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NATIONAL AIDS COMMISSION

Malawi National HIV/AIDS Estimates 2003

Technical Report

January 2004

ACCRONYMS

AIDS	Acquired Immunodeficiency Syndrome
ANC	Antenatal clinic
BLM	Banja La Mtsogolo
CDC	Centres for Disease Control
EPP	Estimates and Projections Package
HIV	Human immunodeficiency Virus
MACRO	Malawi AIDS Counseling and Resource Organization
NAC	National AIDS Commission
UNAIDS	Joint United Nations Programmes on HIV
USAID	United States Agency for International Development

Acknowledgement

The National AIDS Commission and the Ministry of Health and Population sincerely extend gratitude to all organizations and individuals that contributed to the production of the 2003 HIV/AIDS estimates. Special thanks go to USAID and Centers for Disease Control and Prevention (CDC) Malawi for financial and technical support towards the HIV/AIDS estimates workshop.

We are very grateful to the National HIV/AIDS estimates working group that was formed to come up with the 2003 HIV/AIDS estimates. The working group consisted of representatives from National AIDS Commission, Ministry of Health and Population, Policy Project, The Futures Group, Office of the Vice President, CDC, National Statistics Office, University of Malawi (College of Medicine), Family Health International, UNAIDS, MACRO, USAID, Banja La Mtsogolo (BLM) and the Ministry of Economic Planning and Development.

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Estimating National HIV Prevalence in Malawi from Sentinel Surveillance Data: Technical Report

Executive Summary

A technical working group organized by the National AIDS Commission (NAC) has used the latest sentinel surveillance results for 2003 to estimate national HIV prevalence in Malawi using internationally recommended methods; antenatal clinic data and the modeling computer software Estimation and Projection Package (EPP) and Spectrum. This report describes the methodology, assumptions and results of that work.

The estimated HIV/AIDS prevalence in adults (15 to 49 years) in Malawi in 2003 is 14.4%, with a range from 12 to 17%. The analysis indicates that levels of HIV infection in the adult population of Malawi have remained constant for the last seven years. The level of HIV infection among adults in urban areas is over 20 percent. HIV prevalence is about twice as high in the South as in the North and Centre.

The stable prevalence at 12 to 17 percent does not mean the HIV/AIDS problem has gone away. Every year at least 80,000 people are dying from AIDS and as many as 110,000 new infections occur.

There are some hopeful signs. The infection level among young women (15-24 years old) attending antenatal clinics (ANC) in Lilongwe has declined from about 26 percent in 1996 to 16 percent today. For all ANC attendees (15-49) in Lilongwe the level of infection has declined from 26 percent in 1998 to 17 percent in 2003.

Unfortunately, the indications are not positive elsewhere. Infection levels are above 10 percent in all sentinel sites except some rural sites in the Central Region. HIV prevalence is very high, 20-35 percent, in Blantyre, Mzuzu City and several semi-urban sites.

The total number of people infected with HIV is estimated to be between 750,000 and one million people in 2003. This figure includes 60,000 – 80,000 children under the age of 15 who are infected. One-third of those infected live in urban areas and two-thirds in rural areas.

The implications of the epidemic are very serious. They include:

- Over 840 000 children under the age of 18 are orphans, with 45% due to AIDS.
- The death rate for adults 15-49 has tripled since 1990.
- The number of tuberculosis cases is three times higher than it would be without AIDS.

The estimates also indicate that the need for expanded services is large. For example,

- 170,000 people are in need of anti-retroviral therapy.
- An even larger number need voluntary counseling and testing to learn their HIV status.
- Almost 950,000 orphans and vulnerable children need support.
- About 500,000 pregnant women need good antenatal care including HIV counseling and testing. About 80,000 need anti-retroviral therapy to prevent passing the infection to their newborn children.

Introduction

Sentinel surveillance systems for HIV are designed to provide information on trends to policy makers and program planners. The data are useful for understanding the magnitude of the HIV/AIDS problem in certain geographic areas and among special populations and for monitoring the impact of interventions. These data can also be used to prepare estimates of national HIV prevalence suitable for advocacy purposes and district planning. This paper describes the approach used in Malawi to develop an estimate of adult HIV prevalence.

The estimate and report were prepared during a workshop organized by the National AIDS Commission[1]. Participants represented the NAC, Ministry of Health and Population (MOHP), National Statistical Office, Family Health International, MACRO, College of Medicine, UNAIDS, University of Malawi, Department of Human Resources Management and Development, CDC, USAID and was lead by the USAID-funded POLICY Project. This work has built on previous workshops in 1999[2] and 2001[3] that prepared estimates for those years. The work has also benefited from new models produced by UNAIDS Reference Group on Estimates, Models and Projections[4].

To support the UNAIDS and WHO new approach of in-country development of national HIV prevalence estimates for inclusion in the biennial Report on the Global HIV/AIDS Epidemic, particular attention was given to capacity development among the participating agencies. The workshop was organized to include "hands on" training in the methodology and process used to develop the estimates, particularly the modeling computer software Estimation and Projection Package (EPP) and Spectrum.

The HIV sentinel surveillance system in Malawi is implemented by the MOHP and the NAC. Data are analyzed for syphilis and HIV infection among antenatal clinic (ANC) clients. HIV surveillance has been conducted at Queen Elizabeth Central Hospital in Blantyre since 1985. In 1994 a system of 19 sentinel sites was established. Sites were selected to represent the urban, semi-urban and rural areas as well as the northern, central and southern regions. Results from all rounds of surveillance were used in this analysis up to and including 2003[5].

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[1] National AIDS Commission. *Report of a workshop to prepare an estimate of national HIV prevalence in Malawi*. October 21-23, Lilongwe Hotel, Lilongwe.

[2] National AIDS Control Programme and the POLICY Project. *Estimating National HIV Prevalence in Malawi from Sentinel SurveillanceData*. September 1999.

[3] National AIDS Control Programme and the POLICY Project. *Estimating National HIV Prevalence in Malawi from Sentinel SurveillanceData*. May 2001.

[4] UNAIDS Reference Group on Estimates, Modelling and Projections. "Improved methods and assumptions of the HIV/AIDS epidemic and its impact: Recommendations of the UNAIDS Reference Group on Estimates, Modelling and Projections" *AIDS* 2002. 14:W1-W16.

[5] National AIDS Commission. *HIV Sentinel Surveillance Report 2003*. National AIDS Commission, Ministry of Health and Population, Centers for Disease Control and World Health Organization. 3 October 2003.

The estimate of HIV prevalence among all adults aged 15-49 rests on the assumption that prevalence among pregnant women attending ante-natal clinics is similar to prevalence among all adults, including both men and women, in the general population. Various community surveys in sub-Saharan Africa have shown that this is true. As a result UNAIDS recommends that ANC prevalence can be used to represent prevalence among all adults in generalized epidemics such as in Malawi. Additional details, including data from the community surveys, are given in Appendix A.

Methodology

The workshop participants implemented seven major steps to prepare the national estimate.

1. **Curve fitting**. The Estimation and Projections Package (EPP)[6] was used to fit epidemic curves to the prevalence data for each sentinel site. These curves smooth the annual fluctuations inherent in such data and provide a picture of the entire course of the epidemic from the start to today and can be used to project a short time into the future. In some cases the model provides a good fit to the surveillance data and the curve can be used without further modification. In other cases participants used their best judgment to determine the shape of the prevalence curves. Details of the curve fitting methodology and results are presented in Appendix B.

2. **Adjusting for geographic distribution**. Sentinel sites do not exist in all districts of Malawi. Therefore for each district one of the 19 sentinel surveillance sites was selected to represent the urban population of each district and one was selected to represent the rural population. This procedure is described in more detail in the next section.

3. **Estimating the size of the adult population**. The report of the 1998 census (*1998 Population and Housing Census, Report of Final Census Results*, National Statistical Office, Zomba, December 2000) provides the total urban and rural population in each district in 1998 and 1987 and the population growth rates between the censuses in 1977, 1987 and 1998. These data are used to estimate the size of the urban and rural population in each district by year from 1982 to 2010. The growth rate is assumed to remain constant, at the 1987-1998 value, after 1998 in all but seven districts. In Dedza, Ntcheu, Mangochi, Thyolo, Mulanje, Chikwawa and Nsanje the regional average growth rate is used for 1998-2010 because the 1978-1988 growth rates were judged to be abnormally low due to migration. The population 15-49 by district is calculated from the proportion of the total population that is 15-49 in the 1998 census.

