DERIVATION OF THE NUMBER OF CAPSULES PER JARRAH TREE AS A FUNCTION OF TREE SIZE AND DENSITY OF CAPSULES IN THE TREE CROWN

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Introduction

The revision of the jarrah silvicultural guideline has resulted in the proposed requirement to survey areas cut to a regeneration establishment objective (shelterwood silvicultural treatment) to determine the crop of capsules and seed in these areas. The purpose of the survey is to assist with planning for seedbed preparation (soil disturbance and fire) and seedfall (fire) treatments. The draft jarrah silvicultural guideline refers to a silvicultural procedures manual. The draft silvicultural procedures manual includes a table in which the number of capsules per tree is estimated on the basis of tree size class and the density of capsules in the crown of the sample tree.

The purpose of this note is to document the basis for the table of number of capsules per tree.

The procedure is summarised into the following steps:

- Step 1 – Estimating the total weight of capsules per tree;
- Step 2 – Converting the dry weight of capsules to the number of capsules per tree;
- Step 3 – Converting the number of capsules per tree to capsules per hectare and seed per hectare; and
- Step 4 – Calculating the number of capsules per tree for a medium seed crop, heavy seed crop, light seed crop and very light seed crop.

Step 1 – Estimating the total weight of capsules per tree

This step uses the allometric relationship developed by Hingston *et al*. (1990) where:

$$\ln(\text{DW of capsules}) = -7.36 + 2.42 * \ln(\text{dbhob}) \qquad r^2 = 0.57,\ n = 20$$

which means that

$$\text{DW of capsules} = e^{(-7.36 + 2.42 * \ln(\text{dbhob}))}$$

DW = oven dry (70^0C) weight (kg),
dbhob = diameter at breast height over bark (cm)

The total dry weight of capsules is calculated below for a range of tree sizes in Table 1.

DBHOB (cm)	Total DW of capsules (kg)
20	0.90
30	2.39
40	4.79
50	8.22
60	12.79
70	18.57
80	25.65
90	34.11
100	44.01

Table 1: The diameter of a jarrah tree and the corresponding total dry weight (DW) of capsules per tree. The dry weight is calculated using the relationship reported by Hingston *et al*. (1990). The attached spreadsheet (capsule crop for shelterwood.xls) contains the calculations.

The relationship is depicted in Figure 1 below.

