No increased HIV risk in general population near sex work sites: a nationally representative cross-sectional study in Zimbabwe

Mariëlle Kloek[1] *, Caroline A. Bulstra[1,2] *, Sungai T. Chabata[1,3], Elizabeth Fearon[4], Isaac Taramusi[5], Sake J. de Vlas[1], Frances M. Cowan[3,6], Jan A.C. Hontelez[1,2]

1 Department of Public Health, Erasmus MC, University Medical Center Rotterdam, Rotterdam, The Netherlands
2 Heidelberg Institute of Global Health, Heidelberg University Hospital, Heidelberg, Germany
3 Centre for Sexual Health and HIV/AIDS Research, Harare, Zimbabwe
4 Infectious Disease Epidemiology, London School of Hygiene and Tropical Medicine, London, UK
5 National AIDS Council of Zimbabwe, Harare, Zimbabwe
6 Department of International Public Health, Liverpool School of Tropical Medicine, Liverpool, UK

* Contributed equally

Sustainable Development Goal: Good Health and Wellbeing

Abstract

Objectives: Sex work sites have been hypothesized to be at the root of the observed heterogeneity in HIV prevalence in sub-Saharan Africa. We determined if proximity to sex work sites was associated with HIV prevalence among the general population in Zimbabwe, a country with one of the highest HIV prevalences in the world.

Methods: A cross-sectional study using a unique combination of nationally representative geolocated individual level data from 16,121 people 15 to 49 years of age from 400 sample locations; and the locations of 55 sex work sites throughout Zimbabwe, covering an estimated 95% of all female sex workers (FSWs). We calculated the shortest distance by road from each survey sample location to the nearest sex work site, and conducted univariate and multivariate multilevel logistic regressions to determine the association between distance to sex work sites and HIV seropositivity, controlling for age, sex, male circumcision status, number of lifetime sex partners, being a FSW client or being a stable partner of a FSW client.

Results: We found no significant association between HIV seroprevalence and proximity to the nearest sex work site among the general population in Zimbabwe, regardless of which type of site is closest (city site adjusted odds ratio (aOR) 1.010 [95% confidence interval (CI) 0.992–1.028]; economic growth point site aOR 0.982 [95% CI 0.962–1.002]; international site aOR 0.995 [95% CI 0.979–1.012]; seasonal site aOR 0.987 [95% CI 0.968–1.006]; and transport site aOR 1.007 [95% CI 0.987–1.028]). Individual-level indicators of sex work were significantly associated with HIV seropositivity: being a FSW client (aOR 1.445 [95% CI 1.188–1.745]); nine or more partners versus having one to three lifetime partners (aOR 2.072 [95% CI 1.654–2.596]).

Conclusions: Sex work sites do not seem to directly affect HIV prevalence among the general population in surrounding areas. Prevention and control interventions for HIV at these locations should primarily focus on sex workers and their clients, with special emphasis on including and retaining mobile sex workers and clients into services.

This article has been accepted for publication and undergone full peer review but has not been through the copyediting, typesetting, pagination and proofreading process which may lead to differences between this version and the Version of Record. Please cite this article as doi: 10.1111/tmi.13791

Keywords: HIV epidemic, HIV/AIDS, commercial sex work, sub-Saharan Africa, Zimbabwe, HIV transmission.

Introduction

About two-thirds of people living with HIV worldwide reside in sub-Saharan Africa (1), with many countries still experiencing high incidence and prevalence levels in the general population. Throughout the subcontinent, the epidemic is geographically heterogeneous with localized areas of high transmission around big cities, truck route pit-stops and locations with high levels of economic activity (2). Sex work has often been hypothesized to be at the root of the observed geographical heterogeneity (3,4), as sites where sex workers offer their services, here called "sex work sites", are oftentimes also situated at locations with high economic activity. However, whether the presence of sex work sites is associated with higher HIV prevalence in the general population, and thus can directly explain the observed geographical heterogeneity in the epidemic, has never been empirically tested.

Zimbabwe is one of the countries with the highest HIV burden worldwide. Although incidence levels have decreased by 44% over the past decade (1,5), the decline seems to have stalled in recent years (6). HIV prevalence among female sex workers (FSWs) is over 50% according to the latest estimates (2018-2020) by the Centre for Sexual Health and HIV/AIDS Research (CeSHHAR) Zimbabwe (7), an organization focused on HIV implementation research and responsible for running Zimbabwe's nationally scaled healthcare program for FSWs on behalf of the Zimbabwean government (www.ceshhar.org). CeSHHAR runs (mobile) clinics throughout Zimbabwe, offering services at 36 sex work sites (7), and has further mapped the locations of 19 other sex work sites in the country (7). Data on the locations and typology of sex work sites, together with nationally-representative geolocated survey data from the Demographic and Health Survey (DHS) on HIV prevalence and risk behaviour in the general population (2,8) create the unique opportunity to test whether the HIV prevalence in the general population of Zimbabwe is higher among those living in close proximity to sex work sites.

We determined if geospatial heterogeneity in HIV prevalence in the general population in Zimbabwe is associated with proximity to sex work sites. We first calculated travel distance between DHS sample locations and known sex work sites, and used univariate and multivariate logistic regression models to determine the association between distance to the nearest sex work site and HIV prevalence, controlling for demographic and sexual behavioural factors.

