Sampling Culturally Modified Tree Sites

Final Report

Prepared for

The Ministry of Forests, Aboriginal Affairs Branch

by

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in consultation with

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and
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The opinions expressed in this report are those of the author, and do not necessarily represent those of any other individuals, groups, or institutions involved in this study.

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INTRODUCTION

The recent discovery of archaeological sites containing large numbers of CMTs (culturally modified trees) has raised concerns with respect to the present standards for CMT site recording and management. Currently, the Ministry of Small Business, Tourism and Culture, Archaeology Branch operational procedure (*Recording Culturally Modified Trees*), and the provincial standard (*Culturally Modified Trees of British Columbia* [Stryd 1997]) require that, each CMT feature within an archaeological site be individually recorded in detail as a condition of conducting an archaeological inventory, impact assessment or site alteration, unless otherwise specified in the 'Application for Permit'. In addition, Sections 17 and 51 of the *Forest Practices Code Act* require that all "cultural heritage resources" be "identified" and "assessed" prior to harvesting of a cut permit. Given that a number of large CMT sites have been located where it is clearly impractical or impossible to record each feature, permit applicants have been formulating their own sampling schemes. While these methodologies vary considerably from project to project and appear somewhat *ad hoc*, there is currently no clear study of CMT site sampling to provide direction to archaeological consultants or Branch staff.

It is suspected that in cases of sites with very large numbers of relatively homogenous CMTs (e.g., bark-stripped trees) detailed recording of all features is unnecessary from a cultural resource management perspective, in that it involves documentation of a large amount of redundant data. The Ministry of Forests, in consultation with the Archaeology Branch, commissioned this study in order to evaluate this suspicion and to determine whether site sampling schemes can produce data which adequately represent the proportions and variability found within a CMT site from a scientific perspective, while at the same time satisfying legal requirements. Specifically, the purpose of this study is to identify effective strategies for documenting sites containing large numbers of CMTs which will ensure representative recording of their spatial, temporal, and morphological attributes and variability.

This report begins with a discussion of how CMT sites are defined and recorded. This is followed by a brief review of the fundamental principles of sampling theory and their implications with respect to CMT attributes and variability. A review and evaluation of currently employed archaeological sampling schemes is then presented. This is followed by a general discussion of the methodologies and recommendations for effective site sampling strategies. These recommendations are presented as proposed CMT site sampling standards. It should be noted that these are merely 'proposed' standards and it is hoped that review and discussion among all concerned parties will ultimately result in CMT site sampling objectives and guidelines for inclusion in "The CMT Handbook" (i.e*., Culturally Modified Trees of British Columbia*). Appendix A presents relevant data from CMT sites and several sampling experiments conducted in the course of evaluating the various sampling schemes.

CMT SITES

In British Columbia the primary unit of cultural heritage resource management is the '*site*'. Heritage *sites* are protected from adverse impacts by the *Heritage Conservation Act.* This Act defines a heritage site as "land, including land covered by water, that has heritage value to British Columbia, a community or an aboriginal people". "Heritage value" refers to "the historical, cultural, aesthetic, scientific or educational worth or usefulness of a site". Archaeological sites (including CMT sites) qualify as heritage sites by nature of there inherent heritage value.

As defined in 'The CMT Handbook' (Stryd 1997:7): "A CMT is a tree that has been altered by native peoples as part of their traditional use of the forest." Archaeological sites containing CMTs are often referred to simply as 'CMT sites'; however, it is important to acknowledge that other types of archaeological features and remains are sometimes found in association with CMTs. In recognition of this possibility some archaeologists prefer to use the term 'forest utilization site' to describe sites containing CMTs. It is also common for CMTs to be found within sites which contain more 'prominent' features and are thus described as "habitation" or "burial" sites (*etc*..). As this report is concerned exclusively with culturally modified trees, the term 'CMT site' will be used here to encompass all of the above possibilities. *Specifically, for the purposes of this discussion a 'CMT site' refers to any archaeological site containing one or more CMTs*.

In the discussions below it also essential to keep in mind the distinction between a CMT and a 'CMT feature'. As noted above the term CMT refers to a tree which has been culturally modified. Each CMT will display one or more 'features'. A CMT feature consists of "a modification produced by wood or bark removal" (Stryd 1997:29). These include bark strip scars, test holes, planks scars, stumps, log sections, notches, canoe blanks, *etc*. In the context of site sampling it is important to note that on trees with multiple features, each feature potentially represents a discrete 'event' and thus in many cases need to be treated as an independent entity.

The spatial definition of an archaeological site also deserves some discussion. Archaeological sites are usually defined as areas of land which contain a more or less continuous distribution of cultural remains resulting from human activities. In most cases the boundaries of an archaeological site can be defined by determining the extent of contiguous 'cultural deposits'. However, CMT sites present an exception to this procedure. Because CMTs are *discretely* distributed across the landscape, they often pose problems with respect to defining site boundaries. Contiguous 'cultural deposits' usually do not occur between CMTs and consequently site boundaries are not clearly evident. This results in inconsistencies in the way that CMT sites are defined spatially. Some researchers tend to divide or 'split' areas containing CMTs into many small discrete 'sites', while others prefer to group or 'lump' large numbers of CMTs spread over large areas into a single 'site'. An additional and perhaps more troublesome problem is that, in the context of an archaeological impact assessment, site boundaries are often arbitrarily defined based on the size and shape of a given study area, rather than on the true distribution of CMTs on the landscape. There is some concern that such discrepancies in site definition may produce inconsistent and potentially biased research results. However, as will be argued below, well planned recording and sampling strategies can (for the most part) avoid or negate these potential problems.

SAMPLING THEORY

This section presents a brief introduction to the fundamentals of sampling theory. Six sampling concepts will be discussed here: 1) the collectors curve; 2) nature of the observations; 3) desired confidence level; 4) variability among the population; 5) calculation of optimum sample sizes; and 6) sample selection. A basic understanding of these concepts is essential to evaluation of potential sampling strategies.

The Collector's Curve

In any field of investigation there is a log-linear relationship between the number of observations made and the amount of information accumulated. A collectors curve is a graphic representation of this relationship (see Figure 1, below). The premise behind this relationship is that for any given phenomenon there is a finite amount of information which can be acquired or a "saturation point"; and as one approaches this point the number of observations required to obtain new information increases exponentially.

Figure 1. The Collector's Curve.

Specifically, this relationship functions as follows. Initially in any given study, each observation presents 'new' data and thus vastly increases the amount of information accumulated. That is, with very little information accumulated the potential that an observation will produce redundant information is initially quite low, thus the collector's curve displays a steep slope representing a dramatic increase in 'information' (the Y axis) with every increase in 'sample size' (the X axis). However, as more observations are made the potential for repeated or redundant observations gradually increases. As the amount of accumulated information increases the number of observations required to produce "new" information also increases. This is represented graphically by a gradual decrease in the slope of the collectors curve. Eventually the curve reaches a virtually horizontal slope representing the negligible effect of additional observations on the body of accumulated information.

The important ramification of the collector's curve is that during any analysis at some 'point' the pursuit of knowledge becomes ineffectual because of the vast number of additional observations required to acquire 'new' information. The 'point' at which this occurs is primarily dependent on three factors: the nature of observations being made; the desired level of confidence in the results, and inherent variability among the population being studied (Bowman and Kastenbaum 1975:111).

Nature of the Observations

The 'nature of observations' refers to 1) the number of attributes to be compared and 2) the various scales of measurement used. The number of attributes to be compared will directly influence the number of observations (i.e., sample size) required to accurately characterize the population. In general, investigation of a single variable (i.e., univariate analyses) demands fewer observations than bivariate comparisons, while multivariate analyses require even larger samples. Similarly, if a population is to be subdivided during analysis the number of observations required may be somewhat increased. The 'scales of measurement' used will also influence the appropriate sample size. Measurement scales are generally categorized as either: nominal, ordinal, interval or ratio. These scales respectively posses increasingly complex mathematical properties and consequently, each has its own requirements with respect to sampling theory and methodology (Freedman *et al.* 1984).

The 'nature' of observations which are made in a given study will depend on the research questions which are being investigated. With respect to the investigation of culturally modified trees a wide variety of potential research questions exist. A recent informal discussion of CMT investigations, facilitated by the BCAPCA CMT committee (Stafford 1999), produced a list of ongoing and potential research topics, including:

1. CMT technology: materials harvested, kinds of tools used, items manufactured.
2. CMTs as territorial markers.
3. Seasonal movements of a group within a territory.
4. Identification of individuals, families, and groups through 'style' analyses.
5. Human population estimations based on intensity of resource extraction.
6. Traditional use of landscape/habitation site catchment areas.
7. Correlation between small scale climatic episodes and cambium bark stripping.
8. Impacts of 'European contact' on CMT technology and land use.

This is, no doubt, an incomplete list and it is likely that as research continues new and more complex questions will arise. What is important here is the range of variables relevant to the various research topics. While many topics require estimation of the type and volume of resources extracted during a given time period, others demand a precise description of the morphology of the features represented at a site. Technological investigations require data on tool types, tree selection (species, size and age), materials harvested, and evidence of manufacturing; while traditional land use and 'territorial' research calls for documentation of precise geographical and chronological data.

As cultural resource management studies tend to be 'salvage oriented' (rather than 'research oriented') it is important that a wide range of data be collected during archaeological inventory, impact assessment, and impact mitigation projects, so as to ensure that a sufficient permanent record exists to allow a wide range of potential future research queries. This concern for thoroughness is reflected by the wide variety of feature attributes and other detailed site information currently recorded by most researchers. In some cases the data collected exceeds that recommended in *Culturally Modified Trees of British Columbia*. As the specific attributes documented during CMT studies is currently undergoing revisions, review of the value and relevance of each specific attribute will not be attempted here. What is important is to acknowledge that CMT attributes are currently measured using all scales of measurement: i.e., nominal (e.g., tree species, modification type); ordinal (e.g., side of tree); interval (e.g., age in calendar years); and ratio (e.g., length of scar), and most research questions require multivariate analyses and populations which can be subdivided into sub-populations on the basis of age, morphology and spatial distribution. Consequently, relatively large samples are required to ensure proper representation of variability at each site.

Desired Confidence Level (sample error objective)

To some extent a sample will always be representative of the population from which it is selected, however, exactly how accurately it represents the population will vary. The degree of confidence that should be placed in sample results is expressed in terms of a confidence level (i.e, probability factor [e.g., .01, .05., .10]) and confidence interval (i.e., sampling error). These are most commonly seen in association with polling results; e.g., commonly expressed as "results are accurate to within plus or minus 10%, 19 times out of 20". The first value (±10%) refers to the sampling error, the second (19 times out of 20) refers to the confidence (95%) level. Together these standards form what is commonly referred to as the "sample error objective".

Determination of an appropriate sample error objective is necessary to arrive at appropriate sample sizes. The desired degree of confidence depends on the required precision of the results. In circumstances where the data is of critical (e.g., life and death) importance the confidence level is usually set at 99% (i.e., .01 probability) or higher and the acceptable level of sampling error is relatively small (e.g., ± 5%). More commonly the precision of sampling results are not so critical and more lenient confidence standards are used, such as in the polling example above. Currently, there is no standardized sample error objective for CMT site sampling. For the purposes of evaluating the effectiveness of currently employed sampling strategies an arbitrary sample error objective of 'plus or minus 10%, 18 times out of 20' has been adopted here. This standard will be used to assess the adequacy of sample sizes resulting from the various sampling strategies discussed below.

