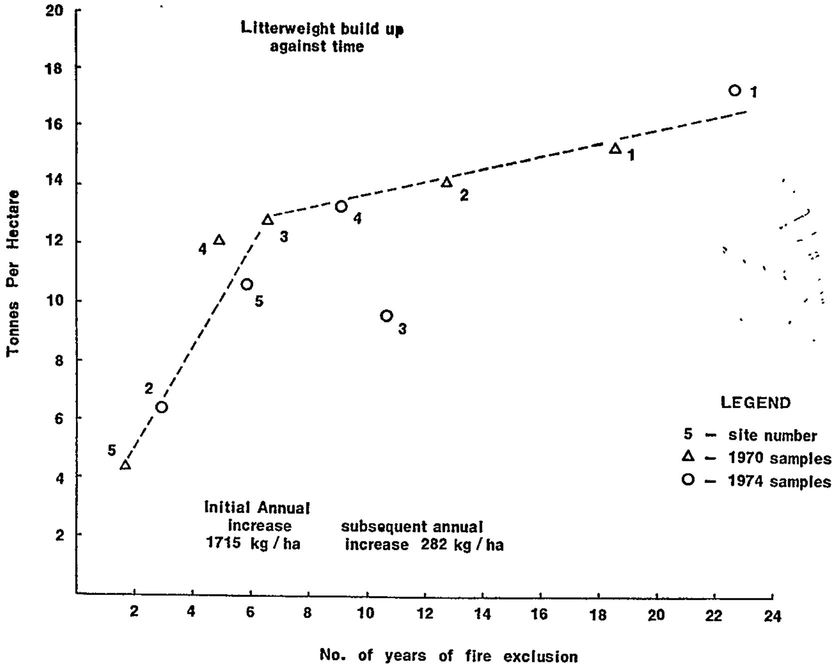
The litterlayer, including grasses, ferns and low herbaceous vegetation less than 0.9 metres in height, was sampled on each site and occasion by the removal of 45 randomly located samples. In order to increase the sampling efficiency, a "ranked set" method of sampling was adopted, as it increases the efficiency of the estimation of the mean relative to "full" random sampling by up to 200 per cent (McIntyre 1952, Halls and Dell 1966, Groves 1974). All samples taken were circular; in 1970 the individual sample area was 0.093 m^2, in 1974 it was 0.1 m^2.

After collection one third of the samples from each site was randomly selected for sorting into component parts. All samples were oven dried at 105° C until no further loss in weight occurred and the percentage composition of the sorted samples of each plot was applied to the oven dry weight of all samples for that plot.

Full details of the weights obtained at each site and sampling period by component parts are given in Appendix 1. The vegetation component of the litterlayer is given in two fractions, viz. green and cured vegetation. This is routine practise in sorting litter samples for fire behaviour studies. The differentiation probably does not assume much importance here as the degree of curing of grasses, etc., varies constantly, depending mainly on seasonal conditions. To obtain the weight of total biomass of that vegetation that was considered part of the litterlayer green and cured fractions can be combined.

Figure 2 below clearly shows the trend in litter build-up against time.

FIGURE 2



Although the low value obtained at the second sampling period on site 3 defies a ready explanation, the results from all other determinations show that a definite pattern of litter build-up occurs in the region.

It can be seen that in the first 6 to 7 years after fire the mean annual increase in weight of the litterlayer is in the order of 1.7 tonnes per hectare, after which the mean annual increase declines to about 0.3 tonnes per hectare.

It is believed that several factors contribute to the substantial differences in annual increments between these periods. Firstly, in the first few years following wildfire, a considerable amount of vegetative material killed but not consumed in the fire progressively declines to the ground to become part of the litterlayer. Secondly, it is possible that the biological and chemical processes that govern litter decomposition do not become efficient until a litterlayer of about 13 tonnes per hectare has been established.

Perhaps the most interesting feature of Figure 2 is that it does not show any tendency for litter build-up to eventually level off. The mean annual increase between years 18 and 23 after fire exclusion is of about the same magnitude as that between years 7 and 13. This is in sharp contrast to results obtained in productive forest sites on the Central Coast of N.S.W. where the litterlayer has been shown to reach an equilibrium weight in the order of 15 to 17 tonnes per hectare, in 3 to 4 years following burning (Van Loon 1969).

