

# Capture–recapture for estimating the size of the female sex worker population in three cities in Côte d’Ivoire and in Kisumu, western Kenya

Bea Vuylsteke<sup>1,2</sup>, Hilde Vandenhoudt<sup>1</sup>, Lilian Langat<sup>1</sup>, Gisèle Semde<sup>2</sup>, Joris Menten<sup>1</sup>, Fredrick Odongo<sup>3</sup>, Ayubu Anapapa<sup>3</sup>, Lazare Sika<sup>4</sup>, Anne Buve<sup>1</sup> and Marie Laga<sup>1</sup>

1 *Institute of Tropical Medicine, Antwerp, Belgium*

2 *Family Health International, Abidjan, Côte d’Ivoire*

3 *Kenya Medical Research Institute, Kisumu, Kenya*

4 *National Institute of Statistics and Applied Economy, Abidjan, Côte d’Ivoire*

## Summary

**OBJECTIVE** To estimate the female sex worker population size in three cities in Côte d’Ivoire and in Kisumu, Kenya.

**METHODS** Capture–recapture was used, calculating size estimates by first ‘tagging’ a number of individuals and, through an independent recapture, calculating the proportion of overlap. The same procedures were used in all four cities. In the first phase, members of the target population were ‘captured’ and ‘marked’ by giving them a capture card. Six days later, in the same places and at the same time, a second sample was ‘captured’, which comprised a certain number of people who were captured in the first round. During the exercise, questions were asked to estimate the coverage of the sex worker clinics.

**RESULTS** Using capture–recapture, the estimated number of female sex workers was 1160 in Yamoussoukro (95% CI 1053–1287), 1202 in Bouaké (95% CI 1128–1279), 1916 in San Pedro (95% CI 1809–2030) and 1350 in Kisumu (95% CI 1261–1443). The proportion of female sex workers in Côte d’Ivoire who had visited the clinic ranged from 15% in Yamoussoukro to 30% in San Pedro and was 34% in Kisumu.

**CONCLUSIONS** Capture–recapture was successfully applied to estimate the population size of female sex workers. These estimations were urgently needed to help mobilize an increased response to HIV, to assess programme coverage and to estimate potential impact of the targeted intervention.

**Keywords** female sex workers, size estimation, capture–recapture, mapping, AIDS prevention, Africa

## Introduction

Sex workers and their clients are a critical group in the spread of HIV infection, in every region in the world (Vuylsteke *et al.* 2008). Targeted interventions that aim to increase condom use and reduce transmission of STIs and HIV infection among sex workers and their clients are feasible and effective (Laga *et al.* 1994; Steen *et al.* 2000; Alary *et al.* 2002; Ghys *et al.* 2002; Wi *et al.* 2006). The effects of sex worker interventions on the incidence of HIV in the general population not only depend on the effectiveness of the interventions in increasing condom use and reducing STI and HIV infection among sex workers, but also on the stage of the epidemic and on the coverage of the interventions (Van Vliet *et al.* 1998). Coverage by interventions is a key parameter in the evaluation of any programme and

requires a fairly accurate estimate of the size of the target population. However, reliable estimates of the size of high risk populations who are involved in covert, stigmatized and socially ostracized activities and who are highly mobile are difficult (Vandepitte *et al.* 2006). Different methods have been used to estimate the size of sex workers populations, including mapping and census, the multiplier method and capture–recapture. The latter method was originally developed to count and track wildlife populations by capturing, tagging and recapturing. Since the early 1990s the method has been used in several countries to estimate the size of hidden or difficult-to-reach human populations such as sex workers, men who have sex with men, homeless persons and intravenous drug users (McKeganey *et al.* 1992; Kruse *et al.* 2003; Khan *et al.* 2004; Minh *et al.* 2004; Geibel *et al.* 2007; Vadivoo *et al.* 2008).

