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**Estimation of the level and trend of adult mortality in  
Zambia**

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**Thesis submitted in partial fulfilment of the requirements  
for the degree of Master of Philosophy in Demography  
in the Faculty of Commerce, University of Cape Town**

**May 2010**

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## PLAGIARISM DECLARATION

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I hereby declare that, except for references to other people's work, which have been acknowledged using the Harvard convention for citation and referencing, this work is the result of my own research produced with normal supervisory assistance from my supervisor and that it has neither in part nor in whole been presented elsewhere for another degree at any other university.

Signed: \_\_\_\_\_

Signed by candidate

Vesper Hichilombwe Chisumpa

Date: 18th May 2010.

University Of Cape Town

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## DEDICATION

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I dedicate this work to my daughter, Lushomo, who was born 11th June, 2009, and my late father, Austen K.C. Hichilombwe, who passed on 25th April, 2008 while I was pursuing my studies.

University Of Cape Town

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## ABSTRACT

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The aim of this study is derive robust and reliable estimates of level and trend in adult mortality in Zambia. To derive the estimates of the level and trend in adult mortality, the study applies the following techniques: the Census Survival method and Preston-Bennett method to Zambian census data for 1980, 1990 and 2000 to estimate life expectancies at age 5 and above as well as probabilities of dying between ages 15 and 60 years; the orphanhood method to 1992, 1996, 2001/2 and 2007 Zambia Demographic and Health Surveys (ZDHS) and 1996, 1998, 2002/3, 2004 and 2006 Living Conditions Monitoring Survey (LCMS) information on survivorship of parents to estimate probabilities of dying between ages 25 and 35 ( $_{10}q_{25}$ ); and 25 and 40 ( $_{15}q_{25}$ ) for females; and 35 and 45 ( $_{10}q_{35}$ ) for males; the siblinghood method using the 1996, 2001/2 and 2007 ZDHS sibling histories data to estimate the probabilities of dying between ages 15 and 50 years ( $_{35}q_{15}$ ) for both males and females; the Generalised Growth Balance and Bennett-Horiuchi “Extended SEG” methods using the 1996, 2004 and 2006 LCMS household deaths in the last 12 months to estimate completeness of reporting of deaths relative to the coverage of surveys and hence the probability of dying between ages 15 and 60. The Census Survival and Preston-Bennett method do not produce accurate measures of mortality, or trend for females but does for males. The orphanhood method does capture some of the trend but fails to provide definitive estimates of mortality. The siblinghood method produces an inconclusive pattern of adult mortality. The GGB and “Extended SEG” methods perform well with the 1996-2004, 1996-2006 inter-survey periods. The methods also perform well with male LCMS data for 2004-2006 inter-survey periods. The GGB and “Extended SEG” methods produced a good fit to age ranges 5+ to 60+. The study finds that adult female mortality is higher than male adult mortality, 69 per cent and 64 per cent, respectively. These adult mortality rates are comparable to estimates from other sources. Further research is needed on how to refine the GGB and SEG method to perform better with survey data. Research is needed to understand why the siblinghood method produced inconclusive estimates of the level and trend of adult mortality. The study recommends that the LCMS survey should add month and year at death to questions on household deaths to deal with the problem of time reference. The 2010 Zambian census should add questions on orphanhood and household deaths.

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# 1 INTRODUCTION

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Improved methods for the assessment of the mortality of adults remain an important piece of unfinished business for demography, and the deficiencies of existing methods will become more apparent as the epidemiological transition directs more and more attention to the issues of adults' health in less developed countries, Preston (1996: 529).

## 1.1 Background to the study

The United Nations (2006a) is concerned with the lack of accurate estimates and methods for ascertaining adult mortality compared to those of child mortality. This is more especially for developing countries that do not have data collection systems that capture vital events on a reliable and continuous basis.

The advent of the Human Immunodeficiency Virus (HIV) and Acquired Immunodeficiency Syndrome (AIDS) epidemic has increased the demand of adult mortality estimates to monitor and determine its impact on mortality. Zambia is one of the countries in sub-Saharan Africa most affected by the AIDS epidemic. The 2001/2002 Zambia Demographic and Health Survey (ZDHS) estimated that 15.6 per cent of Zambians aged between 15 and 49 years are living with the virus (Central Statistical Office, Central Board of Health and ORC Macro 2003). The 2007 ZDHS reported a statistically insignificant decline in HIV prevalence to 14.3 per cent (Central Statistical Office, Ministry of Health, Tropical Diseases Research Centre *et al.* 2009). HIV prevalence in Zambia is high when compared to the African average (Macro International Inc. 2009). Furthermore, the 2004 antenatal clinic surveillance survey estimated that 19 per cent of pregnant women attending antenatal clinics were HIV positive (Ministry of Health and Central Board of Health 2005).

In spite of the high HIV and AIDS prevalence in the country, not much attention has been paid to estimating the levels and trends in adult mortality and ascertaining its socio-economic impact in Zambia. Adult mortality estimates obtained from the ZDHS surveys reports show that adult mortality has increased in Zambia. Adult mortality rates for persons in the reproductive age group 15-49 years increased from 10.9 deaths per 1,000 person-years of exposure in the 1996

ZDHS to 14.1 deaths per 1,000 person-years of exposure in the 2001/2002 ZDHS and marginally declined to 12.5 deaths per 1,000 person-years of exposure in the 2007 ZDHS (Central Statistical Office, Ministry of Health, Tropical Diseases Research Centre *et al.* 2009). Between the 1996 ZDHS and 2001/2002 ZDHS adult mortality rates increased by 29 per cent and declined by 11 per cent between 2001/2002 ZDHS and 2007 ZDHS. A notable decline has been observed in adult male mortality. However, despite this decline in mortality rates, adult mortality in Zambia remains high by African standards. A probable reason for the increase in adult mortality in Zambia is the HIV and AIDS epidemic.

Accurate data on adult mortality from the vital registration system are not available in Zambia because the system is incomplete. Consequently, the only available sources of mortality data available are censuses and surveys. These sources provide us information that we can use with indirect methods to estimate adult mortality in Zambia.

This study uses the following methods to derive estimates of level and trend of adult mortality in Zambia: Census Survival (United Nations 1983, 2002); Preston-Bennett (Preston and Bennett 1983; United Nations 1983); Generalised Growth Balance (Hill 1987; United Nations 2002); Synthetic Extinct Generations (Bennett-Horiuchi) (Bennett and Horiuchi 1981, 1984); survival of parents (orphanhood) (Brass and Hill 1973; Blacker 1977; Timaeus 1992; Timaeus and Nunn 1997; United Nations 2002); and survival of siblings (siblinghood) (Timaeus, Zaba and Ali 2001; United Nations 2002), with census and survey data. These methods are used because they are suitable to the available data.

## **1.2 Statement of the Problem**

In spite of the common understanding of the impact of HIV and AIDS on adult mortality and high prevalence of HIV and AIDS in the adult population aged 15-49; adult mortality estimates in Zambia are not as widely available as those of infant and child mortality. Methods that have been developed to estimate adult mortality have not been extensively used in Zambia to derive estimates of levels and trends of adult mortality.

### 1.3 Objectives of the study

#### 1.3.1 Main objective

The main objective of the study is to derive robust and reliable adult mortality rates for Zambia by applying indirect adult mortality estimation methods to Census, Demographic and Health Survey (DHS) and Living Conditions Monitoring Survey (LCMS) data.

#### 1.3.2 Specific objectives

- (i) Identify the nature and source of all useful data;
- (ii) Evaluate the quality of data utilised in estimating adult mortality in Zambia;
- (iii) Review existing techniques for estimating adult mortality;
- (iv) Review existing adult mortality estimates;
- (v) Estimate the level and trend of adult mortality in Zambia; and
- (vi) Make recommendations to health and other development programmes based on derived adult mortality estimates.

### 1.4 Significance of the study

In a country with high HIV and AIDS prevalence, like Zambia, estimates of adult mortality are relevant in providing a better understanding of the mortality situation for planning, decision-making and implementation of health programmes as well as other developmental programmes. The HIV and AIDS epidemic mainly affects the reproductive and productive age group of 15 to 49 years. The impact of the epidemic on this age group has far reaching implications which are multi-dimensional and have the capacity to reverse any gains in development. For instance, studies show that adult mortality poses a threat to the survival and welfare of children in households that experience adult deaths (Ainsworth, Beegle and Koda 2005; Chapoto and Jayne 2005; Numbissi, Bawah and Zuberi 2005). Other studies have shown declines in national Gross Domestic Product (GDP), agricultural production, human resource loss, and decline in education standards.

In Zambia, a few indirect methods have been used to estimate adult mortality mainly using data from the Census and Demographic and Health

Survey (Central Statistical Office, Central Board of Health and ORC Macro 1997, 2003; Central Statistical Office 2004; Central Statistical Office, Ministry of Health, Tropical Diseases Research Centre *et al.* 2009). In addition, the application of these indirect methods to estimate adult mortality has not been comprehensive. Furthermore, the Living Conditions Monitoring Survey data remains unutilised in the estimation of adult mortality in Zambia.

### **1.5 Organisation of the thesis**

The thesis is organised as follows. Chapter 2 reviews existing methods that are used in estimating adult mortality. The chapter also reviews existing adult mortality estimates in Zambia derived by other studies.

Chapter 3 looks at census-based methods of estimating adult mortality and their results. Chapter 4 presents methods that estimate adult mortality using information of survivorship of close relatives, and the results. Chapter 5 presents death distribution methods of estimating adult mortality and the results. Chapter 6 discusses the results, conclusions and suggests areas of future research. The appendix includes additional information on data quality and some results.

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## 2 LITERATURE REVIEW

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### 2.1 Introduction

This chapter reviews the methods used in estimating adult mortality in populations where systems of data collection are incomplete or inadequate to provide accurate data on mortality. The methods reviewed here are those for which we have data available. The methods are categorised into three groups, first, methods that use census-based age and sex data or intercensal survival; second, methods that use information on survivorship of close relatives to estimate adult mortality; and third, methods that estimate the completeness of death reporting relative to population enumeration. The chapter also reviews adult mortality estimates in Zambia obtained by other studies.

### 2.2 Synopsis of the nature of information used by methods of adult mortality estimation

In Zambia, direct estimates of adult mortality cannot easily be computed due to an incomplete and deficient vital registration system which is unable to provide useful data on deaths. The ZDHS surveys provide information on survivorship of parents of respondents aged less than 15 years as well as information on sibling histories (surviving and dead siblings). The LCMS surveys provide information on survivorship of parents of respondents aged less than 20 years and household deaths in the last 12 months. Zambian censuses have not collected information on survivorship of parents and sibling histories. The 1980 census did not ask questions on household deaths while the 1990 census collected information on household deaths in the last 12 months by sex but without age. Therefore, the Zambian censuses provide only the age and sex population distributions.

Information on household deaths in the last 12 months was previously seen as not being useful for adult mortality estimation for a number of reasons. The most notable reasons are: problems associated with omissions of deaths by household respondents, failure by respondents to clearly distinguish deaths

belonging to the reference period and those which do not, dissolution of households after the death of the household head, and unpleasantness of the event of death may result in some respondents being reluctant to talk about it (United Nations Economic Commission for Africa and Regional Institute for Population Studies 1988; Timaeus 1991b, 1993; Dorrington, Timaeus and Gregson 2007). In addition, the low adult mortality estimates derived from data on deaths reported by households led some countries to drop questions from censuses (United Nations Economic Commission for Africa and Regional Institute for Population Studies 1988). In Zambia, questions on household deaths were dropped from the 2000 population census undertaking, probably for similar reasons.

Dorrington, Timaeus and Gregson (2007) argue that household deaths from household surveys may be of limited use because of small sample sizes. They further note that the quality of information on ages of the deceased persons may be poorer in surveys than in census data. However, they found that it is possible to produce useful estimates of mortality using data on deaths reported by households in the census.

With the advent of methods that correct for completeness of reporting of household deaths under certain assumptions, it is possible to derive plausible adult mortality estimates from these data (Brass 1975; Hill and Trussell 1977; Bennett and Horiuchi 1981, 1984; Preston 1984; Hill 1987; Hill 2001).

This study utilises information on survivorship of parents from the ZDHS surveys and LCMS surveys with the orphanhood method to derive adult mortality estimates. Information from sibling histories obtained by the ZDHS surveys is used with the siblinghood method to derive adult mortality estimates. Household deaths in the last 12 months collected by the LCMS surveys are used with death distribution methods (Generalised Growth Balance and Synthetic Extinct Generations) to produce estimates of adult mortality. Age and sex population distributions from the censuses are used with the Census Survival method and Preston-Bennett method to derive adult mortality estimates.

### 2.3 Methods of adult mortality estimation

In the absence of a complete and efficient vital registration system to provide data on deaths for direct estimation of adult mortality, indirect methods are another possible avenue of deriving adult mortality estimates in most developing countries.

Timaeus and Graham (1989) note that, overall, indirect methods of estimating adult mortality only provide broad estimates and not age-specific mortality rates. They argue that indirect methods are generally weak with respect to detecting abnormal age patterns of adult mortality. In addition, indirect methods of estimating adult mortality are mostly appropriate when applied at the national level rather than at the sub-national level. At the sub-national level, there are many factors at play that lead to the violation of the assumptions of these methods (Timaeus and Graham 1989), in particular that the populations usually cannot be assumed to be closed to migration. In spite of these limitations, indirect methods have remained, at least for now, the main methods of estimating adult mortality in developing countries that have incomplete and deficient vital statistical registration systems.

#### 2.3.1 *Census Survival Method*

The Census Survival method uses the principle of the population balancing equation to estimate mortality in populations lacking death registration data and which have negligible migration (Timaeus and Graham 1989; United Nations 2002). In the absence of migration, mortality becomes the key factor in determining changes in population size at adult ages. The method does not require the application of model life tables. Data requirements of the method are the age and sex distributions, which are readily available for many developing countries that have conducted population censuses. There are a number of variants of the Census Survival method based on the intercensal period, these are: the five-year, ten-year and t-year variants. In this study, we employ the ten-year intercensal variant since the Zambian censuses (1980, 1990, and 2000) we are utilising were conducted 10 years apart. The method assumes that when the intercensal period between two censuses is exactly ten years, ten-year intercensal survival ratios for each age group can be calculated by dividing the population aged  $x+10$  at the

second census by the population aged  $x$  at the initial census, to estimate conditional survival probabilities of age groups.

Two types of conditional survival probabilities ( $l_x$ ) are derived from this method. The first type are conditional survival probabilities ( $l_x$ ) that consider survivorship from the mid-point of age group 0-4 (that is, 2.5) to the mid-point of the next 10 year age group, computed as,  $l_{x+10}/l_{2.5} = (l_{x+10}/l_x)(l_x/l_{2.5})$ , where  $x$  are the mid-points of age groups in ten-year intervals, for example, 2.5, 12.5, 22.5 and so on.

The second type are conditional survival probabilities computed by considering survivorship from the mid-point of age group 5-9 (7.5) to the next 10 year age group using the expression,  $l_{x+10}/l_{7.5} = (l_{x+10}/l_x)(l_x/l_{7.5})$ , where  $x$  are the mid-points of age groups in ten-year intervals, for example, 7.5, 17.5, 27.5 and so on.

Since the two series of conditional survival probabilities represent ten-year intervals instead of five-year intervals that we usually work with, they need to be combined to give survival probabilities for five-year intervals. First, the survivorship to mid-point of age group 0-4 within the age group, ( $l_{2.5}/l_{2.5}$ ), and the survivorship from the mid-point of age group 0-4 to the mid-point of the age group ten years later, ( $l_{12.5}/l_{2.5}$ ), using the expression,  $l_{7.5}/l_{2.5} = 0.5(l_{2.5}/l_{2.5} + l_{12.5}/l_{2.5})$  are averaged. Then the conditional survivorship from the mid-point of age group 5-9 to the mid-point of the next higher age group, ( $l_x/l_{7.5}$ ) is multiplied by the conditional survival probability from the mid-point of age group 0-4 to the mid-point of age group 5-9, ( $l_{7.5}/l_{2.5}$ ). Using the expression  $l_x/l_{2.5} = (l_{7.5}/l_{2.5})(l_x/l_{7.5})$ , the result is a five-year combined conditional survival probability from the mid-point of age group 0-4 to the mid-point of the next higher age group  $x$ , ( $l_x/l_{2.5}$ ).

Conditional survival probabilities from age 5 and above in five-year intervals are then calculated by the expression,  $l_x/l_{2.5} = 0.5(l_{x-2.5}/l_{2.5} + l_{x+2.5}/l_{2.5})$ .

The average person-years lived between age  $x$  and  $x+5$  of those alive at age 2.5,  $({}_5L_x/l_{2.5})$ , are computed by using the expression,  ${}_5L_x/l_{2.5} = 2.5(l_x/l_{2.5} + l_{x+5}/l_{2.5})$ , where  $x$  is the age, 5,10....80.

Total person-years lived above age  $x$ ,  $(T_x)$  are estimated using the expression,  $T_{x-5}/l_{2.5} = T_x/l_{2.5} + {}_5L_{x-5}/l_{2.5}$ . The computation of  $T_x$  values requires life expectancy of the open interval at old ages, this can be estimated from a reliable life table, in the absence of such a table, a model life table can be used by determining the appropriate family of model life tables and the life expectancy at birth of the population, and then, obtain the life expectancy at old age for the selected model table. Provided the open interval is at a sufficiently high age the magnitude of the life expectancy at that age does not have much effect on the estimated life expectancies at other ages because the values of life expectancy at old ages does not vary much, and also estimated life expectancies in younger age are not sensitive to life expectancy values at old ages (United Nations 2002).

Life expectancies from age 5 and above are computed by using the following equation:  $e_x = (T_x/l_{2.5})(l_x/l_{2.5})$ .

The quality of the estimates is assessed further by computing the half inter-quartile range of the distribution and the relative percentage error of the estimates of  $e_5$  and inspecting the census survival ratios.

A plot of the conditional survival ratios on a graph will tell us about the quality of our results; fluctuations in the survival ratios reveal how perfectly we combined the two types of condition survival probabilities (that is,  $l_x/l_{2.5}$  and  $l_x/l_{7.5}$ ) in the younger ages. Conditional survival ratios greater than one reflect problems in the data. Age misreporting or differential completeness of population enumeration by age in the two censuses will also produce survival ratios that are above one. On the other hand, age heaping in the census data does not cause much problems in mortality estimation because of the compensation effect where individuals clustered in certain ages compensate for the short fall in underrepresented ages; hence, eventually cancels out (United Nations 2002). In

applying the census survival method, age exaggeration, especially at old ages, biases the life expectancy estimates as individuals overstate their ages.

The census survival method may provide good estimates of adult mortality when age is accurately reported and the population is closed to migration. However, the method is particularly sensitive to differential completeness of censuses and to age reporting errors (Timaeus and Graham 1989; United Nations 2002).

The census survival method is applicable to Zambia as the country's population experiences low migration at international level. There is insignificant migration of skilled labour to neighbouring countries and overseas. Furthermore, although Zambia received an influx of refugees from neighbouring countries (for example, Angola, Mozambique, Namibia, Democratic Republic of Congo, Rwanda, Somalia and Zimbabwe) during the independence liberation wars and in times of civil strife in these countries, with the attainment of independence and return of peace to most of these countries, the number of refugees dropped significantly before the period covered by this research.

International migration stocks of persons coming into the country accounted for 6.3 per cent of the population in 1969; in 1980, immigrants accounted for 4.0 per cent; in 1990, 2.0 per cent; and 1.0 per cent in 2000. Thus the percentage of the population who are immigrants was low and has dropped to a negligible level over the period (Central Statistical Office 2003). It is not possible to compute international net migration rates for Zambia as data on the numbers of emigrants by age and sex leaving the country are not available. Other sources, however, indicate that the net migration rate in Zambia is low and negative. For instance, the United Nations Population Division (2009) estimated the average annual net migration rate for Zambia to be 1.7 and -1.2 persons per 1,000 population in 1995-2000 and 2000-2005 respectively, while the United States Census Bureau (2009) estimated the net migration rate to be -2 and -3 persons per 1,000 population in 1995 and 2008 respectively.

### 2.3.2 Preston-Bennett Method

Preston and Bennett (1983) propose a method of estimating adult mortality in the intercensal interval using age distributions from two successive censuses. The rationale of the method is to use the two successive census age distributions to derive age-specific growth rates for the intercensal period and use them to transform the age structure of the observed population into a stationary-population equivalent or life table population from which life expectancy at each age is estimated. The computed geometric mean of the two census age distributions provides the intercensal age distribution.

The method does not require the assumption of stability of an underlying model life table, or information on deaths reported by households. The method, however, requires that the population be closed to migration. The method assumes that the pattern of age misreporting is constant and distortions are the same in both censuses, so that, there is no effect on the age pattern of growth rates and consequently, the estimates of life expectancy. Preston and Bennett (1983) recommend that when age misreporting in the data is severe, it is advisable to make reference to the model life tables when using the method. In addition, the cumulation of age-specific growth rates minimises the effect of age reporting errors. The method is applicable to census data even when the intercensal period between the two censuses is not a multiple of five. In addition, it is insensitive to age misstatement at older ages.

Shortcomings of the method are: a high sensitivity at younger ages to differential coverage of the two censuses, a sensitivity to migration and a failure to produce estimates of life expectancy at birth when information on births is lacking (Preston and Bennett 1983).

The mathematical reasoning of the method and equations used in constructing the life table is presented as, 
$$N(x) = N(a) {}_{x-a}P_a \exp\left[-\int_a^x r(u) du\right],$$
 where  $N(x)$  is the number of people aged  $x$ ,  ${}_{x-a}P_a$  is the probability of surviving from age  $a$  to age  $x$  according to period mortality rates, and  $r(u)$  is the growth rate of the population aged  $u$ . This equation can be rearranged as,

$N(x) = N(0) \exp\left[-\int_0^x r(u) du\right] p(x)$ , when age starts from zero. The equation

can also be rewritten as,

$$p(x) = \frac{N(x) \exp\left[\int_0^x r(u) du\right]}{N(0)}, \text{ where } N(0) \text{ is the number of people aged}$$

zero. According to Preston and Bennett (1983), since  $p(x)$  is equal to  $\frac{l_x}{l_0}$  as in the

conventional life table and  $N(0)$  is equivalent to  $l_0$ , the radix of the life table, the

expression  $N(x) \exp\left[\int_0^x r(u) du\right]$  is the equivalent of  $l_x$  (number of survivors to age

$x$ ) in the life table. The number of person-years lived is estimated as,

$${}_n L_y = \int_y^{y+n} N(x) \exp\left[\int_0^x r(u) du\right] dx. \text{ In discrete terms for five-year age groups this}$$

is written as,  ${}_5 L_y = {}_5 N_y \exp\left\{5 \cdot \sum_0^{y-5} {}_5 r_x + 2.5 {}_5 r_y\right\}$ . The total number of person-

years lived above age  $x$  is estimated as,  $T_j = \sum_{y=j}^{\infty} {}_5 L_y$ . The number of survivors

from age  $x$  to the next age is estimated as,  $l_j \cong \frac{{}_5 L_j + {}_5 L_{j-5}}{10}$ . And life expectancy

is estimated as,  $e_j = \frac{T_j}{l_j}$ .

The Preston-Bennett method can be used to estimate mortality in Zambia from census age distributions for 1980, 1990 and 2000. The condition that the population is closed to migration, for Zambia, is satisfied since net migration is low as noted in the earlier section.

### 2.3.3 Orphanhood Method

The orphanhood method for estimating adult mortality was first suggested by Henry (1960), later developed by Brass and Hill (1973) and improved by several

authors (Blacker 1977; Hill and Trussell 1977; Timaeus 1991a, 1992; Timaeus and Nunn 1997). The method is based on the survivorship of the biological mothers or fathers of the respondent. The responses to a question on the survivorship of the mother or father are normally used to generate these data. It is from these data that proportions of persons with mother or father surviving are obtained (Brass and Hill 1973; Blacker 1977; Timaeus and Graham 1989; Timaeus 1991a; United Nations 2002; Timaeus and Jasseh 2004). The proportions of persons with father or mother surviving are then together with the mean age at childbearing used to compute conditional survival probabilities which are eventually translated into standard adult mortality estimates,  ${}_{35}q_{30}$  (probability of a 30 year old person dying before reaching age 65) using a model life table. In cases where orphanhood data are obtained from persons aged less than 15 or 20 years, the standard adult mortality rates computed are: for females, the probability of a 25 year old person dying before reaching age 35 ( ${}_{10}q_{25}$ ); the probability of a 25 year old person dying before reaching age 40 ( ${}_{15}q_{25}$ ); and for males, the probability of a 35 year old person dying before reaching age 45 ( ${}_{10}q_{35}$ ). The estimates of survival probabilities refer to different time periods in the past the location of which can be estimated using the method developed by Brass and Bamgboye (1981) for time location. The orphanhood method computes survival probabilities by assuming that the proportion of parents surviving at time  $t$  would approximate life table survival probabilities  $\left(\frac{l_{y+x}}{l_y}\right)$  for a group of parents born at time  $t - (y + x)$ , where  $x$  is the age of persons at time  $t$  and  $y$  is the age of parents at the time of birth of their children.

Mortality estimates for fathers and mothers are computed differently. First, the mean age at childbearing is computed for both fathers and mothers using births in the last year obtained from a census or survey. The mean age of childbearing for fathers is computed differently by adding the gestational period and the age difference between spouses to the mean age of childbearing of women. The gestational period is added to account for this period in case the father dies

before the child is born (Blacker 1977; United Nations 2002; Timaeus and Jasseh 2004).

To estimate maternal survivorship, the method uses proportions of respondents with surviving mothers in a given age group, and translates them into conditional survival probabilities ( $(l_{M+x}/l_M)$ , where  $M$  is the mean age of mothers at the time of birth of their children (respondents in this case) computed from data on births in the last 12 months prior to the survey or census, and  $x$  is the mid-point of the age group). Using the regression equation,

$l_{25+x}/l_{25} = a_0(x) + a_1(x)M + a_2(x)S(x-5,5)$ , conditional survival probabilities ( $l_{y+x}/l_y$ ) are thus expressed in a form of a linear function of the mean age of mothers and the proportion of respondents in each age group with surviving mothers (Timaeus 1991a, 1992; United Nations 2002). In the regression equation,  $S(x-5,5)$  is the proportion of respondents aged  $x-5$  to  $x$  with surviving mothers;  $a_0$ ,  $a_1$  and  $a_2$  are regression coefficients obtained by regressing  $l_{25+x}/l_{25}$ ,  $M$ , and  $S(x-5,5)$ .

Adult mortality for males is estimated by increasing the age for the conditional probability of survival from age 25 for females to age 35 for males. The reason for this is that husbands are usually older than their wives. The regression equation for males uses different coefficients from those of females. The equation is,  $l_{35+x}/l_{35} = a_0(x) + a_1(x)M + a_2(x)S(x-5,5) + a_3(x)S(x,5)$ , where,  $S(x,5)$  refers to the proportion of respondents aged  $x$  and  $x+5$ , with surviving fathers. A different set of coefficients from those used for mother, derived by Timaeus (1992), are used in estimating adult mortality for males. The Brass general standard model life table or any other appropriate model life tables is used to translate mortality estimates into life table survival probabilities.

The orphanhood method allows the estimation of cohort adult survival over many years in the past, that is, 10-50 years (Blacker 1977; United Nations 2002; Timaeus and Jasseh 2004). The method does not require that the population be stable or closed to migration.

The limitations of the method are: “adoption effect”, “absentee effect”, overrepresentation of large families, understatement of age by women and

overstatement of age by men. “Adoption effect” arises due to misreporting of survivorship of parents, whereby adopting (social) mothers are reported as biological mothers, this makes the method produce estimates that are inaccurate. The “adoption effect” mainly relates to maternal orphanhood and it biases mortality estimates downwards, while, the “absentee effect”, that is, the prolonged absence of fathers from households, relates to paternal orphanhood and it biases mortality estimates upwards. The problem of “adoption effect” is more serious for persons aged below 15 (Preston, Heuveline and Guillot 2001). Large families are often overrepresented while dead parents without surviving children are not represented at all. In addition, adult mortality rates pertain to those parents of children who have survived. Adult mortality estimates are also affected by understatement of age by women (so as to appear younger) and overstatement of age by men (to appear older for reasons of prestige) (Preston, Heuveline and Guillot 2001). Hill (2001) applied the orphanhood method using data from Guatemala and found that female adult mortality was overestimated. Preston, Heuveline and Guillot (2001) also note that the method yielded higher female mortality in Latin America and South Asia when applied based on reports by daughters than sons. They attribute this difference to misreporting of age by daughters and sons.

Adult mortality estimates of mothers based on orphanhood data are biased in populations affected by the HIV and AIDS epidemic, this is because HIV positive women have low fertility and children born to these mothers, who are potential respondents, die at very young ages (Timaues and Nunn 1997; Timaues 1998) and are thus unable to report on the survival of their infected parents. However, this can be corrected, if one can estimate proportions of HIV positive mothers at the time of birth of their children (Timaues and Nunn 1997). In addition, Timaues and Nunn (1997) have proposed revised regression coefficients for converting estimated conditional survival probabilities into life table survival probabilities in AIDS affected populations.

Orphanhood data refer, largely, to middle-aged parents. For women, it is those in their late twenties and thirties, while for men, it is in their late thirties and forties. Because of this, orphanhood data are relevant in examining the impact

of the HIV and AIDS epidemic on general mortality as the prevalence of HIV is more concentrated in this reproductive age group. It is expected that higher mortality will occur in the reproductive age group than the adult mortality age range of 15 to 59.

The Living Conditions Monitoring Survey and Demographic and Health Survey collected information on survivorship of parents from respondents. The LCMS collected information on survivorship of parents of children aged 0 to 18 years, while, the DHS collected for those aged 0 to 14 years. Unfortunately, none of the four Zambian population censuses collected any information on survivorship of parents. There is no documentation from the Zambian Central Statistical Office explaining why this is so.

#### *2.3.4 Siblinghood Method*

The siblinghood method of estimating adult mortality uses sibling history data on sex, date of birth and age at death. These data are obtained from surveys particularly the demographic and health survey. The method allows for the indirect estimation of adult mortality of brothers or sisters of respondents aged 15 years and above who have survived.

The siblinghood method is an extension of the orphanhood method developed by Brass and Hill (1973) and Brass (1975). The original siblinghood method did not attract a lot of interest until Graham, Brass and Snow (1989) used information on the survivorship of the sisters of a respondent to estimate maternal mortality. Since, then, there have been a number of improvements suggested to the siblinghood method (Bicego 1997; Timaeus, Zaba and Ali 2001; Gakidou and King 2006; Obermeyer, Rajaratnam, Park *et al.* 2009).

The rationale of the siblinghood method is that siblings' ages are, mostly, very close to each other including that of the respondent, and therefore, the proportion of the respondent's siblings who are still alive estimates survivorship to the age of the respondent. The method estimates adult mortality by using conditional probabilities of survival from age 15 and above. For example, siblings of a respondent aged  $x$  can be assumed to be born  $x$  years ago, and thus the proportion surviving among these siblings estimates the probability of surviving

to age  $x$ ,  $\frac{l_x}{l_0}$ . In the same vein, this is extended to the proportion of siblings who were alive at age 15, their probability of surviving to age  $x$ , the age of the respondent is estimated as,  $\frac{l_x}{l_{15}}$ . Timaeus and others (Timaeus, Zaba and Ali 2001) have modelled this relationship and is expressed as:

$$\frac{l_x}{l_{15}} = a(x) + b(x)S(x-5,5)$$

where  $S(x-5,5)$  is the proportion of brothers or sisters who were alive at age 15 and are still alive among those reported by respondents aged  $(x-5,5)$ ,  $a(x)$  and  $b(x)$  are coefficients derived by Timaeus, Zaba and Ali (2001) using a simple regression model relating life table survivorship to adult sibling survival data. The survival probabilities are usually converted, via reference to a standard mortality table, into a specific standard mortality rate,  $({}_{35}q_{15})$ , as an index of mortality over time.

