

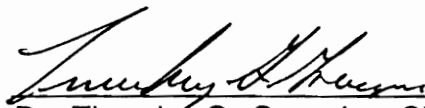
**ASSESSING PETRIFIED WOOD CHANGE IN
PETRIFIED FOREST NATIONAL PARK**

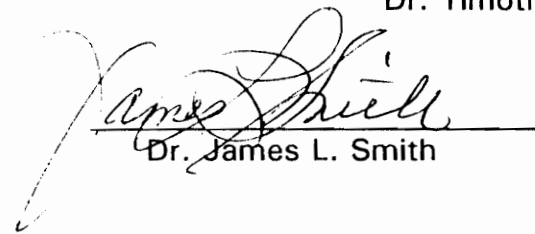
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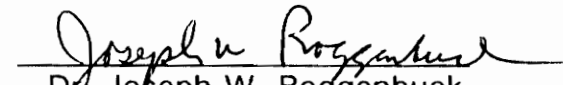
Nicholas Scott Monkevich

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MASTERS OF SCIENCE
in
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Approval:


Dr. Timothy G. Gregoire, Chairman


Dr. James L. Smith


Dr. Joseph W. Roggenbuck

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**ASSESSING PETRIFIED WOOD CHANGE IN
PETRIFIED FOREST NATIONAL PARK**

by

Nicholas Scott Monkevich

Timothy Gordon Gregoire, Chairman

Forestry

(Abstract)

The problem of petrified wood theft was examined in the Petrified Forest National Park. This study accomplished the following 2 objectives:

1. Perform a complete inventory throughout five high use areas at the Petrified Forest National Park
2. Quantify the petrified wood loss within the five high use areas at the Petrified Forest National Park over a one year time period.

Line intersect sampling was used to sample three size classes of petrified wood along with fixed area quadrat samples which sampled two size classes. Line intersect sampling units were established in August 1993 and revisited during August 1994. Line Intersect sampling results suggest that petrified wood displacement within the park does occur but not to the extent that Scher (1990) reports. Quadrat sampling results are not conclusive with regard to petrified wood displacement due to constraints on the sample design.

Acknowledgments

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Chapter 1

Introduction

Study Area

The Petrified Forest National Park is located in northwestern Arizona. The Park encompasses 147 square miles of fossilized resources approximately 230 million years old. The fossilized remains depict an ancient ecosystem that represents a significant period in the evolution of life, the Triassic period of the Mesozoic era (U.S. N.P.S. Plan, 1993). President Theodore Roosevelt first recognized the value of these petrified remains and created the Petrified Forest National Monument in 1906. Subsequent proclamations and Congressional acts expanded the original Park boundaries to current locations.

Petrified wood is viewed by many as the Petrified Forest National Park's most precious resource. Petrified wood comes from a formation deposited 220 to 225 million years ago near the end of the Triassic Period of the Mesozoic era, known as the Chinle Formation (Ash, 1988). Both organic matter (tree boles) and volcanic material was deposited by streamflow. While buried, the organic matter of the ancient tree boles was

replaced by mineral matter. Many of the resulting fossils retained their original form but were endowed with an effulgent array of colors. Approximately 35 million years ago the Chinle formation was forced to the earth's surface (Ash, 1989). Exposure to wind and rain has gradually unearthed the petrified material that lay buried below.

Justification

The problem of petrified wood protection has existed from as early as 1906, when the Petrified National Forest Monument was established. The establishment of the Monument terminated commercial mining of petrified wood within the Park boundaries, but introduced new problems. The Monument attracted tourists wishing to see the petrified wood. Unfortunately, many of these tourists also wished to collect a small memento in remembrance of their visit. The Park's history is replete with programs aimed at minimizing the pilfering of petrified wood by souvenir collectors. Regardless of deterrence programs, Park Rangers still report numerous cases of petrified wood theft. Until now, relatively little has been done to quantify the amount of petrified wood that leaves the Park. Scher

(1990) attempted to quantify petrified wood theft using 45 baited plots along visitor footpaths. Scher's efforts reported the following.

- (1) 8,129 pounds of petrified wood lost per day
- (2) 1.01 pound of petrified wood stolen per person
- (3) 2.73 pounds of petrified wood stolen per vehicle
- (4) 416 pounds of wood stolen per pound recovered

Although Scher's "baited plot" study produced provoking numeric conclusions, the monitoring may not reflect true amounts of petrified wood stolen from the Park. The petrified wood used in these baited plots had already been stolen and recovered at vehicle inspection stations during car searches or along roadsides before the stations. These pieces of petrified wood were probably near gem quality and undoubtedly captured the attention of visitors along the trail. Scher's study may make valid inferences to irregular pieces of petrified wood along visitor trails, but not across the entire Park's petrified wood population. It is also hard to determine actual figures that reflect petrified wood stolen versus relocated within the Park. A tourist may pick up a piece of petrified wood to examine it and return it to the desert floor in a new location. This potential petrified wood displacement by tourists further clouds true figures of wood stolen each year. An unbiased estimate of the amount of petrified wood stolen

from the Park is needed to aid Park Managers in developing theft reduction strategies for the Petrified Forest. Park Officials know of the petrified wood theft problem but not its magnitude. An inventory of the Parks high use areas is needed to estimate actual petrified wood densities in the Park. Further, monitoring the high use areas will furnish estimates of how much wood is displaced. This project fulfills these demands.

Objectives

This study has three objectives. The first objective is to design a feasible inventory methodology for sampling all high use regions of the Petrified Forest National Park that contain petrified wood. The second objective is to establish permanent sampling locations under the design that can be revisited in the future. The final objective is to implement the inventory design and furnish estimates of the amount of petrified wood displaced in the park during a one year time frame (August 1993 - August 1994).

Chapter 2

Line Intersect Sampling Literature Review

Introduction

Line intersect sampling (LIS) was chosen as the sampling tool to provide unbiased estimates of the amount of petrified wood displaced throughout the Park. This literature review depicts LIS as more time and cost efficient than traditional fixed area plots and facile to implement in populations with heterogeneous spatial distributions such as the Park's petrified wood.

A plethora of literature is available on the theory and application of line intersect sampling. LIS is used in many disciplines as a practical way of answering seemingly infeasible sampling questions. Most disciplines build unique constraints into the general LIS theory for field specific applications. However, a general definition is given by Kaiser (1983). Kaiser states, "Line intersect sampling is a method of sampling particles in a region whereby, roughly, a particle is sampled if a chosen line segment, called a 'transect', intersects the particle." This literature review will summarize the history of

line intersect sampling with regard to novel statistical contributions and the Forest inventory domain.

Literature Review

The roots of line intersect sampling can be traced to Buffon's needle problem (1777). The problem can be described as follows. Equidistant parallel lines are drawn on a piece of paper. A needle of length α is randomly located on the paper where α is shorter than a length β between two neighboring lines. Buffon established the geometric probability that the needle intersects the lines is

$$\frac{2}{\pi} * \frac{\alpha}{\beta}. \quad [1]$$

Buffon's result is fundamental to the theory of the LIS and was also used to validate the value of π .

Bertil Matérn (1964) used Buffon's result to estimate the total length of roads using a line survey. Matérn hypothesized a chain consisting of N links each α long. The chain was envisioned on top of equidistant parallel lines so that each link in relation to the lines was determined by a random procedure. Using Buffon's geometric probability [1], the expected number of intersections between the chain and the line-system was

$$\frac{2}{\pi} * \frac{L}{\beta}$$

where $L = N * \alpha$.

Matérn's next step was to consider the network of roads having the total length L . If a set of parallel equidistant lines was placed over the road network (with a randomly chosen direction) the expected number of intersections would be $\frac{2L}{\pi\beta}$. Allowing n to equal the number of road intersections, the total length of roads could be estimated by

$$Y = \frac{\pi}{2} * \frac{n}{t}$$

where $t = 1/\beta$.

Warren and Olsen (1964) were the first to use and develop line intersect sampling in a Forestry setting. These authors have also been credited with coining the term "Line Intersect Sampling". Warren and Olsen used LIS to estimate downed woody debris following a harvesting operation. An estimator was developed conditional to the orientation between the intersection of the line and log. Their conclusions suggested a great increase in efficiency of LIS over fixed radius plots when sampling downed woody debris. The variation between LIS sampling units was much smaller than ordinary fixed area plots, and the sampling time was substantially decreased.

Howard and Ward (1972) studied line intersect sampling using a systematic grid point approach. At this point in LIS history, a sampling unit consisted of a line projected across the entire region of study. Naturally, as the size of the study increased, the amount of work required to sample each line became a burden. Howard and Ward searched for a sampling design to solve this problem for logging residue estimates. Fixed length transects were located in clear-cut areas using a 4 chain by 4 chain systematic grid. Unidirectional, randomly oriented and a unidirectional L shaped pattern at each point in the grid were investigated. Shorter, fixed length transects were proven more efficient than a transect running the entire length of the study. Howard and Ward also discovered a random orientation of lines to work best when topography creates orientation patterns and unidirectional line orientation when there appears to be no general orientation of logging residue.

De Vries (1973a, 1973b) published two papers compiling line intersect sampling theory up to this point in time. These documents also addressed variance estimation and bias. The development of a variance for any quantified solid attribute per unit area was summarized. De Vries assumed sampling on some area with randomly located line intersect

samples, and supposed that all possible estimates are distributed about the total parameter X so that the $\text{VAR}(X) = S^2$. S^2 may be estimated with the traditional estimator

$$s^2 = \frac{\sum_{i=1}^k (x_i - \bar{x})^2}{k - 1} \quad [2]$$

where: x_i = estimate of total X of line i

$\bar{x}$ = mean total estimate from k line transects.

De Vries suggested that this estimate of variance should be conditioned on the set of lengths chosen for the line samples. These line lengths may or may not be equal. The conditional expression for lines of length L_i is given by

$$\hat{\text{VAR}}(X)|L_i (i = 1 \dots k) = \frac{s^2 \sum_{i=1}^k L_i^2}{\left(\sum_{i=1}^k L_i \right)^2}.$$

De Vries also presented the development of variance estimates for a one line sample by analogy to Hájek's Poisson sampling. Estimators for volume per acre, weight per acre, area per acre, density per acre and cover per acre were summarized.

De Vries (1974) developed the theory for multi-stage line intersect sampling. Multi-stage LIS was envisioned to be facile and save time and money. Each line transect was broken into stages. The first stage selected

n elements from a population of N by a randomly located and oriented line. The second stage selected n^* elements from the n first stage elements. Measurements were then taken on the n^* elements and more stages could be defined if needed. De Vries presents the multi-stage variance with assumptions similar to the 1973 documents.

To investigate bias in line intersect sampling, Brown and Roussopoulos (1974) examined sampling fine fuel volume for fire hazard estimation. They found that bias occurs when nonhorizontal particles are assumed horizontal and when average diameters are used to calculate volume for diameter classes. Bias may be eliminated by using two corrective steps. First, the average secant of nonhorizontal particle angles with respect to the sampling plane is used as a multiplicative constant. This constant adjusts the particle to a horizontal position on the sampling plane. Second, the mean quadratic diameter is used for calculations instead of average diameter per class. The authors prove the mean quadratic diameter is needed for unbiased estimates. The authors offer tabulated values for both quadratic means and average secants for branchwood of eight conifers and one hardwood species.

Lucas and Seber (1977) developed the theory for estimating coverage and particle density using line intersect sampling. Unbiased estimators are presented for randomly placed transects over any distribution of particles. Until this paper, researchers usually assumed some generic spatial distribution of particles over the sampling area. Lucas and Seber established designed based inference for LIS estimators without distributional assumptions of particle spatial patterns.

Pickford and Hazard (1978) conducted intensive Monte Carlo simulations with line intersect sampling to determine its precision for different population densities and shape distributions. Population shapes ranged from cylinders to tapered particles. Uniform to randomly distributed particle orientations were examined for each shape. Volume sampling simulations revealed the following conclusions: Substantially more sampling was required for tapered populations to achieve the same accuracy as with cylinders, however tapered pieces did not induce additional bias in the estimate. Sample sizes to achieve a fixed degree of accuracy increased when sampling from uniform cylinders to tapered particles of different sizes. For a fixed total length of sampling line, the population variance decreased

with increasing length of individual line transects. It is harder to control precision when sampling in randomly oriented populations.

Meeuwig *et. al.* (1978) applied line intersect sampling to estimate Pinyon-Juniper cordwood volume. Their efforts were the first attempt to adapt LIS to estimate live stand characteristics. A line was randomly assigned within a Pinyon-Juniper stand. If a tree's crown area (projected to the ground) was intersected by the line, the tree was included in the sample. Traditional measurements such as diameter and height were taken on sampled trees. Estimates of total stand volume or basal area could be generated using the LIS method. However, the width of each sampled tree crown perpendicular to the line transect needs to be measured in the field.

Seber (1979) studied the concept of random length transects. The line transect was envisioned to run across the total length of the study area. Seber proved that some commonly used estimators were biased with random length lines under certain distributional assumptions. For example, consider the density estimator

$$\lambda = X/L$$

where: X = total of some sampled attribute

L = total random line length.

An application of the delta method Taylor expansion must be used to derive the expected value for λ due to the new random term L . The addition of the terms from the Taylor series induce a small bias. Seber suggests this bias can virtually be eliminated by the jackknifing technique.

Kaiser (1983) unified the present theory of line intersect sampling. He developed the comprehensive LIS theory for unbiased estimation for both random and fixed line lengths. Kaiser presented two novel density estimators

$$\hat{\lambda}_1 = \frac{1}{A} \sum_{i=1}^N \frac{t_i y_i}{E(t_i y_i)} x_i$$

and

$$\hat{\lambda}_2 = \frac{1}{A} \sum_{i=1}^N \frac{t_i y_i}{E(t_i y_i | \theta)} x_i$$

where: t_i = indicator variable of inclusion in a sample
 x_i = fixed characteristic
 y_i = auxiliary variable
 θ = angle between particle and line transect.

The estimator $\hat{\lambda}_1$ is unconditional on the orientation between the particle and the line while $\hat{\lambda}_2$ depends on the orientation. The estimators are ubiquitous to many sampling designs and all previous unbiased estimators in LIS literature can be generated from these. Kaiser proved the unbiasedness

of the estimator forms for both random and fixed transect lengths without assumptions of the spatial distribution of the particles.

Hazard and Pickford (1986) performed simulation studies to investigate differences between cable logged and tractor logged sites in the Pacific Northwest. Line intersect sampling for volume was computer simulated with functions designed to describe the orientation of logging residue for a given harvest procedure. The authors compared systematically located line transects with randomly placed lines for both cable and tractor logged populations. At each systematic sampling location, a one, two or three line sampling cluster was simulated. The authors recommend sampling with systematically placed lines on cable logged sites. The cable logged residue tended towards a fixed orientation. Sampling perpendicular to the slash yielded the best estimates. Randomly oriented line transects were recommended for tractor logged residue. The tractor logged residue had no general orientation. Random placement and orientations of lines gave the best results.

Skidmore and Turner (1992) used line intersect sampling to determine accuracy of maps produced from a geographic information system (GIS).

Line transects were randomly placed on the map produced from a GIS. The lines were used to generate a count of the intersections made between forest type boundaries. These counts were used to estimate the total length of type boundary on the map (similar to Matérn, 1964). An estimate of correctly placed boundaries was produced using a similar procedure. Skidmore and Turner proposed the measure of map accuracy,

$$\text{Accuracy} = \frac{S_c^2}{S_t^2} \times 100$$

where: S_c^2 = sampling variance between correct boundary
 S_t^2 = sampling variance between total boundary.

The authors stated that this boundary method of accuracy assessment is conservative compared to previous area methods. True boundary densities were found to be not significantly different from the LIS estimates using a t-test with $\alpha = .05$.

Fox and Raskob (1992) examined the efficiency of line intersect sampling with traditional fixed radius plot and variable radius point sampling. Volume of Pinyon-Juniper woodlands was the target parameter of each sampling method. A sample size of 36 was allocated in Pinyon-Juniper woodland for 0.1 acre fixed radius plot, 10 basal area factor variable points and 100 foot line transects. For consistency, each design was centered at

the same sampling locations. An efficiency rating was used to distinguish between sampling regimes. The efficiency rating used was the square of the standard error for a given sampling design multiplied by the sampling time (Avery and Burkhart, 1983). The LIS method was found to be the most efficient sampling method in Pinyon-Juniper woodlands.

Gregoire and Monkevich (1993) examined the possibility of using the mirage method with line intersect sampling. To date, if part of a line transect fell outside the area of interest, the line falling outside was moved a distance away (so that no particles are tallied twice) from the interior line and brought back into the area parallel to the interior line. Kaiser (1983) discusses the unbiasedness of this regime. Gregoire and Monkevich suggested that a simpler alternative to the current method was simply to fold the portion of the line that falls outside the area back atop the line inside the area and tally intersected particles twice. Gregoire and Monkevich proved the unbiasedness and practicality of this procedure.

Chapter 3

Methods

Introduction

To quantify the amount of petrified wood displaced from the Petrified Forest National Park, a substantial sample with remeasurable sampling units is needed. Sampling must be conducted in all regions of the Park that contain petrified wood and preferably yield unbiased estimates. The dispersion and size distribution of petrified wood throughout the Petrified Forest is irregular. For example, a 10 foot square area may contain several thousand fingernail size flakes of petrified wood or only one large piece. Because all sizes of petrified wood are of interest, line intersect sampling was chosen as the sampling tool to accomplish the objectives. LIS will yield unbiased estimates of Petrified wood totals and be more efficient than fixed area plots for the erratic particle locations.

It should again be emphasized that it is difficult to differentiate between stolen and relocated wood. Stolen wood is Petrified wood that actually leaves the Petrified Forest through a malicious act by a tourist. Relocated wood is Petrified wood that is physically removed from its natural

state and returned to the desert floor in a new location. A relocated piece of wood may be the result of a tourist's curiosity, a natural event (such as erosion), or even could have been inadvertently kicked by sampling technicians for the project.

Sampling Design

The Petrified Forest National Park has never been inventoried to determine the amount of the petrified wood resources. Because this study is a first attempt to estimate the petrified wood resource, the sampling strategy was designed to estimate multiple characteristics of the resource and to provide separate estimates for multiple size classes (non overlapping) of petrified wood. Namely the aggregate volume, density, percent cover and weight were estimated for four size classes of petrified wood. As described below, a stratified sample was designed, where five high-use areas of the Park served as the principle strata and an equal number of sampling locations were established randomly in each. Each high-use area was further stratified into trailside and backcountry regions, and sampling locations were equally allocated between these two substrata.

At each sampling location, both a line transect sample was conducted and a quadrat sample. The methods and measurement protocol of each

sample type are described in detail in succeeding paragraphs. The line transect sampling procedure was adopted as an efficient way to deal with the very heterogeneous spatial distribution of larger particles of petrified wood. The quadrat sample was adopted with the dual intention of sampling small flecks of petrified wood efficiently and providing a means of estimation aggregate weight of petrified wood in all size classes.

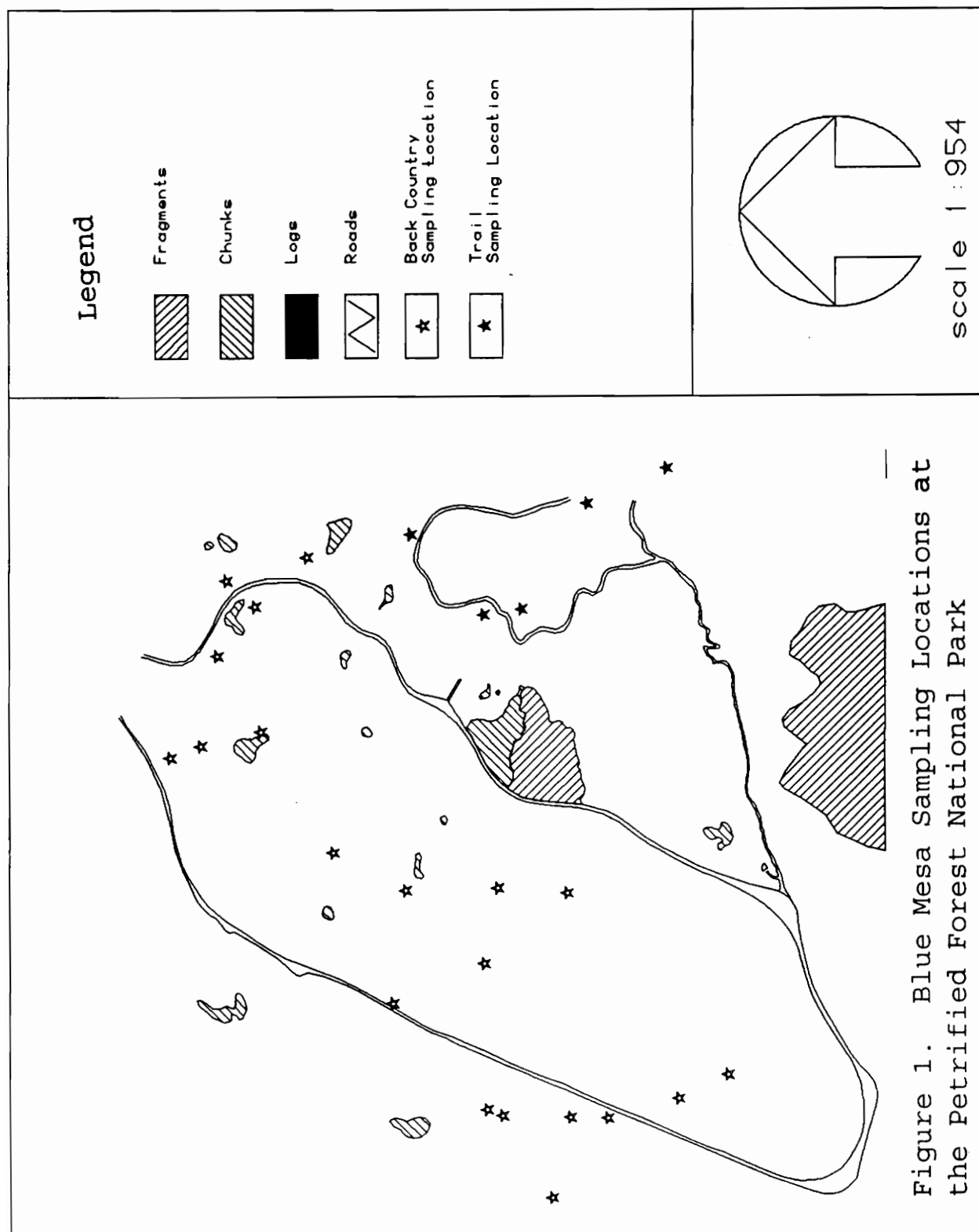
It should be emphasized that the sampling strategy was designed to be as comprehensive of multiple attributes of the petrified wood resource as time and budget permitted. Had this study only been concerned with estimating, say, the density of petrified wood particles with no distinction among various size classes, sampling could have been conducted more intensely to yield more precise estimates for the single attribute. This study's strengths are in the diversity of sampling attributes and size classes. Future inventories may concentrate on only one sampling attribute, in which case design modifications suggested from this study may be advisable.

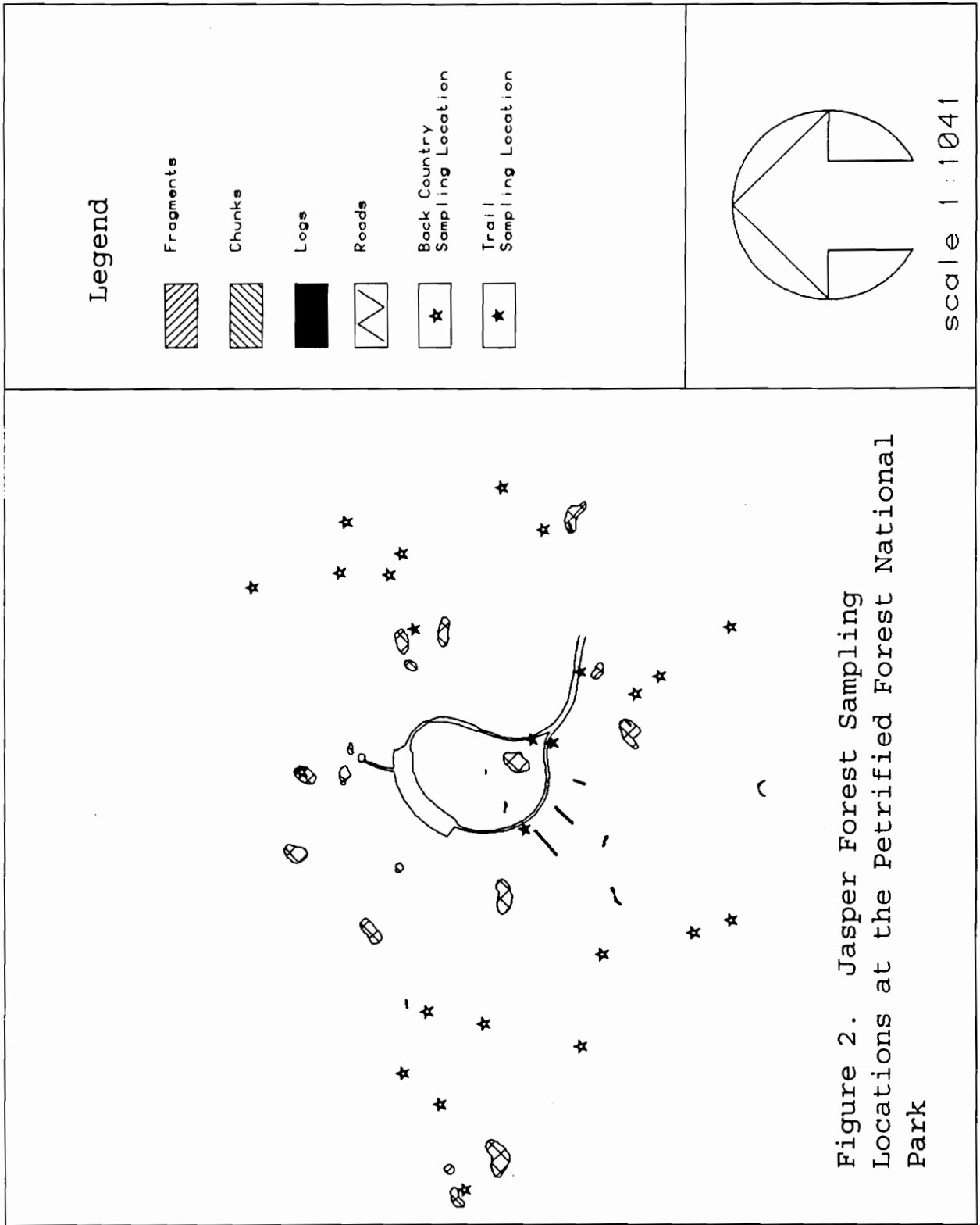
To partition the Park into manageable pieces, five high use areas were delineated as strata using aerial photography of the Petrified Forest National Park. Aside from these five high use areas, the remainder of the Park contains little or no Petrified wood that would be subject to theft. The strata names are Blue Mesa, Jasper Forest, Crystal Forest, Long Logs and

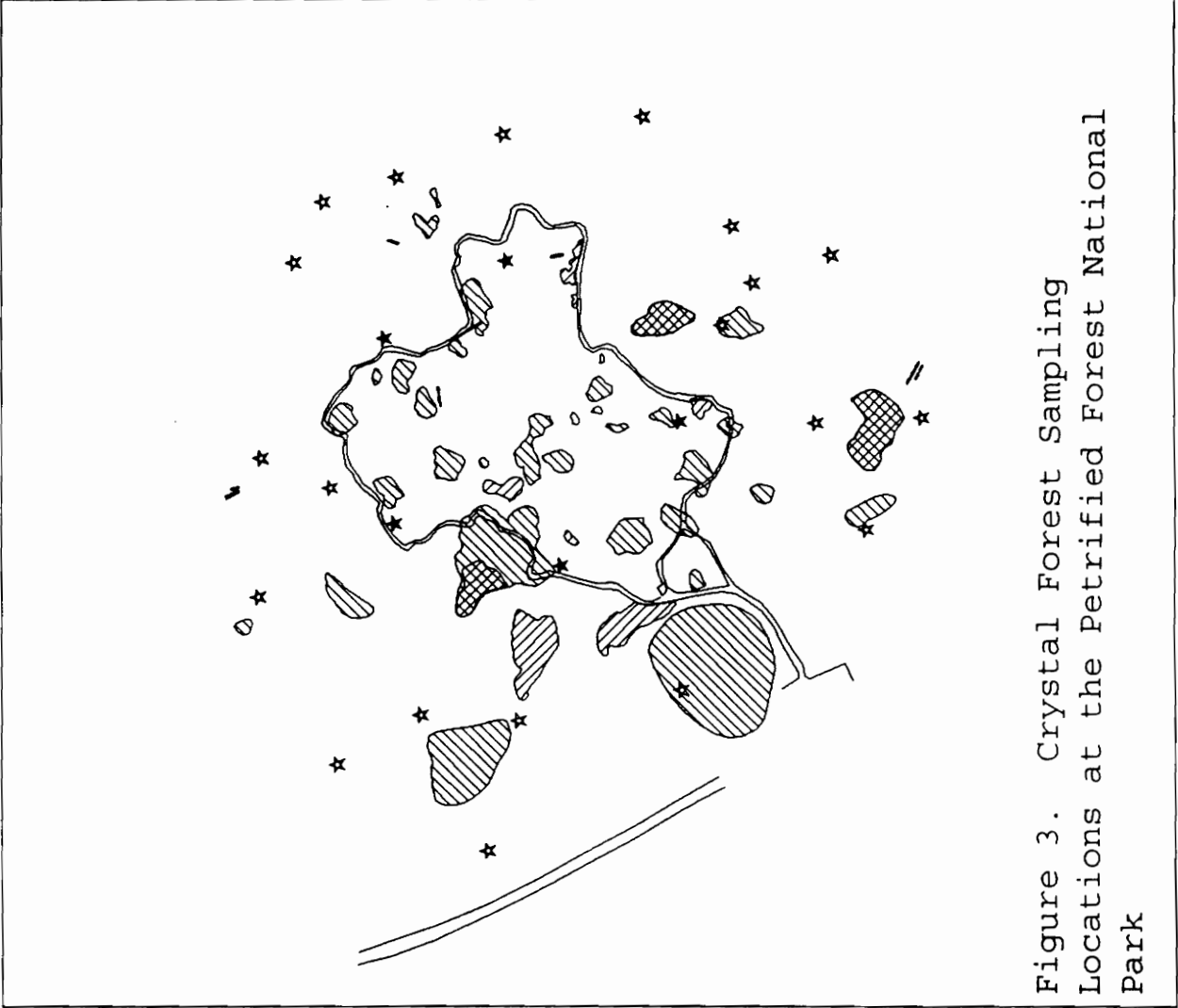
Giant Logs. Each stratum was mapped on paper using aerial photography. The aerial photography was flown by Virginia Polytechnic Institute and State University (May, 1993) to fulfill the objectives of this project. The resulting paper maps had scales of approximately $1'' = 90'$. Features such as roads, visitor trails, permanent landmarks and potential petrified wood areas were included on each map. The maps were digitized with ARC/INFO™ to store each stratum as digital information on a geographic information system and to generate computerized field maps to assist in locating sampling units.

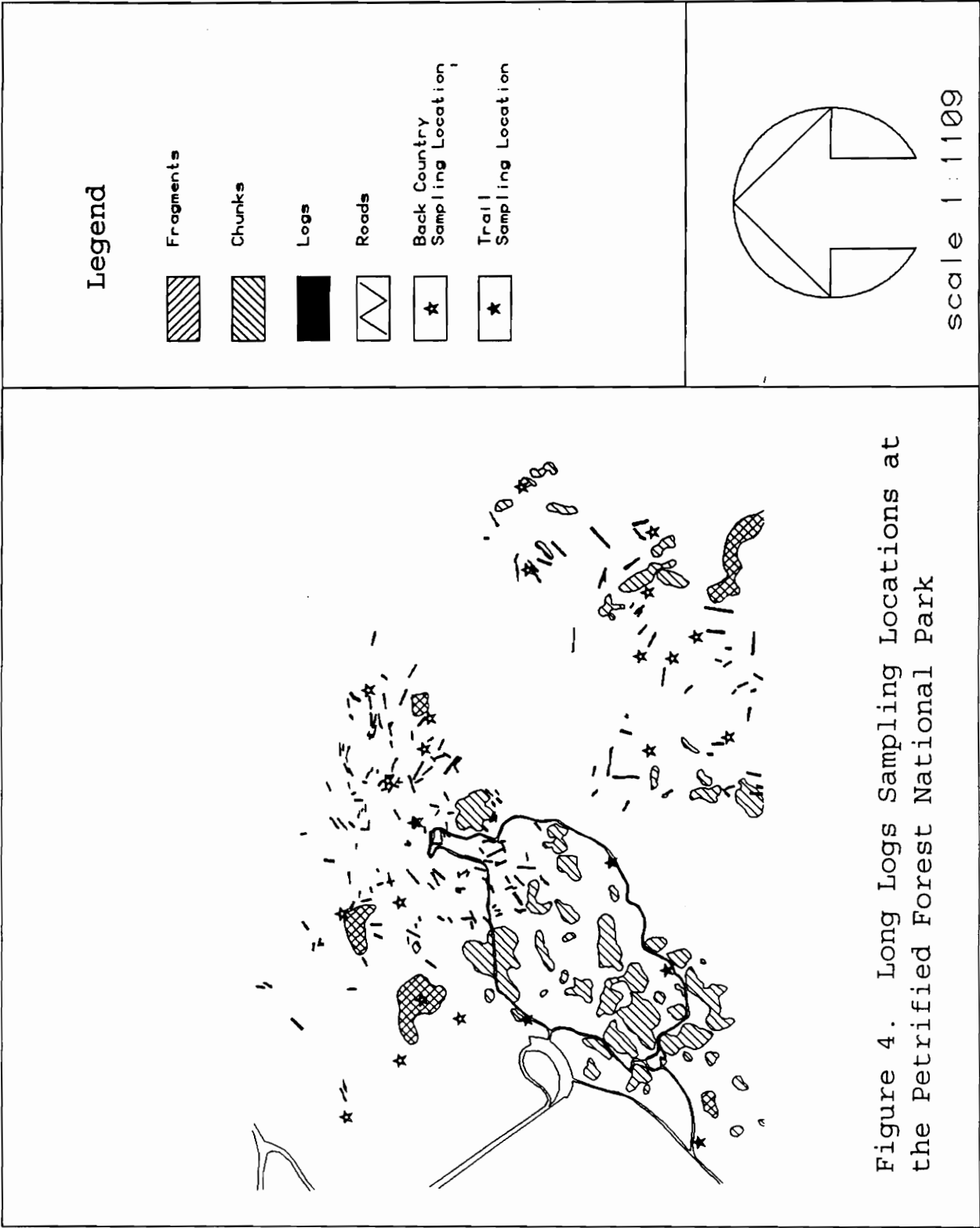
Within each stratum, 35 sampling units were selected. Sampling units were located using random numbers and stratum maps. Twenty of these sampling units (backcountry samples) were located randomly throughout each stratum, restricted from trailside areas. The remaining 15 sampling units (trail side samples) were allocated along visitor trails at fixed distance from trail intervals. The intervals chosen for the trail sampling unit allocation were 0 to 15', 15' to 30' and 30' to 45' corridors from the trail edge. Five of the 15 trail sampling units were placed in each corridor in groups of three partners. The first trail sample unit was randomly allocated within the first 15' trail corridor and with a random angle θ . The remaining 2 partners were allocated a fixed distance (15 or 30 feet) perpendicular to the trail with the same orientation angle θ and distance. Figures 1, 2, 3, 4,

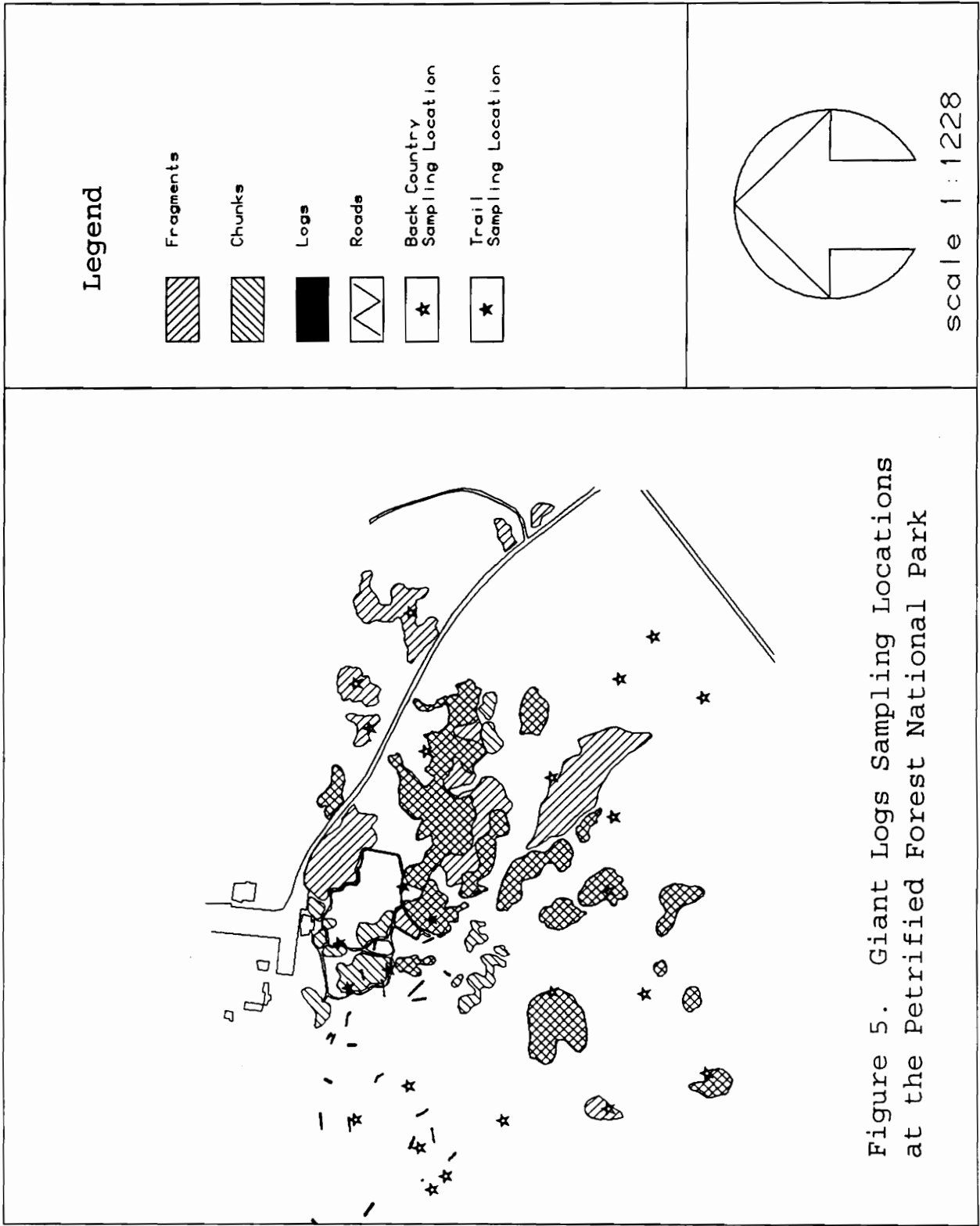
and 5 display sampling locations for each stratum and other data included on the maps.











When a line transect crossed a trail, the transect was simply continued on the other side. When a transect crossed a stratum boundary, the mirage method (Gregoire and Monkevich, 1994) was used to mirror the line back atop itself and retally petrified wood particles.

Park officials hypothesize that the greatest amount of petrified wood theft occurs closest to access sites, such as parking areas, roads, and visitor trails. Trail sampling units are envisioned to determine the amount of Petrified wood displacement and relationships between the theft of wood and distance corridors from the trail. Theft of Petrified wood does not occur in the backcountry areas to any meaningful extent. People are more reluctant to travel into the desert wilderness off man made trails. The backcountry sampling units main purpose are to accurately estimate petrified wood inventory amounts.

A backcountry sampling unit consists of a randomly located and oriented 50' line transect and two 25 square inch quadrat samples. A petrified wood particle was sampled if the chosen line segment intersected the particle. Each line segment was subdivided by petrified wood particle size classes. The subdivision resulted in decreased field sampling time. The first 25 inches of the line (Ls1) would sample particles greater than .25 inches in intersection length along the line. After the first 25 inches, only

particles greater than 1 inch in intersection length were sampled (Ls2). Following the 8 foot marker, petrified wood particles were sampled if greater than 5 inches in intersection length (Ls3). Figure 6 depicts a line transect and sampling rules for a backcountry sampling unit.

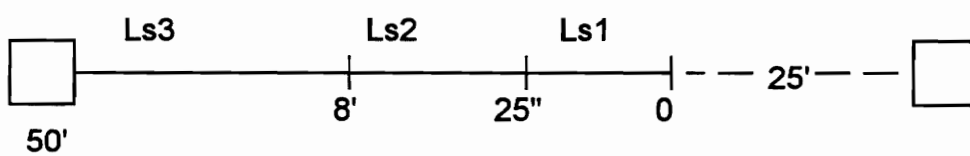
The following measurements were taken on each line transect sampled particle. Intersection length was recorded for all petrified wood size classes. Intersection length was used to generate an estimate of percent cover per acre. Intersection length is the only measurement that was taken on Ls1 due to difficulty of achieving accurate measurement on small particles. Circumference perpendicular to the long axis of the particle was measured for Ls2 and Ls3 segments. The circumference was used to calculate the cross sectional area of each particle, which was then used to generate volume per acre estimates. The particle circumference in the horizontal plane (around the particle) was also tallied for Ls2 and Ls3 segments. The horizontal circumference was used to produce estimates of petrified wood densities per acre. A detailed description of how the line intersect sampling measurements were used is found later in *Data Analysis*.

At the end of each line sampling segment (farthest from the zero end), a square 25 inch quadrat sample was taken during the summer of 1993. The subsequent 1994 inventory positioned the quadrat 25 feet

opposite the zero end of the line. Figures 6 and 7 displays the relationship for the 1993 and 1994 quadrats for a backcountry and trail sample respectively. Petrified wood particles within the quadrat are sampled by two size classes. The first quadrat size class consists of particles less than .25 inches in length. This size class allowed estimates for smaller particles than are sampled by the line segments. The second size class is between .25 and 1 inch in length. This size class acts as a double sample to the first line transect segment. It provides estimates such as weight for the .25" to 1" size class that the line transect did not.

1993 Quadrat
Sample

1994 Quadrat
Sample



Particle Size Sampled

Ls1 $\Rightarrow .25'' \leq \text{Particle Size} \leq \text{infinity}$

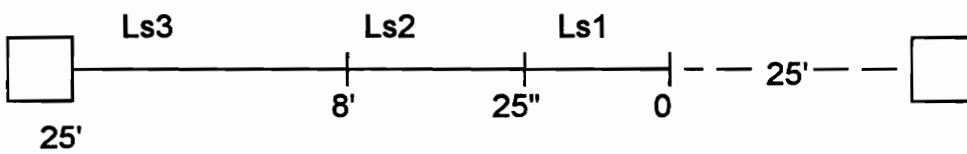
Ls2 $\Rightarrow 1'' \leq \text{Particle Size} \leq \text{infinity}$

Ls3 $\Rightarrow 5'' \leq \text{Particle Size} \leq \text{infinity}$

Figure 6. A Sample Line Transect for a Backcountry Sample at the Petrified Forest National Park

1993 Quadrat
Sample

1994 Quadrat
Sample



Particle Size Sampled

Ls1 $\Rightarrow .25'' \leq \text{Particle Size} \leq \text{infinity}$

Ls2 $\Rightarrow 1'' \leq \text{Particle Size} \leq \text{infinity}$

Ls3 $\Rightarrow 5'' \leq \text{Particle Size} \leq \text{infinity}$

Figure 7. A Sample Line Transect for a Trail Sample at the Petrified Forest National Park

The following measurements were taken on each quadrat sampled size class. The count of particles in each size class was recorded. Each count is used to estimate the density of particles per acre. The area covered by each size class was measured. Area was measured using a board delimited with 1 inch square sections. Area measurement allowed percent cover per acre estimates. The weight and volume of each size class were documented. Weight was measured using a hand held scale. Volume was measured using a calibrated bucket. These measurements are used to generate volume and weight totals per acre. The smaller quadrat size class weight and volume were often too small to record. To rectify the problem, an average weight of the smaller Petrified wood quadrat size class was established. The number of pieces multiplied by the average weight was used to determine totals. The volume of the smaller quadrat size class particles was predicted as a ratio from the larger quadrat size class. A detailed description of how all measurements for both quadrat size classes were used may be found in *Data Analysis*.