Methods

Data - CeSHHAR

CeSHHAR has registered the locations and characteristics of 55 sex work sites throughout Zimbabwe, over the period 2015 to 2017 (7), and GPS coordinates of each site were collected via Google Maps Coordinates (9). Sex work sites are described as 'hotspots' for sex work, and one sex work site can consist of multiple venues were sex work takes place, such as bars, shebeens, streets, brothels, beer halls, sport bars, nightclubs, parking lots at border crossings, truck stops, mining areas, or marketplaces. For example, the city Harare is identified as one sex work site but consists of a huge variety of sex work venues throughout the city, from parking lots to hotels. The sex work sites are originally identified based on expert opinion and reported by Fearon *et al.* (2020) (7). They include 36 CeSHHAR sites, as well as 19 additional sex work locations identified in a structured workshop with experts, based on reached consensus on the presence of each of those sex work locations per province. The identified sex work sites cover an estimated 95% of all female sex workers (FSWs), based on the calculations by Fearon *et al.* (2020) who counted the numbers of FSWs at the different CeSHHAR sites during various times to calculate the proportion of FSWs among the general population at each site (using existing size population size data), which were then used to estimate the number of FSWs at non-CeSHHAR sites (7). All 55 sex work sites were primarily identified as locations where FSWs work, but the sites might also be utilised by male and transgender sex workers. As different sex work sites might attract different types of clients with a different connection the surrounding general population, we added a stratified analysis using five sex work site categories, based on expert opinion: city (city, regional capital), economic growth point (rural areas with rapid economic growth), international (tourism, international business, border), seasonal (mining, farming, fishing, university, army base), or transport (truck stop, transport hub, border) (7). Sites that fit in multiple classifications were classified in each relevant category up to a maximum of three categories per site. This way, a sex work site identified as e.g., truck stop and mining area was included as both a transport and a seasonal site.

Data - DHS

We used the 2015 DHS from Zimbabwe, which included voluntary HIV testing in the general population, and overlaps with the timeframes in which sex work sites were identified, classified, and localized. The survey was conducted using standard DHS methodology; 400 locations (primary sampling units) were randomly sampled throughout the country, weighted by the population density per area, and about 25 randomly selected households were included at each location. HIV status was determined in the DHSs by testing a blood sample from a finger prick with an enzyme-linked immunosorbent assay (ELISA). GPS coordinates of sample locations were randomly displaced up to 2 km for urban and up to 5 km for rural locations, to ensure confidentiality of participants. All males and females aged 15-to-49 years with available HIV test result were included in our analysis.

Besides HIV status and GPS data, we included several demographic and (sexual) behavioural variables in our analyses: age, sex, male circumcision, number of lifetime sex partners, being a FSW client or being a stable partner of someone who reported to be a FSW client. FSW clients were defined based on whether a man had ever, or in the last year, paid for sexual intercourse. Men who reported to have offered gifts and goods in exchange for sex, instead of money, were not defined as FSW clients in our analysis, due to lack of coherency comparing those answers to the other FSW-related questions. Missing values for lifetime sex partners (136 values, 0.84% of all values) were imputed using multiple imputation (10).

In addition to the variables directly extracted from the DHS, we estimated the proportion of all men being a FSW client at each sample location, the proportion of all women being a FSW within 50 km radius around the sample location, and the human mobility level of people at each sample location. The proportions were determined to indicate the proportion of people directly engaging in FSW among the general population, as the relative size (i.e., number of sex workers relative to the population density of the area) is likely more important than absolute size (i.e., the estimated number of sex workers) (7,11). We calculated the proportion of FSW clients as the fraction of all 15-to-49-year-old men at each sample location, as proxy for utility of commercial sex work among men at the sample location. We estimated the proportion of FSWs among the female population around each DHS sample location (in a 50-kilometer radius) by dividing the number of FSWs in the area, based on sex work site size estimates from the CeSHHAR database (7), by the total female population in the area, based on population estimates provided by the WorldPop project (12) and ZimStat (13). The estimates are provided in Supplementary Figure 1. We hypothesized that human mobility might influence the relationship between distance to a sex work site and HIV prevalence, as human mobility is often associated with higher HIV risk (3,14,15). We therefore estimated the human mobility level of individuals in the DHS data based on combining three DHS variables; whether an individual was identified as being mobile in the past year through either being a seasonal worker; being away from home for at least one month; or being away from home more than two times in the past 12 months, with an individual being identified as "mobile" when at least one out of three were answered with "yes". The prevalence of human mobility was then aggregated per DHS sample location, where sample locations with a human mobility prevalence of 50% or more were marked as locations with high human mobility, and sample locations with less than 50% were marked as locations with low human mobility. More details on survey protocols and questionnaires can be found on the DHS website (https://dhsprogram.com/).

Statistical analysis

To predict and visualize geospatial heterogeneity in HIV prevalence among adults throughout Zimbabwe, we applied Ordinary Kriging. This is a commonly used geospatial method to estimate the best linear unbiased prediction of HIV prevalence at unsampled locations based on HIV prevalence levels from known data points, in our study the sample locations from the DHS data (16). An HIV prevalence estimate is predicted for every five-by-five-kilometre grid cell. The method is described in detail elsewhere (2). In the created map of predicted HIV prevalence throughout Zimbabwe we overlaid the locations of all sex work sites to visually examine an association.

Next, we determined the distance between DHS sample locations and sex work sites, calculated as the shortest distance from each DHS sample location to the nearest sex work site via paved and unpaved roads in kilometres (roads available via Open Street Map (17)). We applied these distances to each individual in the DHS data based on their sample location. The proximity calculation is illustrated in Supplementary Figure 2.

To determine the association between HIV prevalence among the general population and proximity to sex work sites, we performed individual-level and multilevel logistic regression analyses with HIV status (positive or negative) as dependent variable and the proximity to the nearest sex work site (distance to any sex work site as well as by type of site, e.g., distance to the nearest city site and distance to the nearest economic growth point site) as independent variables.

We first plotted and determined the untransformed association between travel distance to sex work site, and both HIV prevalence at each sample location, and proportion of men reporting being a FSW clients at each sample location. We then tested the univariate association between general population HIV status and proximity to sex work sites using logistic regression, using a square root transformed proximity variable as the variable most closely resembled a normal distribution using this transformation. However, we also explored associations with categorical, untransformed continuous, and log-transformed proximity variables (Supplementary Figure 3). The associations between HIV status and all demographic and sexual behavioural variables included in this study were also first assessed univariately.

