Description of survey method developed by the Nutrition and Pastoralism Research Project

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Background

There is a common conception that pastoralism is a form of *subsistence* farming and that pastoralist groups exist almost exclusively upon the products of their livestock tending to be both culturally and economically separate from neighbouring populations and from each other. This assumption is almost always untrue. Pastoralists often accumulate wealth and complex *exchange relationships* may exist with agriculturalists, petty traders, livestock traders, government officials, and the formal and informal financial sectors. Involvement in international trade is also common. Pastoralist societies develop, maintain, and apply a deep and validated "folk" understanding of environmental factors (e.g. meteorology), ecological processes, and market conditions pertinent to their survival. The development, maintenance, and application of this knowledge requires the sharing of information which tends to be mediated by formal systems of visiting rules and well-defined social and informational networks which also serve to maintain social and cultural cohesion in these dispersed and mobile societies. The existence of these exchange relationships and informational networks means that a great deal of information can be collected about the structure of pastoralist societies and the location and intended movements of pastoralist groups from their exchange partners as well as from pastoralists themselves. The current difficulties in surveying pastoralist populations are unlikely, therefore, to be due to a lack of readily available and useful information or to the mobility and dispersion of pastoralist groups but to intrinsic weaknesses in the standard EPI-derived survey method which was developed for use in well enumerated sedentary populations as well as to a lack of experience in the collection, validation, and interpretation of qualitative data in NGO survey staff.

This document describes a survey method that may be used to survey pastoralist populations. This method employs both *qualitative* methods and *quantitative* methods. Two approaches are proposed. These are a *social structure* approach and an *enumeration area* approach. The two approaches differ in the way that *primary sample units* (PSUs) are selected. With the social structure approach, PSUs are sampled systematically from a list of potential sampling units. With the enumeration area approach, PSUs are sampled using a systematic spatial sampling method. The choice of approach will usually be dictated by the survey context.

The described method is a *general* method in the sense that its use is not restricted to prevalence estimation in pastoralist populations (e.g. the method could be adapted to estimate vaccine coverage, mortality retrospectively by cross-sectional survey in pastoralist populations, or to estimate prevalence in poorly enumerated sedentary populations distributed over several agro-ecological zones) but this document concentrates upon the application of estimating the prevalence of *acute undernutrition* in pastoralist populations.

Qualitative Activities : Social Structure Approach

The preliminary step in the proposed survey method is to use qualitative methods (e.g. in-depth interviews, semi-structured interviews, observation, pile sorts, informal group discussions, focus groups, iterative methods, triangulation by source and method, sampling to redundancy, &c.) in order to:

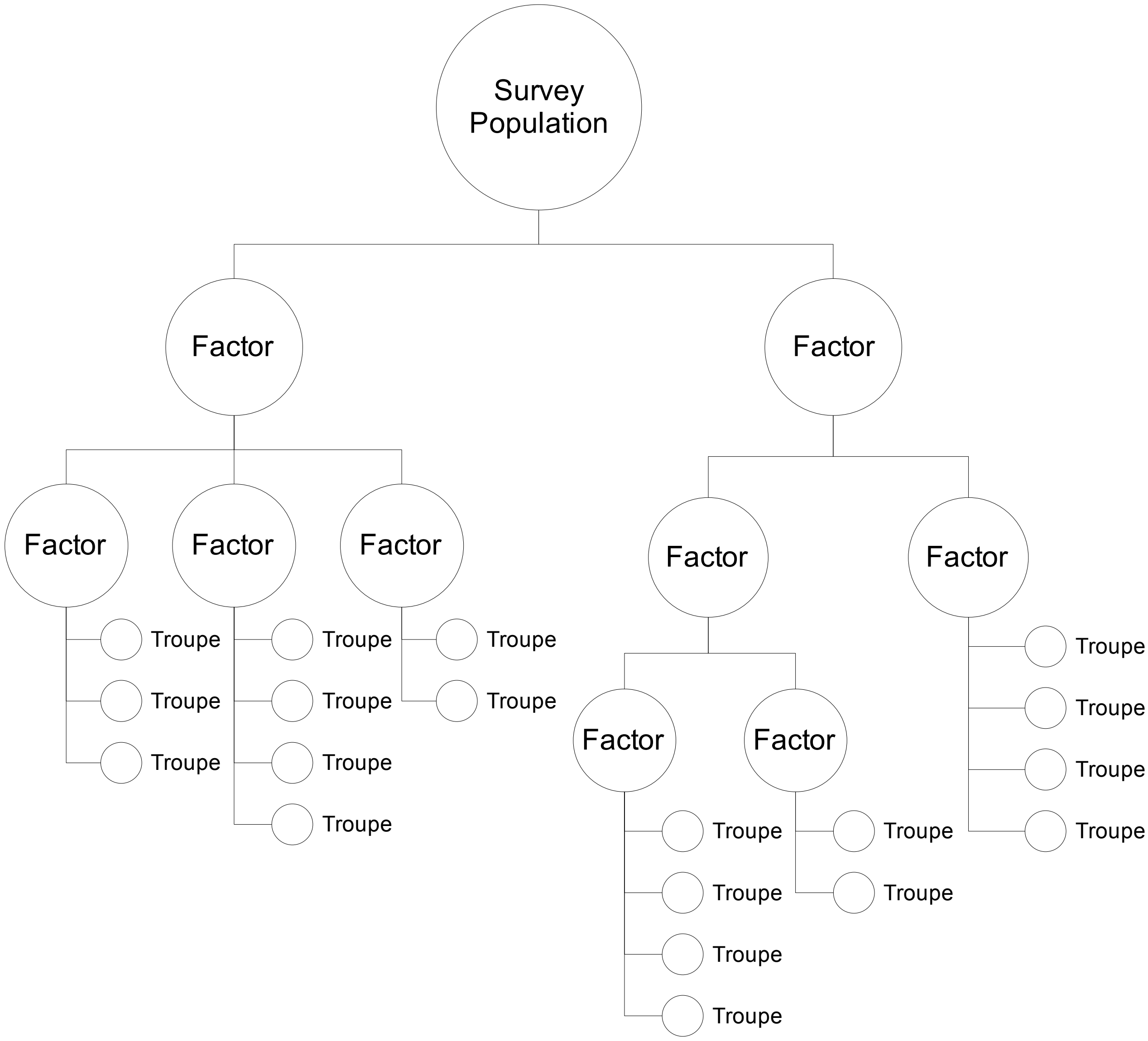
1. Identify the principal *organising factors* of the population to be surveyed (e.g. ethnic group, kinship groupings, traditional access to grazing territory, market access, religion, livestock holdings, water points &c.) and to organise this data into a hierarchical tree structure or *organogram*.

2. Identify each *troupe* (i.e. an identifiable group of households moving together with their livestock) present in the survey area and assign each troupe to an end-node in the tree structure. Nodes are, therefore, exclusive or non-overlapping sets of troupes (i.e. a node may consist of many troupes but a troupe may belong to one and only one group). The troupe (or combination of two or more spatially proximate troupes) is the PSU in the proposed survey method.

3. Locate troupes within the survey area. Only a subset of troupes in the survey area (i.e. those selected for sampling) need to be located. The mobility of troupes means that this activity should take place before and during the quantitative phase of the survey on an ongoing basis.

Figure 1 shows (diagrammatically) the information collected in activities (1) and (2).

Figure 1 : Outcome of qualitative activities (1) and (2)



Quantitative Activities : Social Structure Approach

The quantitative activities of the survey are:

1. Identify the troupes (PSUs) to be sampled. This is achieved by taking a systematic sample of troupes from the structured list of troupes collected and ordered by qualitative activities (1) and (2). This is represented (diagrammatically) in *Figure 2*. This approach has the following advantages:

    (a) A list of troupes to be located and sampled can be created without precise knowledge of troupe locations or populations.

    (b) The sample is not automatically biased in favour of larger troupes (as would be the case with an EPI-derived survey method).

    (c) The sample is likely to include troupes from all main socio-economic and cultural strata in the survey population.

