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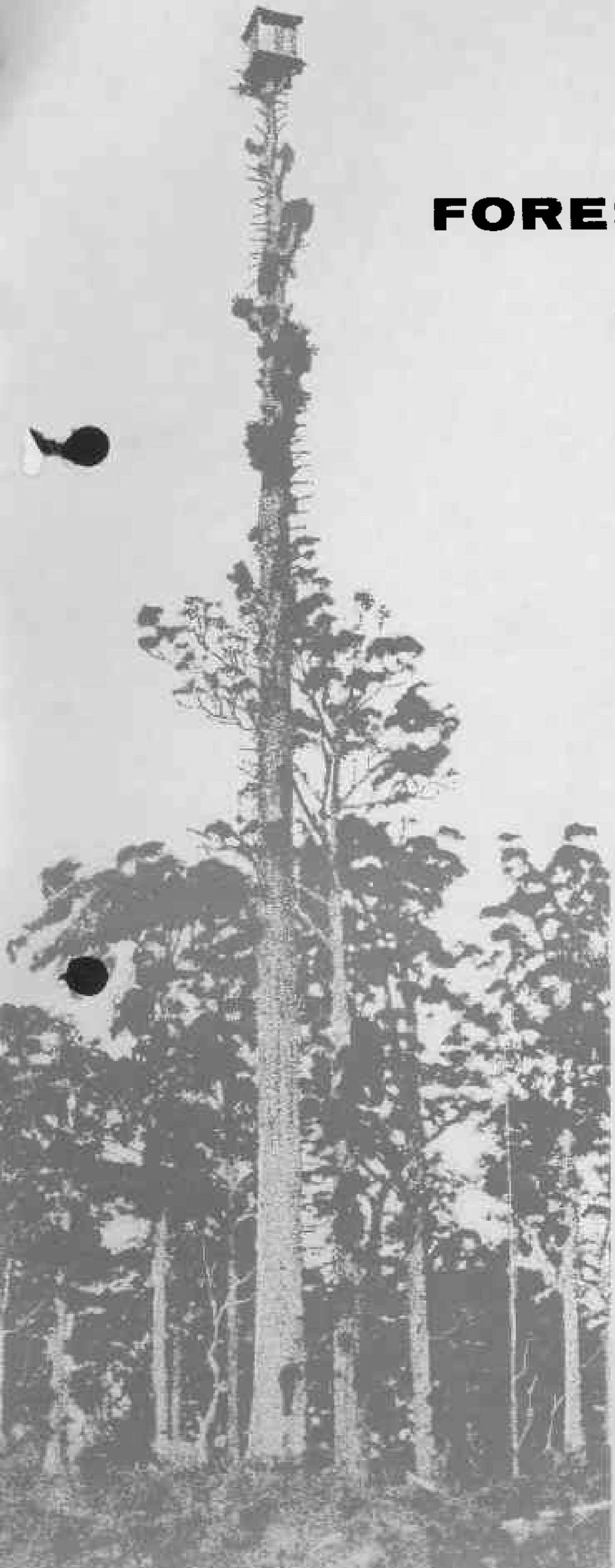

UNDERSTOREY FUELS IN KARRI FOREST

by

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SUMMARY

Fire behaviour in karri scrub understorey can alter rapidly from low intensity flames burning in litter through flaring of foliage to total scrub-consuming conflagrations. To evaluate fuel characteristics in these dense high scrubs for the experimental fire programme, it was necessary to obtain reliable estimates of scrub composition, structure, and weight.

Scrub composition, vertical disposition, height and density were recorded, using a simple rapid point sampling technique developed by Levy and Madden (1933). Scrub weights of green and dry fuel components were obtained by weighing cylinders of foliage taken vertically through the vegetation.

Average total live scrub weight was directly related to the product values of top height and cover density. Weights of live fuel components were also related to total live weight. Histograms constructed to illustrate the vertical disposition of the weight of fuel components enable easy and accurate assessment of fuel quantities available to fires of varied intensities. These scrub fuel loadings will be added to litter fuel quantity in the prediction of fire intensity.

INTRODUCTION

Since 1962 much work has been done by the Fire Research Branch to develop reliable forest fire danger rating and prediction systems.

Current fire danger tables (Harris, 1968) have proven very reliable for the northern jarrah (*Euc. marginata* Sm.) forest environment where the fuel inflammability is reasonably uniform over large forest areas due to low, sparse scrub, gentle undulating topography and lateritic soils. However, the tables are inadequate in the southern regions dominated by karri (*Euc. diversicolor*. F. Muell) forests. Here, varied associations of dense tall scrub, steep topography and deep forest litter, provide more complex fuel conditions than those encountered in the jarrah forests.

The karri scrub understorey affects fire behaviour markedly. It greatly influences the drying rate of the litter fuel; this fuel often being the last to dry out and burn after heavy rains. Inflammability of scrub species varies considerably, depending on their structure, disposition, and moisture content. Scrub flare is a common phenomenon in dry conditions and may be the cause of excessive scorching and damage to trees.

