Assessment of a Capture-Recapture Method for Estimating the Size of the Female Sex Worker Population in Bulawayo, Zimbabwe

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Title Page

Title: Assessment of a Capture-Recapture Method for Estimating the Size of the Female Sex Worker Population in Bulawayo, Zimbabwe

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Running Title: Estimating the size of a sex worker population

Abstract

Purpose: To assess the use of capture-recapture methods for estimating the size of sex worker populations in sub-Saharan Africa.

Methods: We used a capture-mark-recapture method to estimate the size of the bar-based female sex worker population in Bulawayo, Zimbabwe and compared this estimate with an estimate obtained by counting sex workers.

Results: Enumerators counted 6,997 women entering 56 bars known for sex worker activity. For the capture-recapture estimate, we interviewed 1,381 sex workers at 15 bars one Saturday night and 1,469 sex workers at the same bars a week later. Of these 1,469 women, 521 reported being interviewed the previous Saturday. The capture-recapture estimate of 3,894 (1381 * 1469 / 521) was considerably lower than the number counted. When we assumed that half the women returned to the same bar (rather than randomly mix among bars) and based the estimate on bars where the proportion recaptured was more than 20 percent, the estimate (7,855) of the 56-bar population was closer to the estimate obtained by counting.

Conclusions: Estimating the size of populations at risk for transmitting HIV is critical for AIDS prevention. The capture-recapture method may prove useful but requires collecting data to assess the direction and extent of bias in estimates.

Key Words: AIDS, population size, population surveys, epidemiological methods, prostitution, Africa, sampling

List of Abbreviations

AIDS	Acquired Immune Deficiency Syndrome
HIV	Human Immunodeficiency Virus

Introduction

Epidemiological models of the HIV epidemic suggest that the rate of partner acquisition and the pattern of sexual networks can shape the HIV epidemic (1-2). Consequently, valid estimates of the size of sub-groups with high rates of new partner acquisition such as female sex workers are needed. Two decades into the epidemic, however, AIDS prevention program planners still do not have valid estimates of the size of sex worker populations. Available estimates are likely to be underestimates because countries are reluctant to acknowledge the extent of sex work and sex workers themselves are often poorly organized (3-4). Conventional methods for estimating population size are not easily applied to sex worker populations.

This study uses a capture-recapture method to estimate the size of the female sex worker population soliciting from bars in Bulawayo, Zimbabwe and compares the result with an estimate obtained by enumerating sex workers at bars. Capture-recapture methods have been used extensively to estimate the size of wildlife populations and more recently to estimate the size of populations at risk for HIV infection in the United States, Europe, and Thailand (5-9).

We focused on the bar-based sex worker population because AIDS prevention staff in Bulawayo reported that most of the sex work is bar-based. Sex work in Zimbabwe is illegal and almost exclusively involves vaginal sex with male clients following alcohol consumption. We selected Bulawayo for the study because of the capacity of the local intervention team for research and their interest in assessing the extent to which they were reaching their target population. Bulawayo is a manufacturing and transportation center with a population well over 700,000 at the time of the study.

Methods

Study Population

The study population is women socializing at 56 bars identified by self-identified sex workers as places where women solicit clients for sex. The sex workers who identified the bars included over 60 women trained as peer health educators in an AIDS prevention and condom distribution program in Bulawayo. According to these sex workers and the bar managers, every woman entering these bars is engaged in sex work. Bar patronage fluctuates with peak attendance during paydays and holidays. At these times, women who only occasionally engage in sexwork visit the bars. We wanted to estimate the size of the population during a non-peak period to obtain an estimate of the size of the core sex worker population soliciting on a typical day. Thus it is an underestimate of the number of women engaged in at least part-time sex work in Bulawayo during the course of a month or year.

Enumeration Estimate

Approximately 100 enumerators recorded the type, color and pattern of clothes (shoes, shirt, skirt, trousers) worn by each woman entering the 56 bars between 8:00 p.m. and 10:30 p.m. The number of sex workers was estimated by combining the lists and assuming that matching descriptions referred to the same woman.