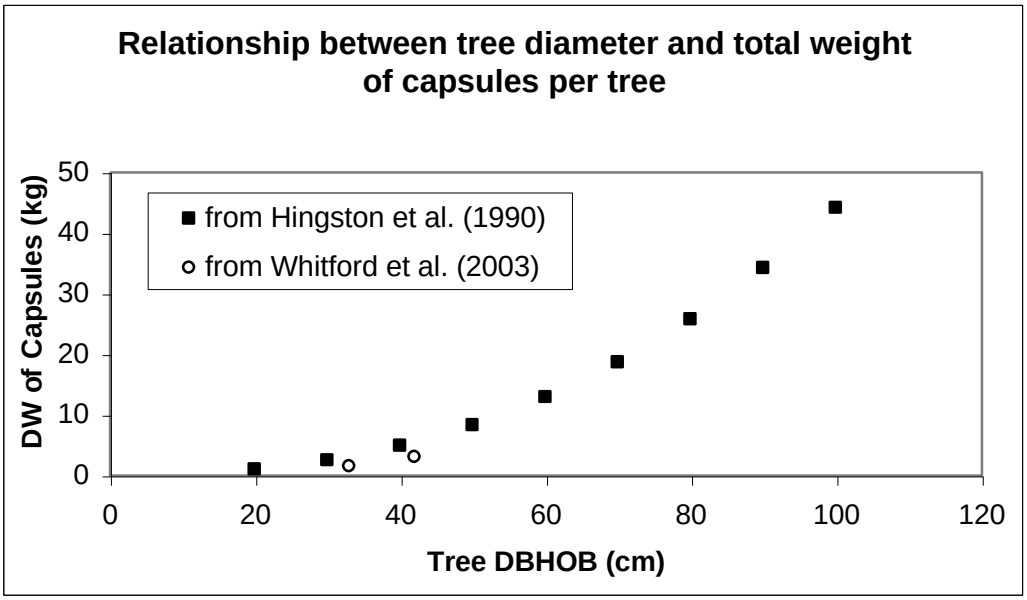

Figure 1: Relationship between the diameter of a jarrah tree and the total dry weight of capsules per tree. The relationship is as reported by Hingston *et al*. (1990). Tree diameter is measured in terms of diameter at breast height over bark (DBHOB – cm) and dry weight of capsules is in terms of kg per tree. Data from heavily thinned plots where Whitford *et al*. (2003) measured the fall of capsules is included for comparative purposes.

The fall of capsules (immature, mature and empty) was measured by Whitford *et al*. (2003) over a three-year period in a thinning and fertilising experiment in an 70-year-old jarrah regrowth stand at Inglehope block in the northern jarrah forest. For the two most heavily thinned treatments average fall of capsules (kg/ha/yr) (from Whitford et al. 2003, Table 6) is plotted against average tree dbhob (cm) for the thinning treatment, in Figure 1. The other thinning treatments are not plotted in Figure 1

because average tree size in these plots is more biased than for the heavily thinned plots. For a given tree dbhob, the Whitford *et al*. data points fall well below those predicted from the Hingston *et al*. relationship. This may indicate that the Hingston *et al*. data was collected when a heavy crop of capsules was present in the crown of the sample trees.

Step 2 – Converting the dry weight of capsules to the number of capsules per tree

This step calculates the number of capsules by dividing the dry weight of capsules (per tree) by the average weight of an individual capsule, where:

Capsules = (DW of capsules (kg) * 1000) / average weight of an individual capsule (g)

where average weight of an individual capsule = 0.7 g (from Whitford *et al*. (2003)

The figure of 0.7 g per capsule is based on the average weight of mature capsules measured from the collection of over 100,000 mature capsules over a three-year period in a thinning and fertilising experiment in a 70-year-old jarrah regrowth stand. Stand density and fertiliser application did not affect average individual weight of mature capsules.

The number of capsules per tree is calculated in Table 2, which builds on Table 1, for a range of tree sizes.

DBHOB (cm)	Total DW of capsules (kg)	No. of capsules per tree
20	0.90	1,279
30	2.39	3,413
40	4.79	6,847
50	8.22	11,749
60	12.79	18,265
70	18.57	26,524
80	25.65	36,641
90	34.11	48,726
100	44.01	62,877

Table 2: The diameter of a jarrah tree, the corresponding total dry weight (DW) of capsules per tree and the number of capsules per tree. The calculation of capsules per tree is described above. The attached spreadsheet (capsule crop for shelterwood.xls) contains the calculations.

The resulting relationship between tree size and number of capsules per tree is depicted below in Figure 2.