In the multivariate analysis, the association between travel distance to sex work sites and HIV status was adjusted for individual-level and sample location-level demographic and sexual behavioural risk factors related to FSW: age, sex, male circumcision, lifetime sex partners, and being identified as a FSW client, estimated proportion of FSWs at each sample location, urban or rural classification of each sample location, and population mobility score of each sample location. The DHS sample location was included as a random effect. The final multilevel multivariate model was developed using a backward selection procedure, where all variables that did not significantly improve the model fit (tested using likelihood tests, $P > 0.05$) were excluded. Finally, we separately fitted univariate and multivariate models stratified by sample location mobility score and urban/rural classification to examine potential effect modification. We used R software version 4.0.1 and ArcGIS Pro version 2.3 to perform the analyses.

Ethics approval

Ethics approval was arranged by USAID (https://dhsprogram.com/Methodology/Protecting-the-Privacy-of-DHS-Survey-Respondents.cfm). No separate consent was required to use the anonymized data.

Results

A total of 16,121 individuals from the DHS data were included in our study (Supplementary Table 1). The overall HIV prevalence in the study population was 14.7% (11.2% among men; 17.5% among women). Over one in five men (21.6%, N = 1,529) reported to have ever visited a FSW, and about half of them (11.6%, N = 822) reported to have visited a FSW during the past year. HIV prevalence among men who ever visited a FSW was 20.5%, vs. 8.6% for men who never did. Less than half of the study population (41.8%) lived in urban areas, where HIV prevalence was higher as compared to rural areas: 19.9% versus 11.0%. HIV prevalence was comparable between people with a low and high mobility score (14.5% versus 15.0% respectively). HIV prevalence levels for the general population and by subpopulation, i.e., men, women, young people (15-to-24 years), stable partners of FSW clients, FSW clients, and FSWs, are shown in Supplementary Figure 4.

The geographical spread of HIV among the general population was highly heterogeneous (Figure 1A). Prevalence varied from just below 7% in north Zimbabwe and the eastern and north-western borders, to over 21% and 24% at border crossings with South Africa and Botswana, respectively. Prevalence was also high (above 18%) in the Victoria Falls area, north of Harare (mining), and in the surrounding areas of Bulawayo (mining area, transport route).

The geographical locations and primary classification of the 55 sex work sites as registered by CeSHHAR are shown in Figure 1B. The nine city sites were located in or close to Harare, Zimbabwe's capital, and in or close to the other four bigger cities: Bulawayo and Gweru in central Zimbabwe; and Mutare, and Marondera in northeast Zimbabwe. The nine economic growth point sites and 32 seasonal sites were mostly located in the rural areas of the country. The ten international sites were located at border crossings with Botswana (Plumtree), Mozambique (Mokumbura and Nyampanda), South Africa (Beitbridge), and Zambia (Chirundu and Kariba) and around tourist locations (Victoria falls) and the large cities. The 21 transport sites were mostly located on the national truck routes throughout the country as well as at the international border crossings.

Figure 2A shows the association between sample location-level HIV prevalence and untransformed distance to the nearest sex work site. There was a large variation in both general population HIV prevalence per sample location, ranging from 0% to 55%, and proximity to nearest sex work site, ranging from 360 meter to 220 km, yet there was no statistically significant association between the two variables ($p = 0.77$). Similarly, Figure 2B shows that there was no significant association between the proportion of FSW clients at a sample location, ranging from 0% to 28%, and proximity to nearest sex work site ($p = 0.92$). Scatterplots of the association between HIV prevalence and square root-transformed proximity to the nearest sex work site by type of site are shown in Supplementary Figure 5.

Table 1 shows the univariate and multivariate associations between square root transformed proximity to sex work sites and demographic and behavioural covariates, and individual HIV status. Univariately, proximity to the nearest sex work site overall was not associated with HIV prevalence (odds ratio (OR) = 0.995 [95% confidence interval (CI) 0.976–1.013], $p = 0.563$). When stratified by type of sex work site, only distance to economic growth point sites was borderline significantly associated with HIV status (OR = 0.984 [0.968–1.000]; $p = 0.050$), with increasing distance being associated with lower HIV prevalence.

When controlling for demographic and behavioural variables in the multivariate models, proximity to sex work sites remained not significantly associated with HIV seropositivity in the general population for any sex work site type: city site adjusted odds ratio (aOR) = 1.010 [95% confidence interval (CI) 0.992–1.028], p = 0.290; economic growth point site aOR = 0.982 [95% CI 0.962–1.002], p = 0.088; international site aOR = 0.995 [95% CI 0.979–1.012], p = 0.564; seasonal site aOR = 0.987 [95% CI 0.968–1.006], p = 0.176; and transport site aOR = 1.007 [95% CI 0.987–1.028], p = 0.500. In contrast, individual level covariates indicative of high-risk behaviour and engaging in commercial sex were significantly associated with HIV prevalence. Reported to have ever engaged in transactional sex (men only) showed a 44% increase in the odds of living with HIV (aOR = 1.445 [95% CI 1.188–1.745], p < 0.001). Similarly, reporting nine or more lifetime sexual partners was associated with an over 2-fold increase in the odds of living with HIV compared to reporting 1-3 lifetime partners (aOR = 2.072 [95% CI 1.654–2.596], p < 0.001). Being circumcised showed a 35% decrease in odds of living with HIV (aOR = 0.654 [95% CI 0.495–0.865], p = 0.003).

Multivariate logistic regression models stratified by rural/urban classification or stratified by mobility score of the DHS sample locations showed similar outcomes on the associations between proximity to sex work sites and HIV seropositivity (Supplementary Tables 2 and 3). Only for the urban sample, proximity to economic growth points was significantly associated with HIV seropositivity in the multilevel model (aOR 0.953 [95% CI 0.925–0.981], p = 0.001).

Discussion

Our analysis of 55 sex work sites and 16,121 individuals from 400 DHS sample locations across Zimbabwe showed no apparent association between proximity to the nearest sex work site and HIV seropositivity among the general population, regardless of which type of sex work site was closest. In contrast, individual-level indicators of FSW and high-risk behaviour were significantly associated with HIV seropositivity, with ever having been a FSW client being associated with a 1½ times increase in the odds of living with HIV, and having nine or more lifetime partners being associate with a more than 2-fold increase in the odds of living with HIV compared to reporting one to three lifetime partners.