Capture-Recapture Estimate

We used a single 'mark' release method (10). A sample of individuals (M) is taken from the population, "marked", and returned to the population. After allowing time for the individuals to mix, a second sample is "captured" (C) of which a certain number (R) were “recaptured”. Under the assumption that the proportion marked in the second sample (R/C) is

a reasonable estimate of the marked proportion in the entire population, the size of the entire population (N) is (10):

$$\frac{R}{C} = \frac{M}{N} \quad \text{or} \quad N = \frac{M * C}{R} .$$

We decided to "mark" 800 women during the first sample and "examine for marks" 800 women from a second sample in order to have 80 percent probability of obtaining an estimate within 20 percent of the true value. We calculated the 95 percent confidence interval by calculating the limits for R/C:

$$\frac{R}{C} \pm 1.96\sqrt{\frac{(R/C)(1-R/C)}{C-1}}$$

and substituting the estimated limits for R/C in the following:

$$N = \frac{1}{(R/C).} * M.$$

The capture-recapture study was conducted on consecutive mid-month Saturday nights. A woman was considered "marked" if she was selected on the first Saturday, consented to the interview, and accepted a token (a pocket calendar or pen). Two different interviews were used. The longer one asked age, where she solicited clients, exposure to the intervention program, condom use, and four items to permit linking responses from a woman interviewed both nights (year born, first name of eldest child, most recent school attended, and home village). The shorter interview included only the linking questions. We expected 30 interviewers to conduct three "long" interviews each hour for six hours and 15 interviewers to conduct four "short" interviews each hour for six hours for a total of 900 interviews. Interviewers were assigned to either the "short" or "long" interview and allocated to bars based on bar size.

When women were interviewed a week later, they were asked whether they had been approached for an interview the previous week. Those who reported affirmatively and could describe the token were considered "recaptured". We expected more than 900 interviews to be conducted the second night.

Selection of 15 bars for capture-recapture

The same fifteen bars were visited both nights including the three largest of the universe of 56 bars. The 12 other bars were selected with the probability of selection proportional to the size of the bar. Interviewing occurred during the six hours before closing. The first person interviewed was the first woman entering the bar after the appointed starting time. After an interview was completed, the next woman entering was interviewed.

Method Assumptions

Three key assumptions of the capture-recapture method are: (1) population closure; (2) mark integrity; (3) and equal catchability. Population closure is defined as no change in population membership between sampling occasions, e.g., due to migration or mortality. We minimized the threat to closure at the design stage by limiting the time between sampling occasions to one week and by including questions to test our assumption that all women interviewed were sex workers. Mark integrity is achieved if marks are not lost and all marks are reported. To ensure mark integrity we minimized the harm arising from being interviewed by assuring anonymity and keeping questionnaires short.

Equal catchability is rarely achieved in estimations of animal populations and is considered an unattainable ideal (14). In this study, we would have achieved equal catchability if an individual's selection the first night was independent of selection the next

weekend and if the women interviewed each night were a simple random sample of all bar-based sex workers. We assessed the extent to which equal catchability was achieved by comparing the probability of being recaptured at each bar.

Protection of Human Subjects

Ethical approval was obtained from Family Health International's Protection of Human Subjects Committee and from the Institutional Review Board of the University of North Carolina School of Public Health.

Results

Enumeration Estimate

Over 100 enumerators counted 6,973 women entering the 56 bars between 8 and 10:30 p.m. on Saturday March 21, 1992. The number of women at a bar ranged from 21 to 515. The median number attending was 106. Only 15 bars had more than 150 women attending.

Capture-recapture Estimate

Interviewers interviewed 1,381 women at the 15 selected bars on June 13, 1992, and 1,469 women the following Saturday night (Table 1). Of the 1,381 women interviewed the first night, 705 (51 percent) were interviewed with the long questionnaire and 676 (49 percent) with the "short" questionnaire. Fewer than 20 women refused the interview entirely although many women refused one or more of the linking questions, making linking questionnaires from the same respondent impossible.