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In 1992 the Institute of Tropical Medicine (ITM), Antwerp, Belgium, set up a dedicated clinic for female sex workers in Abidjan, Côte d'Ivoire, in close collaboration with 'Projet RETRO-CI' of the Centers for Disease Control and Prevention (CDC), Atlanta (USA) and the Ministry of Health, Côte d'Ivoire. The clinic offers HIV prevention and care services, including behaviour communication through peer education, condom promotion and STI treatment to sex workers in a non-stigmatizing and confidential environment. Since 2000 additional sites have been established and by 2008 a total of 13 prevention and care service sites were operational in eleven major towns of Côte d'Ivoire. Since 2004 this programme has been implemented by Family Health International, with technical support from ITM and financial support from the President's Emergency Plan for AIDS Relief (PEPFAR).

In Kisumu, Kenya, a census and a survey were carried out in 1997–1998 among self-acknowledged female sex workers. It was estimated that 1374 sex workers were operating in Kisumu town. The HIV prevalence among a representative sample of these women was 75%. In 2006 ITM, in collaboration with Family Health Options Kenya (FHOK), developed and started implementing an intervention targeting female sex workers in Kisumu. The intervention was modelled after the intervention in Côte d'Ivoire and is funded by PEPFAR.

Reliable estimates of the size of the female sex worker populations were not available in Côte d'Ivoire and outdated in Kisumu. Therefore, in 2008, we decided to conduct a series of studies using the capture–recapture method to estimate the female sex worker population in three cities in Côte d'Ivoire, Yamoussoukro, Bouaké and San Pedro; and in Kisumu, Kenya.

## Methods

### Settings

The cities in Côte d'Ivoire were selected in collaboration with the Ministry of AIDS and the Ministry of Health. Yamoussoukro is the political capital of Côte d'Ivoire, it has a population of approximately 296 000 (census data 2006) and has been receiving an important number of internally displaced persons since the socio-political crisis of 2002. Bouaké is the second largest town of the country with an estimated population of approximately 748 000. San Pedro is an important harbour in the South of the country and has approximately 662 000 inhabitants.

Kisumu is the capital of Nyanza Province, the province in Kenya most heavily affected by the HIV epidemic with a prevalence in the general population of 14.9% (National AIDS/STI Control Programme (NAS COP), Kenya, 2009).

It is the third largest town in Kenya with an estimated population of 450 000 (census data 1999).

### Study population

Female sex workers of all ages were included in the study. Female sex workers were defined as women providing sex in exchange for money or goods.