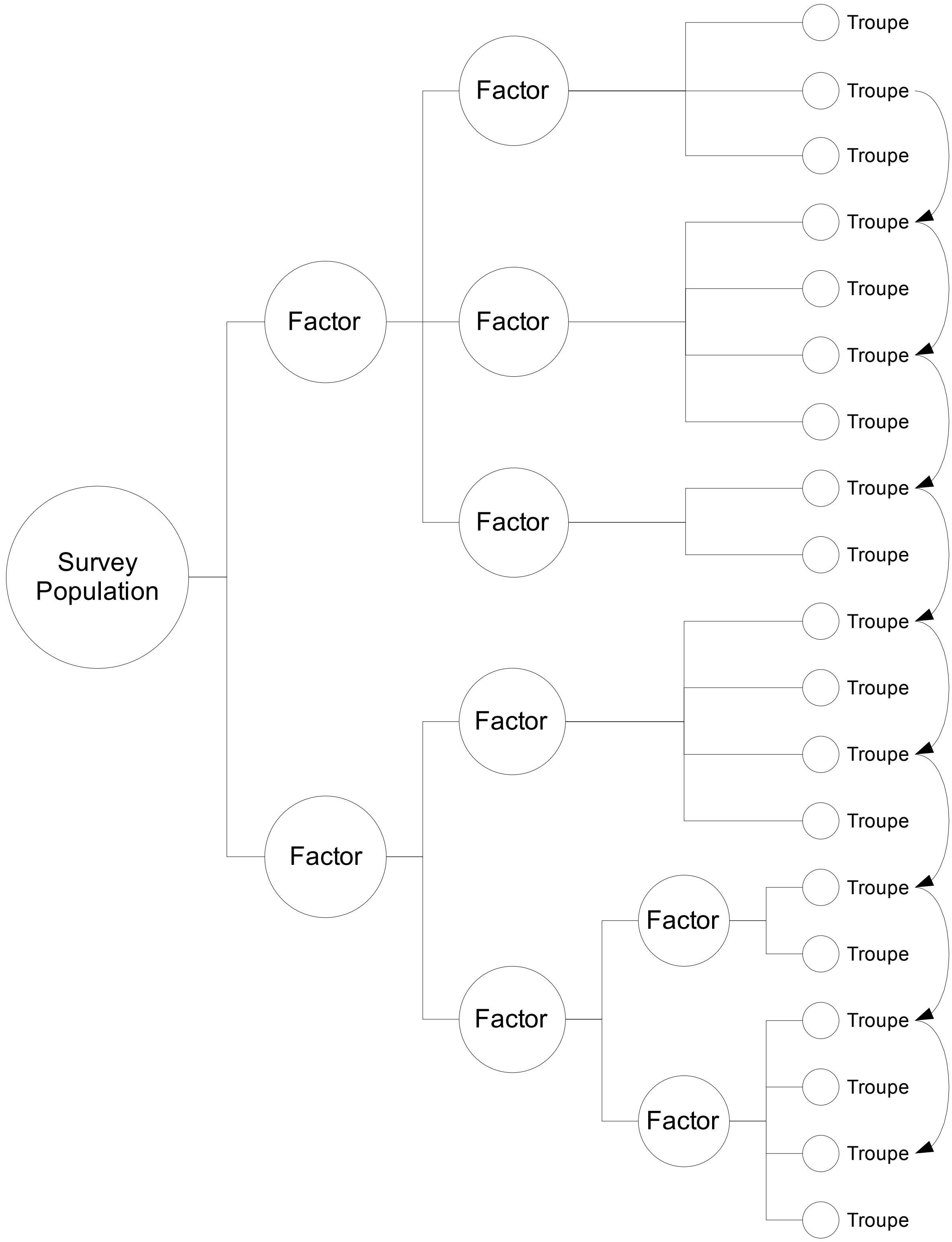
    (d) A spatially representative sample is almost guaranteed (assuming either near-optimal use of available grazing land).

2. Locate the troupes selected to be sampled (this is actually a qualitative activity but since it also takes place during the quantitative survey it is also included here). This is an ongoing process.

3. Sample from the selected troupes. The exact sampling method employed is likely to be constrained by the size of the individual troupes in terms of both the population and the physical separation between households) and the *case-definition* used (see below). With small troupes (e.g. those containing less than about sixty eligible children), it would be sensible to take a house-to-house "census" sample. For larger troupes some form of probability sampling will be required. Various sampling strategies could be employed (e.g. *proximity* sampling, *line-transect* sampling, *random-walk* sampling, *segmentation* followed by proximity sampling) although the use of simple (i.e. without segmentation) proximity sampling may be problematic due to the loss of sampling variation associated with this sampling method.

4. Analyse and report the survey data. Data-analysis procedures are covered in more detail below.

Figure 2 : Selection of troupes (PSUs) to be sampled by systematic sampling (social structure approach)



Qualitative Activities : Enumeration Area Approach

The enumerated area approach requires only that the boundaries of currently active grazing areas can be identified and marked on a map. This data can be collected using qualitative methods. If other data sources such as aerial survey data or satellite remote sensing data (e.g. of vegetation cover and water sources) are available then these could be used. Caution must be exercised to avoid the introduction of bias due to the systematic exclusion of groups with no access to grazing land identifiable by remote sensing and groups with access only to the margins of grazing areas. These biases can be avoided by thorough qualitative investigation and the use of a *buffer* around identified grazing areas (see below). It would be sensible to confirm boundaries using field visits.

Quantitative Activities : Enumeration Area Approach

The enumerated area approach uses a systematic spatial sampling method to identify and sample troupes. One systematic area sampling technique that has been used successfully by NGOs in a variety of contexts is the *centric systematic area sampling* (CSAS) method (see *Figure 3*). Troupes are sampled by selecting the troupe closest to identified sampling locations (a GPS receiver and binoculars will likely prove useful). Caution must be exercised to avoid double sampling (i.e. sampling the same troupe twice as it moves through the sampling area). If an already sampled troupe is identified then a neighbouring troupe is substituted. Within-troupe sampling proceeds as with the social structure approach.

Notes

It is envisaged that the method will utilise a *census sample* for within-troupe sampling. The testing of the method by computer-based simulation presented below assumes census sampling for the within-troupe sample. Case-definitions based upon *mid-upper-arm-circumference* (MUAC) offers considerable flexibility and resource savings compared with case-definitions based upon *weigh-for-height* (W/H). It should be noted that W/H based case-definitions tend to produce upwardly biased estimates of prevalence in pastoralist populations as well as being only weakly associated with malnutrition-related mortality risk and body composition in terms of key nutrient reserves in muscle. It is strongly recommended that the following MUAC based case-definitions are used for this application:

Prevalence to estimate	**Case-definition**
Global acute undernutrition	MUAC < 125 mm or bilateral pitting oedema
Moderate acute undernutrition	110 mm ≤ MUAC < 125 mm without bilateral pitting oedema
Severe acute undernutrition	MUAC < 110 mm or bilateral pitting oedema

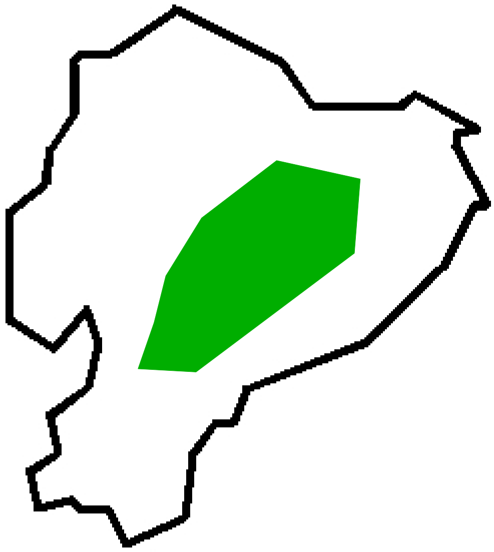
The use of MUAC greatly simplifies data-collection and management. The ability to apply case-definitions with accuracy and precision in the field using banded MUAC straps means that data can be collected using a tally sheet. Only four variable need to be collected and entered for each troupe / PSU:

Variable	**Meaning**
PSU ID	Identifies PSU. It may prove useful to record some extra identifying data to avoid double sampling of troupes.
Number Sampled	The number of children found and examined.
Moderate cases	The number of moderate cases.
Severe cases	The number of severe cases.

Many UNO and NGO workers are unfamiliar with qualitative techniques. Operationalisation of the descibed method would require the development of documentation introducing these methods with *use cases* (case studies) and simple tools for organisation and analysis of qualitative data. Software capable of analysing the quantitative data arising from this survey method will also need to be developed.