Geospatial analyses are increasingly being used to illustrate and explain the heterogeneous spread of HIV (2,8,18). For example, Palk and Blower showed that the heterogeneous spread of HIV in Malawi is associated with having a high number of lifetime sex partners (18). Likewise, in a previous study across seven countries in East and Southern Africa, we showed that the large geographic heterogeneity in HIV prevalence among young adults could be linked to areas of high economic activity (2). In these and other studies, FSW was univocally hypothesized as an important underlying driver of the geospatial HIV heterogeneity (2,18–20). However, this hypothesis was never tested empirically due to the lack of suitable data on locations of sex work sites, FSWs, and FSW clients in areas with nationally representative survey data available. In household surveys such as the DHS, FSWs are often not identifiable as being a sex worker (21). Clients are identifiable, although reliant on self-reported behaviour. Using our unique combination of geolocated individual-level survey data on HIV seropositivity and risk in the general population, and the mapped locations of over 95% of all sex work sites in Zimbabwe, we showed that the hypothesized direct link between proximity to sex work site locations and heterogeneity in HIV prevalence among the general population does not hold for the situation in Zimbabwe.

It is important to note that our results do not refute the well-grounded notion that FSW is a major driver of HIV transmission in Zimbabwe and other settings with generalized epidemics (20,22). On the contrary, our findings clearly demonstrate that at an individual-level, indicators of practicing commercial sex as a client are significantly associated with increased risks for HIV. The lack of a geospatial association between sex work sites and HIV prevalence could be explained by a combination of mobility of both FSWs and clients (14,23–25), and maturity of the HIV epidemic (22). Historically, HIV prevalence has been associated with proximity to busy transport routes, truck drivers and migrant mining labour (26–35), which are often locations for sex work sites (36). However, as epidemics mature, HIV increasingly spreads from transmission hotspots to other areas through bridging populations, diluting the measurable association between HIV prevalence and distance to the hotspots. Furthermore, population mobility is a known key factor among both sex workers and their clients, and the places where they engage in sex are often not equal to places where they live (37). A previous study on FSW in Zimbabwe found that around 20% of FSWs travelled at least a couple of times a year over smaller distances, and 10% travelled long-distance while staying away from home for weeks or sometimes months (14). Clients also do not usually visit FSWs close to where they live, but rather visit FSWs when they spend some time away from home (22). This is also supported by our study, where we found a clear association between proximity to sex work sites and the prevalence of FSW clients among the general population.

Our findings show that effective programmatic planning of the HIV response cannot solely depend on the observed geospatial heterogeneity in HIV prevalence, as previously suggested (2,8,18). While planning testing and treatment services based on geospatial distribution of HIV prevalence within the general population would still suffice, allocating services for key populations requires careful mapping of hotspots and sites independent of general population HIV prevalence levels (7,24). It is essential to better understand what other factors drive the observed geospatial heterogeneity in HIV prevalence - e.g., clustering of cultural, geographical or socio-economic factors, or heterogeneities in access to and uptake of interventions – so that interventions can be tailored accordingly.

The lack of a spill-over effect of HIV to the general population in areas surrounding FSW sites emphasizes that interventions at these areas should primarily be focused on FSWs and clients, preferably through people-centred HIV services specifically for FSWs and clients at the sex work site, with peer-outreach as a central aspect of implementation (38). Including sex workers in the design of such an intervention and hiring them as staff members improves effectiveness and acceptability by ensuring that services are sensitive and acceptable to the target population (38). Given the often-high mobility levels of these subpopulations, good accessibility of services is crucial, especially since FSWs and clients might prefer to access HIV clinics at places away from home or utilize several different clinics depending on where they work and engage in commercial sex. Finally, the increased HIV risk among stable partners of FSW clients highlights the need of focused interventions for these people as well. Reaching these people through their partner who visits FSWs might be challenging; the FSW visiting partner might be not open to disclose this information to the stable partner. Nevertheless, targeted HIV services for FSW clients could for example include their stable partners or include discussing condom use with stable partners.

Our study had some limitations. While the overall number of respondents in the DHS between 15-49 years accepting HIV testing was relatively high at 85% (39), male respondence was slightly lower; 81% compared to 88% among women. It is often hypothesized that those who decline have higher HIV risk (40). However, younger people (15-34 years), often at higher risk of acquiring HIV, were somewhat more likely to participate in the HIV testing in the 2015 DHS. Also in rural areas, with often higher proportions of clients, response rates were generally higher. We therefore do not expect selective non-respondence to have influenced our findings substantially. Furthermore, the sex work sites from the CeSHHAR data were determined based on clinic data collected between 2015 and 2017 as well as locations identified through expert opinion (7), and it is perceivable that some sex work sites in Zimbabwe may not have been captured in our data. Since the DHS are cross-sectional data contain HIV status with no information on lag-time since seropositive status, we cannot make definite claims about causal effects between proximity to sex work sites and HIV risk. Next, there can be underreporting of the amount of FSW visits, or selective non-respondence from the people who visit FSW, but it is very unlikely that this potential bias negates the qualitative interference from our study findings, as we did find that reported FSW visiting was associated with increased HIV prevalence. Finally, it is important to note that this work was focused on FSWs and their clients only, because there were no data available on sex workers who identify as cisgender male, transgender women and transgender men, their clients, and their sex work sites. This does not mean these groups do not exist in Zimbabwe. For example male sex work in Zimbabwe was described by Tsang *et al.* (41). It is perceivable that most of these sex workers would work at, or close by, the sex work sites for FSWs, and it is therefore unlikely that knowing the locations of non-cisgender FSWs would alter the qualitative inference of our results.

