Folder 6

Michigan Department of Natural Resources

RED PINE PRISM SAMPLING

This analysis was undertaken to determine the feasibility of using cumulative tally methods to obtain accurate estimates of combinations of pulpwood and sawlogs when prism sampling red pine in Michigan. The results from any cruise on MDNR Timber Sales should be consistent with results calculated with the Fowler/Hussain VBARs for aspen and red pine. For other species, results should be consistent with Carlson VBAR for pulp and MDNR VBAR for Sawlogs. This is according to the product standards adopted by the Division in 1987.

Cumulative tally of prism tally data is predicated on the assumption of linear increase in the Volume to Basal Area Ratio (VBAR) when related to the increase in height measurement. Though any VBAR relationship using cumulative tally will exhibit problems at the extremes of existing forest conditions, it is possible that such formulas will produce nearly identical results over a wide range of existing conditions. There can be no doubt that cumulative tally of prism data is the most efficient method of field data collection and input. Out of the 13 responses to the committee's request for input, a clear majority were using some form of cumulative tally.

The first step in the analysis was to apply a simple linear regression to the pulpwood volumes obtained by using the Height Independent VBAR formula prepared by Fowler and Hussain. Because trees with 2 through 8 sticks in height are by far and away the most prevalent for any given cruise, only these values were included in the regression. Table 1 indicates the results of this while Figure 1 graphically shows how successful this approximation is.

Table 1: Comparison of Volume to Basal Area results predicted by formulas prepared for individual and cumulative prism tally. Computed directly in Cubic Feet per Square Foot.

		Indiv VBAR	Cumm VBAR	Cumm/ Indiv
	1	6.6832	11.1178	166.3%
	2	14.0973	14.8060	105.0%
Total	3	18.7093	18.4941	98.9%
Number	4	22.6208	22.1822	98.1%
of	5	26.2521	25.8704	98.5%
Merch.	6	29.7433	29.5585	99.4%
Sticks	7	33.1544	33.2466	100.3%
	8	36.5155	36.9348	101.1%
	9	39.8433	40.6229	102.0%
	10	43.1477	44.3110	102.7%

Regression Output for Individual Tally VBAR

Constant	7.429715
Std Err of Y Est	0.470106
R Squared	0.997107
No. of Observations	7
Degrees of Freedom	5
X Coefficient(s)	3.688132
Std Err of Coef.	0.088842

Pulp VBAR (ind) = 11.8783 + 3.2110 * PH - 8.4061/PH

Pulp VBAR (cum) = 7.429715 + 3.688132 * PH

Next, to make a comparison of the various VBAR formulas in use, the individual tally VBAR and cumulative tally VBAR volumes were converted to cords according to the conversion values stated by Fowler and Hussain. Table 2 indicates a possible formula for expediting the conversion.

The comparison shown in Table 3 shows the MDNR VBAR offering the lowest volume per square foot of basal area in all but the 1 stick trees. Clearly the Cummulative VBAR will produce the highest estimate in stands with average heights of less than 2.5 sticks. The assertion here is that very few merchantable red pine trees on any given sale are less than 2 sticks. Any stand with aspen averages that low would be the lowest volume and value stands we would encounter. For those cases, reversion to the Carlson VBAR could produce consistent results.

Table 3. Comparison of Pulpwood VBARs in Cords per Square Foot.

