Estimating the population size of female sex workers, men who have sex with men, and people who inject drugs in Nigeria using the Network Scale-up Method

Collaborating Institutions

Federal Ministry of Health (FMoH), National AIDS & STI Control Program (NASCP), National Agency for the Control of AIDS (NACA), United States Centers for Disease Control and Prevention (CDC), University of Maryland School of Medicine, Baltimore (UMB)

Date: December 10, 2021

Funding Source: The President's Emergency Plan for AIDS Relief (PEPFAR) through the United States Centers for Disease Control and Prevention (CDC) Cooperative Agreement (U2GGH001946) to the University of Maryland, Baltimore (UMB). The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the funding agencies.

National Agency for the Control of AIDS Primary Contact: Gregory Ashefor, MD, Chair, Population Size Estimation National Technical Team, National Agency for the Control of AIDS (NACA), Abuja, Nigeria (email: asheforgrego@yahoo.co.uk)

Federal Ministry of Health Primary Contact: Sunday Aboje, MBBS, Federal Ministry of Health (FMoH), Abuja, Nigeria (email: saboje@yahoo.com)

National AIDS and STDs Control Programme Primary Contact: Adebobola Bashorun, National AIDS and STDs Control Programme (NASCP), Abuja, Nigeria (email: bashogee@gmail.com)

CDC Atlanta Primary Contact: Anne McIntyre, PhD, U.S. Centers for Disease Control and Prevention, Atlanta, Georgia, USA (email: zat4@cdc.gov)

CDC Nigeria Primary Contact: Matthias Alagi, MBBS, MSc, U.S. Centers for Disease Control and Prevention, Abuja, Nigeria (email: pki7@cdc.gov)

UMB Primary Contact: Manhattan Charurat, PhD, Professor, Director, Epidemiology and Prevention, Institute of Human Virology, University of Maryland School of Medicine, Baltimore, MD, USA (email: mcharurat@ihv.umaryland.edu)

Table of Contents

Executive summary

Nigeria is transitioning from a generalized HIV epidemic to one that is concentrated among key populations (KP), specifically female sex workers (FSW), men who have sex with men (MSM) and people who inject drugs (PWID). Accurate population size estimates (PSE) for these KP help to develop and target interventions and inform policy planning. One method of achieving empirical PSE is the network scale-up method (NSUM), which is administered as part of a general population survey and can be used to produce national and sub-national PSE for hidden subpopulations.

An NSUM module was included in the Nigeria AIDS Indicator and Impact Survey (NAIIS), a nationally representative household-based survey conducted during 2018 to estimate HIV incidence, prevalence, viral load, and related risk factors. NAIIS provided sufficient sample sizes to allow NSUM to produce national and state-level PSE for multiple, hidden subpopulations. In this report, we describe the NSUM module, analysis, and PSE for FSW, MSM, and PWID living in Nigeria.

Suggested citation

National Agency for the Control of AIDS (NACA), Nigeria. Estimating the population size of female sex workers, men who have sex with men, and people who inject drugs in Nigeria using the network scale-up method. September 2021.

Editors

Gregory Ashefor (NACA), Matthias Alagi (US CDC Nigeria), Anne McIntyre (US CDC Atlanta), Sylvia Adebajo (UMB Nigeria), Samuel Nwafor (UMB Nigeria), Andrew Mitchell (UMB), and Kristen Stafford (UMB)

Abbreviations and Acronyms

AIDS	Acquired Immunodeficiency Syndrome
CDC	United States Centers for Disease Control and Prevention
FMoH	Federal Ministry of Health
FCT	Federal Capital Territory
FSW	Female Sex Worker
HIV	Human Immunodeficiency Virus
IQR	Interquartile Range
KP	Key Population
MSM	Men who have Sex with Men
NAIIS	Nigeria HIV/AIDS Indicator and Impact Survey
NSUM	Network Scale-up Method
PEPFAR	United States President's Emergency Plan for AIDS Relief
PHC	Population Housing Census
PSE	Population Size Estimation (or Estimate)
PWID	People Who Inject Drugs
STI	Sexually Transmitted Infection
UMB	University of Maryland, Baltimore

Introduction

Population size estimation

Population size estimates (PSE) are essential for many fields of study, including HIV. Key populations (KP), including female sex workers (FSW)(1, 2), men who have sex with men (MSM)(3, 4), and people who inject drugs (PWID)(5, 6), are among those at the highest risk of HIV infection(7-9). These populations are vulnerable to HIV infection due to stigmatized and criminalized behaviors, threats that often prevent them from seeking essential HIV services(3, 10-13). This is of particular importance in sub-Saharan African countries like Nigeria, with approximately 1.8 million people living with HIV, the fourth largest burden of HIV in the world(14). The adult general population HIV prevalence is low, 1.4%(15), but high among FSW (16.7%), MSM (20.9%), and PWID (6.2%). Empirically derived PSE advise HIV program planners and policy developers, and inform the development of appropriate HIV epidemic response efforts(16, 17).

Network scale-up method

One method of achieving empirical PSE is the network scale-up method (NSUM). Based on the assumption that general population personal networks should include the same frequency of hidden populations as randomly selected survey respondents(18-20), NSUM is administered as a module within a general population survey and, with sufficient sample size, may produce national and sub-national PSE for multiple sub-populations of interest. Through a series of questions that elicit how many people respondents know in specified subpopulations with a known population size such as from a census or registry, the average personal network size of survey respondents is calculated. An additional set of questions asks respondents to estimate the number of people they know from target populations where the size is unknown (e.g., key populations). The average personal network size derived from the known populations is used to scale-up the populations whose size is unknown. NSUM has been used to generate PSE for a broad range of subpopulations such as earthquake casualties(21), Iranian student marijuana consumers(22), cases of COVID-19(23), victims of rape(18), people who are homeless(18), women who have had abortions(24, 25), choking in students(26), and key populations at risk for HIV(18, 27-29).

Statistical assumptions of NSUM include the following: 1) social networks are established at random, and everyone in the population is equally likely to know someone in a given subpopulation; 2) survey respondents are completely aware of the characteristics of people within their network, and able to determine whether an individual belongs to a given subpopulation; and 3) survey respondents have perfect recall and are able to provide accurate answers to questions about their networks. When one or more of these assumptions are violated, NSUM can be prone to bias. Specific biases encountered during NSUM PSE include transmission error(30-36), barrier effect(31, 32, 35, 36), response bias or stigma effect(26), and recall(33, 36, 37). Transmission error occurs when a respondent does not know that an acquaintance is a member of a subpopulation. This often results in an underestimate, but may also yield an overestimate if a respondent assumes an acquaintance is a subpopulation member when he/she is not. Transmission error violates the assumption that respondents have perfect knowledge of which subpopulations their alters belong to, and varies widely among different subpopulations. This can be addressed by adjusting for social visibility using a method such as the Game of Contacts(34). The barrier effect describes underestimates that result when subpopulation members have smaller networks or fewer general population members in their network. This violates the assumption that respondents may

be more (or less) less likely to know someone in a subpopulation based on their own characteristics. This can be addressed by collecting a representative survey sample. Response bias or the stigma effect occurs when a survey respondent knows members of a subpopulation but deliberately neglects to disclose their connection, resulting in an underestimate of the subpopulation. This can be reduced by having well-trained interviewers who make the survey respondents comfortable in providing accurate responses to sensitive questions.

Objectives

An NSUM module was included in the Nigeria AIDS Indicator and Impact Survey (NAIIS)(15), a nationally representative household-based survey conducted during 2018 to estimate HIV incidence, prevalence, viral load, and related risk factors. NAIIS provided sufficient sample sizes to allow NSUM to produce national and state-level PSE for multiple, hidden subpopulations. In this report, we describe the NSUM module, analysis, and PSE for FSW, MSM, and PWID living in Nigeria.

