



## 2C. Statistical Sampling

### Introduction

Statistical sampling methods are used in forensic science when all items in a population will not be examined and there is a need to make an inference to that population. The use of statistical sampling methods do not guarantee that a sample is representative of the population but do support representativeness of the sample. If a sample is not representative, the usefulness of the inference being made about the population may be negatively impacted. The relevancy of the population to the question being asked is the topic of the primer on Population Statistics.

### Sampling

The initial decision of whether an item will be sampled for examination (testing, inspection, or analysis) occurs at a scene. Decisions are made based on the case information available, the items available at the scene, what items may best be transported to the facility for examination, and the questions considered at the scene investigation. Further sampling may occur once an item is submitted to a forensic science service provider (FSSP). Whether sampling will have a non-statistical or statistical basis is determined by the anticipated use of the results.

### Non-Statistical Sampling

Forensic science has many instances where examination results from a non-statistical sampling can answer the question being asked. Examples include:

Item 1 = 38 baggies of white powder

Question: Does Item 1 contain cocaine?

One baggie is examined and found to contain cocaine. That test result is reported. The report makes no inference about the contents of the 37 baggies that were not examined.

Item 1a = 15 fragments of material were collected from Item 1, a jacket

Question: Are any of the fragments glass?

Two fragments were examined and found to be glass. Those test results were reported. The report makes no inference to the other thirteen fragments of material not examined.

### Statistical Sampling

There are other instances where the number of items in a finite population can be large, and it would be burdensome to examine all items. Statistical sampling allows less than all items to be examined and for an inference to be made about all items in the population or a large number of items in the population. Example scenarios include:

Item 1 = 200 small baggies containing a white powder

Questions:

- Is cocaine present in at least 100 of the 200 baggies?
- Is cocaine present in all 200 baggies?
- What is the net weight of the powder in all 200 baggies?

### Risks and Opportunities

The decision to use statistical sampling has both risks and opportunities (see Table 1).

Table 1. Comparison of risks and opportunities when using a statistical sample

Risks When Using Statistical Sampling	Opportunities When Using Statistical Sampling
<ul style="list-style-type: none"> <li>• Not all items in the population will be examined</li> <li>• The sample may not be representative of the population; there may be a bias in the sample chosen</li> <li>• A poor or incorrect decision may be made</li> </ul>	<ul style="list-style-type: none"> <li>• Resource savings (e.g., personnel time and consumables)</li> <li>• Reduced handling potential hazardous materials</li> <li>• More timely reporting</li> <li>• Can report on both the items examined and an inference to the population</li> </ul>

### How a Sample Will be Selected

Non-statistical sampling: The number of sampling units that will answer the question being asked are selected. The sampling units may or may not be selected at random.

Statistical sampling methods available, include:

Simple random sampling – The units selected are chosen at random and each has an equal chance of being selected.

Stratified sampling – The population to be sampled is first divided into mutually exclusive (homogenous) subsets or strata, and independent units are selected from each stratum.

Cluster sampling – The units available for sampling are separated into clusters, groups, that may or may not be homogenous. Clusters included in the sample are identified, and all units in those clusters are examined, or further sub-sampling is performed within the clusters.

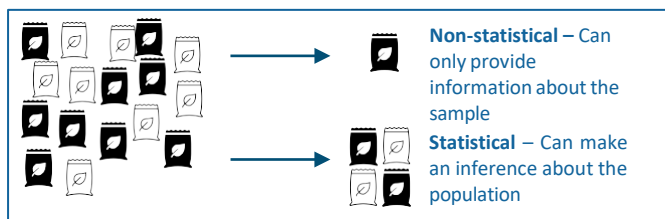
Area sampling – A map serves as the sampling frame, and small land plot units are selected from the larger area.

Composite sampling – Combine a large group of units and conduct a single examination.

Random selection of the sampling units is required for statistical sampling (see Figure 1). Statistical sampling risk can be minimized with a proper method choice. For example, if the units available for sampling are heterogeneous, stratified sampling, if done properly, will lead to a valid inference about the population.



Figure 1. Comparison of statistical vs non-statistical population sampling



## Determining Sample Size

Choosing a statistical sampling method provides *how the units included in the sample will be chosen*. A statistical approach must also be taken when determining *how many units will be included in the sample* to reduce the statistical sampling risk. The number of units selected from the population is called the sample size. The sample size directly impacts the inference that can be made about the population, so more is generally better. Still, there is a point of diminishing returns where examining more units from the population does not meaningfully improve the inference.

Decisions must be made on the level of confidence in the required inference. A challenge with statistical sampling is that people may differ in their opinion on what level of confidence is required to answer the legal question being asked. Either a frequentist or Bayesian approach can be used to determine the sample size at a stated level of confidence.

Table 2: Example using a hypergeometric approach, frequentist perspective, to determine the sample size that is necessary to support an inference that at least 500 packets from a finite population of 800 packets contain cocaine.

Confidence level	Sample size if all packets examined are positive for cocaine	Sample size if two units examined are negative for cocaine
68%	3	9
90%	5	13
95%	7	15
99%	10	19

Note: Increasing the confidence level that 500 out of 800 packets are positive for cocaine increases the required sample size.

Table 3: The scenario has been revised. Now the sample size must support an inference that at least 700 packets out of the 800 packets contain cocaine.

Confidence level	Sample size if all packets examined are positive for cocaine	Sample size if two units examined are negative for cocaine
68%	9	27
90%	17	40
95%	22	47
99%	34	62

Note: Increasing the proportion of the population that is positive for cocaine from 500 out of 800 to 700 out of 800 increased the sample size required at each level of confidence.

