
Measuring Maternal Mortality from a Census: Guidelines for Potential Users

**Kenneth Hill
Cynthia Stanton
Neeru Gupta**

MEASURE *Evaluation* Manual Series, No. 4

MEASURE Evaluation
Carolina Population Center
University of North Carolina at Chapel Hill
123 West Franklin Street, Suite 304
Chapel Hill, North Carolina 27516, USA



The manual series is made possible by support from USAID under the terms of Cooperative Agreement HRN-A-00-97-00018-00. The opinions expressed are those of the authors, and do not necessarily reflect the views of USAID.

July 2001



Printed on recycled paper

Other Titles in the Manual Series

- NO. 1** **Evaluando Proyectos de Prevención de VIH/SIDA: Un Manual con Enfoque en las Organizaciones No Gubernamentales.** Bertrand, Jane T. and Solís, Manuel. July 2000.
- NO. 2** **Quick Investigation of Quality (QIQ): A User's Guide for Monitoring Quality of Care.** MEASURE *Evaluation*. February 2001.
- NO. 3** **Sampling Manual for Facility Surveys for Population, Maternal Health, Child Health and STD Programs in Developing Countries.** MEASURE *Evaluation*. July 2001.

Une version abrégée de ce document est disponible en français, *Mesurer la mortalité maternelle à partir du recensement: Guide pour les utilisateurs potentiels* (35 pp).

Una version abreviada de este documento es disponible en español, *Medición de la Mortalidad Materna a partir de un Censo: Instrucciones para los Usuarios* (35 pp).

Recommended citation:

Measuring Maternal Mortality from a Census: Guidelines for Potential Users. **MEASURE Evaluation Manual Series, No. 4.** Hill, Kenneth, Stanton, Cynthia, Gupta, Neeru. Carolina Population Center, University of North Carolina at Chapel Hill. July 2001.

Preface

Maternal mortality is among the health indicators reflecting the greatest disparity between rich and poor countries. At the 1987 Safe Motherhood Conference in Nairobi, Kenya, attention was drawn to the fact that maternal mortality ratios in the developing world were often 100 times greater than those commonly found in developed countries. Subsequently, the World Bank's 1993 World Development Report showed maternal mortality and morbidity to be the major cause of loss of healthy life among women of reproductive age in developing countries. Over the past decade a number of international fora have declared a reduction in maternal mortality as one of their goals, such as the 1990 World Summit for Children, the 1994 International Conference on Population and Development, the 1995 World Conference for Women, and the 2000 Millennium Summit.

Such increased attention to maternal health has led to much greater demand for maternal mortality estimates at the national and sub-national levels. However, methodologies for measuring and monitoring maternal mortality lag far behind. In many developing countries, currently available data are simply inadequate for providing precise estimates. While civil registration systems are designed to gather the needed statistics on maternal deaths, they remain insufficient in quality of recording in the majority of developing countries and are even found to be problematic in developed countries. Sample surveys that attempt to identify maternal deaths in the household are being increasingly used, but require prohibitively large sample sizes to generate reliable estimates in the short term or at the sub-national level.

Given the shortcomings of civil registration and sample-based methodologies, it has been suggested that census measurement could be more appropriate for producing acceptably precise, cost-effective estimates of maternal mortality and worth further exploration. At least five countries have been identified as having experimented with maternal mortality data collection in a recent census. These countries include Benin, Iran, Laos, Madagascar and Zimbabwe. In November 1998, MEASURE *Evaluation* held a workshop in Nairobi in order to evaluate the use of the census for maternal mortality measurement. Participating were experts who were involved in data collection and those who were experienced with comparative demographic data analyses. They included census representatives from the five countries named above as well as from the Kenyan Central Statistical Office, along with technical advisors from the Johns Hopkins University, the London School of Economics, and the London School of Hygiene and Tropical Medicine.

The present publication is a result of this workshop. Its objectives are to document and evaluate experiences of measuring maternal mortality from a recent census in developing countries, to encourage countries to build upon these experiences, and to compile recommendations for Statistical Offices considering using the census methodology for maternal mortality estimates. The World Health Organization welcomes this document, which should be seen as a work in progress, that will result in an enhanced understanding and contribute significantly to the growing body of methodologies designed to address the challenge of measuring and, ultimately, of reducing maternal mortality.



Dr. Tomris Türmen
Executive Director,
Family and Community Health
World Health Organization

Contents

Preface	i
Acknowledgements	v
List of Abbreviations	vii
Chapter 1: Introduction	1
Chapter 2: Measures of Maternal Mortality	3
2.1. Indicators for Measuring Maternal Mortality	3
2.2. Data Sources	4
2.3. Advantages of Measuring Maternal Mortality through the Census	5
Chapter 3: Data Collection and Tabulation Procedures	7
3.1. Questionnaire Design	7
3.1.1. Collection of Mortality Information in the Census	7
3.1.2. Collection of Fertility Information in the Census	8
3.2. Training of Field Staff	9
3.3. Tabulation Layouts	10
Chapter 4: Methods for Data Evaluation and Adjustment	13
4.1. Evaluating and Adjusting the Population Distribution	13
4.2. Evaluating Completeness of Death Recording	15
4.2.1. Evaluating Completeness of Death Recording using the Brass Growth Balance Method	15
4.2.2. Evaluating Completeness of Death Recording using the General Growth Balance Method	20
4.3. Evaluating Completeness of Birth Recording or Estimating Numbers of Births	25
4.3.1. Evaluating Completeness of Birth Recording using Brass P/F Ratios	25
4.3.2. Estimating Numbers of Births using Reverse Projection	29
4.4. Evaluating the Classification of Deaths as Pregnancy-Related	30
4.5. Putting It All Together: Measuring Maternal Mortality	32
Chapter 5: Data Dissemination and Use	35
References	37
Appendix A: Development of the Brass Growth Balance Equation	39
A.1. Application to Stable Populations	39
A.2. Extension to Non-Stable Populations	39
Appendix B: Development of Methods for Estimating and Evaluating Numbers of Births	41
B.1. Brass P/F Ratio Method for Evaluating Consistency of Fertility Data	41
B.2. Reverse Projection Method for Estimating Numbers of Births	43

Acknowledgements

The authors would like to thank a number of people who helped in the preparation of this report. First, we wish to acknowledge the important contributions of our colleagues from six national census bureaus, who formulated the recommendations presented here during the course of the *Workshop for the Evaluation of Maternal Mortality Data Collected via a Census*, conducted in Nairobi, Kenya, in November 1998. They are: Nicaise Kodjogbé (Benin), W.T. Mapeta (Zimbabwe), Francis Munene (Kenya), Moshe Naghavi (Iran), Victor Rabeza (Madagascar), and Bounthavy Sisouphantong (Lao People's Democratic Republic).

Following the Nairobi workshop, a draft version of this guide was prepared. Siân Curtis, Mandy Rose, Ties Boerma, Carla AbouZahr, Iqbal Shah, Monir Islam, Alphonse MacDonald, Patricia Rowe, Norma Wilson and Mary Mahy were among the individuals who provided useful suggestions to earlier drafts of this final product.

List of Abbreviations

CEB	Children Ever Born
DHS	Demographic and Health Survey
ICPD	International Conference on Population and Development
LTR	Lifetime risk of maternal death
MMRate	Maternal mortality rate
MMRatio	Maternal mortality ratio
OLS	Ordinary Least Squares
P/F Ratio	Parity/Fertility Ratio
PMFD	Proportion of adult female deaths due to maternal causes
RAMOS	Reproductive age mortality surveys
WHO	World Health Organization

Chapter 1: Introduction

Maternal mortality in the developing world has gained greatly increased recognition as an urgent public health concern during the past decade. The 1987 Safe Motherhood Conference in Nairobi, Kenya, successfully drew attention to the fact that maternal mortality ratios in the developing world were often 100 times greater than those common in developed countries, easily identifying maternal mortality as among the health indicators reflecting the greatest disparity between rich and poor countries.

Among the stated goals of the conference was halving maternal mortality worldwide by the year 2000. This goal was similarly adopted by a series of subsequent international health and development conferences, including the 1990 World Summit for Children, the 1994 International Conference on Population and Development (ICPD), and the 1995 World Conference for Women. A number of countries have accepted the same as a national goal.

Despite increased attention to the reduction of maternal mortality, it remains difficult to assess whether the objective has been reached. Many countries did not know what their maternal mortality level was at the time of the Nairobi conference, and many do not know it now. In most developing countries, currently available data are inadequate for providing precise estimates. Very few have comprehensive civil registration systems able to capture the needed statistics on maternal deaths. Systems are even found to be problematic in developed countries. Maternal deaths are often under reported or misclassified as non-maternal.

Although the demand for maternal mortality data at the national and sub-national levels is increasing, methodologies for measuring and monitoring maternal mortality lag far behind. A few alternatives do exist. A number of hospital studies in developing countries have helped shed light on the severity of the problem. However, such estimates tend to be unreliable, as they are generally not representative of the population, which could lead to unpredictable biases. Some community-based studies have also been conducted; however, the

number of maternal deaths recorded is usually statistically unacceptably small. Even data collection through national household surveys that attempt to identify maternal deaths in the household is problematic, given the relative rarity of the event. Large sample sizes are necessary for precise results and may still have wide margins of error. Moreover, estimates at the sub-national level would require visiting a prohibitively large number of households and would not be cost-effective.

With the goal of maternal mortality reduction recently reaffirmed at the ICPD+5 meeting in 1999 and the Millennium Summit in 2000 came the recognition of the need to improve within countries the means for measuring and monitoring maternal mortality levels. One of the key recommendations of the ICPD+5 Programme of Action is seeking improved methods of estimating maternal mortality with data collected through various sources, including a census. An important advantage of using the census is the ability to disaggregate analysis of maternal mortality, such as by sub-national region or household socio-economic group.

Programme of Action of the International Conference on Population and Development + 5

38. The United Nations system and donors should be specifically urged to strengthen the capacity of developing countries, particularly the least developed countries, and those with economies in transition, to undertake censuses and surveys on a regular basis so as to improve vital registration systems, and to develop innovative and cost-effective solutions for meeting data requirements, especially for regular monitoring of the implementation of the goals of the Conference, including improved estimates of maternal mortality.

Only a handful of developing countries have been identified as having collected data relevant to the estimation of maternal mortality in a recent census. They include Benin, Iran, Laos, Madagascar and Zimbabwe. In November 1998, a workshop was held in Nairobi by MEASURE *Evaluation* to review the procedures used by those five countries and to conduct an evaluation of the basic data and methodology. The experiences of these countries' respective Statistical Offices throughout the process were compiled and evaluated, along with contributions from the Kenyan Statistical Office, eventually forming the basis for the recommendations shared in the present document.

The purpose of this publication is to produce guidelines for countries interested in using the census as a source of data for maternal mortality

measures. The chapters that follow are intended to explain how maternal mortality may be estimated by a decennial census. In Chapter 2, some of the issues, methods, and different sources for measuring maternal mortality are explored. Chapter 3 details the procedures for relevant data collection in a census, covering wording of the questions, training of field staff, and tabulation layouts for the results. Chapter 4 describes methods of data evaluation and adjustments that can be applied to compensate for data deficiencies. In addition to methodological development, illustrative applications to the experiences in two countries (Benin and Zimbabwe) are provided. Lastly, Chapter 5 suggests activities to promote data dissemination and use.

Chapter 2: Measures of Maternal Mortality

The International Classification of Diseases, Tenth Revision, gives the following definition of a maternal death:

A maternal death is the death of a woman while pregnant or within 42 days of termination of pregnancy, irrespective of the duration and the site of the pregnancy, from any cause related to or aggravated by the pregnancy or its management but not from accidental causes.

(World Health Organization, 1993)

A true maternal death requires specific cause of death information. This should be distinguished from a pregnancy-related death, which is determined solely by timing of death relative to pregnancy, childbirth and the postpartum period:

A pregnancy-related death is the death of a woman while pregnant or within 42 days of termination of pregnancy, irrespective of cause.

(World Health Organization, 1993)

This chapter describes a variety of data collection methods, some of which identify pregnancy-related deaths rather than true maternal deaths. Regardless of the definition used, the results are generally reported as maternal deaths.

2.1. Indicators for Measuring Maternal Mortality

A number of different indicators have been developed for the measurement of maternal mortality. The most commonly used indicator is the maternal mortality ratio (MMRatio), which refers to the number of maternal deaths per live birth, multiplied by a conventional factor of 100,000:

$$\text{MMRatio} = \frac{\text{Number of maternal deaths}}{\text{Number of live births}} * 100,000$$

The MMRatio was designed to express obstetric risk. In fact, the MMRatio may overestimate obstetric risk by excluding from the denominator pregnancies which do not terminate in a live birth,

but which may be responsible for a maternal death. Though in theory it would be preferable to refine the denominator to include all pregnancies, in practice it is rare that suitable data on pregnancies not resulting in a live birth are available. Care must be taken when comparing the MMRatio across countries as this indicator is not an age-standardized measure.

The MMRatio is frequently, though erroneously, referred to as the maternal mortality rate (MMRate). The MMRate is an indicator of the risk of maternal death among women of reproductive age. The MMRate is usually multiplied by a factor of 1,000:

$$\text{MMRate} = \frac{\text{Number of maternal deaths}}{\text{Number of women aged 15-49}} * 1000$$

While the MMRate provides an indication of the burden of maternal death in the adult female population, it conceals the effect of differing levels of fertility in cross-country comparisons. The relationship between the MMRate and the MMRatio is as follows:

$$\text{MMRatio} = \frac{\text{MMRate}}{\text{General Fertility Rate}}$$

A third indicator is the proportion of adult female deaths due to maternal causes (PMFD), or proportion maternal:

$$\text{PMFD} = \frac{\text{Number of maternal deaths}}{\text{Number of deaths among women 15-49}}$$

A fourth indicator of maternal mortality is the lifetime risk of maternal death (LTR). The LTR reflects the chances of a woman dying from maternal causes over the course of her 35-year reproductive life span. This indicator takes into account the probability of a death due to maternal causes each time a woman becomes pregnant. A common way of calculating the LTR is:

$$\text{LTR} = 35 * \text{MMRate}$$

Different aspects of the level of maternal mortality are reflected in each of the indicators described above. Among them, the MMRatio has received the most attention of policymakers, program managers, and the donor community. But even with highly precise data, a variety of indicators are needed to understand the level and pattern of maternal mortality. For instance, the interplay between changes in maternal mortality and fertility may produce unexpected results. A decrease in the MMRate may simply be reflecting a decline in fertility even under circumstances where the risk of maternal death per birth has remained constant. Fewer births result in fewer maternal deaths, even if no new safe motherhood interventions are in place. Likewise, the PMFD may change substantially if the cause of death structure is altered (for example, due to AIDS mortality). Thus, trends in maternal mortality should be interpreted in light of the risk per woman and per birth, and with consideration of changes in fertility and the distribution of deaths by cause.

Measures of maternal mortality in a society should reflect:

- **The risk of death per woman**
- **The risk of death per birth**
- **The overall level of fertility**
- **The overall level of mortality and distribution by cause**

2.2. Data Sources

In statistically developed settings, maternal mortality is measured from birth and death statistics from civil registration systems. Birth statistics provide the number of live births. Cause of death information provides the number of maternal deaths.

Even in statistically developed settings, the measurement of maternal mortality is problematic. Careful studies in France and the United States, for example, have shown that a substantial proportion, often as much as one third, of deaths that should be recorded as maternal are misclassified (Bouvier-Colle et al., 1991; Berg et al., 1996). Thus indicators of maternal mortality are usually highly underestimated.

In statistically developing settings, the problems of data quality are generally more serious. Cause of death may be attributed by non-health professionals or by professionals who had no direct contact with the deceased, relying on information provided by relatives. In countries lacking complete registration of deaths, alternative approaches may be required for identifying maternal deaths.