A trail sampling unit is identical to a backcountry sampling unit except for the length of the third line segment. The total length of the line was 25 feet due to smaller areas near the trails.

Data Collection Summary

Both trail and backcountry sampling units were located and measured during the summer of 1993 in each stratum. The location of each sampling unit was monumented by small wooden dowels in the ground and inscribed on an aerial photograph. Each sampling unit was revisited during the summer of 1994 to record if any petrified wood was missing or had been added to the line transects.

Data Management

Data were collected using a hand held data recorders. Appendix A contains compiled 1993 and 1994 line intersect and quadrat data. Three programs were written to handle the data collected at Petrified Forest National Park. The program PWSAMP.EXE (Petrified wood Sample) was created for line transect and quadrat data collection. PWSAMP.EXE prompts for, records and edits data in the field. PWSAMP.EXE was used to collect 1993 data and reedit that data in 1994. Source code for PWSAMP.EXE may be found in Appendix B. Field data were then downloaded to a personal computer. PWCALC.EXE (Petrified wood Calculation) was written to summarize and compile the raw data collected

with PWSAMP.EXE. PWCALC.EXE outputs estimates for each line and total mean estimates for both trail and backcountry samples. PWCALC output may be directed to the screen, printer or ASCII file for input into other software packages. PWCALC.EXE source code may be found in Appendix C. WEIGHT.EXE was written to collect and summarize the average weight of the small quadrat size class. Appendix D contains source code for WEIGHT.EXE.

Data Analysis

This section documents the estimators used to calculate target estimates. Calculations were performed individually for each size class estimates for a strata for both backcountry and trail sampling units. Strata estimates were then added together to yield overall totals for each size class. These formulae are coded into PWCALC.EXE.

Figure 8 summarizes the estimators used to compile line intersect sampling data collected at the Petrified Forest. The percent cover estimator yields percentage of ground covered by petrified wood particles from the summation of intersection length. The volume estimator gives cubic foot volume per acre by summing the cross sectional areas of petrified wood particles. The density is given as a function of the horizontal circumference

of the petrified wood particles. The volume and density estimators have conversion factors associated with them. Appendix E summarizes their derivations.

Description	Estimator Form	Units
1) Percent Cover Estimator	$\left(\frac{1}{Lm} \sum_{k=1}^m \sum_{i=1}^{n_k} y_{ik} \right) \times 100$	Percent
2) Volume /Acre Estimator	$\frac{3630\pi}{Lm} \sum_{k=1}^m \sum_{i=1}^{n_k} CSA_{ik}$	Cubic Ft / Acre
3) Density /Acre Estimator	$\frac{43560\pi}{Lm} \sum_{k=1}^m \sum_{i=1}^{n_k} \frac{1}{c_{ik}}$	Number / Acre

where: L = line transect length

m = number of transects sampled

n_k = number of sampled particle for k^{th} transect

y_{ik} = intersection length of i^{th} particle on k^{th} transect (in)

CSA_{ik} = cross sectional area of i^{th} particle on k^{th} transect (in^2)

c_{ik} = horizontal circumference of i^{th} particle on k^{th} transect

Figure 8. Unbiased Line Intersect Estimators Used at the Petrified Forest National Park

Recall the cross sectional area and horizontal circumference of Ls1 particles was not measured due to measurement accuracy of the small particles. To forego this problem, the Ls1 particles were assumed to be circular with diameter equal to its intersection length along the line transect. The Ls1 particle cross sectional area and horizontal circumference were calculated using the particle's intersection length as a circle's diameter and then used in the volume and density estimator formulae.

Figure 9 summarizes the estimators used to compile the larger quadrat size class (Q2) data collected at the Petrified Forest. The percent cover estimator expresses the cross sectional area of the quadrat as a percentage. The volume, weight and density estimators all express the quadrat sampled values on a per acre basis.

The percent cover and density estimator for the smaller quadrat size class (Q1) are identical to the Q2 estimators. As stated earlier, the volume and weight estimators differed for the Q1 quadrat because there often was not enough volume and weight to measure accurately.

The weight estimator of the Q1 quadrat size class was

$$\bar{x}_{wt} \times \frac{10036}{m} \sum_{k=1}^m cnt_i$$

where: $\bar{x}_{wt}$ = average weight of Q1 size class particles
 cnt_i = count of quadrat particles
 m = k_{th} quadrat sampled.

Description	Estimator Form	Units
1) Percent Cover Estimator	$\left(\frac{1}{625m} \sum_{k=1}^m CSA_i \right) \times 100$	Percent
2) Volume / Acre Estimator	$\frac{10036}{m} \sum_{k=1}^m vol_i$	Cubic Ft / Acre
3) Weight / Acre Estimator	$\frac{10036}{m} \sum_{k=1}^m wt_i$	Tons / Acre
3) Density / Acre Estimator	$\frac{10036}{m} \sum_{k=1}^m cnt_i$	Number / Acre

where: m = number of quadrats sampled

CSA_i = cross sectional area of i^{th} quadrat (in^2)

vol_i = volume of i^{th} quadrat (ft^3)

wt_i = weight of i^{th} quadrat (tons)

cnt_i = count of i^{th} quadrat

Figure 9. Unbiased Quadrat Estimators Used at the Petrified Forest National Park

The average weight of Q1 Petrified wood size class was determined with a random sample of 50 Petrified wood particles throughout the Park. The weight was determined to be 7.1412×10^{-9} tons per particle on average. The average weight was simply multiplied by the number of particles per acre to yield an average weight for the Q1 quadrat size class.

The volume estimator used for the Q1 quadrat size class was a ratio type estimator. High correlation's between volume and percent cover lead to the following estimator

$$Vol_{Q1} = \hat{R} \times Percent\ Cov_{Q1}$$

where: Vol_{Q1} = volume of Q1 size class

Percent Cov_{Q1} = percent cover of Q1 size class

$\hat{R}$ = ratio of Q1 percent cover to Q1 volume $\left[\frac{percent}{ft^3} \right]$.

Essentially the volume of Q1 particles was predicted as a function of the percent cover data. The $\hat{R}$'s were determined using ordinary least squares regression without an intercept separately for each stratum using the Q2 quadrat data. It must be assumed that the ratio between percent cover and volume are similar between the Q1 and Q2 quadrat size classes. The fitted $\hat{R}$'s may be found in Table 1.

Table 1. Fitted $\hat{R}$'s (ratio coefficients) for Q1 Volume Estimation at Petrified Forest National Park

Stratum	$\hat{R}$
Blue Mesa	21.4
Crystal Forest	30.0
Giant Logs	18.5
Jasper Forest	19.5
Long Logs	19.6

All estimators discussed previously yield per acre estimates. To achieve total estimates, the backcountry per acre values must be multiplied by the acreage of each stratum and the trail per acre values must be multiplied by the area of the trail corridor. The total area of each stratum was calculated using the stratum maps. The area of each trail corridor was determined using a polar planimeter. These areas were used to adjust per acre estimates to totals for each stratum. Table 2 summarizes the areas sampled in each stratum.

Table 2. Acreage Sampled in each Stratum at the Petrified Forest National Park

Stratum	Total Acreage Sampled	Corridor 1 Area	Corridor 2 Area	Corridor 3 Area
Blue Mesa	139.64	1.29	1.35	1.46
Jasper Forest	95.56	.81	.86	1.01
Crystal Forest	56.21	.96	2.26	1.47
Long Logs	89.96	1.68	1.83	2.42
Giant Logs	75.68	.44	.76	.66

Backcountry Sampling Unit Variance Estimation

Much debate has taken place over the estimation of variance for LIS estimators. Different estimators have been established based on varying assumptions of the spatial distribution of particles on the sampling area. However, no assumption about the distribution of petrified wood on the area is made. A distribution free variance estimator is needed. One trustworthy and fundamental distribution-free variance form is the traditional sampling variance among the individual line estimates as described by De Vries (1973). The De Vries estimator assumes independence among the sampling

units. The backcountry sampling units were allocated randomly therefore making them independent. Letting m denote the number of line transects in a particular backcountry stratum, the De Vries estimator of variance of the estimator $\hat{x}_j$ is

$$S_j^2 = \frac{\sum_{k=1}^m (\hat{x}_{jk} - \hat{x}_j)^2}{m(m-1)} . \quad [3]$$

where j indexes the particle size class (see Figures 5 and 6). This estimator form will also work for backcountry quadrat sample variance estimation.

Trail Sampling Unit Variance Estimation

By design, the trail sampling units are fixed in groups of three. Each group is dependent on the location of the first line transect placed in the first trail corridor. This implies a covariance between the non-overlapping trail corridors. Each group of three sampling units must be treated as an independent sample in any variance calculation. For some trail strata sample x with m groups, corridor $i = 1,2,3$, group number $k = 1,2,3,4,5$, and mean total value $\bar{x}$, the trail variance estimator takes the form

$$\frac{1}{m(m-1)} \sum_{k=1}^m \left(\frac{x_{1k} + x_{2k} + x_{3k}}{n} - \hat{x} \right)^2 \quad [4]$$

where n is the number of available observations within a group ($n \leq 3$). Equation 4 ignores the covariance terms that should arise between the non-overlapping corridors samples. These covariance terms are probably negligible and disregarded for simplicity. It should be noted that the variance estimates using Equation 4 will be approximate. The variance is presumably underestimated so all confidence intervals will be slightly wider than they need to be.

Total Variance Estimation

To estimate variance for total estimates the following scheme was used. Size class variance estimates for backcountry and trail samples (Equations 3 and 4 respectively) were added to yield an overall estimate of total variance for a given target parameter using the rule

$$VAR\left(\sum aX\right) = \sum a^2VAR(X) \quad [5]$$

where: X = random variable of interest

a = some constant.

Confidence Interval Estimation

Confidence intervals are an important part of any inventory project. Without some measure of confidence an estimate may be meaningless. The

following formula was used to form confidence intervals for backcountry, trail and total estimates of the Petrified Forest data,

$$T \pm t_{(n-1), 1-\frac{\alpha}{2}} \times \sqrt{\hat{V}\hat{A}\hat{R}} \quad [6]$$

where: T = some estimate of interest

$t_{(n-1), 1-\frac{\alpha}{2}}$ = t-distribution quantile

$\hat{V}\hat{A}\hat{R}$ = Variance estimate of T.

Equation 5 works for both line intersect and quadrat sampled data provided the variance of the total estimate is defined.

Chapter 4

Percent Cover Results

Introduction

This chapter describes in detail the steps taken to arrive at total and variance estimates of percent cover (% Cov) for both line intersect and quadrat sampling at the Petrified Forest National Park. For a given size class of petrified wood, the step by step methodology used is expounded. Most of the calculations may be duplicated using the data summarized in Appendix A. However, calculations rendering the data available in Appendix A may not be performed because the raw data were too numerous to report. Throughout this chapter all percent cover data for 1993 and 1994 inventories is summarized and graphic representations of change is available.

Line Intersect Percent Cover Estimator

Figure 8, estimator 1 (Methods Section) is the percent cover estimator used to calculate percent ground cover for each line transect. The estimator may be expressed for a single line transect as

$$\left[\frac{1}{L} \sum_{i=1}^n y_i \right] \times 100 \quad [6]$$

where: L = line transect length

n = ith sampled particle along the line transect

y_i = intersection length along the line transect.

As an example, the 1993 intersection length data collected at the Petrified Forest National Park for size class 1 (sc1 = .25" to 1" in intersection length), line 21 at Giant Logs are listed below in Table 3.

Table 3. 1993 Percent Cover Line Intersect Data for Giant Logs, Line 21, Size Class 1

Line Number	Intersection Length in inches
21	.75
21	.94
21	.75
21	.63
21	.44
21	.88

Using Equation 6 to arrive at a total percent cover estimate for Giant Logs line 21, the intersection lengths would be summed and divided by the total length of the line transect for size class 1 (25 inches), and multiplied by 100:

$$\left[\frac{1}{25} (.75+.94+.75+.63+.44+.88) \right] \times 100 = 17.56 .$$

The percent cover is expressed as the percentage of ground area covered by petrified wood particles. Identical methods were used to derive individual line transect totals for all lines in all strata for both backcountry and trail samples.

Quadrat Percent Cover Estimator

Figure 9, estimator 1 (Methods Section) is the percent cover estimator used to calculate percent ground cover for each quadrat. The estimator may be expressed for a single quadrat sample as

$$\left[\frac{1}{625} \times CSA_i \right] \times 100 \quad [7]$$

where: CSA_i = cross sectional area of i^{th} quadrat sample.

As an example, the 1993 cross sectional area for the quadrat size class 1, associated with line 21 in the Giant Logs stratum was 131 square inches. The area delineated for each quadrat sample was 625 square inches, thus the constant in Equation 7. To express the 131 square inches of petrified wood sampled as a percentage, Equation 7 was used as follows:

$$\left[\frac{131}{625} \right] \times 100 = 20.96 .$$

The quadrat percent ground cover was also expressed as a percentage of the ground covered by petrified wood particles. Identical methodology was used to derive percent cover estimates for both quadrat size classes for all strata.

Backcountry Total and Variance Estimation

To arrive at total percent cover estimates for backcountry sampling units, individual line transect and quadrat estimates were calculated (Equations 6 and 7 respectively) and averaged. Table 4 lists the backcountry line intersect 1993 data for Giant Logs, size class 1 collected at the Petrified Forest National Park as an example.

Table 4. 1993 Backcountry Line Intersect Percent Cover Data for the Giant Logs Stratum, Size Class 1 at the Petrified Forest National Park

Line #	% Cov	Line #	% Cov
16	0.0	26	0.0
17	3.8	27	8.8
18	3.1	28	0.0
19	0.0	29	3.0
20	0.0	30	14.8
21	17.6	31	0.0
22	0.0	32	0.0
23	6.0	33	0.0
24	0.0	34	0.0
25	0.0	35	0.0

To arrive at a total line intercept percent cover estimate for Giant Logs size class 1, the data in Table 4 would be manipulated the following way:

$$\frac{0.0 + 3.8 + 3.1 + \dots + 0.0 + 0.0}{20} = 2.86 .$$

To estimate the variance for the total line intercept percent cover estimate above the De Vries Equation 3 was used. Using the data in Table 4 and Equation 3 the calculation becomes:

$$\begin{aligned} & (0.0 - 2.86)^2 \\ + & (3.8 - 2.86)^2 \\ + & . \\ & . \\ & . \\ + & (0.0 - 2.86)^2 \\ + & (0.0 - 2.86)^2 \\ & = 511.28, \end{aligned}$$

dividing by the sample size yields:

$$\hat{VAR}(\%Cov_{sc1}) = \frac{511.28}{(19)20} = 1.35 .$$

To affix a level of confidence to percent cover estimates, Equation 6 was used. A two sided 95 percent confidence interval assuming normality for the Giant Logs line intercept size class 1 percent cover estimate is:

$$2.86 \pm t_{(19),.975} \times \sqrt{1.35}$$

$$= 2.86 \pm 2.093 \times 1.16$$

$$= 2.86 \pm 2.43$$

$$= (.43, 5.29) .$$

Similar methods were used to estimate variance and confidence intervals for the remainder of the backcountry percent cover size class estimates across all strata for both line intersect and quadrat samples.

Summary of Backcountry Percent Cover Estimates

No petrified wood was missing or added in the line intercept backcountry sampling units, therefore the 1993 and 1994 backcountry line intersect estimates are identical. Table 5 summarizes the backcountry line intersect percent cover data for all five strata.

Recall that the quadrat samples were distinct during the 1993 and 1994 inventories (Figure 6). Keep in mind that the percent cover estimates from the two quadrat samples are not as stringently bound to piece by piece petrified wood displacement as the line intersect estimates. Tables 6 and 7 summarize the backcountry quadrat percent cover data for each stratum for 1993 and 1994 respectively.

Table 5. 1993 and 1994 Backcountry Percent Cover Line Intersect Data Summary at Petrified Forest National Park

Blue Mesa			
	Size Class 1	Size Class 2	Size Class 3
Average	1.45	1.75	2.27
Standard Error	0.73	0.60	1.42
Sample Size	20	20	20
95% C. I.	(-0.09, 2.99)	(0.49, 3.02)	(-0.70, 5.25)
Crystal Forest			
Average	3.01	1.15	1.69
Standard Error	1.47	0.69	0.57
Sample Size	20	20	20
95% C. I.	(-0.06, 6.08)	(0.71, 3.59)	(0.50, 2.88)
Giant Logs			
Average	2.85	3.55	1.61
Standard Error	1.16	1.72	0.73
Sample Size	20	20	20
95% C. I.	(0.42, 5.28)	(-0.05, 7.15)	(0.08, 3.15)
Jasper Forest			
Average	4.36	3.25	3.02
Standard Error	1.58	1.11	1.13
Sample Size	20	20	20
95% C. I.	(1.06, 7.67)	(0.92, 5.58)	(0.66, 5.39)
Long Logs			
Average	2.51	2.53	2.35
Standard Error	0.92	0.73	0.78
Sample Size	20	20	20
95% C. I.	(0.59, 4.44)	(0.99, 4.06)	(0.71, 3.99)

Size Class 1 = $.25'' \leq \text{intersection length} < 1''$

Size Class 2 = $1'' \leq \text{intersection length} < 5''$

Size Class 3 = $5'' \leq \text{intersection length}$

Table 6. 1993 Backcountry Percent Cover Quadrat Data Summary at Petrified Forest National Park

Blue Mesa		
	Size Class 0	Size Class 1
Average	0.24	3.26
Standard Error	0.16	1.59
Sample Size	20	20
95% Confidence Int.	(-0.09, 0.58)	(-0.07, 6.60)
Crystal Forest		
Average	0.31	6.87
Standard Error	0.10	2.16
Sample Size	20	20
95% Confidence Int.	(0.09, 0.52)	(2.35, 11.39)
Giant Logs		
Average	0.11	3.82
Standard Error	0.04	1.63
Sample Size	20	20
95% Confidence Int.	(0.03, 0.19)	(0.40, 7.23)
Jasper Forest		
Average	0.29	4.93
Standard Error	0.22	2.26
Sample Size	20	20
95% Confidence Int.	(-0.18, 0.76)	(0.19, 9.66)
Long Logs		
Average	0.09	3.79
Standard Error	0.13	1.83
Sample Size	20	20
95% Confidence Int.	(0.03, 0.15)	(1.01, 6.57)

Size Class 0 = intersection length $\leq .25''$

Size Class 1 = $.25'' < \text{intersection length} < 1''$

Table 7. 1994 Backcountry Percent Cover Quadrat Data Summary at Petrified Forest National Park

Blue Mesa		
	Size Class 0	Size Class 1
Average	0.19	2.13
Standard Error	0.16	1.16
Sample Size	2-	20
95% Confidence Int.	(-0.14, 0.52)	(-0.30, 4.56)
Crystal Forest		
Average	0.26	5.58
Standard Error	0.16	1.64
Sample Size	20	20
95% Confidence Int.	(-0.07, 0.59)	(2.13, 9.02)
Giant Logs		
Average	0.04	3.38
Standard Error	0.01	1.55
Sample Size	20	20
95% Confidence Int.	(0.01, 0.07)	(0.12, 6.63)
Jasper Forest		
Average	0.04	1.65
Standard Error	0.02	1.55
Sample Size	20	20
95% Confidence Int.	(0.01, 0.07)	(0.38, 2.91)
Long Logs		
Average	0.07	3.60
Standard Error	0.02	1.20
Sample Size	20	20
95% Confidence Int.	(0.02, 0.10)	(1.07, 6.12)

Size Class 0 = intersection length $\leq .25''$

Size Class 1 = $.25'' < \text{intersection length} < 1''$

Trail Corridor Average and Variance Estimation

The trail sampling percent cover estimates were broken down differently than were the backcountry estimates, because these sampling units represent the displacement of petrified wood. First, individual corridor averages were calculated. Recall that corridor 1 is 0 to 15 feet on both sides of the trail, corridor 2 is 15 to 30 feet on both sides of the trail and corridor 3 is 30 to 45 feet on both sides of the trail. These corridor averages are intended to show relationships between displacement of petrified wood and distance traveled from the trail. Second, the corridor values were averaged to show overall petrified wood displacement for a given stratum. As an example of how the trail estimates were calculated, Table 8 lists Jasper Forest line intersect data for size class 1, collected at the Petrified Forest National Park during the 1994 inventory.

Table 8. Trail Percent Cover Data for the Jasper Forest Stratum, Size Class 1 at the Petrified Forest National Park

line number	corridor #	% Cover
1	1	missing 94
1	2	missing 94
1	3	missing 94
2	1	6.5
2	2	missing 94
2	3	11.8
3	1	2.5
3	2	20.6
3	3	10.8
4	1	8.8
4	2	5.5
4	3	0
5	1	7.2
5	2	8.5
5	3	20.9

Recall that some trail sampling units were destroyed between inventories. If a sampling units was destroyed during the 1994 inventory, the 1993 data was not used in any calculations (coded missing 94).

To arrive at corridor averages, the individual corridor values were simply averaged as follows:

$$\text{Corridor 1: } \frac{6.5 + 2.5 + 8.8 + 7.2}{4} = 6.25$$

$$\text{Corridor 2: } \frac{20.6 + 5.5 + 8.5}{3} = 11.53$$

$$\text{Corridor 3: } \frac{11.8 + 10.8 + 0.0 + 20.9}{4} = 10.87 .$$

The variances for these individual corridor estimates was calculated using Equation 3. For example, for the Corridor 2 percent cover estimate, the calculation for variance would be:

$$\frac{1}{2(3)} [(20.6 - 11.53)^2 + (5.5 - 11.53)^2 + (8.5 - 11.53)^2] = 21.30.$$

To affix a level of confidence to corridor estimates, Equation 6 was used with $\alpha = .05$ and the appropriate degrees of freedom for each corridor.

Summary of Trail Corridor Percent Cover Estimates

Tables 9, 10, 11, 12, 13, and 14 summarize the line intersect percent cover estimates by corridors and petrified wood size classes for the 1993 and 1994 inventories. Tables 15, 16, 17, and 18 summarize the quadrat

percent cover data by size classes and corridors for the 1993 and 1994 inventories.

The change of petrified wood was calculated (1993 estimate - 1994 estimate) for each corridor in each stratum. The following list of figures displays the percent cover change of petrified wood by corridors for each size class. Note that a negative number suggests an increase of petrified wood while a positive number indicates loss. Figure 10 depicts the relationship between petrified wood change and trail corridors for line intersect data in each stratum respectively. Figure 11 depicts the relationship between trail corridor and wood change for the quadrat data in each stratum respectively.

Table 9. 1993 Size Class 1 Percent Cover Line Intersect Trail Corridor Data Collected at the Petrified Forest National Park

Blue Mesa			
	Corridor 1	Corridor 2	Corridor 3
Average	3.26	2.75	9.03
Standard Err.	1.82	1.90	3.04
n	3	4	4
95 % C.I.	(-4.55, 11.09)	(-3.28, 8.79)	(-0.64, 18.70)
Crystal Forest			
Average	6.90	4.18	4.27
Standard Err.	6.90	0.99	2.33
n	2	4	3
95 % C.I.	(-80.77, 94.57)	(1.03, 7.32)	(-5.78, 14.31)
Giant Logs			
Average	6.76	0.0	1.25
Standard Err.	undefined	0.0	1.25
n	1	3	3
95 % C.I.	N/A	N/A	(-4.14, 6.65)
Jasper Forest			
Average	6.30	11.56	10.91
Standard Err.	1.35	4.62	4.29
n	4	3	4
95 % C.I.	(1.99, 10.60)	(-8.34, 31.44)	(-2.75, 24.56)
Long Logs			
Average	1.92	2.10	4.25
Standard Err.	1.92	2.10	1.64
n	3	4	3
95 % C.I.	(-6.34, 10.18)	(-4.58, 8.78)	(-2.84, 11.34)

Size Class 1 = .25" ≤ intersection length < 1"

Table 10. 1994 Size Class 1 Percent Cover Line Intersect Trail Corridor Data Collected at the Petrified Forest National Park

Blue Mesa			
	Corridor 1	Corridor 2	Corridor 3
Average	3.26	4.39	9.03
Standard Err.	1.82	3.46	3.04
n	3	4	4
95 % C.I.	(-4.55, 11.09)	(-6.63, 15.41)	(-0.64, 18.70)
Crystal Forest			
Average	6.90	3.77	4.27
Standard Err.	6.90	1.01	2.33
n	2	4	3
95 % C.I.	(-80.77, 94.57)	(0.55, 6.98)	(-5.78, 14.31)
Giant Logs			
Average	3.76	0.0	1.25
Standard Err.	undefined	0.0	1.25
n	1	3	3
95 % C.I.	N/A	N/A	(-4.14, 6.65)
Jasper Forest			
Average	5.92	10.60	10.91
Standard Err.	1.38	5.02	4.29
n	4	3	4
95 % C.I.	(1.52, 10.33)	(-11.00, 32.20)	(-2.75, 24.56)
Long Logs			
Average	1.92	2.10	4.25
Standard Err.	1.92	2.10	1.64
n	3	4	3
95 % C.I.	(-6.34, 10.18)	(-4.58, 8.78)	(-2.84, 11.34)

Size Class 1 = $.25'' \leq \text{intersection length} < 1''$

Table 11. 1993 Size Class 2 Percent Cover Line Intersect Trail Corridor Data Collected at the Petrified Forest National Park

Blue Mesa			
	Corridor 1	Corridor 2	Corridor 3
Average	7.91	8.46	2.71
Standard Err.	1.49	5.47	1.59
n	3	4	4
95 % C.I.	(1.51, 14.30)	(-8.95, 25.87)	(-2.35, 7.78)
Crystal Forest			
Average	1.13	0.66	8.07
Standard Err.	1.13	0.39	5.10
n	2	4	3
95 % C.I.	(-13.23, 15.49)	(-0.56, 1.89)	(-13.86, 30.00)
Giant Logs			
Average	4.68	0.43	2.09
Standard Err.	undefined	0.43	2.09
n	1	3	3
95 % C.I.	N/A	(-1.43, 2.30)	(-6.89, 11.07)
Jasper Forest			
Average	1.55	0.0	1.17
Standard Err.	1.04	0.0	0.71
n	4	3	4
95 % C.I.	(-1.75, 4.83)	N/A	(-1.08, 3.43)
Long Logs			
Average	1.41	3.26	0.41
Standard Err.	0.74	2.68	0.41
n	3	4	3
95 % C.I.	(-1.79, 4.60)	(-5.28, 11.79)	(-1.34, 2.15)

Size Class 2 = $1'' \leq \text{intersection length} < 5''$

Table 12. 1994 Size Class 2 Percent Cover Line Intersect Trail Corridor Data Collected at the Petrified Forest National Park

Blue Mesa			
	Corridor 1	Corridor 2	Corridor 3
Average	7.91	8.46	2.71
Standard Err.	1.49	5.47	1.59
n	3	4	4
95 % C.I.	(1.51, 14.30)	(-8.95, 25.87)	(-2.35, 7.78)
Crystal Forest			
Average	1.13	0.66	8.07
Standard Err.	1.13	0.39	5.10
n	2	4	3
95 % C.I.	(-13.23, 15.49)	(-0.56, 1.89)	(-13.86, 30.00)
Giant Logs			
Average	4.68	0.43	2.09
Standard Err.	undefined	0.43	2.09
n	1	3	3
95 % C.I.	N/A	(-1.43, 2.30)	(-6.89, 11.07)
Jasper Forest			
Average	2.27	0.0	0.71
Standard Err.	1.31	0.0	0.71
n	4	3	4
95 % C.I.	(-1.90, 6.43)	N/A	(-1.56, 2.99)
Long Logs			
Average	1.41	3.26	0.41
Standard Err.	0.74	2.68	0.41
n	3	4	3
95 % C.I.	(-1.79, 4.60)	(-5.28, 11.79)	(-1.34, 2.15)

Size Class 2 = $1'' \leq \text{intersection length} < 5''$

Table 13. 1993 Size Class 3 Percent Cover Line Intersect Trail Corridor Data Collected at the Petrified Forest National Park

Blue Mesa			
	Corridor 1	Corridor 2	Corridor 3
Average	1.03	4.54	1.19
Standard Err.	1.03	2.32	1.19
n	3	4	4
95 % C.I.	(-3.39, 5.45)	(-2.83, 11.92)	(-2.59, 4.97)
Crystal Forest			
Average	0.0	1.75	0.0
Standard Err.	0.0	1.06	0.0
n	2	4	3
95 % C.I.	N/A	(-1.61, 5.11)	N/A
Giant Logs			
Average	3.42	0.0	8.56
Standard Err.	undefined	0.0	54.93
n	1	3	3
95 % C.I.	N/A	N/A	(-9.86, 26.97)
Jasper Forest			
Average	1.37	9.21	4.70
Standard Err.	1.37	0.76	2.14
n	4	3	4
95 % C.I.	(-2.98, 5.71)	(5.94, 12.48)	(-2.11, 11.51)
Long Logs			
Average	8.11	8.81	1.22
Standard Err.	7.13	1.89	4.48
n	3	4	3
95 % C.I.	(-22.59, 38.81)	(2.77, 14.84)	(-4.04, 6.48)

Size Class 3 = 5" ≤ intersection length

Table 14. 1994 Size Class 3 Percent Cover Line Intersect Trail Corridor Data Collected at the Petrified Forest National Park

Blue Mesa			
	Corridor 1	Corridor 2	Corridor 3
Average	1.03	4.54	0.46
Standard Err.	1.03	2.32	0.46
n	3	4	4
95 % C.I.	(-3.39, 5.45)	(-2.83, 11.92)	(-1.00, 1.92)
Crystal Forest			
Average	0.0	1.75	0.0
Standard Err.	0.0	1.06	0.0
n	2	4	3
95 % C.I.	N/A	(-1.61, 5.11)	N/A
Giant Logs			
Average	3.42	0.0	8.56
Standard Err.	undefined	0.0	54.93
n	1	3	3
95 % C.I.	N/A	N/A	(-9.86, 26.97)
Jasper Forest			
Average	1.37	9.21	4.70
Standard Err.	1.37	0.76	2.14
n	4	3	4
95 % C.I.	(-2.98, 5.71)	(5.94, 12.48)	(-2.11, 11.51)
Long Logs			
Average	8.11	8.31	1.22
Standard Err.	7.13	2.32	4.48
n	3	4	3
95 % C.I.	(-22.59, 38.81)	(0.93, 15.68)	(-4.04, 6.48)

Size Class 3 = 5" ≤ intersection length

Table 15. 1993 Size Class 0 Percent Cover Quadrat Trail Corridor Data Collected at the Petrified Forest National Park

Blue Mesa			
	Corridor 1	Corridor 2	Corridor 3
Average	0.08	0.07	0.09
Standard Err.	0.08	0.06	0.08
n	3	4	4
95 % C.I.	(-0.08, 0.23)	(-0.11, 0.25)	(-0.15, 0.33)
Crystal Forest			
Average	0.86	0.05	0.21
Standard Err.	0.41	0.03	0.05
n	2	4	3
95 % C.I.	(-4.47, 6.20)	(-0.03, 0.14)	(0.006, 0.42)
Giant Logs			
Average	0.08	0.08	0.10
Standard Err.	undefined	0.03	0.02
n	1	3	3
95 % C.I.	N/A	(-0.03, 0.18)	(-0.03, 0.23)
Jasper Forest			
Average	0.30	1.00	0.46
Standard Err.	0.11	0.50	0.25
n	4	3	4
95 % C.I.	(-0.06, 0.65)	(-1.17, 3.16)	(-0.24, 1.26)
Long Logs			
Average	0.50	0.11	0.08
Standard Err.	0.50	0.04	0.001
n	3	4	3
95 % C.I.	(-1.54, 2.53)	(-0.03, 0.25)	(-0.007, 0.17)

Size Class 0 = intersection length $\leq .25''$

Table 16. 1994 Size Class 0 Percent Cover Quadrat Trail Corridor Data Collected at the Petrified Forest National Park

Blue Mesa			
	Corridor 1	Corridor 2	Corridor 3
Average	0.31	0.50	0.18
Standard Err.	0.21	0.31	0.07
n	3	4	4
95 % C.I.	(-0.10, 0.72)	(-0.52, 1.51)	(-0.03, 0.40)
Crystal Forest			
Average	0.41	0.31	0.08
Standard Err.	0.23	0.22	0.08
n	2	4	3
95 % C.I.	(-2.49, 3.31)	(-0.39, 1.02)	(-0.26, 0.42)
Giant Logs			
Average	0.32	0.02	0.11
Standard Err.	undefined	0.009	0.06
n	1	3	3
95 % C.I.	N/A	(-0.02, 0.06)	(-0.17, 0.39)
Jasper Forest			
Average	0.22	0.14	0.16
Standard Err.	0.11	0.13	0.16
n	4	3	4
95 % C.I.	(-0.13, 0.57)	(-0.42, 0.70)	(-0.25, 0.67)
Long Logs			
Average	0.11	0.61	0.08
Standard Err.	0.10	0.60	0.06
n	3	4	3
95 % C.I.	(0.33, 0.56)	(-1.29, 2.51)	(-0.17, 0.33)

Size Class 0 = intersection length $\leq .25''$

Table 17. 1993 Size Class 1 Percent Cover Quadrat Trail Corridor Data Collected at the Petrified Forest National Park

Blue Mesa			
	Corridor 1	Corridor 2	Corridor 3
Average	2.72	5.70	2.16
Standard Err.	1.92	3.24	0.81
n	3	4	4
95 % C.I.	(-1.04, 6.49)	(-4.60, 15.99)	(-0.41, 4.73)
Crystal Forest			
Average	8.24	3.56	6.35
Standard Err.	6.80	1.62	1.87
n	2	4	3
95 % C.I.	(-78.16, 94.64)	(-1.60, 8.72)	(-1.68, 14.38)
Giant Logs			
Average	0.20	0.85	0.96
Standard Err.	undefined	0.38	0.09
n	1	3	3
95 % C.I.	N/A	(-0.80, 2.51)	(0.56, 1.35)
Jasper Forest			
Average	3.15	14.05	11.88
Standard Err.	1.34	5.31	3.29
n	4	3	4
95 % C.I.	(-1.11, 7.41)	(-8.81, 36.92)	(1.40, 22.36)
Long Logs			
Average	10.03	3.12	1.57
Standard Err.	7.89	1.49	0.60
n	3	4	3
95 % C.I.	(-23.94, 43.99)	(-1.63, 7.87)	(-1.02, 4.17)

Size Class 1 = .25" < intersection length < 1"

Table 18. 1994 Size Class 1 Percent Cover Quadrat Trail Corridor Data Collected at the Petrified Forest National Park

Blue Mesa			
	Corridor 1	Corridor 2	Corridor 3
Average	9.39	9.16	1.31
Standard Err.	4.33	5.08	0.48
n	3	4	4
95 % C.I.	(0.90, 17.87)	(-6.99, 25.31)	(-0.22, 2.84)
Crystal Forest			
Average	5.20	5.79	1.04
Standard Err.	3.76	3.82	0.70
n	2	4	3
95 % C.I.	(-42.57, 52.98)	(-6.35, 17.93)	(-1.97, 4.05)
Giant Logs			
Average	3.20	0.72	1.92
Standard Err.	undefined	0.20	0.96
n	1	3	3
95 % C.I.	N/A	(-0.14, 1.59)	(-2.21, 6.05)
Jasper Forest			
Average	1.08	1.13	1.74
Standard Err.	0.71	1.03	1.61
n	4	3	4
95 % C.I.	(-1.21, 3.37)	(-3.34, 5.59)	(-3.37, 6.86)
Long Logs			
Average	5.07	6.06	2.51
Standard Err.	1.95	5.66	1.66
n	3	4	3
95 % C.I.	(-3.31, 13.45)	(-11.96, 24.08)	(-4.62, 9.64)

Size Class 1 = .25" < intersection length < 1"

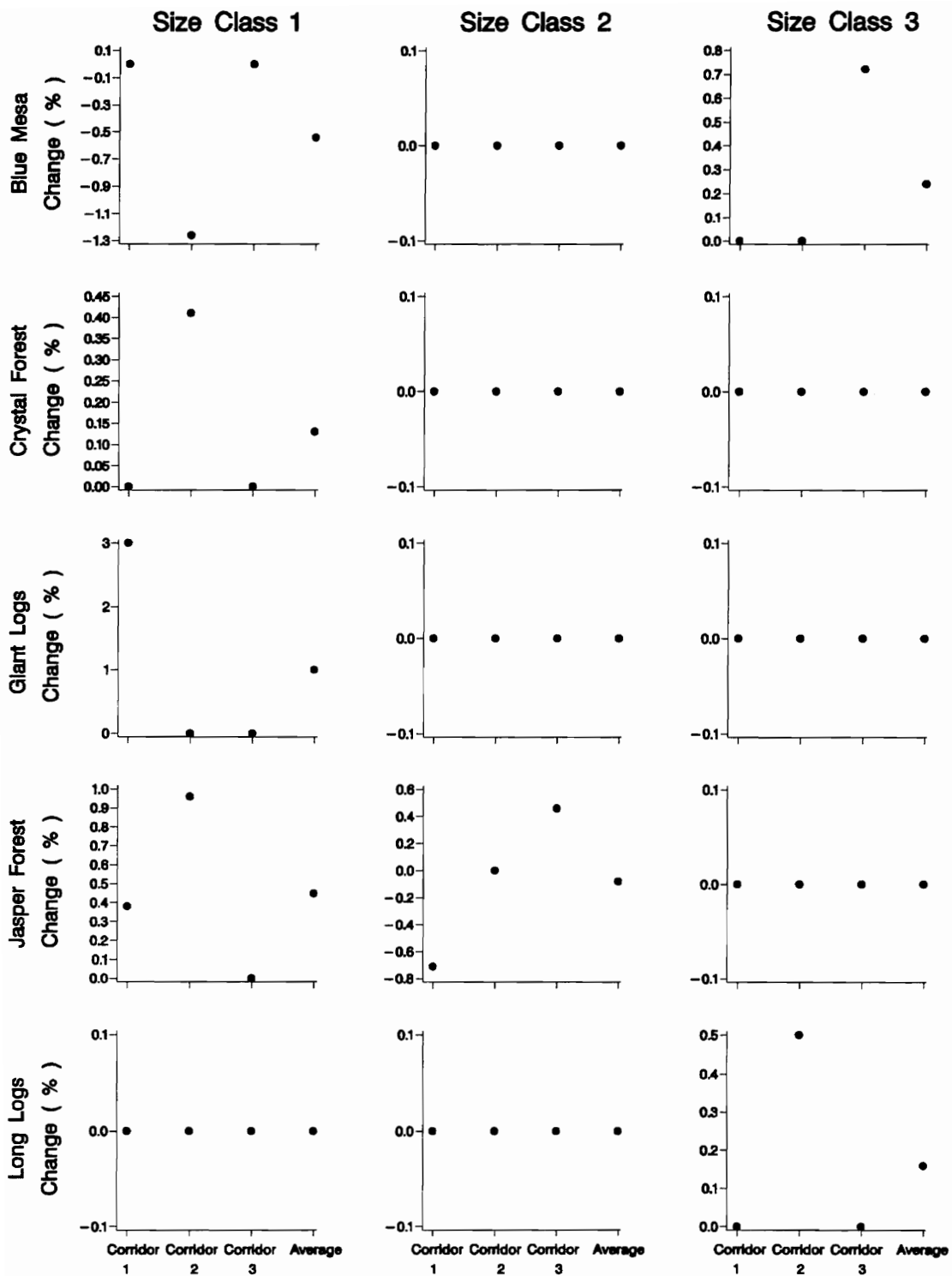


Figure 10. Change in Percent Cover in the Trail Strata As Estimated From Line Intersect Data

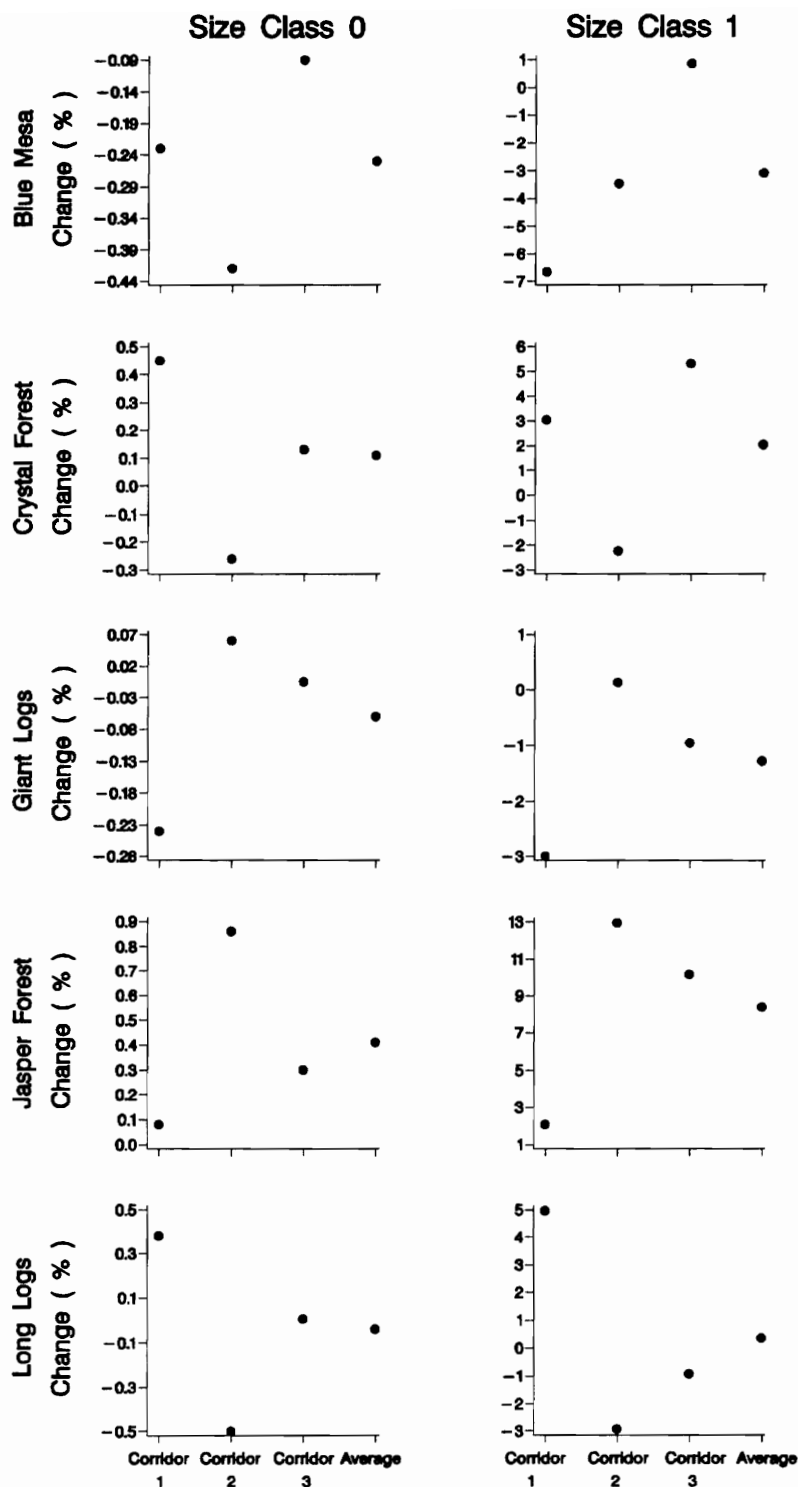


Figure 11. Change in Percent Cover in the Trail Strata As Estimated From Quadrat Data

Trail Total and Variance Estimation

To arrive at a total estimate for the trail sampling units, the individual corridor estimates were averaged for each group and then averaged over the groups. This must be done because the trail sampling units are not independent within each trail group. For example, using the Jasper Forest size class 1 data (Table 8) the calculation is:

$$\begin{aligned} & \frac{1}{4} \left[\frac{6.5 + 11.8}{2} \right. \\ & + \frac{2.5 + 20.6 + 10.8}{3} \\ & + \frac{8.8 + 5.5 + 0.0}{3} \\ & \left. + \frac{7.2 + 8.5 + 20.9}{3} \right] \\ & = 9.35 \end{aligned}$$

To estimate the variance of this estimate, Equation 4 was implemented. Again using the Jasper Forest size class 1 data (Table 8) and noting that some sampling units are missing from each group of three lines, the calculation of variance is:

$$\left[\left(\frac{6.5 + 11.8}{2} \right) - 9.35 \right]^2$$

$$\begin{aligned}
& + \left[\left(\frac{2.5 + 20.6 + 10.8}{3} \right) - 9.35 \right]^2 \\
& + \left[\left(\frac{8.8 + 5.5 + 0}{3} \right) - 9.35 \right]^2 \\
& + \left[\left(\frac{7.2 + 8.5 + 20.9}{3} \right) - 9.35 \right]^2 \\
& = 33.03
\end{aligned}$$

Dividing by the sample size:

$$\hat{VAR}(\%Cov_{sc1}) \equiv \frac{33.03}{3(4)} = 2.75 .$$

Recall that none of the three corridor line segments for the first sample in the Jasper Forest trail data were available in 1994, thus the data could not be used in the calculation of total and variance. Also note that this decreased the sample size from five to 4. The second corridor measurement was missing in 1994 for the second Jasper Forest Trail sample, therefore only the two available measurements were used in the above calculations. Finally, recall that the covariance terms between the corridor units were neglected. This renders the variance for trail sampling units approximate. Identical methods were used to calculate the variance estimates for the remainder of the strata and size classes for both line intersect and quadrat data.