Conclusions

We found no evidence of a relationship between the proximity of sex work sites and HIV prevalence in Zimbabwe. Programmatic planning of (key population) interventions to curb HIV transmission can therefore not be taken merely based on geospatial heterogeneity of the epidemic, but requires careful mapping and considerations of transmission dynamics related to key-populations implicitly. The absence of a geospatial association can be explained by the mobile nature of both FSWs and their clients, as individual level indicators of FSW were still significantly associated with HIV. Given that spill-over of HIV into the general population surrounding sex work site seems limited, prevention and control interventions for HIV at these sites should primarily focus on sex workers and clients, with special emphasis on including and retaining mobile sex workers and their clients into services.

Acknowledgements

We would like to express our gratitude to all the Centre for Sexual Health and HIV/AIDS Research (CeSHHAR) staff and contributors and sex workers who took part in the data collection.

Funding

MK and JH were supported by the Dutch AIDS Foundation (P-29702). The study funders had no role in the study design, data collection, interpretation, or writing of the article. The corresponding author had full access to all study data and final responsibility for the decision to submit for publication.

Data sharing

The data from the USAID Demographic and Health Surveys are openly available via https://dhsprogram.com/. The data from the Centre for Sexual Health and HIV/AIDS Research (CeSHHAR) are available upon request.

References

1. Joint United Nations Programme on HIV/AIDS (UNAIDS). Joint United Nations Programme on HIV/AIDS. UNAIDS data 2020. [Internet]. Geneva; 2020. Available from: https://www.unaids.org/sites/default/files/media_asset/2020_aids-data-book_en.pdf
2. Bulstra CA, Hontelez JAC, Giardina F, Steen R, Nagelkerke NJD, Bärnighausen T, et al. Mapping and characterising

areas with high levels of HIV transmission in sub-Saharan Africa: A geospatial analysis of national survey data. PLoS Med. 2020;17(3):e1003042.

3. Platt L, Grenfell P, Fletcher A, Sorhaindo A, Jolley E, Rhodes T, et al. Systematic review examining differences in HIV, sexually transmitted infections and health-related harms between migrant and non-migrant female sex workers. Sex Transm Infect. 2013;89(4):311–9.
4. Shannon K, Strathdee SA, Goldenberg SM, Duff P, Mwangi P, Rusakova M, et al. Global epidemiology of HIV among female sex workers: Influence of structural determinants. Lancet. 2015;385(9962):55–71.
5. ZIMPHIA. Zimbabwe population-based HIV impact assessment. 2020.
6. United Nations Joint Programme on HIV/AIDS (UNAIDS). UNAIDS Data 2019. 2019;476. Available from: https://www.unaids.org/sites/default/files/media_asset/2019-UNAIDS-data_en.pdf_aidsinfo.unaids.org.
7. Fearon E, Chabata ST, Magutshwa S, Ndori-Mharadze T, Musemburi S, Chidawanyika H, et al. Estimating the Population Size of Female Sex Workers in Zimbabwe: Comparison of Estimates Obtained Using Different Methods in Twenty Sites and Development of a National-Level Estimate. J Acquir Immune Defic Syndr. 2020;85(1):30–8.
8. Cuadros DF, Li J, Branscum AJ, Akullian A, Jia P, Mziray EN, et al. Mapping the spatial variability of HIV infection in Sub-Saharan Africa: Effective information for localized HIV prevention and control. Nature. 2017;7(1):1–11.
9. Google Maps. https://www.google.com/maps/preview.
10. Buuren S van, Groothuis-Oudshoorn K. MICE: Multivariate imputation by chained equations in R. J Stat Softw. 2010;3(45):1–68.
11. 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.
12. WorldPop [Internet]. Available from: http://www.worldpop.org.uk/
13. Agency ZNS. ZimStat [Internet]. [cited 2020 May 4]. Available from: https://www.zimstat.co.zw/
14. Davey C, Dirawo J, Mushati P, Magutshwa S, Hargreaves JR, Cowan FM. Mobility and sex work: why, where, when? A typology of female-sex-worker mobility in Zimbabwe. Soc Sci Med [Internet]. 2019;220(September 2018):322–30. Available from: https://doi.org/10.1016/j.socscimed.2018.11.027
15. Dobra A, Bärnighausen T, Vandormael A, Tanser F. A method for statistical analysis of repeated residential movements to link human mobility and HIV acquisition. PLoS One. 2019;14(6):e0217284.
16. Miller HJ. Tobler's First Law and Spatial Analysis. Ann Assoc Am Geogr. 2004;94(2):284–9.
17. The Humanitarian Data Exchange. Open Street Map Zimbabwe roads [Internet]. [cited 2019 May 10]. Available from: https://data.humdata.org/dataset/hotosm_zwe_roads
18. Palk L, Blower S. Geographic variation in sexual behavior can explain geospatial heterogeneity in the severity of the HIV epidemic in Malawi. BMC Med. 2018;16(1):22.
19. Dzomba A, Govender K, Mashamba-Thompson TP, Tanser F. Mobility and increased risk of HIV acquisition in South Africa: A mixed-method systematic review protocol. Syst Rev. 2018;7(1):1–7.
20. Tanser F, de Oliveira T, Maheu-Giroux M, Bärnighausen T. Concentrated HIV sub-epidemics in generalized epidemic settings. Curr Opin HIV AIDS. 2014;9(2):115.
21. Edwards JK, Hileman S, Donastorg Y, Zadrozny S, Baral S, Hargreaves JR, et al. Estimating sizes of key populations at the national level: considerations for study design and analysis. Epidemiology. 2018;29(6):795.
22. Steen R, Hontelez JAC, Mugurungi O, Mpofu A, Matthijsse SM, Vlas SJ De, et al. Economy, migrant labour and sex work: interplay of HIV epidemic drivers in Zimbabwe over three decades. AIDS. 2019;(April).