However, alternative direct approaches are hampered by the relative rarity of maternal deaths. Despite disparities between developed and developing countries, maternal deaths are rare events. The MMRatio rarely exceeds 1,000 per 100,000 live births. Even at this high level, a population of 2,500 with a birth rate of 40 per 1,000 persons will only include, on average, one maternal death per year. Very large samples are needed to achieve maternal mortality estimates of acceptable precision.

A number of solutions to these problems have been developed. Reproductive age mortality surveys (RAMOS) use multiple sources (for example, civil registration, community informants, household visits) to try to identify all deaths of women of reproductive age within a specified time period, and among those, the deaths that were truly maternal. Samples generally refer to a clearly defined population (AbouZahr, 1998). Although these studies have been very useful, they are expensive and time-consuming to conduct.

Another approach has been the sisterhood method for direct estimation of maternal mortality (Rutenberg and Sullivan, 1991). Questions about the deaths of sisters have been incorporated into a number of sample survey instruments, most prominently in the Demographic and Health Surveys (DHS) program. Respondents, typically themselves women of reproductive age, are asked about each of their sisters' current age or, if applicable, age at death, date when the death occurred, and whether it occurred during a pregnancy, childbirth, or within two months of the end of a pregnancy.

In these surveys, maternal deaths are identified on the basis of time-of-death questions. Strictly speaking, based on the WHO classification, such deaths are *pregnancy-related* rather than true *maternal*. While some non-maternal deaths may be

counted, it is also certain that maternal deaths sometimes go unrecorded because the respondent has incomplete information about, for example, the pregnancy status of the woman at time of death. How closely these two factors balance each other is unknown (Stecklov, 1995; Faveau et al., 1988).

The MMRate is calculated for a given time period before the survey (usually six or more years, in order to ensure a sufficient number of events) as the ratio of sisters' maternal deaths to sister-years of exposure. The indicator can then be converted into an estimate of the MMRatio. Reviews of estimates from direct sisterhood data have raised questions about their accuracy; there are indications that the levels of overall mortality thus estimated are biased downwards (Stanton, Abderahim and Hill, 2000). Even if accurate, the direct sisterhood method in a sample survey does not provide enough observations to analyze regional or socioeconomic differentials in maternal mortality.

Given the lack of satisfactory methods for arriving at empirical estimates of maternal mortality for population sub-groups in statistically developing countries, the possibility of using the decennial population census has been suggested (Stanton, Hobcraft et al., 2001).

The United Nations recommends that, in countries lacking accurate registration of deaths, censuses should include questions on deaths in each household, by age and sex, relating to some fairly short reference period (such as one year) before enumeration (United Nations, 1998a). The addition of questions about the timing of deaths among women of reproductive age relative to a pregnancy provides a basis for calculating maternal mortality indicators from census data. This approach has been used in a small number of developing countries.

Data sources for measuring maternal mortality should include

- **Population distribution by age and sex**
- **Number of deaths over a given period by age and sex**
- **Number of deaths among women aged 15-49 due to maternal causes**
- **Number of live births over the same period**

2.3. Advantages of Measuring Maternal Mortality through the Census

The census offers a number of advantages for estimating maternal mortality over alternative measurement methods. First, if the census has already been planned to include questions on recent household deaths, the additional cost of identifying pregnancy-related deaths will be small. The extra questions on timing of adult female deaths relative to pregnancy, childbirth and the postpartum period would, in a typical developing country, be used in less than one percent of households, thus using little interviewer or data processing time.

In addition, the large number of observations available from census coverage should be sufficient to support analysis of maternal mortality differentials by population sub-group. Surveys rarely offer the large samples needed to provide quality estimates by region or woman's age. Even vital registration systems often lack information for disaggregated analysis by background characteristics, such as household socio-economic status.

Moreover, there is substantial experience in the evaluation of census data on recent deaths by age and recent births by maternal age (United Nations, 1983; Hill, 1987). Standard demographic methods can be applied to evaluate the quality of much of the data used to calculate maternal mortality indicators, and in some cases corrections can be applied to adjust for omissions, date displacements or other data quality problems.

One potential shortcoming of using the census to measure maternal mortality is a certain tendency for households to break up following an adult death. This may yield problems when compiling mortality estimates from household-level sources (United Nations, 1998b). Another disadvantage is periodicity: Censuses are typically taken only once a decade. However, given the large sampling error that affects estimates of rare events, it is probably unrealistic to try to calculate maternal mortality indicators for periods closer together than ten years. Furthermore, given our understanding of the critical role of skilled health care personnel, health infrastructure and access to emergency obstetric

care in reducing numbers of maternal deaths, it is unlikely that dramatic declines in maternal mortality will occur over shorter periods of time in the developing world (Tsui et al., 1997; Stars, 1997).

Collecting information on maternal mortality in the census is particularly advantageous due to

- **Cost-effectiveness compared to large periodic demographic surveys**
- **Ability to disaggregate analyses at the sub-national level**
- **Ability to evaluate completeness of death and birth recording**

Chapter 3: Data Collection and Tabulation Procedures

3.1. Questionnaire Design

Measures of maternal mortality require information on the population by age and sex, the number of deaths by age and sex and of maternal deaths over a given period of reference, and the number of live births over the same period. Collection of information on the age/sex distribution of the population is a necessary element of any census, for which detailed specifications are presented elsewhere (see, for example, United Nations, 1998a). This chapter will concentrate instead on collection of mortality and fertility data.

3.1.1. Collection of Mortality Information in the Census

The collection of information on household deaths involves the identification of all household members who have died within a specified time period, as well as the sex and age, in completed years, of each deceased person. In order to distinguish maternal from non-maternal deaths, questions must be asked to determine the timing of adult female deaths relative to pregnancy, childbirth, abortion, or the postpartum period.

It is recommended that the information be recorded in a self-contained box in a prominent position (such as the front cover) of the census questionnaire. This is preferable to use of a separate sheet, which might reduce the response rate. The basic questions are noted in the box below:

Various alternatives to the wording of these questions exist. The reference period can be defined as time since a well-known day (e.g., “since the end of Ramadan”) rather than in months. It is important to ensure that the period defined is long enough for sufficient numbers of events to be recorded. In a small population, the reference period could be extended to 24 months in order to increase the numbers of events. However, longer periods than this are likely to suffer increased omission or date displacement due to respondent recall errors. Avoid phrasing the question in terms of years: The respondent may interpret “in the last year” as “in this calendar year.” It is also recommended that periods substantially different from multiples of a year be avoided in order to minimize the likelihood of mortality measurement errors due to seasonality.

Although the information is not used for data tabulation and analysis, asking for the name of the deceased is likely to improve recall. It may likewise be worth collecting information on the relationship of the deceased person to the head of the household. Enough lines should be provided in the box to cover any number of deaths that is likely to be reported: Three lines should generally be sufficient.

A combination of date of birth and date of death can replace use of a single question on age at death, if dates are fairly well known and well reported in the population. In settings where childbearing outside marriage is rare, the addition

Has any member of this household died in the last 12 months? If yes, record the following information about each deceased person:								
Name	Sex	Age at Death	If the Deceased was female aged 15-49, at time of death was she:					
			Pregnant?		Giving birth?		Within 2 months of the end of a pregnancy or childbirth?	
			Yes	No	Yes	No	Yes	No
			Yes	No	Yes	No	Yes	No
			Yes	No	Yes	No	Yes	No
			Yes	No	Yes	No	Yes	No

of an initial filter question before the timing-of-death questions for determining whether the woman had ever been married may be required. Moreover in settings where childbearing among younger adolescents is common, it may be preferable to target female deaths at ages 12-49 for the questions on timing of death, rather than the age range 15-49 as defined in the example above. (The numbers of births and maternal deaths below age 15 are rarely very high, however, and can generally be included in the 15-19 years bracket when calculating maternal mortality measures with little impact on accuracy.)

The three distinct timing-of-death questions shown above may be replaced by one “omnibus” question, such as: “Was the woman pregnant, giving birth, or within two months of the end of a pregnancy or childbirth at the time of her death?” But the use of three separate questions is preferred, as this is likely to improve recall (although no formal experiments of resultant data quality have been conducted).

Note that the postpartum period is defined here as two months following the end of pregnancy, as opposed to 42 days as defined by the WHO classification of a maternal death. This approach is used as a means to simplify data collection, and is also used in the DHS. Either duration is considered acceptable as any differences in the recorded number of maternal deaths will likely be very small and have a negligible effect on the results.

Information collected in the census on household deaths should identify:

- All deaths in the household within a specified time period
- The age and sex of each deceased person
- The timing of adult female deaths relative to pregnancy, childbirth and the postpartum period

3.1.2. Collection of Fertility Information in the Census

To allow the calculation of the MMRatio, the census questionnaire must include some basis for estimating fertility. Censuses often include fertility questions, asked of all [ever-married] women of

reproductive age. Women are typically asked for a summary birth history about their live-born children, including how many are still alive and how many have died, as well as information on their last child born alive.

The question for children ever born can be broad:

- “How many live-born children have you given birth to in your whole life? How many are still alive? How many have died?”

Or it can be more detailed (which may improve recall):

- “How many live-born sons have you given birth to who (a) are still alive and live with you? (b) are still alive but live elsewhere? (c) have died?”; and
- “How many live-born daughters have you given birth to who (a) are still alive and live with you? (b) are still alive but live elsewhere? (c) have died?”

These questions provide estimates of women’s lifetime fertility and also of child mortality (from proportions of children deceased).

The estimates of recent fertility are typically based on a question about births in a specific time period. The question can ask whether the woman has had a birth in a recent period, with a possible “yes/no” response, for example:

- “Have you given birth in the last 12 months?” or “since the end of Ramadan?”

Or the question can be posed about the date of the most recent birth, for example:

- “In what month and year was your most recent live birth?”

From this second question the number of children born in the 12 months immediately preceding the census date can later be derived in the data processing stage. It has been suggested, though not conclusively proved, that the latter form is less subject to omission than the first.

Ideally, the census questionnaire should include both questions on lifetime fertility and on recent fertility. However if the questionnaire does not

include recent fertility, an estimate of the number of recent births can be obtained using a method of reverse projection, drawing on information from women's summary birth histories and the population age distribution (see section 4.3.2). Thus it is essential to collect information on lifetime fertility in the same household questionnaire as deaths, but not essential to collect information on recent fertility.

3.2. Training of Field Staff

Careful training of field staff is a necessary (though unfortunately not sufficient) condition for collecting good data. Additional training time to cover the questions related to maternal mortality must be provided in the census timetable. Training for census fieldwork typically follows a tree pattern: The Statistical Office staff centrally trains a small cadre of regional trainers, who in turn train district trainers, who next provide training to field supervisors, who then train the interviewers. Regardless of the actual chain of training, it is essential that adequate time be set aside at each level for the additional questions.

The training should include both classroom instruction and trial fieldwork in the community. Training materials must be developed which include the basic instructions for completing this section of the questionnaire, as well as common scenarios encountered during data collection. Allowing time for the interviewers to role-play asking these questions and recording the answers is a particularly effective and efficient approach to training. Purposive field practice, whereby households with recent deaths in the target group are identified in advance so that interviewers will gain practice asking all of the questions, is desirable, though logistically more complicated.

Common data collection problems for the maternal mortality questions are listed below. All of these issues should be explicitly addressed during training and in the training materials developed for fieldwork.

- **Missing data on maternal deaths:**
Adult female deaths are identified but the questions concerning timing of death relative to pregnancy, childbirth or the postpartum pe-

riod are left blank. Even if the questions were never asked, the likely result is that the death is automatically classified as non-maternal during data entry. Maternal mortality measures are subsequently underestimated.

- **Maternal deaths outside of the specified age range, in particular, maternal deaths at age 0 (zero):**

These cases most likely reflect newborn deaths and not maternal deaths. This type of error suggests that the interviewer did not understand the skip pattern of the questionnaire, and that the interviewer or possibly the respondent did not understand the meaning of the questions. The questions on timing of death relative to pregnancy, childbirth and the postpartum period are to be asked *only* for adult female deaths.

- **Misclassification of adult female deaths as non-maternal:**

Experience from several countries suggests that respondents may voluntarily offer information on cause of death in response to the initial question aimed at identifying deaths in the household. For example: “[Name] died from diabetes, a bad episode of malaria, a heart problem, a car accident,” etc. It is essential that the interviewer follows the skip pattern in the questionnaire and proceeds to the questions on timing of death relative to pregnancy, childbirth or the postpartum period, regardless of other information provided by the respondent.

As previously indicated, maternal deaths are defined in household-based sources according to pregnancy-related timing of death, and not according to the medical or non-medical cause of death. An adult female death may have occurred due to any of the causes mentioned in the example above while the woman was between onset of pregnancy and the two months following childbirth. If such a case is assumed not to be pregnancy-related, the death will be misclassified during data analysis and maternal mortality will be underestimated.

➤ **Anger or grief expressed toward the interviewer:**

Maternal deaths are particularly tragic deaths and may evoke strong reactions from the respondent. Training materials and classroom practice should prepare interviewers for these eventualities in order to maintain good rapport with the respondent and to complete the interview.

3.3. Tabulation Layouts

Publishing quality maternal mortality tabulations from census data involves some advance planning. The data evaluation methods described in Chapter 4 require information on the population and number of deaths by age group and sex, as well as on the number of births by maternal age group. This implies that *raw* data (i.e., unadjusted data on population, deaths, maternal deaths, and births *at all ages*) be kept in a machine-readable form following data entry. Providing tabulations only for maternal deaths will make it impossible to apply valuable techniques of analysis.

A recommended tabulation for the analysis and presentation of national maternal mortality data is presented in Table 3.1, drawing on results from the 1992 National Population Census in Zimbabwe (Central Statistics Office, 1994) for illustrative purposes.

Since an important advantage of using the census to measure maternal mortality is the ability to disaggregate analysis, it is also essential that maternal mortality data be tabulated and presented by region, urban/rural residence, and some socio-economic characteristics of the household (where numbers are sufficient). An example for presenting the MMRatio disaggregated by provinces of Zimbabwe is shown in Figure 3.1.

Countries using this methodology are urged to publish the results even if at first glance the data do not seem to be very good. Recent experience

with collecting retrospective information on household deaths has been mixed. In some cases, the information appears to be good, but in others there has been clear evidence of omission. Occasionally the data have not been published because they seemed to have been affected by omission. However, given the current techniques for evaluating and adjusting such data, they might have been of value but are now lost forever. Also, if only countries that apply this approach successfully publish their results, it will be impossible to arrive at an unbiased assessment of the value of the method.

It is recommended, therefore, that the basic data from these questions always be published in the census raw data volumes. It is also important that analyses of the data be published, including adjustments if necessary. A census is generally followed by the publication of an analytical volume, presenting an analysis of the census results, such as estimates of fertility or mortality, or population projections. Devoting a chapter of this analytical report to describing the analysis of the maternal mortality data, and publishing estimates of maternal mortality indicators by geographic and socio-economic groups based on this analysis, is encouraged.