Estimates of adult mortality rates of siblings can be allocated to the time point to which they refer, by using time location coefficients. Sibling mortality estimates based on information from younger respondents refer to a period closer to the time when the data were collected; while estimates based older respondents refer to a period further back in time. This allows us to examine adult mortality trends over time. Timaeus, Zaba and Ali (2001) have simplified the Brass and Bamgboye (1981) method of estimating time location of survival estimates to the following linear equation

$$T(x) = c(x) - d(x)\ln(S(x-5,5))$$

where  $T(x)$  is the number of years before the survey, and  $c(x)$  and  $d(x)$  are coefficients derived by Timaeus, Zaba and Ali (2001) using data on adult sibling survival.

The assumptions of the method are the following: first, the mortality experience of siblings is independent of one another; second, most respondents have siblings (in low fertility countries with high proportions of individuals with no siblings, this would make the method inappropriate); third, surviving and dead

siblings have an equal chance of being reported; fourth, selection bias is not a major factor; and fifth, the age pattern of mortality is similar to that of model life tables, to enable users to translate estimates into a common mortality index. Again, with the impact of the AIDS epidemic on mortality, the age pattern of mortality is altered as it is concentrated in the age range 20-59 years.

The siblinghood method is prone to underestimate adult mortality due to reporting errors, respondents often omit siblings who died before they were born or when they were young (Stanton, Abderrahim and Hill 1997; Timaeus, Zaba and Ali 2001).

Timaeus, Zaba and Ali (2001) argue that the sibling method performs better in populations with high mortality due to the HIV and AIDS epidemic than other indirect methods of estimating adult mortality because the method is free of selection bias due to HIV and AIDS as there is negligible risk of direct transmission of HIV between siblings. They note, however, that regression coefficients for estimating life table survivorship are moderately biased. Nevertheless, they conclude that estimates of adult sibling survivorship remain robust as indices of monitoring mortality in populations affected by the AIDS epidemic.

### 2.3.5 *Generalized Growth Balance Method (GGB)*

The Generalized Growth Balance (GGB) method (Hill 1987) is a generalisation to all non-stable and closed populations of Brass's (1975) Growth Balance method to estimate the completeness of adult death registration relative to population enumeration. Brass's Growth Balance method is applicable to populations that are stable (with constant birth, death and growth rates) and closed (no migration). In a stable and closed population the growth rate ( $r$ ) is equal to the difference between the entry rate and the exit rate. Using the stable population theory, Brass proposed that in a stable, closed population with the open-ended age interval  $x$  and over  $(x+)$ , the entry rate ( $b(x+)$ ) of population aged  $x$  into the population aged  $x$  and over is equal to the growth rate ( $r(x+)$ ) of the population aged  $x$  and over plus the exit rate ( $d(x+)$ ) of the population aged  $x$  and over, expressed as,

$$b(x+) = r(x+) + d(x+),$$

where  $b(x+)$  is the birth rate of the population aged  $x$  and over, assumed to be constant at all ages,  $d(x+)$  is the death rate of the population aged  $x$  and over, constant at all ages,  $r(x+)$  is the growth rate of the population aged  $x$  and over, constant at all ages. The expression above in a stable population can also be written as,

$$N(x)/N(x+) = r + D(x+)/N(x+),$$

where  $N(x)$  is the population aged  $x$ ,  $N(x+)$  is the population aged  $x$  and over,  $D(x+)$  is the number of deaths to the population aged  $x$  and over,  $r$  is the stable population growth rate. The left hand side represents the “birth” rate (the number who turn  $x$  divided by the population aged  $x$  and over) and the right hand side represents the growth rate plus the death rate (the number of deaths at ages  $x$  and over divided by the population aged  $x$  and over). Furthermore, the death rate is estimated on the basis of deaths reported from a census or survey with completeness  $c$ , which is the completeness of the deaths relative to those estimated from the enumerated population, assumed to be constant at all ages. The inverse of completeness  $c$ ,  $(1/c)$  can be used as an adjustment factor for the observed death rate, expressed as:

$$N(x)/N(x+) = r + 1/c[D(x+)/N(x+)].$$

Therefore, in a stable and closed population the entry rate into each open-ended age interval  $x$  and over ( $x+$ ) is equal to the stable growth rate plus the reported death rate for that age interval  $x$  and over ( $x+$ ) multiplied by inverse of completeness of death reporting,  $(1/c)$ . The expression above is in a form of an equation of a straight line, implying that a linear relationship exists between the entry rate and the exit rate. Therefore, a plot of the entry rate ( $N(x)/N(x+)$ ) against death rate ( $D(x+)/N(x+)$ ) should lie on a straight line with an intercept ( $r$ ), and a slope  $(1/c)$ . The slope of the line relates the entry rate to the exit rate hence estimating the completeness of death reporting relative to the population enumeration.

The assumption of stability is limiting as in reality most populations do not experience constant fertility and mortality, and hence a number of modifications to the Brass Growth Balance method have been proposed. Hill

(1987) modified the Brass Growth Balance method by relaxing the assumption of stability by using data from two censuses to estimate age-specific growth rates (varying at all ages) to make the method applicable to non-stable populations. In a non-stable population, for the open-ended age segments of population  $x+$ , the rate at which the population turns  $x$  minus the growth rate of the population aged  $x+$  must equal the death rate of the population aged  $x+$ . The death rate  $x+$  can be estimated from the population by age at two successive censuses (surveys) and compared to a direct estimate based on the reported deaths from the census (survey); through this comparison the completeness of death reporting relative to population enumeration as well as completeness of one census (survey) to the other can be estimated. In the discrete form, Hill (1987) shows that:

$$\frac{(N1_{x-5} * N2_x)^{0.5}}{5 * (N1_{x+} * N2_{x+})^{0.5}} - \frac{1}{t} \ln\left(\frac{N2_{x+}}{N1_{x+}}\right) \approx \frac{1}{t} \ln\left(\frac{k_1}{k_2}\right) + \frac{(k_1 * k_2)^{0.5}}{c} * \frac{D^o(x+)}{t * (N1_{x+} * N2_{x+})^{0.5}},$$

where  $N1$  and  $N2$  are population enumerations at two time points;  $t$  is the time interval in years between the two population enumerations;  $D^o$  is the number of reported intercensal (inter-survey) deaths; and  $k_1$ ,  $k_2$ , and  $c$  are coverage of the first and second population enumerations, and the completeness of the intercensal (inter-survey) deaths, respectively. When assumptions of the GGB are met points for successive age segments  $x+$  should lie on a straight line. The slope  $((k_1 * k_2)^{0.5} / c)$  serves as the adjustment factor for reported deaths to bring them into consistency with the population enumeration (Hill 1987). The adjustment factor (slope) is estimated by using a method of fitting a straight line, such as, the robust straight line fitting method first proposed by Nair and Srivastava (1942-44) and modified by Tukey (1977) and McNeill (1977). The method uses a simple approach of fitting a straight line with less sensitivity to outliers as compared to the least squares method.

The GGB method requires two population age distributions at two time points, first census (survey) and second census (survey) and age distribution of deaths. The number of deaths could be an average of the annual number of deaths for the whole period (Hill, Stanton and Gupta 2001). The method is applicable to all populations, whether stable or not, and assumes that the population is closed to

migration, coverage of census enumerations is constant with respect to age, and accurate reporting of age for the population and deaths after childhood. The limitations of the method are that, it is sensitive to age misreporting and differential coverage of population enumeration or reporting of deaths by age; and it is sensitive to migration if the growth rates are not corrected for this.

Bhat (2002) proposes an extension of Hill's Generalised Growth Balance method to make it applicable to open-populations experiencing considerable migration. Hill and Queiroz (2004) also propose a procedure with two-stages of adjusting the Generalised Growth Balance method to incorporate migration. This study, however, applies the Generalized Growth Balance method to assess completeness of reporting of deaths and population enumeration of the Living Conditions Monitoring Survey data.

### 2.3.6 *Bennett-Horiuchi (Synthetic Extinct Generations) Method*

Bennett and Horiuchi (1981; 1984) propose a method that assesses the completeness of data on reported deaths without assuming stability of the population age structure. This method is also known as the Synthetic Extinct Generations (SEG) method because it is a synthetic extension of the idea by Vincent (1951) that in a closed population with complete reporting of deaths, the population aged  $x$  at a certain time  $t$  can be estimated by cumulating all deaths pertaining to that cohort until the last person in the cohort is has died.

The Bennett-Horiuchi (SEG) method is a generalisation of the Preston-Coale (Preston, Coale, Trussell *et al.* 1980) method that assumes that in a stable population the numbers in the population at a point in time can be estimated from the deaths by age at that point in time, and the completeness of the reporting of these deaths is assessed by the ratio of the population estimated from the deaths to the observed population at the point in time. The Preston-Coale method can be expressed as,

$$N(a) = \int_a^{\infty} D^*(x) \exp[r(x-a)] dx ,$$

where  $D^*(x)$  is the true number of deaths experienced by persons aged  $x$  in the current population. The expression  $D^*(x)\exp[r(x-a)]$  is an estimated number of persons currently aged  $a$  who will die at age  $x$  in  $x-a$  years time. This is so because in a stable population the number of deaths aged  $x$  in a given year is greater than the number of deaths age  $x$  in the previous year by a factor of  $\exp[r]$  (Preston, Coale, Trussell *et al.* 1980).

The population estimated from the reported deaths is expressed as,

$$\hat{N}(a) = \int_a^{\infty} D^o(x) \exp[r(x-a)] dx, \text{ where } D^o(x) \text{ is the number of}$$

reported deaths and the ratio  $\frac{\hat{N}(a)}{N(a)}$  provides an estimate of the completeness of the reporting of deaths.

Bennett and Horiuchi generalised the Preston, Coale, Trussell *et al* method by introducing age-specific growth rates of a population so as to relax the assumption of stability from the population. They generalised the relationship in a stable, closed population by Preston, Coale, Trussell *et al* to one that can be applied to any closed population without the assumption of stability. Bennett and Horiuchi's generalisation of the Preston, Coale, Trussell *et al* method is expressed as,

$$N(a) = \int_a^{\infty} D^o(x) \exp\left[\int_a^x r(u) du\right] dx,$$

where  $r(u)$  is the growth rate of the population aged  $u$ . The other terms are as defined above.

The Bennett-Horiuchi method estimates the age-specific growth rates from the numbers by age in the population at two points in time. The method uses the following assumptions: the population is closed; accurate reporting of age for both deaths and population; constant completeness of reporting of deaths and coverage of population by age; and there is an age below which age exaggeration does not occur. The method does not suffer to the same extent from biases resulting from age misreporting as the census-based methods.

The shortcomings of the Bennett-Horiuchi (SEG) method are: sensitivity to migration, net out-migration biases estimates of mortality upward while net in-migration biases estimate downward. The method is sensitive to differential coverage of the two censuses; this affects the age-specific growth rates. Underenumeration either in the first or second census would either raise or lower the age-specific growth rates and hence, bias the completeness of death reporting either upward or downward (Bennett and Horiuchi 1981, 1984). Bennett and Horiuchi (1981) propose that the problem of change in census coverage that affects the age-specific growth rates can be dealt with by the “Extended SEG” method where the first census or second census is iteratively adjusted by a constant factor “delta” until the plot of completeness estimates  $c(a) = \frac{\hat{N}(a)}{N(a)}$  lies as horizontal as possible across some age ranges. Hill and Choi (2004) and Hill, You and Choi (2009) suggest that the problem can also be addressed by the “Combined GGB plus SEG” method where the differential census coverage is estimated using the GGB method and then the first census or second census is adjusted for the differential coverage, and then apply the SEG method.

The assumption that there is a high age below which age exaggeration does not occur, may not apply in some populations (Bennett and Horiuchi 1981). Bennett and Horiuchi (1981) recommend that due to age misreporting that occurs at older ages in some populations it advisable to minimise the biases attributable to age misreporting at older ages by reducing the open interval, for example, the open interval can be reduced from 85+ to 60+.

The data requirements for the method are the same as for the GGB method. In this study, the Extended SEG method is applied to the Living Conditions Monitoring Survey data to estimate the completeness of death reporting, and the adjusted deaths are used to estimate adult mortality in Zambia. The Generalized Growth Balance (GGB) and Bennett-Horiuchi (SEG) methods do not appear to have been applied to any Zambian data before. This study is among those that have attempted to derive adult mortality estimates from Zambian data using the Generalized Growth Balance and Bennett-Horiuchi (SEG) methods.

## 2.4 Existing adult mortality estimates in Zambia

### 2.4.1 *Pre-independence demographic estimates*

Prior to independence, demographic data in Zambia were 'scanty', collected using 'crude' methods, and consequently yielded unreliable estimates (Musambachime 1990; Ohadike 1990; Stone 1990). Musambachime (1990) gives an account of demographic data collection in Zambia between the period 1900 and 1930 when the country was established as a colonial territory by the British South Africa Company (BSAC), and divided into two, North-Eastern Rhodesia (NER) and North-Western Rhodesia (NWR). The two were later merged into Northern Rhodesia in 1911.

Musambachime (1990) and (Ohadike 1974) note that while regular periodic counts of non-Africans (mostly Europeans) were undertaken in 1911, 1921, 1931, 1946, 1951, 1956 and 1961, Africans were not enumerated in these counts. Africans were first universally enumerated in 1963, a year prior to independence in 1964. Several researchers (Musambachime 1990; Ohadike 1990; Stone 1990) point out that the collection of demographic data on Africans in the colonial era was based on annual village tours undertaken by District Officers or Native Commissioners. These Officers toured village-to-village taking note of births, deaths and what was happening in the area. Estimates of populations in villages not visited were derived from the numbers of the villages visited. The village tours faced challenges with regard to demographic data collection as the exercise was associated with the collection of tax. Musambachime (1990) points out that due to the change in the payment of tax from paying in kind, to paying money, this led some villagers to flee from their villages and hide, others migrated to neighbouring countries to avoid payment of tax, and a number migrated to seek employment to meet tax demands. These occurrences had demographic consequences.

Stone (1990), however, giving a personal account of his experiences as a Cadet, District Officer, District Commissioner and District Secretary in Northern Rhodesia from 1959 to 1964, describes annual tours of the villages that he undertook. He reports that the purpose of these tours was to observe what was happening in the area and listen to complaints. He visited schools and dispensaries

and took note of local economic activities, village hygiene, and other activities. He stresses that the tours were not aimed at collecting tax, though taxes were paid at the time of the tour due to the presence of the court clerk<sup>1</sup> in the village. He, further, recounts that he conducted population counts soon after arriving in each village. He would read out names of persons from the tax register, each man present was asked the number of wives he had, number and sex of the children. For men absent, the village headman provided details of his family size. Those who acquired new identification certificates (mostly young men) were recorded as new entries in the tax register. Stone (1990) points out figures from each year's village tours were compiled into a district annual report and submitted to the provincial commissioner. In terms of inaccuracies in the data collected, Stone (1990) admits that the processes of data collection were crude, and that population counts were by-products of tours and were not aimed at accurate head-counts. In addition, he notes that potential sources of error could have been in the reports given by village headmen on absent villagers.

Musambachime (1990) notes that methods used to estimate populations and vital rates of districts often varied and were not consistent, and at times the same estimates were repeated and reported for different years. For instance, he cites the repetition of 1929 figures for villages not visited, for 1930 reports. He points out that there was no systematic way of collecting and validating demographic data. He adds that during the colonial rule accurate figures were not available, and estimates based on one or two villages were generalized to the whole district regardless of variations within the district. In terms of estimates of adult mortality, Musambachime (1990:70) reports that, in the colonial era a method was devised of deriving adult deaths by "allowing for an adult death rate of fifteen per thousand". This estimate does not appear to have been based on any empirical data.

Ohadike (1990:258) reviewing the status of mortality in colonial Zambia stated that "mortality has and will remain the terra incognita..." He notes that studies of mortality in Africa are seriously constrained by the lack of reliable data

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<sup>1</sup> The court clerk made his own tours separate from those of the District Commissioner to collect taxes and issue licenses, although he was required to be present at the District Commissioner's or officers' meetings.

compared to those of fertility. The lack of reliable mortality data has resulted in indirect estimation of measures of mortality in Africa. Ohadike (1990) also suggests that some of the possible reasons leading to the dearth of mortality data are, lack of qualified personnel in health and statistics, lack of understanding and appreciation of data collected among the Africans, myths surrounding death which made Africans uncomfortable to talk about it, especially deaths of children. He notes that early estimates of adult mortality in the colonial era were those relating to the occupational hazards at the mines. He cites adult mortality at Roan Antelope mine which declined from 34.6 deaths per thousand in 1930 to 6.6 in 1938. However, he questions the accuracy of this estimate as the drop was too much for such a short period of time for a population that was still experiencing poor health, unhygienic living conditions, and poor nutrition.

#### *2.4.2 Post-independence demographic estimates*

After independence in 1964, Zambia has conducted more organised and complete censuses in, 1969, 1980, 1990, and 2000. In 1974, a sample census<sup>2</sup> of the population was also conducted (Ohadike 1990). Besides the censuses, a number of sample surveys have been undertaken in the country. These surveys include: Demographic and Health Surveys conducted in 1992, 1996, 2001/2002 and 2007; Living Conditions Monitoring Surveys conducted in 1996, 1998, 2002/2003, 2004, and 2006; Sexual Behaviour Surveys conducted in 1998, 2002, 2003, 2005 and 2009; as well as some Labour Force Surveys, Household and Budget Surveys and Agricultural Post-harvest Surveys. These surveys are undertaken for various purposes but have also yielded useful demographic data for estimating and understanding demographic processes in Zambia.

A review of mortality estimates in Zambia shows that more studies have derived measures of infant and child mortality using data from the censuses and surveys than of adult mortality. This is due to the fact that in most cases one is able to get reasonably accurate information about the birth and death of children from censuses and surveys from their mothers. This, however, is not the case with

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<sup>2</sup> A sample of 10,000 households was drawn from urban and rural areas of Zambia from a complete listing of households in the country, and enumerated completely.

adult mortality, as there is (mostly) underreporting of deaths by households. Some adult deaths go unreported due to dissolution of households. In addition, adult mortality is a rare event compared to the mortality of children under the age of five. Consequently, currently available methods for estimating adult mortality are very sensitive to errors in the data and violation of assumptions, which lead to inaccurate estimates of mortality (Preston, Heuveline and Guillot 2001).

Hill (1985), reviewing and analyzing available demographic data in Zambia in the 1980s, noted that information on mortality was limited, and that the vital registration system which could be used to validate the data, was nearly nonexistent. She, then, using the 1969 census and 1974 sample census data, attempted to derive indirectly adult mortality estimates using the Census Survival method. The estimates were “...unbelievable, with...irregularities, ...enormous fluctuations, and ... ridiculously high level of mortality throughout ... adulthood until the very oldest age groups” (Hill 1985: 42). She concluded that it was not possible to derive any reliable adult mortality estimates with these data, even after graduation and adjustment of the data. The lack of accuracy and reliability in these estimates could be attributed to inconsistencies and errors in the 1974 sample census, these include, age misreporting, undercount of adults in age groups 20-70 years, and sampling variability (Hill 1985). The lack of mortality information that can be used directly to derive adult mortality rates implies that mortality can be estimated mostly using indirect methods with data from censuses and surveys (Hill 1985; Hill 1987).

Adult mortality is commonly measured using the probability of a 15 year old person dying before reaching age 60 ( ${}_{45}q_{15}$ ). This is a conditional probability computed for individuals who survived from birth to the age of 15.

In terms of “official” estimates, the Central Statistical Office, in the 1990 Census report, defined adult mortality as that of persons aged 25 and over (Central Statistical Office 1995) based on the definition of an adult by the Ministry of Youth, Sport, and Child Development. Model life tables for both males and females at national level, and by urban and rural residence, were derived using the Princeton North family (Coale and Demeny 1966) of model life tables to

determine adult mortality estimates. Mortpak Lite, a United Nations demographic software package, was used to generate the model life tables. Estimates of adult mortality were presented as probabilities of dying at exact ages from birth. For example, the probabilities of dying at age 25 were estimated at 0.038 and 0.033 for males and females respectively. The corresponding estimates of  ${}_{45}q_{15}$  from this life table were 0.359 for females and 0.401 for males. As expected in most populations, males have a higher probability of dying than females.

Other estimates of adult mortality considered as “official” in Zambia are those from the 1996, 2001/2002 and 2007 Demographic and Health Surveys derived directly using deaths of siblings reported by female respondents aged 15 to 49 years. For the 1996 ZDHS, adult mortality rates of those in the reproductive age group 15 to 49 years were 10.6 deaths per 1,000 person-years of exposure for females and 11.3 deaths per 1,000 person-years of exposure for males. Adult mortality rates for the 2001/2002 DHS were 14.3 deaths per 1,000 person-years of exposure for females and 14.0 deaths per 1,000 person-years of exposure for males. For the 2007 ZDHS, adult mortality rates were 13.2 deaths per 1,000 person-years of exposure for females and 11.9 deaths per 1,000 person-years of exposure for males (Central Statistical Office, Ministry of Health, Tropical Diseases Research Centre *et al.* 2009). These mortality rates refer to the period 0-6 years prior to each survey. It is evident from the two surveys that the sex differential in adult mortality is narrowing with the increase in mortality. The mortality pattern from the 1996 DHS is consistent with that from the 1990 Census where male mortality is higher than that of females. The 2001/2002 and 2007 ZDHS survey mortality estimates suggest that female mortality has caught up with male mortality and could remain higher than male mortality. Overall, these estimates indicate that adult mortality has increased in Zambia.

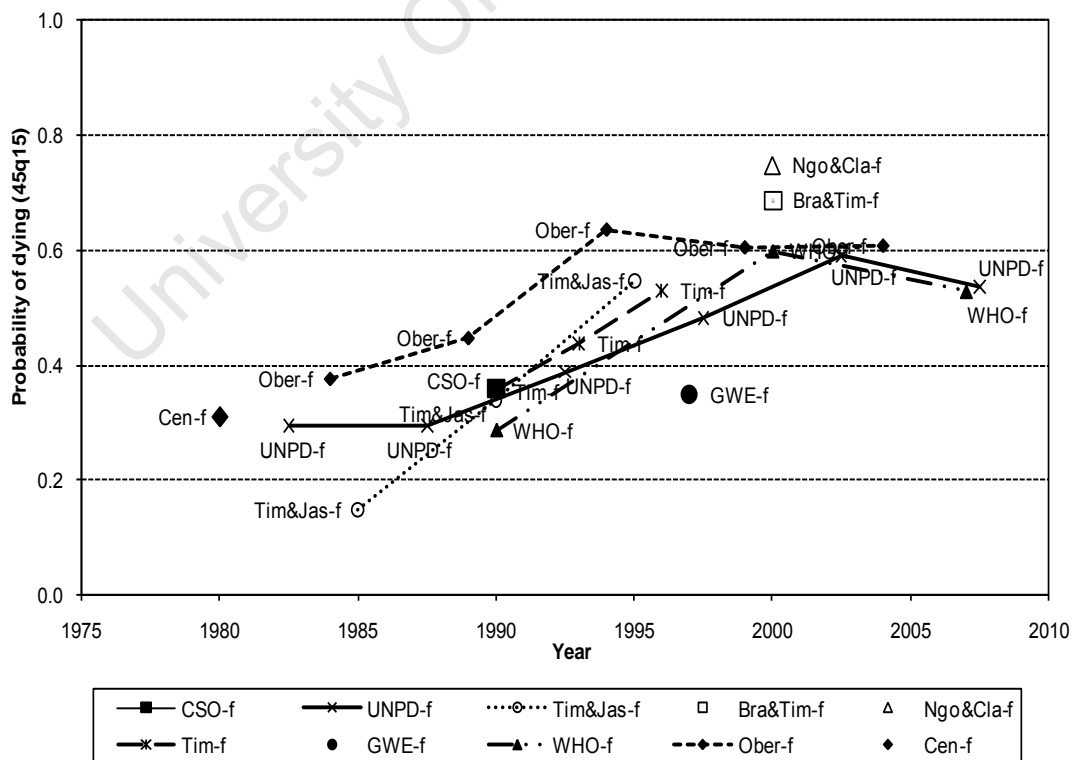
Organisations and independent researchers have also estimated adult mortality in Zambia. For example, using the 1980 Zambian census data, the probability of a 15 year old person dying before reaching age 60 in 1980 was reported in the United Nations World Mortality Report 2005 to be 0.310 and 0.360 for females and males, respectively (United Nations 2006b). This indicates

that females had a higher chance of surviving than males in the 1980s. Furthermore, the United Nations Population Division in its World Population Prospects 2008 Revision has produced estimates of the probability of a 15 year old person dying before reaching age 60 for Zambia for the periods 1980-1985, 1985-1990, 1995-2000, 2000-2005 and 2005-2010. The mortality estimates for the respective periods are: for females, 0.294, 0.294, 0.483, 0.589 and 0.537 while for males they are 0.350, 0.350, 0.561, 0.636 and 0.549 (United Nations Department of Economic and Social Affairs Population Division 2009). The United Nations Population Division also estimated the probability of a 15 year old person dying before reaching age 50 for the same periods. The mortality estimates are 0.192, 0.192, 0.408, 0.524 and 0.459 for females and for males, 0.227, 0.227, 0.465, 0.532 and 0.428 for periods 1980-1985, 1985-1990, 1995-2000, 2000-2005 and 2005-2010, respectively (United Nations Department of Economic and Social Affairs Population Division 2009). Timaeus (1998) using 1996 ZDHS sibling histories data estimated the levels and trends in adult mortality between 1990 and 1996. His estimates of  ${}_{45}q_{15}$  show that male adult mortality increased from 0.386 in 1990 to 0.678 in 1996 and female adult mortality rose from 0.355 in 1990 to 0.530 in 1996. Male mortality is higher than female mortality. Timaeus and Jasseh (2004) using the same 1996 ZDHS sibling histories data, also estimated levels and trends in adult mortality from 1985 to 1995 in Zambia. They derived the adult mortality rates using a modified Poisson regression model that incorporates estimates of HIV incidence and HIV prevalence. Figure 2.1 shows their estimates of the probability of a 15 year old person dying before reaching age 60 for females and males. The estimates indicate that adult mortality has been increasing for both females and males but males have a higher probability of dying than females. Female adult mortality increased from 0.149 in 1985 to 0.547 in 1995 and for males it increased from 0.159 to 0.623 in the same period.

Disparities are notable between the adult mortality estimates of Timaeus (1998) and Timaeus and Jasseh (2004) which could be attributed to methodological differences. Timaeus (1998) did not incorporate epidemiological data on HIV prevalence in his estimates while Timaeus and Jasseh (2004) did.

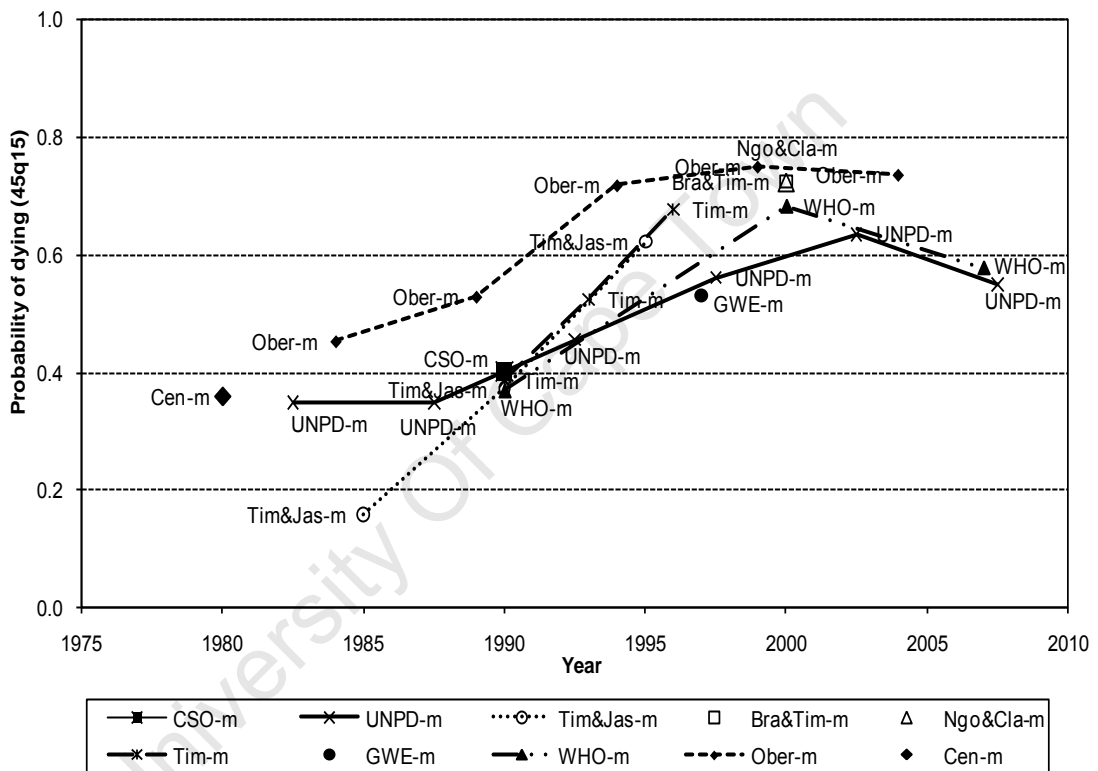
Obermeyer, Rajaratnam, Park *et al.* (2009) also directly estimated adult mortality rates for Zambia using sibling histories data obtained from the 1996, 2001/2 and 2007 ZDHS surveys. They derived the probabilities of a 15 year old person dying before reaching age 60 by age, sex and time period using a logistic regression model. The model also incorporated HIV prevalence. Their adult mortality estimates in Figure 2.1 and Figure 2.2 show that mortality has been increasing over time for both males and females. The probability of a 15 year old person dying before reaching age 60 increased from 0.453 in 1984 to 0.737 in 2004 for males while for females it increased from 0.376 in 1984 to 0.608 in 2004. Males have higher mortality than females. Obermeyer, Rajaratnam, Park *et al.* (2009) claim that by introducing the weights for number of siblings their method corrects for both selection and recall biases encountered when using sibling histories data to estimate adult mortality.

Figure 2.1: Adult female probabilities of a 15 year old person dying before reaching age 60 ( ${}_{45}q_{15}$ ), from various data sources, Zambia



Furthermore, Bradshaw and Timaeus (2006) using World Health Organization (WHO) life tables (compiled by Lopez, Ahmad, Guillot and others in 2002) to analyse levels and trends of adult mortality in sub-Saharan Africa, reported the probabilities of a 15 year old person dying before reaching age 60 for Zambian females and males as 0.687 and 0.725, respectively.

**Figure 2.2: Adult male probabilities of a 15 year old person dying before reaching age 60 ( ${}_{45}q_{15}$ ), from various data sources, Zambia**



Key:

m = male and f = female

Cen-United Nations World Mortality Report 2005; CSO-Central Statistical office (1995); UNPD-United Nations Population Division (,2009); Tim-Timaeus (1998); Tim&Jas-Timaeus and Jasseh (2004); Bra&Tim-Bradshaw and Timaeus (2006); Ngo&Cla-Ngom and Clark (2003); WHO-World Health Organization (2009); GWE-INDEPTH Network (2004); Ober-Obermeyer, Rajaratnam, Park *et al* (2009).

Ngom and Clark (2003), using the same WHO life tables, also reported the probability of a 15 year old person dying before reaching age 60 as 0.749 and 0.725 for females and males, respectively. There is a disparity in female adult mortality rates reported by Bradshaw and Timaeus (2006) and Ngom and Clark (2003).

There is a possibility that the estimate by Ngom and Clark (2003) is a misprint error as it indicates higher female mortality than male mortality when this should not be the case when compared to other estimates around the same period.

WHO (2009) using information from its WHO Mortality Database, estimated the probabilities of a 15 year old person dying before reaching age 60 for females as 0.286, 0.599 and 0.528 while for males as 0.368, 0.683 and 0.578 for the years 1990, 2000 and 2007 respectively. These mortality estimates indicate an increase in adult mortality between 1990 and 2000, followed by a decline between 2000 and 2007. Males are at a higher risk of dying than females.

