Malaria Indicator Survey

Guidelines for Sampling for the Malaria Indicator Survey

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I. GENERAL PRINCIPLES FOR SAMPLING FOR MALARIA INDICATOR SURVEYS

All large-scale sampling activities should be guided by a number of general principles to achieve consistency and the best quality in survey results. This manual presents general guidelines on sampling for the Malaria Indicator Survey (MIS), although some modifications may be required for country-specific situations. This manual is based on The Demographic and Health Survey Sampling and Household Listing Manual.[1]

SURVEY COVERAGE

An MIS sample should cover 100 percent of the target population. The target population typically depends on malaria endemicity (see Section II below), but may also be based on program-targeted areas. The target population may thus be the entire country, all malarious areas for a national survey, or selected regions or malaria-program areas for a sub-national survey. The general sampling principles are the same for each type of survey. For both national and sub-national surveys, exclusions may be necessary because of extreme inaccessibility.

PROBABILITY SAMPLING

Probability sampling must be used. A probability sample is defined as one in which the units are selected with known and nonzero probabilities. This is the only way to get unbiased estimation and to be able to evaluate the sampling errors. The term excludes purposive sampling, quota sampling, and other uncontrolled non-probability methods because they cannot provide precision and/or confidence evaluation of survey findings.

PRE-EXISTING SAMPLING FRAME

A probability sample can only be drawn from an existing sampling frame that provides a complete list of statistical units covering the target population. Since the construction of a new sampling frame is likely to be too expensive, an MIS should use an adequate pre-existing sampling frame. This is possible for most countries where there have been population censuses in recent years. However, an evaluation of the quality and the accessibility of the frame should be part of the protocol of the survey. This may require the cooperation of the country's national bureau of statistics. In the interest of economy and coordination, an MIS could be integrated with an ongoing national survey program. However, as the sampling frame may be limited to malaria endemic areas or program-targeted areas, local assistance in identifying areas for potential exclusion based on malaria endemicity or targeting is advisable (see Sections III and IV below).

SIMPLICITY OF SAMPLING DESIGN

In large-scale surveys, non-sampling errors are usually the most important sources of error and are expensive to control and difficult to evaluate. It is important to minimize this type of error in survey implementation. Therefore, the sampling design for MIS should be as simple and straightforward as

[1] ICF International. 2012. Demographic and Health Survey Sampling and Household Listing Manual. MEASURE DHS, Calverton, Maryland, U.S.A.: ICF International.

possible to facilitate accurate implementation. ICF International's experience with Demographic and Health Surveys (DHS) shows that a two-stage cluster sampling design is appropriate, as discussed in Section VIII of this manual.

Pre-selected Households

To prevent bias, the standard MIS recommends that households be pre-selected in the central office prior to the start of fieldwork rather than by teams in the field. The interviewers are asked to interview only the pre-selected households; no changes or replacements are allowed in the field. To perform pre-selection of households, a complete list of all residential households in each of the selected sample clusters is necessary. This list is usually obtained from a household listing operation conducted before the main survey.

In the sections that follow, the general MIS policy is described in relation to a number of specific aspects of sampling design and implementation.

II. TARGET POPULATION

MIS is designed to measure Roll Back Malaria (RBM) core population-based malaria indicators. Information needed to collect these indicators come from household interviews (for ITN and IRS indicators) as well as from interviews with women of reproductive age (for IPTp and case management indicators). Biomarker testing is also typically done on all children 6-59 months of age in the household (for anemia and parasitemia prevalence estimates).

The target population for households and individuals is limited to those at risk for malaria. Therefore, the *target population* of individuals for MIS is defined as all women of reproductive age (15-49 years old) and all children under five years of age living within malaria endemic or epidemic-prone areas.

Considerations for countries with varied malaria transmission are discussed in Sections III and IV.

III. SURVEY DOMAINS

To compare the survey results for different household characteristics (such as urban and rural areas, different administrative or geographical regions, high- and low-intensity malaria transmission regions, high and low levels of malaria programmatic activity, etc.), the target population is subdivided into *study domains* or major segments of the population for which separate statistics are needed. It is expected that indicators will be tabulated at the national level as well as at the survey-domain level.

For a national survey for countries with endemic and/or epidemic-prone malaria throughout, the coverage should include the entire national territory without omission unless there are justifiable reasons for excluding certain areas. For countries that contain regions without malaria transmission that are excluded from the survey, these regions should constitute a coherent domain. A survey from which a number of scattered zones have been excluded is difficult to interpret and use. If a malaria program implements very different levels of programmatic activity from one malarious area to the next, then "level of programmatic activity" could be a characteristic used to define survey domains. Thus, a survey might measure malaria indicators separately for different parts of the country with different levels of program activity (and a single national estimate could also be calculated).

In order for survey estimates to be reliable at the domain level, it is necessary to ensure that the size of the target population in each survey domain is sufficient, especially when desired levels of precision are required for particular domains. For a design domain, adequate sample size is achieved by allocating the target population at the survey design stage into the requested design domains, and then calculating the sample size for the specific design domains by taking the precision required into account.

If domain-level estimates are required, it is best to avoid a large number of domains because otherwise a very large sample size will be needed which has logistic and quality implications for the survey. The number of domains and the desired level of precision for each must be taken into account in the budget calculation and assessment of the implementation capabilities of the implementing organization. The total sample size needed is the sum of sample sizes needed in all exclusive (first level) domains.

IV. SAMPLING FRAME

A *sampling frame* is a complete list of all sampling units that entirely cover the target population. The existence of a sampling frame allows a probability selection of sampling units. For a multi-stage survey, a sampling frame should exist for each stage of selection. The availability of a suitable sampling frame is a major determinant of the feasibility of conducting an MIS. This issue should be addressed in the earliest planning for a survey. A sampling frame could be an existing sampling frame, an existing master sample, or a sample of a previously executed survey of sufficiently large sample size that allows for the selection of subsamples of the desired size for the MIS. The best frame is the list of *enumeration areas* (EAs) from a recently completed population census.