The present Karri Forest Danger Table (Harris, 1968) is an extrapolation of the successful Jarrah Table containing subjectively selected fuel loadings chosen to account for the scrub fuel differences. However, these corrections, which are incorporated in the Drought Index, do not take into consideration the differences in scrub density, height, disposition, and composition. Consequently the adjusted tables have not met with much success.

It was with the aim of remedying this situation that a detailed scrub fuel study was initiated at the Strickland Road experimental site in 1969.

This project was designed to develop a simple, rapid technique for evaluating fuel characteristics of high dense scrub, so that relationships between the structural parameters and fuel component weights could be evaluated and used to obtain scrub fuel loadings for use in more reliable fire hazard prediction tables for the karri forest.

The project was undertaken in preparation for the experimental fire behaviour studies of the 1969/70 fire study period.

METHODS

The Study Area

The experimental area, located along the Donnelly River twenty miles west of Manjimup, contains a cover of mature and over-mature karri and marri (*Euc. calophylla, R. Br.*). The scrub understorey is representative of a major portion of the karri scrub found in the southern forests. Major understorey species present include *Trymalium spathulatum* (hazel), *Bossiaea aquifolium* (netic), *Acacia pulchella*, *A. strigosa*, *A. divergens*, and *A. urophylla*.

The area, which contains steep topography, was divided into 180 plots by means of bulldozed breaks. The plots of average area one acre, varied considerably in size due to difficulty in negotiating the steep slopes, logs, creeks and trees. Each was sufficiently large for an experimental fire.

Scrub Assessment Method

The major considerations in choosing a suitable sampling method for measuring scrub composition and structure are that the procedure be objective, reproducible, efficient, and adaptable to tall and dense vegetation.

Sampling methods such as the Line Transect and Random Quadrat were found to be unsuitable in the difficult vegetation and the method chosen was based on a system of point sampling developed by Levy and Madden (1933). In the adopted method the observer records the number of contacts made by the plant species at separate height intervals on a long, vertically placed rod. The rod used was ¼" in thickness, thirteen feet in length and marked at one foot intervals to aid recording. Errors introduced by observer interpretation and by the finite rod diameter are acceptable provided the diameter is kept small and all observations are made objectively (Goodall, 1952).

The three major expressions, derived by the point sampling method, of value to the present study are:

(i) Total Cover Density (T.C.D.)

$$\text{T.C.D.} = \frac{\text{total number of contacts recorded on vegetation}}{\text{number of rods with at least one contact}}$$

(ii) Cover Density per Foot (C.D.F.)

$$\text{C.D.F.} = \frac{\text{total number of contacts recorded on the species within one foot}}{\text{number of rods with at least one contact}}$$

(iii) Percentage of cover contributed by each species (P.C.C.)

$$\text{P.C.C.} = \frac{\text{total number of contacts recorded on the species}}{\text{total number of contacts on all species}} \times 100$$

In the present study, the aim of the assessment was to obtain reliable quantitative estimates of scrub composition and structure sampled at the minimum acceptable intensity.

To determine the number of points required for adequate expression of each plot a uniformity trial was conducted on four randomly chosen one acre plots assessed using up to 100 systematically chosen points per plot. The trial indicated that approximately 30 to 40 points are required to give a reliable estimate of plot cover density and percentage cover contribution by the main species (Fig. 1). On the basis of these results, the remaining plots were assessed, using 36 points per acre.

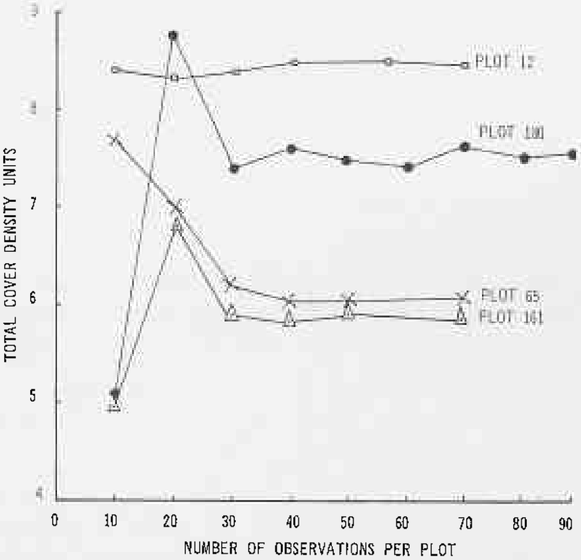

FIGURE 1: *Variation in precision of estimation of total cover density with increasing number of sample points.*

Each of the 180 plots was divided by three equally spaced lines. Six sites were selected along each line and sampling was conducted one yard either side of the 18 sites to give a total of 36 observations. Systematic rather than random point location and a minimal number of points are essential to minimize disturbance to the scrub. Serious disturbance would influence fire behaviour on the plot. Depending on the topography and scrub density in the area, the time taken for two men to observe and record 36 points varied from 30 to 60 minutes.

