ESTIMATION OF FERTILITY LEVELS IN KENYA USING THE REVERSE SURVIVAL TECHNIQUES

BY

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DECLARATION

I, Joseph Rapemo Obala, hereby declare that this is my original work and has not been presented for award of a degree in any other University.

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This Thesis has been submitted for examination with our approval as University Supervisors.

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DEDICATION

To my parents, the late Alfred Hannington Obala and Wilchister Obala, who started it all ... and made life worthwhile!

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ABSTRACT

Indirect techniques of estimating fertility can broadly be divided into two categories. The first category uses the retrospective data on the mean number of children ever born and the births during the last year by mother's age-group. These data are used to yield adjusted estimates of current age specific fertility rates and the total fertility rate. In the second category, sex-age distributions of a population along with information on the rate of growth and a life table available at a point in time are used to estimate the crude birth rate and the gross reproduction rate, and hence the total fertility rate.

In this study, the methods that fall in the second category have been used. We have specifically used the Reverse Survival procedures. For these techniques, the fertility measures are birth rates, which are determined on the basis of reverse projection of persons in the age groups 0-4, 5-9, 0-9 and 0-14 years at the time of enumeration.

The reverse survival technique and some of its extensions have been applied to the 1979 census for Kenya at national, provincial and district level, and the results described using Exploratory Data

Analysis (EDA) procedures. From the results of the thesis, we have observed that the reverse survival method estimates of birth rate agree within approximation errors. The country's estimates of birth rate are 46.3 births per 1000 population (46.3/1000), 49.5/1000, 48.6/1000 and 49.8/1000 for the respective age groups 0-4, 5-9, 0-9 and 0-14 years. The arithmetic mean of these estimates is 48.56/1000. The Coale's method gave 48.77/1000, while the Venkatacharya and Teklu's method gave 50.25/1000. The TFR for Kenya by Rele's method is about 6.20.

At sub-regional level, Central province has the highest TFR of about 7.44, her highest TFR district being Nyandarua (TFR = 8.41), which also happens to be the highest in the republic. The lowest fertility regions are Nairobi (TFR = 4.44) and Rift Valley (TFR = 5.20). The results are close to those obtained by the Gompertz Relational model when sex ratio at birth is taken to be 1.05. In general however, this approach has been observed to give estimates that are lower than those by the methods based on children ever born.

The study reveals that the districts in Nyanza, Coast and Western provinces experience the highest mortality levels. The highest mortality area is South Nyanza district with a life expectancy index of only 40.05 years, infant mortality at a staggering 158.1/1000, and child mortality rate (under 5 years) of 287.2/1000. Lower mortality conditions are experienced in Central province, having life expectancy at 60.81 years. The lowest mortality district is Nyeri, with the following summary indices: e_0 = 64.22 years; IMR = 43.5/1000; CMR = 63.9/1000.

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chapter one

BACKGROUND TO THE PROBLEM

1.1.0 STATEMENT OF THE PROBLEM

With respect to population planning, there is need for accurate information on vital events like fertility, mortality, migration, nuptiality, etc. In developed countries, these information can easily be obtained because of the existence of proper vital registration system. Unfortunately for developing nations in general, and Kenya in particular, these systems are not reliable. The flow data system that is more informative seldom exists outside the cycle of developed countries. The deficiency is simply a facet of the broader problem of underdevelopment. The implication on this is that though direct estimation of demographic parameters is possible from the censuses or surveys as well as the systems, the results are often too inaccurate for any serious work.

The introduction of indirect estimation procedures tended to solve the problem, but also created others. For instance there have been many modifications on the procedures for estimating any particular event within the framework of indirect estimation, each of which come out with a different set of estimates. The result is a great diversity in the estimates and thus the need to compare and contrast on these sets of estimates. Only this way can the most appropriate estimates for development planning be decided for use.

The process of development planning is complex and entails the essential stages of formulation, implementation, and modification of policies, among others for sub-regional and regional development. Each of these stages and dimension of the planning process calls for the use of accurate information. Kenya, with her district focus for rural development is therefore in ardent need for such information if her planners are to succeed with their development programmes. A UN (1986) report indicates that 85% of Kenyans lived in rural areas in 1986 and that development strategies have accorded priorities to the development of these areas. According to the report, the data situation is worse in the rural areas.

1.2.0 OBJECTIVES OF THE STUDY

The general objective of this study is to apply the sex-age distribution, along with information on the rate of growth and a life table to estimate the fertility rate for Kenya at national, provincial and district levels using the 1979 census. Specifically the study aims to :-

(a) use the reverse survival technique and its extensions due to Coale (1981) and Venkatacharya and Teklu (1987) on Kenya's data at district level for a cross-country comparison ;

(b) examine the close similarities in the reverse survival methods and illustrate a robust estimation procedure for birth rate applicable on defective data such as to be found in Kenya ;

(c) compare the results of this approach with others obtained by different methods, e.g the Relational Gompertz and the Coale -Trussell P/F Techniques, and hence assess its suitability.

1.3.0 JUSTIFICATION OF THE STUDY

The previous works on fertility estimation in Kenya have depended mainly on the mean number of children ever born and births during the last year to yield estimates of current age specific fertility and total fertility rate. Osiemo (1986), for instance, applied the Coale-Trussell (1974) model and the Brass' Gompertz Relational Model (1978) to estimate fertility rate for Kenya; while Mwobobia (1982) used the Brass P/F ratio technique for fertility estimation. Both of these techniques are based on the children ever born and births last year. The age-sex structure approach has received relatively little attention and so comparisons have not been made. The importance of this study is therefore in its providing a new set of estimates to enhance evaluation of different methods to fertility estimation, and coming out with more reliable information. Elsewhere, it has been stated that Rele's procedures are only recommended for small administrative areas, the 'small' being left undefined. One can assess the effectiveness of the method on Kenyan districts by comparing its results with others obtained by different method. The suitability of reverse survival techniques that assume closure to migration can also be tested.

Analysis of fertility and mortality are an indispensable part of informed decision making and in evaluation of public policies in the process of social and economic development. The statistics provide useful clues for further investigation as well as the impact of certain programmes on the population. This is why the existing statistical data are continuously being used by the analytical experts to derive more and more estimates. In measuring fertility, total fertility rate has been considered as the best single indicator of reproductive behavior, but in some cases, annual population growth expressed in absolute numbers or rates have been preferred. This thesis adopted the two observations and provided the two estimates to enhance quick comparison, as well as identification of emerging pictures. The issues are not just of academic concern, but have substantial implications for health policies and programmes nationwide.

1.4.0 SCOPE AND LIMITATIONS

The reverse survival estimation of fertility solely depends on mortality estimates. It follows that whatever errors that may be incurred in mortality measurement and estimation will eventually be reflected as errors in fertility estimates. Because of this dependence, the reverse survival technique in this study is used in conjunction with the extension of Brass (1964) technique for the estimation of child mortality. The results are examined using the exploratory data analysis procedures.

The study used the 1979 census data. This implies that the resulting estimates refer to the periods in the neighbourhood of 1979, and may not depict the current situation. Moreover, reverse survival methods being part and parcel of reverse projection implies that the estimates should refer to a period of up to 15 years before the time of enumeration.

The kind of data provided by retrospective information in censuses occasionally fail to contribute significantly to the observed indices of fertility and mortality estimated. The direct estimation of fertility and mortality in this study were based on reports given by women concerning their live births and the subsequent survival of those children. The required data are proportions of population at various ages, particularly childhood ages. The conventional data include births, deaths and child populations by age and mothers age groups. Each of these is subject to potentially large and unpredictable error.

Errors in age reporting have probably been examined more intensively than other reporting errors because of the weight they have on demographic estimation. Censuses often fail to effectively enumerate ages especially, ages 0 and 1. This made it difficult to estimate accurate measures of sex ratio at birth for estimation of fertility by some methods. The errors may be due to coverage, failure to record age and misreporting in recorded ages. There may be a tendency of the enumerators or respondents to report certain ages (or digits) at the expense of others, majorly in cases where age is reported in single years. Besides being sensitive to the presence of age misreporting, the estimation of fertility by reverse projection is also dependent upon the type of mortality estimates used. Other errors are attributable to the design of the census programme, lack of adequate knowledge and understanding of the procedures, deliberate mistakes of respondents or enumerators and memory lapse.

Field studies on human populations also suffer from inaccessibility of some desired data due non-response of some respondents bound by some cultural values or associated social stigma, lack of adequate financial support and the time factor. The 1979 census data failed to give enough information for a more detailed study of reverse survival fertility by the various differentials other than the regional differentials. The study therefore presents results only at national, provincial and district levels, which may hide significant disparities.

1.5.0 LITERATURE REVIEW

Estimation of fertility is an important element in demographic analysis of populations in developing countries. In recent years, various methods of estimating birth rate have been suggested. The following section confines strictly to the historical development of the fertility estimation techniques based on the age-sex structure of the population. Emphasis has been made in the reverse survival technique and its extensions as the main subject in this study.

One of the most significant advances in demography has been the expansion of the stable population theory to take care of non-stability conditions observed in many populations. As first developed by Lotka in 1920's and 1930's, its purpose was to provide better understanding of the vital registration rates of a given period by demonstrating mathematically their ultimate effect if continued indefinitely. The age structure is determined by a starting structure and by the subsequent age specific fertility, mortality and migration. The concept of stable population has been used in many works because it relates fertility and mortality to the age distribution of a population.

One of the early demographers who devised methods dependent on age-sex distribution was Rele. Rele (1967) observed that fertility analysis presented special problems because of the inadequacy of the basic data obtained from the registration of births. He thus set out to develop theories and methods to enable the estimation of fertility measures which could otherwise not be directly computed because of inadequate registration. Rele's methods assumed that the relative age specific fertility rates for women in different reproductive age groups exhibit a certain constant pattern independent of the general level of fertility in the population. He further assumed that the mortality pattern by age is fixed at each level of general mortality, and the whole set of age specific fertility and mortality rates can be specified by one index each of fertility and mortality, 'such as the gross reproduction rate (GRR) for fertility and the expectation of life at birth (e_0) for mortality.' With these assumptions, he established a linear relationship between the child-woman ratio (CWR) and the gross reproduction rate, and showed that the relationship holds for both stable and non-stable populations. This relationship can be extended to relate the total fertility rate (TFR) to the child-woman ratio by using the linear relationship between TFR and GRR.

Rele applied this relationship on the 1971 and 1980 censuses, and the 1976 Intercensal Population Survey to estimate levels and trends of fertility for Indonesia as a whole and each of its 27 provinces. Comparing results with those of another method - the own children method of deriving fertility from population censuses or surveys, it was found that Rele's approach gave lower estimates due to errors in estimating child-woman ratios from the population aged 0-4 years.

Most of the populations of the developing countries were believed to be stable in the 1960's, and the stable population theories were extensively used to estimate fertility parameters. Since the steady decline in mortality in the last decades in most developing areas, and a decline in fertility as well in some of the areas, the assumption of stability has become questionable and many adjustments for stability have been suggested. The estimation of birth rate by the reverse survival technique has been known to demographers for a long time and studies have shown close relationships between the methods.

The first significant adjustment to note was made by Coale (1981) which has been found to be robust under non-stable conditions, and for poor data situations. Coale (1981) suggested the use of the observed proportion under age 15 years for both sexes and the probability of surviving to exact age 5 to locate an appropriate stable population from a family of stable models. This population is used to represent the observed population and its birth rate is used as an estimate for the study population. Coale observed that this method of estimation yields birth rates not very much affected when populations are not stable. The logic behind this adjustment is explained by Coale by treating the estimation of the birth rate as a form of reverse survival method that gives an estimate of the birth rate during the 15 years preceding the last census.

Preston and Coale (1982) made further developments in the discovery of the generalized stable population equations which can be applied to estimate birth rate for non-stable populations. To apply the generalized stable population equations, one needs two age distributions from comparable consecutive censuses in order to estimate the age specific rate of increase of the population. This is unlike the former Coale's (1981) approach and the reverse survival technique where it is essential to have data for two censuses or a reasonably good estimate of the rate of increase of the population for about 7.5 years before the enumeration time.

The concept of reverse survival was again extended by Venkatacharya and Teklu (1987), in which they found a strong linear relationship between the probability of surviving to exact age 5 and the total life table person years lived in the age interval 0 to 15 years. They determined coefficients linking the two measures by fitting a straight line for various model life table families. In the context of the developing countries where one may not have a firm knowledge of the pattern of mortality, the coefficients that correspond to Coale and Demeny West model life tables were suggested because these resulted in minimum percentage error in the estimated birth rate. The model life tables are dependable because true life tables are lacking in most underdeveloped areas.

Venkatacharya and Teklu (1988) used various reverse survival procedures to estimate birth rate for nine African countries (including Kenya for the period 1969-1979) having at least two censuses. The study revealed that even though the use of various age groups resulted in figures referring to different points in time, birth rates based on reverse projection of the 0-4 year old age group were lowest probably due to errors in enumeration of persons in this age group. The age group comprising ages 0-15 years was considered to give the most reliable estimates. For Kenya, birth rate stood at 50.2 birth per 1000 population using the 0-15 year age group and 45.4/1000 population using the 0-4 year age group.

The values in the reverse survival procedures may be increased if they can be applied to a series of overlapping periods using successive censuses. United Nations Manual X, show that such a procedure was applied by Shorter and Macura (1982) to the quinquennial censuses of Turkey taken between 1935 and 1975.

Coale and Trussell (1974) proposed a fertility model that was able to represent the fertility experience of populations where voluntary control was exercised by generalizing the pattern of natural fertility. The model was based on the assumption that marital fertility either follows natural fertility if deliberate birth control is not practiced, or departs from it in a way that increases with age according to a typical pattern. In 1978, Brass sought to reduce the number of parameters determining the shape of the age specific fertility from the three required by Coale and Trussell (1974) to two, by postulating once more, a relational scheme between a standard fertility schedule and any other schedule. This was called the Relational Gompertz model of fertility, (UN, Manual X, 1983).

1.6.0 CONCEPTUAL FRAMEWORK

Most studies examining the effect of sociological or cultural factors on fertility are based on models derived from the demographic transition theory. These studies make the assumption that fertility is likely to decline where there has been sufficient socio-economic development to lessen dependency on familial and other traditional institutions. It is argued that Kenya is in the transitional state and therefore responses to social change have already began. Many models adopt the Bongaarts (1983) frameworks and assess the roles of socio-economic, socio-cultural or sociological factors affecting fertility through intermediate variables. Other fertility studies are descriptive and are therefore not explicitly based on any known theoretical models.