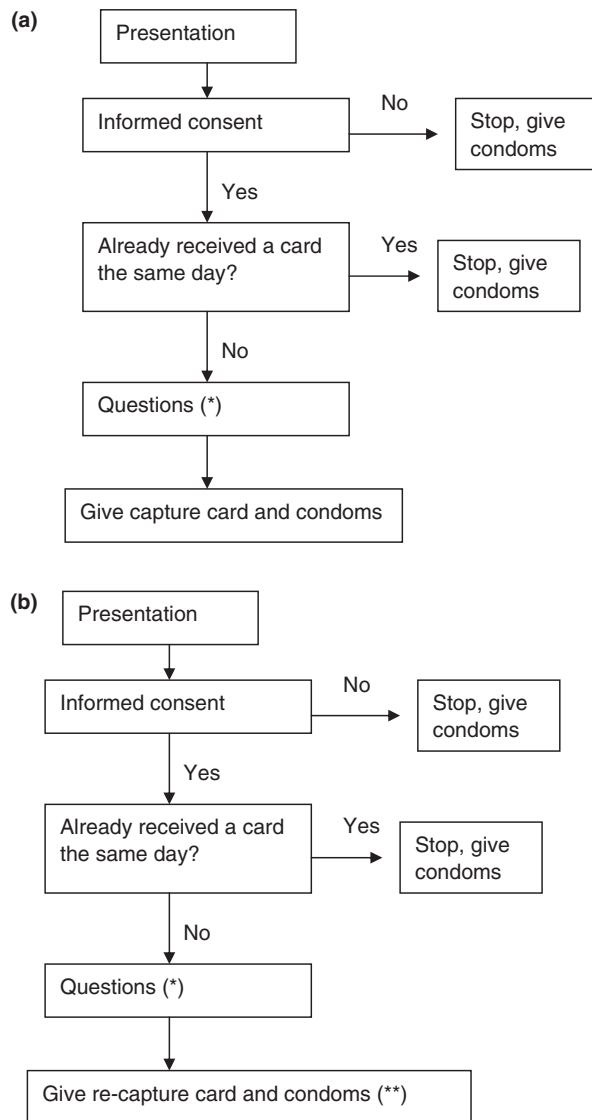
### Procedures

The same procedures were used in all four cities. First, a comprehensive geographical map was made of the hotspots, i.e. locations where female sex workers receive or solicit their clients, including bars and night clubs, hotels, certain streets and lodgings (for the home-based sex workers). Fieldwork for the mapping was carried out by teams of trained research assistants and peer health educators. At each hotspot, the exact location was geo-mapped using a Global Positioning System tool (Garmin GPS 60 and GPSMap 60 Cx in Côte d'Ivoire; GPS Navio in Kisumu). A site questionnaire with questions on number of female sex workers usually present at peak hours, and the busiest time of the day and the week was completed with assistance of a key informant (bar owner, peer leader, etc.). While in Côte d'Ivoire these data were entered on hard copy questionnaires, in Kisumu, Personal Digital/Data Assistants (PDAs) were used for data collection.

Geo-referenced data and information on the sites were entered into an Excel file and recorded on a map. In Côte d'Ivoire ArcView GIS 3.2 was used, in Kenya Google Earth (basic Google-maps website: [maps.google.com](http://maps.google.com); <http://www.gpsvisualizer.com/mapinput>).

These maps were then used to plan the capture–recapture exercise. Towns were subdivided into smaller areas with a limited number of hotspots. Study teams consisting of peer educators and research assistants were each assigned a list of hotspots in a particular area. There were 10 teams of three persons operating in each city in Côte d'Ivoire and 25 teams of two persons in Kisumu. All received 3 days' training on study procedures and ethics and spent 1 day prospecting their hotspots and confirming peak times.

In all four cities, capture was done on a Saturday. On that day, teams visited their assigned hotspots at peak hours. The female sex worker peer educators identified and approached each female sex worker individually, and obtained verbal informed consent for study participation. Consenting sex workers were asked two or three simple questions by a research assistant and were given a capture card (see Figure 1 for study procedures). If the sex worker had already received a study card from a study team that same day, at the same or another place, she was not given

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**Figure 1** Study procedures. (a) First round (capture) \*Cote d'Ivoire: Do you know the sex worker clinic in town? Have you ever visited it? Kisumu: What is your age? Do you know the sex worker clinic in town? Have you ever visited it? If yes, have you visited it during the last 12 months? (b) Second round (re-capture). \*Cote d'Ivoire: Do you know the sex worker clinic in town? Have you ever visited it? Did you receive a capture-card last week? Kisumu: What is your age? Do you know the sex worker clinic in town? Have you ever visited it? If yes, have you visited it during the last 12 months? Did you receive a capture-card last week? \*\*Côte d'Ivoire: in case she did not received a capture card, an identical card as the capture card was given.

another card, to avoid double counting. If the sex worker admitted she had already received a card from a friend or other source, she was considered a new capture. The study

card consisted of two parts. One part was used to record limited information on each participant, the removable part, a picture, was given to the participant by way of 'tag'. The numbers of women who refused, who were unable to consent, and who were seen more than once during the same round, were recorded on a separate form. At the end of the interview, female sex workers were encouraged to visit the dedicated health services. All women approached, regardless of whether they consented to participate or not, were given condoms.

The re-capture took place 6 days later, on a Friday. The same teams visited each hotspot of their assigned area at approximately the same time as the previous week and followed the same procedures (Figure 1). In addition, all participating women were asked if they had received a card the previous week (and were thus captured during the first round).

