UNAIDS/WHO Working Group
on Global HIV/AIDS and STI Surveillance

Guidelines
on Estimating the Size of Populations Most at Risk to HIV

UNAIDS
JOINT UNITED NATIONS PROGRAMME ON HIV/AIDS
UNHCR UNICEF WFP UNDP UNFPA UNODC ILO UNESCO WHO WORLD BANK
World Health Organization

WHO Library Cataloguing-in-Publication Data

Co-published by World Health Organization and UNAIDS.

1.HIV infections – epidemiology. 2.HIV seroprevalence. 3.Populations surveillance – methods.
4.Guidelines. I.UNAIDS/WHO Working Group on Global HIV/AIDS and STI Surveillance.
II.World Health Organization. Dept of HIV/AIDS. III.UNAIDS.

ISBN 978 92 4 159958 0 (NLM classification: WC 503.41)

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Design & layout: L'IV Com Sàrl, Le Mont-sur-Lausanne, Switzerland

Printed in

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Acknowledgements

Global surveillance of HIV and sexually transmitted infections is a joint effort of the World Health Organization (WHO) and the Joint United Nations Programme on HIV/AIDS (UNAIDS). The UNAIDS/WHO Working Group on Global HIV/AIDS and STI Surveillance, initiated in November 1996, is the main coordination and implementation mechanism for UNAIDS and WHO to compile the best information available and to improve the quality of data needed for informed decision-making and planning at the national, regional and global levels.

These guidelines are an update to the previous document "Estimating the Size of Populations at Risk to HIV: Issues and Methods" which was produced in July 2003.

WHO and UNAIDS would like to thank Donna Stroup, Rob Lyerla, Mary Mahy and Carolyn Smith for preparing this document. The Guidelines were developed in part based on work done by Virigina Loo and Tobi Saidel in preparation for a training on size estimation for the Asia region in July, 2009.

Significant contributions were also received from Keith Sabin, Lori Newman, Jesus M. Garcia Calleja, WHO headquarters; Peter Ghys, Eleanor Gouws, Karen Stanecki, Rand Stoneburner, UNAIDS headquarters; Evelyn Kim, Abu Abdul-Quader, United States Centers for Disease Control and Prevention; Virginia Loo, Tobi Saidel, Partnership for Epidemic Analysis; Heidi Frank, University of California San Francisco; members of the UNAIDS/WHO Working Group on HIV and STI Surveillance and members of the Surveillance and Surveys Technical Working Group.

The concepts and material presented in this publication were informed by size estimate workshops held in Bangkok, Thailand in July 2009 and Bucharest, Romania in October 2009.

UNAIDS and WHO would like to acknowledge the contributions of the participants of these meetings, including staff of national AIDS programmes and experts in various fields related to HIV epidemiology.

1. Introduction

1.1. Purpose

Measuring and understanding the impact and magnitude of the human immunodeficiency virus (HIV) epidemic presents many challenges. Yet without accurate measures and estimates of the impact and magnitude of HIV, it is impossible for countries to carry out HIV programme activities, such as:

- Advocating for most-at-risk populations
- Planning and implementing HIV prevention, care and treatment programmes
- Evaluating programmes.

Establishing the size of populations most at risk to HIV allows epidemiologists to develop models which estimate and project HIV prevalence [1] or inform countries of the distribution of HIV incidence within their country[2].

Use this guideline to conduct population size estimate studies to measure and understand the populations most at risk to HIV in your country. Note that the guideline does not cover issues around behavioural and biological surveillance among these populations. Refer to the *Guidelines on Surveillance on Most at Risk Populations and Second Generation Surveillance* in this same series for additional information.

A Participant's Manual and slide presentations for training have been developed in conjunction to these Guidelines and can be found on the UNAIDS website. Alternative materials for conducting training on size estimates in Asia are also available from Partnership for Epidemic Analysis.

1.2. Background

Most countries have developed surveillance systems for tracking HIV infection and the behaviours that spread HIV. However, countries may lack the capacity to estimate the size of populations with behaviours that put them at increased risk for HIV.

Recognizing this, a guideline for *Estimating the Size of Populations at Risk for HIV* was developed in 2003 [3] by Family Health International, the Impact Project, the United States Agency for International Development, the Joint United Nations Programme on HIV/AIDS (UNAIDS), the World Health Organisation and the UN Drug Control Programme.

This document updates the 2003 publication with recently developed methods and techniques, including how to develop national estimates from local estimates. Country experience in using the methods is presented.

1.3. Terminology

Populations at increased risk, or most-at-risk, for HIV are often referred to as *hidden or hard-to-reach*. These populations are composed of individuals who engage in behaviours that are sometimes illegal or stigmatizing so these populations tend to avoid disclosure.

Populations most at risk to HIV are often reluctant to participate in activities or programmes that may personally identify them, such as:

- HIV surveillance activities
- HIV prevention, care and treatment programmes.

1.4 Size estimates for understanding HIV surveillance

Most-at-risk populations are of particular importance for HIV surveillance [4,5]. Knowing the number of people with behaviours that put them at increased risk allows epidemiologists to estimate the future course of the HIV epidemic.

The UNAIDS/WHO Working Group on Global HIV/AIDS and STI Surveillance has identified four populations of specific importance for HIV surveillance:

- Sex workers
- Clients of sex workers
- People who inject drugs
- Men who have sex with men.

1.5. Size estimates for advocacy

To convince policy makers and funders of the existence and magnitude of any public health problem, you need to have a good estimate of the size of the population at risk. It is easier for potential funders to neglect the at-risk population if:

- data are unavailable
- the basis of the estimates is not clear.
- inconsistencies between estimates are not explained

Arguments to implement prevention, care and treatment programmes are more compelling when good estimates of sizes of at-risk populations are available. The estimates of size must be based on sound methods that can be replicated.

Advocacy is important at different levels. In countries with decentralized public health systems and decision making, such as China, India, Indonesia, Nigeria and Mexico, local governments may see limitations in using national data to advocate for and influence public health action in their region. Local information is needed to develop more appropriate interventions when epidemics are diverse and vary from region to region within a country.

1.6. Size estimates for prevention, care and treatment programmes

Planning and implementing prevention, care and treatment efforts are more difficult with populations at increased risk to HIV as compared to interventions for the general public. Governments may find it politically challenging to invest in services for people who inject drugs, men who have sex with men and sex workers and their clients because of the stigma toward these groups. Yet serving these groups has the greatest potential for curbing the epidemic in some countries.

Estimates of population size are needed to help with decisions on how resources should be allocated for better programme planning and management. For example:

- HIV prevalence data may show that infection among male sex workers in a certain area is 22 percent, while it is only 11 percent among female sex workers. A first interpretation of these data may suggest that twice as much funding should be targeted toward programmes for male sex workers as for female sex workers.
- However, if you then learn that this area has 5,000 male sex workers and 50,000 female sex workers, then we can estimate that the area has 1,100 male sex workers and 5,500 female sex workers infected. If male and female sex workers have, on average, the same number of clients, it will be appropriate to dedicate more prevention resources to commercial sex between men and women than to that between men and men.

Prevention of new HIV infections requires providing services to most-at-risk populations. It is difficult to plan for adequate services for a specific population if you have no idea how many people are involved. You might have these questions:

- How many sexually-transmitted infection (STI) screening kits are needed to conduct regular screening for all sex workers in a community?
- How many clean needles are needed for a needle exchange programme for the country's drug users?
- How many outreach workers are needed if your programme wishes to contact 50 percent of men who have sex with men at least once a month?

Countries need to determine where to focus their financial resources and how to cost their response. To do this, an accurate estimate of the size of the population is needed to determine the magnitude of the response [6,7].

1.7. Size estimates for HIV programme evaluation

Recently, resources for HIV prevention and risk reduction have shifted away from pilot programmes toward larger-scale prevention programmes. International donors expect measurable progress toward targets. Countries able to document progress are more likely to benefit from funding from international donors. Documenting progress will include, in part, accurately estimating the size of clearly defined populations to provide a measure of HIV prevalence.

1.8. A word of caution

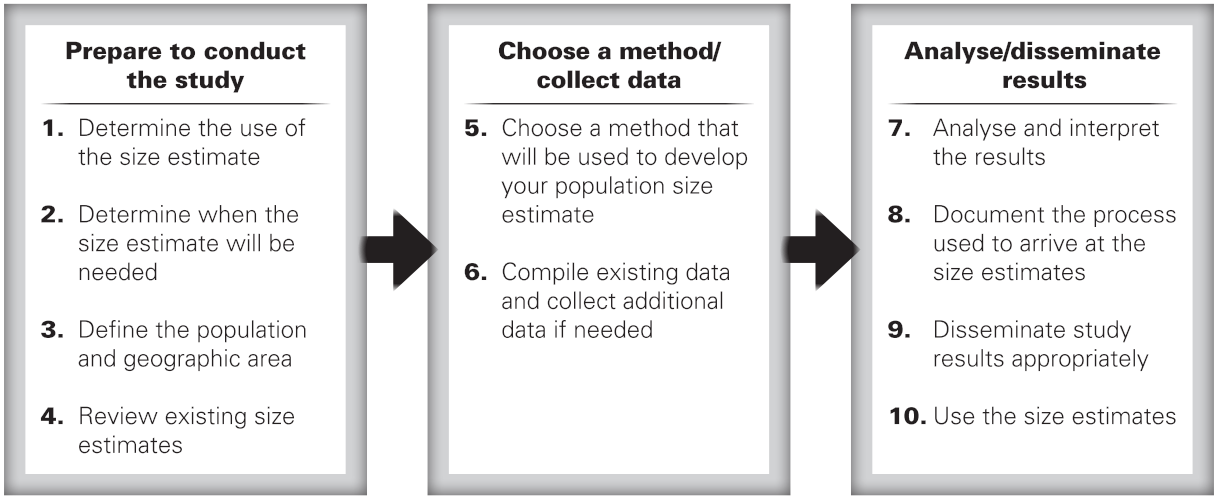
Healthcare researchers assume that population size estimates will be used for a better public health response. Remember that a number of these populations share behaviours that are illegal or stigmatised. Size estimates of the at-risk populations (say, persons who inject drugs) may lead to:

- unwanted or inaccurate reporting in the media or a punitive response by law enforcement
- increased stigma and discrimination.

Take care with the dissemination and use of the resulting size estimates and the data collected to create the estimates. Take measures to ensure the constructive use of the data if you plan to estimate the size of a population.

Remember that good population size estimates are not sufficient for monitoring the HIV epidemic. These data must be combined with other forms of surveillance data from most at risk populations. Similarly, size estimation should not be considered an intervention. If there is no commitment to provide services, do not waste resources with repeated size estimation studies.

Figure 1.1. Process for estimating the size of hidden populations
Additional details provided later in this document



1.9. Process: how to develop a population size estimate

Figure 1.1 below shows a general process for estimating the size of hidden populations. The ten steps are shown in three general areas: prepare, choose a method/collect data then analyse/disseminate results.

The remainder of this document covers the ten steps above. Clear guidance is provided on the different methods with their strengths and weaknesses.

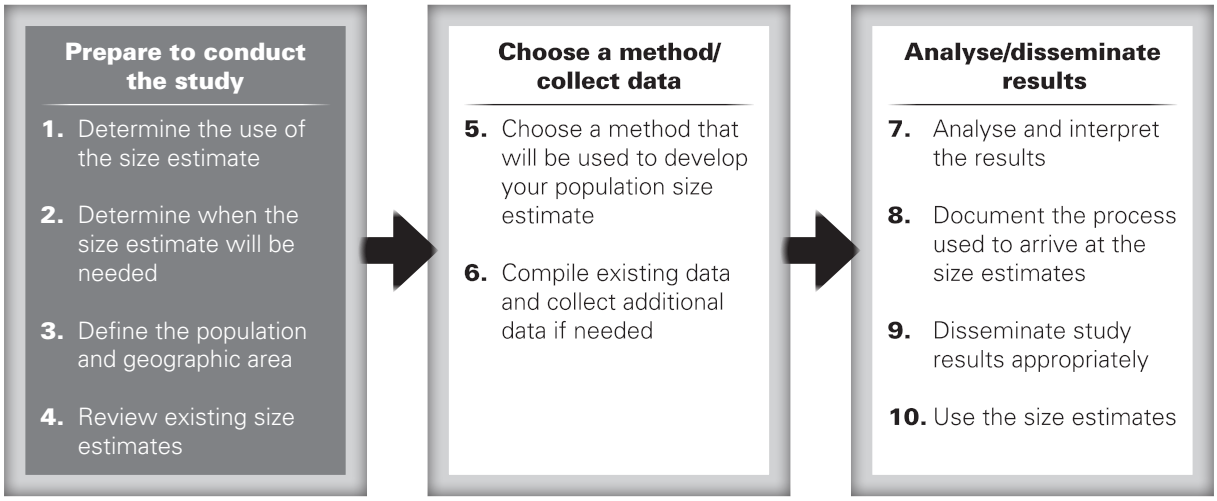
- Prepare, Steps 1–4, Section 2
- Choose a method/collect data, Steps 5–6, Section 3
- Analyse/disseminate, Steps 7–10, Section 4

2. Prepare to conduct population size estimates, Steps 1–4

The first four steps of the process are general preparations you will undertake when you are planning to do a population size estimate. It may be useful to develop the protocol for your size estimates exercise as you complete these steps.

Section 4 of this guideline provides advice on documenting your population size estimation exercise, including how to add to your original protocol so that other study teams or your own team can reproduce your results. Review that section before you begin your estimation exercise so that you have a clear picture of where you are going.

Figure 2.1. Prepare to conduct your population size estimate



2.1. Step 1: Determine the use of the size estimate

The planned use of the estimate influences the method you will choose in step 5. For example:

- If your purpose is to estimate how many people inject drugs in a single city so that programmes can provide drug treatment for all, one method would be used.
- If your purpose is to provide an estimate of national HIV infection or of the size of populations at-risk, you would use a different method.