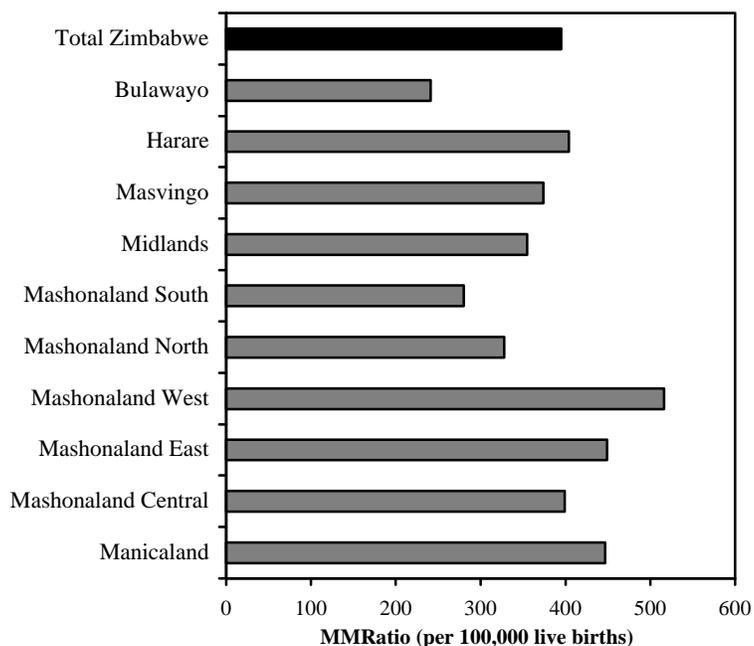
Census publications of maternal mortality estimates should include:

- **Raw data on the population by age and sex**
- **Raw data on the number of deaths over the reference period by age and sex**
- **Raw data on the number of deaths among women aged 15-49 due to maternal causes**
- **Raw data on the number of births over the same period by age of the mother**
- **Maternal mortality indicators including adjustments if necessary, and disaggregated by age, region, and household socio-economic status**

TABLE 3.1:
National Data on Maternal Mortality by Women s Age Group, Zimbabwe, 1992 Census

Age Group	Number of Women	Number of Women s Deaths in the Last 12 Months	Number of Deaths due to Maternal Causes	Number of Live Births in the Last 12 Months by Maternal Age Group	MMRatio (per 100,000 live births)	MMRate (per 1,000 women)	Proportion of Deaths due to Maternal Causes	Lifetime Risk of Maternal Death (per 1,000 women)
15-19	632,510	1,555	215	51,532	417	0.34	0.14	1.7
20-24	523,060	2,265	342	113,965	300	0.65	0.15	3.3
25-29	376,495	2,379	308	77,393	398	0.82	0.13	4.1
30-34	326,299	2,073	214	58,693	365	0.66	0.10	3.3
35-39	259,555	1,873	189	37,559	503	0.73	0.10	3.6
40-44	189,509	1,496	93	15,224	611	0.49	0.06	2.5
45-49	143,441	1,354	58	4,520	1,283	0.40	0.04	2.0
Total	2,450,869	12,995	1,419	358,886	395	0.58	0.11	20.3

FIGURE 3.1: Maternal Mortality Ratio by Province, Zimbabwe, 1992 Census



Questions used for measuring the numbers of recent deaths, maternal deaths, and births in the 1992 Zimbabwe Census:

- Did any deaths occur in the household in the last 12 months? If yes, was the deceased male or female? How old was the deceased (age in completed years)?
- For deaths among women aged 12-49 and other than accidents: Did she die while pregnant, while giving birth or within about one month after giving birth?
- For women currently aged 12-49: When was [NAME'S] last live birth (month, year)?

Chapter 4: Methods for Data Evaluation and Adjustment

Given the common data problems for measuring maternal mortality, an evaluation of the data quality is especially important. As previously described, data required for maternal mortality estimates from a census include population distribution by age and sex, the number of deaths over a reference period by age and sex, the number of live births over the same reference period, and the number of deaths due to maternal causes. Data quality evaluation thus requires four steps: 1) evaluation of the population structure; 2) evaluation of the completeness of recording the number of deaths; 3) evaluation of the completeness of recording the number of live births; and 4) evaluation of the classification of adult female deaths as maternal. In cases of deficiencies, the collected data may need to be adjusted to arrive at a reliable estimate of the maternal mortality indicators. This chapter describes methods for each step and provides illustrative examples using data from the 1992 Zimbabwe census and the 1992 Benin census.

Questions to be addressed when evaluating data for maternal mortality measures:

- Is the population distribution by age and sex complete?
- Is the number of recorded deaths complete?
- Is the number of recorded births complete?
- Is the number of recorded maternal deaths complete?

4.1. Evaluating and Adjusting the Population Distribution

Table 4.1 shows the raw data from the 1992 Zimbabwe census on population size and numbers of deaths by sex and five-year age group (up to 75 years and over). As seen in columns 2 and 3, information on current age is missing from a certain number of the population. The first step is to adjust the population structure to account for cases with missing age. A simple way to do the adjustment is to distribute these cases proportionately: For each sex, multiply the number of persons in each age category by the total population, and then divide by the total minus the number of cases with missing information. Thus, for example, the adjusted number of females in the quinquennial age group 20 to 24 years (${}_5N_{20}^{adj}$) is obtained as:

$$\begin{aligned} \text{Adjusted number of females aged 20-24} &= \text{Observed number of females aged 20-24} \\ &\quad * \text{Total observed female population} \\ &\quad / (\text{Total observed female population} \\ &\quad \quad \text{Number of females missing age information}) \\ {}_5N_{20}^{adj} &= {}_5N_{20}^{obs} * N_{total}^{obs} / (N_{total}^{obs} - N_{missing}^{obs}) \\ &= 523,060 * 5,329,011 / (5,329,011 - 18,034) \\ &= 524,836 \end{aligned}$$

The same step must be repeated for each age group and for both sexes. Adjusted numbers of population distribution for Zimbabwe are shown in columns 6 and 7 of Table 4.1.

The quality of the population distribution can also be evaluated using a number of other techniques, such as examination of age ratios or sex ratios. Although they can be revealing of the existence of data deficiencies, such techniques are not detailed here since they provide little basis for adjustment.

TABLE 4.1:

Population and Deaths in the Last 12 Months by Age and Sex, Zimbabwe, 1992 Census

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Age Group (a, a+5)	Female Population ${}_5N_a$	Male Population ${}_5N_a$	Female Deaths in the Last 12 Months ${}_5D_a$	Male Deaths in the Last 12 Months ${}_5D_a$	Adjusted Female Population ${}_5N^{adj}_a$	Adjusted Male Population ${}_5N^{adj}_a$	Adjusted Female Deaths in the Last 12 Months ${}_5D^{adj}_a$	Adjusted Male Deaths in the Last 12 Months ${}_5D^{adj}_a$
0 - 4	795,728	788,963	15,636	18,720	798,430	791,447	16,308	19,417
5 - 9	832,469	821,319	1,436	1,548	835,296	823,904	1,498	1,606
10 - 14	731,846	724,905	934	1,119	734,331	727,187	974	1,161
15 - 19	632,510	615,728	1,555	1,227	634,658	617,666	1,622	1,273
20 - 24	523,060	466,837	2,265	1,843	524,836	468,307	2,362	1,912
25 - 29	376,495	335,713	2,379	2,591	377,773	336,770	2,481	2,688
30 - 34	326,299	280,066	2,073	2,868	327,407	280,948	2,162	2,975
35 - 39	259,555	229,360	1,873	2,531	260,436	230,082	1,954	2,625
40 - 44	189,509	174,266	1,496	2,210	190,153	174,815	1,560	2,292
45 - 49	143,441	145,437	1,354	2,053	143,928	145,895	1,412	2,129
50 - 54	147,339	133,261	1,447	2,045	147,839	133,681	1,509	2,121
55 - 59	86,729	94,713	1,074	1,789	87,024	95,011	1,120	1,856
60 - 64	84,213	95,510	1,490	2,361	84,499	95,811	1,554	2,449
65 - 69	50,902	51,202	1,195	1,900	51,075	51,363	1,246	1,971
70 - 74	62,479	58,279	1,647	2,436	62,691	58,463	1,718	2,527
75 +	68,403	52,026	4,844	5,053	68,635	52,190	5,052	5,241
Not Known	18,034	15,952	1,834	1,947				
15-49	2,450,869		12,995		2,459,191		13,553	
Total	5,329,011	5,083,537	44,532	54,241	5,329,011	5,083,537	44,532	54,241

Selected demographic indicators from Zimbabwe censuses:

- ◆ Total Population (in thousands): 10,412 in 1992; 7,608 in 1982
- ◆ Annual growth rate 1982-1992: 3.1%
- ◆ Crude birth rate: 34.5 births per 1,000 population in 1992; 39.5 in 1982
- ◆ Crude death rate: 9.5 deaths per 1,000 population in 1992; 10.8 in 1982

4.2. Evaluating Completeness of Death Recording

Before proceeding to the analysis of the completeness of death recording, some data adjustment of the age distribution of deaths may be required. As seen in columns 4 and 5 of Table 4.1, age at death is missing from a certain number of deaths. Using the same method for adjusting for missing population age information, the adjusted number of female deaths in the age interval 20 to 24 years (${}_5D^{adj}_{20}$), for example, is calculated as:

$$\begin{aligned} & \text{Adjusted number of female deaths at ages 20-24} \\ &= \text{Observed number of female deaths at ages 20-24} \\ & \quad * \text{Total observed female deaths} \\ & \quad / (\text{Total observed female deaths} \\ & \quad \quad \text{Number of female deaths missing age information}) \\ {}_5D^{adj}_{20} &= {}_5D^{obs}_{20} * D^{obs}_{total} / (D^{obs}_{total} - D^{obs}_{missing}) \\ &= 2,265 * 44,532 / (44,532 - 1,834) \\ &= 2,362 \end{aligned}$$

Likewise, the same step must be repeated for each age group and for both sexes. Adjusted numbers of deaths for Zimbabwe are shown in columns 8 and 9.

Next, the issue of whether the numbers of deaths recorded in the census accurately reflect the true death rate in the population must be considered. Some additional adjustment may be required to transform the reported death rate into a more complete measure of actual mortality conditions.

Questions to be addressed when evaluating completeness of death recording in a census:

- Is the age distribution of all deaths complete?
- What is the coverage of death recording?
- Can the recorded numbers of deaths be adjusted for data deficiencies while reflecting the population's true mortality conditions?

A variety of methods exist for evaluating the completeness of death recording. Most of these methods rely on mathematical relationships between the age distribution of deaths and the age distribution of the population, and make certain simplifying assumptions about error patterns. One methodology that is simple to apply, and relatively

straightforward conceptually, is the *Brass Growth Balance Equation* (Brass, 1975; United Nations, 1983) and extensions of it.

The Brass Growth Balance Method described in this section compares age-specific death rates based on the number of deaths reported in a census with the death rates implied by the population age distribution. It can be used to estimate the completeness of death recording relative to population recording. The completeness estimate may then be applied as an adjustment factor against the reported deaths of women of reproductive age. This straightforward way of evaluating completeness of death recording, based on the assumption that the population is characterized by a constant growth rate, is presented first. A feature of such a population is constant death and growth rates at all ages over an extended period of time. An extended version of the methodology, appropriate for use in populations with varying growth rates, is then illustrated. This method essentially compares the death rates based on recorded number of deaths with the death rates implied by changes in the population age distribution across two censuses. The methodological presentations are supplemented with applications to data from Zimbabwe and Benin.

4.2.1. Evaluating Completeness of Death Recording using the Brass Growth Balance Method

Drawing on the *Brass Growth Balance Equation*, based on an assumption of constant birth, death and growth rates in a stable population, and given data on the age distribution of deaths from the census, the numbers of deaths recorded can be evaluated for completeness and, if necessary, adjusted.

By definition, a “stable” population, where fertility and mortality remain unchanging over an extended period of time, acquires a constant rate of growth and a fixed age structure (even if the total is changing, the proportionate structure by age remains the same). Since the age structure is fixed and the growth rate is constant, the growth rate of all age groups must also be constant.

Moreover, in any population, the growth rate (r) is equal to the difference between the entry rate and the exit rate. If there is no migration, entries will be births, and exits will be deaths, so the birth rate (b) is equal to the death rate (d) plus the growth rate. This applies not only to the whole population, but also to open-ended age segments of the population (population aged a and over).

Thus in a stable population, the entry rate into each open-ended age segment (if entries are regarded as “birthdays” at the lower boundary of the age segment) is equal to the true death rate for that segment plus the constant growth rate. If deaths are incompletely reported, the true death rate will be equal to the observed death rate divided multiplied by an unknown factor, the inverse of the completeness of death recording (assumed to be a constant c). This relationship can be expressed using the following equation:

$$b_{a+} = r + (1/c) * d_{a+}$$

A plot of the entry rate against the observed death rate for all age groups should show a straight line. Note that the Brass Growth Balance Method, in common with other methods presented here, assumes that the completeness of death recording is the same at all ages. Further development of the methodology is presented in Appendix A.

Table 4.2 and Figure 4.1 show the application of the method to data for females from the 1992 Zimbabwe Census. Given information on the age distribution of deaths from the census, it is possible to evaluate the completeness of death recording by estimating the entry rate into each open-ended age segment. This involves first cumulating the (adjusted) population and numbers of deaths among females from the highest ages down to the lowest. The population in the highest age category is simply the population 75 and over as seen in column 2 of Table 4.2 (i.e. 68,635 at age 75 and over). The next highest category, aged 70 and over, includes the population 75 and over plus the population 70-74 years:

$$\begin{aligned} & \text{Cumulated female population at ages 70 and over} \\ & = \text{Female population at ages 75 and over} \\ & \quad + \text{Female population at ages 70-74} \\ N_{70+} & = N^{\text{adj}}_{75+} + {}_5N^{\text{adj}}_{70} \\ & = 68,635 + 62,691 \\ & = 131,326 \end{aligned}$$

An extra five-year age group is added in progression, until the population aged 0 and over is simply the total population: 5,329,011. The procedure for cumulating the number of deaths is the same:

$$\begin{aligned} & \text{Cumulated female deaths at ages 70 and over} \\ & = \text{Female deaths at ages 75 and over} \\ & \quad + \text{Female deaths at ages 70-74} \\ D_{70+} & = D^{\text{adj}}_{75+} + {}_5D^{\text{adj}}_{70} \\ & = 5,052 + 1,718 \\ & = 6,770 \end{aligned}$$

Results are shown in columns 4 and 5 for cumulated populations and numbers of deaths respectively.

The next step is to estimate the number of entries or birthdays (B_a) into each open-ended age segment. This involves making use of the age distribution. The number of persons passing through any age a in a year can be estimated as one-fifth of the average population in the five-year age groups on each side of age a . Using a geometric mean, the calculation for age 20, for example, is:

$$\begin{aligned} & \text{Female birthdays at age 20} \\ & = 1/5 * (\text{Female population at ages 15-19} \\ & \quad * \text{Female population at ages 20-24})^{1/2} \\ B_{20} & = 1/5 * ({}_5N^{\text{adj}}_{15} * {}_5N^{\text{adj}}_{20})^{1/2} \\ & = 1/5 * (634,658 * 524,836)^{1/2} \\ & = 115,428 \end{aligned}$$

Note that, because there is no population under age 0, this expression cannot be used to estimate births. Since the highest 75 and over age group is not a five-year group, an estimate at age 75 cannot be made either. This expression only serves to estimate birthdays (B_a) for ages 5 through 70, with results shown in column 6.

TABLE 4.2:
Application of the Brass Growth Balance Method to Evaluate Completeness of Death
Recording for Women, Zimbabwe, 1992 Census

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Age a	Adjusted Female Population ${}_5N^{adj}_a$	Adjusted Female Deaths ${}_5D^{adj}_a$	Cumulated Female Population at age a N_{a+}	Cumulated Female Deaths at age a D_{a+}	Female Birthdays at age a B_a	Birthday Rate at age a = (6) / (4) b_{a+}	Death Rate at age a = (5) / (4) d_{a+}
0	798,430	16,308	5,329,011	44,532			0.0084
5	835,296	1,498	4,530,581	28,224	163,331	0.0361	0.0062
10	734,331	974	3,695,285	26,726	156,638	0.0424	0.0072
15	634,658	1,622	2,960,954	25,752	136,536	0.0461	0.0087
20	524,836	2,362	2,326,296	24,130	115,428	0.0496	0.0104
25	377,773	2,481	1,801,460	21,768	89,055	0.0494	0.0121
30	327,407	2,162	1,423,687	19,287	70,338	0.0491	0.0135
35	260,436	1,954	1,096,280	17,125	58,402	0.0533	0.0156
40	190,153	1,560	835,844	15,171	44,507	0.0532	0.0182
45	143,928	1,412	645,691	13,611	33,087	0.0512	0.0211
50	147,839	1,509	501,763	12,199	29,174	0.0581	0.0243
55	87,024	1,120	353,924	10,690	22,685	0.0641	0.0302
60	84,499	1,554	266,900	9,570	17,150	0.0643	0.0359
65	51,075	1,246	182,401	8,016	13,139	0.0720	0.0439
70	62,691	1,718	131,326	6,770	11,317	0.0862	0.0515
75+	68,635	5,052	68,635	5,052			0.0736
Total	5,329,011	44,532					

All the pieces needed to estimate the entry (birthday) rate and exit (death) rate for each open-ended age segment are now available, that is, the numbers of birthdays and deaths for each open-ended age segment divided by the cumulated population at that age respectively. In an application to 1992 Zimbabwe census data for the female population at age 20, the rates would be:

$$\begin{aligned} &\text{Female birthday rate at ages 20 and over} \\ &= \text{Female birthdays at age 20} \\ &\quad / \text{Female population at ages 20 and over} \\ b_{20+} &= B_{20} / N_{20+} \\ &= 115,428 / 2,326,296 \\ &= 0.0496 \end{aligned}$$

And for the death rate at the same age:

$$\begin{aligned} &\text{Female death rate at ages 20 and over} \\ &= \text{Female deaths at ages 20 and over} \\ &\quad / \text{Female population at ages 20 and over} \\ d_{20+} &= D_{20+} / N_{20+} \\ &= 24,130 / 2,326,296 \\ &= 0.0104 \end{aligned}$$

Results for Zimbabwe are presented in Table 4.2 (columns 7 and 8). In addition, Figure 4.1 graphs the birthday rate against the death rate for all applicable age groups.