The percentage that each component of the litterlayer contributes to the total weight at each site and period are also shown in Appendix 1. These contributions vary between sites and periods, which is not surprising considering the range in years of fire exclusion (1.8–22.8 years) and the wide geographic distribution of the sites and resulting differences in elevation, aspect, climate and composition and density of their flora.

A short summary of the percentage composition of litter components for the study mean is given in Table 1 below, which also indicates the ranges encountered.

TABLE 1

The percentage composition of the litter layer

Component	Percentage Composition	Range
Twigs 0–0.6 cm	18.5	8.8–26.1
Twigs 0.6–2.5 cm	16.1	15.1–23.7
Twigs Total (0–2.5 cm)	34.6	26.4–49.8
Bark	9.1	4.6–15.0
Leaves	23.3	17.4–32.9
Green Vegetation	10.9	3.2–27.1
Cured Vegetation	5.6	1.9– 9.8
Miscellaneous decomposing matter	16.4	8.5–22.9

There is a remarkable similarity in the percentage contribution that the various littercomponents make to the total litterweights in a wide range of forest types as is shown in Table 2.

TABLE 2

Comparing the percentage composition of litterweight components between forest types

Type location	Twigs 0–2.5 cm	Bark	Leaves	Vegetation		Misc. dec. m.
				Green	Cured	
Blue Mountains	35	9	23	11	6	16
Silvertop ash; Eden	35	8	24	6	12	15
Dry blackbutt; Kendall	35	6	27	4	2	25
Spotted gum/ironbark; Taree	35	5	28	7	7	18
Tableland hardwoods; Armidale	33	5	20	12	12	18
Grey gum/ironbark; Kempsey	25	8	20	9	17	21
Moist blackbutt; Bellangry	40	12	23	3	5	17

In the processing of littersamples of the 1970 collections, no differentiation was made between sizes of twigs. All twig weight data for that year are based on twigs in the 0–2.5 cm size class. Twigs in the 1974 collections were separated in 2 classes, one consisting of twigs 0–0.6 cm in diameter, the other of twigs between 0.6 and 2.5 cm in diameter.

Several authorities concerned with fuel weights exclude the weight of twigs over 0.6 cm. If this practise is adopted, it can be seen that the total litterweights obtained in the 1974 collections should be reduced by quantities ranging between 582 and 2 551 kg/ha, reductions equivalent to between 8.8 per cent and 26.1 per cent of total weights respectively.

B. Weight of the Understorey Vegetation

To obtain estimates of the weight of the understorey vegetation occurring on the study sites, all vegetation occurring on quadrats 0.836 m^2 in size was clipped at ground level and removed to the laboratory for oven-dry weight determinations.

The number of quadrats clipped at each sample site and period was the same as that of the litter samples (45) and each quadrat was located immediately north of the random litter sample points. Grasses, ferns and the low herbaceous vegetation that formed part of the litterweight samples were excluded from the samples, as were arboreal species exceeding 5 cm in diameter at breast height, as these were considered part of the overstorey. The height of the tallest understorey stem occurring on each quadrat was also measured.

The understorey samples were treated in identical manner to those of the litterlayer, i.e., one third of their number was sorted into component parts and the percentage composition of sorted samples was applied to the weight of all samples of each site. Oven drying was again at a temperature of 105° C.

Reference has been made in the previous section to the fact that an uppersize limit of 2.5 cm was adopted to the diameter of twigs, branches and woody material removed to derive the weight of the litterlayer. In order to maintain parity with the litterweight data understorey weights are in the first instance given to that same size limit.

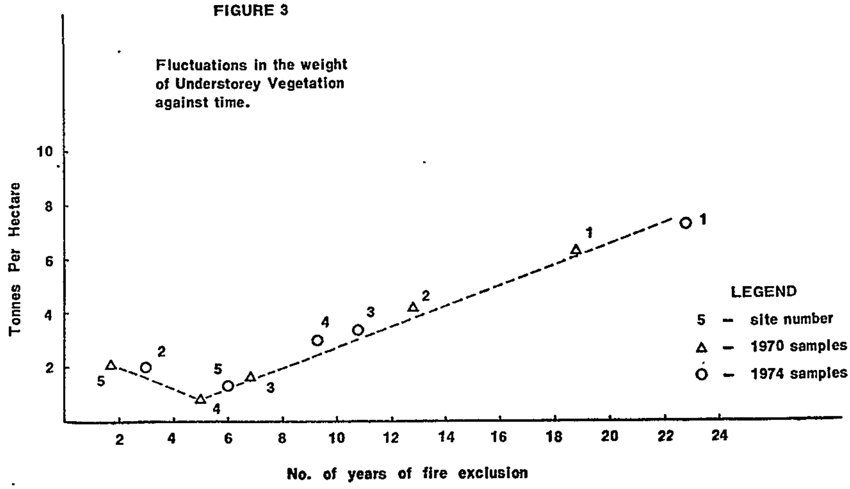
Unfortunately at the first sampling period no distinction was made between live and dead understorey. Consequently the weights of understorey vegetation available for the most recently burnt sites would have included a substantial quantity of dead material, killed but not consumed in the fires. The fact that fire killed understorey gradually declines to become part of the litterlayer has already been discussed.