The difference in adult mortality estimates between WHO ones, and those based on WHO data by other authors, are probably due to different methods used. The WHO estimates are derived from a model life table that uses health statistics data reported by individual countries from their vital registration systems. For countries, such as Zambia, with incomplete vital registration systems, the WHO estimates the level of adult mortality by employing estimated under-five mortality rates that are applied to the WHO modified logit life table system; in addition the impact of AIDS on mortality is also taken into account (World Health Organisation (WHO) 2007).

Timaeus and Jasseh (2004) also estimated Zambian adult mortality using the orphanhood method with orphanhood data from the 1992 and 1996 ZDHS surveys. They incorporated adjustments proposed by Timaeus and Nunn (1997) that allow for the fact that in populations impacted by the AIDS epidemic the estimates are affected by HIV-related selection bias. Timaeus and Nunn (1997) recommend the use of revised regression coefficients that account for the AIDS epidemic when applying regression equations to convert proportions of respondents with mothers alive into life table conditional survival probabilities. Timaeus and Jasseh (2004) established trends in mortality from 1987 to 1992. For females, they computed probability of a 25 year old person dying before reaching age 35 ( $_{10}q_{25}$ ), and probability of a 25 year old person dying before reaching age 40 ( $_{15}q_{25}$ ), while for males the probability of a 35 year old person dying before reaching age 50 ( $_{15}q_{35}$ ). The probabilities of dying, estimated using the

orphanhood data are:  $_{10}q_{25}$ , 0.048 in 1987; 0.127 in 1992; and  $_{15}q_{25}$ , 0.054 in 1987 and 0.099 in 1992 for females, and for males,  $_{15}q_{35}$ , 0.097 in 1987 and 0.175 in 1992. Though adult mortality estimates from orphanhood data are not as accurate as those from sibling birth histories, these estimates show increasing adult mortality for both males and females. Figure 2.1 and Figure 2.2 show that adult mortality estimates from the various sources indicate that mortality increased over time for both males and females. UNPD estimates are comparable with other estimates.

Sankoh, Ngom, Clark *et al.* (2006) estimated adult mortality for the Gwembe Demographic Sentinel Surveillance (DSS) in Southern Zambia. Their estimates show that the probability of a 20 year old person dying before reaching age 50 is higher for males than females, 0.40882 and 0.37281 respectively. Kelly, Feldman, Ndubani *et al.* (1998) in their study of adult mortality in four high-density townships in Lusaka found no difference in death rates between males and females. The probability of a 15 year old person dying before reaching age 60 ( $_{45}q_{15}$ ) for both sexes was estimated at 0.778.

Chapoto and Jayne (2005), using data from a longitudinal survey of rural Zambia conducted between 1999 and 2004 found that adult mortality was higher among females than males, 15.4 and 14 per 1,000 persons respectively. This finding is similar to the 2001/2002 ZDHS and 2007 ZDHS adult mortality estimates (Central Statistical Office, Ministry of Health, Tropical Diseases Research Centre *et al.* 2009). Furthermore, Dzekedzeke, Siziya and Fylkesnes (2008) in a prospective cohort study of male and female HIV positive and negative individuals in the age group 15-49, in Chelston (an urban area) and Kapiri Mposhi (a rural area) conducted between 1995 and 1999 shows higher female adult mortality than male adult mortality. Dzekedzeke, Siziya and Fylkesnes (2008) also show that unlike previously where adult mortality and overall mortality rates were lower in urban areas than rural areas, the situation is changing; mortality is now higher in urban areas (urban females, 19.6 deaths per 1,000 and rural females, 10.2 deaths per 1,000 while for urban males, 13.4 deaths per 1,000 and rural males, 9.3 deaths per 1,000) than in rural areas. Dzekedzeke, Siziya and Fylkesnes (2008) found high

mortality in urban areas due to high prevalence of HIV and AIDS in these areas than rural areas.

Overall, estimates of levels and trends of adult mortality from the literature reviewed indicate that adult mortality in Zambia has been increasing gradually with the advent of the HIV and AIDS epidemic. Initially, mortality was lower among adult females than males but this is slowly changing in favour of males. The same situation existed between urban and rural mortality, despite all the many health facilities available in urban areas, adult mortality is increasing compared to the rural areas.

The literature review has revealed that there are gaps in estimation of adult mortality in Zambia. First, the Living Conditions Monitoring Survey data has not been utilised to estimate adult mortality. Second, orphanhood data and sibling histories data collected by the 2001/2002 and 2007 ZDHS surveys appear not to have been utilised in publicly available published studies to estimate adult mortality in Zambia using standard orphanhood and siblinghood methods. Third, the level of completeness of reporting of household deaths in the last 12 months remains unknown. Fourth, it appears there has not been any application of death distribution methods, that is, the Generalised Growth Balance method and the Synthetic Extinct Generations method to Zambian data to estimate adult mortality. Fifth, there has not been a study on Zambia that has used a number of different adult mortality estimation methods and applies them to appropriate data obtained from several different sources to derive levels and trends of adult mortality. It is the purpose of this study to fill some of these gaps.

The next chapter looks at estimating adult mortality using census-based methods.

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## 3 ESTIMATING ADULT MORTALITY USING CENSUS-BASED METHODS

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### 3.1 Introduction

This chapter estimates levels and trends of adult mortality using the Census Survival method and Preston-Bennett method. Section 3.2 presents the Census Survival method, data source, and data quality. Section 3.3 presents the results of applying the Census Survival method. Section 3.4 presents the Preston-Bennett method and the results of applying the method are presented in Section 3.5.

### 3.2 Estimating adult mortality using the Census Survival Method

#### 3.2.1 *Data source*

This study uses the 1980, 1990 and 2000 census data to derive adult mortality rates using the Census Survival method. The 1980 census was the first decennial census, with a census night of 25th July. The second decennial census was conducted in 1990 from 20th August to 5th September, with a census night of 20th August. The 2000 census was the third decennial census and was conducted from 16th October to 15th November, with a census night of 25th October. The census populations are: 5,661,801 in 1980; 7,383,097 in 1990; and 9,337,425 in 2000.

The three censuses collected information on background characteristics of households; household members; housing characteristics; agriculture; background characteristics of persons; fertility; mortality; migration; national registration; and electoral information using household and individual questionnaires.

All the three censuses did not collect sufficient information on household deaths to be useful for adult mortality estimation. For example, the 1980 census did not ask a question on household deaths in the last year. The 1990 census, on the other hand, collected information on household deaths in the last 12 months by sex, but without the age of the deceased persons. While, the 2000 census did not ask any questions on household deaths in the last 12 months, the questions were dropped without any reasons being given. In addition, the three decennial

censuses did not collect any information on survivorship of parents or siblings (sibling history) that could be used by the orphanhood or siblinghood methods to estimate adult mortality. The Zambian censuses only provide information on the age and sex distributions of the populations for deriving adult mortality estimates, using census-based methods.

The census age distributions data by sex used in this study exist in the form of raw data tables (descriptive or statistical tables) obtained with permission from the Zambian Central Statistical Office. The 1980 and 1990 raw data tables are published while the 2000 tables exist in an electronic form and can only be viewed using a software known as Census and Survey Processing System (CSPro)<sup>3</sup> Text Viewer.

### *3.2.2 Data quality*

A Post Enumeration Survey (PES) is normally conducted to evaluate the consistence and quality of census data collected. A Post Enumeration Survey was conducted in December, 1990 against which the 1990 census was evaluated. The results of the PES were published in a report and indicate that omissions of persons in the age group 0-4 years were the highest. Omission rates for males are higher than for females. Persons aged less than 30 years were more likely to be omitted than older persons. Underenumeration of females was highest in age group 65-69 years (Central Statistical Office 1994). Another PES was conducted between February and March 2001 to evaluate the 2000 census; however, the results of this survey have not been published to date.

#### *3.2.2.1 Population distributions by age and sex*

Age data collected from censuses suffer from errors arising from misstatement of age, digit preference, age exaggeration at older ages and misreporting of age. There is the need for these data to be evaluated for inconsistencies before they are used for any analysis as failure to do may lead obtaining spurious results. Age and sex composition of a population can be evaluated for errors graphically by a visual

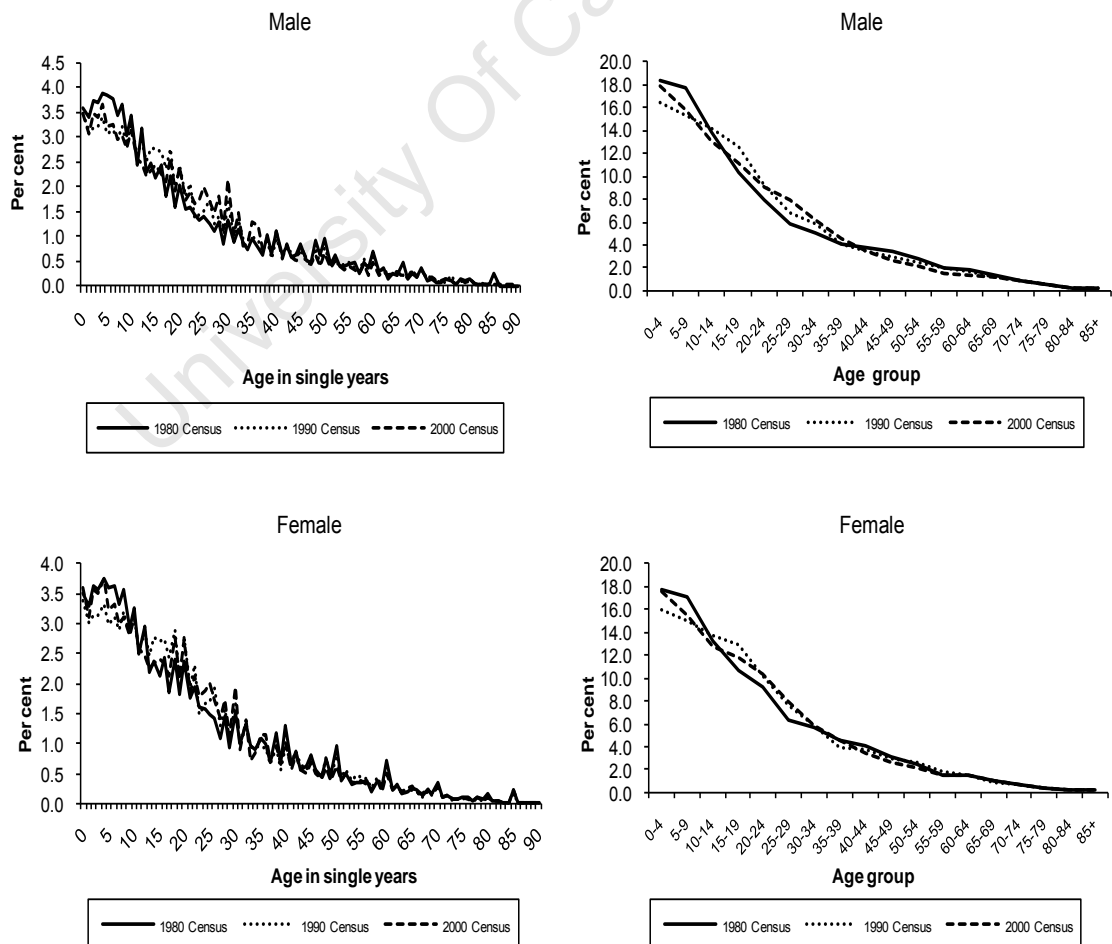
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<sup>3</sup> Census and Survey Processing System (CSPro) is a software package for entering, editing, tabulating, and disseminating data from censuses and surveys, developed by United States Census Bureau, Macro International, and Serpro S.A.

inspection of the percentage distribution of the population against single-year ages or five-year age groups. The percentage distribution of the population by age is expected to decline gradually with increasing age, and failure to reflect this expected pattern would indicate irregularities in the age data or are affected by migration.

Figure 3.1 shows the percentage distribution of males by single and grouped age for the three censuses. The percentage distribution of age by single years shows fluctuations in the reporting of age in all the three censuses. These fluctuations indicate age heaping or digit preference of ages ending with certain numbers. The figure also shows the percentage distribution of males grouped into standard five-year ages. Grouping ages into five-year categories acts as a smoothing mechanism of heaping and digit preferences observed in the single ages.

**Figure 3.1: Percentage distribution of male and female population by single and grouped age, Census 1980-2000**



The graph shows that the 1980 census probably underenumerated the age group 10-34. The 1990 and 2000 census underenumerated the age group 0-4. The figure also shows single-year and five-year age distributions of females from the three censuses. The graph for single-year age distributions indicates fluctuations in the reporting of age by females. Female age reporting shows more pronounced fluctuations than for males. The five-year smoothed graph for females indicates smoother age distributions than is observed in the single ages. Irregularities in the reporting of age data are, however, visible. It is evident there is either underenumeration or underreporting of females in age groups 10-14 to 20-24 in the 1980 census. The figure shows that the 1990 census undercounted age group 0-4.

### 3.2.2.2 Age Ratios

Age ratios are also used to assess the quality of reporting of age and sex data in populations where international net migration is negligible and fertility has been constant. Age ratios are normally calculated for five-year age groups by dividing the population of a given five-year age group in question by the average population of the two adjacent five-year age groups, times 100 (Shryock and Siegel 1976). Age ratios that do not deviate much from 100 indicate accurate age reporting, and those that do, point to age misreporting, digit preference, omissions, and possibly international net migration.

**Figure 3.2: Male and female Age Ratios by age group, Census 1980-2000**

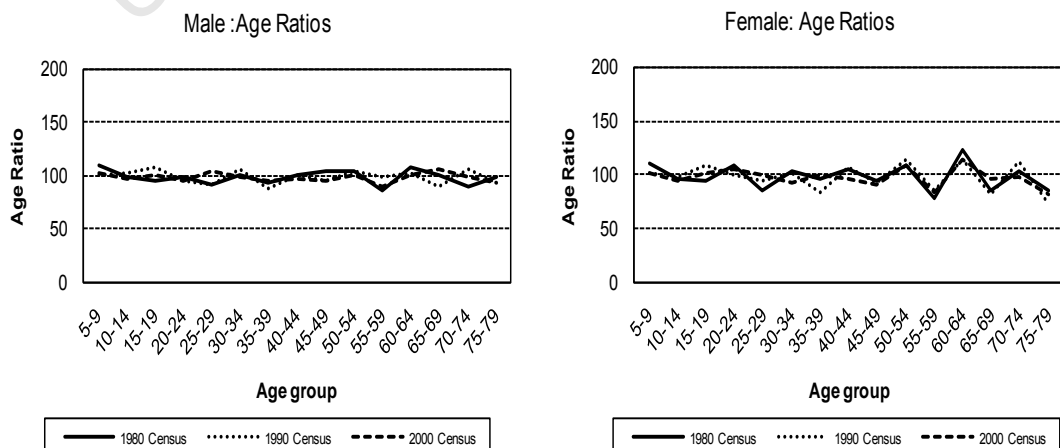


Figure 3.2 above shows the age ratios for males and females calculated from the census data. The census age ratios for males show less pronounced deviations from 100 than those of women. The deviations for females are more pronounced after age 50 years and above. The magnitudes of the deviations of age ratios from 100 for females are larger than for males. This indicates that for all the three censuses male age reporting is better than for females.

#### *3.2.2.3 United Nations Age-Sex Accuracy Index*

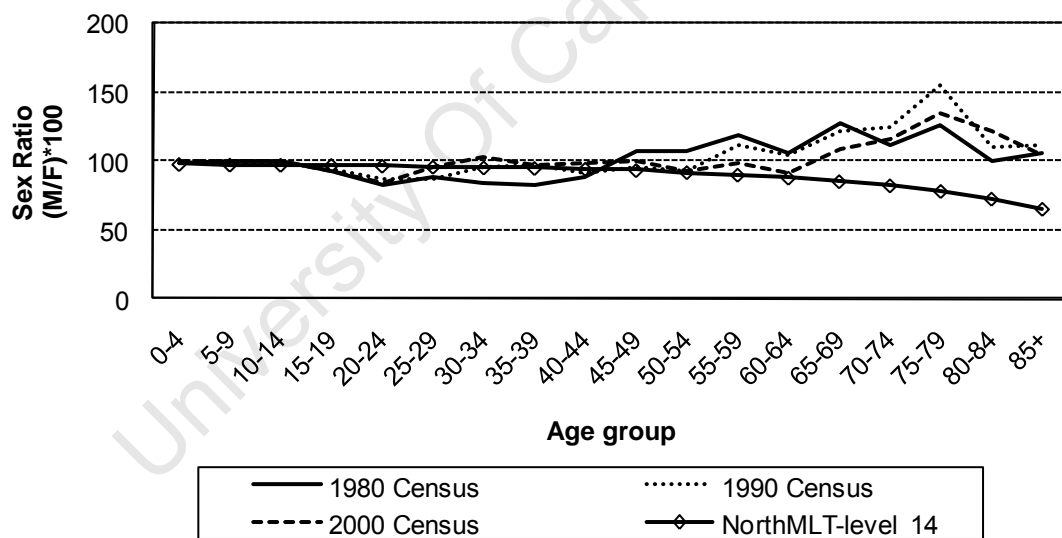
The United Nations (UN) Age-Sex Accuracy index shows an improvement in data quality over the period of the three censuses from 1980 to 2000. The index has decreased from 39.9 in 1980 to 31.7 in 1990 and then to 28.7 in 2000. The UN Age-Sex Accuracy index is the sum of absolute mean deviations from 100 of age ratios of males and females, three times the absolute mean of age-to-age differences of sex ratios (Shryock and Siegel 1976). The UN interpretation of the index is that an index less than 20 indicates the data are “accurate”; an index ranging from 20-40 implies that the data are “inaccurate”; and an index above 40 means the data are highly “inaccurate”. Using this interpretation all the age-sex data from the three censuses are inaccurate.

#### *3.2.2.4 Sex Ratios*

Sex ratios (ratio of the number of males to females in a population) can be used to assess the quality of age and sex data by examining the excess of males or females in each age group (Shryock and Siegel 1976). Normally, it is expected that sex ratios will start above 100 and decline progressively with advance in age, slowly at first and more rapidly at the older ages. This is due to sex differentials in mortality which favour women. The pattern of sex ratios by age can reveal the presence of errors of age misreporting, in or out migration, and omission. A sex ratio that is above 100 indicates an excess of males over females (as would be the case where more boys are born than girls (usual)), while a sex ratio that is below 100 means more females than males. Large deviations from the value of 100 are indicative of errors in data if there are no plausible reasons to explain the departure.

Figure 3.3 shows sex ratios computed from census data. The sex ratios show an excess of females from age group 10-14 to age group 40-44, and an excess of males from age 45 and above in the 1980 census. For the 1990 census, there is a deficiency of males from age group 10-14 to 30-34, and a surplus of males from age group 55-59 and above. As for the 2000 census, there is an excess of females from age group 10-14 to 30-34, thereafter, there is a deficiency of females from the age of 50 and above. It can be observed from the sex ratios of the three censuses that there is an irregular pattern of sex ratios from age group 60-64 and above where there are more males than females. This is an unexpected pattern and is indicative of errors in the age data or enumeration in older ages. The deficiency of females at older ages could be attributed to underenumeration of this segment of the population or overenumeration of males at older ages.

Figure 3.3: Sex ratios by age group, Census 1980-1990



The excess of males relative to females at older ages in Zambia is a national phenomenon as evidenced from three censuses. In the absence of a plausible reason to explain this phenomenon, we can only deduce that it is an indication of errors in age data at older ages attributable to probably age misreporting or enumeration of males or females.

A comparison of the sex ratios computed from the censuses with those calculated from the Princeton North model life tables (Coale, Demeny and

Vaughan 1983) in Figure 3.3 shows that the sex ratios from the three censuses do not decline progressively with increase in age while those of the model life table do. The choice of family or level of the model life table does not change the conclusion. This indicates irregularities in the reporting of age or enumeration especially in ages 60 and above.

#### 3.2.2.5 *Intercensal Cohort Analysis*

Intercensal cohort analysis is used to evaluate the quality of census data by examining the survivorship of an age group enumerated in the first census to the second census. We expect that if the population does not experience significant international net migration then the survivorship ratio of an age group enumerated in the first census to the second census a number of years later should be less than one, since mortality will be the only factor determining survivorship from one age group to the next. Survival ratios exceeding one indicate underenumeration or age understatement of a particular age group in the first census or overenumeration or age overstatement in the second census. In addition, if age and sex data are consistent, intercensal cohort survival ratios are expected to decline smoothly with advance in age. A departure from this pattern indicates irregularities and inconsistencies in the distribution by age.

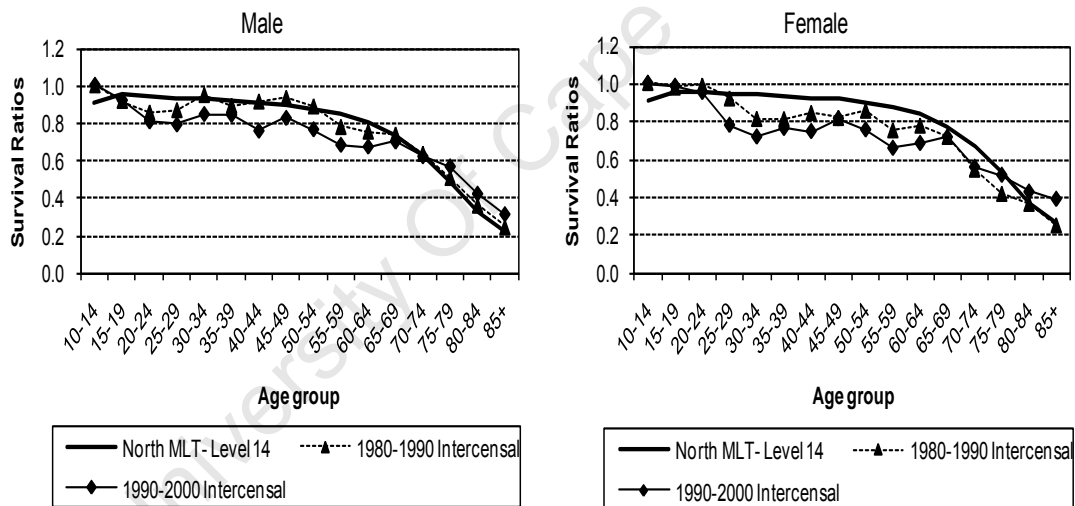
Furthermore, intercensal survival ratios of females are expected to be generally higher than those of males due to the fact that females experience lower mortality than males. Survival ratios are calculated by dividing the population at each age in the first census into population at each age that is ten years older in the second census. Intercensal cohort analysis is performed here to assess the age data for each sex prior to the application of the Census Survival Method and the Preston-Bennett Method. These two methods use age data to estimate adult mortality rates, hence, the quality of the age data needs to be assessed as errors in the data affect the derived mortality estimates.

Figure 3.4 presents the intercensal cohort analysis performed on the 1980-1990 and 1990-2000 intercensal periods. The figure shows that for both intercensal periods the survival ratios for males and females are lower than one indicating that generally the data are of reasonable quality. However, there are irregularities for

the age group 0-4 as survival ratios exceed one for both sexes in the two intercensal periods. This indicates underenumeration of the age group 0-4. Underenumeration of this age group is typical in most populations of developing countries. In both intercensal periods, survival ratios for the other age groups are less than one.

The figure also shows a comparison of the intercensal survival ratios with those of a standard model life table of the North family of the Princeton model life tables (Coale, Demeny and Vaughan 1983). The comparison indicates that survival ratios of males for the 1980-1990 intercensal period are closer to those of the standard model life table. However, survival ratios for the intercensal period 1990-2000 deviate from those of the standard.

**Figure 3.4: Intercensal cohort analysis by sex, 1980, 1990 and 2000 censuses of Zambia**



Survival ratios for females are lower than those of males and they deviate much from those of the standard model life table. At older ages, 70 years and above, survival ratios for the intercensal period 1990-2000 deviate from the standard for both males and females. The comparison of survival ratios shows that the data for the 1980-1990 intercensal period for males are more reasonable than that of females for the same period. However, survival ratios for the 1990-2000 intercensal period for both males and females indicate that the data are not as reasonable as that of the 1980-1990 intercensal period.

### 3.2.3 Method

The ten-year census survival method is applied to Zambia census data to estimate life expectancies at age 5 and above and the probability of dying between ages 15 and 60 years, ( ${}_{45}q_{15}$ ). The age-sex data have been evaluated as described in the data quality section above. Unstated ages are re-distributed by pro-rating them to ages 20 years and above. Age exaggeration is clearly visible in the data for ages 65 years and above. Age and sex data have been smoothed using Arriaga light smoothing procedure prior to applying the method (Arriaga 1994).

We apply the census survival method first to the intercensal period 1980-1990 and then to 1990-2000 intercensal period for males and females. Census survival ratios are computed first and an inspection of the ratios indicates the presence of any irregularities in the census data. Survival ratios above one indicate underenumeration of persons in the earlier census or overenumeration in the later census. Migration is also another factor that could make survival ratios exceed one.

The two types of conditional survival probabilities are then computed by assuming that individuals are concentrated at the mid-points of age groups (age groups 0-4 and 5-9). Since the computed conditional survival probabilities represent ten-year intervals instead of five-year intervals, we convert them to five-year intervals by averaging the survivorship within age group 0-4 and survivorship from age group 0-4 to next ten-year age group. Life table conditional survival probabilities are then computed, followed by person-years lived. Total person years lived above age  $x$  are estimated as explained in Section 2.3.1. Finally, life expectancies from age 5 and above are estimated as well as the probability that a person aged 15 will die before reaching their 60th birthday.

### 3.3 Census Survival Method Results

Diagnostics of the survival ratios (Table A.3.1 and Table A.3.2) in the 1980-1990 and 1990-2000 intercensal periods for both males and females show that except for the age group 0-4 where the ratios are above one, indicating underenumeration of this age group in the first census, which is a common problem in African census enumeration; the survival ratios for other age groups are below one. The survival ratios decline progressively with increase in age coupled with fluctuations that

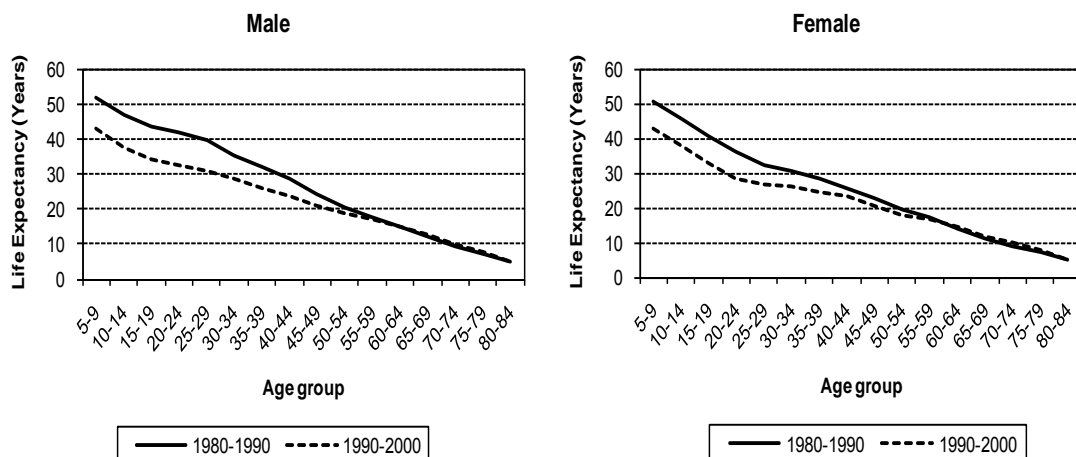
probably indicate underenumeration or overenumeration of age groups in either the earlier or later census.

To estimate mortality in Zambia we use the life expectancies produced by the method and also compute of the probability of dying between ages 15 and 60 years. Differences in the level of mortality are determined by examining the sequence of life expectancies at each successive age. When the level of mortality is constant in the intercensal period, the life expectancies are expected to decline regularly by small amounts, and big differences indicate an increase in mortality.

Table A.3.1 and Table A.3.2 in the appendix present the Census Survival method estimates of life expectancies for males and females for the 1980-1990 and 1990-2000 intercensal periods, respectively. It can be observed in both intercensal periods that the life expectancies of males are higher than those of females, indicating higher female mortality, which is not expected, especially in the 1980-1990 intercensal period with less impact by the AIDS epidemic. The high female adult mortality in both intercensal periods could be attributed to age misreporting by females since the data quality assessment indicates that males reported their ages better than females. The Census Survival method is sensitive to age misreporting.

Figure 3.5 below shows that life expectancies are lower in the 1990-2000 intercensal period than the 1980-1990 intercensal period. This could probably be attributed to the impact of the AIDS epidemic.

**Figure 3.5: Estimated life expectancies by age and sex, Census 1980-2000**



There are big differences in the life expectancies with age among adults in the 1990-2000 intercensal period, indicating sharp increases in adult mortality during this period. The probability of a 15 year old person dying before reaching age 60 ( ${}_{45}q_{15}$ ) increased from 0.4529 for males and 0.5306 for females in the 1980-1990 period to 0.6710 and 0.7046 for males and females, respectively in the 1990-2000 intercensal period. Differential coverage among the censuses may also be influencing the estimated mortality rates. In addition, we assumed zero net migration in deriving the mortality estimates, and this may have a small impact on the mortality rates.

### 3.4 Estimating adult mortality using Preston-Bennett method

We apply the Preston-Bennett method to the 1980, 1990 and 2000 census age distributions to estimate life expectancies at age 5 and above and the probability of a 15 year old person dying before reaching age 60, ( ${}_{45}q_{15}$ ).

The assessment of the quality of census age and sex data has already been discussed above. The smoothing of age and sex data in applying the Census Survival method also apply to the Preston-Bennett method.

With respect to the AIDS epidemic that has affected the Zambian population, we expect that the 1980-1990 intercensal period is not significantly affected by the epidemic and will produce higher life expectancy values than the 1990-2000 intercensal period where the impact of the epidemic on mortality is significant and hence, low life expectancy values are expected.

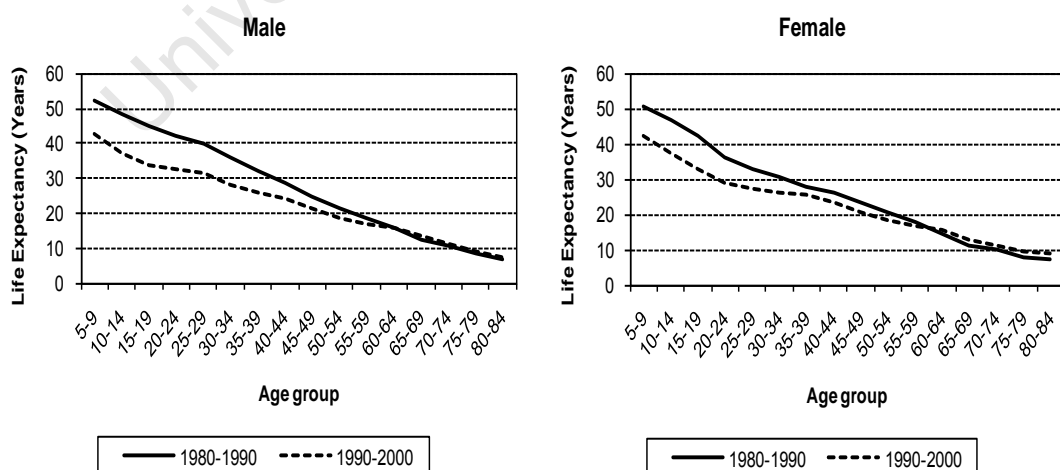
Intercensal age-specific growth rates are first calculated and then intercensal mid-period age distribution by computing the geometric mean of the first and second census age distributions. To the effect of age errors, intercensal age-specific growth rates are cumulated from age 5 and above to the mid-point of each successive higher age. For the open age interval the cumulation is done in such a way as to minimise biases from weighting factors. The geometric mean (average) intercensal mid-period age distribution is then converted into a stationary population. Person-years lived are then computed and life expectancies at age 5 and above are also estimated. The probability of a 15 year old person dying before reaching age 60, ( ${}_{45}q_{15}$ ) is also estimated.