		Indiv VBAR	Cumm VBAR	MDNR VBAR	Carlson VBAR
	1	0.083	0.137	0.086	0.100
	2	0.171	0.181	0.144	0.150
Total	3	0.227	0.224	0.201	0.200
Number	4	0.271	0.267	0.251	0.250
of	5	0.311	0.308	0.296	0.300
Merch.	6	0.348	0.349	0.333	0.350
Sticks	7	0.383	0.389	0.368	0.400
	8	0.417	0.428	0.391	0.450
	9	0.455	0.466		0.500
	10	0.493	0.504		0.550

Table 4 lists the Sawlog VBARs calculated when both topwood and sawlogs are present in a tree. According to Fowler and Hussain the best estimate is derived by calculating the total volume in the tree and subtracting the topwood portion. This leaves you with the sawlog portion in cubic feet. On the other hand, effective cumulative tally requires that sawlog volumes be subtracted from total volumes to obtain pulp volumes. For purposes of this analysis, table 4 includes only volumes for height combinations encountered among the 802 trees tallied for the VBAR research. A weighted average was calculated from these VBARs. These were compared to the volumes calculated by the Sawlog VBAR formula. The calculated values range little from the average VBAR. As a result, this average VBAR seems suitable for regression analysis for the purposes of considering cumulative tally of sawlogs and pulp.

Table 4: Volume to Basal Area results predicted by formulas prepared by Fowler/Hussain. Pulpwood VBAR - Residual VBAR in CuFt/SqFt

		Number of Topwood Sticks							
		0	1	2	3	4	5	6	Average
	1	7.8312	8.3678	8.5905	8.3646	7.9662	7.4209	6.7257	7.8953
	2	14.9301	14.3077	14.5696	14.5099	14.4079	14.2806		14.5010
Number	3	19.6495	19.1830	19.6285	19.6577	19.6506			19.5539
of	4	23.7742	23.5623	24.2479	24.3768	24.4409			24.0804
Sawlog	5	27.6609	27.6730	28.6111	28.8462	28.9781			28.3538
Sticks	6	31.4286	31.6227	32.8102	33.1525				32.2535
	7	35.1284	35.4682	36.8977	37.3451				36.2099
	8	38.7856	39.2427	40.9057					39.6447

Figure 1.