To affix a level of confidence to these estimated trail totals, Equation 6 was used with the appropriate degrees of freedom and $\alpha = .05$.

Summary of Trail Total Percent Cover Estimates

Tables 19 and 20 summarize the trail line intersect percent cover total estimates for 1993 and 1994 respectively. Tables 21 and 22 summarize the trail quadrat percent cover total estimates for 1993 and 1994 inventories respectively.

Table 19. 1993 Trail Percent Cover Line Intersect Data Summary at Petrified Forest National Park

Blue Mesa			
	Size Class 1	Size Class 2	Size Class 3
Average	5.16	5.98	2.28
Standard Error	1.00	3.67	0.97
n	4	4	4
95% C. I.	(1.99, 8.34)	(-0.11, 12.08)	(-0.80, 5.36)
Crystal Forest			
Average	4.70	4.76	1.95
Standard Error	1.14	1.99	0.85
n	4	4	4
95% C. I.	(1.07, 8.34)	(-1.58, 11.09)	(-0.76, 4.67)
Giant Logs			
Average	1.67	1.78	4.66
Standard Error	1.67	1.10	1.76
n	3	3	3
95% C. I.	(-3.86, 6.17)	(-2.95, 6.49)	(-2.91, 12.23)
Jasper Forest			
Average	9.39	1.03	4.75
Standard Error	1.66	0.25	0.81
n	4	4	4
95% C. I.	(4.11, 14.67)	(0.26, 1.79)	(2.18, 7.34)
Long Logs			
Average	3.64	3.41	7.47
Standard Error	1.63	2.60	2.48
n	4	4	4
95% C. I.	(-1.54, 8.83)	(-4.87, 11.69)	(-0.41, 15.36)

Size Class 1 = .25" ≤ intersection length < 1"

Size Class 2 = 1" ≤ intersection length < 5"

Size Class 3 = 5" ≤ intersection length

Table 20. 1994 Trail Percent Cover Line Intersect Data Summary at Petrified Forest National Park

Blue Mesa			
	Size Class 1	Size Class 2	Size Class 3
Average	5.71	5.98	2.04
Standard Error	1.08	1.91	0.84
n	4	4	4
95% C. I.	(2.28, 9.13)	(-0.11, 12.08)	(-0.62, 4.70)
Crystal Forest			
Average	4.49	4.76	1.95
Standard Error	1.05	1.99	0.85
n	4	4	4
95% C. I.	(1.15, 7.84)	(-1.58, 11.09)	(-0.76, 4.47)
Giant Logs			
Average	0.84	1.78	4.66
Standard Error	0.48	1.10	1.76
n	3	3	3
95% C. I.	(-1.13, 2.80)	(-2.95, 6.49)	(-2.91, 12.23)
Jasper Forest			
Average	8.96	1.11	4.75
Standard Error	1.54	0.37	0.81
n	4	4	4
95% C. I.	(4.05, 13.87)	(-0.07, 2.30)	(2.18, 7.34)
Long Logs			
Average	3.64	3.41	7.31
Standard Error	1.63	2.60	2.57
n	4	4	4
95% C. I.	(-1.54, 8.83)	(-4.87, 11.69)	(-0.89, 15.50)

Size Class 1 = $.25'' \leq \text{intersection length} < 1''$

Size Class 2 = $1'' \leq \text{intersection length} < 5''$

Size Class 3 = $5'' \leq \text{intersection length}$

Table 21. 1993 Trail Percent Cover Quadrat Data Summary at Petrified Forest National Park

Blue Mesa		
	Size Class 0	Size Class 1
Average	0.08	2.17
Standard Error	0.4	1.22
Sample Size	4	4
95 % C. I.	(-0.05, 0.20)	(-1.71, 6.07)
Crystal Forest		
Average	0.25	5.18
Standard Error	0.10	1.60
Sample Size	4	4
95 % C. I.	(-0.06, 0.56)	(0.08, 10.28)
Giant Logs		
Average	0.09	0.84
Standard Error	0.02	0.26
Sample Size	3	3
95 % C. I.	(-0.006, 0.18)	(-0.28, 1.96)
Jasper Forest		
Average	0.52	9.09
Standard Error	0.26	2.37
Sample Size	4	4
95 % C. I.	(-0.23, 1.27)	(1.56, 16.64)
Long Logs		
Average	0.19	4.15
Standard Error	0.22	3.94
Sample Size	4	4
95 % C. I.	(-0.50, 0.89)	(-8.39, 16.70)

Size Class 0 = intersection length $\leq .25''$

Size Class 1 = $.25'' < \text{intersection length} < 1''$

Table 22. 1994 Trail Percent Cover Quadrat Data Summary at Petrified Forest National Park

Blue Mesa		
	Size Class 0	Size Class 1
Average	0.19	5.63
Standard Error	0.14	2.74
Sample Size	4	4
95 % C. I.	(-0.24, 0.63)	(-3.13, 14.39)
Crystal Forest		
Average	0.21	3.88
Standard Error	0.14	2.12
Sample Size	4	4
95 % C. I.	(-0.22, 0.64)	(-2.87, 10.63)
Giant Logs		
Average	0.08	1.46
Standard Error	0.05	0.66
Sample Size	3	3
95 % C. I.	(-0.16, 0.32)	(-1.40, 4.32)
Jasper Forest		
Average	0.17	1.37
Standard Error	0.12	0.80
Sample Size	4	4
95 % C. I.	(-0.19, 0.54)	(-1.17, 3.91)
Long Logs		
Average	0.65	7.75
Standard Error	1.11	10.05
Sample Size	4	4
95 % C. I.	(-2.89, 4.19)	(-24.24, 39.74)

Size Class 0 = intersection length $\leq .25''$

Size Class 1 = $.25'' < \text{intersection length} < 1''$

Total Percent Cover Summary

To achieve a total estimate of percent cover for each stratum, the backcountry and trail total amounts were added together. The variance of these totals was estimated by using Equation 5 and confidence intervals were calculated using Equation 6. As an example, Table 23 lists trail and backcountry totals for Jasper Forest 1993 line intersect percent cover, size class 2.

Table 23. Trail and Backcountry Percent Cover Line Intersect Total Estimates for Jasper Forest size Class 2

Sampling Type	Total	Variance
Trail	1.03	0.06
Backcountry	3.25	1.23

The total 1993 line intersect percent cover estimate for Jasper Forest size class 2 would be:

$$3.25 + 1.03 = 4.28.$$

Using Equation 5 to estimate the variance of the above total would suggest:

$$\hat{VAR}(1993\% Cov) = 0.06 + 1.23 = 1.29.$$

Similar methods were used to calculate totals for all strata in each size class. Tables 24 and 25 summarize line intersect total estimates for 1993 and 1994 respectively. Tables 26 and 27 summarize quadrat total estimates for 1993 and 1994 respectively.

The difference in percent cover estimates was calculated (1993 - 1994) for each size class in each stratum. Figures 12 and 13 depict these

relationships for line intersect and quadrat data respectively. Note that a negative number indicates a gain in percent cover, while a positive number suggests a loss.

Table 24. Total Line Intersect Percent Cover Estimates for 1993 Inventory at Petrified Forest National Park

Blue Mesa			
	Size Class 1	Size Class 2	Size Class 3
Total	6.61	7.73	4.55
Standard Error	1.24	3.72	1.72
Sample Size	24	24	24
95% C. I..	(4.05, 9.17)	(0.04, 15.42)	(0.99, 8.11)
Crystal Forest			
Total	7.71	5.91	3.64
Standard Error	1.86	2.11	1.02
Sample Size	24	24	24
95% C. I..	(3.86, 11.56)	(1.55, 10.27)	(1.52, 5.76)
Giant Logs			
Total	4.52	5.33	6.27
Standard Error	2.03	2.04	1.91
Sample Size	23	23	23
95% C. I..	(0.31, 8.73)	(1.11, 9.55)	(2.33, 10.21)
Jasper Forest			
Total	13.75	4.28	7.77
Standard Error	2.29	1.14	1.39
Sample Size	24	24	24
95% C. I..	(9.01, 18.49)	(1.93, 6.63)	(4.89, 10.65)
Long Logs			
Total	6.15	5.94	9.82
Standard Error	1.87	2.70	2.60
Sample Size	24	24	24
95% C. I..	(2.28, 10.02)	(0.35, 11.53)	(4.44, 15.20)

Size Class 1 = $.25'' \leq \text{intersection length} < 1''$

Size Class 2 = $1'' \leq \text{intersection length} < 5''$

Size Class 3 = $5'' \leq \text{intersection length}$

Table 25. Total Line Intersect Percent Cover Estimates for 1994 Inventory at Petrified Forest National Park

Blue Mesa			
	Size Class 1	Size Class 2	Size Class 3
Total	7.16	7.73	4.31
Standard Error	1.30	2.00	1.65
Sample Size	24	24	24
95% C. I..	(4.46, 9.86)	(3.59, 11.87)	(0.90, 7.72)
Crystal Forest			
Total	7.50	5.91	3.64
Standard Error	1.81	2.11	1.02
Sample Size	24	24	24
95% C. I..	(3.76, 11.24)	(1.55, 10.27)	(1.52, 5.76)
Giant Logs			
Total	3.69	5.33	6.27
Standard Error	1.26	2.04	1.91
Sample Size	23	23	23
95% C. I..	(1.09, 6.29)	(1.11, 9.55)	(2.33, 10.21)
Jasper Forest			
Total	13.32	4.36	7.77
Standard Error	2.21	1.17	1.39
Sample Size	24	24	24
95% C. I..	(8.76, 17.88)	(1.94, 6.78)	(4.89, 10.65)
Long Logs			
Total	6.15	5.94	9.66
Standard Error	1.87	2.70	2.69
Sample Size	24	24	24
95% C. I..	(2.28, 10.02)	(0.35, 11.53)	(4.10, 15.22)

Size Class 1 = $.25'' \leq \text{intersection length} < 1''$

Size Class 2 = $1'' \leq \text{intersection length} < 5''$

Size Class 3 = $5'' \leq \text{intersection length}$

Table 26. Total Quadrat Percent Cover Estimates for 1993 Inventory at Petrified Forest National Park

Blue Mesa		
	Size Class 0	Size Class 1
Total	0.32	5.43
Standard Error	0.43	2.00
Sample Size	24	24
95 % C. I.	(-0.57, 1.21)	(1.28, 9.58)
Crystal Forest		
Total	0.56	12.05
Standard Error	0.14	2.69
Sample Size	24	24
95 % C. I.	(0.27, 0.85)	(6.49, 17.61)
Giant Logs		
Total	0.20	4.66
Standard Error	0.04	1.65
Sample Size	23	23
95 % C. I.	(0.11, 0.29)	(1.24, 8.08)
Jasper Forest		
Total	0.81	14.02
Standard Error	0.34	3.27
Sample Size	24	24
95 % C. I.	(0.11, 1.51)	(7.24, 20.80)
Long Logs		
Total	0.28	7.94
Standard Error	0.26	4.34
Sample Size	24	24
95 % C. I.	(-0.25, 0.81)	(-1.05, 16.93)

Size Class 0 = intersection length $\leq .25''$

Size Class 1 = $.25'' < \text{intersection length} < 1''$

Table 27. Total Quadrat Percent Cover Estimates for 1994 Inventory at Petrified Forest National Park

Blue Mesa		
	Size Class 0	Size Class 1
Total	0.38	7.76
Standard Error	0.21	2.98
Sample Size	24	24
95 % C. I.	(-0.06, 0.82)	(1.60, 13.92)
Crystal Forest		
Total	0.47	9.46
Standard Error	0.21	2.68
Sample Size	24	24
95 % C. I.	(0.03, 0.91)	(3.91, 15.01)
Giant Logs		
Total	0.12	4.84
Standard Error	0.05	1.68
Sample Size	23	23
95 % C. I.	(0.01, 0.23)	(1.35, 8.33)
Jasper Forest		
Total	0.21	3.02
Standard Error	0.12	1.74
Sample Size	24	24
95 % C. I.	(-0.04, 0.46)	(-0.59, 6.63)
Long Logs		
Total	0.72	11.35
Standard Error	1.11	10.12
Sample Size	24	24
95 % C. I.	(-1.58, 3.02)	(-9.59, 32.29)

Size Class 0 = intersection length $\leq .25''$

Size Class 1 = $.25'' < \text{intersection length} < 1''$

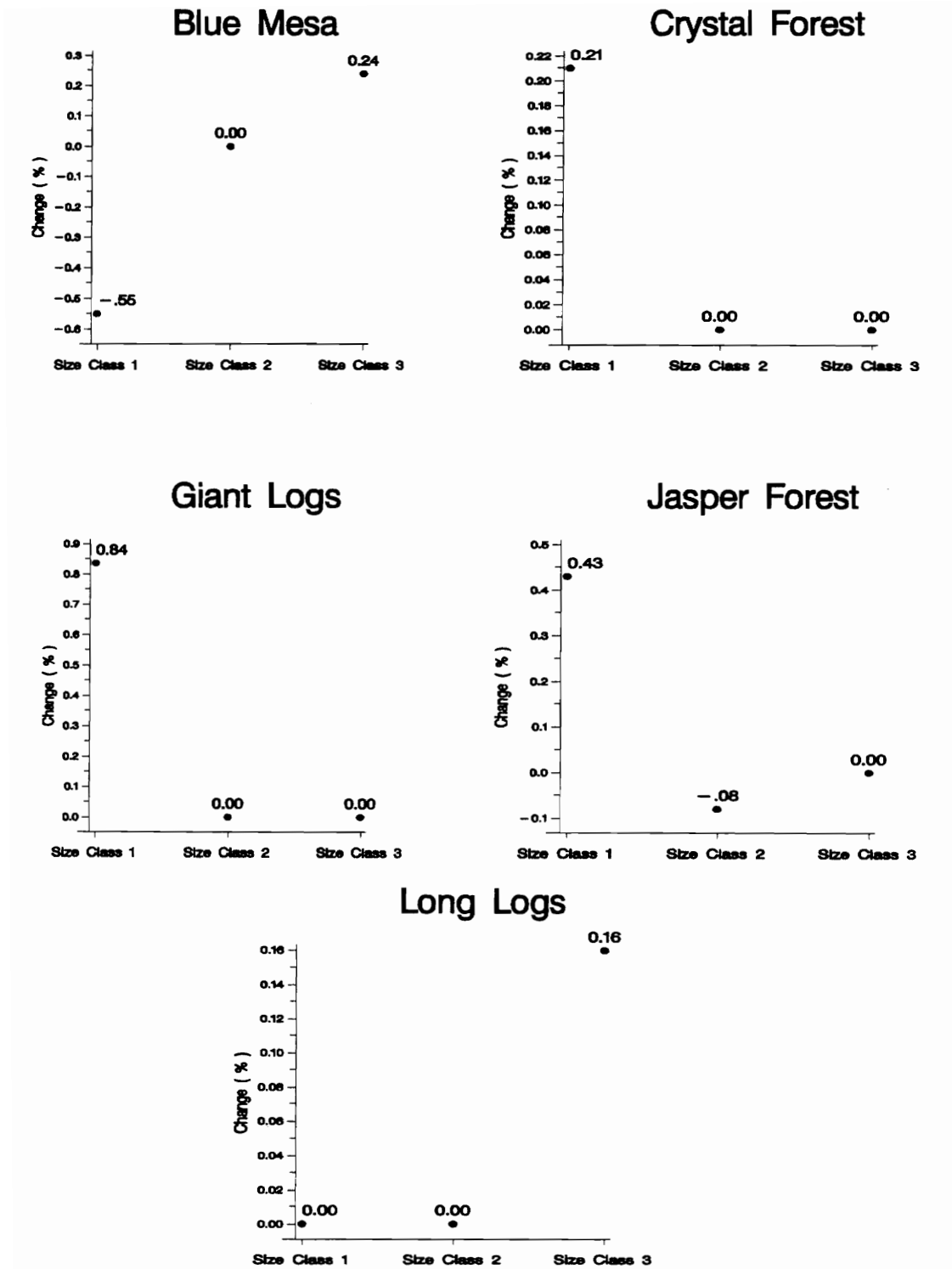


Figure 12. Overall Change in Percent Cover as Estimated From Line Intersect Data

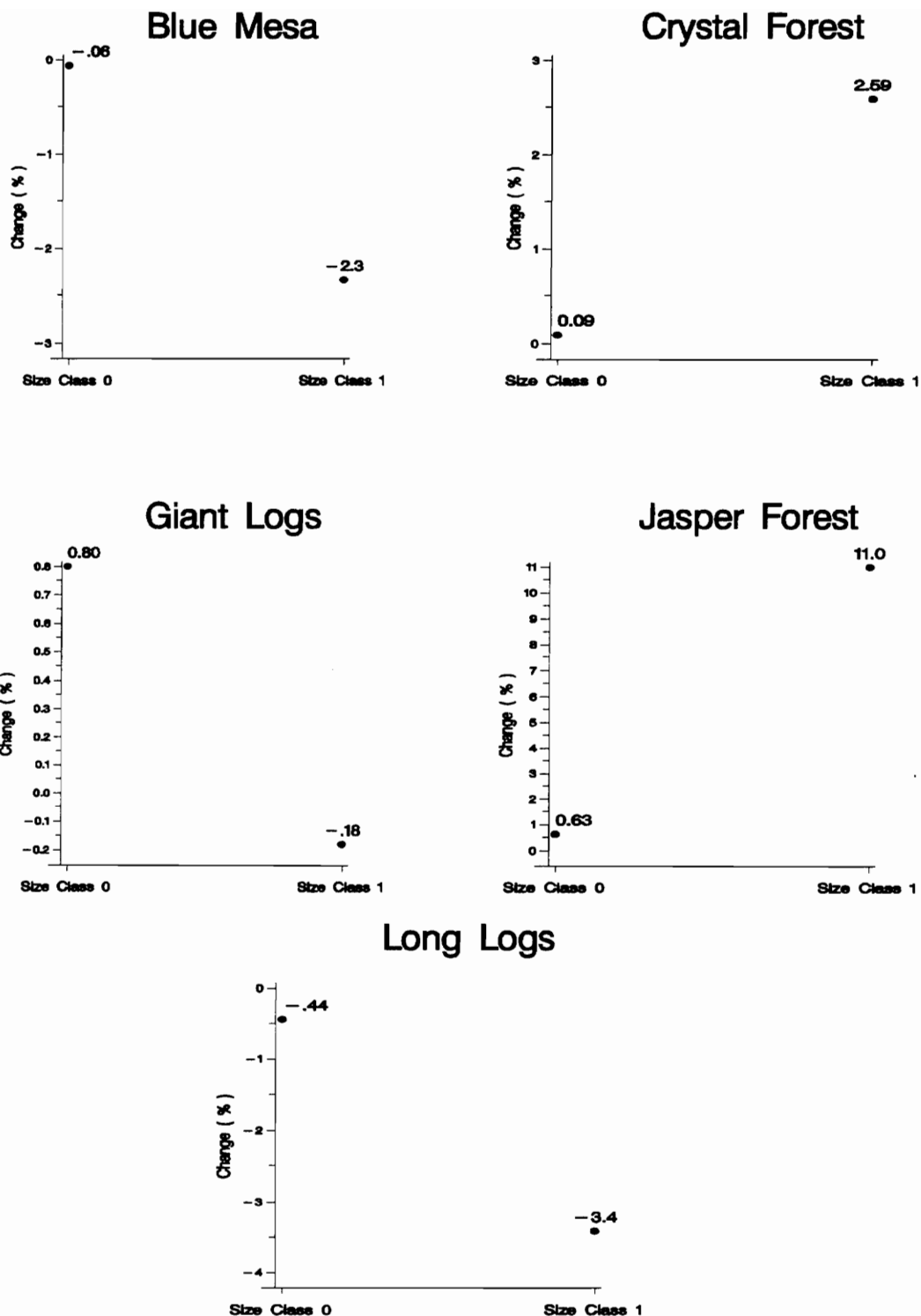


Figure 13. Overall Change in Percent Cover as Estimated From Quadrat Data

Chapter 5

Density Results

Introduction

This chapter describes the detailed steps taken to arrive at total and variance estimates of density (number of petrified wood particles) for both line intersect and quadrat sampled data at the Petrified Forest National Park. Most of the calculations in this chapter can be duplicated using the data summarized in Appendix A. However, calculations rendering the data displayed in Appendix A may not be performed because the raw data were too numerous to report. Throughout this chapter, all density data for the 1993 and 1994 inventories is summarized and graphic representations of change is available.

Line Intersect Density Estimator

Figure 8, estimator 3 (Methods Section) is the density per acre estimator used to calculate density of petrified wood particles for each line transect. The estimator may be expressed for a single line transect as

$$\frac{43560\pi}{L} \sum_{i=1}^n \frac{1}{c_i} \quad [8]$$

where: L = line transect length

n = i^{th} sampled particle along the line transect

c_i = horizontal circumference of i^{th} particle.

As an example, the horizontal circumference 1993 data collected at the Petrified Forest National Park for size class 2 ($sc2 = 1''$ to $5''$ in intersection length), line 3 at Giant Logs are listed below in Table 28.

Table 28. 1993 Horizontal Circumference Line Intersect Data for Giant Logs, Line 3, Size Class 2.

Line Number	Horizontal Circumference in feet
3	0.58
3	0.67
3	0.25
3	0.62

Using Equation 8 to arrive at a total density per acre estimate for Giant Logs line 3, the reciprocal of the horizontal circumference measurements would be summed, then multiplied by 43560π and finally divided by the length of the line (8 feet):

$$\frac{43560 \times 3.14}{8} \left[\frac{1}{0.58} + \frac{1}{0.67} + \frac{1}{0.25} + \frac{1}{0.62} \right] = 150962.$$

The 1993 density per acre estimate for Giant Logs line transect 3 is 150962 particles per acre. This estimate must now be multiplied by the total

acreage sampled in this stratum. Line transect 3 in Giant Logs is a trail, corridor 3 sample. From Table 2 the total acreage sampled for Giant Logs trail corridor 3 is .66 acres. The total line transect estimate for Giant Logs is:

$$150962 \times 0.66 = 99635 .$$

Identical methods were used to derive individual line transect totals for all lines in all strata for both backcountry and trail samples

Quadrat Density Estimator

Figure 9, estimator 4 (Methods Section) is the density estimator used to calculate the number of petrified wood particle per acre for each quadrat. The estimator may be expressed for a single quadrat as:

$$10036 \times cnt_i \quad [9]$$

where: cnt_i = number of particles in i^{th} quadrat.

As an example, the 1993 Giant Logs line 3 count of petrified wood particles in size class 1 was 27. To express the 27 particles on a per acre basis, Equation 9 was used as follows:

$$10036 \times 27 = 270972 .$$

The quadrat estimate must be multiplied by the total acreage sampled to achieve a total for the quadrat sampled. Using the appropriate value from Table 2, the calculation is:

$270972 \times 0.66 = 178842 .$

Identical methodology was used derive density estimates for both quadrat size classes for all strata.

Backcountry Total and Variance Estimation

To arrive at total density estimates for backcountry sampling units, individual line transect and quadrat estimates were calculated (Equation 8 and 9 respectively) and averaged. The averages were then multiplied by the backcountry area sampled. Table 29 lists the 1993 backcountry line intersect density per acre estimates for Giant Logs, size class 2 collected at the Petrified Forest National Park as an example. Note that I have reported the per acre estimates and not the total estimates.

Table 29. 1993 Backcountry Density Data for the Giant Logs Stratum, Size Class 2 at the Petrified Forest National Park

Line #	Density / Acre	Line #	Density / Acre
16	20599	26	0
17	29478	27	31662
18	43314	28	0
19	0	29	56604
20	0	30	165650
21	390623	31	0
22	0	32	0
23	0	33	0
24	0	34	0
25	0	35	0

To arrive at a total line intersect density estimate for Giant Logs size class 2, the data in Table 29 would be manipulated the following way:

$$75.68 \left[\frac{20599 + 29478 + \dots + 0 + 0}{20} \right] = 2,792,327.$$

To estimate the variance for the total line intersect density estimate above, the De Vries Equation 3 was used. Using the data in Table 29, Equation 3, and multiplying by the total acreage sampled the calculation becomes:

$$\begin{aligned} & 75.68^2 [(20599 - 36897)^2 \\ & + (29478 - 36897)^2 \\ & + . \\ & + . \\ & + (0 - 36897)^2 \\ & + (0 - 36897)^2] \\ & 9.174 \times 10^{14}, \end{aligned}$$

dividing by the sample size yields:

$$\hat{VAR}(Den_{sc2}) = \frac{9.174 \times 10^{14}}{(19)20} = 2.412 \times 10^{12}.$$

To affix a level of confidence to backcountry density estimates, Equation 6 was used. A two sided 95 percent confidence interval assuming normality for the Giant Logs size class 2 density estimate is:

$$2,792,327 \pm t_{(19),.975} \times \sqrt{2.412 \times 10^{14}}$$

$$2,792,327 \pm 2.093 \times 1,553,773$$

$$2,792,327 \pm 3,252,047$$

$$(-459,720, 6,044,374) .$$

Similar methods were used to estimate variance and confidence intervals for the remainder of the backcountry density size class estimates across all strata for both line intersect and quadrat samples.

Summary of Backcountry Density Estimates

No petrified wood was missing or added in the line intersect backcountry sampling units, therefore the 1993 and 1994 backcountry line intersect estimates are identical. Table 30 summarizes the backcountry line intersect density data for all five strata.

The quadrat samples are not identical between 1993 and 1994. Recall that the quadrat sampling were two distinct samples during each inventory (Figure 6). Tables 31 and 32 summarize the backcountry quadrat density data for each stratum for 1993 and 1994 inventories respectively.

Table 30. 1993 and 1994 Backcountry Density Line Intersect Data Summary at Petrified Forest National Park

Blue Mesa			
	Size Class 1	Size Class 2	Size Class 3
Average	43,925,988	2,650,321	131,533
Standard Error	26,618,987	903,988	59,308
Sample Size	20	20	20
95% C. I.	(-11,787,552, 99,639,528)	(758,274, 4,542,368)	(7401, 255,665)
Crystal Forest			
Average	30,414,891	3,147,322	49,139
Standard Error	17,292,255	997,053	13,712
Sample Size	20	20	20
95% C. I.	(-5,777,796, 66,607,581)	(1,060,490, 5,234,154)	(20,314, 77,964)
Giant Logs			
Average	25,445,728	2,792,331	36,365
Standard Error	10,317,733	1,553,772	15,682
Sample Size	20	20	20
95% C. I.	(2,573,723, 48,317,733)	(-459,712, 6,044,376)	(3,542, 69,189)
Jasper Forest			
Average	80,872,174	2,974,327	108,082
Standard Error	30,247,328	1,283,864	30,700
Sample Size	20	20	20
95% C. I.	(17,564,515, 144,179,834)	(287,199, 5,661,454)	(3,542, 69,189)
Long Logs			
Average	45,996,016	3,199,096	71,605
Standard Error	16,531,353	924,138	23,732
Sample Size	20	20	20
95% C. I.	(11,395,893, 80,596,138)	(1,264,876, 5,133,316)	(21,935, 121,276)

Size Class 1 = $.25'' \leq \text{intersection length} < 1''$

Size Class 2 = $1'' \leq \text{intersection length} < 5''$

Size Class 3 = $5'' \leq \text{intersection length}$

Table 31. 1993 Backcountry Density Quadrat Data Summary at Petrified Forest National Park

Blue Mesa		
	Size Class 0	Size Class 1
Average	25,576,043	37,488,173
Standard Error	17,061,180	14,740,383
Sample Size	20	20
95% Confidence Int.	(-10,133,005 61,285,092)	(6,636,553 68,339,794)
Crystal Forest		
Average	16,077,521	55,791,820
Standard Error	5,590,908	16,381,473
Sample Size	20	20
95% Confidence Int.	(4,375,751, 27,779,292)	(21,505,397, 90,078,243)
Giant Logs		
Average	7,101,554	35,545,746
Standard Error	2,825,420	13,395,675
Sample Size	20	20
95% Confidence Int.	(1,187,950, 13,015,157)	(7,508,598, 63,582,893)
Jasper Forest		
Average	21,914,068	56,727,225
Standard Error	16,134,194	31,089,556
Sample Size	20	20
95% Confidence Int.	(-11,854,800, 55,682,936)	(-8,343,216, 1.22x10 ⁸)
Long Logs		
Average	7,944,979	47,353,882
Standard Error	2,592,462	16,404,993
Sample Size	20	20
95% Confidence Int.	(2,518,957, 13,371,002)	(13,018,232, 81,689,533)

Size Class 0 = intersection length $\leq .25''$

Size Class 1 = $.25'' < \text{intersection length} < 1''$

Table 32. 1994 Backcountry Density Quadrat Data Summary at Petrified Forest National Park

Blue Mesa		
	Size Class 0	Size Class 1
Average	12,472,700	35,526,175
Standard Error	8,854,593	22,663,397
Sample Size	20	20
95% Confidence Int.	(-6,059,963, 31,005,364)	(-11,908,316, 82,960,667)
Crystal Forest		
Average	8,631,090	43,099,039
Standard Error	4,594,659	13,214,757
Sample Size	20	20
95% Confidence Int.	(-985,532, 18,247,713)	(15,440,551, 70,757,528)
Giant Logs		
Average	2,354,526	41,735,870
Standard Error	794,497	18,723,186
Sample Size	20	20
95% Confidence Int.	(691,643, 4,017,407)	(2,548,240, 80,923,499)
Jasper Forest		
Average	2,810,320	17,588,732
Standard Error	851,845	6,333,057
Sample Size	20	20
95% Confidence Int.	(1,027,408, 4,593,233)	(4,333,642, 30,843,822)
Long Logs		
Average	4,559,334	42,207,703
Standard Error	1,408,567	14,044,089
Sample Size	20	20
95% Confidence Int.	(1,611,204, 7,507,465)	(12,813,424, 71,601,981)

Size Class 0 = intersection length $\leq .25''$

Size Class 1 = $.25'' < \text{intersection length} < 1''$

Trail Corridor Average and Variance Estimation

The trail sampling density estimates were broken down differently than were the backcountry estimates. Again, this is due to the fact that these sampling units represent the displacement of petrified wood. First, individual corridor averages were calculated. Recall that corridor 1 is 0 to 15 feet on both sides of the trail, corridor 2 is 15 to 30 feet on both sides of the trail and corridor 3 is 30 to 45 feet on both sides of the trail. Second, the corridor values were averaged to show overall petrified wood density displacement for a given strata. As an example of how the density trail calculations were done, Table 33 lists Long Logs quadrat data for size class 0, collected at the Petrified Forest National Park during the 1993 inventory. A reminder that trail sampling units not found during the 1994 inventory were not used, even though there is data from the 1993 inventory.

Table 33. Trail Quadrat Density Data for the Long Logs Stratum, Size Class 0 at the Petrified Forest National Park

line number	corridor #	density / acre
1	1	missing 94
1	2	missing 94
1	3	missing 94
2	1	1164176
2	2	80288
2	3	50180
3	1	30108
3	2	0
3	3	100360
4	1	0
4	2	160576
4	3	60216
5	1	missing 94
5	2	70252
5	3	missing 94

To arrive at corridor averages, the individual corridor values were simply averaged and multiplied by the acreage sampled in each corridor as follows:

$$\text{Corridor 1:} \quad 1.68 \times \left[\frac{1,164,176 + 30,108 + 0}{3} \right] = 668,799$$

$$\text{Corridor 2:} \quad 1.83 \times \left[\frac{80,288 + 0 + 160,576 + 70,252}{4} \right] = 142,336$$

$$\text{Corridor 3:} \quad 2.42 \times \left[\frac{50,180 + 100,360 + 60,216}{3} \right] = 170,010 .$$

The variances for these individual corridor estimates were calculated using Equation 3. Note that I have chosen to calculate the variance on a per acre

basis and then multiply by the square of corridor acreage sampled. For example, for the Corridor 1 density estimate, the calculation for variance is:

$$\frac{168^2}{2(3)} [(1,164,176 - 398,095)^2 + (30,108 - 398,095)^2 + (0 - 398,095)^2] = 414,316.164,749.$$

To affix a level of confidence to corridor estimates, Equation 6 was used with $\alpha = .05$ and the appropriate degrees of freedom for each corridor.

Summary of Trail Corridor Density Estimates

Tables 34, 35, 36, 37, 38, and 39 summarize the line intersect density data by corridors and petrified wood size classes for the 1993 and 1994 inventories. Tables 40, 41, 42, and 43 summarize the quadrat density data by size classes and corridors for the 1993 and 1994 inventories.

The density change of petrified wood was calculated (1993 estimate - 1994 estimate) for each corridor in each stratum. The following figures displays the density change of petrified wood by corridors for each size class. Note that a negative number suggests an increase in petrified wood density while a positive number indicates loss. Figure 14 depicts the relationship between petrified wood density change and trail corridors for line intersect data in each stratum. Figure 15 depicts the relationship

between trail corridors and petrified wood change for the quadrat data in each stratum.

Table 34. 1993 Size Class 1 Density Line Intersect Trail Corridor Data Collected at the Petrified Forest National Park

Blue Mesa			
	Corridor 1	Corridor 2	Corridor 3
Average	408,630	512,910	2,244,304
Standard Err.	248,548	377,679	930,409
n	3	4	4
95 % C.I.	(-660,971, 1,478,132)	(-688,865, 1,714,685)	(-716,259, 5,204,869)
Crystal Forest			
Average	1,845,478	1,862,170	995,436
Standard Err.	1,845,478	213,406	518,076
n	2	4	3
95 % C.I.	(-21,603,163, 25,294,119)	(1,183,111, 2,541,229)	(-1,233,849, 3,224,721)
Giant Logs			
Average	264,643	0	58,722
Standard Err.	undefined	0	58,722
n	1	3	3
95 % C.I.	N/A	N/A	(-193,961, 311,405)
Jasper Forest			
Average	1,088,153	2,331,773	2,424,415,
Standard Err.	286,919	877,598	909,531
n	4	3	4
95 % C.I.	(175,175, 2,001,129)	(-1,444,531, 6,108,079)	(469,712, 5,318,544)
Long Logs			
Average	430,490	520,905	1,627,209
Standard Err.	430,490	520,905	684,885
n	3	4	3
95 % C.I.	(-1,421,908, 2,282,888)	(-1,136,615, 2,178,425)	(-1,319,851, 4,574,269)

Size Class 1 = .25" ≤ intersection length < 1"

Table 35. 1994 Size Class 1 Density Line Intersect Trail Corridor Data Collected at the Petrified Forest National Park

Blue Mesa			
	Corridor 1	Corridor 2	Corridor 3
Average	408,630	722,046	2,244,304
Standard Err.	248,548	581,332	930,409
n	3	4	4
95 % C.I.	(-660,971, 1,478,132)	(-1,127,752 2,571,844)	(-716,259, 5,204,869)
Crystal Forest			
Average	1,845,478	1,516,410	995,436
Standard Err.	1,845,478	318,209	518,076
n	2	4	3
95 % C.I.	(-21,603,163, 25,294,119)	(503,866, 2,528,954)	(-1,233,849, 3,224,721)
Giant Logs			
Average	264,643	0	58,722
Standard Err.	undefined	0	58,722
n	1	3	3
95 % C.I.	N/A	N/A	(-193,961, 311,405)
Jasper Forest			
Average	954,446	1,930,946	2,424,415,
Standard Err.	298,557	859,819	909,531
n	4	3	4
95 % C.I.	(4,437, 1,904,455)	(-1,768,859, 5,630,751)	(469,712, 5,318,544)
Long Logs			
Average	430,490	520,905	1,627,209
Standard Err.	430,490	520,905	684,885
n	3	4	3
95 % C.I.	(-1,421,908, 2,282,888)	(-1,136,615, 2,178,425)	(-1,319,851, 4,574,269)

Size Class 1 = .25" ≤ intersection length < 1"

Table 36. 1993 Size Class 2 Density Line Intersect Trail Corridor Data Collected at the Petrified Forest National Park

Blue Mesa			
	Corridor 1	Corridor 2	Corridor 3
Average	88.136	96,685	29,106
Standard Err.	5,601	71,543	18,364
n	3	4	4
95 % C.I.	(64,031, 112,241)	(-130,964, 324,336)	(-29,329, 87,541)
Crystal Forest			
Average	12,248	40,479	148,453
Standard Err.	12,248	26,280	94,113
n	2	4	3
95 % C.I.	(-143,384, 167,882)	(-43,144, 124,104)	(-256,517, 553,424)
Giant Logs			
Average	940	7,467	33,211
Standard Err.	undefined	7,467	33,211
n	1	3	3
95 % C.I.	N/A	(-24,666, 39,601)	(-109,698, 176,121)
Jasper Forest			
Average	13,581	0	23,196
Standard Err.	12,780	0	15,472
n	4	3	4
95 % C.I.	(-27,086, 54,250)	N/A	(-26,037, 72,428)
Long Logs			
Average	62,995	49,160	32,837
Standard Err.	48,234	31,914	32,837
n	3	4	3
95 % C.I.	(-144,556, 270,547)	(-52,390, 150,711)	(-108,462, 174,138)

Size Class 2 = $1'' \leq \text{intersection length} < 5''$

Table 37. 1994 Size Class 2 Density Line Intersect Trail Corridor Data Collected at the Petrified Forest National Park

Blue Mesa			
	Corridor 1	Corridor 2	Corridor 3
Average	88.136	96,685	29,106
Standard Err.	5,601	71,543	18,364
n	3	4	4
95 % C.I.	(64,031, 112,241)	(-130,964, 324,336)	(-29,329, 87,541)
Crystal Forest			
Average	12,248	40,479	148,453
Standard Err.	12,248	26,280	94,113
n	2	4	3
95 % C.I.	(-143,384, 167,882)	(-43,144, 124,104)	(-256,517, 553,424)
Giant Logs			
Average	940	7,467	33,211
Standard Err.	undefined	7,467	33,211
n	1	3	3
95 % C.I.	N/A	(-24,666, 39,601)	(-109,698, 176,121)
Jasper Forest			
Average	13,989	0	16,343
Standard Err.	12,668	0	16,343
n	4	3	4
95 % C.I.	(26,321, 54,300)	N/A	(-35,660, 68,347)
Long Logs			
Average	62,995	49,160	32,837
Standard Err.	48,234	31,914	32,837
n	3	4	3
95 % C.I.	(-144,556, 270,547)	(-52,390, 150,711)	(-108,462, 174,138)

Size Class 2 = $1'' \leq \text{intersection length} < 5''$

Table 38. 1993 Size Class 3 Density Line Intersect Trail Corridor Data Collected at the Petrified Forest National Park

Blue Mesa			
	Corridor 1	Corridor 2	Corridor 3
Average	806	7,691	2,407
Standard Err.	806	4,102	2,408
n	3	4	4
95 % C.I.	(-2,661, 4,272)	(-5,361, 20,745)	(-5,253, 10,069)
Crystal Forest			
Average	0	1,406	0
Standard Err.	0	948	0
n	2	4	3
95 % C.I.	N/A	(-1,612, 4,425)	N/A
Giant Logs			
Average	555	0	2,585
Standard Err.	undefined	0	2,134
n	1	3	3
95 % C.I.	N/A	N/A	(-6,598, 11,768)
Jasper Forest			
Average	1,315	1,372	1,212
Standard Err.	1,315	407	1,048
n	4	3	4
95 % C.I.	(-2,870, 5,502)	(-382, 3,128)	(-2,123, 4,547)
Long Logs			
Average	1,700	14,749	3,951
Standard Err.	900	5,808	3,951
n	3	4	3
95 % C.I.	(-2,173, 5,575)	(-3,733, 33,231)	(-13,052, 20,955)

Size Class 3 = $5'' \leq$ intersection length

Table 39. 1994 Size Class 3 Density Line Intersect Trail Corridor Data Collected at the Petrified Forest National Park

Blue Mesa			
	Corridor 1	Corridor 2	Corridor 3
Average	806	7,691	1,367
Standard Err.	806	4,102	1,367
n	3	4	4
95 % C.I.	(-2,661, 4,272)	(-5,361, 20,745)	(-2,984, 5,720)
Crystal Forest			
Average	0	1,406	0
Standard Err.	0	948	0
n	2	4	3
95 % C.I.	N/A	(-1,612, 4,425)	N/A
Giant Logs			
Average	555	0	2,585
Standard Err.	undefined	0	2,134
n	1	3	3
95 % C.I.	N/A	N/A	(-6,598, 11,768)
Jasper Forest			
Average	1,315	1,372	1,212
Standard Err.	1,315	407	1,048
n	4	3	4
95 % C.I.	(-2,870, 5,502)	(-382, 3,128)	(-2,123, 4,547)
Long Logs			
Average	1,700	13,748	3,951
Standard Err.	900	6,185	3,951
n	3	4	3
95 % C.I.	(-2,173, 5,575)	(-5,933, 33,430)	(-13,052, 20,955)

Size Class 3 = $5'' \leq \text{intersection length}$

Table 40. 1993 Size Class 0 Density Quadrat Trail Corridor Data Collected at the Petrified Forest National Park

Blue Mesa			
	Corridor 1	Corridor 2	Corridor 3
Average	51,785	77,904	128,210
Standard Err.	51,785	73,457	109,547
n	3	4	4
95 % C.I.	(-171,048, 274,619)	(-155,837, 311,646)	(-220,370, 476,790)
Crystal Forest			
Average	592,525	56,703	191,787
Standard Err.	43,355	26,996	59,623
n	2	4	3
95 % C.I.	(41,650, 1,143,400)	(-29,198, 142,605)	(-64,770, 448,346)
Giant Logs			
Average	52,990	61,018	66,238
Standard Err.	undefined	28,876	23,261
n	1	3	3
95 % C.I.	N/A	(-63,237, 185,275)	(-33,858, 166,333)
Jasper Forest			
Average	254,036	779,663	423,193
Standard Err.	115,745	435,452	242,792
n	4	3	4
95 % C.I.	(-114,265, 622,338)	(-1,094,089, 2,653,416)	(-349,373, 1,195,759)
Long Logs			
Average	668,799	142,335	170,010
Standard Err.	643,673	60,158	37,099
n	3	4	3
95 % C.I.	(-2,100,930, 3,438,528)	(-49,087, 333,758)	(10,372, 329,647)

Size Class 0 = intersection length $\leq .25''$

Table 41. 1994 Size Class 0 Density Quadrat Trail Corridor Data Collected at the Petrified Forest National Park

Blue Mesa			
	Corridor 1	Corridor 2	Corridor 3
Average	362,500	436,942	245,430
Standard Err.	260,649	217,086	83,826
n	3	4	4
95 % C.I.	(-759,073, 1,484,074)	(-253,825, 1,127,710)	(-21,305, 512,166)
Crystal Forest			
Average	269,767	538,682	93,435
Standard Err.	348,483	348,483	93,435
n	2	4	3
95 % C.I.	(-1,688,899, 2,228,435)	(-570,193, 1,647,557)	(-308,616, 495,486)
Giant Logs			
Average	176,634	12,712	52,990
Standard Err.	undefined	6,726	40,471
n	1	3	3
95 % C.I.	N/A	(-16,232, 41,657)	(-121,160, 227,140)
Jasper Forest			
Average	99,582	97,817	116,568
Standard Err.	64,384	89,325	116,568
n	4	3	4
95 % C.I.	(-105,288, 304,453)	(-286,550, 482,185)	(-254,351, 487,488)
Long Logs			
Average	101,162	647,397	153,818
Standard Err.	84,862	641,289	93,364
n	3	4	3
95 % C.I.	(-264,000 466,326)	(-1,393,187, 2,687,981)	(-247,927, 555,565)

Size Class 0 = intersection length $\leq .25''$

Table 42. 1993 Size Class 1 Density Quadrat Trail Corridor Data Collected at the Petrified Forest National Park