RESULTS AND DISCUSSION

Scrub Assessment

Cover density and percentage cover contribution by major species were calculated for each plot. Cover density was also determined for each one foot height interval for the major species and the total vegetation. These values were plotted against height. The resultant line trends provide pictorial representation of the scrub density profile for each plot. Figure 2 is a typical example of a netic dominant scrub profile.

These density profile graphs proved useful in illustrating the differences in scrub disposition between plots and also formed the basis of selection of structural parameters used to categorize plots within the same scrub types.

Structural parameters selected were average cover density and average top height. Cover density was calculated by the formula given earlier. Top height was determined from each of the density profile graphs as the top of the height range within which the vegetation exceeded a value for cover density per foot of 0.25 (Fig. 2). It will be shown later that the top height value derived from point sampling approximates the average co-dominant height of the scrub representing the general top level of the scrub canopy. It excludes those irregularities in the scrub canopy caused by the occasional taller individual shoot or branch.

Each plot was then categorized according to the present cover contribution of the major species to the total scrub cover (P.C.C.).

A graphical method using an equilateral triangle was employed to classify each of the plots into separate scrub types. This plotting procedure is used by soil physicists in determining the mechanical composition of soil. However, instead of using the three main soil components, the triangle apices were the three main scrub components of netic, hazel and Other Species, i.e. all Acacia species, bracken and grasses. Each side of the triangle was divided into intervals of one per cent, so that apices A, B, and C represented 100 per cent contribution by Other Species, hazel and netic respectively (Fig. 3). In use, plots lying on the base line BC contain no Other Species, and those on line DF contain equal percentages of hazel.