[6] The EPP program is available free of charge. The program and manual can be downloaded from the internet at www.unaids.org.

4. **Estimating the number of adults infected in each district.** The number of people infected with HIV in each district is estimated separately for the urban and rural populations and then summed. For both the urban and rural populations the number of people infected is calculated by multiplying the number of people between the ages of 15 and 49 by the estimated and projected HIV prevalence for the chosen surveillance site.

5. **Estimating national adult HIV prevalence.** HIV prevalence among adults is calculated by dividing the number of people infected with HIV by the size of the population between the ages of 15 and 49.

6. **Estimating the range of uncertainty.** There are many sources of potential error involved in preparing these estimates. Prevalence estimates at ANC sites have an error of plus or minus 5 percentage points for rural sites with sample sizes of about 200 women to plus or minus 3 percent in urban sites with sample sizes around 800 women. There are uncertainties in finding the best fitting curves for each site and in equating prevalence from ante-natal clinics to the general adult population. Another source of error of unknown size is the use of 19 sentinel sites to represent the entire country. The assignment of sentinel sites to each district was based on the best judgment of the participants during the 2001 prevalence estimation workshop. UNAIDS has recommended that the error range around national estimates in generalized epidemics with good surveillance systems, such as Malawi, is plus or minus 20 percent[7]. This figure was applied to the point estimate of prevalence to generate the range around that estimate.

7. **Calculating additional indicators of interest.** The final step was to use the estimate of adult HIV prevalence over time to calculate additional national indicators of interest such as overall infections, the number of child infections, new infections each year, AIDS deaths, life expectancy, orphans and tuberculosis cases. These indicators are projected using the Spectrum[8] program which combines the prevalence estimate with patterns describing other epidemiological characteristics (such as the distribution of infection by age and sex, the mother-to-child transmission rate, the survival time from infection with HIV and the effect of HIV on fertility) and with a full demographic projection. Additional details of the Spectrum projection are given in Appendix C.

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[7] UNAIDS Reference Group on Estimates, Modelling and Projections. "Improved methods and assumptions of the HIV/AIDS epidemic and its impact: Recommendations of the UNAIDS Reference Group on Estimates, Modelling and Projections" *AIDS* 2002. 14:W1-W16.

[8] Spectrum is a system of policy models that includes modules for making demographic and HIV/AIDS projections. It has been developed by the USAID-funded POLICY Project. The model and manual can be downloaded from the website of the Futures Group at www.FuturesGroup.com

Assigning sentinel sites to represent districts

Malawi has 28 districts. It would be impossible to establish an urban and rural sentinel site in each district. Therefore, the prevalence in the urban and rural population in each district is represented by one of the 19 sentinel sites. For each district a sentinel site was chosen to represent the urban population and a site to represent the rural population. This selection was done on the basis of geography and similarity of key characteristics. The characteristics considered are shown in Table 1. A similar exercise was conducted during the 2001 national estimate workshop. Participants started with the assignments from 2001 and considered whether any changes were required. Suggested assignment changes were minor, in the interest of consistency for monitoring trends, a final decision was made that sentinel site representation should stay the same as that used in 2001.

Table 1. Characteristics used in assigning sentinel sites to represent districts

Geographic proximity
Socio-cultural factors (practices, rites)
Development levels (infrastructure, schools, shops, etc.)
Access to major transportation routes (main highways, lake, railroad)
Economic aspects (agriculture, estates, commercial centers, cross-border trade)
Migration (migrant farmers/laborers, cross-border migration, economic opportunity)
Sexual networks
History
HIV prevalence of surveillance sites

Table 2 shows the districts and the sentinel sites that were chosen to represent them. The reasons for the assignments are presented in Appendix D. In some cases, no single site was appropriate to represent a district. In these cases two sites were selected and the average prevalence of the two sites was used.

Table 2. Districts and sentinel sites used to represent them

Region	District	Urban site	Rural site
North	Chitipa	[illegible]	[illegible]-Kaporo
	Karonga	Nkhata Bay	Kaporo
	Rumphi	Rumphi	[illegible]
	Nkhata Bay	Nkhata Bay	Mbalachanda-Kaporo
	[illegible]	[illegible]	[illegible]
	Mzuzu City	St. John's	[illegible]
	[illegible]	[illegible]	[illegible]
Central	Kasungu	Mchinji	Kamboni
	[illegible]	[illegible]	[illegible]
	Nkhotakota	Thonje-Mchinji	Thonje
	[illegible]	[illegible]	[illegible]
	Salima	Mchinji-Nkhotakota	Nkhata Bay-Kaporo
	[illegible]	[illegible]	[illegible]
	Mchinji	Mchinji	Kamboni
	[illegible]	[illegible]	[illegible]
	Ntcheu	Ntcheu	Kasina
	[illegible]	[illegible]	[illegible]
	Machinga	Mangochi	Gawanani
	[illegible]	[illegible]	[illegible]
	Zomba	Blantyre	Gawanani-Milepa
	[illegible]	[illegible]	[illegible]
	Blantyre	Blantyre	Milepa-Mianga
	[illegible]	[illegible]	[illegible]
	Thyolo	Mulanje	Mianga
	[illegible]	[illegible]	[illegible]
	Phalombe	Milepa	Milepa
	[illegible]	[illegible]	[illegible]
	Nsanje	Nsanje	Milepa-Mianga

Note: Where two sites are listed, such as Milepa-Mianga, the average prevalence in the two sites is used.

Results

The results of applying this methodology to the sentinel surveillance data are shown for 2003 in Table 3. Adult HIV prevalence is 14.4% with a range of 12-17% in the country as a whole and 23.0% (19-28%) in urban areas. The total number of people infected is between 750,000 and 1,080,000.

Table 3. Estimates of HIV infection in Malawi in 2003

Indicator	Value	Low	High
National adult prevalence (15-49)	14.4%	12%	17%
Number of infected adults	760,000	630,000	910,000
Number of infected adult women	440,000	370,000	530,000
Urban adult prevalence	23.0%	19%	28%
Rural adult prevalence	12.4%	10%	15%
Number of infected rural adults	530,000	440,000	640,000
Number of infected children (0-14)	70,000	60,000	80,000
Number infected over age 50	60,000	50,000	70,000
Total HIV+ population	900,000	750,000	1,080,000

Figure 1 shows the adult HIV prevalence over time in the country as a whole and in urban and rural areas. Prevalence for the entire country increased rapidly from the late 1980s to the early 1990s. By the middle of the 1990s prevalence stabilized and has remained roughly constant since. It is expected to remain at about the same level for the next few years if current conditions continue. Expanded implementation of prevention interventions, however, could change this projection and lead to declining prevalence in the future.

Figure 2 shows prevalence by region. Prevalence is clearly highest in the Southern Region where it is about double the level in the Centre and North. The exact pattern of prevalence increase by region before 1994 is uncertain since there is very little surveillance information for that period and many sites that started in 1994 had already reached stable prevalence. Therefore, curves with different shapes before 1994 would fit the surveillance data equally well.