23. Deane KD, Samwell Ngalya P, Boniface L, Bulugu G, Urassa M. Exploring the relationship between population mobility and HIV risk: Evidence from Tanzania. Glob Public Health. 2016;1–16.
24. Davey C, Dirawo J, Mushati P, Magutshwa S, Hargreaves JR, Cowan FM. Mobility and sex work: why, where, when? A typology of female-sex-worker mobility in Zimbabwe. Soc Sci Med. 2019;220(1):322–30.
25. Richter M, Chersich MF, Vearey J, Sartorius B, Temmerman M, Luchters S. Migration status, work conditions and health utilization of female sex workers in three South African cities. J Immigr Minor Heal. 2014;16(1):7–17.
26. Barongo LR, Borgdorff MW, Mosha FF, Nicoll A, Grosskurth H, Senkoro KP, et al. The epidemiology of HIV-1 infection in urban areas, roadside settlements and rural villages in Mwanza Region, Tanzania. AIDS. 1992;6(12):1521–8.
27. Boerma JT, Urassa M, Nnko S, Ng'weshemi J, Isingo R, Zaba B, et al. Sociodemographic context of the AIDS epidemic in a rural area in Tanzania with a focus on people's mobility and marriage. Sex Transm Infect. 2002;78(suppl 1):i97--i105.
28. Bwayo J, Plummer F, Omari M, Mutere A, Moses S, Ndinya-Achola J, et al. Human immunodeficiency virus infection in long-distance truck drivers in east Africa. Arch Intern Med. 1994;154(12):1391–6.
29. Colvin M, Sharp B. Sexually transmitted infections and HIV in a rural community in the Lesotho highlands. Sex Transm Infect. 2000;76(1):39–42.
30. Glynn JR, Pönnighaus J, Crampin AC, Sibande F, Sichali L, Nkhosa P, et al. The development of the HIV epidemic in Karonga District, Malawi. Aids. 2001;15(15):2025–9.
31. Mbugua GG, Muthami LN, Mutura CW, Oogo SA, Waiyaki PG, Lindan CP, et al. Epidemiology of HIV infection among long distance truck drivers in Kenya. East Afr Med J. 1995;72(8):515–8.
32. Parker RG, Easton D, Klein CH. Structural barriers and facilitators in HIV prevention: a review of international research. Aids. 2000;14:S22--S32.
33. Tanser F, LeSueur D, Solarsh G, Wilkinson D. HIV heterogeneity and proximity of homestead to roads in rural South Africa: An exploration using a geographical information system. Trop Med Int Heal. 2000;5(1):40–6.
34. Wawer MJ, Serwadda D, Musgrave SD, Konde-Lule JK, Musagara M, Sewankambo NK. Dynamics of spread of HIV-I infection in a rural district of Uganda. Br Med J. 1991;303(6813):1303–6.
35. Williams BG, Gouws E. The epidemiology of human immunodeficiency virus in South Africa. Philos Trans R Soc London Ser B Biol Sci. 2001;356(1411):1077–86.
36. Wilson D, Halperin DT. "Know your epidemic, know your response": a useful approach, if we get it right. Lancet [Internet]. 2008;372(9637):423–6. Available from: http://www.sciencedirect.com/science/article/pii/S0140673608608831
37. Platt L, Grenfell P, Meiksin R, Elmes J, Sherman SG, Sanders T, et al. Associations between sex work laws and sex workers' health: A systematic review and meta-analysis of quantitative and qualitative studies. PLoS Med. 2018;15(12):e1002680.
38. World Health Organization (WHO). Consolidated guidelines on HIV prevention, diagnosis, treatment and care for key populations. Bull World Health Organ [Internet]. 2016; Available from: https://www.who.int/publications/i/item/9789241511124
39. USAID. Zimbabwe Demographic and Health Survey 2015. Rockville, Maryland, USA; 2016.
40. United Nations Joint Programme on HIV/AIDS (UNAIDS), World Health Organization. Guidelines for measuring national HIV prevalence in population-based surveys Guidelines for measuring national HIV prevalence in

population-based surveys [Internet]. Geneva, Switzerland; 2006. Available from: https://data.unaids.org/pub/manual/2005/20050101_gs_guidemeasuringpopulation_en.pdf

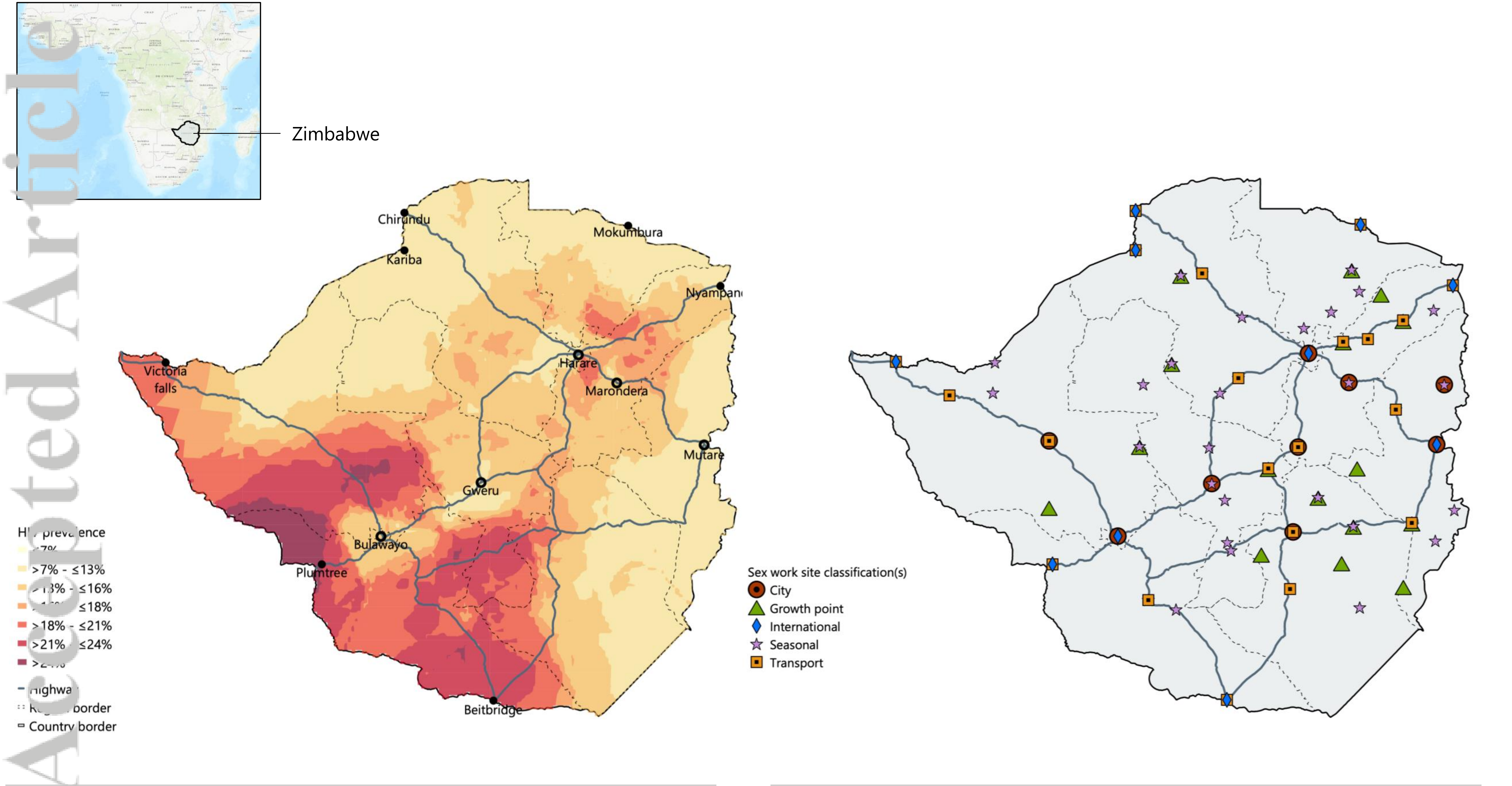
41. Tsang EY, Qiao S, Wilkinson JS, Fung AL, Lipeleke F, Li X. Multilayered stigma and vulnerabilities for HIV infection and transmission: a qualitative study on male sex workers in Zimbabwe. Am J Mens Health. 2019;13(1):1557988318823883.