The long questionnaire provided characteristics of the women (Table 2). More than half were over age 30; 70% had more than a primary school education; and half had been in sex work more than five years. About two-thirds of the women had attended at least three AIDS prevention meetings in the past six months, and about 80 percent reported ever using condoms. Condom use with clients was higher than with steady partners.

Of the 1,469 women interviewed the second night, three reported being interviewed earlier that evening, and 521 reported being interviewed the previous week. In no case were more women interviewed at a bar than had been counted at the bar or recaptured at a bar than had been marked previously at that bar.

The capture-recapture estimate of the 56 bar population is 3,894 (1,381 * 1,469 / 521). The 95 percent confidence intervals (4,184 and 3,644) do not include the enumeration study estimate of 6,973.

Discussion

The gap between the capture-recapture and the enumeration estimates is too large to conclude that the capture-recapture method provided a valid estimate of the size of the sex worker population. No single explanation fully explains the difference, and both estimates may have been biased. None of the capture-recapture assumptions was fully met. The reasons why the enumeration estimate may be biased, our assessment of the failure of this study to meet the capture-recapture assumptions, and alternative estimates are discussed.

Enumeration Estimate

We anticipated that the enumeration estimate would be a "gold standard" estimate of the size of the mid-month sex worker population soliciting at these 56 bars. Enumerators counted every woman entering a bar where sex work was practiced using a method that should have minimized the number of women counted twice. Even so, the March enumeration estimate may have underestimated the number of women soliciting from bars in June for several reasons. First, women who arrived before 8:00 p.m. or after 10:30 were not included in the count. This is probably not a significant factor, however, as few people arrive before 8:00 p.m. and the largest bars close at 10:30. Second, more women may have turned to sex work as a national drought worsened in the period between March and June. Third, women who stayed away from the bar one night were not included in the enumeration estimate, but were included in the capture-recapture estimate.

Assessment of Capture-Recapture Assumptions

Closure. Fully meeting the closure assumption requires: (1) that the mid-month sex worker population did not change between sampling occasions; (2) that all members of the mid-month bar-based sex worker population were seeking clients at bars; and (3) that all

women at the bars were bar-based sex workers. We used a narrow definition of bar-based sex work and conducted the study on consecutive Saturday nights that were not at month-end to minimize changes in population membership. Even with this narrow definition, however, closure was not fully achieved as 11 percent of the women interviewed reported that they did not solicit from bars.

Mark integrity. There was no evidence that mark integrity was compromised when the mark was defined as accepting a token of the interview on the first night. On the second night, 98 percent of those reporting they had been interviewed the week before could describe the token they had received.

Equal catchability. In wildlife applications, capture probabilities have been shown to vary with time or trapping occasion; by behavioral responses to being trapped the first time; by individual animal; or a combination of these (11). Although we can only speculate on the causes, equal catchability was not attained in this study. The estimated proportion of women recaptured at each bar ranged from 11 to 58 percent (Table 1).

The most important source of bias in our capture-recapture estimate is the assumption that women randomly mix among bars. Under this assumption, the capture-recapture estimate of 3,894 refers to the size of the 56 bar population. However, if women always return to the same bar, the estimate refers to the 15-bar population where the study was conducted. If the linking variable had worked, the proportion of recaptured women interviewed at two different bars would have provided a reasonable estimate of the extent of mixing among bars and could have been used to adjust the capture-recapture estimate. Insight into the extent of mixing among bars is available from other sex worker studies. In Harare, Zimbabwe, for example, 65 percent of sex workers reported that their most recent client was

a repeat client, suggesting that women often solicit from the same site (12). Of 85 sex workers interviewed at bars in Bulawayo in 1989, 59% reported soliciting clients from other bars; 59% reported soliciting at hotels; and 38% reported soliciting at discos. These data suggest that most women solicit at more than one site, but that they don't randomly select sites. In both Harare and Bulawayo, a majority of women report having one client per night on the 3-4 nights per week that they work and that they often take the client home. In Harare, women usually live within 500 meters of the bar. This also suggests that women do not randomly choose a bar, but visit a bar convenient to their residence. Consequently, although it is impossible to precisely estimate the extent of mixing among bars, the proportion of women who visited the same bar on both of the Saturday nights in our study, is probably greater than 30% and less than 80%.