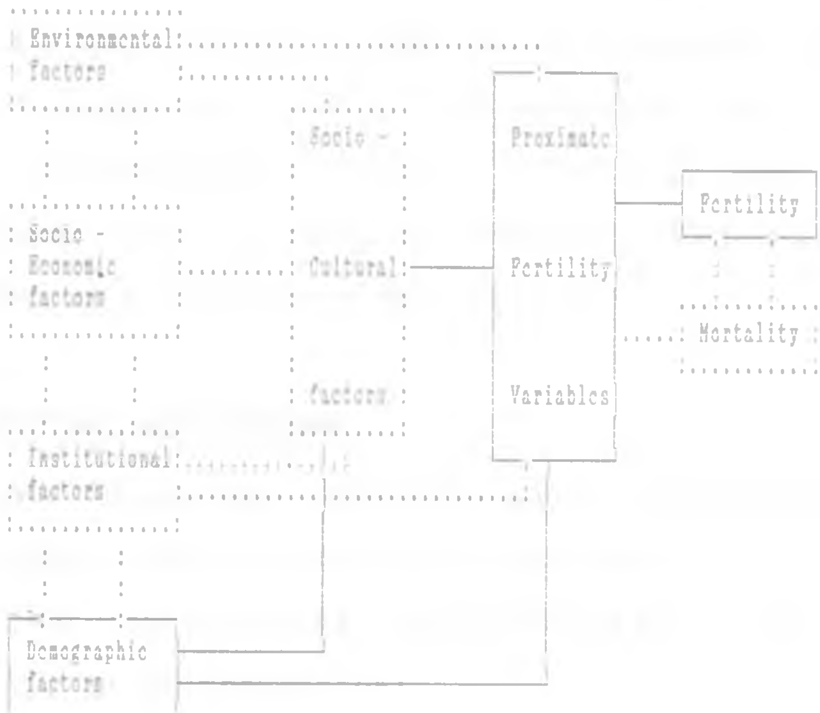
The fertility studies in Kenya are mainly confined to analysis of secondary data collected by CBS at censuses and large scale surveys. Studies dependent on these types of data are in most cases predetermined in the kind of analysis procedures followed. Most studies are quantitative and use either simple descriptive methods or advanced multivariate analytical techniques. Some of the statistical techniques applied particularly for deriving fertility estimates have been borrowed from the developed countries where the data is more accurate. These techniques assume that the data in underdeveloped areas are largely under-reported and tend to exaggerate estimates.

According to the Mosley and Chen (1984) framework, there is an interrelationship between fertility and mortality. This study modified the model, considering the fact that the reverse survival techniques derives fertility estimates using some mortality estimates. In this model, we state that, "The fertility of any population is likely to be affected by environmental, socio - cultural and institutional factors, along with socio - economic status of the population at community levels through a set of proximate determinants".

This framework draws attention to insights regarding mortality - fertility interactions. The model however is only adopted at conceptual level because the study was carried at district level, hence analysis at personal characteristics could not be carried. Figure 1.1 is a conceptual model for the modified framework.

1.6.1 CONCEPTUAL MODEL

Fig 1.1
A modified Mosley & Chen (1984) model



The above diagram illustrates some of the direct relationships between the underlying determinants, the proximate determinants, and fertility. The basic facts to note are that conceptually, Socio - economic, institutional, environmental, and demographic factors are generally considered as independent variables, while socio - cultural factors, which effectively act as a modulator of behavior can be considered as dependent variables. Environmental, demographic and institutional factors may operate on proximate determinants directly, while the socio - economic factors are generally constrained by cultural factors. The independent variables also operate on each other in one way or other in shaping up the resulting relationships.

Although the conceptual framework is broad enough, the actual operation has been limited to only one key concept. This is because the data used did not cover all the concepts. The available data only covered demographic factors in detail. Hence, the cells covering these other concepts are marked in dotted lines to bring out the sort of relationship that exists.

1.6.2 CONCEPTUAL HYPOTHESES

The following conceptual hypotheses can be derived from the foregoing discussion on the conceptual framework :-

(a) that environmental factors may affect the fertility of any given population;

(b) that socio-economic factors are likely to affect the fertility in any given population;

(c) that factors relating to institutions in any given society may have an effect on the fertility of the society;

(d) that socio-cultural factors are likely to affect the fertility in any given population;

(e) that demographic factors can affect the fertility of any given population;

(f) that the environmental, socio-economic, institutional and demographic factors may affect the fertility of any given population through the socio-cultural factors.

These conceptual hypotheses, however are neither operationalized nor tested due to some limitations of the methods applied. The Reverse Survival estimation procedures make use of whole populations as basis for proportions, which is why the study was carried only at regional level. At district or provincial level, the results may point at certain differences but is also likely to hide certain important disparities within the regions.

1.6.3 ANALYSIS AND INTERPRETATION OF KEY CONCEPTS

The key concepts in the conceptual framework are environmental, socio-cultural, institutional, socio-economic and demographic factors; and fertility. All these concepts can be applied in the analysis and fertility estimation in any population if they are all covered sufficiently by the available data. In the context of this thesis, the data available only covers demographic factors to a reasonable detail. The meanings attached to these concepts are as per the definitions given below.

Fertility is the actual birth performance of a biologically fecund woman in her reproductive ages. A woman who is bearing children is fertile; a woman is considered fecund if she is capable of bearing live offsprings. The opposite terms are infertility, also referred to as childlessness and infecundity which is synonymous with sterility. A woman may choose to remain infertile by not marrying, or by practicing highly effective contraception. Fertility of a woman or group of women may be measured by the birth rate, total fertility rate, gross reproduction rate, and completed fertility, among other indicators of reproductive behavior.

Socio-economic factors refer to the characteristics of mothers, or in general, parents in the society. In the context of the study, mother's skills, education or knowledge, health status, resource commands in terms of occupation, and time are considered as socio-economic factors. Of particular interest in these factors are the individual characteristics of each parent and the collective characteristics of both parents in the household, under the hypothesis that fertility is a function of the status.

Environmental factors include surroundings, circumstances, or other factors that may influence the behavior of members of a given society, but are out of the society's control. These will include only natural phenomena, such as climate, soil fertility and water resources, prevalence of disease, sanitary conditions, and topology.

Cultural factors relate to long-established laws, customs, traditions, norms, preferences, tastes and values, meant to be as a guide to generally accepted behavior among members of a society, particularly with regard to fertility. This refers to types of marriage, age at first marriage, age at first and last birth, acceptance of extramarital sexual intercourse, divorces and remarriages, etc.

The Institutional factors are used in this context to refer to some factors that may lead to differences in fertility and mortality rates through the influence of the distribution patterns of the scarce resources. In most developing countries where highly centralized political -administrative systems exercise substantial control over many sectors of economy, fertility may be shaken due to some lack of certain essential aspects of socio - economic development. Here we would like to draw attention to infrastructure, bureaucracies, health and family planning programmes (contraceptives, sterilization and abortion), production, distribution and consumption of resources.

Formal demography is defined by Shryock and Siegel (1976) as being concerned with size, distribution, structure and change of populations. In analyzing and interpreting the concepts of demographic factors therefore, there is need to define explicitly what is meant by the size, distribution, structure or change of a population. These are the variables that were considered in this thesis as demographic factors.

The size of a population is simply the number of persons (or units) in the population. Distribution refers to the arrangement of the population in space at a given time, that is, geographically or among various types of residential areas. The structure on the other hand is the distribution of the population among its sex and age groupings. This has been the most commonly used form of data in this analysis. Change in a population is its growth or decline in the absolute size, or its structural units, the components of which are births, deaths and migration. The available data provides for births and deaths, but not migration.

The data that were subjected to various techniques of analysis were mainly demographic, relating to age, sex, parity, number of dead children, etc. It has been recommended in this work that data be made available to test the factors drawn from the concepts included in the framework above.

chapter two

METHODS OF DATA ANALYSIS

2.0.0 INTRODUCTION

This chapter describes the techniques introduced in the previous chapter to be applied in this thesis. The following techniques are discussed in detail:

i) Linear interpolation and extrapolation;

ii) The Coale-Trussell technique for estimating mortality;

iii) Rele's method for estimating Total Fertility Rate;

iv) The Reverse Survival Technique for estimating birth rate and its extensions by Coale (1981) and Venkatacharya and Teklu (1987). Also discussed here is the computation of the annual growth rate.

2.1.0 LINEAR INTERPOLATION

Linear interpolation is a procedure of estimating the second coordinate of a point that lies between two other points whose coordinates are known. The basic assumption in the procedure is that the scale between the two points is regular and therefore the unknown point is a linear combination of the known points.

In deriving the linear interpolation equation, it is argued that two points necessarily make a straight line, and if a third point also falls on the line, then its coordinates must conform to the gradient (slope) of the line. Thus for any two points, $A(x_1,y_1)$ and $B(x_2,y_2)$, let there be a third point $C(x,y)$ such that the latter point coincides with the line joining the points A and B, then the gradient of the line segments AC and AB are equal. Mathematically we can write

$$\text{grad}(AC) = \text{grad}(AB).$$

but

$$\text{grad}(AC) = (y-y_1)/(x-x_1) \text{ and } \text{grad}(AB) = (y_2-y_1)/(x_2-x_1).$$

Therefore

$$(y-y_1)/(x-x_1) = (y_2-y_1)/(x_2-x_1). \qquad \ldots.(2.1)$$

Assuming x is known, equation (2.1) can be rearranged to give

$$y = (1-\alpha)y_1 + \alpha y_2 \qquad \ldots.(2.2)$$

where $\alpha = (x-x_1)/(x_2-x_1)$.

Similarly if y is known, then

$$x = (1-\beta)x_1 + \beta x_2$$

where $\beta = (y-y_1)/(y_2-y_1)$. α and β in the above cases are called the interpolating factors.

Generally, a third pair can be computed when two pairs and one coordinate of the third pair are known. The interpolation procedure has been be called for in many sections of analysis in the subsequent chapters of this thesis.

2.1.1 LINEAR EXTRAPOLATION

Linear extrapolation may also be required in the computations of some steps leading to the calculation of birth rate, particularly where observed value falls outside the range of the table values for interpolation. The assumptions in interpolation still hold, but the derivation of the extrapolation equation takes a slightly different turn.

Consider the three points A, B and C referred to in section 2.0.1 above and assume the unknown point C now lies outside the range of the known points, A and B, and that the straight line joining A to B when extended passes through point C. Using the same notations and argument, we can write,

$$\text{grad}(BC) = \text{grad}(AB)$$

$$\text{i.e} \quad (y-y_2)/(x-x_2) = (y_2-y_1)/(x_2-x_1). \qquad ....(2.3)$$

This equation, when x values are known reduces to

$$y = (1 + \alpha_1)y_2 - \alpha_1 y_1 \qquad ....(2.4)$$

where $\alpha = (x-x_2)/(x_2-x_1)$.

Similarly,

$$x = (1 + \alpha_2)x_2 - \alpha_2 x_1$$

where $\beta = (y-y_2)/(y_2-y_1)$. ....(2.5)

2.2.0 THE COALE-TRUSSELL TECHNIQUE FOR ESTIMATING MORTALITY (1975)

Before estimating birth rate and total fertility rate for Kenya using the various formulae that have been introduced in the previous chapter, it is necessary to know some mortality estimates and identify the stable population parameters corresponding to the same probability of surviving to age 5, l(5) and proportion of population under age 15, C(15), as the subject population.

To calculate the estimates of child mortality and expectation of life at birth, Trussell's technique, an extension of Brass's (1964) child mortality estimation technique was used. This procedure of infant and child mortality estimation was first developed by Brass (1964), and later improved by Sullivan (1972) and Trussell (1974). Brass developed a procedure to convert D(i) - the proportion dead among children ever born to women in successive five-year age groups i, into estimates of the probability of dying between birth and exact childhood ages x, denoted by q(x). D(i) is the ratio of children dead to children ever born for the women in age group i.

The basic form of the estimation equation proposed by Brass is

$$q(x) = K(i) \times D(i) \quad \ldots.(2.6)$$

in which there is a one-to-one relationship between x and i. The correspondence is :

i	1	2	3	4	5	6	7
x	1	2	3	5	10	15	20

In equation (2.5) the multipliers K(i), is meant to adjust for the non-mortality factors that determine the proportion dead, D(i). K(i) depends on the nature of the fertility and mortality patterns and the age structure of the female population, and is estimated by the equation

$$K(i) = a(i) + P(1)/P(2)b(i) + P(2)/P(3)c(i) \quad ....(2.7)$$

where P(i) is the average parity of the women in the i^{th} age group, given by the ratio of children ever born to women in age group i, CEB(i), to the female population in the age group i, FP(i), and the coefficients a(i), b(i) and c(i) are the Trussell's coefficients for estimating child mortality. The coefficients are given in table 2.1. Trussell estimated a set of multipliers by using least squares regression to fit equation (2.6) to data generated from observed fertility patterns and the Coale-Demeny model life tables. The complement of q(x) is the probability of surviving to exeat age x, given by

$$l(x) = 1.0 - q(x) \quad ....(2.8)$$

Table 2.1
Coefficients for estimation of child mortality multipliers, Trussell variant, when children are grouped by five year age group of mother

Age group	Index i	North model a(i)	North model b(i)	North model c(i)	West model a(i)	West model b(i)	West model c(i)
15-19	1	1.1119	-2.9870	0.8507	1.1415	-2.707	0.7663
20-24	2	1.2390	-0.6865	-0.2745	1.2563	-0.5381	-.2637
25-29	3	1.1884	0.0421	-0.5156	1.1851	0.0633	-.4177
30-34	4	1.2046	0.3037	-0.5656	1.1720	0.2341	-.4272
35-39	5	1.2586	0.4236	-0.5898	1.1865	0.308	-.4452
40-44	6	1.2240	0.4222	-0.5456	1.1746	0.3314	-.4537
45-49	7	1.1772	0.3486	-0.4624	1.1639	0.319	-.4435

Source : UN Manual X, 1983 pp.77

Two major kinds of error can be identified when using this method;

(i) that the interviewed women may have children who experience lower mortality than the children of women who have died, and

(ii) that older women have a tendency not to mention dead children, either deliberately or due to memory lapse.

Assumptions made in this method therefore are that the death risk of a child is only a function of the age of the child and not other factors such as mother's age. Another important assumption is that the most reliable data are obtained from women aged between 20 and 34 years, and only such data was used in this thesis in building up estimates of child mortality.

2.2.1 DATA REQUIRED FOR THE COALE-TRUSSELL TECHNIQUE

The following data required for this estimation procedure was used in this study :

i) number of children ever born (CEB) classified by sex and five-year age group of mother;

ii) number of children surviving (CS),or children dead (CD) classified by sex and five-year age group of mother;

iii) total number of women classified by five-year age group irrespective of marital status.

The classification by sex for children surviving or dead in (i) and

(ii) above is desirable, and not essential (UN, Manual X, 1983).

2.3.0 RELE'S METHOD FOR ESTIMATING FERTILITY (1967)

Rele (1967) established a linear relationship between the child-woman ratio (CWR) and the gross reproduction rate (GRR), and showed that this relationship holds for both stable and non-stable populations. Since then, this technique has been used occasionally to estimate fertility of sub-national populations. It has been found to be useful for studying sub-national variations in fertility by small geographical areas. The relationship can be expressed as :

$$GRR = a + b(CWR) \qquad ....(2.9)$$

in which a and b are coefficients whose values depend on the level of mortality in the subject population. The coefficients are available for different mortality levels corresponding to life expectancy at birth (e_0) of 20, 30, ...70, and are displayed in table 2.7 below. Since the total fertility rate (TFR) is a constant function of GRR, it follows that there is a linear relationship between CWR and TFR.

We have

$$TFR = (1+SRB) \times GRR \qquad ....(2.10)$$

where SRB is the sex ratio at birth. Therefore on substitution, the total fertility rate can be obtained from the equation

$$TFR = (1+SRB) \times [a + b(CWR)]. \qquad ....(2.11)$$

Rele (1967) provided coefficients for four kinds of child-woman ratio, namely $P_{(0-4)}/W_{(15-44)}$; $P_{(0-4)}/W_{(15-49)}$; $P_{(5-9)}/W_{(20-49)}$; and $P_{(5-9)}/W_{(20-54)}$, where P refers to the population of both sexes, W refers to women only, and the subscripts refer to the age group to be considered. Rele (1967) explained that when $P_{(0-4)}$ is used, the value of TFR calculated refers to the five-year period prior to the survey and when $P_{(5-9)}$ is used, it refers to 5-9 years before the survey.