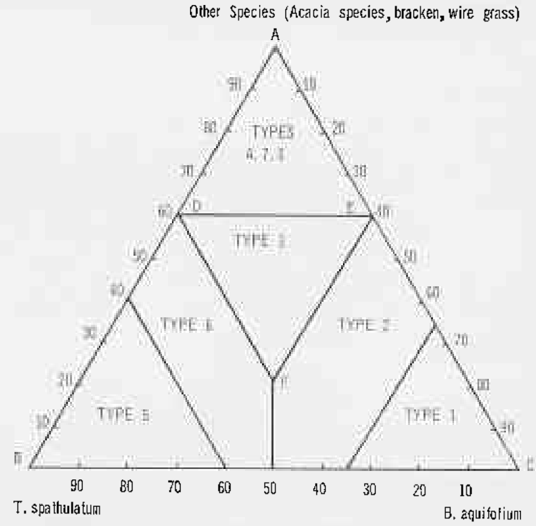

FIGURE 3: *Triangular plotting system employed to classify scrub types.*

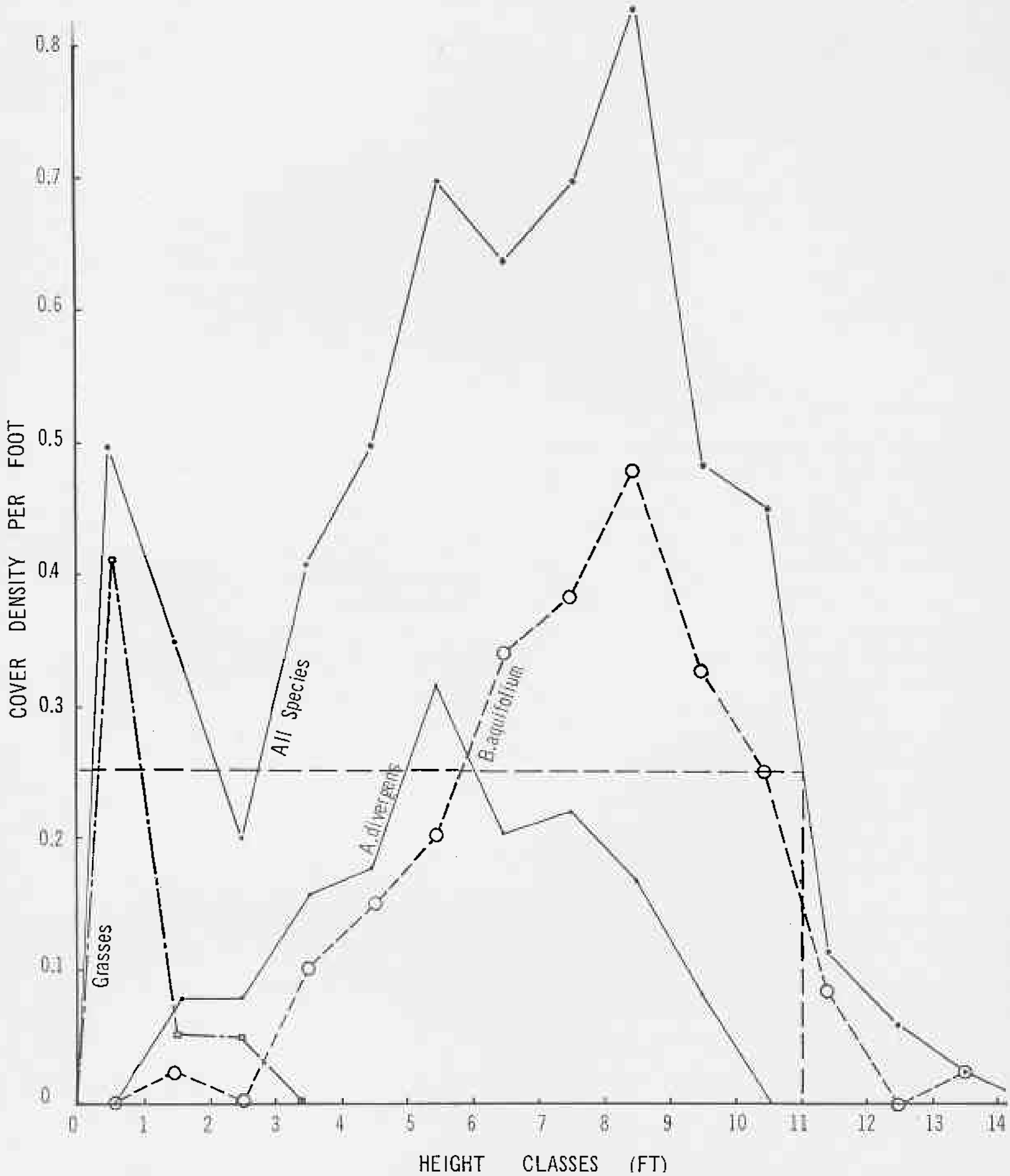

FIGURE 2: *Cover density profile of a netic (*Bossiaea aquifolium*) dominant scrub type containing some* Acacia divergens *and wire grass. Total cover density is 6.0 and point top height calculated at a cover density per foot of 0.25 is 11.1 feet.*

When data for all the 180 plots were located within the triangle, several distinct scrub types became evident. The triangle was divided into six sections, all but one of which represented a separate scrub type. The exception was the section containing the highest proportion of Other Species (O.S.). This group was further separated into three classes according to the main species of Acacia present.

The eight scrub classes were:

(1) Netic only (> 65%).

(2) Netic dominant (> 40%) plus O.S.

(3) Mixture of netic, hazel and O.S.

(4) *A. pulchella* dominant ± netic and O.S.

(5) Hazel only (> 60%).

(6) Hazel dominant (> 40%) + netic, O.S.

(7) Swamp type (*A. divergens*, swordgrass mainly).

(8) *A. strigosa* dominant + netic.

Scrub Weighing

Once a description of scrub composition, density and height was obtained, it became possible to consider sampling for the weight of scrub fuel mass. The task of sampling every plot was beyond the resources of the fire research team and it was necessary to limit sampling to those plots exhibiting the extremes in both height and density within each of the scrub classes. To ensure adequate sampling of the full range of height and density within each class, the following six categories were chosen:

A. Tallest plots
(i) Densest (ii) Least Dense

B. Intermediate height plots
(i) Densest (ii) Least Dense

C. Shortest plots
(i) Densest (ii) Least Dense

The height and density values were those determined previously from the point density-profile graph.

Scrub weight sampling was conducted on a systematic basis, using every fourth site of the original 36 point sample sites as the new positions for sampling weights. The sampling number of nine per acre was determined from tests conducted on four trial plots from three different scrub classes. These indicated that an acceptably small co-efficient of variation would be obtained from nine samples for all scrub types except those dominated by hazel. In this case it was shown that 12 samples were sufficient to cover this sparse, variable scrub type.

The method employed involved the weighing of all live and dead scrub material present within a hypothetical vertical cylinder. The cylinder, of 1.66 ft. radius, was described by a sliding wire arm attached to a twelve foot centre pole. The radius of assessment was calculated to give an oven-dry scrub weight in terms of tons per acre from metric data by a simple conversion factor of 200.

All material within two foot height intervals was removed by cutting and separated into live and dead. Each of these categories was further broken up into the four diameter classes of less than $\frac{1}{8}$ inch, $\frac{1}{8}-\frac{1}{2}$ inch, $\frac{1}{2}-1$ inch, and greater than 1 inch. Samples of all scrub components were obtained for each height interval for moisture determination. These were oven dried at 105°C and the calculated moisture content percentages were used to convert the air dry weight to equivalent oven dry weight values.

At the time of sampling, estimates of the average co-dominant height of the scrub canopy in the vicinity of the sample sites were recorded for comparison with the arbitrary top height derived from point top height at cover density per foot (C.D.F.) of 0.25. The comparisons revealed little difference between the two height estimates for all scrub groups except the *A. strigosa* and *A. pulchella* dominant scrub groups. Here the calculated top height values were higher than the field estimates in all cases.

The C.D.F. base value of 0.25 appears to be too low for these fine leaved, dense Acacia species, as it includes those scrub canopy irregularities normally ignored in the field assessment. A much better comparison between the calculated and the measured height values exists by increasing the C.D.F. base value to 0.50 for the Acacia scrub groups, whilst retaining the 0.25 density value for the other scrub groups (Fig. 4).