We will learn more about those methods in the next unit. For now, remember that population size estimates are meant to quantify the problem. That is, you are trying to accurately count/estimate population size, not provide access to them for programmes and services. The estimate alone will not solve the problem or provide access to populations at highest risk.

Do you have sufficient resources to mount a new data collection effort? Determine this up front. If you do not have sufficient resources and can just use existing data, adjust your plan on how to present the estimate.

2.2. Step 2: Determine when the size estimate will be needed

When will a size estimate be needed in the coming years? Find this out to determine when to conduct your estimation. As described earlier, there can be multiple purposes or uses for a population size estimate. It may be needed more than once. For example:

- Consider the timing of the national strategic planning process. A population size estimate provides critical information during these planning periods.
- Size estimates are necessary for national costing exercises and justifying funding requests.
- Carry out a size estimate to inform programme and surveillance efforts.
- Coordinate your size estimation plans with planned HIV monitoring and evaluation activities.
- Determine household survey schedules.

The timing of these activities will help you determine when to conduct a population size estimation. Try to do a new estimation every two years because population size changes over time.

2.3. Step 3: Define the population and geographic area

Defining the population and geographic area poses a number of challenges which are described below. It will be important that all stakeholders agree on these aspects before moving forward with your estimation.

2.3.1. Define the population

Often, the most difficult problem in population size estimation is defining the population. For HIV, the general concern is with people whose behaviour puts them at increased risk of infection.

Not all members of a population are at the same level of risk. For example, unprotected anal sex between two men in a monogamous relationship is less risky than a man having unprotected anal sex with a male sex worker. Transsexuals, gay or bisexual men have different levels of risk, yet all are in the category of men who have sex with men.

In another example, the population of people who inject drugs may include healthcare workers who have access to sterile equipment and a strong motivation to conceal their drug use. This population has little risk of HIV infection. You would probably not capture this group in your population size estimate of persons who inject drugs.

Age is important when defining the population for a size estimate. Programme managers and policy makers often need age information to design effective programmes. For example, in some countries a large proportion of sex workers are under 18. If your estimate does not include persons under 18, you will have a significant undercount of sex workers. If people under 18 are specifically not included in the estimate for ethical reasons, state this clearly up front in your plan and when disseminating your results.

Think about how to entirely capture your population of interest. For example, males may acquire drugs for their female partners. To find this hidden population of females who inject drugs, you would have to ask male injectors whether they procure drugs for a female partner.

Keep in mind that risk behaviours change over time. The behaviours may be affected by the economy, tourism, politics, disasters, seasonal migration and successful prevention efforts. This will affect the prevalence of risk behaviours. Since behaviours define the population, the size of the population will change.

Here are some examples of changes:

- A local election may lead to increased enforcement of laws against selling sex. The sex workers may go to other cities or stop selling sex temporarily.
- An outreach programme targeting persons who inject drugs may change risk behaviours. This may change the number of persons considered to be injecting drug users.

The population definition should reflect the population which is of interest and should be directly related to the behaviour that results in the transmission of HIV. For example,

- "men who have had anal sex with other men in the past six months" would be a more accurate definition than "prisoners"
- "sex workers who have received cash for vaginal sex in the past two weeks" would be a more accurate definition than "women frequenting bars"
- "men who have paid for sex in the past one year" would be a more accurate definition than "truck drivers"

The definition should be very specific (including criteria related to frequency or how recently they have done the behaviour) and should be relevant to the purpose of doing the size estimate.

In your results, acknowledge populations you may not have captured either by the way the population was defined, or the limitations of the method used.

It is often necessary to use proxy definitions for at risk populations which are not a distinct social group. A proxy definition uses a socio-demographic characteristic of a group, such as occupation, or places associated with risk behaviour where risk groups are often found (such as men at beer halls, male migrants living in dormitories, etc.). The proxy definition is not the cause of the increased risk to HIV. For example, truckers are often used as a proxy definition for clients of sex workers, because some studies show a higher proportion of truckers reported being clients of sex workers than men in the general population. However, driving a truck on its own is not a risk for acquiring HIV.

A proxy definition is almost always imperfect. Some people who meet the proxy definition may not engage in the risk behaviour, and vice versa, some people who have the risk behaviour may not meet the proxy definition.

The proxy definition is only useful if there is evidence that a high proportion of individuals in the group practice the high risk behaviour of interest. When using data from proxy groups to describe the epidemic, be clear why a proxy group is adopted and document any local data that demonstrate the proxy group does define a population with higher risk behaviours.

2.3.2. Think about your population's geographic area

Population members at different locations may have different behaviours. These differences will be important for planning the size estimation exercise.

You may wonder if the differences among locations make it impossible to generalise estimates from one city to the rest of the country. The answer is: you will need to adjust your estimates based on these differences. For example, you may need to stratify areas of high, medium and low prevalence of risk behaviour or aggregate estimates from key provinces to create a national estimate. Later in this guideline, we show how to aggregate estimates.

When we say *aggregate*, we mean *combine* several local estimates. This is not as easy as it sounds. Local estimates tend to focus on the total number of people needing services over a given planning cycle, such as a year. But the target population may not be in the geographic area for the whole time. For example:

- Sex workers may only sell sex in a city for six months before moving to another city where they are considered "new stock" and can command higher prices. If you were to do a population size estimation of these sex workers, your annual total would be twice as high as the total at any one time.
- Sex workers who work in the capital on weekdays might travel to resort islands to serve holiday clients on weekends. National estimates based on a sum of capital city + resort islands estimates will count the same women more than once, as they move back and forth between capital city and resort islands.

The migration described above will likely result in inaccurate estimates. You will need to understand migration in the sex industry and other predictors of mobility to make good estimates in such situations.

2.3.3. Improve your definitions with formative research and mapping

When you are preparing to do a size estimate, **formative research** should be used to improve your understanding of the population of interest. Formative research is research conducted during the planning of your study to determine the best ways to reach the population. The results of this research should help

you decide on the population definition and the geographic definition.

Formative research often involves qualitative techniques such as open ended interviews, observation, focus group discussions. Formative research for size estimation might include:
- talking to members of the population at increased risk to HIV,
- talking to persons who provide services to that population, persons who reside or work in areas where the population congregates
- observing the population
- reading existing literature on the population.

By conducting formative research it is possible to learn:
- whether the population is visible
- which sub-groups of the population are not visible
- where the population congregates
- where the population receives services
- what time of day the population is approachable for data collection
- how the population networks
- who the gatekeepers are to the population
- how they react and interact with public officials such as survey implementers or police

Most importantly, this information will help you determine possible data sources and sampling methods.

For most size estimation exercises, **geographic mapping** will also be useful. Geographic mapping describes the universe of places where the population congregates. Geographic mapping can also provide a rough estimate of the population size and characteristics of the locations where the population congregates.

Mapping is a process or tool and is not a size estimation method on its own. It is often used with census and enumeration but is also useful to help with the other methods described in this document.

Mapping is also essential for planning programmes and services for at risk populations. Interaction with members of the population or persons familiar with the population will be useful when designing and improving HIV prevention programmes.

In summary, formative research provides the social mapping for the size estimation exercise. It will help you define and describe the population of interest, it will help you understand the factors which influence their behavior, and determine the best way to reach the population. While geographic mapping will provide the physical description and the characteristics of the area where you will be working.

2.4. Step 4: Review available data

In estimating the size of most-at-risk populations, different approaches or methods will be needed in different situations. You will need to adapt your plans and methods to make them suitable for your country and populations.

2.4.1. What data are available?

Many of the methods described later in this guideline rely on data taken from existing sources. Before undertaking a population size estimate, uncover existing data for different geographic areas.

The 2003 version of this guideline provided a tool to help countries organize data sources according to the population. That tool is provided in this document as Appendix A. The tool is useful for anyone thinking about an estimation project.

Find out if the data are accessible. Do not assume that one government agency has a comprehensive idea about what data are collected by other agencies. For example:
- A ministry of public health may not have access to data collected by law enforcement.
- Law enforcement may hesitate to share numbers because they feel that the presence of sex workers or drug users reflects a failure on their part.
- Clinics may be reluctant to share data due to confidentiality concerns.

Now evaluate the data. Are they appropriate for population size estimation?

- Do the data allow identification of members of the particular population? For example, prison records may not allow identification of people who use drugs since many drug users in prisons may be charged with other offenses. This produces unacceptable missing data that will bias population size estimates.
- Is the data quality good? For example, workers in clinics may not pursue risk factor information for fear of alienating people in treatment. This produces unacceptable missing data that will bias population size estimates.
- Do legal or other regulations prevent the use of existing data sources by public health analysts?

If existing data are judged to be inadequate or insufficient, consider planning new data collection activities in the country. Again, think about existing activities. For example, a survey can be revised with additional questions to provide information for population size estimates. You might use:

- a national census
- an HIV surveillance activity
- a national health status survey.

2.4.2. What previous size estimates are available?

Continue your preparations by studying existing population size estimates. When you review previous estimates, consider:

- the method used
- the definition of the population
- the results
- how the estimate was used.

Find out what challenges were encountered and overcome in previous size estimates studies. Try to think of ways to avoid these issues in future studies.

Examine the source of existing estimates. Evaluate possible conflicts of interest. It is commonly assumed that calculations underestimate the size of populations-at-risk because of concerns of stigma [8]. But organizations may have an interest in high estimates for the populations they serve because a higher estimate means more funding for activities and programmes.

Addressing ethical issues

This is an essential part of your preparation if you plan to collect data on populations of persons at an increased risk of HIV. In many cases, the HIV surveillance target population are, themselves, vulnerable populations. Collection and storage of data on individuals and their risk behaviours may place excess risk of harm to these populations due to stigmatization, economic loss or legal liability [9]. Legal protections of confidentiality may be changing [10].

- Give target populations special protection. Offer privacy during data collection. Ensure data confidentiality measures are in place. Respect for individual privacy creates a perception of confidentiality that enhances the completeness of reporting.
- The ethical principal of "beneficence", or do no harm, extends to providing benefits to surveillance subjects. These benefits include, at a minimum, providing:
  - information about HIV and AIDS
  - counselling and treatment to the extent possible with local resources or participation in future services.
- Young people are particularly vulnerable to exploitation, abuse and other harmful outcomes. If you plan to collect data from adolescents, consult guidelines for this [11].
- Include representatives or legal counsel from the community represented by the target population when you are planning a size estimation.

3. Choose a method then collect data, Steps 5–6

In the next two steps of the process, you will choose a methodology that fits your target population then collect data.

Figure 3.1. Choose a method then compile or collect data

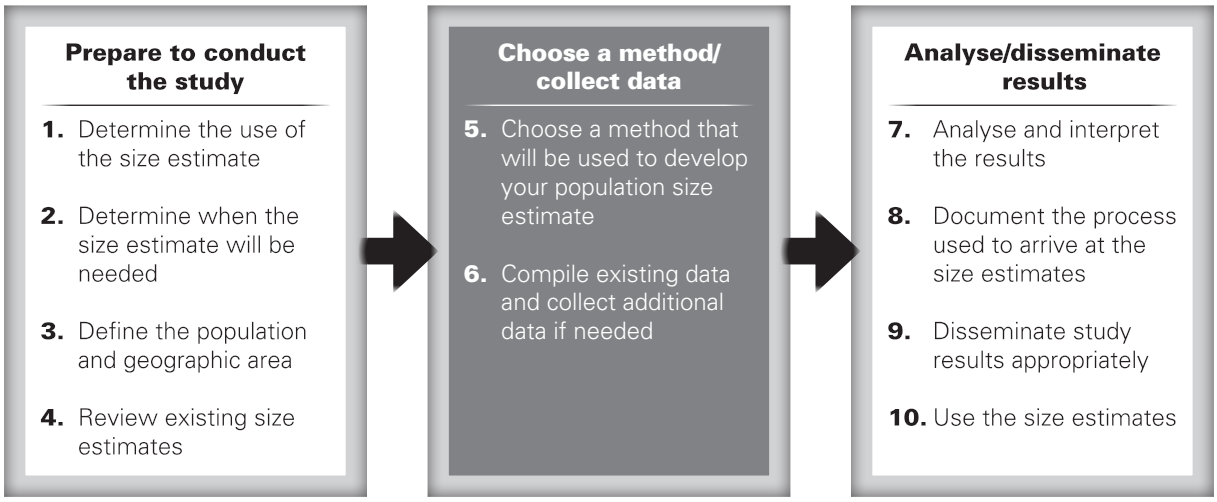


Table 3.1 shows the possible methods you might employ. Each method is then described in the pages that follow the table.

3.1. Step 5: Choose a method to create your population size estimate

The systematic application of methods will encourage more useful at-risk population size estimates for HIV worldwide. Be wary of simple before and after comparisons or reporting selective estimates.

3.1.1. Access to hidden populations

Populations at increased risk for HIV are often referred to as hidden or hard-to-reach. However, some hidden populations are easier to access than others as shown below.

Less hidden sex workers	More hidden sex workers
Sex workers based in brothels: clients come to the brothel. Your study will be conducted in the brothel.	*Call girls:* they have no fixed location but go wherever the client wants to meet. You will not be able to go to any particular location to find them.

It is important that you understand and consider the level of access when you are choosing a size estimation method.

3.1.2. Access to clients of institutions

Institutions that can provide access to individuals or their records may have clients that are at increased risk for HIV. For example:

- drug treatment clinics
- emergency wards

- the justice system
- STI clinics
- public institutions such as schools.

Access to individuals through institutions may be easier than locating the population in the field. However remember that if you are drawing a sample from an institution the sample may not be representative. For example:

- Newer users and users who are not dependent on criminal activity to support their drug use will not be well-represented in jails and the criminal justice system.
- IDU in treatment are not currently injecting, in theory
- Emergency wards will over-represent users of toxic substances.
- STI services will represent sex workers with the riskiest behaviours.

Your knowledge of institutional policies concerning data access and confidentiality will help you to effectively collect data and estimate the population size.