#### Estimating the size of the sex worker population

Capture–recapture calculates size estimates by first 'tagging' a number of individuals and, through an independent recapture, calculating the proportion of overlap. In the first round, sex workers are 'captured' by giving them a capture card. Put otherwise, a sample of individuals (C1) is captured from the population of female sex workers, 'marked or tagged' using a card. The sample of women approached and 'captured' in the second round (C2) comprises a certain number of women who were captured in the first round (R or recaptured), i.e. women who had received the card in the first round. Under the assumption that the proportion of recaptured women in the second round (R/C2) is an unbiased estimate of the marked proportion in the unknown population (C1/N), an estimate of the size of the entire population (N) can be made by equating the two proportions:

$$\frac{R}{C2} = \frac{C1}{N}$$

$$\text{Or, } N = C1 * C2 / R.$$

Some sex workers were not willing to participate in the study or were unable to provide consent. This proportion of women  $P_{\text{refuse}}$  was estimated as the total number of refusals (including those unable to provide consent because of language barriers or being too drunk) divided by the total number of instances a sex worker was approached (including those who were approached more than once on the same day etc.) over the two visits. The total number of female sex workers was then estimated as  $N_{\text{total}} = N / (1 - P_{\text{refuse}})$ . Confidence intervals for the estimates of N and  $N_{\text{total}}$  were obtained using the non-parametric boot-

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strap method. This is a computer-intensive, resampling-based approach that allows the estimation of confidence intervals without the need for distributional assumptions (Buckland & Garthwaite 1991). In the non-parametric bootstrap, the observed data are resampled to create a series of 'pseudo-experiments'. For each of these 'pseudo-experiments',  $N$  was estimated and the resulting distribution of estimates was used to construct the 95% confidence interval for  $N$  and  $N_{\text{total}}$ .

Population size estimates were also obtained during the mapping exercise through the site questionnaire. The number of sex workers usually present at peak hours was estimated by key informants and recorded in that questionnaire. The total number for all sites was calculated and used as alternative population size estimates.

### Ethical approval

Both studies were approved by the Ethical Committee of the University of Antwerp, Belgium. Ethical clearance for the study in Côte d'Ivoire was also obtained from the National Ethical Committee of Life Sciences and Health, Abidjan and the Protection of Human Subjects Committee of Family Health International. The protocol was scientifically reviewed by the Associate Director of Science Office of the National Center for HIV, Hepatitis, STI and tuberculosis prevention at the US Centers for Disease Control and Prevention, Atlanta (CDC). The protocol for Kisumu was approved by the Institutional Review Boards of the Kenya Medical Research Institute and CDC.

### Results

The three capture–recapture surveys in Côte d'Ivoire took place between February and November 2008. In Kisumu the capture–recapture exercise was done in September 2008. In all sites, mapping was finalized 2–4 weeks prior to the capture.

During the capture–recapture, most sex workers were met in bars, clubs and dance venues. Of all sex worker encounters in Yamoussoukro, 66% were in bars, clubs and dance venues; for Bouaké and San Pedro, these figures were 62% and 51%, respectively. In Kisumu the proportion was the highest (87%). Table 1 presents the estimates of the size of the female sex worker populations in the four cities based on the capture–recapture exercise. A substantial number of sex workers were encountered twice during the same round, but on a different site. The total numbers of sex workers captured during round 1 and during round 2 was similar in the four cities. The proportion of sex workers recaptured ( $R/C_2$ ) varied from 38% in Yamoussoukro to 57% in Bouaké. The number of refusals, both in

round 1 and round 2, was significantly higher in Kisumu than in the three cities in Côte d'Ivoire.

A comparison between the population size estimates resulting from the short questionnaire applied to key-informants during mapping and estimates resulting from the capture–recapture is presented in Table 2. Both methods yielded different results in each city, and no pattern was seen.

Table 3 shows the coverage of the interventions. The proportion of female sex workers in Côte d'Ivoire who knew about the dedicated services ranged from 36% in Yamoussoukro to 53% in San Pedro and 15%–30% had actually visited the clinic in town. These figures tended to be higher in cities where services had been established for a longer time. In Kisumu, 58% of sex workers had already heard of the services and 34% had actually visited the clinic.