Figure 1. Estimate of national adult prevalence by place of residence

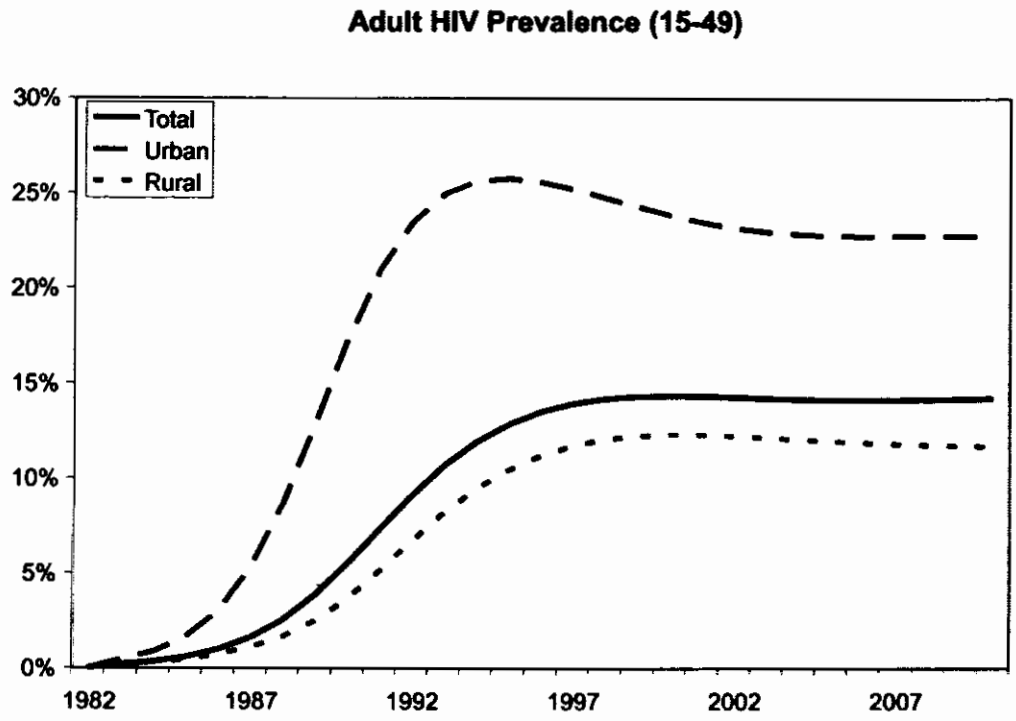
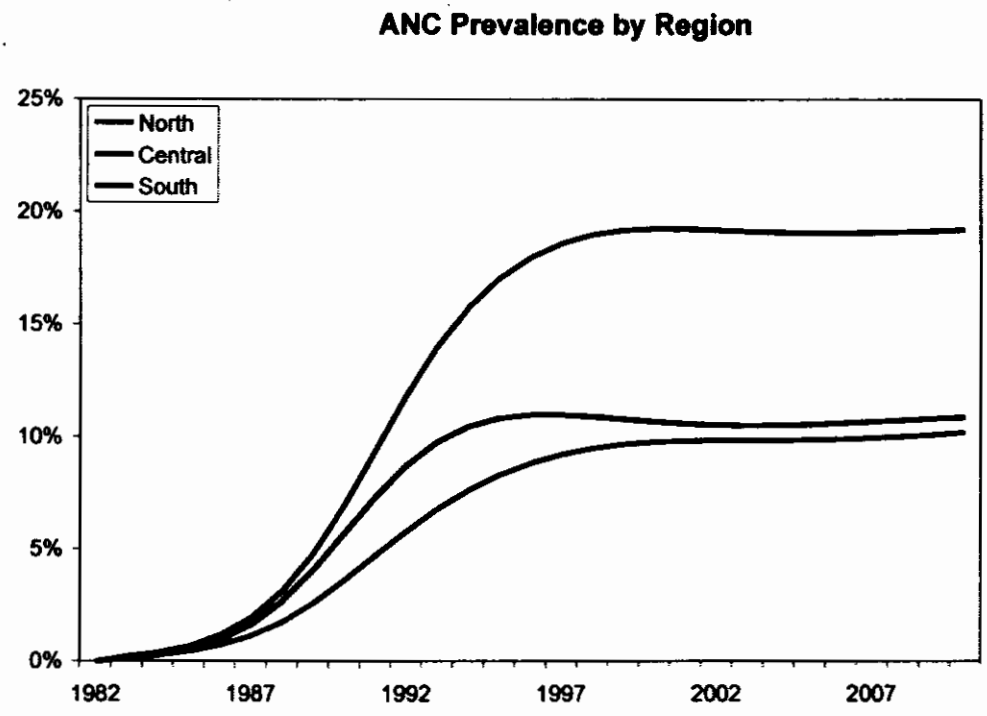


Figure 2. Estimate of national adult prevalence by region



This methodology produces estimates of the number of people infected by district (Table 4). These estimates should be used with caution since in many cases they are based on prevalence from sites in other districts. However, they do give some indication of the level of infection by district.

Table 4. Estimates of adults 15-49 infected with HIV by district, 2003

North	**75,000**	**South**	**475,000**
Chitipa	7,000	Mangochi	54,000
Karonga	16,000	Machinga	32,000
Rumphi	6,000	Balaka	22,000
Nkhata Bay	10,000	Zomba Rural	41,000
Mzimba	22,000	Zomba Municipality	13,000
Mzuzu City	13,000	Chiradzulu	18,000
Likoma	1,000	Blantyre Rural	29,000
Centre	**216,000**	Blantyre City	99,000
Kasungu	21,000	Mwanza	12,000
Nkhotakota	10,000	Thyolo	46,000
Ntchisi	9,000	Mulanje	42,000
Dowa	21,000	Phalombe	17,000
Salima	24,000	Chikwawa	33,000
Lilongwe Rural	29,000	Nsanje	17,000
Lilongwe City	63,000		
Mchinji	12,000		
Dedza	16,000		
Ntcheu	12,000		

Additional indicators describing the magnitude and impact of the epidemic are shown in Table 5. At least 80,000 people are dying each year from AIDS as a result of past infections. That number will increase in the coming years as a result of new infections that are occurring today. The mortality impact is large among adults age 15-49 where the annual number of deaths is 250% higher than it would be without AIDS. This high level of mortality has produced a sharp rise in the number of children who are orphaned. Currently the number of orphans from all causes may be at least 840,000, with 45% due to AIDS. Almost 950,000 orphans and vulnerable children need support. The high level of mortality has also reduced life expectancy at birth to about 40 years. It would be about 56 without AIDS in 2003.

Table 5. Indicators of the impact of the epidemic in 2003 and 2010 assuming no reduction in HIV prevalence

Indicator	2003	Projection for 2010 assuming no reduction in prevalence
Annual number of AIDS deaths	87,000	96,000
Increase in the annual number of deaths to adults 15-49 due to AIDS	250%	260%
Increase in the number of tuberculosis cases due to AIDS	190%	180%
Life expectancy with and without AIDS	40/56	43/59

These estimates imply high levels of need for services as shown in Table 6. About 170,000 people have a need for care and treatment including the treatment of opportunistic infections associated with AIDS and anti-retroviral therapy. Over 500,000 women give birth each year. They all need access to HIV counseling and testing to determine their HIV status. If all women were tested, about 80,000 would need Nevirapine or other anti-retroviral treatment to prevent the transmission of the infection to their child.

Table 6. Indicators of the need for services 2003 and 2010 assuming no reduction in HIV prevalence

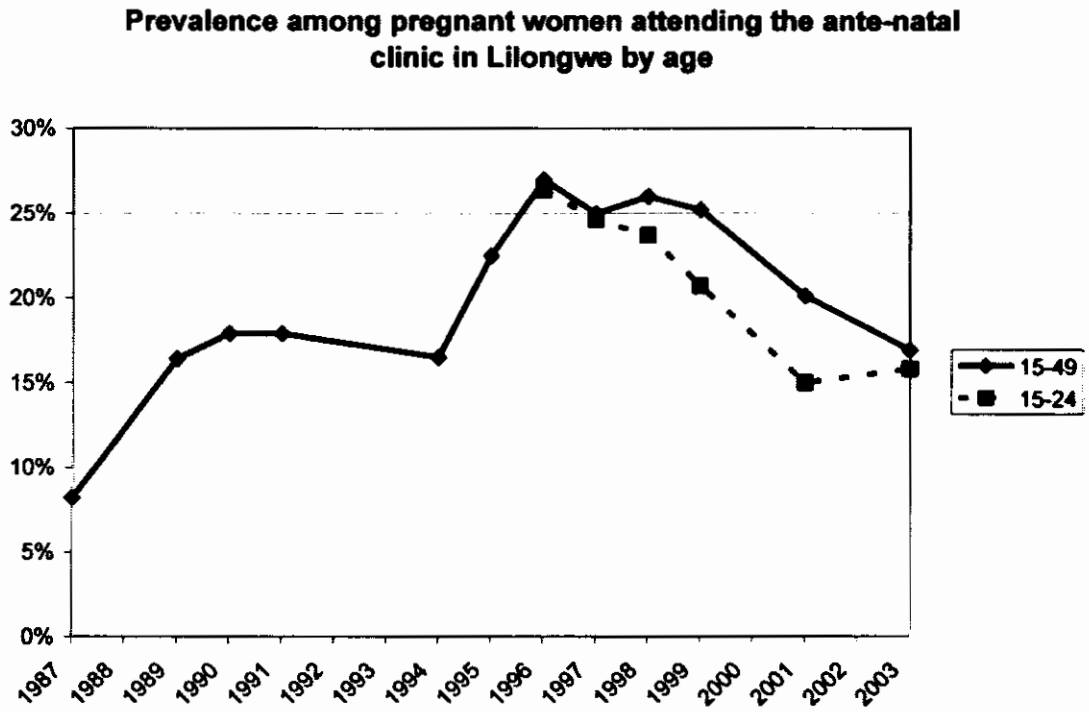
Indicator	2003	[illegible]
Number of people needing advanced treatment including anti-retroviral therapy	170,000	190,000
Number of pregnant women in need of HIV counseling and testing	520,000	570,000
Number of HIV+ pregnant women needing anti-retroviral therapy to prevent transmitting HIV to their child	80,000	89,000