Variability Among the Population

Statistical formulae for determining appropriate sample sizes require prior knowledge of the degree of variability among the population. The degree of variability in a population is expressed as the "coefficient of variation" (CV). The CV is calculated as the sample standard deviation divided by the sample mean, usually expressed as a percentage. Most circumstances require that standard deviation and mean values be calculated for the attribute of interest, prior to determining the sample size. This is usually done using a 'pilot study' or 'pilot data' from a small sample of the population. In cases where such data is not available, arbitrary or predicted CV values are sometimes used and then reevaluated after the sample is taken. In most cases archaeologists do not have access to pilot data for the population (i.e., the site) which they are investigating, however, arbitrary CV values or assumed values based on data from other sites can be used.

In order to obtain some idea of the variability among CMT site attributes an informal review of data from a variety of recorded CMT sites was conducted (see Appendix A). This review focused on the most common feature types: bark strips, and included examination of major attributes such as scar length, height above germination (HAG), tree diameter (DBH), and feature age. Data from both interior (cambium bark-stripped pine) and coastal (bark-stripped cedar) sites were examined. Briefly, this review indicates that the variability (i.e., CV) among CMT attributes generally ranges from 10% to 70%. Attributes which consistently display the highest degrees of variability include scar width and HAG measurements, which produce CV values between 50% and 70%. Feature ages (calculated in years BP [i.e., years before AD 1950]) among coastal sites also display considerable variability (typically 40% to 55%). Interior CMT sites display less variability in feature ages (usually less than 40%).

Calculation of Optimum Sample Sizes

The number of observations required to satisfy a given sample error objective with minimal effort (or cost) is often referred to as the 'optimum sample size' (Cochran 1977:95). Sampling statistics provide various means of determining optimum sample sizes. In most cases once an estimate of variability within a population is known and a desired sample error objective established the optimum sample size can be determined mathematically. For example, for univariate analyses of ratio data from a population of finite size the appropriate number of observations for a population can be determined using the formula:

$$n = \frac{t^2 x CV^2 x N}{N x E^2 + t^2 x CV^2}$$

where:
n = number of observations (optimum sample size)
t = probability factor
CV = coefficient of variation
E = error objective
N = population size

Notes: The probability factor (t) is determined by referring to a table of probability values for the selected confidence level given n-1 degrees of freedom. This is necessarily an iterative process in that multiple values for 't' must be tried until the solution is found. An excellent example of the application of this formula is provided in the *Cruising Manual* (MOF 1999: Section 2.6.1).

Application of this formula, using the sample error objective of 'plus or minus 10%, 18 times out of 20', produces the following optimum sample sizes:

Table 1. Examples of optimum sample sizes.

Population (N)	Optimum Sample Size (n)			
	Coefficient of Variation (CV)			
	30%	40%	50%	60%
5	5	5	5	5
10	8	9	9	9
20	12	14	16	17
30	15	19	21	23
40	16	22	26	29
50	18	24	30	34
60	19	26	33	38
70	20	28	35	42
80	20	29	38	45
90	21	31	40	48
100	21	32	41	50
200	23	37	52	67
300	24	39	57	75
400	25	41	59	80
500	25	42	61	83
1000	26	43	65	90
10000	26	45	69	98

Table 1 illustrates that the optimum sample sizes for a population of size 'N' will vary significantly depending on the degree of inherent variability (CV). For example, a population of 1000 which displays relatively little variability (e.g., CV = 30%) would require a sample of only 26 observations to be accurately characterized, while a population of identical size which displays twice as much variability (i.e., CV=60%) would require 90 observations to ensure accurate representation. It is important to note that these sample sizes would be appropriate for characterization of a single attribute (e.g., feature age), but may not be sufficient to allow precise multivariate analyses.

Sample Selection

Simple random sampling is commonly advocated by statisticians as the most unbiased approach to sample selection. Through a completely random sample selection process, this methodology endeavors to ensure that the expectations and/or preconceptions of the researcher do not influence the data which are collected. Simple random samples of sufficient size will presumably provide data which are representative of a population as whole; however, this is often not adequate for archaeological analyses. As discussed above many of the research questions which can be potentially addressed through CMT investigations require more than estimation of mean values or characterization of a single attribute. CMT features in a single site potentially differ along several dimensions of variation: e.g., age, spatial distribution, and morphology. Ideally to obtain samples which are appropriate for detailed intra-site analyses the method of sample selection should ensure representation of spatial, temporal, and morphological variability. A simple random sample would be unlikely to result in data which are representative of all attributes over all these dimensions of variation. Consequently, simple random sampling is rarely used in archaeology. It is often more appropriate to use a partially or largely judgmental sampling strategy.

To ensure even spatial representation systematic sample selection is commonly employed in archaeology. Such methodologies consist of observations being made a standardized spatial intervals (e.g., transects, grid units, or plots). Systematic sampling methods are often used in archaeology because of their efficiency, and ease of implementation. However, it is unlikely that a simple systematic sampling strategy can accommodate representation of more than one dimension of variation. In order to ensure even representation over more than one dimension of variation some form of sample stratification is usually employed.

Sample stratification is also a common strategy used in archaeology, usually in conjunction with a systematic sampling scheme. Sample selection is stratified basically for two reasons: 1) to delimit sub-populations which are themselves domains of study and 2) to decrease the standard deviation of the samples. In order to ensure that data collected will be adequate for detailed intra-site analyses (i.e., spatial, temporal, or morphological analyses) some form of sample stratification is usually employed. This ensures that an adequate number and range of observations are obtained to allow comparisons within and between sub-populations within a site. While in most instances this type of stratification will increase the total number of observations required to accurately characterize the population, this will not necessarily always be true. As the coefficient of variation is directly related to the range of attribute values, the smaller this range is in a population, the fewer observations required to obtain an accurate estimate. In some cases it may be possible to increase sampling efficiency by stratifying large diverse populations into smaller more uniform sub-populations. For example, if a site displays features which clearly fall into two sub-groups on the basis of age, it can be safely assumed that the variability in feature age will be much less within each sub-group than for the site population as a whole. Consequently the coefficient of variation can be assumed to be much lower than that for the entire site population and a smaller number of samples (dates) needed to obtain an accurate demographic estimate.

CURRENT CMT SITE SAMPLING METHODOLOGIES

Judgmental Sampling

The majority of archaeological data gathering ‘methodologies’ currently implemented in British Columbia are best characterized as judgmental sampling strategies. These include most archaeological excavation projects but also encompass many CMT inventories. In these instances determination of the appropriate number and specific features which are recorded is based largely on the judgment of the individual researcher. In some of these studies, the types of features recorded may include primarily those which are relevant to a specific local or regional research problem or of particular interest to the researcher or local First Nations. More commonly, sample size and selection appear to be determined based largely on practical considerations, such as accessibility, block boundaries, and time constraints. Occasionally, some degree of systematic sample selection is employed (e.g., every 10th CMT encountered is recorded in detail); however, even in such cases the resulting sample size is largely arbitrary and the sample interval is irregular and influenced spatially by factors such as the point of access, cut block boundaries, cruise strip lines, creeks, and topography.

Discussion

The logistical realities of archaeological field work usually dictate the incorporation of some judgmental aspect to any sampling strategy. Not all archaeological sites and features are equal from the perspective of the information they can potentially yield. This is particularly true of CMTs which can vary substantially in the quality of features displayed and their suitability for dating. Indeed, it should be the responsibility of the archaeologist to use their ‘judgment’ while in the field to ensure that the data collected will be of value and the level of effort to obtain the data, appropriate. Judgmental sampling strategies can take advantage of the experience of a researcher to ensure that the ‘most important’ information is collected. In the case of data gathered for specific research purposes, partially or largely judgmental sample selection is often appropriate to ensure that the data collected is relevant to the research problem. Judgmental sampling is also often very efficient, in terms of required field time, due to the role of scheduling and logistical considerations in its implementation. However, from a cultural resource management perspective there are a number of serious problems with the widespread use of unstandardized judgmental sampling. As currently implemented, judgmental sampling schemes are extremely inconsistent between researchers and frequently considerable methodological variability is evident even among individual crews. Furthermore, the specific sampling criteria are rarely explicitly stated and consequently there is no means of assessing whether or not the resulting sample is representative of the site as a whole. While some researchers may have the experience and skill to ‘know’ which features are important to record and which to ignore with respect to a particular research problem, there is no guarantee that the data will provide an accurate representation of the site for use by future researchers. Because of the inevitable inconsistencies between researchers and the unknown quality of the resulting data, judgmentally collected samples are frequently of little use as research data in investigations for which they were not specifically collected.

Transect Sampling

Transect sampling has been employed quite commonly in archaeology as a survey method, but has also been used recently as a means of recording individual CMT sites. There is currently little consistency in the use of this strategy, though most studies employ linear transects of standardized widths (typically 30 to 50 m) traversed at regular intervals within a block. In most cases, timber cruise strip lines are used as base lines for the transects. CMTs encountered during each traverse are documented to varying levels of detail and a subsample of features are sometimes dated (usually to establish the maximum age of the site). It is notable that most researchers qualify this strategy as an assessment or inventory level survey, and state that is not intended as a mitigation strategy.

Discussion

Transect sampling can be an extremely efficient methodology because site survey and site recording can be done simultaneously. The method does not require any ‘backtracking’ on the part of field workers and so avoids redundant traverses. When conducted consistently and reported in detail this methodology can provide valuable data with respect to site and feature distributions, which can be readily incorporated into predictive models of site potential. However, from the perspective of impact assessment and management this methodology as currently employed is inadequate.

In order to evaluate the effectiveness of transect sampling three hypothetical sampling experiments were performed using data from previously recorded CMT sites: DkSp-44, HjRl-4 and DkRj-1, (see Appendix A: sampling experiment #1) with populations of 940, 252 and 163 respectively. The experiment employed 30 meter wide, north-south oriented transects spaced at 100 m intervals within each survey study area. All features which fell within the transect areas were considered to be ‘recorded’. The resulting data sets were then evaluated with respect to adequacy of sample size and spatial representation.

The methodology worked best on the site with the largest number of features. 333 of the 940 CMTs from site DkSp-44 fell within the transects providing a more than adequate sample in terms of sample size and all major feature clusters within the site were represented by multiple observations. However even given the relatively large sample size the results did not provide an accurate estimation of total site population (i.e., within 10% sample error). The resulting data sets from the smaller sites also proved to be satisfactory. In both cases the resulting sample sizes (82 of 252, and 64 of 163) were appropriate for populations with 60% variation. While in both cases these samples would be adequate to characterize each population as a whole, whether or not the samples would not allow for detailed intra-site analyses is questionable. In the case of HjRl-4 the transects completely failed to ‘capture’ features from two of the ten clusters which constitute the site. DkRj-1 consists of a more uniform distribution of CMTs and consequently was better represented spatially by the resulting sample.

Overall the experimental results reveal that transect sampling can produce adequate data sets, however, there are a number of problems with this methodology, particularly as an assessment level survey strategy. The method is primarily feature oriented (rather than site oriented) and consequently basic site information is not obtained during survey. First, the method does not allow for site boundaries to be accurately defined, and while it may allow for estimations of the number of CMTs within a block, it is not an effective means of identifying the distribution or number of features within a site or even the number of sites present within a given area. As noted during the sampling experiments, the methodology works best if CMTs are distributed uniformly throughout a study area. However, CMTs are commonly found in clustered or linear distributions, which are not readily identified using systematic transects. In fact, it is quite easy for CMT clusters to be missed entirely, while linear distributions, are even less likely to be detected using this methodology. Furthermore, even CMT density estimates based on transect sampling should be treated with suspicion. Because of the high degree of variability in CMT distributions, estimates based on sparsely distributed transects can easily be grossly inaccurate. For example a transect which happens to go through the middle of a dense cluster of CMTs can result in overestimation of the number of features in a given area. More commonly transects may completely miss CMT clusters resulting in erroneously low estimations. It is also likely that rare and unusual features will be missed during transect sampling, due to sparse survey coverage. Finally, because of the inability of the method to define ‘sites’ there is no way of assessing whether or not the resulting sample is representative of the site or sites which were encountered.