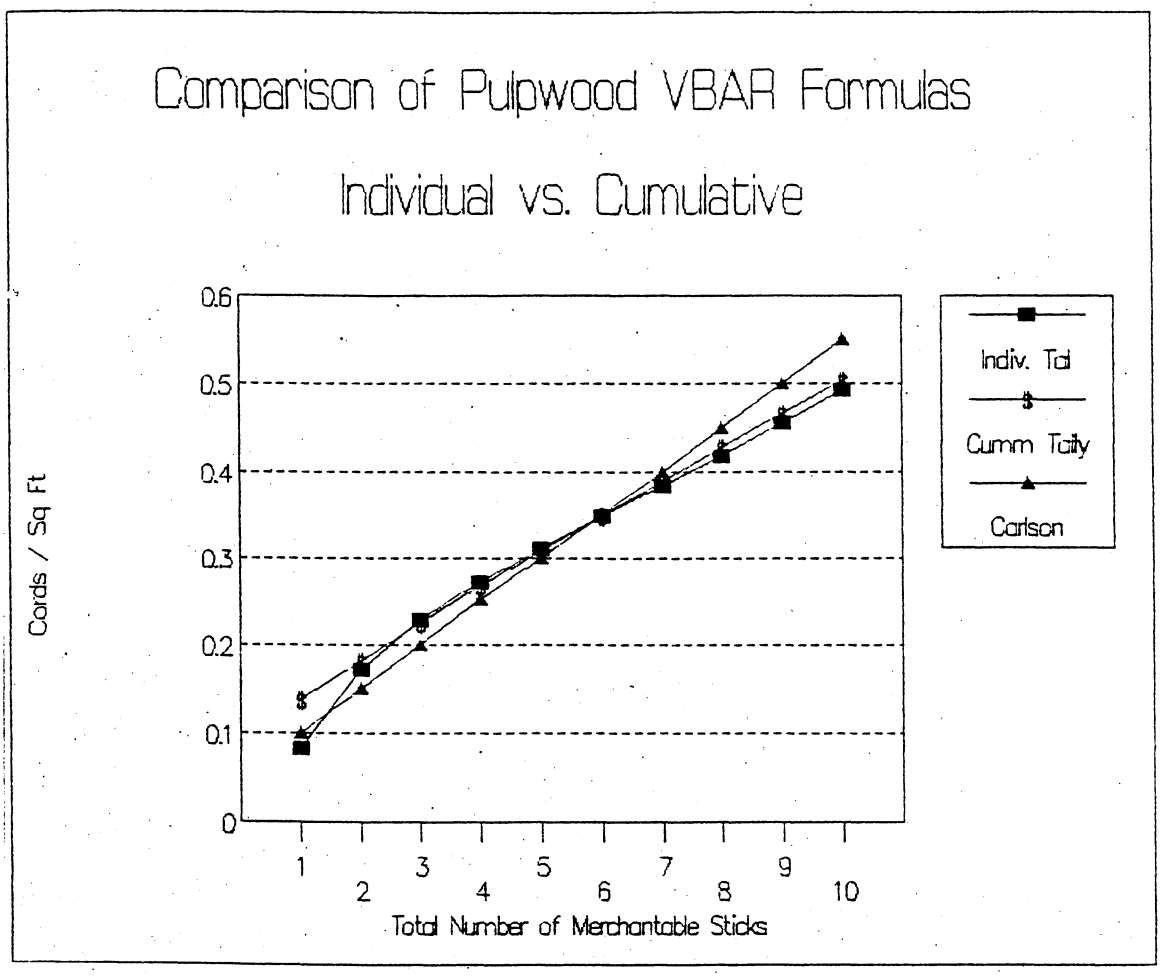


Table 2. Cubic Foot to Cord Conversion.
Cords = (.012467-.00012*PH) * Cubic Feet

		Cords per Cubic Ft	Actual cf to cd	Predicted cf to cd	Pred to Actual
	1	77	0.0125	0.0124	99.1%
	2	79	0.0122	0.0122	100.8%
Total	3	79	0.0122	0.0121	99.9%
Number	4	80	0.0120	0.0120	100.2%
of	5	81	0.0119	0.0119	100.5%
Merch.	6	82	0.0117	0.0118	100.9%
Sticks	7	83	0.0116	0.0117	101.1%
	8	84	0.0114	0.0116	101.4%
	9	84	0.0114	0.0115	100.4%
	10	84	0.0114	0.0114	99.5%

Regression Output for:
CF to Cord Conversion

Constant	0.012467
Std Err of Y Est	0.000087
R Squared	0.950197
No. of Observations	10
Degrees of Freedom	8
X Coefficient(s)	-0.00012
Std Err of Coef.	9.55E-06

Table 5. Volume to Basal Area results predicted by formulas prepared for cumulative prism tally. Computed directly in CuFt/SqFt
(Sawlog VBAR = ~~5.320702~~ 5.7791 + ~~4.442412~~ 4.2488 * No Of Sawlog Sticks)