Evidence of behavior change in Lilongwe

The annual estimates of prevalence at sentinel surveillance sites fluctuate from year to year depending on random variation due to small sample sizes. A prevalence estimate that is lower in 2003 than in 2001 does not necessarily indicate that prevalence has declined. It could be due to random variation. This is the pattern seen in most sites. Furthermore, prevalence can decline simply because many infected people are dying. The rapid increase in the number of new infections in the late 1980s and early 1990s means that the number of deaths is increasing rapidly today. This will naturally lead to a small decline in prevalence in some sites.

In Lilongwe, however, the pattern is different. Prevalence for the entire sample in Lilongwe has declined from 26% in 1998 to 17% in 2003 (Figure 3). While some of this is undoubtedly due to a high death rate, prevalence has also declined markedly among young people in Lilongwe. Prevalence among pregnant women aged 15-24 years attending the antenatal clinic in Lilongwe declined from 26% in 1996 to 16% today. This is strong evidence that behavior has changed among young people in Lilongwe. However, further investigative research is necessary to ascertain this observation and to characterize the behaviour change. Unfortunately we do not see a similar pattern elsewhere.

Figure 3. HIV prevalence among pregnant women attending the ante-natal clinic in Lilongwe



Rapid rise of prevalence in Nsanje

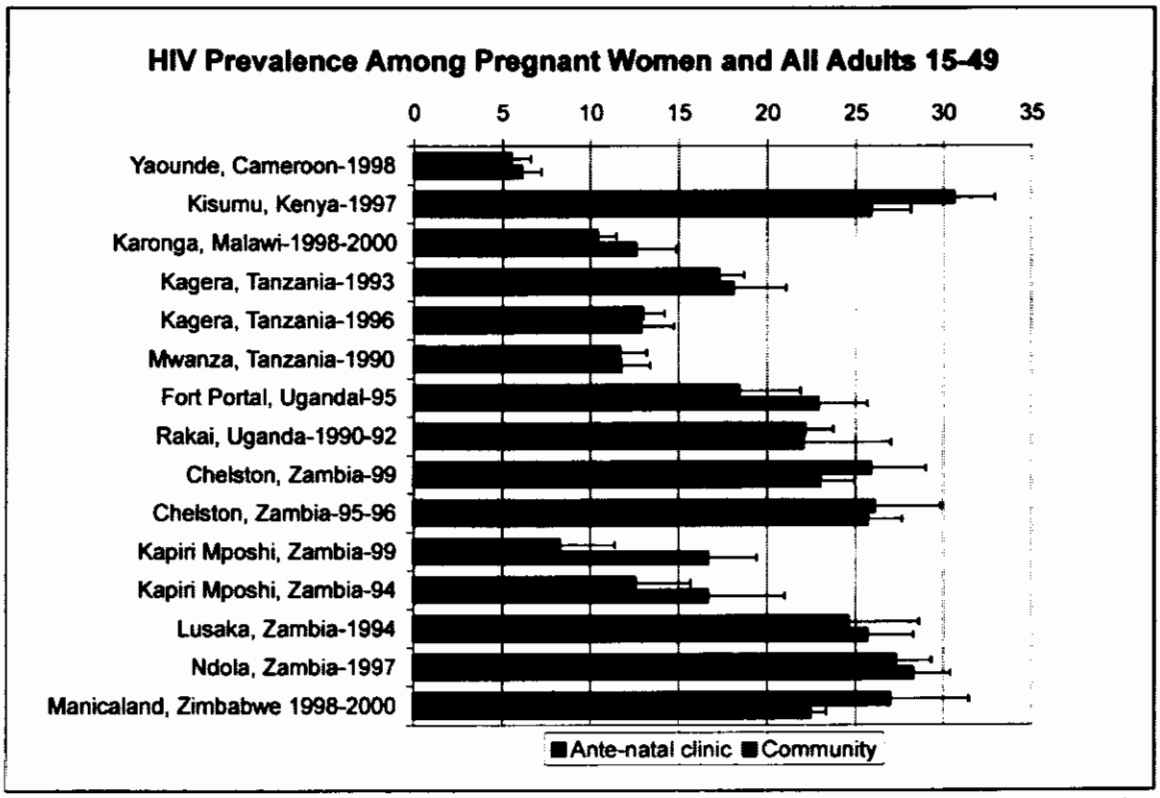
The sentinel surveillance data from Nsanje merit special attention. Since 1997 prevalence has increased from 21% to 33% in 2003, with prevalence over 30% in 2001 as well. This is the highest-level recorded anywhere in Malawi. Very little is known about why this is happening. There is an urgent need to investigate this further to find out what is causing the rapid rise to such high levels and what can be done to prevent future infections. It also indicates that the area around Nsanje will need special attention for care and treatment in the coming years.

Appendix A. Using Data from Ante-natal Clinics to Represent HIV Prevalence Among All Adults 15-49

Women attending antenatal clinics differ from the general adult population. They are all sexually active and have at least some unprotected sex. Furthermore, studies from several African sites have shown that women with HIV have lower fertility than those without infection; meaning that they are less likely to visit antenatal clinics. As a result, ANC data tend to under-estimate prevalence among women. These data also show, however, that male prevalence is lower than female prevalence. For the 15-49 age group, these differences tend to cancel each other. As a result, prevalence among pregnant women is a good indicator of prevalence among all adults 15-49, without adjustment. Figure 4 shows this comparison for several sites with data on both populations. (This conclusion is only valid for the population 15-49. For some sub-populations, such as 15-19, there are significant differences in prevalence between pregnant women and all adults.)