Sensitivity Analysis

The estimates are very sensitive to changes in the assumptions of catchability and mixing (Table 3). For example, the population estimate more than quadruples (from 3,894 to 18,614) if we assume that sex workers always return to the same bar (i.e., no mixing) and the size of the 56 bar population is 56 times the average size of the 15 bars (332) in the capture-recapture study. Even if we take into account that the three largest bars were sampled separately, the estimate only drops to 18,035 (1181 + 53*318).

A plot of the capture-recapture estimates, the number counted, the proportion recaptured, and the absolute number of recaptures (Figure 1) reveals that the largest gap in the two measures occurred at bars where fewer than ten women were recaptured and the proportion recaptured was less than 20 percent. These are both indicators of estimate

instability. When the five bars that did not recapture at least 20 percent of those marked the first night are excluded from the stratified approach used above to estimate the size of the 56 bar population, the estimate drops to 13,473.

The final set of estimates assumes that half of the women return to the same bar and are available for recapture there and the other half randomly visit one of the other bars. Those who visit a different bar have a 25% probability (14/55) of visiting one of the 15 bars where they could be recaptured. The estimated size of the 56 bar population under these assumptions is 9,106. If we repeat this approach but only use data on the number marked, captured, and recaptured from bars where R/C was greater than 20 percent, the estimate drops to 7,855, an estimate close to the enumeration estimate. This sensitivity analysis demonstrates the considerable sensitivity of the estimates to the proportion assumed to be returning to the same bar.

Conclusion

Although the allure of capture-recapture methods is that an accurate population estimate can be made based on partial surveys of the population, we found that enumerating the 56 bar sex worker population was feasible and the findings easier to interpret. The capture-recapture study took two nights to conduct and did not work as anticipated because women would not supply information that would allow interviews from the same woman to be matched. Enumeration required 100 trained enumerators, but data collection was completed in one night and required no personal contact. At the 15 bars where the capture-recapture study was conducted, enumerators counted 2,864 women. Only 16 fewer interviews were conducted at these 15 bars for the capture-recapture survey.

Strategies for improving the method to enumerate women appear more straightforward than methods to improve the capture-recapture method. For example, methods to measure and adjust the enumeration estimate could include interviewing a sample of women entering bars about which other bars they have already visited or having two sets of enumerators count women entering a sample of bars.

Counting appears especially attractive given the sensitivity of the estimates to changes in assumptions of mixing and catchability. After this study was conducted in Bulawayo, one of the authors (Wilson) implemented a similar protocol in Mutare, Zimbabwe and also found it difficult to ensure that the underlying assumptions held and that the estimates were valid (12). Undoubtedly, some of the pitfalls that we encountered in interpreting the capture-recapture estimates could have been avoided had we better anticipated the data needed to test each assumption and to adjust the estimates when assumptions were not met. For example, three sampling occasions would have permitted estimates of catchability; less personal

questions might have been more acceptable for linking interviews from the same individual; and recaptured women could have been asked where they were previously interviewed. Another strategy would be to limit the capture-recapture study to the largest sites and use other methods to determine what proportion of the total is comprised by these sites. Finally, the capture-recapture estimates for a subset of sites could be validated by enumeration. If hybrid methods become attractive, an approach to estimating confidence intervals for these estimates should be developed.