The current problems with transect sampling are not insurmountable. The primary factor limiting the effectiveness of this methodology is the use of arbitrary transect widths and intervals. If site boundaries and estimations of population sizes are available prior to sampling, the transect widths and intervals can be tailored to ensure adequate sample sizes and spatial coverage. In most sites consisting of a very large number of a single feature type, transect sampling can be extremely efficient, requiring only systematic coverage of a relatively small proportion of the site area. However, sites with highly clustered and/or a wide variety feature types will require a sampling strategy which allows more thorough spatial coverage. This may consist of contiguous transect coverage throughout the site area to ensure documentation of all rare feature types, while recording common features during every second, third or fourth traverse, depending on the number and density of such features. If carefully designed such stratified transect sampling strategies could result in appropriate sample sizes, temporal and morphological representation and adequate spatial coverage.

BCAPCA Sampling Strategy

In April of 1999 the British Columbia Association of Consulting Archaeologists (BCAPCA 1999:Section F) adopted the following approach for detailed recording of CMTs:

> *"1. The number of CMT feature recording forms completed during Impact Assessment will be the minimum stipulated below, unless altered under the conditions of a Heritage Permit:*
>
> - *a) all aborignally logged trees. A sketch of the feature will be included;*
> - *b) all features present for sites with up to 10 CMTs;*
> - *c) either of the sampling approaches presented below for sites with more than 10 CMTs"*
>   - *i) the first 10 and every second CMT for sites with more than 10 CMTs, until a sample of 40 is reached, and subsequently for apparently rare or particularly significant features.*
>   - *ii) A spatially and numerically representative sample of CMTs.*
>
> *2. CMT feature recording forms will be completed for any CMT marked for stem round sampling.*
>
> *3. If CMTs are to be harvested, consideration will be given to complete recording of every CMT that is felled. For harvested aboriginal logging features, consideration will be given to mitigative work including detailed mapping and excavation, and collection of clear examples of traditional tool marks."*

This policy allows considerable flexibility, and leaves the level of effort largely at the discretion ("consideration") of the investigator. It does however define what could be considered a minimum CMT sample requirement, consisting of all aboriginally logged trees, plus the first ten and every second CMT (non-logging feature) for sites with more than 10 CMTs, until a sample of 40 is reached.

Discussion

The BCAPCA strategy is the only method currently used which employs an explicit system of sample stratification, to ensure representation of feature types. It also tries to accommodate the logistical problems associated with recording features in rugged and densely vegetated terrain, particularly common in coastal environments. In this respect the strategy is efficient, in that it does not require the researchers to traverse the same terrain more than once. If implemented broadly the strategy would also ensure some level of consistency in data collection.

To evaluate the effectiveness of the BCAPCA CMT sampling strategy a series of experiments were performed using data from two previously recorded CMT sites: DkSp-44 and FlSe-7 (see Appendix A: sampling experiments #2 and #3). Using the BCAPCA sampling strategy, multiple hypothetical samples were drawn from each of these sites. The sample assemblages were then compared to the total population to determine the accuracy of the results. For each site samples were drawn using three variations of the BCAPCA standard. The first consisted of a simple random sample of 40 CMTs drawn without replacement from each site population. The second sample was drawn according to a literal interpretation of the BCAPCA recording standards. Specifically it included the first ten CMTs encountered during survey and every second CMT after that until a sample of 40 was obtained. The third sample was again drawn according to the BCAPCA recording standards, but starting at the 'other end' of the site. That is, it included the last ten CMTs recorded plus every second CMT prior to that until a sample of 40 was reached.

The results of these experiments revealed several weaknesses of the BCAPCA strategy. First, and most obviously the resulting maximum sample size (i.e., 40) is inadequate for very large sites. This was evident among the assemblage from site DkSp-44 which included 636 bark-stripped features. While the samples did characterize some attributes with an acceptable level of accuracy (e.g., scar length and tree diameter [DBH]), attributes displaying more than 40% variability (e.g., HAG and scar width) were inconsistently represented. The second and more serious problem with the methodology is the substantial spatial bias produced depending on how the site is approached. Again, this was evident among the larger of the two sites. For DkSp-44 significant differences were particularly evident in the samples obtained from the second and third drawings, which represent features from opposite 'ends' of the site. Not only does this result in inaccuracies in the characterization of the population but the resulting spatial coverage is insufficient to allow for any kind of intra-site spatial analyses.

Additional problems are also associated with this limited spatial coverage. Given that the methodology only requires consideration of the first seventy non-logging features encountered, it is unclear how or even if site boundaries are defined. This would present problems if multiple clusters of CMTs were encountered during a study, in that considerable inconsistencies are likely to occur between researchers depending on whether or not they consider each cluster a distinct site. Furthermore, it is questionable that such spatial clusters would even be recognized given the spatially restricted recording scheme. Overall this sampling methodology is clearly not appropriate for very large CMT sites and is unlikely to produce consistently representative samples for most sites with more than 100 CMTs.

Plot Sampling

Several recent investigations have employed sampling strategies which use systematically distributed observation points or ‘plots’ as a means of documenting CMTs within development areas. Such a strategy has been recently adopted by the Vanderhoof Forest District as a standard sampling procedure for documenting sites containing more than 100 CMTs or spanning areas greater than 10 ha (MOF 1998). In some cases the archaeologists have used previously established timber cruise plots as convenient observation points while in others a 100 m grid is ‘established’ over the study area. All CMTs which fall within 10 m of a plot location are recorded in detail, while others which are observed during traverses between plots are simply tallied. This survey strategy is based on the timber cruise methodology employed by foresters. In theory the method allows for the estimation of the density of CMTs within a given area while at the same time documenting a ‘representative’ sample of features from throughout the site.

While the application of this methodology to archaeological investigations is intriguing, the validity of the current application of this approach is questionable. Below is a brief description of timber cruise methodologies as defined by the Ministry of Forests, this is followed by a discussion of their application in archaeology.

Timber Cruise Methodologies

The Ministry of Forests *Cruising Manual* (MOF 1999: Section 2.2) defines several types of timber cruise methodologies. The most appropriate methodology may vary depending on the size and nature of the study area (i.e., cut blocks vs. road right-of-ways vs. patch cuts), the stand type and the harvesting method. Most methods employ some type of systematic sampling scheme though a “100 percent cruise” is sometimes considered appropriate (“for certain forest stands and valuable species”). This discussion will deal exclusively with systematic sampling schemes employed in cruising of *cut permits* (i.e., blocks) as these methods appear to be most applicable to archaeological site inventories and sampling.

As stated in the *Cruising Manual* “the prime objective of the cruise of a cutting permit is to obtain an estimate of the volume of timber that will be permitted for harvesting and the sampling design will be based on that criterion” (MOF 1999:Section 2.2.2). Specifically, the cruise consists of a systematic sampling strategy designed to provide an estimate of timber volume with a sample error objective of plus or minus 15%, 19 times out of 20 (for scale-based sales), or plus or minus 8%, 19 times out of 20 (for cruise-based sales) (MOF 1999:Sections 2.1.1 and 2.1.2). This scheme requires calculation of an appropriate number of observation areas (typically 0.08 to 0.10 ha plots) for each cutting permit, based on the estimated variability in timber volume. Estimation of timber volume variability is usually obtained through ‘pilot studies’ of timber volume within the specific cutting permit or more commonly through use of data from similar previously cruised areas. The sample size formula presented above (page 6) is used to determine the appropriate number of plots. With ‘N’ being equal to the maximum possible number of plots within a cut block (i.e., the total number of hectares within a block divided by the plot size).

Once the appropriate number of plots is determined they are systematically distributed throughout the cutting permit in a grid pattern. The grid spacing is unique to each study area, and is arrived at through a (in office) trial and error process implementing the following criteria: 1) the number of plots must not be less than ‘n’, determined using the above formula; 2) plots must be at uniform fixed intervals throughout the study area, 3) a minimum of two full measure plots must fall within each timber type, 4) the sampling intensity (i.e., plot size) must be consistent throughout the study area and 5) plot spacing must not exceed 200 m. This is usually done by initially placing an arbitrary grid (e.g., 100 m x 100 m) over the study area and then repositioning and re-scaling the grid (in 5 m intervals) until all of the above criteria are satisfied.

In many cases the number of plots required within a cutting permit can be reduced through stratification of the area by stand type. This is because timber volume variability *within* each individual stand type will generally be much less than variability *across* various stand types. Since the number of samples is a direct function of timber volume variability, treating each stand type as a distinct population will usually be more efficient than lumping all types together.

Discussion

The application of timber cruise methodology to archaeological site sampling is potentially possible and may ultimately be an effective means of documenting archaeological sites. Generally this methodology has several advantages over those discussed above. First, because the method is founded in sound statistical theory, when applied correctly it should provide data which is reliable from a statistically perspective. Second, the systematic nature of the methodology allows results of each study to be readily compared to others. Third, the method is efficient in that an optimum sample size is selected. However, as will be discussed below, there are a number of potentially prohibitive complications which deserve consideration.

In order to test the effectiveness of plot sampling a series of experiments were conducted (Appendix A: site sampling experiment #4). The plot sampling strategy was applied as defined in the Vanderhoof Forest District guidelines to three previously recorded sites DkSp-44, HjRl-4 and DkRj-1. This involved imposing a 100 m grid over each site area with a fixed plot located within each grid unit. CMTs which fell within 10 m of each plot were considered to be ‘recorded’.

In all three cases the methodology failed to produce satisfactory samples. The resulting samples were consistently too small to provide accurate representation of the site data. Furthermore, the plot sampling strategy failed to produce samples which were spatially representative of the sites. This was particularly true of site HjRl-4 which consists of ten dense clusters of CMTs scattered over a large area. The first application of the plot sampling methodology to this site resulted in a sample size of 0 of 252 CMTs, as none of the observation plots fell within or near any of the CMT clusters. The grid was then readjusted to ensure that at least one cluster was intercepted. This resulted in a total 13 CMTs being captured by the plots. This included representation from 5 of the ten clusters, though four of these were each only represented by a single CMT. The grid was then again repositioned in attempt to obtain a larger and more representative sample (an option which would not normally be available to field researchers), however, this proved to be impossible as the circular 20 m observation plots at 100 m intervals consistently missed most of the CMT clusters. Similar though less pronounced problems occurred during experiments on the two other sites. For Site DkSp-44 the plot sample resulted in only 45 of 940 CMTs being 'recorded', while for site DkRj-1 only 9 of 163 CMTs fell within the observation plots. In both cases these samples are too small to even ensure accurate characterization of most attributes and are grossly insufficient to allow subdivision of the site data for spatial or morphological analyses.

Clearly the primary problem with this methodology is its intensity. In the examples above the plot interval (100 m) is inadequate to produce samples of appropriate size. If the plot intervals were decreased to 40m, the sample sizes would be increased five-fold (on average), and be more appropriate from a statistical perspective. However, the use of arbitrary plot intervals, to some extent negates the statistical validity and efficiency of this methodology, in that the statistical precision of the resulting samples will always be highly variable depending on the number and density of features present. To be conducted properly the timber cruise methodology requires prior knowledge of the size of the population being sampled. Because in forestry the population is simply a function of the total size of the cutting permit divided by the size of the plot areas, a precise value for 'N' can be used in calculation of the appropriate number of plots (n). However, archaeologists do not have an equivalent means of determining the site population (i.e., number of CMTs) prior to survey nor are they likely to be able to predict the number of CMTs which will fall within 10 m of each plot and consequently can not easily calculate the appropriate number of plots or plot interval.