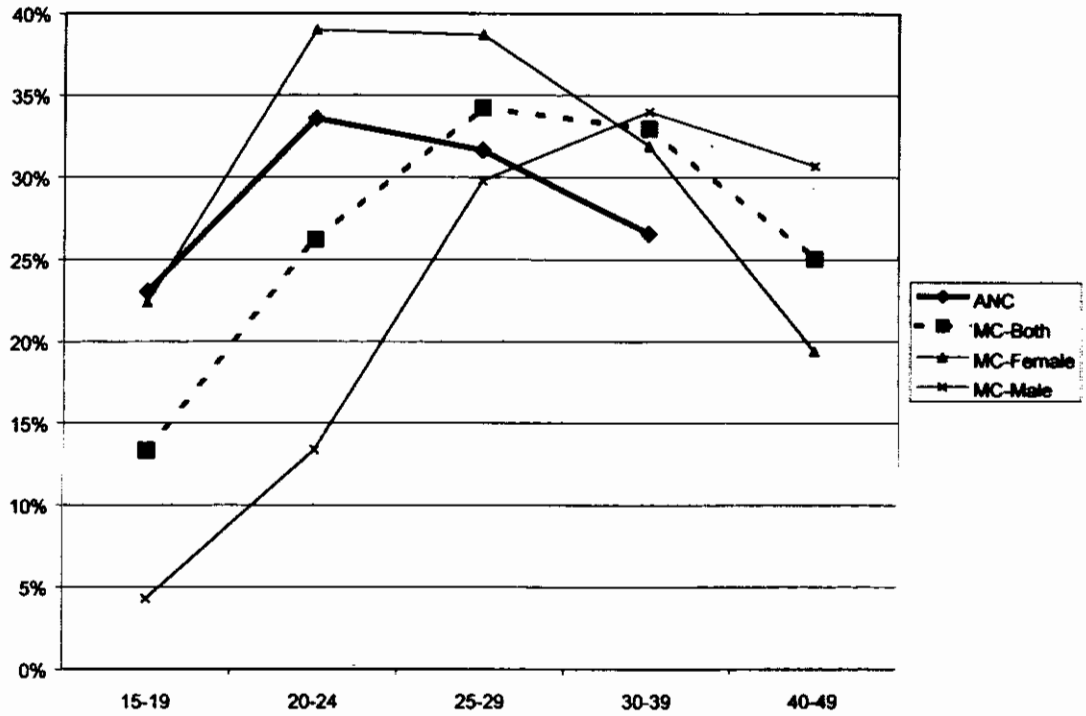
Figure 5 shows age-specific levels for Kisumu, Kenya. It compares age-specific prevalence from the ANC in 1998 with data from a community survey conducted by the Multi-Centre study of Kisumu. It shows that ANC data tend to under-estimate female prevalence, except at the youngest ages. The under-estimate is due to the suppressing effect of HIV infection on fertility. At the youngest ages, the fact that all ANC attendees are sexually active raises ANC prevalence relative to all females at that age. The ANC data over-estimate male prevalence, except in the over 30 age groups. For the total population, ANC data over-estimate prevalence below age 25 and under-estimate over age 25. For the entire 15-49 age group these differences cancel out. As a result, ANC prevalence is a reasonable estimate of total prevalence among males and females aged 15-49.

Figure 4. Comparison of HIV prevalence among pregnant women and all adults aged 15-49



Sources:
Yaounde: Glynn *et al. AIDS* 2001.
Kisumu : Glynn *et al. AIDS* 2001.
Karonga : Crampin *et al. AIDS 2003, 17 :1817-1825.*
Kagera : Kwesigabo *et al.* 2000.
Mwanza : Kigadye *et al. AIDS* 1993, 7, 843-855.
Fort Portal : Kilian *et al.* 1999.
Rakai : Wawer *et al. AIDS* 1997, 11, 1023-1030.
Chelston : Fylkenses *et al.* 1998 and Fylkenses *et al.* 2001.
Kapiri Mposhi : Fylkenses *et al.* 1998 and Fylkenses *et al.* 2001.
Lusaka : Fylkenses *et al. AIDS* 1997, 11, 339-345.
Ndola : Glynn *et al. AIDS* 2001.
Manicaland : Gregson *et al.* 2002.

Figure 5. Comparison of ANC prevalence with general population prevalence for Kisumu, 1998

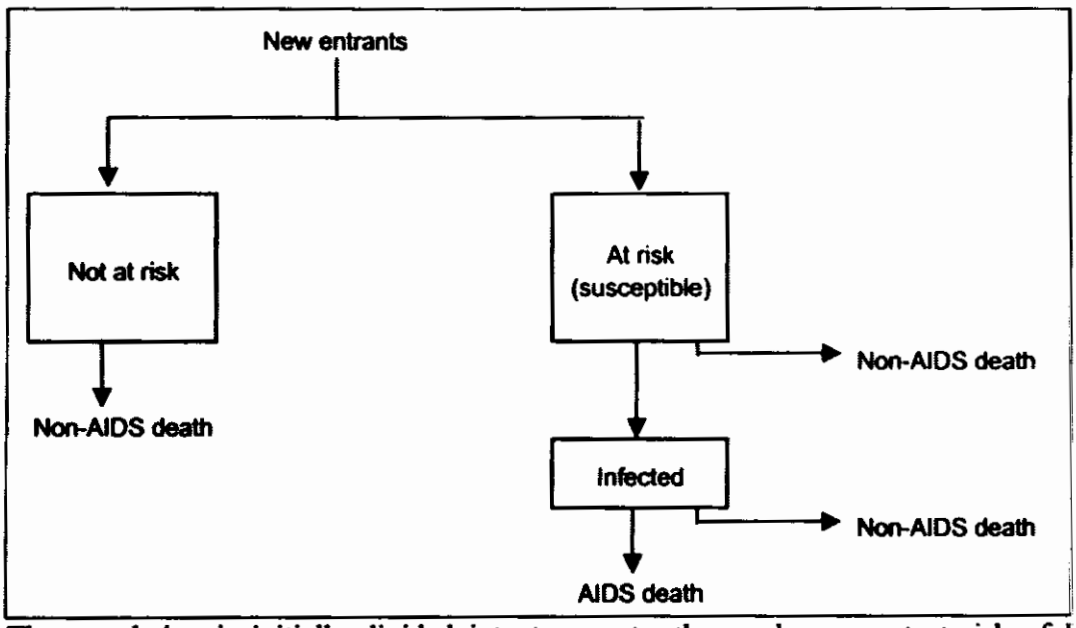


Source: Kahindo, M., Nyang, J., Chege, J. "Multicentre study On factors determining the differential spread of HIV in Africa - Preliminary results of the Kisumu study site" 2nd National Conference on HIV/AIDS in Kenya, 28-30 October 1998, Nairobi, Kenya and sentinel data from the National AIDS and STDs Control Programme, Nairobi.

Appendix B. Curve Fitting

For most sites, surveillance data are available annually from 1994. For some sites data are available for years prior to 1994. The average sample size is about 800 in urban sites, 500 for the semi-urban sites and about 200 for rural sites. To smooth the fluctuations resulting from small sample sizes, a curve is fit to the sentinel data. The curve indicates the trend through the available data points. Values from these curves (rather than the actual sentinel site point estimates) are used to estimate national prevalence.

The curve fits were done using a model prepared by the UNAIDS Reference Group on Estimates, Models and Projections, called the Estimation and Projection Package (EPP). EPP is a simple epidemiological model that produces the basic epidemic curve shapes found in most HIV epidemics. The model structure is shown below.



The population is initially divided into two parts, those who are not at risk of HIV infection and those who are at risk. People would not be at risk if they are not sexually active, if they have only one partner who has no outside partners, or if they successfully use condoms all the time. New entrants are children reaching the age of 15. They can enter either population group. Some of those who are at risk will become infected and progress to AIDS death. All population groups are subject to this risk of dying from causes other than AIDS.

The dynamics of this model are described by four parameters:

- t_0 – The initial year of the epidemic.
- f_0 – The initial proportion of the population that is in the at-risk category.
- r – The force of infection. This governs the rate at which people in the susceptible population become infected.

- ϕ – A parameter that affects the distribution of new entrants to the not at-risk and at-risk categories.

The model is defined as follows:

Z = at-risk population
X = not at-risk population
Y = infected
$N = X + Y + Z$

$$\frac{dX}{dt} = (1 - f(X/N)).E_t - \mu X$$

$$\frac{dZ}{dt} = f(X/N).E_t - (\mu + rY/N + \iota)Z$$

$$\frac{dY}{dt} = (rY/N + \iota)Z - \int_0^t (rY_x/N_x + \iota_x)Z_x.g(t-x)dx$$

where $f(X/N)$ is the fraction of those individuals entering the adult population (E_t) who enter the at-risk group Z, and is given by

$$f(X/N) = \frac{\exp\left[\phi(\frac{X}{N} - (1 - f_0))\right]}{\exp\left[\phi(\frac{X}{N} - (1 - f_0))\right] + \frac{1}{f_0} - 1}$$

μ = the non-AIDS death rate
ι = 1 for the first year of the epidemic and 0 for all other years
g = function describing the proportion progressing to AIDS death by the number of years since HIV infection

The population not at risk (X) is increased by new entrants and reduced by non-AIDS deaths (μX). The population at risk (Z) is increased by new entrants and reduced by non-AIDS deaths and new HIV infections (rY/N). The infected population (Y) is increased by new infections (rY/N and ι) and decreased by progression to AIDS death.