In most cases, an area sampling frame, which is a list of the EAs in a complete census, is available. This list should be thoroughly evaluated before it is used. The sampling frame used for the MIS should be as up-to-date as possible. It should cover the whole country or subnational area included in the survey, without omission or overlap. Maps should exist for each area unit or at least groups of units with clearly defined boundaries. Each area unit should have a unique identification code or a series of codes that, when combined, can serve as a unique identification code. Each unit should have at least one measurement of size estimate (population and/or number of households). If other characteristics of the area units (e.g., socioeconomic level) exist, they should be evaluated and retained because they can be used for stratification.

Regions within countries without endemic or epidemic-prone malaria should either be excluded from the sampling frame of EAs or treated as a separate domain (stratification by urban and rural residence should still be done). For some countries, simply excluding highland areas (with mean ambient monthly temperatures below 18˚ C) may suffice. Within others, advice from experts from the ministry of health, local universities, or resident experts in malaria, as well as information from the scientific literature and/or malaria risk maps should be sought in developing the most appropriate sampling frame. However, in practice this task may prove challenging because boundaries of malaria endemicity are not always clearly defined or known. As countries move towards elimination, some endemic countries will shift categories. For the most recent data on malaria transmission risk see the Malaria Atlas Project website (http://www.map.ox.ac.uk/).

A pre-existing master sample (which is a random sample of all EAs) can be accepted only where there is confidence in the master sample design, including such detailed sampling design parameters as sampling method, stratification, and inclusion probability of the selected primary sampling unit. The task for the MIS is then to design a subsampling procedure, which produces a sample in line with MIS requirements. This will not always be possible. However, the larger the master sample is in relation to the desired MIS subsample, the more flexibility there will be for developing a subsampling design. A key question with a pre-existing sample is whether the listing of dwellings/households is still current or whether it needs to be updated. If the listing is more than a year old it will require updating, and may need to be done more frequently in certain settings. If updating is required, use of a pre-existing sample may not be economical. The potential *advantages* of using a pre-existing sample are: (1) economy, and (2) increased analytic power through comparative analysis of two or more surveys. The *disadvantages* are: (1) the problem of adapting the sample to MIS requirements, and (2) the problem of repeated interviews with the same household or person in different surveys, resulting in respondent fatigue or contamination. One way to avoid this last problem is to keep just the primary sampling units and reselect the households for the MIS.

In the rare case when neither a census frame nor a master sample is available then alternative frames should be considered. Examples of such frames are:

- A list of electoral zones with estimated number of qualified voters for each zone
- A gridded high resolution satellite map with estimated number of structures for each grid
- A list of administrative units such as villages with estimated population for each unit

A main concern when using alternative frames are coverage problems, that is, does the frame completely cover the target population? Usually checking the quality of an alternative frame is more difficult because of a lack of information either from the frame itself or from administrative sources. Another problem is the size of the primary sampling unit. Since the alternative frame is not specifically created for a population census or household based survey, the size of the PSUs of such frames may be too large or too small for a MIS survey. A third problem is identifying the boundaries of the sampling units due to the lack of cartographic materials. Again, please keep in mind that the need for alternative frames is rare.

In the first two examples of alternative sampling frames, the standard MIS two-stage sampling procedure can be applied by treating the electoral zones or the grids of satellite map as the PSUs. In the third case, when a list of administrative units larger than villages (e.g. sub-districts, wards or communes) is available, for example, a complete list of all communes in a country may be easier to get than a complete list of villages, then it is necessary to use a selection procedure that includes more than two stages. In the first stage, select a number of communes; in each of the selected communes, construct a complete list of all villages residing in the commune; select one village per commune as a MIS cluster, then proceed with the subsequent household listing and selection as in a standard MIS. This procedure works best when the number of communes is large and the commune size is small. A list of administrative units that are small in number but large in size is not suitable for a MIS sampling frame because this situation will result in large sampling errors.

No matter what kind of sampling frame will be used, it is always necessary to check the quality of the frame before selecting the sample. Following are several things that need to be checked when using a conventional sampling frame:

- Coverage
- Distribution
- Identification and coding
- Measure of size
- Consistency

There are several easy but useful ways to check the quality of a sampling frame. For example, for a census frame, check the total population of the sampling frame and the population distribution among urban and rural areas and among different regions/administrative units obtained from the frame with that from the census report. Any important differences may indicate that there may be coverage problems. If the frame provides information on population and households for each EA, then the average number of household members can be calculated, and a check for extreme values can help to find incorrect measures of size of the PSUs. If information on population by sex is available for each EA, then a sex ratio can be calculated for each EA, and a check for extreme values can help to identify non-residential EAs. If the EAs are associated with an identification (ID) code, then check the ID codes to identify miscoded or misplaced EAs. A sampling frame with full coverage and of good quality is the first element for a MIS survey; therefore, efforts should be made to guarantee a good start for the project.

For a nationally representative survey, geographic coverage of the survey should include the entire national territory unless there are strong reasons for excluding certain areas. If areas must be excluded, they should constitute a coherent domain. A survey from which a number of scattered zones have been excluded is difficult to interpret and to use.

V. STRATIFICATION

Stratification is the process by which the survey population is divided into subgroups or *strata* that are as homogeneous as possible using certain criteria. The purpose of stratification is to enhance the sample representativeness with a given total sample size, thereby reducing sampling errors. *Explicit stratification* is the actual sorting and separating of the units into the specified strata; within each stratum, the sample is selected independently. *Systematic sampling* of units from an ordered list (with a fixed interval between selected households) can also achieve the effect of stratification. This is called *implicit stratification*.

The principal objective of stratification is to reduce sampling error. In a stratified sample, the sampling error depends on the population variance existing within the strata but not between the strata. For this reason, it pays to create strata with low internal variability (or high homogeneity). Another major reason for stratification is that, where marked differences exist between subgroups of the population (e.g., urban vs. rural areas), stratification allows flexible selection of the sample allocation and design separately for each subgroup.