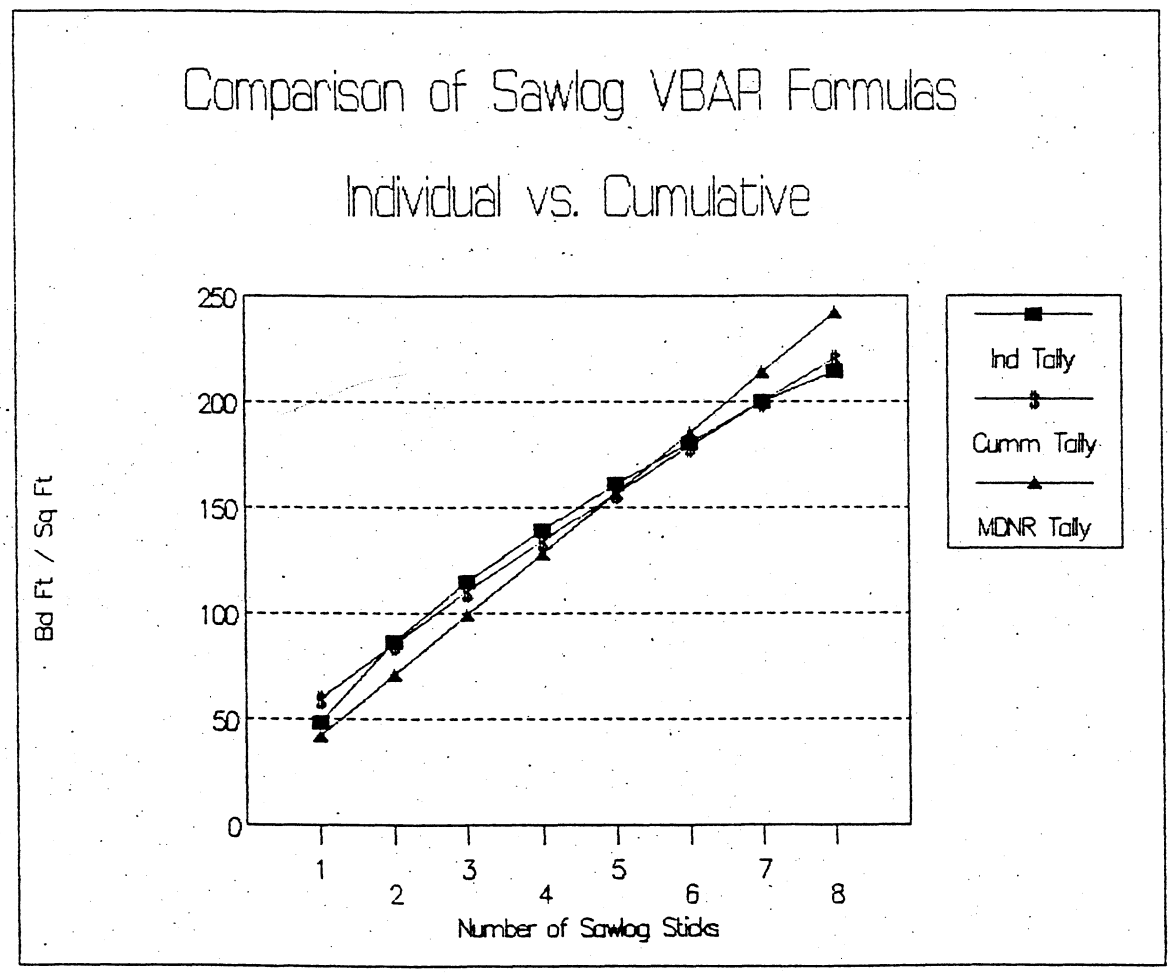
Number of Sawlog Sticks	Ave Indiv VBAR	Cumm VBAR	Cumm/ Indiv
1	7.8953	9.7631	123.7%
2	14.5010	14.2055	98.0%
3	19.5539	18.6479	95.4%
4	24.0804	23.0904	95.9%
5	28.3538	27.5328	97.1%
6	32.2535	31.9752	99.1%
7	36.2099	36.4176	100.6%
8	39.6447	40.8600	103.1%

Regression Output for Average Individual Sawlog VBAR

Constant	5.320702
Std Err of Y Est	1.129069
R Squared	0.990856
No. of Observations	8
Degrees of Freedom	6
X Coefficient(s)	4.442412
Std Err of Coef.	0.174219

Table 5 shows how closely a simple linear regression can approximate the values obtained from table 4. Figure 2 graphically demonstrates the close fit.

Figure 2.



Fowler and Hussain did not address Cubic Foot to Board Foot conversion in their research on aspen. Such a conversion formula is addressed in a paper entitled "Tree Volume and Biomass Equations for the Lake States" prepared by Jerold T. Hahn in 1984. He developed a formula using Robert Stone's data using DBH, height in Feet (H), and a representation of the top diameter (T) .

$$T = (1.00001 - \text{Top DOB}/\text{DBH})$$

$$\text{Bd Ft} = 17.7488 + 7.3846*\text{Cu Ft} - 2.3523*\text{DBH} - 0.89945*H + 2.0726*T$$

Of course, DBH is not available from our cruises while this formula demands it. My solution was to solve for DBH in the height and diameter independant VBAR formulas using the height independant VBARs from the Aspen research. Table 6 lists the VBARs used the formula, the resulting DBHs, and the Board Foot VBARs calculated with the formula listed above.