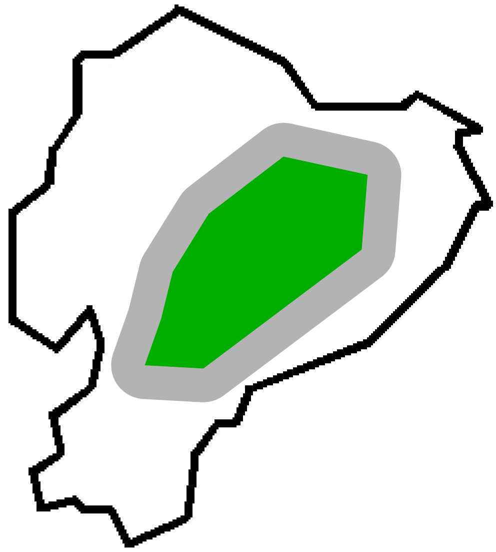
Figure 3 : CSAS Sampling

a : Identify Grazing Area(s)



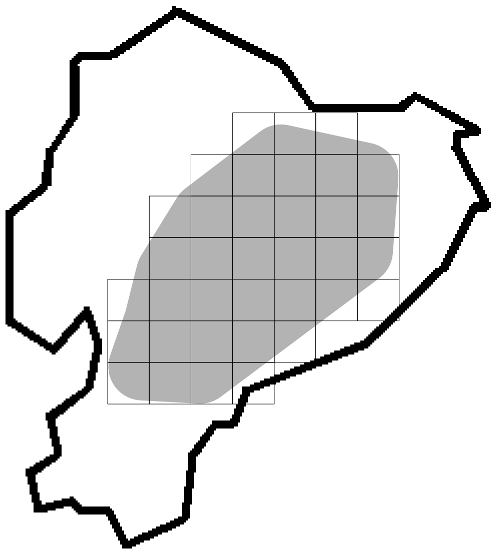
Use qualitative methods, field visits, aerial surveys, and satellite data to identify current grazing areas

b : Draw Buffer Zone(s)



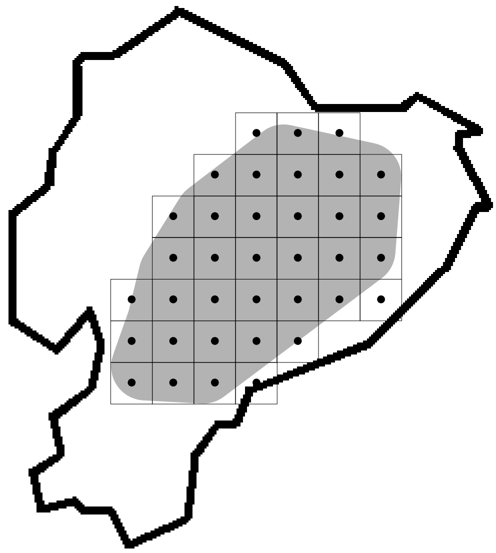
Mark buffer zone to avoid problems of exclusion of marginal groups and *boundary effects*

c : Draw Grid



Draw grid over grazing area(s) and buffer zone(s)

d : Select Sampling Locations



Mark sampling locations at the centre of each quadrat

The survey prevalence estimator

The estimator of prevalence used in the proposed survey method is based upon the arithmetic mean of the prevalence observed in each PSU weighted by the eligible population in each PSU (i.e. the within-PSU sample size if a census sample is employed). A similar approach is commonly employed in surveys using stratified sampling because it allows for the variation in the sizes of the surveyed PSUs.

Box 1 shows an example of this *weighted-mean prevalence* approach.

Box 1 : Example of the weighted-mean prevalence estimator

The following data originates from a survey using 10 PSUs (sampled troupes) sampled from many potential PSUs (all troupes):

PSU	Sample Size	Cases	Prevalence
1	26	4	15.4%
2	12	1	8.3%
3	16	1	6.3%
4	15	3	20.0%
5	10	2	20.0%
6	30	3	10.0%
7	11	2	18.2%
8	17	4	23.5%
9	16	1	6.3%
10	16	1	6.3%

The estimated prevalence is:

$$\hat{\theta}=\frac{26\times15.4+12\times8.3+16\times6.3+15\times20.0+10\times20.0+30\times10.0+11\times18.2+17\times23.5+16\times6.3+16\times6.3}{26+12+16+15+10+30+11+17+16+16}=13.0$$

The described survey method uses a *bootstrap* estimator of prevalence based upon the weighted-mean prevalence estimator described above. *Box 2* presents a summary description of the bootstrap estimator.

One thousand (1000) bootstrap replicates were used in the computer-based simulations undertaken to investigate the behaviour of the proposed survey method and described in this report.

Box 2 : The bootstrap estimator

This example uses the same data as the example presented in *Box 1*:

PSU	1	2	3	4	5	6	7	8	9	10
w	26	12	16	15	10	30	11	17	16	16
$\hat{\theta}$	15.4%	8.3%	6.3%	20.0%	20.0%	10.0%	18.2%	23.5%	6.3%	6.3%

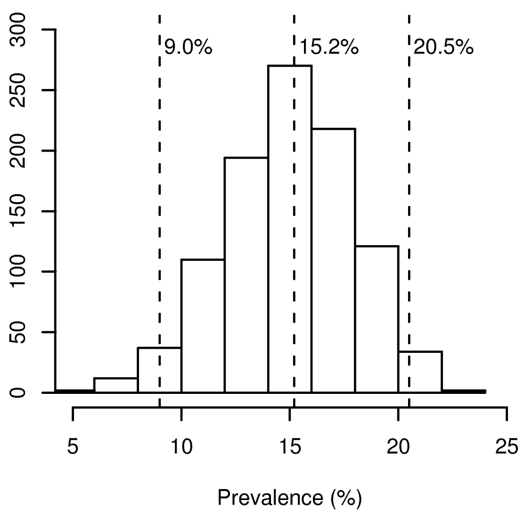
A large number of *bootstrap replicates* (typically 1000 or more) are taken from the survey data. A bootstrap replicate is a set of *n* weight-prevalence pairs sampled randomly *with replacement* from the survey data (where *n* is the number of PSUs used in the survey). Data for a single PSU may appear several times in a bootstrap replicate or not at all. Here are three bootstrap replicates taken from the example survey data:

PSU	6	1	2	1	4	8	9	5	2	2
w	30	26	12	26	15	17	16	10	12	12
$\hat{\theta}$	10%	15.4%	8.3%	15.4%	20%	23.5%	6.3%	20.0%	8.3%	8.3%

PSU	2	8	5	2	10	5	1	1	6	3
w	12	17	10	12	16	10	26	26	30	16
$\hat{\theta}$	8.3%	23.5%	20.0%	8.3%	16.3%	20.0%	15.4%	15.4%	10.0%	6.3%

PSU	4	2	6	9	5	5	6	5	1	2
w	15	12	30	16	10	10	30	10	26	12
$\hat{\theta}$	20.0%	8.3%	10.0%	6.3%	20.0%	20.0%	10.0%	20.0%	15.4%	8.3%

A weighted-mean prevalence estimate is calculated and recorded for each bootstrap replicate. The median of these estimates is the *point estimate* of the prevalence. Differences amongst the estimates are due to sampling variation. The 2.5th percentile of the distribution of the estimates is the lower 95% confidence limit of the point estimate of the prevalence. The 97.5th percentile of the distribution of the estimates is the upper 95% confidence limit of the estimated prevalence.