An application to data from the 1992 National Population Census of Benin (Institut national de la statistique et de l'analyse économique, 1994), which also collected information on deaths in the household by age and sex, is shown in Table 4.3. Results are displayed graphically in Figure 4.2.

Questions used for measuring the numbers of recent deaths, maternal deaths, and births in the 1992 Benin Census:

- Were there any deaths in the household since January 1, 1991? If yes: record the name, sex, date of death (day, month, year), and age at death (month, year).
- What were the circumstances of the death: Did the deceased die during pregnancy? Following delivery (or during the postpartum period)? Did the deceased die of other causes?
- Were there any births in the household since January 1, 1991? If yes: record the name, sex, and date of birth (month, year) by mother's line number.

TABLE 4.3:
Application of the Brass Growth Balance Method to Evaluate Completeness of Death Recording for Women, Benin, 1992 Census

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Age a	Female Population ${}_5N_a$	Female Deaths in the Last 12 Months ${}_5D_a$	Adjusted Female Population ${}_5N^{adj}_a$	Adjusted Female Deaths in the Last 12 Months ${}_5D^{adj}_a$	Cumulated Female Population at age a N_{a+}	Cumulated Female Deaths at age a D_{a+}	Female Birthdays at age a B_a	Birthday Rate at age a = (8) / (6) b_{a+}	Death Rate at age a = (7) / (6) d_{a+}
0	450,913	5,938	451,209	5,956	2,525,219	11,169			0.0044
5	441,643	681	441,933	683	2,074,010	5,213	89,309	0.0431	0.0025
10	263,932	256	264,105	257	1,632,078	4,530	68,328	0.0419	0.0028
15	221,465	270	221,610	271	1,367,973	4,273	48,385	0.0354	0.0031
20	216,125	333	216,267	334	1,146,362	4,002	43,784	0.0382	0.0035
25	217,351	316	217,494	317	930,096	3,668	43,376	0.0466	0.0039
30	161,871	339	161,977	340	712,602	3,351	37,539	0.0527	0.0047
35	132,021	258	132,108	259	550,625	3,011	29,256	0.0531	0.0055
40	95,637	246	95,700	247	418,517	2,752	22,488	0.0537	0.0066
45	71,045	201	71,092	202	322,818	2,506	16,497	0.0511	0.0078
50	62,940	256	62,981	257	251,726	2,304	13,383	0.0532	0.0092
55	36,694	200	36,718	201	188,745	2,047	9,618	0.0510	0.0108
60	49,854	331	49,887	332	152,027	1,847	8,560	0.0563	0.0121
65	26,884	207	26,902	208	102,140	1,515	7,327	0.0717	0.0148
70	28,767	318	28,786	319	75,238	1,307	5,566	0.0740	0.0174
75+	46,422	985	46,452	988	46,452	988			0.0213
Not Known	1,655	34							
15-49	1,115,515	1,963	1,116,247	1,969					
Total	2,525,219	11,169	2,525,219	11,169					

As seen in Figure 4.1 for the application to Zimbabwe, the points for the birth rates and the death rates for the different ages line up more or less linearly. This suggests that the degree of completeness of death recording is essentially constant across all age groups. Standard statistical regression techniques (using any spreadsheet or statistical software package) can be applied for determining the best linear fit to the data. The slope of the straight line that is returned from such calculation is an estimate of the inverse of the completeness of death recording (relative to the coverage of the population), while the intercept is an estimate of the population growth rate that is assumed constant over time.

Using *ordinary least squares* (OLS) regression to fit the best straight line for the array of birthday rates against death rates gives an intercept of 0.038 and a slope of 0.793. The OLS-fitted line is shown in Figure 4.1. The estimate of the “stable” growth rate in this case is a fast 3.8 percent per year. The estimated coverage of death recording is $1/0.793$, or 1.26. In other words, recording of deaths appears more than 100 percent complete.

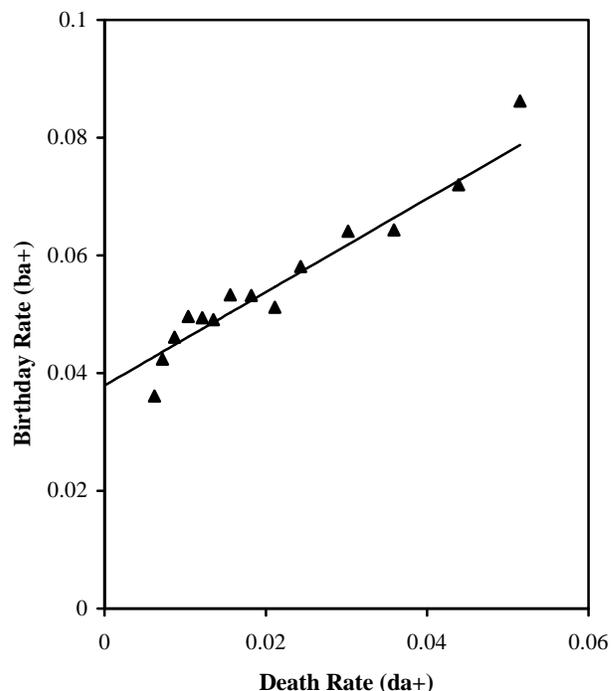
With regard to Benin (Figure 4.2), it is immediately clear from even a cursory inspection of the graph that the slope of the line indicates substantial underreporting of deaths. It is also evident that the fit of the OLS regression line to the points is much less close in the Benin case than in the Zimbabwe application, indicating the likelihood that errors other than proportionately constant omission of deaths are affecting the data. The OLS-fitted line has a slope of 2.1 and an intercept of 0.036. Thus the population’s growth rate is also found to be high at 3.6 percent annually. Since the slope estimates the reciprocal of the completeness of death recording, coverage of deaths is only 48 percent ($1/2.1$ or 0.48) of the expected number.

Such outcomes are possible under a number of circumstances. For one, deaths in a household were identified as those having occurred within a specific period prior to enumeration. In the case of Zimbabwe, if some deaths that occurred before the reference period were included, recording would appear to be over-complete. Additionally, the deaths coverage estimate is relative to the population coverage. If the census missed a substantial

proportion of the population, whereas deaths were accurately recorded, the Brass estimate would indicate more than complete death coverage. In either case, the assumption that the degree of completeness of death recording is invariant with age may be incorrect. Unfortunately there is no reliable way to test these hypotheses.

Another possibility is that the underlying assumption of this method of constant mortality and fertility conditions over an extended period of time is not met. The rapid rates of population growth suggest that these societies are in a transitional demographic phase. This is especially true for Zimbabwe, where evidence from other sources indicates that the country had experienced declining mortality for a long period before 1992, and that fertility began to decline sharply in the 1980s. Thus the assumption of stability is not correct in this case. Fortunately an evaluation of death coverage can be made while correcting for changing mortality and fertility rates in the population. As will be seen in section 4.2.2, this involves simply comparing changes in the age distribution across two different information sources over time.

FIGURE 4.1: Application of the Brass Growth Balance Method to Data for Women, Zimbabwe, 1992 Census



4.2.2. Evaluating Completeness of Death Recording using the General Growth Balance Method

In the discussion of interpretation above, it was noted that results might be distorted due to changes in fertility and mortality in the period prior to enumeration, and that the assumption of stability in the population structure thus would not hold. However, completeness of death recording can be estimated using some additional information about population growth, in particular, by using successive censuses to measure changes across age groups.

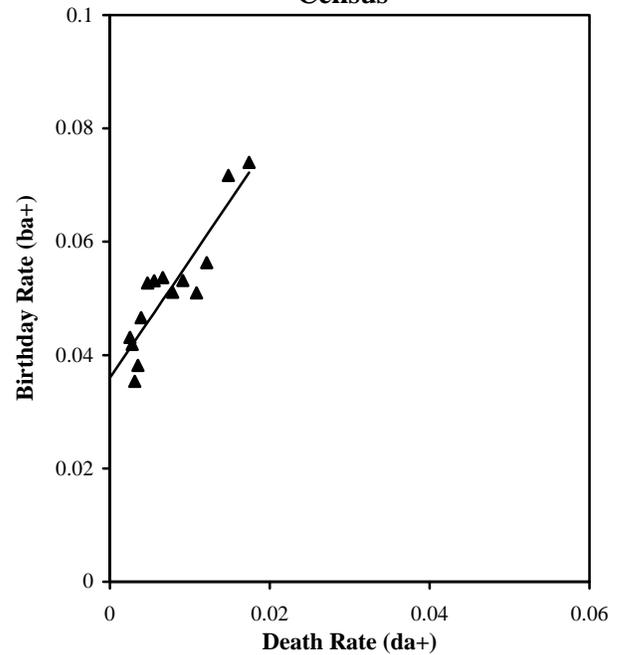
Recall that the entry rate into each open-ended age segment is equal to the reported death rate for that segment multiplied by an unknown constant (the inverse of completeness of death recording) plus the growth rate. In a non-stable population, the growth rate of each open-ended segment (which can now vary across ages) can be calculated from two successive census age distributions. Thus the entry rate minus the growth rate is equal to the death rate multiplied by the constant, or:

$$b_{a+} - r_{a+} = (1/c) * d_{a+}$$

A plot of the difference between the entry rate and the growth rate against the observed death rate should produce a linear array with an intercept at the origin and a slope equal to the inverse of completeness of death recording.

The *General Growth Balance Method* requires two population age distributions and an age distribution of deaths for the intervening period. The interval between population counts should be fairly short, for example not more than about 15 years and preferably less. The age distribution of deaths could be taken from the average annual number of deaths over the entire period, or from deaths having occurred during the year roughly in the

FIGURE 4.2: Application of the Brass Growth Balance Method to Data for Women, Benin, 1992 Census



middle of the period, or even solely from the deaths at the beginning or end of the period. In the present case, the death distribution pertains to the end of the time period. (While this is not optimal, particularly in a highly non-stable population, it should not result in major errors.)

The generalized method is applied in Table 4.4 to the 1982 and 1992 censuses for Zimbabwe. Data on the female population by five-year age group (adjusted to account for missing age information) from the 1982 census are shown in column 2 of the table.

TABLE 4.4:

Application of the General Growth Balance Method to Evaluate Completeness of Death Recording for Women, Zimbabwe, 1982 and 1992 Censuses

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Age a	Female Population by Age Group 1982 ${}_5N_{1a}$	Cumulated Female Population at age a 1982 N_{1a+}	Cumulated Female Population at age a 1992 N_{2a+}	Cumulated Female Deaths at age a 1992 D_{a+}	Female Birthdays at age a 1982-1992 B_a	Entry Rate at age a 1982-1992 b_{a+}	Growth Rate at age a 1982-1992 r_{a+}	Entry Rate Growth Rate at age a 1982-1992 = (7)-(8) $b_{a+} - r_{a+}$	Death Rate at age a 1982-1992 d_{a+}
0	665,350	3,827,850	5,329,011	44,532			0.0331		0.0099
5	619,300	3,162,500	4,530,581	28,224	149,099	0.0394	0.0359	0.0035	0.0075
10	518,740	2,543,200	3,695,285	26,727	134,873	0.0440	0.0374	0.0066	0.0087
15	412,610	2,024,460	2,960,954	25,753	114,756	0.0469	0.0380	0.0089	0.0105
20	364,200	1,611,850	2,326,296	24,131	93,070	0.0481	0.0367	0.0114	0.0125
25	281,060	1,247,650	1,801,460	21,769	74,185	0.0495	0.0367	0.0128	0.0145
30	206,760	966,590	1,423,687	19,287	60,670	0.0517	0.0387	0.0130	0.0164
35	170,170	759,830	1,096,280	17,125	46,410	0.0509	0.0367	0.0142	0.0188
40	139,530	589,660	835,844	15,172	35,977	0.0512	0.0349	0.0163	0.0216
45	110,390	450,130	645,691	13,612	28,342	0.0526	0.0361	0.0165	0.0252
50	90,880	339,740	501,763	12,199	25,550	0.0619	0.0390	0.0229	0.0295
55	60,800	248,860	353,924	10,690	17,786	0.0599	0.0352	0.0247	0.0360
60	65,260	188,060	266,900	9,570	14,335	0.0640	0.0350	0.0290	0.0427
65	38,860	122,800	182,401	8,016	11,547	0.0772	0.0396	0.0376	0.0536
70	30,500	83,940	131,326	6,770	9,872	0.0940	0.0448	0.0492	0.0645
75+	53,440	53,440	68,635	5,052			0.0250		0.0834
Total	3,827,850								

Some procedural modifications compared to the Brass method for stable populations are required (see Appendix A for details). First, it is possible to refine the calculation of the “birthday” rate at age a when data are available from two censuses. This involves considering observations of both cohorts that will pass through age a after the first census, and cohorts that have already passed through age a by the time of the second census. A good estimate of the number of intercensal birthdays at age 20, for example, can be obtained as:

$$\begin{aligned} & \text{Intercensal female birthdays at age 20} \\ &= 1/5 * (\text{Female population aged 15-19 in 1982} \\ & \quad * \text{Female population aged 20-24 in 1992})^{1/2} \\ B_{20} &= 1/5 * ({}_5N_{15} * {}_5N_{20})^{1/2} \\ &= 1/5 * (412,610 * 524,836)^{1/2} \\ &= 93,070 \end{aligned}$$

where $N1$ and $N2$ represent the populations recorded in the 1982 and 1992 censuses respectively.

Likewise, using a geometric mean to estimate the intercensal age-specific population, the entry rate b_{a+} can be calculated as:

$$\begin{aligned} & \text{Female birthday rate at ages 20 and over} \\ &= \text{Female birthdays at age 20} \\ & \quad / \text{Female population at ages 20 and over} \\ b_{20+} &= B_{20} / (N_{120+} * N_{220+})^{1/2} \\ &= 93,070 / (1,611,850 * 2,326,296)^{1/2} \\ &= 93,070 / 1,936,399 \\ &= 0.0481 \end{aligned}$$

The growth rate r_{a+} for the same open-ended age interval is defined as:

$$\begin{aligned} & \text{Female growth rate at ages 20 and over} \\ &= (1/t) * \log_e(\text{Female population 20+ in 1992} \\ & \quad / \text{Female population 20+ in 1982}) \\ r_{20+} &= (1/t) * \log_e(N_{220+} / N_{120+}) \\ &= (1/10) * \log_e(2,326,296 / 1,611,850) \\ &= 0.0367 \end{aligned}$$

where t is the intercensal interval, in this case 10 years.