Second, as mentioned above the primary objective of a timber cruise is to estimate the volume of timber within a cutting permit. Because there is only one attribute of concern the process of devising an effective sampling strategy is relatively straightforward. The objectives of archaeological site sampling are considerably more complex. With respect to CMT sites the major attributes of concern include: site size; number of CMTs present, types of features present; and the age of the features. In addition many other 'secondary' variables may also be of interest including: the spatial distribution of the CMTs (linear, clustered, dispersed etc…), the number of features per tree, the age of the trees when modified, the quantity of material extracted, and the types of tools used. The variety and complexity of these data require sampling strategies which will provide information beyond characterization of a single attribute. In most cases this will require some form of stratification to ensure adequate representation of rare and unique features.

Third, a key element of the timber cruise methodology is an understanding of the nature of timber volume variability. In most cases foresters have a wealth of data on which to estimate this value. Furthermore, as timber volume is largely a function of biological phenomena, it should behave in a relatively predictable manner, so reasonable estimates can be made for even poorly studied areas. In contrast, little investigation of variability among CMT attributes has been conducted, nor can assumptions be made about the distribution of features from one location to the next. CMTs are artificial phenomena which are the result of relatively poorly understood human behaviors and are not distributed continuously across the landscape like forests.

Furthermore plot sampling shares many of the limitations of transect sampling. These include, a general inability to precisely determine site boundaries, spatial organization of features, or identification of rare or unique feature types. In most cases plot sampling is even more susceptible to these shortcomings than transect sampling. As illustrated above, it is quite probable that entire clusters of CMTs will be missed by plot sampling and linear CMT alignments would be almost impossible to detect using this methodology.

In order for plot sampling to be employed as an effective means of documenting CMT sites a considerable amount of information about the site would have to be gathered prior to the investigation. In particular, a fairly precise estimate of the number and density of CMTs within the site would have to be determined and the variability among the population assessed. Ideally the location of each feature should be mapped to ensure that the plot locations result in appropriate samples. In most cases this would require an intensive survey of the site prior to sampling. While this may be possible in some environments, it is unlikely to be as efficient as transect sampling, and ultimately is likely to be less effective.

CONCLUSIONS AND RECOMMENDATIONS

Each of the methodologies discussed above display serious shortcomings as strategies for CMT site sampling. Both the BCAPCA sampling strategy and plot sampling displayed inadequacies with respect to spatial coverage. Both produced results which were spatially biased according to how a site was physically approached. Transect sampling proved to be more effective at achieving an even and unbiased representation of features from throughout a given site; however, even this method was hindered by non-uniform feature distributions such as clusters and linear alignments. Furthermore, none of the methods, as applied, are sensitive to statistical sample size requirements. Consequently, they either result in redundant observations or more commonly samples of insufficient size.

As repeatedly stated above in order to ensure representation of features over multiple dimensions of variation some form of sample stratification is required. Of the methods discussed above only the BCAPCA sampling strategy addresses this issue, in that it stratifies samples according to feature type. It is agreed here that this is an appropriate first step. In addition, it is believed that through stratification according to spatial cluster detailed spatial analyses can be accommodated. Furthermore, such spatial stratification negates some of the problems of site boundary definition; in that sample intensity is equivalent regardless of whether multiple clusters are defined as a single site or several sites. In some cases stratification according to age may also be valuable, allowing for detailed studies of temporal variability within a site. This is likely to be particularly true for sites which contain a number of very old features. As well as being relatively rare, older features may be more difficult to identify and accurately date, consequently the sampling intensity should be greater for such features.

Many of the shortcomings of the above methods can be overcome through determination of optimum sample sizes prior to sampling. However, this may require some changes to the general operating procedures of most researchers. Specifically, it would require an initial assessment of the size and distribution of features within the site prior to detailed recording of features. Below is a proposed CMT site sampling strategy which endeavors to overcome the shortfalls of the previously applied methods.

Recommended CMT Site Sampling Strategy

Ideally a two stage approach to CMT site sampling should be taken. The objectives of the first stage (Site Assessment) should be to obtain basic information which will allow for informed resource management decision-making. The purpose of second stage (Impact Mitigation) should be to obtain a sample sufficiently representative to act as the permanent record for a site (or portion of a site) which is likely to adversely impacted.

Stage 1: (Site Assessment)

The first stage should include: identification of site boundaries, estimation of the number and types of CMTs present, determination of the spatial organization of the CMTs, assessment of feature attribute variability and estimation of the maximum age of features at the site.

Identification of site boundaries should be determined through intensive field reconnaissance. In cases of extremely large sites, which extend significantly beyond the boundaries of a given study area, it may be appropriate to estimate site boundaries outside of impact areas. It is however most important that portions of the site likely to be impacted by development are precisely defined.

An estimation of the number and types of features within the site (or portion of the site likely to be impacted) should be obtained in a systematic fashion. In some cases it may be possible to count 100 % of the features, though tallying features (by type) while traversing broadly spaced transects should provide adequate data. In most cases 20 m wide transects at 100 m intervals would likely result in reasonable population estimates. It is important to note that when dealing with large numbers of CMTs a precise estimation of the total site population is not critical. The differences in appropriate sample sizes becomes relatively slight as total populations increase. In most cases it would be more efficient to err on the side of caution and make several extra feature observations, than to expend a great deal of time arriving at a precise estimate of the total number of CMTs.

The spatial organization of the features should be characterized in terms of density and distribution. If distinct spatial patterning of features is evident (i.e., distinct clusters or linear distributions) these should be identified and their approximate locations mapped. For more uniformly distributed features the transect tallies above can be used to estimate average feature densities.

A small number of features (i.e., minimum 10) of each type should be documented in detail to provide a basis for the determination of attribute variability. Selection of features for documentation should be done in as random a fashion as possible to avoid investigator biases. This may be accomplished by recording features encountered at arbitrary (or better yet random) spatial or ordinal intervals. Under no circumstances should these features be selected judgmentally, (i.e., selection of 'the best' or 'most typical' examples of each feature type) as this will greatly bias the resulting variability data.

Data should be gathered which will allow for a reasonable estimate of the maximum age of the site. This may include obtaining increment core, wedge or disc samples from judgmentally selected features which appear to represent the earliest site occupation. However, in some cases reasonable maximum age estimations may be arrived at through other means (e.g., through consideration of stand age, presence of stone tool marks, maturity of nursing trees, scar depth/lobe thickness).

Stage 2: (Impact Mitigation)

In situations where a significant portion of a site is to be adversely impacted and some form of impact mitigation is warranted a "Stage 2" site sampling strategy should be formulated and implemented. The objectives of the sampling strategy should be to ensure accurate characterization of a site population in terms of: feature age, type, number and spatial distribution. The sample should also allow for identification of gross changes in feature characteristics through time and space. That is, it should be sufficient to allow subdivision of individual types (e.g., bark strips) into small numbers of subgroups (2 to 4) based on age, spatial distribution and/or subtype. Specifically, this should include a systematic sampling scheme which satisfies the following criteria:

Sample Stratification

The sample should be stratified so as to ensure adequate representation of features by type, age, and spatial distribution. This should be done by defining distinct sub-populations of features to be sampled as follows:

> <u>Stratification by type:</u> Whenever more that one type of feature is present sub-populations should be defined on the basis of feature type (e.g., logging features *vs.* bark strips).
>
> <u>Stratification by spatial cluster:</u> When two or more distinct spatial clusters are apparent each cluster should be treated as a sub-population.
>
> <u>Stratification by age:</u> When it is apparent that some features are significantly older or more recent than the majority, these should be defined as a distinct sub-population.

At the discretion of the researcher additional stratification may also be employed. For example stratification by sub-type (e.g., rectangular *vs.* tapered bark strips) may also be appropriate in some situations, particularly when a rare or poorly understood sub-type is encountered.

Sample Size

For each sub-population a sample of CMTs should be recorded in detail. The sample size for each sub-population should be no less than is require to accurately* characterize the most highly variable feature attribute. This should be done through use of Table 2 below, using the total number of CMTs in each sub-population as 'N' values. When a precise estimation of maximum attribute variability is not available a value of 70% should be assumed.

In addition, for each sub-population a sample of features should be dated. The appropriate number of dates should again be determined through use of Table 2. Note that when determining appropriate numbers of features for dating the total sub-population (N) is equal to the *number of cultural features* rather than the *number of CMTs*. When a precise estimation of age variability is not available a value of 50% should be assumed. All dated features should be recorded in detail.

It should be noted that the criteria presented represent the minimum standard for site sampling. The data gathered may not be appropriate for all potential analyses, particularly those which require very precise chronological control. Investigators are encouraged to tailor their sampling strategies to accommodate local or regional research problems and to record and date more than the minimum number of features whenever possible.

Table 2. Recommended Minimum Sample Sizes.

Sub-population Size (N)	**Minimum Sample Size (n)**											
	Coefficient of Variation (CV)											
	20%	25%	30%	35%	40%	45%	50%	55%	60%	65%	70%	75%
5	4	4	5	5	5	5	5	5	5	5	5	5
10	6	7	8	8	9	9	9	9	9	9	9	10
20	8	10	12	13	14	15	16	16	17	17	18	18
30	9	12	15	17	19	20	21	22	23	24	25	25
40	10	13	16	19	22	24	26	28	29	30	31	32
50	11	14	18	21	24	27	30	32	34	35	37	38
60	11	15	19	23	26	30	33	35	38	40	42	44
70	11	15	20	24	28	32	35	39	42	44	46	49
80	11	16	20	25	29	34	38	41	45	48	51	53
90	11	16	21	26	31	35	40	44	48	51	54	57
100	12	16	21	26	32	37	41	46	50	54	58	61
200	12	17	23	30	37	44	52	59	67	74	81	87
300	12	18	24	32	39	48	57	66	75	84	93	102
400	12	18	25	32	41	50	59	70	80	90	101	112
500	13	18	25	33	42	51	61	72	83	95	106	118
600	13	18	25	33	42	52	62	74	85	98	110	123
700	13	18	25	33	43	53	63	75	87	100	113	127
800	13	18	26	34	43	53	64	76	88	102	115	129
900	13	19	26	34	43	53	65	77	90	103	117	132
1000	13	19	26	34	43	54	65	77	90	104	119	134
5000	13	19	26	35	45	56	69	82	97	114	131	150
10000	13	19	26	35	45	56	69	83	98	115	133	152

*Accuracy standard = sample error objective of plus or minus 10%, 18 times out of 20.

Sample Selection

Selection of CMTs to be recorded in detail should be done in a systematic fashion to ensure relatively even and unbiased spatial representation. In most cases some form of transect sampling will be most efficient and effective. In cases of sites with very large numbers of features concentrated in a relatively small area, plot sampling may be more appropriate. Transects or plots should be spaced to ensure that the appropriate sample sizes are achieved for each sub-population. Generally, this will require considerable forethought, particularly when more than one feature type is present. In such instances a scheme which allows sampling of multiple sub-populations (feature types) simultaneously will be most efficient. Such a scheme may involve alternating what is recorded during each transect. For example rare features (such as logging features) would be recorded during every transect while very common features (bark-stripped cedars) may be documented only during every third or fourth transect.

In some cases the difficulties of designing a minimum sampling strategy may outweigh the efficiency benefits. In such cases it may be shrewd to simply use a standardized procedure which is sure to result in the selection of an ample number of features: such as recording all rare features and every second or third common feature. When such a procedure is used the adequacy of the resulting sample size should be double checked against Table 2.

The complexity of the above sampling scheme may seem overwhelming to some researchers, however, some general rules of thumb can be applied.