3.1.3. Overview of the methods

Table 3.1 introduces two categories of methods:

- Methods based on data collected from an at-risk population
- Methods based on data collected from the general population.

Table 3.1. Categories of methods for estimating population size

Category 1: Methods based on data collected from at-risk population	
Method name	Short description
Census/enumeration, section 3.2.1 of this guideline	Census counts all members of the population. Enumeration maps an area, counts a fraction of the population in selected areas, and inflates the value to create an estimate.
Capture-recapture, section 3.2.2	Calculates the total size of a population based on two independent captures of population members. The number of members captured in both samples is used to derive an estimate of the total number in the population.
Multiplier, section 3.2.4	Compares two independent sources of data for populations to estimate the total number in the population.
Category 2: Methods based on data collected from the general population	
Population survey, section 3.3.1	Includes questions on high risk behaviours in general population survey
Network scale-up, section 3.3.2	Includes questions on high risk behaviours of respondents' acquaintances in general population survey

3.2. Methods that use data collected from the population at risk

3.2.1. Census and enumeration methods

The simplest methods in this guideline are the census and enumeration methods.

How these methods work

Census methods try to count every individual in an at-risk population. This requires developing a complete list of places that the population may congregate. For example, you might visit every brothel in the city or country and collect information on the number of sex workers based in each brothel. This count has to take place in a very short period of time. Otherwise, sex workers moving between sites may lead to double counting.

Enumeration methods are very similar. Instead of counting every individual:
- Start with a sampling frame or list. A sampling frame is the complete list of individuals (or sites) from which a sample can be chosen.
- Choose a sample of units (such as brothels or shooting galleries) from that list
- Count only the individuals in those chosen units.
- Scale up the number counted according to the size and structure of the sample frame.

For example, for a size estimate of sex workers in brothels in your area:
- break the population into quadrants of a city or districts within a country
- count the number of brothels in each area
- visit a third of the brothels (chosen randomly) to get an average number of workers per brothel
- multiply the average number of workers per brothel by the total number of brothels counted.

In this example, the sampling frame is your list of all brothels or a geographic breakdown of the country or community.

By mapping before you begin, you can be sure to cover all possible geographic areas.

Another approach would be to separate (stratify) the total population of sex workers by the venues where they sell their services (so street-based, brothel-based, call girls and so forth). When you map or stratify, you ensure that you have counted the full population.

Strengths and weaknesses
Census and enumeration methods are straightforward to calculate. They have the advantage of being understood by policy makers who may not be experts in public health statistical or sampling methods. Where a list or sampling frame exists and where the population of interest is well defined and accessible, the census method is less time and resource-consuming than other methods.

The census method does not perform as well for hidden populations or for situations where the population at risk is geographically dispersed. In these situations, the count cannot be completed in a short enough time to compensate for migration so you may count individuals two or more times. Your estimate will be too high. Also, a census is expensive to conduct.

The enumeration method shares some of the strengths and weaknesses of the census method. However, since enumeration covers a fraction of the population, it usually requires fewer resources and is less expensive to conduct. With well-trained community guides covering small areas, enumeration can provide better access to hidden populations. If you choose to use the enumeration method, assess whether data collected from the regions or types of establishments differ in important ways.

If the population is very hard to reach, census and enumeration methods tend to underestimate population size when compared to other methods. However, if the population is poorly defined and persons who are not truly part of the population are captured in the count, the population will be overestimated. If the census or enumeration is conducted over a period of time individuals might be counted twice leading to an overestimate.

Detailed example of census and enumeration
Programme managers in a city suspect that the number of female sex workers has risen over the past 15 years. The programme managers need an accurate, updated estimate. They plan to use the estimate to apply for funding from international AIDS organizations for outreach and prevention services for female sex workers. They also want to know whether the reported female sex worker population might vary by type of establishment so that future services can be targeted correctly.

Two methods were used to derive the estimate: One was a census and the other was a combination of census and enumeration methods.

Using the census method to estimate the number of female sex workers
1. Four trained staff visited every entertainment establishment within the study area
2. These staff counted the individual sex workers.

3. They also asked managers how many sex workers were out with clients or not working for health reasons.

A total of 3,521 sex workers were identified. They were found as follows:
- 42% in karaoke centres
- 26% in hair salons
- 7% street-based
- The remainder were found in massage centres and night clubs.

Thus, the census method suggested that the population size of sex workers who tended to gather in or near these kinds of establishments was 3,521.

Using the census and enumeration method to estimate the number of female sex workers

1. The investigators obtained a list of all registered establishments in the study area. There were:
   - 27 karaoke centres
   - 31 hair salons
   - 16 massage centres
   - 42 nightclubs.
2. Field workers verified the list of establishments by visiting each of the establishments over a three-day period. They found that five of the karaoke centres had closed and three new ones had opened.
3. Field workers visited a random sample of 5 karaoke centres, 6 hair salons, 4 massage centres and 8 nightclubs in one day. They counted the number of sex workers present and asked about regular employees who were absent for health or other reasons.
4. While verifying the list, the field workers had asked the owners to report on the number of sex workers in their establishment. This provided a census estimate of the number of sex workers based on owners reports (similar to the census in the first example).
5. The field workers found that in no case did the number of sex workers they counted in the sample vary by more than 5% from the total reported by the establishment owner.
6. The field workers recorded the number of sex workers with the possible underreporting margin of error as follows:
   - Karaoke centres: 25 centres, 674 workers, no discrepancies
   - Hair salons: 31 hair salons, 723 workers, discrepancies 1-4% (730 to 752)
   - Massage centres: 16 centres, 512 workers, discrepancies 1-3% (517 to 527)
   - Nightclubs: 42 clubs, 1,227 workers, discrepancies 2-5% (1,251 to 1,288)

The study team prepared two estimates from the enumeration data collected and compared the two estimates.

Estimate and error calculation 1: This approach makes two assumptions:
- The locations sampled are a random sample from all such locations
- There is no variability in the discrepancies or likelihood of reporting correctly by type of establishment (that is, any observed variation in underreporting is due to chance).

If we agree to these assumptions, then we need an overall estimate of underreporting for all establishments. If we go back to the discrepancies for the individual centres visited, we can derive an overall estimate of underreporting of 3.2% (the average of the discrepancies). Our estimate is the sum of all numbers reported from the establishments, along with a range of error of 3.2%: 674 + 723 + 512 + 1,227 = 3,136 with a range from 3,036 to 3,236.

Estimate and error calculation 2: This approach assumes that the observed variation in the likelihood of reporting correctly reflects true differences. In this case, we should apply the discrepancies for each type of establishment separately then add the estimates.
- First, an upper limit for all establishments can be obtained by summing the upper estimates: 674 + 752 + 527 + 1,288 = 3,241
- Similarly, a lower point estimate can be obtained from adding the lower limit figures from all types of establishments: 674 + 730 + 517 + 1,251 = 3,172
- A reasonable single estimate would be the midpoint of the two: (3,241 + 3172) / 2 = 3,206

It is rare that one estimate is seen to be the correct estimate. Three different estimates were derived in this example: the estimate from the census, the estimate using the first error adjustment and the estimate using the second error adjustment. Each provided a different value. The investigators then considered the strengths and weaknesses of each method as well as the assumptions to determine the best estimate. Using an average of the methods, the investigators estimated that there were approximately 3,350 sex workers in the city.

3.2.2. Capture-recapture method

Capture-recapture techniques were first used in 1662 to estimate the population of London. It was not until 150 years later that LaPlace laid out the mathematical formulation for capture-recapture. In the early 1900s, the method was adapted to study wildlife populations [12, 13]. The method has been known as the Lincoln-Peterson estimator in wildlife, Chandra-Sekar-Deming method in demography, and sometimes the dual-system estimator [14]. Other terms sometimes used include "mark and recapture" and "capture and release" [15].

How this method works

A simple example of the procedure is as follows:

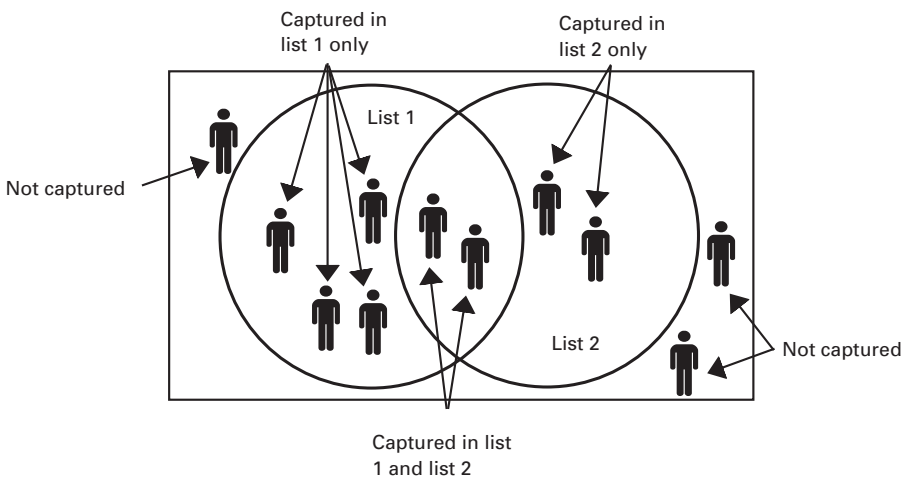
- Map all the sites where the population can be found
- Go to the sites and tag all of the members of the population at the site (either give them a card or some memorable gift). Keep a count of the persons tagged.
- Return to the sites a week later and retag all of the persons encountered.
- In the second visit, count:
  - members who were counted in the first sample
  - members who are being counted for the first time in the second sample.

In situations where it is not feasible to visit all of the sites or all of the sites are not known a variation of this method can be used.

- Select a sample of individuals from the population. Ideally the sample will be random, with each member of the population having an equal chance of being selected. This sample can be a list of sex workers attending an STI clinic, or a survey.
- Note persons selected in some fashion (for clinic attendees you might have their names or clinic patient identifier number, or survey respondents might have been given a card or will remember completing the survey).
- Collect a second sample at a later time. The second sample should be independent of the first sample (either sample from a different clinic or institution or conduct a different survey).
- In the second sample, determine:
  - How many people were also counted in the first sample (sex workers who visited the STI clinic or respondents interviewed in the first survey)
  - How many people are being counted for the first time in the second sample.
- The number of individuals observed in each sample and the number in both samples is recorded.

These numbers are used to estimate population size. This is done by multiplying the number captured in the first sample by the number captured in the second sample and dividing by the number captured in both samples. (See below for mathematical explanation.)

Figure 3.2. Illustrating the capture-recapture method



In at-risk population estimates, two general approaches to capture-recapture have been used:

- In the *direct contact approach*, the field team contacts members of the target population, for example the people interviewed in the survey. At a later point, the field team revisits the population through a different independent contact (such as a second survey), and asks whether they responded to the first survey. If so, they are recorded.
- In the *no direct contact approach*, the team uses existing lists (for example STI clinic registration data and a brothel registry) to determine if the same individual is captured on both lists.

There are some important assumptions in the capture-recapture method:

1. The population is closed. That is, the population available to be captured in the second sampling (recapture) includes exactly the same set of individuals as it did for the first. There is no in- or out-migration. This assumption is easily violated in studies of persons who inject drugs or sex workers, where there is large turnover (people joining or leaving the population) and often lots of movement.

   The change in population between sample 1 and sample 2 can be caused by several things, for example:
   - people who inject drugs who are included in the first sample are more likely than others to leave the population by moving away, dying or ceasing to use.
   - new drug users might enter the population
   - People who inject drugs who attend treatment programmes may be more likely to reduce their use of drugs for a period.

2. Identifying information is collected in both samples. Individuals captured in both samples can be matched.

3. Capture in the second sample is independent of sample in the first. That is, people in the first sample are not more or less likely to be included in the second sample than people who were not included in the first sample.

   If being included in the first sample increases a person's chance of being included in the second sample, the total population will be underestimated. For example, if the study team returns to the same street corner or brothel to recapture sex workers, certain sex workers will probably be favoured in the recapture sample. Techniques have been developed to detect dependencies between samples [16].

4. Each person in the population should have an equal chance of being included in the sample. This would suggest that the sample is random.

5. Capture-recapture estimates based on small samples or too few matched individuals can be misleading[17]. *Make sure there are enough members in the samples to produce meaningful results.*

Table 3.2. Avoid violating assumptions in your capture-recapture

Assumption… and effect if it is violated	How to plan your study to avoid violating the assumption
The population is closed (there is no in or out migration). If this assumption is violated: • A decrease in the population size for the second sample will produce an overestimate of the population size. • An increase in the population size for the second sample will produce an underestimate of the population size.	• Shorten the time between samples. • Avoid sampling on unusual days, such as festival days. • Carefully define the boundaries of selected sites. • Enlist community support. • Ensure your team understands the points above.
Matching is reliable (you can identify persons captured in both samples). • If you do not identify a match, your estimate will be too high • If you identify a match incorrectly, your estimate will be too low	Collect sufficient identifying data for each member of your samples so that you can match who has been captured before.

Every member has an equal chance of being caught in a sample. • If some members of the population are less likely to be included in the sample, your results will likely be an undercount.	• Before your study begins, investigate how the local community defines the population. • Carefully select study sites.
The two samples are independent (selection in the first capture is not related to selection in the second capture). • If not, your results will be biased.	• Use separate teams to collect each sample. • Use different informants/local guides for each sample.
The sample size for each capture is large enough to be meaningful. • If not, your results will not be precise.	Increase the size of the target population for both lists (or survey).

Based on table created by Donna Stroup, Data for Solutions.