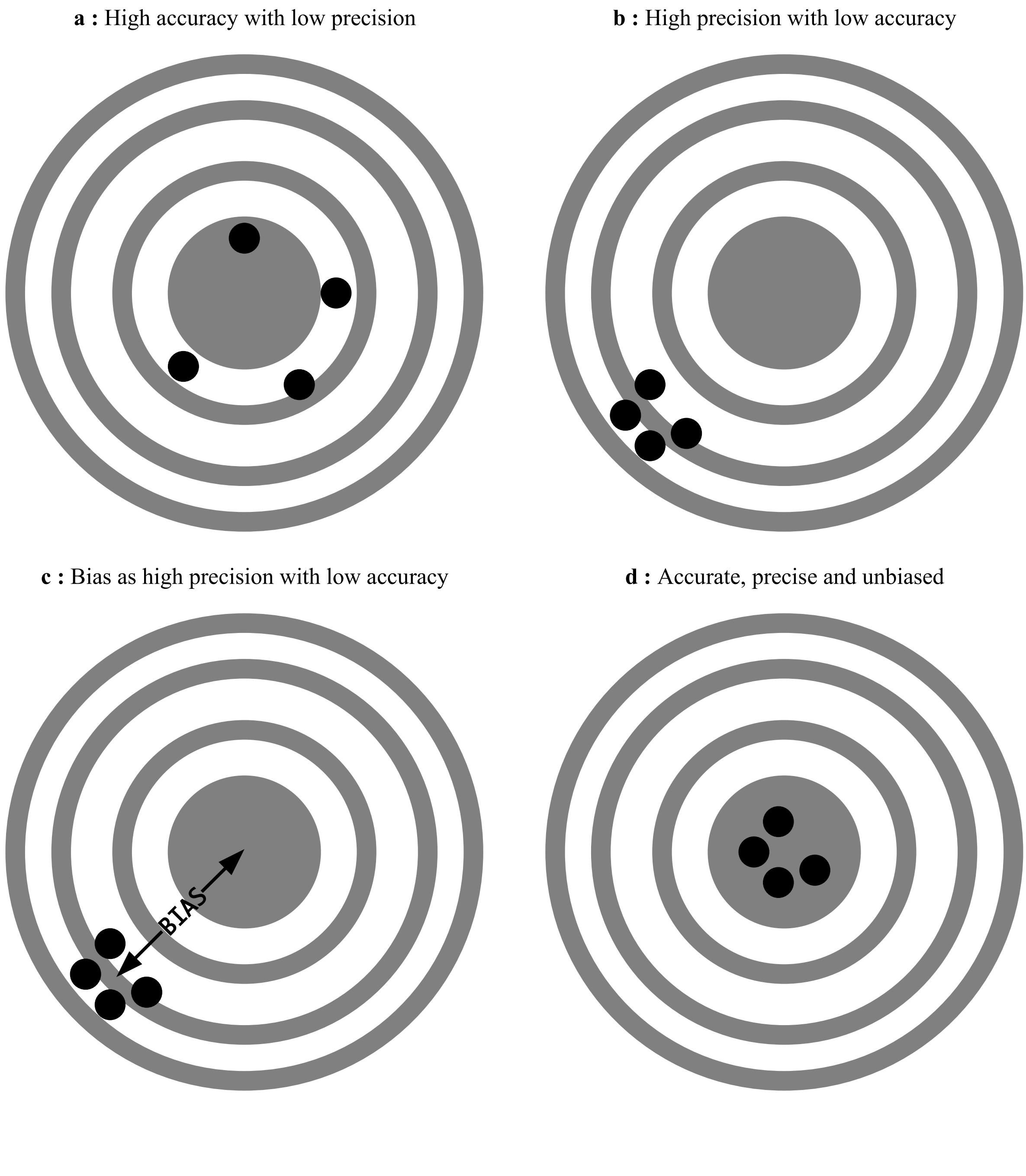


The histogram (right) shows the distribution of prevalence estimates calculated from 1000 bootstrap replicates taken from a survey employing 10 PSUs undertaken in a population with a true prevalence of 15% and a mean troupe size of 15 eligible children. The dashed lines correspond to the 2.5th, 50th, and 97.5th percentiles of the distribution. In this example, the prevalence is estimated to be 15.2% and the 95% confidence interval ranges from 9.0% to 20.5%.

Accuracy, precision, and bias

Three key properties of any survey method are *accuracy*, *precision*, and (lack of) *bias*. Accuracy, precision, and bias may be described using a target analogy in which the prevalence estimates returned by surveys are represented by arrows that are fired at a target and the true prevalence is represented by the centre of the target. Accuracy describes the proximity of the arrows to the centre of the target. Arrows hitting closer to the centre of the target are more accurate (*Figure 4.a*). A survey method that returns prevalence estimates close to the true prevalence is accurate. If a large number of arrows are fired at the target then *precision* would describe the size of the cluster of arrows. Firing is precise if all of the arrows are clustered tightly together (*Figure 4.b*). A survey method that returns prevalence estimates from the same population that are close to each other is precise. A survey method may be precise but inaccurate (*Figure 4.b*). Such a survey method would be biassed and consistently return prevalence estimates that are either above or below the true prevalence (*Figure 4.c*). It is **not** possible for a survey method to be accurate but imprecise. Using the target analogy, if the arrows are not clustered close to each other then they cannot all be close to the centre of the target (*Figure 4.a*). The average position of the arrows might yield an accurate estimate of the location of the centre of the target but the individual arrows are not likely to be accurate. The ideal survey method is one that is both accurate and precise. Such a method will also be unbiassed (*Figure 4.d*).

Figure 4 : The *target analogy* for accuracy, precision, and bias



a : High accuracy with low precision

b : High precision with low accuracy

c : Bias as high precision with low accuracy

d : Accurate, precise and unbiased

Accuracy, precision, and bias

Accuracy and bias may be measured using the *root mean square error* (*RMSE*). The *error* (*E*) is the amount by which an estimate differs from the true value of the quantity being estimated. The mean-square error (*MSE*) is defined as:

$$MSE(\hat{\theta}) = (\hat{\theta} - \theta)^2$$

where:

$\hat{\theta}$	=	The estimate
θ	=	The true value of the quantity being estimated

The *MSE* needs to be estimated. This is usually done using the sample mean:

$$\widehat{MSE}(\hat{\theta}) = \frac{1}{n}\sum_{i=1}^{n}(\hat{\theta}_i - \theta)^2$$

Where *n* is the number of surveys performed. In the work described in this report we estimate the *MSE* of the proposed survey method using computer-based sampling simulations.

The *RMSE* is the square root of the *MSE*:

$$RMSE(\hat{\theta}) = \sqrt{MSE(\hat{\theta})}$$

The *RMSE* is the sum of the standard deviation of the estimator and the bias of the estimator:

$$RMSE(\hat{\theta}) = \sigma(\hat{\theta}) + Bias(\hat{\theta}, \theta)$$

The *RMSE*, therefore, assesses both the quality of the estimator in terms of the magnitude of the error (*E*) and the magnitude of the bias. Small errors yield small values of *RMSE*. With quasi-normally distributed errors approximately 95% of estimation errors will be within ± 1.96 × *RMSE* of the true value of the quantity being estimated. If the *RMSE* and the standard deviation of the estimator agree with each other then the estimator is unbiased. Bias may also be estimated by examining the distribution of the estimation errors across many surveys.

Precision may be measured by the width of the 95% confidence interval of an estimate. Wide confidence intervals reflect low precision (*Figure 4.a*). Narrow confidence intervals reflect high precision (*Figure 4.b*, *Figure 4.c*, and *Figure 4.d*).

The levels of precision and accuracy obtained by a survey method depend on the survey method itself and the overall sample size. Surveys employing larger sample sizes will tend to be more precise (and, hence, more accurate) than surveys employing smaller sample sizes. The simulations presented in this report investigate the accuracy and precision of the proposed survey method with different sample sizes. The sample size is specified as the mean number of eligible children in each PSU and the number of PSUs employed since this is the information that is likely to be available when planning a survey.

The Computer-based Simulations

The performance of the proposed survey method was assessed using computer-based simulations.

A set of five populations were generated consisting of 5,000 troupes with mean troupe populations of 5, 10, 15, 20 and 30 eligible children. A modified *log-normal* distribution was used to generate the troupe populations. This was specified using the following parameters:

μ	=	Desired mean troupe population (i.e. 5, 10, 15, 20, and 30)
σ	=	Standard deviation of troupe population (1.4 for all populations)
minimum	=	Minimum troupe population (2 for all populations)
maximum	=	Maximum troupe population (60 for $\mu \leq 20$ and 75 for $\mu = 30$)
n	=	Number of troupes (5000 for all populations)

This approach yielded populations with the desired mean troupe population (μ) as well as considerable heterogeneity in troupe populations. For example, *Figure 5* shows the distribution of troupe populations in a simulated population defined by the parameters $\mu = 15$, $\sigma = 1.4$, *minimum* = 2, *maximum* = 60, and $n = 5000$.

Within each population, seven levels of prevalence (i.e. 5%, 10%, 15%, 20%, 30%, 40%, and 50%) were simulated with each troupe being assigned the number of cases found in a simple random sample, with a size equal to the individual troupe population, from a population with the desired prevalence. This approach yielded populations with the desired overall prevalences and considerable between-troupe heterogeneity in prevalence. For example, *Figure C* shows the distribution of per-troupe prevalence in the population described in *Figure 6* with an overall prevalence of 15%.

The proposed survey method was simulated by sampling (using systematic sampling) six different numbers of PSUs (i.e. 10, 20, 30, 40, 50, and 60) from each simulated population. The within-PSU samples were treated as census samples. Prevalence was estimated for each PSU and the individual estimates combined as outlined in *Box 1* and *Box 2*. Each combination of PSU size, prevalence, and number of PSUs sampled was simulated 10,000 times. Measures of accuracy, precision, and bias were estimated for each combination of PSU size, prevalence, and number of PSUs sampled. There were 210 combinations of PSU size, prevalence, and number of PSUs sampled (i.e. $5 \times 7 \times 6 = 210$). The results presented here are, therefore, based on 2.1 million simulated surveys.

The results of these simulations can be used as sample-size nomograms which can be used to estimate the required sample size based on desired levels of precision.