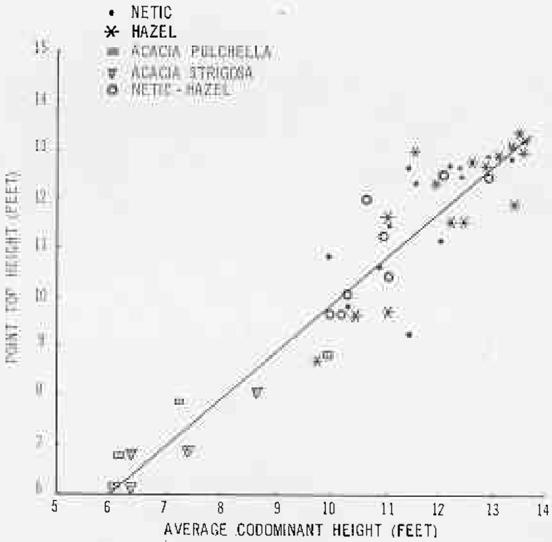

FIGURE 4: *Comparison of point derived top height with average co-dominant height estimated in the field. Point top height of netic dominant, hazel dominant and mixed netic-hazel scrub types were derived at cover density per foot of 0.25. Point top height of* Acacia pulchella *and* A. strigosa *was derived at a cover density per foot of 0.50.*

Total Live and Scrub Component Weight Relationships

A preliminary examination of live scrub weight data indicated the possible existence of constant relationships between the scrub component weights and the total live weight for all scrub types.

The weights of live material less than $\frac{1}{8}$ inch diameter were plotted against the total live weight and two linear regressions were evident. The netic dominant and the Acacia species dominant scrub types could be combined in one regression, whereas the hazel scrub groups separated out in a regression above the first. Those classes containing mixtures of netic, hazel and Other Species, fell in between these two lines (Fig. 5).

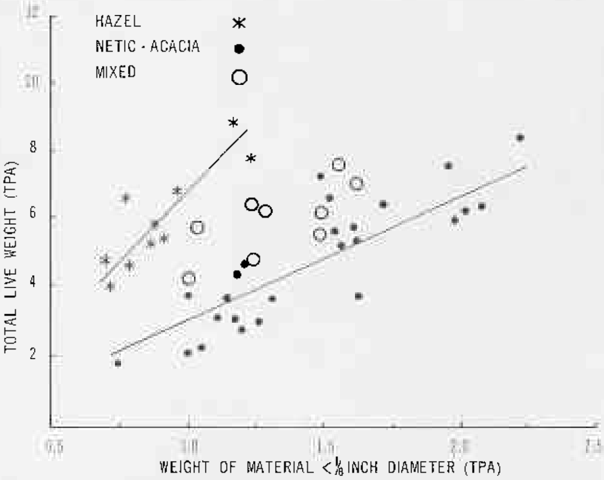

FIGURE 5: *Relationship between total live weight in tons per acre (T.P.A.) and weight of material less than $\frac{1}{8}$ inch diameter.*

The weights of live material $\frac{1}{8}$ to $\frac{1}{2}$ inch diameter and also the weights of all material greater than $\frac{1}{8}$ inch diameter, were plotted against total live weight. Again two distinct linear regressions were formed in each case (Fig. 6). The netic and acacia species groups separated out above the hazel dominant groups, with the mixed species groups falling between these two.

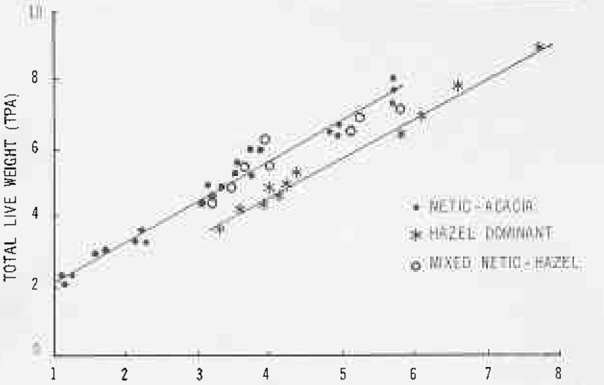

FIGURE 6: *Relationship between total live weight and weight of live material greater than $\frac{1}{8}$ inch diameter. Units in tons per acre.*

These graphs demonstrate clearly that the netic-Acacia scrub types have a higher proportion of foliage and a lower ratio of stem and branch material than the hazel dominant types. This information should be of great use to the fire manager and researcher in his determination of the amounts and proportions of scrub material which becomes available to burn during controlled and wild fires.

Figure 7 illustrates the relationships found to be present between the various live scrub size component weights and the total live weight within the netic and Acacia species dominant scrub groups. Similar treatment of the data for dead material, however, failed to show up any relationships existing between the total dead weight and the weights of the dead material of various size classes. Since the co-efficient of variation was not greater than twelve per cent for all scrub groups, it was apparent that the weight values of dead material less than $\frac{1}{2}$ inch diameter did not vary much between samples within scrub classes. It was therefore decided to obtain the mean weight of each size class and to use this value for all plots within a scrub group, irrespective of scrub height and density.