At the second sampling period, dead material was separated from the live understorey as shown in Appendix 2 which gives full details of the understorey weight determinations for all sites and both periods.

Figure 3 provides a more readily perceptible conception of fluctuations in understorey weight.

FIGURE 3

Fluctuations in the weight of Understorey Vegetation against time.



It can be seen that after a "settling down" period of about 5 years in which the weight of mainly killed understorey is reduced, a virtually linear increase in understorey weights occurs with time at least for the period under review.

Appendix 2 also indicates the percentage composition that various understorey components make to the total litterweight, while Table 3 provides a short summary.

TABLE 3

The percentage composition of understorey vegetation

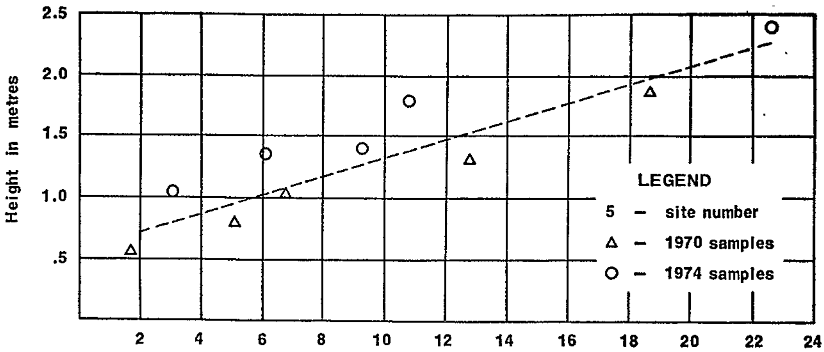
Component	Mean	Range
1. branches and twigs 0–0.6 cm diameter	34.4	25.5–41.4
2. branches and twigs 0.6–2.5 cm diameter	39.4	32.0–54.5
Subtotal	73.8	62.4–86.9
3. leaves	24.5	12.4–37.6
4. fruits and flowers	1.7	0 – 7.6

The results of the height measurement of the tallest understorey stem encountered at each quadrat are depicted in Figure 4.

The mean heights of the understorey are shown to increase slowly but gradually and again no falling off in height increments can be detected with increases in age of the understorey.

FIGURE 4

Height (m) of understorey against years of fire exclusion



A list of the most common understorey species encountered at each site is given in Appendix 3, while Plates 1–5 (Appendix 4) illustrate the general appearance of each site at the time the first sampling was carried out in 1970.

C. Total Fine Fuel Weight

By combining the weight of the litterlayer with that of the understorey vegetation, one can obtain an estimate of total fine fuel weight (material up to 2.5 cm diameter). Values obtained are shown in Figure 5.

Again the data for site 3 at period 2 appear to be anomalous. The highest value after 22.8 years of fire exclusion is nearly 25 tonnes per hectare, about twice the value obtained at age 6. The graph suggests that the total fine fuel weight will continue to increase.

