Point-3-P Alternative Timber Cruise Procedure

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Our goal.

Develop some innovative procedures that would make variable plot cruises of highly variable Redwood timber stands more accurate, without increasing the cost of cruise projects.

Our base theory.

Variable plot timber cruises seek to gather enough data on the two major components of stand volume calculations, average basal area per acre and average tree V-BAR, which is expressed as the ratio: volume per tree / basal area per tree to gain acceptable statistics for a cruise, including standard deviation and standard error.

Dr. Iles has suggested that basal area per acre could be more variable than the V-BAR. During a variable plot field cruise, basal area variability is captured by determining the number of trees "in" on cruise plots, through the use of a Relaskop. Capturing V-BAR variability is accomplished by taking individual tree measurements, such as DBH, form factor and bole height. If, as Dr. Iles has suggested, basal area variability is more variable than V-BAR, cruisers should really be spending a proportionally greater amount of their field time taking more plots and less tree volume measurements; this idea is in opposition to what is taught in many cruising courses. Often, cruisers are taught to take complete measurements on every "in" tree on a plot; this requires a significant amount of time and generally results in many cruisers completing only 12-16 cruise plots per work day.

The purpose of the tests we conducted was to determine if we could achieve a more accurate cruise without increasing the cost of cruise projects.

To achieve our goal we needed to:

1. Figure out the best balance of field time between collecting tree counts at plots and taking tree volume measurements.

2. Figure out how to save some time in the existing field procedure, so that we can use the saved time to complete more plots in a cruise project.

To determine the best balance of time spent on plots to volume measurements, we wanted to see what would happen if we reduced the amount of sets of tree measurements over the amounts we normally take. The goal of our existing cruise procedure is to average 1.5 sets of tree volume measurements for every plot in a cruise project. We had already adopted using the large BAF selection system, as taught by Dr. Iles, to select which "in" trees to take the volume measurements on. In our old cruise procedure we would strive to select one of the big relaskop BAFs available, such as the 250, that would allow us to average 1.5 trees selected per plot to measure. In our experiment we wanted to determine if there would be an adverse effect on accuracy if we reduced this average 1.5 trees per plot. Taking an accurate set of full tree measurements may require 5-10 minutes of field time. Although we realize that many cruisers simply estimate the various tree measurements they collect, all of our full tree measurements are measured with various cruise instruments, such as the laser hypsometer.

To find another corner to cut to save additional time in the cruise procedure, we conferred with several of our fellow cruisers in the Redwood Region about which data collection chores seemed to take up significant amounts of the time on plot. The cruisers all agreed that doing limiting distance checks on "borderline" trees on a variable plots consumes a lot of field time. Limiting distance checks are required in variable plot cruising whenever a tree looks "borderline" "in" or "out", when examined through a relaskop. Limiting distance checks are also often required on trees that are partially, or completely screened by a closer tree and cannot be examined through the relaskop. We realize that many cruisers may do more or less limiting checks in the course of their cruise projects, depending on many factors, including their experience using the relaskop, the amount of brush in the timber stand, how lazy or big of a hurry they are in, etc… Conscientious cruisers, working in the Redwood Region, routinely feel the need to make a lot of limiting distance checks; often 1-3 per plot. Many cruisers may not be aware of the adverse effect of making an incorrect tree count on a variable plot. We calculated the effect of missing a tree on one plot during a 1-plot-per-acre grid cruise:

One missed tree * BAF (54) * Ave V-BAR of a 19" DBH Redwood tree (141) * Acres per Plot (1)= **7,614 bd-ft** of error applied to the total stand cruise volume, not volume per acre.

Of course, many cruisers would argue that their tree count mistakes "balance out" over all of the plots done in a cruise. Tree count mistakes happen for a variety of reasons, including trees screened by other trees or heavy brush, trees that are not completely round, cruiser fatigue or being in a rush, etc… Since the conditions that cause tree count mistakes to occur can vary, we feel that the extent of the tree count errors can be expected to vary enough so that they may not balance out over a cruise. Since there are a variety of issues that can have a cumulative affect on the accuracy of final cruise volumes, conscientious cruisers working in the Redwood Region tend to prefer to make the extra effort to do the limiting distance checks, in an effort to remove as much error from their cruises as possible. Unfortunately, limiting distance checks can take 4-8 minutes per tree; so saving time on this issue could amount to a significant savings, which could be re-invested back into the cruise project.