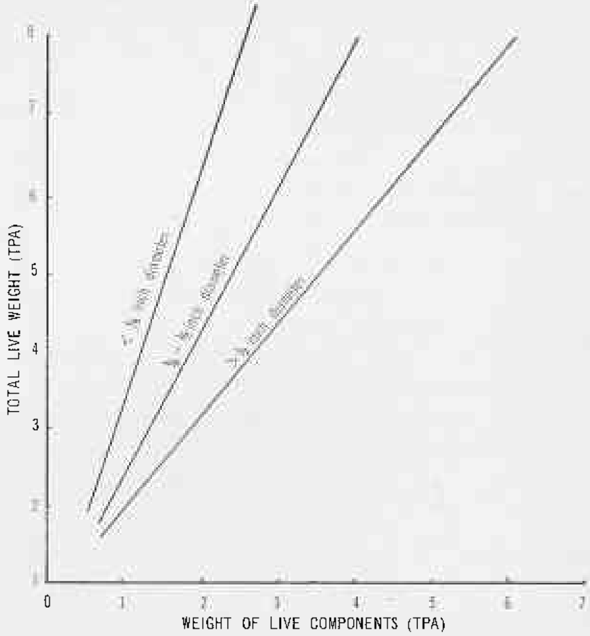

FIGURE 7: *Relationship between total live weight and weights of various size components of netic-Acacia species dominant scrub types. All relationships are highly significant.*

Scrub Weight and Scrub Height-Density Relationships

Having established the presence of reasonably close relationships between the weights of the various live scrub components and total live weight, the next task was to investigate the presence of relationships between live scrub weight and the derived quantitative expressions of scrub height and density.

Values of average top height and cover density were separately plotted against total live fuel weight. The results indicated that both height and density parameters were directly related to scrub fuel weight, although individually these do not give a sufficiently accurate estimate of fuel weight. I+ was therefore decided to combine height and density by plotting graphically their product against total live fuel weight.

An examination of the scatter of points revealed that it was possible to combine the live weights of both netic and Acacia species dominant scrub groups in a single linear regression (Fig. 8). A graphical plot of the hazel dominant groups indicated a slightly curved regression above the first, whilst the points for the mixed species scrub groups fell between these two functions (Fig. 9).

These relationships make possible the estimation of total live weight values of scrub types of known average top height and cover density. Thus a direct estimation of scrub weight may be made by using the point sampling technique to determine top height and cover density.

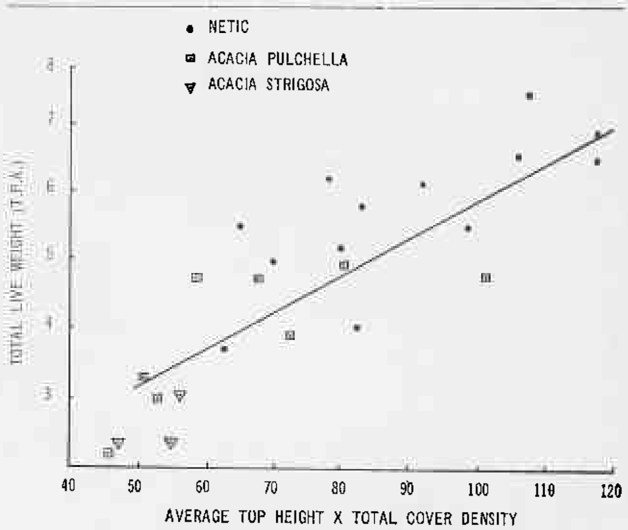

FIGURE 8: *Relationship between total live weight and the product of average top height and total cover density.*

Scrub Weight Profile Histograms

To accurately predict the scrub fuel weight available for burning it was necessary to determine how the weights of the various scrub components were distributed throughout the understorey profile.

From the scrub weight field data, the weights of the three live scrub components within 2 ft. height intervals were plotted against the top height-cover density value of each sample plot, within a particular scrub group. A line of best fit was then drawn for each size class, and this resulted in three consistent and logical trends for each height interval.

The data from these graphs were combined into a series of weight-profile histograms for each scrub group, with each histogram spanning 20 units of the height-density product range. These histograms provide easy and quick reference for the calculation of live scrub fuel weights available for burning on scrub types of known average top height and cover density. Figure 10 shows two ranges of product values (80-100 and 100-120) for the netic dominant scrub group.

A similar treatment was attempted for the dead scrub material, but no real trends existed between plots of different height-density product values. It was decided, therefore, that one average weight value would be sufficient for each height interval for all sample plots within a scrub group, irrespective of its top height and cover density (Fig. 11).