Corresponding author: Caroline A. Bulstra, Department of Public Health, Erasmus MC, University Medical Center Rotterdam, P.O. Box 2040, 3000 CA Rotterdam, The Netherlands. Email: c.bulstra@erasmusmc.nl

Figure legends

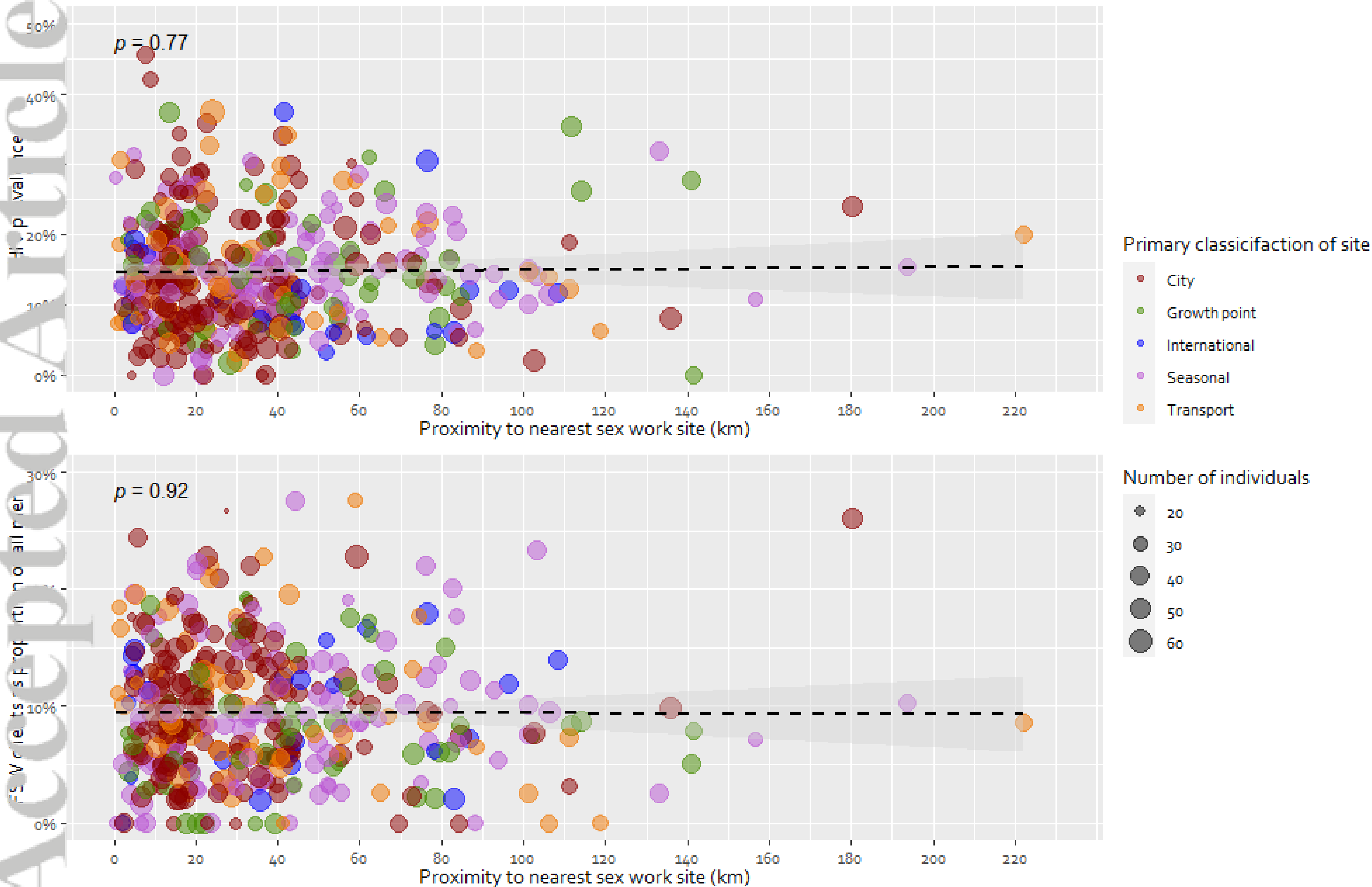
Figure 1. HIV prevalence among the general population in Zimbabwe (panel A) and sex work sites in Zimbabwe by type (panel B). HIV prevalence estimates are acquired using Ordinary Kriging (shown by 5 km^2) and are based on the Zimbabwe 2015 DHS data of males and females (aged 15-49 years). DHS data obtained though https://dhsprogram.com/. Sex work site sites are obtained via CeSHHAR Zimbabwe (http://ceshhar.org/). Twenty-one sites were identified as transport sites, 32 as seasonal sites, 10 as international sites, nine as city sites and nine as economic growth point sites.