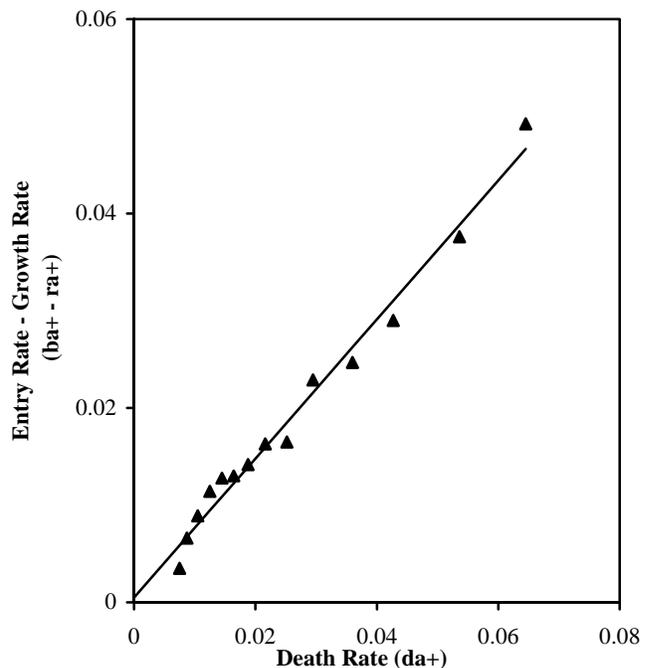
Finally, the death rate d_{a+} is calculated as:

$$\begin{aligned} & \text{Female death rate at ages 20 and over} \\ &= \text{Female deaths at ages 20 and over} \\ & \quad / \text{Female population at ages 20 and over} \\ d_{20+} &= D_{20+} / (N_{120+} * N_{220+})^{1/2} \\ &= 24,131 / 1,936,399 \\ &= 0.0125 \end{aligned}$$

Results across all ages are presented in Table 4.4 for the entry rate (column 7), growth rate (column 8) and death rate (column 10). A plot of the difference between the entry and growth rates against the death rate is illustrated in Figure 4.3. OLS regression has been used to fit a straight line to the observations. Note that the points approximate a straight line better in Figure 4.3 (the *general* method) than in Figure 4.1 (the *stable* method).

The regression line has an intercept of 0.0005 and a slope of 0.715. The intercept close to the origin indicates that there was little significant change in

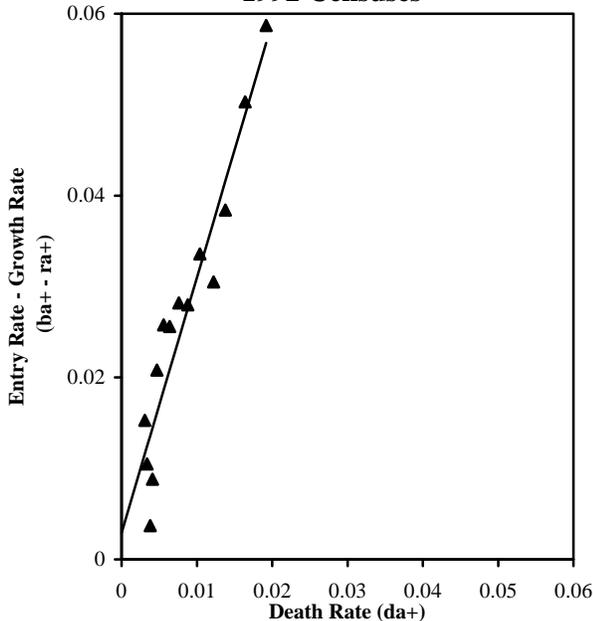
FIGURE 4.3: Application of the General Growth Balance Method to Data for Women, Zimbabwe, 1982 and 1992 Censuses



population coverage across the two censuses, about 0.5 percent (see Appendix A, section 2, for details). The completeness of death recording (relative to the average completeness of population coverage) can be calculated from the slope: $1/0.715$ or 1.40. This result suggests a substantial level of “over-reporting” of deaths, to the tune of about 40 percent.

An application of the General Growth Balance Method can be found for Benin in Table 4.5 and Figure 4.4. This involves a comparison of the death rates based on number of deaths reported in the year preceding the 1992 census with changes in the population age structure between the 1979 and 1992 censuses (in this case t , the intercensal interval, equals 13 years). The OLS-fitted line in Figure 4.4 is found to have a slope of 2.8 and an intercept of 0.0029. The value of the slope suggests that the number of deaths recorded in the census was under-complete, some 36 percent of the expected number ($1/2.8$, or 0.357). The value of the intercept suggests possible changes in population coverage between the 1979 and 1992 censuses.

FIGURE 4.4: Application of the General Growth Balance Method to Data for Women, Benin, 1979 and 1992 Censuses



Given these findings, the question arises of whether or not to adjust the observed number of deaths in the 1992 Zimbabwe census for apparent *over-coverage*, and in the 1992 Benin census for *under-coverage*.

There is no simple answer. In the case of Zimbabwe, the application of the General Growth Balance Method provides fairly good evidence that the number of adult female deaths reported for the 12 month-period before the 1992 census was substantially larger than the expected annual average number for the intercensal period 1982-1992. The method relies on information for the age distribution of deaths reported in 1992, whereas the evaluation of completeness is relative to population change over the period 1982 to 1992. As previously indicated, recent growth of the adult female population in Zimbabwe has been rapid, over 3.5 percent annually, which alone would account for a substantial portion of this result. Moreover, a certain amount of the discrepancy could be attributed to population undercoverage or change in coverage across censuses. (In the present example it is reassuring that the intercept is close to zero, indicating minimal change in census coverage.) It is also possible that adult female mortality increased substantially late in the intercensal period, when the HIV/AIDS epidemic would have started to have a major effect on mortality in Zimbabwe. Thus the reported number of deaths for the year before the 1992 census is probably not unreasonable. Under the circumstances of Zimbabwe, the available methodology does not permit a more precise conclusion.

Using the results of the evaluation of completeness of death recording, however, it is possible to adjust the number of adult female deaths recorded in 1992 to estimate the “complete” average annual number of deaths for the intercensal period 1982-1992. The appropriate adjustment factor is simply the slope of the OLS-fitted line shown in Figure 4.3, applied to the number of observed deaths among women of reproductive age (adjusted for missing age information):

$$\begin{aligned}
& \text{Complete number of female deaths at ages 15-49} \\
& = \text{Adjusted number of female deaths at ages 15-49} \\
& \quad * (1 / \text{Completeness of recorded deaths}) \\
{}_{35}D^{\text{complete}}_{15} &= {}_{35}D^{\text{adj}}_{15} * (1 / c) \\
&= 13,553 * 0.715 \\
&= 9,690
\end{aligned}$$

This estimate represents the “true” annual average number of adult female deaths for the period 1982 to 1992.

In the Benin example, the application of the General Growth Balance Method suggests that the coverage of deaths in the 1992 census is only about a third of the expected number. Clearly, the number of adult female deaths will need to be adjusted in order to arrive at an unbiased estimate of maternal mortality. The slope of the OLS-fitted line in Figure 4.4 provides an adjustment factor for deaths in the 1992 census relative to the average coverage of the two censuses. Using this factor, the adjusted

TABLE 4.5:
Application of the General Growth Balance Method to Evaluate Completeness of Death Recording for Women, Benin, 1979 and 1992 Censuses

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Age a	Female Population by Age Group 1979 ${}_5N1_a$	Cumulated Female Population at age a 1979 $N1_{a+}$	Cumulated Female Population at age a 1992 $N2_{a+}$	Cumulated Female Deaths at age a 1992 D_{a+}	Female Birthdays at age a 1979-1992 B_a	Entry Rate at age a 1979-1992 b_{a+}	Growth Rate at age a 1979-1992 r_{a+}	Entry Rate Growth Rate at age a 1979-1992 = (7)-(8) $b_{a+} - r_{a+}$	Death Rate at age a 1979-1992 d_{a+}
0	351,457	1,734,271	2,525,219	11,169					
5	286,374	1,382,814	2,074,010	5,213	78,821	0.0465	0.0312	0.0153	0.0031
10	148,519	1,096,440	1,632,078	4,530	55,003	0.0411	0.0306	0.0105	0.0034
15	132,393	947,921	1,367,973	4,273	36,284	0.0319	0.0282	0.0037	0.0038
20	158,444	815,528	1,146,362	4,002	33,842	0.0350	0.0262	0.0088	0.0041
25	151,947	657,084	930,096	3,668	37,127	0.0475	0.0267	0.0208	0.0047
30	103,912	505,137	712,602	3,351	31,376	0.0523	0.0265	0.0258	0.0056
35	86,779	401,225	550,625	3,011	23,433	0.0499	0.0243	0.0256	0.0064
40	64,563	314,446	418,517	2,752	18,226	0.0502	0.0220	0.0282	0.0076
45	55,796	249,883	322,818	2,506	13,550	0.0477	0.0197	0.0280	0.0088
50	46,041	194,087	251,726	2,304	11,856	0.0536	0.0200	0.0336	0.0104
55	30,183	148,046	188,745	2,047	8,223	0.0492	0.0187	0.0305	0.0122
60	34,438	117,863	152,027	1,847	7,761	0.0580	0.0196	0.0384	0.0138
65	22,185	83,425	102,140	1,515	6,087	0.0659	0.0156	0.0503	0.0164
70	20,453	61,240	75,238	1,307	5,054	0.0745	0.0158	0.0587	0.0193
75+	40,787	40,787	46,452	988					
Total	1,734,271								

average annual number of deaths for the intercensal period 1979-1992 is:

$$\begin{aligned} & \text{Complete number of female deaths at ages 15-49} \\ & = \text{Adjusted number of female deaths at ages 15-49} \\ & \quad * (1 / \text{Completeness of recorded deaths}) \\ {}_{35}D^{\text{complete}}_{15} & = {}_{35}D^{\text{adj}}_{15} * (1 / c) \\ & = 1,969 * 2.8 \\ & = 5,513 \end{aligned}$$

4.3. Evaluating Completeness of Birth Recording or Estimating Numbers of Births

Census questionnaires that collect information on fertility typically include a question on women's lifetime fertility, or on their recent fertility (such as the number of births in a defined time period before enumeration, or the date of the most recent live birth), or both. The approach used to estimate and evaluate numbers of births (the denominator of the MMRatio) depends on the type of data available from the census.

If the census included both questions on recent births and on the total number of children ever born, the *Brass Parity/Fertility Ratio* technique can be used to evaluate and, if necessary, adjust completeness of birth recording. This method is described in section 4.3.1.

If the census did not include a question on recent fertility, but did include a summary birth history, the number of births in a defined time period before the census can be estimated using the method of *Reverse projection*. In essence, the population of a given age is projected backwards in time to estimate numbers of recent births. The method draws on an estimate of child mortality derived from numbers of children ever born and children surviving. The method is presented in detail in section 4.3.2.

The 1992 Zimbabwe census collected information on women's lifetime fertility and on the date of the last live birth. The 1992 Benin census asked about both children ever born and births in the year preceding enumeration. Thus in both cases the Brass P/F Ratio Method can be used to evaluate and, if necessary, adjust the number of reported births in the 12-month period preceding the census.

In addition, for illustrative purposes, information on lifetime fertility alone for Zimbabwe will be used to demonstrate the Reverse Projection method.

Questions to be addressed when evaluating the number of births recorded in a census:

- What is the coverage of birth recording?
- Can the recorded numbers of births be adjusted for data deficiencies while reflecting the population's true fertility conditions?

4.3.1. Evaluating Completeness of Birth Recording using Brass P/F Ratios

The *Brass P/F Ratio Method* is used to evaluate the completeness of birth recording for a given reference period preceding the census. These ratios reflect the consistency between information on lifetime fertility and current fertility across women's age groups.

Reporting of lifetime fertility, or average parity (P), is considered essentially accurate among younger women, for whom there are typically fewer recall errors and omissions compared to older women. On the other hand, the number of births in a given reference period can be distorted due to date displacement, a problem that would be likely to occur to a similar degree across age groups. Fertility rates computed from numbers of recent births can be cumulated to obtain measures equivalent to average parities. However, if the recent births are not completely recorded, these parity equivalents (F) will be smaller than reported average parities. The overall degree of completeness of recent birth recording can be evaluated by analyzing parity/fertility (P/F) ratios by women's age group. In a context of constant fertility, an average of the ratios for the 20-24 and 25-29 age groups is a robust indicator for assessing consistency of birth information. (The ratio for women aged 15-19 is generally not considered because fertility among adolescents often does not follow standard models.)

Data and application of the P/F Ratio Method for Zimbabwe are shown in Table 4.6. The total numbers of children ever born by women's age group as recorded in the census are presented in

column 3, while numbers of births in the 12-month period preceding enumeration are in column 4. From this information, the P/F ratios can be calculated for each five-year age group $\{i=1,2,\dots,7\}$ over the women's reproductive life span $\{15-19, 20-24, \dots, 45-49\}$ respectively.

Average parity (P) is calculated simply by dividing the number of children ever born alive to women of a given age group (CEB_i) by the total number of women in the same age category (N_i). Thus, for the age group 25-29 ($i=3$), for example:

$$\begin{aligned} \text{Average parity for the age group 25-29} &= \text{Children ever born to women aged 25-29} \\ &\quad / \text{Number of women aged 25-29} \\ P_3 &= CEB_3 / N_3 \\ &= 955,180 / 376,495 \\ &= 2.537 \end{aligned}$$

This measure reflects the cumulated number of children born during the women's reproductive span. Information on current fertility can also be cumulated to arrive at an indicator comparable to average parity, or "lifetime-equivalent" fertility (F). This is measured by summing current age-specific fertility rates from the beginning of the

childbearing years. In particular, age-specific fertility rates (f_i) are calculated by dividing the number of births in the past 12-month period to women of the given age group (T_i) by the number of women in the same age category (N_i). Thus, for the age group 25-29:

$$\begin{aligned} \text{Fertility rate for the age group 25-29} &= \text{Births in the past year to women aged 25-29} \\ &\quad / \text{Number of women aged 25-29} \\ f_3 &= T_3 / N_3 \\ &= 77,393 / 376,495 \\ &= 0.206 \end{aligned}$$

Note that in this example, the births recorded are those over the last year, but women's age is classified by age at the time of the census. On average, the births had actually occurred to women aged a half-year younger at maternity than the observed age. Some adjustment is needed to account for this discrepancy when calculating lifetime fertility equivalents (see Appendix B for details).

From the age-specific fertility rates, lifetime fertility equivalents (F) are calculated by interpolation using a quadratic formula which involves,

TABLE 4.6:
Application of the Brass P/F Ratio Method to Evaluate Completeness of Recent Birth Recording for Women of Reproductive Age, Zimbabwe, 1992 Census

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Age Group	Female Population	Children Ever Born	Births in the Last 12 Months	Average Parity = (3) / (2)	Age-Specific Fertility = (4) / (2)	Lifetime Fertility Rate Equivalent	P/F Ratio = (5) / (7)
i	N_i	CEB_i	T_i	P_i	f_i	F_i	P_i / F_i
15-19	632,510	119,455	51,532	0.189	0.081	0.189	1.000
20-24	523,060	585,382	113,965	1.119	0.218	1.064	1.052
25-29	376,495	955,180	77,393	2.537	0.206	2.123	1.195
30-34	326,299	1,312,175	58,693	4.021	0.180	3.079	1.306
35-39	259,555	1,370,045	37,559	5.278	0.145	3.885	1.359
40-44	189,509	1,186,628	15,224	6.262	0.080	4.409	1.420
45-49	143,441	966,556	4,520	6.738	0.032		
Total	2,450,869	6,495,421	358,886				

for each age group i , summing the rates for all younger age groups, and then adding an appropriate adjustment for fertility within the age group itself. This latter adjustment is based on the pattern of fertility in the given age group and the next group (see Appendix B for details). For example, for the age group 25-29:

$$\begin{aligned} & \text{Lifetime fertility equivalent at ages 25-29} \\ & = 5 * (\text{Sum of fertility rates at ages under 25}) \\ & \quad + 3.392 * \text{Fertility rate at ages 25-29} \\ & \quad - 0.392 * \text{Fertility rate at ages 30-34} \\ F_3 & = 5 * (f_1 + f_2) + 3.392 * f_3 - 0.392 * f_4 \\ & = 5 * (0.081 + 0.218) + 3.392 * 0.206 - 0.392 * 0.180 \\ & = 1.495 + 0.699 - 0.071 \\ & = 2.123 \end{aligned}$$

Results from the calculation of the lifetime fertility equivalents across age groups are presented in column 7 of Table 4.6. No value is given for the age group 45-49 because the interpolation procedure applied here would need an age-specific fertility rate for the age group 50-54. (Given the small number of births observed among women aged 45-49, interest in calculating a corresponding P/F ratio for the purposes of evaluating completeness of data on recent fertility is minimal anyway.)