Table 2.2
Coefficients a and b for estimating TFR from CWR using Rele's Method (1967)

child-woman ratio		Expectation of Life, e(o).					
		20	30	40	50	60	70
P(0-4)	a	-.0909	-0.1211	-0.1370	-0.1529	-0.1645	-0.1754
W(15-44)	b	4.5907	4.1821	3.9298	3.7375	3.5556	3.3878
P(0-4)	a	0.0547	0.0284	0.0129	-0.0059	-0.0182	-0.0309
W(15-49)	b	4.7680	4.3293	4.0617	3.8589	3.6628	3.4829
P(5-9)	a	-.1162	-0.1311	-0.1436	-0.1574	-0.1675	-0.1779
W(20-49)	b	5.2927	4.4991	4.0940	3.3801	3.5967	3.3894
P(5-9)	a	0.0245	0.0106	0.0021	-0.0110	-0.0226	-0.0345
W(20-54)	b	5.4711	4.6398	4.2262	3.9480	3.7014	3.4821

Source : ESCAP, Asian Population Studies Series No.63-E, UN, New York, 1987 : 15.

Even though the coefficients were estimated for stable populations, the technique gives robust results for populations that are not stable, (Rele, 1967). The relationship between child-woman ratio and gross reproduction rate is insensitive to normal variations in population age structure. An estimate of mortality is also required for Rele's estimation procedure, namely the expectation of life at birth. Fortunately this has been provided by the foregoing Coale-Trussell technique. This estimation procedure like other reverse survival techniques is relatively insensitive to errors in the estimation of mortality. None-the-less, if mortality were decreasing in the past few decades, holding mortality constant would have an effect of overestimating fertility during the later years.

In practice, the life expectancy computed rarely coincides with the coefficient given in table 2.2. This calls for a linear interpolation to be able to obtain the exact total fertility rate. The procedure is to calculate the total fertility rate on the lower and the upper side of the observed expectation of life, e_0, using the coefficients at given life expectancies and interpolate to obtain the TFR corresponding to the observed e_0.

2.3.1 DATA REQUIRED

The data input for the Rele's method are as follows:

i) Female population by five-year age group;

ii) Population of children by sex and five year age group;

iii) An estimate of the life expectancy at birth of the subject population.

2.4.0 THE REVERSE SURVIVAL TECHNIQUE FOR ESTIMATING FERTILITY

The reverse survival technique was used in this thesis for fertility estimation. The index is birth rate for the technique and its extensions by Coale (1981) and Venkatacharya and Teklu (1987). The estimates were derived for all districts and provinces in Kenya, and at national level. The reverse survival techniques feature under the category of methods based on the sex-age distribution of the population at the time of enumeration. The basic assumption in this method is that the population under study need be closed to migration. The study follows this assumption in computations. However before the techniques can be applied, some estimates of mortality, and a life table for each area under study must be made available. To obtain these estimates, the Coale - Trussell technique (1975) has been used to construct Life Tables and hence derive the required mortality measures.

Migration presents a problem in reverse survival estimation procedures, and any evidence suggesting significant level of migration during the period being considered makes it necessary to attempt correction. This imposed a condition on this study, that it could only proceed if it was assumed that there was net minimum flow into or out of the study regions. The assumption is more plausible at national level, but may not augur well for the districts and provinces that are areas of in and out migration. The reverse survival methods are however relatively less sensitive to errors in mortality estimation (Rele, 1987).

The methods are heavily dependent upon the accuracy of the reported age distributions of the population being studied. In order to avoid such problems, or minimize their effect on the final estimates, data was grouped into reasonably broad age groups as this eliminates age heaping and wrong dating. The reverse survival methods also depends on the choice of the model used in the construction of a life table. According to UN, Manual X, (1983) the differential effects are greater the further one reverse-survives the observed population into the past.

2.4.1 THE MEANING OF REVERSE SURVIVAL

In a closed population, children aged x at time t, are just the survivors of the births that occurred x years ago, that is, at time t-x. It is thus easily inferred that the number of births occurring x years ago can be estimated by using life-table survivorship probabilities to 'resurrect' numerically those no longer present among the population aged x. This method is known as 'reverse survival' or 'reverse projection' because the population aged x are reverse projected to age x-k by moving it with a suitable life table k years into the past (UN, Manual X, 1983).

2.4.2 INPUT DATA FOR REVERSE SURVIVAL ESTIMATION

The data required for the reverse survival estimation of fertility are :

i) The population under age 15 years, classified by five-year age groups and sex;

ii) The total population of all ages at the time of enumeration;

iii) An estimate of the growth rate for the periods preceding the survey ; and

iv) Estimate of mortality parameters that would permit the construction of a life table up to age 15. The necessary information on mortality has been provided earlier.

2.4.3 ESTIMATION OF GROWTH RATE

The annual rate of population growth, $r(t)$, has been computed assuming exponential population growth over the period 1969-1979. Under this condition, we can write,

$$P_t = P_0 \exp[r(t)T], \qquad ....(2.12)$$

where P_0 is the initial population; P_t is the population at a later time; and T is the time interval under consideration. On re-arranging, we obtain the growth rate formula as :

$$r(t) = (\ln P_t - \ln P_0)/T \qquad .....(2.13).$$

2.4.4 DEFINITIONS OF SOME NOTATIONS

On the basis of this data, the following definitions were used:

t: discrete time measured in years;

n: length of the interval under consideration;

${}_nP_x(t)$: number of persons (males and females) of the age group $(x,x+n)$;

$P(t)$: number of persons at all ages at time t, equal to sum of all ${}_nP_x(t)$ over all ages or age groups, for some n;

$c(x,t)$: proportion of the population in the age group (x,x+n);

$C(x,t)$: proportion of the population under exact age x at time t, given by summing c(x,t) over n for some x;

$B(t-n,t)$: number of births in the n-year period (t-n,t) preceding the census;

$b_k(t)$: birth rate based on the age group (k,k+n);

${}_nL_x$: person-years lived in a life table in the time interval (x,x+n);

$s(x,t)$: survival ratio of persons aged (x,x+n) to the next n-year age group, given from the life table by ${}_nL_{x+n}/{}_nL_x$.

l_0: The radix, which is the initial assumed life table population. This index may also be taken for the survival probability at any age x, l(x);

$s(b,t)$: survival ratio of births at time t, to the age group 0-n at time t. This is given from the life table by ${}_nL_0/n.l(o)$;

$r(t)$: rate of increase of population of all ages at time t;

$r(x,t)$: rate of increase in the population of the age group (x,x+n).

2.4.5 COALE'S EXTENSION OF THE REVERSE SURVIVAL TECHNIQUE (1981)

For a population closed to migration and is experiencing constant age specific fertility and mortality rates, the long run (stable) constant age distribution is given by

$$C(a,t)=be^{-ar(t)}p(a,t)$$

....(2.14)

where b is the birth rate, r(t) is the population growth rate, and p(a,t) is the survival probability at age a, at time t.

The proportion of the stable population under age 15 at time t is obtained from equation (2.14) by a continuous summation of the proportions at each age upto age 15, given by the equation,

$$C(15,t)=\int_0^{15}C(a,t)\,da$$

or

$$C(15,t)=b\int_0^{15}e^{-ar(t)}p(a,t)\,da$$

....(2.15)

which can be approximated to

$$C(15,t)=\frac{be^{-7.5r(t)}\,{}_{15}L_0}{l_0}$$

....(2.16)

on using simplifying assumptions.

Alternatively, the 15 year interval can be broken into age groups 0-4, 5-9, and 10-14 years. Therefore, another approximation for C(15,t) becomes,

$$C(15,t) = b_s[{}_5L_0.\exp(-2.5r_s) + {}_5L_5.\exp(-7.5r_s) + {}_5L_{10}.\exp(-12.5r_s)]/l_0 \qquad ....(2.17)$$

using stable population parameters.

Coale's method (1981) involves the selection of a model stable population whose birth rate is taken to represent that of the study population. The selection of a model stable population on the basis of the proportion of the population under age 15 years, C(15,t), for both sexes and the probability of surviving to exact age 5, l(5), in order to estimate birth rate has the following desirable properties :

(i) The proportion under age 15 for both sexes combined is often less affected by age mis-reporting than any other points on the cumulated age distribution. The use of l(5) as an indicator of mortality in childhood also enhances the overall robustness of this method. Mortality estimated in this way is fairly reliable and when mortality has been changing, it refers to a period located some six to seven years before the time of the interview, about the appropriate time of reference for estimating the average birth rate during the 15 years preceding enumeration;

(ii) Model stable populations identified on the basis of c(15,t) and l(5) from the four families of Coale-Demeny model life tables have nearly the same birth rate and total fertility rate. Coale (1981) observed that the birth rates of stable populations having the same proportion under age 15 and the same level of mortality did not vary much irrespective of the family of the model life table used;

(iii) The selection of a model stable population on the basis of C(15,t) and l(5) provides an estimate of the birth rate that closely matches the average birth rate during the 15 years preceding enumeration even when the population under study is far from stable, (UN, Manual X, 1983).

Now, looking back at equation (2.16), we can put $b = b_s$ and $r(t) = r_s$ for a stable case, so that

$$C(15,t) = b_s.\exp[-7.5r_s]\,{}_{15}L_0/l_0. \qquad ....(2.18)$$

This can be substituted in the reverse survival birth rate equation based on age group 0-15 years to obtain the birth rate b_c, due to Coale (1981) as follows:[1]

$$b_0(t) = l_0 \times C(15,t)\exp[7.5r(t)]/{}_{15}L_0 \,.$$

Substituting for C(15,t) in this equation, we get

$$b_c = b_s.\exp[7.5(r(t)-r_s)] \qquad ....(2.19)$$

which is simply b_s, the birth rate of a stable population, adjusted by the factor $\exp[7.5(r(t)-r_s)]$ to take care of the non - stable situation.

---

[1] The derivation of equation (3.13) is fully described in section 3.3.2 under reverse survival for cummulated populations. The same equation is also applied when deriving equation 3.14 for Venkatacharya and Teklu's extension.

2.4.5 VENKATACHARYA AND TEKLU'S EXTENSION OF THE REVERSE SURVIVAL TECHNIQUE (1987)

Venkatacharya and Teklu (1987) found a strong linear relationship between ${}_{15}L_0$ and l(5), which can be expressed as

$$ {}_{15}L_0 = u + v\,l(5) \qquad ....(2.20)$$

where u and v are constants obtained by fitting a straight line between ${}_{15}L_0$ and l(5) for various model life table families. In the context of the developing countries where one may not have a firm knowledge of the pattern of mortality, the values of u and v that correspond to Coale and Demeny West model life tables should be used because they result in minimum percentage error in the estimated birth rate. The model life tables are dependable also because true life tables are lacking in most populations in underdeveloped areas. Values of u and v are tabulated below for all the families:

Table 2.3

The values of u and v for Coale-Demeny Model Life Tables assuming linear relationship between ${}_{15}L_0$ and l(5).

Family	u	v	R^2
West	0.365	14.599	0.99997
North	0.140	14.800	0.99988
East	0.309	14.663	0.99998
South	0.553	14.415	0.99995

Source: Asian and Pacific Population Forum vol. 1, Aug.87 pp.11

Using this relationship we can compute birth rate b_v, according to Venkatacharya and Teklu (1987). The relationship (equation 2.20) can be substituted in the reverse survival birth rate equation based on age group 0-15 years to obtain the desired birth rate according to Venkatacharya and Teklu, b_v, written as

$$b_v = l_0 \times C(15,t)\exp[7.5r(t)]/[u + vl(5)] \qquad \text{....(2.21)}$$

chapter three

FERTILITY AND MORTALITY ESTIMATIONS AT NATIONAL LEVEL

3.0.0 INTRODUCTION

The following is the detailed estimation procedure discussed in chapter two applied to the 1979 census data at National level. In the later chapters, only the results of the analysis will be given at provincial and district levels. The data for the Coale -Trussell estimation procedure are given in table 3.1 below.

Table 3.1
Children ever born and dead by mothers' five-year age groups

Age gr	i	FP(i)	CEB(i)	CD(i)	P(i)	D(i)	K(i)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
15-19	1	1066139	284565	33051	0.266911	0.116145	0.950443
20-24	2	827501	1270661	158688	1.535540	0.124886	1.004233
25-29	3	541261	1976346	278828	3.651373	0.141082	0.978888
30-34	4	412491	2223515	368762	5.390452	0.165846	1.019533
35-39	5	325367	2105212	388507	6.470268	0.184545	1.084198
40-44	6	273702	1921108	417855	7.018976	0.217507	1.067942
45-49	7	221965	1591775	403092	7.171288	0.253234	1.043337
50-54	8	191022	1319983	384009	--	--	--

From the data, one can compute the average parity of women in age group i obtained by dividing the number of children ever born by women in age group i by the number of women in that age group, that is

$$P(i) = CEB(i)/FP(i)$$

Column (7) presents the proportion of children dead to women of age group i, obtained by the relation :

$D(i) = CD(i)/CEB(i)$,

ie.the ratio of column (5) to column (4).

The multiplier, K(i), is obtained using the equation

$K(i) = a(i) + b(i)P(1)/P(2) + c(i)P(2)/P(3)$.

The Trussell's coefficients a(i), b(i) and c(i) are given in table 2.1 for the North and West models. Using these coefficients, child mortality estimates, q(x) is given by the relation;

$q(x) = K(i) \times D(i)$,

where q(x) is the probability of dying before exact childhood x. From q(x), the probability of surviving to exact age x is obtained as a complement. This is, if this probability is denoted by l(x), then

$l(x) = 1.0 - q(x)$.

As an example, consider the age group 25-29 years for i = 3. The average parity of women in this age group is

$P(3) = CEB(3)/FP(3)$

$= 1976346/54161$

$= 3.651373$;

and the proportion of children dead to these women is

$D(3) = CD(3)/CEB(3)$

$= 278828/1976346$

$= 0.141082$.

P(i) and D(i) columns indicate, as expected, that both average number of children ever born and proportion of children dead increases with age of women.

Now, using the P(i) values obtained in a similar manner as P(3), we can calculate K(i), the adjustment factor for the non-mortality factors that determine the proportions of children dead to women in each of the age groups i. In particular, K(3) for the North model (table 2.1) is obtained as

$$K(3) = a(3) + b(3)xP(1)/P(2) + c(3)xP(2)/P(3)$$

$$= 1.1884 + 0.0421x0.266911/1.535540 + -0.5156x1.535540/3.651373$$

$$= 0.978888.$$

From these calculations, the probability of dying before exact age 3, q(3) is given by

$$q(3) = K(3) \times D(3)$$

$$= 0.978888 \times 0.141082$$

$$= 0.138104$$

Therefore, the probability of surviving to exact age 3 is

$$l(3) = 1.0 - q(3)$$

$$= 1.0 - 0.138104$$

$$= 0.861895.$$

l(x) has been computed for childhood ages x = 1, 2, 3, 5, 10, 15 and 20 and presented in table 3.2.

3.1.0 CALCULATION OF THE MORTALITY LEVEL

Table 3.2 outlines steps leading to obtaining of the mortality levels at National level. The first three columns of the table have been mentioned above. Columns (4) and (5) in this table are selected from standard tables, the Coale - Demeny model life tables. Column (4) is selected such that the probability of surviving from birth to exact age x is the next lower value, and column (5) such that the probability of surviving from birth to the exact age x is the next higher value. These columns are herein referred to as lower l(x) and upper l(x) respectively. Column (6), the lower mortality level is the level of mortality that corresponds to the lower l(x) value. Column (7) is the interpolated mortality level which should reflect on the observed probability of surviving to exact age x. The interpolation equation is given in terms of the column labels as:

$$(7) = (6) + [(3)-(4)]/[(5)-(4)].$$

For instance, the mortality level corresponding to age x = 3 is

$$\text{Mortality level} = 14 + (0.861895-0.85139)/(0.8686-0.85139)$$
$$= 14.61075$$

Table 3.2
Calculation of mortality level: North model

Age x	q(x)	l(x)	lowerl(x)	Upperl(x)	lower level	actual level
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	0.110389	0.889610	0.88497	0.89613	13	13.41578
2	0.125414	0.874585	0.86841	0.88329	14	14.41499
3	0.138104	0.861895	0.85139	0.86860	14	14.61045
5	0.169086	0.830913	0.82886	0.84904	14	14.10177
10	0.200083	0.799916	0.77729	0.80185	13	13.92126
15	0.232285	0.767714	0.76138	0.78736	13	13.24382
20	0.264208	0.735791	0.71487	0.74346	12	12.73176

It may be desirable to perform the linear interpolation procedure for all x under consideration, but it is only necessary to perform the interpolations for x = 2, 3 and 5, as these are the values considered accurate for the estimation of mortality level. The mortality level will be taken as the arithmetic mean of the three interpolated mortality levels corresponding to ages x = 2, 3 and 5.