Methods

Sampling and data collection

The Nigeria AIDS Indicator and Impact Survey (NAIIS) was a nationally representative household-based survey conducted during 2018 to estimate HIV incidence, prevalence, viral load, and HIV-related risk factors(15). Nigeria geopolitical departments include 36 states and the Federal Capital Territory (FCT). For the purposes of this paper, we will refer to FCT as a state. In each of the 37 states, 25 enumeration areas (EAs) with the rural and urban distribution based on the most recent (2006) census were selected using probability proportional to size. During the second stage of sampling, 25 households were selected at random. One eligible adult 18-54 years of age from each household was selected at random to complete the NSUM survey module. This sampling design allowed for sufficient precision to produce national and state-specific population size estimates. To achieve sufficient precision for subnational unit estimates, one adult per household was selected. If there was more than one eligible adult per household, the respondent was selected at random by the tablet to complete the NSUM module.

Network scale-up method

NAIIS participants selected for the NSUM module were asked a series of questions about the number of people in their social network. These included how many people they knew from subpopulations with known population sizes, and how many people they knew who belonged to subpopulations whose sizes were unknown. To “know” someone is based on local context. Interviewer instructions to respondents explained that it meant people you know by sight and name and who know you by sight and name, and who you have had dinner or drinks or some other type of social interaction with in the past 12 months, from 18-64 years unless otherwise specified, and who lived in Nigeria.

Known populations

Known populations include those with public statistics that are collected regularly such as census data, government or national registries, or nationally representative surveys. The ideal questions are those that an acquaintance would know about people in their personal network such as marital status, births or deaths, and employment status. Questions about sensitive topics or medical conditions that are not visible are harder for respondents to answer correctly. Our sources of known populations were the most recent Nigeria census, the 2006 Population Housing Census (PHC) (38), and the 2018 Nigeria Demographic and Health Survey (39). We selected 21 populations that represented between 0.1% and

4.0% of the general population to improve recall (Table 1). During the 2006 PHC, Nigeria's population was approximately 140.4M (38). We used 18-64 years age groups by sex and applied proportions of known populations to intercensal estimates for 2018 when Nigeria's population had grown to 195.9M (40).

To obtain the denominator of our estimator, we calculated the average personal network size using the 21 known populations listed in Table 1. As the 21 known populations were based on 2006 PHC proportions applied to 2018 intercensal projections, we expected to have varying levels of quality. Consistent with other NSUM analyses (34, 35), we reviewed frequency distributions and ran regression models without intercepts to output scatterplots with regression lines to compare known population sizes with average network sizes. We had the most confidence in known populations whose results were closest to the regression line. Those with extreme responses were excluded, as well as those deemed as having potential to be misinterpreted by survey respondents. Seven known populations were retained after this process, including accountants, bankers, divorcees, widows/widowers, PhD or advanced degree holders, ministers or religious leaders, and civil servants.

Table 1. Known populations based on 2018 Demographic and Health Survey questions or categories from the 2006 Population Housing Census

	Known Population	**Estimated 2018 Population (Nigeria)**
	How many people do you know…	
1	…18-64 years, whose spouse has died	1,227,943
2	…18-64 years, who are divorced	545,753
3	…with a PhD or advanced degree	886,848
4	…who cannot see (disability)	136,438
5	…who are accountants	2,046,572
6	…who are administrative officers	1,569,039
7	…who are patent medicine sellers	341,095
8	…who are smoked fish and meat sellers	1,500,820
9	…who are catering or lodging service workers	68,219
10	…who are factory workers	68,219
11	…who are military personnel	136,438
12	…who are teachers (including governesses)	68,219
13	…who are ministers or religion	68,219
14	…who are barbers, hairdressers, saloonists, and beauticians	68,219
15	…who are farmers (general)	1,500,820
16	…who are Civil Servants	2,728,763
17	…who are fishermen or fisherwomen	2,524,106
18	…who are bankers	341,095
19	…who are furniture makers	68,219
20	…who are fashion designers such as tailors, dress makers, and seamstresses	750,410
21	…who are drivers (general)	613,972

Key and priority populations

Respondents were asked about subpopulations whose sizes were to be estimated using responses to the known populations in combination with personal network size. A total of seven key and priority populations were included in the NSUM module. Descriptions of the populations included in each question were crafted deliberately to limit misperception among respondents. Exact language of questions pertaining to FSW, MSM, and PWID, the three key populations within the scope of this report, are shown in Table 2. The PSE presented in this report for MSM were calculated as a sum of individual PSE for men who have sex with other men, exclusively, and men who have sex with men and women.

Table 2. Network scale-up module questions for female sex workers, men who have sex with men, and people who inject drugs, Nigeria 2018

Female sex workers: Some women sell sex to men, as their main income or to support their children. How many women do you know who sell sex to men?
Men who have sex with men: Some men have sex with only women, some men have sex with only men, and some have sex with both men and women. • How many men do you know who have sex with other men **and** women? • How many men do you know who **only** have sex with other men?
People who inject drugs: There are people who use drugs that they inject into themselves to get high or feel strong. How many people do you know who inject non-prescription drugs?

Data analysis

Population size estimation

Population size estimates for FSW, MSM, and PWID were calculated using a modified, basic scale-up estimator with bootstrapped 95% CI (30).

The modified basic scale-up estimator is used to estimate the network size for each respondent. Modified refers to sampling from the frame population (e.g., adults, heads of households) rather than the entire population (e.g., adults and children) which is the basic scale-up estimator(30).

$$\widehat{N}_H = \frac{\widehat{y}_{F,H}}{\widehat{d}_{F,F}} \times N_F = \frac{\widehat{y}_{F,H}}{\widehat{d}_{F,F} \big/ N_F}.$$

Where:

- F is the frame population (adults, aged 18-54 years)
- H is hidden population
- $y_{F,H}$ is the estimator for the numerator
- $d_{F,F}$ is the total number of connections between adults, so questions should reflect those relationships

For Nigeria and each of the 37 states, we calculated the percentage that FSW, MSM, and PWID PSE represented in the general population, aged 18-64 years. Data were obtained from 2018 general population intercensal projections based on the 2006 PHC(38). We used male population data for MSM, female population data for FSW, and general population estimates for PWID.

Adjustment for social visibility using the Game of Contacts

Transmission error occurs when NSUM respondents are unaware that members of their personal networks belong to the subpopulation(s) of interest, and can result in underestimated PSE. We can address this by adjusting NSUM estimates with external data from the same population. We used the Game of Contacts(34) to assess social visibility among FSW, MSM, and PWID in Nigeria. Through a standardized evaluation process to identify physical and staff capacity to host Game of Contact activities, we identified nine key population service providers to be our survey sites ("game centers"), safe locations to perform eligibility screening and administer the survey ("game") to FSW, MSM, and PWID participants. Security, safety, and funding restricted our efforts to nine locations, including three sites for FSW (Imo, Kaduna, and Oyo), four sites for MSM (Anambra, FCT, Kaduna, and Oyo), and two sites for PWID (Kaduna and Lagos). Each site recruited approximately 250 participants from the targeted KP.

Similar eligibility criteria and definitions as the NAIIS NSUM module were applied for the Game of Contacts. Age of participants was 18-54 years, with additional criteria including female sex at birth for FSW, and male sex at birth for MSM. The "game" component of the survey entailed the presentation of a series of names to participants, who were then asked how many people they knew by each name. The definition of "to know" was identical to the NAIIS NSUM module: to know by sight and name, have had some personal contact within the past 12 months, and live in Nigeria. In each game, participants were shown 12 male and 12 female names the tablet displayed in random order. For each name (alter), how many (name) did they know? Does (name) know you are (FSW, MSM, or PWID)? Is (name) (FSW, MSM, or PWID)? If participants knew more than one person with the same name, the process was repeated for each person.