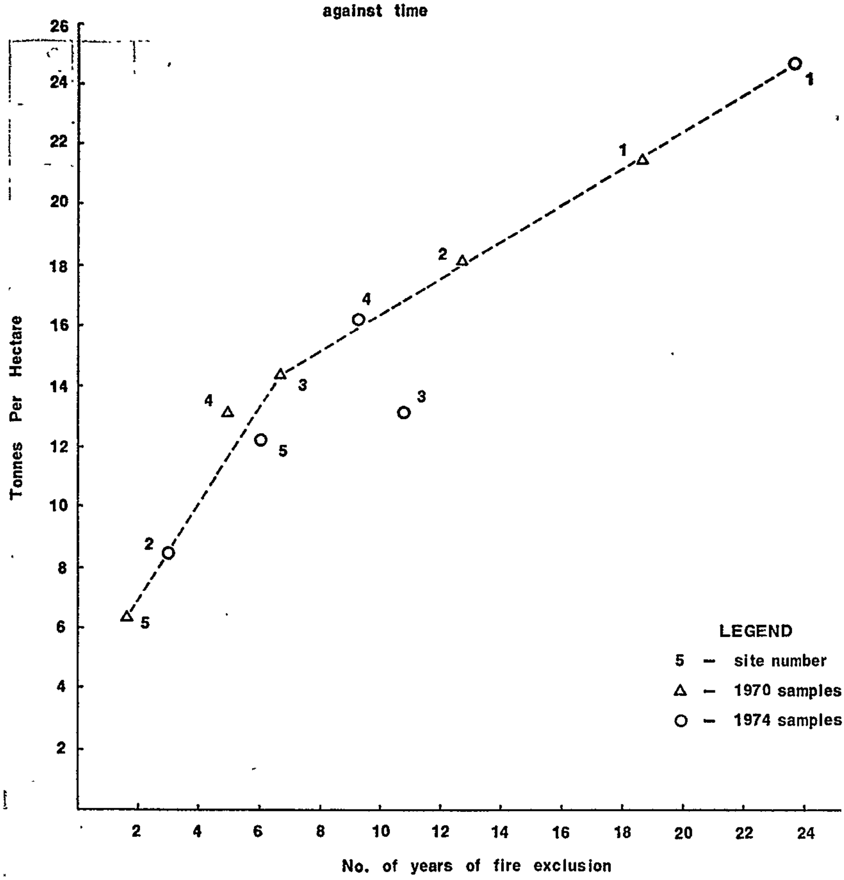
However, if this increase continues at the current annual increment of 635 kg/ha as it did between years 6.7 and 22.8 following fire, it would require well over a century of fire exclusion before weights approached those occasionally quoted as occurring in "some bush areas", e.g., 75.4 tonnes per hectare (Anon. 1974).

Most of the bushland in the Blue Mountains carries a fairly sparse overstorey. The basal area of the overstorey on the study sites averaged 16.76 m²/ha (range 13.09–20.2 m²/ha) while its dominant height varied between 12.8 m and 20.4 m.

Partly because of the open nature of the overstorey, the understorey is dense and can number up to 30 000 stems per hectare, which is considerably in excess of the number normally encountered in commercial forest stands.

FIGURE 5

Total Fine Fuel build-up against time



Nevertheless, the contribution that this understorey makes to the total fine fuel weight is surprisingly small. Overall this contribution averaged 21.1 per cent and ranged between 7.4 per cent and 32.2 per cent.

D. Weight of Larger Material in the Understorey

In addition to the understorey weights up to the 2.5 cm size limit given in the preceding section, some material exceeding that size was also encountered in some of the samples.

With the exception of site 1, the weight of this material does not assume much importance, as is shown in Table 4.

TABLE 4

The weight of understorey material over 2.5 cm in kg/ha

Site No.	Years since last fire	Live material	Dead material	Total
1	22.8	2401	209	2610
1	18.6	N.D.	N.D.	2209
2	12.8	N.D.	N.D.	66
3	10.9	670	..	670
5	6.0	..	1838	1838
2	3.0	..	45	45

N.D. (No data collected).

It should be noted that all the material in this category obtained on site 5 consisted of dead material, obviously killed during the last wildfire which occurred 6 years before sampling.

EXPERIMENTAL FUEL WEIGHTS

The second study, although more specifically designed to test the effects of repeated prescribed burning on the composition and density of the understorey vegetation, has since its inception in 1971, provided a substantial amount of information on fuel weights. While it is not yet possible to report on the primary aim of this experiment, fuel weight data obtained so far are presented here to compare with the results of the first study.

The study area, located on 6 ha of the Blue Mountains National Park in the vicinity of Lawson, was last burnt by a wildfire in November 1957. The site was divided into six plots each 1 ha in size by means of 3 m wide tritter trails. After evaluation of fuel weights and vegetation on each plot in June 1971, the plots were paired upon their similarity in these parameters and one plot from each pair was then randomly allocated to be prescribed burnt, while the others serve as unburnt controls. The first burns were carried out in September 1971 and fuel weights in each plot have been sampled in June of each subsequent year.