Figure 5 : Distribution of troupe populations in a simulated population
(μ = 15, σ = 1.4, *minimum* = 2, *maximum* = 60, *n* = 5,000)

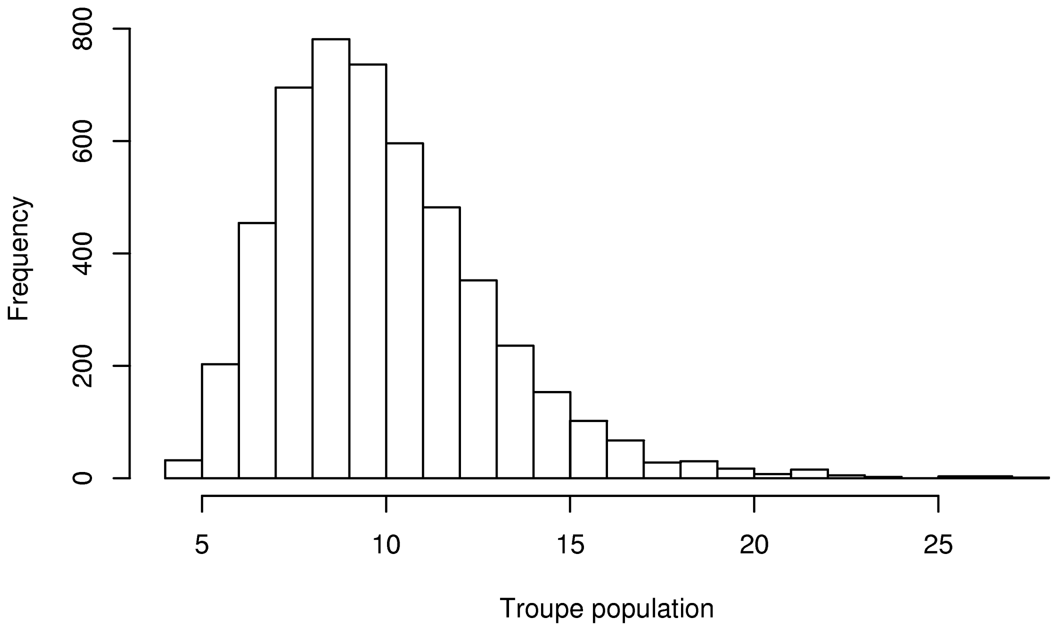
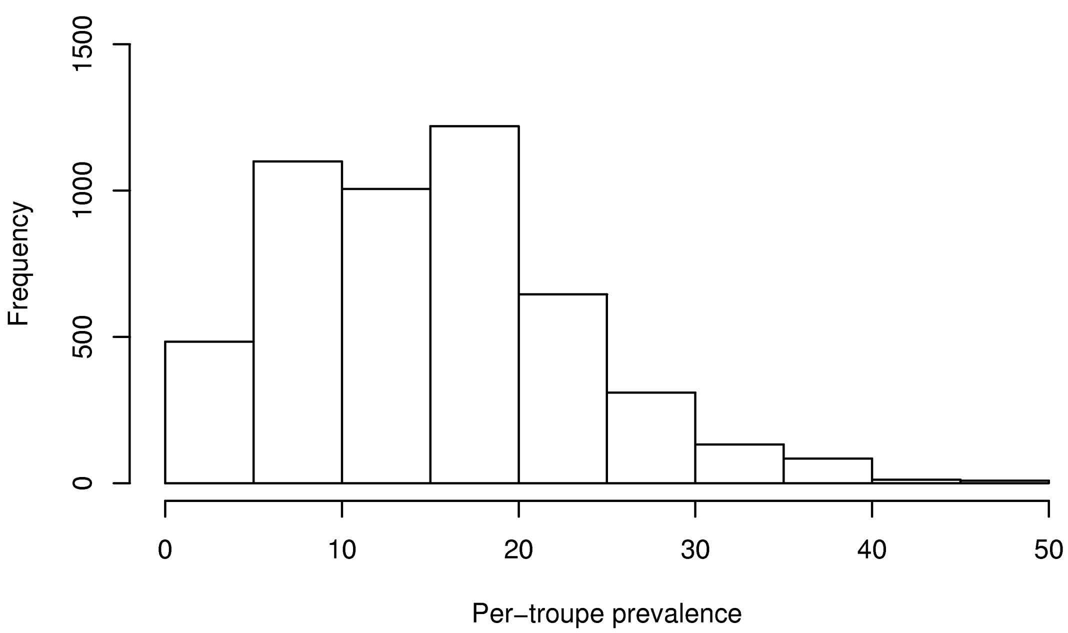


Figure 6 : Distribution of per-troupe prevalence in a simulated population with an overall prevalence of 15%



Results of the Computer Based Simulations

Figure 7, *Figure 8*, *Figure 9*, *Figure 10*, *Figure 11*, *Figure 12*, and *Figure 13* show the results of the simulations in terms of the precision, presented as the mean width of the 95% confidence interval, achieved by the proposed survey method in populations with different levels of prevalence and different mean troupe sizes.

Figure 14 shows the relationship between accuracy measured by RMSE and the standard deviation of the estimated prevalences. A small amount (i.e. 0.1%) of *jitter* has been added to the plotted points so as to improve the appearance of the chart. The true relationship is, therefore, closer than it appears to be in *Figure 14*. The dashed line represents a perfect correspondence between the RMSE and the standard deviation of the estimated prevalence. The *RMSE* is the sum of the standard deviation of the estimator and the bias of the estimator:

$$RMSE(\hat{\theta}) = \sigma(\hat{\theta}) + Bias(\hat{\theta}, \theta)$$

Since:

$$RMSE(\hat{\theta}) \simeq \sigma(\hat{\theta})$$

the proposed survey method is very nearly unbiased.

Figure 15 shows the mean magnitude of the observed estimation errors. The proposed survey method is very nearly unbiased.

Using the results

The results plotted in *Figure 7*, *Figure 8*, *Figure 9*, *Figure 10*, *Figure 11*, *Figure 12*, and *Figure 13* may be used as nomograms for the purposes of calculating the required sample size in specific situations. For example, *Figure 16* reproduces *Figure 8* (10% prevalence) and shows how this chart may be used to calculate the sample size required to estimate a prevalence of 10% with a 95% confidence interval of ± 3% in a population with a mean troupe size (*μ)* of 20 eligible children. In this example, the required sample size is about 38 troupes.

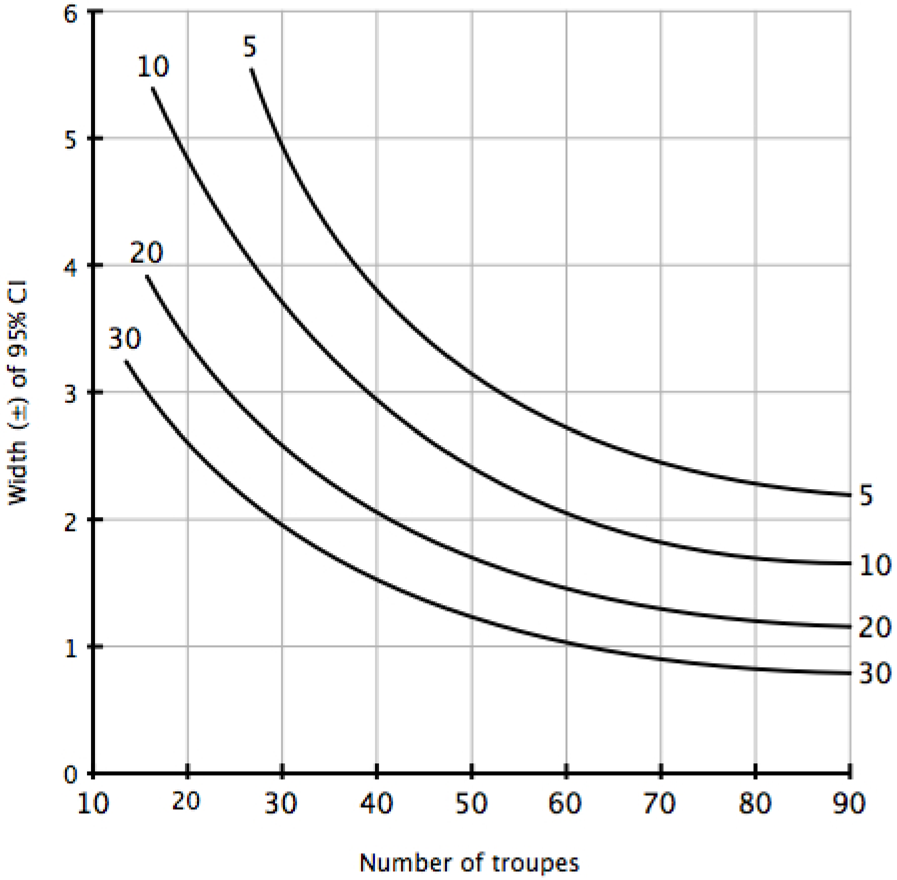
In situations where the mean troupe size is small and the number of PSUs required to achieve acceptable levels of precision is larger than is practicable to collect then clusters of neighbouring troupes may be used to create larger "super-troupes". For example, four neighbouring troupes from a population with a mean troupe size of five may be combined to create a "super-troupe" with a mean troupe size of twenty. Caution must be exercised to avoid sampling the same troupe twice.

The simulations presented in this report used populations with considerable between-troupe heterogeneity in prevalence and a large number of potential PSUs (i.e. 5000). This means that the sample sizes obtained from the nomograms presented in this report are suitable for use in populations in which there is considerable between-troupe heterogeneity in prevalence and / or a large number of potential PSUs. They are also safe to use in more homogeneous populations and / or populations with smaller numbers of potential PSUs since the sample sizes obtained from the nomograms will be larger than required for such populations. This is similar to the practice of using a design-effect of 2.0, which is usually larger than is required, in two-stage cluster-sampled nutritional anthropometry surveys. New nomograms may be developed as experienced is gained with the proposed survey method.