### 3.5 Preston-Bennett Method Results

To measure mortality in the Zambian population we use the life expectancies derived from the Preston-Bennett method. We expect that the sequence of life expectancies at each successive age to decline regularly by small amounts, if there has not been an increase in mortality in the intercensal period. Otherwise, big differences in life expectancies between successive ages indicate an increase in mortality in the intercensal period. Table A.3.3 and Table A.3.4 show the results of applying the Preston-Bennett method to the 1980-1990 and 1990-2000 intercensal periods, respectively. The results are similar to those obtained by the Census Survival method, generally higher mortality for females than males, and an increase in mortality from the 1980-1990 intercensal period to the 1990-2000 intercensal period as shown in Figure 3.6.

An examination of life expectancies for adult ages 15 to 60 indicates large declines with respect to age, especially for the second intercensal period, implying increase in adult mortality. The probability of a 15 year old person dying before reaching age 60 ( ${}_{45}q_{15}$ ) increased from 0.4328 for males and 0.5123 for females in the 1980-1990 period to 0.6828 and 0.7145 for males and females, respectively in the 1990-2000 intercensal period.

Figure 3.6: Estimated life expectancies by age and sex, Census 1980-2000



Overall, the Census Survival method and Preston-Bennett method give similar results of the probability of a 15 year old person dying before celebrating the 60th birthday for both males and females. However, the results of the two

methods with respect to the level of adult mortality appear not to be accurate as mortality is higher for females than males in the two intercensal periods which is not expected. The two methods show that adult mortality for both males and females increased in the 1990-2000 intercensal period. Furthermore, the estimated mortality rates may also be affected by the differential coverage of the censuses. As noted earlier, migration is also another factor that may have a small influence mortality rates.

The next chapter estimates adult mortality using information on the survival of close relatives.

University Of Cape Town

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## 4 ESTIMATING ADULT MORTALITY USING INFORMATION ON THE SURVIVAL OF CLOSE RELATIVES

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### 4.1 Introduction

This chapter presents methods that estimate the level and trend of adult mortality using information on the survival of close relatives. Section 4.2 presents the orphanhood method, data sources, and data quality. Section 4.3 presents the results of adult mortality estimates derived using the orphanhood method. Section 4.4 presents the siblinghood method, data source and data quality. The results of applying the siblinghood method to derive levels and trends of adult mortality are presented in Section 4.5.

### 4.2 Deriving adult mortality rates using the Orphanhood method (survival of parents)

#### 4.2.1 Data source

To derive adult mortality estimates using the orphanhood method, information on the survivorship of parents collected by the 1992, 1996, 2001/2 and 2007 ZDHS surveys and 1996, 1998, 2002/3, 2004 and 2006 LCMS surveys is utilised.

##### 4.2.1.1 Demographic and Health Surveys

Four demographic and health surveys have been conducted in Zambia so far, in 1992, 1996, 2001-2002, and 2007. The demographic and health survey is a nationally representative canvass of a sample of women of reproductive age between 15 and 49 years and men aged between 15 and 59 years. The DHS uses a multi-stage cluster stratified sample design. The 1992 and 1996 surveys used the 1990 census of population and housing sample frame, while the 2001-2002 and 2007 surveys used the 2000 census sample frame. The sample frame consists of Census Supervisory Areas (CSAs) which are further subdivided into Standard Enumeration Areas (SEAs) in both urban and rural areas. CSAs and SEAs are selected using probability proportion to size while households are selected at SEA level from clusters using equal probability systematic sampling. The DHS sample

is not self-weighting at a national level due to the fact there is variation in population size among provinces in Zambia, provinces with small population sizes are oversampled to ensure that they meet the required number of observations that facilitate computation of representative estimates. The DHS computes and provides sample weights for this purpose to ensure that estimates derived are representative at provincial and national level.

The 1992 ZDHS sampled 6,709 households and interviewed 6,209 households representing a response rate of 96.1 per cent. The survey interviewed 7,060 women with a response rate of 97.4 per cent. Men were not sampled. The second survey, 1996 ZDHS sampled 8,016 households and successfully interviewed 7,286 representing a response rate of 98.9 per cent. Women and men interviewed were 8,021 and 1,849 respectively. The response rates were 96.7 per cent and 90.5 per cent for women and men, respectively. The third survey, 2001/2 ZDHS sampled 8,050 households and interviewed 7,126 households with a response rate of 98.2 per cent. The survey interviewed 7,658 women and 2,145 men with response rates of 96.4 per cent and 88.7 per cent, respectively. The fourth survey, 2007 ZDHS sampled 7,969 households and interviewed 7,164 households representing a response rate of 97.8 per cent. Interviewed women and men were 7,146 and 6,500 with response rates of 96.5 per cent and 91 per cent, respectively.

Information on the survivorship of parents of persons less than 15 years old in a household was collected from each household by asking whether the biological mother or father of the person was alive or not. The 2007 survey extends this to persons aged less than 18. The ZDHS surveys also collected information on births in the last year (12 months).

#### *4.2.1.2 Data quality*

There is no clearly established procedure for determining the accuracy of data collected on the survivorship of parents. There are no dates or age at death collected for the dead parents against which the information can be evaluated. However, orphanhood data for young respondents are affected by “adoption effect” with too few respondents reporting that their parents are not alive. Table A.4.1 in the appendix shows the number and percentage of respondents reporting

the survivorship of their parents in the ZDHS surveys. The table shows that over 90 per cent of the respondents in all the surveys reported their biological mother is alive. Less than 10 per cent of the respondents reported their mothers being dead. And zero per cent of the respondents did not know the survival status of their mothers. As for biological fathers, in the 1992 and 1996 ZDHS surveys over 90 per cent of the respondents reported that their biological father was alive while in the 2001/2 and 2007 ZDHS surveys less than 90 per cent did so. About 12 per cent of the respondents reported that their biological father was dead in the 2001/2 and 2007 ZDHS surveys while less than 10 per cent did so in the 1992 and 1996 ZDHS surveys. In the 1992 ZDHS survey, 0.1 per cent of the respondents did not know the survival status of their biological father while in the 1996, 2001/2 and 2007 ZDHS surveys 0.3 per cent did not. The proportion of respondents who did not know the survival status of their parents is not significant.

#### *4.2.1.3 Living Conditions Monitoring Survey*

Five Living Conditions Monitoring Surveys have been conducted in Zambia so far, in 1996, 1998, 2002/3, 2004 and 2006. The data sets used in this study were obtained from the Zambian Central Statistical Office with permission and were provided on a Compact Disc-Read Only Memory (CD-ROM) (Central Statistical Office and World Bank Unpublished).

The LCMS survey is conducted by the Central Statistical Office and funded by the World Bank. It is a nationwide survey targeted at households with the objective of soliciting information to be used in monitoring the impact of government policies and programmes on the welfare of the population. It is a non-traditional demographic survey.

The survey interviews households ranging from 9,000 to nearly 20,000 in selected Standard Enumerations Areas (SEAs) from Census Supervisory Areas (CSAs) country wide. The LCMS survey employs a two-stage stratified cluster sample design, at first stage SEAs are selected with Probability Proportional to Estimated Size (PPES). At second stage, households are selected systematically from the SEA listing. The survey is designed to provide reliable estimates at national, urban, rural, provincial, and district levels. The LCMS survey sample is

not self-weighting, sample weights were computed to correct for the differential representation of the sample at national and sub-national levels. The 1996 and 1998 LCMS surveys used the 1990 census of population and housing sample frame, while the 2002/3, 2004 and 2006 surveys used a sample frame obtained from the 2000 census of population and housing.

The 1996 LCMS survey sampled 11,763 households representing a total of 61,455 persons in the sample. A total of 16,740 households were sampled by the 1998 LCMS survey, 16,710 were interviewed representing 93,469 persons in the sample. The 2002/3 LCMS survey sampled 9,706 households representing 54,067 persons in the sample. A total of 19,340 households were sampled by the 2004 LCMS survey representing a sample population of 103,242 persons. The 2006 LCMS survey sampled 18,622 households representing 97,742 persons in the sample.

The 1996 LCMS survey was conducted from September to October, 1996 a period of one month. The 1998 LCMS survey was undertaken from November to December, 1998. The 2002/3 LCMS survey is unique from the other surveys as it was conducted for 12 months, from the beginning of November, 2002 to end of October, 2003. The 2004 LCMS survey data collection was conducted from November to December, 2004. The 2006 LCMS survey data collection was undertaken from 26th November to 15th December, 2006.

Using a household schedule the LCMS surveys collected information on the survivorship of parents (mother (father) alive or dead) for members of households aged 20 years and less. This information is useful in estimating adult mortality using the orphanhood method.

#### *4.2.1.4 Data quality*

Table A.4.2 in the appendix shows the number and percentages of respondents reporting the survivorship of their parents in the LCMS surveys. The table shows that over 90 per cent of respondents reported that their biological mother is alive. The respondents reporting that their biological father is alive are less than 90 per cent. The percentage of respondents reporting that their biological mother is dead is less than 10 per cent in all the LCMS surveys while this percentage is higher for biological fathers, 17.8 per cent for 1996 LCMS survey, 13.1 per cent for 1998

LCMS survey, and about 15 per cent for the 2002/3, 2004 and 2006 LCMS surveys. The percentage of respondents reporting that they did not know the survival status of the parents is either 0 per cent or 0.1 per cent for biological mothers while it is between 0.3 per cent and 0.8 per cent for biological fathers. The survival status of biological fathers is more likely not to be known than that of biological mothers. The proportions are, however, small.

#### 4.2.2 Method

Using orphanhood data from the ZDHS surveys and LCMS surveys, we estimate adult mortality rates for both males and females. For females, the conditional probability of a 25 year old person surviving before age 35, and the probability of a 25 year old person surviving before age 40 years are translated into the probability of a 25 year old person dying before reaching age 35 ( $_{10}q_{25}$ ), and the probability of a 25 year old person dying before reaching age 40, ( $_{15}q_{25}$ ). For males, only one estimate is derived from ZDHS survey orphanhood data, the probability of a 35 year old person dying before reaching 45, ( $_{10}q_{35}$ ). From the LCMS survey orphanhood data, three adult mortality rates are obtained for females ( $_{10}q_{25}$ ,  $_{15}q_{25}$ , and  $_{20}q_{25}$ ) while for males, two adult mortality rates are estimated ( $_{10}q_{35}$  and  $_{15}q_{35}$ ). To facilitate comparison of male and female adult mortality rates derived from the orphanhood data of the ZDHS surveys and LCMS surveys, only two female adult mortality rates,  $_{10}q_{25}$  and  $_{15}q_{25}$ , and one male adult mortality rate,  $_{10}q_{35}$ , are compared. The reason for using the selected measures is that the ZDHS surveys only collected orphanhood information for persons aged below 15 years, while the LCMS surveys collected this information from persons aged 20 years and less. In addition, the commonly used measure of adult mortality, the probability of a 15 year old person dying before reaching age 60, ( $_{45}q_{15}$ ) is also computed for both males and females. We obtain this measure from a model life table by first determining the mortality level implied by the orphanhood adult mortality estimate and then computing the  $_{45}q_{15}$  value at this mortality level.

In populations that are significantly affected by the AIDS epidemic, such as the Zambian population, there is HIV-related bias introduced in orphanhood adult mortality estimates. Timaeus and Nunn (1997) show that there is a relationship between the survival of mothers and vertical transmission of HIV from mother-to-child which biases the orphanhood adult mortality estimates upwards if not adjusted for. This occurs in the reported proportions of mothers alive which increases with HIV prevalence at a rate that is dependent on percentage reduction in fertility of HIV positive women relative to that of negative women (Timaeus and Nunn (1997), as well as the percentage of vertical transmission to children from mothers. Therefore, we expect that with high prevalence of HIV in the female population aged 15 to 49 years as is the case for Zambia, the vertical transmission from mother-to-child will be high, so will be the proportionate reduction in the fertility of HIV positive women, leading to more bias in the reporting of the survivorship of mothers (Timaeus and Nunn 1997). A correction factor has been proposed by Timaeus and Nunn (1997) to be used in making adjustments to the reports of proportions of mothers alive.

Another bias that the AIDS epidemic introduces in orphanhood adult mortality estimates is in the use of regression coefficients in the standard regression orphanhood method to convert proportions with mothers or fathers alive to life table conditional probabilities of surviving from age 25 for women and age 35 for men. The existing regression coefficients used with the standard method by Timaeus (1992) tend to overestimate the converted life table conditional survival probabilities because they were derived from populations not affected by the AIDS epidemic, therefore, the unusual age patterns of mortality resulting from the impact of the epidemic are not taken into account. This is evident as AIDS mortality is concentrated in the reproductive age groups of 15 to 49 years, hence, producing age patterns that differ from those of the commonly used model life tables which were applied to derive coefficients for the standard orphanhood method (Timaeus 1992; Timaeus and Nunn 1997). In addition, the use of the mean age of childbearing in the standard orphanhood method is meant to account for differences in ages of mothers over the period of exposure to the risk of dying. However, these ages are impacted on by heavy AIDS mortality. This problem of

regression coefficients overestimating life table survivorship mainly affects ages below 25 years; ages 25 years and above are not affected and do not require adjustment. Timaeus and Nunn (1997) have proposed provisional revised regression coefficients to be used with the standard orphanhood method in populations affected by the AIDS epidemic.

Following these proposed adjustments to address biases introduced by the AIDS epidemic in orphanhood adult mortality estimates, we adjust for HIV-related bias by using the correction factors proposed by Timaeus and Nunn (1997). United Nations Joint Programme on HIV and AIDS (UNAIDS) estimated adult HIV prevalence rates for females aged 15 to 49 years for Zambia are employed (UNAIDS/WHO 2009). Using these HIV prevalence rates, we interpolate for each age group the estimated HIV prevalence of mothers at the time of birth of their children; for the age group 5 to 9 years, an HIV prevalence rate is estimated for the period 7.5 years before the reference date of the survey, while for age group 10-14, we use 12.5 years before the survey reference date. This is done for both the ZDHS and LCMS obtained mortality estimates. For LCMS surveys, we also compute the estimated HIV prevalence rate for age group 15-19 years, 17.5 years before the survey reference date. These estimated HIV prevalence rates for females are also used in adjusting the proportions of fathers alive to derive male adult mortality rates.

We derive the adult mortality rates from orphanhood data by first reproducing the Timaeus and Jasseh (2004) adult mortality rates estimated by using the 1992 and 1996 ZDHS orphanhood data. The reproduced adult mortality rates serve as the base from which to derive mortality estimates using orphanhood data from the 2001/2 and 2007 ZDHS surveys as well as the 1996, 1998, 2002/3, 2004 and 2006 LCMS surveys. Timaeus and Jasseh (2004: 762) adjusted downwards the estimated HIV prevalence of women at birth of their children by 47.5 per cent for the proportion of children aged 10-14 with mothers alive. They halved the estimated HIV prevalence for the proportion of children aged 5 to 9 years with mothers alive. For fathers, Timaeus and Jasseh (2004: 762) reduced the estimated HIV prevalence by 60 per cent for children with fathers alive. Timaeus and Jasseh (2004: 762) justify the use of 60 per cent adjustment as being based on concordance

of HIV infection in couples. However, they did not explain how they arrived at the 47.5 per cent adjustment. In addition, they do not provide the HIV prevalence rates used, but one can solve for them as part of the process of reproducing their estimates of mortality.

In order to facilitate comparability between Timaeus and Jasseh (2004) adult mortality estimates and ours, we use the same percentage reductions to proportions of children with mothers alive or fathers alive as in Timaeus and Jasseh (2004). However, for the subsequent surveys, 2001/2 and 2007 ZDHS surveys and the 1996, 1998, 2002/3, 2004 and 2006 LCMS surveys, we use the UNAIDS HIV prevalence rates and interpolate for the required periods.

To account for the distortions in the age pattern of mortality due to the AIDS epidemic, regression coefficients proposed by Timaeus and Nunn (1997) are utilised, with the assumption that for periods before 1996 the impact of the AIDS epidemic on mortality was less significant, and therefore, we use the Timaeus (1992) regression coefficients. This is the case with adult mortality rates derived from using 1992 ZDHS orphanhood data, where the standard orphanhood method is used with the usual regression coefficients. For periods after 1996, the impact of the AIDS epidemic on age patterns of mortality is more significant, therefore, revised regression coefficients proposed by Timaeus and Nunn (1997) are employed. For the 1996 ZDHS orphanhood data, the revised regression coefficients are used for age group 5-9, while for age group 10-14, Timaeus (1992) regression coefficients are used. For the 2001/2 and 2007 ZDHS surveys, we convert the proportions of mothers alive to life table conditional survivorships using the revised regression coefficients with the standard orphanhood method. For the 1996 and 1998 LCMS surveys orphanhood data, we use the revised regression coefficients for age group 5 to 9 years, while for age groups 10-14 and 15-19, Timaeus (1992) regression coefficients are used. For the 2002/3, 2004 and 2006 LCMS surveys orphanhood data, we use the revised regression coefficients for all the age groups. For paternal survivorship estimates, we use Timaeus' unpublished regression coefficients (personal communication, R.E. Dorrington,

2009)<sup>4</sup> for age group 5-9 years while for the other age groups we apply Timaeus (1992) regression coefficients.

The derived conditional survival probabilities of mothers or fathers need to be translated into common mortality indices. For females, the common mortality indices are:  $_{10}q_{25}$  and  $_{15}q_{25}$ , while for males the index is:  $_{10}q_{35}$ . The adult mortality measure,  $_{45}q_{15}$ , is also computed. Since the Zambian population is heavily impacted by the AIDS epidemic in the 20-59 age group, we need to use a standard model life table that accounts for AIDS in translating into common mortality indices. The commonly available model life tables such as the Brass General Standard model life table (Brass, Coale, Demeny *et al.* 1968) and Princeton model life tables (Coale, Demeny and Vaughan 1983) do not account for the AIDS epidemic.

We have available from the United Nations Population Division (UNPD) population estimates and projections data for the years 1950 to 2010 that incorporate the AIDS epidemic for Zambia (United Nations Department of Economic and Social Affairs Population Division 2009). Using population and deaths by age and sex from these population estimates and projections we derive model life tables based on the estimated time reference points for the conditional survival probabilities estimated by the orphanhood method. Using the Brass logit transformation relation (Brass, Coale, Demeny *et al.* 1968), period model life tables are derived by interpolating for the population and deaths by age and sex specific to the time reference point of the estimated conditional survival probability from the orphanhood method. A period life table is then generated by using the interpolated population and deaths. This period life table is then used as a standard for the estimated conditional survival probability from the orphanhood method. Conditional survival probabilities that are equivalent to the estimated conditional probabilities from the orphanhood method are then computed. The logits for each conditional survival probability from the period life table (standard), and those obtained from the orphanhood method are then calculated. Using the Brass logit transformation relation (Brass, Coale, Demeny *et al.* 1968), we calculate alpha ( $\alpha$ ),

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<sup>4</sup> Timaeus' unpublished regression coefficients:  $a_0 = -0.5578$ ,  $a_1 = 0.0004$ ,  $a_2 = 1.4708$ ,  $a_3 = 0.0695$

the level of mortality for each estimated conditional survival probability from the orphanhood method. We then use the estimated alpha ( $\alpha$ ) to generate a new life table using the logit transformation by setting beta ( $\beta$ ) the shape of mortality, equal to one. A new life table for each estimated conditional survival probability from the orphanhood method is generated and used for translation into common adult mortality indices.

Since, the Brass General standard model life table (Brass, Coale, Demeny *et al.* 1968) does not incorporate the AIDS epidemic, it is used here to obtain comparable estimates with those from others that used it for translation. Only adult mortality estimates translated into common mortality indices using the model life tables derived from UNPD population estimates and projections data are presented. We have chosen to use UNPD life tables as standard for converting conditional survival probabilities into life tables because, first, we are able to generate standard period life tables specific for Zambia that incorporate the AIDS epidemic and second, we are able to use UNPD life tables to obtain estimates for comparison with our estimates and check for the level and trend of adult mortality. It should be noted that UNPD mortality estimates that we are using to compare our mortality estimates with are not a “gold” standard against which to validate the estimates. UNPD mortality estimates have their own limitations related the nature of data and methods used to derive them, but have been used simply because they do incorporate the AIDS epidemic.

Inter-survey adult mortality rates are also computed using a synthetic cohort procedure developed by Zlotnik and Hill (1981) and reflect mortality levels between surveys.

### 4.3 Orphanhood Method Results

We apply the standard orphanhood method to data on survival of parents for age groups 5 to 9 and 10 to 14 to derive estimates of adult mortality for both males and females. Estimates derived from data based on the age group 5 to 9 represent adult mortality in the previous 10 years and less, while estimates based on age group 10 to 14 represent the mortality for the period 15 years and less. These

estimates reflect adult mortality for younger parents, that is, females in their late twenties and thirties and males in their late thirties and forties. To establish the levels of adult mortality, conditional survival probabilities derived for both males and females have been translated into common mortality indices, and trends are approximated by their time reference points.

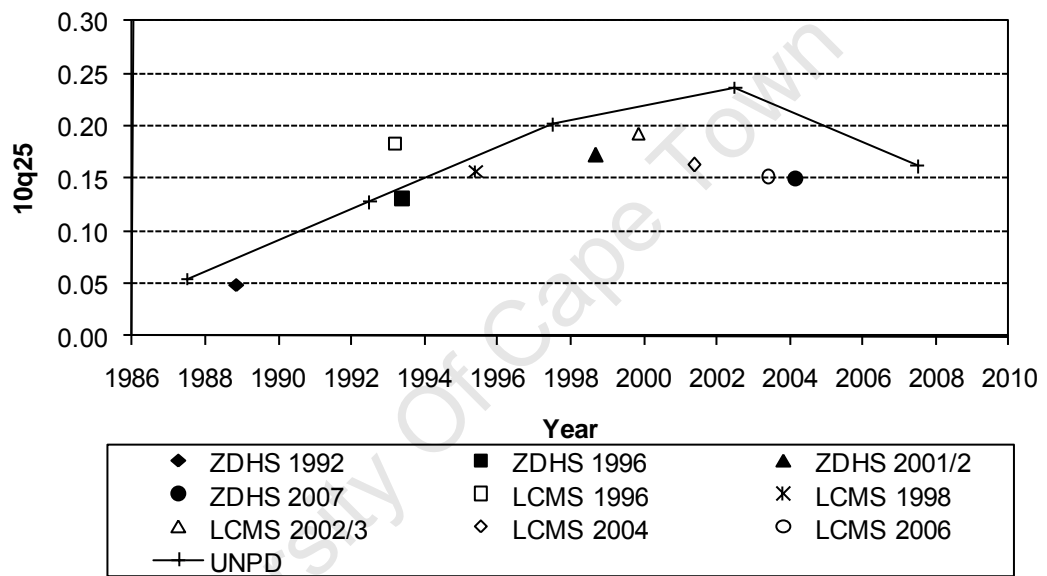
Figures 4.1 to 4.10 below present the levels and trends in female and male adult mortality rates estimated from orphanhood data obtained from the 1992-2007 ZDHS surveys and 1996-2006 LCMS surveys using the standard orphanhood method with adjustments pertaining to HIV-related biases and revised regression coefficients. Inter-survey estimates reflect the level of adult mortality between two periods in the surveys.

Figure 4.1 examines the levels and trends of probabilities of a 25 year old female dying before reaching age 35 ( $_{10}q_{25}$ ). The figure compares the levels and trends in adult mortality derived from ZDHS surveys and LCMS surveys. The figure indicates that female survivorship between ages 25 and 35 years declined over time. The probability of a 25 year old person dying before reaching age 35 was low in the 1980s about 5 per cent, this increased gradually in the late 1990s and early 2000s, and appears to have stabilised at a level of about 15 per cent in the 2000s. In the 1980s, the UNPD estimate derived from life tables based on UNPD population estimates and projections was about 6 per cent which increased to about 13 per cent by the early 1990s, then 20 per cent in the mid 1990s and continued to above 20 per cent in the early 2000s before declining to about 16 per cent in the late 2000s. UNPD estimates are higher than our estimates between the mid-1990s and mid-2000s. However, UNPD estimates and our estimates show a similar pattern of mortality. Generally, both the ZDHS surveys and LCMS surveys mortality estimates indicate the same pattern of levels and trends in adult mortality. However, the LCMS survey mortality estimates are less internally consistent than the ZDHS survey estimates. Adult male mortality between ages 35 and 45 years follows a similar pattern as female mortality in Figure 4.1.

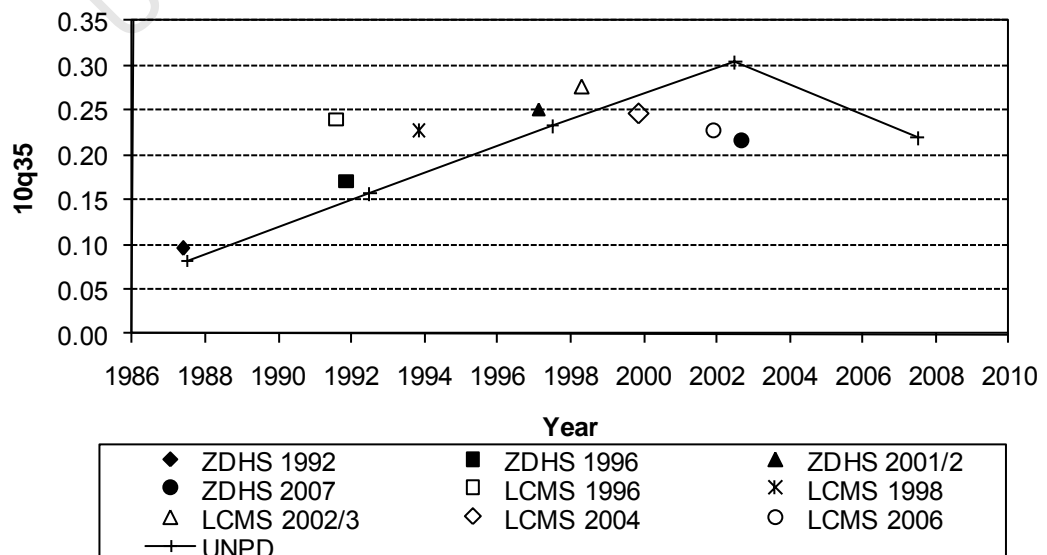
And Figure 4.2 shows that the probability of a 35 year old person dying before reaching age 45 for males has increased over the years. The probability of

dying increased from about 10 per cent in the late 1980s to about 25 per cent in the mid-1990s to early 2000s. Male adult mortality increased more than female adult mortality. These estimates are close to UNPD estimates from the mid-1980s to the late 1990s. The UNPD estimate of the probability of a 35 year old male person dying before reaching age 45 is about 8 per cent for late 1980s and this increased to about 23 per cent in the mid-1990s. The UNPD estimates are higher in the early 2000s period.

**Figure 4.1: Adult female probability of a 25 year old person dying before reaching age 35, ( ${}_{10}q_{25}$ ), ZDHS 1992-2007 and LCMS 1996-2006**



**Figure 4.2: Adult male probability of a 35 year old person dying before reaching age 45, ( ${}_{10}q_{35}$ ), ZDHS 1992-2007 and LCMS 1996-2006**



Adult mortality rates that are lower than UNPD estimates may be attributed to the adoption effect or UNPD estimates may be too high. The 1996 LCMS estimate is off the UNPD estimates. The 1996 LCMS survey recorded lower percentage of fathers alive and a higher percentage of fathers dead relative to the other surveys (see Table A.4.2).

Figure 4.3 examines adult female mortality between two survey periods. The figure shows that as obtained in Figure 4.1, the probability of a 25 year old person dying before reaching age 35 has remained constant at about 15 per cent to 20 per cent since the late 1990s. Both the ZDHS surveys and LCMS surveys mortality rates estimate similar levels and trends of female mortality between age 25 and 35 in the inter-survey periods. UNPD estimates are higher than our estimates, except in the late 2000s period when mortality estimates are about 15 per cent.

**Figure 4.3: Inter-survey adult female probability of a 25 year old person dying before reaching age 35, ( $_{10}q_{25}$ ), ZDHS 1992-2007 and LCMS 1996-2006**

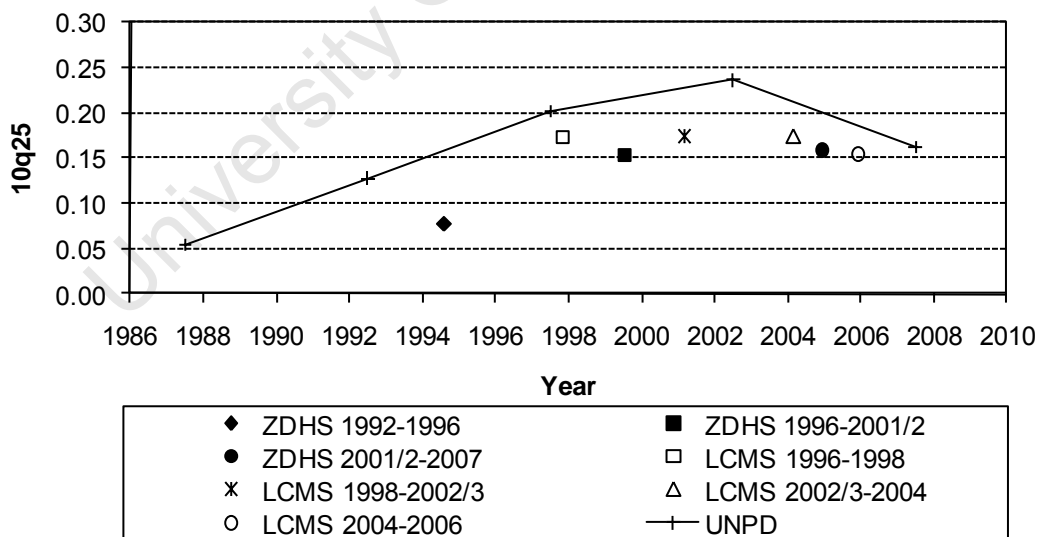


Figure 4.4 also indicates that the probability of a 35 year old person dying before reaching age 45 for males has stabilised at between 20 per cent and 25 per cent from the late 1990s. The 2001/2-2007 ZDHS inter-survey period and the 2004-2006 LCMS inter-survey periods produce male adult mortality rates that are

consistent to each other between ages 35 and 45 years. Our estimates are closer to UNPD estimates only in the late 2000s.

**Figure 4.4: Inter-survey adult male probability of a 35 year old person dying before reaching age 45, ( ${}_{10}q_{35}$ ), ZDHS 1992-2007 and LCMS 1996-2006**

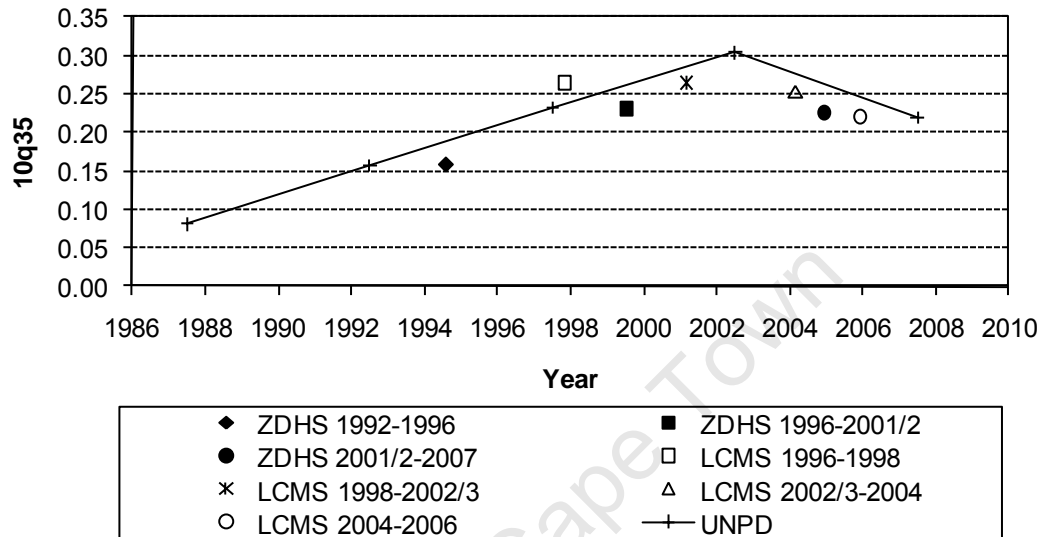


Figure 4.5 shows levels and trends in female adult mortality between ages 25 and 40 years. The figure indicates that the probability of a 25 year old person dying before reaching age 40 for females was low in the late 1980s about 6 per cent and increased gradually from the 1990s and appears to have remained constant at between 20 per cent and 25 per cent since the mid-1990s.