Since we have noticed that cruisers tend to make tree count mistakes on plots with higher tree counts, we needed a random selection process that would weight the higher count plots encountered in the course of a cruise more for selection. We considered the possibility of using a form of Point-3-P, for which there is a thorough discussion of in chapter 13 of Dr. Iles excellent book, "**A Sampler of Inventory Topics**".

3-P, probability proportional to prediction, is a weighted random selection process, normally associated with impractical Forest Service 100% tree tallies. The 3-P process is a random selection tool that can give cruisers the ability to make unbiased selections on a wide variety of forest estimates. These estimates can later be corrected by a simple adjustment factor calculated by dividing the verified sample figure by the estimate figure. P-3-P is applying the 3-P selection process at the plot level to select entire plots for sampling.

Since it would be an unacceptable expenditure of time to re-visit all of our cruise plots, we needed to develop and test a simple P-3-P program that we could utilize, before leaving each plot in the field, to determine if the plot should be sampled. Plot samples consist of simply making a careful check of the estimated tree count, using limiting distance checks as necessary. With both Dr. Iles and Dr. Wiant's help, we wrote a simple P-3-P program to function in pocket excel, which is commonly found in many models of PDAs, such as the HP IPAQ. If we could save some time by skipping many of the limiting distance checks that we would normally deem necessary, we could re-invest this time savings back into the project by doing more plots. Doing more plots would work toward more effectively capturing the basal

area variability of the timber stands, along with offering other advantages, which we will mention in the recommendations part of this paper.

The specific cruise equipment we used during our experiment included:
1. A corvalis microtech data collector to store all of our field data. DBH, form factor, and bole height for one selected tree(these make up a set of full tree measurements) and just DBHs for all of the other "in" trees on the plot.
2. An impulse 200 laser hypsometer for shooting limiting distances and bole heights on measure trees. We feel that modern timber cruisers should really not be doing limiting distance checks without an Impulse 200, as the other available rangefinders, such as the Optic-Logic & Bushnell, do not yield the necessary accuracy.
3. The Super Ace cruise compiler for calculating our volumes per plot, including tree measurements. We need to state here that we realize that the SuperAce compiler does not use V-BAR to calculate volumes per acre; rather it uses some kind of linear regression formula. We understand that many people reading this paper may have a problem with our scientific method here, using a cruise program that does not utilize V-BAR in its volume calculations. The program is all we had available and we are simply using it to compare the volume per acre figures from 2 different cruise procedures. We once ran some field data through 2 other cruise programs and determined that the SuperAce figures were consistent with the figures calculated by the other compilers.
4. A Trimble Recon hand held data collector to run the P-3-P program on.
5. A Biltmore stick. We used to Biltmore stick to collect DBHs on all trees "in" on plot, except for the full measurement trees. Nearest one inch.
6. Spencer tape. We used the spencer tape to take DBHs on the selected full measurement trees only and borderline "in"/"out" trees. Nearest one inch for measure trees and nearest 10ths for borderline trees.
   The only specific tools, other than the usual cruise equipment, really required to implement our cruise procedure are the simple P-3-P program loaded on an IPAQ PDA. These procedures should work with any cruise software.

OUR PROCEDURES.

For our test, we selected a 4-acre young-growth Redwood harvest plan unit, on which complete cruise measurements had earlier been taken on every single tree in the unit, to serve as an accurate base control to compare to our tests results. Cruisers, used to working in other areas, may not realize that only cruising a jungle stand is probably more challenging than "spinning plots" in a Redwood stand, all things considered. Redwood timber stands are highly variable in tree size, tree spacing, and species composition; include in a heavy brush component, generally poor weather, & steep terrain and cruisers should be prepared for a challenging experience. Even using BAFs of 71.11 or 80, we've had plots where there were old growth Redwood trees only "in" by 6", 90' out from plot center.