Stratification should be introduced only at the first stage of sampling. At the dwelling/household selection stage, systematic sampling is used for convenience; however, no attempt should be made to reorder the dwelling/household list before selection in the hope of increasing the implicit stratification effect. Such efforts generally have a negligible effect.

Stratification could be single-level or multi-level. Single-level stratification is used to divide the population into strata according to certain stratification criteria. A multi-level stratification is used first to divide the population into first-level strata according to certain stratification criteria, and then to subdivide the first-level strata into second-level strata, and so on. A typical two-level stratification is region-urban/rural stratification. An MIS is usually multi-level stratified.

Strata should not be confused with survey domains. A survey domain is a population subgroup for which separate survey estimates are desired (e.g., urban areas/rural areas). A stratum is a subgroup of homogeneous units (e.g., subdivisions of an administrative region) in which the sample may be designed differently and is selected separately. Survey domains and strata could be the same but they need not be. For example, survey domains could be the first-level stratum in a multi-level stratification. A survey domain could consist of one or several lower-level strata. If only implicit stratification is used, then no explicit strata exist.

At a minimum, the MIS should use explicit stratification to create separate survey domains for urban and rural residence. Where possible, it may also prove useful to use explicit stratification to create specific domains for high- and low-intensity malaria transmission. Where data are available, explicit stratification could also be done on the basis of socioeconomic zones or more directly relevant characteristics such as the level of female literacy or the presence of health facilities in the areas. These kinds of information could be obtained from administrative sources. Within each explicit stratum, the units can then be ordered according to location, thus providing implicit geographic stratification.

VI. SAMPLE SIZE DETERMINATION

The issue of sample size determination is only partly a technical one. Under the same survey conditions, the larger the sample size, the better the survey precision and the more elaborate the analyses that can be sustained. However, the survey conditions will change once sample size reaches a certain level. The challenge in deciding on the sample size for a survey is to balance the demands of analysis with the capability of the implementing organization and the constraints of funding.

An appropriate sample size for an MIS is the minimum number of persons (e.g., currently pregnant women, children under age five, young children who have been ill with fever, births in the two years preceding the survey) within malaria endemic or epidemic-prone areas for whom the desired precision can be achieved for indicators at the national level and at the domain level, if there are domains. If the funding is fixed, the sample size is the maximum number of persons that the funding can cover. Precision at the national level is usually not a problem. In most cases, sample size is decided to guarantee precision at the domain level with appropriate allocation of the sample. Apart from survey costs, the total sample size depends on the desired precision at the domain level and the number of domains.

If a unique *relative precision* (i.e., *relative standard error [RSE]*, see note under Table 1 below) is desired for all domains, the domain sample size depends on the variability and the size of the domain. The total sample size is the sum of the sample sizes over all domains for which desired precisions are guaranteed. In Table 1 we give an example of the calculation of sample size in a domain according to different levels of desired relative precision for estimating the indicator: The proportion of women who had a birth in the two years preceding the survey who received intermittent preventive treatment of malaria for pregnant women (IPTp) during the most recent pregnancy. If the domain size is large enough that the finite population correction is negligible, Table 1 gives the required gross sample size with estimated parameters from a DHS. The estimated parameters are the proportion of women who had a birth in the two years preceding the survey who received IPTp during the most recent pregnancy, the design effect,[2] and the assumed overall response rate for women.[3] For example, if we require a RSE of 12 percent, we should select 1,524 households (enough to obtain 396 women age 15-49 who had a birth in the two years preceding the survey) in this particular domain. Assuming a 90 percent response rate, we expect to obtain completed interviews with 356 women age 15-49 who had a birth in the two years preceding the survey.

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[2] DEFT is a survey parameter calculated in the sampling error tables for selected indicators for all MIS final report. DEFT is the square root of DEFT (see note 2 in Table 1) about its use in sample size calculation.

[3] The assumed overall response rate for women can usually be obtained from a previous survey.

Table 1. Sample Size for Estimating the Proportion of Women Who Received IPT During The Most Recent Pregnancy Among Women Who Had a Birth in the Two Years Preceding the Survey

Estimated proportion	23.4%	Double click to activate Excel. The green colored cells can be overwritten		
Estimated Deft	1.25			
No.of births in last 2 yrs/HH	0.26			
Gross response rate	90.0%			
Relative Standard Error (RSE)	Sample Size (Individual)	Sample Size (Household)	95% confidence limits	
			Lower CL	Upper CL
15.0%	254	977	16.4%	30.4%
14.0%	290	1116	16.8%	30.0%
13.0%	337	1297	17.3%	29.5%
12.0%	396	1524	17.8%	29.0%
11.0%	470	1808	18.3%	28.5%
10.0%	569	2189	18.7%	28.1%
9.5%	630	2424	19.0%	27.8%
9.0%	703	2704	19.2%	27.6%
8.5%	787	3027	19.4%	27.4%
8.0%	889	3420	19.7%	27.1%
7.5%	1012	3893	19.9%	26.9%
7.0%	1160	4462	20.1%	26.7%
6.5%	1346	5177	20.4%	26.4%
6.0%	1579	6074	20.6%	26.2%
5.5%	1879	7227	20.8%	26.0%
5.0%	2274	8747	21.1%	25.7%
3.0%	6316	24293	22.0%	24.8%

Note for relative standard error: The RSE of an estimator is the ratio of its standard error over its estimated value. This measure is independent of the scale of the parameter to be estimated and therefore a unique RSE can be used for all indicators. 2**RSE* is the half-length of the *relative confidence interval* (with a confidence level of 95 percent) of the estimated proportion *P*. The half-length of the confidence interval is 2**P***RSE*. For example, for *RSE*=0.12 and *P*=0.234, the half-length of the relative confidence interval is 0.24, while the half-length of the confidence interval is 0.056. This means that with a sample size of 396 women who had a birth in the two years preceding the survey or 1,524 households, a confidence interval of *P* will have lower and upper confidence limits 0.178 and 0.290, respectively.