Table 6. Conversion of Cubic Ft VBARs to Board Foot VBARs by calculating DBH and using Hahn's Formula.

		Cu Ft VBAR	Derived DBH	Bd Ft VBAR
	1	7.90	8.64	48.54
	2	14.50	10.46	86.20
Number	3	19.55	11.31	114.44
of	4	24.08	12.16	138.80
Sawlog	5	28.35	13.04	161.19
Sticks	6	32.25	14.27	180.00
	7	36.21	15.32	199.65
	8	39.64	16.98	214.02

Table 7 compares the Board Foot and Cubic Foot values for these data points and shows the results of a regression of this conversion data.

Table 7. Cubic Foot to Board Foot Conversion
Board Feet (Int) = (6.180454-.09877*SH) * Cubic Feet

		Bd Ft VBAR	Cu Ft VBAR	BF / CF	Predicted BF / CF
	1	48.54	7.90	6.15	6.08
	2	86.20	14.50	5.94	5.98
Number	3	114.44	19.55	5.85	5.88
of	4	138.80	24.08	5.76	5.79
Sawlog	5	161.19	28.35	5.68	5.69
Sticks	6	180.00	32.25	5.58	5.59
	7	199.65	36.21	5.51	5.49
	8	214.02	39.64	5.40	5.39

Regression Output for Cu Ft to Bd Ft Conversion	
Constant	6.180454
Std Err of Y Est	0.036805
R Squared	0.980553
No. of Observations	8
Degrees of Freedom	6
X Coefficient(s)	-0.09878
Std Err of Coef.	0.005679

Table 8 compares the results of applying this conversion to the Red Pine VBARs to the other commonly used Sawlog VBARs. The figures compare well within reason, lending support to validity of this conversion formula.

Table 8. Comparison of Sawlog VBARs in Board Feet per Square Feet

		Indiv VBAR	Cumm VBAR	MDNR VBAR	Carlson VBAR	ZCruise VBAR
Number of Sawlog Sticks	1	48.54	59.4	40.0	50.0	41.9
	2	86.20	85.0	70.0	75.0	70.5
	3	114.44	109.7	100.0	100.0	99.0
	4	138.80	133.6	130.0	125.0	127.6
	5	161.19	156.6	160.0	150.0	156.2
	6	180.00	178.7	180.0	175.0	184.8
	7	199.65	199.9		200.0	213.3
	8	214.02	220.2		225.0	241.9