For each survey site ("game center"), the transmission rate, τ (tau), was calculated(34).

$$\hat{\tau} = \frac{\sum_i (w_i/\pi_i)}{\sum_i (x_i/\pi_i)}$$

- τ: probability that a randomly chosen name (list) will be aware that the respondent is connected to target population
- w: number of alters that are aware that respondent is in target population
- x: total number of alters
- π: probability of selection for respondent

Results from the Game of Contacts suggested high social visibility for FSW and PWID, and PSE for these subpopulations were not adjusted. Measures of social visibility obtained for MSM were markedly lower, indicating that PSE should be adjusted to avoid underestimation. Adjustment factors obtained from Game of Contacts sites in FCT (2.12; 95% CI: 1.90, 2.36), Kaduna (1.81; 95% CI: 1.66, 1.98), and Oyo (2.13; 95% CI: 1.73, 2.68), were applied to state-level PSE based on geographic proximity. The FCT adjustment factor was applied to the national MSM PSE.

Comparisons

We compared our PSE with the general population (Tables 4-7) by state, KP, and age group. Using 2018 projections based on the 2006 PHC(38), we calculated the percent of the general population represented by our PSE. For FSW, we used the adult (18-54 years) female population. For MSM, we used the adult (18-54 years) male population. For PWID, we used the adult (18-54 years) total (male and female combined) population. In addition, we summarized the number and percentage of the NAIIS NSUM respondents in each state who resided in urban enumeration areas (EA) out of all (urban and rural) EA as a proxy for urban/ rural distribution of FSW, MSM, and PWID by state.

Human subjects research approval

All survey procedures were aligned with recommendations from the ethics and regulatory board. Human subject review was conducted by the CDC Institutional Review Board (IRB), the UMB IRB and the Nigerian National Health Research Ethics Committee.

Results

Of 229,762 adults sampled in NAIIS, 67,834 were aged 18-54 years and selected for the supplementary NSUM module. From this subset, 61,676 consented to participate and completed the NSUM questionnaire. Selected characteristics of these respondents are detailed in Table 3.

Table 3. Characteristics of NAIIS NSUM respondents, Nigeria 2018

Characteristic	n*	Percent (95% CI)*
Age (years)		
Mean	61,676	31.4 (31.4, 31.5)
Median (IQR)	61,676	30.0 (23.0, 40.0)
Age group (years)		
18-24	13,746	29.7 (29.2, 30.3)
25-34	21,185	32.1 (31.5, 32.6)
35-44	16,197	23.5 (23.0, 24.0)
45-54	10,548	14.7 (14.3, 15.0)
Place of Residence		
Urban	26,723	47.7 (45.8, 49.6)
Rural	34,953	52.3 (50.4, 54.2)
Sex		
Male	27,352	51.6 (50.9, 52.2)
Female	34,324	48.4 (47.8, 49.1)
Marital status		
Never married	15,479	30.6 (29.9, 31.4)
Married or living together	41,585	64.2 (63.4, 65.0)
Divorced or separated	2,098	2.4 (2.3, 2.6)
Widowed	2,428	2.6 (2.5, 2.8)
Religion		
Christian	36,267	49.9 (48.7, 51.0)
Islam	24,884	49.4 (48.2, 50.6)
Traditional	415	0.6 (0.5, 0.7)
No religion	87	0.1 (0.1, 0.1)
Education		
No education	10,789	16.7 (16.0, 17.5)
Primary	11,500	16.8 (16.3, 17.3)
Secondary	24,479	40.4 (39.6, 41.1)
Tertiary	10,930	17.4 (16.7, 18.1)
Other	3,925	8.6 (7.9, 9.3)
Wealth quintile		
Lowest	10,807	17.7 (16.6, 18.9)
Second	11,617	19.1 (18.2, 20.0)
Middle	13,227	19.8 (19.0, 20.6)
Fourth	13,497	21.2 (20.4, 21.9)
Highest	12,528	22.2 (21.3, 23.2)
HIV status		
Positive	1,093	1.4 (1.3, 1.6)
Negative	56,238	91.4 (91.0, 91.8)
Untested	4,345	7.2 (6.8, 7.6)

*Data are presented as n (%) unless otherwise indicated. Abbreviations: CI, confidence interval; IQR, interquartile range; NAIIS, Nigeria AIDS Indicator and Impact Survey; NSUM, network scale-up method.

Population size estimates

The following sections present national (Table 4) and state-level (Tables 5-7) PSE for FSW, MSM, and PWID in Nigeria. All PSE include a point estimate and 95% CI, rounded to the nearest hundred, and are presented alongside the corresponding proportion of each KP relative to the adult (18-54 years) general population according to 2018 intercensal projections. Female population data were used for FSW, male population data were used for MSM, and both male and female population data were used for PWID. State-level PSE were grouped by region.

Table 4. National population size estimates for female sex workers, men who have sex with men, and people who inject drugs, Nigeria 2018

KP	PSE	PSE 95% CI	PSE % of general population*	PSE % of general population* 95% CI
FSW	810,900	(762,800, 859,100)	1.8	(1.8, 2.0)
MSM	747,200	(601,200, 917,700)	1.6	(1.3, 2.0)
PWID	943,900	(879,200, 1,008,600)	1.1	(0.8, 1.2)

*Reflects 2018 intercensal projections for adults based on the 2006 Population Housing Census. Female population data were used for FSW, male population data were used for MSM, and both male and female population data were used for PWID.

Abbreviations: CI, confidence interval; KP, key population; PSE, population size estimate

Table 5. Population size estimates for female sex workers by state, Nigeria 2018

Region	State	PSE	PSE 95% CI	PSE/ Gen Pop*		EA distribution**		
				%	(95% CI)	% Urban	N Urban	N Total
North Central	Benue	32,300	(20,100, 44,500)	2.5	(1.5, 3.4)	16.0	271	1,699
	FCT	7,000	(4,600, 9,300)	2.0	(1.3, 2.6)	91.7	1,677	1,828
	Kogi	12,900	(7,800, 18,000)	1.3	(0.8, 1.8)	56.4	877	1,555
	Kwara	8,600	(5,400, 11,800)	1.3	(0.8, 1.8)	54.0	743	1,376
	Nasarawa	10,400	(7,700, 13,200)	2.3	(1.7, 2.9)	33.1	545	1,645
	Niger	9,400	(4,500, 14,200)	0.8	(0.4, 1.2)	23.5	407	1,729
	Plateau	11,700	(7,500, 15,800)	1.2	(0.7, 1.6)	34.4	651	1,892
North East	Adamawa	23,700	(10,900, 36,400)	2.5	(1.1, 3.8)	31.4	511	1,628
	Bauchi	18,700	(12,800, 24,500)	1.3	(0.9, 1.7)	14.2	224	1,582
	Borno	17,400	(7,200, 27,700)	1.4	(0.6, 2.2)	64.4	385	598
	Gombe	15,700	(9,200, 22,200)	2.6	(1.5, 3.7)	30.7	536	1,747
	Taraba	19,500	(12,100, 26,900)	3.2	(2.0, 4.4)	17.4	312	1,793
	Yobe	7,300	(4,000, 10,500)	1.2	(0.7, 1.7)	23.3	308	1,320
North West	Jigawa	22,700	(14,800, 30,600)	1.6	(1.1, 2.2)	53.2	969	1,821
	Kaduna	43,700	(31,000, 56,400)	2.1	(1.5, 2.7)	59.3	975	1,645
	Kano	62,700	(43,500, 82,000)	2.0	(1.4, 2.6)	63.6	960	1,510
	Katsina	16,400	(8,700, 24,000)	0.9	(0.5, 1.3)	16.4	246	1,498
	Kebbi	11,500	(6,200, 16,900)	1.2	(0.6, 1.7)	19.8	297	1,499
	Sokoto	15,700	(8,600, 22,700)	1.4	(0.8, 2.0)	32.3	483	1,494
	Zamfara	12,100	(6,700, 17,500)	1.2	(0.7, 1.8)	39.1	354	905
South East	Abia	25,400	(17,700, 33,100)	2.8	(2.0, 3.7)	34.0	662	1,947
	Anambra	47,100	(34,300, 59,900)	3.3	(2.4, 4.1)	82.9	1,409	1,699
	Ebonyi	12,900	(8,500, 17,300)	2.0	(1.3, 2.7)	19.0	387	2,033
	Enugu	33,800	(26,300, 41,400)	3.0	(2.4, 3.7)	31.9	554	1,735
	Imo	52,100	(34,700, 69,500)	3.9	(2.6, 5.2)	30.6	550	1,795
South South	Akwa Ibom	48,100	(31,400, 64,900)	3.6	(2.4, 4.9)	12.9	247	1,921
	Bayelsa	18,700	(15,400, 22,000)	4.7	(3.9, 5.5)	25.9	489	1,888
	Cross River	32,900	(23,300, 42,400)	3.8	(2.7, 3.8)	21.6	395	1,827
	Delta	55,700	(42,300, 69,200)	4.0	(3.0, 5.0)	42.2	777	1,842
	Edo	34,800	(25,300, 44,300)	3.4	(2.4, 4.3)	56.7	1,076	1,898
	Rivers	75,600	(57,000, 94,200)	4.1	(3.1, 5.1)	35.9	614	1,711
South West	Ekiti	11,700	(8,500, 14,900)	1.6	(1.2, 2.0)	76.3	1,214	1,592
	Lagos	123,500	(102,500, 144,600)	3.7	(3.0, 4.3)	87.0	2,290	2,631
	Ogun	24,700	(15,800, 33,600)	2.0	(1.3, 2.7)	64.1	913	1,425
	Ondo	28,300	(18,300, 38,200)	2.5	(1.6, 3.4)	46.8	783	1,672
	Osun	20,500	(15,000, 26,100)	1.8	(1.3, 2.3)	86.6	1,356	1,566
	Oyo	40,600	(25,600, 55,700)	2.0	(1.3, 2.8)	73.8	1,276	1,730