Note on the DEFT: For cluster surveys, a two-step process is commonly used to determine sample size. First, one determines an initial sample size by ignoring the clustering. Second, one calculates a final sample size by multiplying the initial sample size by the quantity $(DEFT)^2$. In the above example, if clustering is ignored, the initial sample size is 254 (e.g. after accounting for non-response). The final sample size is 254 * $(1.25)^2$, or 396.

The estimated quantities at the top of Table 1 can usually be obtained from previous surveys or from administrative records. The total sample size for a country with several domains is the sample size obtained in Table 1 multiplied by the number of domains if the same precision is required for all domains. With this example, the total sample size for a country having six domains with approximately the same level of malaria transmission will need to be 9,144 households. In the electronic version of this report, double clicking on the table will activate a Microsoft Excel spreadsheet in which all parameters in green cells can be overwritten for specific requirements.

Table 2 shows a similar example for the indicator: *The proportion of children under five who slept under a mosquito net last night*. The example shows the calculation of sample size in a domain according to different levels of desired relative precision (i.e., RSE) for estimating this indicator. With the same DEFT and response rate, this example assumes that the proportion of children under five who slept under a mosquito net last night is much lower than the proportion of women who receive IPTp against malaria during pregnancy (data from an MIS/DHS/MICS or other national survey), but in this case the number of households needed depends on the average number of children under five per household. For example, if we require the same relative standard error of 12 percent, we need to select only 1,182 households in this particular domain and we expect to obtain information about 925 children under five years of age.

Combined with the results in the first example, if we select 1,524 households in this particular domain, we can guarantee a relative standard error of 12 percent for estimating both the proportion of women who had a birth in the two years preceding the survey who received IPTp against malaria during the most recent pregnancy and the proportion of children under age five who slept under a mosquito net last night. Therefore, for a country with six regions, a sample size of 9,144 households can guarantee the same precision for each domain.

Table 2. Sample Size for Estimating the Proportion of Children Under Age Five Who Slept Under a Mosquito Net Last Night

Estimated proportion	10.5%	Double click to activate Excel. The green colored cells can be overwritten		
Estimated Deft	1.25			
# of Children -5/HH	0.87			
Gross response rate	90.0%			
Relative Standard Error (RSE)	Sample Size (Individual)	Sample Size (Household)	95% confidence limits	
			Lower CL	Upper CL
15.0%	658	756	7.4%	13.7%
14.0%	756	869	7.6%	13.4%
13.0%	877	1008	7.8%	13.2%
12.0%	1028	1182	8.0%	13.0%
11.0%	1224	1407	8.2%	12.8%
10.0%	1480	1701	8.4%	12.6%
9.5%	1640	1885	8.5%	12.5%
9.0%	1828	2101	8.6%	12.4%
8.5%	2049	2355	8.7%	12.3%
8.0%	2314	2660	8.8%	12.2%
7.5%	2632	3025	8.9%	12.1%
7.0%	3022	3474	9.0%	12.0%
6.5%	3504	4028	9.1%	11.9%
6.0%	4112	4726	9.2%	11.8%
5.5%	4893	5624	9.3%	11.7%
5.0%	5920	6805	9.5%	11.6%
3.0%	16444	18901	9.9%	11.1%

The domain sample sizes often need to be balanced between domains under budget constraints. In practice, it is often the case that the total sample size is fixed according to available funding, and then the sample is allocated to each domain. In case of very tight budget constraints and approximately the same level of malaria prevalence, we may equally allocate the total sample to the domains (in this case small domains are oversampled). In some cases, we want to over sample a specific domain, for example, for conducting some in-depth analysis in a high-intensity malaria transmission region. The method (and the tables) presented in the following section may be used to allocate the sample at the domain level because the domains are usually first-level strata. Regardless of the method used for allocation, the above calculation of domain sample size can give us an idea about the precision we may achieve in each domain with a given sample size.

For more detailed information regarding calculation of standard errors please refer to the *Demographic and Health Survey Sampling and Household Listing Manual* [1].

VII. STRATUM SAMPLE ALLOCATION

Once the total sample size of a domain has been fixed, we need to appropriately allocate the sample to strata within the domain. This allocation is aimed at strengthening the sample efficiency at the domain level. Assuming a constant survey cost across strata within the domain, the optimum allocation of the sample depends on the stratum size and the stratum variability on the indicator to be estimated. The *optimum allocation* is optimal for the indicator on which the allocation is based, but it may not be appropriate for another indicator. For a multipurpose survey, if the strata are not too different in size, a safe allocation that is good for all indicators is a *proportional allocation*, with sample size proportional to the stratum size. This allocation introduces a constant sampling fraction across strata within the domain. Because the MIS is a multipurpose survey, a proportional allocation of the sample is recommended if the strata are not too different in size. If the strata sizes are very different, small strata may receive a very small sample size. If precisions are considered at the stratum level (e.g., if the strata are first-level strata of survey domains), a *power allocation* with an appropriate power value may be used to guarantee sufficient sample size in small strata. A power value of 1 gives proportional allocation, a power value of 0 gives *equal size allocation*, a power value between 0 and 1 gives an allocation between proportional allocation and equal size allocation. In Table 3, we give an example of sample allocation in a domain of nine strata with a proportional allocation. The minimum stratum sample size is 61 for stratum 7. The actual total sample size may be slightly different from the desired sample because of rounding. See the *Demographic and Health Survey Sampling and Household Listing Manual* for more details (including formulae)[1].

Table 3. Sample Size Allocation—Proportional Allocation

Sample Size	1000	
Power Value	1.000	
Stratum	**Proportion**	**Allocation**
1	0.098	98
2	0.153	153
3	0.136	136
4	0.090	90
5	0.134	134
6	0.148	148
7	0.061	61
8	0.099	99
9	0.081	81

Note: The stratum measure of size could be *absolute size* or *relative size.* Here we used the relative size, which is the proportion of the stratum. To change the *sample size*, *power value, stratum* and *proportion*, double click on the table to activate Microsoft Excel.