3.1.1 CONSTRUCTION OF A LIFE TABLE

The average mortality level obtained above is used in the construction of a life table as now discussed. We use the average mortality level for l(2), l(3) and l(5), that is

$$\text{avg. mortality level} = [l(2)+l(3)+l(5)]/3$$

$$= [14.41499 + 14.61045 + 14.10177]/3$$

$$= 14.37574$$

When the West model was used, similar computations give the average mortality level of 14.36862.

In order to obtain the probability of surviving to exact age x corresponding to the average mortality level of the study population, a linear interpolation is performed using the integral values between which the average mortality level falls - herein referred to as the lower and upper mortality levels. This probability is referred to in this thesis as 'the actual l(x)', that is the actual probability of surviving to exact age x for the study population. From the Coale - Demeny model tables, the l(x) values that correspond to mortality levels 14 and 15 are read, and interpolation is performed between these probabilities to obtain the actual probability of surviving to exact age x. This is the probability of surviving to exact age x that corresponds to the mortality level, 14.37574 for the North model and 14.36862 for the West model. The interpolation equation the mortality level estimation is

actual l(x) = l(x) at level 14 + a[l(x) at level 15]

where a = (14.37574-14)/(15-14) is the interpolation factor. At the national level, the probability of surviving to age x = 5 is given by

l(5) = 0.82886 + (0.84904 x 0.37574)

= 0.836442

This is the probability of surviving to exact age 5 that corresponds to the average mortality level 14.37574 of Kenya using the North model.

Next, assume a radix, l(0) which is the probability of surviving to age 0. It is customary in these procedures to assume that this probability is unit, so that the computation begin with, say an initial 100,000 persons aged 0. On the life table, this is denoted by l_0, and represents the number of survivors at age 0 (in general, l_x). Table 3.3 gives the whole computation of actual l(x) for ages x = 1, 5, 10, ... 75+.

For x = 0, it was assumed that every person is born alive, that is to say, only live births are treated. Hence l(0) = 1 at both levels 14 and 15. Only the actual l(x) column, [i.e l(x) computed for levels 14.37574 or 14.36862] is required for the construction of a life table. In practice, it is traditional to assume that there are 100,000 persons alive at birth, i.e l_0 = 100,000. Then multiplication of the actual l(x) values by l_0 gives the number of persons still alive at various ages x = 0, 1, 5, ... 75+. This is the l_x column of the life table (Table 3.4).

Table 3.3

Computation of actual probability of dying before exact age x, North and West Models.

Age x	North model, level 14.37574 l(x) level 14	l(x) level 15	actual l(x)	West model, level 14.36862 l(x) level 14	l(x) level 15	actual l(x)
0	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000
1	0.89613	0.90699	0.90021	0.88476	0.89740	0.88942
5	0.82886	0.84904	0.83644	0.83174	0.85205	0.83923
10	0.80185	0.82525	0.81064	0.81658	0.83858	0.82469
15	0.78736	0.81220	0.79669	0.80540	0.82857	0.81394
20	0.77059	0.79669	0.78039	0.78938	0.81406	0.79848
25	0.74896	0.77646	0.75929	0.76804	0.79462	0.77784
30	0.72599	0.75495	0.73687	0.74495	0.77353	0.75549
35	0.70143	0.73191	0.71288	0.71950	0.75015	0.73080
40	0.67449	0.70651	0.68652	0.69100	0.72365	0.70304
45	0.64404	0.67745	0.65659	0.65837	0.69277	0.67105
50	0.61014	0.64466	0.62311	0.62040	0.65598	0.63352
55	0.56857	0.60372	0.58178	0.57242	0.60873	0.58580
60	0.51779	0.55332	0.53114	0.51311	0.54922	0.52642
65	0.45153	0.48651	0.46467	0.43668	0.47149	0.44951
70	0.36666	0.39967	0.37906	0.34517	0.37662	0.35676
75+	0.26441	0.29308	0.27518	0.24090	0.26645	0.25032

The rest of the life table functions are defined on the basis of l_x by Kpedekpo (1982) as follows: Let n be the time interval for which the computations are carried, then with the usual notations,

$_nP_x$, the probability of surviving between ages x and x+n is given by

$$_nP_x = l_{x+n}/l_x \ ;$$

$_nq_x$, the probability of dying between ages x and x+n is given by the relation

$_nq_x = 1 - {}_nP_x$;

$_nd_x = l_x - l_{x+n}$, is the number of persons who die between ages x and x+n ;

$_nL_x$, the person-years lived between ages x and x+n, are given by the following formulae for different segments of the life table:

$_1L_0 = 0.3l_0 + 0.7l_1$

$_4L_1 = 1.3l_1 + 2.7l_5$

$_5L_x = 2.5(l_x + l_{x+n})$, for x = 5, 10, ... 70, and

$L_{75+} = l_{75+} \log_{10} l_{75+}$

T_x, the total person years lived from age x to the oldest possible age is given by

$T_x = T_{x+n} + {}_nL_x$,

or

$$T_x = \sum_{i=x}^{75+} nL_i$$

$e_x = T_x/l_x$ is the expectation of life at age x, for x = 0, 1, 5,.......,75+.

The above descriptions and formulae applied to the data of Kenya at national level made it possible to derive the following life table using the North model.

Table 3.4
Life Table for Kenya : North Model

Age x (1)	$_nq_x$ (2)	$_np_x$ (3)	l_x (4)	$_nd_x$ (5)	$_nL_x$ (6)	T_x (7)	e_x (8)
0	0.099789	0.900210	100000	9978.945	93014.73	5095785	50.95785
1	0.070836	0.929163	90021	6376.809	342866.8	5002771	55.57334
5	0.030845	0.969154	83644	2580.011	411771.1	4659904	55.71099
10	0.017207	0.982792	81064	1394.893	401833.9	4248133	52.40453
15	0.020459	0.979540	79669	1630.032	394271.6	3846299	48.27828
20	0.027037	0.972962	78039	2110.020	384921.4	3452027	44.23447
25	0.029529	0.970470	75929	2242.141	374041.0	3067106	40.39424
30	0.032555	0.967444	73687	2398.887	362438.5	2693065	36.54728
35	0.036978	0.963021	71288	2636.135	349850.9	2330626	32.69299
40	0.043593	0.956406	68652	2992.772	335778.6	1980775	28.85235
45	0.050994	0.949005	65659	3348.292	319926.0	1644996	25.05350
50	0.066333	0.933666	62311	4133.328	301221.9	1325070	21.26542
55	0.087038	0.912961	58177	5063.721	278229.3	1023848	17.59863
60	0.125139	0.874860	53114	6646.665	248953.3	745619	14.03809
65	0.184237	0.815762	46467	8561.020	210934.1	496666	10.68849
70	0.274045	0.725954	37906	10388.07	163561.4	285732	7.537846
75+	1.000000	0.000000	27518	27518.24	122170.5	122170	4.439620

From this life table, one can read a number of mortality estimates. The life expectancy at birth, e_0, which is directly related to mortality level, has been chosen for the purposes of discussion. This index exists in literature as one of the best summary indicators of mortality. Further, q(2) and q(5) which are the probabilities of dying before exact ages 2 and 5 respectively ; and the probabilities of dying in the age intervals 0-1, 1-4, and 0-5 years, respectively denoted by $_1q_0$, $_4q_1$, and $_5q_0$ are added to emphasize the emerging picture. These indices are in one way or other related to each other, and therefore, a discussion of one would suffice.

At a glance, one notices from table 3.4 that Kenya had not made good her effort to improve the expectation of life at birth by the time of the census. This is evident from the life expectancy (column 8) which presents the life expectation at ages x = 0, 1, 5, ... 75+. For the whole republic, e_0 stands at 50.96 years by the North model. Thus, Kenyans, as at 1979 expected to live at least 20 years less than any person born and brought up in a more developed nation like Sweden or Japan, where the figure was well over 70 years as at 1979. Other interesting points in life are of e_5, e_{15}, and e_{50}, whose values are 55.71, 48.28 and 21.27 years respectively. More estimates of mortality are presented in table 3.5 below.

Table 3.5

Mortality estimates for Kenya 1979

			Index of mortality				
Model	e_0	level	$_1q_0$	$_4q_1$	$_5q_0$	q(2)	q(5)
North	50.958	14.376	0.09979	0.07084	0.17063	0.12541	0.16909
West	51.306	14.369	0.11058	0.05643	0.16701	0.13136	0.17133

A study of the figures in table 3.5 indicate that the mortality estimates by the West model give values close to the North model estimates and close to the earlier works by Kichamu 1986, and Mudaki, 1986. This study however suggests that this estimation procedure, like most others that involve age data and reports on birth and death, might have brought about the small inconsistencies due to omission of children dead and/or surviving particularly at ages 0-4 years either deliberately as is dictated by some traditions and customs, or by memory lapse as is expected of older women. Most marked differences occur in the infant and child mortality estimates in which the West model implies that there is excessive death during the first year of life, and proportionately lower in the next four years of life. Contrary to this observation, the North model estimates of infant and child mortality are close to each other, but the net effect in the first five years nears that of the West model.

3.2.0 RELE'S METHOD

This method, an elaborate variation on the demographic technique of reverse survival, is based on counts of children and mothers in a census. Only the age - sex distribution for the population by five year age group is required, and is presented in table 3.6 below at national level. The following is an application of the technique.

Table 3.6

Children under age 15 by five year age groups and Female in Reproductive ages in 1979, and Total population in Kenya in 1969 and 1979.

Female Population

Age gr	i	FP(i)
15-19	1	1066139
20-24	2	827501
25-29	3	541261
30-34	4	412491
35-39	5	325367
40-44	6	273702
45-49	7	221965
50-54	8	191022

Children's Population

Age(s)	Male	Female	Total
0	279392	282758	562150
0-4	1422021	1421385	2843406
5-9	1247091	1244749	2491840
10-14	1050932	1023839	2074771
0-9	2669112	2666134	5335246
0-14	3720044	3689973	7410017

Total Pop. in 1969	....	....	10943000
Total Pop. in 1979	7607113	7719948	15327061

Annual growth rate 1969-1979, r(t) = 0.033691
Sex ratio at birth, SRB = 0.988095

3.2.1 COMPUTATIONAL PROCEDURE

With this data, one can compute the following:

(i) child-woman ratio, broadly defined as the ratio of children at various childhood ages to women of reproductive age, for instance, for the children in age group 0-4 years and women in the age group 15-44 years, we have:

$$P_{(0-4)}/W_{(15-44)} = 2843406/3446461$$

$= 0.8250219.$

(ii) sex-ratio at birth - the ratio of male to female population under age 1 at the time of enumeration:

$$SRB = 279392/282758$$
$$= 0.988095$$

(iii) an estimate of total fertility rate by the relation

$$TFR = (1+SRB) \times (a+b(CWR)).$$

To use this relationship, one must identify the coefficients a and b that correspond to the next lower and next upper life expectancies with respect to the observed life expectancy for the study population. For Kenya the operational life expectancy is 50.96 years. Therefore, the calculation is done using the coefficients at $e_0 = 50$ to obtain the 'lower TFR' and using coefficients at $e_0 = 60$ to obtain the 'upper TFR'. The terms 'lower' and 'upper' are used here in relation to e_0, otherwise it is noted that the so called lower TFRs are higher than the upper TFRs. This approach may be taking into account the replacement effect, in which the higher mortality areas experience higher fertility (Preston, 1978).

We have that:

$$TFR = (1+SRB)(a + bCWR).$$

Therefore, for the child-woman ratio based on the children aged 0-4 years and women aged 15-44 years, lower TFR = (1+0.988905)x(-0.1529 + 3.7375x0.8250219)

= 5.826352, and

upper TFR = (1+0.988905)x(-0.1645 + 3.5556x0.8250219)

= 5.504934.

An interpolation is then done to obtain the TFR corresponding to the observed life expectancy for the country. The estimation equation is;

$$TFR = (upp.TFR - low.TFR)(obs\ c_0 - low.c_0)/(upp.c_0 - low.c_0) + low.\ TFR.$$

This gives

TFR = (5.504934-5.826352)x(50.96-50)/(60-50)

+ 5.826352

= 5.795565.

The results of the computations for all the child-woman ratios are summarized in table 3.7.

Table 3.7
TFR estimates for Kenya by Rele's method (1967)
Sex-Ratio at Birth = 0.988905

	lower TFR	upper TFR[2]	Interpolated TFR North	West
CWR1[3]	5.826352	5.504934	5.795565	5.784365
CWR2	5.934750	5.608110	5.903462	5.892080
CWR3	6.121825	6.514091	6.159399	6.173067
CWR4	6.980026	6.519612	6.935925	6.919882
Average total fertility rate			6.198588	6.192349

Table 3.7 is a summary of estimates of total fertility rate at national level by Rele's method using the North and West models. Note that the estimates for both the models are similar except for the interpolated TFRs. This is because the lower and upper TFRs use the same range of life expectancy, hence same Rele's factors a and b. For all regions whose e_0's fall within the same range, this will be the case. The estimates of life expectancy at birth obtained by the Trussell technique has been very useful in the computations of total fertility rate by the method and the coefficients provided by Rele permitted calculation of four different types of TFR based on the four definitions of child-woman ratio.

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[2] The lower and upper TFRs refer to the total fertility rates computed at the lower level of life expectancy and upper level of life expectancy, respectively. The relative sizes of the figures are relevant only to the extent that TFR seems to be higher at lower life expectancies.

[3] CWR's subscripted 1,2,3 and 4 are the child to woman ratios respectively for the populations aged 0-4 to women aged 15-44, 0-4 to women aged 15-49, 5-9 to women aged 20-49 and 5-9 to women aged 20-54.

As has been indicated in the previous sections, when P_{0-4} is used, the TFR estimated refers to the past 0-5 years before the enumeration time t. On average, this is at time t-2.5, where t is the census time. Similarly, when P_{5-9} is used, the TFR estimated refers on average to time t-7.5. The four computations at national level boil down to only two reference points in time before the census. A mean value provided in this case refers to a time mid-way between the other two reference points, time t-5.0.

The results show that the total fertility rate computed for the time 2.5 years before the 1979 census is lower than the estimate for a time 7.5 years before the census. The picture that emerges is that either fertility has shown a brief decline in Kenya over the past 10 years preceding the 1979 census, or there is a remarkable under-reporting of children in the younger age groups. On the other hand, if one looks across the estimates, it becomes evident that older women report higher fertility than younger ones.

In view of the UN, Manual X (1983) observation that there is difficulty in measuring and recording age, particularly for the ages 0 and 1, it follows that there is also a serious problem in estimating the sex-ratio at birth. This value measures the ratio of males to females who have not reached their first birth day at the time of enumeration. Although data was available for the population aged 0 from the 1979 census, it was suspected that this could be subject to large and unpredictable error which could affect the estimates of total fertility rate by the Rele's technique. As a check to a possible disparity in completeness of this data at all levels, the study standardized sex ratio at birth at 1.05 in order to obtain rates independent of the measure. The same computational procedure gave the following results (table 3.8).