These estimates are lower than those derived from UNPD life tables. A possible reason again may be the adoption effect. The UNPD estimate of the probability of a 25 year old person dying before reaching age 40 is about 9 per cent for the late 1980s which increased to about 28 per cent in the mid-1990s. The 1996 LCMS survey and 1996 ZDHS survey probabilities of a 25 year old person dying before reaching age 40 are consistent to each other. The LCMS survey mortality estimates are less internally consistent.

Figure 4.5: Adult female probability of a 25 year old person dying before reaching age 40, ( ${}_{15}q_{25}$ ), ZDHS 1992-2007 and LCMS 1996-2006

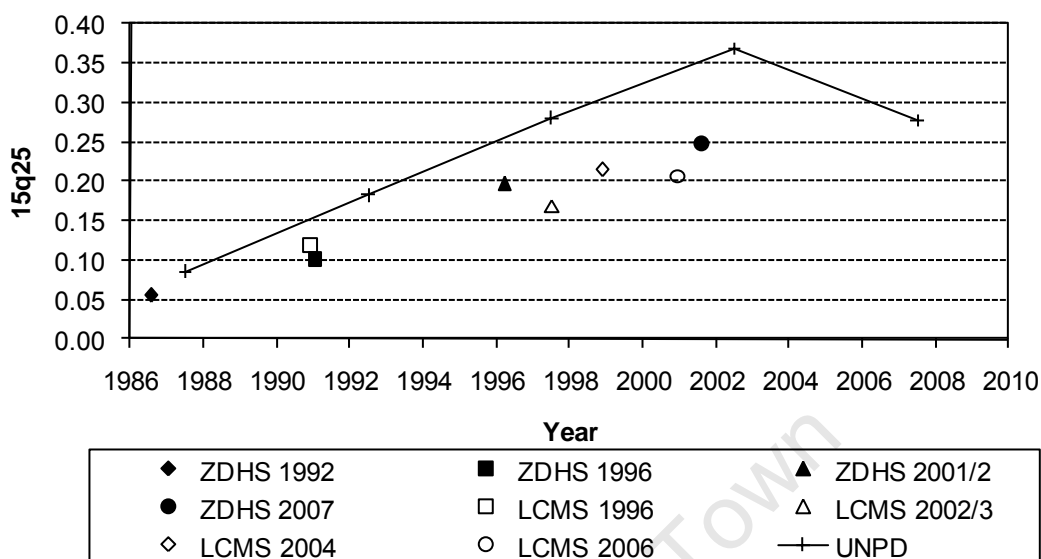
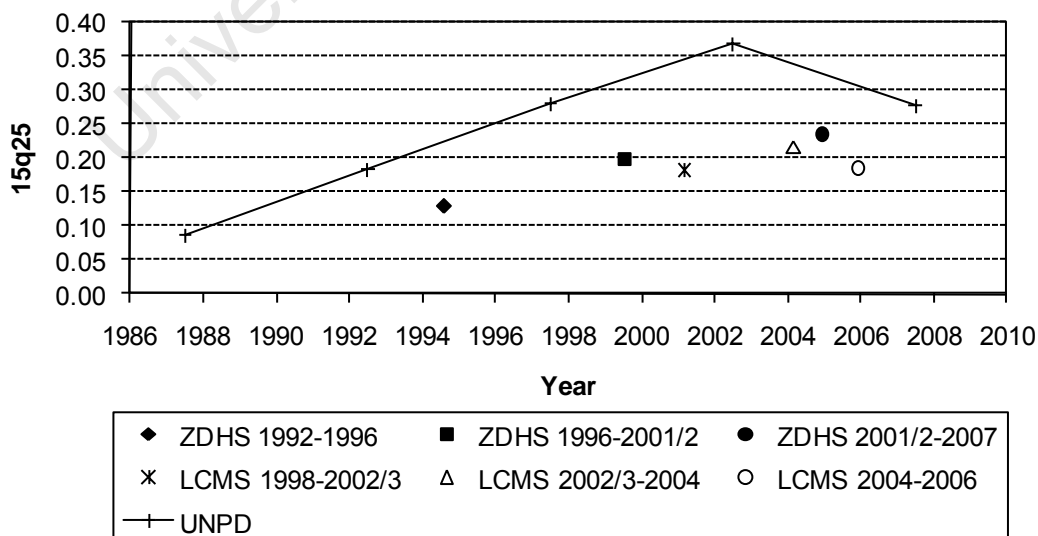


Figure 4.6 reinforces the point that the female probability of a 25 year old person dying before reaching age 40 in the inter-survey periods has stabilised at between 20 per cent and 25 per cent since 2000.

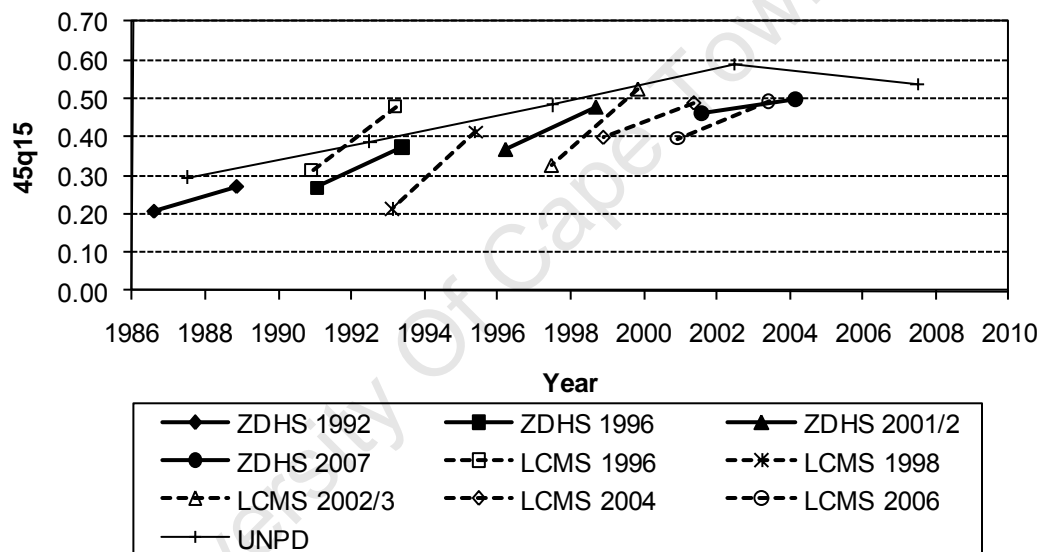
Figure 4.6: Inter-survey adult female probability of a 25 year old person dying before reaching age 40, ( ${}_{15}q_{25}$ ), ZDHS 1992-2007 and LCMS 1996-2006



The probability of a 15 year old person dying before reaching age 60 for females appears to have increased over time as shown in Figure 4.7. Adult female

mortality started to increase from about 21 per cent in the mid-1980s to about 29 per cent in the late 1980s. These estimates are lower than those derived from UNPD life tables, which estimate the probability of a 15 year old person dying before reaching age 60 is above 30 per cent in the late 1980s. The LCMS surveys mortality estimates though less internally consistent are in agreement with ZDHS surveys mortality estimates, indicating that adult female mortality between ages 15 and 60 years has increased in Zambia. The probability of a 15 year old person dying before reaching age 60 has remained at about 50 per cent since 2000.

**Figure 4.7: Adult female probability of a 15 year old person dying before reaching age 60, ( ${}_{45}q_{15}$ ), ZDHS 1992-2007 and LCMS 1996-2006**



Adult male mortality increased more than that of females. Males experience higher probabilities of a 15 year old person dying before reaching age 60 as indicated in Figure 4.8. The probability of dying started to increase from about 40 per cent in the late 1980s to about 50 per cent in the early 1990s. From the mid-1990s, the probability of a 15 year old person dying before reaching age 60 varies between 50 per cent and slightly above 60 per cent. These estimates approximate those derived from UNPD life tables from the 1980s to late 1990s. LCMS surveys and ZDHS surveys mortality estimates portray the same picture of adult mortality, though LCMS surveys mortality estimates are less internally consistent. The 2006 LCMS and 2007 ZDHS surveys adult mortality estimates are

consistent with each other. The 1996 LCMS survey mortality estimate is an outlier.

**Figure 4.8: Adult male probability of a 15 year old person dying before reaching age 60, ( ${}_{45}q_{15}$ ), ZDHS 1992-2007 and LCMS 1996-2006**

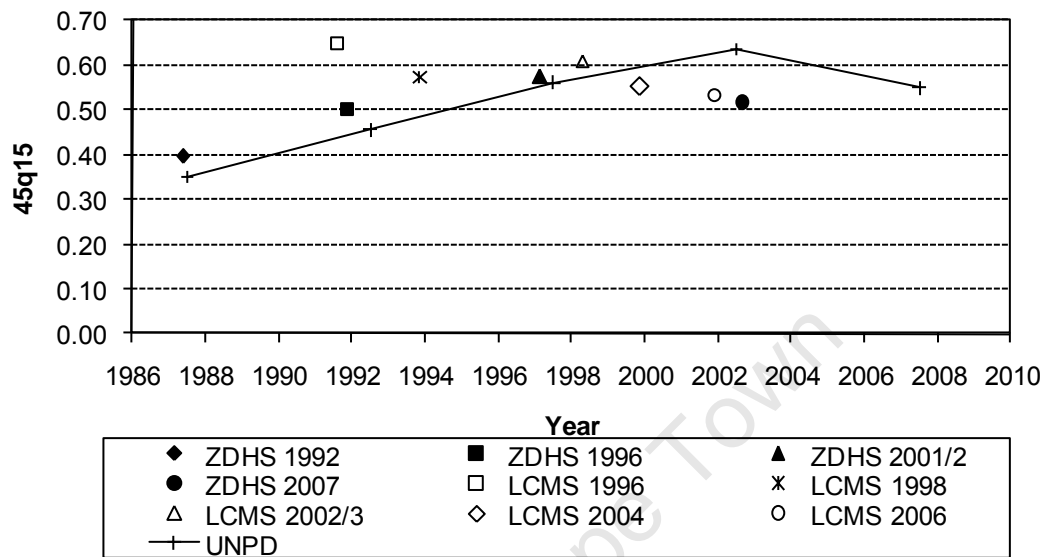


Figure 4.9 and Figure 4.10 show the inter-survey adult mortality estimates for females and males, respectively.

**Figure 4.9: Inter-survey adult female probability of a 15 year old person dying before reaching age 60, ( ${}_{45}q_{15}$ ), ZDHS 1992-2007 and LCMS 1996-2006**

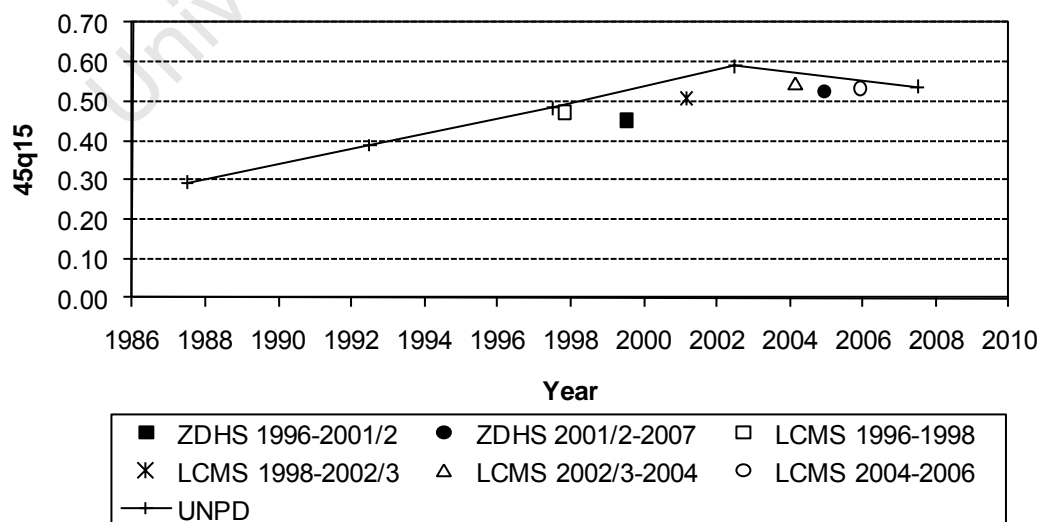


Figure 4.10: Inter-survey adult male probability of a 15 year old person dying before reaching age 60, ( ${}_{45}q_{15}$ ), ZDHS 1992-2007 and LCMS 1996-2006

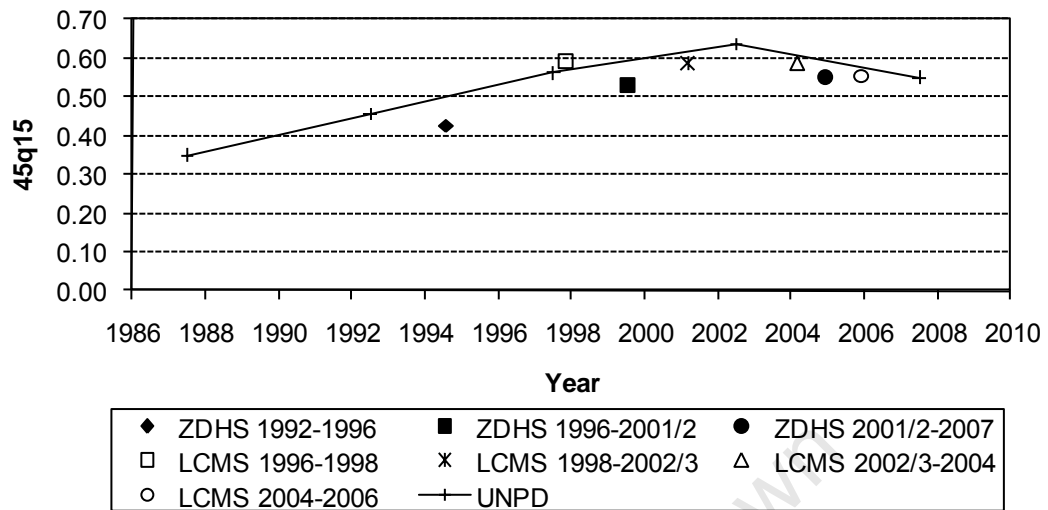


Figure 4.9 indicates that female adult mortality between inter-survey cohorts and periods has remained constant at 50 per cent from 2001 to 2005.

The 1998-2002/3 LCMS, 2002/3-2004 LCMS, 2004-2006 LCMS and 2001/2-2007 ZDHS inter-survey mortality estimates are consistent with each other. The adult male probability of a 15 year old person dying before reaching age 60 has also remained constant at about 50 per cent to 60 per cent from about 1997 to 2005. The 2004-2006 LCMS and 2001/2-2007 ZDHS inter-survey mortality estimates are consistent to each other. The inter-survey mortality estimates are slightly lower than UNPD estimates.

Overall, we have estimated the approximate levels and trends of adult mortality rates from LCMS and ZDHS surveys orphanhood data by making adjustments pertaining to the HIV-related bias and using revised regression coefficients that account for the AIDS epidemic in affected populations. The estimates indicate that the levels of female adult mortality between ages 25 and 35 years have remained constant at about 15 per cent from the mid-1990s. The female mortality rate between ages 25 and 40 years has also remained constant at between 20 per cent and 25 per cent since 2000. Adult male mortality between ages 35 and 45 years has increased over time and has remained between 20 per cent and 25 per cent from the late 1990s to late 2000s. The probability of a 15 year old person

dying before reaching age 60 for both males and females has increased over time and has stabilised at about 60 per cent for males and 50 per cent for females.

Adult mortality estimates derived from both the LCMS surveys and ZDHS surveys show the same pattern of adult mortality in Zambia, although, LCMS mortality estimates are less internally consistent.

We investigated the impact of replacing our standard model life tables derived from UNPD population estimates and projections data with Brass' General standard model life table (Brass, Coale, Demeny *et al.* 1968), which does not allow for the changing impact of AIDS on mortality, to translate the estimated conditional survival probabilities of dying into common mortality indices (for females,  $_{10}q_{25}$ , and  $_{15}q_{25}$ ; for males  $_{10}q_{35}$  and  $_{15}q_{35}$ ; and  $_{45}q_{15}$ ). A comparison of adult mortality rates obtained from the two types of standard model life tables indicated that mortality rates translated by using Brass's General Standard (not shown here) are lower than those estimated by using the model life tables derived from the UNPD population estimates and projections.

#### 4.4 Deriving adult mortality rates using Siblinghood method

##### 4.4.1 Data source

The 1996, 2001/2 and 2007 ZDHS provide information on survivorship of siblings (sibling history: date of birth, date of death, current age, age at death, sex, and survival status of siblings). In terms of information pertaining to adult mortality estimation, questions on survivorship of the respondent's siblings were asked. It should be noted that only women respondents were asked questions relating to adult mortality. This is because questions on adult mortality are meant to collect information on maternal mortality as well; women are more likely to report accurately a maternal death than men.

Each female respondent was asked about the survivorship of all her siblings or all live births of her natural mother. To obtain the total number of siblings, each respondent was asked the number of children her mother gave birth to, including herself. To ensure that births of siblings are reported accurately, respondents were asked to give the number of births their mother had before the

respondent was born. To further assist the respondent to recall the siblings' births, she was asked to give the name of the next oldest brother or sister. The respondent was further asked to state the sex of the siblings. To determine the survivorship of each sibling, respondents were asked to state whether the sibling was still alive or not. For the siblings who were dead, respondents were asked to state the number of years ago the sibling died as well as the age at death. It should be noted that the 1992 ZDHS did not collect information on survivorship of siblings and hence it cannot be used to derive mortality estimates from such data.

#### *4.4.2 Data quality*

Sibling histories data are prone to errors of recall since they are based on information collected retrospectively. There is no well established procedure of assessing the quality of sibling histories data; however, these data can be assessed by examining the numbers of siblings reported by respondents, completeness of reporting of ages, age at death and number of years since death. Table A.3.3 in the appendix shows the numbers and percentages of respondents reporting the survivorship of their siblings. The table shows that respondents are highly knowledgeable about the survival status of their siblings, with only 6 out of over 50,000 siblings for whom survival status was not known in the 1996 ZDHS. In the 2001/2 ZDHS, it was 5 out of over 45,000 and in the 2007 ZDHS, 22 out of over 40,000. Knowledge about the survival status of siblings is higher for sisters than brothers; probably this could be because brothers are mostly not at home and travel a lot. The completeness of reporting of age at death and number of years since death for deceased siblings is universal in all the three ZDHS surveys. Completeness of reporting of age for surviving siblings is nearly universal in all the surveys, with over 90 per cent of the ages reported. In the 1996 ZDHS survey, 2.4 per cent of the dead siblings had both age and year since death missing, this dropped to 0.2 per cent in the 2001/2 ZDHS survey, and increased to 1.2 per cent in the 2007 ZDHS survey. Imputation of dates of birth and death for dead siblings missing this information was done using reported ages of surviving siblings and age at death and number of years since death of dead siblings before the data were made available for public use (Stanton, Abderrahim and Hill 1997).

#### 4.4.3 Method

The assessment of the quality of data has been done as explained above. No adjustments to the data have been done except those that were made before the data was made publicly available.

Proportions of siblings surviving are obtained by dividing the number of living brothers or sisters aged 15 and above by the total number of living and dead siblings aged 15 and above reported by women aged 15-49 years. The conditional survival probabilities from age 15 to the next higher age are estimated by applying the siblinghood method with coefficients derived by Timaeus, Zaba and Ali (2001). Since the conditional survival probabilities refer to an ill-defined time location, a modification of the Brass and Bamgboye (1981) time location method proposed by Timaeus, Zaba and Ali (2001) is used to estimate the date to which the rates apply.

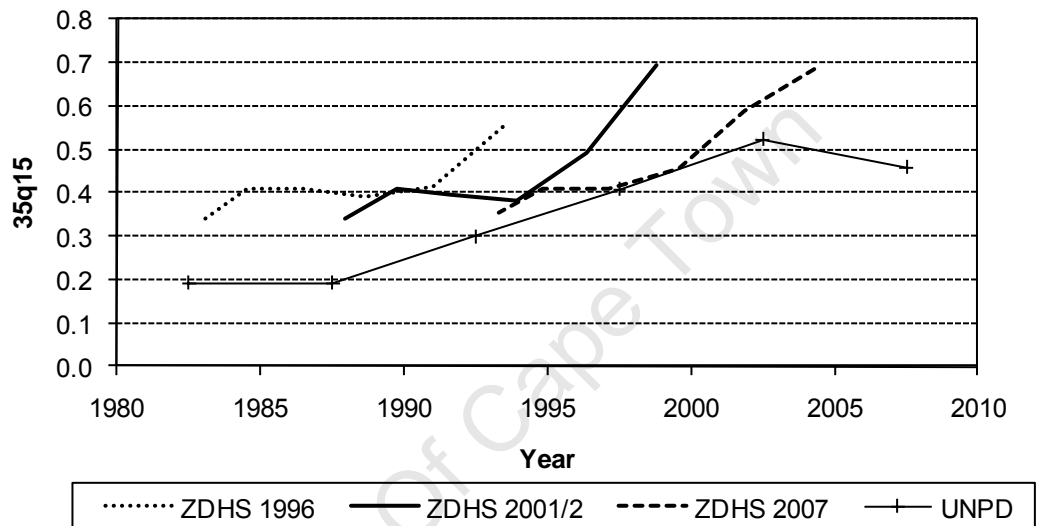
Having calculated the conditional survival probabilities and their time locations, the conditional survival probabilities are then translated into a common adult mortality index,  $(_{35}q_{15})$ , using a known model life table. As noted earlier, most of the commonly available model life tables (Princeton model life tables (Coale, Demeny and Vaughan 1983) and Brass General Standard model life table (Brass, Coale, Demeny *et al.* 1968)) do not incorporate the HIV and AIDS epidemic. We use the same derived period model life tables described under the orphanhood method that account for HIV and AIDS as standard model life tables based on United Nations Population Division estimates and projections for the years 1950 to 2010 for translating the conditional survival probabilities into common adult mortality indices  $_{35}q_{15}$  and  $_{45}q_{15}$ .

#### 4.5 Siblinghood Method Results

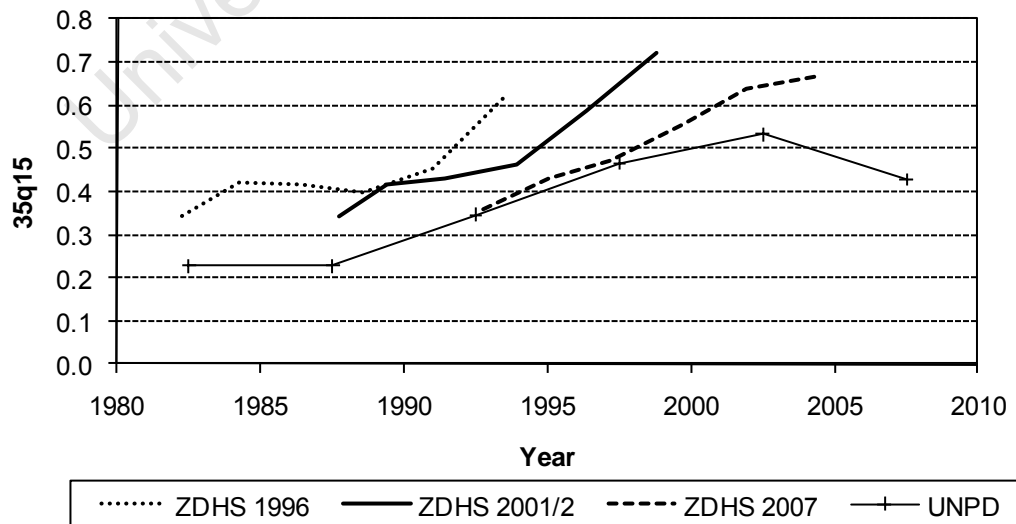
The adult mortality measure derived using the siblinghood method, the probability of a 15 year old person dying before reaching age 50, refers to adult mortality in the reproductive age group 15-49 years where HIV and AIDS prevalence is also concentrated. The results of applying the siblinghood method are presented in Figures 4.11 to 4.14 below. Figure 4.11 shows the adult female probability of a 15 year old person dying before reaching age 50. The figure shows

no definitive picture of adult female mortality. High estimates of mortality rates can be observed in the recent period of each of the three surveys. The estimates are at variance with those derived from the UNPD life tables. However, the estimated adult female mortality rates ( ${}_{35}q_{15}$ ) range from 0.3537 for respondents aged 45-49, to 0.6860 for respondents aged 20-24.

**Figure 4.11: Adult female probability of a 15 year old person dying before reaching age 50, ( ${}_{35}q_{15}$ ), ZDHS 1996–2007**



**Figure 4.12: Adult male probability of a 15 year old person dying before reaching age 50, ( ${}_{35}q_{15}$ ), ZDHS 1996–2007**

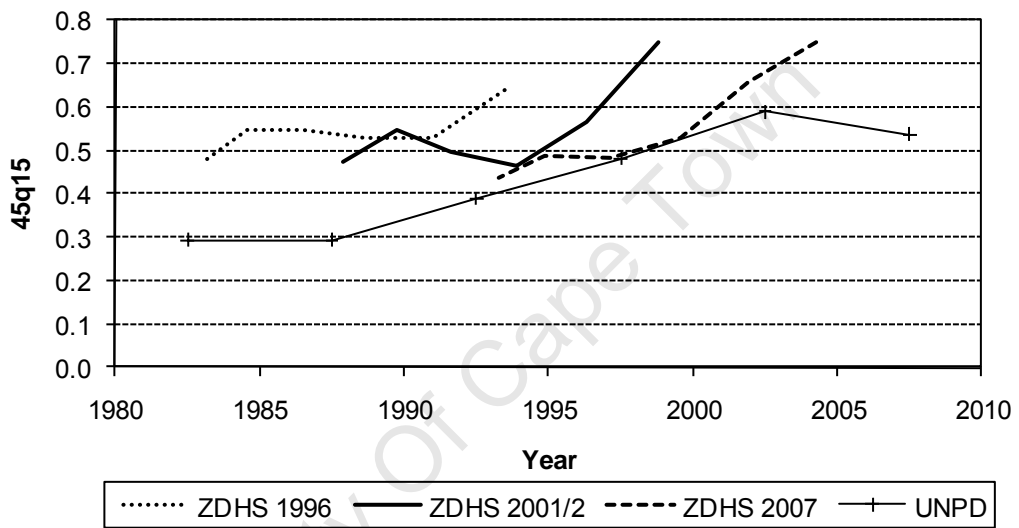


A similar picture emerges for adult male mortality in Figure 4.12. There is no clear conclusion with respect to the pattern of mortality. The adult male probability of

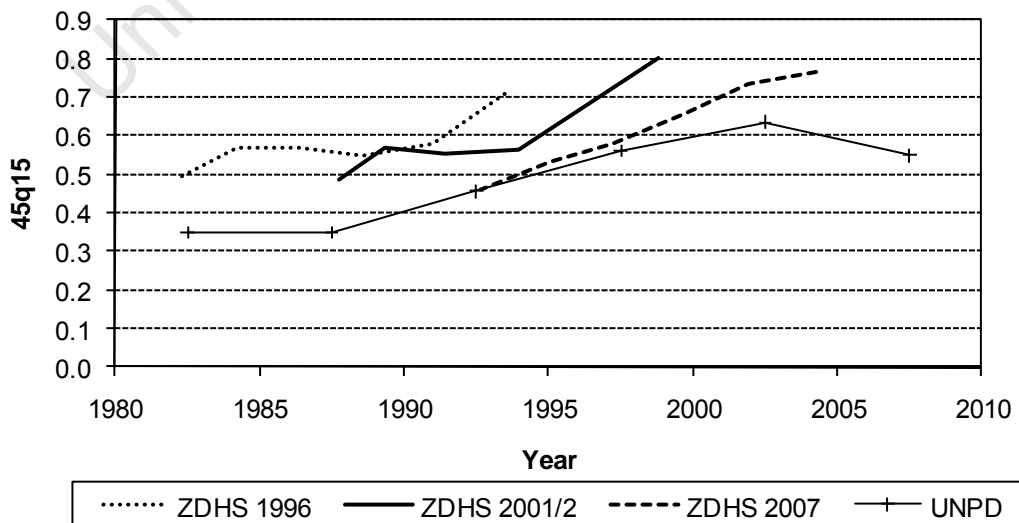
a 15 year old person dying before reaching age 50 ranges from 0.3547 for respondents aged 45-49, to 0.6681 for respondents aged 20-24. UNPD estimates indicate that adult male mortality is higher than female mortality.

The probability that one who survives to age 15 and dies before celebrating their 60th birthday is presented in Figure 4.13 and Figure 4.14 for females and males respectively.

**Figure 4.13: Adult female probability of a 15 year old person dying before reaching age 60,  ${}_{45}q_{15}$ , ZDHS 1996–2007**



**Figure 4.14: Adult male probability of a 15 year old person dying before reaching age 60,  ${}_{45}q_{15}$ , ZDHS 1996–2007**



UNPD estimates show that the probability of a 15 year old person dying before reaching age 60 for females has also increased over the years to over 50 per cent in the 2000s period and may be declining. Adult male probability of a 15 year old person dying before reaching age 60 is higher than that of females and has also increased over time to about 60 per cent in the 2000s period. Our estimates on the other hand do not show a conclusive pattern of mortality for both males and females.

Although the mortality pattern of our estimates is not conclusive, as shown in Figures 4.11 to 4.14, we can observe that mortality rates for both males and females in the recent past for each survey rise sharply. This may be attributed to the fact that, there are more surviving younger sibling respondents reporting on their older siblings (dead or alive) than surviving older siblings reporting on their siblings. In some cases older siblings may not have any surviving sibling to report on their deaths.

It can also be observed that there are points of overlap for the estimated adult female mortality rates for the three ZDHS surveys, this is not the case with derived adult male mortality rates only two surveys overlap the 1996 ZDHS and 2001/2 ZDHS. The 2007 ZDHS is different.

Overall, adult mortality estimates derived from UNPD life tables indicate that adult mortality in Zambia has increased over the years. However, we cannot draw any conclusive observations about the pattern of adult male and female mortality from the estimates derived from the three surveys based sibling history data. On the other hand, the range of the level of these mortality rates is around those obtained by Obermeyer, Rajaratnam, Part et al (2009) and WHO (2006; 2009).

The next chapter looks at estimating adult mortality using death distribution methods.

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## 5 ESTIMATING ADULT MORTALITY USING DEATH DISTRIBUTION METHODS

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### 5.1 Introduction

This chapter presents death distribution methods of estimating levels and trends of adult mortality. Section 5.2 presents the Generalized Growth Balance method, Bennett-Horiuchi (Synthetic Extinct Generations) method, data source, and data quality. The results of applying death distribution methods are presented in Section 5.3. Section 5.4 compares the levels and trends of adult mortality rates derived by the six methods using a summary adult mortality measure, the probability of a 15 year old person dying before reaching age 60.