If we impose a condition such that the sample size should not be smaller than 100 in each stratum, after trying various power values, we find that a power value of 0.19 is appropriate as shown in Table 4. In this case, we would have a minimum sample size of 100 for stratum 7. The small strata are oversampled compared with a proportional allocation. Oversampling some small strata is frequently encountered in sample allocation for domain-level strata if domain-level tabulations are required.

Table 4. Sample Size Allocation—Power Allocation

Sample Size	1000	
Power Value	0.190	
Stratum	**Proportion**	**Allocation**
1	0.098	109
2	0.153	119
3	0.136	116
4	0.090	108
5	0.134	116
6	0.148	118
7	0.061	100
8	0.099	109
9	0.081	105

The above discussion also applies to sample size allocation to first-level strata/domains in a country where the total sample size is fixed. A proportional allocation is good for all indicators and provides the best precision for the country as a whole. However, if comparisons across domains are required and the total sample size is limited, an equal size allocation is recommended. A power allocation is a compromise between the proportional allocation and the equal size allocation.

VIII. A TWO-STAGE SAMPLE SELECTION PROCEDURE

ICF International's DHS program uses a convenient and practical sample selection procedure on the basis of experience from past surveys—a two-stage systematic sampling procedure. In the first stage, every EA in the country within malaria endemic or epidemic-prone areas is assigned a measure of size equal to the number of households or the population in the EA (probability proportional to size or PPS). In each stratum, a sample of EAs with a predetermined sample size is then selected independently with probability proportional to this measure of size. In the selected EAs, a listing procedure is performed such that all dwellings and households are listed. This procedure is important for correcting errors existing in the sampling frame, and it provides a sampling frame for household selection (see details in Section X below, the *Demographic and Health Survey Sampling and Household Listing Manual* [3]). In the second stage, after a complete household listing is conducted in the EAs, a fixed number of households are selected by equal probability systematic sampling in the selected EAs. In each selected household, a household questionnaire is completed to identify women age 15-49 and children under five. (For details of systematic sampling, refer to *Demographic and Health Survey Sampling and Household Listing Manual* [1] and *Sampling Techniques* [2].)

The implementation of a sample selection procedure involving the selection of an area sample is usually straightforward. Most countries possess convenient area sampling frames, generally in the form of the EAs defined during the most recent population census. These generally come with sketch maps and size counts and, in principle, the EAs do not vary greatly in population size. However, in most countries, there are no satisfactory lists of dwellings and/or households in these EAs (in particular, no address system outside the more affluent parts of the cities). Survey personnel usually have to make their own lists, although sometimes they can share with other surveys or select a subsample from a master sample.

The advantages of this two-stage cluster sampling procedure can be summarized as follows:

1) It guarantees a representative sample of the target population when a list of all target individuals is not available which prohibits a direct sampling of target individuals;

2) A household listing procedure after the selection of the first stage and before the main survey provides a sampling frame for household selection in the central office;

3) The use of residential households as the second-stage sampling unit guarantees the best coverage of the target population; and

4) It reduces unnecessary sampling errors by avoiding more than two stages of selection (which usually uses a large PSU in the first stage of selection).

IX. SIZE OF THE SAMPLE TAKEN PER EA

After the total sample size has been fixed and before the selection of the EAs, we must decide on the number of households to be selected in each EA and then calculate the total number of EAs that need to be selected from the survey domains/strata. The optimum number of households to be selected per EA depends on the variable under consideration, the size of the EA, and the relative sampling cost per EA and per household.

A larger sample size within each EA can reduce survey field costs, but it can also reduce the survey precision if the households are very similar on the variable under consideration within the EA. Because the EAs usually consist of geographically coherent households, experience shows that a strong homogeneity exists among the households within an EA (see *Optimum Sub-sampling in Demographic and Health Surveys* [3]). Furthermore, because an MIS is multipurpose, it is suggested that a large sample size within each EA should be avoided. For a moderately average EA size of 100-300 households and a relative cost of 5 (i.e., the cost of household listing and mapping in an EA is 5 times the cost of interviewing a household), the optimum sample size ranges from 20 to 40 households (see *Optimum Sub-sampling in Demographic and Health Surveys* [3]). Regarding the difference of relative cost between urban and rural EAs, a smaller sample size in urban EAs and a larger sample size in rural EAs are expected (e.g., 25 households per urban EA and 30 households per rural EA are average sample sizes for most of the DHS surveys). For more details regarding calculation of optimal sample sizes per EA, refer to the *Demographic and Health Survey Sampling and Household Listing Manual* [1] and *Optimum Sub-sampling in Demographic and Health Surveys* [3].

X. HOUSEHOLD LISTING OPERATION

After the EAs are selected, a complete listing of dwellings/households in the EAs is necessary before the selection of households. The listing operation consists of visiting each of the selected clusters, recording on listing forms a description of every structure together with the names of the heads of the households found in the structure, and drawing a location map of the cluster as well as a sketch map of the structures in the cluster, recording on listing forms a description of every structure together with the names of the heads of the households in the structures and other characteristics. The mapping and listing operation represents an appreciable field cost, but there is no reliable substitute method for avoiding this step.

The listing operation represents one of the most important bias correction procedures in the survey, especially when the sampling frame is outdated. The listing operation will provide complete information on the number of residential households, households occupied, and households vacant. This information is necessary for an equal probability random selection of households in the second stage. With the household listing prior to the main survey, it is possible to pre-select the sample households in advance and the interviewers are asked to interview only the pre-selected households without replacement of non-responding households. With the sketch map and the household listing of the cluster produced in the household listing operation, the sampled households can be easily relocated by interviewers later. The fieldwork procedure for DHS surveys is designed to be replicable and therefore allows easy supervision; all these elements are designed to prevent serious bias during data collection.