- for sub-populations consisting of fewer than 30 features, 100 % recording is likely to be most efficient.
- for sub-populations consisting of approximately 150 features, half (or every second feature) should be documented.
- for sub-populations consisting of approximately 400 features, one-quarter should be documented.
- for sub-populations consisting of approximately 700 features, one-sixth should be documented.
- for sub-populations consisting of greater than 1200 features, one-tenth should be documented.

These samples can be obtained simply by spacing transects to cover the appropriate percentage of the site or alternately by recording every second, fourth, sixth or tenth CMT while traversing the entire site area.

In some cases it may not be possible or desirable to conduct CMT site sampling in two distinct stages as described above. In situations where logistics or scheduling preclude this approach some compromises may need to be made. In these cases it may be more efficient to use a ‘sample-as-you-survey’ approach (though it is still essential that all of objectives of stage 1 and 2 above are ultimately satisfied). For example, recording all “rare” features and every second “common” feature encountered will produce adequate samples, provided that the site consists of more than 150 CMTs. When using such an approach it should be recognized that if the site turns out to contain fewer features than anticipated, some backtracking may be required in order to satisfy the minimum sampling standards. Conversely, if the site proves to contain many more than 150 features, it may be more efficient to revert to a two stage approach.

Selection of features for dating may follow the procedures discussed above, however, in most cases some degree of judgmental selection should be employed to ensure that the features will provide reasonable age estimates. It is recognized that not all features can be dated and furthermore, some features will produce more precise dates than others. Obviously, these factors should be taken into consideration when selecting specific features for dating.

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APPENDIX A: CMT Attribute Variability Data and Experimental Analyses.

Table A1: CMT Morphological Attribute Variability for Bark-Strip Features.

Site	Sample Size (n)	Attribute	Mean (cm)	Standard Deviation	Coefficient of Variation
DkSp-44	1004	Scar Length	735.8	283.4	38%
	634	DBH	47.9	17.5	40%
	393	HAG	58.0	31.6	54%
FlSe-7	77	Scar Length	95.1	39.6	42%
		Scar Width	8.9	5.4	61%
	74	Tree Circ.	105.4	20.2	19%
	60	HAG	43.8	27.3	62%
HjRl-4	238	Scar Length	70.2	32.4	46%
		Scar Width	7.8	4.9	64%
		Tree Circ.	87.2	20.6	24%
	114	HAG	37.7	26.9	71%

Data Sources: FlSe 7 Prince and Carlson 1998; HjRl-4 Farvacque and Bowyer 1999;

Table A2: CMT Age (in years BP) Variability for Coastal Bark-Stripped Cedars.

Locality	Sample Size (n)	Mean (years BP)	Standard Deviation	Coefficient of Variation
Head Bay	17	80.5	44.6	55%
Mooyah Bay	35	56.1	30.2	54%
Port Eliza	62	112.6	50.5	45%
Tahsis Inlet	23	51.0	14.1	28%
Weasel Creek	21	86.2	40.8	47%
Meares Island	202	108	54.4	50%

Data Source: Pegg 1998.

Table A3: CMT Age (in years BP) Variability for Interior Bark-Stripped Pines.

Site	Sample Size (n)	Mean (years BP)	Standard Deviation	Coefficient of Variation
DkRj-1	186	71.7	28.0	39%
FjSq-14	5	38.6	14.3	37%
FkSg-5	6	46.2	7.2	16%
FlSe-6	15	54.4	20.0	37%
FlSe-7	9	79.2	9.3	12%
GaSe-18	5	63.4	9.3	15%
GaSe-19	14	66.7	4.5	7%
GaSe-20	9	59.7	14.8	25%
HjRl-4	35	79.5	16.3	21%

Data Sources: DkRj-1: Wada and Bailey 1999; HjRl-4 Farvacque and Bowyer 1999; all other sites: Prince and Carlson 1999

Sampling Experiment #1

Purpose: To evaluate the effectiveness of transect sampling as a means of documenting CMT sites.

Approach: Using a standardized transect sampling methodology, hypothetical samples were drawn from known "populations" of CMTs. The resulting sample assemblage sizes were then assessed with respect to their ability to accurately characterize the original population.

CMT Data: Sites DkSp-44, HjRl-4 and DkRj-1

Site DkSp-44, recorded by Arcas Consulting Archeologists Ltd. (Jackson and Pratt 1999), consists of approximately 10,000 CMTs located at Boston Point, Cook Channel, Vancouver Island. Over 2000 CMTs were mapped, though not all of these were documented in detail. 940 mapped CMTs which fell within the most intensively surveyed portion of the site were used as the "site population" in this experiment.

Site HjRl-4, recorded by Big Pine Heritage Consulting and Research Ltd. (Farvacque and Bowyer 1999), is located near Donnie Creek in the Fort St. John Forest District. The site consists of 252 CMTs arranged in 10 discrete clusters over an area approximately 1 km long by 0.5 km wide.

Site DkRj-1, recorded by Golder Associates (Wada and Bailey 1999), is located near Yale in the Chilliwack Forest District. The site consists of a single 'dispersed' cluster of 163 CMTs distributed over a 0.6 km X 1.0 km area.

For each of the above sites hypothetical 30 meter wide, north-south oriented transects spaced at 100 m intervals where placed within each survey study area (i.e., cut permit area). All features which fell within the transect areas were considered to be 'recorded'.

Results:

Tables A4 through A6 indicate the CMTs 'recorded' during each transect as well as the total number of CMTs 'recorded' for each site. For site DkRj-1 the cluster from which each recorded CMT is also indicated.

Table A4. Transect Sampling Results for Site DkSp-44. 30 meter wide transects at 100 m intervals.

Transect #	Recorded CMTs
1	733, 798, 814
2	771, 772, 811
3	248, 253, 243, 246, 247, 244, 245, 250, 252, 249, 251, 280, 300, 124, 125, 126, 127
4	53, 30, 31, 18, 42, 26, ?, ?, 34, 35, 36, 37, 38, 19, 39, 16, 15, 17, 87, 20, 21, 85, 86, 97, 22, 23, 70, 71, 72, 544, 96, 77, 78, 89, 80, 98, 571, 90, 91, 93, 92, 568, 570, 572, 573, 560, 562, 564, 566, 101, 102, 99, 100, 114, 115, 105, 539, 103, 104, 106, 107, 108, 109, 110, 111, 559, 561, 584, 589, 590, 593, 575, 577, 578, 579, 581, 582, 583, 594, 618, 614, 613, 610, 615, 616, 620, 622, 624, 626, 634, 635A, 623, 617, 619, 621, 63?, 640, 625, 627, 629, 631, 646, 648, 650, 642, 644, 637, 651, 641, 652, 653
5	219, 218, 217, 180, 181, 178, 179, 183, 182, 176, 172, 173, 170, 166, 171, 164, 167, 168, 169, 210, 209, 208, ?, 427, 429, 439, 431, 433, 455, 437, 451, 453, 457, 442, 435, 441, 440, 461, 444, 443, 463, 459, 445, 446, 447, 448, 478, 496, 488, 475, 477, 479, 494, 473, 529, 492, 500, 527, 487, 490, 193, 497, 483, 484, 486, 515, 523, 501, 402, 485, 4??, 482, 493, 553, 476, 478, 517, 510, 511, 519, 521, 512, 507, 508, 509, 514, 721, 720, 722, 716, 712, 714, 718, 710, 723, 725, 706, 708, 704, 678, 680, 682, 694, 684, 709, 711, 707, 681, 685, 687, 689, 693, 696, 697, 698, 699, 700, 702, 677, 705, 703, 701, 675, 674, 673, 826, 828
6	301, 279, 299, 281, 282, 278, 285, 286, 303, 284, 316, ?, 315, 317, 322, 32?, 738, 740, 742, 744, 849, 851, 731, 839, 840, 841, 835, 837, 762, 764, 765, 756, 754, 753, 755, 757, 763, 758, 759, 764, 755, 748, 750, 749, 746, 747
7	310, 312, 856, 858, 854, 860, 866, 864, 868, 870, 87?, 874, 876, 878, 888, 886, 892, 890, 879, 882, 884, 894, 900, 898, ???
Total # CMTs	Recorded: 333 of 940

Note: CMT numbers obscured on site map indicated by ‘?’.

Table A5. Transect Sampling Results for Site HjRl-4. 30 meter wide transects at 100 m intervals.

Transect #	Recorded CMTs
1	Cluster 13: E, F, G, H, J, M, N, P, Q, R
2	Cluster 13: AG, AF, AC Cluster 2: D, E, F, G, K, J, H, L, P, B, Q Cluster 9: Q, S, T, U, V, W
3	Cluster 9: H, G,
4	Cluster 10: B, D, E, F, G, H, K, J
5	Cluster 1: BB, BC, BD, BA, AZ, AT, AS, AM Cluster 5: C, B, D, E, G, F
6	Cluster 1: AD, AC, AB, Z, X, Y, W, A, D, F, E, J, K, T, U, R, S, Q Cluster 5: AT, AU, AV, AW, AS Cluster 7: L, K, M
7	Cluster 7: J
8	Cluster 7: D
Total # CMTs	Recorded: 82 of 252

Table A6. Transect Sampling Results for Site DkRj-1. 30 meter wide transects at 100 m intervals.

Transect #	Recorded CMTs
1	58, 55, 53, 54
2	7, 4
3	50, 51, 52, 46, 47, 44, 43, 38
4	1, 2, 123, A, 8, 135, 133, 132, 131
5	28, 29, 30, 31, 32, 33, 34
6	73, 75, C, 66, 74, 71
7	87, 88, 83, 122, 91, 84, 85, 86, 70, 77, 78, 68, 67, 81, 69
8	144, 143, 145
9	106, 111, 110, 112, 113, 114, 126, 102, 101, 130
Total # CMTs	Recorded: 64 of 163

Conclusions:

The methodology worked best on the site with the largest number of features. 333 of the 940 CMTs from site DkSp-44 fell within the transects. This sample exceeds the minimum required sample size for a population displaying 135% variation in any attribute (to an sample error objective of ± 10%, 18 times out of 20). Simple extrapolation of the sample population to estimate the total population (i.e., 333 X 3.3) yields a value of 1099. This result can no be considered an accurate estimation of total site population (i.e., within 10% sample error), however, it is likely that a more detailed analysis of feature density within the site area would provide a more accurate result.

The resulting data sets from the smaller sites (HjRl-4 and DkRj-1) proved to also be satisfactory with respect to sample size. In both cases the resulting sample sizes (82 of 252, and 64 of 163) exceed the minimum sample sizes required to characterize populations with 60% variation. However, in the case of HjRl-4 the transects completely failed to ‘capture’ features from two of the ten clusters which constitute the site. DkRj-1 consists of a more uniform distribution of CMTs and consequently was better represented spatially by the resulting sample. Again the sample results do not provide a simple means of accurately estimating total site populations. In both cases simple extrapolation of the sample populations to determine total site populations results in over-estimation of the number of CMTs (271 and 211 respectively).

Sampling Experiment #2

Purpose: To evaluate the effectiveness of the CMT sampling strategy standards adopted by the BC Association of Professional Consulting Archaeologists.

Approach: Using the BCAPCA sampling strategy, multiple hypothetical samples were drawn from a known "population" of CMTs. The sample assemblages were then compared to the total population to determine the accuracy of the results.

CMT Data: Site DkSp-44

The site, recorded by Arcas Consulting Archeologists Ltd. (Jackson and Pratt 1999), consists of approximately 10,000 CMTs located at Boston Point, Cook Channel, Vancouver Island. Over 2000 CMTs were documented. Of these, approximately 700 were documented in detail. The analyses presented here draw from detailed data on 636 bark stripped trees which collectively displayed 1004 bark scars.