*Reflects 2018 intercensal projections for female adults based on the 2006 Population Housing Census

**Describes number and proportion of NSUM respondents who resided in urban areas

Abbreviations: CI, confidence interval; PSE, population size estimate; EA, enumeration area

Table 6. Population size estimates for men who have sex with men by state, Nigeria 2018

Region	State	PSE	PSE 95% CI	PSE/ Gen Pop*		EA distribution**		
				%	95% CI	% Urban	N Urban	N Total
North Central	Benue	17,800	(9,400, 28,100)	1.3	(0.7, 2.1)	16.0	271	1,699
	FCT	5,500	(2,900, 8,800)	1.4	(0.7, 2.2)	91.7	1,677	1,828
	Kogi	7,100	(2,100, 13,300)	0.7	(0.2, 1.3)	56.4	877	1,555
	Kwara	6,700	(2,000, 13,800)	1.2	(0.3, 2.4)	54.0	743	1,376
	Nasarawa	10,300	(5,100, 16,600)	2.3	(0.9, 4.0)	33.1	545	1,645
	Niger	11,400	(4,900, 19,300)	0.9	(0.4, 1.5)	23.5	407	1,729
	Plateau	11,100	(4,800, 18,800)	1.2	(0.5, 2.0)	34.4	651	1,892
North East	Adamawa	22,700	(9,500, 38,600)	2.5	(1.0, 4.2)	31.4	511	1,628
	Bauchi	23,900	(12,600, 37,100)	1.6	(0.9, 2.5)	14.2	224	1,582
	Borno	13,700	(500, 29,200)	1.0	(0.0, 2.1)	64.4	385	598
	Gombe	15,700	(6,000, 27,000)	2.5	(1.0, 4.3)	30.7	536	1,747
	Taraba	17,800	(8,300, 29,300)	3.2	(1.5, 5.3)	17.4	312	1,793
	Yobe	7,900	(800, 16,300)	1.3	(0.1, 2.7)	23.3	308	1,320
North West	Jigawa	27,700	(12,800, 45,300)	2.1	(1.0, 3.4)	53.2	969	1,821
	Kaduna	50,400	(15,000, 92,200)	2.3	(0.7, 4.1)	59.3	975	1,645
	Kano	80,300	(48,000, 118,100)	2.1	(1.2, 3.0)	63.6	960	1,510
	Katsina	19,900	(7,400, 34,600)	1.0	(0.4, 1.7)	16.4	246	1,498
	Kebbi	11,200	(4,400, 19,200)	1.2	(0.5, 2.1)	19.8	297	1,499
	Sokoto	21,700	(5,400, 40,900)	2.0	(0.5, 3.8)	32.3	483	1,494
	Zamfara	5,300	(1,900, 9,400)	0.6	(0.2, 1.0)	39.1	354	905
South East	Abia	22,500	(11,600, 38,600)	2.7	(1.4, 4.6)	34.0	662	1,947
	Anambra	50,200	(23,800, 89,000)	3.4	(1.6, 6.0)	82.9	1,409	1,699
	Ebonyi	7,100	(2,900, 13,300)	1.5	(0.6, 2.8)	19.0	387	2,033
	Enugu	26,700	(13,900, 45,500)	2.8	(1.4, 4.7)	31.9	554	1,735
	Imo	49,100	(25,700, 83,600)	3.7	(1.9, 6.2)	30.6	550	1,795
South South	Akwa Ibom	32,200	(13,400, 60,100)	2.4	(1.0, 4.4)	12.9	247	1,921
	Bayelsa	9,400	(4,400, 16,800)	2.4	(1.1, 4.3)	25.9	489	1,888
	Cross River	24,800	(12,200, 43,500)	2.9	(1.4, 5.1)	21.6	395	1,827
	Delta	24,600	(9,800, 46,600)	1.7	(0.7, 3.3)	42.2	777	1,842
	Edo	23,100	(6,400, 48,000)	2.2	(0.6, 4.6)	56.7	1,076	1,898
	Rivers	81,900	(44,300, 137,000)	4.0	(2.2, 6.7)	35.9	614	1,711
South West	Ekiti	4,700	(1,300, 9,800)	0.7	(0.2, 1.5)	76.3	1,214	1,592
	Lagos	68,400	(35,800, 116,300)	1.6	(0.8, 2.7)	87.0	2,290	2,631
	Ogun	11,700	(3,500, 23,900)	0.9	(0.3, 1.9)	64.1	913	1,425
	Ondo	12,000	(3,300, 25,100)	1.1	(0.3, 2.2)	46.8	783	1,672
	Osun	7,100	(1,300, 16,000)	0.6	(0.1, 1.4)	86.6	1,356	1,566
	Oyo	14,300	(3,800, 30,000)	0.7	(0.2, 1.4)	73.8	1,276	1,730

*Reflects 2018 intercensal projections for male adults based on the 2006 Population Housing Census.

**Describes number and proportion of NSUM respondents who resided in urban areas.

Abbreviations: CI, confidence interval; PSE, population size estimate; EAs, enumeration area

Table 7. Population size estimates for people who inject drugs by state, Nigeria 2018