### 5.2 Deriving mortality estimates using Generalised Growth Balance (GGB) and Bennett-Horiuchi (Synthetic Extinct Generations (SEG)) methods

#### 5.2.1 Data source

The 1996, 1998, 2004 and 2006 LCMS surveys provide age distributions of population and household deaths in the last 12 months by sex for use with the GGB and SEG methods. The background of these surveys has already been described earlier.

##### 5.2.1.1 Data quality

The quality of data of age-sex populations distributions obtained from the LCMS surveys is presented in Figure 5.1 which shows the percentage distributions of males and females by single-year age and five-year age groups. The figure shows that single-year ages for both males and females fluctuate with age indicating age heaping or digit preference of ages ending in certain numbers. There is underenumeration of children aged 5 for both males and females. Five-year age groups for both males and females show smoother age distributions than is observed in single-year ages. However, the figure shows underenumeration of age group 0-4 by the 1998, 2002/3, 2004 and 2006 LCMS surveys. The 1996 LCMS survey underenumerated age groups 5-9 to 10-14 for both males and females. The

figure also shows age heaping for females between age groups 15-19 and 20-24. The figure also show that age groups 25-29 and above decline regularly with increase in age for both males and females.

Figure 5.2 shows the age ratios for males and females derived from the LCMS survey data. Generally, the age ratios for both males and females show minor deviations from 100. However, for ages 50 years and above the magnitudes of the deviations from 100 are bigger than in younger ages, indicating the presence of age misreporting.

**Figure 5.1: Percentage distribution of male and female population by single and grouped age, LCMS 1996-2006**

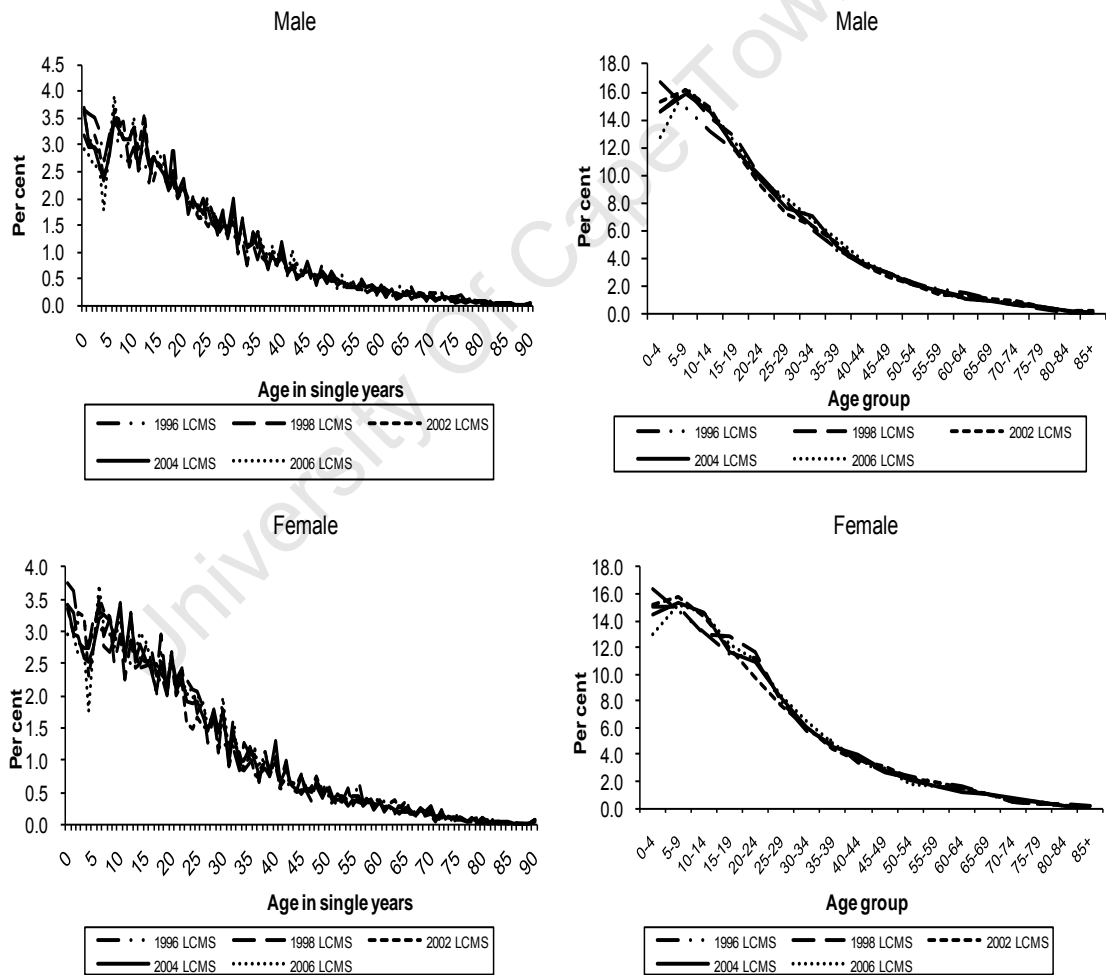
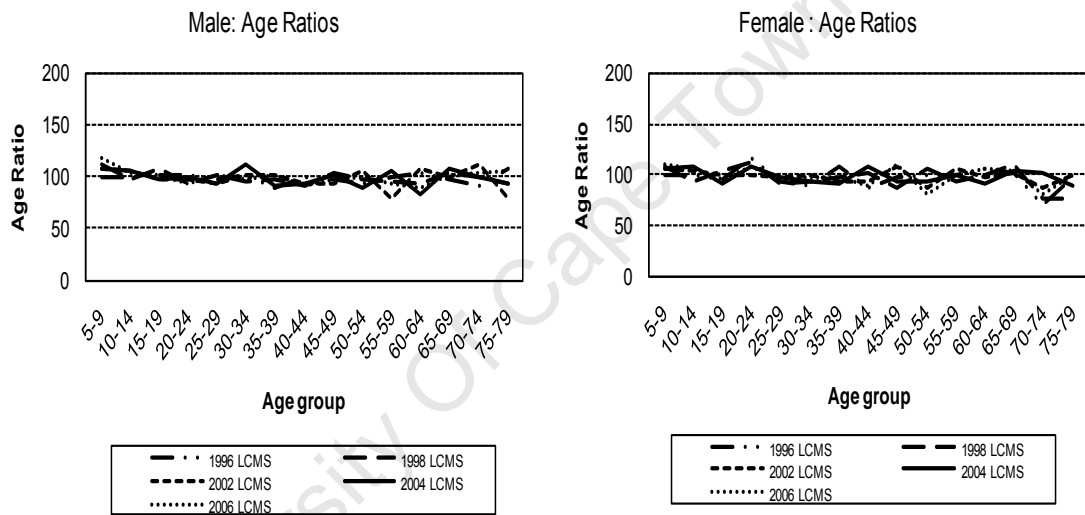


Figure 5.3 shows sex ratios calculated from the LCMS surveys data. Overall, in all the surveys, the sex ratios do not follow the expected pattern of declining regularly with increase in age. There are fluctuations in the distribution

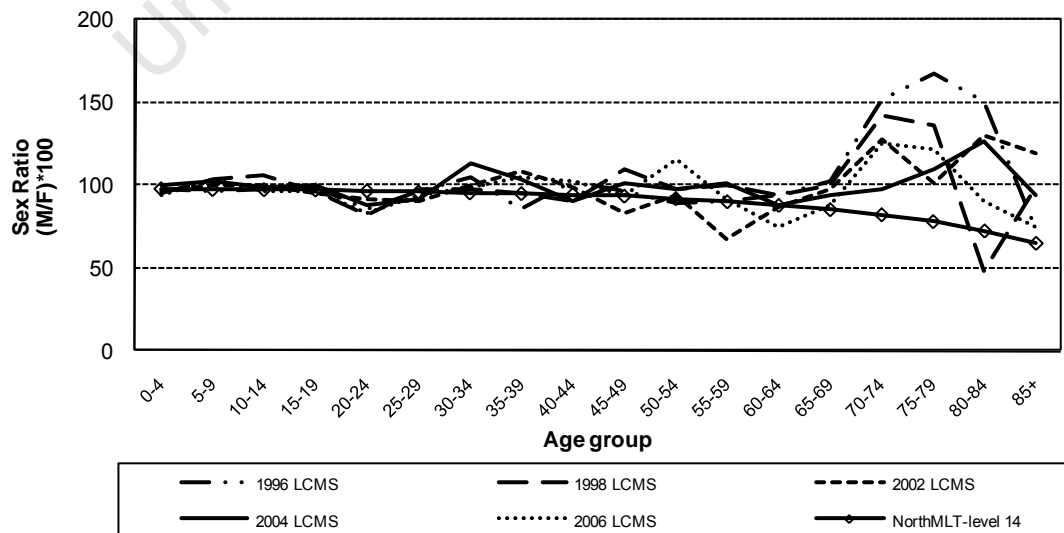
of the sex ratios. The figure shows that there is an excess of females in age groups 10-14 to 25-29 and a surplus of males in older ages from age group 60-64 and above. In the absence of a plausible reason to explain the excess of males in older ages, this could be attributed to irregularities in the age data at these ages.

A comparison of LCMS survey sex ratios with those obtained from the Princeton North model life table (Coale, Demeny and Vaughan 1983) shows that LCMS survey sex ratios do not conform to the expected pattern. Irregularities in the reporting of age are more pronounced in ages 60 and above.

**Figure 5.2: Male and Female Age ratios by age group, LCMS 1996-2006**



**Figure 5.3: Sex ratios by age group, LCMS 1996-2006**



### 5.2.1.2 Household deaths in the last 12 months

This section evaluates household deaths in the last 12 months collected by the LCMS surveys. Using a detailed household questionnaire, the LCMS surveys collected information on deaths in households in the last 12 months prior to each survey. The LCMS surveys captured household deaths by asking for the number of people that died in the household in the last 12 months. The age and sex of deceased persons were recorded. Households collected this information up to a maximum number of six deceased persons.

Figure 5.4 presents the number of household deaths in the last 12 months before the survey, collected by the 1996, 1998, 2004 and 2006 LCMS surveys.

**Figure 5.4: Number of household deaths in the last 12 months before the survey by age group and survey, LCMS 1996-2006**

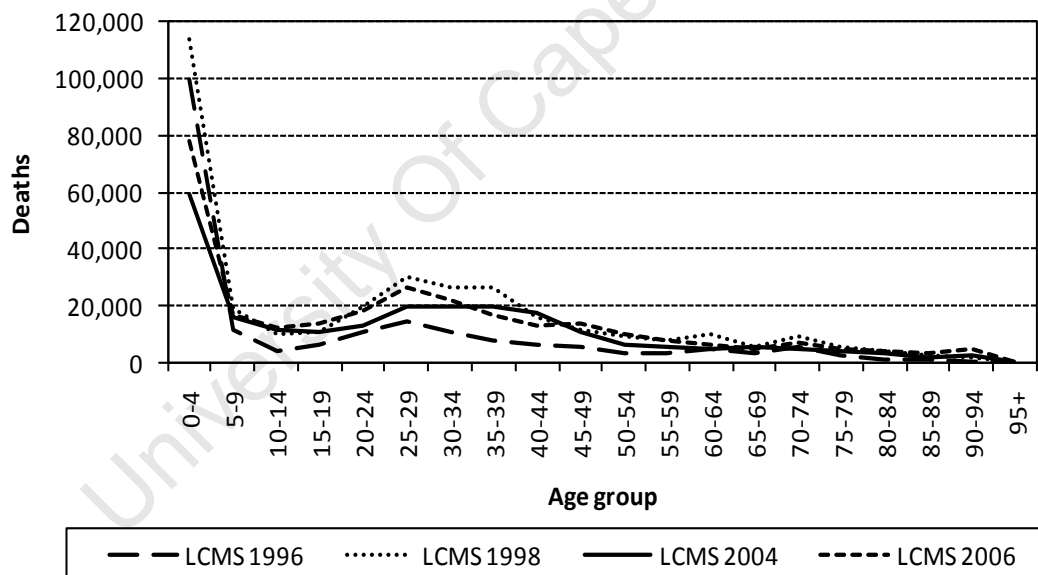
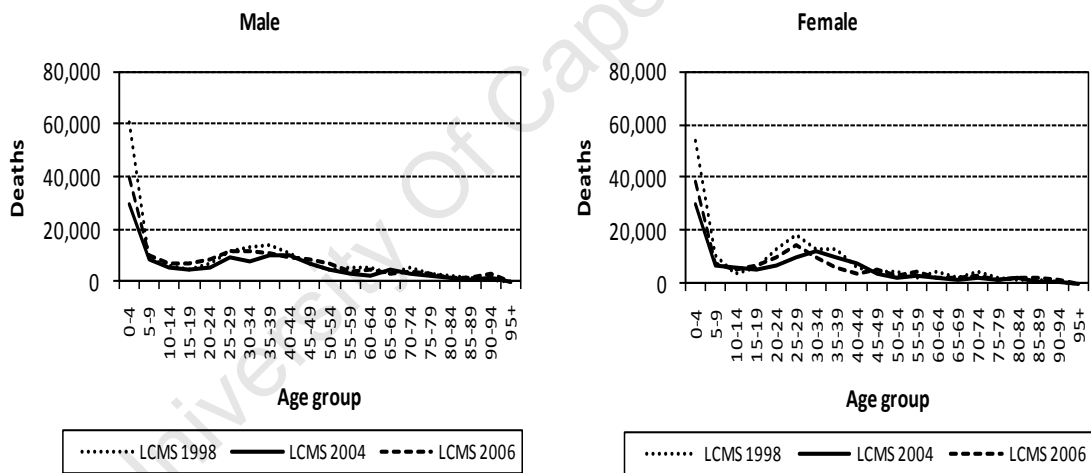


Figure 5.4 shows that reporting of under-five deaths varies by survey. The 1998 LCMS survey reported the highest number of under-five deaths while the 2006 LCMS survey collected the lowest. The variations in the reporting of under-five deaths among the LCMS surveys indicate that generally deaths are less complete in this age group than those of ages 5 and above. The figure shows higher mortality in age group 0-4 and in the reproductive age group 15-49 than in the other age groups. It is evident from the figure that more deaths are concentrated in the age group 20-44 and the peak of deaths is in the age group 25-29. The high

concentration of deaths in the reproductive age group 15-49 as evident in all the surveys could be attributed to the impact of the HIV and AIDS on mortality. Generally, the 1998 LCMS survey reported more deaths than the other surveys while the 1996 reported fewer deaths.

Figure 5.5 presents the number of household deaths in the last 12 months before the survey by age and sex. The 1996 LCMS survey did not collect household deaths by sex and is not included in the figure below. Figure 5.5 shows that there is higher male mortality in the age group 20-49 and more deaths are concentrated in the age group 25-39. The peak of the deaths is in the age group 30-39.

**Figure 5.5: Number of male and female household deaths in the last 12 months before the survey by age group and survey, LCMS 1998-2006**



There are more female deaths in the reproductive age group 15-49 than male deaths. Female deaths peak in the age group 20-29. Male mortality is higher than female mortality after the reproductive ages.

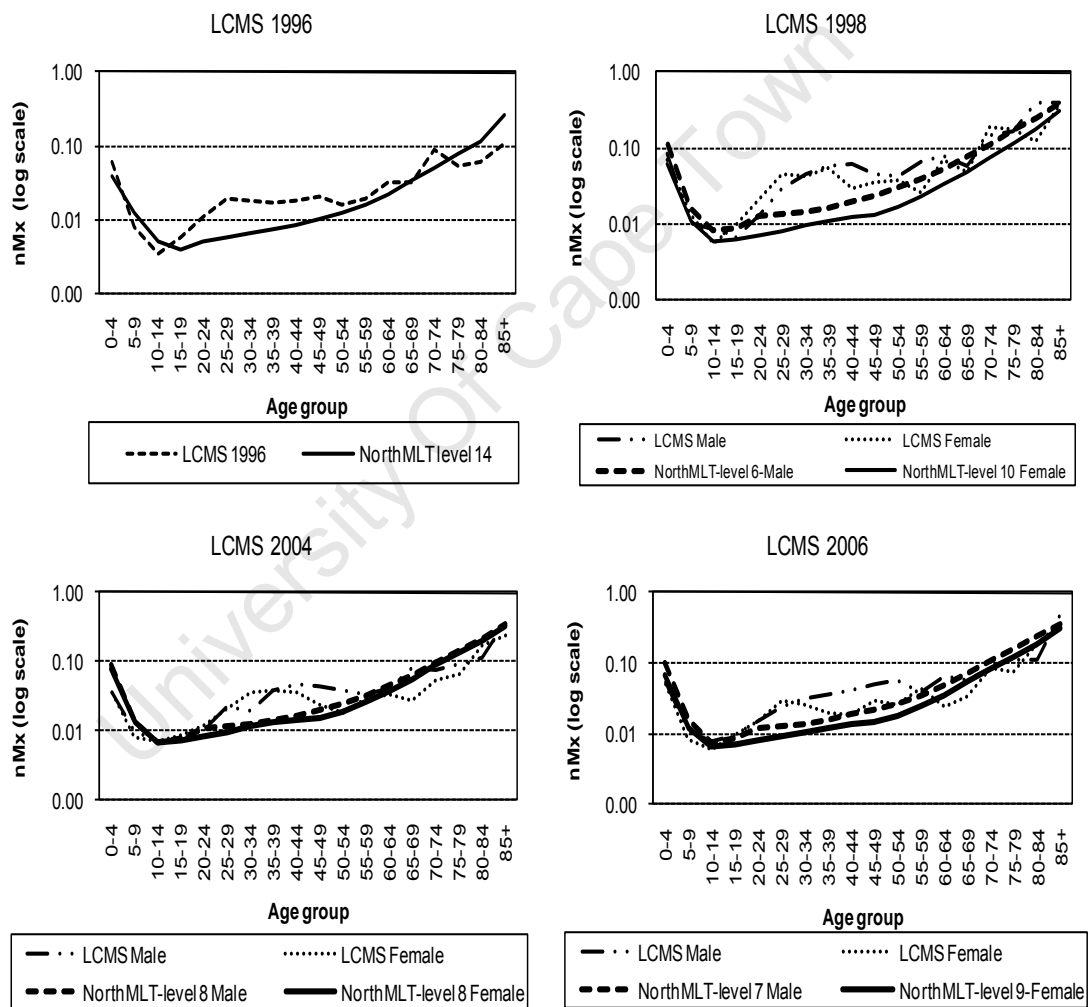
The overall sex ratios of household deaths in the last 12 months are 104, 106 and 118 males per 100 females for 1998, 2004 and 2006, respectively. The sex ratios indicate higher mortality for males than females generally.

Higher female mortality than male mortality in the reproductive ages (15-49) is consistent with the gender differences in the prevalence of HIV that have been observed. Female HIV prevalence is 1.3 times higher than that of males

(Central Statistical Office, Ministry of Health, Tropical Diseases Research Centre *et al.* 2009).

Figure 5.6 shows the age-specific mortality rates ( ${}_nM_x$ ), in logarithmic scale, computed from household deaths in the last 12 months collected by the surveys. A comparison is made with age-specific mortality rates ( ${}_nM_x$ ) computed from the Princeton North family of model life tables (Coale, Demeny and Vaughan 1983).

**Figure 5.6: Age-Specific Mortality Rates (log scale), LCMS 1996-2006**



The age-specific mortality rates of the age group 10-14 computed from the observed deaths are used to enter the model life tables and determine a suitable level of mortality that matches with that of the observed age group 10-14. The choice of the age group 10-14 to enter the model life tables is based on the

assumption that the HIV and AIDS epidemic does not heavily affect this age group. Figure 5.6 shows that the mortality pattern from the LCMS surveys across age groups follows an expected trend observed in most populations; higher mortality at under-five that declines rapidly in the age group 5-14 and then rises gradually in subsequent ages, with higher mortality in older ages.

The figure also shows mortality that is affected by the HIV and AIDS epidemic as evidenced by the high concentration of mortality in the reproductive age group 15-49 for both males and females. This pattern of mortality is not common in populations less affected by the AIDS epidemic. A comparison of the age-specific mortality rates computed from LCMS survey household deaths with those obtained from the Princeton North model life tables (Coale, Demeny and Vaughan 1983) clearly shows that the Zambian mortality pattern does not match that of model life tables in these times of the AIDS epidemic. All the LCMS surveys show evidence of the impact of the AIDS epidemic on mortality in the reproductive age group while the Princeton North model life tables (Coale, Demeny and Vaughan 1983) do not.

Household deaths in the last 12 months collected from surveys are prone to reference period errors, which result in omissions of deaths or overreporting of deaths not within the reference period as well as underreporting of deaths. The LCMS surveys collected deaths by asking households to report any deaths that occurred in the last 12 months before the survey. There was no dating involved such as the month and year of death.

Households were asked to report up to six deaths that occurred in the household in the last 12 months. Tabulations of deaths indicate age misreporting of the deceased persons at ages 65 and above. There are deaths with missing ages and those with missing sex. These are more pronounced at older ages.

Generally, household deaths in the last 12 months collected by surveys have been found to be unreliable due to underreporting of deaths (Dorrington, Timaeus and Gregson 2007); however, they do provide an overall picture of the pattern of mortality in a population.

## 5.2.2 *Methods*

### 5.2.2.1 *Generalized Growth Balance (GGB)*

We decided to drop the 1998 LCMS survey due to errors in the household deaths which we could not resolve. For instance, the survey collected more household deaths than expected in a year; indicating a problem with at least period referencing.

Data quality evaluation has been performed on age distribution by sex, and household deaths of all the surveys as elaborated above. Age distributions of populations by sex are obtained from tabulations using the household roster file. Unstated ages were redistributed while cases with missing age and sex were treated as missing. Cases of individuals with missing sex but with age were also treated as missing especially at older ages (it is easier to know someone's sex and not to remember his/her age). Tabulations by age show heaping at older ages especially above 65 years.

Sex ratios do not decline gradually as expected, an indication of problems in the data. Graphs of population age distribution by percentage and absolute numbers, however, show the expected pattern of declining progressively with age as shown in the figures above. To minimise the effect of age exaggeration observed for ages 65 years and above on the mortality estimates, the open-ended age interval was adjusted from 85+ to 65+.

Deaths are obtained from the question asked on deaths in the household in the last 12 months, which is a separate file in the LCMS raw data. Tabulations of deaths indicate that there are a lot of deaths at older ages included in ages 65 years and above. An effort was made to ensure that false entries at old ages were minimised and cases lacking complete information on deaths were removed. It is worth noting here again that the 1996 LCMS collected household deaths by age but not by sex.

The final datasets we have to work with that are of reasonable quality are the 1996, 2004 and 2006 LCMS. We first apply the GGB method to the 2004 and 2006 LCMS data by sex (males and females separately); and then, apply GGB method to both sexes combined to represent the national total estimates. For the

national total, we have estimates for the following periods: first, a two-year period 2004-2006; second, an eight-year period 1996-2004; and third, a ten-year period 1996-2006.

In order to apply the GGB method, the age and sex population distributions from the surveys are smoothed using Arriaga's light smoothing procedure to smooth out random fluctuations from the population age distribution (Arriaga 1994), and then inter-survey deaths were estimated from the growth rate using the number of reported deaths from the first survey and the next survey.

The age-specific growth rates of household deaths between two successive surveys are calculated taking into account the time interval between the surveys. Household deaths by age in the first survey are the initial deaths ( $D_{(0)}$ ) in the integration and the time interval between the two surveys determines the period for which deaths are cumulated. Thus total deaths are obtained as:

$D_{(0,T)} = \int_0^T D_{(0)} e^{rt} .dt$ , which reduces to  $D_{(0,T)} = \frac{D_{(0)}}{r} [e^{rt} - 1]$ , where  $r$  is the growth rate; and  $t$  is the time interval between surveys in years.

To obtain reasonably robust straight line fits for the GGB method, we fit the straight line to the age ranges 5+ to 55+ for males and 10+ to 60+ for females.

After a reasonable fit of the straight line, deaths are adjusted using the slope of the line. We use the adjusted deaths to generate a life table with life expectancies at age 5 and above from which we infer the adult mortality rates. From the generated life tables, we compute the adult mortality rates  ${}_{45}q_{15}$  which we compare with estimates from other sources.

### 5.2.2.1 Bennett-Horiuchi (*Synthetic Extinct Generations*)

The Bennett-Horiuchi (SEG) method uses data from two population enumerations as well as deaths reported in the intercensal or inter-survey period. Noting all data assessments and adjustments to population enumerations and deaths reported in the LCMS surveys as mentioned under the GGB method, we then applied the

Bennett-Horiuchi (SEG) method to estimate the completeness of reporting of deaths.

Since the Bennett-Horiuchi (SEG) method is sensitive to differential coverage of the two surveys, which affects the estimated growth rates. To correct this problem we use the “Extended SEG” (Bennett and Horiuchi 1981; Hill, You and Choi 2009) by introducing ‘delta’ a factor for correcting the differential coverage of the surveys and make adjustments to balance the ratio of the estimated and observed populations. We adjusted ‘delta’ iteratively until the plot of the level of completeness by age as far as possible across a range of some ages. To confirm our results obtained by this method we employed an alternative method that corrects for the same problem of differential coverage of two surveys, the “Combined GGB-SEG” (Hill and Choi 2004; Hill, You and Choi 2009). To apply the method, the GGB method is first used to estimate the survey coverage, and which in turn is used to adjust the survey population with respect to the estimated coverage change, and then the SEG method is applied. The “Extended SEG” method and “Combined GGB-SEG” method yield the same results. Life tables with life expectancies at age 5 and above, generated from these two methods are then used to estimate the adult mortality rate  ${}_{45}q_{15}$ . We then compare our estimated adult mortality rates with estimates from other sources.

### **5.3 Generalized Growth Balance and Synthetic Extinct Generations**

#### **Methods Results**

Results obtained from the application of the Generalised Growth Balance (GGB) method and the Bennett-Horiuchi’s Synthetic Extinct Generations (SEG) method to household deaths and population enumeration in the LCMS surveys are presented below. Section 5.3.1 presents results of completeness of death and population enumeration and Section 5.3.2 presents adult mortality estimates derived by applying the two methods after making adjustments to deaths and populations reported by the surveys.

### 5.3.1 Completeness

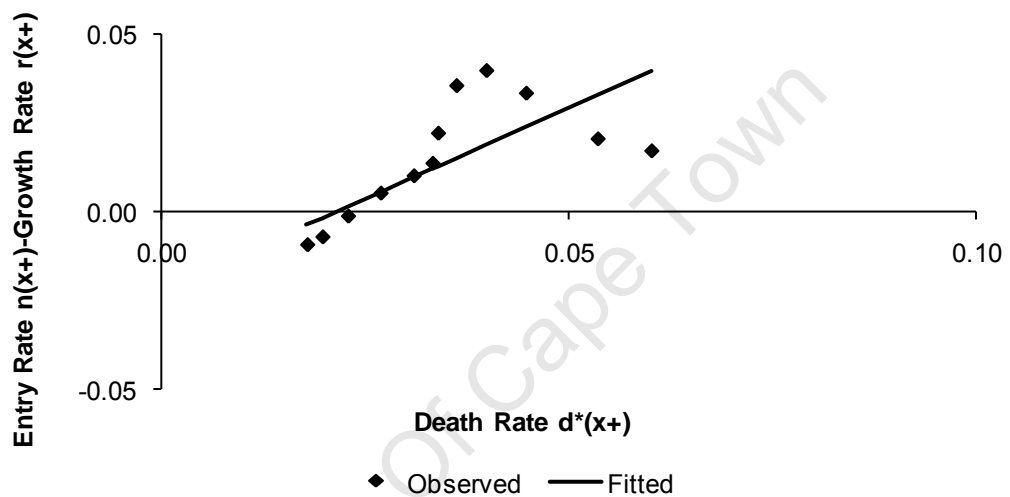
To estimate the completeness of death and population reporting in the surveys we fit straight lines to data points in the age range 5+ to 60+ using the robust straight line fitting method. Hill (1987) recommends that to minimise errors due to age exaggeration of deaths at older ages, the fitting of line should be done to data points below the age of 60. Hill, You and Choi (2009) also recommend fitting to the age range 5+ to 65+ because it covers late child and most adult experience and produces more stable results. The assessment of age data obtained by the LCMS surveys indicates that there is age exaggeration at older ages above 65 years. Therefore, we decided to fit the straight lines to data points in the age range 5+ to 60+. This is supported by the several combinations of age ranges we tried out in fitting the lines to data points (results not shown here), the age range 5+ to 60+ produced relatively stable results. Another age range that has been used in other studies is the 15+ to 55+ because it covers the adult mortality age group, 15 to 60 years, for which the common mortality index, the probability of a 15 year old person dying before reaching age 60, is computed. In our computations, fitting lines to data points in the age range 15+ to 55+ did not produce stable results in most instances using the LCMS survey household deaths and population data.

Results of applying the GGB method are easily understood when presented in graphical form as this facilitates visual inspection of patterns and goodness of fit. Figure 5.7 presents a scatter plot of the entry rate minus growth rate against the death rate for females in the inter-survey period 2004-2006. The y-axis represents the death rate for ages  $x+$  obtained by the difference between the entry rate  $x+$  and the growth rate  $x+$ , and the x-axis represents the observed death rate for ages  $x+$ . The slope of the fitted data points provides an adjustment factor needed to correct the observed death rates to the estimated death rates (entry rate minus growth rate). The intercept, on the other hand, provides an estimate of the relative completeness between the two surveys being used in the analysis.

Figure 5.7 shows that the fit of the observations to a straight line are not good for the inter-survey period 2004-2006 for females. This indicates that there is age misreporting in both the deaths and population for females. Age segments 5+ to

10+ and 35+ to 60+ are outside the fitted line indicating problems in death and population reporting by age. Figure 5.7 indicates that the GGB method has not worked well for females for the inter-survey period. The plot confirms the existence of age exaggeration in the reporting of deaths and population at older ages.

**Figure 5.7: Female plot of entry rate minus growth rate against death rate, Generalised Growth Balance Method, LCMS 2004-2006**



The results of a diagnostic plot of applying the Extended SEG method to estimate completeness of household deaths and population reporting for females in the inter-survey period 2004-2006 are presented in Figure 5.8. The figure shows that completeness (Ratio  $c(x)$ ) of reporting of female adult deaths varies by age and falls progressively with age, except at older ages. This result is not very different from the plot obtained by GGB method above. Figure 5.8 indicates that completeness of reporting of female adult deaths is below 1 from ages 20 to 50, suggesting underreporting of deaths in these ages.

The figure also shows clear exaggeration of age at death as indicated by the big increase for females at older ages 60+. It should be noted that prior to applying the Extended SEG method completeness of reporting of female adult deaths ascended by age due to changes in survey coverage. Hill and Choi (2004) and Hill, You and Choi (2009) note that this problem of change in survey

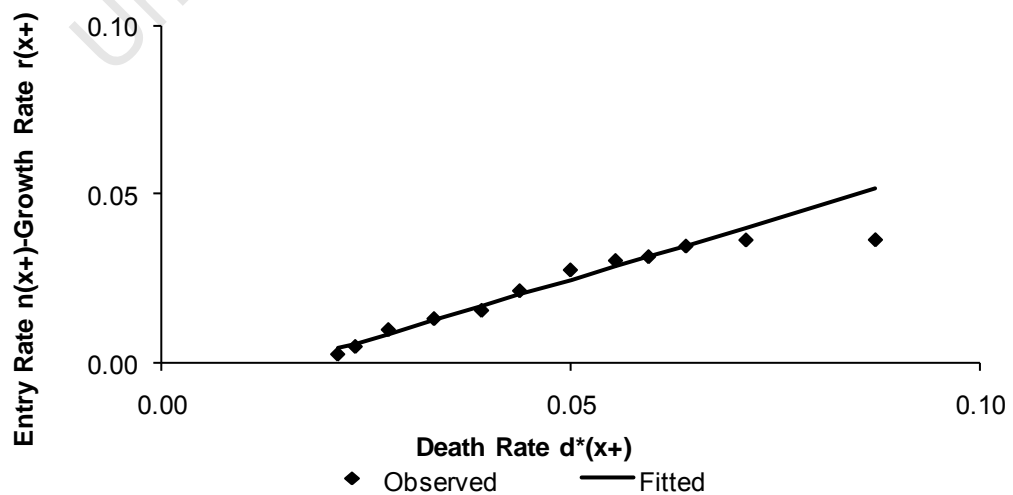
coverage is overcome by applying the Extended SEG method or the Combined GGB plus SEG method described earlier. The basic SEG method yields different results from the Extended SEG and the Combined GGB plus SEG.