Using the capture-recapture method with a random sample from a population of interest

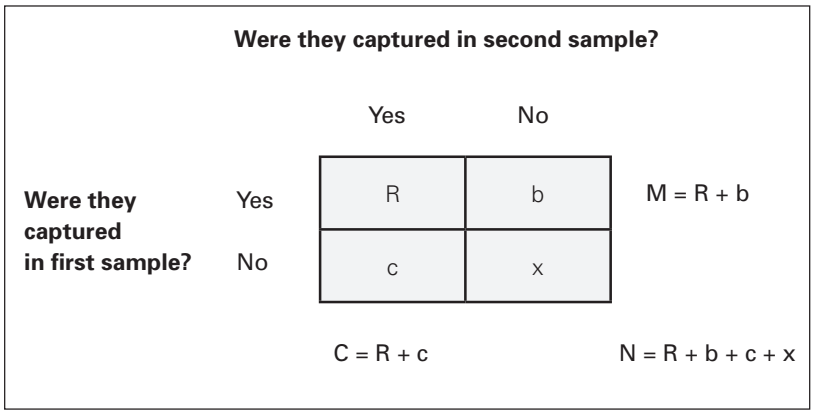
The basic capture-recapture methodology begins with a random sample from the population of interest [18]. If the assumptions stated hold, the estimated population size is:

$$N = \frac{MC}{R},$$

where
N = Estimate of total population size
M = Total number of people "captured" and "marked" on the first visit
C = Total number of people "captured" and "marked" on the second visit
R = Number of people captured on the first visit that were then recaptured on the second visit (i.e., included in both samples).

In Figure 3.3 below, a 2 x 2 table:
- The top row of the table includes all people captured in the first sample
- The first column includes all people captured in the second sample
- The total number, *N*, includes all those in both samples as well as those missed by both samples.

Figure 3.3. Capture-recapture data from a random sample of a population of interest



To calculate the sample size required for this method you should consider the following. The combined total of sample 1 and sample 2 should be larger than the total number expected in the population (M + C > N) and the number captured in both samples is larger than 7 (R > 7)[19]. Naturally you will not know the total number of people in the population (N) so you will need to make a rough guess.

Strengths and weaknesses
A simple two-sample capture-recapture method is relatively easy to use. This method does not require much data. It also does not require statistical expertise.

But the method relies on assumptions that are hard to meet:
- two samples must be independent and not correlated
- each population member has an equal, or known, chance of selection
- each member must be correctly identified as 'capture' or 'recapture'
- no major in/out migration may occur
- the sample sizes of each capture must be large enough to be meaningful.

Detailed example
A simple example of capture-recapture data.

A study team is using the capture-recapture method to determine the size of an at-risk population.
1. The study team mapped the area they wish to study,
2. One member of the team goes to the area to "capture" individuals:
   - 50 individuals are marked on the first visit, *M*
3. A second team member goes to the area to recapture individuals:
   - 25 of those individuals captured on the first visit are recaptured on the second visit, *R*

The field worker concludes that the probability of capturing a previously-marked individual on the second visit is:
$R / M = 25 / 50 = 0.50$.

The field worker assumes on the second day that all individuals in the actual population, *N*, have the same capture probability as the recaptured individuals. The field worker thinks on the second visit, "I know that today I recaptured 50% of the people I marked during my first visit. Today I probably also captured 50% of the individuals that I did not mark on my first visit. In fact, today I probably captured 50% of all the individuals present in the study site regardless of whether or not those individuals were marked on my first visit." This can be expressed as:

$$\frac{C}{N} = \frac{R}{M}$$

Using the capture-recapture method with programme data
To implement capture-recapture using programme data, identify the individuals captured in two data sources.

Be clear and specific when you decide how to match. A good way to proceed is to adopt a rigid definition and do the analysis. Then relax the matching criteria, repeat the analysis, and compare the results [20].

Unless your data sets are enormous, the best way to match is manually. Spreadsheets and electronic databases can help by sorting in different ways.
- Two lists sorted by sex and date of birth may assist in matching individuals. Birth dates may differ slightly or age computed from birth date may differ from reported age.
- If names are available, they may not be much help because some names can be so similar or people give a different version of their name at different visits.

It is also possible to calculate a confidence interval to give a range of error for the estimate of total population size: $95\%CI = N \pm 1.96\sqrt{Var(N)}$

Where Var(N) is calculated as: $\frac{MC \bullet (M - R) \bullet (C - R)}{R^3}$

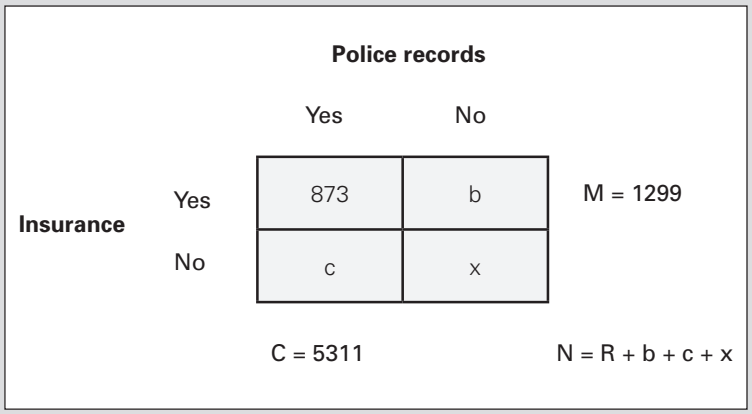
Detailed example of capture-recapture method with programme data [21]

A country is experiencing rapidly expanding injection drug use associated with HIV. The country needs to estimate of the number of injecting drug users to evaluate the feasibility of intervention programs. The health ministry has data available from two existing data sources:

- Data source one is comprised of records from a social insurance system based on residency. This database includes information on out-patient and in-patient/hospital care and on reimbursed medications. Thus, it could be used for people receiving drug treatment or who have had a drug overdose.
- Data source two is a police database with information on criminal offences including the means of administering illicit drugs (that is, injected or not).
- Both data sources contain information on gender, day/month/year of birth and initials.
- Investigators decide to restrict analysis to persons 15-44 years old. Records outside this age range, records without full identifying information or multiple records with the same unique set of identifiers are to be deleted from the analysis.
- Insurance records identify 1299 injecting drug users.
- Police records identify 5311.
- 873 persons are identified in both data sources.

From these data, the team prepares Figure 3.4.

Figure 3.4. Capture-recapture using programme data from police and insurance record



Thus, the total number of injection drug users in the population is estimated as
N = 5311 x 1299 / 873 = 7,903

The team's statistician determines that the variance, a measure of the uncertainty of the estimate, is:

$$\frac{MC \bullet (M-R) \bullet (C-R)}{R^3} = \frac{1299 \bullet 5311 (1299-873) \bullet (5311-873)}{873^3} = 19{,}604$$

The 95% confidence interval for this estimate is:
N + 1.96 √19604 = N +1.96 * 140 or from 7,629 to 8,177.

These are reasonable calculations if the assumptions hold: both samples are selected randomly and the two sources are independent. The team assumes no relationship between a person having access to the social insurance system and being included in the police database. If the assumption of independence is not satisfied, the estimate may be biased. A viable interpretation of these results is to report, "we estimate the number of IDU, aged 15–44, in the country falls between 7500 and 8200 in 2009". This is sufficiently accurate for most programme planning.

3.2.3. Nomination methods

These methods are sometimes used in conjunction with multiplier or capture recapture methods because no alternatives are available to survey hidden populations. However, nomination methods are not recommended for estimating the size of a hidden population.

How these methods work

Nomination methods start with a limited but visible and accessible part of a larger population such as:

- drug users in treatment programs
- men who attend openly gay establishments.

These persons are contacted and asked to provide either contact information or refer other individuals who share their risk behaviour. If the referred individuals come in, they are asked to provide other names or refer other members and so on. For this reason, variations of this method are often called respondent-driven, snowball or chain sampling methods.

Strengths and weaknesses

Nomination methods give the promise of providing access to hidden populations because they rely on members of the population to help find additional members [22]. However, caution is needed with these methods.

Most hidden populations are usually composed of persons whose behaviour is the most illegal or stigmatized. Individuals who participate in illegal and stigmatised behaviour will not want to give names and identifying information for fear of adverse consequences. On the other hand, those populations tend to be highly connected. Referrals may be duplicates [23]. Thus, the collection of identifying information is essential in order to eliminate duplicated persons.

Nomination methods start with visible members of the group who may not be representative of the complete population at risk [24]. Take, for example, the problem of developing an HIV prevention programme for injecting drug users in a city. If we start with initial contacts with persons who inject drugs and are enrolled in a private drug treatment programme, they might be more affluent than other drug users in the population. Thus nomination methods that rely on this treatment programme as the only point of entry may miss other parts of the drug user population entirely.

The utility of nomination methods depends on the connectivity of members of the population. Any sample from a nomination method will over-represent those with large personal networks because they will have a larger number of paths leading to them. Thus, more socially isolated members of the population with low levels of interaction with other networks will be neglected in this type of sampling.

To overcome the selection biases described above, multiple samples and sophisticated statistical methods are needed during data analysis [25].

Nomination methods are useful for conducting formative research as part of pre-surveillance activities or in gaining access to a population in need of services. But for estimating population size, these methods are not recommended.

3.2.4. Multiplier method

The multiplier method is highly dependent on the quality of the existing data. You will need to review how the existing data were collected before you use the data to produce estimates.

How this method works

The method relies on two sources of data.

- The first source should be a count or listing from programme data including only the population whose size is being estimated (number of sex workers who attended an STI clinic in the last month, number of persons who inject drugs visiting a needle exchange programme)
- The second source should be a representative survey of the populations whose size is being estimated.

In the survey ask the respondents whether they received the service. Divide the number who received the service by the proportion reporting receiving the service in the survey to estimate the population size. This can be expressed as:

$$S = \frac{\text{\# of key population in STI registry records}}{\text{\% population reported being registered}}$$

The basic principle is this. For the number of people being estimated in the population:

Those who appear at a specific institution during a certain time period, such as sex workers at STI clinics	=	the proportion of the population who attended the institution x the total size of the population

For example:

- If the number of sex workers who sought care at an STI clinic in 2005 is known to be 1,000 from clinic records
- If approximately 10% of sex workers attended an STI clinic in 2005 (from a survey of sex workers)
- Then the STI care-seeking figure can be multiplied by 10 (or divided by 10%) to get an estimate of the size of the sex worker population.

Similarly, if you have a list of STI clinic attendees of whom only a proportion are sex workers you could use the following.

$$S = \frac{P_1}{P_2} \bullet M$$

Where:
S = estimated total number of sex workers
$P1$ = proportion of sex workers on a list of STI clinic attendees
$P2$ = proportion of sex workers who attended the STI clinic among a cross-sectional survey of sex workers
M = number of individuals on the STI clinic attendee list

This estimate is mathematically equivalent to a capture-recapture calculation but the interpretation is somewhat different.

Table 3.3 provides a sample list of data sources for the multiplier method when the target group is injecting drug users.

Table 3.3. Potential data sources for estimate of persons who inject drugs [26]

Data Source	Example
Drug treatment program	Drug users attending treatment agencies or in residential care
Drug agencies	Drug users contacted by outreach workers
Needle exchange programs	Drug users registered at needle-exchange programs
Hospital/ER	Drug users needing emergency treatment due to overdose
Laboratories	Drug users tested for HIV, HCV, or Hep B virus
Police/prisons	Drug users arrested for drug use or other crimes
Probation	Drug users on probation
Social services	Drug users assisted by social services
Mortality statistics	Deaths due to opiate overdose

Another version of multiplier method involves the distribution of a unique object to members of the population. Similar to a capture-recapture method, use those receiving the unique object as the count of the first population.

Use the unique object multiplier when services do not exist for the population of interest. The study team controls:

- how many objects are handed out to the population
- what type of object is handed out
- who receives the object (a member of the defined population)
- when the object is handed out (in the time period of the survey).

In a survey ask how many respondents received the unique object. Use the formula above to estimate the population size.

Strengths and weaknesses

The multiplier method is preferable to census and enumeration methods when the sampling frame is questionable or when the population is difficult to reach. The multiplier method is straightforward if data sources are available. This method is flexible and useful in many circumstances.

However, the two sources of data:

- Must be independent (everyone with a chance to be on the list should have a chance to be in the survey). Similarly, everyone on the list should be a member of the population you are trying to estimate and this population should also be captured randomly in the survey. In reality, most surveys will have some amount of selection bias and the survey team needs to decide whether that bias is independent of the likelihood of being included on the list.
  - The first data source (multiplier) need not be random but should be specific to the group being estimated. That is, if the team is using STI clinic data to estimate size of the sex worker population, they must exclude non sex-workers from the list. This is in direct contrast to capture-recapture estimates.
  - The second source (the survey) should be random and encompass the group in the multiplier but it can include others as well. That is, it can include both brothel and street-based sex workers even if the multiplier includes only brothel-based sex workers.
- Must define the population in the same way (the two populations for the data sources are equivalent)
- Must have aligned time periods, age ranges and geographic areas

Keep in mind, data collected from existing sources may be inaccurate.

Detailed examples

Detailed example 1: Sex workers in China

Consider an example with sex workers in China [27]. Two surveys were carried out in one province:

- In the first survey, 92 female STI clinic clients (at one of 16 registered STI clinics) were enrolled after informed consent. The total number of female STI clinic attendees (842 women) over 6 months was determined from medical records. Of the 92 female STI clinic attendees interviewed, 45 (48.9%) were classified as sex workers. It is assumed that this sample of 92 is representative of the 842 women attending the clinic.

- A second survey was conducted among the community female sex worker population through anonymous interviews at their place of work. They were asked whether they had visited any of a list of STI clinics in the past three months. From the survey of sex workers in the community, 16.2% (47/327) had visited the STI clinic from the first survey. Thus, the estimated size of the female sex worker population is:

$$S = \frac{48.9\%}{16.2\%} \bullet 842 = 2{,}500$$

Detailed example 2: Using programme based and unique object multipliers in India [28]

Programme managers used two multipliers to estimate the size of the sex worker populations in 6 states in India. They conducted a series of integrated biological and behavioural surveys among sex workers to use with the multipliers.