Table 3.8
TFR estimates for Kenya by Rele's method (1967)
Sex-Ratio at Birth = 1.05

	lower TFR	upper TFR	Interpolated TFR North	Interpolated TFR West
CWR1	6.007770	5.676344	5.976024	5.964475
CWR2	6.119543	5.782733	6.087281	6.075545
CWR3	6.312444	6.716923	6.351187	6.365281
CWR4	7.197367	6.722616	7.151892	7.135349
Average total fertility rate			6.391596	6.385163

The estimates in this table are high when compared to those of table 3.7. The explanation is that the sex ratio at birth used here is higher than most of the values observed in the sub-regions. These estimates are nearer to others obtained by other methods existing in literature which confirms the possible loss of information regarding reporting of children who have not attained age 1.

3.3.0 THE REVERSE SURVIVAL TECHNIQUES

In the reverse survival method, we reverse project persons in given age groups backwards in time, for instance, persons in the age group 5-9 at time t when projected 5 years backwards result in persons in the age group 0-4 at time t-5, and births during the 5 years preceding time t-5.

Data on children ever born and children dead have been used in the previous section to estimate probabilities of survivorship in childhood, according to the North model, and the same for the West model. A life table has also been constructed for Kenya in this section, but only the relevant portions are presented here for estimation purposes.

Table 3.9

Life Table for Kenya upto age 20 : North model

Age x	${}_nq_x$	${}_np_x$	l_x	${}_nd_x$	${}_nL_x$	T_x	e_x
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
0	0.099789	0.900210	100000	9978.945	93014.73	5095785	50.95785
1	0.070836	0.929163	90021	6376.809	342866.8	5002771	55.57334
5	0.030845	0.969154	83644	2580.011	411771.1	4659904	55.71099
10	0.017207	0.982792	81064	1394.893	401833.9	4248133	52.40453
15	0.020459	0.979540	79669	1630.032	394271.6	3846299	48.27828
20	0.027037	0.972962	78039	2110.020	384921.4	3452027	44.23447

This portion of the life table, and a similar one derived from the West model were used to calculate birth rates based on children in the age groups 0-4, 5-9, 0-9 and 0-14 years. The ${}_nL_x$ values, column (6), are needed for computations of birth rate. In particular, ${}_1L_0$, ${}_4L_1$, ${}_5L_5$ and ${}_{10}L_5$ in combinations to obtain ${}_5L_0$, ${}_{10}L_0$, and ${}_{15}L_0$.

3.3.1 REVERSE SURVIVAL TECHNIQUE FOR PERSONS AGED 0-4 AND 5-9 YEARS

Suppose a population census (or survey) was taken at time t, the persons aged 0-4 years are survivors of the births in the five years preceding the census, that is, in the time interval (t-5,t). Similarly persons aged 5-9 years at the time of the census are survivors of the births in the time interval (t-10,t-5) before the census.

With notations as defined earlier, the population aged 0-4 years at time t is given by

$$ {}_5P_0(t) = B(t-5,t) \times s(b,t) $$

$$ = B(t-5,t) \times {}_5L_0/5.l_0 \qquad \text{....(3.1)} $$

for n = 5, which on rearrangement gives

$$ B(t-5,t) = 5.l_0 \times {}_5P_0(t)/{}_5L_0 \qquad \text{....(3.2)} $$

Therefore assuming that births are uniformly distributed over the five year interval, we can obtain annual births by dividing the births in the five years by 5, i.e

$$ \text{annual births} = l_0 \times {}_5P_0(t)/{}_5L_0 \qquad \text{....(3.3)} $$

In order to obtain birth rate for the period (t-5,t) we need the mid-year population which forms the denominator. Thus the birth rate based on age-group 0-4 years at time t is given as:

$$ b_0(t) = \text{annual births/mid-year population.} $$

There are two ways of obtaining the mid-year population. One is to reverse project all the age groups from time t to time t-5, and take the mean of the total populations at time t-5 and t. The second method is to use an estimate of the rate of growth of the population during the time interval (t-5,t) and use this rate to obtain population at time t-2.5. Since the population as at 1969 is available, the latter approach was used in the study. The growth rate can be estimated by the equation

$$r(t) = (\ln P_t - \ln P_0)/T \qquad \ldots.(3.4)$$

where P_t and P_0 refer to the population in 1979 and 1969 respectively, and T (=1979-1969) is the time interval between the censuses.

For Kenya 1979, the population was 15,327,061, while in 1969 there were 10,943,000 persons. The time interval between the censuses is 10 years. Therefore, inserting these values in equation (3.4), we have

$$r(t) = (\ln 15327061 - \ln 10943000)/10$$

$$= 0.033961.$$

This rate was used to determine the mid-year populations for the calculations at national level. A similar argument was used to estimate the population growth rate at district and provincial levels. A complete set of estimates for all sub-regions is provided in appendix 7.

Using r(t) obtained above, the birth rate can be estimated by the equation

$$b_0(t) = \text{annual births}/P(t)\exp[-2.5r(t)]$$

which reduces to

$$b_0(t) = l_0 \times C(5,t)\exp[2.5r(t)]/{}_5L_0 \quad ....(3.5)$$

in which $C(5,t) = {}_5P_0(t)/P(t)$ is the proportion of the population aged under 5 years.

Table 3.6 provides the five-year age-sex distribution upto age 15. This together with the portion of the life table upto age 20 provided in table 3.8 are the necessary information for the computation in equation (3.5). We calculate the proportion of the population under age 5 by dividing the total population under age 5 years by the country's total population in 1979, i.e

$$C(5,t) = 2843406/15327061$$

$$= 0.1855154$$

To obtain the person-years lived between ages 0 and 5 years, we have to sum the person-years lived between ages 0 and 1, and the person years lived between ages 1 and 4, because this value is not directly obtainable from the life table. This gives,

$${}_5L_0 = {}_1L_0 + {}_4L_1$$

$$= 93015 + 342867$$

$$= 435882$$

Assuming the radix, l_0 = 100,000 we can now apply equation (3.5), and obtain

$$b_0(t) = 100000 \times 0.1855154 \exp[2.5 \times 0.033691]/435882 \ .$$

$$= 0.046301 \text{ or } 46.3 \text{ births per } 1000 \text{ population.}$$

Applying the West model, we get 45.92/1000 population.

Similarly, for the age group 5-9 we can write

$$ {}_5P_5(t) = {}_5P_0(t) \times s(5,t). \quad ....(3.6)$$

Further substitution using equation (2.12) yields

$$ {}_5P_5(t) = B(t-10,t-5) \times s(b,t-5) \times s(5,t)$$

$$ = B(t-10,t-5) \times [{}_5L_5/{}_5L_0] \times [{}_5L_0/5.l_0] \quad ....(3.7)$$

Again, assuming that births are uniformly spread over the period, the annual births is given by

$$ \text{annual births} = l_0 \times {}_5P_5(t)/{}_5L_5 \quad ....(3.8)$$

The mid-year population during the time period (t-10,t-5) is obtained on the same lines as in the case for 0-4 year age group, only that reverse survival now should be done twice. If the rates of growth of the population during the periods (t-10,t-5) and (t-5,t) are denoted by r(1) and r(0) respectively, then the mid-year population for the period (t-10,t-5) can be written as

$$P(t-7.5) = P(t)\exp[-2.5r(1)]\exp[-5r(0)].$$

If we have two censuses separated by 10 years, then we use the intercensal growth rate, r(t). The mid-year population is then given by

$$P(t-7.5) = P(t)\exp[-7.5r(t)] \quad ....(3.9)$$

The same argument and assumptions are used to obtain birth rate based on the 5-9 year age group,and this yields

$$b_5(t) = l_0 \times c(5,t)\exp[7.5r(t)]/{}_5L_5 \quad ....(3.10)$$

In this equation, c(5,t) is the proportion of the population aged between 5 and 10 years old, and is obtained as,

$$c(5,t) = \text{pop. between 5 and 9/total pop. in 1979}$$
$$= 2491840/15327061$$
$$= 0.1625778.$$

The person-years lived between ages 5 and 9 can be read directly from the life table, and has a value of ${}_5L_5 = 411771$. Therefore, the birth rate based on the 5-9 year age group is given by

$$b_5(t) = 100000 \times 0.1625778 \exp[7.5 \times 0.033691]/411771$$
$$= 0.0508328 \text{ or } 50.8 \text{ births per 1000 population.}$$

The West model give 49.52/1000 population.

When studying the above estimates of birth rate by reverse surviving the 0-4 and 5-9 populations, note should be taken that the birth rates refer to different points in time with respect to enumeration time. Therefore, we can only draw inferences from these results on the basis of two conditions; one, that fertility rates remained nearly constant over the ten year period preceding the enumeration time, 1979 and compare the two estimates, or two, assume fertility changed remarkably over this period and assess the amount and direction of the change.

From the values, it is clear that the birth rate estimated by the reverse projecting 0-4 population is lower than the rate estimated by reverse projecting the 5-9 populations, if it is assumed that fertility rates remained constant over the fifteen years prior to 1979. Much of the disparities can be attributable to reporting errors of the population, especially in the youngest age groups.

Omission of children under age 5 and shifting of some children from age group 0-4 to 5-9 due to age misreporting can explain the underestimates in age group 0-4 years, and consequently, the overestimates in age group 5-9 years. The estimates in this age group may also be exaggerated by heaping at age five. Furthermore, censuses often fail to enumerate children completely, especially at ages 0 and 1 years, therefore it is frequent for the estimated number of births referring to the year or two preceding the time of enumeration to be low.

3.3.2 REVERSE SURVIVAL TECHNIQUE FOR CUMULATED POPULATIONS

The logic behind the reverse survival of population aged 0-4 and 5-9 years can be extended to cumulated populations under ages 10 and 15 as follows:

$${}_{10}P_0(t) = B(t-10,t) \times s(b,t)$$

when n = 10, which on simplification gives

$$\text{annual births} = l_0 \times {}_{10}P_0(t)/{}_{10}L_0 \qquad \text{....(3.11)}$$

and birth rate based on the cumulated population under age 10 as

$$b_0(t) = l_0 \times C(10,t)\exp[5r(t)]/{}_{10}L_0 \qquad \text{....(3.12)}$$

In a similar fashion, we substitute the values in the equation (2.23) and obtain the birth rate. We have

$b_0(t)$ = 0.0486 or 48.6 births per 1000 population.

Similarly, for the first 15 years from birth, n = 15, we have

$${}_{15}P_0(t) = B(t-15,t) \times s(b,t)$$

which reduces to

$$b'_{A}(t) = l_0 \times C(15,t)\exp[7.5r(t)]/{}_{15}L_0 \quad ....(3.13)$$

$$= 0.049818 \text{ or } 49.82 \text{ births per 1000 population.}$$

Presented above are North model estimates. The West model estimates are not very different from their corresponding North model counterparts. Based on the age group 0-9 years, the birth rate is 47.78/1000 population, whereas reverse surviving the population aged 0-14 years give a birth rate of 48.67/1000 population. The estimates by these cumulated populations are bounded above and below by those of smaller age intervals i.e 0-4 and 5-9 years. In other words, the reverse survival of age group 0-4 years grossly underestimates the birth rate, while the reverse survival of the 5-9 year age group overestimates it. Ideally, we should rely more on estimates by the wider age groups given that the latter are less prone to age misreporting and age shifting errors.

According to UN, Manual X (1983), problems of misreporting are especially acute when reverse projected data are classified by single years of age, since age heaping is likely to produce spurious peaks and troughs in the estimates obtained. The fact that estimates on cumulated populations are close to each other within approximation limits further supports the idea that these estimates are less affected by errors of misreporting and shifting. Moreover their estimates are nearer to the mean value. Grouped data are often used in order to avoid some of the problems of misreporting, and to minimize their effects on the final results.

By the foregoing observations, the average annual number of births estimated by reverse projecting the population aged from 0 to 4 years is likely to underestimate the true number of births occurring during the five year period immediately preceding enumeration. This age group is also affected by heaping at age 5, which implies more estimated annual births in the age group 5-9 years at the loss of in the latter.

3.3.3 EXTENSIONS OF THE REVERSE SURVIVAL TECHNIQUE

3.3.4 IDENTIFYING STABLE POPULATIONS

In tables 3.10, we have identified birth rates and annual growth rates corresponding to C(15) and l(5) of the population of Kenya in 1979 for females and males. The descriptions that follow are based on the North model life tables of the Coale-Demeny model life tables, and the whole process is repeated for the West model family and results presented in tables 3.11 and 3.12.

Describing briefly, table 3.10, the proportion under 15 years of both sexes using the 1979 census is C(15) = 0.483459 at national level. From table 3.2, it is seen that the mortality level corresponding to l(5) is 14.10177 for the North model. To select the stable birth rates and annual growth rates, we shall use female and male life tables separately because model life tables for both sexes are not available.

Table 3.10
Identifying stable population based on C(15) and l(5)
North Model Males and Females
Mortality level 14.10177

	Level 14		Level 15		Level 14.10177		
i	$C_i(15)$	$b_{i(s)}$	$C'_i(15)$	$b'_{i(s)}$	$C^*_i(15)$	$b^*_{i(s)}$	$r_{i(s)}$
1	0.4578	0.04626	0.4525	0.04463	0.457260	0.046094	0.030
2	0.4913	0.05135	0.4862	0.04961	0.490780	0.051172	0.035

$C(15) = 0.483459$ $b_s = 0.050063$ $r_s = 0.033907$

	Level 14		Level 15		Level 14.10177		
i	$C_i(15)$	$b_{i(s)}$	$C'_i(15)$	$b'_{i(s)}$	$C^*_i(15)$	$b^*_{i(s)}$	$r_{i(s)}$
1	0.4494	0.04435	0.4440	0.04285	0.448850	0.044197	0.030
2	0.4835	0.04937	0.4783	0.04776	0.482970	0.049206	0.035

$C(15) = 0.483459$ $b_s = 0.049277$ $r_s = 0.035071$

Using female life table at level 14, the proportion of population under age 15 is $C_1(15) = 0.4494$ for a population growing annually at a rate of 0.030 and $C_2(15) = 0.4835$ for a population growing annually at a rate of 0.035. The corresponding rates at level 15 are $C'_1(15) = 0.4440$ and $C'_2(15) = 0.4783$. Hence, in order to obtain the corresponding estimates, $C^*_{i(15)}$, at level 14.10177, one uses the linear interpolation equation as follows :

$$C^*_1(15) = C_1(15) + a_1[C'_1(15) - C_1(15)]$$

where $a_1 = (15-14.10177)/(15-14)$ is the interpolating factor. The equation can be simplified to

$$C^*_1(15) = a_1 C'_1(15) + (1.0 - a_1)C_1(15).$$

Thus $C^*_1(15) = 0.10177 \times 0.4440 + (1.0 - 0.10177) \times 0.4494$

$= 0.448850.$

Similarly,

$$C^*_2(15) = a_1 C'_2(15) + (1-a_1)C_2(15).$$

$= 0.10177 \times 0.4783 + (1.0 - 0.10177) \times 0.4835$

$= 0.482970.$

We perform another interpolation using the same factor to obtain the stable population birth rate, $b_{i(s)}$, corresponding to the observed mortality level, 14.10177. At level 14, the birth rates corresponding to growth rates 0.030 and 0.035 are respectively

$$b_{1(s)} = 0.04435 \quad \text{and} \quad b_{2(s)} = 0.04937,$$

while at level 15, the rates are

$$b'_{1(s)} = 0.04285 \quad \text{and} \quad b'_{2(s)} = 0.04776.$$

Therefore at level 14.10177 we have

$$b^*_{1(s)} = 0.10177 \times 0.04285 + (1.0 - 0.10177) \times 0.04435$$
$$= 0.044197,$$

and in the same way,

$$b^*_{2(s)} = 0.10177 \times 0.04776 + (1.0 - 0.10177) \times 0.04937$$
$$= 0.049206.$$

We then use the observed proportion under age 15 years, C(15), and the interpolated proportions for the stable population, $C^*_i(15)$, for i = 1, 2 to get the second interpolating factor. We require this for the computation of stable population parameters b_s and r_s.