**Figure 5.8: Estimated female completeness of death reporting by Extended Synthetic Extinct Generations Method, LCMS 2004-2006**



Figure 5.9 presents a scatter plot of the entry rate minus growth rate against the death rate for males in the inter-survey period 2004-2006.

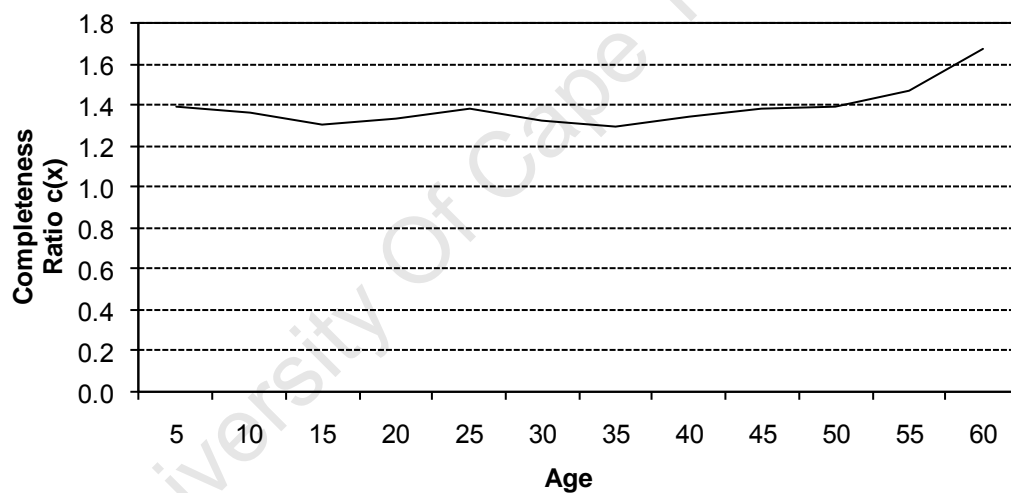
**Figure 5.9: Male plot of entry rate minus growth rate against death rate, by Generalised Growth Balance Method, LCMS 2004-2006**



The figure shows a good fit of the data points, except for age segments 55+ to 60+ that do not lie on the fitted line. The good fit for males indicates that age reporting for deaths and population in the inter-survey period 2004-2006 was less problematic than that of females. This also shows that the GGB method has worked well for males than females.

Figure 5.10 presents a diagnostic plot of applying the Extended SEG method to estimate completeness of household deaths and population reporting for males in the inter-survey period 2004-2006.

**Figure 5.10: Estimated adult male completeness of death reporting by Extended Synthetic Extinct Generations Method, LCMS 2004-2006**



The figure shows that completeness of the reporting of male adult deaths is most constant across ages, age variations are not very pronounced, except for ages 55 and above that exhibit exaggeration of age at death reporting. The figure also shows that levels of completeness for males are higher across all ages when compared to those of females. Dorrington, Timaeus and Gregson (2007) found a similar pattern of results of sex differential completeness of death reporting among Africans. Thomas and Hill (2007) also found a similar pattern of results for Lesotho. Figure 5.10 also shows that the levels of completeness of death reporting for males are above 1 across all ages, suggesting overreporting of male household deaths.

Table 5.1 presents the estimated levels of completeness of reporting of deaths by sex in the inter-survey period 2004-2006. The table shows that the level of completeness of death for males estimated by the GGB method is 137.8 per cent while for females it is 95.4 per cent. The Extended SEG method estimates the level of completeness at 137.1 per cent for males and 93.6 per cent for females. It is evident from all the methods that there are chances of overreporting of male deaths and slight underreporting of female deaths relative to the survey populations.

**Table 5.1: Relative Completeness of Household deaths by Sex, LCMS 2004-2006, Zambia**

Indicator and Method	Males	Females
GGB	1.378	0.954
Extended SEG	1.371	0.936
Combined GGB+SEG	1.404	0.916
k1/k2	0.978	0.956

The intercept ( $k1/k2$ ) indicates better coverage of the 2006 LCMS survey population relative to the 2004 LCMS survey population for both males and females. The estimates show that male coverage was 2 per cent and female coverage was 4 per cent more complete in the 2006 LCMS survey relative to the 2004 LCMS survey.

Figure 5.11 presents a scatter plot of the entry rate minus growth rate against the death rate combined for males and females in the inter-survey period 2004-2006. The figure shows a poor fit, age segments 35+ to 45+ and 50+ to 60+ lie off the fitted line.

Figure 5.12 presents a diagnostic plot of applying the Extended SEG method to estimate completeness of household deaths and population reporting for both sexes in the inter-survey period 2004-2006. The figure shows that completeness of reporting of deaths is constant for age segments 5+ to 30+. For age segments 35+ to 45+ completeness of reporting is below 1 while for age segments 50+ to 60+ there is evidence of exaggeration of age of deaths relative to the population.

Figure 5.11: Combined male and female plot of entry rate minus growth rate against death rate, by Generalised Growth Balance Method, LCMS 2004-2006

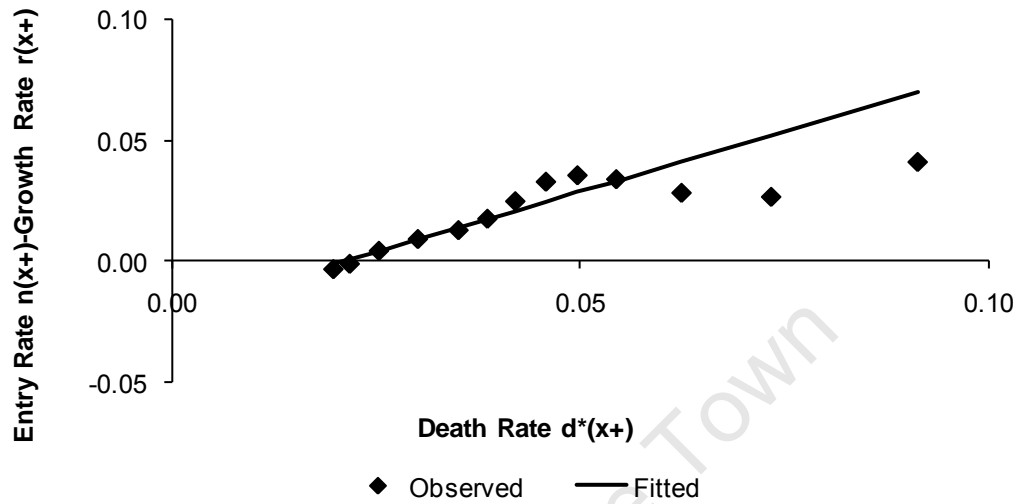


Figure 5.12: Estimated combined male and female completeness of death reporting by Extended Synthetic Extinct Generations Method, LCMS 2004-2006

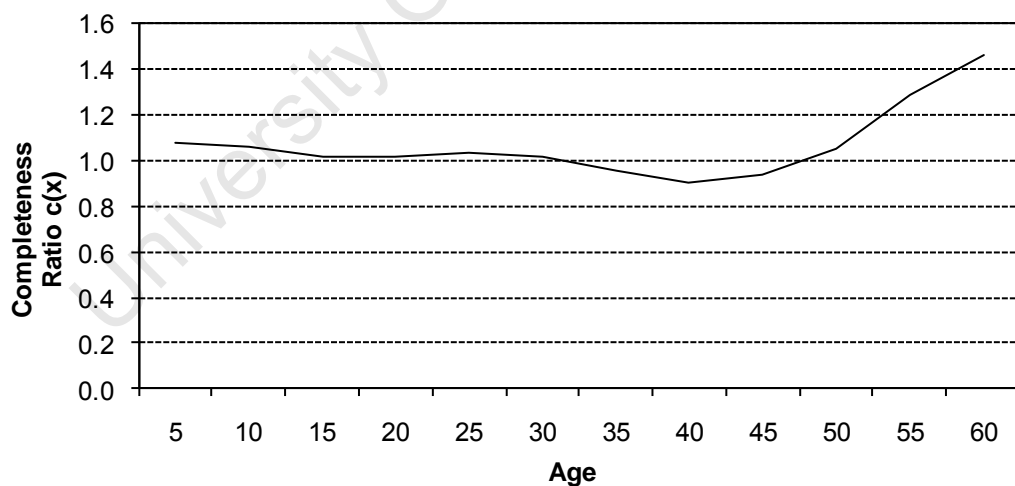
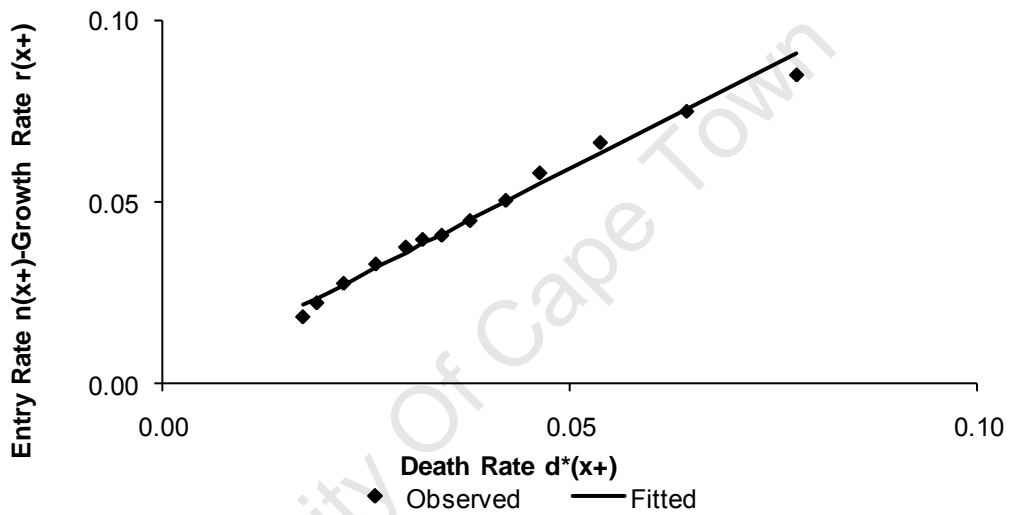


Figure 5.13 presents a scatter plot of the entry rate minus growth rate against the death rate combined for males and females in the inter-survey period 1996-2004. The figure shows a good fit, age segments that lie off the fitted line are not very far from the line. The fit indicates that the method has worked well for the inter-survey period 1996-2004. Figure 5.14 shows a diagnostic plot of applying the Extended SEG method to estimate completeness of household deaths and

population reporting for both sexes in the inter-survey period 1996-2004. The figure shows that completeness of reporting of deaths in the eight-year inter-survey period has been largely constant with respect to age, with minor age variations. The level of completeness of reporting of deaths is below 1 across all ages indicating underreporting of deaths during the period.

**Figure 5.13: Combined male and female plot of entry rate minus growth rate against death rate, by Generalised Growth Balance Method, LCMS 1996 - 2004**



**Figure 5.14: Estimated combined male and female completeness of death reporting by Extended Synthetic Extinct Generations Method, LCMS 1996 - 2004**

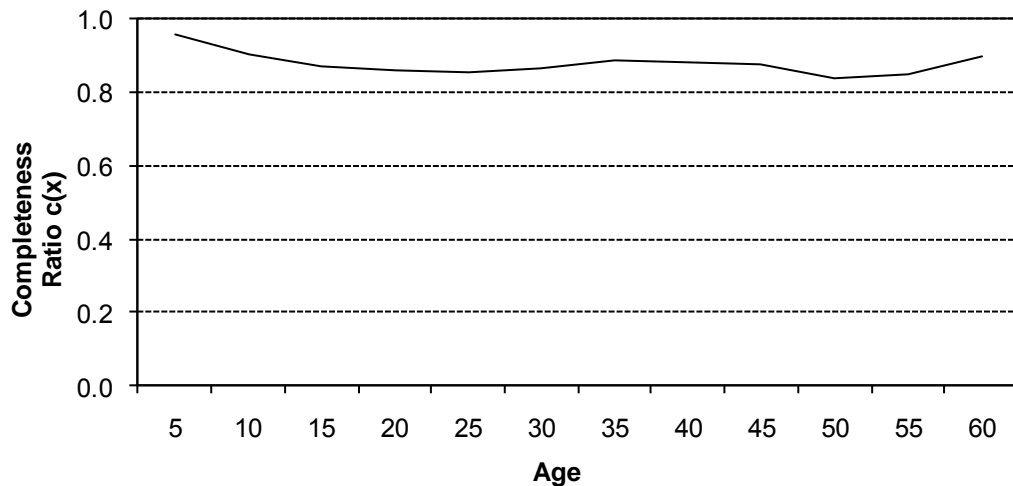


Figure 5.15 presents a scatter plot of the entry rate minus growth rate against the death rate for males and females combined in the inter-survey period 1996-2006.

**Figure 5.15: Combined male and female plot of entry rate minus growth rate against death rate, by Generalised Growth Balance Method, LCMS 1996 - 2006**

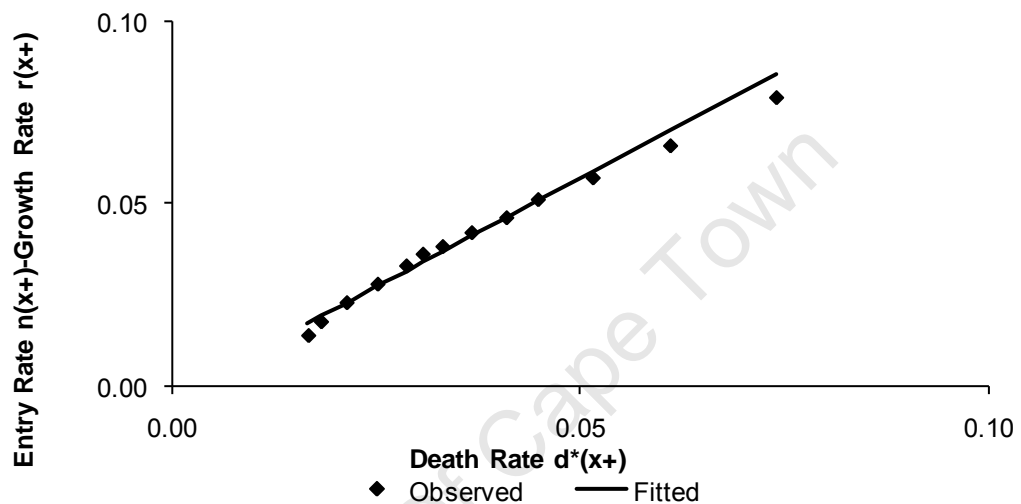


Figure 5.15 shows a good fit to the data points, though age segments 5+, 55+ to 60+ lie off the fitted line. The good fit indicates that the GGB method has worked well to estimate completeness for the ten-year period.

Figure 5.16 above shows a diagnostic plot of applying the Extended SEG method to estimate completeness of household deaths and population reporting for both sexes in the inter-survey period 1996-2006. The figure shows that completeness of reporting of deaths in the 10 year period has been largely constant with respect to age. The level of completeness of reporting of deaths is below 1 indicating underreporting of deaths.

**Figure 5.16: Estimated combined male and female completeness of death reporting by Extended Synthetic Extinct Generations Method, LCMS 1996 – 2006**

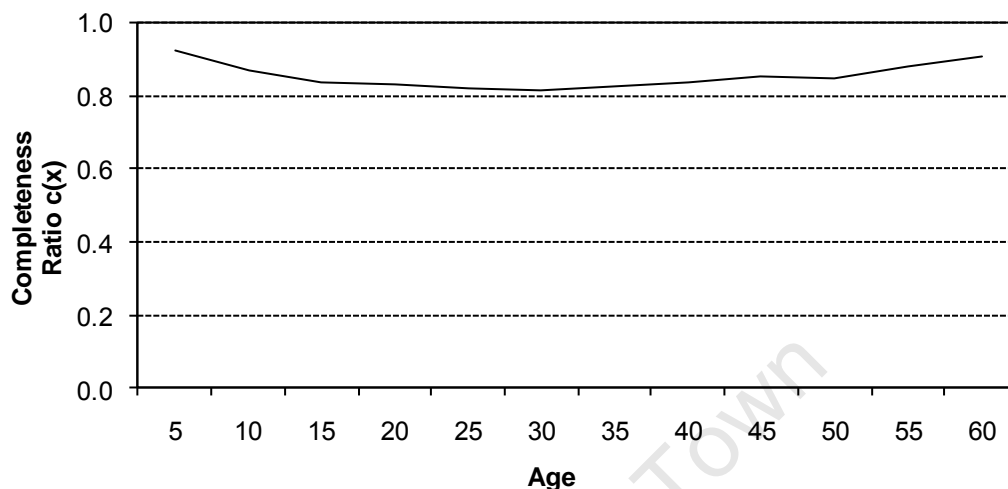


Table 5.2 below presents the relative completeness of reporting of deaths estimated by the GGB and SEG methods in the three inter-survey periods.

**Table 5.2: Relative Completeness of Household deaths by Inter-survey Period, LCMS 1996-2006, Zambia**

Indicator and Method	Inter-survey Period		
	1996-2004	1996-2006	2004-2006
GGB	0.865	0.830	0.987
Extended SEG	0.871	0.843	1.011
Combined GGB+SEG	0.864	0.832	0.990
k1/k2	1.016	0.975	0.959

The table shows that completeness of reporting of deaths estimated by the GGB method in the 1996-2004 period was 86.5 per cent; 83 per cent in the 1996-2006 period; and 98.7 per cent in the 2004-2006 period. The Extended SEG method estimated completeness at 87.1 per cent, 84.3 per cent and 101.1 per cent for the 1996-2004, 1996-2006 and 2004-2006 periods, respectively. Again it can be noted that the Extended SEG method produces higher values of the completeness of reporting of deaths than the GGB method.

### 5.3.2 Adult Mortality Estimates

The summary measure of adult mortality used here is the probability of a 15 year old person dying before reaching age 60. Table 5.3 presents the probability of a 15 year old person dying before reaching age 60 by sex for the inter-survey period 2004-2006. After adjustments, the GGB method estimates that 63 per cent of males and 67 per cent of females would die before celebrating their 60th birthday.

**Table 5.3: Adult probability of a 15 year old person dying before reaching age 60 ( ${}_{45}q_{15}$ ) by Sex, LCMS 2004-2006, Zambia**

Method	Males	Females
GGB	0.6345	0.6739
Extended SEG	0.6405	0.6890
Combined GGB+SEG	0.6276	0.6890

The Extended SEG method and the Combined GGB plus SEG method estimate the same value of the probability of a 15 year old person dying before reaching age 60, for females, 69 per cent as expected. The estimated level of mortality for females is close to those obtained by Bradshaw and Timaeus (2006) and WHO (2006). For males, the methods produce the very similar values of the summary measure of adult mortality (Extended SEG, 64 per cent and Combined GGB plus SEG, 63 per cent). It can be noted that in the inter-survey period 2004-2006, adult female mortality is higher than adult male mortality. This pattern of sex differentials in adult mortality has also been observed by the 2007 Zambia Demographic and Health Survey report from recent direct adult mortality estimates based on sibling histories.

Table 5.4 presents the combined male and female probabilities of a 15 year old person dying before reaching age 60 for Zambia for the three inter-survey periods, 2004-2006 which represents adult mortality in a two-year period; 1996-2004 representing adult mortality for an eight-year period; and the 1996-2006 period represents adult mortality for a duration of ten years. The 2004-2006 period represents the most recent adult mortality, and the probability that all 15 year olds in Zambia would die before celebrating their 60th birthday is 70 per cent.

**Table 5.4: Adult probability of a 15 year old person dying before reaching age 60 ( ${}_{45}q_{15}$ ) by Inter-survey Period, LCMS 1996-2006, Zambia**

Method	Inter-survey Period		
	1996-2004	1996-2006	2004-2006
GGB	0.6950	0.6965	0.7101
Extended SEG	0.6957	0.6957	0.7090
Combined GGB+SEG	0.6957	0.6957	0.7090

The GGB, Extended SEG, and Combined GGB plus SEG methods estimate approximately the same probability of a 15 year old person dying before reaching age 60. It can be noted that the probability of a 15 year old person dying before reaching age 60, for the two inter-survey periods 1996-2004 and 1996-2006, has remained consistent at about 70 per cent. The Extended SEG method and Combined GGB plus SEG method produce the same results for the two periods. The GGB method on the other hand produces slightly different results during the same period. It can be observed from both Table 5.3 and Table 5.4 that the Extended SEG method produces slightly higher adult mortality estimates than the GGB method.

#### **5.4. Comparison of levels and trends of adult mortality estimates derived from the six methods**

In this section we compare the levels and trends of the probability of a 15 year old person dying before reaching age 60 derived from the six main adult mortality estimation methods used in our analyses.

Figure 5.17 presents the probabilities of a 15 year old person dying before reaching age 60 for females derived from the six adult mortality estimation methods. As noted earlier, the UNPD estimates are used for comparing the derived mortality rates by the different methods and are not a “gold” standard. The Preston-Bennett method estimates the probability of a 15 year old female person dying before reaching age 60 at about 50 per cent around the mid-1980s, this increased to 70 per cent in the mid-1990s. However, these estimates are above the UNPD estimates indicating that they are unreliable.

Estimates of female adult mortality derived from the siblinghood method indicate that the probability of a 15 year old person dying before reaching age 60

ranged from 40 per cent in the mid-1990s to 70 per cent around 2000s period. Estimates of the level of female adult mortality before the year 2003 are lower than UNPD estimates.

Adult mortality rates for females derived by the orphanhood method estimate the probability of a 15 year old female person dying before reaching age 60 at 50 per cent from the late 1990s to mid-2000s. However, these estimates are lower than the UNPD estimates probably due to adoption effect.

The Extended SEG method estimates the probability of a 15 year old female person dying before reaching age 60 at about 69 per cent around mid-2000s. This estimate is higher than the UNPD estimate.

**Figure 5.17: Adult female probability of a 15 year old person dying before reaching age 60, ( ${}_{45}q_{15}$ ): Estimates from various sources and methods, Zambia 1980 - 2007**

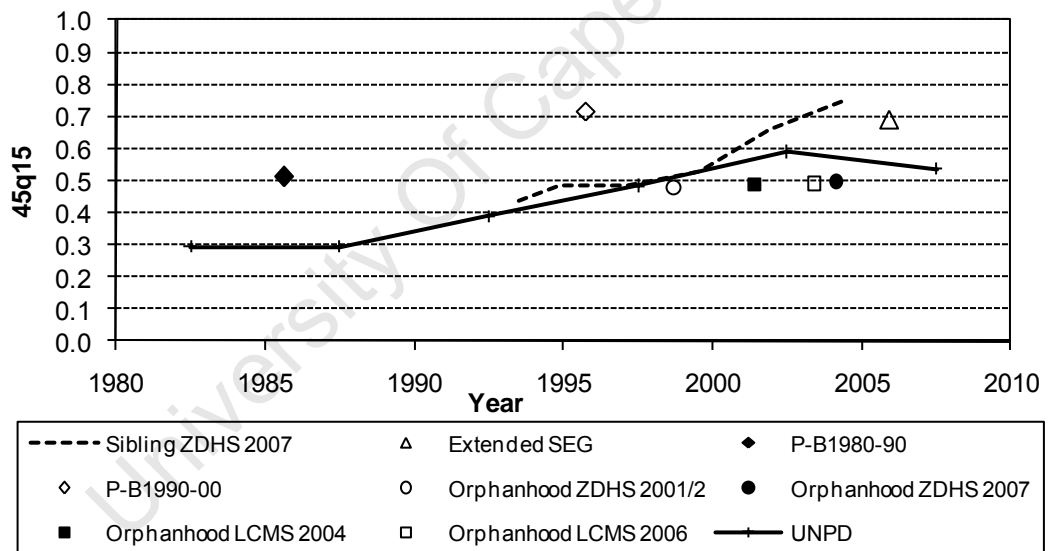
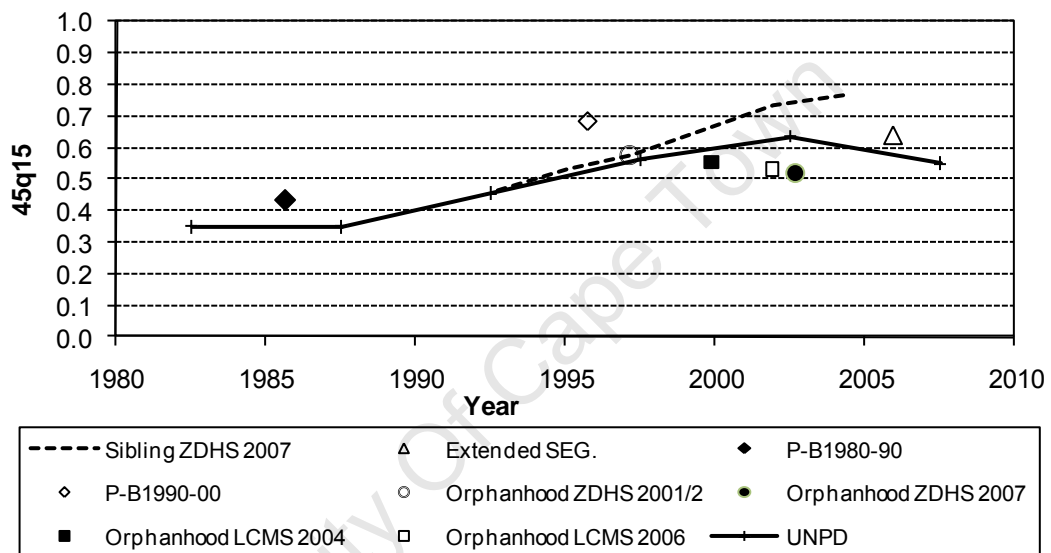


Figure 5.18 shows the estimates of the probability of a 15 year old male person dying before reaching age 60 by the various methods. The Preston-Bennett method estimates  ${}_{45}q_{15}$  at about 40 per cent in the mid-1980s this increased to about 65 per cent in the mid-1990s. These estimates are consistent with those of the UNPD for the same periods as shown in Figure 5.18. Since the Preston-Bennett method is sensitive to age misreporting, this could be attributed to better age reporting among males than females as shown in the data assessment section.

The orphanhood method estimates  ${}_{45}q_{15}$  at about 50 per cent around the 2000s period. The estimates are lower than the UNPD estimates of  ${}_{45}q_{15}$  due to the absentee effect. The siblinghood method estimates  ${}_{45}q_{15}$  ranging from 45 per cent in the mid-1990s to 70 per cent around 2000s. The estimates prior to 2000 are lower than UNPD estimates.

**Figure 5.18: Adult male probability of a 15 year old person dying before reaching age 60, ( ${}_{45}q_{15}$ ): Estimates from various sources and methods, Zambia 1980 - 2007**



The Extended SEG method estimates  ${}_{45}q_{15}$  at about 60 per cent around mid-2000s. This estimate is consistent with the UNPD estimate. Again, the data assessment indicates that males reported their ages better than females in the LCMS surveys.

Though we have used the UNPD mortality estimates as a reference to check the level and trend of our adult mortality estimates, they too, may have their own deficiencies related to the quality of data and methods used to derive the estimates. This means that UNPD mortality estimates are subject to some uncertainty as well and this needs to be borne in mind when considering the comparisons.

The next chapter presents the discussion and conclusions of the study.

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## 6 DISCUSSION AND CONCLUSIONS

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The knowledge of levels and trends of adult mortality in African countries like Zambia is restricted by the incomplete coverage of the vital registration system. It is therefore imperative that we make full use of existing data to understand the levels and trends of adult mortality in order, inter alia, to monitor the impact of the AIDS epidemic as well as design appropriate policies and programmatic interventions.

The objective of this study was to derive robust and reliable estimates of the level of and trend in adult mortality for Zambia by applying indirect methods of adult mortality estimation to Census, Demographic and Health Survey and Living Conditions Monitoring Survey data.

Six methods were employed in the study in accordance to the nature of available data, Census Survival Method; Preston-Bennett methods; Orphanhood method; Siblinghood method; Generalised Growth Balance method; and Synthetic Extinct Generations method.

The study introduced new areas of focus, first, the study used the growth rate in the number of reported deaths in the first survey and the next survey to obtain inter-survey deaths when applying the death distribution methods. This method is considered more accurate. Second, the study used the UNPD life tables as standard for converting conditional survival probabilities into life table probabilities with the orphanhood and siblinghood methods instead of the commonly available model life tables such as the Brass General Standard (Brass, Coale, Demeny *et al.* 1968) or Princeton model life tables (Coale, Demeny and Vaughan 1983). The reasons for this are: one, the commonly available model life tables do not incorporate HIV and AIDS making them inappropriate for use in populations affected by the AIDS epidemic like Zambia. We were able to derive period standard life tables for Zambia that account for the HIV and AIDS epidemic using UNPD population estimates and projections data incorporating the AIDS epidemic, and used them to translate estimated conditional survival

probabilities into common mortality indices. Two, we were able to use mortality estimates derived from the UNPD life tables as a way of comparing our estimates to existing ones to check the level and trend of adult mortality in Zambia. However, UNPD mortality estimates are not a “gold” standard as they may also be subject to some error.

The study used underutilised data from the Living Conditions Monitoring Surveys to estimate levels and trends of adult mortality using death distribution methods. The data from the Living Conditions Monitoring Surveys posed a lot of challenges as their quality is not as good as those of the Demographic and Health Surveys. This meant a lot of time was spent interrogating and adjusting the data for it to be usable. The 1998 LCMS survey had to be dropped due to problems we could not resolve in the death data. Some reasonable results were, however, obtained from the other surveys. It is encouraging that results obtained from applying the orphanhood method to 2002/3, 2004 and 2006 LCMS surveys were consistent with the 2001/2, and 2007 ZDHS surveys.

The study could not draw a definitive pattern of adult mortality from applying the siblinghood method. The estimates derived for both males and females are not consistent with UNPD estimates. Hence, the results from the siblinghood method cannot be compared with UNPD estimates. Sibling adult mortality rates based on reports of younger surviving respondents rise sharply for both males and female, this may be attributed to more surviving younger sibling respondents reporting on their older siblings than are surviving old siblings to report on their sibling. The range of the adult mortality rates are, however, around those of Obermeyer, Rajaratnam, Park *et al* (2009) and WHO (2006; 2009).

The study found that adult mortality rates estimated using the orphanhood method applied to LCMS and ZDHS surveys were consistent with those of the UNPD for the early to mid-1980s period in a number of cases. Around the 2000s, however, these estimates were lower possibly due to the problem of adoption effect.

The study first reproduced orphanhood mortality estimates by Timaeus and Jasseh (2004) and used these as a base to produce mortality estimates from ZDHS and LCMS survey orphanhood data. The study also reproduced the direct

DHS sibling adult mortality estimates in ZDHS reports as a way of validating our computations.

Results of the adult mortality rate  $_{45}q_{15}$  obtained by the Census Survival method and Preston-Bennett method were consistent with UNPD estimates for males and not females. This is because males reported their ages better than females as indicated in the data assessment. The Preston-Bennett method just like the Census Survival method does not provide an accurate estimate of the level of adult mortality but does indicate that adult mortality increased in Zambia in the second intercensal period and the probable reason could be attributed to the impact of the AIDS epidemic.

The Generalised Growth Balance method and the Bennett-Horiuchi (SEG) methods did not work well for LCMS female data for the intersurvey period 2004-2006. The problem could be attributed to inaccurate reporting of both deaths and population for females.