Region	State	PSE	PSE 95% CI	PSE/ Gen Pop*		EA distribution**		
				%	95% CI	% Urban	N Urban	N Total
North Central	Benue	30,500	(15,700, 45,400)	1.2	(0.6, 1.7)	16.0	271	1,699
	FCT	9,600	(5,900, 13,200)	1.3	(0.8, 1.8)	91.7	1,677	1,828
	Kogi	11,500	(6,400, 16,500)	0.6	(0.3, 0.8)	56.4	877	1,555
	Kwara	11,300	(6,000, 16,600)	0.9	(0.5, 1.4)	54.0	743	1,376
	Nasarawa	20,600	(14,900, 26,300)	2.5	(1.8, 3.2)	33.1	545	1,645
	Niger	14,400	(8,400, 20,500)	0.6	(0.3, 0.8)	23.5	407	1,729
	Plateau	23,000	(14,600, 31,300)	1.2	(0.8, 1.6)	34.4	651	1,892
North East	Adamawa	40,400	(24,900, 55,900)	2.2	(1.3, 3.0)	31.4	511	1,628
	Bauchi	49,700	(37,700, 61,700)	1.7	(1.3, 2.2)	14.2	224	1,582
	Borno	33,300	(19,300, 47,300)	1.3	(0.7, 1.8)	64.4	385	598
	Gombe	28,600	(20,300, 36,800)	2.3	(1.6, 3.0)	30.7	536	1,747
	Taraba	18,700	(11,800, 25,600)	1.6	(1.0, 2.2)	17.4	312	1,793
	Yobe	11,300	(6,000, 16,700)	0.9	(0.5, 1.4)	23.3	308	1,320
North West	Jigawa	37,100	(25,500, 48,800)	1.4	(0.9, 1.8)	53.2	969	1,821
	Kaduna	68,900	(48,700, 89,100)	1.6	(1.1, 2.1)	59.3	975	1,645
	Kano	133,000	(95,600, 170,300)	1.9	(1.4, 2.4)	63.6	960	1,510
	Katsina	46,700	(27,700, 65,700)	1.2	(0.7, 1.7)	16.4	246	1,498
	Kebbi	19,600	(10,500, 28,700)	1.0	(0.6, 1.5)	19.8	297	1,499
	Sokoto	28,800	(16,100, 41,500)	1.3	(0.7, 1.9)	32.3	483	1,494
	Zamfara	32,400	(17,800, 47,000)	1.7	(0.9, 2.5)	39.1	354	905
South East	Abia	25,600	(17,100, 34,100)	1.5	(1.0, 2.0)	34.0	662	1,947
	Anambra	32,200	(20,900, 43,500)	1.1	(0.7, 1.5)	82.9	1,409	1,699
	Ebonyi	14,500	(10,000, 19,100)	1.3	(0.9, 1.7)	19.0	387	2,033
	Enugu	24,300	(18,500, 30,100)	1.2	(0.9, 1.5)	31.9	554	1,735
	Imo	38,200	(26,000, 50,400)	1.4	(1.0, 1.9)	30.6	550	1,795
South South	Akwa Ibom	24,100	(14,800, 33,400)	0.9	(0.6, 1.2)	12.9	247	1,921
	Bayelsa	9,100	(6,900, 11,300)	1.2	(0.9, 1.4)	25.9	489	1,888
	Cross River	27,900	(18,000, 37,700)	1.6	(1.0, 1.6)	21.6	395	1,827
	Delta	48,200	(30,700, 65,700)	1.7	(1.1, 2.3)	42.2	777	1,842
	Edo	25,900	(18,400, 33,400)	1.2	(0.9, 1.6)	56.7	1,076	1,898
	Rivers	43,000	(29,800, 56,100)	1.1	(0.8, 1.4)	35.9	614	1,711
South West	Ekiti	11,400	(6,300, 16,400)	0.8	(0.5, 1.2)	76.3	1,214	1,592
	Lagos	52,900	(40,100, 65,700)	0.7	(0.5, 0.9)	87.0	2,290	2,631
	Ogun	17,600	(8,700, 26,600)	0.7	(0.4, 1.1)	64.1	913	1,425
	Ondo	13,800	(7,400, 20,300)	0.6	(0.3, 0.9)	46.8	783	1,672
	Osun	18,600	(8,200, 28,900)	0.8	(0.4, 1.3)	86.6	1,356	1,566
	Oyo	38,500	(20,200, 56,800)	0.9	(0.5, 1.4)	73.8	1,276	1,730

*Reflects 2018 intercensal projections for adults based on the 2006 Population Housing Census.

**Describes number and proportion of NSUM respondents who resided in urban areas.

Abbreviations: CI, confidence interval; PSE, population size estimate; EAs, enumeration areas

Discussion

Nationally representative household-based surveys are large, costly, and time consuming, but offer a rare opportunity to produce empirical KPSE. This is the first time national and state-specific PSE for FSW, MSM, and PWID have been calculated in Nigeria and each of the 37 states. In 2018, state-level PSE for these subpopulations were produced using multiple-source capture-recapture or programmatic mapping and enumeration, and are listed alongside our estimates for comparison (appendices 1-3) (41, 42). In brief, multiple-source capture-recapture methods consisted of three rounds of venue-based data collection in which unique objects were distributed to KP members. In subsequent rounds of data collection, interviewers asked KP members if they had received a unique object in order to determine overlap between capture rounds. Latent class models were used to generate median PSE alongside 80% highest density intervals as a measure of precision. Programmatic mapping and enumeration consisted of a single visit to each venue, in which enumerators counted the number of KP members present, with the resulting PSE equal to the sum of all KP members observed at each venue. While less costly, this strategy is prone to significant underestimation of the KP(s) of interest; it is unlikely that all members of the population will be present at venues during the brief period of data collection, and we expected PSE obtained from programmatic mapping and enumeration to much smaller than those obtained from NSUM or multiple-source capture-recapture. The following sections discuss the PSE obtained from NSUM, multiple-source capture-recapture, and programmatic mapping and enumeration in Nigeria and elsewhere in sub-Saharan Africa.

Female sex workers

Our guidelines for expected FSW PSE were based on literature from sub-Saharan Africa (0.4%–4.3% in urban areas)(43), West/Central Africa (0.6%–3.0%)(9), and UNAIDS findings which estimate that FSW account for roughly 1% of the adult female population (41). All unadjusted, national and state-level PSE for FSW fell within 0.4%-4.3% of the general population, with the exception of Bayelsa State, where FSW were estimated to account for 4.7% of the adult female population. The inflated PSE for FSW in Bayelsa State may be attributable to its petroleum-based economy and predominantly male workforce, conditions which may be conducive to an uptick in sex work. Indeed, PSE for FSW in Nigeria's 9 crude-oil producing states (Abia, Akwa Ibom, Bayelsa, Delta, Edo, Imo, Lagos, and Ondo)(44) represented much higher proportions of the adult female population, accounting for 9 of the 14 highest relative PSE observed for FSW throughout Nigeria. The PSE for FSW in Benue and Akwa Ibom States were comparable to estimates obtained from multiple-source capture-recapture (Appendix 1). In the remaining states with existing FSW PSE (from multiple-source capture-recapture or programmatic mapping and enumeration), results from NSUM were not consistent. Multiple-source capture-recapture PSE were much higher than NSUM PSE in FCT and Nasarawa State, and lower than NSUM PSE in Cross River, Rivers, and Lagos States. The most likely explanation for these discrepant results is a varying definition of the FSW study population between the NSUM and multiple-source capture-recapture activities. For our NSUM PSE exercise, FSW were defined as 'women who sell sex to men, as their main income or to support their children', whereas the multiple-source capture-recapture activity used a broader definition: 'women who have received money or goods in exchange for sexual services, either regularly or occasionally, in the 12 months preceding this activity.' In FCT and Nasarawa State, where prior PSE were exceedingly high, some women may have been counted as FSW during multiple-source capture-recapture who did not meet the definition used in NSUM. The explanation is less clear in Cross River, Rivers, and Lagos States, where NSUM PSE were larger than those obtained from multiple-source

capture-recapture. Timing of the activity may be relevant here, as the final rounds of multiple-source capture-recapture data collection were conducted very close to the winter holidays. This may have reduced social visibility of venue-based FSW, limiting recruitment and ultimately lowering the PSE. As expected, all PSE obtained from programmatic mapping and enumeration were markedly lower than those obtained from NSUM.

Men who have sex with men

According to UNAIDS guidance released in 2020, MSM PSE should represent at least 1% of the adult male population (45). Crude PSE for MSM were overwhelmingly short of this threshold at both the national and state-levels, with PSE from 21 of 37 states suggesting that MSM make up less than 1% of the adult male population. As previously mentioned, all PSE for MSM were adjusted for social visibility using adjustment factors obtained from the Game of Contacts. After adjustment, PSE were increased significantly and largely fell above 1% of the adult male population. Exceptions included PSE from Ekiti, Kogi, Niger, Ogun, Osun, Oyo, and Zamfara states, where the MSM proportion of the adult male population ranged from 0.6% to 0.9%. When compared with prior MSM PSE in Nigeria, our results were largely consistent with those obtained from multiple-source capture-recapture (Benue, FCT, Nasarawa, Akwa Ibom, Cross River, Rivers, and Lagos States). This was encouraging, and lends support to our method of adjusting MSM PSE for social visibility. Similar to the case for FSW, the PSE obtained from programmatic mapping and enumeration (Gombe, Taraba, Kaduna, Kano, Abia, Anambra, Enugu, Imo, Edo, and Oyo States; Appendix 2) were much lower than NSUM PSE, and none fell above 1% of the adult male population in these states. Programmatic mapping and enumeration may be particularly prone to underestimating PSE for MSM due to the low social visibility of this population in Nigeria. MSM hotspots tend to be harder to find, and enumerators may find it difficult to record accurate counts of MSM at hotspots, as individual interviews are not conducted to confirm eligibility.