Data source 1: Programme based multipliers and unique object multipliers
- Multiplier 1 came from service statistics recorded by organizations working with female sex workers
- Multiplier 2 came from a unique object distributed to female sex workers

Data source 2: Survey
- The integrated biological and behavioural surveys were sampled using either respondent-driven sampling or time-location sampling. These sampling methods approximate probability sampling methods to obtain a random sample.

The questions used in the survey were designed to be compatible with the data routinely collected and available from local service providers. Indicators included:
- proportion reporting being registered with the service provider
- proportion reporting contact by a peer in the past month
- proportion reporting receiving a project health card in the past year
- proportion visiting the service provider in the past year or past three months.

These indicators for multipliers presented some challenges. For example when using *registration with the service provider*, it was found that:
- Some service provider required registration while others did not
- Some service provider gave out registration cards, others did not
- Sometimes community members knew they were registered with a service provider, other times they did not. (This may have been due to the variability in the degree of branding of the service provider recognizable by the community.)

In using *visit to clinic in past three months*, duplication was a problem:
- Only service providers that did individual tracking could provide information on the number of individuals who had visited the clinic during a given timeframe
- Others had information on number of visits, but not on number of individuals.

Due to anticipated challenges with these methods, an additional multiplier was used that could be controlled by the survey team. This was known as the unique object multiplier. The team distributed an object in advance of the survey.

In several of the districts, the object distributed was a key chain, designed to be uniquely memorable. The key chain was distributed before the survey to persons within the bounds of the survey coverage area who matched the definition of the population whose size was being estimated. Respondents were asked in the survey if they had received the key chain.

In the majority of cases, both the programme based multipliers and the unique object multiplier combined with the survey yielded lower size estimates than existing data from programme mapping data. Reasons for this discrepancy could have included problems with the different data sources.
Potential problems with data source 1:
- Ineligible people were included in the programme counts
- Unique object were distributed to ineligible people

Potential problems with data source 2:
- Selection bias in the survey leading to non-independence between data sources. This could happen if those in contact with the service provider are more likely to be included in the survey than those not in the programme.
- The survey questions were not specific or adequately matched to the programme-based multipliers

- People reported having received a unique object or being in a programme when they had not received the object or were not in the programme
- The survey sample was not truly random.

Although the key chain was not randomly distributed, this did not violate the assumptions for the method.

The main safeguard against these biases is to make sure the probability survey is as close as possible to being random. The unique object method has the potential advantage of being easier to control by the survey team so that some biases are avoided.

3.3. Method based on data collected from the general population

Populations most at risk to HIV are often hidden because they are stigmatized or engaged in illegal activities. Members of these populations are especially hesitant to identify their behaviours for fear of punishment. Thus conducting surveys of such individuals can be challenging as they often do not want to identify themselves to a study team.

3.3.1. Surveys

In most circumstances, surveys directly asking about extremely high risk behaviours are also not recommended for estimating the size of most-at-risk populations. As described above populations at increased risk to HIV are likely to avoid answering such questions truthfully. In addition behaviours that put people at increased risk to HIV are often so rare that a very large sample size would be required from a survey to establish the prevalence of such behaviours within a population. The description of the method is included in the guidelines because it is a common method for collecting public health data and can in rare situations be used to collect behaviours with low stigma.

How this method works

Surveys of the general population are very common in most countries. They are most often administered to residents of a household drawn from a sample frame that is representative at a national or regional level:

- In industrialized countries, telephone surveys are possible [29].
- In developing countries, data are generally collected by survey teams visiting households doing face-to-face interviews [30].
- Youth in school can be reached through school-based surveys. Be careful to consider the representativeness of individuals attending school versus the remaining population [31] of the same age that is not in school.

To estimate the size of the hidden population, respondents in a general household survey are asked if they inject drugs, sell sex, purchase sex, or, if male, have sex with other men. These are not always easy questions to insert in a survey given the stigma, discrimination and illegality of these behaviours. The wording and location of these questions in the survey are important aspects to consider.

Strengths and weaknesses

Surveys are generally easy to implement. Surveys are longstanding methods in the statistical literature [32], so results will be relatively easy to analyse and defend and are politically influential. In general, it is fairly easy to find a sample frame for a general population survey.

Surveys are less useful when behaviour is rare because it may not be reflected in the sample selected. Those at risk may not be found in households, schools or other institutions. In addition, if behaviour has been stigmatized within a society, respondents will be less truthful with the interviewer, especially if the interview is not conducted in a confidential setting [33].

Thus, in most settings, it is difficult to create a population size estimate based on direct questioning about highly stigmatized behaviours within a household-based survey.

3.3.2. Network scale-up

The network scale-up method is currently being considered for estimating the size of hard-to-reach populations. (Adjustments for the known biases in this method are still being developed so the method should be regarded as "under-development".) The method uses information collected in general population household surveys to estimate the size of hidden populations. However, instead of asking about the respondent's own behaviour, this method asks about the behaviour of the respondent's acquaintances.

Based on the average number of individuals that respondents know in hidden populations and the average personal network size, the proportion of people in the most at risk population is estimated.

How this method works

There are three steps to the network scale-up method:

1. Estimate the average personal network size of the general population.
2. Ask the general population how many individuals they know in each of the hidden populations of interest.
3. Calculate the estimated population size and adjust for known biases.

For example:

- If a respondent knows 300 people and two of those people inject drugs, you can estimate that 2/300th of the general population are injecting drug users.
- When you combine that estimate with the total population size of the country, say 300 million, you can estimate that two million people inject drugs in the country.
- Your estimate can be improved by averaging over many respondents with different network sizes and number of persons they know who inject drugs.

Step 1 – Determine personal network size

In step 1, we estimate personal network size. That is, how many people does the respondent know? In most cultures, the idea of "knowing" someone or counting who we know is not specific [34]:

- Does who you know apply to current acquaintances or everyone you have known in your lifetime?
- How well must you know someone to count them in your network?
- If you name someone as your acquaintance, must they also name you as one of theirs?

How you define a personal network will have to be defined for your estimate then used consistently over time. Previous network scale-up studies have used this definition:

"A person who should be counted in your personal network is someone who knows you and you know them, by sight and name. You can contact them or they can contact you. You have talked to them within the last two years. The person lives in X". (X being the specific area of reference.)

Two methods have been explored for estimating personal network size: the *summation method* (section a below) and the *known population method* (section b below). The summation method should be used in situations where statistical resources or records are unreliable or unavailable.

A. The Summation Method of Estimating Personal Network Size

In this method, you will ask respondents for a direct estimate of their personal network size. To break this down into a manageable task, the respondent is asked to count how many acquaintances he has in each of a set of mutually-exclusive, but exhaustive, categories. By summing up the number of acquaintances in each category we have a direct estimate of the number of people the respondent knows.

As a rule of thumb, people are able to count up to 20 individuals without writing out a list. If a category is likely to routinely contain more than 20 people, sub-divide the category. A partial list of possible categories is provided in Table 3.4 below. Again, try to ensure that the categories overlap as little as possible.

Table 3.4. Possible categories of acquaintances for the summation method

- Immediate family
- Other birth family/family of spouse/partner
- Co-workers
- Other people at work
- Best friends
- People known through hobbies/recreation
- People known through ... (religious organizations, neighbourhoods, school)
- People known through others
- Childhood acquaintances or friends
- People who provide a service

One option to get accurate answers on a personal network size is to provide a visual prompt. The respondents will know in advance what categories will be covered and should be able to avoid counting an acquaintance in multiple categories.

Clearly, the choice of categories for a summation method of estimating average network size is culturally dependent. Develop this list at the country level and test it to ensure that the list avoids overlap as much as possible and is exhaustive.

B. The Known Population Method of Estimating Personal Network Size

Another alternative for estimating personal network size is the known population method. You will ask respondents about the number of people they know in specific populations for which a true value is known.

For example if census data show there are 3,200 adults named Michael in the country with 300,000 people. The mean number of acquaintances named Michael (calculated from the respondents) is 5.57. The estimated personal network size can be calculated as:

$$\frac{5.57}{3200} \bullet 300{,}000 \approx 522$$

Continuing with this example, imagine a survey done in the general population of 300,000 individuals. In addition to the set of questions to estimate respondents' personal network size (such as the number of acquaintances named Michael), respondents were also asked how many people they knew who were born in a different country. To estimate average network size, the same calculation that was done for the name Michael is done for each of the known populations.

Tips on selecting known populations:

- Ideally, 20 to 30 known populations will be used to create a reliable estimate of personal network size.
- To make a fairly accurate estimate, the known populations should be on average 0.1% to 4% of the total population.
- Research has shown that this method works best if the known populations are similar to the general population (same age group, same sex).

Subpopulations used in a hypothetical study are given in Table 3.5 below.

Table 3.5. Known population method: examples of sub-populations used to estimate average network size

Sub-population	Size of sub-population in the country	Mean number known to respondents
Had a child in last 12 months	4,000	3.20
Has diabetes	6,500	2.43
Opened business in last 12 months	630	0.83
Moved house in last 12 months	8,200	1.68
Voted for X in last election	20,000	3.33
Was born in a different country	22,000	4.76
Is widowed & < 65 years of age	3,300	2.83
Is named Michael	3,200	5.57

This method allows not only for quantification of uncertainty but also is a reality check of the estimates of hidden population size. We can test the accuracy of the known population method by estimating the number of adults named Michael from our known populations and comparing that value to the value provided by the census. Naturally if the accuracy of the known populations is not good it will bias the results.

An estimate of average social network size in the United States was found to be 290 [35, 36], but little work has been done in international contexts. The value of 290 was found using both the summation method and the known populations method.

Step 2 – **Ask the general population how many people they know in the hidden population**
The network scale-up method requires asking people in the general population how many people they know in the populations most at risk to HIV [37].

Respondents are asked how many people they know who inject drugs, sell sex, purchase sex, or, are men who have sex with men. These questions are not always easy to insert in a survey given the common stigma and illegality of these behaviours. The wording and location of these questions in the survey are important aspects to consider.

- Interviewers should be trained on how to ask these questions.
- The confidentiality of the interview must be assured.
- The wording of these questions is critical. If the wording is left to the interviewer to determine there will be variations in the responses due to the interpretation of the people who are classified in the hidden populations.

Step 3 – Calculate the estimated population size and adjust for known biases
In step 3, calculate the size estimate by dividing the average number of people in the known populations by the average network size and multiplying by the total adult population.

There are several problems associated with the approaches described for estimating personal network size and the resulting size estimates:

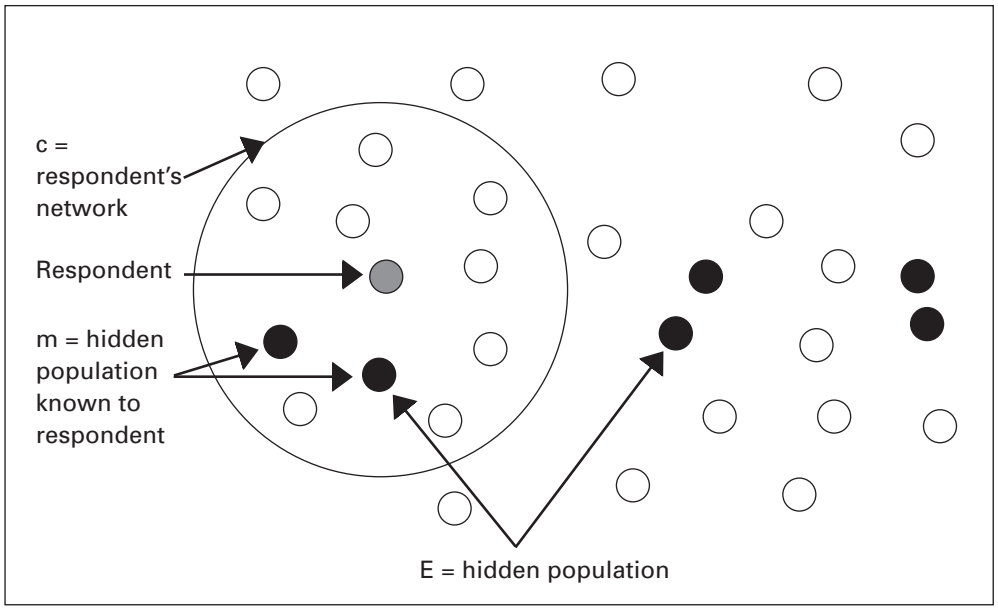
- The size of a network may vary among individuals.
- A respondent may be unaware that someone in his/her network is a member of the population of interest (known as "transmission error") [38].
- The position of a respondent may cause him/her to know fewer members of the population than would be expected (barrier effects). For example, people in rural areas may be less likely to know someone who injects drugs [39].
- Some populations might not admit knowing individuals with the hidden behaviours.

Current efforts are focused on how to adjust for these errors. For example studies are underway to measure transmission error based on surveys of most at risk populations. In addition statisticians are looking into the sample size required to conduct a network scale up survey and the estimation of variance.

Figure 3.5 below displays the concept of the network scale-up method.

- The whole box is the total population *T*.
- *c* is one individual's acquaintances (or personal network size)
- *m* are persons who inject drugs among those acquaintances
- *E* is the size of the hidden population (the value of interest)
- *N* is the total number of people in the survey

Figure 3.5. How the network scale-up method works



We can then estimate E using the below formula where the subscripts are the survey respondents, 1 through *N*.

$$\hat{e} = \frac{m_1 + m_2 + m_3 \ldots m_N}{c_1 + c_2 + c_3 \ldots c_N} \bullet T$$

Strengths and weaknesses

The technique may have significant advantages over existing methods:

- It does not require members of hidden populations to identify themselves to a survey team.
- The questions can be incorporated into existing household surveys so estimates can be generated at the level of those surveys, typically national or provincial.
- The method can create size estimations for multiple hidden populations in one survey.