RESULTS II

A. The Weight of the Litterlayer

Analysis of over 1 000 litterweight samples previously taken in plots of a similar size had indicated that 15 randomly located samples, 0.1 m^2 in size in each plot were required to estimate litterweight to be within 5 per cent of the true mean at the 0.01 probability level (N. Omar pers. comm.).

As that degree of confidence was considered adequate for the purpose of this study, 16 randomly located samples of that size were collected in each of the plots, giving a total of 48 samples for each of the two treatments.

The litterweight samples were identical to those described in the first study, with material exceeding 2.5 cm in diameter being excluded from the samples. In this experiment all samples were sorted into component parts and oven dried in forced draught ovens at 105° C for at least 24 hours.

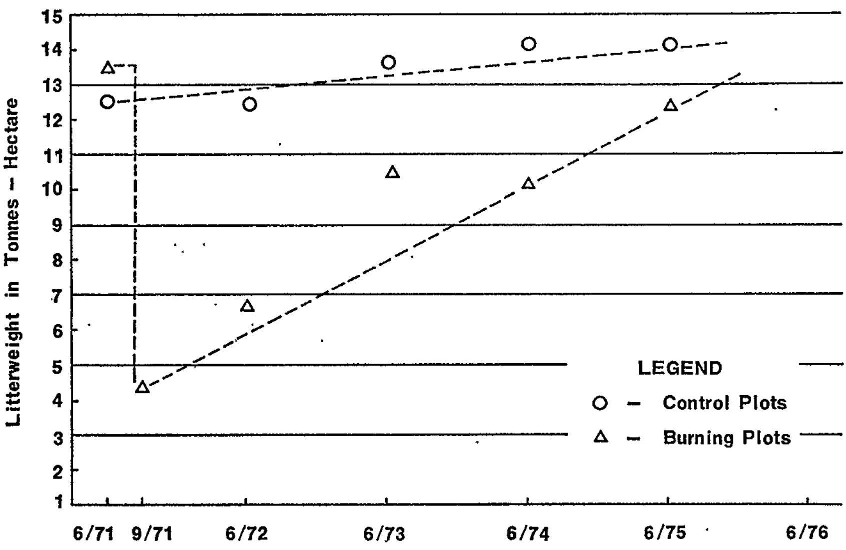
The mean litterweights obtained at the first sampling period (June 1971) were 12.89 kg/ha for the control plots and 13.64 kg/ha for the burning plots. At that time the site had not been burnt for 13.6 years. Reference to Figure 2 will show that these weights are slightly less (*ca* 1 tonne per hectare) than those suggested to occur after that period of fire exclusion. Nevertheless the weights tend to support rather than reject the postulated rate of litter build-up shown in the first study.

The fire intensity of the September 1971 prescribed burns ranged between 173 and 200 kw/m. The reduction in the weight of the litterlayer varied between 66 per cent and 68 per cent, reducing it to 4 512 kg/ha.

Subsequent fluctuations in litterweights for both the control and burnt plots are shown in Figure 6.

FIGURE 6

Litterweights of
Frequent burning study



The top line in Figure 6 shows the mean weights of the litterlayer in the control plots, which slowly increase against time. The mean annual weight increment in the period June 1971–June 1975 is 311 kg/ha which is in very close agreement to the mean annual increment of 282 kg/ha shown in Figure 2 for comparable periods of fire exclusion.

The bottom line shows litterweight recovery of the prescribed burnt plots. It can be seen that the value obtained for the June 1973 sampling appears abnormally high. Unfortunately, due to an inadvertent oversight, the sampling intensity that year was reduced by half of that used on all other occasions, which undoubtedly has reduced the reliability of the estimates for that period, and may have affected the mean value.

All other values for the burnt plots conform closely to a definite pattern. The figure also extrapolates weight increases for the period June 1975–June 1976, if current trends continue. This shows that by June 1976 (4.75 years after burning) litter weights of the two treatments should be roughly equal.

B. The Weight of the Understorey

As the prime objective of this study is to evaluate fire effects on understorey vegetation, it was not considered desirable to estimate its weight by destructive sampling in the study area. Instead, some 205 stems covering a range of the most common species and height classes were cut down at ground level in an area adjacent to the study site, and removed to the laboratory for separation into component parts and oven dry weight determinations. The results of these measurements are given in Table 5, while the most common understorey species are listed in Appendix 3.