The P/F ratio can now be calculated for each age group, for example:

$$\begin{aligned} & \text{P/F ratio for the age group 25-29} \\ & = \text{Average parity at ages 25-29} \\ & \quad / \text{Lifetime fertility equivalent at ages 25-29} \\ P_3 / F_3 & = 2.537 / 2.123 \\ & = 1.195 \end{aligned}$$

Ratios for each applicable age group are shown in column 8. The average for the age groups 20-24 and 25-29 is 1.124. This suggests that the recorded number of births in the last 12 months before the 1992 Zimbabwe census may have been *under*-complete, and should be adjusted upward by a factor of some 12 percent.

It is important to recall that the P/F ratio technique simply evaluates consistency between information on lifetime fertility and current fertility. Although the simple average P/F ratio for the combined age group 20-29 is 1.124, the use of this adjustment factor to compensate for the completeness of recent birth recording is only appropriate in a context of constant fertility over an extended period of time.

On the other hand, a trend of increasing P/F ratios with age, as seen in Table 4.6, probably reflects strong effects of declining fertility. In a situation where fertility is falling over time, average parity, which is based on women's lifetime experiences, will exceed cumulated current fertility (assuming complete recording of recent births). Consequently, the P/F ratios will be greater than one. They will also tend to increase with age, since lifetime fertility among younger women has occurred more recently and will differ little from cumulated current fertility.

The P/F ratio for women aged 20-24 should not be very much affected by changing fertility patterns, as most of their reproductive experiences are recent. The ratio for women aged 25-29 will be somewhat more affected, but still not hugely. The trend of P/F ratios across these two age groups can be linearly extrapolated to estimate a reasonable "current P/F ratio" at the time of enumeration in a situation of changing fertility. The extrapolation procedure can be illustrated using results from Zimbabwe:

$$\begin{aligned} & \text{P/F ratio adjusted for current fertility conditions} \\ & = \text{P/F ratio at ages 20-24} \\ & \quad - (\text{P/F ratio at ages 25-29} \\ & \quad \quad - \text{P/F ratio at ages 20-24}) \\ P/F^{\text{current}} & = P_2/F_2 - (P_3/F_3 - P_2/F_2) \\ & = 1.052 - (1.195 - 1.052) \\ & = 0.909 \end{aligned}$$

This result suggests that the number of recent births recorded in the census is *over*-complete, after taking into account changing fertility. The number of recorded births can then be multiplied by the " P/F^{current} " adjustment factor to obtain the "true" number of births:

$$\begin{aligned}
& \text{Complete number of births in the last 12 months} \\
& = \text{Observed number of births in last 12 months} \\
& \quad * \text{Completeness of recorded births} \\
T_{\text{complete}} &= T_{\text{obs}} * P/F_{\text{current}} \\
&= 358,886 * 0.909 \\
&= 326,227
\end{aligned}$$

Given that fertility is falling in most parts of the developing world, and as such the assumption of constant fertility usually does not hold, this latter adjustment factor is preferred.

For Benin, the application of the P/F Ratio method is shown in Table 4.7. While there is less evidence of fertility decline, the number of births recorded in the census does appear to have been affected by under-reporting. The factor for adjusting the number of recent births can either be taken as the mean of the P/F ratios for the 20-24 and 25-29 years age groups (1.323), or can be calculated as follows:

$$\begin{aligned}
& \text{Completeness of recorded births} \\
& = \text{P/F ratio at ages 20-24} \\
& \quad - (\text{P/F ratio at ages 25-29} \\
& \quad \quad - \text{P/F ratio at ages 20-24}) \\
P/F_{\text{adjusted}} &= P_2/F_2 - (P_3/F_3 - P_2/F_2) \\
&= 1.348 - (1.297 - 1.348) \\
&= 1.399
\end{aligned}$$

Using this factor, the adjusted number of births in the 12-month period prior to the 1992 Benin census is:

$$\begin{aligned}
& \text{Complete number of births in the last 12 months} \\
& = \text{Observed number of births in last 12 months} \\
& \quad * \text{Completeness of recorded births} \\
T_{\text{complete}} &= T_{\text{obs}} * P/F_{\text{adjusted}} \\
&= 174,793 * 1.399 \\
&= 244,535
\end{aligned}$$

The method should not be considered as a precise evaluation tool, however. Further details on the use of the P/F ratio technique are found in Appendix B.

TABLE 4.7:
Application of the Brass P/F Ratio Method to Evaluate Completeness of Recent Birth Recording for Women of Reproductive Age, Benin, 1992 Census

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Age Group i	Female Population N _i	Children Ever Born CEB _i	Births in the Last 12 Months T _i	Average Parity = (3) / (2) P _i	Age-Specific Fertility = (4) / (2) f _i	Lifetime Fertility Rate Equivalent F _i	P/F Ratio = (5) / (7) P _i / F _i
15-19	221,465	87,716	22,197	0.396	0.100	0.253	1.565
20-24	216,125	336,722	47,564	1.558	0.220	1.156	1.348
25-29	217,351	649,368	49,669	2.988	0.229	2.303	1.297
30-34	161,871	692,122	30,464	4.276	0.188	3.331	1.284
35-39	132,021	685,874	17,385	5.195	0.132	4.109	1.264
40-44	95,637	543,819	5,741	5.686	0.060	4.539	1.253
45-49	71,045	416,592	1,773	5.864	0.025		
Total	1,115,515	3,412,213	174,793				

4.3.2. Estimating Numbers of Births using Reverse Projection

In the absence of direct information on recent fertility, numbers of births can be estimated from information on the population age distribution and women's summary birth histories compiled in the census (if the latter includes numbers of surviving children as well as children ever born).

The children under age 5 at the time of enumeration represent the survivors of all births over the last five years (in a population with no migration). The recorded number of children under age 5 can be used to estimate the number of births in the past five-year interval by allowing for rates of survivorship. In particular, the survivorship among children ever born to women aged 30-34 is considered a robust indicator of the level of child mortality under a wide variety of conditions.

The 1992 Zimbabwe Census collected information on the numbers of children ever born and children surviving by woman's age. From this information child survivorship can be approximated and then used to *reverse project* the estimated number of births from the recorded number of children.

The number of children aged under 5 enumerated in the census was 1,589,877 (791,447 males and 798,430 females, adjusted for missing age information). Women aged 30-34 reported a total of 1,312,175 children ever born and 1,199,801 children still alive. The proportion of children surviving from birth to age 5, or p_5 , is estimated as:

$$\begin{aligned} \text{Child survivorship to age 5} &= \text{Living children born to women aged 30-34} \\ &\quad / \text{Children ever born to women aged 30-34} \\ p_5 &= LC_4 / CEB_4 \\ &= 1,199,801 / 1,312,175 \\ &= 0.914 \end{aligned}$$

The following procedure can then be applied to approximate survivorship to the *age group* 0-4 years:

$$\begin{aligned} \text{Child survivorship to age group 0-4} &= 1.82 * \text{survivorship to age 5} \\ &\quad - 1.54 * (\text{survivorship to age 5})^2 \\ &\quad + 0.72 * (\text{survivorship to age 5})^3 \\ {}_5L_0/5 * l_0 &= 1.82 * p_5 - 1.54 * p_5^2 + 0.72 * p_5^3 \\ &= 1.82 * 0.914 - 1.54 * 0.914^2 + 0.72 * 0.914^3 \\ &= 1.663 - 1.287 + 0.550 \\ &= 0.926 \end{aligned}$$

Dividing the number of observed children aged under 5 by this child survivorship gives an estimate of the number of births over the five-year period before enumeration. Thus, to obtain the average annual number of births:

$$\begin{aligned} \text{Estimated annual number of births} &= 1/5 * \text{Number of observed children aged 0-4} \\ &\quad / \text{Child survivorship to age group 0-4} \\ T_{\text{estimated}} &= 1/5 * {}_5N_0 / ({}_5L_0/5 * l_0) \\ &= 1/5 * 1,589,877 / 0.926 \\ &= 343,386 \end{aligned}$$

Further details on the reverse projection methodology can be found in section 2 of Appendix B.

4.4. Evaluating the Classification of Deaths as Pregnancy-Related

The fourth census data component for measuring maternal mortality that requires evaluation is the classification of adult female deaths as pregnancy-related (that is, deaths occurring during pregnancy, delivery, or the postpartum period). However, there are no established methods for this evaluation, and very little knowledge of empirical regularities against which observations can be compared. A best proposal is to simply look at patterns by age group.

The proportion of deaths due to maternal causes is generally expected to follow the age-specific fertility distribution, but to be rather higher at both very young and older ages to reflect the greater obstetric risks for women in these categories. Thus plotting the PMFD against fertility rates by age group may allow some (albeit weak) check on data quality.

Likewise, plotting the maternal mortality ratio by age provides a certain visual check: The MMRatio is expected to follow a J-shape by age group, decreasing between 15-19 and 20-24, changing little until around age 35, and then increasing more rapidly afterwards.

Figures 4.5 and 4.6 present these two check mechanisms respectively using raw data from the 1992 Zimbabwe census. Each tends to follow the expected pattern, suggesting fairly decent quality of the classification of adult female deaths due to maternal causes. But these checks are informal, and provide no basis for formal evaluation or adjustment for data deficiencies.

In the case of the 1992 Benin census (Figures 4.7 and 4.8), while basic assessments suggest that the age distributions of the maternal mortality indicators do not follow as closely the expected patterns, the deviations are not considered sufficient to warrant any adjustment, particularly given the arbitrary nature of such a process.

Figure 4.5: Proportion of Deaths due to Maternal Causes and Fertility Rate by Age Group, Zimbabwe, 1992 Census

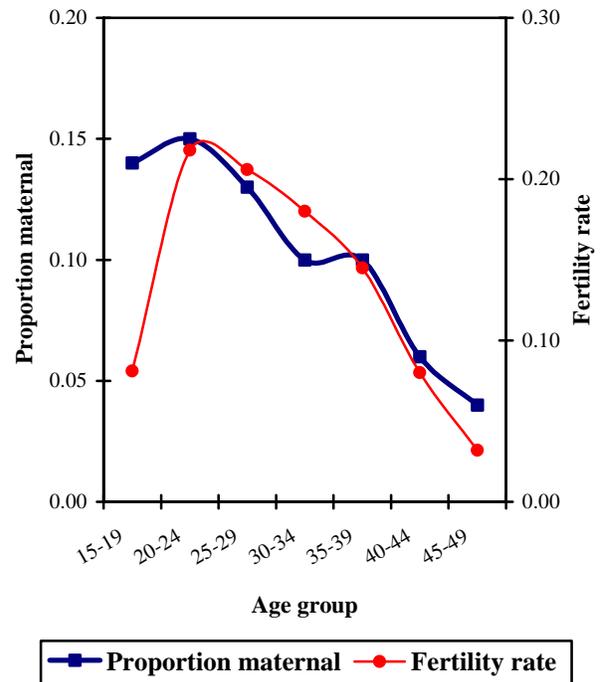
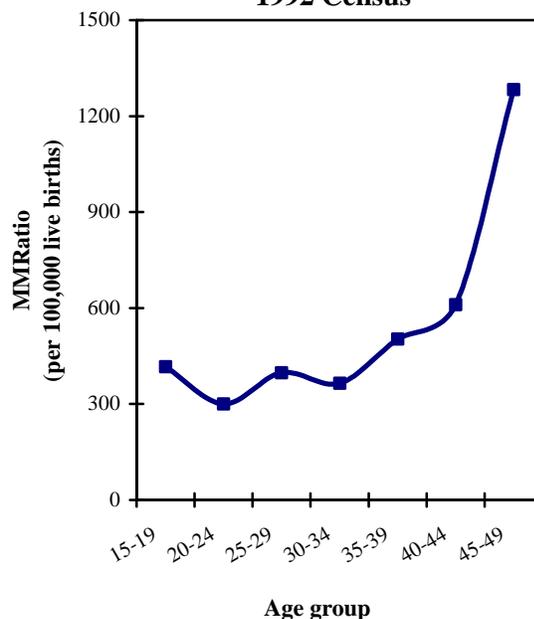


Figure 4.6: Maternal Mortality Ratio by Age Group, Zimbabwe, 1992 Census



If the evaluation had indicated major problems with the identification of deaths as maternal, it might be possible to use some form of adjustment, though only with extreme caution. A possibility could be to “borrow” information on the PMFD from another source, such as hospital records or sample surveys. For example, the 1996 Benin DHS included an application of the sisterhood methodology for direct estimation of maternal mortality (Kodjogbé et al., 1997). However the number of adult female deaths recorded in the DHS is very small compared to the number compiled in the census (166 versus 1801), and may not necessarily provide a more consistent distribution by age group (Figure 4.9).

In any case, given the absence of formal methods for evaluating the quality of classification of deaths as maternal, it is generally recommended not to adjust the age distribution of deaths due to maternal causes.

Figure 4.7: Maternal Mortality Ratio by Age Group, Benin, 1992 Census

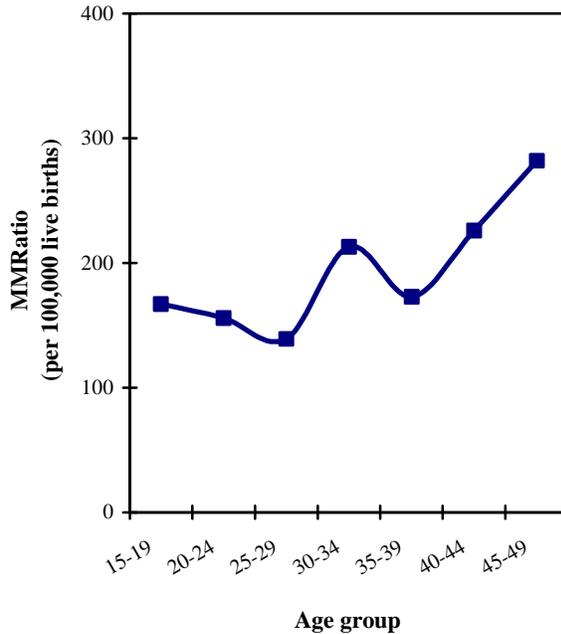


Figure 4.8: Proportion of Deaths due to Maternal Causes and Fertility Rate by Age Group, Benin, 1992 Census

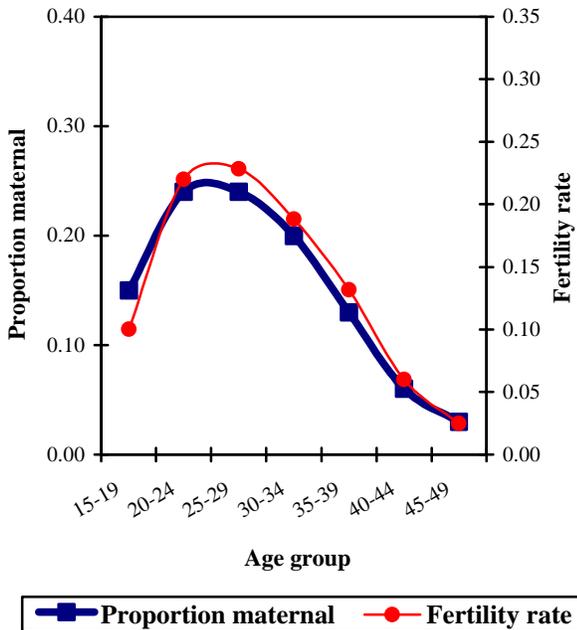
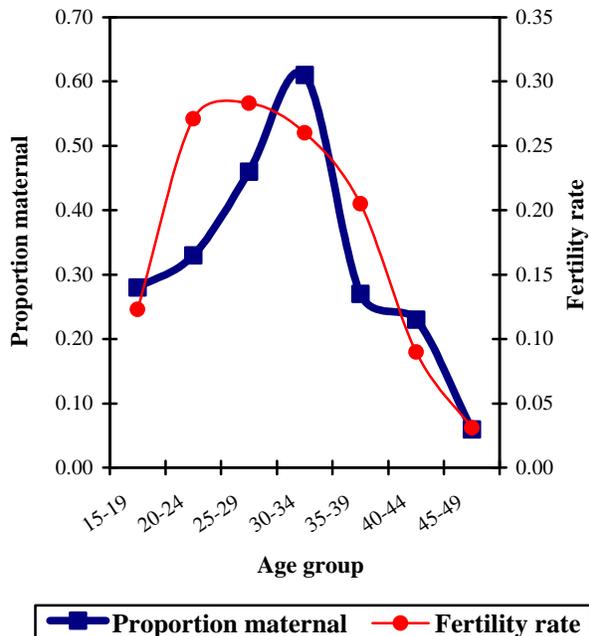


Figure 4.9: Proportion of Deaths due to Maternal Causes and Fertility Rate by Age Group, Benin, 1996 DHS



4.5. Putting It All Together: Measuring Maternal Mortality

The methods described above provide mechanisms for assessing the quality of the basic data collected in a census to calculate measures of maternal mortality. For the most part, these methods also provide a basis for adjusting the reported numbers to compensate for data deficiencies, such as frequent omissions or date displacements. However, before making any adjustment, the assumptions underlying the evaluation method must be clearly understood. The analyst must clarify against which numbers an adjustment factor should be applied, and to what time frame the adjusted numbers pertain.