The interpolating factor is defined by the equation,

$$a_2 = [C(15) - C^*_1(15)]/[C^*_2(15) - C^*_1(15)]$$
$$= (0.483459-0.448850)/(0.482970-0.448850)$$
$$= 0.9858707.$$

With this factor, the stable population birth rate is given by the equation

$$b_s = a_2 b'_{2(s)} + (1-a_2) b'_{1(s)},$$

$= 0.9858707 \times 0.049206 + (1.0 - 0.9858707) \times 0.044197$

$= 0.049277;$

and the stable population growth rate is given by

$r_s = \alpha_s r_{2(s)} + (1-\alpha_s) r_{1(s)}.$

$= 0.9858707 \times 0.035 + (1.0 - 0.9858707) \times 0.030$

$= 0.035071.$

According to Coale (1981) b_s and r_s are the stable population parameters corresponding to those of the study population which are used to represent the population. Tables 3.11 and 3.12 have been developed in the same manner with relevant figures accordingly replaced.

Table 3.11
West Model Females (mortality level 13.86629)

	Level 13		Level 14		Level 13.86629		
i	$C_i(15)$	$b_{i(s)}$	$C'_i(15)$	$b'_{i(s)}$	$C^*_i(15)$	$b^*_{i(s)}$	$r_{i(s)}$
1	0.4537	0.04570	0.4485	0.04402	0.449195	0.044244	0.030
2	0.4873	0.05077	0.4823	0.04897	0.482968	0.049210	0.035
	C(15) = 0.483459		b_s = 0.049282		r_s = 0.035072		

Table 3.12
West Model Males (Mortality level 13.86629)

	Level 13		Level 14		Level 13.86629		
i	$C_i(15)$	$b_{i(s)}$	$C'_i(15)$	$b'_{i(s)}$	$C^*_i(15)$	$b^*_{i(s)}$	$r_{i(s)}$
1	0.4592	0.04731	0.4538	0.04549	0.454522	0.045733	0.030
2	0.4920	0.05244	0.4869	0.05049	0.487581	0.050750	0.035
	C(15) = 0.483459		b_s = 0.050125		r_s = 0.034376		

3.3.5 CALCULATION OF BIRTH RATE BY THE COALE'S METHOD

The above described tables show some steps leading to the calculation of birth rate for Kenya by the Coale derived methods based on stable population equations.

Using equation (2.19) i.e $b_A = b_s.\exp[7.5(r(t)-r_s)]$, we can compute birth rate due to Coale, having obtained estimates of stable population birth rate, b_s, stable population growth rate, r_s, and the country's growth rate for the period 1969-1979, r(t). Using the North model females, we have

$$b_A = 0.049277 \exp[7.5(0.033691 - 0.035071)]$$

$$= 0.048770$$ or 48.77 births per 1000 population,

and similarly, for the West model females, we have

$$b_c = 0.049282 \exp[7.5(0.033961 - 0.035072)]$$

$$= 0.048775$$ or 48.78 births per 1000 population.

For the male model life tables, the corresponding rates are 49.98 and 49.87 births per 1000 population.

If we use the alternative approach to estimating the proportion under 15, (equation 2.17), we have for the North model females,

$$C(15,t) = b_s[{}_5L_0.\exp(-2.5r_s) + {}_5L_5.\exp(-7.5r_s) + {}_5L_{10}.\exp(-12.5r_s)]/l_0$$

$$= 0.049277 \times [435882 \exp(-2.5\times0.035071) + 411771\exp(-7.5\times0.035071) + 401834\exp(12.5\times0.035071)]/100000$$

$= 0.0480477,$

and $b'_c = C(15,t)\exp(7.5r(t))/{}_{15}L_0$

$= 0.0480477 \exp(7.5x0.033961)/1249487$

$= 0.049508$ or 49.51 birth per 1000 population.

For the West model females, the same relationships give

$C(15,t) = 0.491049$ and $b'_c = 0.049431$ or 49.43/1000.

Using the male model life tables, our estimates are 50.7/1000 by the North model and 50.5/1000 by the West model.

Coale's estimation procedure has been shown to be an extension of the reverse survival method of obtaining birth rate from the proportion under age 15, with a life table corresponding to l(5), and r(t) (Venkatacharya and Teklu 1987a). However the former equation

$$b_0(t) = l_0 \times C(15,t)\exp[7.5r(t)]/{}_{15}L_0 .$$

appears simpler because it does not contain stable parameters resulting to some computational ease, but requires the use of model life tables if one is not available for the study population.

3.4.0 EXTENSION BY VENKATACHARYA AND TEKLU

We know from equation 3.13 that for cummulated population 0-15 years, the birth rate is given by

$$b_0(t) = l_0 \times C(15,t)\exp[7.5r(t)]/{}_{15}L_0 .$$

Also, from equation 2.20,

$${}_{15}L_0 = u + vl(5).$$

Therefore, on substitution, we have

$$b_v = \frac{l_0 C(15,t)\, e^{7.5r(t)}}{u+vl(5)}$$

....(3.14)

which is the Venkatacharya and Teklu's equation for birth rate. The North model estimate is

b_v = 100000x0.483459 exp(7.5x0.033961)/[0.145 + 14.809x83544]

= 0.050250 or 50.25 births per 1000 population.

and the West model estimate is

b_v = 100000x0.483459 exp(7.5x0.033961)/[0.365 + 14.599x85205]

= 0.047510 or 47.5 births per 1000 population,

It is interesting to note that birth rates by Coale's and Venkatacharya & Teklu's methods are remarkably close to each other and this has prompted their discussion under one heading. Theoretically, these estimates should be identical within the approximations used, in line with the earlier explanation that the equations that yield the estimates are merely improvements on the equation of reverse projecting population in the age group 0-14 years. The equations are not identical but it has been shown (Venkatacharya and Teklu, 1987a) that the Coale equation is reducible to the Venkatacharya equation. However, Venkatacharya and Teklu (1987b) attributed the small differences to errors in approximations made and interpolation (or extrapolation) of b_s and r_s from the model stable populations.

Looking at these estimates against the others discussed above, and assuming that fertility fluctuated over the 15 year period before 1979, then a distinct pattern of fertility decline can be observed in Kenya, assuming uniform shifting and misreporting in all the districts. If t denotes the census year, then we have computed estimates of birth rate for times t-2.5, t-5.0, and t-7.5 on average before the census time. Whichever estimate we take referring to time t-7.5, it is evident that fertility (in terms of birth rate) declined in the immediate 10 or so years before 1979. If however we assume that the fluctuation in fertility was not remarkable during the 10 or so period preceding the 1979 census, then there is a noticeable underestimation by reverse surviving the youngest age group, and overestimation by reverse surviving the 5-9 year age group. This can be explained by under-reporting in the 0-4 year age group, due to shifting them to 5-9 year age group.

The West model estimates present a similar trend of variation as that of the North model, but presents higher rates for 0-4 age group estimates by the reverse survival techniques than other age groups. b_{v} and $b_{\wedge}$ do not give any distinct pattern of differences.

chapter four

MORTALITY AND FERTILITY ESTIMATION AT PROVINCIAL AND DISTRICT LEVEL

4.0.0 INTRODUCTION

In chapter three, we have described the various methods and estimation formulae for some demographic parameters pertaining to fertility and mortality. This chapter goes a depth further and use the same methods at provincial and district levels. A similar format has been followed in the presentation of this chapter, as the one in the previous chapter, but it has not been found to be necessary to give all the details of the computations here. As much as possible, the presentation avoids the detailed tables at this stage, as these are provided in the appendices.

4.1.0 ESTIMATION OF MORTALITY

Following the lead of chapter three discussions, we have come up with the mortality estimates presented in table 4.1 below. Again, these are provided first because they are necessary before we can be able to identify the stable population parameters corresponding to the same probability of surviving to age 5 and the proportion of the population under age 15. In the discussion which follows, the terms high and low are used in relative sense, and in the context of the inter-regional comparison in Kenya.

Table 4.1

Mortality estimates for Kenya 1979
North Model

Region	Index of mortality e_0	level	$_1q_0$	$_4q_1$	$_5q_0$	q(2)	q(5)
NAIROBI	58.233	17.497	0.06752	0.04031	0.10783	0.08893	0.09982
CENTRAL	60.809	18.613	0.05692	0.03131	0.08823	0.06512	0.09309
Kiambu	61.041	18.713	0.05598	0.03053	0.08651	0.06830	0.08678
Kirinyaga	56.723	16.847	0.07391	0.04593	0.11985	0.07950	0.10171
Muranga	60.230	18.361	0.05926	0.03326	0.09253	0.06644	0.09935
Nyandarua	60.844	18.628	0.05678	0.03119	0.08797	0.06572	0.09373
Nyeri	64.223	20.108	0.04354	0.02039	0.06393	0.04767	0.06970
COAST	46.176	12.344	0.12317	0.09609	0.21926	0.16535	0.20701
Kilifi	42.128	10.646	0.14564	0.11756	0.26320	0.19640	0.24556
Kwale	44.119	11.485	0.13430	0.10770	0.24201	0.17743	0.22357
Lamu	45.713	12.150	0.12558	0.09870	0.22428	0.19045	0.20284
Mombasa	53.460	15.447	0.08832	0.05934	0.14765	0.11100	0.14616
Taita Taveta	53.127	15.304	0.08981	0.06079	0.15060	0.11264	0.14837
Tana River	46.507	12.483	0.12146	0.09424	0.21570	0.17219	0.19817
EASTERN	55.122	16.158	0.08902	0.05229	0.13319	0.09596	0.13986
Embu	57.182	17.046	0.07192	0.04414	0.11606	0.08183	0.12459
Isiolo	51.618	14.654	0.09677	0.06773	0.16449	0.12066	0.16713
Kitui	48.814	13.459	0.10991	0.08170	0.19161	0.14188	0.18592
Machakos	55.745	16.426	0.07818	0.04980	0.12798	0.09515	0.13169
Marsabit	52.885	15.200	0.09091	0.06184	0.15275	0.12472	0.13859
Meru	58.381	17.561	0.06690	0.03976	0.10668	0.07143	0.11960
N. EASTERN	51.117	14.444	0.09905	0.07007	0.16912	0.13143	0.16402
Garissa	57.001	16.965	0.07271	0.04485	0.11756	0.12652	0.10232
Mandera	50.337	14.110	0.10268	0.07383	0.17650	0.14266	0.16424
Wajir	51.203	14.481	0.09865	0.06966	0.16831	0.12817	0.16536
NYANZA	44.700	11.728	0.13107	0.10406	0.23513	0.16460	0.23066
Kisii	54.878	16.054	0.08195	0.05325	0.13521	0.09254	0.14507
Kisumu	42.093	10.642	0.14585	0.11775	0.26360	0.17461	0.26345
Siaya	40.767	10.091	0.15368	0.12504	0.27873	0.19820	0.26618
S. Nyanza	40.050	9.793	0.15810	0.12912	0.28722	0.20205	0.27147
RIFT VALLEY	52.533	15.050	0.09249	0.06338	0.15587	0.11003	0.15833
Baringo	47.077	12.721	0.11849	0.09106	0.20956	0.16302	0.19412
Elg. Marakwet	52.425	15.003	0.09298	0.06386	0.15684	0.12047	0.14931

Kajiado	60.496	18.477	0.05819	0.03237	0.09055	0.06970	0.09162
Kericho	57.049	16.986	0.07250	0.04466	0.11716	0.08627	0.11814
Laikipia	59.410	18.005	0.06259	0.03605	0.09864	0.07359	0.09884
Nakuru	56.109	16.582	0.07660	0.04836	0.12496	0.09263	0.12537
Nandi	54.663	15.962	0.08290	0.05414	0.13704	0.10341	0.13664
Narok	56.260	16.647	0.07594	0.04776	0.12370	0.08811	0.12866
Samburu	58.704	17.700	0.06555	0.03860	0.10415	0.08588	0.09819
Trans Nzoia	53.982	15.670	0.08597	0.05708	0.14305	0.10778	0.13976
Turkana	50.829	14.320	0.10039	0.07145	0.17184	0.12627	0.17400
Uashin Gishu	57.714	17.273	0.06970	0.04221	0.11192	0.08699	0.12023
West Pokot	43.436	11.201	0.13809	0.11058	0.24867	0.17736	0.23668
WESTERN	48.092	13.149	0.11337	0.08553	0.19889	0.14587	0.19127
Bungoma	50.073	13.997	0.10390	0.07510	0.17900	0.13503	0.16859
Busia	42.101	10.645	0.14580	0.11771	0.26351	0.18770	0.25591
Kakamega	49.239	13.640	0.07946	0.18735	0.18735	0.13742	0.18021

By the standards of other regions in Kenya, Provinces in Western Kenya are worst hit by high mortality. The two provinces, Western and Nyanza, fall third last and last respectively in descending order of life expectancy. The other high mortality province is Coast. People from Nyanza expect to live for only 44.70 years, followed by Coast (e_0 = 46.18 years) and Western (e_0 = 48.09 years) provinces. In view of the high proportion of population that they hold, these provinces are probably the cause for Kenya's life expectancy to have a low value of only 51 years. Moreover, these areas contribute significantly to the migration streams in most parts of the country (Oucho, 1986), so that the carry over effect of the mortality determinants from these places can affect the whole country. The districts within these high mortality provinces experience some of the lowest life expectancy at birth (in the world). South Nyanza and Siaya districts in Nyanza province have the lowest e_0 in Kenya, of about 40.0 years, and Kisumu of about 42.09 years. Only Kisii district is an island in mortality comparisons within Nyanza province, having e_0 at 54.89 years, about 10 years above the provincial estimate. Similarly Mombasa and Taita Taveta districts outdo all other districts in Coast province in mortality comparisons. The next lower life expectancy districts after Kisumu are to be found in Western province (Busia district : e_0 = 42.10) and Coast province (Kilifi district : e_0 = 42.13).

Central province, followed by Nairobi province enjoys the longest period of expected life at birth in Kenya, but only of 60.81 and 58.23 years respectively which is quite low when compared to the more developed countries, where the index as at 1979 was well over 70 years. On the low mortality, high life expectancy side are Nyeri and Kiambu districts where the expectation of life are 64.22 and 61.04 years, respectively.

In the provinces that lie in between the regions described above as high and low mortality areas, the variations in life expectancy are mostly between expectancy of 50 to 60 years. In Rift Valley province, all districts but Baringo and West Pokot districts have e_0's between 50 and 60 years, and only Kajiado exceeds 60 years but by a small margin. Eastern and North Eastern provinces show the same trends of life expectancies as Rift Valley, with values between 50 and 60 years, but for a few areas having only Kitui district with e_0 of 48.81 years. These three provinces have at least one common characteristic, namely that they together form a significant portion of the arid and semi-arid Kenya, and that parts of their areas are inhabited by nomadic tribesmen who are sparsely populated. These could have had an influence on the quality of data that were collected in the 1979 census from the areas. However, we are not absolving the other areas from the difficulties encountered in the data collection stage. The Siaya District Development Plan (1983-1988) indicated that there was remarkable incompleteness in the data pertaining to Nyanza province in the 1979 census.