TABLE 5

Mean weight (oven-dry weight) per stem in grams of understorey vegetation by component parts and height classes

Height class (m)	Actual mean height (m)	No. of stems sampled	Woody material			Foliage	Fruit	Total
			0–0.6 cm	0.6–1.25 cm	1.25–2.5 cm			
0.9–1.5	1.2	78	43.2	19.0	6.7	25.9	.04	94.7
1.5–2.1	1.8	69	71.0	62.9	40.9	56.0	.2	231.0
2.1–2.7	2.3	33	136.5	123.6	99.6	81.2	.09	441.1
2.7–3.3	2.9	25	120.0	99.7	184.5	74.1	3.3	481.5

The weight of material exceeding 2.5 cm diameter is again excluded. The mean weight per stem increases with its height and this relationship is almost linear.

Although full analyses of understorey densities, determined on 44 randomly located quadrats in each of the 6 study plots, have not yet been completed, preliminary results enable the calculation of the approximate numbers per hectare of understorey stems by height classes.

While the limitations in the accuracy of obtaining understorey weights by this method cannot be overemphasized, the exercise is of interest in order to obtain some comparison with weights obtained in the first study.

Table 6 below gives estimates of the understorey weights of the study sites by grouping all stems in 0.6 m height classes on a per hectare basis and multiplying the number in each height class by the mean weight for that class.

TABLE 6

The approximate weight of understorey vegetation in kg/ha by 0.6 m height classes

Height class (m)	No. of stems per hectare	Mean weight per stem (g)	Total weight kg/ha
.9–1.5	12 853	94.7	1 192
1.5–2.1	8 391	231.0	1 938
2.1–2.7	3 921	441.1	1 729
2.7–3.3	1 235	481.5	594
Total	26 400	..	5 453

Reference to Figure 3 will show that the mean value of 5.4 tonnes per hectare obtained in this manner is higher than that postulated there to occur after 13.6 years of fire exclusion (*ca* 4.2 tonnes per hectare). The latter figure is, however, thought to be more reliable.

Extending the size limit of understorey weights to include material in the 2.5 to 5.0 cm diameter class would only increase the weight of understorey in this study by 429 kg/ha.

If the weight of the litterlayer in this study is combined with that of the understorey, the total value of 18.72 kg/ha coincides with that suggested to occur at 13.6 years as total fuel weight in Figure 5 of the first study. It appears that despite minor differences in their constituents, fuel weights of both studies are in very close agreement.

Photographs 6–8 (Appendix 4) show the understorey in one of the study plots prior to the burn in June 1971, immediately after the burn (October 1971) and its recovery by June 1975.

It is hoped that the fuel data presented in this report will not only assist in the formulation of fire management policies for this important natural bushland area, but that it will also provide more substance to the perennial debates concerning the use of prescribed burning in the region.

ACKNOWLEDGMENTS

The technical assistance of J. E. Cooper and W. Buckler in the collection and processing of samples is gratefully acknowledged. W. Buckler also took the photographs shown in the text.

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APPENDIX 1

Showing the weight of the litter layer by component parts
(Top line of each entry gives weight in kg/ha: bottom line the percentage composition)

Years since fire	Site	Twigs 0.6–2.5 cm	Twigs 0–0.6 cm	Twigs 0–2.5 cm	Bark	Leaves	Vegetation		Misc. matter	Total
							Green	Cured		
1.8	5^1	..	..	1 656 36.6	213 4.7	789 17.4	1 227 27.1	105 2.2	531 11.7	4 522
3.0	2^2	582 8.8	1 164 17.6	1 746 26.4	992 15.0	1 614 24.4	642 9.7	364 5.5	1 250 18.9	6 615
5.0	4^1	..	..	3 654 29.8	1 446 11.8	2 622 21.4	1 890 15.4	1 112 9.1	1 533 12.5	12 259
6.0	5^2	1 887 17.3	1 647 15.1	3 534 32.4	502 4.6	3 033 27.8	1 505 13.8	491 4.5	1 855 17.0	10 909
6.7	3^1	..	..	4 834 37.4	804 6.2	4 253 32.9	412 3.2	474 3.7	2 148 16.6	12 925
9.2	4^2	2 450 18.5	2 185 16.5	4 635 35.0	1 337 10.1	2 556 19.3	1 218 9.2	1 298 9.8	2 185 16.5	13 242
10.9	3^2	2 551 26.1	2 317 23.7	4 868 49.8	948 9.7	2 551 26.1	391 4.0	186 1.9	831 8.5	9 775
12.8	2^1	..	..	4 167 29.7	1 148 8.2	3 336 23.7	1 739 12.4	769 5.5	2 902 20.5	14 051
18.6	1^1	..	..	5 516 35.9	1 411 9.2	2 935 19.1	873 5.7	1 107 7.2	3 509 22.9	15 352
22.8	1^2	2 008 11.5 16.4	3 806 21.8 18.9	5 814 33.3 34.6	2 043 11.7 9.1	3 667 21.0 23.3	1 537 8.8 10.9	1 100 6.2 5.6	3 300 18.9 16.4	17 461