"Site Population" (N=636)
This includes data from all 636 bark stripped trees mentioned above.
Three samples were drawn as follows

"Sample 1" (n=40)
This is a simple random sample of 40 CMTs drawn without replacement from the above population. The selected sample includes 70 bark strip features.

"Sample 2" (n=40)
This is a sample drawn according to the BCAPCA recording standards. Specifically it included the first ten CMTs encountered during survey and every second CMT after that until a sample of 40 was obtained. The selected sample includes 62 bark strip features.

"Sample 3" (n=40)
This sample was again drawn according to the BCAPCA recording standards, but starting at the 'other end' of the site. That is, it included the last ten CMTs recorded plus every second CMT prior to that until a sample of 40 was reached. The selected sample includes 48 bark strip features.

Results:

As displayed by Figure A1 the resulting samples provide accurate representation of mean values for those attributes which posses little variability (i.e., HAG, and scar length), but are less successful at characterizing more variable attributes such as "number of scars" and "scar width". Sample 3 failed to provide values within 10% measurement error of the actual population mean for these latter attributes.

The discrepancies in the sample results are more clearly evident in their overall characterization of each attribute. Figures A2 and A3 present data profiles for each attribute. Figures A2 and A3 indicate that when graphed, the data collected for each sample do not consistently provide an accurate characterization of the actual site population. In particular, the data from Sample 3 provide misleading representations of all four selected attributes. Sample 2 displays inaccurate profiles for "HAG" and "side of tree". Sample 1 (the simple random sample) provided the best results, though even here deviations in the characterization of "scar length" and "# of scars/cmt" are evident.

Conclusions:

The resulting samples are inconsistent in their representation of the site population as a whole. This is particularly true of Samples 2 and 3 which represent sub-populations from "opposite" ends of the site. Neither of these samples produced data which consistently characterized the feature attributes for the site as whole, though the Sample 2 results were somewhat better than those for Sample 3.

Clearly the BCAPCA CMT sampling strategy cannot be considered a particularly effective means of sampling large CMT sites such as DkSp-44. The maximum sample size (n=40) is likely the primary limiting factor with respect to the effectiveness of this methodology, though spatial biases inherent in the methodology are also evident.

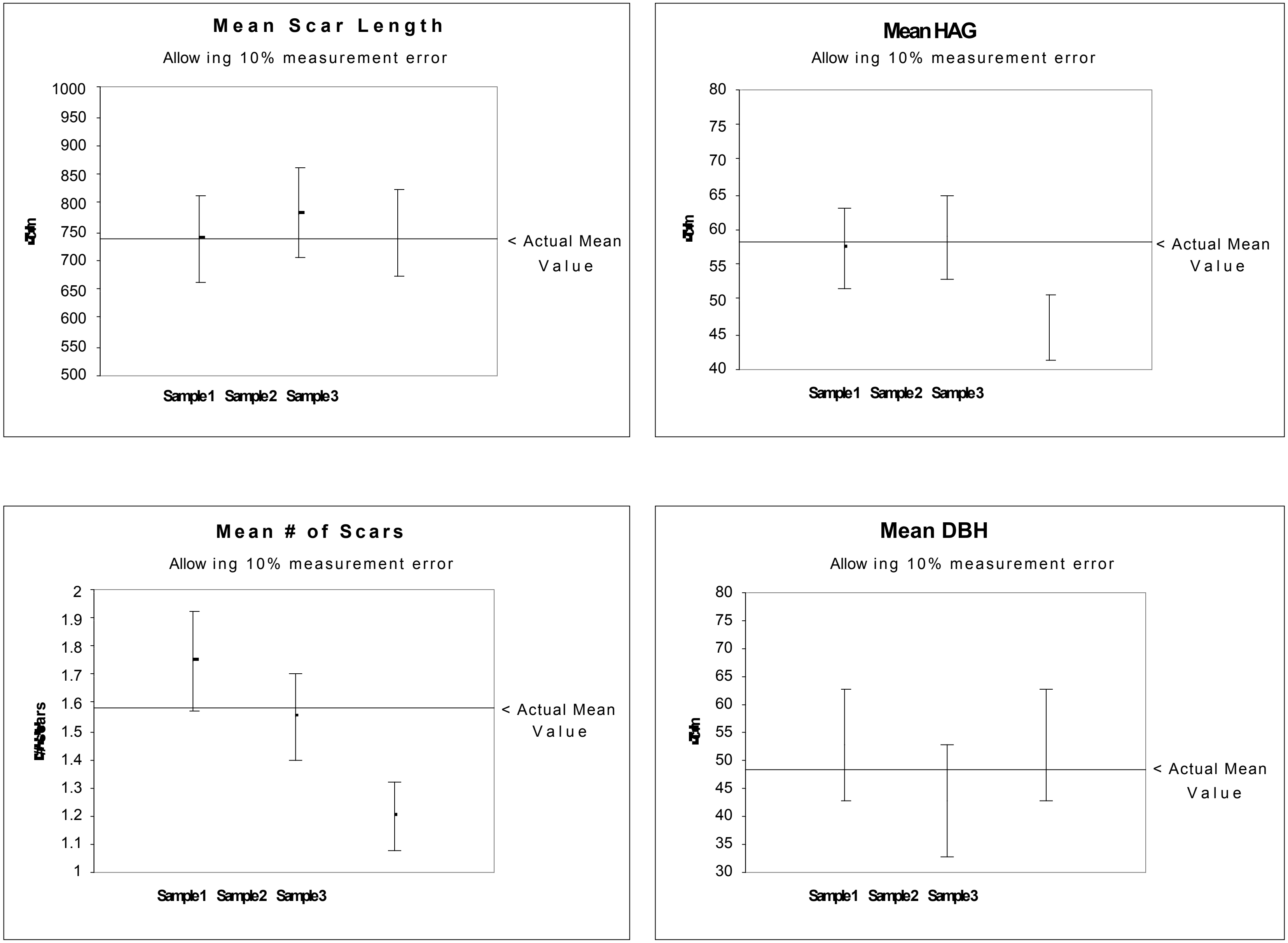
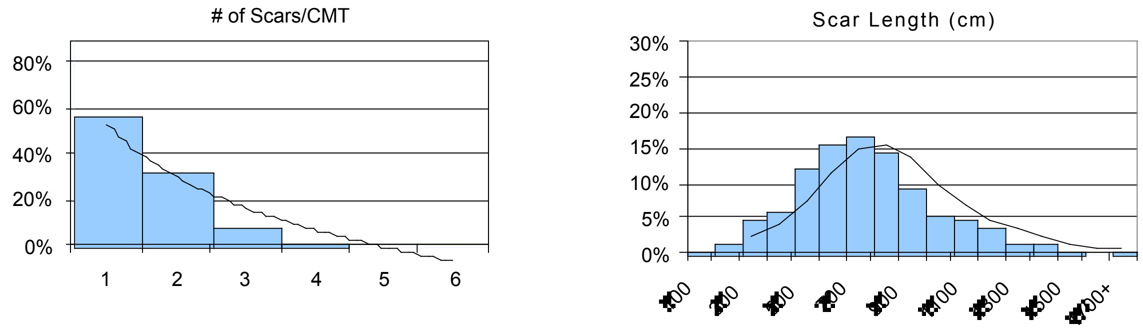
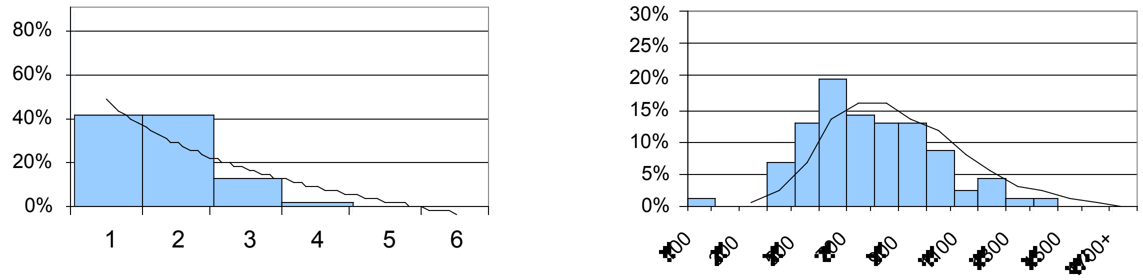


Figure A1: Comparisons of sample means to actual population means from site DkSp-44, for four selected CMT attributes.

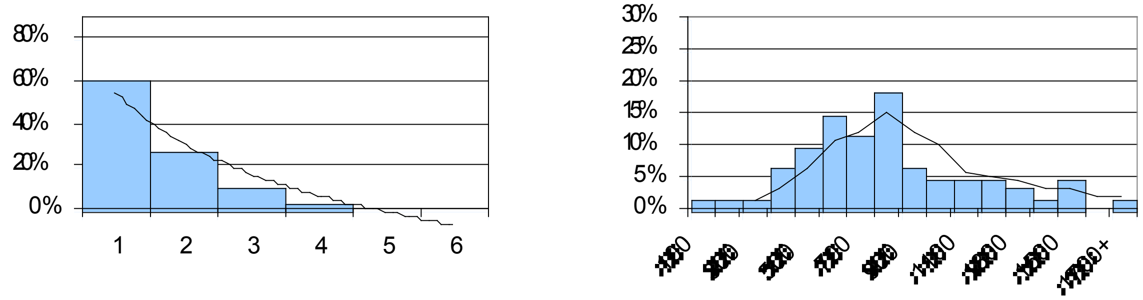
Site Population



Sample 1



Sample 2



Sample 3

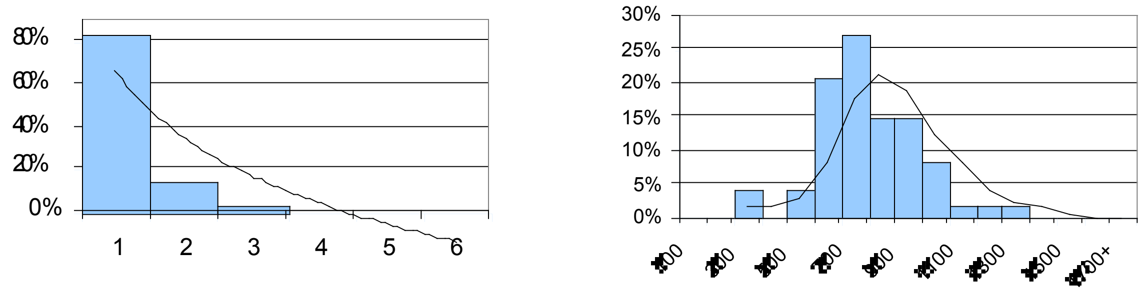
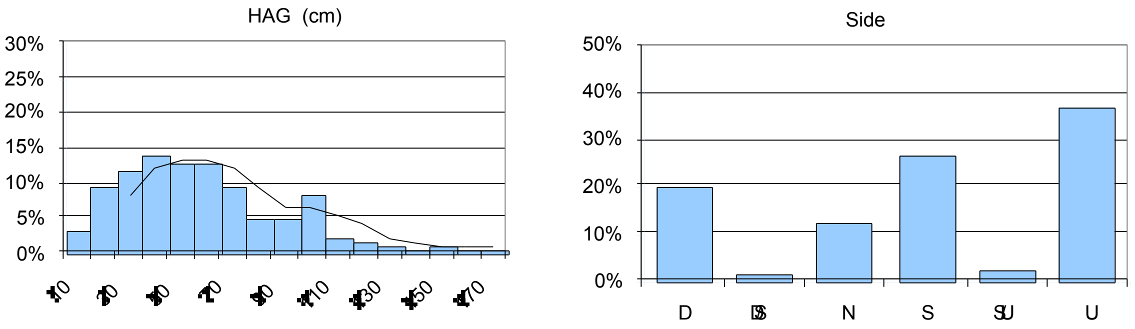
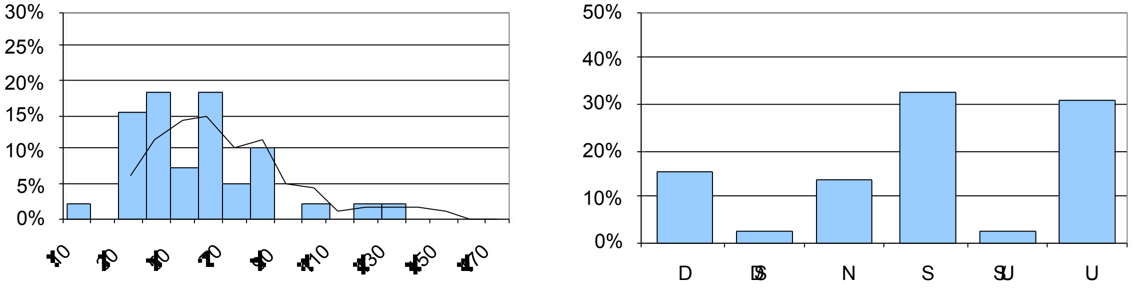


Figure A2: Comparisons of sample profiles to actual population profiles for DkSp-44, for selected CMT attributes (# of scars/CMT and scar length).