Other documents

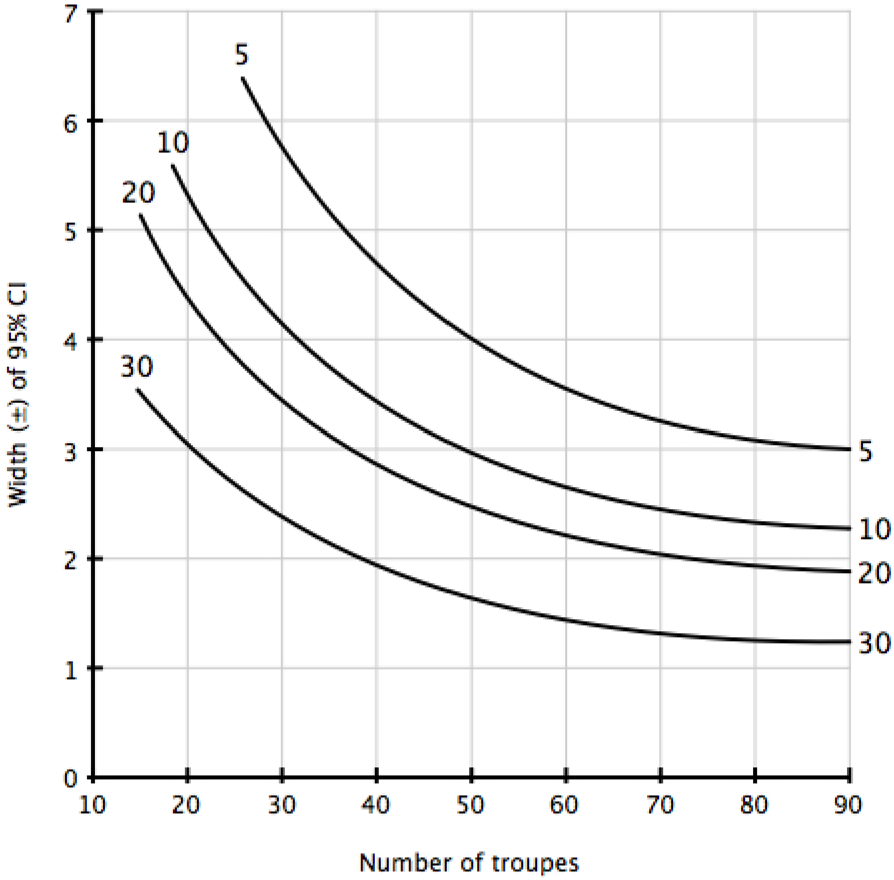
This document is part of a series describing this method. Other documents in this series include the results of field trials of the method and a field-guide for surveyors

Figure 7 : Precision sampling from populations with 5% prevalence and different mean troupe sizes (μ)



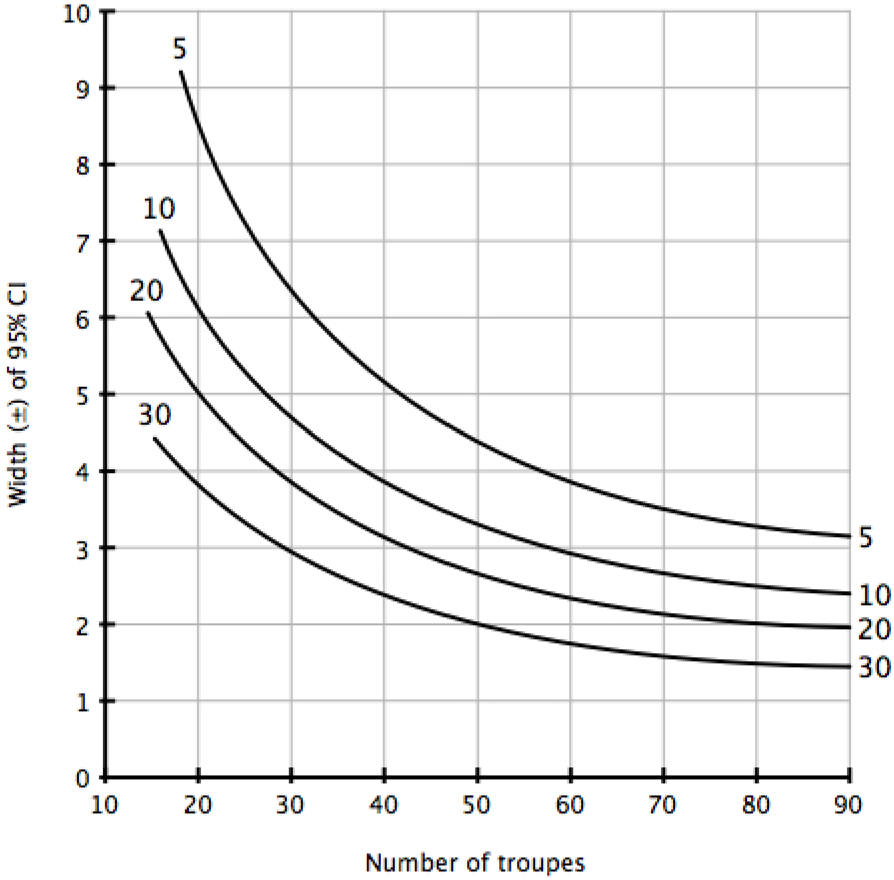
Line labels refer to mean troupe size (μ)

Figure 8 : Precision sampling from populations with 10% prevalence and different mean troupe sizes (μ)



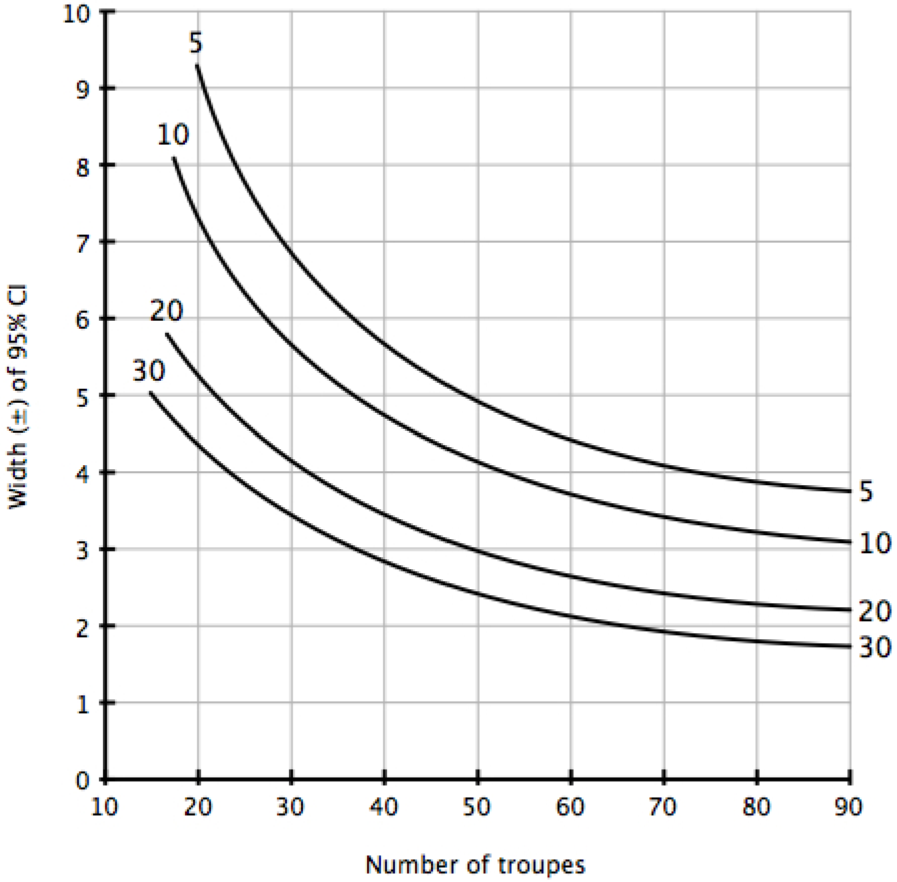
Line labels refer to mean troupe size (μ)

Figure 9 : Precision sampling from populations with 15% prevalence and different mean troupe sizes (μ)