The GGB and Bennett-Horiuchi (SEG) methods, on the other hand, appear to have worked well for males fitting to age range 5+ to 60+. The application of "Extended SEG" and "Combined GGB-SEG" methods produced reasonable levels of completeness of death reporting. Adult mortality estimates are derived from the life tables constructed from adjusted deaths and age distributions for the 1996-2004 and 1996-2006 are plausible for Zambia. The GGB and "Extended SEG" results for female adult mortality in the 2004-2006 inter-survey period are in accord with the estimates derived by 2001/2 ZDHS and 2007 ZDHS indicating that female adult mortality is now higher than male adult mortality

It should be noted that with respect to the death distribution methods there is no consensus as to which method is better, what age ranges should be used to obtain the final result, and how to interpret the patterns of diagnostic plots. Therefore, because of the lack of consensus on these issues there is some uncertainty on estimates derived from these methods.

Overall, all the six methods applied to the three sets of data sources are in agreement that adult mortality in Zambia has increased. These adult mortality

estimates are within the ranges of estimates of levels and trends produced by other sources as well as those from models that use more data and assumptions.

Unfortunately the study has not managed to derive robust and reliable adult mortality estimates for Zambia, however, it has managed to derive estimates that are comparable to already existing adult mortality estimates using different types of indirect methods and data sources. The study has also used underutilised data sources (LCMS surveys) to derive adult mortality estimates that are comparable to the commonly available demographic sources (DHS surveys). It should also be noted that there is no 'gold standard' reference point which can be used to validate our adult mortality estimates whether they are robust and reliable.

Further research is needed to understand why the siblinghood method has not worked well to produce conclusive patterns of adult mortality estimates for both males and females. Another research is required to produce robust and reliable adult mortality estimates for Zambia using more refined methods since this study has set the base. Further research is required on how Generalised Growth Balance and Bennett-Horiuchi (SEG) methods can be further refined to perform well with survey data as data from this source is becoming more available.

The study makes the following recommendations: first, the vital registration system in Zambia needs investment in form of infrastructure, training of staff, Information Communication Technology (ICT) equipment for it to be able to produce high quality data that would enable us to estimate mortality rates directly; second, the 2010 Zambian census should include questions on household deaths that will capture age, sex, month and year of death. Questions on orphanhood (survival status of father or mother) should also be included and asked to all household members; third, the Demographic and Health Surveys should include questions on household deaths in the last year and should capture age, sex, month and year of death. In addition, orphanhood data should be collected from all household members, this will help in reducing the "adoption effect". Fourth, current questions on household deaths in the LCMS surveys should be improved to include the month and year of death to minimise time

reference problems of misplacing deaths to years in which they did not occur. Fifth, there is need for the LCMS survey to improve supervision on data processing so as to minimise errors in the data. In addition, more documentation is needed on the structure of the data, for example, a data dictionary or data user's guide.

Furthermore, in light of the study findings whereby the level of both male and female adult mortality is high in Zambia, the study recommends that health interventions should focus more on averting further increase in adult mortality. In the same vein, development programmes should pay more attention to addressing the socio-economic challenges that are consequences of high mortality in Zambia.

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## APPENDIX

**Table A.3.1: Application of the Ten-Year Census Survival Method to Zambia's Population, by sex: 1980-1990**

Age group (i)	Census Population		Age x (4)	Census Survival Ratio P2(x,10)/P1(x-10) (5)	Probability of survival	Probability of survival	Merged Probability of survival lx/2.5 (8)	Interpolated age x (9)	Probability of survival to age x lx/l2.5 (10)	Estimated Conditional life table functions				
	1980 P1(x,5) (2)	1990 P2(x,5) (3)			from age 2.5 years lx/2.5 (6)	from age 7.5 years lx/7.5 (7)				Person-years lived between exact age x and x+5 5Lx/l2.5 (11)	Total person years lived above age x Tx/l2.5 (12)	Estimated life expectancy from life table ex (13)	Estimated life expectancy from life table e5 (14)	
	(1)	(2)			(3)	(4)				(5)	(6)	(7)	(8)	(9)
<b>Males</b>														
0-4	507782	595163	2.5	1.0080	1.0000		1.0000							
5-9	491381	553193	7.5	0.9246			1.0000	1.0040	5	1.0020	5.0200	52.3086	52.20	52.20
10-14	384016	511845	12.5	0.8623	1.0080			1.0080	10	1.0060	4.9354	47.2886	47.01	49.41
15-19	284668	454345	17.5	0.8751			0.9246	0.9283	15	0.9682	4.6674	42.3532	43.75	50.02
20-24	221009	331150	22.5	0.9559	0.8692			0.8692	20	0.8988	4.3490	37.6858	41.93	52.55
25-29	163922	249108	27.5	0.8979			0.8091	0.8124	25	0.8408	4.1561	33.3369	39.65	54.37
30-34	137834	211268	32.5	0.9213	0.8309			0.8309	30	0.8216	4.0045	29.1808	35.52	53.60
35-39	111372	147181	37.5	0.9399			0.7265	0.7294	35	0.7802	3.8190	25.1763	32.27	54.39
40-44	103347	126980	42.5	0.8952	0.7655			0.7655	40	0.7474	3.6824	21.3573	28.57	54.43
45-49	94950	104678	47.5	0.7852			0.6828	0.6856	45	0.7255	3.5273	17.6749	24.36	53.07
50-54	77941	92512	52.5	0.7605	0.6852			0.6852	50	0.6854	3.2429	14.1476	20.64	52.47
55-59	54808	74552	57.5	0.7449			0.5361	0.5383	55	0.6118	2.8536	10.9047	17.83	53.96
60-64	48944	59273	62.5	0.6421	0.5211			0.5211	60	0.5297	2.4768	8.0511	15.20	56.28
65-69	35865	40825	67.5	0.5135			0.3994	0.4009	65	0.4610	2.0721	5.5742	12.09	56.13
70-74	22934	31429	72.5	0.3656	0.3346			0.3346	70	0.3678	1.5951	3.5022	9.52	57.02
75-79	15099	18415	77.5	0.2489			0.2050	0.2059	75	0.2702	1.0859	1.9071	7.06	56.26
80-84	7439	8385	82.5		0.1223			0.1223	80	0.1641		0.8212	5.00	54.70
85+	6683	7274												
<b>Females</b>														
0-4	512245	603365	2.5	1.0081	1.0000			1.0000						
5-9	492890	564638	7.5	0.9841			1.0000	1.0041	5	1.0020	5.0203	50.9411	50.84	50.84
10-14	384375	516401	12.5	0.9943	1.0081			1.0081	10	1.0061	5.0105	45.9208	45.64	47.37
15-19	308299	485050	17.5	0.9264			0.9841	0.9881	15	0.9981	4.9833	40.9104	40.99	45.80
20-24	268452	382178	22.5	0.8181	1.0024			1.0024	20	0.9952	4.8852	35.9271	36.10	43.76
25-29	184177	285600	27.5	0.8174			0.9116	0.9153	25	0.9588	4.5664	31.0419	32.37	42.97
30-34	164235	219634	32.5	0.8496	0.8201			0.8201	30	0.8677	4.1296	26.4756	30.51	44.81
35-39	133930	150543	37.5	0.8232			0.7452	0.7482	35	0.7841	3.7665	22.3460	28.50	46.59
40-44	116233	139541	42.5	0.8618	0.6968			0.6968	40	0.7225	3.4470	18.5795	25.72	47.18
45-49	88038	110255	47.5	0.7582			0.6134	0.6159	45	0.6563	3.1613	15.1325	23.06	48.37
50-54	72416	100165	52.5	0.7829	0.6004			0.6004	50	0.6082	2.8547	11.9712	19.68	48.37
55-59	46084	66747	57.5	0.7235			0.4651	0.4670	55	0.5337	2.5056	9.1164	17.08	50.40
60-64	45969	56697	62.5	0.5500	0.4701			0.4701	60	0.4685	2.1813	6.6108	14.11	51.20
65-69	28226	33341	67.5	0.4220			0.3365	0.3378	65	0.4040	1.7555	4.4295	10.96	50.43
70-74	20610	25285	72.5	0.3694	0.2586			0.2586	70	0.2982	1.2470	2.6740	8.97	52.99
75-79	11920	11912	77.5	0.2558			0.1420	0.1426	75	0.2006	0.7991	1.4271	7.11	55.29
80-84	7428	7614	82.5		0.0955			0.0955	80	0.1191		0.6280	5.28	55.91
85+	6278	6555												

Source: Central Statistical Office Census Tables (Central Statistical Office[Zambia]. 1985, 1994). Author's computations.

**Table A.3.2: Application of the Ten-Year Census Survival Method to Zambia's Population, by sex: 1990-2000**

Age group (i)	Census Population		Age x	Census Survival Ratio $P2(x,10)/P1(x-10)$	Probability	Probability	Merged Probability of survival $lx/2.5$	Interpolated age x	Probability of survival to age x $lx/2.5$	Estimated Conditional life table functions				
	1990 $P1(x,5)$	2000 $P2(x,5)$			of survival from age 2.5 years $lx/2.5$	of survival from age 7.5 years $lx/7.5$				Person-years lived between exact age x and x+5 $5Lx/2.5$	Total person years lived above age x $Tx/2.5$	Life expectancy at age x $ex$	Estimated life expectancy from life table $e5$	
	(2)	(3)			(6)	(7)				(8)	(11)	(12)	(13)	(14)
<b>Males</b>														
0-4	595,163	825,789	2.5	1.0103	1.0000		1.0000							
5-9	553,193	729,181	7.5	0.9279		1.0000	1.0051	5	1.0026	5.0257	43.0831	42.97	42.97	
10-14	511,845	601,279	12.5	0.8129	1.0103		1.0103	10	1.0077	4.9480	38.0574	37.77	38.75	
15-19	454,345	513,320	17.5	0.7965		0.9279	0.9327	15	0.9715	4.6211	33.1094	34.08	38.06	
20-24	331,150	416,083	22.5	0.8529	0.8213		0.8213	20	0.8770	4.1477	28.4883	32.48	40.14	
25-29	249,108	361,901	27.5	0.8485		0.7391	0.7429	25	0.7821	3.7594	24.3406	31.12	42.14	
30-34	211,268	282,439	32.5	0.7629	0.7005		0.7005	30	0.7217	3.4677	20.5812	28.52	42.68	
35-39	147,181	211,356	37.5	0.8322		0.6271	0.6303	35	0.6654	3.1194	17.1135	25.72	43.14	
40-44	126,980	161,179	42.5	0.7706	0.5344		0.5344	40	0.5824	2.7796	13.9941	24.03	45.74	
45-49	104,678	122,486	47.5	0.6869		0.5219	0.5246	45	0.5295	2.4942	11.2145	21.18	46.30	
50-54	92,512	97,850	52.5	0.6775	0.4118		0.4118	50	0.4682	2.1356	8.7204	18.63	47.56	
55-59	74,552	71,905	57.5	0.7042		0.3585	0.3603	55	0.3861	1.7643	6.5847	17.06	51.64	
60-64	59,273	62,678	62.5	0.6253	0.2790		0.2790	60	0.3197	1.4651	4.8204	15.08	55.84	
65-69	40,825	52,499	67.5	0.5708		0.2524	0.2537	65	0.2664	1.2012	3.3553	12.60	58.30	
70-74	31,429	37,066	72.5	0.4235	0.1745		0.1745	70	0.2141	0.9344	2.1541	10.06	59.80	
75-79	18,415	23,301	77.5	0.3131		0.1441	0.1448	75	0.1596	0.6725	1.2197	7.64	60.25	
80-84	8,385	13,311	82.5		0.0739		0.0739	80	0.1094		0.5472	5.00	54.70	
85+	7,274	10,667												
<b>Females</b>														
0-4	603,365	830,931	2.5	1.0017	1.0000		1.0000							
5-9	564,638	731,901	7.5	0.9859		1.0000	1.0008	5	1.0004	5.0042	42.7747	42.76	42.76	
10-14	516,401	604,367	12.5	0.9539	1.0017		1.0017	10	1.0012	4.9886	37.7705	37.72	38.19	
15-19	485,050	556,676	17.5	0.7819		0.9859	0.9867	15	0.9942	4.9132	32.7819	32.97	35.76	
20-24	382,178	492,589	22.5	0.7207	0.9555		0.9555	20	0.9711	4.5864	27.8687	28.70	34.00	
25-29	285,600	379,247	27.5	0.7655		0.7708	0.7715	25	0.8635	3.9838	23.2823	26.96	35.14	
30-34	219,634	275,434	32.5	0.7494	0.6886		0.6886	30	0.7300	3.4241	19.2985	26.43	38.33	
35-39	150,543	218,631	37.5	0.8159		0.5901	0.5906	35	0.6396	2.9823	15.8744	24.82	40.09	
40-44	139,541	164,597	42.5	0.7579	0.5161		0.5161	40	0.5533	2.6307	12.8921	23.30	42.34	
45-49	110,255	122,834	47.5	0.6615		0.4815	0.4819	45	0.4990	2.3387	10.2614	20.57	42.74	
50-54	100,165	105,762	52.5	0.6868	0.3911		0.3911	50	0.4365	1.9786	7.9227	18.15	44.45	
55-59	66,747	72,933	57.5	0.7190		0.3185	0.3188	55	0.3549	1.6216	5.9441	16.75	49.44	
60-64	56,697	68,797	62.5	0.5621	0.2686		0.2686	60	0.2937	1.3566	4.3224	14.72	53.20	
65-69	33,341	47,994	67.5	0.5203		0.2290	0.2292	65	0.2489	1.0976	2.9659	11.91	54.14	
70-74	25,285	31,869	72.5	0.4323	0.1510		0.1510	70	0.1901	0.8131	1.8683	9.83	57.68	
75-79	11,912	17,348	77.5	0.3947		0.1192	0.1193	75	0.1351	0.5685	1.0552	7.81	60.77	
80-84	7,614	10,931	82.5		0.0653		0.0653	80	0.0923		0.4867	5.28	55.91	
85+	6,555	10,294												

Source: Central Statistical Office Census Tables (Central Statistical Office[Zambia]. 1994, Unpublished). Author's computations.

**Table A.3.3: Application of the Census-Based Preston-Bennett Method to Zambia's Population, by sex: 1980-1990**

Start of Age interval (x)	Population on August 15 1980 (N1)	Population on August 20 1990 (N2)	GeoMean Number of Persons in Age Interval (5Nx)	Average Annual Growth Rate in Interval (5rx)	Sum of Age-Specific Growth Rates to Mid-point of Interval (S(x))	Stationary Population in Interval (5Lx)	Stationary Population Above Age x (T(x))	Number Surviving to Age x in Stationary Population (l(x))	Estimated life expectancy at Age x (e(x))	Implied Estimated life expectancy at Age 5 (e <sub>5</sub> )
<b>Males</b>										
0	507,782	595,163	549,739	0.0159	0.0396	571,969	6,599,732	-	-	-
5	491,381	553,193	521,372	0.0118	0.1089	581,335	6,027,763	115,330	52.27	52.27
10	384,016	511,845	443,347	0.0287	0.2102	547,047	5,446,428	112,838	48.27	50.86
15	284,668	454,345	359,635	0.0467	0.3986	535,784	4,899,381	108,283	45.25	51.87
20	221,009	331,150	270,531	0.0404	0.6163	501,050	4,363,597	103,683	42.09	52.77
25	163,922	249,108	202,075	0.0418	0.8218	459,616	3,862,546	96,067	40.21	55.20
30	137,834	211,268	170,646	0.0426	1.0329	479,357	3,402,930	93,897	36.24	54.81
35	111,372	147,181	128,031	0.0278	1.2091	428,954	2,923,574	90,831	32.19	54.24
40	103,347	126,980	114,556	0.0206	1.3301	433,180	2,494,620	86,213	28.94	55.17
45	94,950	104,678	99,695	0.0097	1.4059	406,660	2,061,440	83,984	24.55	53.53
50	77,941	92,512	84,915	0.0171	1.4730	370,424	1,654,780	77,708	21.29	54.21
55	54,808	74,552	63,922	0.0307	1.5926	314,273	1,284,356	68,470	18.76	56.88
60	48,944	59,273	53,862	0.0191	1.7172	299,954	970,084	61,423	15.79	58.39
65	35,865	40,825	38,265	0.0129	1.7974	230,877	670,130	53,083	12.62	58.42
70	22,934	31,429	26,847	0.0315	1.9084	181,007	439,253	41,188	10.66	62.71
75	15,099	18,415	16,675	0.0198	2.0366	127,806	258,246	30,881	8.36	64.72
80	7,439	8,385	7,898	0.0120	2.1161	65,541	130,440	19,335	6.75	69.01
85	6,683	7,274	6,972	0.0085	2.2309	64,899	64,899	-	-	-
<b>Females</b>										
0	512,245	603,365	555,941	0.0163	0.0409	579,136	6,548,336	-	-	-
5	492,890	564,638	527,546	0.0136	0.1157	592,240	5,969,201	117,138	50.96	50.96
10	384,375	516,401	445,524	0.0295	0.2233	557,003	5,376,961	114,924	46.79	48.70
15	308,299	485,050	386,705	0.0453	0.4102	582,795	4,819,958	113,980	42.29	47.43
20	268,452	382,178	320,307	0.0353	0.6115	590,387	4,237,163	117,318	36.12	43.78
25	184,177	285,600	229,349	0.0438	0.8092	515,145	3,646,776	110,553	32.99	43.86
30	164,235	219,634	189,926	0.0290	0.9913	511,796	3,131,631	102,694	30.49	44.79
35	133,930	150,543	141,994	0.0117	1.0931	423,619	2,619,835	93,541	28.01	45.72
40	116,233	139,541	127,355	0.0183	1.1679	409,464	2,196,217	83,308	26.36	48.46
45	88,038	110,255	98,522	0.0225	1.2697	350,711	1,786,752	76,018	23.50	49.39
50	72,416	100,165	85,167	0.0324	1.4068	347,743	1,436,042	69,845	20.56	50.59
55	46,084	66,747	55,461	0.0370	1.5803	269,349	1,088,298	61,709	17.64	51.98
60	45,969	56,697	51,052	0.0209	1.7252	286,581	818,950	55,593	14.73	53.24
65	28,226	33,341	30,677	0.0166	1.8191	189,168	532,369	47,575	11.19	51.31
70	20,610	25,285	22,828	0.0204	1.9117	154,428	343,201	34,360	9.99	58.62
75	11,920	11,912	11,916	-0.0001	1.9626	84,816	188,773	23,924	7.89	61.33
80	7,428	7,614	7,520	0.0025	1.9686	53,849	103,957	13,867	7.50	73.59
85	6,278	6,555	6,415	0.0043	2.0556	50,108	50,108	-	-	-

Source: Central Statistical Office Census Tables (Central Statistical Office[Zambia]. 1985, 1994). Author's computations.

**Table A.3.4: Application of the Census-Based Preston-Bennett Method to Zambia's Population, by sex: 1990-2000**

Start of Age interval (x)	Population on August 20 1990 (N1)	Population on October 25 2000 (N2)	GeoMean Number of Persons in Age Interval (5Nx)	Sum of Age-			Stationary Population Above Age x (T(x))	Number Surviving to Age x in Stationary Population (l(x))	Estimated life expectancy at Age x (e(x))	Implied Estimated life expectancy at Age 5 (e <sub>5</sub> )
				Average Annual Growth Rate in Interval (5rx)	Specific Growth Rates to Mid-point of Interval (S(x))	Stationary Population in Interval (5Lx)				
<b>Males</b>										
0	595,163	825,789	701,056	0.0322	0.0804	759,765	7,401,928	-	-	-
5	553,193	729,181	635,120	0.0271	0.2287	798,301	6,642,163	155,807	42.63	42.63
10	511,845	601,279	554,763	0.0158	0.3360	776,334	5,843,863	157,463	37.11	38.00
15	454,345	513,320	482,933	0.0120	0.4056	724,465	5,067,529	150,080	33.77	37.67
20	331,150	416,083	371,195	0.0224	0.4916	606,872	4,343,064	133,134	32.62	40.32
25	249,108	361,901	300,254	0.0367	0.6394	569,064	3,736,192	117,594	31.77	43.06
30	211,268	282,439	244,275	0.0285	0.8024	544,936	3,167,128	111,400	28.43	42.54
35	147,181	211,356	176,373	0.0355	0.9625	461,801	2,622,192	100,674	26.05	43.70
40	126,980	161,179	143,061	0.0234	1.1100	434,081	2,160,391	89,588	24.11	45.90
45	104,678	122,486	113,233	0.0154	1.2071	378,624	1,726,310	81,271	21.24	46.43
50	92,512	97,850	95,144	0.0055	1.2595	335,238	1,347,686	71,386	18.88	48.18
55	74,552	71,905	73,216	-0.0036	1.2644	259,244	1,012,447	59,448	17.03	51.57
60	59,273	62,678	60,952	0.0055	1.2692	216,865	753,203	47,611	15.82	58.48
65	40,825	52,499	46,296	0.0247	1.3447	177,631	536,338	39,450	13.60	62.30
70	31,429	37,066	34,131	0.0162	1.4469	145,060	358,708	32,269	11.12	64.79
75	18,415	23,301	20,715	0.0231	1.5452	97,130	213,648	24,219	8.82	67.32
80	8,385	13,311	10,565	0.0454	1.7165	58,792	116,518	15,592	7.47	72.46
85	7,274	10,667	8,809	0.0376	1.8800	57,726	57,726	-	-	-
<b>Females</b>										
0	603,365	830,931	708,064	0.0314	0.0786	765,952	7,416,083	-	-	-
5	564,638	731,901	642,852	0.0255	0.2209	801,751	6,650,131	156,770	42.42	42.42
10	516,401	604,367	558,655	0.0155	0.3232	771,823	5,848,380	157,357	37.17	37.55
15	485,050	556,676	519,630	0.0135	0.3957	771,848	5,076,557	154,367	32.89	35.65
20	382,178	492,589	433,885	0.0249	0.4918	709,522	4,304,709	148,137	29.06	34.42
25	285,600	379,247	329,109	0.0279	0.6238	614,102	3,595,187	132,362	27.16	35.40
30	219,634	275,434	245,957	0.0222	0.7490	520,171	2,981,085	113,427	26.28	38.09
35	150,543	218,631	181,420	0.0367	0.8962	444,539	2,460,914	96,471	25.51	41.31
40	139,541	164,597	151,552	0.0162	1.0284	423,829	2,016,375	86,837	23.22	42.18
45	110,255	122,834	116,375	0.0106	1.0955	348,034	1,592,546	77,186	20.63	42.89
50	100,165	105,762	102,925	0.0053	1.1354	320,335	1,244,512	66,837	18.62	45.66
55	66,747	72,933	69,772	0.0087	1.1705	224,912	924,177	54,525	16.95	50.02
60	56,697	68,797	62,455	0.0190	1.2397	215,764	699,265	44,068	15.87	57.33
65	33,341	47,994	40,002	0.0358	1.3767	158,481	483,501	37,424	12.92	58.70
70	25,285	31,869	28,387	0.0227	1.5230	130,178	325,020	28,866	11.26	65.13
75	11,912	17,348	14,375	0.0369	1.6721	76,526	194,842	20,670	9.43	70.56
80	7,614	10,931	9,123	0.0355	1.8533	58,209	118,316	13,473	8.78	-
85	6,555	10,294	8,214	0.0443	1.9902	60,107	60,107	-	-	-

Source: Central Statistical Office Census Tables (Central Statistical Office[Zambia]. 1994, Unpublished). Author's computations.

**Table A.4.1: Number and Percentage distribution of survivorship of parents by survey, ZDHS 1992-2007**

Survey	Biological Mother				Biological Father			
	Number unweighted	Percent	Number weighted	Percent	Number unweighted	Percent	Number weighted	Percent
<b>ZDHS 1992</b>								
Alive	15,603	97.2	16,054	97.2	15,101	94.2	15,556	94.3
Dead	453	2.8	463	2.8	918	5.7	927	5.6
Don't Know	0	0.0	0	0.0	18	0.1	16	0.1
Total	16,056	100.0	16,517	100.0	16,037	100.0	16,499	100.0
<b>ZDHS 1996</b>								
Alive	17,543	95.6	17,737	95.5	16,700	91.1	16,840	90.8
Dead	796	4.3	826	4.4	1,583	8.6	1,663	9.0
Don't Know	3	0.0	3	0.0	44	0.2	49	0.3
Total	18,342	100.0	18,566	100.0	18,327	100.0	18,551	100.0
<b>ZDHS 2001/2</b>								
Alive	17,017	94.0	16,930	93.9	15,917	87.9	15,805	87.7
Dead	1,084	6.0	1,088	6.0	2,123	11.7	2,154	12.0
Don't Know	6	0.0	7	0.0	62	0.3	56	0.3
Total	18,107	100.0	18,025	100.0	18,102	100.0	18,016	100.0
<b>ZDHS 2007</b>								
Alive	18,133	93.4	18,109	93.3	17,070	88.0	17,099	88.2
Dead	1,278	6.6	1,292	6.7	2,271	11.7	2,240	11.6
Don't Know	1	0.0	1	0.0	54	0.3	51	0.3
Total	19,412	100.0	19,402	100.0	19,395	100.0	19,390	100.0

Source: Author's computations from ZDHS data files

**Table A.4.2: Number and Percentage distribution of survivorship of parents by survey, LCMS 1996-2006**

Survey	Biological Mother				Biological Father			
	Number unweighted	Percent	Number weighted	Percent	Number unweighted	Percent	Number weighted	Percent
LCMS 1996								
Alive	10,047	90.7	1,517,159	90.7	9,030	81.4	1,369,720	81.6
Dead	1,016	9.2	154,589	9.2	1,976	17.8	294,262	17.5
Don't Know	12	0.1	1,430	0.1	93	0.8	14,026	0.8
Total	11,075	100.0	1,673,178	100.0	11,099	100.0	1,678,007	100.0
LCMS 1998								
Alive	51,466	93.4	5,564,818	93.1	47,639	86.5	5,133,618	86.0
Dead	3,613	6.6	408,603	6.8	7,194	13.1	811,022	13.6
Don't Know	26	0.0	4,060	0.1	231	0.4	26,654	0.4
Total	55,105	100.0	5,977,481	100.0	55,064	100.0	5,971,294	100.0
LCMS 2002/3								
Alive	29,453	91.8	5,893,375	91.9	26,970	84.1	5,417,973	84.5
Dead	2,595	8.1	517,873	8.1	4,940	15.4	961,428	15.0
Don't Know	25	0.1	3,964	0.1	154	0.5	34,286	0.5
Total	32,073	100.0	6,415,213	100.0	32,064	100.0	6,413,687	100.0
LCMS 2004								
Alive	52,045	91.8	5,507,810	92.0	47,687	84.3	5,043,694	84.4
Dead	4,623	8.2	477,211	8.0	8,656	15.3	905,953	15.2
Don't Know	48	0.1	3,704	0.1	236	0.4	24,345	0.4
Total	56,716	100.0	5,988,725	100.0	56,579	100.0	5,973,991	100.0
LCMS 2006								
Alive	52,115	92.5	6,317,001	93.1	47,677	84.7	5,779,603	85.2
Dead	4,213	7.5	468,980	6.9	8,467	15.0	984,309	14.5
Don't Know	25	0.0	1,965	0.0	178	0.3	19,712	0.3
Total	56,353	100.0	6,787,947	100.0	56,322	100.0	6,783,624	100.0

Source: Author's computations from LCMS data files

**Table A.4.3: Number and Percentage distribution of survivorship of siblings by survey, ZDHS 1996-2007**

Survey	Brother				Sister				Total			
	Number unweighted	Percent	Number weighted	Percent	Number unweighted	Percent	Number weighted	Percent	Number unweighted	Percent	Number weighted	Percent
ZDHS 1996												
Alive	20,007	79.6	20,233	79.4	20,537	81.4	20,851	81.3	40,544	80.5	41,083	80.3
Dead	5,115	20.4	5,264	20.6	4,681	18.6	4,796	18.7	9,796	19.5	10,060	19.7
Don't Know	2	0.01	2	0.01	3	0.01	4	0.02	5	0.01	6	0.0
Total	25,124	100.0	25,499	100.0	25,221	100.0	25,650	100.0	50,345	100.0	51,149	100.0
ZDHS 2001/2												
Alive	18,892	78.8	18,938	78.8	19,017	80.0	18,955	79.9	37,909	79.4	37,893	79.4
Dead	5,071	21.2	5,093	21.2	4,751	20.0	4,761	20.1	9,822	20.6	9,853	20.6
Don't Know	3	0.01	3	0.01	2	0.01	3	0.01	5	0.01	5	0.01
Total	23,966	100.0	24,033	100.0	23,770	100.0	23,719	100.0	47,736	100.0	47,752	100.0
ZDHS 2007												
Alive	16,749	81.6	16,901	81.4	16,491	81.3	16,565	81.2	33,240	81.4	33,466	81.3
Dead	3,758	18.3	3,861	18.6	3,793	18.7	3,827	18.8	7,551	18.5	7,689	18.7
Don't Know	15	0.07	12	0.06	11	0.05	10	0.05	26	0.1	22	0.1
Total	20,522	100.0	20,774	100.0	20,295	100.0	20,402	100.0	40,817	100	41,177	100.0

Source: Author's computations from ZDHS data files

**Table A.5.1: Selected estimated probabilities of dying between ages 15 and 60 years by sex, various sources and methods, Zambia**

<b>Method</b>	<b>Data Source</b>	<b>Year (Reference Period)</b>	<b>Male</b>	<b>Female</b>
<b><i>Census Survival Method</i></b>				
1980-1990	1980 and 1990 Census	1985	0.453	0.531
1990-2000	1990 and 2000 Census	1995	0.671	0.705
<b><i>Preston-Bennett Method</i></b>				
1980-1990	1980 and 1990 Census	1985	0.433	0.512
1990-2000	1990 and 2000 Census	1995	0.683	0.715
<b><i>Orphanhood Method</i></b>				
ZDHS 1992	ZDHS 1992 Orphanhood	1988	0.396	0.271
ZDHS 1996	ZDHS 1996 Orphanhood	1992	0.502	0.374
ZDHS 2001/2	ZDHS 2001/2 Orphanhood	1997	0.575	0.479
ZDHS 2007	ZDHS 2007 Orphanhood	2003	0.518	0.499
LCMS 1996	LCMS 1996 Orphanhood	1993	0.649	0.479
LCMS 1998	LCMS 1998 Orphanhood	1995	0.573	0.413
LCMS 2002/3	LCMS 2002/3 Orphanhood	2000	0.608	0.524
LCMS 2004	LCMS 2004 Orphanhood	2001	0.553	0.489
LCMS 2006	LCMS 2006 Orphanhood	2003	0.533	0.491
<b><i>Inter-survey Orphanhood Method</i></b>				
ZDHS 1992-1996	ZDHS 1992 & 1996 Orphanhood	1995	0.425	0.233
ZDHS 1996-2001/2	ZDHS 1996 & 2001/2 Orphanhood	2000	0.531	0.451
ZDHS 2001/2-2007	ZDHS 2001/2 & 2007 Orphanhood	2005	0.550	0.526
LCMS 1996-1998	LCMS 1996 & 1998 Orphanhood	1998	0.591	0.472
LCMS 1998-2002/3	LCMS 1998 & 2002/3 Orphanhood	2001	0.586	0.507
LCMS 2002/3-2004	LCMS 2002/3 & 2004 Orphanhood	2004	0.588	0.545
LCMS 2004-2006	LCMS 2004 & 2006 Orphanhood	2006	0.553	0.533
<b><i>Siblinghood Method</i></b>				
ZDHS 1996	ZDHS 1996 sibling history	1991	0.580	0.527
ZDHS 2001/2	ZDHS 2001/2 sibling history	1996	0.683	0.567
ZDHS 2007	ZDHS 2007 sibling history	2002	0.735	0.658
<b><i>Death Distribution Methods</i></b>				
GGB	LCMS 2004-2006	2005	0.635	0.674
Extended SEG	LCMS 2004-2006	2005	0.641	0.689

Source: Author's computations from ZDHS, LCMS and Census data