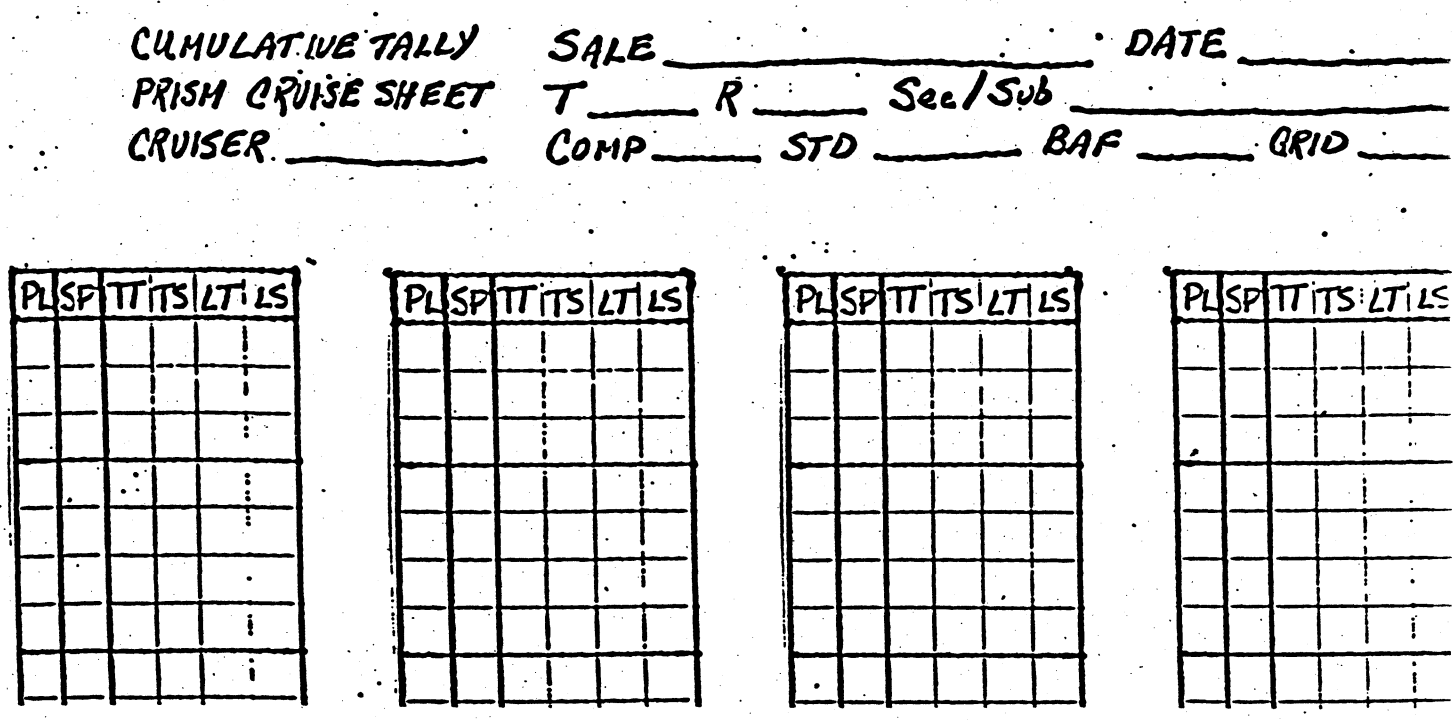
It is important to note that differences do exist between the Individual and Cummulative VBARs. But these are in tenths and hundredths of cords and in board feet (not Thousand Board Feet. With these factors in mind, it is likely that virtually all cruises that include red pine will obtain consistent results from a cummulative tally or individual tally according to our product standards.

The cumulative tally sheet proposed here includes the collection of the following data items for each species group encountered on a plot:

PL: Plot Number
SP: Species Code
TT: Total Number of Merchantable Trees
TS: Total Number of Merchantable Sticks
LT: Number of Trees with at least 1 Sawlog Stick
LS: Total Number of Log Sticks

Figure 3 shows the Cumulative Tally Cruise Sheet.

Figure 3.



Data reduction with this cumulative tally data is as follows:

1) Sum up each data item (TT, TS, LT, LS)

2) Total CF/Ac = [(7.4297 *$\sum$TT + 3.6881 *$\sum$TS) * BAF] / Number of Plots

3) Sawlog CF/Ac = [~~(5.3207~~ 5.7791 *$\sum$LT + ~~4.4624~~ 4.2488 *$\sum$LS) * BAF] / Number of Plots

4) Pulp CF/Ac = Total CF/Ac - Sawlog CF/Ac

Conversions:

5) Pulp Cords/Ac = [.012467 - .00012 * ($\sum$TS -$\sum$LS)/$\sum$TT] * Pulp CF/Ac

6) Sawlog MBF/Ac = ([6.1805 - .09877 *$\sum$LS /$\sum$LT] * Sawlog CF/Ac) / 1000