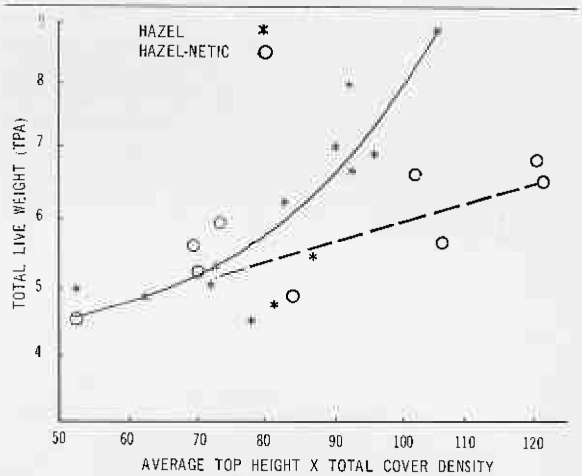

FIGURE 9: *Relationships between total live weight and the product of average top height and total cover density for hazel and mixed hazel-netic scrub type.*

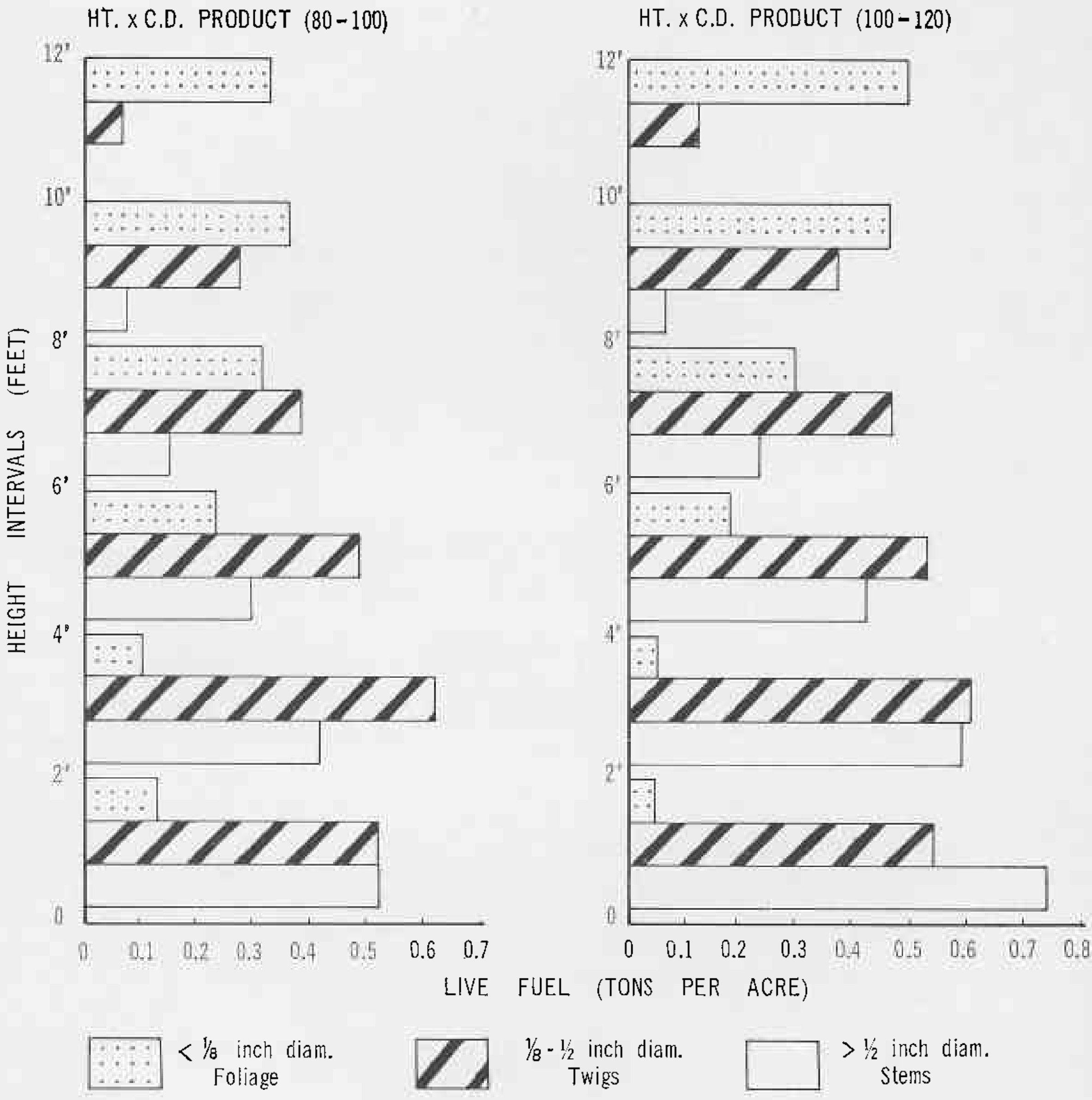

Figure 10: *Weight profile histograms of live scrub components for a netic dominant scrub type. Each histogram covers twenty units within the height cover density product range.*