Blue Mesa			
	Corridor 1	Corridor 2	Corridor 3
Average	271,875	447,104	534,818
Standard Err.	162,218	148,004	379,767
n	3	4	4
95 % C.I.	(-46,072, 589,823)	(-23,846, 918,054)	(-673,600, 1,743,237)
Crystal Forest			
Average	1,478,905	1,071,694	998,280
Standard Err.	871,927	1,832,321	34,423
n	2	4	3
95 % C.I.	(-9,599,808, 12,557,618)	(-760,627, 2,904,016)	(850,156, 1,114,405)
Giant Logs			
Average	26,495	129,665	119,227
Standard Err.	undefined	48,440	30,354
n	1	3	3
95 % C.I.	N/A	(-78,773, 338,103)	(-11,385, 249,840)
Jasper Forest			
Average	414,587	2,134,724	1,677,567
Standard Err.	193,853	1,124,460	851,238
n	4	3	4
95 % C.I.	(-202,255, 1,031,430)	(-2,703,828, 6,973,276)	(-1,031,071, 4,386,206)
Long Logs			
Average	3,051,746	749,324	420,976
Standard Err.	2,570,453	1,329,301	119,257
n	3	4	3
95 % C.I.	(-8,008,916, 14,112,409)	(-534,976, 2,123,625)	(-92,187, 934,140)

Size Class 1 = .25" < intersection length < 1"

Table 43. 1994 Size Class 1 Density Quadrat Trail Corridor Data Collected at the Petrified Forest National Park

Blue Mesa			
	Corridor 1	Corridor 2	Corridor 3
Average	1,238,542	2,086,484	432,250
Standard Err.	1,096,946	2,610,836	181,291
n	3	4	4
95 % C.I.	(141,596, 2,335,488)	(-524,351, 4,697,320)	(-144,619, 1,009,120)
Crystal Forest			
Average	905,649	1,803,168	177,035
Standard Err.	712,957	1,033,496	111,382
n	2	4	3
95 % C.I.	(-8,153,188, 9,964,485)	(-1,475,417, 5,091,753)	(-302,242, 656,312)
Giant Logs			
Average	2654,950	81,358	340,019
Standard Err.	undefined	33,051	177,129
n	1	3	3
95 % C.I.	N/A	(-60,863, 223,580)	(-422,169, 1,102,208)
Jasper Forest			
Average	101,615	201,389	382,647
Standard Err.	45,322	180,242	352,700
n	4	3	4
95 % C.I.	(-42,600, 245,829)	(-574,195, 976,973)	(-739,643, 1,504,939)
Long Logs			
Average	887,985	1,946,783	882,432
Standard Err.	500,288	1,807,539	628,395
n	3	4	3
95 % C.I.	(-1,264,758, 3,040,728)	(-3,804,806, 7,698,372)	(-1,821,555, 3,586,419)

Size Class 1 = .25" < intersection length < 1"

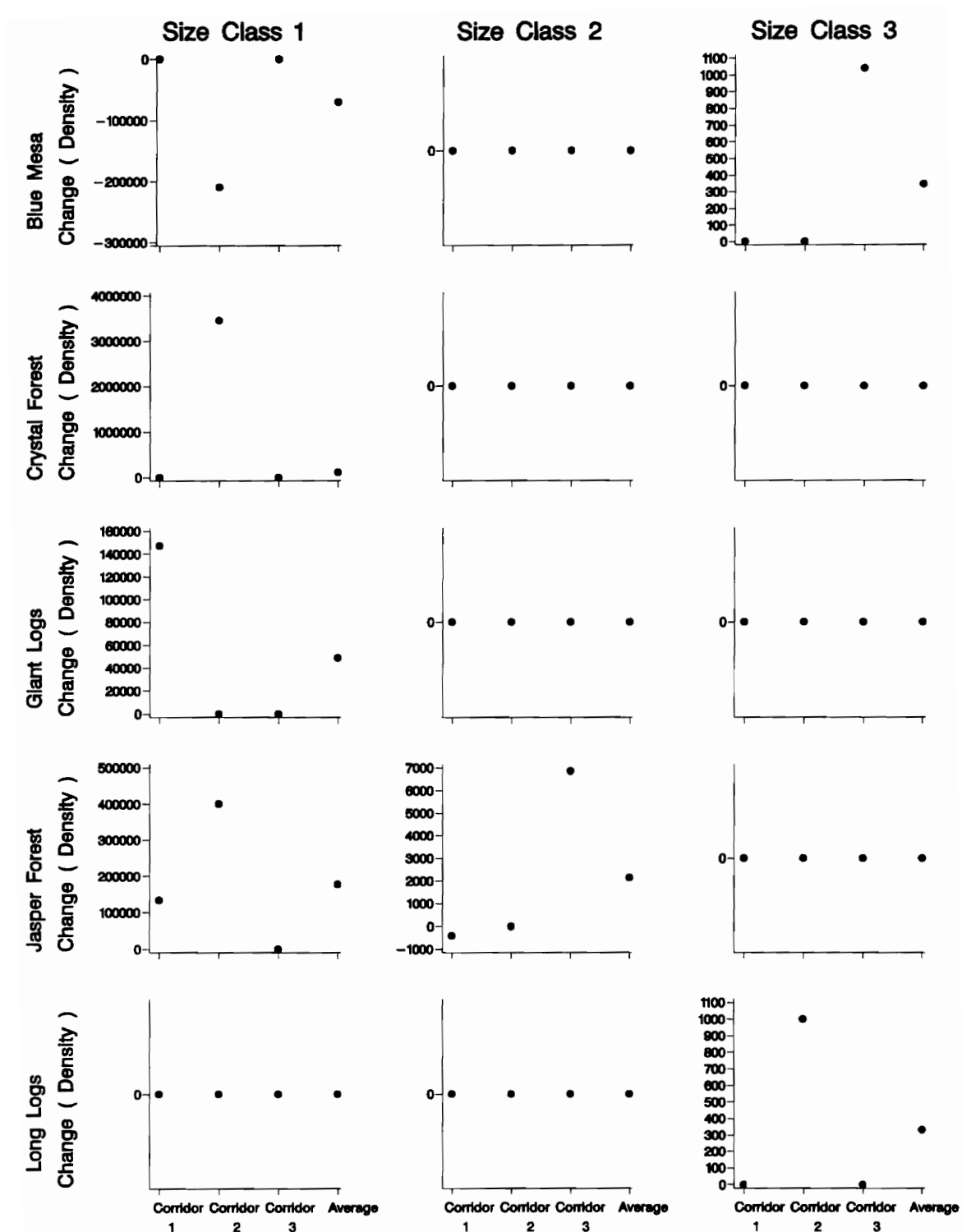


Figure 14. Change in Density in the Trail Strata As Estimated From Line Intersect Data

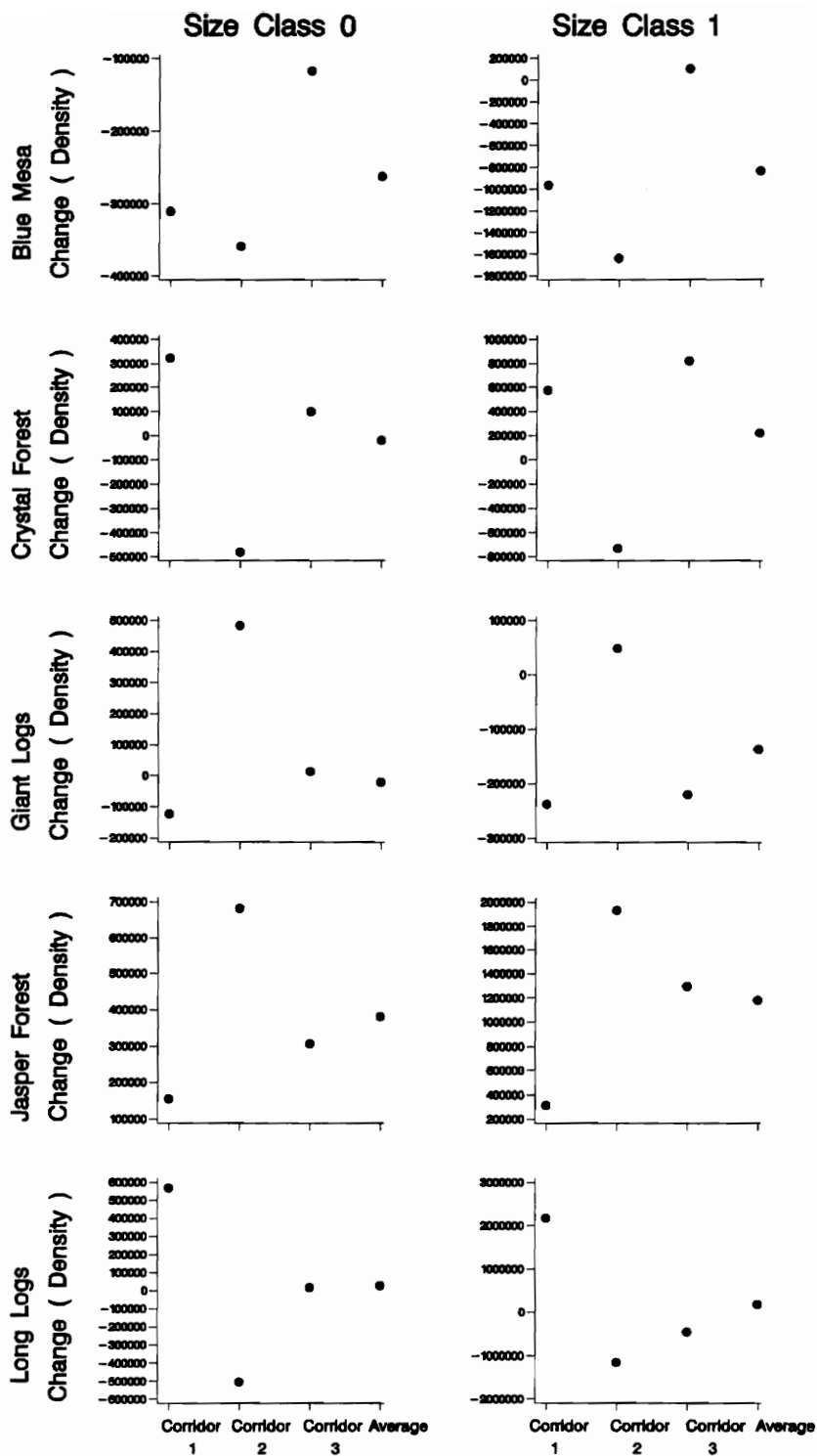


Figure 15. Change in Density in the Trail Strata As Estimated From Quadrat Data

Trail Total and Variance Estimation

Recall that each group of trail lines is dependent upon the location of the corridor 1 line transect. This dependency must be taken into account for trail total calculations. To arrive at a total estimate for the trail sampling units, the individual corridor estimates were averaged for each group and then averaged over the groups. For example, using the Long Logs Quadrat data (Table 33) and the corridor acreage (Table 2) the total calculation is:

$$\begin{aligned} & \frac{1}{4} \left[\frac{(1,164,176 \times 1.68) + (80,288 \times 1.83) + (51,180 \times 2.42)}{3} \right. \\ & + \frac{(30,108 \times 1.68) + (0 \times 1.83) + (100,360 \times 2.42)}{3} \\ & + \frac{(0 \times 1.68) + (160,576 \times 1.83) + (60,216 \times 2.42)}{3} \\ & \left. + \frac{(70,252 \times 1.83)}{1} \right] \\ & = 278,574 \end{aligned}$$

To estimate the variance of this estimate, Equation 4 was implemented. Again using the Long Logs size class 0 quadrat data (Table 33) and noting that some sampling units are missing from some groups, the calculation for trail variance is:

$$\left[\left(\frac{(1,164,176 \times 1.68) + (80,288 \times 1.83) + (51,180 \times 2.42)}{3} \right) - 278,574 \right]^2$$

$$\begin{aligned}
& + \left[\left(\frac{(30,108 \times 1.68) + (0 \times 1.83) + (100,360 \times 2.42)}{3} \right) - 278,574 \right]^2 \\
& + \left[\left(\frac{(0 \times 1.68) + (160,576 \times 1.83) + (60,216 \times 2.42)}{3} \right) - 278,574 \right]^2 \\
& + \left[\left(\frac{(70,252 \times 1.83)}{1} \right) - 278,574 \right]^2 \\
& = 287,525,930,844
\end{aligned}$$

Dividing by the sample size:

$$\hat{V}AR(Den_{sc1}) \equiv \frac{287,525,930,844}{3(4)} = 23,960,494,237 .$$

Recall that none of the three corridor line segments for the first sample in the Long Logs trail data were not available, thus these data could not be used in the calculation of total and variance. Also note that this decreased the sample size to 4. Note that only sampling units available from the trail data were used in the calculation. Recall that the covariance terms between the corridor sampling units were neglected. This renders the variance for trail sampling units approximate. Identical methods were used to calculate the variance estimates for the remainder of the strata and size classes for both line intersect and quadrat data.

To affix a level of confidence to these trail totals, Equation 6 was used with the appropriate degrees of freedom and $\alpha = .05$.

Summary of Trail Density Estimates

Tables 44 and 45 summarize the trail line intersect density total estimates for 1993 and 1994 respectively. Tables 46 and 47 summarize the trail quadrat density total estimates for 1993 and 1994 inventories respectively.

Table 44. 1993 Trail Density Line Intersect Data Summary at Petrified Forest National Park

Blue Mesa			
	Size Class 1	Size Class 2	Size Class 3
Average	1,146,888	68,697	3,687
Standard Error	300,831	22,587	1,752
n	4	4	4
95% C. I.	(189,643, 2,104,133)	(-3,176, 140,571)	(-169, 7,543)
Crystal Forest			
Average	1,497,940	75,804	536
Standard Error	327,175	29,606	327
n	4	4	4
95% C. I.	(456,876, 2,539,014)	(-18,402, 170,012)	(-205, 1,277)
Giant Logs			
Average	48,978	20,444	1,354
Standard Error	48,978	20,287	1,030
n	3	3	3
95% C. I.	(-161,177, 259,735)	(-66,835, 107,742)	(-3,081, 5,790)
Jasper Forest			
Average	1,916,429	14,983	1,189
Standard Error	417,432	6,792	909
n	4	4	4
95% C. I.	(588,157, 3,244,701)	(-6,631, 36,597)	(-1,703, 4,082)
Long Logs			
Average	1,035,329	62,689	10,790
Standard Error	381,407	29,003	5,551
n	4	4	4
95% C. I.	(-178,307, 2,248,967)	(-29,600, 154,979)	(-6875, 28,457)

Size Class 1 = $.25'' \leq \text{intersection length} < 1''$

Size Class 2 = $1'' \leq \text{intersection length} < 5''$

Size Class 3 = $5'' \leq \text{intersection length}$

Table 45. 1994 Trail Density Line Intersect Data Summary at Petrified Forest National Park

Blue Mesa			
	Size Class 1	Size Class 2	Size Class 3
Average	1,216,599	68,697	3,340
Standard Error	284,898	22,587	1,545
n	4	4	4
95% C. I.	(310,053, 2,123,146)	(-3,176, 140,571)	(-60, 6,742)
Crystal Forest			
Average	1,325,060	75,804	536
Standard Error	293,096	29,606	327
n	4	4	4
95% C. I.	(392,427, 2,257,693)	(-18,402, 170,012)	(-205, 1,277)
Giant Logs			
Average	32,623	20,444	1,354
Standard Error	17,868	20,287	1,030
n	3	3	3
95% C. I.	(-44,265, 109,512)	(-66,835, 107,742)	(-3,081, 5,790)
Jasper Forest			
Average	1,749,369	12,834	1,189
Standard Error	353,935	7,694	909
n	4	4	4
95% C. I.	(623,148, 2,875,590)	(-11,648, 37,318)	(-1,703, 4,082)
Long Logs			
Average	1,035,329	62,689	10,457
Standard Error	381,407	29,003	5,614
n	4	4	4
95% C. I.	(-178,307, 2,248,967)	(-29,600, 154,979)	(-7,409, 28,323)

Size Class 1 = $.25'' \leq \text{intersection length} < 1''$

Size Class 2 = $1'' \leq \text{intersection length} < 5''$

Size Class 3 = $5'' \leq \text{intersection length}$

Table 46. 1993 Trail Density Quadrat Data Summary at Petrified Forest National Park

Blue Mesa		
	Size Class 0	Size Class 1
Average	84,657	408,385
Standard Error	56,420	116,506
Sample Size	4	4
95 % C. I.	(-94,872, 264,188)	(37,662, 779,108)
Crystal Forest		
Average	213,210	1,040,616
Standard Error	45,506	366,914
Sample Size	4	4
95 % C. I.	(68,410, 358,011)	(-126,905, 2,208,137)
Giant Logs		
Average	57,327	114,667
Standard Error	18,482	41,284
Sample Size	3	3
95 % C. I.	(-22,203, 136,858)	(-62,981, 292,315)
Jasper Forest		
Average	431,058	1,276,851
Standard Error	225,423	617,058
Sample Size	4	4
95 % C. I.	(-286,238, 1,148,356)	(-686,627, 3,204,329)
Long Logs		
Average	287,574	1,172,748
Standard Error	154,600	675,095
Sample Size	4	4
95 % C. I.	(-213,363, 770,512)	(-975,405, 3,320,902)

Size Class 0 = intersection length $\leq .25''$

Size Class 1 = $.25'' < \text{intersection length} < 1''$

Table 47. 1994 Trail Density Quadrat Data Summary at Petrified Forest National Park

Blue Mesa		
	Size Class 0	Size Class 1
Average	336,457	1,229,589
Standard Error	88,668	374,693
Sample Size	4	4
95 % C. I.	(54,313, 618,600)	(37,313, 2,421,866)
Crystal Forest		
Average	280,105	1,008,279
Standard Error	163,844	544,507
Sample Size	4	4
95 % C. I.	(-241,249, 801,458)	(-714,344, 2,740,902)
Giant Logs		
Average	43,846	210,220
Standard Error	33,947	104,399
Sample Size	3	3
95 % C. I.	(-102,231, 189,923)	(-239,010, 659,451)
Jasper Forest		
Average	101,246	223,614
Standard Error	80,439	166,559
Sample Size	4	4
95 % C. I.	(-154,713, 357,206)	(-306,379, 753,608)
Long Logs		
Average	708,081	2,318,985
Standard Error	621,405	1,688,429
Sample Size	4	4
95 % C. I.	(-1,269,230, 2,685,393)	(-3,053,598, 7,691,568)

Size Class 0 = intersection length $\leq .25''$

Size Class 1 = $.25'' < \text{intersection length} < 1''$

Total Density Summary

To achieve a total estimate of density for each stratum, the backcountry and trail total amounts were added together. The variance of these totals was estimated by using Equation 5 and confidence intervals were calculated with Equation 6. As an example, Table 48 lists trail and backcountry totals for Crystal Forest 1993 line intersect density, size class 2.

Table 48. Trail and Backcountry Density Line Intersect Total Estimates for Crystal Forest Size Class 2

Sampling Type	Total	Variance
Trail	75,804	876,515,236
Backcountry	3,147,322	994,114,684,809

The 1993 line intersect density total for Crystal Forest size class 2 would be:

$$75,805 + 3,147,322 = 3,223,127.$$

The variance of the above estimate using Equation 5 is:

$$\hat{VAR}(1993\ Den) = 876,515,236 + 994,114,684,809 = 994,991,200,045 .$$

Similar methods were used to calculate totals for all strata in each size class. Tables 49 and 50 summarize line intersect density totals to 1993 and 1994 respectively. Tables 51 and 52 summarize quadrat density total estimates for 1993 and 1994 respectively.

The difference in density total estimates was calculated (1993 - 1994) for each size class in each stratum. Figure 16 and 17 depict these relationships for the line intersect and quadrat data respectively. Note that a negative number indicates a gain in density, while a positive number suggest a loss.

Table 49. Total Line Intersect Density Estimates for 1993 Inventory at Petrified Forest National Park

Blue Mesa			
	Size Class 1	Size Class 2	Size Class 3
Total	45,072,876	2,719,018	135,220
Standard Error	26,620,687	904,270	59,334
Sample Size	24	24	24
95 % C. I.	(-10,005,325, 100,151,077)	(848,083, 4,589,953)	(12,458, 257,982)
Crystal Forest			
Total	31,912,831	3,223,126	49,675
Standard Error	17,295,350	997,492	13,716
Sample Size	24	24	24
95 % C. I.	(-3,871,248, 67,696,910)	(1,159,314, 5,286,938)	(21,297, 78,053)
Giant Logs			
Total	25,494,706	2,812,775	37,719
Standard Error	10,317,849	1,553,904	15,716
Sample Size	23	23	23
95 % C. I.	(4,147,076, 46,842,336)	(-402,253, 6,027,803)	(5,203, 70,235)
Jasper Forest			
Total	82,788,603	2,989,310	109,271
Standard Error	30,250,208	1,283,882	30,713
Sample Size	24	24	24
95 % C. I.	(20,200,922, 145,376,284)	(332,958, 5,645,662)	(45,725, 172,817)
Long Logs			
Total	47,031,345	3,261,785	82,395
Standard Error	16,535,752	924,593	24,373
Sample Size	24	24	24
95 % C. I.	(12,818,874, 81,243,816)	(1,348,802, 5,174,768)	(31,968, 132,822)

Size Class 1 = $.25'' \leq \text{intersection length} < 1''$

Size Class 2 = $1'' \leq \text{intersection length} < 5''$

Size Class 3 = $5'' \leq \text{intersection length}$

Table 50. Total Line Intersect Density Estimates for 1994 Inventory at Petrified Forest National Park

Blue Mesa			
	Size Class 1	Size Class 2	Size Class 3
Total	45,142,587	2,719,018	134,873
Standard Error	26,620,512	904,270	61,288
Sample Size	24	24	24
95 % C. I.	(-9,935,251, 100,220,425)	(848,083, 4,589,953)	(8,067, 261,679)
Crystal Forest			
Total	31,739,951	3,223,126	49,675
Standard Error	17,294,739	997,492	13,716
Sample Size	24	24	24
95 % C. I.	(-4,042,863, 67,522,756)	(159,214, 5,286,938)	(21,297, 78,053)
Giant Logs			
Total	25,478,351	2,812,775	37,719
Standard Error	10,317,748	1,553,904	15,716
Sample Size	23	23	23
95 % C. I.	(4,130,929, 46,825,773)	(-402,253, 6,027,803)	(5,203, 70,235)
Jasper Forest			
Total	82,621,543	2,987,161	109,271
Standard Error	30,249,399	1,283,887	30,713
Sample Size	24	24	24
95 % C. I.	(20,035,537, 145,207,549)	(330,799, 5,643,523)	(45,725, 172,817)
Long Logs			
Total	47,031,345	3,261,785	82,062
Standard Error	16,535,752	924,593	24,387
Sample Size	24	24	24
95 % C. I.	(12,818,874, 81,243,816)	(1,348,802, 5,174,768)	(31,605, 132,519)

Size Class 1 = $.25'' \leq \text{intersection length} < 1''$

Size Class 2 = $1'' \leq \text{intersection length} < 5''$

Size Class 3 = $5'' \leq \text{intersection length}$

Table 51. Total Quadrat Density Estimates for 1993 Inventory at Petrified Forest National Park

Blue Mesa		
	Size Class 0	Size Class 1
Total	25,660,700	37,896,558
Standard Error	17,061,273	14,740,843
Sample Size	24	24
95 % C. I.	(-6,939,074, 60,960,474)	(7,397,753, 68,395,363)
Crystal Forest		
Total	16,290,731	56,842,436
Standard Error	5,591,093	16,385,582
Sample Size	24	24
95 % C. I.	(4,722,759, 27,858,703)	(22,940,668, 90,744,204)
Giant Logs		
Total	7,158,881	35,660,413
Standard Error	2,825,480	13,395,739
Sample Size	23	23
95 % C. I.	(1,312,962, 13,004,800)	(7,944,630, 63,376,196)
Jasper Forest		
Total	22,345,126	58,004,076
Standard Error	16,135,769	31,095,679
Sample Size	24	24
95 % C. I.	(-11,039,779, 55,730,031)	(-6,332,884, 122,341,036)
Long Logs		
Total	8,232,553	48,526,630
Standard Error	2,597,068	16,418,878
Sample Size	24	24
95 % C. I.	(2,859,220, 13,605,886)	(14,555,972, 82,597,288)

Size Class 0 = intersection length $\leq .25''$

Size Class 1 = $.25'' < \text{intersection length} < 1''$

Table 52. Total Quadrat Density Estimates for 1994 Inventory at Petrified Forest National Park

Blue Mesa		
	Size Class 0	Size Class 1
Total	12,809,156	36,755,764
Standard Error	8,855,037	22,666,494
Sample Size	24	24
95 % C. I.	(-5,511,915, 31,130,227)	(-10,141,212, 83,652,740)
Crystal Forest		
Total	280,105	1,008,279
Standard Error	163,844	544,507
Sample Size	24	24
95 % C. I.	(-58,888, 619,098)	(-118,306, 2,134,864)
Giant Logs		
Total	2,398,372	41,946,090
Standard Error	795,222	18,723,477
Sample Size	23	23
95 % C. I.	(753,058, 4,043,686)	(3,207,216, 80,684,964)
Jasper Forest		
Total	2,911,566	17,812,346
Standard Error	855,634	6,335,247
Sample Size	24	24
95 % C. I.	(1,141,258, 4,681,874)	(4,704,720, 30,919,972)
Long Logs		
Total	5,267,415	44,526,688
Standard Error	1,539,547	14,145,219
Sample Size	24	24
95 % C. I.	(2,082,092, 8,452,738)	(15,260,229, 73,793,147)

Size Class 0 = intersection length $\leq .25''$

Size Class 1 = $.25'' < \text{intersection length} < 1''$

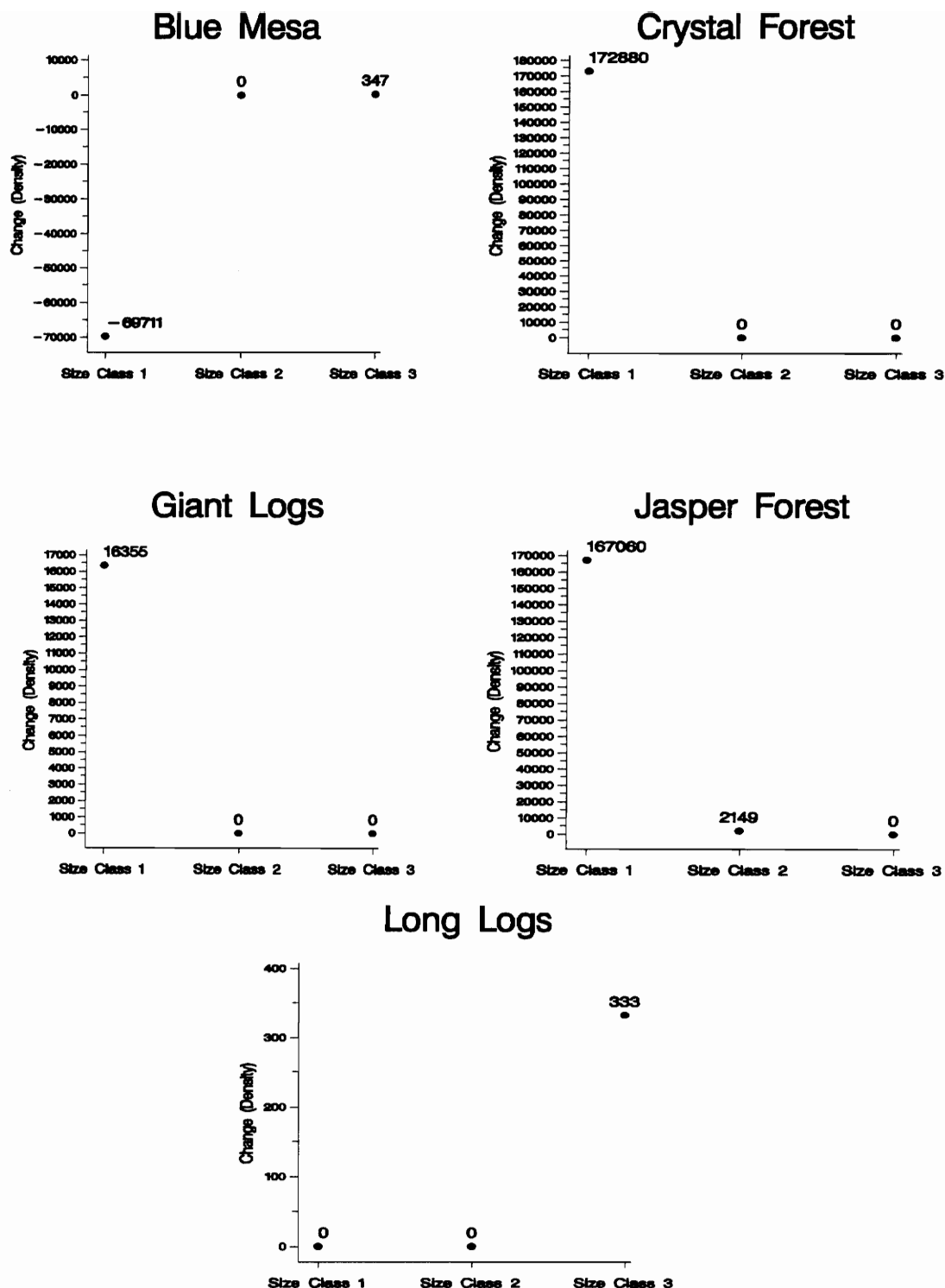


Figure 16. Overall Change in Density as Estimated From Line Intersect Data

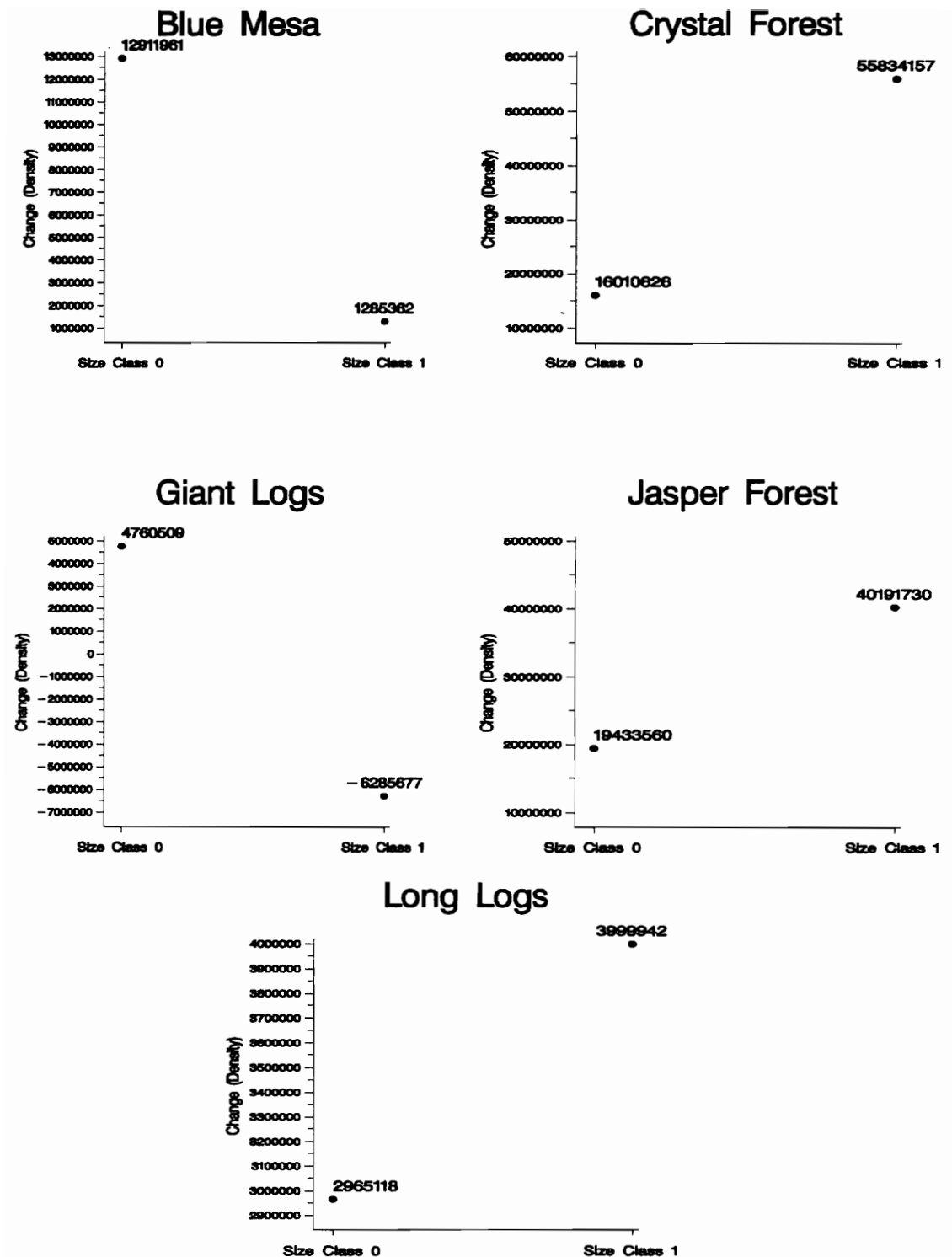


Figure 17. Overall Change in Density as Estimated From Quadrat Data

Chapter 6

Volume Results

Introduction

The chapter describes the detailed steps taken to arrive at total and variance estimates of volume for both line intersect and quadrat sampled data at the Petrified Forest National Park. Most of the calculations in this chapter can be duplicated using the data in Appendix A. However, calculations that made the data available in Appendix A can not be performed because the raw data were too numerous to report. Throughout this chapter, all volume data for 1993 and 1994 inventories is summarized and graphic depiction's of change are available.

Line Intersect Volume Estimator

Figure 8, estimator 2 (Methods Section) is the volume per acre estimator used to calculate volume of petrified wood particles for each line transect in cubic feet per acre. The estimator may be expressed for a single line transect as:

$$\frac{3630\pi}{L} \sum_{i=1}^n CSA_i \quad [10]$$

where: L = line transect length

$n = i^{\text{th}}$ sampled particle along the line transect

CSA_i = cross sectional area (in^2) of i^{th} particle.

As an example, the 1993 cross sectional area data collected at the Petrified Forest National Park for size class 3 ($sc3$ = particle $> 5''$ in intersection length), line 5 at Long Logs are listed in Table 53.

Table 53. 1993 Cross Sectional Line Intersect Data for Long Logs, Line 5, Size Class 3.

Line Number	Cross Sectional Area (in^2)
5	20.03
5	16.74
5	11.05
5	12.82

Using Equation 10 to arrive at a total volume per acre estimate for Long Logs line 5, the cross sectional areas of each particle were added and multiplied by 3630π and finally divided by the length of the line (300 inches):

$$\frac{3630 \times 3.14}{300} [20.03 + 16.74 + 11.05 + 12.82] = 2303.96 \text{ ft}^3/\text{ac.}$$

The 1993 volume per acre estimate for Long Logs line transect 5 is 2303 cubic feet per acre. This estimate must now be multiplied by the total acreage sampled in this stratum. From Table 2, the total acreage sampled for Long Logs trail corridor 2 is 1.83 acres. The total line transect cubic volume estimate for Long Logs line 5 is:

$$2303.96 \times 1.83 = 4216.24 \text{ ft}^3.$$

Identical methods were used to derive individual volume line transect totals for all lines in all strata for both backcountry and trail samples.

Quadrat Volume Estimator

Figure 9, estimator 2 (Methods Section) is the volume estimator used to calculate the volume of petrified wood particles per acre for each quadrat. The estimator may be expressed for a single quadrat as:

$$10036 \times vol_i \quad [11]$$

where: vol_i = volume of particles in i^{th} quadrat.

As an example, the 1993 Long Logs line 7 volume of petrified wood particles in size class 1 was 0.0098 cubic feet. To express this volume on a per acre basis, Equation 11 was used as follows:

$$10036 \times 0.0098 = 98.35 \text{ ft}^3/\text{ac}.$$

The quadrat estimate must be multiplied by the total acreage sampled to achieve a total for the quadrat sampled. Using the appropriate value from Table 2, the calculation is:

$$98.35 \times 1.68 = 165.23 \text{ ft}^3.$$

Identical methodology was used to derive volume estimates for both quadrat size classes for all strata.

Backcountry Total and Variance Estimation

To achieve total volume estimates for backcountry sampling units, individual line transect and quadrat estimates were calculated (Equation 10 and 11 respectively) and averaged. The averages were then multiplied by the backcountry area sampled. Table 54 lists the 1994 backcountry data line intersect volume data for Crystal Forest, size class 1 collected at the Petrified Forest National Park as an example. Note that I have chosen to report the per acre estimates and not total estimates.

Table 54. 1994 Backcountry Volume (ft³) Estimates for the Crystal Forest Stratum, Size Class 1 at the Petrified Forest National Park.

Line #	Volume / Acre	Line #	Volume / Acre
16	271.4	26	1175.0
17	444.1	27	307.1
18	720.9	28	0
19	0	29	0
20	19.2	30	0
21	0	31	0
22	0	32	0
23	0	33	271.4
24	0	34	0
25	0	35	0

To arrive at a total line intersect volume estimate for Crystal Forest size class 1, the data in Table 54 would be averaged and multiplied by the total acreage sampled:

$$56.21 \left[\frac{271.4 + 444.1 + \dots + 0 + 0}{20} \right] = 9019.2 \text{ ft}^3.$$

To estimate the variance for the line intersect volume estimate above, the De Vries Equation 3 was used. Using the data in Table 54, Equation 3, and multiplying by the total acreage sampled the calculation becomes:

$$\begin{aligned}
 & 56.21^2[(271.4 - 160.5)^2 \\
 & + (444.1 - 160.5)^2 \\
 & + . \\
 & + . \\
 & + (0 - 160.5)^2 \\
 & + (0 - 160.5)^2] \\
 & = 5765480942
 \end{aligned}$$

dividing by the sample size yields:

$$\hat{V}AR(Vol_{sc1}) = \frac{5765480942}{(19)20} = 15172318.3 \text{ ft}^6.$$

To affix a level of confidence to backcountry volume estimates, Equation 6 was used. A two sided 95 percent confidence interval assuming normality for the Crystal Forest size class 1 volume estimate is:

$$\begin{aligned}
 & 9019.2 \pm t_{(19),.975} \times \sqrt{15172318.3} \\
 & 9019.2 \pm 2.093 \times 3895.2 \\
 & 9019.2 \pm 8152.6 \\
 & (866.6 \text{ ft}^3, 17171.8 \text{ ft}^3) .
 \end{aligned}$$

Summary of Backcountry Volume Estimates

No petrified wood was missing or added in the line intersect backcountry sampling units, therefore the 1993 and 1994 backcountry line intersect estimates are identical. Table 55 summarizes the backcountry line intersect volume data for all five strata.

The quadrat samples are not identical between 1993 and 1994. Recall that the quadrat sampling were two distinct samples during each inventory (Figure 6). Tables 56 and 57 summarize the backcountry quadrat volume data for each strata for 1993 and 1994 inventories respectively.

Table 55. 1993 and 1994 Backcountry Volume (ft³) Line Intersect Data Summary at Petrified Forest National Park

Blue Mesa			
	Size Class 1	Size Class 2	Size Class 3
Average	9368	32371	410412
Standard Error	12746	12746	255925
Sample Size	20	20	20
95% C. I.	(296, 18440)	(5693, 59048)	(-125240, 946064)
Crystal Forest			
Average	9019	10294	81586
Standard Error	3895	3873	37346
Sample Size	20	20	20
95% C. I.	(866, 17172)	(2187, 18401)	(3239, 159933)
Giant Logs			
Average	12986	34419	162202
Standard Error	5233	15761	94364
Sample Size	20	20	20
95% C. I.	(2033, 23938)	(1430, 67409)	(-35301, 359706)
Jasper Forest			
Average	21545	51067	622989
Standard Error	7632	18472	386964
Sample Size	20	20	20
95% C. I.	(5570, 37519)	(12403, 89730)	(-186927, 1432907)
Long Logs			
Average	11839	32174	211891
Standard Error	4618	13528	91144
Sample Size	20	20	20
95% C. I.	(2174, 21505)	(3859, 60490)	(21125, 402656)

Size Class 1 = .25" ≤ intersection length < 1"

Size Class 2 = 1" ≤ intersection length < 5"

Size Class 3 = 5" ≤ intersection length

Table 56. 1993 Backcountry Volume (ft³) Quadrat Data Summary at Petrified Forest National Park

Blue Mesa		
	Size Class 0	Size Class 1
Average	732	10382
Standard Error	480	5044
Sample Size	20	20
95% Confidence Int.	(-272, 1738)	(-176, 20940)
Crystal Forest		
Average	519	10497
Standard Error	176	4337
Sample Size	20	20
95% Confidence Int.	(149, 889)	(1419, 19574)
Giant Logs		
Average	157	5552
Standard Error	53	2248
Sample Size	20	20
95% Confidence Int.	(46, 269)	(847, 10258)
Jasper Forest		
Average	540	11599
Standard Error	415	4266
Sample Size	20	20
95% Confidence Int.	(-329, 1410)	(2688, 20529)
Long Logs		
Average	161	7812
Standard Error	50	2890
Sample Size	20	20
95% Confidence Int.	(54, 266)	(1761, 13862)

Size Class 0 = intersection length $\leq .25''$

Size Class 1 = $.25'' < \text{intersection length} < 1''$

Table 57. 1994 Backcountry Volume (ft³) Quadrat Data Summary at Petrified Forest National Park

Blue Mesa		
	Size Class 0	Size Class 1
Average	570	8910
Standard Error	476	4971
Sample Size	2-	20
95% Confidence Int.	(-426, 1567)	(-1493, 19315)
Crystal Forest		
Average	445	7864
Standard Error	266	2064
Sample Size	20	20
95% Confidence Int.	(-112, 1002)	(3544, 12185)
Giant Logs		
Average	59	7339
Standard Error	20	3427
Sample Size	20	20
95% Confidence Int.	(17, 101)	(165, 14514)
Jasper Forest		
Average	82	4691
Standard Error	31	1779
Sample Size	20	20
95% Confidence Int.	(16, 148)	(966, 8417)
Long Logs		
Average	115	11498
Standard Error	36	4437
Sample Size	20	20
95% Confidence Int.	(40, 190)	(2210, 20786)

Size Class 0 = intersection length $\leq .25''$

Size Class 1 = $.25'' < \text{intersection length} < 1''$

Trail Corridor Average and Variance Estimation

The trail sampling volume estimates are presented differently than were the backcountry estimates because these sampling units are those in which there was a displacement of petrified wood. First, individual corridor averages were calculated. Recall that corridor 1 is 0 to 15 feet on both sides of the trail, corridor 2 is 15 to 30 feet on both sides of the trail and corridor 3 is 30 to 45 feet on both sides of the trail. These corridor averages are intended to show relationships between theft of petrified wood and distance traveled from the trail. Second, the corridor values were averaged to show overall petrified wood displacement for a given stratum. As an example of how the trail volume estimates were calculated, Table 58 lists Jasper Forest line intersect data for size class 1, during the 1993 inventory.

Table 58. 1993 Trail Volume (ft³) Data for the Jasper Forest Stratum, Size Class 1 at the Petrified Forest National Park

line number	corridor #	Volume / Acre
1	1	missing 94
1	2	missing 94
1	3	missing 94
2	1	0
2	2	0
2	3	216
3	1	203
3	2	0
3	3	56
4	1	0
4	2	0
4	3	101
5	1	missing 94
5	2	279
5	3	missing 94

Recall that some trail sampling units were lost between inventories. If a sampling units was destroyed between surveys, the 1993 data was not used in any calculations (coded missing 94).

To arrive at corridor averages, the individual corridor values were simply averaged and multiplied by the acreage sampled in each corridor as follows:

$$\text{Corridor 1:} \quad 1.68 \times \left[\frac{0 + 203 + 0}{3} \right] = 113.7 \text{ ft}^3$$

$$\text{Corridor 2:} \quad 1.83 \times \left[\frac{0 + 0 + 0 + 279}{4} \right] = 127.7 \text{ ft}^3$$

$$\text{Corridor 3:} \quad 2.42 \times \left[\frac{216 + 56 + 101}{3} \right] = 300.8 \text{ ft}^3.$$

The variances for these individual corridor estimates were calculated using Equation 3. Note that I have chosen to calculate the variance on a per acre basis and multiply by the square of the corridor acreage sampled. For example, for the Corridor 1 volume estimate, the calculation for variance would be:

$$\frac{1.68^2}{2(3)} \left[(0 - 67.7)^2 + (203 - 67.7)^2 + (0 - 67.7)^2 \right] = 12923.14 \text{ ft}^6.$$

To affix a level of confidence to corridor estimates, Equation 6 was used with $\alpha = .05$ and the appropriate degrees of freedom for each corridor.

Summary of Trail Corridor Volume Estimates

Tables 59, 60, 61, 62, 63 and 64 summarize the line intercept volume data by corridors and petrified wood size classes for the 1993 and 1994 inventories. Tables 65, 66, 67, and 68 summarize the quadrat volume data by size classes and corridors for the 1993 and 1994 inventories.