### Discussion

In the past, most studies used mapping and census to estimate the number of sex workers (Vandepitte *et al.* 2006). Census is a straightforward method and less time-consuming than capture–recapture, because it can be done during the mapping. However, census methods are not well suited to hidden and very mobile populations. Double counting because of high mobility may result in an overestimation, and a large invisible population will result in an underestimation of the population size. In our study, size estimates reported during mapping were lower in some cities, and higher in others. In the absence of a 'gold standard', it is difficult to draw a conclusion on the most reliable method.

Capture–recapture was previously described as a relative simple method to assess the size of high-risk populations (Kruse *et al.* 2003). However, in our experience, capture–recapture was harder to conduct well than its initially simple-looking method would have suggested. Capture–recapture has both operational and methodological challenges. Although the assistance of sex worker peer educators was crucial for the successful conduct of the capture–recapture, a team of experienced researchers was needed to train research assistants, coordinate, standardize and supervise field work.

There are four conditions that need to be fulfilled to give reliable estimates with the capture–recapture method (Family Health International, 2003). We designed the methods and procedures of the study to adhere to these conditions as much as possible. First, recapture was done 6 days after the capture visit. Given this short time-frame, the number of sex workers moving in or out of town between the two rounds is likely to be very small,

B. Vuylsteke *et al.* **Estimating female sex worker population size****Table 1** Number of female sex workers in the capture–recapture

	Côte d'Ivoire			Kenya
	Yamous-soukro	Bouaké	San Pedro	Kisumu
<b>First round</b>				
Total number of FSW captured (C1)	441	688	949	651
Number of duplicate captures * (% of C1)	217 (49.2)	260 (37.8)	96 (10.1)	168 (25.8)
Number of refusals	20	38	35	166
Number of FSW unable to consent	–	–	–	38
<b>Second round</b>				
Total number of FSW captured (C2)	447	627	862	680
Number of FSW recaptured (R)	170	359	427	328
Number of new captures (C2–R)	277	268	435	352
Number of duplicate captures* (% of C2)	142 (31.8)	64 (10.2)	53 (6.1)	164 (24.1)
Number of refusals	12	14	29	169
Number of FSW unable to consent (†)	–	–	–	38
Estimation of number FSW by capture–recapture (CI 95%)	1160 (1053–1287)	1202 (1128–1279)	1916 (1809–2030)	1350 (1261–1443)
Estimation of number FSW accounting for refusals (CI 95%)	1189 (1079–1320)	1240 (1163–1322)	1978 (1865–2099)	1684 (1564–1809)

\*Duplicate captures: FSW captures more than once on the same day. Duplicate captures were not given a brochure.

†In Côte d'Ivoire, this number was not recorded separately, but was included in the number of refusals.

**Table 2** Comparison between the population size estimates resulting from the questionnaire during the mapping and the capture–recapture

	Estimated number of female sex workers	
	Reported during mapping	Results from the capture–recapture
<b>Côte d'Ivoire</b>		
Yamousoukro	1903	1195
Bouaké	1208	1250
San Pedro	1562	1980
<b>Kenya</b>		
Kisumu	2290	1692

meeting the condition of a closed population. In addition, capture and recapture dates were chosen away from events which may involve a large influx or outflux of sex workers during the exercise. The second condition is that all

**Table 3** Coverage of sex worker services in the different sites

	Côte d'Ivoire			Kenya
	Yamousoukro	Bouaké	San Pedro	Kisumu
Year of starting sex worker services at the clinics	2006	2007	2001	2006
Total number of FSW captured at least once (C1+(C2–R))	718	956	1384	1003
Already heard about the SW services	36%	41%	53%	58%
Ever visited the SW clinic	15%	17%	30%	34%
Visited the SW clinic during last 12 months*	–	–	–	29%

\*Only available for Kisumu.

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members of the female sex workers population have the same probability of being captured. Comprehensive mapping was done and capture was realized during peak hours on week-ends, in all mapped sites. However, some sex workers have inherent lower probabilities to be caught than others. Call girls, for instance, who work exclusively from home, were not approached in this study and their number could not be estimated. The third condition is the independency of samples (Chao *et al.* 2001). To limit dependency, we chose different days of the week to conduct the two rounds, as sex workers may have their habits, e.g. on Saturdays a sex worker may always go to a certain bar. If she is captured on a Saturday in that bar, she will have a higher probability to be re-captured on the next Saturday in the same bar. However, we could not eliminate all dependency; women captured during the first round for instance may be more likely to be captured again if they recognize the field assistants. A positive dependency among samples, the most likely situation, will lead to an underestimation of the number of sex workers. The fourth condition is the accuracy of the re-capture history. The picture cards used in our study were neutral, not valuable enough to solicit misreporting, but attractive enough not to be forgotten.