Figure 2. HIV prevalence among the general population (age 15-49 years) (panel A) and the proportion of all men who ever visited a FSW (panel B) in relation to proximity to the nearest sex work site, by DHS sample location. Colours represent the primary classification of the sex work site. Sizes of the bubbles represent the number of individuals in each DHS sample location, numbers shown in legend are approximations. Dashed lines represent smoothed generalized logistic regression fits for the associations, for all types of sex work sites together.



A HIV prevalence among the general population (15-49 years)

B Location and classification of sex work sites



p = 0.77
50%
40%
20%
0%
0
20
40
60
80
100
120
140
160
180
200
220
Proximity to nearest sex work site (km)
p = 0.92
30%
10%
0%
0
20
40
60
80
100
120
140
160
180
200
220
Proximity to nearest sex work site (km)
Primary classicifaction of site
City
Growth point
International
Seasonal
Transport
Number of individuals
20
30
40
50
60

Table 1. Univariate and multivariate multilevel logistic regression analysis of HIV status among Zimbabwean males and females age 15-49. Both univariate and multivariate models are adjusted for DHS sample location random effects.

			Univariate analysis			Multivariate analysis		
Covariate	***N***	**HIV prevalence**	**OR [95% CI]**	**P-value**		**aOR [95% CI]**	**P-value**	
Proximity to the nearest female sex work site (km, square root transformed)								
All sites	16,121	14.7%	0.995 [0.976–1.013]	0.563		-		
Proximity to the nearest female sex work site (km, square root transformed) by type								
City	6,481[1]	14.5%	0.998 [0.986–1.009]	0.692		1.010 [0.992–1.028]	0.290	
Economic growth point	2,325[1]	15.5%	0.984 [0.968–1.000]	0.050	*	0.982 [0.962–1.003]	0.088	.
International	999[1]	12.2%	1.001 [0.990–1.012]	0.884		0.995 [0.979–1.012]	0.564	
Seasonal	4,124[1]	15.3%	0.988 [0.974–1.003]	0.124		0.987 [0.968–1.006]	0.176	
Transport	2,192[1]	14.5%	1.006 [0.990–1.023]	0.462		1.007 [0.986–1.028]	0.500	
Percentage of FSW clients as proportion of all men in survey at sample location								
<5%	3,493	12.8%	1	-		-		
5%-15%	10,125	15.1%	1.208 [1.022; 1.426]	0.026	*	-		
≥15%	2,503	15.8%	1.259 [1.012; 1.567]	0.039	*	-		
Percentage of FSWs as proportion of the female population in 50 km radius around sample location								
<5%	7,378	14.0%	1			1		
5%-15%	4,964	16.0%	1.173 [1.008–1.365]	0.039	*	1.155 [0.986–1.353]	0.075	.
≥15%	1,483	14.2%	1.017 [0.804–1.286]	0.889		1.118 [0.874–1.431]	0.375	
Sex								
Male	7,069	11.2%	1			1		
Female	9,052	17.5%	1.684 [1.535–1.849]	<0.001	***	2.540 [2.202–2.930]	<0.001	***
Age								
15-24 years	6,739	5.1%	1			1		
25-34 years	4,922	16.7%	3.848 [3.368–4.397]	<0.001	***	2.454 [2.085–2.890]	<0.001	***
34+ years	4,460	27.0%	7.324 [6.437–8.335]	<0.001	***	5.001 [4.261–5.868]	<0.001	***
Sex work client ever (males only)								

Yes	1,529	20.5%	2.710 [2.312–3.177]	<0.001	***	1.440 [1.188–1.745]	<0.001	***
No	5,540	8.6%	1			1		
Sex work client in the last year (males only)								
Yes	822	19.7%	2.101 [1.728–2.553]	<0.001	***	-		
No	6,247	10.1%	1			-		
Partner of FSW client (females only)								
Yes	787	19.7%	1.147 [0.949–1.386]	0.157		-		
No	8,265	17.3%	1			-		
Lifetime number of sex partners								
None	3,309	3.4%	0.172 [0.141–0.211]	<0.001	***	0.519 [0.407–0.662]	<0.001	***
1-3	9,651	16.0%	1			1		
4-9	2,251	22.8%	1.501 [1.337–1.685]	<0.001	***	1.999 [1.713–2.332]	<0.001	***
9+	910	23.2%	1.538 [1.300–1.818]	<0.001	***	2.072 [1.654–2.596]	<0.001	***
Circumcised (males only)								
Yes	1,150	7.4%	0.558 [0.440–0.708]	<0.001	***	0.654 [0.495–0.865]	0.003	**
No	5,916	11.9%	1			1		
Sample location-level human mobility prevalence								
High	6,334	13.4%	1.088 [0.995–1.190]	0.064	.	-		
Low	9,787	15.6%	1			-		
Type of place of residence								
Urban	6,737	19.9%	1.087 [0.996–1.187]	0.063	.	-		
Rural	9,384	11.0%	1			-		

Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

[1] Number of individuals per type was calculated based on the primary classification of the sex work site that was closest to that individual. However, sex work sites could have up to three classifications assigned to them.

N = Number of observations, aOR = Adjusted Odds Ratio, CI = Confidence Interval, N/A = Not Applicable, '-' = Covariate not present in multivariate regression model