It is not acceptable to omit the listing procedure. Methods in which interviewers select clusters themselves, and methods in which interviewers select households themselves (for example selecting households at fixed intervals during a random walk up to a predetermined quota) are not acceptable. These methods do not guarantee a nonzero probability to every potential respondent; second, the procedure is not replicable, which complicates the field work supervision; and third, it can end up with a sample of easy units because of the lack of effort to make call backs to households or individuals who were not available at the first attempt to interview. *It is more efficient to reduce the sample size and retain the listing operation.*

Listing costs can be reduced by using segmentation to decrease the size of some of the big EAs; however, segmentation generates its own costs, and skill in map making and map interpretation is required. For more details about segmentation, see Section XI below. For more details about the listing operation, refer to the *MIS Household Listing Manual* or the *Demographic and Health Survey Sampling and Household Listing Manual* [1].

It is quite probable that some traditional tools in the household listing process will be modified in the future by using more sophisticated technology such as the geographic positioning systems (GPS) in order to collect more precise location information for the selected EAs. With such tools survey implementers can produce more precise distribution maps of the structures with less supervision than the traditional approach. The main feature is that every selected EA and every selected structure/dwelling can be located with high precision and thus relocated later, if desirable. In addition, GPS information is increasingly used in data analysis and presentation. At a minimum, collecting one coordinate for every selected cluster is recommended unless this information is already available from the sample frame used for the survey (i.e., census frame). See the *MIS Household Listing Manual* for more details of the household listing operation. Please note that even in the case in which GPS are used to collect coordinates of households for mapping, this information should be aggregated to the cluster level before the data are shared publically for protection of confidentiality of survey respondents.

XI. SEGMENTATION, MAPPING, AND LISTING

A census EA is sometimes too large (up to 800 households) to be economically feasible for a single survey to undertake the listing of all households in the EA. Such EAs need to be segmented into smaller areas for a further stage of area sampling before household listing begins. In some cases, the census maps are not accurate enough for the work of segmentation to be done in the office. A field operation may be needed to map and segment these oversized EAs. To better control the fieldwork, it is recommended that only the fieldwork coordinator or team supervisor be given the authority to decide which EA should be segmented and how many segments will be created in the EA.

To segment an EA, a standard segment size should be adopted: typically, about 200 households would be an appropriate segment size if 25-30 households are to be selected in the entire EA. Segmentation becomes progressively more difficult as segments become smaller because there are not enough natural boundaries to delineate very small segments. Moreover, concentration of the sample into smaller segments increases the sampling error; because neighbors' characteristics are correlated, a smaller segment captures less of the variety existing in the population, which leads to less efficient sampling. There is a point beyond which it is not useful to attempt further segmentation. As a general rule, the average segment size should not be less than 100 households.

If it is possible, it is recommended that segments of approximately equal size be created. In most cases, segmentation can only be carried out in the field. Each selected EA, whether due for segmentation or not, should be visited to verify maps. When this has been done, the same team can proceed to create the designated number of segments and to delineate them clearly on the map of the unit. If size measures (e.g., the number of households) are required using a quick count, these can be obtained at the same time. For more details of the segmentation operation, see the *MIS Household Listing Manual*.

Selection of the sample segment in each segmented EA is the next step. It is important to prevent biased selection. Clear instructions on how to select the segment should be given to the team doing the segmentation in the field, together with necessary parameters (i.e., the random number). A probability proportional to segment size selection is recommended (see the *MIS Household Listing Manual* for more details). Furthermore, control procedures should be introduced to ensure that no conscious biased selection occurs.

The next step is mapping and listing. Mapping refers to drawing a sketch map of the selected EA (or segment of an EA) that shows, to the extent possible, the location of the dwellings together with landmarks found in the EA. The listing should be on a dwelling and household basis (i.e., listing of inhabited dwellings together with all households residing in each dwelling), including dwellings where households are absent at the time of the visit by the listing team. The subsequent interview should cover the current occupants of the listed dwelling whether or not they occupied it at the time of listing. Normally, listing should not be done by the interviewers and for this reason and logistical reasons a gap of at least one month is to be expected. For more details, refer to the *MIS Household Listing Manual*.

XII. HOUSEHOLD SELECTION

Once the mapping and household listing operation is completed, the household lists should be sent to the central survey office for the selection of households. The recommended household selection procedure is equal probability, systematic sampling using the enumerated list of occupied residential households. This procedure consists of selecting the sample households from the listing with a random start by the following criteria:

1. The first selected sample household is *k* (*k* is the serial number of the household in the listing) if and only if:

$$(k\text{-}1)/L < Random \leq k/L$$

2. The subsequent selected households are those having serial numbers:

$$k + (j\text{-}1)*I\ , \quad \text{(rounded to integers)}$$

   for $j = 2, 3, \ldots n$; where L is the total number of households listed in the EA, *Random* is a random number between (0, 1), $I = L/n$ is the sampling interval, and n is the number of households to be selected in the EA.

It is important to note that the *random* numbers should be independent from EA to EA. Usually, a Microsoft Excel spreadsheet is prepared for household selection. When household listing results are entered, the selected households will appear automatically in the designated places. ICF International has developed a variety of Microsoft Excel templates for household selection to meet different requirements [4]. Table 5 gives a sample template for household selection.

Table 5. Sample Template for Household Selection

EA ID Information		HHs Listed	# of HHs to be selected	Selection interval	Random (0-1)	HOUSEHOLD SELECTED														
						1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
XXXX	XXXX	250	20	12.50	0.98385	13	25	38	50	63	75	88	100	113	125	138	150	163	175	188
XXXX	XXXX	234	20	11.70	0.61076	8	19	31	43	54	66	78	90	101	113	125	136	148	160	171
XXXX	XXXX	197	20	9.85	0.50400	5	15	25	35	45	55	65	74	84	94	104	114	124	134	143
XXXX	XXXX				0.00938															
XXXX	XXXX				0.36631															
XXXX	XXXX				0.75011															
XXXX	XXXX				0.07051															
XXXX	XXXX				0.70154															

Note: In the electronic version of this report, double clicking will display the whole spreadsheet.