A Bayesian approach considers the forensic science practitioner’s belief, their confidence, that the units in the population have the

characteristic of interest (e.g., the units do contain cocaine, or the units do contain child pornography). The information that is considered is unique to the forensic science practitioner based on their experience and case-specific information. There is no one correct way to quantify belief, confidence. Other people may not share the same belief and would calculate a different sample size. Generally, using a Bayesian approach will yield a smaller required sample size than the hypergeometric approach.

## Uncertainty in Statistical Sampling

When a sample is used to estimate a population statistic, it will differ from the true population statistic (e.g.,  $\bar{x}$  to estimate  $\mu$ ). How much it differs can be expressed as an uncertainty, also referred to as sampling variability or sampling error, that can be calculated to estimate the impact of bias and variability in the sample selected. Many different samples can be drawn from the population, and each would lead to a different estimate of the population statistic. By looking at the variability in the statistic based on a number of different samples, the uncertainty, or standard error, can be calculated and communicated along with the statistic. If sampling is multi-stage, then any estimate of uncertainty will need to look at all stages of sampling.

When a hypergeometric approach is used, as in the example provided, uncertainty is expressed by the confidence level and accounted for in spreadsheets using formulas designed for this purpose.

## Key Takeaways

1

Statistical sampling methods support representativeness but do not guarantee that a sample is representative of the population. If the samples are not representative, the usefulness of the inference being made may be negatively impacted.

2

A “good sample” to answer one question may not be a good sample to answer a different question.

3

Statistical sampling allows for an inference, with a frequentist confidence statement, to be made about a population.

## Related Primers

General Statistics      Population Statistics

## Learn More

ASTM 2548-16 - Standard Guide for Sampling Seized Drugs for Qualitative and Quantitative Analysis

[CSAFE Sampling for Forensic Practitioners Short Course](#)

CSAFE: Statistical Thinking for Forensic Practitioners

[ENSFI DWG Qualitative Sampling Calculator](#)

[UNODC Guidelines on Representative Drug Sampling](#)

Part of NIST SP 1500-28

<https://doi.org/10.6028/NIST.SP.1500-28>



## Glossary Primer 2C Statistical Sampling

Term	Definition	Reference	Primer Nos.
Characteristic	Distinguishing feature	ISO 3534-2:2006 Statistics – Vocabulary and symbols – Part 2: Applied statistics, International Organization for Standardization, Geneva, Switzerland	1G Algorithms; 2C Statistical Sampling
Cluster	Part of a population divided into mutually exclusive groups of sampling units related in a certain manner	ISO 3534-2:2006 Statistics – Vocabulary and symbols – Part 2: Applied statistics, International Organization for Standardization, Geneva, Switzerland	2C Statistical Sampling
Multi-stage sampling	Sampling in which the sample is selected by stages, the sampling units at each stage being selected from subunits of the larger sampling units chosen at the previous stage	ISO 3534-2:2006 Statistics – Vocabulary and symbols – Part 2: Applied statistics, International Organization for Standardization, Geneva, Switzerland	2C Statistical Sampling
Population	Totality of items under consideration	ISO 3534-1:2006 Statistics – Vocabulary and symbols – Part 1: General statistical terms and terms used in probability, International Organization for Standardization, Geneva, Switzerland	2A General Statistics; 2C Statistical Sampling; 2D Population Statistics
Random sampling	Sampling where a sample of n sampling units is taken from a population in such a way that each of the possible combinations of n sampling units has a particular probability of being taken	ISO 3534-1:2006 Statistics – Vocabulary and symbols – Part 1: General statistical terms and terms used in probability, International Organization for Standardization, Geneva, Switzerland	2C Statistical Sampling
Sample (General Statistics)	Subset of a population made up of one or more sampling units	ISO 3534-1:2006 Statistics – Vocabulary and symbols – Part 1: General statistical terms and terms used in probability, International Organization for Standardization, Geneva, Switzerland	2A General Statistics; 2C Statistical Sampling; 2D Population Statistics
Sample size	Number of sampling units in a sample.	ISO 3534-1:2006 Statistics – Vocabulary and symbols – Part 1: General statistical terms and terms used in probability, International Organization for Standardization, Geneva, Switzerland	2C Statistical Sampling



Term	Definition	Reference	Primer Nos.
Sampling (Statistical Sampling)	Act of drawing or constituting a sample	ISO 3534-1:2006 Statistics — Vocabulary and symbols — Part 1: General statistical terms and terms used in probability, International Organization for Standardization, Geneva, Switzerland	2C Statistical Sampling
Sampling unit	An item, group of items, or segment of material, that can be selected as part of a probability sampling plan	ASTM E456-13a(2022) Standard Terminology Relating to Quality and Statistics, ASTM International, West Conshohocken, PA, 2006	2C Statistical Sampling
Simple random sampling	Sampling where a sample of n sampling units is taken from a population in such a way that all the possible combinations of n sampling units have the same probability of being taken	ISO 3534-1:2006 Statistics — Vocabulary and symbols — Part 1: General statistical terms and terms used in probability, International Organization for Standardization, Geneva, Switzerland	2C Statistical Sampling
Stratified sampling	Sampling in which the population to be sampled is first divided into mutually exclusive subsets or strata, and independent samples taken within each stratum	ASTM E456-13a(2022) Standard Terminology Relating to Quality and Statistics, ASTM International, West Conshohocken, PA, 2006	2C Statistical Sampling
Stratum	Mutually exclusive and exhaustive sub-population considered to be more homogeneous with respect to characteristics investigated than the total population	ISO 3534-1:2006 Statistics — Vocabulary and symbols — Part 1: General statistical terms and terms used in probability, International Organization for Standardization, Geneva, Switzerland	2C Statistical Sampling