People who inject drugs

Prior investigations have produced PSE for PWID ranging from 0.1% to 0.6% in sub-Saharan Africa (5) and <0.1% to 1.6% in West and Central Africa (9). Our unadjusted, national and state-level PWID PSE were predominantly larger than estimates from sub-Saharan Africa, with results from just 3 states falling within 0.1%–0.6% of the general population (Kogi, Niger, Ondo: all 0.6%). The estimates from West/ Central Africa were more comparable to our results, as PWID PSE represented 1.6% or lower of the adult general population in 30/37 states. The seven states with PWID PSE representing greater than 1.6% of the adult general population included Bauchi (1.7%), Zamfara (1.7%), Delta (1.7%), Kano (1.9%), Adamawa (2.2%), Gombe (2.3%), and Nasarawa (2.5%). The PWID PSE obtained from NSUM were comparable to state-level PSE from multiple-source capture-recapture in 4/7 states (Benue, Akwa Ibom, Cross River, and Rivers States; Appendix 3), and higher than PSE from multiple-source capture-recapture in the remaining 3 states (FCT, Nasarawa, and Lagos). While the definitions of PWID used in NSUM and multiple-source capture-recapture were similar, there were minor differences that may have contributed to the discrepant PSE. In multiple-source capture-recapture, PWID were defined as ‘any person who has injected drugs (illicit, non-prescribed, and illegal) recreationally at least once in the 12 months preceding this activity’. The NSUM module asks ‘How many people do you know who inject non-prescription drugs?’, not restricting to individuals who inject illicit/ illegal drugs, or those who have injected within the past 12 months. However, it is unclear why this effect may have influenced results in certain states but not others. To improve comparability of future PSE, activities should strive to make

use of the exact same definitions for each KP, including PWID. Similar to the cases for FSW and MSM, PSE from programmatic mapping and enumeration were categorically lower than NSUM PSE.

Limitations

This report has several limitations. We used 2006 Census results and applied 2018 age and sex distributions to generate known population estimates. It is possible that there was migration across states that would have impacted our state-level PSE; however, cross-state migration would not have impacted national data unless there were mass influx/exodus of populations between 2006 and 2018.

Game of Contacts estimates of social visibility were not available in every state and may not be generalizable to other states, or at the national level. Ideally, independent adjustment factors should be obtained from each state and for each target KP to improve specificity. Furthermore, our estimates of social visibility were obtained from convenience samples, and may be prone to sampling bias.

The language of each question in the NSUM module was crafted carefully, but there is always potential for misunderstanding among respondents or incorrect delivery from interviewers, especially when questionnaires are translated into local languages. Participants may have had difficulty making the distinction between FSW and women who engage in transactional sex, which would have increased the resulting PSE. Similarly, participants may have struggled to differentiate PWID from non-injectable drug users.

Conclusions

The nationally representative PSE for FSW, MSM, and PWID detailed in this report will be helpful in scaling resources to reduce the burden of HIV among these subpopulations in Nigeria. Our results were largely consistent with previous studies in sub-Saharan Africa that have used methods such as NSUM or multiple-source capture-recapture, emphasizing the importance of using empirical methods to estimate the size of these key populations.

References

1. Okafor UO, Crutzen R, Ifeanyi O, Adebajo S, Van den Borne H. HIV prevalence and high-risk behaviour of young brothel and non-brothel based female sex workers in Nigeria. BMC Res Notes. 2017;10(1):380.
2. Baral S, Beyrer C, Muessig K, Poteat T, Wirtz AL, Decker MR, et al. Burden of HIV among female sex workers in low-income and middle-income countries: a systematic review and meta-analysis. The Lancet Infectious Diseases. 2012;12(7):538-49.
3. Emmanuel G, Folayan MO, Ochonye B, Umoh P, Wasiu B, Nkom M, et al. HIV sexual risk behavior and preferred HIV prevention service outlet by men who have sex with men in Nigeria. BMC Health Serv Res. 2019;19(1):261.
4. Beyrer C, Baral SD, van Griensven F, Goodreau SM, Chariyalertsak S, Wirtz AL, et al. Global epidemiology of HIV infection in men who have sex with men. Lancet. 2012;380(9839):367-77.
5. Degenhardt L, Peacock A, Colledge S, Leung J, Grebely J, Vickerman P, et al. Global prevalence of injecting drug use and sociodemographic characteristics and prevalence of HIV, HBV, and HCV in people who inject drugs: a multistage systematic review. Lancet Glob Health. 2017;5(12):e1192-e207.
6. Strathdee SA, Hallett TB, Bobrova N, Rhodes T, Booth R, Abdool R, et al. HIV and risk environment for injecting drug users: the past, present, and future. Lancet. 2010;376(9737):268-84.
7. Papworth E, Ceesay N, An L, Thiam-Niangoin M, Ky-Zerbo O, Holland C, et al. Epidemiology of HIV among female sex workers, their clients, men who have sex with men and people who inject drugs in West and Central Africa. J Int AIDS Soc. 2013;16 Suppl 3(4Suppl 3):18751.
8. Ochonye B, Folayan MO, Fatusi AO, Bello BM, Ajidagba B, Emmanuel G, et al. Sexual practices, sexual behavior and HIV risk profile of key populations in Nigeria. BMC Public Health. 2019;19(1):1210.
9. Sabin K, Zhao J, Garcia Calleja JM, Sheng Y, Arias Garcia S, Reinisch A, et al. Availability and Quality of Size Estimations of Female Sex Workers, Men Who Have Sex with Men, People Who Inject Drugs and Transgender Women in Low- and Middle-Income Countries. PLoS One. 2016;11(5):e0155150.
10. MacAllister J, Sherwood J, Galjour J, Robbins S, Zhao J, Dam K, et al. A comprehensive review of available epidemiologic and HIV service data for female sex workers, men who have sex with men, and people who inject drugs in select West and Central African countries. J Acquir Immune Defic Syndr. 2015;68 Suppl 2:S83-90.
11. Crowell TA, Keshinro B, Baral SD, Schwartz SR, Stahlman S, Nowak RG, et al. Stigma, access to healthcare, and HIV risks among men who sell sex to men in Nigeria. Journal of the International AIDS Society. 2017;20(1):21489.
12. Schwartz SR, Nowak RG, Orazulike I, Keshinro B, Ake J, Kennedy S, et al. The immediate eff ect of the Same-Sex Marriage Prohibition Act on stigma, discrimination, and engagement on HIV prevention and treatment services in men who have sex with men in Nigeria: analysis of prospective data from the TRUST cohort. Lancet HIV. 2015;2(7):e299-306.
13. Strömdahl S, Onigbanjo Williams A, Eziefule B, Emmanuel G, Iwuagwu S, Anene O, et al. An assessment of stigma and human right violations among men who have sex with men in Abuja, Nigeria. BMC International Health and Human Rights. 2019;19(1):7.
14. Central Intelligence Agency. The World Factbook 2021: Nigeria Washington, DC: Central Intelligence Agency; 2020 [Available from: https://www.cia.gov/the-world-factbook/field/hiv-aids-people-living-with-hiv-aids/country-comparison/.
15. Federal Ministry of Health Nigeria. Nigeria HIV/AIDS Indicator and Impact Survey (NAIIS) 2018: Technical Report. Abuja, Nigeria; 2019.
16. Mishra S, Boily M-C, Schwartz S, Beyrer C, Blanchard JF, Moses S, et al. Data and methods to characterize the role of sex work and to inform sex work programs in generalized HIV epidemics: evidence to challenge assumptions. Annals of Epidemiology. 2016;26(8):557-69.