The change of petrified wood was calculated (1993 estimate - 1994 estimate) for each corridor in each stratum. The following figures display the volume change of petrified wood by corridors for each size class. Note that a negative number suggests an increase of petrified wood volume while a positive number indicates loss. Figure 18 depicts the relationship between petrified wood volume change and trail corridors for line intersect data in each stratum respectively. Figure 19 depicts the relationship between trail corridor and wood volume change for the quadrat data in each strata respectively.

Table 59. 1993 Size Class 1 Volume (ft³) Line Intersect Trail Corridor Data Collected at the Petrified Forest National Park

Blue Mesa			
	Corridor 1	Corridor 2	Corridor 3
Average	158	120	413
Standard Err.	86	81	125
n	3	4	4
95 % C.I.	(-211, 528)	(-138, 378)	(16, 811)
Crystal Forest			
Average	158	280	187
Standard Err.	158	94	108
n	2	4	3
95 % C.I.	(-1847, 2162)	(-19, 580)	(-277, 651)
Giant Logs			
Average	113	0	35
Standard Err.	undefined	0	35
n	1	3	3
95 % C.I.	N/A	N/A	(-114, 184)
Jasper Forest			
Average	146	259	321
Standard Err.	33	108	126
n	4	3	4
95 % C.I.	(40, 252)	(-207, 724)	(-78, 722)
Long Logs			
Average	114	127	301
Standard Err.	114	127	116
n	3	4	3
95 % C.I.	(-375, 602)	(-278, 534)	(-196, 799)

Size Class 1 = .25" ≤ intersection length < 1"

Table 60. 1994 Size Class 1 Volume (ft³) Line Intersect Trail Corridor Data Collected at the Petrified Forest National Park

Blue Mesa			
	Corridor 1	Corridor 2	Corridor 3
Average	158	200	413
Standard Err.	86	158	125
n	3	4	4
95 % C.I.	(-211, 528)	(-303, 705)	(16, 811)
Crystal Forest			
Average	158	263	187
Standard Err.	158	95	108
n	2	4	3
95 % C.I.	(-1847, 2162)	(-39, 566)	(-277, 651)
Giant Logs			
Average	70	0	35
Standard Err.	undefined	0	35
n	1	3	3
95 % C.I.	N/A	N/A	(-114, 184)
Jasper Forest			
Average	141	245	321
Standard Err.	34	115	126
n	4	3	4
95 % C.I.	(32, 249)	(-250, 742)	(-78, 722)
Long Logs			
Average	114	127	301
Standard Err.	114	127	116
n	3	4	3
95 % C.I.	(-375, 602)	(-278, 534)	(-196, 799)

Size Class 1 = .25" ≤ intersection length < 1"

Table 61. 1993 Size Class 2 Volume (ft³) Line Intersect Trail Corridor Data Collected at the Petrified Forest National Park

Blue Mesa			
	Corridor 1	Corridor 2	Corridor 3
Average	1839	952	400
Standard Err.	1238	628	2359
n	3	4	4
95 % C.I.	(-3491, 7170)	(-426, 4797)	(-346, 1146)
Crystal Forest			
Average	119	115	1114
Standard Err.	119	83	710
n	2	4	3
95 % C.I.	(-1395, 1634)	(-149, 380)	(-1942, 4171)
Giant Logs			
Average	14674	11	52
Standard Err.	undefined	11	52
n	1	3	3
95 % C.I.	N/A	(-35, 57)	(-171, 276)
Jasper Forest			
Average	1102	0	53
Standard Err.	1023	0	35
n	4	3	4
95 % C.I.	(-2154, 4340)	N/A	(-57, 164)
Long Logs			
Average	236	726	47
Standard Err.	159	672	47
n	3	4	3
95 % C.I.	(-450, 923)	(-1413, 2867)	(-154, 247)

Size Class 2 = 1" ≤ intersection length < 5"

Table 62. 1994 Size Class 2 Volume (ft³) Line Intersect Trail Corridor Data Collected at the Petrified Forest National Park

Blue Mesa			
	Corridor 1	Corridor 2	Corridor 3
Average	1839	952	400
Standard Err.	1238	628	2359
n	3	4	4
95 % C.I.	(-3491, 7170)	(-426, 4797)	(-346, 1146)
Crystal Forest			
Average	119	115	1114
Standard Err.	119	83	710
n	2	4	3
95 % C.I.	(-1395, 1634)	(-149, 380)	(-1942, 4171)
Giant Logs			
Average	14674	11	52
Standard Err.	undefined	11	52
n	1	3	3
95 % C.I.	N/A	(-35, 57)	(-171, 276)
Jasper Forest			
Average	1120	0	37
Standard Err.	1041	0	37
n	4	3	4
95 % C.I.	(-2192, 4432)	N/A	(-79, 153)
Long Logs			
Average	236	726	47
Standard Err.	159	672	47
n	3	4	3
95 % C.I.	(-450, 923)	(-1413, 2867)	(-154, 247)

Size Class 2 = 1" ≤ intersection length < 5"

Table 63. 1993 Size Class 3 Volume (ft³) Line Intersect Trail Corridor Data Collected at the Petrified Forest National Park

Blue Mesa			
	Corridor 1	Corridor 2	Corridor 3
Average	344	2185	261
Standard Err.	344	820	261
n	3	4	4
95 % C.I.	(-1136, 1824)	(-426, 4787)	(-569, 1092)
Crystal Forest			
Average	0	3076	0
Standard Err.	0	1910	0
n	2	4	3
95 % C.I.	N/A	(-3002, 9155)	N/A
Giant Logs			
Average	681	0	2353
Standard Err.	undefined	0	1236
n	1	3	3
95 % C.I.	N/A	N/A	(-2967, 7674)
Jasper Forest			
Average	363	6402	3094
Standard Err.	363	1139	1787
n	4	3	4
95 % C.I.	(-792, 1519)	(1497, 11307)	(-2592, 8781)
Long Logs			
Average	12589	5383	480
Standard Err.	11313	2056	480
n	3	4	3
95 % C.I.	(-36093, 61272)	(-1159, 11926)	(-1587, 2549)

Size Class 3 = 5" ≤ intersection length

Table 64. 1994 Size Class 3 Volume (ft³) Line Intersect Trail Corridor Data Collected at the Petrified Forest National Park

Blue Mesa			
	Corridor 1	Corridor 2	Corridor 3
Average	344	2185	110
Standard Err.	344	820	110
n	3	4	4
95 % C.I.	(-1136, 1824)	(-426, 4787)	(-241, 463)
Crystal Forest			
Average	0	3076	0
Standard Err.	0	1910	0
n	2	4	3
95 % C.I.	N/A	(-3002, 9155)	N/A
Giant Logs			
Average	681	0	2353
Standard Err.	undefined	0	1236
n	1	3	3
95 % C.I.	N/A	N/A	(-2967, 7674)
Jasper Forest			
Average	363	6402	3094
Standard Err.	363	1139	1787
n	4	3	4
95 % C.I.	(-792, 1519)	(1497, 11307)	(-2592, 8781)
Long Logs			
Average	12589	5183	480
Standard Err.	11313	2203	480
n	3	4	3
95 % C.I.	(-36093, 61272)	(-1828, 12195)	(-1587, 2549)

Size Class 3 = 5" ≤ intersection length

Table 65. 1993 Size Class 0 Volume (ft³) Quadrat Trail Corridor Data Collected at the Petrified Forest National Park

Blue Mesa			
	Corridor 1	Corridor 2	Corridor 3
Average	2.2	2.0	2.9
Standard Err.	2.2	2.5	0.9
n	3	4	4
95 % C.I.	(-2.1, 9.7)	(-2.1, 14.0)	(0.5, 6.4)
Crystal Forest			
Average	24.8	3.7	9.4
Standard Err.	12.1	1.9	2.1
n	2	4	3
95 % C.I.	(-128.9, 178.5)	(-2.37, 9.7)	(0.3, 18.5)
Giant Logs			
Average	0.7	1.1	1.2
Standard Err.	undefined	0.4	0.4
n	1	3	3
95 % C.I.	N/A	(-0.5, 2.6)	(-0.3, 2.8)
Jasper Forest			
Average	4.7	16.8	8.9
Standard Err.	1.8	8.4	4.9
n	4	3	4
95 % C.I.	(-0.9, 10.3)	(-19.6, 53.1)	(-6.8, 24.8)
Long Logs			
Average	16.3	4.0	3.9
Standard Err.	15.6	1.6	2.9
n	3	4	3
95 % C.I.	(-51.0, 83.6)	(-1.1, 9.0)	(-0.3, 8.2)

Size Class 0 = intersection length ≤ .25"

Table 66. 1994 Size Class 0 Volume (ft³) Quadrat Trail Corridor Data Collected at the Petrified Forest National Park

Blue Mesa			
	Corridor 1	Corridor 2	Corridor 3
Average	8.6	14.3	5.7
Standard Err.	5.7	9.2	2.1
n	3	4	4
95 % C.I.	(-2.7, 19.8)	(-15.1, 43.7)	(-1.0, 12.5)
Crystal Forest			
Average	11.9	21.0	3.5
Standard Err.	6.6	15.1	3.5
n	2	4	3
95 % C.I.	(-71.6, 95.3)	(-27.1, 69.1)	(-11.7, 18.7)
Giant Logs			
Average	2.6	0.3	1.3
Standard Err.	undefined	0.1	0.8
n		3	3
95 % C.I.	N/A	(-0.3, 0.8)	(-2.1, 4.7)
Jasper Forest			
Average	3.5	2.3	3.2
Standard Err.	1.7	2.2	3.2
n	4	3	4
95 % C.I.	(-2.1, 9.0)	(-7.1, 11.8)	(-6.9, 13.2)
Long Logs			
Average	3.7	21.9	3.7
Standard Err.	3.4	21.5	2.7
n	3	4	3
95 % C.I.	(-11.1, 18.5)	(-46.5, 90.3)	(-8.1, 15.5)

Size Class 0 = intersection length $\leq .25''$

Table 67. 1993 Size Class 1 Volume (ft³) Quadrat Trail Corridor Data Collected at the Petrified Forest National Park

Blue Mesa			
	Corridor 1	Corridor 2	Corridor 3
Average	86	144	93
Standard Err.	83	57	42
n	3	4	4
95 % C.I.	(-77, 248)	(-37, 327)	(-43, 227)
Crystal Forest			
Average	168	187	162
Standard Err.	131	95	42
n	2	4	3
95 % C.I.	(-1497, 1834)	(-117, 493)	(-17, 342)
Giant Logs			
Average	0	9.9	12.9
Standard Err.	undefined	9.9	0
n	1	3	3
95 % C.I.	N/A	(-32.7, 52.4)	N/A
Jasper Forest			
Average	43	257	275
Standard Err.	15	96	58
n	4	3	4
95 % C.I.	(-4, 91)	(-154, 668)	(91, 460)
Long Logs			
Average	251	107	57
Standard Err.	175	53	29
n	3	4	3
95 % C.I.	(-505, 1008)	(-60, 274)	(-67, 181)

Size Class 1 = .25" < intersection length < 1"

Table 68. 1994 Size Class 1 Volume (ft³) Quadrat Trail Corridor Data Collected at the Petrified Forest National Park

Blue Mesa			
	Corridor 1	Corridor 2	Corridor 3
Average	337	329	31
Standard Err.	160	173	19
n	3	4	4
95 % C.I.	(21, 649)	(-223, 881)	(-28, 91)
Crystal Forest			
Average	90	501	42
Standard Err.	60	422	26
n	2	4	3
95 % C.I.	(-672, 851)	(-845, 1846)	(-69, 152)
Giant Logs			
Average	34	10.9	46
Standard Err.	undefined	3.9	26
n	1	3	3
95 % C.I.	N/A	(-6.1, 27.9)	(-66, 157)
Jasper Forest			
Average	17	111	99
Standard Err.	16	56	47
n	4	3	4
95 % C.I.	(-33, 66)	(-128, 352)	(-51, 247)
Long Logs			
Average	273	473	315
Standard Err.	126	449	269
n	3	4	3
95 % C.I.	(-269, 816)	(-957, 1903)	(-840, 1470)

Size Class 1 = .25" < intersection length < 1"

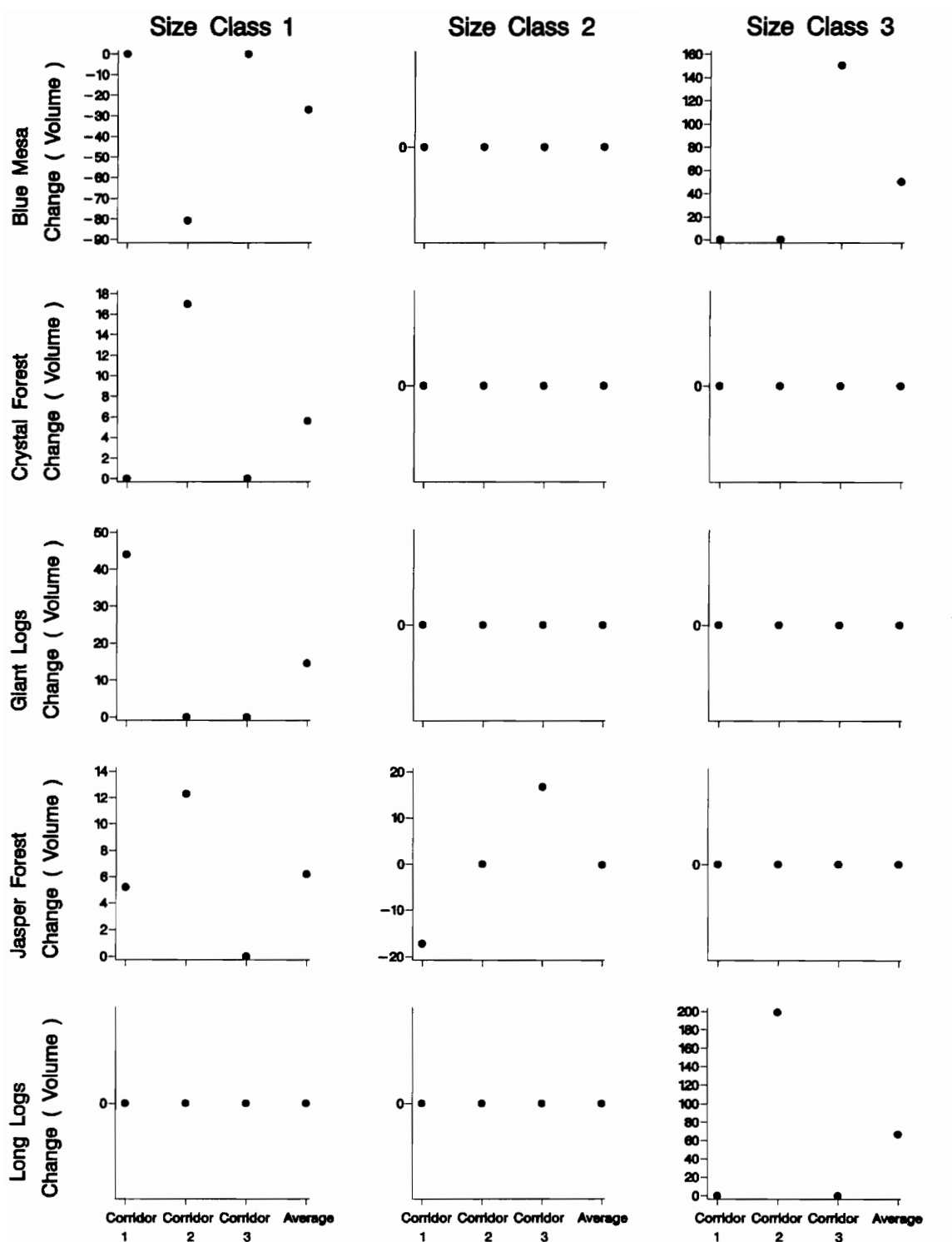


Figure 18. Change in Volume (cubic feet) in the Trail Strata As Estimated From Line Intersect Data

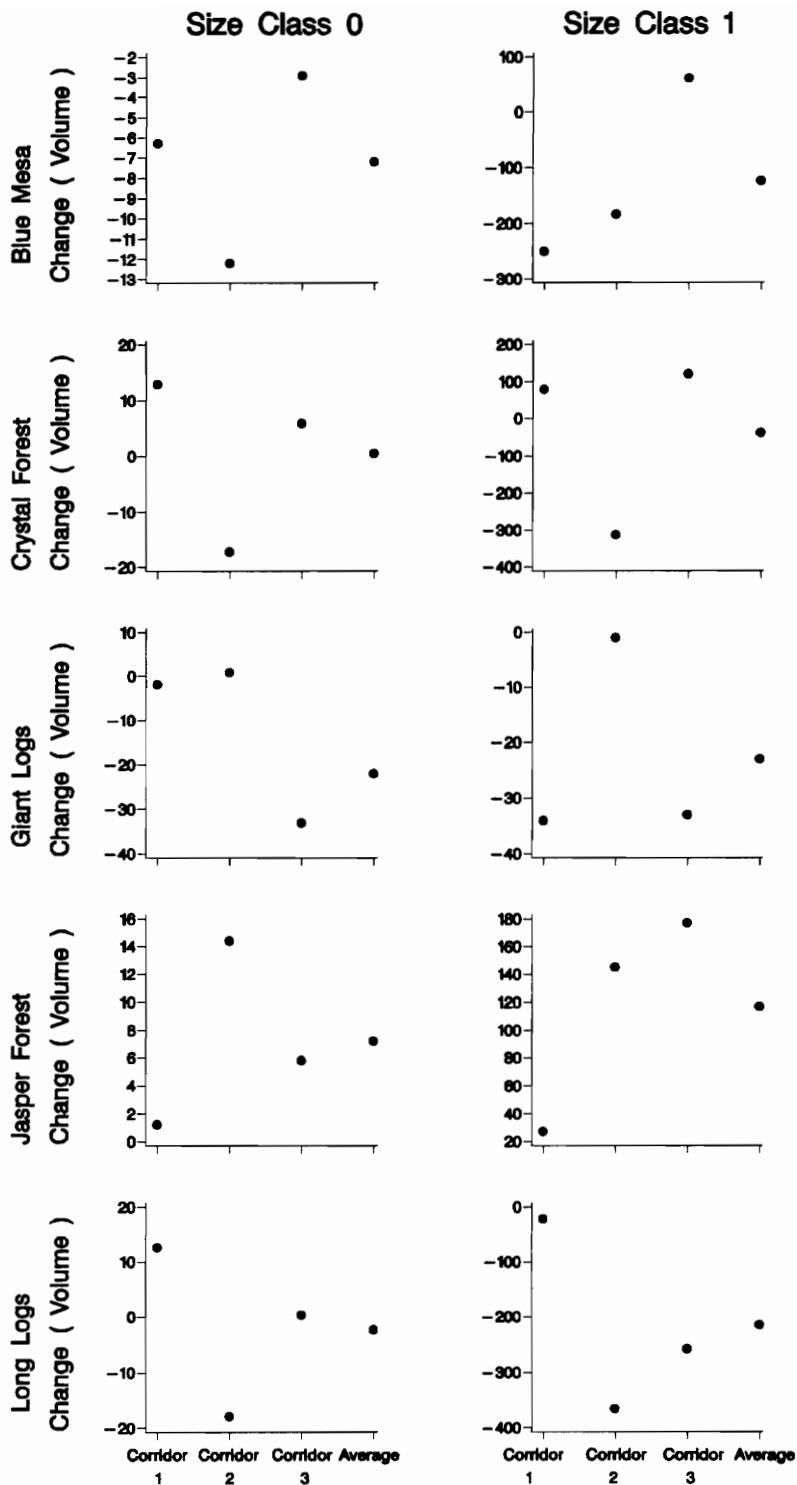


Figure 19. Change in Volume (cubic feet) in the Trail Strata As Estimated From Quadrat Data

Trail Total and Variance Estimation

Recall that each group of trail lines is dependent upon the location of the corridor 1 line transect. This dependency must be taken into account for trail total calculations. To arrive at a total estimate for the trail sampling units, the individual corridor estimates were averaged for each group and then averaged over the groups. For example, using the Long Logs line intersect size class volume 1 data (Table 58) and the corridor acreage's sampled (Table 2) the calculation is:

$$\begin{aligned} & \frac{1}{4} \left[\frac{(0 \times 1.68) + (0 \times 1.83) + (216 \times 2.42)}{3} \right. \\ & + \frac{(203 \times 1.68) + (0 \times 1.83) + (56 \times 2.42)}{3} \\ & + \frac{(0 \times 1.68) + (0 \times 1.83) + (101 \times 2.42)}{3} \\ & \left. + \frac{(279 \times 1.83)}{1} \right] \\ & = 231.3 \text{ ft}^3. \end{aligned}$$

To estimate the variance of this estimate, Equation 4 was implemented. Again using the Long Logs 1993 size class 1 data (Table 58) and noting that some sampling units are missing from each group of three lines, the calculation of variance is:

$$\left[\left(\frac{(0 \times 1.68) + (0 \times 1.83) + (216 \times 2.42)}{3} \right) - 231.3 \right]^2$$

$$\begin{aligned}
& + \left[\left(\frac{(203 \times 1.68) + (0 \times 1.83) + (56 \times 2.42)}{3} \right) - 231.3 \right]^2 \\
& + \left[\left(\frac{(0 \times 1.68) + (0 \times 1.83) + (101 \times 2.42)}{3} \right) - 231.3 \right]^2 \\
& + \left[\left(\frac{(279 \times 1.83)}{1} \right) - 231.3 \right]^2 \\
& = 109409.6
\end{aligned}$$

Dividing by the sample size:

$$\hat{VAR}(Vol_{sc1}) \cong \frac{109409.6}{3(4)} = 9117.5 \text{ ft}^6.$$

Recall that all three corridor line segments for the first sample in the Long Logs trail data was not available, thus the data could not be used in the calculation of total and variance. Also note that this decreased the sample size from five to 4. Only sampling units available from the trail data were used in the calculation. Recall that the covariance terms between the corridor units were neglected. This renders the variance for trail sampling units approximate. Identical methods were used to calculate the variance estimates for the remainder of the strata and size classes for both line intersect and quadrat trail data.

To affix a level of confidence to these trail totals, Equation 6 was used with the appropriate degrees of freedom and $\alpha = .05$.

Summary of Trail Total Volume Estimates

Tables 69 and 70 summarize the trail line intersect volume total estimates for 1993 and 1994 respectively. Tables 71 and 72 summarize the trail quadrat volume total estimates for 1993 and 1994 inventories respectively.

Table 69. 1993 Trail Volume (ft³) Line Intersect Data Summary at Petrified Forest National Park

Blue Mesa			
	Size Class 1	Size Class 2	Size Class 3
Average	237	941	978
Standard Error	42	467	372
n	4	4	4
95% C. I.	(103, 371)	(-537, 2419)	(-206, 2164)
Crystal Forest			
Average	227	481	1353
Standard Error	45	259	929
n	4	4	4
95% C. I.	(82, 370)	(-344, 1305)	(-1602, 4309)
Giant Logs			
Average	24	1661	1252
Standard Error	24	1614	546
n	3	3	3
95% C. I.	(-80, 126)	(-5287, 8611)	(-1100, 3604)
Jasper Forest			
Average	242	391	3092
Standard Error	42	333	356
n	4	4	4
95% C. I.	(108, 375)	(-668, 1451)	(1957, 4227)
Long Logs			
Average	231	770	6103
Standard Error	95	657	3259
n	4	4	4
95% C. I.	(-72, 535)	(-1322, 2863)	(-4267, 16475)

Size Class 1 = .25" ≤ intersection length < 1"

Size Class 2 = 1" ≤ intersection length < 5"

Size Class 3 = 5" ≤ intersection length

Table 70. 1994 Trail Volume (ft³) Line Intersect Data Summary at Petrified Forest National Park

Blue Mesa			
	Size Class 1	Size Class 2	Size Class 3
Average	264	941	928
Standard Error	48	467	337
n	4	4	4
95% C. I.	(112, 415)	(-537, 2419)	(-146, 2004)
Crystal Forest			
Average	218	481	1353
Standard Error	39	259	929
n	4	4	4
95% C. I.	(95, 341)	(-344, 1305)	(-1602, 4309)
Giant Logs			
Average	19	1661	1252
Standard Error	19	1614	546
n	3	3	3
95% C. I.	(-26, 65)	(-5287, 8611)	(-1100, 3604)
Jasper Forest			
Average	236	392	3092
Standard Error	40	340	356
n	4	4	4
95% C. I.	(108, 363)	(-692, 1476)	(1957, 4227)
Long Logs			
Average	231	770	6037
Standard Error	95	657	3290
n	4	4	4
95% C. I.	(-72, 535)	(-1322, 2863)	(-4432, 16506)

Size Class 1 = .25" ≤ intersection length < 1"

Size Class 2 = 1" ≤ intersection length < 5"

Size Class 3 = 5" ≤ intersection length

Table 71. 1993 Trail Volume (ft³) Quadrat Data Summary at Petrified Forest National Park

Blue Mesa		
	Size Class 0	Size Class 1
Average	2.3	100
Standard Error	1.2	38
Sample Size	4	4
95 % C. I.	(-1.5, 6.1)	(-19, 220)
Crystal Forest		
Average	9.3	162
Standard Error	3.1	54
Sample Size	4	4
95 % C. I.	(-0.6, 19.3)	(-9, 333)
Giant Logs		
Average	1.0	10.7
Standard Error	0.3	5.3
Sample Size	3	3
95 % C. I.	(0.1, 2.0)	(-12.3, 33.6)
Jasper Forest		
Average	9.0	185
Standard Error	4.2	35
Sample Size	4	4
95 % C. I.	(-4.2, 22.2)	(73, 297)
Long Logs		
Average	6.9	118
Standard Error	47.9	48
Sample Size	4	4
95 % C. I.	(-33.9, 271.1)	(-34, 271)

Size Class 0 = intersection length $\leq .25''$

Size Class 1 = $.25'' < \text{intersection length} < 1''$

Table 72. 1994 Trail Volume (ft³) Quadrat Data Summary at Petrified Forest National Park

Blue Mesa		
	Size Class 0	Size Class 1
Average	9.3	213
Standard Error	3.4	97
Sample Size	4	4
95 % C. I.	(-1.6, 20.2)	(-94, 520)
Crystal Forest		
Average	10.9	270
Standard Error	7.0	210
Sample Size	4	4
95 % C. I.	(-11.4, 33.1)	(-399, 941)
Giant Logs		
Average	0.9	29
Standard Error	0.5	15
Sample Size	3	3
95 % C. I.	(-1.5, 3.3)	(-35, 92)
Jasper Forest		
Average	3.0	77
Standard Error	2.1	29
Sample Size	4	4
95 % C. I.	(-3.6, 9.6)	(-14, 168)
Long Logs		
Average	24	608
Standard Error	21	408
Sample Size	4	4
95 % C. I.	(-43, 90)	(-689, 1905)

Size Class 0 = intersection length ≤ .25"

Size Class 1 = .25" < intersection length < 1"

Total Volume Summary

To achieve a total estimate of volume for each strata, the backcountry and trail total amounts were added together. The variance of these totals was estimated by using Equation 5 and confidence intervals were calculated using Equation 6. As an example, Table 73 lists trail and backcountry totals for Giant Logs 1994 quadrat volume, size class 1.

Table 73. Trail and Backcountry Volume (ft³) Quadrat Total Estimates for Giant Logs size Class 1

Sampling Type	Total	Variance
Trail	29	219
Backcountry	7340	4260096

The total 1994 quadrat volume estimate for Giant Logs size class 1 would be:

$$29 + 7340 = 7369 \text{ ft}^3$$

Using Equation 5 to estimate the variance of the above total would suggest:

$$\hat{VAR}(1994Vol) = 219 + 4260096 = 4260315 \text{ ft}^6.$$

Similar methods were used to calculate totals for all strata in each size class. Tables 74 and 75 summarize volume line intersect total estimates for 1993 and 1994 respectively. Tables 76 and 77 summarize volume quadrat total estimates for 1993 and 1994 respectively.

The difference in volume estimates was calculated (1993 - 1994) for each size class in each stratum. Figures 20 and 21 depict these relationships for line intersect and quadrat data respectively. Note that a

negative number indicates a gain in volume, while a positive number suggests a loss.

Table 74. Total Line Intersect Volume (ft³) Estimates for 1993 Inventory at Petrified Forest National Park

Blue Mesa			
	Size Class 1	Size Class 2	Size Class 3
Total	9605	33312	411390
Standard Error	12746	12755	255925
Sample Size	24	24	24
95% C. I..	(-16767, 35977)	(6923, 59701)	(-118119, 940899)
Crystal Forest			
Total	9246	10775	82939
Standard Error	3895	3882	37358
Sample Size	24	24	24
95% C. I..	(1187, 17305)	(2744, 18806)	(5646, 160232)
Giant Logs			
Total	13010	36080	163454
Standard Error	5233	15843	94366
Sample Size	23	23	23
95% C. I..	(2183, 23837)	(3300, 68860)	(-31788, 358696)
Jasper Forest			
Total	21787	51458	626081
Standard Error	7632	18475	386964
Sample Size	24	24	24
95% C. I..	(5996, 37478)	(13233, 89683)	(-174548, 1426710)
Long Logs			
Total	12070	32944	217994
Standard Error	4619	13544	91202
Sample Size	24	24	24
95% C. I..	(2513, 21627)	(4922, 60966)	(29297, 406691)

Size Class 1 = .25" ≤ intersection length < 1"

Size Class 2 = 1" ≤ intersection length < 5"

Size Class 3 = 5" ≤ intersection length

Table 75. Total Line Intersect Volume (ft³) Estimates for 1994 Inventory at Petrified Forest National Park

Blue Mesa			
	Size Class 1	Size Class 2	Size Class 3
Total	9632	33312	411340
Standard Error	12746	12755	255925
Sample Size	24	24	24
95% C. I..	(-16740, 36004)	(6923, 59701)	(-118169, 940849)
Crystal Forest			
Total	9237	10775	82939
Standard Error	3895	3882	37358
Sample Size	24	24	24
95% C. I..	(1178, 17296)	(2744, 18806)	(5646, 160232)
Giant Logs			
Total	13005	36080	163454
Standard Error	5233	15843	94366
Sample Size	23	23	23
95% C. I..	(2178, 23832)	(3300, 68860)	(-31788, 358696)
Jasper Forest			
Total	21781	51459	626081
Standard Error	7632	18475	386964
Sample Size	24	24	24
95% C. I..	(5990, 37572)	(13234, 89684)	(-174548, 1426710)
Long Logs			
Total	12070	32944	217928
Standard Error	4619	13544	91203
Sample Size	24	24	24
95% C. I..	(2513, 21627)	(4922, 60966)	(29228, 406628)

Size Class 1 = .25" ≤ intersection length < 1"

Size Class 2 = 1" ≤ intersection length < 5"

Size Class 3 = 5" ≤ intersection length

Table 76. Total Quadrat Volume (ft³) Estimates for 1993 Inventory at Petrified Forest National Park

Blue Mesa		
	Size Class 0	Size Class 1
Total	734	10482
Standard Error	480	5044
Sample Size	24	24
95 % C. I.	(-259, 1727)	(46, 20918)
Crystal Forest		
Total	528	10659
Standard Error	176	4337
Sample Size	24	24
95 % C. I.	(164, 893)	(1685, 19633)
Giant Logs		
Total	158	5563
Standard Error	53	2248
Sample Size	23	23
95 % C. I.	(48, 268)	(912, 10214)
Jasper Forest		
Total	549	11784
Standard Error	415	4266
Sample Size	24	24
95 % C. I.	(-310, 1408)	(2957, 20611)
Long Logs		
Total	168	7930
Standard Error	69	2890
Sample Size	24	24
95 % C. I.	(25, 311)	(1950, 13910)

Size Class 0 = intersection length ≤ .25"
Size Class 1 = .25" < intersection length < 1"

Table 77. Total Quadrat Volume (ft³) Estimates for 1994 Inventory at Petrified Forest National Park

Blue Mesa		
	Size Class 0	Size Class 1
Total	579	9123
Standard Error	476	4972
Sample Size	4	24
95 % C. I.	(-406, 1564)	(-1164, 19410)
Crystal Forest		
Total	456	8134
Standard Error	266	2075
Sample Size	24	24
95 % C. I.	(-95, 1006)	(3842, 12426)
Giant Logs		
Total	60	7368
Standard Error	20	3427
Sample Size	23	23
95 % C. I.	(19, 101)	(277, 14459)
Jasper Forest		
Total	85	4768
Standard Error	31	1779
Sample Size	24	24
95 % C. I.	(21, 149)	(1087, 8449)
Long Logs		
Total	139	12106
Standard Error	42	4456
Sample Size	24	24
95 % C. I.	(53, 225)	(2887, 21325)

Size Class 0 = intersection length $\leq .25''$

Size Class 1 = $.25'' < \text{intersection length} < 1''$

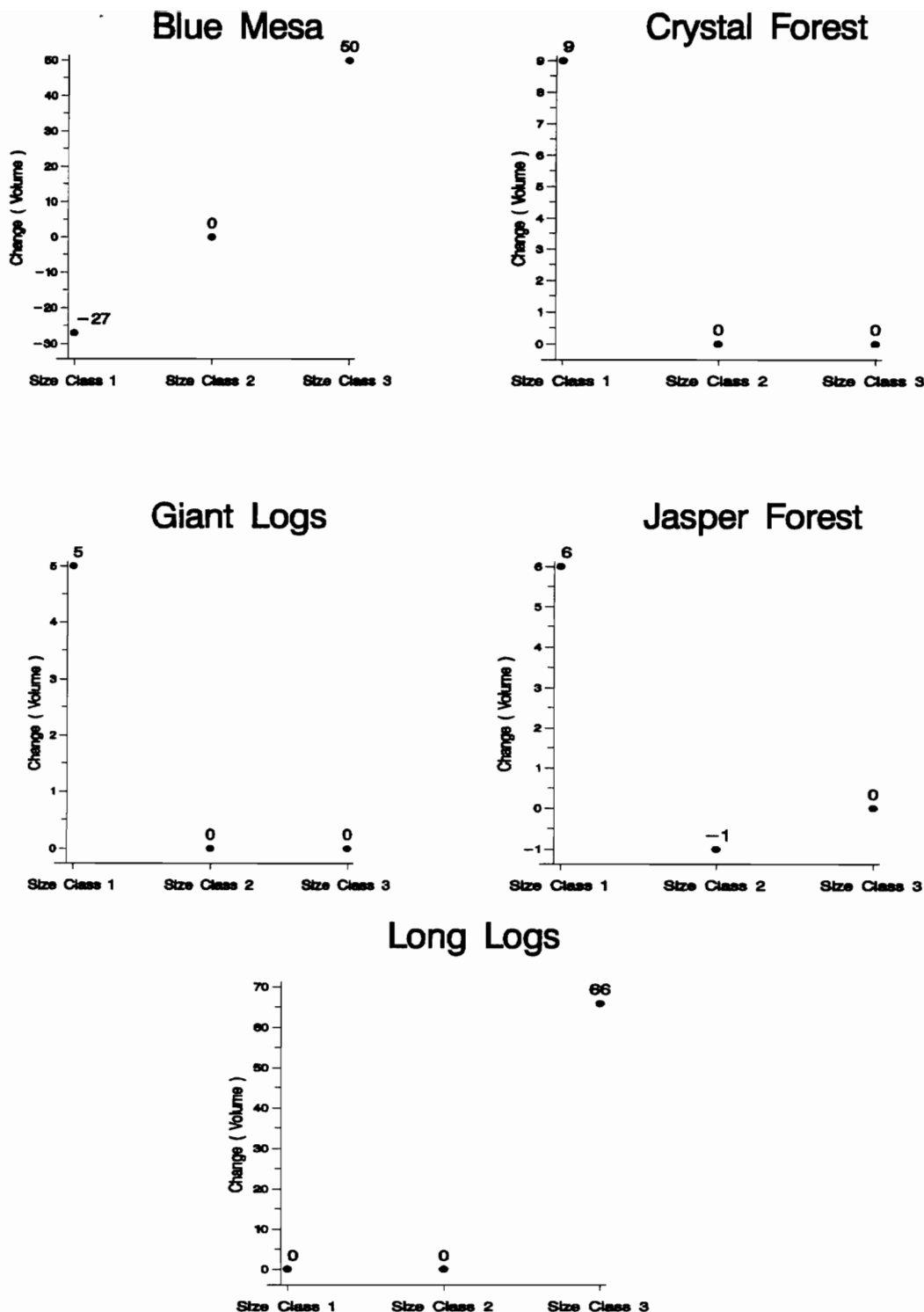


Figure 20. Overall Change in Volume (cubic feet) as Estimated From Line Intersect Data

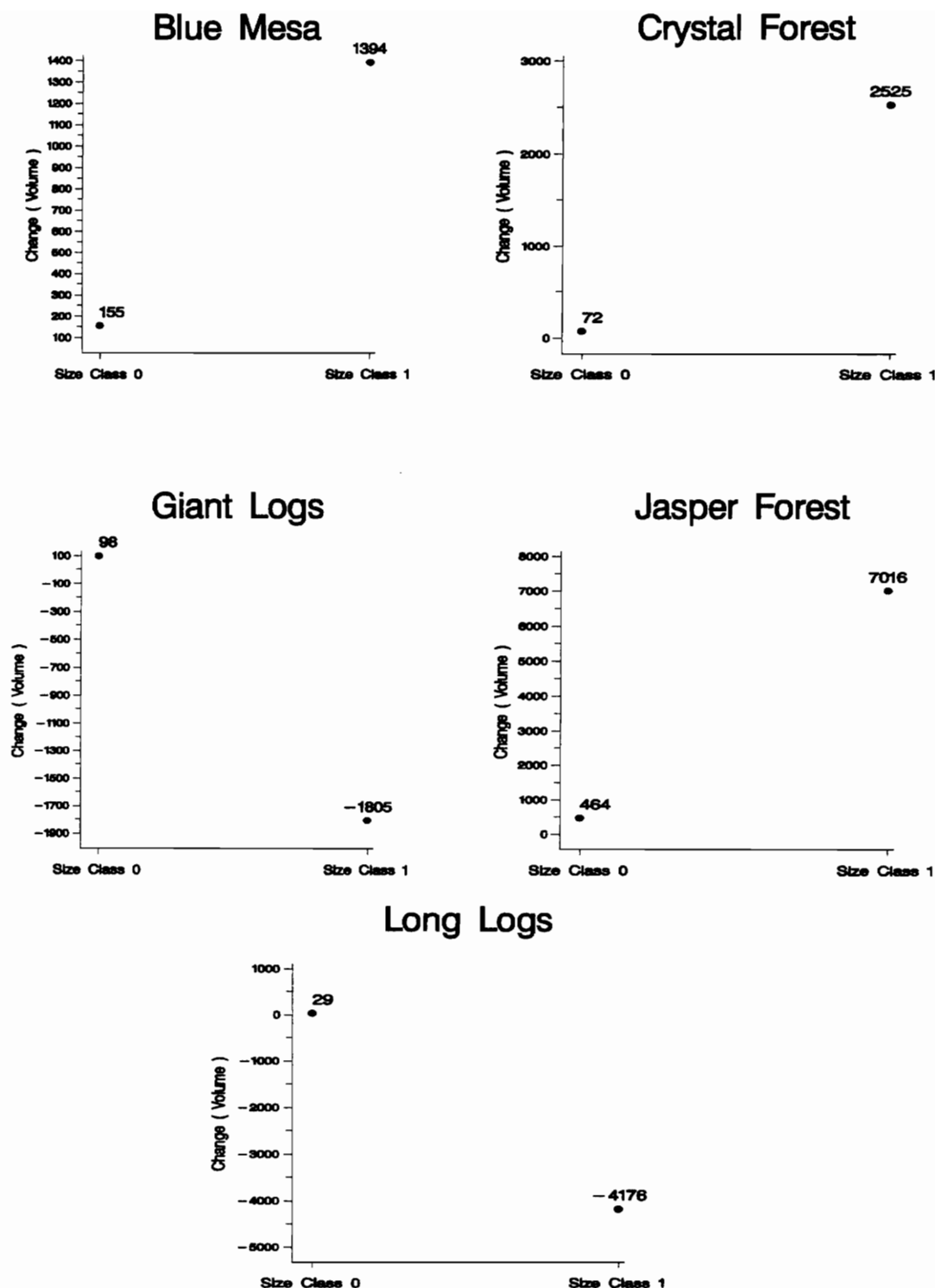


Figure 21. Overall Change in Volume (cubic feet) as Estimated From Quadrat Data

Chapter 7

Weight Results

Introduction

This chapter describes the detailed steps taken to achieve total and variance estimates for the quadrat weight sampling at the Petrified Forest National Park. Many of the calculations in this chapter can be duplicated using the data in Appendix A, but calculations rendering the data available in Appendix A can not be performed because the raw data were too copious to report. Recall that weight was only estimated for the quadrat samples and not for line intersect sampling. Throughout this chapter, all weight data for 1993 and 1994 are summarized and change is graphically depicted.

Quadrat Weight Estimator

Figure 9, estimator 3 is the weight estimator used to calculate the weight of petrified wood particles per acre for each quadrat. The estimator may be expressed for a single quadrat as:

$$10036 \times wt_i \quad [12]$$

where wt_i = weight (tons) of particles in i^{th} quadrat.

As an example, the 1994 Crystal Forest line 19 weight of petrified wood particles in size class 0 was 2.7137×10^{-7} tons. Recall that this quadrat weight was derived by multiplying the number of particles in quadrat 19 by the average weight of a quadrat size class 0 particle (Methods Section). To express this weight on a per acre basic, Equation 12 was used as follows:

$$10036 \times 2.7137 \times 10^{-7} = .0027 \text{ tons / acre.}$$

Now this quadrat estimate must be multiplied by the total acreage sampled to obtain a total for the quadrat sampled. Using the appropriate value from Table 2, the calculation is:

$$.0027 \times 56.21 = 0.15 \text{ tons.}$$

Identical methodology was used to derive weight estimates for all quadrat size classes for all strata.

Backcountry Total and Variance Estimation

To obtain total weight estimates for backcountry sampling units, individual quadrat estimates were calculated (Equation 12) and averaged. The averages were then multiplied by the backcountry area sampled. As an example, Table 78 lists the 1993 backcountry quadrat weight data for Jasper Forest, size class 0 collected at the Petrified Forest National Park. Note that I have chosen to report the per acre estimates and not total estimates.

Table 78. 1993 Backcountry Weight (tons) Data for the Jasper Forest Stratum, Size class 0 at the Petrified Forest National Park

Line #	Tons / Acre	Line #	Tons / Acre
16	2.5	26	0.0
17	2.3	27	0.4
18	6.3	28	1.9
19	22.0	29	0.0
20	1.3	30	0.0
21	3.2	31	0.0
22	14.1	32	0.0
23	29.5	33	0.0
24	0.7	34	1.0
25	0.0	35	0.0

To arrive at a total weight estimate for Jasper Forest size class 0, the data in Table 78 would be averaged and then multiplied by the total acreage sampled:

$$95.56 \times \left[\frac{2.5 + 2.3 + \dots + 1.0 + 0}{20} \right] = 441.3 \text{ tons.}$$

To estimate the variance of this estimate, the De Vries Equation 3 was used. Using the data in Table 78, Equation 3 and multiplying by the total acreage sampled, the calculation becomes:

$$\begin{aligned} &95.56^2 \left[(2.5 - 4.6)^2 \right. \\ &+ (2.3 - 4.6)^2 \\ &+ \dots \\ &+ \dots \\ &+ (1.0 - 4.6)^2 \end{aligned}$$

$$+ (0 - 4.6)^2 \Big]$$

$$= 11396855.3$$

dividing by the sample size yields:

$$\hat{VAR}(Weight_{sc2}) = \frac{11396855.3}{(19)20} = 29991.7 \text{ tons}^2.$$

To affix a level of confidence to backcountry weight estimates, Equation 6 was used. A two sided 95 percent confidence interval assuming normality for the Jasper Forest size class 1 weight estimate is:

$$441.3 \pm t_{(19),.975} \sqrt{29991.7}$$

$$441.3 \pm 2.093 \times 173.2$$

$$441.3 \pm 362.5$$

$$(78.8, \quad 803.8) .$$

Summary of Backcountry Weight Estimates

Methodology identical to the previous sections was used to generate backcountry quadrat values for all strata. Tables 79 and 80 summarize the backcountry quadrat weight data for each strata for 1993 and 1994 inventories respectively.