A greater challenge in sub-Saharan Africa than estimating the size of the regular bar-based sex worker population, however, is estimating the size of the larger dynamic population of women who engage in sex work on a part-time basis or at less visible locations. Our narrow definition of bar-based sex work excluded women who solicited from streets, their homes, or informal bars and women who trade sex for services and money but do not consider themselves to be sex workers. Rather than being closed, the sex worker population in sub-Saharan Africa is dynamic and open, reflecting a response to the demand for services, economic need, and individual circumstances (13-15). Estimating the size of the larger dynamic population is at least as important for understanding the HIV epidemic as the cross-sectional estimates presented here.

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TABLES

Table 1: Number of women counted and interviewed at 15 selected bars

Bar Number	Number Counted at Bar in March, 1992	Number Interviewed June 13, 1992 M	Number Interviewed June 21, 1992 C	Number interviewed both nights. R	Proportion of Captured that were ReCaptured (R/C)
1	57	36	30	7	0.23
2	82	35	34	9	0.26
3	95	18	48	8	0.17
4	104	22	36	4	0.11
5	118	100	49	8	0.16
6	128	69	98	30	0.31
7	144	58	100	32	0.32
8	152	108	108	47	0.44
9	171	66	49	10	0.20
10	193	86	118	39	0.33
11	205	187	204	90	0.44
12	206	112	85	10	0.12
13*	279	127	179	103	0.58
14*	415	161	131	55	0.42
15*	515	196	198	69	0.35
Total	2864	1381	1469	521	

* These are the three largest bars selected with a probability of 1.

Table 2: Characteristics of women interviewed the first night of the Capture-Recapture Study

Characteristic	Percentage (N=705)
Age	
< 21	7.1
21-25	20.8
26-30	19.3
31-35	22.7
> 35	30.0
Total	100.0
Years of Education	
0-6	29.4
7-9	50.2
10 +	20.4
Total	100.0
Marital status	
Married	12.0
Separated/ Divorced	25.7
Widowed	16.1
Never Married	46.1
Total	100.0
Years in Sex work	
< 1	0.0
1-2	20.0
3-4	29.5
5-6	20.4
>6	30.1
Total	100.0
Where solicits clients	
At bars	89.0
On the street	51.3
At home	54.7
% Ever attended meeting	80.4
Meetings attended in past 6 months	
0	19.6
1-2	13.3
3+	67.2
Total	100.0
% Ever received condoms	76.6

Characteristic	Percentage (N=705)
Taught by peer educator:	
Never	16.6
1-2 times	14.2
3+ times	69.2
Total	100.0
Percent who had seen:	
AIDS drama	76.9
AIDS video	76.1
AIDS T-shirt	90.9
Condom Use	
Ever heard of	94.5
Ever used	79.7
Used w last client	65.6
Easy to obtain	88.7
Last used condom	
In past week	54.2
In past month	20.7
In past 6 months	2.7
Over six months	1.0
Never used	21.4
Total	100.0
Use with clients	
Never	20.8
< half the time	9.8
Half the time	14.0
> half the time	12.3
Always	43.0
Total	100.0
Use with steady partner	
Never	27.8
< half the time	12.5
Half the time	11.8
> half the time	11.6
Always	36.3
Total	100.0

Table 3: Estimated size of 56 bar population under various catchability assumptions

Assumptions	Capture Recapture Estimate	% of Count (6973)
Random Mixing	3894	55.8%
All return to the same bar and total population=		
• Mean size of 15 bars * 56	18,614	267%
• Sum of 3 largest bars + 53 * 12 bar mean	18,035	259%
• Sum of 3 largest bars + 53 * mean of bars w >20% R/C	13,473	193%
Half return to the same bar and the rest randomly mix with a proportionate number going to the other sampled bars with total population=		
• (.5M + .5M/55*14) * C / R)	9106	131%
• (.5M + .5M/55*8) * C / R) where M,C,R only from bars where R/C > 20%	7855	112%

Comparison of the number counted, the number estimated by capture-recapture methods, the number of women recaptured (R), and the proportion recaptured (R/C) at each of the 15 bars