We had one experienced cruiser, Ken Lucas, complete 30 plots in the stand on a 1x1 chain spacing grid. Completing the 30 plots required 6.25 hours. A 30-plot cruise, employing our old cruise procedures and on the same size plot grid, would normally have taken about 11 hours to complete.

During the field cruise phase:
1. Set up the P-3-P program after arriving on the first plot-
   1) enter the total plots expected to be completed in the stand. We had space in our test stand for 30 plots.
   2) Enter the estimate of the average tree count expected. We attempt to select a BAF that will result in an average tree count of 6. We used an 80.2 BAF for our test cruise.
   3) Enter the number of samples deemed necessary; these are the number of plots that it will be necessary to verify tree counts on, using limiting distance checks as necessary. We wanted to select 33% of our plots to sample.
2. Set a well-defined plot center, such as stick stuck firmly in the ground.
3. Using the relaskop, examine all trees in the vicinity, starting with the tree closest to plot center and swinging in a clockwise direction. Move off of the plot center as necessary to attempt to examine trees that are screened by other trees or brush. For the P-3-P estimate/sample procedure to be effective, it is very important that the cruiser not vary his estimate routine from plot to plot. Exercise discipline to not go to unusual efforts to resolve a "borderline" tree situation, such as measuring out to the tree. Be consistent in the efforts used to decide if a tree is "in" or "out" on plot. Note, and remember, any borderline trees, as each tree is examined in order for status. Always move some distance off plot center to scan the area for additional trees.

4. Enter the tree count into the P-3-P program **only after you have taken due care not to miss any obvious trees**. Often, cruisers, who are tired or in a rush, will miss trees in their examination. Scan the near distance for small trees and the far distance for large trees. Always move off the plot center to check for screened trees in the vicinity.

   If the program selects the plot, then complete all limiting distance checks as necessary on trees identified earlier as borderline "in" or "out". Make a thorough effort to determine the accurate tree count and enter into the P-3-P program. Do not change the tree count entered during step 2 in the cruise notes or data collector. Enter the accurate tree count only in the designated space in the P-3-P program.

   If the program does not select the plot, proceed with the next step.

5. For our test, we followed the convention of selecting the closest tree to plot center to take the set of full measurements on; this is not a completely unbiased method of selection. After conferring with Dr Iles on this selection issue, we would like to recommend using the following tree selection method- Count 3 trees back, starting with the last tree determined "in" on the plot, and take the set of full measurements on this tree.

6. Move to the next plot and repeat steps 2-5.

During the office data processing phase:

   The following procedure is the one we followed for our test. This procedure differs from the processing procedure we now use, and will outline later in this paper, by weighting the effect of the size of each miscounted tree. In other words, we wanted to try this procedure to determine if making a miscount on a large DBH tree has the same affect on accuracy as missing a small DBH tree.

1. Download the CMT SuperEasy cruise and Trimble P-3-P data files into a desktop pc, also loaded with the adjustment ratio calculation spreadsheet.

2. Edit the mistakes out of the main Ace cruise file.

3. Run and print out copies of the Ace plot tree, plot tree volume, statistics, and species volume lists. **The plot tree list is the hardcopy record of the field data.**

4. Using the 3-P spreadsheet downloaded from the Trimble Recon or other data collector:

   1) Note and write down the numbers of all plots selected for limiting distance **samples** on a piece of paper.

   2) Refer to the 3-P spreadsheet:

   Compare the ACE file plot tree list to the 3-P spreadsheet, listing the DBHs, to determine which tree DBHs need to be added or subtracted

from the ACE plot tree list. Remember, the main Ace file plot tree list includes the sample plots where the tree count discrepancies were corrected on the sample plots in the field; it will be necessary to change these corrections to calculate an adjustment ratio later. For any plots on the spreadsheet that do not have the same tree count as the plot tree list write down the plot number and DBH of the trees that will have to be added or subtracted later from the main Ace cruise file on a piece of paper. This becomes the "tree correction list".