Though an equal probability, systematic sample is easy to select, centralization of the household selection is necessary so that the completeness of the household listing operation can be assessed by experienced survey staff. Discrepancies between the expected and the listed number of households must be evaluated. Problem areas should be revisited. Sampling fractions could also be readjusted so as to give the expected number of households. In cases where it is not feasible to centralize household selection, especially when regional household listing teams are employed and travel is difficult, supervisors could be trained to do the selection in the field. However, in this situation, the evaluation of the quality may not be possible.

XIII. THE HOUSEHOLD INTERVIEWS

While logistically more difficult, it is *strongly recommended* that the household interviews for the MIS be conducted during or right after the rainy season. If the household interviews are conducted during the dry season when mosquito nuisance is lowest, it is likely that reported household insecticide treated net (ITN) possession and use and other important malaria prevention and treatment indicators will be underestimated. However, it should be expected that conducting the interviews during the rainy season will likely increase survey costs per EA; thus, the budget for the survey should be prepared accordingly. Conducting survey fieldwork during the rainy season may also render some remote areas more problematic to access. However, such remote or difficult-to-access areas should be included in the survey if at all possible to avoid selection bias.

After the selection of households, the interviewing team will be sent to the EAs and an assigned workload for visiting the selected households will be given to each interviewer. The interviewer must visit only the households she has been assigned; she must not change or replace a previously selected household with another household. Any unusual circumstances (dwellings not found, destroyed, or vacant) must be properly documented and reported.

Once the interviewer locates an assigned household and after careful verification, the interviewer will begin the household interview by listing household members and visitors, identifying eligible respondents for the individual interview, and asking questions about household characteristics and mosquito nets owned by the household. Eligible women are defined as those who are in the specified age group (15-49), and are either usual members of the selected household or who slept in the household the night before the interviewer's visit. Eligible children (about whom questions on diagnostics and treatment are asked) are defined as biological children of interviewed women who were born in the year of the interview or in the previous five calendar years. Eligible children for biomarker testing are those less than 6 years of age and greater than 6 months of age who are usual members of the selected household or who slept in the household the night before, and for whom consent was given to participate.

Conscious omission of eligible individuals on the part of an interviewer by mis-reporting their age outside of the eligible age group is a real concern. Measures to eliminate this problem should be undertaken. For example, the field editor should check the consistency of each completed questionnaire and, if suspicious things are identified, should return to the household for further verification of key items such as the number of household members, number of eligible individuals and number of children under age five. These checks can be automated when using electronic data collection tools.

In the event of failure to contact a household or an eligible person in the first visit, the interviewer is required to make at least two repeat visits, or call backs, on different days and at different times of the day before the interview is abandoned. The process of making call backs may require the teams to stay in a cluster for two to three days. If an entire cluster is covered in one day, the potential for non-response bias needs to be considered and care taken to ensure that call-backs are completed. Both theory and practice prove that call backs and efforts to get difficult units to respond to the survey are the best way to remove bias and reduce the non-sampling errors to a minimum.

Additional details about the household interview procedures can be found in the interviewer's manual.

XIV. DATA COLLECTION WITH A TABLET COMPUTER

Over the past few decades, a succession of innovative technologies has revolutionized data collection procedures. Intelligent units including cell phones, palm computers, and tablet computers have all been used in the data collection of nationally-representative surveys. This section describes briefly the main advantages and disadvantages of the data collection technologies using a tablet computer. The Madagascar MIS 2011 used a tablet computer in household listing, household selection, and interviews. With these new tools in data collection, it is important to understand how to ask each question and how to handle problems that may arise during an interview. The interviewers need to know how to correctly record the answers given by the respondents and follow the specific instructions of the survey questionnaire. For more details, please refer to the *MIS Interviewer's Manual* in this toolkit or to the *DHS Interviewer Manual* [5].

The computer-assisted personal interview (CAPI) allows the collection of data directly into an electronic form at the time of the interview. It has advantages and disadvantages compared to the traditional paper and pencil questionnaire interview. The main advantage is the ability to produce better data while the main disadvantage is the additional effort required to prepare the data collection instruments and train the interviewers to handle the machine efficiently.