The function f(X/N) determines the proportion of new entrants to the adult population that enter the at-risk population. Initially this proportion is set by f_0. As the epidemic progresses those in the at-risk category become infected with HIV and die. Since the

death rate will be higher in the at-risk category than among those not at risk, the proportion of the population at risk will gradually decline. This will produce a prevalence curve that rises to a peak value and then declines rapidly to low levels. In many epidemics, however, prevalence stabilizes at or near its peak value. This can be simulated by directing more entrants to the at-risk category as the proportion of the population in the at-risk category declines. The parameter ϕ determines the size of this effect. At high values of ϕ new entrants will join the at-risk category in large enough numbers so that the proportion of the total population in the at-risk category remains nearly constant. When ϕ is zero the proportion of entrants going to the at-risk category does not change from its initial value. Negative values of ϕ cause the proportion of entrants to the at-risk category to drop as AIDS deaths increase.

These equations can produce a prevalence curve that can fit a wide variety of epidemic shapes by adjusting the four parameters: $\mathbf{t_o}$, $\mathbf{f_o}$, **r**, and **phi**.

EPP uses this model to find prevalence curves that fit available surveillance data. The parameter μ (the non-AIDS death rate) is estimated for each country from the population estimates and projections of the United Nations Population Division. The progression to AIDS death (g) is assumed to be constant throughout the projection. It is a weibull function that has been fitted to available information on survival times. The progression pattern used in EPP is discussed below.

New entrants to the adult population at time t, E_t are calculated from the births of HIV negative children B^-_{t-15} occurring 15 years previously and the probability of surviving to age 15, l. The number of births is simply the birth rate multiplied by the size of the adult population. However, some children will be born infected. We assume that they do not survive to age 15. Thus the number of children born without HIV infection is determined by calculating births to HIV-negative adults (b(X+Z)) and HIV-negative births to HIV-positive adults (b'Y(1-v) where v is the perinatal transmission rate and b' is the birth rate adjusted for the reduction in fertility caused by HIV infection, ε.

$$E_t = B^-_{t-15} \cdot l$$

$$B^-_{t-15} = b \cdot \left[X_{t-15} + Z_{t-15} + (1-v) \cdot \varepsilon \cdot Y_{t-15}\right]$$

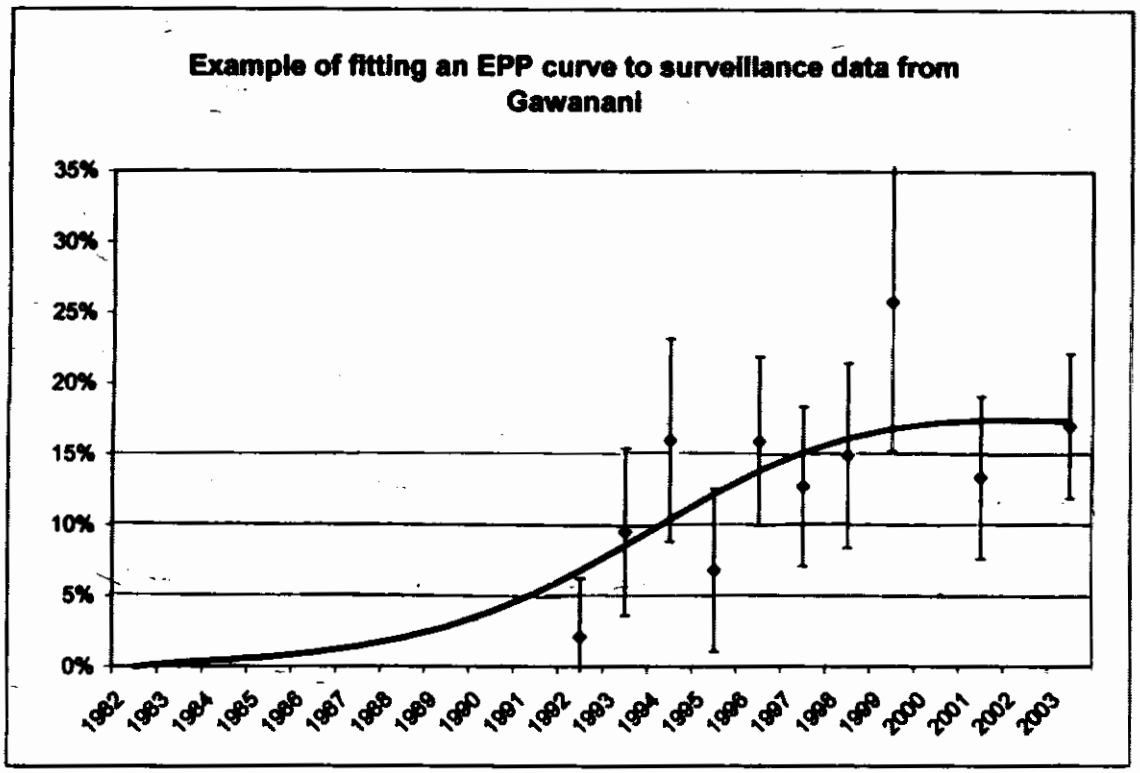
This approach is implemented in the EPP model by assuming that the parameters l (survival to age 15), b (birth rate), ε (fertility reduction caused by HIV), v (perinatal transmission rate) and the distribution g (progression from infection to AIDS death) are fixed. The initial values of the population size, survival to age 15 and the birth rate are derived from the population estimates of the United Nations Population Division.

EPP searches for the best values of the four remaining parameters $\mathbf{t_o}$ (start year), $\mathbf{f_o}$ (fraction at-risk), **r** (force of infection and **phi** (adjustment for AIDS deaths). The best values are defined as those that produce the prevalence curve that best fits the

surveillance data. The best fit is determined by minimizing the sum of the squared errors (the differences between the model curve and the surveillance estimates in each year).

An example of fitting a curve to surveillance data using EPP is shown in Figure 6 for Gawanani Rural Hospital in Machinga District. The projection of these curves to 2012 is meant to indicate the future situation, if past trends continue. These projections are not a prediction of what we expect to happen, since we expect that prevention programs will eventually lead to a reduction in HIV prevalence.

Figure 6. Curve fit to surveillance data for Gawanani Rural Hospital



These curves have been fit to the data in all 19 sites. In most cases the EPP program is able to determine the best fitting curve. In some cases this does not happen and the curve is fit manually. Many of the manual curve fits were required because there are few sites with data points describing the early phases of the epidemic. In these cases the model could not determine when prevalence reached at plateau.

Table 7 shows the parameters used to fit each site. The value of f_0 represents the proportion of the population at risk of infection early in the epidemic. The value of **phi** indicates to what extent people with high risk behaviors who die from AIDS are replaced by others adopting high risk behaviors. High values of **phi**, above 50, indicate a high degree of replacement. Low values, near zero, indicate very little replacement. The **r** value is the force of infection. It determines how steeply the epidemic rises during the explosive phase. Since **r** depends on f_0 it is not possible to compare these values of one

site with another unless they have the same value of f_o. The start year of the epidemic is indicated by t_o. It is set to 1982 in almost all cases.