The other indices of mortality presented in table 3.1 have a direct relationship with expectation of life, so that the trend of differences they present are similar to those of e_0. However, it is worth noting that infant and child mortality in Kenya is still quite high (columns (4) and (5)), ranging from the lowest values in Central province (IMR = 56.9/1000; CMR = 31.3/1000) to the highest values in Nyanza province (IMR = 131.1/1000; CMR = 104.1/1000). Within these provinces we also find the lowest infant and child mortality rates, namely Nyeri district (IMR = 43.5/1000; CMR = 20.1/1000), and Kiambu district (IMR = 56.0/1000; CMR = 30.5/1000) as well as the highest infant and child mortality rates, i.e Siaya district (IMR = 153.7/1000; CMR = 125.0/1000), and South Nyanza district (IMR = 158.1/1000; CMR = 129.1/1000). This is according to the North model computations.

On the West model approximations, the various provinces and districts retain there respective positions with regard to the named mortality indices. This model underestimates most of the indices, but only to a limited extent. The picture observed at national level that there is a tendency for excessive deaths to occur during infancy and less deaths during childhood, according to the West model is still maintained. The West model estimates of infant and child mortality bounds those of the North model above and below, that is, if we compare IMR for the West and North models, the West model estimate is higher; whereas on comparing the CMRs, the West model estimate is lower. The sum of the two indices representing the mortality rate in the entire age group 0-5 years for the West model is in most cases lower than the North model. The West model estimates are presented in the appendices.

4.2.0 ESTIMATES OF TOTAL FERTILITY RATE BY RELE'S METHOD

Rele's method has been applied here to the age-sex distribution 1979 census data at district and provincial level to estimate total fertility rate for each region. The results are summarized in table 4.2. The table summarizes the estimates of total fertility rate at provincial and district levels by Rele's method using the North model. The four computations for each area boil down to only two reference points in time before the census, namely 2.5 and 7.5 years before the 1979 census. A mean value provided in this case refers to a time mid-way between the other two reference points. This is at time t-5.0 if t is the census time.

Table 4.2

Estimates of Total Fertility Rate by the Rele's Method. North Model

REGION	SRB	CWR1[ⱡ] t-2.5	CWR2 t-2.5	CWR3 t-7.5	CWR4 t-7.5	MEAN t-5
		Time Reference Total Fertility Rates				
NAIROBI	0.986976	4.432568	4.723024	4.113659	4.500093	4.442336
CENTRAL	0.995994	6.700023	6.726570	8.247967	8.087923	7.440620
Kiambu	1.016121	6.362265	6.453744	7.682196	7.678923	7.044282
Kirinyaga	0.983545	6.574289	6.605592	7.785707	7.828357	7.198486
Muranga	0.994526	7.159573	7.127397	8.495065	8.278008	7.765010
Nyandarua	0.982043	7.550425	7.545988	9.351246	9.195357	8.410754
Nyeri	0.983834	6.262922	6.278515	8.281873	8.045966	7.217319
COAST	0.975233	5.663698	5.746053	5.699230	6.233121	5.835525
Kilifi	0.940660	5.826246	5.851624	6.264206	6.476579	6.104663
Kwale	0.978116	5.940285	6.005005	6.252082	6.658906	6.214069
Lamu	0.972148	6.085646	6.200836	6.926018	7.221781	6.608570
Mombasa	0.999106	4.702078	4.890872	4.333257	4.926658	4.713216
Taita Taveta	0.987881	6.175572	6.143474	7.161529	7.668820	6.787348
Tana River	1.052203	6.495429	6.606266	6.981079	7.535464	6.904559
EASTERN	1.010896	6.410278	6.462585	7.096507	7.339254	6.827156
Embu	1.019658	6.806788	6.835706	7.585214	7.682761	7.227617
Isiolo	1.037426	5.740634	5.890914	5.312035	5.832976	5.694139
Kitui	1.003608	6.265628	6.322770	7.070994	7.526575	6.796491
Machakos	1.017609	6.443883	6.503332	7.551711	7.648783	7.036927
Marsabit	0.976769	5.362588	5.473318	5.356493	5.781094	5.493373
Meru	1.006976	6.455613	6.490483	6.889095	6.994462	6.707413
N. EASTERN	1.056338	5.617339	5.842658	6.274215	6.955864	6.172519
Garissa	1.042316	5.750358	5.963900	7.040641	7.318436	6.518333
Mandera	1.039745	5.440181	5.647932	5.878767	6.471453	5.859583
Wajir	1.082617	5.482645	5.726745	6.113995	6.793105	6.029122
NYANZA	0.976641	6.381615	6.342758	6.820637	7.171998	6.679252
Kisii	0.985931	7.261361	7.577325	8.038811	8.546275	7.855943
Kisumu	0.947490	5.666181	5.639103	5.858302	6.210763	5.843587
Siaya	0.946392	5.735127	5.548931	6.287201	6.174562	5.936455
S. Nyanza	1.003347	6.106979	6.075775	6.943409	6.937811	6.515993
RIFT VALLEY	0.996543	4.465206	4.701139	5.401593	6.123577	5.172878
Baringo	0.997635	6.659595	6.680374	7.020552	7.642342	7.000715

[ⱡ] CWR's subscripted 1,2,3 and 4 are the child to woman ratios respectively for the populations aged 0-4 to women aged 15-44, 0-4 to women aged 15-49, 5-9 to women aged 20-49 and 5-9 to women aged 20-54.

Elg Marakwet	0.989566	6.044802	6.025192	6.496481	7.069836	6.409077
Kajiado	0.950654	6.498892	6.577922	7.104433	7.133056	6.828575
Kericho	0.994876	7.158657	7.234842	7.877333	8.187502	7.614583
Laikipia	0.977633	7.142284	7.179448	7.844864	7.853377	7.504993
Nakuru	1.025165	6.987433	7.100536	7.640266	8.061991	7.447556
Nandi	0.992527	7.227710	7.252251	7.532352	8.040128	7.513110
Narok	0.973863	7.033290	7.024714	6.945723	7.321859	7.081396
Samburu	0.987013	5.845982	5.799264	6.097326	6.254460	5.999258
Trans Nzoia	0.996054	7.570031	7.588986	7.568906	8.241632	7.742388
Turkana	0.977672	3.756369	3.923790	4.558286	5.335720	4.393541
Uashin Gishu	1.030374	6.777007	6.879624	7.563791	7.847716	7.267034
West Pokot	0.967506	7.574265	7.571093	6.476392	6.753312	7.093765
WESTERN	0.950291	6.910845	6.870143	7.022039	7.847716	7.130300
Bungoma	1.003474	7.617194	7.643094	7.235970	8.229255	7.681378
Busia	0.985651	6.347268	6.271944	6.615577	6.746790	6.495394
Kakamega	0.959070	6.894671	6.839108	7.142709	7.947617	7.206026

The table shows that the total fertility rate computed for the times t-2.5 are consistently lower than those for times t-7.5, except for Nairobi and Coast provinces. The picture that emerges is that fertility has shown a brief decline in most areas in Kenya over the past 10 years preceding the 1979 census. On the other hand, if one looks across the estimates for most regions, it becomes evident that older women report higher fertility than younger ones. That is, if we consider only women in the age group 15-44, the estimated fertility is lower than that considering women in the age group 15-49 for the same age group of children. A similar trend can also be obaserved when comparing TFRs based on children aged 5-9 years and women in age categories 20-49 and 20-54. Given that the estimation procedure has taken care of the extra age interval 45-49 when we are using the 0-4 year age group, or 50-54 when use is made of the 5-9 year age group, this result suggests that older women had higher fertility than the younger ones while assuming that female reproductive performance after age 50 is negligible. Furthermore, because the age groups of women considered encompasses the entire child-bearing ages with reservation for the age group 12-15 where fertility performance is small, we can reaffirm our earlier observation that fertility briefly declined.

If fertility tended to remain constant, or even increase, then the underestimate in the five year prior to the enumeration is probably due to under-enumeration of children aged 0-4 years relative to women aged 15-44 and 15-49 years; and the shifting of children out of this youngest age group into age group 5-9. When these two estimates are averaged together to give a TFR for the approximate 10 year period before the enumeration, there is still an underestimate, perhaps in consequence of the under-enumeration of children 0-4 years old. This may be a deliberate move as per the dictates of some traditions and customs, or unintentional due to lapse in memory particularly among the older women. However, if the under-enumeration of children and women is about uniform throughout the country, then the fertility levels are necessarily comparable and present the correct trend of differences. We have no concrete basis for this argument, that the extent of under-enumeration was the same, but there is cause to believe that some factors that tend to bring about incompleteness in data during a national census in a third world country in general, and in Kenya in particular are common. Moreover, various irregularities were reported over the census, whose net effects are misreported or misplaced events.

A similar trend of discussions holds for the West model estimates as for the North model. However, on comparing the two sets of estimates, no distinct pattern of differences can be observed. The mean values coincide considerably for most areas. The West model estimates are lower than the North model estimates only for Nairobi, Central and Rift Valley provinces, but still the differences are negligible.

4.3.0 ESTIMATES OF BIRTH RATE BY THE REVERSE SURVIVAL TECHNIQUES

For the reverse survival techniques, the study examines the results obtained for Kenya 1979 census data by way of comparing the initial reverse survival technique, and its extensions: Coale's method based on stable population equations and the Venkatacharya and Teklu's method based on the relationship between the probability of surviving to exact age five and the total person years lived in the age interval 0-15 years. Table 4.3 gives the estimates at provincial and district levels for the North model.

Table 4.3

Estimates of Birth Rate by the Reverse Survival methods on different age groups and Extensions, North Model

	Reverse survival of age groups						
	0-4	0-9	0-14	5-9	mean	b_{n}	b_{2}
	Reference time of the birth rates						
AREA	t-2.5	t-5	t-7.5	t-7.5	t-7.5	t-7.5	t-7.5
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
NAIROBI	0.03662	0.03633	0.03653	0.03516	0.03616	0.03690	0.03601
CENTRAL	0.04376	0.04653	0.04831	0.04942	0.04700	0.04881	0.04859
Kiambu	0.04292	0.04545	0.04723	0.04802	0.04590	0.04773	0.04702
Kirinyaga	0.04337	0.04559	0.04719	0.04785	0.04600	0.04765	0.04761
Muranga	0.04634	0.04941	0.05109	0.05261	0.04986	0.05162	0.05100
Nyandarua	0.04648	0.04864	0.04989	0.05084	0.04896	0.05042	0.04742
Nyeri	0.04050	0.04385	0.04611	0.04747	0.04448	0.04662	0.04500
COAST	0.04555	0.04837	0.04839	0.05121	0.04838	0.04878	0.04735
Kilifi	0.05024	0.05460	0.05370	0.05935	0.05447	0.05413	0.05316
Kwale	0.04832	0.05181	0.05120	0.05546	0.05170	0.05161	0.05052
Lamu	0.04895	0.05768	0.06125	0.06926	0.05907	0.06175	0.05677
Mombasa	0.03708	0.03703	0.03612	0.03655	0.03670	0.03645	0.03466
Taita Taveta	0.04222	0.04610	0.04788	0.05036	0.04664	0.04831	0.04726
Tana River	0.05051	0.05779	0.06253	0.06602	0.05921	0.06304	0.05989
EASTERN	0.04534	0.04822	0.04952	0.05119	0.04857	0.04999	0.04998
Embu	0.04666	0.04906	0.05086	0.05138	0.04949	0.05136	0.05111
Isiolo	0.04455	0.04497	0.04470	0.04481	0.04476	0.04512	0.04425
Kitui	0.04524	0.04984	0.05198	0.05497	0.05051	0.05242	0.05158
Machakos	0.04486	0.04879	0.05056	0.05303	0.04931	0.05104	0.05058
Marsabit	0.04294	0.04819	0.05304	0.05389	0.04952	0.05352	0.04911
Meru	0.04575	0.04651	0.04639	0.04694	0.04640	0.04685	0.04681
N. EASTERN	0.04152	0.04599	0.05010	0.05094	0.04713	0.05051	0.04904
Garissa	0.04410	0.05206	0.06007	0.06145	0.05442	0.06066	0.05801
Mandera	0.03812	0.03876	0.03913	0.03939	0.03885	0.03946	0.03740
Wajir	0.04179	0.04705	0.05213	0.05296	0.04848	0.05258	0.05000
NYANZA	0.04753	0.04877	0.04972	0.04987	0.04897	0.05012	0.05011
Kisii	0.05453	0.05609	0.05733	0.05740	0.05634	0.05779	0.05726
Kisumu	0.04177	0.04190	0.04089	0.04187	0.04161	0.04127	0.04034
Siaya	0.04530	0.04811	0.04984	0.05112	0.04859	0.05023	0.04965
S. Nyanza	0.04711	0.04921	0.05102	0.05135	0.04967	0.05143	0.05060
RIFT VALLEY	0.04799	0.05044	0.05142	0.05276	0.05065	0.05188	0.05151
Baringo	0.04637	0.04791	0.04815	0.04934	0.04795	0.04855	0.04685
Elg. Marakwet	0.03866	0.03748	0.03505	0.03630	0.36870	0.03537	0.03083
Kajiado	0.04893	0.05290	0.05473	0.05687	0.05336	0.05531	0.05611
Kericho	0.04756	0.04763	0.04670	0.04734	0.04731	0.04716	0.04595

Laikipia	0.05045	0.05728	0.06313	0.06476	0.05891	0.06377	0.06473
Nakuru	0.04283	0.04951	0.05550	0.05697	0.05120	0.05603	0.05285
Nandi	0.04758	0.04903	0.04932	0.05018	0.04903	0.04978	0.04919
Narok	0.05166	0.05539	0.05653	0.05901	0.05565	0.05707	0.05825
Samburu	0.04078	0.03983	0.03852	0.03874	0.03947	0.03891	0.03469
Trans Nzoia	0.05558	0.06248	0.06915	0.06964	0.06421	0.06979	0.05306
Turkana	0.03026	0.03130	0.02989	0.03235	0.03095	0.03015	0.02872
Uashin Gishu	0.04668	0.04976	0.05135	0.05281	0.05015	0.05185	0.05008
West Pokot	0.06295	0.06666	0.07264	0.06883	0.06777	0.07323	0.07367
WESTERN	0.05043	0.05237	0.05386	0.05490	0.05269	0.05432	0.05331
Bungoma	0.05313	0.05417	0.05574	0.05461	0.05441	0.05622	0.05497
Busia	0.05172	0.05483	0.05767	0.05776	0.05552	0.05813	0.05757
Kakamega	0.04863	0.05058	0.05161	0.05245	0.05082	0.05205	0.05058

Columns (2) through (5) are birth rates by reverse survival of age groups 0-4, 0-9, 0-14 and 5-9 years, respectively. Column (6) is the arithmetic mean of the birth rates obtained for the four age groups. The birth rates refer to different points in time with respect to enumeration time as shown.

The birth rate estimated by the reverse projecting 0-4 population is lower than the rate estimated by reverse projecting all other age groups, and than estimates by the extensions of the technique. This is true for all provinces except Nairobi, where the birth rate based on the 0-4 age group is higher. The trend is also seen in district level estimates. Further, it can be observed that birth rate based on age group 5-9 years is an overestimate when compared to the estimates based on 0-4, 0-9, and 0-14 years, if the assumption that fertility rates remained constant over the fifteen years prior to 1979 holds. Perhaps this trend of differences is due to misstatement of ages which affects the age group 0-4 most,(UN, Manual X,1983; Shryock and Siegel, 1988) coupled with transfer of these children to the next older age group 5-9. The high birth rate based on 0-4 year age group for Nairobi, Mombasa and Kisumu may be due to the fact that these areas are urban and home for mainly persons self selected in terms of education who are likely to give better records of dates of their children.