5. Select the sample plots in the main Ace cruise file; the ones that had limiting distance checks done for them. Copy only these plots into a separate Ace file named "correct".

6. Run and print out the plot tree list-volume report for the "correct" file.

7. Copy all of the plots from the "correct" file into a new ACE file named "uncorrect".

8. **Add or subtract the tree DBHs in the tree edit mode of the "uncorrect" file as directed by correction list made earlier.**

9. Run & print out the plot tree list- volume reports for the "uncorrect" file.

10. Open the adjustment ratio calc spreadsheet and enter the following data-

  1) Referring to the plot tree list-volume reports for both the "correct" and "uncorrect" files- enter the plot Net Volume (Bd-Ft) per Acre by plot for both the uncorrected and corrected sample plots.

  2) Referring to the main Ace file plot tree list-volumes report- enter the plot Net Volume (Bd-Ft) per Acre for the **estimate** plots only.

11. The adjustment ratio calc spreadsheet should follow the calculation procedure-

  1) The adjustment ratio =
  Correct volume per sample plot / uncorrect volume per sample plot

  3) Average the adjustment ratios for all of the sample plots.

  4) Calculate the Average, SD, CV, and SE of the adjustment ratio. The SE of the ratio should be lower than 5% to insure that enough limiting distance samples were taken. If the SE is still too high, more plots will have to be sampled.

  5) Adjusted volume per plot=
  Average adjustment ratio * the estimate volume per plot

  6) The calculate the final adjusted average volume per acre:
  average all of the volumes per plot, including the corrected sample plots and the adjusted estimate plots.

14. Refer to the main Ace cruise file species volume report to obtain the accurate species composition percent. To determine the volumes by species per acre or for the stand:

   (Species composition percent / 100) * the adjusted average volume

15. Refer to the main Ace file statistics report to evaluate the net volume SE to verify that enough plots were taken.

   We recommend the following processing procedure as a much faster, much simpler alternative to the above procedure. This procedure weights all tree miscounts equally.

1. Sum all of the estimated tree counts listed in the IPAQ for those plots that were selected only.

2. Sum all of the sample tree counts listed in the IPAQ for those plots that were selected only.

3. The cruise **adjustment factor** =

   the sample count sum / the estimate count sum

4. Multiply the stand volume or volume per acre calculated by the adjustment factor to calculate the final volume figure.

Our test results.

   To determine the most optimum blend of cruise measurements, we tried a variety of count/cruise mixes, in order to determine accuracy "thresholds". An accuracy threshold is a count/cruise combination where the error of the cruise verses the base control volume per acre and/or the standard error (SE) reaches an unacceptable level. These "thresholds" tell us how far we can push our shortcuts and maintain a "comfort level" with the cruise accuracy.

   We have confidence in the base control stand, because we did a 100% inventory of every tree in it:

1. Each tree was marked immediately after it was counted and measured.

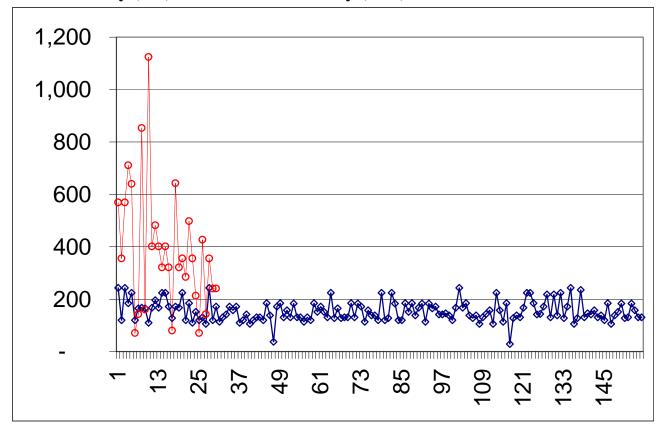2. Len carefully measured the acreage by traversing the perimeter of the test unit.

3. The DBH of each tree was taped or checked with a Biltmore stick and the bole heights were all measured with an impulse laser hypsometer.