Table 79. 1993 Backcountry Quadrat Weight (tons) Data Summary at Petrified Forest National Park

Blue Mesa		
	Size class 0	Size class 1
Average	0.18	338.1
Standard Error	0.12	161.2
Sample Size	20	20
95% Confidence Int	(-0.07, 0.43)	(0.7, 675.5)
Crystal Forest		
Average	0.11	283.6
Standard Error	0.04	92.9
Sample Size	20	20
95% Confidence Int	(0.03, 0.19)	(89.1, 478.1)
Giant Logs		
Average	0.05	198.2
Standard Error	0.02	83.5
Sample Size	20	20
95% Confidence Int	(0.008, 0.09)	(23.5, 373.0)
Jasper Forest		
Average	0.16	441.6
Standard Error	0.11	173.2
Sample Size	20	20
95% Confidence Int	(-0.08, 0.40)	(79.2, 804.1)
Long Logs		
Average	0.06	254.1
Standard Error	0.02	86.4
Sample Size	20	20
95% Confidence Int	(0.02, 0.09)	(73.2, 435.1)

Size class 0 = intersection length $\leq .25''$

Size class 1 = $.25'' < \text{intersection length} < 1''$

Table 80. 1994 Backcountry Quadrat Weight (tons) Data Summary at Petrified Forest National Park

Blue Mesa		
	Size class 0	Size class 1
Average	0.09	175.2
Standard Error	0.06	83.6
Sample Size	20	20
95% Confidence Int	(-0.04, 0.22)	(0.9, 350.9)
Crystal Forest		
Average	0.06	189.4
Standard Error	0.03	49.1
Sample Size	20	20
95% Confidence Int	(-0.007, 0.13)	(86.6, 292.2)
Giant Logs		
Average	0.01	143.6
Standard Error	0.005	75.9
Sample Size	20	20
95% Confidence Int	(0.005, 0.02)	(-15.5, 302.6)
Jasper Forest		
Average	0.02	101.9
Standard Error	0.006	38.2
Sample Size	20	20
95% Confidence Int	(0.007, 0.03)	(21.9, 182.0)
Long Logs		
Average	0.03	190.9
Standard Error	0.01	69.1
Sample Size	20	20
95% Confidence Int	(0.01, 0.05)	(46.4, 335.5)

Size class 0 = intersection length $\leq .25''$

Size class 1 = $.25'' < \text{intersection length} < 1''$

Trail Corridor Average and Variance Estimation

The trail sampling units were broken down in a different way than were the backcountry estimates because these sampling units represent the displacement of petrified wood. First individual corridor averages were calculated. Recall that corridor 1 is 0 to 15 feet on both sides of the trail, corridor 2 is 15 to 30 feet on both sides of the trail, and corridor 3 is 30 to 45 feet on both sides of the trail. Second, the corridor values were averaged to show overall petrified wood change for a given stratum. As an example of how trail weight calculates were performed, Table 81 lists Blue Mesa quadrat data for size class 0, collected at the Petrified Forest National Park during the 1994 inventory.

Table 81. 1994 Trail Weight (tons) Data for the Blue Mesa Stratum, Size class 0 at the Petrified Forest National Park

line number	corridor #	Weight / Acre
1	1	missing 94
1	2	missing 94
1	3	missing 94
2	1	missing 94
2	2	1.0
2	3	0.8
3	1	2.5
3	2	1.3
3	3	0.3
4	1	3.0
4	2	1.7
4	3	0.1
5	1	10.0
5	2	20.5
5	3	0.1

Recall that some trail sampling units were destroyed between inventories. If a sampling unit was destroyed during the 1994 inventory, the 1993 data was not used in any calculations (coded missing 94).

To obtain corridor averages, the individual corridor values were averaged and multiplied by the acreage sampled in each corridor as follows:

$$\text{Corridor 1:} \quad 129 \times \left[\frac{2.5 + 3.0 + 10.0}{3} \right] = 6.67 \text{ tons}$$

$$\text{Corridor 2:} \quad 135 \times \left[\frac{1.0 + 1.3 + 1.7 + 20.5}{4} \right] = 8.27 \text{ tons}$$

$$\text{Corridor 3:} \quad 146 \times \left[\frac{0.8 + 0.3 + 0.1 + 0.1}{4} \right] = 0.47 \text{ tons.}$$

The variances of these individual corridor estimates was calculated using Equation 3. Note that I have chosen to calculate the variance on a per acre basis and multiply by the square of the corridor acreage sampled. For example, for the corridor 1 weight estimate, the calculation for variance is:

$$\frac{129^2}{2(3)} \left[(2.5 - 5.2)^2 + (3.0 - 5.2)^2 + (10.0 - 5.2)^2 \right] = 9.75 \text{ tons}^2.$$

To affix a level of confidence to each corridor estimate, Equation 6 was used with $\alpha = .05$ and the appropriate degrees of freedom for each corridor.

Summary of Trail Corridor Weight Estimates

Tables 82, 83, 84 and 85 summarize the quadrat weight data by corridors and petrified wood size classes for the 1993 and 1994 inventories. The change of petrified wood weight was calculated (1993 estimate - 1994 estimate) for each corridor in each stratum. Figure 22 depicts the relationships between petrified wood weight change and trail corridors for quadrat sampled data in each stratum.

Table 82. 1993 Size class 0 Weight (tons) Quadrat Trail Corridor Data Collected at the Petrified Forest National Park

Blue Mesa			
	Corridor 1	Corridor 2	Corridor 3
Average	0.0004	0.0006	0.0009
Standard Err.	0.0004	0.0005	0.0008
n	3	4	4
95 % C.I.	(-0.0004, 0.001)	(-0.001, 0.002)	(-0.001, 0.003)
Crystal Forest			
Average	0.004	0.0004	0.001
Standard Err.	0.0003	0.0002	0.0004
n	2	4	3
95 % C.I.	(0.0003, 0.008)	(-0.0002, 0.001)	(-0.0005, 0.003)
Giant Logs			
Average	0.0004	0.0004	0.0005
Standard Err.	undefined	0.0002	0.0002
n	1	3	3
95 % C.I.	N/A	(-0.0005, 0.001)	(-0.0002, 0.002)
Jasper Forest			
Average	0.002	0.006	0.003
Standard Err.	0.0008	0.003	0.002
n	4	3	4
95 % C.I.	(-0.0008, 0.004)	(-0.002, 0.009)	(-0.002, 0.009)
Long Logs			
Average	0.005	0.001	0.001
Standard Err.	0.005	0.0004	0.0002
n	3	4	3
95 % C.I.	(-0.02, 0.02)	(-0.0004, 0.002)	(0.000007, 0.002)

Size class 0 = intersection length $\leq .25''$

Table 83. 1994 Size class 0 Weight (tons) Quadrat Trail Corridor Data Collected at the Petrified Forest National Park

Blue Mesa			
	Corridor 1	Corridor 2	Corridor 3
Average	0.003	0.003	0.002
Standard Err.	0.002	0.002	0.0006
n	3	4	4
95 % C.I.	(-0.001, 0.006)	(-0.002, 0.008)	(-0.0001, 0.004)
Crystal Forest			
Average	0.002	0.004	0.0007
Standard Err.	0.001	0.002	0.0007
n	2	4	3
95 % C.I.	(-0.01, 0.02)	(-0.004, 0.01)	(-0.002, 0.004)
Giant Logs			
Average	0.001	0.00009	0.0004
Standard Err.	undefined	0.00005	0.0003
n		3	3
95 % C.I.	N/A	(-0.0001, 0.0003)	(-0.0009, 0.001)
Jasper Forest			
Average	0.0007	0.0007	0.0008
Standard Err.	0.0005	0.0006	0.0008
n	4	3	4
95 % C.I.	(-0.0008, 0.002)	(-0.002, 0.003)	(-0.002, 0.003)
Long Logs			
Average	0.0007	0.005	0.001
Standard Err.	0.0006	0.005	0.0007
n	3	4	3
95 % C.I.	(-0.002, 0.003)	(-0.01, 0.02)	(-0.002, 0.004)

Size class 0 = intersection length ≤ .25"

Table 84. 1993 Size class 1 Weight (tons) Quadrat Trail Corridor Data Collected at the Petrified Forest National Park

Blue Mesa			
	Corridor 1	Corridor 2	Corridor 3
Average	3.8	6.0	3.5
Standard Err.	3.0	2.5	0.9
n	3	4	4
95 % C.I.	(-2.1, 9.7)	(-2.1, 14.0)	(0.5, 6.4)
Crystal Forest			
Average	4.3	3.7	7.4
Standard Err.	3.4	1.9	2.1
n	2	4	3
95 % C.I.	(-38.5, 47.2)	(-2.4, 9.7)	(-1.8, 16.5)
Giant Logs			
Average	0.0	0.5	0.7
Standard Err.	undefined	0.3	0.1
n	1	3	3
95 % C.I.	N/A	(-0.7, 1.2)	(0.5, 1.0)
Jasper Forest			
Average	1.4	5.9	9.7
Standard Err.	0.5	2.0	1.5
n	4	3	4
95 % C.I.	(-0.2, 3.0)	(-2.9, 14.6)	(4.9, 14.6)
Long Logs			
Average	9.0	4.2	2.2
Standard Err.	6.3	1.9	1.1
n	3	4	3
95 % C.I.	(-18.2, 36.3)	(-1.8, 10.2)	(-2.6, 7.1)

Size class 1 = .25" < intersection length < 1"

Table 85. 1994 Size class 1 Weight (tons) Quadrat Trail Corridor Data Collected at the Petrified Forest National Park

Blue Mesa			
	Corridor 1	Corridor 2	Corridor 3
Average	6.7	8.2	0.4
Standard Err.	3.1	6.5	0.3
n	3	4	4
95 % C.I.	(0.6, 12.8)	(-12.3, 28.8)	(-0.4, 1.2)
Crystal Forest			
Average	2.1	10.3	0.8
Standard Err.	1.3	8.0	0.5
n	2	4	3
95 % C.I.	(-14.8, 18.9)	(-15.0, 35.7)	(-1.6, 3.1)
Giant Logs			
Average	0.6	0.3	0.9
Standard Err.	undefined	0.1	0.5
n	1	3	3
95 % C.I.	N/A	(-0.3, 0.8)	(-1.1, 3.0)
Jasper Forest			
Average	0.3	1.1	1.4
Standard Err.	0.3	0.6	0.6
n	4	3	4
95 % C.I.	(-0.5, 1.1)	(-1.6, 3.8)	(-0.6, 3.4)
Long Logs			
Average	7.6	7.1	4.6
Standard Err.	4.6	6.8	3.8
n	3	4	3
95 % C.I.	(-12.4, 27.6)	(-14.6, 28.8)	(-11.7, 20.9)

Size class 1 = .25" < intersection length < 1"

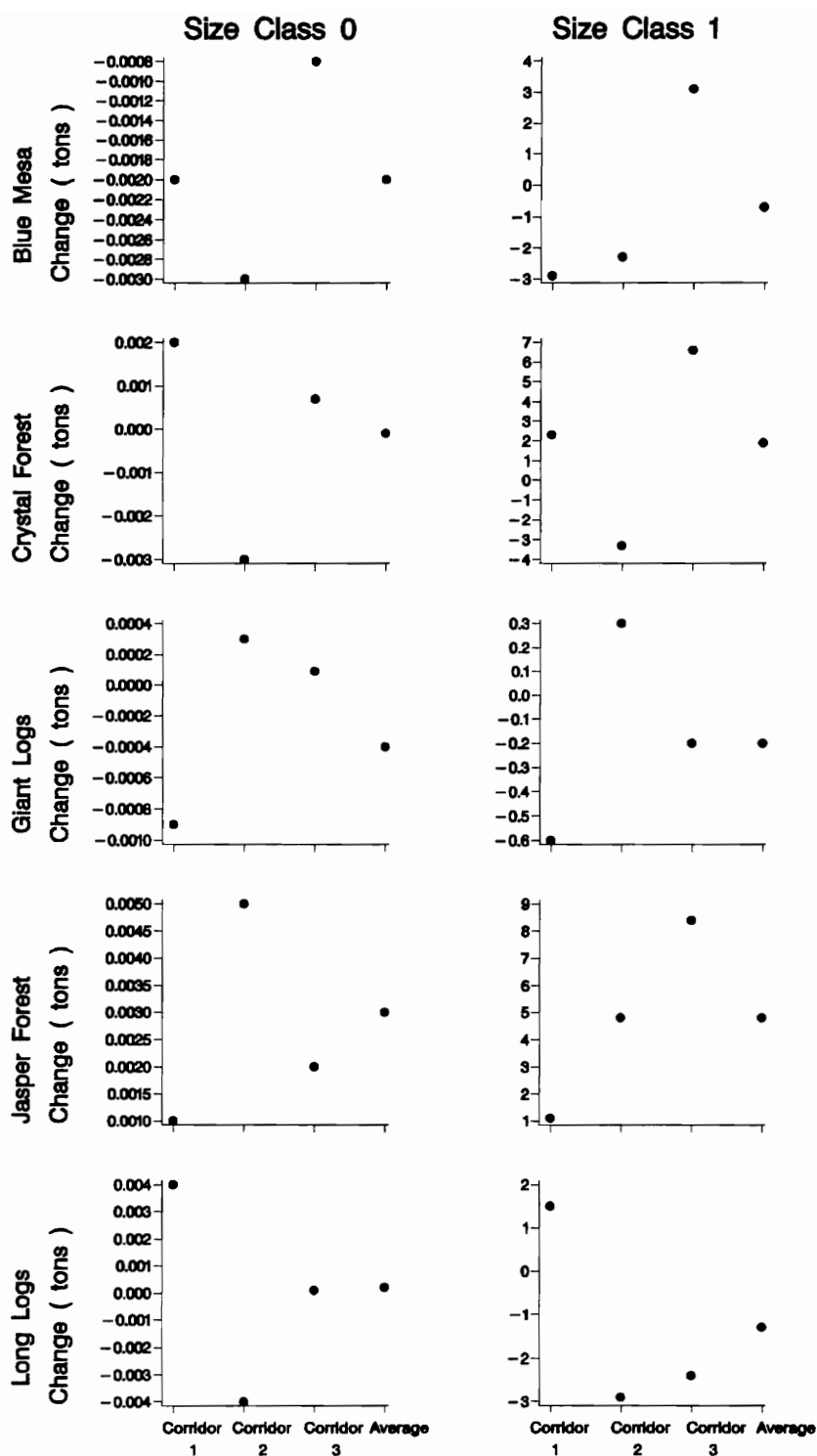


Figure 22. Change in Weight (tons) in the Trail Strata As Estimated From Quadrat Data

Trail Total and Variance Estimation

To arrive at a total estimate for the trail sampling units, the individual corridor estimates were averaged for each group and then averaged over the groups. This was done because each group of trail lines is dependent upon the location of the corridor 1 sample. For example, using the Blue Mesa size class 1 weight data (Table 81) and the corridor acreage's sampled (Table 2) the calculation is:

$$\begin{aligned} & \frac{1}{4} \left[\frac{(1.0 \times 1.35) + (0.8 \times 1.46)}{2} \right. \\ & + \frac{(2.5 \times 1.29) + (1.3 \times 1.35) + (0.3 \times 1.46)}{3} \\ & + \frac{(3.0 \times 1.29) + (1.7 \times 1.35) + (0.1 \times 1.46)}{3} \\ & \left. + \frac{(10.0 \times 1.29) + (20.5 \times 1.35) + (0.1 \times 1.46)}{3} \right] \\ & = 4.68 \text{ tons.} \end{aligned}$$

To estimate the variance of this estimate, Equation 4 was implemented. Again using the Blue Mesa size class 1 weight data (Table 81) and noting that some sampling units are missing from some groups of three lines, the calculation for variance is:

$$\left[\left(\frac{(1.0 \times 1.35) + (0.8 \times 1.46)}{2} \right) - 4.68 \right]$$

$$\begin{aligned}
& + \left[\left(\frac{(25 \times 1.29) + (1.3 \times 1.35) + (0.3 \times 1.46)}{3} \right) - 4.68 \right]^2 \\
& + \left[\left(\frac{(3.0 \times 1.29) + (1.7 \times 1.35) + (0.1 \times 1.46)}{3} \right) - 4.68 \right]^2 \\
& + \left[\left(\frac{(10.0 \times 1.29) + (20.5 \times 1.35) + (0.1 \times 1.46)}{3} \right) - 4.68 \right]^2 \\
& = 105.87
\end{aligned}$$

dividing by the sample size:

$$\hat{VAR}(Weight_{sc2}) \equiv \frac{105.87}{3(4)} = 8.82 \text{ tons}^2.$$

Recall that the first three quadrat samples were not available for the Blue Mesa stratum, so the data could not be used in the calculation of total and variance. Only sampling units that were available were used in the calculation of total and variance. Also recall that the covariance terms between the corridor units were neglected. This renders the variance for trail sampling totals approximate. Identical methods were used to calculate the variance estimates for the remainder of the strata and size classes for quadrat weight data. To affix a level of confidence to these trail totals, Equation 6 was used with the appropriate degrees of freedom and $\alpha = .05$.

Summary of Trail Total Weight Estimates

Methods as described previously were used to calculate totals and variance estimates for trail weight data. Tables 86 and 87 summarize these trail quadrat weight total estimates for 1993 and 1994 respectively.

Table 86. 1993 Trail Weight (tons) Quadrat Data Summary at Petrified Forest National Park

Blue Mesa		
	Size class 0	Size class 1
Average	0.0006	4.2
Standard Error	0.0004	1.3
Sample Size	4	4
95 % C. I.	(-0.0007, 0.001)	(-0.09, 8.5)
Crystal Forest		
Average	0.001	6.1
Standard Error	0.0003	2.0
Sample Size	4	4
95 % C. I.	(0.0005, 0.003)	(-0.4, 12.6)
Giant Logs		
Average	0.0004	0.5
Standard Error	0.0001	0.1
Sample Size	3	3
95 % C. I.	(-0.0002, 0.001)	(-0.09, 1.1)
Jasper Forest		
Average	0.003	5.6
Standard Error	0.001	0.8
Sample Size	4	4
95 % C. I.	(-0.002, 0.008)	(3.0, 8.3)
Long Logs		
Average	0.002	4.6
Standard Error	0.002	1.6
Sample Size	4	4
95 % C. I.	(-0.002, 0.01)	(-0.6, 9.7)

Size class 0 = intersection length $\leq .25''$

Size class 1 = $.25'' < \text{intersection length} < 1''$

Table 87. 1994 Trail Weight (tons) Quadrat Data Summary at Petrified Forest National Park

Blue Mesa		
	Size class 0	Size class 1
Average	0.002	4.7
Standard Error	0.0006	3.0
Sample Size	4	4
95 % C. I.	(0.0004, 0.004)	(-4.8, 14.1)
Crystal Forest		
Average	0.002	5.5
Standard Error	0.001	4.0
Sample Size	4	4
95 % C. I.	(-0.002, 0.005)	(-7.27, 18.3)
Giant Logs		
Average	0.0003	0.6
Standard Error	0.0003	0.3
Sample Size	3	3
95 % C. I.	(-0.0007, 0.001)	(-0.0007, 0.001)
Jasper Forest		
Average	0.0007	1.0
Standard Error	0.0006	0.4
Sample Size	4	4
95 % C. I.	(-0.001, 0.003)	(-0.3, 2.2)
Long Logs		
Average	0.005	10.0
Standard Error	0.004	5.9
Sample Size	4	4
95 % C. I.	(-0.009, 0.02)	(-8.9, 28.9)

Size class 0 = intersection length $\leq .25''$

Size class 1 = $.25'' < \text{intersection length} < 1''$

Total Weight Summary

To achieve a total estimate of weight for each strata, the backcountry and trail total amounts were added together. The variance of these totals was estimated by using Equation 5 and confidence intervals were calculated using Equation 6. As an example, Table 88 lists trail and backcountry totals for Long Logs 1994 quadrat weight, size class 1.

Table 88. Trail and Backcountry Weight (tons) Quadrat Total Estimates for Long Logs size class 1

Sampling Type	Total (tons)	Variance (tons ²)
Trail	10.0	34.81
Backcountry	190.9	4774.81

The total 1994 quadrat weight estimate for Long Logs size class 1 would be:

$$10.0 + 190.9 = 200.9 \text{ tons}$$

Using Equation 5 to estimate the variance of the above total would suggest:

$$\hat{VAR}(1994Weight) = 34.81 + 4774.81 = 4809.62 \text{ tons}^2.$$

Similar methods were used to calculate totals for all strata in each size class. Tables 89 and 90 summarize weight quadrat total estimates for 1993 and 1994 respectively.

The difference in weight estimates was calculated (1993 - 1994) for each size class in each stratum. Figure 23 depicts these relationships for quadrat data. Note that a negative number indicates a gain in weight, while a positive number suggests a loss.

Table 89. Total Quadrat Weight (tons) Estimates for 1993 Inventory at Petrified Forest National Park

Blue Mesa		
	Size class 0	Size class 1
Total	0.18	342.3
Standard Error	0.12	161.2
Sample Size	24	24
95 % C. I.	(-0.07, 0.43)	(8.8, 675.8)
Crystal Forest		
Total	0.11	289.7
Standard Error	0.04	92.9
Sample Size	24	24
95 % C. I.	(0.03, 0.19)	(97.4, 482.0)
Giant Logs		
Total	0.05	198.7
Standard Error	0.02	83.5
Sample Size	23	23
95 % C. I.	(0.01, 0.09)	(25.9, 371.5)
Jasper Forest		
Total	0.16	447.2
Standard Error	0.11	173.2
Sample Size	24	24
95 % C. I.	(-0.06, 0.39)	(88.8, 805.6)
Long Logs		
Total	0.06	258.7
Standard Error	0.02	86.4
Sample Size	24	24
95 % C. I.	(0.02, 0.10)	(79.9, 437.5)

Size class 0 = intersection length $\leq .25''$

Size class 1 = $.25'' < \text{intersection length} < 1''$

Table 90. Total Quadrat Weight (tons) Estimates for 1994 Inventory at Petrified Forest National park

Blue Mesa		
	Size class 0	Size class 1
Total	0.09	179.9
Standard Error	0.06	83.7
Sample Size	24	24
95 % C. I.	(-0.03, 0.22)	(6.8, 353.0)
Crystal Forest		
Total	0.06	194.9
Standard Error	0.03	49.3
Sample Size	24	24
95 % C. I.	(-0.001, 0.12)	(93.0, 296.8)
Giant Logs		
Total	0.01	144.2
Standard Error	0.01	75.9
Sample Size	23	23
95 % C. I.	(-0.003, 0.02)	(-12.8, 301.2)
Jasper Forest		
Total	0.02	102.9
Standard Error	0.01	38.2
Sample Size	24	24
95 % C. I.	(0.01, 0.03)	(23.9, 181.9)
Long Logs		
Total	0.04	200.9
Standard Error	0.01	69.4
Sample Size	24	24
95 % C. I.	(0.01, 0.06)	(57.4, 344.4)

Size class 0 = intersection length $\leq .25''$

Size class 1 = $.25'' < \text{intersection length} < 1''$

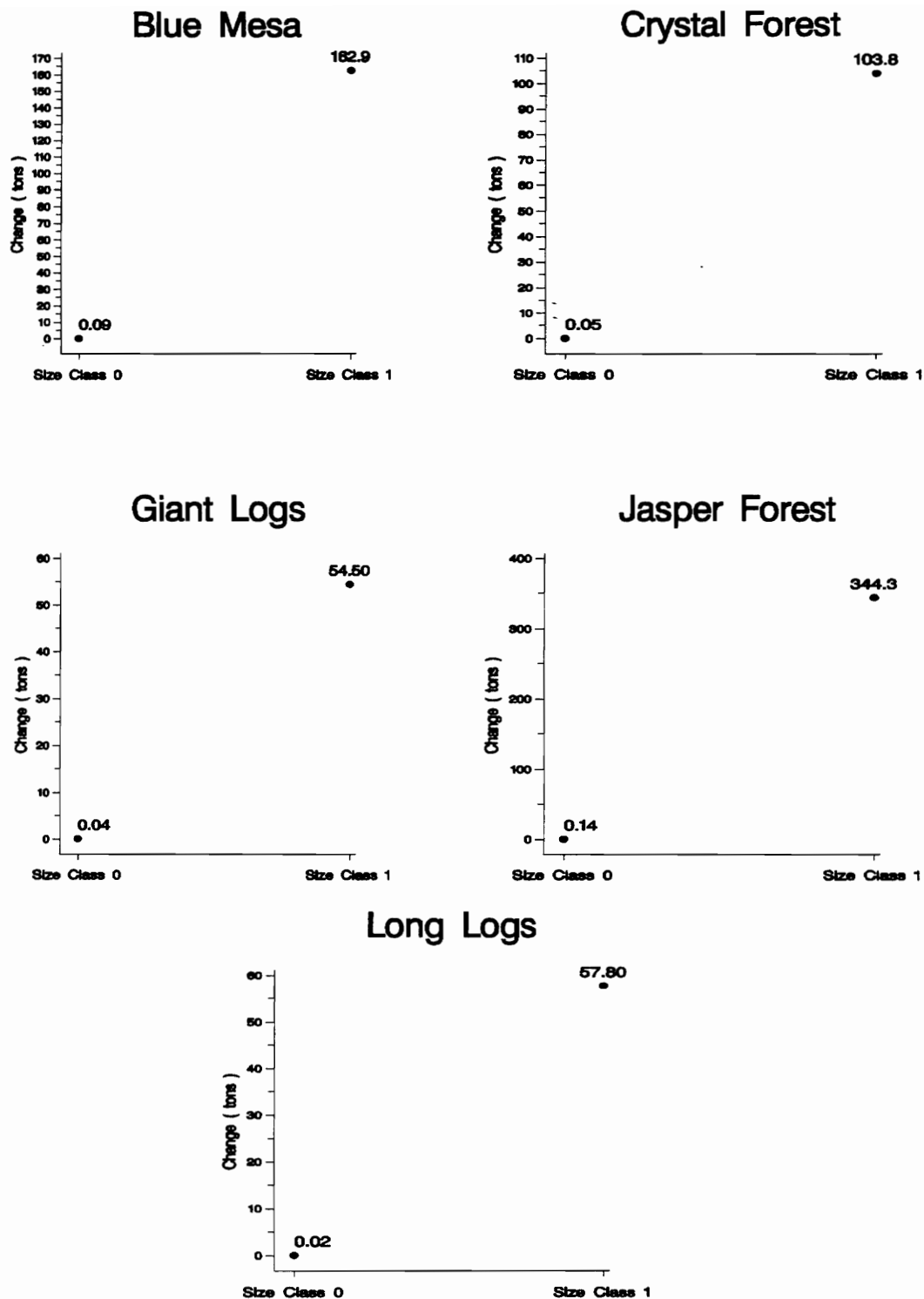


Figure 23. Overall Change in Weight (tons) as Estimated From Quadrat Data

Chapter 8

Discussion

Introduction

This chapter addresses strengths and weaknesses of the quadrat and line intersect estimates. It also summarizes totals (added across strata) for all size classes of petrified wood for both quadrat and line intersect samples. Recommendations for conducting future inventories of petrified wood is also given.

Comparison Between Line Intersect and Quadrat Estimates for Petrified Wood Size Class 1 Particles

Volume, percent cover and density were estimated from both line intersect and quadrat samples. The line intersect size class 1 coincided with quadrat size class 1 estimates using different sampling methodology. The line intersect method tallied particles of inclusion that intersected the line transect, while the quadrat sample tallied particles if they were contained inside a particular square area. The following discussion will attempt to determine whether line intersect or quadrat methods gave better estimates for volume, percent cover and density than the other.

The coefficient of variation of an estimate is an indicator of the precision attained in a survey. It is expressed as a unitless ratio of standard error of an estimate divided by the estimate. The smaller the coefficient of variation is, the more precise the estimate. The coefficient of variation of an estimate $\hat{\theta}$ is expressed as:

$$cve(\hat{\theta}) = \frac{\sqrt{\widehat{VAR}(\hat{\theta})}}{\hat{\theta}}. \quad [13]$$

Presumably the coefficients of variations for the quadrat and line intersect sampled estimates should paint a winner. Table 91 summarizes the coefficients of variation for 1993 and 1994 inventories for size class 1 petrified wood particles.

Table 91. Coefficients of Variation for Line Intersect and Quadrat Size Class 1 Petrified Wood Totals for 1993 and 1994 Inventories

Blue Mesa				
Estimate	Line Intersect <i>cve</i>		Quadrat <i>cve</i>	
	1993	1994	1993	1994
% Cover	0.188	0.182	0.368	0.384
Density	0.591	0.590	0.390	0.620
Volume (ft ³)	1.327	1.323	0.482	0.548
Crystal Forest				
% Cover	0.241	0.241	0.223	0.283
Density	0.542	0.545	0.288	0.540
Volume (ft ³)	0.421	0.424	0.407	0.255
Giant Logs				
% Cover	0.449	0.342	0.354	0.347
Density	0.405	0.405	0.376	0.446
Volume (ft ³)	0.402	0.402	0.404	0.421
Jasper Forest				
% Cover	0.167	0.166	0.233	0.544
Density	0.365	0.366	0.536	0.356
Volume (ft ³)	0.350	0.350	0.362	0.465
Long Logs				
% Cover	0.304	0.304	0.547	0.892
Density	0.352	0.352	0.338	0.318
Volume (ft ³)	0.383	0.383	0.364	0.368

With the exception of a few estimates for several strata, Table 91 depicts that coefficients of variation are similar for line intersect and quadrat sampling. The outliers include Blue Mesa percent cover, Blue Mesa volume, Jasper Forest percent cover and Long Logs percent cover. Line intersect

sampling seemed to do better (in terms of *cve*'s) for the percent cover estimates in Blue Mesa, Jasper Forest and Long Logs while the quadrat sampling seemed to outperform line intersect sampling for the volume estimate in the Blue Mesa stratum.

The *cve*'s do not portray one method of sampling as clearly better than the other. A glance at Tables 24-27, Tables 49-52, and Tables 74-78 suggests that the magnitude of the estimates are similar for all characteristics sampled but the change estimates (1993 - 1994, Figures 12, 13, 16, 17, 20, and 21) for the quadrat samples was significantly larger when compared with a paired t-test using $\alpha = .05$. The main difference between the line intersect and quadrat sampling estimates is caused by how rigidly field sampling was conducted. The line intersect sampling units established in 1993, retallied the same petrified wood particles in 1994. The quadrat sampling units, although placed in the same general areas during the 1993 and 1994 inventories tallied two distinct groups of petrified wood particles. These quadrat samples are essentially two independent samples. The quadrat sampling units could show change over the sampling characteristic due to sampling variation alone. The line intersect estimates that show change of petrified wood actually had individual pieces of petrified wood removed or added to line transects.

Although the estimates for the line intersect and quadrat size class 1 samples are similar in magnitude, more confidence is placed upon the line intersect estimates. The quadrat sampling unit change estimates are probably more affected by random error than the line intersect estimates. For this reason, percent cover, volume and density estimates from line intersect size class 1 are favored over quadrat estimates.

Total Petrified Wood Loss Summary

The stratum total amounts of petrified wood were used to calculate the total amounts of petrified wood displaced during the one year study period. The individual stratum 1994 totals were subtracted from the 1993 totals and then added together across all 5 strata. The following 2 tables display calculated change and change relative to 1994 inventory estimates. Table 92 summarizes the total petrified wood change for the line intersect sampling units. Table 93 summarizes the total petrified wood change for quadrat sampling units. Note that positive number indicates a loss of petrified wood while a negative number suggests a gain.

Table 92. Estimated Change and Relative Change (in Parenthesis) in the Amount of Petrified Wood For All Strata From Line Intersect Sampling

Percent Cover			
	Size Class 1	Size Class 2	Size Class 3
Total	0.92 (2.4%)	-0.08 (-0.3%)	0.40 (1.3%)
Standard Error ¹	0.51	0.04	0.11
Sample Size	119	119	119
95% C. I.	(-0.08, 1.92)	(-0.15, -0.009)	(0.18, 0.62)
Density			
Total	286,584 (0.1%)	2,149 (0.01%)	680 (0.2%)
Standard Error ¹	107,816	961	186
Sample Size	119	119	119
95% C. I.	(75,263, 497,904)	(265, 4,032)	(314, 1,045)
Volume (ft ³)			
Total	-7 (-0.01%)	-1 (-0.0006%)	116 (0.008%)
Standard Error ¹	14.7	0.4	32.2
Sample Size	119	119	119
95% C. I.	(-35.7, 21.8)	(-1.9, -0.1)	(52.8, 179.2)

Size Class 1 = .25" ≤ intersection length < 1"
Size Class 2 = 1" ≤ intersection length < 5"
Size Class 3 = 5" ≤ intersection length

$$^1 \text{ Std Error} = \sqrt{\sum_{i=1}^5 \hat{V}\hat{A}R(Estimate_{1993,} - Estimate_{1994,})}$$

where: Estimate_{1993i} = 1993 inventory estimate for ith stratum
Estimate_{1994i} = 1994 inventory estimate for ith stratum

Table 93. Estimated Change and Relative Change (in Parenthesis) in the Amount of Petrified Wood For All Strata From Quadrat Sampling

Percent Cover		
	Size Class 0	Size Class 1
Total	0.27 (14.2%)	7.67 (21.1%)
Standard Error ¹	0.37	5.77
Sample Size	119	119
95% C. I.	(-0.46, 1.00)	(-3.63, 18.97)
Density		
Total	56,081,064 (70.4%)	95,025,514 (66.9%)
Standard Error ¹	7,126,371	27,313,092
Sample Size	119	119
95% C. I.	(42,113,378, 70,048,750)	(41,491,853, 148,559,175)
Volume (ft ³)		
Total	819 (38.3%)	4,954 (10.7%)
Standard Error ¹	174.0	4281.7
Sample Size	119	119
95% C. I.	(477.9, 1,160.0)	(-3,438, 13,346)
Weight (tons)		
Total	0.34 (60.7%)	713.8 (46.5%)
Standard Error ¹	0.05	120.7
Sample Size	119	119
95% C. I.	(0.25, 0.43)	(477.1, 950.4)

Size Class 0 = intersection length ≤ .25"

Size Class 1 = .25" < intersection length < 1"

$$^1 \text{ Std Error} = \sqrt{\sum_{i=1}^5 \text{VAR}(\text{Estimate}_{1993i} - \text{Estimate}_{1994i})}$$

where: Estimate_{1993i} = 1993 inventory estimate for ith stratum
Estimate_{1994i} = 1994 inventory estimate for ith stratum

Table 92 suggests that there is some discrepancy among the line intersect total estimates. For example, size class 2 percent cover and volume increased between inventories, while size class 2 density decreased. This phenomenon has to do with the nature of line intersect sampling and the addition and subtraction of irregularly shaped petrified wood particles. Recall that intersection length was measured to obtain percent cover, horizontal circumference for density, and cross sectional area for volume. An example of what happened to cause this discrepancy follows. The total intersection lengths tallied in 1993 were greater than in the 1994 inventory resulting in a gain of percent cover, while the total horizontal circumferences tallied in 1993 was greater than in 1994 resulting in a loss of density. One can easily justify this by looking at several pieces of petrified wood in the line intersect size class 2.

For the size class 1 line intersect discrepancy, the problem runs deeper. Recall that line intersect size class 1 particles were assumed to be circular with radius equal to a particles intersection length. This was done because measuring instruments were not precise enough to obtain horizontal circumferences and cross sectional areas of minute pieces of petrified wood. This discordance would suggest that the circularity assumption may have caused a problem similar to the line intersect size class 2. The percent cover and volume line intersect size class 1 estimates

are also bothersome because their confidence intervals contain zero, while the size class 1 density estimate doesn't.

In terms of relative change, all line transect estimates did not change much between 1993 and 1994 inventories. However, the line intersect total change estimates suggest some displacement of petrified wood over the one year study period. The pocket sized pieces (size class 2) decreased by 2,149 pieces of petrified wood. This size class of petrified wood is probably the most common to be picked up, examined, and stolen by tourists. This study has no way of determining how many of the estimated 2,149 pieces were actually stolen or relocated. However, if all 2,149 pieces were assumed to have been stolen, the Petrified Forest National Park may have a small pilfering problem. Similar arguments can be made for other size classes and sampling attributes.

Table 93 indicates that the quadrat loss totals also display some incongruity. Not only are the size class 1 change value significantly larger than the line intersect size class 1 estimates, but the two percent cover total estimate confidence intervals contain zero. In terms of relative change, the estimates for all sampling attributes changed dramatically between inventories.

Using the quadrat change and relative change totals would suggest a large petrified wood theft problem in the Petrified Forest National Park.

However, it is hard to believe that 713 tons of quadrat size class 2 particles were stolen over a one year time frame in the light of the paired line intersect results. It is also hard to believe that the quadrat samples estimated 95,025,514 pieces of petrified wood with intersection lengths between .25" and 1", while the line intersect sampling estimated 286,584. It is my recommendation that the change estimates given from quadrat data are not trusted. The best use for the quadrat data may be to average over all totals to achieve good estimates of the amount of petrified wood in size classes 0 and 1, rather than to use them to calculate what changed between inventories. The quadrat samples are essentially two distinct samples and would serve a purely inventory oriented purpose well, but serve to estimate change poorly in comparison to the repeated line intersect samples.

Recommendations for Future Sampling

This section summarizes some recommendations I have to anyone interested in further or future sampling of the petrified wood resource.

The first topic I would like to discuss has to do with time and efficiency of field sampling. In my opinion, four major improvements can be made to my sampling design in terms of efficiency. First, field sampling goes much more smoothly and quickly when there are two people

conducting the sampling. It took approximately 6 weeks of field sampling alone during the first summer, and only 2 weeks to re-measure the same locations during the second summer with myself and an assistant. Not only can field work be divided into individual responsibilities for two people, but motivation and morale are also heightened with a partner. Second, choosing one sampling attribute to focus on will greatly increase field productivity. Making one measurement (instead of 3) on each petrified wood particle will surely save time in the field. Also under this point, is the possibility that only one sampling attribute is of interest. Perhaps volume and percent cover are hard to conceptualize for some users and only density is needed. Simply use my density techniques and disregard the volume and percent cover methodology. Third, choosing fewer size classes of petrified wood will increase field productivity and the precision of sampling estimates. For the same reasons as decreasing the sampling attributes estimated, decreasing the size classes of petrified wood will significantly decrease field sampling time. It is my personal recommendation that the fleck size pieces ($< 1''$) are not inventoried in the future. Not only is it hard to get accurate measurements on small pieces of petrified wood, but these pieces are easily moved by natural forces (rain, erosion, and wind). Finally, with regard to field sampling efficiency, I recommend that only line intersect sampling be used and the quadrat sampling disregarded. Each quadrat

sampling unit took at least twice the time of measuring a line intersect sample. Also recall that the quadrat sampling units gave confusing results and may misguide some users.

A few final suggestions follow. The wooden dowels wrapped in pink flagging (used to mark the ends of the line transect on the ground) did not work well. It was often difficult to get the dowel into the hard desert floor and the intense sun quickly disintegrated the flagging. The combination of these two shortcomings often made it difficult to relocate line transects in 1994. It is my recommendation that painted metal spikes be used to keep track of sampling locations in the future. My final comment has to do with the allocation of trail side sampling units. Because the locations of the corridor 2 and 3 depended on where the corridor 1 sample was placed, the trail average and variance calculations were messy. To alleviate this problem, simply randomly locate all sampling locations within each corridor stratum. This will render the trail samples independent and make the calculations more straightforward for people not highly trained in statistics.

Closing

The objectives of this study were to develop and implement a sampling design to estimate amounts of petrified wood in five high use areas of the Petrified Forest National Park and to furnish estimates of the

change of petrified wood over a one year study period. The objectives were fulfilled using line intersect and quadrat sampling during the summers of 1993 and 1994. Line intersect sampling results suggest that the petrified wood theft problem is less serious than reported by Scher (1990). Quadrat sampling results are not conclusive due to the fact that sampling was independent between 1993 and 1994 inventories.

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Appendix A

Petrified Forest National Park Data Summary

This appendix lists statistics summarized from individual sampling locations at the Petrified Forest National Forest during the summers of 1993 and 1994. Sampling type is depicted with a 1 or 2. A one represents a back country sampling unit and a 2 represents a trail sampling unit. The trail sampling unit groups are listed in the following manner. The trail sampling units are listed in groups. For example Blue Mesa line numbers 11,12, and 13 would represent a group of three line transects or one trail sample. Line 11 would be the sample in the first trail corridor, line 12 the second corridor sample and line 13 the third corridor sample. Blue Mesa lines 14, 15 and 16 would have the same pattern. This pattern holds for all strata. Missing values in the 1994 data sets indicate that the sampling unit was destroyed or could not be located. Although all 1993 data are listed in this appendix, if the 1994 sample was not available, the 1993 data was not used for analysis.

The units of the data are as follows. Percent cover is given as a percent. Volume is given in cubic feet per acre. Density is given in number per acre. Weight is given in tons per acre. A data key may be found below.