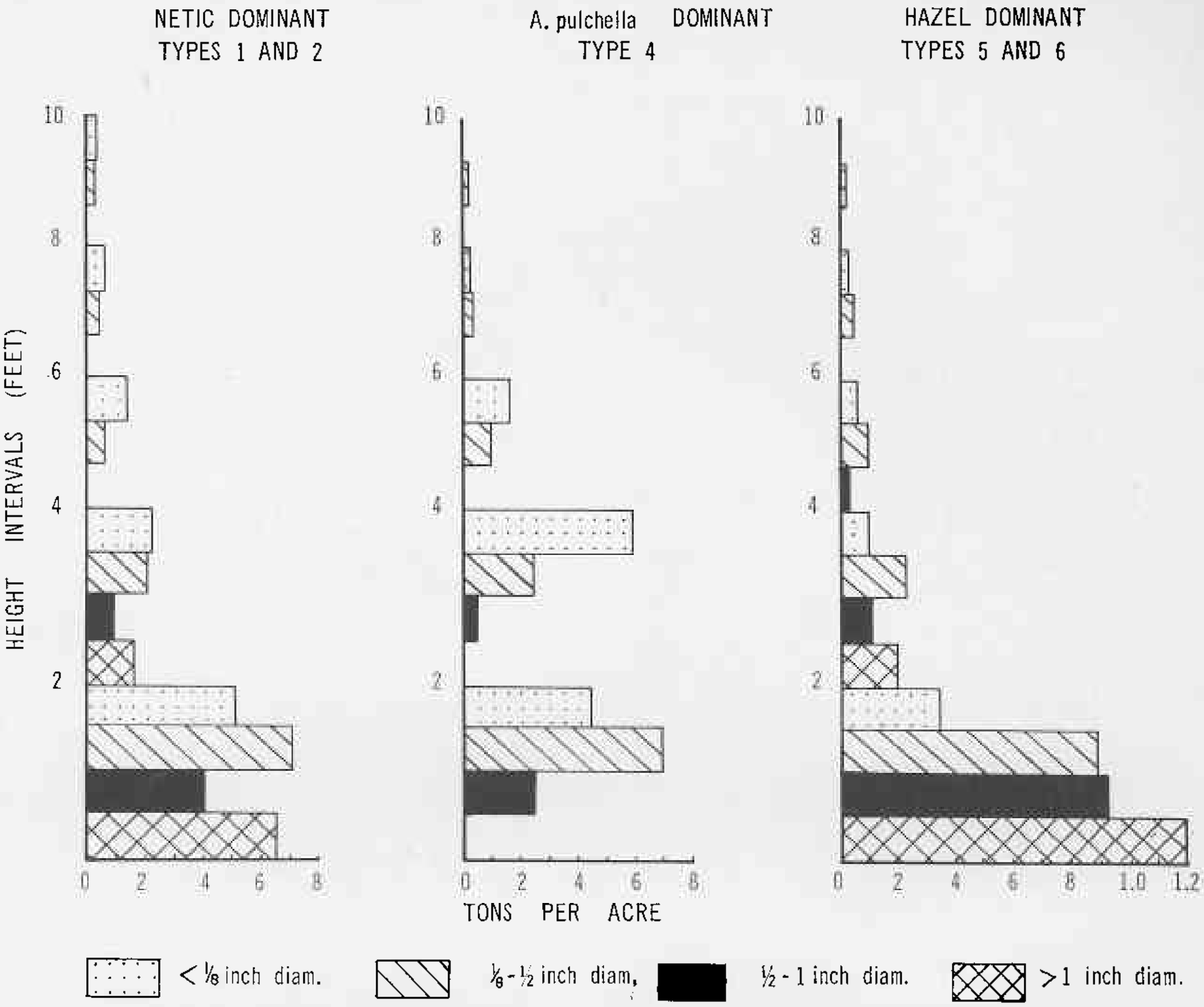

FIGURE 11: *Weight profile histograms of dead scrub size components for three different scrub types. Each histogram represents the entire height cover density product range.*

CONCLUSIONS

The present study successfully identified close relationships existing between live scrub fuel weight and the product of the structural parameters of scrub cover density and top height for all scrub fuels encountered.

The weights of live scrub structural components were demonstrated to be direct linear functions of the total live weight. Netic dominant and *Acacia strigosa* and *A. pulchella* dominant scrub types were combined into a single, close regression, whilst hazel dominant groups separated into a slightly parabolic line above the first. Plots containing mixtures of the two main groups fell in between these regressions.

Thus, the values of average cover density and top height determined by the point sampling method, are the only structural parameters required in order to estimate the weight of total live material as well as that of the various scrub size components.

The weights of dead scrub material of various diameter classes did not vary with change in scrub height and density, so that it was possible to adopt mean weight values for the entire range of heights and densities within each scrub type.

A series of histograms was constructed for each main scrub group which illustrated the height distribution of the three size components of live scrub throughout the entire range of scrub top heights and cover densities.

A single histogram indicating the height distribution of the weights of the four size classes of dead scrub material, was constructed to cover the entire range of top height-cover density product values within each main scrub group. In this case, it was unnecessary to split the range of product values into groups, as done with the live scrub weights, since no trends were evident between these values and the dead scrub weights.

It is planned to investigate further the relationships between scrub weight and the structural parameters of several other common karri understorey scrub types and to expand the present data into older and younger age groups.

At the completion of this work, it should be possible to determine the scrub fuel weights of all common karri understorey scrub types within a proposed control burn area, simply by employing the point sampling method to obtain scrub top height and cover density. Thereby, the amounts of live and dead scrub fuels available may be determined from the calculated formulae and profile histograms.

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