17. Viswasam N, Lyons CE, MacAllister J, Millett G, Sherwood J, Rao A, et al. The uptake of population size estimation studies for key populations in guiding HIV responses on the African continent. PLoS One. 2020;15(2):e0228634.
18. Killworth PD, McCarty C, Bernard HR, Shelley GA, Johnsen EC. Estimation of Seroprevalence, Rape, and Homelessness in the United States Using a Social Network Approach. Evaluation Review. 1998;22(2):289-308.
19. Killworth PD, Johnsen EC, McCarty C, Shelley GA, Bernard HR. A social network approach to estimating seroprevalence in the United States. Social Networks. 1998;20:23-50.
20. McCarty C, Killworth PD, Bernard HR, Johnsen EC, Shelley GA. Comparing two methods for estimating network size. Human Organization. 2001;60(1).
21. Bernard HR, Johnsen EC, Killworth PD, Robinson S. Estimating the size of an average personal network and of an even subpopulation. In: Kochen M, editor. The Small World. New Jersey, USA: Ablex Press; 1991. p. 159-75.
22. Halimi L, Babamiri M, Hamidi Y, Majdzadeh SR, Soltanian AR. Indirect estimation of student marijuana consumers population in Hamadan using PRM and NSU methods. Med J Islam Repub Iran. 2020;34:160.
23. Soltanian AR, Bashirian S, Basti SA, Karami M, Ostovar A, Khazaei S. Estimation of the Hidden Population with COVID-19 Disease. Int J MCH AIDS. 2020;9(2):217-9.
24. Rastegari A, Baneshi MR, Haji-Maghsoudi S, Nakhaee N, Eslami M, Malekafzali H, et al. Estimating the Annual Incidence of Abortions in Iran Applying a Network Scale-up Approach. Iran Red Crescent Med J. 2014;16(10):e15765.
25. Sully E, Giorgio M, Anjur-Dietrich S. Estimating abortion incidence using the network scale-up method. Demographic Research. 2020;43(56):1651-84.
26. Snidero S, Morra B, Corradetti R, Gregori D. Use of the scale-up methods in injury prevention research: An empirical assessment to the case of choking in children. Social Networks. 2007;29(4):527-38.
27. Nikfarjam A, Shokoohi M, Shahesmaeili A, Haghdoost AA, Baneshi MR, Haji-Maghsoudi S, et al. National population size estimation of illicit drug users through the network scale-up method in 2013 in Iran. Int J Drug Policy. 2016;31:147-52.
28. Teo AKJ, Prem K, Chen MIC, Roellin A, Wong ML, La HH, et al. Estimating the size of key populations for HIV in Singapore using the network scale-up method. Sex Transm Infect. 2019;95(8):602-7.
29. Paniotto V, Petrenko T, Kupriyanov V, Pakhok O. Estimating the Size of Populations with High Risk for HIV Using the Network Scale-up Method (Ukraine): Analytical Report. Kiev International Institute of Sociology; 2009.
30. Feehan DM, Salganik MJ. Generalizing the Network Scale-Up Method: A New Estimator for the Size of Hidden Populations. Sociol Methodol. 2016;46(1):153-86.
31. Shelley GA, Bernard HR, Killworth P, Johnsen E, McCarty C. Who knows your HIV status? What HIV+ patients and their network members know about each other. Social Networks. 1995;17:189-217.
32. Shelley GA, Killworth PD, Bernard HR, McCarty C, Johnsen EC, Rice RE. Who Knows Your HIV Status II?: Information Propagation Within Social Networks of Seropositive People. Human Organization. 2006;65(4).
33. Maltiel R, Raftery AE, McCormick TH, Baraff AJ. Estimating Population Size Using the Network Scale Up Method. Ann Appl Stat. 2015;9(3):1247-77.
34. Salganik MJ, Mello MB, Abdo AH, Bertoni N, Fazito D, Bastos FI. The Game of Contacts: Estimating the Social Visibility of Groups. Soc Networks. 2011;33(1):70-8.

35. Salganik MJ, Fazito D, Bertoni N, Abdo AH, Mello MB, Bastos FI. Assessing Network Scale-up Estimates for Groups Most at Risk of HIV/AIDS: Evidence From a Multiple-Method Study of Heavy Drug Users in Curitiba, Brazil. American Journal of Epidemiology. 2011;174(10):1190-6.
36. Killworth P, McCarty C, Johnsen E, Bernard H. Investigating the Variation of Personal Network Size Under Unknown Error Conditions. Sociological Methods & Research - SOCIOL METHOD RES. 2006;35:84-112.
37. McCormick TH, Zheng T, editors. Adjusting for Recall Bias in 'How Many X's Do You Know?' Surveys. Conference Proceedings of the Joint Statistical Meetings; 2007; Salt Lake City, Utah.
38. National Population Commission [Nigeria]. Population and Housing Census 2006 [Available from: https://nigeria.opendataforafrica.org/xspplpb/nigeria-census.
39. National Population Commission [Nigeria] I. Nigeria Demographic and Health Survey 2018 Key Indicators Report. Abuja, Nigeria, and Rockville, Maryland, USA; 2019.
40. The World Bank. Population Total--Nigeria 2018 [Available from: https://data.worldbank.org/indicator/SP.POP.TOTL?end=2018&locations=NG&start=1960.
41. National Agency for the Control of AIDS [Nigeria]. Key population geographic mapping and size estimation-Nigeria 2018. Abuja; 2019.
42. National Agency for the Control of AIDS [Nigeria]. Mapping and size estimation of key populations in Nigeria: six states and the Federal Capital Territory. Abuja; 2019.
43. Vandepitte J, Lyerla R, Dallabetta G, Crabbé F, Alary M, Buvé A. Estimates of the number of female sex workers in different regions of the world. Sex Transm Infect. 2006;82 Suppl 3(Suppl 3):iii18-25.
44. Ite AE, Ibok UJ, Ite MU, Petters SW. Petroleum Exploration and Production: Past and Present Environmental Issues in the Nigeria¡¯s Niger Delta. American Journal of Environmental Protection. 2013;1(4):78-90.
45. UNAIDS. Recommended Population Size Estimates of Men Who Have Sex with Men. 2020.

Appendices

Appendix 1. Comparison of population size estimates for female sex workers by state, Nigeria 2018

		Network Scale-up Method (NSUM)				Other PSE Methods[a]			
				PSE/Gen Pop[b]				PSE/Gen Pop[b]	
Region	State	PSE	PSE 95% CI	%	95% CI	PSE	PSE 95% CI	%	80% HDI
North Central	Benue	32,300	(20,100, 44,500)	2.5	(1.5, 3.4)	46,700	(27,500, 113,900)	3.6	(2.1, 8.7)
	FCT	7,000	(4,600, 9,300)	2.0	(1.3, 2.6)	45,700	(23,100, 56,700)	13.0	(6.6, 16.1)
	Nasarawa	10,400	(7,700, 13,200)	2.3	(1.7, 2.9)	55,600	(26,000, 73,700)	12.1	(5.7, 16.1)
North East	Gombe	15,700	(9,200, 22,200)	2.6	(1.5, 3.7)	4,818		0.8	
	Taraba	19,500	(12,100, 26,900)	3.2	(2.0, 4.4)	4,417		0.7	
North West	Kaduna	43,700	(31,000, 56,400)	2.1	(1.5, 2.7)	23,479		1.1	
	Kano	62,700	(43,500, 82,000)	2.0	(1.4, 2.6)	12,143		0.4	
South East	Abia	25,400	(17,700, 33,100)	2.8	(2.0, 3.7)	7,920		0.9	
	Anambra	47,100	(34,300, 59,900)	3.3	(2.4, 4.1)	36,607		2.5	
	Enugu	33,800	(26,300, 41,400)	3.0	(2.4, 3.7)	3,824		0.3	
	Imo	52,100	(34,700, 69,500)	3.9	(2.6, 5.2)	4,893		0.4	
South South	Akwa Ibom	48,100	(31,400, 64,900)	3.6	(2.4, 4.9)	64,300	(44,100, 84,900)	4.8	(3.3, 6.4)
	Cross River	32,900	(23,300, 42,400)	3.8	(2.7, 3.8)	15,300	(11,900, 20,000)	1.7	(1.4, 2.3)
	Edo	34,800	(25,300, 44,300)	3.4	(2.4, 4.3)	8,829		0.9	
	Rivers	75,600	(57,000, 94,200)	4.1	(3.1, 5.1)	14,500	(14,100, 15,200)	0.8	(0.8, 0.8)
South West	Lagos	123,500	(102,500, 144,600)	3.7	(3.0, 4.3)	48,200	(30,900, 76,100)	1.4	(0.9, 2.3)
	Oyo	40,600	(25,600, 55,700)	2.0	(1.3, 2.8)	11,242		0.6	