4. The CV of this stand was calculated to be 63%; this is just a little under the 67% CV that is considered the average for the area.

   We copied Dr. Iles with our field data and he calculated the individual and combined statistics of the two cruise components for the 30 plots; basal area (count trees) and V-BAR. The combined standard error was calculated using "Bruce's equation. The combined SE of the test cruise was 11.1%. Notice something interesting when we break the SE down:

V-BAR Standard Error= 2%
Basal Area Standard Error= 11%

The basal area is clearly contributing way more error to the cruise than the volume measurements. Dr. Iles then thought it would be helpful to graph the two components. This graph displays the experiment's **basal area variability (red)** and **V-BAR variability (blue):**

Notice the extreme "peaks" and "valleys" on the red graph (the different basal areas, or tree counts, graphed for all 30 plots). Major variability from plot to plot. Now notice how relatively stable the blue graph (the average volume of each plot). We could draw two conclusions from this graph:
1. We need to take a lot of plots in these THP units in order to lower the basal area sampling error, and thus the overall sampling error.
2. We could take less full tree measures on each plot, if necessary to save time, since the V-BAR does not appear to be that variable.
    The tree counts did not balance on 3 plots out of the 15 plots that were sampled during the cruise test. The mistakes Ken made included:
1. Counting an extra 19" DBH tree "in". This tree was behind another tree in a clump and no clear view of it was available. Ken made his best estimate.

2. Missed counting a 13" DBH tree. Ken had a clear view of the tree from plot center, but the tree was not cylindrical shaped and the side facing the plot appeared smaller in the relaskop.
3. Missed counting a 19" DBH tree. This tree was at the back of a clump, with a very poor view from anywhere near plot center; it was even difficult getting a straight horizontal distance measurement during the sampling effort.

 Our formulas for calculating the volume error potentially introduced into the cruise by the net miscount of one tree:

Correct Tree Count(156) / Net Incorrect Tree Count(155)= 1.0065%
Less than 1% potential volume per acre error. The following calculations are used to determine the incorrect tree count error vs. the base control volume:
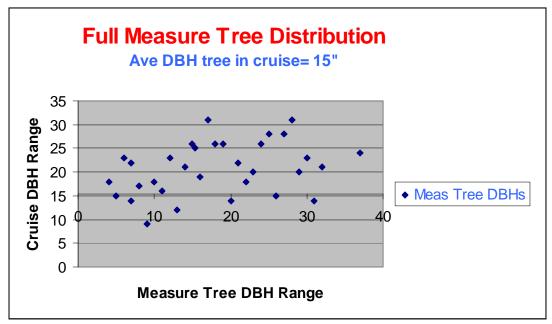
Plot Spacing (66')^2 / 43,560 = 0.1 acres per plot

Net one missed tree * BAF used (80.3) * Ave V-BAR of a 19" DBH(141) * acres per plot (0.1)= 1,132 bd-ft total tract volume error

1,132 bd-ft is 0.4% of the base control tract volume. Apparently, missing one tree, at this high sample intensity, appears to have contributed only a very small amount of error.

Here's the effect of missing a tree on a **plot intensity of 1 per acre:**
One missed tree * BAF (80.3) * Ave V-BAR of a 19" DBH (141) * Acres per Plot (1)= **11,322 bd-ft or 4.4% of the total tract cruise volume.**
Tighter plot spacing appears to greatly reduce the effect of missing trees on cruise accuracy.

 As mentioned earlier, we followed a convention of measuring only the closest tree to plot center and one each of the rare species encountered during the cruise. We felt it was important to get a more even distribution of measured trees throughout the stand. Using this alternate method of selecting full tree measures, we wanted to insure that we were getting enough full tree measures of the larger DBH-size trees; which contribute more to the volume of the cruise than the smaller trees. The average size tree in this cruise was 15.3" DBH. The volume per acre distribution is 22% for trees with DBHs of 15" or under and 78% for trees larger than 15" DBH. The following graph confirms that we did measure a greater percentage of larger diameter trees:

Full Measure Tree Distribution
Ave DBH tree in cruise= 15"

Even though this test does not seem to indicate a problem with selecting the tree closest to plot center for taking full measurements on, we still recommend selecting the third tree from the end to reduce possible bias.