At the time of publication of this guideline, there are still a number of adjustments required for estimates produced from network scale-up:

- Adjustments to account for the barrier effect – some subgroups may not associate with members of the general population.
- Adjustments to account for the transmission effect – A respondent may be unaware someone in his/her network engages in the behaviour of interest.

Additional Information on the network scale-up method is available at http://nersp.osg.ufl.edu/~ufruss/scale-up.htm

Detailed example of network scale up

A recent pilot survey of network scale up was conducted in one city in Asia. (The data presented here are fictitious since the results have not been published.)

Step 1: Estimate the average personal network size:

1. The study team decided to estimate the personal network size using both the summation method and the known population method.
2. For the summation method, formative research was conducted to determine the most appropriate, mutually exclusive, yet exhaustive list of possible acquaintance categories. Seventeen categories were established.
3. Questions about the 17 categories of acquaintances were added to a general population survey. For example:
   - How many adults do you know who are part of your immediate family?
   - How many adults do you know through your work?
4. Respondents were told not to count the same person in more than one category. In addition they were told *only* to count people who live in the specified City.
5. The study team summed the categories for each respondent and an average network size was estimated for the city.
   - *Average personal network size using summation (mean value of all respondents): 131*
6. In addition, 40 known populations were initially identified. These populations were narrowed down to 20 populations based on the availability of recent statistics for the city and whether the populations were between approximately 0.2% and 4% of the adult population.
7. Questions were added to the survey about how many acquaintances the respondent had in each of the 20 known populations. For example:
   - How many adults do you know who are named Michael?
   - How many adults do you know who are practicing doctors?

   Respondents were told they could count people more than once. They were reminded to only count people who lived in the specified city.
8. The study team compared the estimated number of people in the known populations with the statistics available from that city for the same year. The study team was able to estimate the average personal network using the known population statistics and the respondents' answers.
   - Average number of practicing doctor's known to the respondents (m): 4.2
   - Percent of practicing doctor's of the adult population (E/T): 3%
   - *Known populations average personal network size (c): $c = T/E \times m = 1/0.03 \times 4.2 = 140$*

Step 2: Collect information on the most at risk populations

In addition to the questions to estimate personal network size, 4 questions necessary to capture the number of acquaintances in the most at risk populations were added to the survey. These questions were carefully worded based on advice from different stakeholders. For example:

- *How many adults do you know who inject drugs? Average value (0.397)*
- *How many women do you know who sell sex? Average value (1.82)*

Step 3: Calculate the size estimate and adjust for known biases

Using the known population estimate of the personal network size, the study team calculated the proportion of the average personal network that was made up of adults who inject drugs or sold sex.

The adult population in the city is approximately 600,000. The study team estimated:

- the number of persons who inject drugs in the city: 0.397/140 x 600,000 = ~1,700.
- The number of women who sell sex in the city: 1.82/140 x 600,000 = ~7,800

An additional set of questions was added to the survey to adjust for the reduced likelihood that someone will share a very stigmatized behaviour with their acquaintances. After asking the respondent about each of the known populations they were asked about their "respect" for each of the known populations. For example:

- On a scale of 1 to 5 how much do you respect doctors?
- On a scale of 1 to 5 how much do you respect men named Michael?

The average value of this response provided a level of respect for the different populations. For example doctors were given a very high level of respect while persons who inject drugs were given a very low level. The study team developed an adjustment factor for the results based on the prestige measure. The size estimate was reduced proportionally to correct for the lower likelihood of a respondent admitting that he or she knew a person who injects drugs.

3.4. Summary of size estimation methods

Table 3.6 provides an overview of the different methods and their advantages and disadvantages. Use this table as a quick reference when choosing a size estimation method.

Table 3.6. Summary of methods for estimating population size

Category 1: Methods based on data collected in an at-risk population		
Method name and description	**Advantages**	**Disadvantages**
Census method counts all members of the population. **Enumeration** develop a sampling frame then counts all members of the population at a sample of places listed in the sampling frame.	Census method is easy to explain as it simply attempts to count all members of the population Enumeration method maps then covers just a fraction of the population.	• Most-at-risk populations are often hidden. Both methods will miss members of the population not visible to the public. • Community guides are necessary to improve access. • Census is time-consuming and expensive to conduct • Enumeration method requires a reliable sample frame of venues. • Overestimate if population is mobile and double counted • Underestimate if populations are well hidden.
Capture-Recapture methods calculates the total size of a population based on two independent captures (samples) of population members: • Capture 1: 'tag' and count number tagged. • Capture 2: 'tag': keep track of who was 'retagged' and who is 'first time tagged'.	• A simple two-sample capture-recapture method is relatively easy to use. • Does not require much data. • Does not require statistical expertise.	Relies on assumptions that are hard to meet in normal field conditions: • Two samples are independent and not correlated. • Each population member has an equal chance of selection. • Each member is correctly identified as 'capture' or 'recapture'. • No major in/out migration is occurring. • Sample size is large enough to be meaningful.
Multiplier methods compare two independent sources of data for most-at-risk populations • Source 1: count/listing of persons who accessed a service • Source 2: proportion of population who accessed service from representative survey of population of interest	• Straightforward if data sources are available. • Flexible method, useful in many circumstances.	• The two data sources must be independent. • The data sources must define the population in the same way. • Time periods, age ranges and geographic areas from the two data sources are not always aligned. • Data collected from existing sources may be inaccurate.

Category 2: Methods based on data collected from the general population		
Method name and description	**Advantages**	**Disadvantages**
Population survey methods with general population behaviour questions. • Directly ask respondents whether they have specific behaviours that put them at increased risk to HIV (such as selling sex, injecting non-medical drugs, men having sex with other men)	• Surveys are common and familiar. • Straightforward to analyse and easy to explain to data users.	• Difficult to use when the behaviours are rare or stigmatized. • Only reaches people residing in households, schools or other institutions used to create the sampling frame. • Respondents are unlikely to admit to high risk or stigmatized behaviours if interview is not confidential or if interviewer is not skilled at establishing trust and rapport.
Network scale-up methods are based on the idea that people's social networks reflect the general population. • Ask a random sample in the general population to estimate number of people they know, and how many of those people have the behaviour of interest.	• Can generate estimates from general population rather than hard-to-reach populations. • Individuals are often more likely to report on the behaviour of others instead of their own behaviour • A single survey can be used to create size estimates for multiple hidden populations.	• Average personal network size difficult to estimate. • Subgroups may not associate with members of the general population. • Respondent may be unaware someone in his/her network engages in behaviour of interest. • Respondents may be hesitant to admit to knowing individuals with the specified behaviour.

Source: Adapted from "Monitoring and Evaluation Guidelines for HIV Prevention for Men Who Have Sex with Men". MERG Technical Working Group on Most at Risk Populations. Draft December 2009.

3.5. Guidance on selecting methods to estimate the size of at-risk populations

Estimation results are subject to political as well as scientific use. The discussions in this document are intended only as general guidance. Survey teams in various cultural situations will need to make adaptations for their locale.

Estimating the size of sex work client populations

In countries where buying or selling sex is fairly prevalent and not highly stigmatized, a household survey is an appropriate method of estimation.

- For example, in some countries in Asia, 5% to 25% of adult men report having paid for sex in the past year. The proportion of respondents reporting buying sex can be applied to census denominators in various strata, such as age.
- If population surveys already exist, adding a few questions can be cost effective.
- For countries uncomfortable asking sensitive questions about paying for sex on surveys, multiplier methods can be used with behavioural data on number of partners from surveillance of sex workers.

Estimating the size of sex worker populations

- Census methods have been shown to be useful for brothel-based sex workers.
- Use enumeration for situations where there are large numbers of venues and the sex workers do not move quickly between locations.
- Use capture-recapture to estimate the size of street-based sex worker populations when it is not possible to create a list of venues or conduct a census.
- Multiplier methods will be useful for local estimates however it might be challenging to find lists from administrative sources to provide a multiplier for a national estimate.

Estimating the population size of persons who inject drugs

- General population surveys are generally not useful for estimating the size of injecting drug populations because the sample size is not large enough to capture drug users. Expect underreporting with this group due to their fear of legal repercussions.
- In most countries, there are more existing data sources (such as treatment data, arrests, and registries) on drug use than for other risk behaviours. However care should be taken to make sure these sources are complete and accurate.
- Capture-recapture methods should be considered in settings where programme data sources are of reasonably good quality and where injection drug use is not punishable by imprisonment or death. Any procedure relying on names or other identifying information in a context where such risk behaviour could result in severe punishment is likely to produce inaccurate estimates.
- Multiplier methods can be useful where treatment service records are of good quality. In this case, since multipliers vary by place, the national estimate should aggregate as many local area estimates as are available.

Estimating the population size of men who have sex with men

The population of men who have sex with men is often well hidden and often not captured in routine data collection.

- If men are open about having sex with other men, a census conducted at gathering locations could be useful.
- If no programme data sources are available, a cost effective option is to include same-sex behaviour on existing general population surveys. However these estimates are likely to be underreported, especially in settings where such behaviours are highly stigmatized.

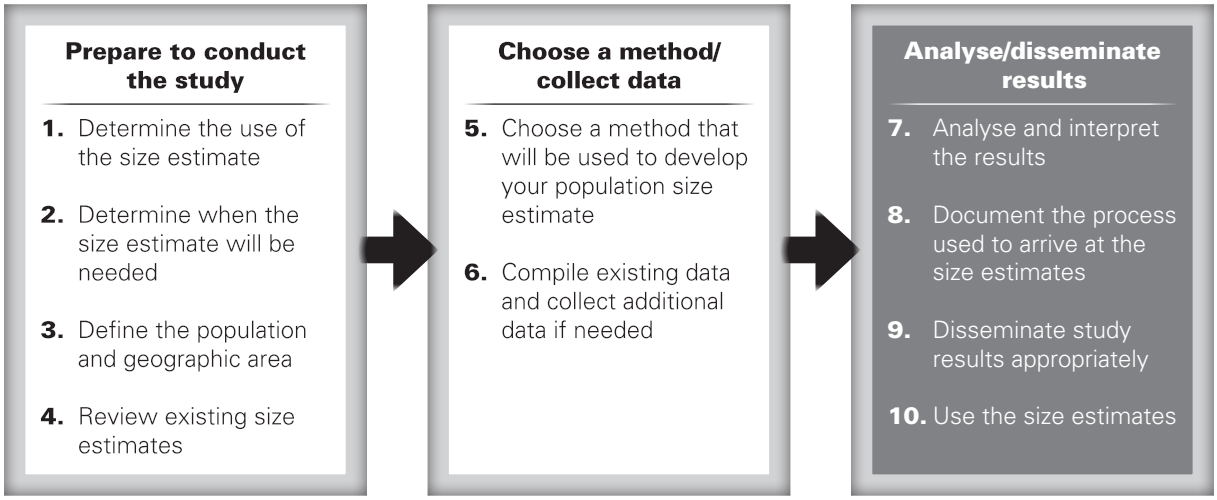
3.6. Step 6: Collect the data

Now that you have decided on which method you will use you will either compile the required sources to create the estimate or you will need to collect data. The specific instructions for collecting data are included in the descriptions of the methods in the previous section.

4. Analyse and disseminate results, Steps 7–10

In the final phase of the process, you will analyse and disseminate your results. Estimates of the size of most-at-risk populations are likely to be uncertain. As we discussed in Section 3, each method has its own specific strengths and weaknesses. You will need to keep the uncertainty and biases in mind when it is time to analyse results. This section describes some of the issues to consider and provides real world examples.

Figure 4.1. Analyse and disseminate results



4.1. Step 7: Analyse the results

Once the exercise is completed and an estimated population size is available the results must be interpreted. This includes explaining the confidence in the estimate, reconciling multiple estimates, extrapolating the results to national estimates, and creating any sub-population estimates that are needed.

4.1.1. Sampling error and bias in size estimates

Analyse and report on the sampling error of the size estimate. Even in a perfect survey, a sample selected randomly from a population will almost never be exactly the same as the entire population. This is the result of sampling error. Most statistical methods allow for estimation of sampling error (e.g., the variance, or a confidence interval).

You have probably heard or read statements such as the following:

- The survey was based on 570 interviews conducted between March 20 and 31. The sampling error was plus or minus 4.5 percentage points.
- 48% felt that there may be too many sex workers in the country... . The poll of 996 adults was conducted 1-3 May and has a margin of sampling error of plus or minus 3 percentage points.

These descriptions are reporting confidence intervals. The technical definition of a (95%) confidence interval is this: if you repeat the same data collection procedure many times, with the same methodology and same sample size, approximately 95% of the intervals that you compute will contain the true value for the population. The confidence interval gives us some idea of the range of error that may be expected for an estimate.

We use confidence intervals to compare the results of different estimation activities. For example:

- An estimate of the female sex worker population in a region 5 years ago was 5,767 ± 215.
- A new estimate for that same region today, using the same estimation method was 6,102 ± 178.
- Can we say that the size of the sex worker population has increased?
- Clearly, the new estimate of 6,102 is greater than the previous one of 5,767.
- However, if we consider the confidence intervals, the estimate five years ago (5,552 to 5,982) seems to overlap the updated estimate (5,924 to 6,280).
- Thus we would say that the estimates are really no different, and the apparent difference in estimates can be explained by sampling variability.

Bias results when the data were collected incorrectly or the sampled population does not adequately represent the population of interest. Bias can result from several sources; the two most important for population size estimation are:

- Measurement bias – measurements are taken (questions are asked) incorrectly.
- Sampling bias – data are collected from a non-representative sample

Bias can be present in surveys and other data sets even if sampling and analysis are done correctly. Neither a large sample size nor statistical methods can correct for bias. In most cases, bias cannot be quantitatively measure or calculated.

Since we cannot control for bias by larger samples or statistical methods (there is no cure), it is important to prevent it. This prevention is most effective if done prior to data collection by ensuring that survey questions are valid and reliable, using correct measurement techniques, and carrying out the sampling correctly and randomly. Thus it is recommended that you have experts review your survey plans, provide ongoing training to field workers, ensure field supervision, and perform interim quality checks on data.