[a]Other population size estimates were obtained in 2018 using programmatic mapping and enumeration (Abia, Anambra, Edo, Enugu, Gombe, Imo, Kaduna, Kano, Oyo, and Taraba states, or multiple-source capture-recapture (Akwa Ibom, Benue, Cross River, FCT, Lagos, Nasarawa, and Rivers states). Results from multiple-source capture-recapture are presented alongside 80% highest density intervals.
[b]Reflects 2018 intercensal projections for adults based on the 2006 Population Housing Census
Abbreviations: CI, confidence interval; HDI, highest density interval; NSUM, network scale-up method; PSE, population size estimate.*Reflects

Appendix 2. Comparison of population size estimates for men who have sex with men by state, Nigeria 2018

		Network Scale-up Method (NSUM)				Other PSE Methods[a]			
				PSE/Gen Pop[b]				PSE/Gen Pop[b]	
Region	State	PSE	PSE 95% CI	%	95% CI	PSE	PSE 95% CI	%	80% HDI
North Central	Benue	17,800	(9,400, 28,100)	1.3	(0.7, 2.1)	10,800	(8,000, 13,100)	0.8	(0.6, 1.0)
	FCT	5,500	(2,900, 8,800)	1.4	(0.7, 2.2)	8,200	(6,500, 10,700)	2.0	(1.6, 2.7)
	Nasarawa	10,300	(5,100, 16,600)	2.3	(0.9, 4.0)	5,000	(3,700, 6,400)	1.4	(1.0, 1.7)
North East	Gombe	15,700	(6,000, 27,000)	2.5	(1.0, 4.3)	1,901		0.3	
	Taraba	17,800	(8,300, 29,300)	3.2	(1.5, 5.3)	749		0.1	
North West	Kaduna	50,400	(15,000, 92,200)	2.3	(0.7, 4.1)	8,601		0.4	
	Kano	80,300	(48,000, 118,100)	2.1	(1.2, 3.0)	20,144		0.5	
South East	Abia	22,500	(11,600, 38,600)	2.7	(1.4, 4.6)	1,953		0.2	
	Anambra	50,200	(23,800, 89,000)	3.4	(1.6, 6.0)	3,455		0.2	
	Enugu	26,700	(13,900, 45,500)	2.8	(1.4, 4.7)	1,623		0.2	
	Imo	49,100	(25,700, 83,600)	3.7	(1.9, 6.2)	822		0.1	
South South	Akwa Ibom	32,200	(13,400, 60,100)	2.4	(1.0, 4.4)	34,600	(12,000, 72,400)	2.5	(0.9, 5.3)
	Cross River	24,800	(12,200, 43,500)	2.9	(1.4, 5.1)	3,200	(2,700, 3,600)	0.4	(0.3, 0.4)
	Edo	23,100	(6,400, 48,000)	2.2	(0.6, 4.6)	1,126		0.1	
	Rivers	81,900	(44,300, 137,000)	4.0	(2.2, 6.7)	41,400	(8,400, 61,800)	2.0	(0.4, 3.0)
South West	Lagos	68,400	(35,800, 116,300)	1.6	(0.8, 2.7)	81,400	(4,800, 127,400)	1.9	(0.1, 3.0)
	Oyo	14,300	(3,800, 30,000)	0.7	(0.2, 1.4)	3,981		0.2	

[a]Other population size estimates were obtained in 2018 using programmatic mapping and enumeration (Abia, Anambra, Edo, Enugu, Gombe, Imo, Kaduna, Kano, Oyo, and Taraba states, or multiple-source capture-recapture (Akwa Ibom, Benue, Cross River, FCT, Lagos, Nasarawa, and Rivers states). Results from multiple-source capture-recapture are presented alongside 80% highest density intervals.
[b]Reflects 2018 intercensal projections for adults based on the 2006 Population Housing Census
Abbreviations: CI, confidence interval; HDI, highest density interval; NSUM, network scale-up method; PSE, population size estimate.

Appendix 3. Comparison of population size estimates for people who inject drugs by state, Nigeria 2018

		Network Scale-up Method (NSUM)				Other PSE Methods[a]			
					PSE/Gen Pop[b]				PSE/Gen Pop[b]
Region	State	PSE	PSE 95% CI	%	95% CI	PSE	PSE 95% CI	%	80% HDI
North Central	Benue	30,500	(15,700, 45,400)	1.2	(0.6, 1.7)	27,600	(22,900, 35,600)	1.0	(0.9, 1.4)
	FCT	9,600	(5,900, 13,200)	1.3	(0.8, 1.8)	3,400	(2,800, 4,100)	0.5	(0.4, 0.5)
	Nasarawa	20,600	(14,900, 26,300)	2.5	(1.8, 3.2)	6,900	(5,800, 7,600)	0.8	(0.7, 0.9)
North East	Gombe	28,600	(20,300, 36,800)	2.3	(1.6, 3.0)	6,577		0.5	
	Taraba	18,700	(11,800, 25,600)	1.6	(1.0, 2.2)	1,080		0.1	
North West	Kaduna	68,900	(48,700, 89,100)	1.6	(1.1, 2.1)	9,232		0.2	
	Kano	133,000	(95,600, 170,300)	1.9	(1.4, 2.4)	6,859		0.1	
South East	Abia	25,600	(17,100, 34,100)	1.5	(1.0, 2.0)	3,654		0.2	
	Anambra	32,200	(20,900, 43,500)	1.1	(0.7, 1.5)	3,287		0.1	
	Enugu	24,300	(18,500, 30,100)	1.2	(0.9, 1.5)	1,162		0.1	
	Imo	38,200	(26,000, 50,400)	1.4	(1.0, 1.9)	2,735		0.1	
South South	Akwa Ibom	24,100	(14,800, 33,400)	0.9	(0.6, 1.2)	22,500	(15,100, 30,900)	0.8	(0.6, 1.1)
	Cross River	27,900	(18,000, 37,700)	1.6	(1.0, 1.6)	20,100	(11,500, 25,500)	1.2	(0.7, 1.5)
	Edo	25,900	(18,400, 33,400)	1.2	(0.9, 1.6)	549		0.0	
	Rivers	43,000	(29,800, 56,100)	1.1	(0.8, 1.4)	30,400	(7,600, 44,600)	0.8	(0.2, 1.1)
South West	Lagos	52,900	(40,100, 65,700)	0.7	(0.5, 0.9)	9,400	(7,100, 13,400)	0.1	(0.1, 0.2)
	Oyo	38,500	(20,200, 56,800)	0.9	(0.5, 1.4)	14,741		0.4	

[a]Other population size estimates were obtained in 2018 using programmatic mapping and enumeration (Abia, Anambra, Edo, Enugu, Gombe, Imo, Kaduna, Kano, Oyo, and Taraba states, or multiple-source capture-recapture (Akwa Ibom, Benue, Cross River, FCT, Lagos, Nasarawa, and Rivers states). Results from multiple-source capture-recapture are presented alongside 80% highest density intervals.
[b]Reflects 2018 intercensal projections for adults based on the 2006 Population Housing Census
Abbreviations: CI, confidence interval; HDI, highest density interval; NSUM, network scale-up method; PSE, population size estimate.