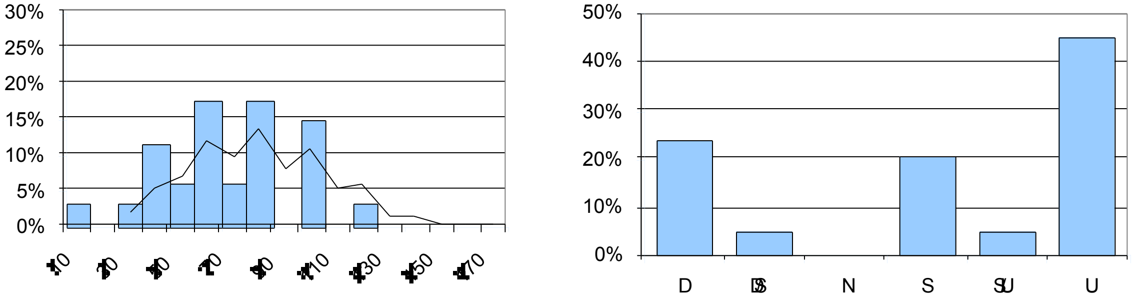
Site Population



Sample 1



Sample 2



Sample 3

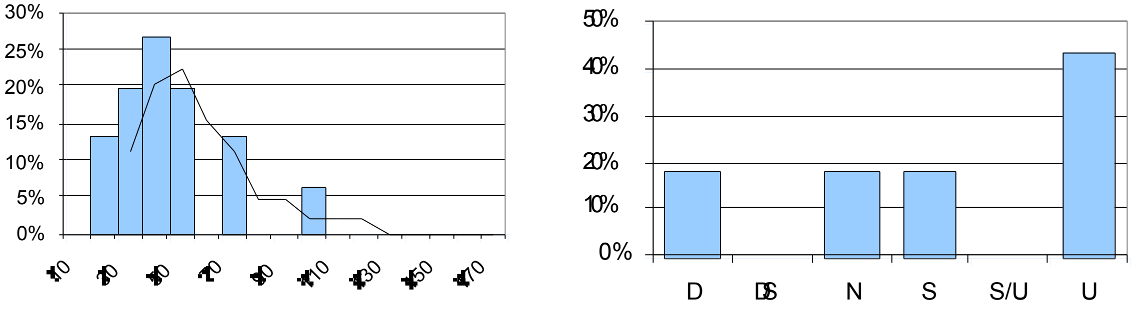


Figure A3: Comparisons of sample profiles to actual population profiles for DkSp-44, for selected CMT attributes (height above germination [HAG] and side).

Sampling Experiment #3

Purpose: To evaluate the effectiveness of the CMT sampling strategy standards adopted by the BC Association of Professional Consulting Archaeologists.

Approach: Using the BCAPCA sampling strategy, multiple hypothetical samples were drawn from a known "population" of CMTs. The sample assemblages were then compared to the total population to determine the accuracy of the results.

CMT Data: Site FlSe 7

This site was recorded by Traces Archeological Research and Consulting Ltd. under Permit 1997-198. The site is located near Chowsunket Lake on the Nechako Plateau in the central interior of British Columbia and consists of more than 165 cambium stripped pine CMTs (Prince and Carlson 1999). The analyses presented here draw from detailed data on 74 bark stripped trees which collectively displayed 77 bark scars.

"Site Population" (N=74)
This includes data from all 74 bark stripped trees mentioned above. Three samples were drawn as follows

"Sample 1" (n=40)
This is a sample drawn according to the BCAPCA recording standards. Specifically it included the first ten CMTs encountered during survey and every second CMT after that until a sample of 40 was obtained. The selected sample includes 42 bark strip features.

"Sample 2" (n=40)
This sample was again drawn according to the BCAPCA recording standards, but starting at the 'other end' of the site. That is, it included the last ten CMTs recorded plus every second CMT prior to that until a sample of 40 was reached. The selected sample includes 40 bark strip features.

"Sample 3" (n=40)
This is a simple random sample of 40 CMTs drawn without replacement from the above population. The selected sample includes 42 bark strip features.

Results:

As displayed by Figure A4 the resulting samples consistently provide accurate representation of mean values tree circumference, HAG, and scar length, but are less successful at characterizing "scar width". However only Sample 1 failed to provide a mean sample value which was within 10% measurement error of the actual population mean.

The samples also provide reasonable representation of population profiles for each attribute. Figures A5 and A6 indicate that when graphed, the data collected for each sample provide relatively accurate characterization of the actual site population, though some minor discrepancies are apparent. In particular the data from Sample 1 provide a somewhat misleading representations of scar lengths and widths (i.e., skewed to the right, compared to the population profile).

Conclusions:

The resulting samples appear, for the most part, to accurately represent the population as a whole. The BCAPCA sampling strategy proved to be much more effective at characterizing this relatively small site population (74 features), compared to the larger population of the previous experiment. This is not surprising given that the sample size (n=40) represents 54% of the population. What is perhaps most interesting is that despite the relatively large sample size in at least one instance the sample did not accurately characterized the population mean for a given attribute.

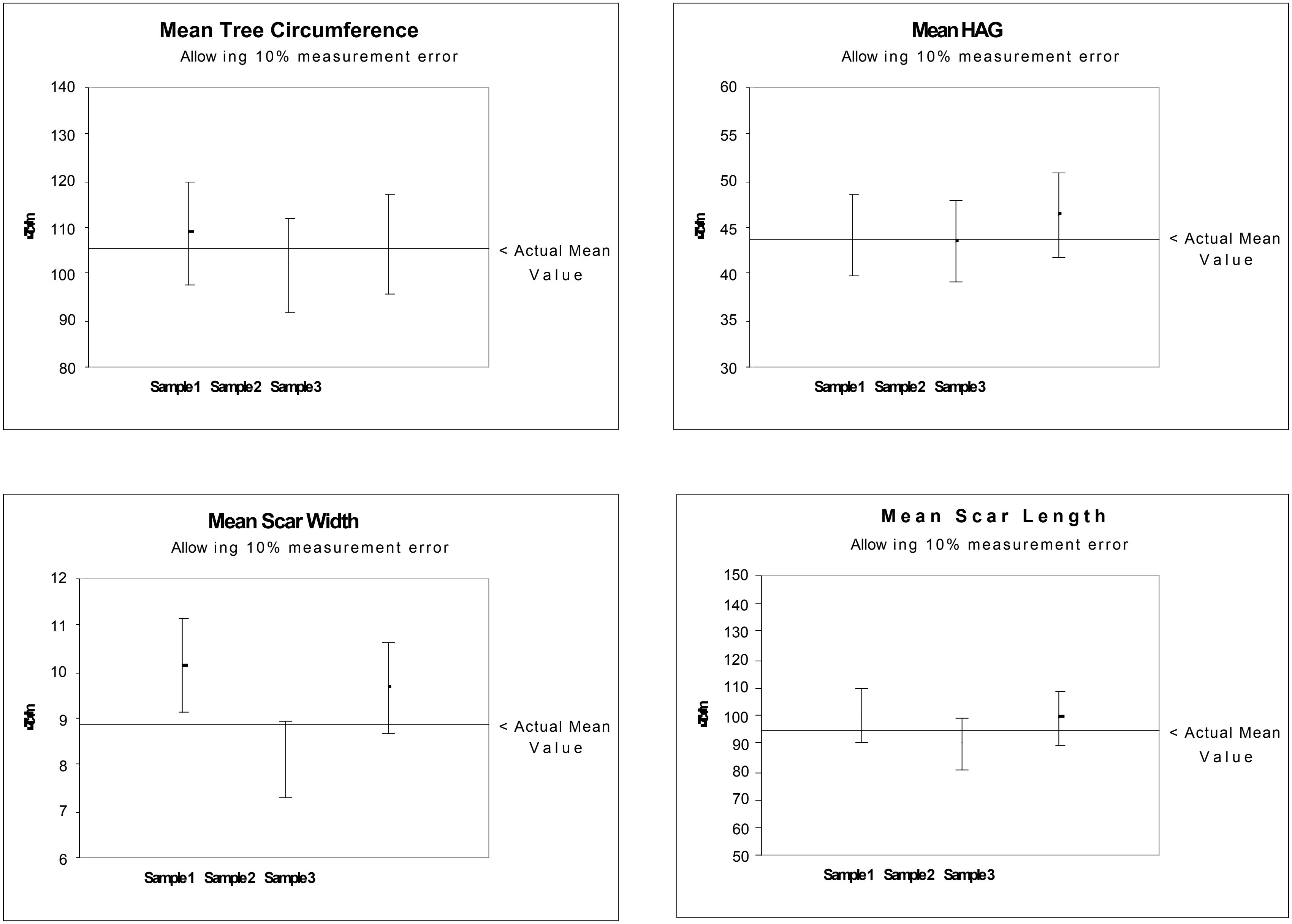
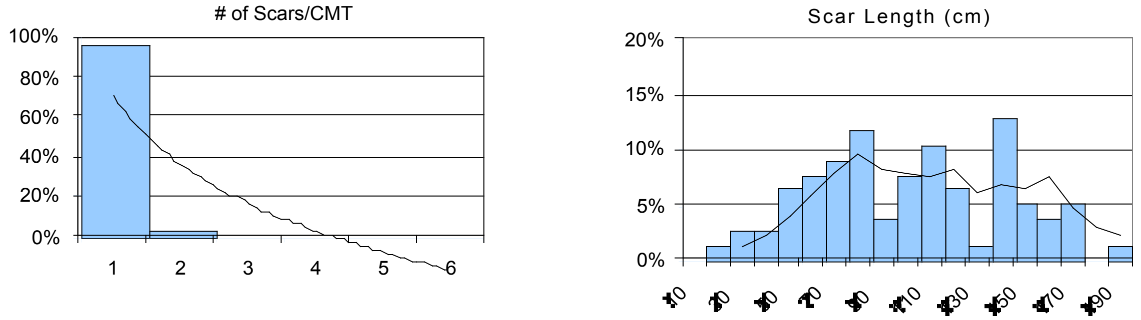
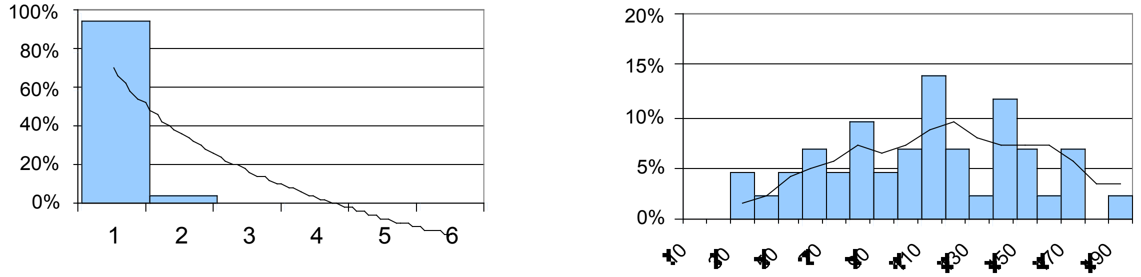


Figure A4: Comparisons of sample means to actual population means from site FlSe 7, for four selected CMT attributes.