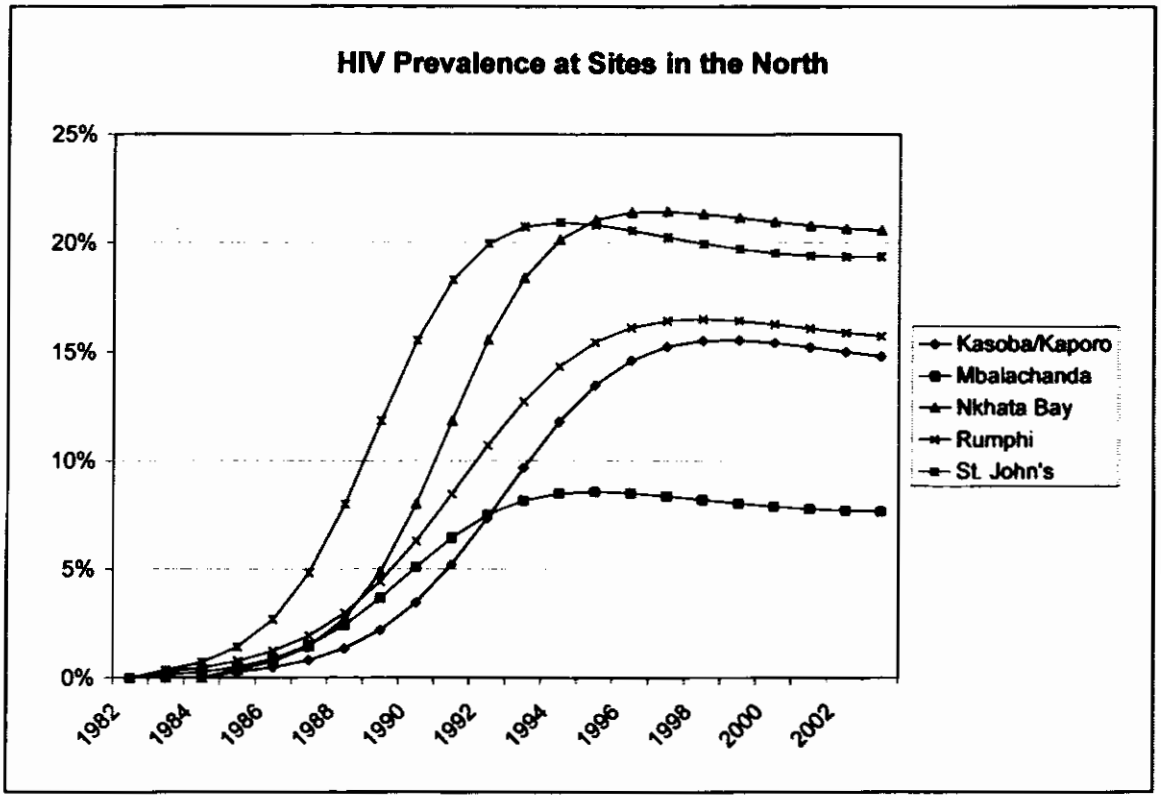
Table 7. Curve Fit Parameters by Sentinel Site

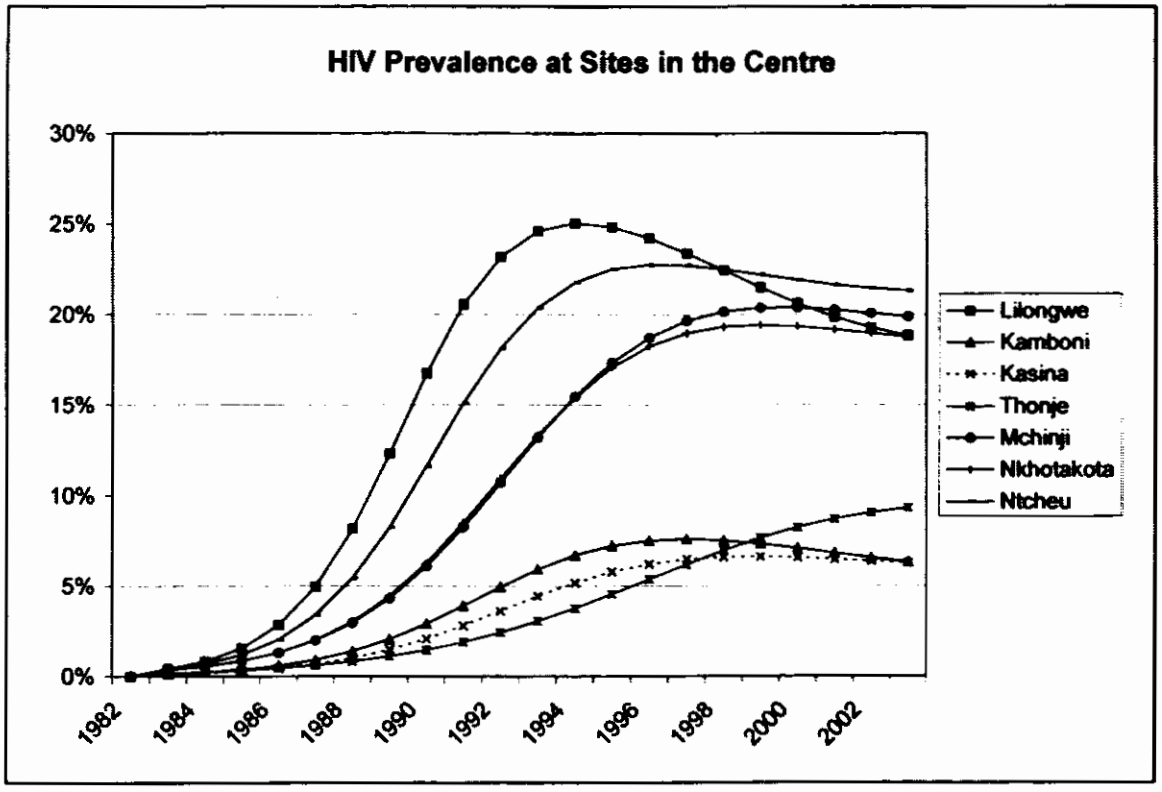
Rumphi	North	Semi-urban	2.55	0.217	102	1982	Model
Mbalanchanda	North	Rural	6.00	0.110	100	1982	Custom
Lilongwe	Centre	Urban	2.21	0.315	15	1982	Custom
St. Anne's	Centre	Semi-urban	2.00	0.260	93	1982	Custom
Thonje	Centre	Rural	2.46	0.153	125	1982	Model
Kasina	Centre	Rural	5.29	0.095	100	1982	Custom
Mulanje	South	Semi-urban	1.81	0.336	56	1982	Custom
Nsanje	South	Semi-urban	0.66	0.553	79	1982	Model
Gawanani	South	Rural	1.77	0.252	73	1982	Model

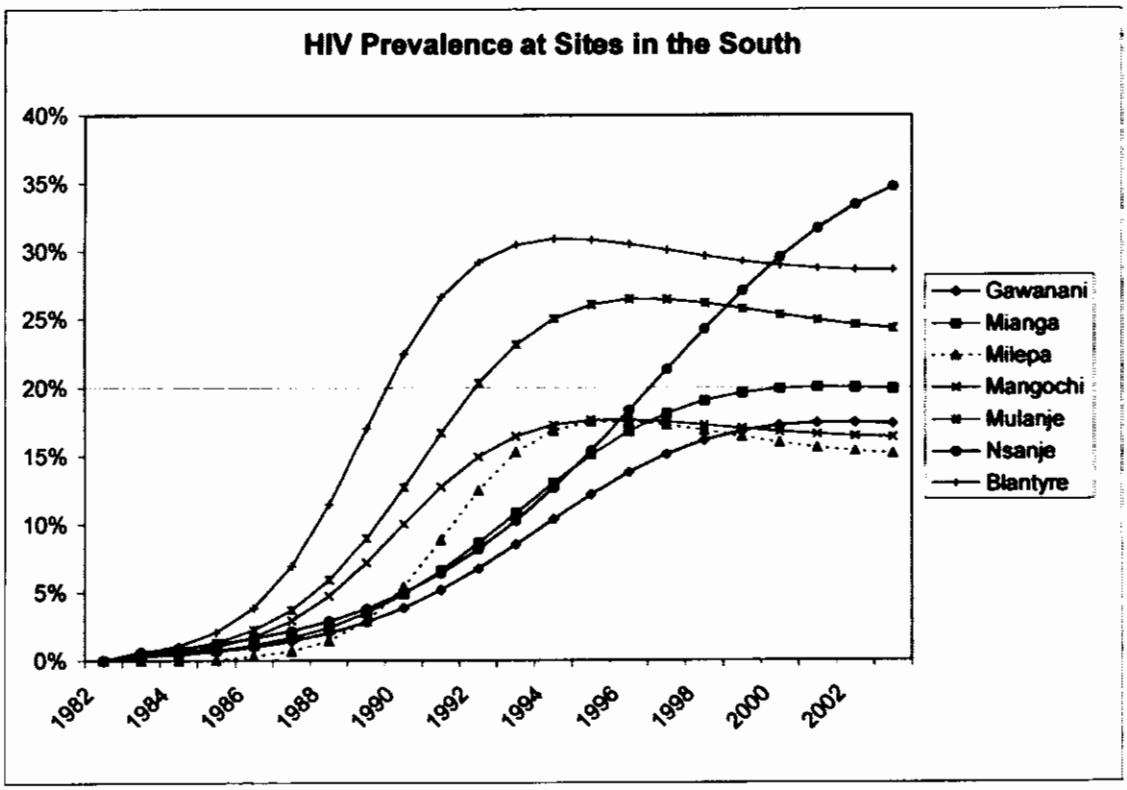
Note: The last column indicates "Model" if the best fitting model curve was used and "Custom" if the parameters values were modified from those of the best fit.