Data Key		
Ls1	Size Class 1	.25" < intersection length < 1"
Ls2	Size Class 2	1" ≤ intersection length < 5"
Ls3	Size Class 3	5" ≤ intersection length
Q1	Size Class 0	intersection length ≤ .25 "
Q2	Size Class 1	.25" ≤ intersection legnth < 1"

Blue Mesa 1993 Line Intersect Data Summary

Line	Type	Percent Cover			Volume Per Acre			Number Per Acre		
		Ls1	Ls2	Ls3	Ls1	Ls2	Ls3	Ls1	Ls2	Ls3
11	2	13.1	0.0	0.0	514	0	0	3708841	0	0
12	2	2.2	0.0	3.1	96	0	3323	448046	0	1563
13	2	4.3	1.7	1.2	191	143	273	1023909	28978	1563
14	2	0.0	4.8	3.9	0	1073	11184	0	1455	3853
15	2	0.0	2.0	2.8	0.0	26.8	1376.7	0	27576	2121
16	2	10.0	4.7	0.0	328.4	480.9	0.0	2065624	52298	0
17	2	0.0	6.5	3.1	0.0	521.4	800.1	0	69508	1874
18	2	8.0	0.0	4.5	254.3	0.0	2436.2	1185194	0	6978
19	2	6.4	6.1	4.8	226.9	615.8	715.5	633238	27445	6597
20	2	6.3	6.3	0.0	229.1	410.5	0.0	665184	60279	0
21	2	0.0	7.7	0.0	0.0	812.1	0.0	0	29591	0
22	2	2.8	0.0	0.0	85.2	0.0	0.0	363631	0	0
23	2	3.5	10.9	0.0	138.6	3345.5	0.0	285120	75182	0
24	2	3.0	24.1	10.9	100.7	1981.9	2662.5	334541	229309	13692
25	2	17.0	0.0	0.0	491.9	0.0	0.0	3086287	0	0
1	1	13.6	0.0	0.0	514.2	0.0	0.0	3708841	0	0
2	1	2.2	0.0	3.1	96.3	0.0	3323.1	448046	0	382
3	1	4.3	1.7	1.2	190.6	143.1	272.9	1023909	28978	1563
4	1	0.0	4.8	3.9	0.0	1072.8	11184.0	0	1455	3853
5	1	0.0	8.3	1.8	0.0	1024.3	501.2	0	101704	3273
6	1	3.8	4.5	0.0	271.4	487.4	0.0	266921	47883	0
7	1	0.0	2.7	28.6	0.0	356.6	35522.0	0	15831	7471
8	1	0.0	1.3	1.1	0.0	67.3	528.0	0	55153	1315
9	1	5.1	1.3	0.0	269.3	58.3	0.0	843602	36377	0
10	1	0.0	2.1	1.2	0.0	152.1	342.7	0	26304	745
26	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
27	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
28	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
29	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
30	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
31	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
32	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
33	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
34	1	0.0	8.3	4.7	0.0	1274.6	7107.4	0	65908	238
35	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0

Blue Mesa 1994 Line Intersect Data Summary

Line	Type	Percent Cover			Volume Per Acre			Number Per Acre		
		Ls1	Ls2	Ls3	Ls1	Ls2	Ls3	Ls1	Ls2	Ls3
11	2									
12	2									
13	2									
14	2									
15	2	0.0	2.0	2.8	0.0	26.8	1376.7	0	27576	2121
16	2	10.0	4.7	0.0	328.4	480.9	0.0	2065624	52298	0
17	2	0.0	6.5	3.1	0.0	521.4	800.1	0	69508	1874
18	2	14.6	0.0	4.5	493.6	0.0	2436.2	1804855	0	6978
19	2	6.4	6.1	1.8	226.9	615.8	303.7	633238	27445	3747
20	2	6.3	6.3	0.0	229.1	410.5	0.0	665184	60279	0
21	2	0.0	7.7	0.0	0.0	812.1	0.0	0	29591	0
22	2	2.8	0.0	0.0	85.2	0.0	0.0	363631	0	0
23	2	3.5	10.9	0.0	138.6	3345.5	0.0	285120	75182	0
24	2	3.0	24.1	10.9	100.7	1981.9	2662.5	334541	229309	13692
25	2	17.0	0.0	0.0	491.9	0.0	0.0	3086287	0	0
1	1	13.6	0.0	0.0	514.2	0.0	0.0	3708841	0	0
2	1	2.2	0.0	3.1	96.3	0.0	3323.1	448046	0	382
3	1	4.3	1.7	1.2	190.6	143.1	272.9	1023909	28978	1563
4	1	0.0	4.8	3.9	0.0	1072.8	11184.0	0	1455	3853
5	1	0.0	8.3	1.8	0.0	1024.3	501.2	0	101704	3273
6	1	3.8	4.5	0.0	271.4	487.4	0.0	266921	47883	0
7	1	0.0	2.7	28.6	0.0	356.6	35522.0	0	15831	7471
8	1	0.0	1.3	1.1	0.0	67.3	528.0	0	55153	1315
9	1	5.1	1.3	0.0	269.3	58.3	0.0	843602	36377	0
10	1	0.0	2.1	1.2	0.0	152.1	342.7	0	26304	745
26	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
27	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
28	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
29	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
30	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
31	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
32	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
33	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
34	1	0.0	8.3	4.7	0.0	1274.6	7107.4	0	65908	238
35	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0

Blue Mesa 1993 Quadrant Inventory Data Summary

Line	Type	Density per Acre		Percent cover		Tons per acre		Volume per acre	
		Q1	Q2	Q1	Q2	Q1	Q2	Q1	Q2
11	2	1204320	1103960	2.8	15.2	0.0086	9.5	59.9	219.0
12	2	2207920	843024	1.6	4.9	0.0158	3.1	35.1	117.0
13	2	40144	461656	0.1	4.3	0.0003	3.2	2.1	144.0
14	2	0	1726192	0.0	0.1	0.0000	0.3	0.9	0.0
15	2	10036	70252	0.0	1.0	0.0001	0.3	0.9	0.0
16	2	40144	150540	0.0	1.6	0.0003	1.3	1.0	0.0
17	2	0	100360	0.0	1.0	0.0000	1.3	0.0	3.9
18	2	220792	230828	0.2	1.0	0.0016	2.2	5.1	78.1
19	2	311116	1144104	0.3	4.6	0.0022	4.1	6.8	136.6
20	2	0	70252	0.0	0.6	0.0000	0.0	0.0	0.0
21	2	0	491764	0.0	14.7	0.0000	7.2	0.0	175.6
22	2	0	120432	0.0	1.0	0.0000	2.5	0.0	78.1
23	2	120432	461656	0.2	6.6	0.0009	7.5	5.1	195.1
24	2	0	531908	0.0	6.1	0.0000	7.9	0.0	175.6
25	2	0	50180	0.0	1.4	0.0000	1.7	0.0	39.0
1	1	1204320	1103960	2.9	15.2	0.0086	9.5	61.6	218.6
2	1	2207920	843024	1.6	5.0	0.0158	3.1	35.1	117.1
3	1	40144	461656	0.1	4.3	0.0003	3.2	2.6	144.4
4	1	0	1726192	0.0	29.0	0.0000	21.3	0.0	683.0
5	1	0	20072	0.0	0.1	0.0000	0.0	0.0	0.0
6	1	20072	220792	0.0	1.9	0.0001	1.3	0.5	46.8
7	1	110396	692484	0.1	7.7	0.0008	7.4	2.7	234.2
8	1	0	40144	0.0	0.3	0.0000	0.4	0.0	19.5
9	1	60216	70252	0.1	0.4	0.0004	0.0	1.7	0.0
10	1	0	10036	0.0	0.2	0.0000	0.7	0.0	0.0
26	1	0	0	0.0	0.0	0.0000	0.0	0.0	0.0
27	1	0	0	0.0	0.0	0.0000	0.0	0.0	0.0
28	1	0	0	0.0	0.0	0.0000	0.0	0.0	0.0
29	1	0	0	0.0	0.0	0.0000	0.0	0.0	0.0
30	1	0	0	0.0	0.0	0.0000	0.0	0.0	0.0
31	1	0	0	0.0	0.0	0.0000	0.0	0.0	0.0
32	1	0	60216	0.0	0.6	0.0000	0.7	0.0	11.7
33	1	0	0	0.0	0.0	0.0000	0.0	0.0	0.0
34	1	20072	120432	0.0	0.7	0.0001	1.0	0.7	11.7
35	1	0	0	0.0	0.0	0.0000	0.0	0.0	0.0

Blue Mesa 1994 Quadrant Inventory Data Summary

Line	Type	Density per Acre		Percent cover		Tons per acre		Volume per acre	
		Q1	Q2	Q1	Q2	Q1	Q2	Q1	Q2
11									
12									
13									
14									
15	2	120432	712556	0.2	3.2	0.0009	1.0	3.4	97.6
16	2	190684	662376	0.2	2.7	0.0014	0.8	5.1	58.5
17	2	40144	371332	0.0	3.8	0.0003	2.5	1.0	117.1
18	2	50180	853060	0.1	3.7	0.0004	1.3	1.2	78.1
19	2	230828	210756	0.2	1.0	0.0016	0.3	3.8	19.5
20	2	120432	702520	0.2	6.4	0.0009	3.0	3.4	156.1
21	2	762736	1284608	1.4	5.4	0.0054	1.7	30.8	175.6
22	2	250900	200720	0.3	1.0	0.0018	0.1	6.8	3.9
23	2	682448	1806480	0.7	17.9	0.0049	10.0	15.4	507.4
24	2	361296	3331952	0.3	24.3	0.0026	20.5	6.8	624.5
25	2	0	110396	0.0	0.5	0.0000	0.1	0.0	3.9
1	1	0	80288	0.0	1.6	0.0000	0.1	0.0	3.9
2	1	0	40144	0.0	0.3	0.0000	0.1	0.0	3.9
3	1	0	50180	0.0	0.2	0.0000	0.1	0.0	3.9
4	1	1244464	3251664	3.2	23.0	0.0089	10.0	68.5	683.0
5	1	140504	682448	0.2	5.8	0.0010	2.5	4.1	117.1
6	1	10036	80288	0.0	1.6	0.0001	1.0	0.2	39.0
7	1	341224	451620	0.3	5.4	0.0024	7.5	6.5	273.2
8	1	0	100360	0.0	1.7	0.0000	1.0	0.0	58.5
9	1	0	110396	0.0	1.0	0.0000	1.0	0.0	39.0
10	1	0	60216	0.0	1.0	0.0000	0.7	0.0	39.0
26	1	0	0	0.0	0.0	0.0000	0.0	0.0	0.0
27	1	0	0	0.0	0.0	0.0000	0.0	0.0	0.0
28	1	0	0	0.0	0.0	0.0000	0.0	0.0	0.0
29	1	0	0	0.0	0.0	0.0000	0.0	0.0	0.0
30	1	0	0	0.0	0.0	0.0000	0.0	0.0	0.0
31	1	0	0	0.0	0.0	0.0000	0.0	0.0	0.0
32	1	0	60216	0.0	0.6	0.0000	0.7	0.0	11.7
33	1	0	0	0.0	0.0	0.0000	0.0	0.0	0.0
34	1	50180	120432	0.1	0.5	0.0004	0.7	2.4	3.9
35	1	0	0	0.0	0.0	0.0000	0.0	0.0	0.0

Crystal Forest 1993 Line Intersect Data Summary

Line	Type	Percent Cover			Volume Per Acre			Number Per Acre		
		Ls1	Ls2	Ls3	Ls1	Ls2	Ls3	Ls1	Ls2	Ls3
1	2	4.4	0.0	4.2	74.0	0.0	4090	2120021	0	1167
2	2	0.0	0.0	14.5	0.0	0.0	20068	0	0	1481
3	2	0.0	0.0	12.3	0.0	0.0	38067	0	0	952
4	2	6.5	0.0	0.0	171	0.0	0.0	1496630	0	0
5	2	4.3	0.0	4.3	111.0	0.0	3484.8	1023909	0	713
6	2	0.0	6.7	0.0	0.0	618.6	0.0	0	83310	0
7	2	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
8	2	6.3	1.2	0.0	229.1	47.5	0.0	665184	48849	0
9	2	10.8	0.0	4.8	298	0.0	1272	2560490	0	413
10	2	8.9	1.8	5.5	264	5147	1794	2110399	3015	6498
11	2	4.6	0.0	0.0	130.7	0.0	0.0	946506	0	0
12	2	8.0	17.5	0.0	254.3	1656.6	0.0	1185194	219658	0
13	2	13.8	2.3	0.0	328.8	248.4	0.0	3844746	25518	0
14	2	1.5	1.4	2.8	25.8	156.3	1960.2	660278	22796	1776
15	2	4.8	0.0	0.0	127.1	0.0	0.0	846309	0	0
16	1	3.8	7.2	3.8	271.4	430.4	1360.2	266921	157798	3072
17	1	6.8	3.7	1.3	444.1	253.5	686.6	601462	144328	1094
18	1	14.6	0.0	0.0	720.9	0.0	0.0	2683904	0	0
19	1	0.0	4.2	2.8	0.0	270.7	1957.3	0	121111	2128
20	1	1.0	10.2	9.5	19.2	438.6	9870.7	1003622	272078	2777
21	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
22	1	0.0	0.0	2.6	0.0	0.0	1375.8	0	0	1740
23	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
24	1	0.0	1.6	0.0	0.0	73.0	0.0	0	40708	0
25	1	0.0	1.4	0.0	0.0	50.7	0.0	0	58956	0
26	1	26.4	8.0	1.0	1175.0	1269.0	1017.6	5748145	169565	912
27	1	4.0	3.3	2.4	307.1	243.6	1375.8	250906	114045	2476
28	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
29	1	0.0	0.0	6.3	0.0	0.0	10051.1	0	0	61
30	1	0.0	2.2	0.9	0.0	519.2	254.4	0	13678	1731
31	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
32	1	0.0	1.2	0.0	0.0	114.1	0.0	0	27576	0
33	1	3.8	0.0	0.0	271.4	0.0	0.0	266921	0	0
34	1	0.0	0.0	3.4	0.0	0.0	1079.9	0	0	1492
35	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0

Crystal Forest 1994 Line Intersect Data Summary

Line	Type	Percent Cover			Volume Per Acre			Number Per Acre		
		Ls1	Ls2	Ls3	Ls1	Ls2	Ls3	Ls1	Ls2	Ls3
1	2									
2	2									
3	2									
4	2									
5	2	4.3	0.0	4.3	111.0	0.0	3484.8	1023909	0	713
6	2	0.0	6.7	0.0	0.0	618.6	0.0	0	83310	0
7	2	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
8	2	6.3	1.2	0.0	229.1	47.5	0.0	665184	48849	0
9	2									
10	2									
11	2	3.0	0.0	0.0	100.7	0.0	0.0	334541	0	0
12	2	8.0	17.5	0.0	254.3	1656.6	0.0	1185194	219658	0
13	2	13.8	2.3	0.0	328.8	248.4	0.0	3844746	25518	0
14	2	1.5	1.4	2.8	25.8	156.3	1960.2	660278	22796	1776
15	2	4.8	0.0	0.0	127.1	0.0	0.0	846309	0	0
16	1	3.8	7.2	3.8	271.4	430.4	1360.2	266921	157798	3072
17	1	6.8	3.7	1.3	444.1	253.5	686.6	601462	144328	1094
18	1	14.6	0.0	0.0	720.9	0.0	0.0	2683904	0	0
19	1	0.0	4.2	2.8	0.0	270.7	1957.3	0	121111	2128
20	1	1.0	10.2	9.5	19.2	438.6	9870.7	1003622	272078	2777
21	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
22	1	0.0	0.0	2.6	0.0	0.0	1375.8	0	0	1740
23	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
24	1	0.0	1.6	0.0	0.0	73.0	0.0	0	40708	0
25	1	0.0	1.4	0.0	0.0	50.7	0.0	0	58956	0
26	1	26.4	8.0	1.0	1175.0	1269.0	1017.6	5748145	169565	912
27	1	4.0	3.3	2.4	307.1	243.6	1375.8	250906	114045	2476
28	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
29	1	0.0	0.0	6.3	0.0	0.0	10051.1	0	0	61
30	1	0.0	2.2	0.9	0.0	519.2	254.4	0	13678	1731
31	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
32	1	0.0	1.2	0.0	0.0	114.1	0.0	0	27576	0
33	1	3.8	0.0	0.0	271.4	0.0	0.0	266921	0	0
34	1	0.0	0.0	3.4	0.0	0.0	1079.9	0	0	1492
35	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0

Crystal Forest 1993 Quadrant Inventory Data Summary

Line	Type	Density per Acre		Percent cover		Tons per acre		Volume per acre	
		Q1	Q2	Q1	Q2	Q1	Q2	Q1	Q2
1	2	110396	240864	0.1	1.3	0.0008	1.3	3.6	20.0
2	2	782808	1284608	0.8	4.9	0.0056	2.5	24.0	78.0
3	2	20072	1113996	0.0	1.5	0.0001	5.0	0.6	59.0
4	2	541944	732628	0.5	2.4	0.0039	1.0	15.0	31.0
5	2	10036	732628	0.0	5.4	0.0001	2.5	0.5	97.6
6	2	100360	722592	0.1	6.9	0.0007	5.0	3.6	117.1
7	2	572052	632268	0.4	1.4	0.0041	1.0	13.2	39.0
8	2	0	0	0.0	0.0	0.0000	0.0	0.0	0.0
9	2	50180	712556	0.1	1.4	0.0004	4.4	2.4	98.0
10	2	10036	60216	0.0	0.0	0.0001	1.3	2.2	31.0
11	2	50180	100360	0.1	1.8	0.0004	1.5	3.6	39.0
12	2	210756	642304	0.3	9.3	0.0015	7.5	8.4	156.1
13	2	662376	2448784	1.3	15.0	0.0047	8.0	38.4	312.2
14	2	40144	1063816	0.1	7.0	0.0003	8.5	2.4	195.1
15	2	80288	672412	0.2	2.9	0.0006	2.5	7.2	58.5
16	1	782808	2539108	1.0	14.4	0.0056	13.5	28.8	312.2
17	1	10036	361296	0.0	3.5	0.0001	3.2	0.0	85.9
18	1	1485328	4335552	1.6	39.0	0.0106	30.1	48.0	1522.1
19	1	381368	1103960	0.3	7.5	0.0027	3.6	9.6	117.1
20	1	80288	1093924	0.1	7.0	0.0006	5.0	3.6	136.6
21	1	0	20072	0.0	0.2	0.0000	0.0	0.0	0.0
22	1	50180	80288	0.1	0.4	0.0004	0.0	1.9	0.0
23	1	0	10036	0.0	0.2	0.0000	0.0	0.0	0.0
24	1	20072	220792	0.0	2.2	0.0001	1.5	1.0	39.0
25	1	682448	2890368	0.6	14.6	0.0049	10.0	18.0	312.2
26	1	511836	2037308	0.6	13.3	0.0037	9.4	18.0	312.2
27	1	100360	802880	0.1	5.4	0.0007	4.4	3.6	117.1
28	1	0	0	0.0	0.0	0.0000	0.0	0.0	0.0
29	1	50180	0	0.1	0.0	0.0004	0.0	3.6	0.0
30	1	1274572	3181412	1.3	19.2	0.0091	12.5	38.4	468.3
31	1	60216	250900	0.1	1.9	0.0004	1.3	1.9	39.0
32	1	230828	893204	0.3	8.3	0.0016	6.3	8.4	273.2
33	1	0	30108	0.0	0.2	0.0000	0.0	0.0	0.0
34	1	0	0	0.0	0.0	0.0000	0.0	0.0	0.0
35	1	0	0	0.0	0.0	0.0000	0.0	0.0	0.0

Crystal Forest 1994 Quadrant Inventory Data Summary

Line	Type	Density per Acre		Percent cover		Tons per acre		Volume per acre	
		Q1	Q2	Q1	Q2	Q1	Q2	Q1	Q2
1	2								
2	2								
3	2								
4	2								
5	2	270972	40144	0.2	0.1	0.0019	0.5	7.2	3.9
6	2	0	30108	0.0	0.1	0.0000	0.1	0.0	3.9
7	2	120432	200720	0.2	1.4	0.0009	0.8	5.5	31.2
8	2	0	1967056	0.0	16.6	0.0000	15.1	0.0	780.6
9	2								
10	2								
11	2	20072	100360	0.0	0.8	0.0001	0.3	1.2	19.5
12	2	0	60216	0.0	0.6	0.0000	0.3	0.0	19.5
13	2	441584	1686048	0.6	9.0	0.0032	3.5	19.2	156.1
14	2	662376	1083888	1.0	5.6	0.0047	2.5	28.8	82.0
15	2	190684	270972	0.2	2.4	0.0014	1.3	7.2	62.4
16	1	301080	1806480	0.3	6.0	0.0022	6.5	9.6	234.2
17	1	40144	682448	0.0	5.9	0.0003	5.0	1.2	175.6
18	1	80288	1485328	0.1	17.9	0.0006	12.5	2.9	429.3
19	1	1645904	4455984	3.2	29.4	0.0118	12.0	96.0	624.5
20	1	80288	682448	0.1	6.1	0.0006	5.0	3.8	175.6
21	1	0	0	0.0	0.0	0.0000	0.0	0.0	0.0
22	1	40144	120432	0.0	1.2	0.0003	0.7	1.4	27.3
23	1	0	0	0.0	0.0	0.0000	0.0	0.0	0.0
24	1	20072	180648	0.0	0.6	0.0001	0.3	1.0	19.5
25	1	0	521872	0.0	3.8	0.0000	2.5	0.0	117.1
26	1	210756	1836588	0.3	12.2	0.0015	7.5	8.6	312.2
27	1	140504	843024	0.1	5.4	0.0010	2.5	3.6	136.6
28	1	0	0	0.0	0.0	0.0000	0.0	0.0	0.0
29	1	60216	963456	0.1	7.4	0.0004	4.5	3.8	195.1
30	1	341224	843024	0.3	5.6	0.0024	2.5	9.6	136.6
31	1	100360	662376	0.5	8.6	0.0007	5.0	16.3	156.1
32	1	0	70252	0.0	0.4	0.0000	0.3	0.0	19.5
33	1	0	60216	0.0	0.3	0.0000	0.3	0.0	19.5
34	1	10036	120432	0.0	0.6	0.0001	0.3	0.5	19.5
35	1	0	0	0.0	0.0	0.0000	0.0	0.0	0.0

Giant Logs 1993 Line Intercept Data Summary

Line	Type	Percent Cover			Volume Per Acre			Number Per Acre		
		Ls1	Ls2	Ls3	Ls1	Ls2	Ls3	Ls1	Ls2	Ls3
1	2	4.0	0.0	0.0	102	0	0	1173004	0	0
2	2	0.0	1.3	0.0	0.0	42.5	0.0	0	29478	0
3	2	0.0	6.3	13.0	0.0	236.6	4350.0	0	150962	10332
4	2	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
5	2	0.0	0.0	4.2	0.0	0.0	877	0	0	5209
6	2	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
7	2	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
8	2	0.0	0.0	10.3	0.0	0.0	15736	0	0	486
9	2	7.1	0.0	7.7	286	0.0	10170	568426	0	566
10	2	6.8	4.7	3.4	258.8	33350.6	1548.8	601462	2137	1264
11	2	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
12	2	3.8	0.0	0.0	158.1	0.0	0.0	266921	0	0
13	2	0.0	2.9	0.0	0.0	572	0.0	0	14613	0
14	2	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
15	2	0.0	0.0	12.7	0.0	0.0	6346.5	0	0	1418
16	1	0.0	2.1	3.4	0.0	164.3	6964.9	0	20599	1687
17	1	3.8	3.4	0.0	271.4	397.5	0.0	266921	29478	0
18	1	3.1	10.9	1.0	186.9	2498.5	332.3	321674	43314	1638
19	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
20	1	0.0	0.0	6.7	0.0	0.0	6531.1	0	0	798
21	1	17.6	29.2	4.3	1036.1	2135.0	3618.6	2189625	390623	1285
22	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
23	1	6.0	0.0	0.0	359.7	0.0	0.0	683383	0	0
24	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
25	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
26	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
27	1	8.8	1.7	0.0	506.0	85.7	0.0	1047014	31662	0
28	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
29	1	3.0	4.6	0.0	172.8	823.9	0.0	334541	56604	0
30	1	14.8	19.2	4.2	899.1	2991.4	1412.1	1881400	165650	3565
31	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
32	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
33	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
34	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
35	1	0.0	0.0	12.8	0.0	0.0	24006.3	0	0	636

Giant Logs 1994 Line Intercept Data Summary

Line	Type	Percent Cover			Volume Per Acre			Number Per Acre		
		Ls1	Ls2	Ls3	Ls1	Ls2	Ls3	Ls1	Ls2	Ls3
1	2									
2	2	0.0	1.3	0.0	0.0	42.5	0.0	0	29478	0
3	2	0.0	6.3	13.0	0.0	236.6	4350.0	0	150962	10332
4	2									
5	2									
6	2									
7	2									
8	2									
9	2									
10	2	3.8	4.7	3.4	158.1	33350.6	1548.8	266921	2137	1264
11	2	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
12	2	3.8	0.0	0.0	158.1	0.0	0.0	266921	0	0
13	2									
14	2	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
15	2	0.0	0.0	12.7	0.0	0.0	6346.5	0	0	1418
16	1	0.0	2.1	3.4	0.0	164.3	6964.9	0	20599	1687
17	1	3.8	3.4	0.0	271.4	397.5	0.0	266921	29478	0
18	1	3.1	10.9	1.0	186.9	2498.5	332.3	321674	43314	1638
19	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
20	1	0.0	0.0	6.7	0.0	0.0	6531.1	0	0	798
21	1	17.6	29.2	4.3	1036.1	2135.0	3618.6	2189625	390623	1285
22	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
23	1	6.0	0.0	0.0	359.7	0.0	0.0	683383	0	0
24	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
25	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
26	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
27	1	8.8	1.7	0.0	506.0	85.7	0.0	1047014	31662	0
28	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
29	1	3.0	4.6	0.0	172.8	823.9	0.0	334541	56604	0
30	1	14.8	19.2	4.2	899.1	2991.4	1412.1	1881400	165650	3565
31	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
32	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
33	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
34	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
35	1	0.0	0.0	12.8	0.0	0.0	24006.3	0	0	636

Giant Logs 1993 Quadrant Inventory Data Summary

Line	Type	Density per Acre		Percent cover		Tons per acre		Volume per acre	
		Q1	Q2	Q1	Q2	Q1	Q2	Q1	Q2
1	2	180648	331188	0.2	1.3	0.0013	1.0	3.7	20.0
2	2	90324	281008	0.1	1.6	0.0006	1.3	1.5	39.0
3	2	60216	270972	0.1	1.1	0.0004	1.0	1.5	19.5
4	2	0	0	0.0	0.0	0.0000	0.0	0.0	0.0
5	2	20072	110396	0.0	1.3	0.0001	1.3	0.6	39.0
6	2	20072	120432	0.1	0.7	0.0001	0.7	0.9	20.0
7	2	80288	471692	0.1	3.4	0.0006	3.5	1.5	98.0
8	2	120432	411476	0.2	3.4	0.0009	2.5	2.9	78.0
9	2	0	0	0.0	0.0	0.0000	0.0	0.0	0.0
10	2	120432	60216	0.1	0.2	0.0009	0.0	1.5	0.0
11	2	140504	170612	0.1	0.6	0.0010	0.7	2.2	0.0
12	2	170612	150540	0.2	1.0	0.0012	1.3	3.0	19.5
13	2	20072	60216	0.1	0.2	0.0000	0.4	0.6	8.0
14	2	10036	60216	0.0	0.3	0.0001	0.0	0.6	0.0
15	2	70252	120432	0.1	0.8	0.0005	1.0	1.2	19.5
16	1	130468	511836	0.2	3.7	0.0009	2.3	3.0	78.1
17	1	0	0	0.0	0.0	0.0000	0.0	0.0	0.0
18	1	0	180648	0.0	0.8	0.0000	0.5	0.0	3.9
19	1	220792	883168	0.3	5.4	0.0016	3.5	5.2	117.1
20	1	10036	70252	0.0	0.6	0.0001	1.0	0.3	19.5
21	1	712556	2067416	0.7	21.0	0.0051	12.5	12.6	390.3
22	1	0	0	0.0	0.0	0.0000	0.0	0.0	0.0
23	1	240864	1445184	0.3	10.2	0.0017	7.5	5.9	195.1
24	1	120432	2890368	0.2	26.4	0.0009	18.8	3.7	468.3
25	1	130468	0	0.2	0.0	0.0009	0.0	3.7	0.0
26	1	0	0	0.0	0.0	0.0000	0.0	0.0	0.0
27	1	70252	260936	0.1	2.5	0.0005	1.9	2.2	50.7
28	1	190684	592124	0.2	2.6	0.0014	2.4	3.7	78.1
29	1	0	0	0.0	0.0	0.0000	0.0	0.0	0.0
30	1	20072	281008	0.0	2.1	0.0001	1.9	0.6	66.3
31	1	0	0	0.0	0.0	0.0000	0.0	0.0	0.0
32	1	0	0	0.0	0.0	0.0000	0.0	0.0	0.0
33	1	30108	80288	0.0	0.5	0.0002	0.0	0.7	0.0
34	1	0	0	0.0	0.0	0.0000	0.0	0.0	0.0
35	1	0	130468	0.0	0.6	0.0000	0.0	0.0	0.0

Giant Logs 1994 Quadrant Inventory Summary

Line	Type	Density per Acre		Percent cover		Tons per acre		Volume per acre	
		Q1	Q2	Q1	Q2	Q1	Q2	Q1	Q2
1	2								
2	2	20072	150540	0.0	0.9	0.0001	0.3	0.6	19.5
3	2	40144	903240	0.1	2.9	0.0003	2.3	1.8	136.6
4	2								
5	2								
6	2								
7	2								
8	2								
9	2								
10	2	401440	602160	0.3	3.2	0.0029	1.3	5.9	78.1
11	2	30108	150540	0.0	1.0	0.0002	0.7	0.4	19.5
12	2	200720	642304	0.2	2.9	0.0014	2.0	4.1	70.3
13	2					0.0000			
14	2	0	20072	0.0	0.3	0.0000	0.1	0.0	3.9
15	2	0	0	0.0	0.0	0.0000	0.0	0.0	0.0
16	1	0	0	0.0	0.0	0.0000	0.0	0.0	0.0
17	1	10036	0	0.0	0.0	0.0001	0.0	0.1	0.0
18	1	0	240864	0.0	0.8	0.0000	0.5	0.0	3.9
19	1	30108	240864	0.0	1.0	0.0002	0.3	0.7	19.5
20	1	30108	642304	0.0	5.0	0.0002	3.5	0.4	234.2
21	1	0	20072	0.0	0.1	0.0000	0.0	0.0	0.0
22	1	0	0	0.0	0.0	0.0000	0.0	0.0	0.0
23	1	80288	1655940	0.1	6.2	0.0006	6.0	2.1	195.1
24	1	120432	3131232	0.2	23.0	0.0009	19.1	3.0	585.4
25	1	0	0	0.0	0.0	0.0000	0.0	0.0	0.0
26	1	0	0	0.0	0.0	0.0000	0.0	0.0	0.0
27	1	160576	1043744	0.2	8.6	0.0011	6.0	3.6	195.1
28	1	80288	3893968	0.1	21.8	0.0006	2.5	1.8	702.5
29	1	0	0	0.0	0.0	0.0000	0.0	0.0	0.0
30	1	0	0	0.0	0.0	0.0000	0.0	0.0	0.0
31	1	0	0	0.0	0.0	0.0000	0.0	0.0	0.0
32	1	0	0	0.0	0.0	0.0000	0.0	0.0	0.0
33	1	50180	80288	0.1	0.5	0.0004	0.1	1.0	3.9
34	1	0	0	0.0	0.0	0.0000	0.0	0.0	0.0
35	1	60216	80288	0.2	0.4	0.0004	0.0	3.0	0.0

Jasper Forest 1993 Line Intersect Data Summary

Line	Type	Percent Cover			Volume Per Acre			Number Per Acre		
		Ls1	Ls2	Ls3	Ls1	Ls2	Ls3	Ls1	Ls2	Ls3
1	2	4.4	0.0	4.2	74	0.0	4090	2120021	0	1167
2	2	0.0	0.0	14.5	0.0	0.0	20068	0	0	1481
3	2	0.0	0.0	12.3	0	0	38067	0	0	952
4	2	6.5	0.0	0.0	171.2	0.0	0.0	1496630	0	0
5	2	5.8	6.4	2.8	104	263	1960	3115568	187718	156
6	2	11.9	2.9	10.3	372.8	144.9	8060.1	2664206	64725	85
7	2	2.5	4.4	0.0	71.0	298.6	0.0	398263	64056	0
8	2	20.6	0.0	9.1	552.5	0.0	9203.9	4134242	0	1601
9	2	10.8	0.0	4.8	298.0	0.0	1272.0	2569490	0	413
10	2	8.9	1.8	5.5	263.9	5147.2	1793.8	2110399	3015	6498
11	2	5.5	0.0	10.6	171.7	0.0	4847.6	732804	0	2416
12	2	0.0	0.0	3.6	0.0	0.0	2923.7	0	0	4302
13	2	7.3	0.0	0.0	214.3	0.0	0.0	1368301	0	0
14	2	8.5	0.0	8.0	178.1	0.0	8282.5	3267050	0	773
15	2	21.0	1.8	0.0	603.9	66.5	0.0	4367952	27139	0
16	1	10.2	0.0	8.1	570.5	0.0	17488.5	1828364	0	1357
17	1	1.1	8.6	3.4	24.1	1200.5	4750.7	896091	50663	469
18	1	3.9	9.2	21.4	289.0	1911.6	80399.4	258666	67937	3302
19	1	12.5	14.1	5.4	623.9	2106.1	3605.0	2084894	66061	3673
20	1	0.0	0.0	2.3	0.0	0.0	988.4	0	0	3063
21	1	3.1	6.6	4.3	186.9	2774.8	3244.8	321674	36908	597
22	1	15.8	6.2	2.5	766.1	704.6	1172.3	3434742	74260	2521
23	1	3.0	5.7	2.3	172.8	675.8	1038.3	334541	73378	2630
24	1	9.9	0.0	7.3	521.7	0.0	16102.3	1801866	0	1321
25	1	26.1	14.5	3.6	1310.0	1314.5	1597.4	5304832	253298	3687
26	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
27	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
28	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
29	1	1.5	0.0	0.0	44.3	0.0	0.0	660278	0	0
30	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
31	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
32	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
33	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
34	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
35	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0

Jasper Forest 1994 Line Intersect Data Summary

Line	Type	Percent Cover			Volume Per Acre			Number Per Acre		
		Ls1	Ls2	Ls3	Ls1	Ls2	Ls3	Ls1	Ls2	Ls3
1	2									
2	2									
3	2									
4	2	5.0	0.0	0.0	145.4	0.0	0.0	836352	0	0
5	2									
6	2	11.9	2.9	10.3	372.8	144.9	8060.1	2664206	64725	85
7	2	2.5	4.4	0.0	71.0	298.6	0.0	398263	64056	0
8	2	20.6	0.0	9.1	552.5	0.0	9203.9	4134242	0	1601
9	2	10.8	0.0	4.8	298.0	0.0	1272.0	2569490	0	413
10	2	8.9	4.7	5.5	263.9	5232.6	1793.8	2110399	5027	6498
11	2	5.5	0.0	10.6	171.7	0.0	4847.6	732804	0	2416
12	2	0.0	0.0	3.6	0.0	0.0	2923.7	0	0	4302
13	2	7.3	0.0	0.0	214.3	0.0	0.0	1368301	0	0
14	2	5.6	0.0	8.0	131.6	0.0	8282.5	1868814	0	773
15	2	21.0	0.0	0.0	603.9	0.0	0.0	4367952	0	0
16	1	10.2	0.0	8.1	570.5	0.0	17488.5	1828364	0	1357
17	1	1.1	8.6	3.4	24.1	1200.5	4750.7	896091	50663	469
18	1	3.9	9.2	21.4	289.0	1911.6	80399.4	258666	67937	3302
19	1	12.5	14.1	5.4	623.9	2106.1	3605.0	2084894	66061	3673
20	1	0.0	0.0	2.3	0.0	0.0	988.4	0	0	3063
21	1	3.1	6.6	4.3	186.9	2774.8	3244.8	321674	36908	597
22	1	15.8	6.2	2.5	766.1	704.6	1172.3	3434742	74260	2521
23	1	3.0	5.7	2.3	172.8	675.8	1038.3	334541	73378	2630
24	1	9.9	0.0	7.3	521.7	0.0	16102.3	1801866	0	1321
25	1	26.1	14.5	3.6	1310.0	1314.5	1597.4	5304832	253298	3687
26	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
27	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
28	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
29	1	1.5	0.0	0.0	44.3	0.0	0.0	660278	0	0
30	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
31	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
32	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
33	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
34	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
35	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0

Jasper Forest 1993 Quadrant Inventory Summary

Line	Type	Density per Acre		Percent cover		Tons per acre		Volume per acre	
		Q1	Q2	Q1	Q2	Q1	Q2	Q1	Q2
1	2	120432	80288	0.1	0.3	0.0009	1.9	2.5	5.9
2	2	120432	40144	0.1	0.2	0.0009	0.0	1.6	4.7
3	2	40144	110396	0.0	0.3	0.0003	0.4	0.6	6.2
4	2	120432	30108	0.2	0.4	0.0009	0.0	3.9	0.0
5	2	110396	511836	0.2	0.4	0.0008	2.3	3.9	78.0
6	2	150540	1063816	0.2	13.4	0.0011	11.3	3.6	351.3
7	2	411476	732628	0.5	5.4	0.0029	2.8	10.2	78.1
8	2	762736	2579252	0.9	18.9	0.0054	7.3	17.2	390.3
9	2	80288	772772	0.1	5.8	0.0006	5.7	2.3	156.1
10	2	50180	210756	0.0	1.4	0.0004	1.7	0.6	58.5
11	2	110396	170612	0.2	3.4	0.0008	2.5	3.8	78.1
12	2	321152	632268	0.3	7.8	0.0023	9.0	6.3	195.1
13	2	672412	1073852	0.4	5.4	0.0048	2.5	8.6	78.1
14	2	1846624	4696848	1.9	19.8	0.0132	10.6	37.5	429.3
15	2	1124032	4174976	1.2	20.5	0.0080	12.5	23.4	390.3
16	1	80288	381368	0.1	4.2	0.0006	2.5	1.9	78.1
17	1	0	70252	0.0	3.7	0.0000	2.3	0.0	58.5
18	1	541944	1073852	0.6	6.6	0.0039	6.3	10.9	156.1
19	1	110396	1716156	0.1	13.8	0.0008	22.0	1.6	624.5
20	1	0	70252	0.0	1.6	0.0000	1.3	0.0	39.0
21	1	20072	110396	0.0	1.2	0.0001	3.2	0.3	78.1
22	1	40144	953420	0.0	13.1	0.0003	14.1	0.9	437.1
23	1	3392168	6463184	4.5	44.2	0.0242	29.5	87.5	624.5
24	1	230828	50180	0.3	0.7	0.0016	0.7	5.5	39.0
25	1	0	471692	0.0	5.4	0.0000	7.5	0.0	175.6
26	1	0	0	0.0	0.0	0.0000	0.0	0.0	0.0
27	1	20072	30108	0.0	0.1	0.0001	0.0	0.5	0.0
28	1	50180	120432	0.1	0.4	0.0004	0.4	1.3	3.9
29	1	80288	270972	0.1	2.9	0.0006	1.9	2.3	78.1
30	1	0	0	0.0	0.0	0.0000	0.0	0.0	0.0
31	1	0	0	0.0	0.0	0.0000	0.0	0.0	0.0
32	1	0	0	0.0	0.0	0.0000	0.0	0.0	0.0
33	1	0	0	0.0	0.0	0.0000	0.0	0.0	0.0
34	1	20072	90324	0.0	0.8	0.0001	1.0	0.5	35.1
35	1	0	0	0.0	0.0	0.0000	0.0	0.0	0.0

Jasper Forest 1994 Quadrant Inventory Summary

Line	Type	Density per Acre		Percent cover		Tons per acre		Volume per acre	
		Q1	Q2	Q1	Q2	Q1	Q2	Q1	Q2
1	2								
2	2								
3	2								
4	2	140504	250900	0.3	3.2	0.0010	1.3	6.3	78.1
5	2								
6	2	0	80288	0.0	0.3	0.0000	2.8	0.0	195.1
7	2	10036	0	0.1	0.0	0.0001	0.0	1.6	0.0
8	2	20072	50180	0.0	0.2	0.0001	2.5	0.3	195.1
9	2	0	10036	0.0	0.1	0.0000	0.7	0.0	39.0
10	2	0	70252	0.0	0.5	0.0000	0.0	0.0	0.0
11	2	0	0	0.0	0.0	0.0000	0.0	0.0	0.0
12	2	0	0	0.0	0.0	0.0000	0.0	0.0	0.0
13	2	341224	180648	0.5	0.6	0.0024	0.1	9.4	3.9
14	2	321152	652340	0.4	3.2	0.0023	1.3	7.8	195.1
15	2	461656	1425112	0.6	6.6	0.0033	2.0	12.5	156.1
16	1	40144	260936	0.1	2.6	0.0003	2.0	1.9	117.1
17	1	50180	210756	0.1	1.1	0.0004	1.0	2.2	42.9
18	1	60216	160576	0.1	1.6	0.0004	1.0	1.3	39.0
19	1	30108	230828	0.0	3.4	0.0002	1.3	0.9	78.1
20	1	30108	40144	0.0	0.5	0.0002	0.3	0.3	19.5
21	1	0	100360	0.0	1.8	0.0000	1.2	0.0	35.1
22	1	160576	1023672	0.3	9.8	0.0011	6.5	6.3	320.0
23	1	60216	531908	0.1	4.3	0.0004	2.5	1.9	117.1
24	1	40144	883168	0.0	7.4	0.0003	5.0	0.6	195.1
25	1	0	20072	0.0	0.1	0.0000	0.1	0.0	3.9
26	1	0	0	0.0	0.0	0.0000	0.0	0.0	0.0
27	1	40144	60216	0.0	0.1	0.0003	0.0	0.5	0.0
28	1	70252	120432	0.1	0.4	0.0005	0.4	1.3	3.9
29	1	0	0	0.0	0.0	0.0000	0.0	0.0	0.0
30	1	0	0	0.0	0.0	0.0000	0.0	0.0	0.0
31	1	0	0	0.0	0.0	0.0000	0.0	0.0	0.0
32	1	0	0	0.0	0.0	0.0000	0.0	0.0	0.0
33	1	0	0	0.0	0.0	0.0000	0.0	0.0	0.0
34	1	0	0	0.0	0.0	0.0000	0.0	0.0	0.0
35	1	0	0	0.0	0.0	0.0000	0.0	0.0	0.0

Long Logs 1993 Line Intersect Data Summary

Line	Type	Percent Cover			Volume Per Acre			Number Per Acre		
		Ls1	Ls2	Ls3	Ls1	Ls2	Ls3	Ls1	Ls2	Ls3
1	2	3.0	0.0	0.0	52	0.0	0.0	1320556	0	0
2	2	3.2	0.0	0.0	56	0.0	0.0	1272243	0	0
3	2	2.0	1.4	0.0	56	43	0.0	501811	51810	0
4	2	0.0	1.7	0.0	0.0	321.7	0.0	0	18584	0
5	2	0.0	0.0	10.1	0.0	0.0	2304.1	0	0	11815
6	2	7.5	0.0	0.0	216.4	0.0	0.0	1234615	0	0
7	2	5.8	2.5	22.3	202.9	100.4	20933.0	768732	93908	1214
8	2	0.0	0.0	7.7	0.0	0.0	5814.1	0	0	620
9	2	2.2	1.2	0.0	56.1	57.9	0.0	448046	40708	0
10	2	0.0	0.0	2.0	0.0	0.0	1548.8	0	0	1824
11	2	0.0	1.8	4.3	0.0	90.7	533.9	0	34195	5178
12	2	3.0	0.0	3.7	100.7	0.0	595.9	334541	0	4899
13	2	9.2	20.9	4.0	250	4695	1748	1882026	139246	5043
14	2	8.4	11.2	13.2	279.4	1498.3	3415.6	1138591	73259	14627
15	2	9.0	5.6	3.7	257	917	637	2044350	29014	7840
16	1	0.0	5.3	0.0	0.0	465.4	0.0	0	129681	0
17	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
18	1	0.0	0.0	6.9	0.0	0.0	9626.6	0	0	1737
19	1	4.5	0.0	5.7	217.1	0.0	2860.6	994819	0	3937
20	1	1.5	0.0	0.0	44.3	0.0	0.0	660278	0	0
21	1	3.5	6.6	5.0	237.8	1078.9	2109.1	285120	76389	2966
22	1	14.0	4.9	1.0	860.3	389.2	129.8	2230442	86469	1495
23	1	0.0	9.4	1.2	0.0	2758.1	186.9	0	17837	1425
24	1	11.5	0.0	10.5	565.6	0.0	16634.1	2378867	0	190
25	1	0.0	1.4	0.0	0.0	50.7	0.0	0	68389	0
26	1	2.5	8.0	0.0	121.9	880.7	0.0	398263	86689	0
27	1	8.2	7.0	1.8	368.0	1046.4	1017.6	2283275	58496	912
28	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
29	1	3.0	3.1	0.0	172.8	134.4	0.0	334541	63673	0
30	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
31	1	1.5	5.0	9.8	44.3	349.3	9740.9	660278	123604	2455
32	1	0.0	0.0	5.1	0.0	0.0	4802.3	0	0	803
33	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
34	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
35	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0

Long Logs 1994 Line Intersect Data Summary

Line	Type	Percent Cove			Volume Per Acre			Number Per Acre		
		Ls1	Ls2	Ls3	Ls1	Ls2	Ls3	Ls1	Ls2	Ls3
1	2									
2	2									
3	2									
4	2	0.0	1.7	0.0	0.0	321.7	0.0	0	18584	0
5	2	0.0	0.0	10.1	0.0	0.0	2304.1	0	0	11815
6	2	7.5	0.0	0.0	216.4	0.0	0.0	1234615	0	0
7	2	5.8	2.5	22.3	202.9	100.4	20933.0	768732	93908	1214
8	2	0.0	0.0	7.7	0.0	0.0	5814.1	0	0	620
9	2	2.2	1.2	0.0	56.1	57.9	0.0	448046	40708	0
10	2	0.0	0.0	2.0	0.0	0.0	1548.8	0	0	1824
11	2	0.0	1.8	2.3	0.0	90.7	96.8	0	34195	2990
12	2	3.0	0.0	3.7	100.7	0.0	595.9	334541	0	4899
13	2									
14	2	8.4	11.2	13.2	279.4	1498.3	3415.6	1138591	73259	14627
15	2									
16	1	0.0	5.3	0.0	0.0	465.4	0.0	0	129681	0
17	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
18	1	0.0	0.0	6.9	0.0	0.0	9626.6	0	0	1737
19	1	4.5	0.0	5.7	217.1	0.0	2860.6	994819	0	3937
20	1	1.5	0.0	0.0	44.3	0.0	0.0	660278	0	0
21	1	3.5	6.6	5.0	237.8	1078.9	2109.1	285120	76389	2966
22	1	14.0	4.9	1.0	860.3	389.2	129.8	2230442	86469	1495
23	1	0.0	9.4	1.2	0.0	2758.1	186.9	0	17837	1425
24	1	11.5	0.0	10.5	565.6	0.0	16634.1	2378867	0	190
25	1	0.0	1.4	0.0	0.0	50.7	0.0	0	68389	0
26	1	2.5	8.0	0.0	121.9	880.7	0.0	398263	86689	0
27	1	8.2	7.0	1.8	368.0	1046.4	1017.6	2283275	58496	912
28	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
29	1	3.0	3.1	0.0	172.8	134.4	0.0	334541	63673	0
30	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
31	1	1.5	5.0	9.8	44.3	349.3	9740.9	660278	123604	2455
32	1	0.0	0.0	5.1	0.0	0.0	4802.3	0	0	803
33	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
34	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
35	1	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0