APPENDIX 2

Showing the weight of understorey vegetation by component parts, total vegetation weight (A), and total fine fuel weight (B) (top line of each entry gives weight in kg/ha, bottom line, the percentage composition, L. denotes live material, D. dead material, T. total).

Years since fire	Site	Woody material 0–0.6 cm	Woody material 0.6–2.5 cm	Total	Leaves	Fruit	Total Understorey Weight A	Understorey and Litter Weight Combined B
1.8	5^1	819	1 053	1 872	282	..	2 154	6 675
		38.0	48.9	86.9	13.1			
3.0	2^2	L. 333	L. 457	790	414	55	..	..
		15.9	21.9	37.8	19.8	2.6		
..	..	D. 413	D. 416	829	..	..		
		19.8	19.9	39.7				
..	..	T. 746	T. 873	1 619	..	..	2 088	8 703
		35.7	41.8	77.5				
5.0	4^1	252	404	656	324	..	980	13 239
		25.7	41.2	66.9	33.1			
6.0	5^2	L. 405	L. 339	744	324	3	..	..
		31.1	26.0	57.1	24.9	0.2		
..	..	D. 113	D.119	232	..	..	..	..
		8.7	9.1	17.8	..			
..	..	T. 518	T. 458	976	..	..	1 303	12 212
		39.8	35.1	74.9				
6.7	3^1	617	603	1 220	445	..	1 665	14 590
		37.1	36.2	73.3	26.7			
9.2	4^2	1 058	960	2 018	966	15	2 999	16 241
		35.3	32.0	67.3	32.2	0.5		
10.9	3^2	1 048	1 131	2 179	1 311	..	3 490	13 265
		30.0	32.4	62.4	37.6			
12.8	2^1	1 660	1 420	3 080	925	..	4 005	18 056
		41.4	35.5	76.9	23.1			
18.6	1^1	1 546	3 308	4 854	752	463	6 069	21 421
		25.5	54.5	80.0	12.4	7.6		
22.8	1^2	L. 2 490	L. 2 092	4 582	1 623	428	..	..
		33.9	28.5	62.3	22.1	5.8		
..	..	D. 1 390	D. 578	717	..	..	..	..
		1.9	7.9	9.8				
..	..	T. 2 629	T. 2 670	5 299	..	..	7 350	24 811
		35.8	36.3	72.1				
		34.4	39.4	73.8	24.5	1.7		
		25.5–41.4	32.0–54.5	62.4–86.9	12.4–37.6	0–7.6		

APPENDIX 3

Check list of main species occurring on the study sites
(Sites 1–5 refer to study 1, site 6 to study 2)

	Site					
	1	2	3	4	5	6
Acacia sp.	x	x	x	x	x	x
Ackama paniculata				x		
Angophora costata		x	x			x
Banksia sp.	x	x	x	x	x	x
Bossiaca heterophylla						x
Callistemon sp.		x				
Casuarina sp.	x					
Caustis pentandra			x			
Ceratopetalum gummiferum			x	x	x	
Davesia sp.		x		x	x	x
Dillwynia retorta	x	x	x		x	x
Elaeocarpus reticulatus			x			
Epacris microphylla	x		x			
Eucalyptus sp.	x	x	x	x	x	x
Gompholobium sp.	x		x			x
Grevillea oleoides			x		x	x
Haemodorum planifolium					x	
Hakea sp.	x	x		x		x
Hibbertia sp.	x					
Isopogon sp.	x	x				
Lambertia formosa	x	x		x	x	x
Lepromeria acida						x
Leptospermum sp.	x	x		x	x	x
Leucopogon lanceolatus						x
Lomatia silaifolia	x		x	x	x	
Lomandra sp.		x	x	x	x	
Patersonia sp.				x		
Persoonia sp.	x	x	x	x	x	x
Petrophile pedunculata						x
Platylobium formosum			x		x	
Platysace linearifolia			x	x	x	x
Pultenea sp.			x	x		x
Sambucus australasica				x		
Syncarpia glomulifera			x			
Telopea speciosissima	x			x		x
Tristania conferta			x			