As previously described, the maternal mortality ratio (MMRatio) refers to the number of maternal deaths per live birth. In the example of Zimbabwe, the MMRatio for the 12-month period preceding the 1992 census can be estimated as:

$$\begin{aligned}\text{MMRatio} &= \frac{\text{Number of maternal deaths}}{\text{Number of live births}} * 100,000 \\ &= 1419 / 358,886 * 100,000 \\ &= 395\end{aligned}$$

Although by convention the indicator is multiplied by a factor of 100,000, this implies a potentially misleading degree of accuracy. As the present analyses suggest, the data collected pertaining both to the number of deaths and the number of births in the reference period contain certain deficiencies. The number of deaths has been evaluated to be over-complete to the tune of some 40 percent using the *General Growth Balance* method. The number of births is considered over-complete by some 10 percent using the *P/F Ratio* technique. Moreover if the total number of deaths is considered in need of adjustment, then an attempt must be made to evaluate the number of deaths due to maternal causes as well. However, there are no formal tools to conduct the latter.

The analyst must be the ultimate arbiter of whether or not to adjust the numbers under each circumstance. For example, while the number of deaths may show signs of over-reporting using the *General Growth Balance* method, this evaluation tool estimates the degree of completeness drawing on

an assumed intercensal average of the distribution of deaths. Meanwhile, the PMFD refers only to deaths compiled for the year before the last census. Since the time frames do not correspond exactly, it may be preferred not to adjust the numbers of deaths at all so as to maintain consistency.

Zimbabwe is a case in point. Both the effects of population growth and recent steeply rising mortality rates (and possibly depressing fertility rates) resulting from the HIV epidemic may be distorting analyses using intercensal averages or assumptions of stability in mortality and fertility conditions. Under such conditions of rapid demographic change, there may not be fully satisfactory evaluation procedures available and data adjustments may not necessarily be justified.

Repeated applications of the census-based method may eventually provide a solution. Inclusion of questions aimed at identifying all household deaths and pregnancy-related deaths in two successive censuses would render possible estimates of the average PMFD for the intercensal period. This would improve the conceptual fit between the completeness of death recording using the *General Growth Balance Method* and the PMFD. Multiple applications of the methodology are likely to bring improvements in evaluation tools, allowing calculation of adjustment factors for the numbers of maternal deaths.

Likewise, any adjustment factor applied to the number of recent deaths should also be used for evaluating the number of births in the same time period. The *P/F Ratio* method previously described essentially evaluates completeness of birth recording at the time of the census, even given a crude allowance for recent change in fertility patterns. The method can also be applied to a “hypothetical intercensal cohort” using fertility information from two observations in time (as indicated in Appendix B), in which case the evaluation would pertain to an intercensal average. In the absence of direct information on recent fertility, the method of *reverse projection*, which draws on information on the numbers and survivorship of children in the 0-4 age group, can be used to estimate the average annual number of births in the five years before the census. In any case, it is important to recognize the true reference period for the number of births used,

and attempt to ensure as much consistency as possible with the other data being used in calculating the maternal mortality measures.

For Zimbabwe, direct reporting of recent births gave a total of 358,886 in the 12 months before the 1992 census. The P/F Ratio analysis suggests that this is some 10 percent higher than expected, and should be closer to 326,227 births. Using the reverse projection method gives an annual average of 343,386 births for the five-year period preceding enumeration. The results are reasonably consistent, and either one could be taken as a satisfactory estimate of the number of births in the year before the census.

The adjusted MMRatio using the “complete” number of maternal deaths and births (the latter estimated using the P/F Ratio method) in the preceding 12-month period would be:

$$\begin{aligned} \text{MMRatio}^{\text{adj}} &= \frac{\text{Complete no. of maternal deaths} * 100,000}{\text{Complete no. of live births}} \\ &= 1015 / 326,227 * 100,000 \\ &= 311 \end{aligned}$$

The resulting tabulation of maternal mortality indicators adjusted for missing age information and apparent over-reporting of recent deaths, maternal deaths and births in the census (assumed constant by age group) are presented in Table 4.8. It is possible to obtain a series of estimates depending on the different combinations of numbers on deaths and births used. Given the demographic conditions and apparent quality of reporting in the case of Zimbabwe, the overall recommendation may be not to adjust the raw data at all (Stanton, Hobcraft et al., 2001). Again, the final decision belongs to the analyst.

TABLE 4.8:
Maternal Mortality Indicators by Women s Age Group, Data Adjusted for Missing Age Information and Completeness of Death and Birth Recording, Zimbabwe, 1992 Census

Age Group	Adjusted Number of Women	Adjusted Number of Women s Deaths in the Last 12 Months	Adjusted Number of Deaths due to Maternal Causes	Adjusted Number of Live Births in the Last 12 Months by Maternal Age Group	Adjusted MMRatio (per 100,000 live births)	Adjusted MMRate (per 1,000 women)	Adjusted Proportion of Deaths due to Maternal Causes	Adjusted Lifetime Risk of Maternal Death (per 1,000 women)
15-19	634,658	1,160	154	46,843	328	0.24	0.13	1.2
20-24	524,836	1,689	245	103,594	236	0.47	0.15	2.4
25-29	377,773	1,774	220	70,350	313	0.58	0.12	2.9
30-34	327,407	1,546	153	53,352	287	0.47	0.10	2.4
35-39	260,436	1,397	135	34,141	396	0.52	0.10	2.6
40-44	190,153	1,116	67	13,839	481	0.35	0.06	1.8
45-49	143,928	1,010	42	4,109	1,010	0.29	0.04	1.5
Total	2,459,191	9,690	1,015	326,227	311	0.41	0.11	14.4

Adjustment factors: Deaths and Maternal deaths 0.715; Births 0.909

With regard to Benin, the evaluations of the consistency of death recording using the Brass Growth Balance and General Growth Balance methods suggested that coverage of female deaths in the 1992 census was somewhere between one-half and one-third of the expected number. Given the substantially different results, any adjustment depends on which method has been used. It should be noted that the population growth rate estimated by the Brass version (3.6 percent) is higher than expected for this country. There may have been errors in the census data that biased the results, and this would also bring into question any adjustment. Results from the General version may be prefer-

able, but published analyses should responsibly present both estimates.

For illustrative purposes, maternal mortality measures for Benin, using both the raw census data and data adjusted for missing age information as well as completeness of death coverage (using the General Growth Balance Method) and birth coverage (using the P/F Ratio method), are presented in Table 4.9. The adjustments are those eventually recommended after careful review of the results, bearing in mind as always the country's demographic situation.

TABLE 4.9:
Maternal Mortality Indicators by Women's Age Group, Data Unadjusted and Adjusted for Missing Age Information and Completeness of Death and Birth Recording, Benin, 1992 Census

Age Group	Number of Women	Number of Women's Deaths in the Last 12 Months	Number of Deaths due to Maternal Causes	Number of Live Births in the Last 12 Months	MMRatio (per 100,000 live births)	MMRate (per 1,000 women)	Proportion of Deaths due to Maternal Causes	Lifetime Risk of Maternal Death (per 1,000 women)
Unadjusted Data								
15-19	221,465	243	37	22,197	167	0.17	0.15	0.9
20-24	216,125	304	74	47,564	156	0.34	0.24	1.7
25-29	217,351	286	69	49,669	139	0.32	0.24	1.6
30-34	161,871	323	65	30,464	213	0.40	0.20	2.0
35-39	132,021	230	30	17,385	173	0.23	0.13	1.2
40-44	95,637	231	13	5,741	226	0.14	0.06	0.7
45-49	71,045	184	5	1,773	282	0.07	0.03	0.4
Total	1,115,515	1,801	293	174,793	168	0.26	0.16	9.1
Data Adjusted for Missing Age Information and Completeness of Death and Birth Recording								
15-19	221,610	758	104	29,744	334	0.47	0.14	2.4
20-24	216,267	935	207	63,736	311	0.96	0.22	4.8
25-29	217,494	888	193	66,556	278	0.89	0.22	4.5
30-34	161,977	952	182	40,822	427	1.12	0.19	5.6
35-39	132,108	725	84	23,296	345	0.64	0.12	3.2
40-44	95,700	691	36	7,693	453	0.38	0.05	1.9
45-49	71,092	565	14	2,376	564	0.20	0.03	1.0
Total	1,116,247	5,513	820	244,535	335	0.73	0.15	25.6
Adjustment factors: Deaths and Maternal deaths 2.8; Births 1.399								

Chapter 5: Data Dissemination and Use

These guidelines were designed to aid Statistical Offices in developing countries to plan for and implement data collection and publish estimates of maternal mortality from a national population census. The methods described in Chapters 2 through 4 covered data requirements; questionnaire development, training of fieldwork personnel and tabulation layouts; and data evaluation, adjustment and analysis. Repeating the exercise in successive censuses is likely to lead to improvements in the estimation and evaluation procedures.

Given the competition for additional questions in a census, the decision to measure maternal mortality in the census should be reached through careful consideration and discussion with interested parties. Ideally a commitment should be established in advance to investigate purposeful ways to put the data to use. Along with representatives from the Statistical Office, it is recommended that representatives of the Ministry of Health, as well as the donor community, be involved in these discussions from the beginning. Once the decision is made to measure maternal mortality, a plan to maintain the involvement of these interested parties is critical.

The following is a list of ways in which interest and demand for these data can be maintained:

- Make advance plans and set schedules for publication and data use, which take into account a realistic estimate of the time needed for data processing and analysis.
- Develop a data collection plan that includes regular decennial reporting on maternal mortality from the census.
- Prepare in advance to have data compiled from appropriate sources on maternal health service utilization and other process indicators of access to and quality of obstetric services to complement the census-based maternal mortality data.
- Solicit involvement from representatives of the Ministry of Health, donor agencies or other

interested parties in the development of the tabulation plan for the census volume. If more tabulations are requested than can be reasonably included in the main census volume, propose a separate publication focused solely on maternal mortality, produced jointly with the Statistics Office.

- Plan in advance to have interested parties outside of the Statistics Office disseminate aspects of the maternal mortality census data.
- Make advance plans to organize meetings with governmental agencies, non-governmental organizations and the donor community to discuss policy implications and next steps following the publication of the census data.

References

- AbouZahr C, 1998. "Maternal Mortality Overview." In: *Health Dimensions of Sex and Reproduction*, Volume III, Global Burden of Disease and Injury Series, Edited by C. Murray and A. Lopez. World Health Organization, Harvard School of Public Health and World Bank, pp. 132-134.
- Berg C, Atrash H, Koonin L, and Tucker M, 1996. "Pregnancy-Related Mortality in the United States, 1987-1990." *Obstetrics and Gynecology*, 86:700-705.
- Bouvier-Colle MH, Varnoux N, Costes P, and Hatton F, 1991. "Reasons for the under-reporting of maternal mortality in France, as indicated by a survey of all deaths among women of childbearing age." *International Journal of Epidemiology*, 20(3):717-721.
- Brass W, 1975. *Methods for Estimating Fertility and Mortality from Limited and Defective Data*. Chapel Hill, NC: Carolina Population Center, University of North Carolina.
- Brass W, 1964. "Uses of census or survey data for the estimation of vital rates." Paper prepared for the African Seminar on Vital Statistics, Addis Ababa, 14-19 December.
- Central Statistics Office, 1994. *Census 1992: Zimbabwe National Report*. Harare: Zimbabwe Central Statistics Office.
- Coale AJ and Demeny P, 1966. *Regional Model Life Tables and Stable Populations*. Princeton, NJ: Princeton University Press.
- Faveau V, Koenig M, Chakraborty J, and Chowdhury A, 1988. "Causes of Maternal Mortality in Rural Bangladesh, 1976-1985." *Bulletin of the World Health Organization*, 66(5):643-651.
- Hill K, 1987. "Estimating census and death registration completeness." *Asian and Pacific Census Forum*, 1(3): pp. 8-13,23-24.
- Institut national de la statistique et de l'analyse économique, 1994. *Deuxième recensement général de la population et de l'habitation, février 1992. Résultats définitifs*. Cotonou: Bureau central du recensement, Institut national de la statistique et de l'analyse économique.
- Kodjogbé N, Mboup G, Tossou J, de Souza L, Gandaho T, Guédémé A, Houedokoho T, Houndékon R, Tohouegnon T, Zomahoun S, Capo-Chichi V, and Cossi A, 1997. *Enquête Démographique et de Santé, République de Bénin 1996*. Calverton, MD: Institut national de la statistique et de l'analyse économique and Macro International.
- Rutenberg N and Sullivan J, 1991. "Direct and indirect estimates of maternal mortality from the sisterhood method." In: *Proceedings of the Demographic and Health Surveys World Conference*, Volume III. Columbia, MD: Macro International, pp. 1669-1696.
- Stanton C, Abderrahim N, and Hill K, 2000. "An Assessment of DHS Maternal Mortality Indicators." *Studies in Family Planning*, 31(2):111-123.
- Stanton C, Hobcraft J, Hill K, Kodjogbe N, Mapeta W, Munene F, Naghavi M, Rabeza V, Sisouphantong B, and Campbell O, 2001. "Every Death Counts: Measurement of Maternal Mortality via a Census." *Bulletin of the World Health Organization*, 79 (7): 657-664.

Stars A, 1997. "The Safe Motherhood Action Agenda: Priorities for the Next Decade." Report prepared for the Safe Motherhood Technical Consultation. Colombo, Sri Lanka: Family Care International in collaboration with the Inter-Agency Group for Safe Motherhood.

Stecklov G, 1995. "Maternal mortality estimation: Separating pregnancy-related and non-pregnancy-related risks." *Studies in Family Planning*, 26(1):33-38.

Tsui A, Wasserheit J, and Haaga J (Eds.), 1997. "Healthy pregnancy and childbearing." In: *Reproductive Health in Developing Countries: Expanding Dimensions and Building Solutions*. Washington, DC: National Research Council, National Academy Press, 314 pp.

United Nations/Department of Economic and Social Affairs, 1998a. *Principles and Recommendations for Population and Housing Censuses, Revision 1*. New York: United Nations Publications, Sales No. E.XVII.8, 274 pp.