The following tests are things we tried in our effort to find the best blend of cruise measurements and time. The "error" in the tables refers the amount of volume that the test method is off of the base control volume. The first 6 tests reflect what the experienced cruiser was able to achieve, **without making any adjustments to the volume per acre for the tree count errors-**

Test 1. The unadjusted volume per acre achieved by the experienced cruiser doing 30 plots, with limiting distance checks on 15 of them and one full tree measure on each plot (total 30).				
30 cruise plots, 15 limiting distance check plots, & 30 full tree measures				
Method	Net Vol. per Acre	Error	SE	Time
Test 1	63,744 BF	Less than 1%	11.2%	6.75 Hr.s
Base Control	63,837 BF	N/A	N/A	65 Hr.s

The questions we have after reviewing this test:
- How was the cruiser able to achieve such a small error without making any adjustment to the volume?
- Do we even need to consider using a sample adjustment method at all?
Some points on these questions:
- We used a unusually high plot intensity for this experiment, allowing

more effective capture of the basal variability; which contributes the most error to a cruise.

- Note the 11.2% SE achieved. This means that we are only 68% sure that the actual volume is within +/- 7,100 bd-ft of the calculated cruise volume; which, in this case, it is; but normally we would not have a base control volume to confirm our accuracy. Please note later in this section, that the ratio SEs of the adjusted volumes show a lot tighter variance range.
- The cruiser depended on a P-3-P program to select the 15 plots to do the limiting distance checks on; this eliminated possible bias that could have introduced additional error.
- This test does not, necessarily show how less experienced, or less conscientious cruisers would do in a similar situation.

Test 2. The unadjusted volume per acre achieved by the experienced cruiser doing only half (15, randomly selected) of the specified number of plots (30), with limiting distance checks on only half of these plots (7) and a full tree measure on each plot(15)

15 cruise plots, 7 limiting distance check plots, & 15 full tree measures

Method	Net Vol. Per Acre	Error	SE	Time
Test 2	63,342	Less than 1%	14.3%	3.4 Hr.s
Base Control	63,837	N/A	N/A	65 Hr.s

The 14% SE achieved in this test is common for these 15-plot THP unit cruises in this area, using our old cruise procedure. We are uncomfortable with an SE that high, since we are only 68% sure that the true volume could fall anywhere within the range 54,284-72,400 bd-ft per acre.

Test 3. The unadjusted volume per acre achieved by the experienced cruiser doing 30 plots, with limiting distance checks on just 33% (10) of the plots and full tree measures on all of them.

30 cruise plots, 10 limiting distance check plots, & 30 full tree measures

Method	Net Vol. Per Acre	Error	SE	Time
Test 3	63,447	Less than 1%	11.2%	6.2 Hr.s
Base Control	63,837	N/A	N/A	65 Hr.s

This test gives us some assurance that we can reduce the number of limiting distance checks.

Test 4. The unadjusted volume per acre achieved by the experienced cruiser doing 30 plots, with 33% (10) limiting distance samples and full tree measures on 83% (25, randomly selected) of the plots.

30 cruise plots, 10 limiting distance check plots, & 25 full tree measures

Method	Net Vol. per Acre	Error	SE	Time
Test 4	60,839	-4.7%	11.5%	5.8
Base Control	63,837	N/A	N/A	65 Hr.s

We've made a significant reduction in the numbers of full tree measurements with this test and note a significant increase in the error.

Test 5. The unadjusted volume per acre achieved by the experienced cruiser doing 30 plots, with 33% (10) limiting distance samples and full tree measures on 66% (20, randomly selected) of the plots.

30 cruise plots, 10 limiting distance check plots, & 20 full tree measures

Method	Net Vol. per Acre	Error	SE	Time
Test 5	66,761	+4.6%	11.6%	5.4 Hr.s
Base Control	63,837	N/A	N/A	65 Hr.s

Test 6. The unadjusted volume per acre achieved by the experienced cruiser doing 30 plots, with 33% (10) limiting distance samples and full tree measures on 50% (15, randomly selected) of the plots.