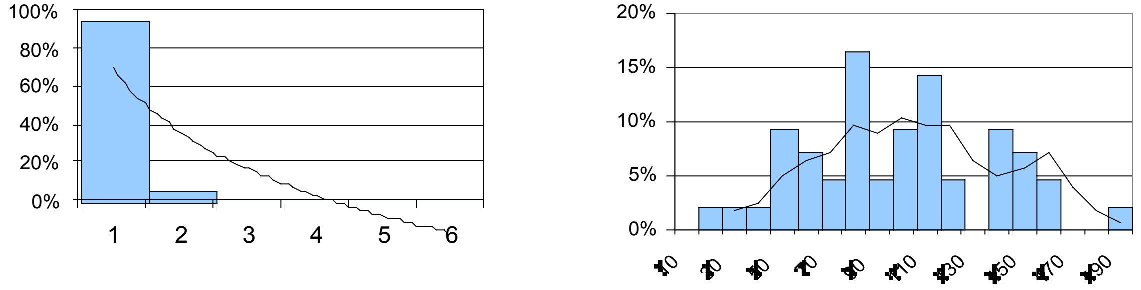
Site Population



Sample 1



Sample 2



Sample 3

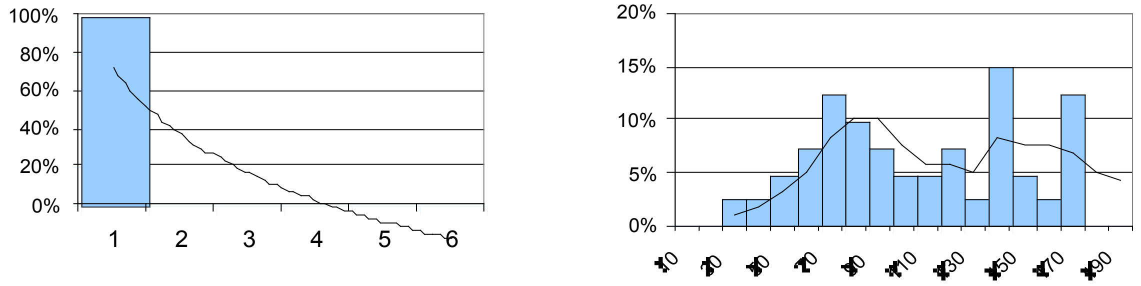


Figure A5: Comparisons of sample profiles to actual population profiles for FlSe 7, for selected CMT attributes (# of scars/CMT and scar length).

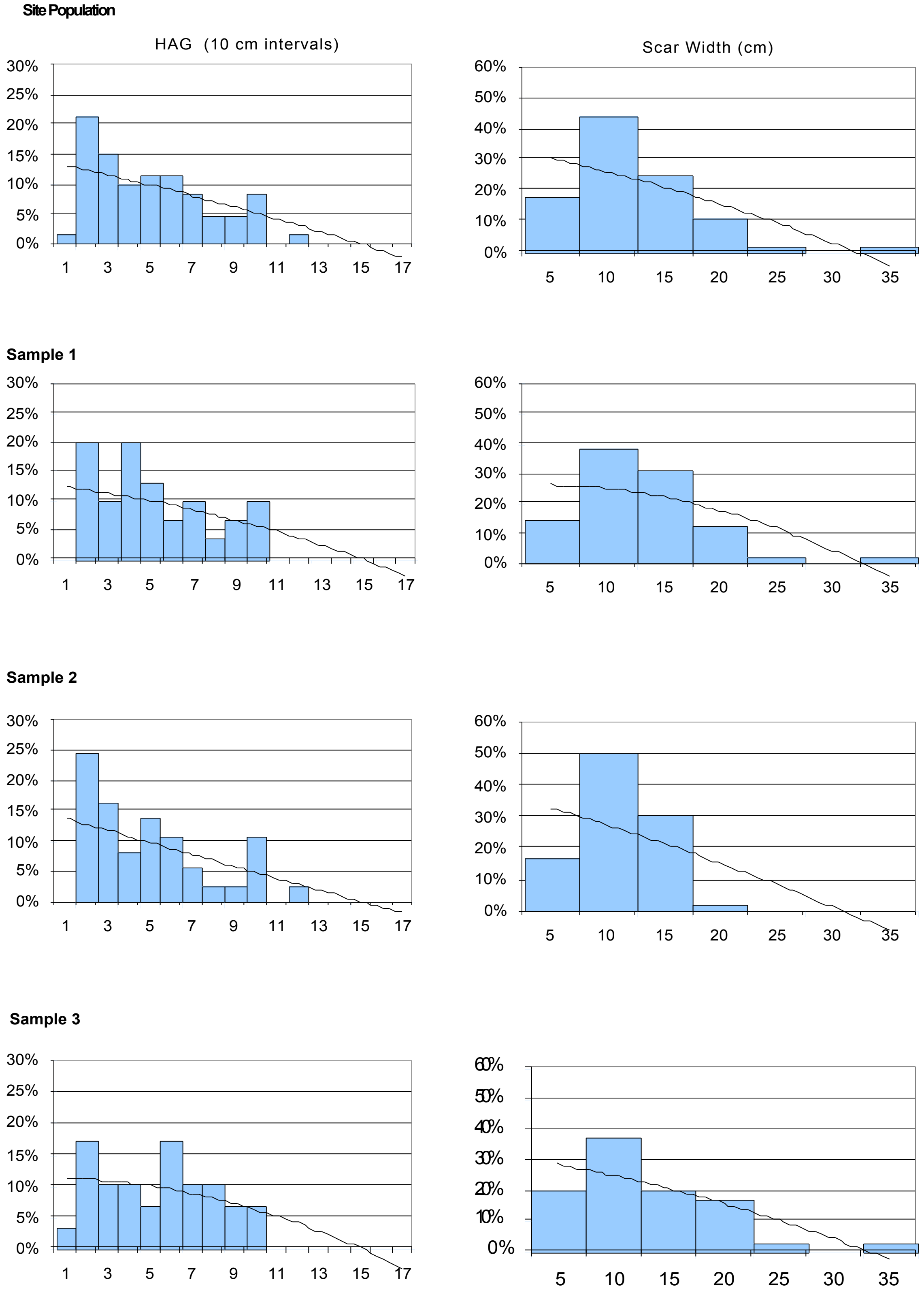


Figure A6: Comparisons of sample profiles to actual population profiles for FlSe 7, for selected CMT attributes (height above germination [HAG] and scar width).

Sampling Experiment #4

Purpose: To evaluate the effectiveness of the CMT site sampling standards adopted by the Vanderhoof Forest District.

Approach: Using the Vanderhoof Forest District "plot sampling" methodology, hypothetical samples were drawn from known "populations" of CMTs. The resulting sample assemblage sizes were then assessed with respect to their ability to accurately characterize the original population.

CMT Data: Sites DkSp-44, HjRl-4 and DkRj-1

Site DkSp-44, recorded by Arcas Consulting Archeologists Ltd. (Jackson and Pratt 1999), consists of approximately 10,000 CMTs located at Boston Point, Cook Channel, Vancouver Island. Over 2000 CMTs were mapped, though not all of these were documented in detail. 940 mapped CMTs which fell within the most intensively surveyed portion of the site were used as the "site population" in this experiment.

Site HjRl-4, recorded by Big Pine Heritage Consulting and Research Ltd. (Farvacque and Bowyer 1999), is located near Donnie Creek in the Fort St. John Forest District. The site consists of 252 CMTs arranged in 10 discrete clusters over an area approximately 1 km long by 0.5 km wide.

Site DkRj-1, recorded by Golder Associates (Wada and Bailey 1999), is located near Yale in the Chilliwack Forest District. The site consists of a dense cluster of 163 CMTs.

For each of the above sites hypothetical plot samples were selected. The plots consisted of 20 meter diameter areas with their center points spaced at 100 m intervals throughout the study area (i.e., site area). All features which fell within the plot areas were considered to be 'recorded'.

Results:

Tables A7 through A9 indicate the CMTs 'recorded' at each plot as well as the total number of CMTs 'recorded' for each site. For site DkRj-1 the cluster from which each recorded CMT is also indicated. It should be noted that two trials were necessary for site DkRj-1 since no features were 'recorded' during the first attempt.

Table A7. Plot Sampling Results for Site DkSp-44. 20 meter diameter plots at 100 m intervals.

Plot #	Recorded CMTs
1	None
2	814, 812
3	None
4	792, 793
5-11	None
12	269, 178, 179, 177, 180, 181
13	449, 452, 450, 489, 471, 454, 456, 469, 393, 468, 412, 444, 463, 445, 446, 447, 448, 475, 477, 479, 488, 473
14	None
15	10, 24, 25, 34, 35, 36, 37, 38, 19, 39
16-18	None
19	561, 559
20-22	None
23	852
24	None
Total # CMTs	Recorded: 45 of 940

Table A8. Plot Sampling Results for Site HjRl-4. 20 meter diameter plots at 100 m intervals.

Plot #	Recorded CMTs
1-5	None
6	Cluster 13: R
7-8	None
9	Cluster 9: Q
10	None
11	Cluster 2: C
12	None
13	Cluster 8: D
14-18	None
19	Cluster 1: AT, AS, AQ, AP, AR, BA, AZ
20-26	None
27	Cluster 1: L, M
28-33	None
Total # CMTs	Recorded: 13 of 252

Table A9. Plot Sampling Results for Site DkRj-1. 20 meter diameter plots at 100 m intervals.

Plot #	Recorded CMTs
1-9	None
10	117, 120, 121, 118
11-12	None
13	20, 21, 22
14-23	None
24	129, 105
25-26	None
Total # CMTs	Recorded: 9 of 163

Conclusions:

In all three cases the resulting samples (45 of 940, 13 of 252 and 9 of 163) are too small to provide accurate representation of the site data (to a sample error objective of ± 10%, 18 times out of 20), assuming attribute variability of 60%. The sample from DkSp-44 is closest to being adequate and would be suitable for a population displaying 45% variability.

The plot sampling strategy also failed to produce samples which were spatially representative of the sites. This was particularly true of site HjRl-4. The first application of the plot sampling methodology to this site resulted in a sample size of 0 of 252 CMTs, as none of the observation plots fell within or near any of the CMT clusters. The grid was then readjusted to ensure that at least one cluster was intercepted. This resulted in a total 13 CMTs being captured by the plots. This included representation from 5 of the ten clusters, though four of these were each only represented by a single CMT. The grid was then again repositioned in attempt to obtain a larger and more representative sample, however, this proved to be impossible as the circular 20 m observation plots at 100 m intervals consistently missed most of the CMT clusters. Similar though less pronounced problems occurred during sampling of the two other sites. For Site DkSp-44 approximately half of the recorded CMTs are associated with a single plot area (Plot 13). For site DkRj-1 only 3 of 26 plot areas contained CMTs. Clearly, in all three cases the samples are grossly insufficient to allow subdivision of the site data for spatial analyses.