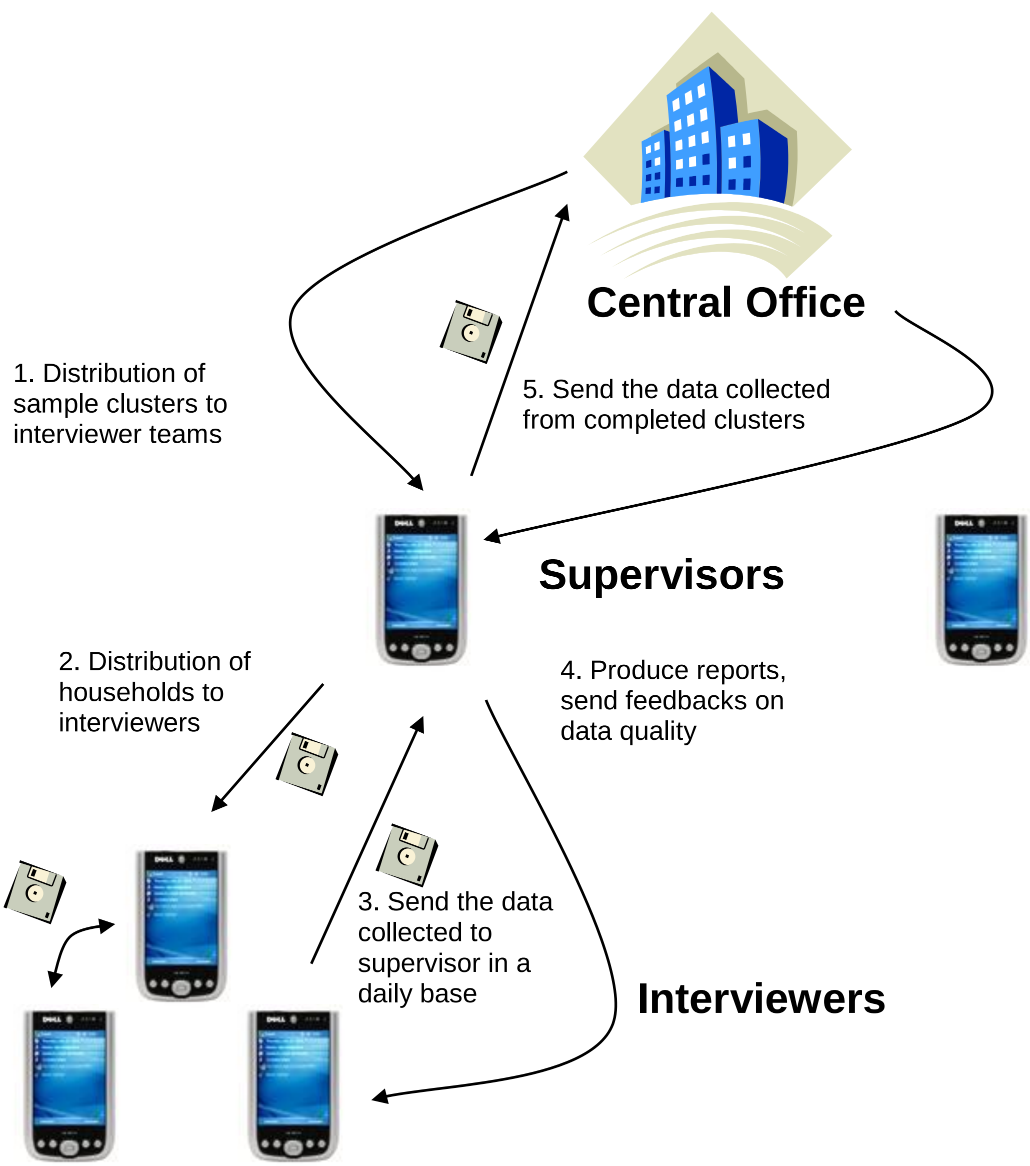
Advantages:

- Cleaner data:
  - Ability to review a range of controls immediately
  - The program automatically skips to the correct next question based on an answers to previous questions, thus avoiding skip and filter errors
  - The ability to check data consistency during the interview
  - Dynamic adaptation of questions on the screen presents survey questions in correct format to the respondent, including the use of the names of household members already entered
- Data available for advanced treatment or for immediate analysis right after collection, providing:
  - Ability to better track the data collection process at all stages
  - Ability to produce quality control tables at the early stage data collection
  - Ability to produce preliminary results at early stage after completion of data collection
- Reduction of the need of secondary edition of the data, providing :
  - Reduced total time in data processing
- Reduction the cost of questionnaire printing; only about 5 percent of paper questionnaire will be printed for the purposes of training/exercises in case of system failure during the main fieldwork training
- Deleting the cost of following survey budget compared to a paper-pencil survey:
  - Supervisors
  - Questionnaire management and archiving personnel
  - Data entry personnel
  - Computers for data entry
  - Questionnaire storage places and furniture
  - Questionnaire transportation cost
- Supports multiple languages

Disadvantages:

- Cost of the equipment for data collection, though this cost is often balanced by the saving cost of questionnaire printing
- Requires a great effort to prepare the program data collection procedures including household listing, household selection, and household interviews
- Compared to paper pencil questionnaire, the final questionnaire is needed at an earlier stage of the project due to fieldwork procedures programming compared to paper pencil questionnaire
- Can facilitate 'cheating'; however this can be mitigated with proper supervision and follow up of the fieldwork and data quality control once data are received from the field

Figure 1. Diagram of Workflow Using a Tablet Computer in Data Collection



XV. WEIGHTING THE SURVEY DATA

Because of the potential non-proportional allocation of the sample and the difference in response behavior across the survey domains, sampling weights will be required for any analysis using MIS data to ensure the actual representativeness of the sample. Since the usual MIS sample is a two-stage stratified cluster sample, sampling weights will be calculated based on sampling probabilities that will be calculated separately for each sampling stage and for each cluster. We use the following notations:

P_{1hi}: first stage's sampling probability of the i^{th} cluster in stratum h
P_{2hi}: second-stage's sampling probability within the i^{th} cluster (households)
P_{hi}: overall sampling probability of any households of the i^{th} cluster in stratum h

Let a_h be the number of clusters selected in stratum h, M_{hi} the number of households according to the sampling frame in the i^{th} cluster, and $\sum M_{hi}$ the total number of structures in the stratum h. The probability of selecting the i^{th} cluster in stratum h is calculated as follows:

$$P_{1hi} = \frac{a_h \, M_{hi}}{\sum M_{hi}}$$

Let g_{hi} (g_{hi}=25 for all h and i for LMIS 2009) be the number of households selected in the i^{th} cluster in stratum h. The second stage's selection probability for each household in the cluster is calculated as follows:

$$P_{2hi} = \frac{g_{hi}}{M_{hi}}$$

The overall selection probability of each household in cluster i of stratum h is therefore the product of the selection probabilities:

$$P_{hi} = P_{1hi} \times P_{2hi} = \frac{a_h g_{hi}}{\sum M_{hi}}$$

The sampling weight for each household in cluster i of stratum h is the inverse of its selection probability:

$$W_{hi} = 1 / P_{hi}$$

A spreadsheet containing all sampling parameters and selection probabilities was constructed to facilitate the calculation of sampling weights. Household sampling weights and the individual sampling weights are obtained by adjusting the above calculated weight to compensate household non response and individual non response, respectively. These weights are further normalized at the national level to produce un-weighted cases equal to weighted cases for both households and individuals at national level. The normalized weights are valid for estimation of proportions and means at any aggregation levels, but not valid for estimation of totals. Because of the potential for refusals to malaria testing, a malaria testing weight for children under five years of age or any other group tested may be calculated separately if a malaria testing is included in an MIS. For additional guidance on generating or applying weights refer to the DHS sampling and listing manual [1].

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