30 cruise plots, 10 limiting distance check plots, & 15 full tree measures

Method	Net Vol. per Acre	Error	SE	Time
Test 6	39,476	-38.2%	9.5%	4.9 Hr.s
Base Control	63,837	N/A	N/A	65 Hr.s

This test confirms that we definitely crossed an accuracy threshold when we reduced the set of full tree measurements to 20. Totally unacceptable error at this level.

Test 6. The unadjusted volume per acre achieved by the experienced cruiser doing 30 plots, with no limiting distance checks and tree measures on every plot.

30 cruise plots, no limiting distance check plots, & 30 full tree measures

Method	Net Vol. Per Acre	Error	SE	Time
Cruiser	63,430	Less than 1%	11.3%	5
Base Control	63,837	N/A	N/A	65 Hr.s

After reviewing this test and noting earlier that the basal area of the miscounted trees represented less than 1% of the total basal area cruised, we

can, therefore, suggest that experienced cruisers could do less limiting distance checks, without reducing the accuracy an excessive amount. However, since **the P-3-P selection process will not select 0 count plots for sampling**, the program would never select a plot with some borderline "out" trees and no "in" trees to sample. We, therefore, recommend making all 0-count plots automatic sample plots. This will introduce a minor bias, since cruisers will know, during the estimate step, that the 0 count plot must be sampled. However, since most cruises generally do not have a large number of 0 count plots, this bias should not be a problem.

   The following 5 tests were made with different amounts of limiting distance sample plots:

Test 7. The proposed P-3-P limiting distance sample method, without any shortcuts.				
30 cruise plots, 15 limiting distance check plots, & 30 full tree measures				
Method	Net Vol. per Acre	Error	Ratio SE	Time
Test 7	60,486	-5.2%	1.5%	7.75 Hr.s
Base Control	63,837 BF	N/A	N/A	65 Hr.s

A ratio SE of 1.5% means that we are 95% sure that the actual volume per acre should fall within the range 59,304-63,123 bd-ft

Test 8. The proposed P-3-P limiting distance sample method, with a reduction of the number of samples to 33% of the total plots taken(10).				
30 cruise plots, 10 limiting distance check plots, & 30 full tree measures				
Method	Net Vol / Acre	Error	Ratio SE	Time
Test 8	59,891	-6.2%	1.6%	7.75 Hr.s
Base Control	63,837 BF	N/A	N/A	65 Hr.s

With this ratio SE of 1.6%, we are 95% sure that the actual volume will be within +/-2,010 bd-ft of the adjusted volume per acre.

Test 9. The proposed P-3-P limiting distance sample method, with a reduction of the number of samples to 17% of the total plots taken(5)-				
30 cruise plots, 5 limiting distance check plots, & 30 full tree measures				
Method	Net Vol. per Acre	Error	Ratio SE	Time
Ratio Adjust.	57,779	-9.5%	2.1%	7.2 Hr.s
Base Control	63,837	N/A	N/A	65 Hr.s

Test 10. The proposed P-3-P limiting distance sample method, with samples on half the plots (15) and full tree measures taken on 66% (20) of the plots.
30 cruise plots, 15 limiting distance check plots, & 20 full tree measures

Method	Net Vol. per Acre	Error	Ratio SE	Time
Ratio Adjust.	60,662	-5.0%	1.6%	7 Hr.s
Base Control	63,837	N/A	N/A	65 Hr.s

Test 11. The proposed P-3-P limiting distance sample method, with samples on half the plots (15) and full tree measures taken only on 50% (15) of the plots.
30 cruise plots, 15 limiting distance check plots, & 15 full tree measures

Method	Net Vol. per Acre	Error	Ratio SE	Time
Ratio Adjust.	48,643	-23.8%	2.2%	6.5 Hr.s
Base Control	63,837	N/A	N/A	65 Hr.s

We have crossed an accuracy "threshold" with this method. A 23.8% error is unacceptable.