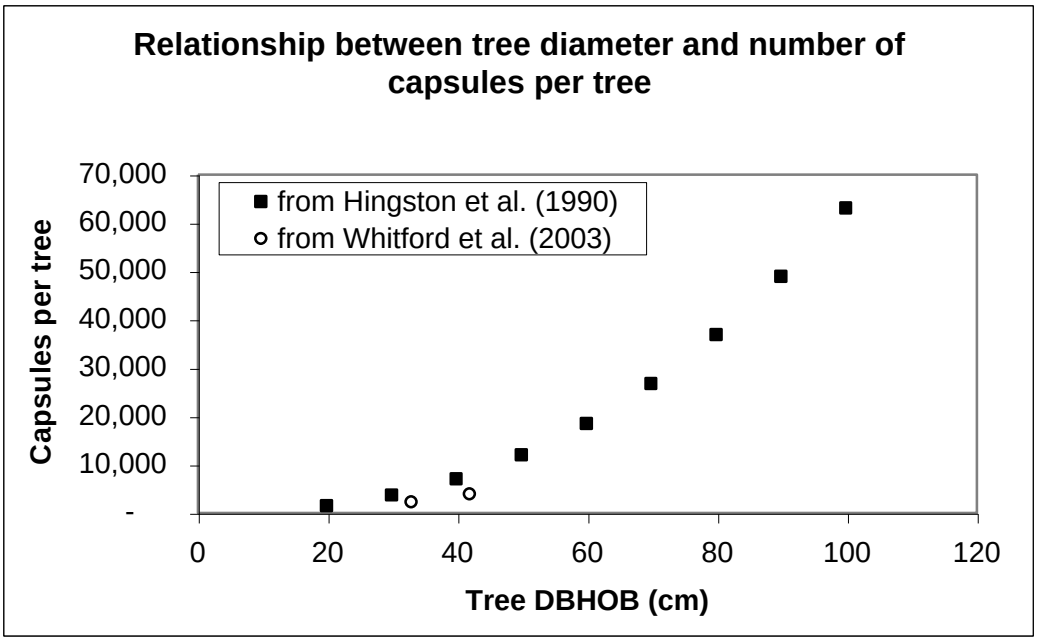

Figure 2: Relationship between the diameter of a jarrah tree and the number of capsules per tree. Tree diameter is measured in terms of diameter at breast height over bark (DBHOB – cm). Data from heavily thinned plots where Whitford *et al.* (2003) measured the fall of capsules is included for comparative purposes.

The fall of capsules (immature, mature and empty) was measured by Whitford *et al*. (2003) at Inglehope. For the two most heavily thinned treatments the average number of capsules that fell (from Whitford *et al*. 2003, Table 6) is plotted against average tree dbhob (cm) for the thinning treatment, in Figure 2 above. The other thinning treatments are not plotted in Figure 2 because average tree size in these plots is more biased than for the heavily thinned plots. For a given tree dbhob, the Whitford *et al*. data points fall well below those predicted from the Hingston *et al*. relationship. This may indicate that the Hingston *et al*. data was collected when a heavy crop of capsules was present in the crown of the sample trees.

Step 3 – Converting the number of capsules per tree to capsules per hectare and seed per hectare

The purpose of this step is to allow comparison of the number of capsules and seed per hectare estimated using the Hingston *et al*. relationship and direct measurements of capsule and seedfall at the Inglehope experiment site. This step requires the calculation of the number of trees per hectare to allow conversion from a tree basis to a per hectare basis. Number of trees per hectare is calculated:

Trees per hectare = stand basal area / tree basal area

Where stand basal area is assumed to be 23 m^2/ha as this the average basal area of jarrah trees in the plots measured by Hingston et al. (1990); and
tree basal area (m^2) = πr^2 = 3.142 * (dbhob (cm)/200)^2

Capsules per hectare is then calculated as:

Capsules per hectare = capsules per tree * trees per hectare

and seed per hectare is calculated as:

Seed per hectare = capsules per hectare * average seed per capsule

where average seed per capsule = 1.56 (from Whitford *et al*. 2003).

The calculations are shown in Table 3 below, which builds on Tables 1 and 2, for a range of tree sizes.

DBHOB (cm)	Total DW of capsules (kg)	No of capsules per tree	Tree basal area (m2)	Stand basal area (m2/ha)	Stocking (stems/ha)	Capsule crop (no/ha)	Seed crop (no/ha)
20	0.90	1,279	0.0314	23	732	936,502	1,460,943
30	2.39	3,413	0.0707	23	325	1,110,369	1,732,175
40	4.79	6,847	0.1257	23	183	1,252,972	1,954,637
50	8.22	11,749	0.1964	23	117	1,376,080	2,146,684
60	12.79	18,265	0.2828	23	81	1,485,593	2,317,525
70	18.57	26,524	0.3849	23	60	1,584,957	2,472,532
80	25.65	36,641	0.5027	23	46	1,676,386	2,615,162
90	34.11	48,726	0.6363	23	36	1,761,400	2,747,785
100	44.01	62,877	0.7855	23	29	1,841,095	2,872,108

Table 3: The diameter of a jarrah tree, the corresponding total dry weight (DW) of capsules per tree, the number of capsules per tree, the calculation of stocking of trees, the capsule crop and seed crop. The calculation of capsules per hectare and seed per hectare are described above. The attached spreadsheet (capsule crop for shelterwood.xls) contains the calculations.