Implications of not knowing whether you have bias in your survey include making inappropriate decisions about programmes based on invalid results. You might:

- fail to provide needed services,
- waste resources on providing unneeded services, or
- lose credibility by providing invalid estimates.

At the very least, you have wasted the resources and time because the results do not reflect the true situation in the population.

4.1.2. How to use local study results to reach a national estimate

Most of the methods discussed in this guideline are more easily applied at the local level than at the national level:

- Programme data are usually applicable to a geographic region that is smaller than a country.
- It is easier to develop lists of venues where the populations of interest congregate in a city or district. It would be much harder to develop a national list of all venues that sex workers or persons who inject drugs frequent.
- Programme data collection may be more consistent at a local level. If several regional treatment clinics provide data for persons who inject drugs, then methods and the quality of recordkeeping may vary widely from region to region.

Can population size estimates from local studies be used to extrapolate to a national population size estimate? In this case, extrapolate means using the data from some locations or areas to estimate for other areas. You will also see the term *synthetic estimation* used for this. The purpose of extrapolation is to generalize from a series of local studies.

For example, say you are developing an estimate of the national population size of sex workers. To be valid, the larger regions should have the same data sources as the local areas. To extrapolate, you would:

- Map the larger area, such as country, breaking it down into smaller areas and combining areas with similar characteristics
- Collect data in some of the small areas (data may already exist or collect new data)
- Use an extrapolation procedure with your data to create a national estimate.

Extrapolation methods may be simple or complex. Simple extrapolation might apply the same percentage to all areas. Consider the example provided below.

Detailed example of a simple extrapolation from local estimates to a national estimate

Imagine you live in a country that wants to get a national estimate on persons who inject drugs so that prevention and treatment services can be improved.

A local study in Region R produced an estimate of 37,000 persons who inject drugs. You want to extrapolate that finding to the entire country [40]. You may think, "One-third (1/3) of the population of the country resides in Region R. So I believe that there are 111,000 (3 x 37,000) persons who inject drugs in the country." But there is a problem with this approach. It assumes no regional differences in drug use. If Region R is a major urban area, port city or border crossing, then it may not be representative of more rural regions in your country.

Now suppose you obtain national data on drug treatment and fatal drug overdoses. These data show consistently that about half the persons in treatment and half the drug deaths are from region R. Now you change your assumption. The national number of persons who inject drugs is not proportional to population, but to numbers of drug deaths. Using this approach, we would estimate that 2 x 37,000 or 74,000 is the size of the population of people who inject drugs in your country.

More complex extrapolation tries to account for other factors: socio-economic factors, geographic area, different sub-populations. Ask yourself these questions:

- Is there geographic variability? If so, applying one percentage to a whole population may not be appropriate.
- How local are the data? If the area is too large, the local estimate may not be truly local and thus may be inaccurate.
- In the local surveys, do the at-risk population definitions match?
- Do the local data apply to the specific at-risk population you are developing an estimate for? For example, does sex work in urban areas refer to all types of sex work: brothel-based, street-based and entertainment-establishment based? Or do the local data just consider a subset of these groups?
- What types of men who have sex with men are included in the local data you have obtained: higher-risk MSM, venue-based MSM, any man who has sex with a man?

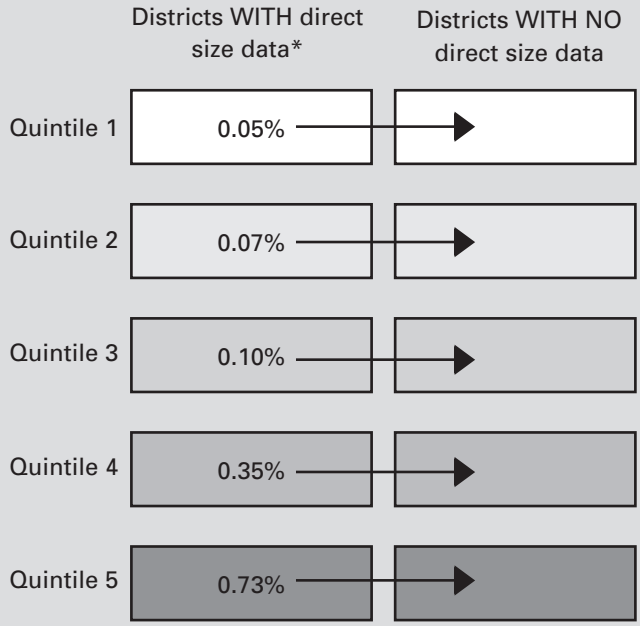
Detailed example of a complex extrapolation of sex workers in Indonesia

Of Indonesia's 440 districts, only some had data estimating the size of the sex worker population. However, a national survey of village leaders was conducted in villages in each of the 440 districts. In this survey, the following question was asked:

"Are there sex work spots in your village?"

- Investigators calculated the percent of district villages whose leaders said YES to this question.
- All 440 districts were ranked by the percentage of villages in that district with sex work spots. This ranking was distributed into quintiles (that is, ranked 1, 2, 3, 4 or 5). In other words, districts with the highest proportion of villages with sex work spots were assigned to the highest quintile, 5, and districts with the lowest proportion of villages with sex work spots were in the lowest quintile, 1.
- For each district with size estimation data, investigators used these data to calculate the average percentage of the adult female population that are female sex workers.
- These data were aggregated to come up with an average size of sex worker population for each of the five quintiles, ranging from 0.05 percent of the adult female population in Quintile 1 to 0.73 percent in Quintile 5 (see Figure 4.2).
- These averages were then applied to districts without data in the matching quintile group as shown below. Table 4.1 shows how this calculation was done for four districts, based on the known size of the district's adult female population and its ranking by quintile.

Figure 4.2. Indonesia's extrapolation for female sex workers



* Average size of FSW population as a percentage of the adult female population

Table 4.1. Estimated population size by district

District	Adult female pop. size (a)	Quintile (b)	% from quintile (c)	Estimated # of sex workers in district (a) X (c)
District A	250,456	2	0.07	175
District B	1,329,875	5	0.73	9708
District C	546,982	2	0.07	383
District D	356,968	3	0.10	357

4.1.3. Using multiple size estimates to create the best estimate

There is no reason for your country or local area to limit itself to a single method for estimating the size of a population most-at-risk to HIV. Find as many data sources as you can to improve your estimate.

- Using estimates from multiple methods allows for checks and balances. If results are vastly different we can go back and consider the assumptions and the method to find out which one was incorrect.
- Estimates from multiple sources which are similar will improve the credibility of the final estimate.

Before evaluating different estimates it is important to make sure the estimates are comparable. This might be documented by creating a matrix that explicitly describes the different estimates that will be compared.

- Describe the definition of the population for each estimate
- Describe the geographic region covered by the estimate
- Describe the method and the possible violations of the assumptions for that method
- Based on the violations of the assumptions document whether the estimate is likely to be an overestimate or an underestimate
- Finally include the estimate created by each method

Such a matrix will provide a clear and transparent description of the evidence available for determining the final estimate.

Detailed example of using multiple results

An unnamed country was recently estimating the number of persons who inject drugs in City Y. They had a number of different data sources from which to calculate size estimates.

- A recent general population survey had asked questions for network scale up.
- Programme data provided information on the number of persons who were registered in their "narcology" registry.
- Programme data were available on the number of people enrolled in a harm reduction project.
- 328 persons who inject drugs were handed a key chain (or unique object) by outreach workers.
- A survey using respondent driven sampling provided information on the proportion of persons injecting drugs who were enrolled in the harm reduction programme, who were registered with narcology, and who received the harm reduction key chain.

The different results for persons who inject drugs showed a range of estimates.

Method	Estimates of persons who inject drugs in City Y
Network scale up (adjusted for stigma	7,896
Multiplier method (Needle exchange)	7,774
Multiplier method (unique object)	8,548–42,620
Multiplier method (Narcology)	3,483
Programme records (Narcology)	2,220

The programme managers compared the results and determined:

- Results were fairly consistent between the programme data multiplier and network scale-up: 7,774 and 7,896
- (Only 3 respondents in the survey reported receiving key chains. The small number of key chains returned in the survey resulted in a very large confidence interval for the unique object estimate: 8,548 – 42,620, however the lower bound is close to the other estimates
- The narcology data, even when combined with a multiplier, gives a very low number: 3,483. The narcology registration is likely to be incorrect for City Y since the registry classifies people by where they enrolled and not where they are currently living.

Based on the understanding of the different biases and strengths and weaknesses of the methods the programme managers were able to determine a best estimate: they estimated that the number of persons who inject drugs in City Y was approximately 8,000.

4.1.4. Estimating the population size of most-at-risk adolescents

Programmes aimed at preventing HIV infection are often targeted to specific age groups. This is especially true among populations such as sex workers or injecting drug users:

- Programmes for recent initiators of the behaviour (or younger people) focus on changing life styles (such as interventions to develop alternative work skills or drug treatment programmes).
- Programmes for persons who have had the behaviour for a number of years, and who are generally older, tend to focus on changing specific behaviours (such as increasing condom use or using safe needles).

When possible, collect local size estimates by different age groups. For example, in a local study, consider the number of people in the population under age 25 or over age 25. This may be challenging if you are using the methods described in this guideline because age information is not commonly collected in these methods.

Another option is to use data available from a recent survey of the same population to identify the proportion of the population in different age groups. For example if a survey was conducted using respondent-driven sampling of injecting drug users in a city, and 17 percent of those who responded to the survey were less than 25. You could apply that proportion to your size estimates and estimate the number of young people who inject drugs. (However, if there are large biases to the sampling structure the proportions in different age groups might be biased.)

Before you begin estimation calculations, be sure to learn the parameters set for inclusion in the survey. In many surveys, adolescents under the age of 18 are purposefully excluded because of ethical concerns.

You may find no survey exists that provides unbiased estimates of the proportion in the population under age 25. If so, consider adding a component to the proposed methods that allows you to make an estimate of at-risk adolescents.

- If enumeration or census methods are used, the addition of a simple classification by age could be added to the enumeration tool.
- If a unique identifier is used, a mark on the object or colour of the object could be used to identify if the recipient is less than 25 years old.
- If you are using the multiplier method (recall that this method relies on programme records), service providers might not always have the age of the attendees.
- If network scale-up is being used, you would have to ask an additional question after each population of interest. For example, "Among the sex workers that you know, how many are under age 25?" The results of these questions will introduce additional biases so this method should only be used as a last resort.

4.2. Step 8: Document the process

The most important step in size estimation comes after you create the size estimate. Consider how to improve the long term use of the estimate.

- Carefully document all details of how the method was carried out if the estimation method is to be replicated to produce comparable results.
- Use clear and appropriate language.

Size estimates are more useful when they are updated over time and can be studied for changes. Increases or decreases in the population size of most-at-risk populations are more useful if they can be associated with interventions.

Keep in mind that the methods described in this guideline produce estimates with a large degree of uncertainty. This could make it difficult to measure significant changes in the population size. Also consider changes in the larger population (such as increasing or decreasing total population size or increasing numbers of young people) when you are looking for long term trends.

Stating the steps, assumptions, techniques and calculations taken to create the population size estimate will allow future researchers (or even the same team) to replicate the process in the future. Having comparable measures of size estimates should be a very high priority for policy and programme managers who need to measure the impact of their programmes and policies.

Start your documentation with the protocol as it was initially developed. The protocol must include:

- an explanation of why the population was chosen
- the definition used for the population
- the geographic area of the estimate
- the method chosen for the estimate
- the assumptions required for the method
- any violations of those assumptions.

Clearly describe the data sources you used for the size estimate. If decisions were made about whether or not to use a data source, include a decision tree diagram to describe how those decisions were made.

In addition, amend the protocol to include explanations of any challenges that came up during the estimation exercise and how they were handled. For example, you may have had challenges with sampling or survey implementation that could have biased the results. Data handling and data processing issues may have resulted in changes to the analysis plan.

It is important to document which parts of the at-risk population may be missed entirely. For example if female drug users who receive the drugs from their partners were not captured in a survey of individuals at a drug treatment clinic, the documentation should highlight that such individuals were not counted in the exercise. Such issues should be carefully noted in the dissemination materials as well.

Finally the researchers should include a section in the documentation on whether they believe the estimate is an under or an over estimate and should include the reasons for that conclusion.

4.3. Step 9: Disseminate the results

Size estimates of populations at increased risk to HIV can be politically sensitive. Also, the media may misinterpret the results. When you are disseminating a size estimate, study the wording and mechanisms carefully before you release results.

There are several ways to release this information:

- a press release
- a technical report
- a briefing to policy makers
- a briefing with members of the population or a non-government organisation that provides services or represents that population.

It may be useful to develop a table that lists stakeholders who need access to the results with the method you propose for sharing the results, the timing of the release and any other useful information. Timing the dissemination activities based on the priority level of the stakeholder allows the study team time to incorporate feedback from earlier sessions into a final report. Also, creating a table will help you to determine what products are needed from the estimation exercise. Table 4.2 provides an example.

Table 4.2. Example of dissemination plan matrix

Stakeholder	Method of sharing	Timing of dissemination
Civil society organisations, most-at-risk population	Briefing	First
Policy and programme managers	Briefing, executive summary	Second
Development partners	Technical report	Third
Media	Press release	Fourth

Sometimes the results of the estimation may threaten a community. For example, if a small community (general population) learns that there are over 2,000 persons who inject drugs in their city, there might be a backlash against persons who inject drugs.

Incorporating messages about how to prevent or treat drug addiction in your final report might avoid such situations. Programme managers who work with most-at-risk populations should be involved in the development of the report and other products you plan to disseminate.

4.4. Step 10: Use the size estimates

Using the estimates appropriately for programme and planning activities is critical. The job of the study team who created the size estimates is still not complete, even after it has been disseminated.