United Nations/Fund for Population Activities, 1998b. *Issues in Measuring and Monitoring Maternal Mortality: Implications for Programmes*. Technical and Policy Paper No.1. New York: United Nations Publications.

United Nations/Department of International Economic and Social Affairs, 1983. *Manual X: Indirect Techniques for Demographic Estimation*. Populations Studies No.81. New York: United Nations Publications, Sales No. E.83.XIII.2, 304 pp.

World Health Organization, 1993. *International Statistical Classification of Diseases and Related Health Problems, 10th Revision, Instruction Manual, Volume 2*. Geneva: World Health Organization, 134 pp.

Appendix A: Development of the Brass Growth Balance Equation

In any population, the growth rate (r) is equal to the difference between the entry rate and the exit rate. If there is no migration, entries will be births, and exits will be deaths, so the birth rate (b) is equal to the growth rate plus the death rate (d). This simple truth applies not only to the whole population, but also to open-ended age segments of the population, if entries are regarded as birthdays at the lower boundary of the age segment rather than just births.

Thus, considering the population of the open-ended age interval a and over ($a+$), the growth rate of that group is equal to the difference between the “birth” rate (the number of a^{th} birthdays divided by the population aged a and over) and the death rate (the number of deaths at ages a and over divided by the population a and over):

$$b_{a+} = r_{a+} + d'_{a+} \quad (1)$$

The estimated death rate at age a , d'_{a+} , can be calculated on the basis of deaths compiled from a census or other source recorded with completeness c (that is, the coverage of the numbers of deaths relative to the population coverage, assumed to be constant at all ages). Thus the population’s true death rate can be found through an adjustment as follows:

$$d_{a+} = (1/c) * d'_{a+}$$

and hence:

$$b_{a+} = r_{a+} + (1/c) * d'_{a+} \quad (2)$$

A.1. Application to Stable Populations

A population that experiences unchanging fertility and mortality over a period of several decades acquires a constant or “stable” rate of growth and a fixed age structure (even if the total is changing, the proportionate structure by age remains the same). Since the age structure is fixed and the growth rate is constant, the growth rate of all age

groups must also be constant. In other words, in a stable population, r_{a+} will be constant across all ages a . Equation (2) therefore becomes:

$$b_{a+} = r + (1/c) * d'_{a+} \quad (3)$$

Thus in a stable population the entry rate into each open-ended age segment is equal to the reported death rate for that segment multiplied by an unknown constant (the reciprocal of completeness of death recording) plus another unknown constant (the stable rate of population growth). A plot of the entry rate against the observed death rate for a range of ages a should show a straight line of intercept r and slope $1/c$.

It is possible to estimate the age-specific entry and death rates given data on the age distribution of the population and numbers of deaths recorded in the census. The entry rate at age a , b_{a+} , can be estimated using a geometric mean of the population in the five-year age groups on each side of age a :

$$b_{a+} = (1/5) * ({}_5N_{a-5} * {}_5N_a)^{1/2} / N_{a+}$$

where ${}_5N_{a-5}$ and ${}_5N_a$ are the populations of the age groups $(a-5, a)$ and $(a, a+5)$ respectively, and N_{a+} is the population age a and over. The estimated death rate, d'_{a+} , can be calculated as:

$$d'_{a+} = D'_{a+} / N_{a+}$$

where D'_{a+} is the number of reported deaths at ages a and over.

A.2. Extension to Non-Stable Populations

With some additional information about population growth, the stability assumption can be relaxed, and a generalized growth balance approach can be applied to any population closed to migration. Equation (2), which does not assume stability, can be rearranged as:

$$b_{a+} - r_{a+} = (1/c) * d'_{a+} \quad (4)$$

Thus a plot of the entry rate minus the growth rate against the observed death rate for all ages should produce a linear array with an intercept at the origin and a slope equal to the reciprocal of completeness of death recording. Using information on the population distribution by five-year age groups from successive censuses to measure the entry and growth rates, an estimate of completeness can be made even in a non-stable population. The entry rate by age group is calculated as:

$$b_{a+} = (1/5) * ({}_5N1_{a-5} * {}_5N2_a)^{1/2} / (N1_{a+} * N2_{a+})^{1/2}$$

where $N1$ and $N2$ are the populations at census one and two respectively. The growth rate is defined as:

$$r_{a+} = (1/t) * \log_e (N2_{a+} / N1_{a+})$$

where t is the intercensal interval. Meanwhile the observed death rate over the same period is estimated as:

$$d_{a+} = D_{a+} / (N1_{a+} * N2_{a+})^{1/2}$$

The question then arises of how to interpret an application in which the intercept does not appear to be zero. Given that the entry and growth rates, b_{a+} and r_{a+} , are calculated from two successive censuses, one explanation for a non-zero intercept could be a change in census population coverage. Such a change (if constant across age groups) has a fixed effect on the growth rate but no overall effect on the age-specific entry rate. Defining the completeness of population coverage at the first and second censuses as $k1$ and $k2$ respectively, the coverage factors can be seen to cancel out in the numerator and the denominator when calculating the entry rate:

$$b_{a+} = (1/5) * \frac{((1/k1 * {}_5N1'_{a-5}) * (1/k2 * {}_5N2'_a))^{1/2}}{((1/k1 * N1'_{a+}) * (1/k2 * N2'_{a+}))^{1/2}}$$

substituting observed population counts for the true values at census one and two, $(1/k1) * N1'$ and $(1/k2) * N2'$ respectively. On the other hand, substituting observed for true values in the calculation of the growth rate reveals:

$$\begin{aligned} r_{a+} &= (1/t) * \log_e \left(\frac{(1/k2 * N2'_{a+})}{(1/k1 * N1'_{a+})} \right) \\ &= (1/t) * \log_e (N2'_{a+} / N1'_{a+}) + (1/t) * \log_e (k1/k2) \\ &= r'_{a+} + (1/t) * \log_e (k1/k2) \end{aligned}$$

where r'_{a+} is the observed growth rate for the open-ended age interval $a+$. The second term is a constant across all ages.

The true death rate becomes:

$$\begin{aligned} d_{a+} &= (1/c * D'_{a+}) / \left(\frac{(1/k1 * N1'_{a+}) * (1/k2 * N2'_{a+})}{(k1 * k2)^{1/2} * 1/c * D'_{a+}} \right)^{1/2} \\ &= \left((k1 * k2)^{1/2} * 1/c * D'_{a+} \right) / (N1'_{a+} * N2'_{a+})^{1/2} \\ &= \left((k1 * k2)^{1/2} * 1/c \right) * d'_{a+} \end{aligned}$$

Thus:

$$b'_{a+} - r'_{a+} = (1/t) * \log_e (k2/k1) + \left((k1 * k2)^{1/2} * 1/c \right) * d'_{a+} \quad (5)$$

Notice that the first term on the right hand side is positive, with $k2$ and $k1$ inverted in order to change the sign of the term. Plotting the observed entry rate minus the observed growth rate against the observed death rate for each age a should result in a straight line fit, with the intercept determined by the change in population coverage across censuses (assumed constant across all ages), and the slope equal to the reciprocal of the completeness of death recording relative to the average population coverage.

Appendix B: Development of Methods for Estimating and Evaluating Numbers of Births

B.1. Brass P/F Ratio Method for Evaluating Consistency of Fertility Data

The *Brass Parity/Fertility Ratio Method* (Brass, 1964; United Nations, 1983) is used to assess the consistency of information on recent fertility with information on lifetime fertility collected from a census or other data source.

Lifetime fertility is measured by the average number of children ever born by women of a given age. Called from now on *average parity (P)*, this is a cumulative indicator, reflecting the sum of all children born during the reproductive life of each cohort.

Information on women's current fertility can also be cumulated to arrive at an indicator comparable to average parity. This is measured by summing current age-specific fertility rates from the beginning of the childbearing span. If childbearing is considered to start at the age of 15, cumulative fertility at exact age 20 can be arrived at by adding the age-specific fertility rate for each year between 15 and 19 (or five times the rate for the quinquennial group 15-19). Likewise, cumulative fertility at age 25 can be obtained by adding the age-specific fertility rate for each year between 20 and 24 (or five times the rate for the 20-24 years group) to the cumulative fertility at age 20.

Thus the current age-specific fertility rates can be cumulated at point ages (20, 25, 30, and so on) to arrive at estimates of "lifetime-equivalent" fertility (*F*): The average number of children a group of women would have if they experienced the current age-specific rates throughout their reproductive lives.

The two indicators can also be compiled for five-year age groups. Average parity is simply the average number of children ever born by women of the given age group. Fertility equivalents by women's age group can be estimated using interpolation between point values; for example, the average fertility equivalent for women aged 20-24

years can be approximated as an intermediate value between the fertility equivalent at exact age 20 and that at exact age 25.

The steps involved for calculating the parity/fertility (*P/F*) ratio by age group are as follows.

- *Calculation of Average Parity (P)*

The average parity (*P*) for women of a given age group (*i*) is calculated by dividing the total number of children ever born alive to women of that age category (*CEB_i*) by the number of women in the same age group (*N_i*):

$$P_i = CEB_i / N_i$$

where $i=\{1,2,\dots,7\}$ for each respective five-year age group {15-19, 20-24, ..., 45-49}.

Note that *N_i* should consider all women of reproductive age, whether married or not, and should not exclude women who failed to provide information on the number of children ever born. (Widespread experience suggests that women who fail to provide information on lifetime fertility are predominantly childless, and that subtracting them from the denominator tends to bias the average parity upwards).

- *Calculation of Age-Specific Fertility (f)*

Age-specific fertility (*f*) is calculated for each five-year age group (*i*) based on the ratio between the total number of live births reported in a year to women of that age (*T_i*) and the number of women of the same age category (*N_i*):

$$f_i = T_i / N_i$$

Several points need to be made about this calculation. The first regards the case of when information is collected in the census itself by means of a question on the number of births to women of reproductive age in the 12 months before enumeration. The woman's age would probably be recorded and tabulated in completed years at the

time of enumeration. But the number of births are recorded as those that occurred in the 12 months before the census, and thus occurred on average when maternal age was about a half-year younger than the age recorded at the census. This difference needs to be taken into account when interpolating for age-specific parity equivalents.

The second point concerns the instance when the census asks about the number of births in some reference period that is not exactly 12 months (for example, “since the end of Ramadan”). An additional adjustment may be required to estimate age-specific fertility rates, particularly if the difference from 12 months is more than a month or so either way. This second adjustment takes into account the difference between the woman’s recorded age at the time of enumeration and age at maternity, which will be more or less than the standard half-year average discrepancy, depending on whether the given reference period is longer or shorter than 12 months respectively. No further modification of the age pattern of fertility is required, as the difference for non-annual periods will affect all age groups proportionately leaving no overall influence.

The third point covers what to do if the question posed is not about births in a reference period preceding the census, but rather about the date (month and year at least) of the woman’s most recent birth. With data in this format, only births that occurred in the 12 months prior to the date of interview must be tabulated. This result is then equivalent to the data format above and, if tabulated by the woman’s age at the time of interview, simply needs the same adjustment raised in point 1 to compensate for average age at maternity.

- **Calculation of “Lifetime Fertility Equivalents” (F)**

“Lifetime fertility equivalents” by age group (F_i) are calculated from age-specific fertility rates (f_j) by first summing rates across age groups to produce cumulated rates at exact ages, and then interpolating between the cumulated rates to produce fertility equivalents for the age groups.

A simple way to do this is to assume that the cumulative fertility function is quadratic between

exact ages separated by 5 years. An approximation for F_i for the five-year age groups 15-19 ($i=1$) through 40-44 ($i=6$) follows:

$$F_i = 5 * \sum_{j=1}^{i-1} f_j + 2.917 * f_i - 0.417 * f_{i+1} \quad (1)$$

This equation (1) is used only if the available information on woman’s age is the true age at maternity. An adjustment factor may be required based on the question used in the data source to measure recent fertility (see above). More likely, age information collected in the census refers to the woman’s age in completed years at the time of enumeration, in other words at the end of the 12-month reference period for births. In this case, the following interpolation is used:

$$F_i = 5 * \sum_{j=1}^{i-1} f_j + 3.392 * f_i - 0.392 * f_{i+1} \quad (2)$$

Parity/fertility ratios (P/F_i) can now be calculated for each age group. A ratio equal to one suggests complete consistency between women’s lifetime fertility and recent fertility information collected in the census.

However, in a context of changing fertility it is unlikely that women’s past fertility experiences will closely correspond to current fertility conditions at the time of enumeration. This is particularly true among older women, for whom most of their reproductive outcomes generally would have occurred further in the past compared to their younger counterparts. The trend of P/F ratios for younger age groups can be extrapolated forward to estimate the “current” P/F ratio at the time of enumeration. A rough approximation involves subtracting the difference between the ratios for the 20-24 and 25-29 age groups from the 20-24 ratio, assuming that maternity would have occurred to women aged 20-24 on average about 2.5 years before enumeration and to those aged 25-29 some 5 years earlier.

A more satisfactory approach to evaluating consistency of fertility information under conditions of changing fertility, if data availability permits, is to use “hypothetical cohort” parity measures. This extension to the general P/F Ratio method presented here is fully explained in *Manual X* (United

Nations, 1983). Data requirements for this method include women's age-specific lifetime fertility information collected from two independent data sources, such as two successive censuses, preferably separated in time by a period of some 5 to 10 years. Essentially, the method entails calculating average parities by women's five-year age groups for both censuses. Changes in average parity by cohort of women are calculated, and then used to obtain an average parity distribution for the intercensal period. The general P/F Ratio analysis can then be applied to this "hypothetical" cohort reflecting fertility change in the intercensal period against information on current fertility rates.

B.2. Reverse Projection Method for Estimating Numbers of Births

The number of births during a defined period before enumeration can be estimated from information collected in the census on the population age distribution and on women's summary birth histories (if information on child survivorship is also collected).

The children under age 5 observed in the census represent survivors of the total number of births over the last five years (in a population with no migration). Allowing for rates of survivorship, the number of observed children aged 0-4 can then be used to estimate the number of births in the past five-year interval. Specifically:

$${}_5T_{t-5} = {}_5N_0 / ({}_5L_0/l_0)$$

where ${}_5T_{t-5}$ is the number of births in the five years before the census, ${}_5N_0$ is the enumerated population under age 5, and ${}_5L_0/l_0$ is the probability of surviving from birth to the age group 0-4 for the five-year period before enumeration.

Child survivorship can be approximated from information on women's birth histories available

from the census. The proportion surviving among children ever born to women aged 30-34 is a robust estimate of the probability of child survival to age five, p_5 , under a wide variety of conditions. Although more formal approaches are possible (United Nations, 1983), for current purposes high precision is not necessary, and the following approximations are considered adequate.

Child survivorship from birth to the age group 0-4 can then be approximated using a weight formula as follows:

$${}_0L_5/l_0 \cong w * p_0 + (1 - w) * p_5 \quad (1)$$

The value of the weight, w , varies with the level of mortality. In practice, an equation can be derived using constants based on smoothed cohort survivorship probabilities from the Coale-Demeny regional model life tables (Coale and Demeny, 1966):

$$w = 0.82 * p_5 - 0.72 * (p_5)^2$$

By definition, the probability of a live-born child surviving to age 0, p_0 , is set equal to one. Substituting the weight formula into equation (1), the following estimate for child survivorship to the age group 0-4 is obtained:

$$\begin{aligned} {}_5L_0/l_0 &\cong [0.82 * p_5 - 0.72 * p_5^2] * p_0 + \{1 - [0.82 * p_5 - 0.72 * p_5^2]\} * p_5 \\ &= [0.82 * p_5 - 0.72 * p_5^2] + [p_5 - 0.82 * p_5^2 + 0.72 * p_5^3] \\ &= 1.82 * p_5 - 1.54 * p_5^2 + 0.72 * p_5^3 \quad (2) \end{aligned}$$

Experience with census counts suggests that the population under age 5 tends to be underreported, so this method may yield somewhat conservative estimates. An option may be to take an average of the reverse-projected numbers of births in the last five years based on the populations in both the 0-4 and 5-9 age groups.