For this next test we wanted to see the effects on accuracy if we deliberately introduced serious basal area error into the cruise to simulate an inexperienced or unconscientious cruiser getting sloppy doing his tree counts. We changed the tree count on every third plot in the Ace cruise file. On 66% of the artificial miscount plots we deleted a tree and on the remaining 33% of the miscount plots we added a tree.

Test 12. Introduction of tree miscount of 33% of the plots.
30 cruise plots, with 10 plots that have missing or added trees

Method	Net Vol. per Acre	Error	Ratio SE	Time
Test 12	62,057	-2.8%	11.4	3.75 Hr.s
Base Control	63,837	N/A	N/A	65 Hr.s

Surprisingly, introducing tree count error appears to have had a noticeable, but not a major, adverse effect on the volume. We think the volume error is being significantly mitigated in this case by the close spacing of the plots; remember that we did 30 plots in a 4-acre area.

Summary points.

- The cruiser was able to complete double the amount of plots in the same amount of time by doing less limiting distance checks and taking only 1 set of full tree measurements on every plot. Of course, in the "real world" cruise units are a lot larger and we can rarely justify a plot grid of one chain. However, we've been using these techniques in "real world" cruises since this first experiment in November, 2003 and estimate that we've gained an actual 50-66% savings in time.
- We found that the majority of the stand variability is the basal area figure, gained from making more tree counts.
- Sets of full tree measurements can be reduced below 35 in a single cruise. Many cruisers routinely take 60 actual sets of tree measurements and estimate an additional 120 sets during a single cruise effort. This is way "overkill".
- Following the convention of selecting the closest tree to plot center did not seem to affect the DBH selection distribution.
- Tighter plot spacing mitigates the effect of tree count error.

Our recommendations.

1. When in doubt, go with the tighter plot grid option. We've increased the amount of plots we prefer to complete in our cruise units from 30 to 50, using this method. For highly variable units, we'd even recommend selecting a plot grid that allows 60-70 plots to be completed inside the cruise area. Three additional points we'd like to make in support of tighter plot grids:

    1) Once you've selected and started on a plot grid, you're committed; you can't change the grid without introducing bias into the cruise. However, you can randomly select some of the plots in a grid to skip.

    2) Don't cruise a plot off of the grid for any reason. If a plot falls outside the cruise area for any reason, don't try to "jam it into" the cruise area. Completing a plot too close another plot constitutes an "over sampling of that area, which is another form of bias. Select a plot grid that will allow you to some skip plots, without the loss of the data affecting the cruise.

    3) Besides capturing basal area variability better and reducing the effect of miss-counts, tighter grids allow you to select a larger BAF that would reduce the average tree count per plot to under 6; this could be an advantage in cruise situations where there are large diameter trees in the stand, with a heavy brush component or excessively steep terrain. Select

a large BAF that will result in the "in" trees being right "in your face" at plot center, so that you don't have to worry about missing trees behind the brush screen. A tighter grid means more plots, which means more trees counted "in" over the whole cruise; so a cruiser can get by without the optimum average count of 6 trees per plot.

If a cruiser already uses relatively intensive plot grids, than our method will result in them being able to offer their clients a cost savings.

2. We recommend taking a minimum of 25-30 sets of full tree measurements, including "rare" species encountered on plot in each cruise. For cruises of individual units that exceed 45 plots, cruisers may be able to get by with taking only one set of measures on every other plot. In no case should cruisers take less than 25-30 sets of full tree measurements on an individual cruise unit.

3. Since "zero count" plots do not get selected by 3-P programs, we recommend making every zero count plot an automatic sample plot.

4. We would really like to see more testing done of these procedures, especially on cruises with plot grids over 3 chains. The way to check these procedures is to simply implement them at each plot center, followed by your conventional procedures; this constitutes a check cruise. Keep the results of the 2 cruises separate during data collection and compare the final volume figures generated by the two procedures.

Please feel free to email Ken with any comments or questions at his website: **www.tsiwood.com**