The curve fits for the individual sites by region are shown in Figure 7 below.

Figure 7. Prevalence curves fit to each sentinel site by region






HIV Prevalence at Sites in the South
40%
35%
30%
25%
20%
15%
10%
5%
0%
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Gawanani
Mianga
Milepa
Mangochi
Mulanje
Nsanje
Blantyre

Appendix C. Spectrum Projections

The HIV prevalence estimates have been used with the Spectrum model to project the consequences of these figures. Two modules of Spectrum have been used, DemProj and AIM. DemProj projects the population by age and sex and displays a full range of demographic indicators while AIM calculates the number of people infected with HIV, AIDS cases, AIDS deaths, AIDS orphans and other consequences of AIDS.

The demographic projection is based on the census of 1977, 1987 and 1998. The population by age and sex in the base year (1982) is from the population projection reported in "Malawi Population Census, 1977, Analytical Volume, Vol. II." The basis for the other demographic inputs is as follows:

Total fertility rate and age distribution of fertility:
1982: Family Formation Survey, 1984
1984: Family Formation Survey, 1984;
1991: Demographic and Health Survey
1998: 1998 Census
1998-2010: Population and Housing Census 1998, Analytical Report, Population Projections

Life expectancy without AIDS:
1982-1998: "Malawi Population Census, 1987, Analytical Report, Volume VII."
1998 : 1998 Census
1999-2000: Same rate of increase as life expectancy assumption in the national population projections from Population and Housing Census 1998, Analytical Report, Population Projections

Model life table: Coale-Demeny South.

Sex ratio at birth: Calculation based on 1998 census.

International migration: The effect of international migration is assumed to be zero. The projection begins in 1982, before the Mozambique refugee immigration/emigration of 1986 - 1995.

The HIV/AIDS assumptions were derived as follows:

Adult HIV prevalence: from this report

Start year of epidemic: assumed to be about 1982 since the first AIDS cases were identified in 1985.

Incubation period: Following UNAIDS recommendations the median time from infection to AIDS death for adults is assumed to be 9 years (8.6 years for males and 9.4 years for females). For children a faster progression to death is used[9].

The age distribution of HIV prevalence: Calculated from surveillance data for females "Sentinel Surveillance Report 1998" Table 8. For males the ratios are calculated from the distribution of reported AIDS cases, "AIDS Cases Surveillance 1998 Report" adjusted five years younger to account for the lag from HIV to AIDS.

The results of the Spectrum projections are shown in Tables 8 and 9.

Table 8. HIV/AIDS indicators for adults 15-49, 1982-2007

	1982	1987	1992	1997	2002	2007
HIV population						
Total	0	52,251	356,669	649,255	750,108	836,649
Males	0	30,015	163,141	272,798	316,875	355,928
Females	0	22,234	193,527	376,455	433,232	480,722
Prevalence	0.0	1.6%	9.3%	14.3%	14.4%	14.2%
New HIV infections						
Total	0	21,944	88,536	71,491	76,760	90,309
Males	0	11,541	37,494	30,411	34,270	39,368
Females	0	10,401	51,045	41,079	42,490	50,940
Incidence	0.0%	0.8%	3.0%	2.5%	2.4%	2.4%
New AIDS cases						
Total	0	[illegible]	9,065	38,344	59,958	64,887
Males	0	412	4,648	16,594	24,415	27,006
Females	0	[illegible]	[illegible]	21,751	35,542	37,884
Annual AIDS deaths						
Total	0	[illegible]	[illegible]	31,258	57,182	63,418
Males	0	159	3,040	13,758	23,211	26,158
Females	0	[illegible]	2,664	17,500	33,971	37,260

[9] UNAIDS Reference Group on Estimates, Modelling and Projections. "Improved methods and assumptions of the HIV/AIDS epidemic and its impact: Recommendations of the UNAIDS Reference Group on Estimates, Modelling and Projections" *AIDS* 2002. 14:W1-W16.

Table 9. HIV/AIDS indicators for children under 15, 1982-2007

	1982	1987	1992	1997	2002	2007
HIV population						
Total	0	2,399	23,552	56,933	72,721	80,468
Males	0	1,198	11,698	28,075	35,633	39,318
Females	0	1,201	11,854	28,857	37,087	41,150
New HIV infections						
Total	0	1,537	12,176	23,041	25,630	27,072
Males	0	773	6,118	11,578	12,879	13,603
Females	0	765	6,058	11,463	12,751	13,469
New AIDS cases						
Total	0	352	4,859	14,941	20,205	21,735
Males	0	174	2,385	7,297	9,840	10,593
Females	0	178	2,474	7,644	10,365	11,142
Annual AIDS deaths						
Total	0	343	4,773	14,760	20,018	21,568
Males	0	169	2,336	7,186	9,722	10,484
Females	0	174	2,437	7,574	10,296	11,084

Reasons for assigning sites to districts

District	Urban Site	Rural Site
North		
Chitipa	Kaporo Geographic proximity; similar in size, culture & development level	Mbalachandra-Kaporo Mbalachandra: Similar proximity to & cross-border activity with Zambia Kaporo: Similar in culture & proximity to & cross-border activity with Tanzania
Karonga	Nkhata Bay Similar in culture, social-economic activities; cross-border trade	Kaporo*
Rumphi	Rumphi*	Mbalachanda Similar in culture, agricultural activities & level of development
Nkhata Bay	Nkhata Bay*	Mbalachandra-Kaporo Mbalachandra: Geographic proximity; similar in culture, agricultural practices & economic activity Kaporo: Similar lake-related economic activities
Mzimba	Rumphi Similar in size, population & level of economic & social activity	Mbalachanda*
Mzuzu City	St. John's Hospital*	
Likoma	Nkhata Bay-Kaporo Similar to both sites in culture, population size & lake-related economic activities; frequent contact with Nkhata Bay	Nkhata Bay-Kaporo Similar to both sites in culture, population size & lake-related economic activities; frequent contact with Nkhata Bay
Central		
Kasungu	Mchinji Similar in culture/language, agricultural practices, commerce & road networks	Kamboni*
Nkhotakota	St. Anne's Hospital*	Kamboni

District	Urban Site	Rural Site
		Similar culture & agricultural practices
Ntchisi	Thonje-Mchinji Thonje: Similar in development level, schools & recreational activities Mchinji: Similar in culture, agricultural practices & commerce	Thonje Similar in development level, schools & recreational activities
Dowa	Mchinji Similar urban area, commerce & along busy transportation route,	Thonje*
Salima	Nkhotakota-Mchinji Nkhotakota: Similar in culture, religion & lake-related activities Mchinji: Similar transportation route, commerce activities & culture for western half of district	Kamboni-Thonje Kamboni: Similar in culture & agricultural activities Thonje: Similar in development level & recreational activities
Lilongwe	Lilongwe Central Hospital*	Kasina Similarly very rural; similar in culture, social & agricultural activities
Dedza	Ntcheu Similarly located on border along same highway, similar in agricultural & trade activities & economic migration	Kasina Similarly rural; similar in culture & agricultural activities
Ntcheu	Ntcheu*	Kasina Similarly rural; similar in culture & agricultural activities
Mchinji	Mchinji*	Kamboni Similar in culture, level of development, agricultural activities
South		
Mangochi	Mangochi*	Gawanani
Machinga	Mangochi	Gawanani
Balaka	Mangochi-Ntcheu	Gawanani
Zomba	Blantyre	Gawanani-Milepa

District	Urban Site	Rural Site
Chiradzulu	Mulanje	Milepa
Blantyre	QECH	Milepa-Mianga
Mwanza	Mchinji Similar in cross-border trade & proximity to urban center	Gawanani
Thyolo	Mulanje Similar agri-estates	Mianga
Mulanje	Mulanje*	Mianga
Chikwawa	Nsanje Geographical proximity; similar in culture	Milepa-Milanga
Nsanje	Nsanje*	Milepa-Milanga
Phalombe	Milepa	Milepa