Size estimates should be used for designing and developing intervention programmes to help individuals avoid risky behaviours:

- Condom distribution
- Clean needle exchange
- Drug treatment programmes
- Microfinance economic opportunities to facilitate preventing/leaving sex work

The estimated number of people in the populations will help determine the magnitude and the resources needed for such interventions.

Size estimates should also be included in the process of knowing your epidemic. The size estimates can be used in creating national prevalence estimates in low and concentrated epidemic countries. In addition, the size estimates are needed for creating models on where future infections will take place.

Teams developing the national strategic plan and costing those plans will need the estimates to determine the resources required for most at risk populations.

Finally the size estimates are often used as denominators for reporting on international monitoring indicators (such as the UN General Assembly Special Session on HIV indicators). When applying for grants from international organisations, countries are requested to include information on size estimates for their most-at-risk populations.

The implementers of the size estimate exercise should ideally ensure that the size estimates are being used, and being used correctly, in these different applications.

Appendix A. Useful data sources for size estimation

Table 1. Drug-related data

Data source	Does it exist?	For what cities/areas?	Data quality?	If it exists, is it available for regular estimation work?	If not, how feasible to set up data collection?	Can you bring examples to the meeting?
Behavioural Sentinel Surveys (BSS)						
Other focused surveys						
Household surveys						
HIV surveillance						
Register of addicts						
Treatment centre data						
Police data, by reason for arrest						
Court data, by reason for trial						
Prison data, by reason for conviction						
Hospital data on drug-related death						
Mortality data on drug-related death						
Health service data on positive drug tests						
Employment agency data on positive drug tests						
Data from needle exchange programmes						
Data from outreach programmes						
Research studies						
Anything alse?						

Table 2. Data related to sex work

Data source	Does it exist?	For what cities/areas?	Data quality?	If it exists, is it available for regular estimation work?	If not, how feasible to set up data collection?	Can you bring examples to the meeting?
BSS among sex workers						
BSS among clients						
Other focused surveys among sex workers						
Mapping of brothels/red light districts						
Registry of brothels						
Police data on brothels						
Registry of "short stay" hotels						
Registry of karaoke bards or "entertainment places"						
Other focused surveys among clients						
Household surveys of consumption of commercial sex						
HIV surveillance						
Register of sex workers						
STI clinic data						
Police data, by reason for arrest						
Court data, by reason for trial						
Prison data, by reason for conviction						
Condom sales or distribution data						
Data from outreach programmes						
Research studies						
Anything else?						

Table 3. Data related to MSM/transvestites

Data source	Does it exist?	For what cities/areas?	Data quality?	If it exists, is it available for regular estimation work?	If not, how feasible to set up data collection?	Can you bring examples to the meeting?
BSS among MSM/ transvt						
BSS among clients						
Other focused surveys among MSM/transvt						
Mapping of cruising areas						
Registry of bars or "entertainment places"						
Household surveys with questions about same-sex experience						
HIV surveillance						
MSM clinic data						
STI clinic data						
Data from outreach programmes						
Research studies						
Anything else?						

References

1 Vandepitte, J., et al., *Estimates of the number of female sex workers in different regions of the world*. Sexually Transmitted Infections 2006, 82(Supplement 3): iii18-iii25.

2 Gouws, E., et al., *Short term estimates of adult HIV incidence by mode of transmission: Kenya and Thailand as examples.* Sexually Transmitted Infections 2006, 82(Supplement 3): iii51-iii55.

3 FHI, Impact, USAID, UNAIDS, WHO, and UNDCP. Estimating the Size of Populations at Risk for HIV: Issues and Methods. 2003:03-36E. Available at http://data.unaids.org/pub/Manual/2003/20030701_gs_estpopulationsize_en.pdf. Accessed 22 February 2010.

4 Lyerla R, Gouws E, Garcia-Calleja JM. The quality of sero-surveillance in low- and middle-income countries: status and trends through 2007. Sexually Transmitted Infections 2008, 84(Supplement 1):i85-i91.

5 Barcal K, Schumacher JE, Dumchev K, Moroz LV. A situational picture of HIV/AIDS and injection drug use in Vinnitsya, Ukraine. Harm Reduction Journal 2005, 2:16 doi:10.1186/1477-7517-2-16 (accessed 22 February 2010).

6 Heimer, R. and E. White, Estimation of the number of injection drug users in St. Petersburg, Russia. Drug and Alcohol Dependence, 2010. In Press, Corrected Proof.

7 Mastro TD, et al. Estimating the number of HIV-infected injection drug users in Bangkok: a capture-recapture method. Am J Publ Health 1994;1094-99.

8 Brown P. Rate of HIV transmission among Africans in UK "underestimated". BMJ 2000; 320(7237): 735.

9 Fairchild AL, Gable L, Gostin LO, Bayer R, Sweeney P, Janssen RS. Public Goods, Private Data: HIV and the History, Ethics, and Uses of Identifiable Public Health Information. Public Health Reports 2007;122:7-15.

10 Baker MG, Fidler DP. Global public health surveillance under new international health regulations. Emerg Infect Dis 2006;12:1058-65.

11 Schenk K, Williamson J. 2005. Ethical Approaches to Gathering Information from Children and Adolescents in International Settings: Guidelines and Resources. Washington, DC: Population Council, 2005.

12 Pollock KH. Modeling capture, recapture and removal statistics for estimation of demographic parameters for fish and wildlife populations. J Amer Stat Assn 1991;86:225-38.

13 Botero CA, Mudge AE, Koltz AM, Hochachkat WM, Veherncamp SL. How reliable are methods for estimating repertoire size. Ethology 2008;114:1227-38.

14 Wittes JT, Colton T and Sidel VW. Capture-recapture models for assessing the completeness of case ascertainment using multiple information sources. J Chronic Dis 1974;27:25-36.

15 Hook EB, Regal RR. Capture-recapture methods in epidemiology: methods and limitations. Epidemiol Rev 1995;17:243-64. (Corrigenda in Am J Epidemiol 1998;148:1219).

16 Tilling K. Capture-recapture methods-useful or misleading? Int J Epidemiol 2001;30:12-14.

17 Blanxart MF, Olmos JG, Serrano MLH, Cebollero MP. Validation of the capture-recapture method. Psicothema 2000;12 (Suppl2):231-5.

18 Millar T, Comingo-Salvany A, Eastwood C, Hay G. Glossary of terms relating to capture-recapture methods. J Epidemiol and Comm Health 2008;62(8):677-81.

19 Robson, et al. Sample Size in Petersen Mark-Recapture Experiments. Transactions of the American Fisheries Society, 1964. **93**(3): p. 215-226.

20 Mastro TD, et al. Estimating the number of HIV-infected injection drug users in Bangkok: a capture-recapture method. Am J Publ Health 1994;1094-99.

21 Uuskűla A, Rajaleid K, Talu A, Abel K, Rüütel K, Hay G. Estimating injection drug use prevalence using state wise administrative data sources: Estonia 2004. Addition Research and Theory: 2007;16:411-24.

22 Heckathorn DD. Respondent-driven sampling II: deriving valid population estimates from chain-referral samples of hidden populations. Social Problems 2002;49:11-34.

23 Ove F, Snijders T. Estimating the size of hidden populations using snowball sampling. J Official Stat 1994;10:53-67.

24 Erickson BH. Some problems of inference from chain data. Sociological Methodology 1979:10;276-302.

25 Heckathorn DD. Respondent-driven sampling II. Deriving valid population estimates from chain-referral samples of hidden populations. Social Problems 2002; 49(1):11-34.

26 Hickman et al. Estimating drug prevalence: review of methods with special reference to developing countries, Bulletin on Narcotics, UN Office on Drugs and Crime, 2004.

27 Zhang D, Wang L, Lv F, et al. Advantages and challenges of using census and multiplier methods to estimate the number of female sex workers in a Chinese city. AIDS Care 2007;19:17-9.

28 Saidel T. Estimating population sizes in the absence of a "gold standard": multiplier method in India. Presented at UNAIDS/WHO Reference Group Meeting, Amsterdam, December 2008.

29 Link M, Battaglia M, Frankel M, Osborn L, Mokdad A. Address-based versus random-digit dial sampling; comparison of data quality from BRFSS mail and telephone surveys. In: Proceedings of the 2005 Federal Committee on Statistical Methodology Research Conference [CD-ROM]; Arlington, Virginia. Available at http://www.fcsm.gov/events/papers05.html. Accessed 24 February 2009.

30 Measure DHS+ (2000) Demographic and Health Surveys. www.macroint.com/dhs 2000 Macro International Calverton, MD. Accessed 24 February 2009.

31 CDC. Methodology of the Youth Risk Behavior Surveillance System *Morbidity & Mortality Weekly Report* 2004;53(RR-12):1–13.

32 Kalsbeek WD. The Use of Surveys in Public Health Surveillance: Monitoring High-Risk Populations. Chapter in Monitoring the Health of Populations (Brookmeyer R, Stroup DF eds). New York: Oxford University Press, 2004.

33 Nath MB. A gendered response to HIV/AIDS in South Asia and the Pacific: insights from the pandemic in Africa. Gender & Development. 2006;14:11-22.

34 McCarty, C., 1997, Subgroups in personal networks: The inside view. American Journal of Community Psychology 1997.

35 Kochen M, ed. The Small World. Norwood NJ: Ablex, 1989.

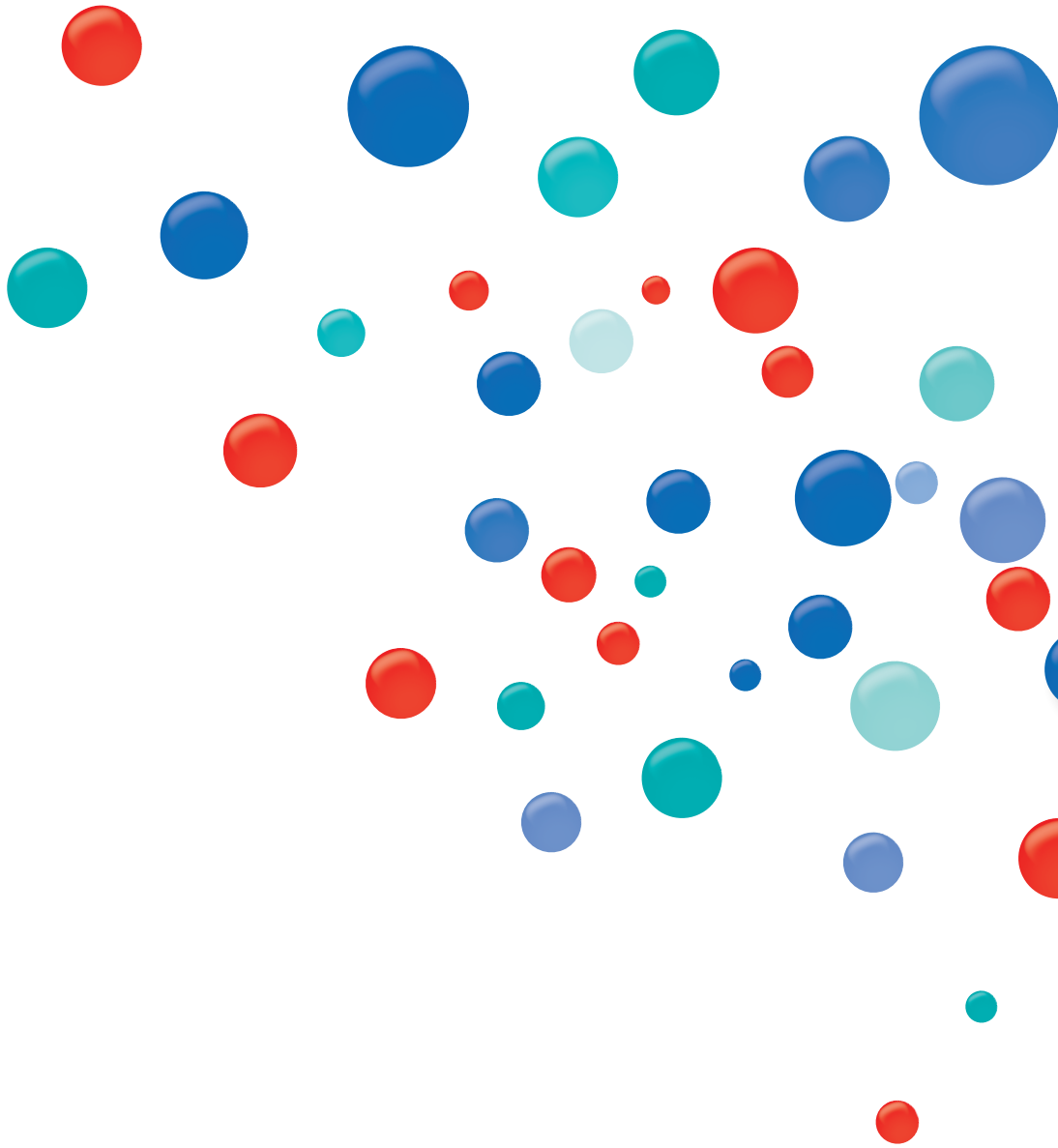
36 Killworth PD, McCarty C, Johnsen EC, Bernard HR, Shelley GA. Investigating the variation in personal network size under unknown error conditions. Sociological Methods and Research 2006; 35:84-112.

37 Bernard HR, Johnsen EC, Robinson S. Esimating the size of an average personal network and of an event subpopulation: some empirical results. Social Science Research 1991;20:109-21.

38 Laumann EO, Gagnon JH, Michaels S., Michael RT, Schumm LP. Monitoring AIDS and other rare population events: A network approach, Journal of Health and Social Behavior 1993;34:7-22.

39 Killworth PD, McCarty C, Johnsen EC, Bernard HR, Shelley GA. Investigating the variation in personal network size under unknown error conditions. Sociological Methods and Research 2006; 35:84-112.

40 Lynskey M, Hall W. Jurisdictional trends in opiod deaths 1988-1995. Australian and New Zealand Journal of Public Health. 1998;23:519-24.



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ISBN 978 92 4 1599580