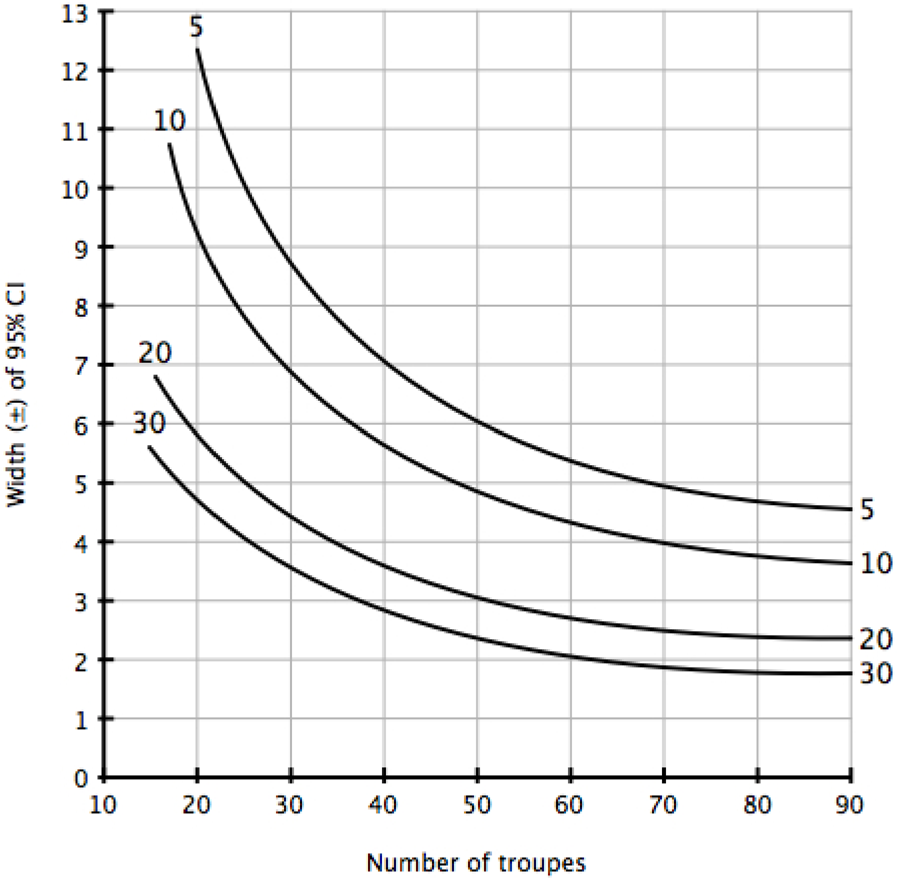
Line labels refer to mean troupe size (μ)

Figure 10 : Precision sampling from populations with 20% prevalence and different mean troupe sizes (μ)



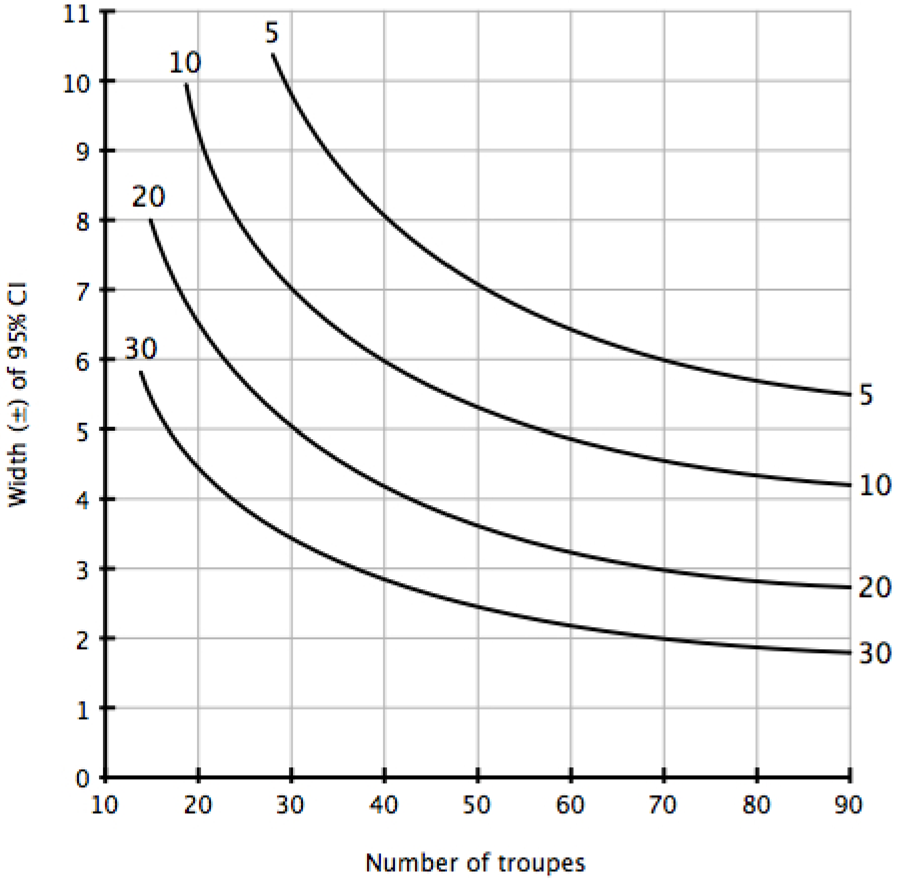
Line labels refer to mean troupe size (μ)

Figure 11 : Precision sampling from populations with 30% prevalence and different mean troupe sizes (μ)



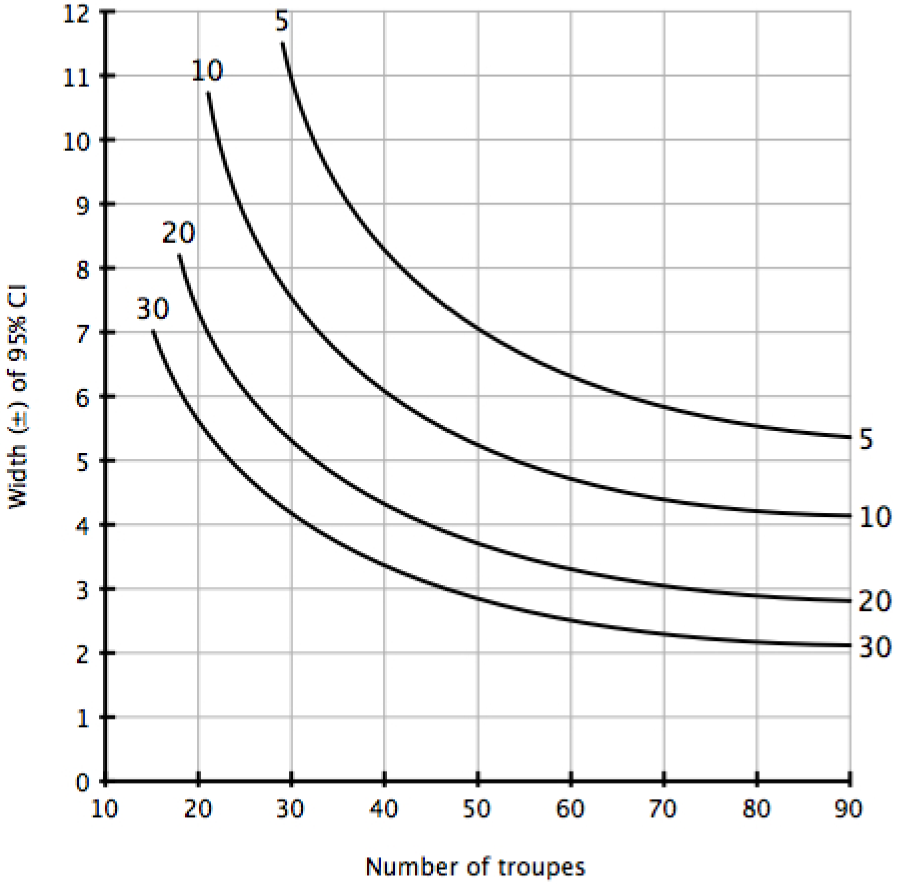
Line labels refer to mean troupe size (μ)

Figure 12 : Precision sampling from populations with 40% prevalence and different mean troupe sizes (μ)



Line labels refer to mean troupe size (μ)

Figure 13 : Precision sampling from populations with 50% prevalence and different mean troupe sizes (μ)



Line labels refer to mean troupe size (μ)

Figure 14 : Relationship between the RMSE and standard deviation of the estimated prevalence