Long Logs 1993 Quadrant Inventory Data Summary

Line	Type	Density per Acre		Percent cover		Tons per acre		Volume per acre	
		Q1	Q2	Q1	Q2	Q1	Q2	Q1	Q2
1	2	20072	80288	0.0	0.3	0.0001	0.5	0.5	6.3
2	2	0	0	0.0	0.0	0.0000	0.0	0.0	0.0
3	2	220792	652340	0.3	5.1	0.0016	4.4	5.9	98.0
4	2	1164176	4857424	1.4	25.6	0.0083	12.6	28.3	351.3
5	2	80288	612196	0.2	4.8	0.0006	3.6	3.1	97.6
6	2	50180	90324	0.0	0.4	0.0004	0.0	0.9	0.0
7	2	30108	592124	0.0	4.5	0.0002	3.5	0.8	97.6
8	2	0	0	0.0	0.0	0.0000	0.0	0.0	0.0
9	2	100360	170612	0.1	1.9	0.0007	1.3	2.4	31.2
10	2	0	0	0.0	0.0	0.0000	0.0	0.0	0.0
11	2	160576	993564	0.2	6.4	0.0011	4.4	3.9	117.1
12	2	60216	260936	0.1	2.4	0.0004	1.5	1.6	39.0
13	2	0	0	0.0	0.0	0.0000	0.0	0.0	0.0
14	2	70252	130468	0.1	1.3	0.0005	1.2	1.6	19.5
15	2	70252	401440	0.1	4.5	0.0005	3.8	1.9	98.0
16	1	140504	250900	0.1	1.6	0.0010	1.0	2.2	27.3
17	1	220792	80288	0.2	0.3	0.0016	0.3	4.7	0.0
18	1	0	0	0.0	0.0	0.0000	0.0	0.0	0.0
19	1	120432	863096	0.1	4.3	0.0009	4.0	2.4	78.1
20	1	0	130468	0.0	0.4	0.0000	0.0	0.0	0.0
21	1	70252	2850224	0.0	20.0	0.0005	12.0	0.9	468.3
22	1	521872	1485328	0.5	12.8	0.0037	9.0	9.4	312.2
23	1	0	60216	0.0	0.2	0.0000	0.0	0.0	0.0
24	1	10036	70252	0.0	0.3	0.0001	0.3	0.2	0.0
25	1	90324	521872	0.0	3.8	0.0006	2.8	0.9	78.1
26	1	110396	371332	0.1	2.4	0.0008	2.5	2.4	78.1
27	1	30108	742664	0.0	6.7	0.0002	4.4	0.9	136.6
28	1	0	0	0.0	0.0	0.0000	0.0	0.0	0.0
29	1	120432	2438748	0.2	17.3	0.0009	15.1	4.7	429.3
30	1	0	70252	0.0	0.6	0.0000	0.3	0.0	0.0
31	1	270972	180648	0.3	1.0	0.0019	1.3	5.5	27.3
32	1	0	180648	0.0	1.8	0.0000	1.5	0.0	39.0
33	1	0	0	0.0	0.0	0.0000	0.0	0.0	0.0
34	1	40144	80288	0.0	0.7	0.0003	0.7	0.8	23.4
35	1	20072	150540	0.0	1.5	0.0001	1.5	0.6	39.0

Long Logs 1994 Quadrant Inventory Data Summary

Line	Type	Density per Acre		Percent cover		Tons per acre		Volume per acre	
		Q1	Q2	Q1	Q2	Q1	Q2	Q1	Q2
1	2								
2	2								
3	2								
4	2	0	220792	0.0	3.0	0.0000	2.0	0.0	78.1
5	2	10036	190684	0.0	0.7	0.0001	0.3	0.6	19.5
6	2	140504	883168	0.2	5.8	0.0010	5.0	3.8	351.3
7	2	20072	240864	0.0	3.2	0.0001	1.5	0.3	97.6
8	2	0	0	0.0	0.0	0.0000	0.0	0.0	0.0
9	2	20072	130468	0.0	1.4	0.0001	0.7	0.2	35.1
10	2	160576	1124032	0.3	9.0	0.0011	10.0	6.3	312.2
11	2	0	40144	0.0	0.5	0.0000	0.3	0.0	19.5
12	2	30108	80288	0.0	0.3	0.0002	0.1	0.6	3.9
13	2								
14	2	1405040	4024436	2.4	23.0	0.0100	15.1	47.2	995.2
15	2								
16	1	0	50180	0.0	0.4	0.0000	0.7	0.0	3.9
17	1	0	10036	0.0	0.1	0.0000	0.0	0.0	0.0
18	1	0	0	0.0	0.0	0.0000	0.0	0.0	0.0
19	1	100360	622232	0.1	5.8	0.0007	2.5	2.5	136.6
20	1	0	0	0.0	0.0	0.0000	0.0	0.0	0.0
21	1	120432	1374932	0.1	14.2	0.0009	7.0	2.2	429.3
22	1	240864	2368496	0.2	11.5	0.0017	6.0	4.7	429.3
23	1	20072	1204320	0.0	9.9	0.0001	4.5	0.3	195.1
24	1	70252	160576	0.1	0.8	0.0005	0.1	2.7	3.9
25	1	60216	471692	0.0	3.5	0.0004	2.3	0.8	175.6
26	1	10036	170612	0.0	0.6	0.0001	0.7	0.2	3.9
27	1	200720	1766336	0.3	16.5	0.0014	13.0	6.3	819.6
28	1	0	0	0.0	0.0	0.0000	0.0	0.0	0.0
29	1	80288	943384	0.1	7.8	0.0006	5.0	2.5	351.3
30	1	60216	60216	0.1	0.2	0.0004	0.1	1.6	3.9
31	1	50180	180648	0.1	0.6	0.0004	0.7	1.9	3.9
32	1	0	0	0.0	0.0	0.0000	0.0	0.0	0.0
33	1	0	0	0.0	0.0	0.0000	0.0	0.0	0.0
34	1	0	0	0.0	0.0	0.0000	0.0	0.0	0.0
35	1	0	0	0.0	0.0	0.0000	0.0	0.0	0.0

Appendix B

PWSAMP.EXE SOURCE CODE

Programming Comments

The following computer program was developed using Borland C + + . The program has two main functions. First to collect and record new data at the Petrified Forest and second to edit existing data files. Variable names are documented for data structures. The remaining code is documented, however line by line descriptions are futile with object oriented programming. The code was compiled using a small memory model but may be temperamental on some machines. Compilation using a medium or large memory model will remedy the problem.

```

/* *****
*** PWSAMP.EXE           Nicholas S. Monkevich           5-5-94           ***

*** Input - output routine for data collection at the Petrified Forest           ***
*** National Park, Arizona.           ***

*** Masters of Science Field Work           ***
***** */

#include <conio.h>           // include library files
#include <iostream.h>
#include <stdio.h>           // during compile time
#include <stdlib.h>
#include <ctype.h>
#include <fstream.h>

void new_header_data(void); // declare a function to open a new data storage
                           // file and write a header to it

int old_header_data(int); // declare a function to open old data file and
                           // append it as needed

void sample_data(void); // declare a function to input new data

void more_data(void); // declare a function to prompt for more data

void edit_data(int max_line); // declare a function to edit old LIS data


struct data           // make a data structure for call functions
{
    int line_num;           // line number variable
    float int_dist;           // LIS intercept distance variable
    float circum;           // LIS perpendicular circumference variable
    float hor_circum;           // LIS horizontal dircumference variable
    float weight;           // QUAD weight variable
    float cs_area;           // QUAD cross sectional area variables
    float volume;           // QUAD volume variable
    float count;           // QUAD number variable
    char line_seg; // SHARED (LIS AND QUAD) line segment variable

};

```

```

data data_array[250]; // declare a dummy array for the data structure

data *data_pnt;           // declare a pointer to point at the data structure
                           // array

ofstream ofile;           // create output file stream

main(void) {

    // output main menu to the screen

    char what_to_do;       // define some local variables
    int x, max_line;

    cout << "1 - Sample New Data\n";
    cout << "2 - Edit Old Data\n\n";
    cout << "Enter Choice - ";
    what_to_do = getch();

    switch(what_to_do)
    {

        case '1':

            data_pnt = data_array; // set the pointer to the first data array element

            new_header_data();      // call the new_header_data function

            for(x = 0; x <= 250; x ++, data_pnt ++ )
            {
                sample_data();      // call the sample routine

                more_data();        // call the routine to exit or record more data
            }
            break;

        case '2':

            data_pnt = data_array; // set pointer to first data array element

            max_line = old_header_data(0); // call the old_header_data function

            edit_data(max_line);

            break;
    }
}

```

```

        default:
            exit(0);
        }
return(0);
}

void new_header_data(void)           // opens a storage file and writes a header
{

char in_name[20];           // define local variables
char stratum[80];

    clrscr();
    cout << "Enter New Filename ";
    cout << "\nFilename = ";
    cin >> in_name;

    ofile.open(in_name); // set up the output
    ofile.precision(5.2);
    ofile.width(8);      // file

    if (!ofile) cerr << "\nCan't Open File!";

    cout << "Enter Stratum ";
    gets(stratum);
    ofile << "Stratum = " << stratum << endl ;
}

int old_header_data(int counter)      // opens an existing storage file and reads
                                      // the contents into an array
{

char in_name[20];
char out_name[20];
char stratum[80];

    // Open the input file and input the data into Array

    FILE * infile;

```

```

clrscr();
cout << "Enter Input Filename";
cout << "\nFilename = ";
cin >> in_name;

while (kbhit()); // "eat" any char already in keyboard buffer

if ((infile = fopen(in_name,"r")) == NULL)
{
    perror("\nCan't Open Input! ");
    return(0);
}

infile = fopen(in_name,"r");

while (!feof(infile))
{
    fscanf (infile, "%2i %3c %7f %7f %7f", &data_pnt->line_num,
            &data_pnt->line_seg, &data_pnt->int_dist,
            &data_pnt->circum,
            &data_pnt->hor_circum);

    data_pnt++;
    counter++;
}

fclose(infile);

// Open the File for Output

clrscr();
cout << "Enter Output Filename";
cout << "\nFilename = ";
cin >> out_name;

ofile.open(out_name); // set up the output
ofile.precision(5.2);
ofile.width(8);        // file stream

if (!ofile) cerr << "\nCan't Open Output!";

cout << "Enter Stratum - ";
gets(stratum);
ofile << "Stratum = " << stratum << endl ;

```

```

        return(counter);
    }

void sample_data(void)    // takes sample input from the keyboard and
                        // write the information to the data storage file
{
    char samp_choice;
    char store_it;
    char correct;
    int counter = 1;

    // get initial line number
    clrscr();
    cout << "Enter line number";
    cout << "\nLine number - ";
    cin >> data_pnt->line_num;

    data_pnt->line_seg = '1'; // set initial value of line_seg

    // Use a loop to collect the line intercept data

    while (data_pnt->line_seg != '9')
    {

        clrscr();
        cout << " * Now Sampling " << data_pnt->line_num;
        cout << "\n\nLine Segment sampled";
        cout << "\n'9' to Quad sampling";
        cout << "\nNew Segment # - ";
        data_pnt->line_seg = getch();

        if (data_pnt->line_seg == '9') continue;

        // get routing variable for switch

        clrscr();
        cout << " * Now sampling " << data_pnt->line_num;
        cout << "\n\nInter. Dist. - ";
        cin >> data_pnt->int_dist;
    }
}

```

```

// assign switch character value

if (data_pnt->int_dist <= .25)
samp_choice = 'A';
if ((data_pnt->int_dist >= .25)&&
(data_pnt->int_dist <= 1))
samp_choice = 'B';
if (data_pnt->int_dist >= 1)
samp_choice = 'C';

// switch to collect and output data

switch (samp_choice)
{
case 'A':
clrscr();
cout << "\aEnter correct # !";
cout << "\nPress any key... ";getch();
break;

case 'B':
cout << "\n\nCcorrect? (y or n) - ";
store_it = toupper(getch());if (store_it != 'Y') continue;

ofile << data_pnt->line_num
<< "," << data_pnt->line_seg
<< "," << data_pnt->int_dist
<< endl;
break;

case 'C':
cout << "Perp. Circ. - ";
cin >> data_pnt->circum;
cout << "Horiz. Circ. - ";
cin >> data_pnt->hor_circum;
cout << "\nCorrect? (y or n) - ";
store_it = toupper(getch());if (store_it != 'Y') continue;

ofile << data_pnt->line_num
<< "," << data_pnt->line_seg
<< "," << data_pnt->int_dist
<< "," << data_pnt->circum
<< "," << data_pnt->hor_circum << endl;
break;

default:
continue;
}
}

```

```
// Use a loop to collect the Quadrant Subsample Data
```

```
while (counter <= 2)
{
    clrscr();
    cout << " * Now Sampling " << data_pnt->line_num;
    cout << "\n\nEnter Q" << counter << " Count - ";
    cin >> data_pnt->count;
    cout << "Enter Q" << counter << " Area - ";
    cin >> data_pnt->cs_area;
    cout << "Enter Q" << counter << " Weight - ";
    cin >> data_pnt->weight;
    cout << "Enter Q" << counter << " Volume - ";
    cin >> data_pnt->volume;

    // check if quadrant input for errors

    clrscr();
    cout << " * Now Sampling " << data_pnt->line_num;
    cout << "\n\nQ" << counter << " Count = " <<
    data_pnt->count;

    cout << "\nQ" << counter << " Area = " <<
    data_pnt->cs_area;

    cout << "\nQ" << counter << " Weight = " <<
    data_pnt->weight;

    cout << "\nQ" << counter << " Volume = " <<
    data_pnt->volume;

    cout << "\n\nCorrect? (y or n)";
    correct = toupper(getche());

    switch(correct)
    {
    case 'Y':
        ofile << data_pnt->line_num << ",Q" << counter
            << "," << data_pnt->count
            << "," << data_pnt->cs_area
            << "," << data_pnt->weight
            << "," << data_pnt->volume << endl;
        break;

    case 'N':
```

```

        continue;

    default:
        clrscr();cout << "\nInvalid choice ";
        cout << "\nHit any key... ";getch();continue;
    }

    counter + +;
}

}

```

```

void more_data(void) // choice routine that continues to collect data
                    // or exists program
{
char fin_choice;

    clrscr();
    cout << "\n\nCollect More data?";
    cout << "\n(y or n)";
    fin_choice = toupper(getch());

    switch(fin_choice)
    {
    case 'N':
        ofile.close();
        clrscr();
        exit(0);
        break;

    case 'Y':
        clrscr();
        break;

    default:
        ofile.close();
        clrscr();
        exit(0);
    }

}

```

```

void edit_data(int lines)
{
    char choice;
    char edit_choice;
    char edit_store_it;

    float edit_int_dist;
    float edit_circum;
    float edit_hor_circum;
    float edit_line_seg;
    float edit_line_num;

    data_pnt = data_array;

    for (int w = 0; w < lines; w ++, data_pnt++)
    {

        clrscr();
        cout << "line-num = " << data_pnt->line_num;
        cout << "\nline-seg = " << data_pnt->line_seg;
        cout << "\nint-dist = " << data_pnt->int_dist;
        cout << "\nperp-circum = " << data_pnt->circum;
        cout << "\nhor-circum = " << data_pnt->hor_circum;

        cout << "\n\nInclude? (Y,N,A)";
        choice = toupper(getch());

        switch(choice)
        {

            case 'Y':
                ofile << data_pnt->line_num
                << "," << data_pnt->line_seg
                << "," << data_pnt->int_dist
                << "," << data_pnt->circum
                << "," << data_pnt->hor_circum
                << endl;
                break;

            case 'N':
                clrscr();
                cout << "Deleting Item";
                cout << "\nPress any key...";
                getch();
                break;

```

```

case 'A':
    clrscr();

    ofile << data_pnt->line_num
    << "," << data_pnt->line_seg
    << "," << data_pnt->int_dist
    << "," << data_pnt->circum
    << "," << data_pnt->hor_circum
    << endl;

    cout << "Line Num - ";
    cin >> edit_line_num;

    cout << "Line Seg. - ";
    cin >> edit_line_seg;

    cout << "Inter. Dist. - ";
    cin >> edit_int_dist;


    // assign switch character value

    if (edit_int_dist <= .25)
        edit_choice = 'A';
    if ((edit_int_dist >= .25)&&(edit_int_dist <= 1))
        edit_choice = 'B';
    if (edit_int_dist >= 1)
        edit_choice = 'C';


    // switch to collect and output data

    switch (edit_choice)
    {
    case 'A':
        clrscr();
        cout << "\aEnter correct # !";
        cout << "\nPress any key... ";getch();
        break;

    case 'B':
        cout << "\n\nCcorrect? (y or n) - ";
        edit_store_it = toupper(getch());if (edit_store_it != 'Y')
            continue;

        ofile << edit_line_num

```

```

        << "," << edit_line_seg
        << "," << edit_int_dist
        << endl;
    break;

case 'C':
    cout << "Perp. Circ. - ";
    cin >> edit_circum;
    cout << "Horiz. Circ. - ";
    cin >> edit_hor_circum;
    cout << "\nCorrect? (y or n) - ";
    edit_store_it = toupper(getch());if (edit_store_it != 'Y')
    continue;

    ofile << edit_line_num
        << "," << edit_line_seg
        << "," << edit_int_dist
        << "," << edit_circum
        << "," << edit_hor_circum << endl;
    break;

default:
    continue;

    }

}

}

}

```

Appendix C

PWCALC.EXE SOURCE CODE

Programming Comments

The following computer program was developed using Borland's Turbo Basic. The program inputs a data file and summarizes vital statistics for both line intersect and quadrant data. The program allows for output to the screen, printer, or file by using three unique subroutines. Documentation is offered by main program section. The code was compiled using a math coprocessor.

```

rem *****
rem *** PWCALC.EXE          Nicholas S. Monkevich          7-15-93 ***

rem *** written to summarize Line intersect sampling data collected at the ***
rem *** Petrified Forest National Park ***

rem *** Master of Science Field work ***

$dynamic
gosub header
begin:
clear

dim card$(500), areanum(500),samptype(500),linenum(500),lineseg(500),numacre(50)
dim intdist(500), count(500),perpcir(500),csarea(500),horcir(500),weight(500),vol(500)
dim l1tot(500), l2tot(500), l3tot(500),l1pert(500),l2pert(500),l3pert(500),quadseg(50)
dim l1hort(500),l2hort(500),l3hort(500),l1covest(50),l2covest(50),l3covest(50)
dim l1volest(50),l2volest(50),l3volest(50),l1denest(50),l2denest(50),l3denest(50)
dim q1nacre(50),q2nacre(50),q1csa(50),q2csa(50),q1weight(50),q2weight(50),q1vol(50)
dim q2vol(50)

cls
locate 5,5:print "A list of card format files is below. Please enter"
locate 6,5:print "the full filename (including extension) you wish to load."
?:?:?:?

shell "dir *.crd /b"
locate 8,7:input "Filename - ",ofile$

open ofile$ for input as # 1
open "lines.fil" for output as # 2
open "quad1.fil" for output as # 3
open "quad2.fil" for output as # 4
b = 1
counter = 0

rem *****
rem ***** Entering Card Format Data into Usable Arrays *****
rem *****
do while not eof(1)

    line input # 1 ,card$(b)
    areanum(b) = val(mid$(card$(b),1,1))

    rem ** get some info for later **
    if areanum(b) = 1 then strata$ = "Blue Mesa"
    if areanum(b) = 2 then strata$ = "Jasper Forest"
    if areanum(b) = 3 then strata$ = "Crystal Forest"
    if areanum(b) = 4 then strata$ = "Long Logs"

```

```

if areanum(b) = 5 then strata$ = "Giant Logs"

samptype(b) = val(mid$(card$(b),2,1))
linenum(b) = val(mid$(card$(b),3,2)):linenum = linenum(b)
lineseg(b) = val(mid$(card$(b),5,1))

if lineseg(b) = 0 then gosub printnul
if lineseg(b) >= 1 and lineseg(b) <= 3 then gosub linesamp
if lineseg(b) = 5 or lineseg(b) = 6 then gosub quadrant

counter = counter + 1

loop
close

rem *****
rem ***** Get Line Intercept Sampling Estimates *****
rem *****
open "lines.fil" for input as # 1

while not eof(1)
input #1 ,linenum(x),samptype(x),lineseg(x),intdist(x),perpcir(x),horcir(x)
let w = linenum(x)
let samptype(w) = samptype(x)
let lineseg(w) = lineseg(x)

rem ** yi % cover summations **
if intdist(x) <= 1 then l1tot(w) = l1tot(w) + intdist(x)
if intdist(x) > 1 and intdist(x) <= 5 then l2tot(w) = l2tot(w) + intdist(x)
if intdist(x) > 5 then l3tot(w) = l3tot(w) + intdist(x)

rem ** yi volume summations **
if intdist(x) <= 1 then l1pert(w) = l1pert(w) + (((intdist(x)/2)^2)*3.14):rem assume
random caliper = per cir
if intdist(x) >= 1 and intdist(x) <= 5 then l2pert(w) = l2pert(w) +
((perpcir(x)*perpcir(x))/(4*3.14))
if intdist(x) > 5 then l3pert(w) = l3pert(w) + ((perpcir(x)^2)/(4*3.14))

rem ** yi density summations **
if intdist(x) = 0 then wender

if intdist(x) <= 1 then l1hort(w) = l1hort(w) + 1/(intdist(x)*3.14):rem assume random
caliper = hor cir
if intdist(x) >= 1 and intdist(x) <= 5 then l2hort(w) = l2hort(w) + 1/horcir(x)
if intdist(x) > 5 then l3hort(w) = l3hort(w) + 1/horcir(x)

wender:
wend

rem ** get counters for mean estimates **

```

```

for c = 1 to w
  if samptype(c) = 1 then bckcnt = bckcnt + 1
  if samptype(c) = 2 then trcnt = trcnt + 1
next c

rem ** prepare the line estimates for output **
for z = 1 to w

  if samptype(z) = 1 then bckwood else trail

bckwood:
  l1covest(z) = (1/25)*l1tot(z)*100
  l1covtob = l1covtob + l1covest(z)/bckcnt
  l2covest(z) = (1/96)*l2tot(z)*100
  l2covtob = l2covtob + l2covest(z)/bckcnt
  l3covest(z) = (1/600)*l3tot(z)*100
  l3covtob = l3covtob + l3covest(z)/bckcnt

  l1volest(z) = ((3630*3.14)/50)*l1pert(z)
  l1voltob = l1voltob + l1volest(z)/bckcnt
  l2volest(z) = ((3630*3.14)/192)*l2pert(z)
  l2voltob = l2voltob + l2volest(z)/bckcnt
  l3volest(z) = ((3630*3.14)/1200)*l3pert(z)
  l3voltob = l3voltob + l3volest(z)/bckcnt

  if l1hort(z) > 0 then l1denest(z) = ((6272640*3.14)/25)*(l1hort(z))
  l1dentob = l1dentob + l1denest(z)/bckcnt
  if l2hort(z) > 0 then l2denest(z) = ((43560*3.14)/8)*(l2hort(z))
  l2dentob = l2dentob + l2denest(z)/bckcnt
  if l3hort(z) > 0 then l3denest(z) = ((43560*3.14)/50)*(l3hort(z))
  l3dentob = l3dentob + l3denest(z)/bckcnt

  goto loopr

trail:
  l1covest(z) = (1/25)*l1tot(z)*100
  l1covtot = l1covtot + l1covest(z)/trcnt
  l2covest(z) = (1/96)*l2tot(z)*100
  l2covtot = l2covtot + l2covest(z)/trcnt
  l3covest(z) = (1/300)*l3tot(z)*100
  l3covtot = l3covtot + l3covest(z)/trcnt

  l1volest(z) = ((3630*3.14)/50)*l1pert(z)
  l1voltot = l1voltot + l1volest(z)/trcnt
  l2volest(z) = ((3630*3.14)/192)*l2pert(z)
  l2voltot = l2voltot + l2volest(z)/trcnt
  l3volest(z) = ((3630*3.14)/600)*l3pert(z)
  l3voltot = l3voltot + l3volest(z)/trcnt

```

```

if l1hort(z) > 0 then l1denest(z) = ((6272640*3.14)/25)*(l1hort(z))
l1dentot = l1dentot + l1denest(z)/trcnt
if l2hort(z) > 0 then l2denest(z) = ((43560*3.14)/8)*(l2hort(z))
l2dentot = l2dentot + l2denest(z)/trcnt
if l3hort(z) > 0 then l3denest(z) = ((43560*3.14)/25)*(l3hort(z))
l3dentot = l3dentot + l3denest(z)/trcnt

loop:
next z
close # 1

rem *****
rem ***** Get Quadrant Sampling Estimates *****
rem *****
open "quad1.fil" for input as # 1
open "quad2.fil" for input as # 2

while not eof(1)
input #1, linenum(x),samptype(x),quadseg(x),count(x),csarea(x),weight(x),vol(x)
let n = linenum(x)
if samptype(x) = 1 then country else tral

country:
q1nacre(n) = count(x)*10036
q1nactob = q1nactob + q1nacre(n)/bckcnt

q1csa(n) = (csarea(x)/625)*100
q1csatob = q1csatob + q1csa(n)/bckcnt

q1weight(n) = (weight(x)*10036)/2000
q1wetob = q1wetob + q1weight(n)/bckcnt

q1vol(n) = (vol(x)*10036)*.0388889
q1voltob = q1voltob + q1vol(n)/bckcnt

goto sender

tral:
q1nacre(n) = count(x)*10036
q1nactot = q1nactot + q1nacre(n)/trcnt

q1csa(n) = (csarea(x)/625)*100
q1csatot = q1csatot + q1csa(n)/trcnt

q1weight(n) = (weight(x)*10036)/2000
q1wetot = q1wetot + q1weight(n)/trcnt

```

```

q1vol(n) = (vol(x)*10036)*.0388889
q1voltot = q1voltot + q1vol(n)/trcnt

sender:
wend

while not eof(2)
input #2, linenum(x),samptype(x),quadseg(x),count(x),csarea(x),weight(x),vol(x)
let n = linenum(x)
if samptype(x) = 1 then boonie else walks

boonie:
q2nacre(n) = count(x)*10036
q2nactob = q2nactob + q2nacre(n)/bckcnt

q2csa(n) = (csarea(x)/625)*100
q2csatob = q2csatob + q2csa(n)/bckcnt

q2weight(n) = (weight(x)*10036)/2000
q2wetob = q2wetob + q2weight(n)/bckcnt

q2vol(n) = ((vol(x)*10036)*.0388889)
q2voltob = q2voltob + q2vol(n)/bckcnt

goto roundup

walks:
q2nacre(n) = count(x)*10036
q2nactot = q2nactot + q2nacre(n)/trcnt

q2csa(n) = (csarea(x)/625)*100
q2csatot = q2csatot + q2csa(n)/trcnt

q2weight(n) = (weight(x)*10036)/2000
q2wetot = q2wetot + q2weight(n)/trcnt

q2vol(n) = ((vol(x)*10036)*.0388889)
q2voltot = q2voltot + q2vol(n)/trcnt

roundup:
wend
close

rem *****
rem ** User Selected Output Subroutines *****
rem *****

cls?:print " Data Analysis is Complete. Please enter the letter"

```

```

print " of where you would like the output to go. Note - the screen"
print " is the default setting!"
print:print:print " s - screen"
print " p - printer"
print " f - file"
Print:?:input "Your choice - ",choice$

if choice$ = "p" or choice$ = "P" then printer
if choice$ = "f" or choice$ = "F" then fileme

rem *****
rem ** output to the screen ** *** output to the screen **
rem *****

cls:rem ** heading **
print "Stratum = ", strata$
print "Line Intersect Sampling Estimates
Print:print " Percent Cover Cubic Ft / Acre Number Per Acre"
print "Line Num Area Ls1 Ls2 Ls3 Ls1 Ls2 Ls3 Ls1 Ls2 Ls3"

for p = 1 to w
if samptype(p) = 1 then type$ = "BC" else type$ = "TR"
print p,type$;using
"####.#";l1covest(p),l2covest(p),l3covest(p);using"#####";l1volest(p),l2volest(p),l3volest
(p);using"#####";l1denest(p),l2denest(p),l3denest(p)

rem ** esthetic values **
if p = 15 or p = 30 then print:input "Enter to Continue. . . ",cont
if p = 15 or p = 30 then cls
if p = 15 or p = 30 then print "Stratum = ", strata$
if p = 15 or p = 30 then print "Line Intersect Sampling Estimates
if p = 15 or p = 30 then print:print " Percent Cover Cubic Ft / Acre
Number Per Acre"
if p = 15 or p = 30 then print "Line Num Area Ls1 Ls2 Ls3 Ls1 Ls2 Ls3 Ls1
Ls2 Ls3"

next p
print
print "Line Intersect Sampling Estimates Are .... "
print:print " Mean Per Cover Mean Cubic Ft/Ac Mean Number Per Acre"
print " Ls1 Ls2 Ls3 Ls1 Ls2 Ls3 Ls1 Ls2 Ls3"
print "Back Country = ";using
"####.#";l1covtob,l2covtob,l3covtob;using"#####";l1voltob,l2voltob,l3voltob;using"####
#####";l1dentob,l2dentob,l3dentob
print
print " Trails = ";using
"####.#";l1covtot,l2covtot,l3covtot;using"#####";l1voltot,l2voltot,l3voltot;using"#####
#####";l1dentot,l2dentot,l3dentot
print:input "Enter to Continue. . . ",cont

rem *****

```

```

rem ** begin Quadrant Output ***
rem *****

cls:print"Stratum = " , strata$
print"Quadrant Sampling Estimates"
Print:print "          Number Per Acre      % Cover      Tot Tons / Ac  Tot Volume/Ac"
print "Line Num   Area  Q1   Q2      Q1   Q2      Q1   Q2      Q1   Q2"

for p = 1 to w
if samptype(p) = 1 then type$ = "BC" else type$ = "TR"

print p,type$;using "#####";q1nacre(p),q2nacre(p);using
"####.##";q1csa(p),q2csa(p),q1weight(p),q2weight(p);using "#####";q1vol(p),q2vol(p)

  rem ** esthetic values **
if p = 15 or p = 30 then print:input "Enter to Continue. . . ",cont
if p = 15 or p = 30 then cls
if p = 15 or p = 30 then print "Stratum = " , strata$
if p = 15 or p = 30 then print "Quadrant Sampling Estimates"
if p = 15 or p = 30 then Print:print "          Number Per Acre      % Cover      Tot Tons /
Ac  Tot Volume/Ac"
if p = 15 or p = 30 then print "Line Num   Area  Q1   Q2      Q1   Q2      Q1   Q2
Q1   Q2"

next p

print
print "Quadrant Sampling Totals Are .... "
print:print "          Mean Num/Acre   Mean % Cover   Mean Tons/Ac   Mean Vol/Ac"
print"          Q1   Q2      Q1   Q2      Q1   Q2      Q1   Q1"
print "Back Country = ";using
"#####";q1nactob,q2nactob;using"####.##";q1csatob,q2csatob,q1wetob,q2wetob;usi
ng"#####";q1voltob,q2voltob
print
print "    Trails = ";using
"#####";q1nactot,q2nactot;using"####.##";q1csatot,q2csatot,q1wetot,q2wetot;using
"#####";q1voltot,q2voltot
print:input "Enter to Continue . . . ",cont
goto byebye

rem *****
rem ** output to the printer **  ** output to the printer **
rem *****
printer:

cls:rem ** heading **
lprint "Stratum = " , strata$
lprint "Line Intersect Sampling Estimates

```

```

Iprint:Iprint "          Percent Cover   Cubic Ft / Acre   Number Per Acre"
Iprint "Line Num   Area  Ls1  Ls2  Ls3  Ls1  Ls2  Ls3  Ls1    Ls2    Ls3"

for p = 1 to w
if samptype(p) = 1 then type$ = "BC" else type$ = "TR"
Iprint p,type$;using
"####.#";l1covest(p),l2covest(p),l3covest(p);using"#####";l1volest(p),l2volest(p),l3volest
(p);using"#####";l1denest(p),l2denest(p),l3denest(p)
next p

Iprint
Iprint "Line Intersect Sampling Estimates Are .... "
Iprint:Iprint "          Mean Per Cover   Mean Cubic Ft/Ac   Mean Number Per Acre"
Iprint"          Ls1  Ls2  Ls3   Ls1  Ls2  Ls3   Ls1    Ls2    Ls3"
Iprint "Back Country = ";using
"####.#";l1covtob,l2covtob,l3covtob;using"#####";l1voltob,l2voltob,l3voltob;using"####
#####";l1dentob,l2dentob,l3dentob
Iprint
Iprint "    Trails = ";using
"####.#";l1covtot,l2covtot,l3covtot;using"#####";l1voltot,l2voltot,l3voltot;using"#####
####";l1dentot,l2dentot,l3dentot
Iprint

rem *****
rem ** begin Quadrant Output **
rem *****
Iprint:Iprint:Iprint:Iprint
Iprint"Stratum = " , strata$
Iprint"Quadrant Sampling Estimates"
Iprint:Iprint "          Number Per Acre   % Cover   Tot Tons / Ac   Tot Volume/Ac"
Iprint "Line Num   Area  Q1   Q2   Q1   Q2   Q1   Q2   Q1   Q2"

for p = 1 to w
if samptype(p) = 1 then type$ = "BC" else type$ = "TR"
Iprint p,type$;using "#####";q1nacre(p),q2nacre(p);using
"####.#";q1csa(p),q2csa(p),q1weight(p),q2weight(p);using"#####";q1vol(p),q2vol(p)
next p

Iprint
Iprint "Quadrant Sampling Totals Are .... "
Iprint:Iprint "          Mean Num/Acre   Mean % Cover   Mean Tons/Ac   Mean Vol/Ac"
Iprint"          Q1   Q2   Q1  Q2   Q1  Q2   Q1  Q1"
Iprint "Back Country = ";using
"#####";q1nactob,q2nactob;using"####.#";q1csatob,q2csatob,q1wetob,q2wetob;usi
ng"#####";q1voltob,q2voltob
Iprint
Iprint "    Trails = ";using
"#####";q1nactot,q2nactot;using"####.#";q1csatot,q2csatot,q1wetot,q2wetot;using
"#####";q1voltot,q2voltot
Iprint

```

```

goto byebye

rem *****
rem ** output to a filename ** ** output to a filename **
rem *****
fileme:

cls:print "Enter the name of the file you wish the data stored in"
input "Filename - ";filename$
open filename$ for output as # 1

rem ** loops to spit out data **
for p = 1 to w
write #1,
p,samptype(p),l1covest(p),l2covest(p),l3covest(p),l1volest(p),l2volest(p),l3volest(p),l1denest
(p),l2denest(p),l3denest(p)
next p

write #1, " "
for p = 1 to w
write #1,
p,samptype(p),q1nacre(p),q2nacre(p),q1csa(p),q2csa(p),q1weight(p),q2weight(p),q1vol(p),q
2vol(p)
next p

cls:
locate 5,5:print "File has been Writen"
locate 6,5:input "Enter to Continue",cont

byebye:
cls:locate 5,5:print " R = Run "
locate 5,15:color 31,1:print "QCALC.EXE"
locate 5,26:color 15,1:print "Again"
locate 6,5:print " E = Exit To Dos"
locate 8,6:input " Your choice - ",cht$
if cht$ = "r" or cht$ = "R" then begin else end

rem *** delete work files ***
shell "del *.fil"

rem ***** Subroutines *****

header:

color 15,1
cls:locate 3,30:color 31,1:print "QCALC.EXE"

```

```

color 15,1:locate 5,5:print "Welcome to the Petrified Wood Data Analysis Program. This"
locate 6,5:print "was developed for analyzing line intercept data collected at"
locate 7,5:Print "the Petrified National Forest, Arizona. Remember that the"
locate 8,5:print "data must in card format. For information on the data format"
locate 9,5:print "requirements view the card.fmt file. Although this program"
locate 10,5:print "will not calculate variances, it does derive line segment totals"
locate 11,5:print "and allows file output for further analysis in statistical"
locate 12,5:print "packages."
print:print:print

```

```

Input " Enter to Continue ... ",en
return

```

```

printnul:

```

```

    write #2, linenum(b),samptype(b),linseg(b),0,0,0

```

```

return

```

```

linesamp:

```

```

    intdist(b) = val(mid$(card$(b),6,5))
    perpcir(b) = val(mid$(card$(b),11,5))
    horcir(b) = val(mid$(card$(b),16,5))

```

```

    write #2, linenum(b),samptype(b),lineseg(b),intdist(b),perpcir(b),horcir(b)

```

```

return

```

```

quadrant:

```

```

    count(b) = val(mid$(card$(b),6,5))
    csarea(b) = val(mid$(card$(b),11,5))
    weight(b) = val(mid$(card$(b),16,5))
    vol(b) = val(mid$(card$(b),21,5))

```

```

    if lineseg(b) = 5 then write # 3,
linenum(b),samptype(b),lineseg(b),count(b),csarea(b),weight(b),vol(b)
    if lineseg(b) = 6 then write # 4,
linenum(b),samptype(b),lineseg(b),count(b),csarea(b),weight(b),vol(b)
return

```

Appendix D

WEIGHT.EXE SOURCE CODE

Programming Comments

The following computer program was developed using Borland C + + . The programs function is to collect weights of Petrified Wood Particles, store those weights in a data file and output the average weight and variance of the particles sampled. The variable names are fairly self-explanatory. The code is documented throughout to aid in explanation. The code compiled easily using a small memory model without a math coprocessor.

```

/* *****
*** WEIGHT.EXE          Nicholas S. Monkevich          5-5-94          ***
*** input routine for LS1 wieght estimatation at the Petrified Forest Naitonal Park ***
*** Masters of Science Field Work ***
***** */

#include <conio.h>
#include <iostream.h>          // include during compile time
#include <stdio.h>
#include <stdlib.h>            // these library files
#include <math.h>
#include <fstream.h>

ofstream ofile;              // set up the out-file stream

struct in_data
{
    // define a data structure for
    float weight;
    float variance_part;      // the array variables
};

in_data in_data_array[250];   // declare a dummy array for the data structure

in_data *in_data_pnt;         // declare a pointer to point at the data structure
                                // array

main(void) {

    float total=0;             // define local variables for
    float ave_weight=0;
    float samp_size=0;
    float variance=0;          // the main function!
    float stnd_error=0;
    char name[20];
    int n=1;
    int x=1;

```

```

clrscr();
cout << "Enter Storage Filename ";
cout << "\nFilename = ";
cin >> name;

ofile.open(name);
ofile.precision(5.2);
ofile.width(8);

if (!ofile) cerr << "\nCan't Open File!";
clrscr();
cout << "Enter the Sample Size - ";
cin >> samp_size;

in_data_pnt = in_data_array;

while (n <= samp_size)
{
    clrscr();
    cout << "Sample = " << n ;
    cout << "\n\nParticle Weight - ";
    cin >> in_data_pnt->weight;

    ofile << in_data_pnt->weight << endl;

    total = total + in_data_pnt->weight;

    in_data_pnt++;
    n++;
}

ave_weight = total / samp_size;

in_data_pnt = in_data_array;

while (x <= samp_size)
{
    in_data_pnt->variance_part = pow((ave_weight - in_data_pnt->weight),2);
    variance = variance + in_data_pnt->variance_part;

    in_data_pnt++;
    x++;
}

```

```

    }

    stnd_error = sqrt(variance / (samp_size - 1));

    ofile << "Sample Size = " << samp_size << endl;
    ofile << "Total Weight = " << total << endl;
    ofile << "Average Weight = " << ave_weight << endl;
    ofile << "Variance = " << variance << endl;
    ofile << "Standard Error = " << stnd_error << endl;

    return(0);

}

```

Appendix E

Derivation of Line Intersect Conversion Factors

This appendix derives several conversion constants for Kaiser’s (1983) line intercept sampling estimators. These are merely two examples of how constants can be calculated given units of measure. These conversion constants were used to adjust line intercept data collected at the Petrified Forest National Park for the density per acre and volume per acre estimators. It should be noted that some line intersect data units were converted to correctly use these estimators with the derived constants

Conversion Constant Derivation For The Volume Per Acre Estimator

Kaiser's (1983) unbiased estimator, conditional on the orientation of θ is,

$$\hat{\lambda} = \frac{1}{A} \sum \frac{t_i y_i}{E(t_i y_i | \theta)} x_i$$

Here: $\lambda = \frac{\text{volume}}{\text{acre}}$; the target parameter

$$t_i = \text{indicator variable} \begin{cases} 1 & \text{if sampled} \\ 0 & \text{otherwise} \end{cases}$$

y_i = cross sectional area of particle sampled perpendicular to long axis
in square inches per acre

x_i = volume per acre in cubic inches per acre

L = line transect length in inches

θ = angle between line transect and sampled particle

A = total area sampled in acres

For the volume per acre conditional estimator $E(t_i y_i | \theta) = \frac{2Lx_i}{\pi A}$. See Kaiser (1983) for a more detailed description. We want $\hat{\lambda}$ to be in units of cubic feet per acre, thus we must scale the $E(t_i y_i | \theta)$ to have the same units of measure as y_i .

Recall:

$$E(t_i y_i | \theta) = \frac{2Lx_i}{\pi A} \left[\frac{\text{in}^4}{\text{acre}} \right] \quad \text{units in } \text{in}^4 / \text{acre}$$

Adjusting the units:

$$E(t_i y_i | \theta) = \frac{2Lx_i}{\pi A} \left[\frac{\text{in}^4}{\text{acre}} \right] \times \frac{1 \text{ acre}}{43560 \text{ ft}^2} \times \frac{1 \text{ ft}^2}{144 \text{ in}^2} = \frac{2Lx_i}{(6272640)\pi A} \left[\text{in}^2 \right]$$

Plugging the expectation into the $\hat{\lambda}$ estimator:

$$\hat{\lambda} = \frac{1}{A} \sum \left(\frac{t_i y_i}{\frac{2Lx_i}{(6272640)\pi A}} \right) x_i = \frac{6272640\pi}{2L} \sum_s y_i \left[\frac{\text{in}^3}{\text{acre}} \right]$$

One final adjustment:

$$\hat{\lambda} = \frac{6272640\pi}{2L} \sum_s y_i \left[\frac{in^3}{acre} \right] \times \frac{1ft^3}{1728in^3}$$

So, for the volume per acre estimator:

$$\hat{\lambda} = \frac{3630\pi}{L} \sum_s y_i \left[\frac{ft^3}{acre} \right]$$

Conversion Constant Derivation For The Density Per Acre Estimator

Kaiser's (1983) unbiased estimator, conditional on the orientation of θ ,

$$\hat{\lambda} = \frac{1}{A} \sum \frac{t_i y_i}{E(t_i y_i | \theta)} x_i.$$

Here: t_i = indicator variable $\begin{cases} 1 & \text{if sampled} \\ 0 & \text{otherwise} \end{cases}$

$$y_i = 1$$

$$x_i = 1, \text{ so } \hat{\lambda} = \frac{\text{number}}{\text{acre}}$$

L = line transect length in feet

θ = angle between line transect and sampled particle

A = total area sampled in acres

C_i^* = circumference of particle sampled in feet

For the density per acre estimator $E(t_i y_i | \theta) = \frac{C_i^* L}{\pi A}$. See Kaiser (1983) for a more detailed description. We want $\hat{\lambda}$ to be in units of x per acre, so we must scale the $E(t_i y_i | \theta)$ to be dimensionless the following way:

Recall:

$$E(t_i y_i | \theta) = \frac{C_i^* L}{\pi A} \left[\frac{\text{ft}^2}{\text{acre}} \right] \quad \text{units in } \text{ft}^2 / \text{acre}$$

Adjusting the Units:

$$E(t_i y_i | \theta) = \frac{C_i^* L}{\pi A} \left[\frac{\text{ft}^2}{\text{acre}} \right] \times \frac{1 \text{ ac}}{43560 \text{ ft}^2}$$

Plugging into the estimator:

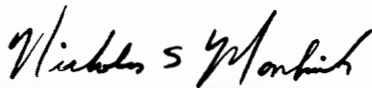
$$\hat{\lambda} = \frac{1}{A} \sum \left(\frac{t_i y_i}{C_i^* L} \right) x_i = \frac{43560\pi}{L} \sum_s \frac{x_i}{C_i^*}$$

So, for the density per acre estimator:

$$\hat{\lambda} = \frac{43560\pi}{L} \sum_s \frac{x_i}{C_i^*} \left[\frac{x}{acre} \right]$$

Vita

Nicholas Scott Monkevich was born August 9, 1969 in Fort Knox, Kentucky. In May 1987, he graduated Cum Laude from Notre Dame High School in Harper Woods, Michigan. In May 1992, he graduated Magna Cum Laude from Michigan Technological University with a degree in Forestry. He worked as a research technician during his final year at Michigan Tech where he co-authored a paper, Comparing N-Tree Distance Sampling with Point and Plot Sampling in Northern Michigan Forest Types, published in the *Northern Journal of Forestry*. In January 1992, he continued his education at Virginia Technological University and State University where he earned a Masters of Science in Forestry, November 1994. During his stay at Virginia Tech he co-authored another paper with Timothy G. Gregoire, entitled The Reflection Method of Line Intersect Sampling to Eliminate Boundary Bias, published in the *Journal of Environmental and Ecological Statistics*.



Signed

10-31-94

Date