The correct identification of sex workers at the hotspots is a key factor to the success of the capture–recapture. The involvement of sex worker peer educators as field workers was of utmost value, as was also reported in Madagascar (Kruse *et al.* 2003). Peer educators not only are in the best position to identify other sex workers, but they also inspire confidence to potential participants. However, it cannot be excluded that a certain number of sex workers were missed because of non-identification. The number of refusals was much higher in Kisumu than in Côte d'Ivoire. There may be different explanations for this, including misclassification, bad timing and lack of trust in the research. In Côte d'Ivoire, peer educators confirmed that participants were active sex workers before asking consent. This was not done in Kisumu, so we cannot exclude that some women approached by the peer educators in Kisumu were not involved in sex work and refused participation for that reason. In sites where the team operated late at night, sex workers were already busy negotiating with their clients and were more likely to refuse participation. Finally, peer educators in Kisumu thought the refusal rate had to do with mistrust, not knowing what would happen to the data collected, rather than misclassification.

To deal with the refusals, we assumed consistent refusal among sex workers. The correction used in the analysis (for  $N_{\text{total}}$ ) assumes that women who refuse to participate do so consistently at all encounters at both

rounds, thus constituting a subpopulation of women who can never be captured. The size of this population is estimated by the number of refusals divided by the number of contacts (totalled over both visits). However, if women were to refuse participation at random, e.g. when they are in conversation with a potential client, the unadjusted ( $N$ ) estimate would have been more correct. A third possibility is that the population who refuse participation changes between capture and recapture visits. This would occur when some women who refuse participation at the capture visit consent to participate at the recapture visit (e.g. because they are encouraged by peers). In this situation, the total population estimate may be biased.

Other challenges during the implementation of this study were police raids which happened during re-capture in Bouaké and San Pedro, despite the prior visits of the investigator's team to the police in all cities to inform them about the study. In Kisumu, heavy rainfall hampered field work during the second round.

One of the major advantages of the capture–recapture is the direct contact with sex workers, allowing a few simple questions. In our study, we were able to assess the coverage of the intervention, which was rather low in all cities. This may partly be explained by the inclusion of indirect, occasional, sex workers in the capture–recapture survey. Interventions tend to target predominantly direct, self-acknowledged sex workers, because they are easier to reach than indirect sex workers. Efforts should be made to increase coverage by scaling up prevention outreach to all identified hotspots, by intensifying one-to-one and group session contacts with peer educators and by improving the quality and attractiveness of services. Geographical mapping of hotspots was essential to plan the capture–recapture exercise but also resulted in an updated practical tool for improving prevention outreach by local implementing NGOs. In this perspective, it is important that researchers and programme managers jointly undertake a capture–recapture exercise not only for estimation purposes, but also for planning and redirecting field activities.

In conclusion, capture–recapture was successfully applied to estimate the population size of female sex workers both in Côte d'Ivoire and in Kisumu, Kenya. These estimations were urgently needed to help mobilize an increased response to HIV, to assess programme coverage and to estimate potential impact of the targeted intervention. However, in the absence of a 'gold standard', estimates can not be validated and may be under- or overestimated. More work needs to be done on comparing different methods to estimate the size of sex worker populations.

### Acknowledgements

The study was funded by the Directorate-General for Development Cooperation (DGDC), Belgium and the President's Emergency Plan for AIDS for AIDS Relief (PEPFAR), United States of America.

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**Corresponding Author** Bea Vuylsteke, Institute of Tropical Medicine, Nationalestraat 155, Antwerp, Belgium. Tel.: +32-3-2476651; Fax: +32-3-2476532. E-mail: bvuykste@itg.be