APPENDIX 4

Plate 1 Study No. 1 Site No. 1 1970

Plate 2 Study No. 1 Site No. 2 1970

APPENDIX 4

Plate 3 Study No. 2 June 1971

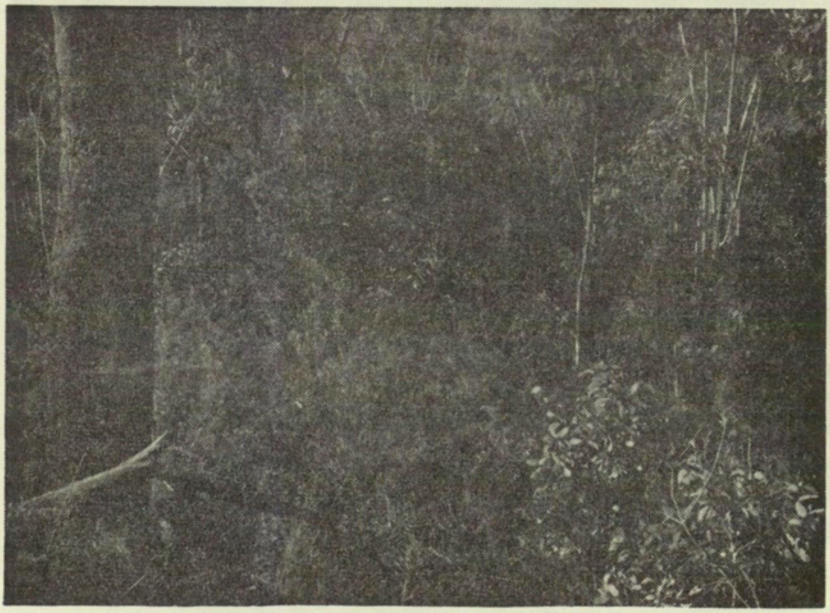

Plate 4 Study No. 1 Site No. 3 1970

APPENDIX 4

Plate 5 Study No. 1 Site No. 4 1970

APPENDIX 4

Plate 6 Study No. 1 Site No. 5 1970

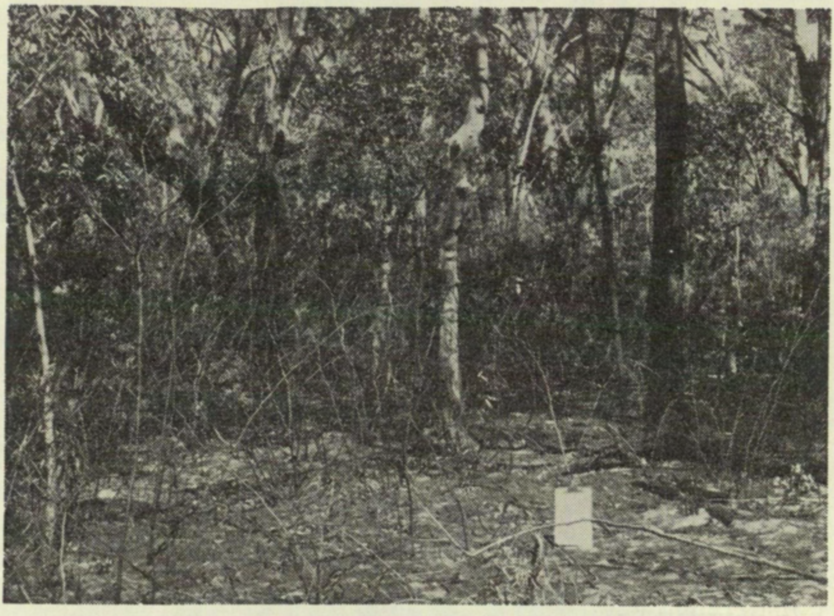

Plate 7 Study No. 2 October 1971

APPENDIX 4

Plate 8 Study No. 2 June 1975

F.C. of N.S.W. Photofile

Plate 1—L740/4A; 2—735/3;
3—727/15; 4—735/13; 5—/6;
6—H 3257; 7—3590; 8—GC 5027

NOTES

NOTES

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