Comparison of the estimated capsule crop (number per hectare) in the table above with the number of capsules that fell at Inglehope (Whitford *et al*. 2003, Tables 3 and 4) shows that the estimates in Table 3 above are much higher than the numbers measured by Whitford *et al*. Average fall of capsules at Inglehope was about 250,000 per hectare per year, which is about 25 per cent of the figures above for similar sized trees (30 – 40 cm dbhob). This may indicate that the Hingston *et al*. data was collected when a heavy crop of capsules was present in the crown of the sample trees.

Comparison of the estimated seed crop (number per hectare) in Table 3 above with the number of seed that fell at Inglehope (Whitford *et al*. 2003, Tables 3 and 4) and earlier studies (Whitford *et al*. 2003, Figures 8 and 9) shows that the estimates in Table 3 above are much higher than the seedfall measured by Whitford *et al*. or by earlier researchers. Average seedfall at Inglehope was about 450,000 per hectare per year and average seedfall measured by Kimber in the 1960's was about 250,000 per hectare per year, which is about 25 per cent of the figures above for similar sized trees (30 – 40 cm dbhob). This may indicate that the Hingston *et al*. data was collected when an exceptionally heavy crop of capsules was present in the crown of the sample trees.

Step 4 – Calculating the number of capsules per tree for a medium seed crop, heavy seed crop, light seed crop and very light seed crop

Given that the seed crop calculated in Table 3 above was about four times that of an average seed crop, the number of capsules per tree was divided by four to calculate the number of capsules per tree for an medium crop of capsules. A heavy capsule crop was calculated as double that of an medium capsule crop, a light seed crop was calculated as one-half that of an medium capsule crop, and a very light capsule crop was calculated as one-quarter that of an medium capsule crop.

This results in Table 4 below, which is included in the draft silvicultural surveys procedures manual.

	Capsule density in the tree crown			
Tree size (dbhob cm)	Heavy	Medium	Light	Very Light
20	600	300	200	100
30	1,700	900	400	200
40	3,400	1,700	900	400
50	5,900	2,900	1,500	700
60	9,100	4,600	2,300	1,100
70	13,300	6,600	3,300	1,700
80	18,300	9,200	4,600	2,300
90	24,400	12,200	6,100	3,000
100	31,400	15,700	7,900	3,900

Table 4: The number of capsules per tree as a function of tree diameter and the density of capsules in the tree crown. The calculation of capsules per tree is described above. The attached spreadsheet (capsule crop for shelterwood.xls) contains the calculations.

Research and development

The estimated number of capsules per tree in Table 4 above has been derived on the basis of information that was not designed specifically for this purpose. Additionally, the capsule and seed crop estimated on the basis of the relationship developed by Hingston *et al*. (1990) appears to give results that do not align with information collected by Whitford *et al*. (2003). Consequently, there is a need for further research to seek to verify the estimates in Table 4 above by measuring the number of capsules per tree for a range of tree size classes and density of capsule crops, using field sampling. This work should include the establishment of a set of photographic standards for the categories of capsule density in the tree crown used in Table 4. If the verification exercise shows the estimates of capsules per tree are not sufficiently accurate for field application then a further research project will be required to develop allometric relationships to predict the capsule crop. The approach adopted by Whitford (1991) for estimating the leaf area of jarrah trees may serve as a useful model.

References

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Whitford, K., Stoneman, G. and Mellican, A. (2003). SPP 93/0094 – Establishment of jarrah (*Eucalyptus marginata*) in shelterwood areas and on dieback 'graveyard' sites – Experiment B – Effect of stand density and fertilizing on seed-fall. Draft report of May 2003. Science Division, Department of Conservation and Land Management.