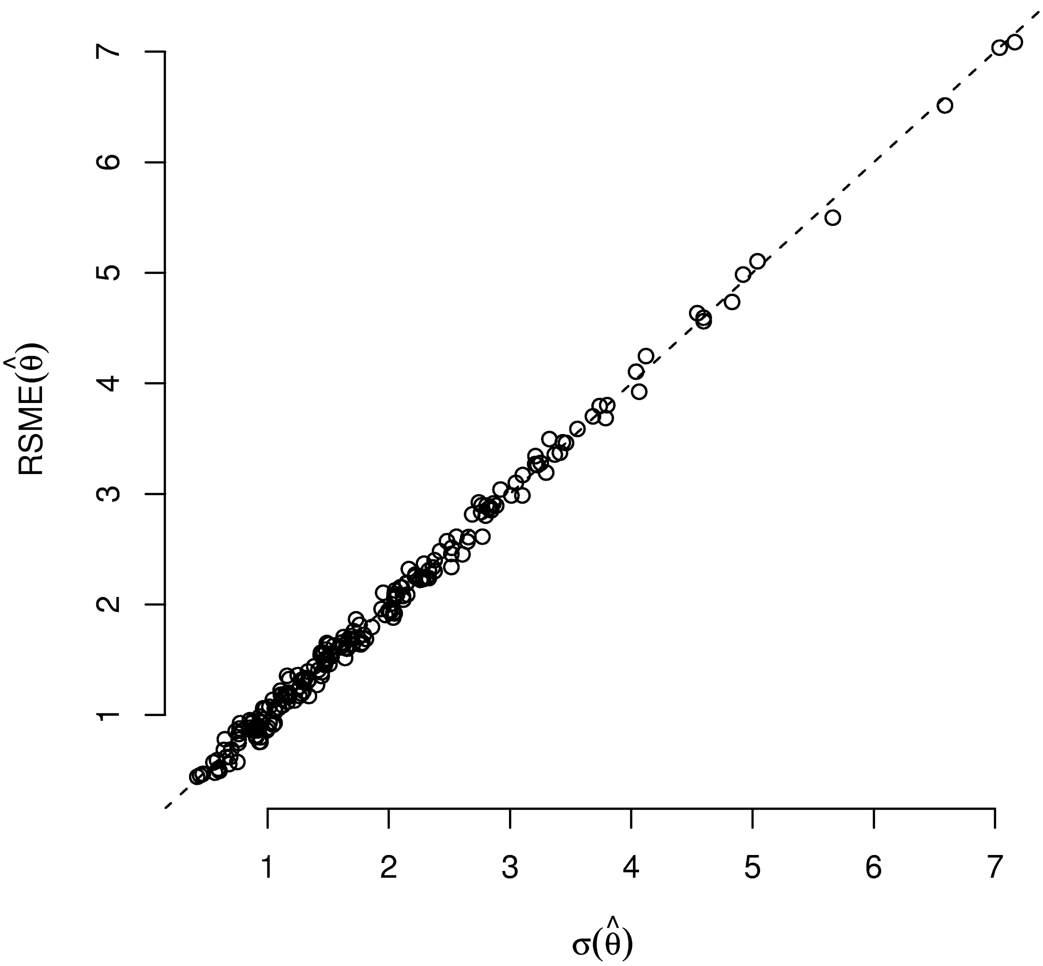


Figure 15 : Mean magnitudes of observed estimation errors

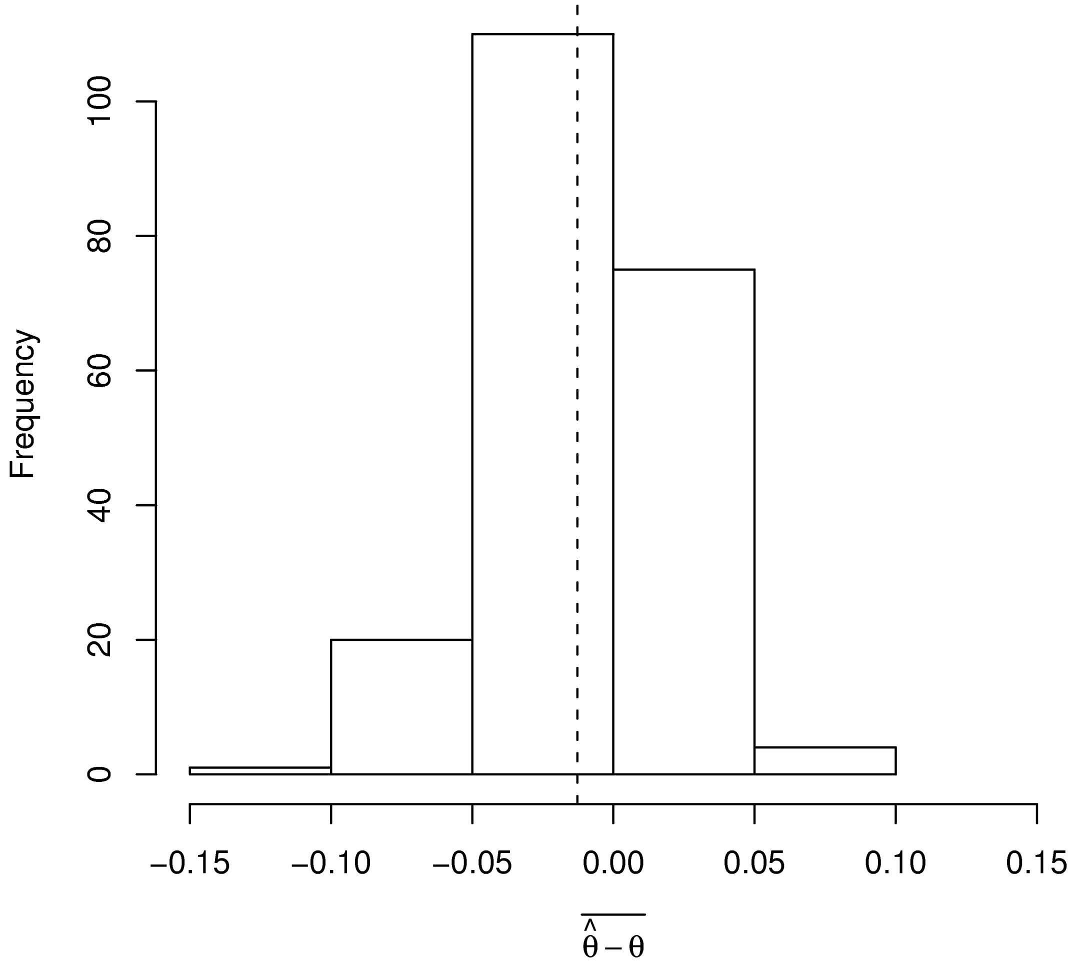
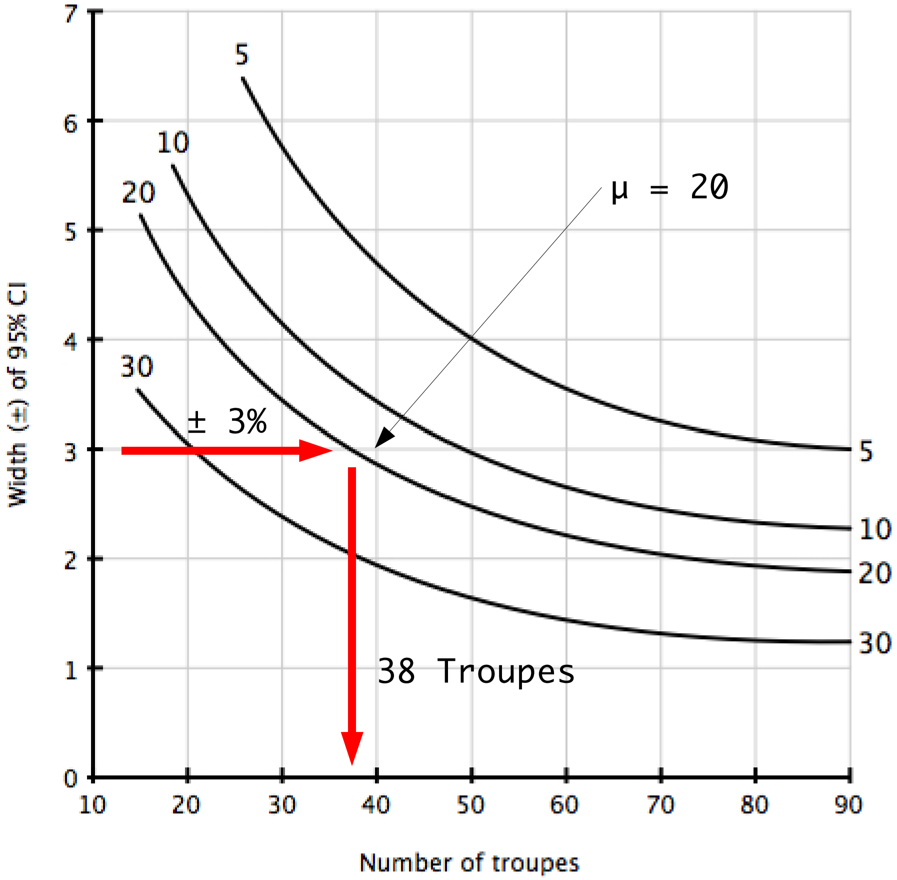


Figure 16 : Sample size nomogram example (see text)



Line labels refer to mean troupe size (μ)