Birth rates based on broader age groups 0-9 and 0-14 years (columns 3 and 4) give estimates close to the mean of the four birth rate estimates (column 6). More closer is the birth rate estimate by the broadest age group 0-14 years. This is due to minimized shifting and age reporting errors in the age group. Errors in age reporting are usually reduced by cummulation of ages and estimates based on such groups are more robust, (UN 1983). For all the areas, estimates for cumulated populations, age groups 0-9 and 0-14 years, are close to each other. A comparison of columns (3) and (4) shows that lower birth rate in column (3) implies that shifting, omission or misreporting errors are more pronounced at early ages. The fact that the two do not coincide strengthens the point that some events go unrecorded, and that reverse projection when taken too far into the past is a source of error.

Assuming that fertility fluctuated over the 15 year period before 1979, then a distinct pattern of fertility differences and declines can be observed in comparing the estimates of the regions. This observations is based also on the assumption that shifting and misreporting are fairly uniform throughout the regions. If t denotes the census year, then columns (2), (3) and (4) give birth rates that refer on average to times t-2.5, t-5 and t-7.5 respectively. Columns (5) and (6) for age groups 5-9 and mean of the estimates also refer on average to the time t-7.5. Whichever estimate is taken that refer to time t-7.5, it is evident that fertility declined in the immediate 10 or so years before 1979. If this argument is acceptable, then the study suggests that the decline was due to a brief impact of family planning services and probably due to enrolment of more women at the neighbourhood of age 15 to schools following the 1974 presidential decree of free education in lower primary. The observed decline is consistent with the KDHS(1989) observation that fertility in Kenya continues to fall, but throws storms of doubt into the allegation of Sindiga (1985) that` despite the establishment of the family planning campaign about two decades ago (in 1967), the project has not made an effect because the country's growth rate rose to a record breaking 4.1% in 1984.

The estimates obtained by Venkatacharya and Teklu's method and Coale's method are shown in columns (7) and (8) respectively. It is interesting to note that birth rates in these columns are remarkably close to each other, as well as to those under column (6), though Coale's method estimates are slightly lower than those of Venkatacharya's method. From the works of Venkatacharya and Teklu (1987a), the equations giving these estimates are mathematically similar, the only difference lies on the approach to approximations. Therefore it is not as a surprise that the columns should be nearly identical.

4.4.0 COMPARISON OF RELE'S METHOD ESTIMATES WITH EXISTING ESTIMATES

One of the major objectives of this study was to apply the reverse survival techniques and compare its results with those obtained by other demographic analysis techniques. For comparison purposes, therefore, table 3.3 presents results of past works on fertility estimation in Kenya by Osiemo (1986) using the 1979 census data. The author used the Gompertz Relational model (1978) and the Coale-Trussell model to estimate total fertility rate for Kenya at district level.

The present study computed two estimates of total fertility rate; the first used the estimates of the sex ratio at birth assuming the available data for the population aged 0 was accurate enough; and the second considering possible mis-statements or omissions at this age and fixing the sex ratio at birth at an average of 1.05 for all the regions. The computational procedure was the same but the latter set of estimates came out to be generally lower, save for a few cases where it was higher. The reason for this is that the estimates of sex ratio at birth were ranging from 0.97 and 1.08 but most of these were less than the 1.05 value used in the second set of the estimates.

Table 4.4
A summary of the fertility levels at the National, Provincial and District levels, Kenya, 1979.

Region	G-R-M Average	C-T-M[£] Kmean	Adjusted Rele's Average[*]	Rele's Average[**]
KENYA	6.78	8.1	6.2	6.39
NAIROBI	6.395	4.86	4.44	4.58
CENTRAL	7.13	8.47	7.44	7.64
Kiambu	6.92	8.16	7.04	7.16
Kirinyaga	6.99	8.7	7.2	7.44
Murang'a	7.505	8.5	7.77	8.21
Nyandarua	7.625	9.47	8.41	8.7
Nyeri	6.785	8.16	7.22	7.46
COAST	5.555	7.1	5.84	6.06
Kilifi	5.62	7.36	6.1	6.45
Kwale	5.62	7.33	6.21	6.44
Lamu	5.8	7.32	6.61	6.87
Mombasa	4.565	5.66	4.71	4.83
Tana River	6.195	8.13	6.79	6.77
Taita Taveta	6.635	8.06	6.9	7
EASTERN	6.545	8.29	6.83	6.99
Embu	7.1	8.93	7.23	7.34
Isiolo	5.915	6.79	5.69	5.73
Kitui	6.34	8.1	6.8	6.95
Machakos	6.815	8.58	7.04	7.15
Marsabit	5.545	6.46	5.49	5.7
Meru	6.355	8.13	6.71	6.85
N. EASTERN	5.365	6.99	6.17	6.15
Garissa	5.68	7.92	6.52	6.54
Mandera	5.52	7.3	5.86	5.89
Wajir	5.205	7.12	6.03	5.93
NYANZA	6.785	8.69	6.68	6.9
Kisii	7.84	10.03	7.86	8.11
Kisumu	6.92	8.1	5.84	6.15
Siaya	6.535	7.83	5.93	6.25
South Nyanza	6.71	8.5	6.52	6.67
RIFT VALLEY	6.905	8.48	5.17	5.31

[£]The Gompertz Relational Model (G-R-M) and Coale-Trussel Model (C-T-M) estimates are obtained from Osiemo (1986) Msc. Thesis. Rele's estimates with superscript * are based on the observed sex ratio at birth for each area, while those with suscript ** are based on fixed sex ratio at birth 1.05.

Baringo	6.76	8.71	7	7.18
E. Marakwet	5.965	7.69	6.41	6.6
Kajiado	6.22	7.98	6.83	7.12
Kericho	7.635	9.11	7.61	7.82
Laikipia	7.035	8.64	7.5	7.7
Nakuru	7.39	8.85	7.45	7.54
Nandi	7.12	8.57	7.51	7.65
Narok	6.465	8.03	7.08	7.35
Samburu	6.355	6.97	6	6.29
Trans Nzoia	7.93	9.32	7.74	7.95
Turkana	4.305	6.72	4.39	4.55
Uashin Gishu	6.865	8.66	7.27	7.09
West Pokot	6.255	8.29	7.09	7.39
WESTERN	7.69	8.96	7.13	7.49
Bungoma	8.295	9.42	7.68	7.86
Busia	6.84	8.07	6.49	6.71
Kakamega	7.705	9.07	7.21	7.54

Estimates by Rele's method gives generally lower values because of the kind of data involved. The most likely source of error in this approach is that of age misreporting since only the population by sex and age are the main data used in the method. The adjusted Rele's method estimates which are obtained by setting the sex ratio at birth at an average of 1.05 gives TFR values higher than the estimates from the actual ratios. This observation suggests that the most probable error encountered in enumeration during the 1979 census was omission, particularly of the male children and/or a corresponding over enumeration of female births. The estimates by this adjustment are nearer to, but slightly higher than those obtained by Osiemo using the Gompertz Relational Model. Exceptions are again observed in most districts of Nyanza province and virtually all districts in Western province where Rele's method estimates are still lower. A few districts in the Rift Valley Province also show similar trends.

The low Rele's method estimates against Gompertz relational model estimates may also be thought of in the light of the reference times, bearing in mind that the two techniques were applied on the same data. The former technique is a reverse estimation process. This implies that its results refers to a time slightly earlier than that of the Gompertz relational model, which gives the current fertility rates. This result may suggest that fertility showed a slight increase, but the stronger point to note here is that there is high possibility of data loss in age reporting.

In the table, it is also interesting to note that estimates by Rele's procedures are quite close to those by Gompertz Relational Model, but are very low in comparison to those by the Coale_Trussell Model. The latter estimates are also considerably higher than the Gomperz Relational Model.

Table 3.5 also presents some more estimates for comparison. In this table, the items of comparison are the birth rates by the reverse survival technique and its extensions by Coale and Venkatacharya & Teklu, against birth rates by the Coale-Trussell model. In the former comparison of total fertility rate, it was observed that the Coale-Trussell model gave exaggerated estimates compared to the two sets of estimates by Rele's technique or the Gompertz relational model. In this table, it is again observed that the birth rates obtained by the Coale Trussell model are higher than those by the Reverse survival techniques. The estimates by reverse projection may be effected by errors in age reporting, but this should not cause the wide disparity given that the age groups considered in this case are wide enough to reduce this risk to an agreeable extent.

Table 4.5

Estimates of Birth Rate by the Reverse Survival Techniques and the Coale Trussell Model. 1979 census data

Region	Birth rate	Reverse Survival Methods $b_{(a,a)}$	Coale	Venk & Teklu
KENYA	.0554	.0486	.04878	.05025
NAIROBI	.0379	.03633	.03601	.03690
CENTRAL	.0486	.04653	.04859	.04881
Kiambu	.0502	.04545	.04702	.04773
Kirinyaga	.0496	.04559	.04761	.04765
Murang'a	.0471	.04941	.05100	.05162
Nyandarua	.0517	.04864	.04742	.05042
Nyeri	.0462	.04385	.04500	.04662
COAST	.0541	.04837	.04735	.04878
Kilifi	.0595	.0546	.05316	.05413
Kwale	.0558	.05181	.05052	.05161
Lamu	.0497	.05768	.05677	.06175
Mombasa	.0458	.03703	.03466	.03645
T. River	.0566	.0461	.04726	.04831
T. Taveta	.0498	.05779	.05989	.06304
EASTERN	.0528	.04822	.04998	.04999
Embu	.0537	.04906	.05111	.05136
Isiolo	.0496	.04497	.04425	.04512
Kitui	.0538	.04984	.05158	.05242
Machakos	.0531	.04879	.05058	.05104
Marsabit	.0434	.04819	.04911	.05352
Meru	.0524	.04651	.04681	.04685
N. EASTERN	.0461	.04599	.04904	.05051
Garissa	.0503	.05206	.05801	.06066
Mandera	.0469	.03876	.0374	.03946
Wajir	.048	.04705	.05000	.05258
NYANZA	.0597	.04877	.05011	.05012
Kisii	.0633	.05609	.05726	.05779
Kisumu	.0567	.0419	.04034	.04127
Siaya	.0546	.04811	.04965	.05023
S.Nyanza	.0609	.04921	.0506	.05143

R. VALLEY	.0541	.05044	.05151	.05188
Baringo	.0577	.04791	.04685	.04855
E. Marakwet	.0507	.03748	.03083	.03537
Kajiado	.0566	.0529	.05611	.05531
Kericho	.0566	.04763	.04595	.04716
Laikipia	.0513	.05728	.06473	.06377
Nakuru	.0534	.04951	.05285	.05603
Nandi	.0527	.04903	.04919	.04978
Narok	.0529	.05539	.05825	.05707
Samburu	.0477	.03983	.03469	.03891
T. Nzoia	.056	.06248	.05306	.06979
Turkana	.052	.0313	.02872	.03015
U. Gishu	.0546	.04976	.05008	.05185
W. Pokot	.0578	.06666	.07367	.07323
WESTERN	.0581	.05237	.05331	.05432
Bungoma	.0598	.05417	.05497	.05622
Busia	.0602	.05483	.05757	.05813
Kakamega	.0568	.05058	.05058	.05205

Source: Osiemo (1986). p. Adjusted birth rate.
[1] Reverse survival birth rate estimate based on the 0-9 year age group.
[2] Birth rate estimate by Coales' extension of reverse survival of the 0-14 year age group.
[3] Birth rate estimate by Venkatacharya and Teklu's extension of reverse survival of the 0-14 year age group.

4.5.0 A SUMMARY OF RESULTS

Having described the various methods and steps of the demographic techniques of analysis leading to the estimation of fertility and mortality in previous sections, this section is now devoted to a summary of the outcome of the computations. The demographic techniques of analysis used in this study gave estimates of fertility and mortality at national level and for all the provinces and districts in Kenya. The techniques have made use of age-sex distribution data and life tables constructed for the regions, as well as model life tables in the estimation procedures. The discussions have been done by way of comparison of the techniques, comparison between the regions as well as suggesting possible explanations for the disparities.

The results have given us some trends of variation, especially in mortality, where we have observed that Coastal and Lakeside districts of Kenya looses substantial proportions of their children at early ages, about 100 deaths per 1000 population at infancy, and a further 70 deaths per 1000 population during early childhood. The expectation of life is about 51 years for Kenyans, extremes lying at about 40 years in South Nyanza district at the lowest and 64 years in Nyeri district at the highest. Other high mortality areas are Siaya and Kisumu (Nyanza), Kilifi and Lamu (Coast),and Busia (Western); whereas low mortality areas include Nyandarua, Muranga and Kiambu (Central), and Kajiado (Rift Valley).

Going by the North model estimates, fertility levels are equally high in most parts of Kenya. Central and Western provinces can be considered as high fertility regions while Nairobi area is a low fertility region. Coast and Rift Valley provinces are torn between the two extremes, having some districts with extra high fertility and others in the lowest end of the estimates. Eastern and North Eastern provinces feature in Rele's method and Reverse survival method as low fertility provinces, whereas Nyanza has considerably high fertility rates. In general, Central province has the highest fertility, in view of the many of her districts that rank high in their fertility rates.

Central province has a total fertility rate ranging from about 6.70 to 8.09 by the Rele's technique for different child-woman ratios, with an average TFR of 7.44. This TFR corresponds to an average birth rate of about 46 births per 1000 population according to the North model, by the reverse survival techniques. Her highest fertility district is Nyandarua where the total fertility rate ranges from 7.55 to 9.35; and birth rates from 45 to 49 births per 1000 population. At aggregate level, Nairobi and Rift Valley provinces experience lowest fertility. Nairobi has an average total fertility rate of 4.44 and birth rate of 36/1000; while Rift Valley has the respective indices at 5.17 and 51/1000.

A district level analysis and comparison shows that high fertility levels are dominated by the Rift Valley districts of West Pokot, Trans Nzoia, Laikipia and Narok, and in the Western province, there are Bungoma and Busia districts. Highest TFRs were observed in Trans Nzoia, West Pokot, Nyandarua and Kisii districts. In the analysis by the Coale's method, some districts especially in the Rift Valley, Eastern and North Eastern provinces had growth rates outside the interpolation range of the Coale-Demeny model life tables, perhaps as a consequence of high rate of in migration in Rift Valley province or outflow from Eastern and North Eastern Province, and probably high rates of fertility. For these cases, (Lamu, Tana River, Marsabit, Garissa, Kajiado, Elgeyo Marakwet, Laikipia, Nakuru, Narok, Turkana and West Pokot), it was considered necessary to use linear extrapolation equations in order to obtain the required stable population birth and growth rates.

High fertility has however, been observed for cases within Rift Valley only. Similar cases in Coast, Eastern and North Eastern provinces and some of the cases in Rift Valley have shown remarkably low fertility levels. Examples are Lamu, Turkana and Marsabit. Tana River district, by the same standards is a high fertility area. The inconsistencies in some estimates may be attributed to incompleteness of the census data. The cases of Turkana and Elgeyo Marakwet were different from the others, in that they were experiencing negative population growth rates over the period 1969 to 1979. In this study, these districts showed low fertility. Studies in migration have shown that in Rift Valley province, Baringo, Elgeyo Marakwet, Kericho, Nandi, Samburu, Turkana and West Pokot have negative intra-provincial net migration. The rest of the districts in the province experience net gains, (Sly, 1984).

At national level, TFR is about 6.20 for the North model and 6.19 for the West model. The birth rate is on the average 47.5 births per 1000 population. If reference is made to the estimate based on cumulated population under age 15 to be nearest to the correct value, then birth rate for the country is about 49.82 births per 1000 population. However it should be understood that these birth rates refer to about 7.5 years before the 1979 census.

chapter five

DESCRIPTIVE STATISTICAL ANALYSIS

5.0.0 INTRODUCTION

A summary of the mortality and fertility estimates obtained in chapter three are given in table 5.1. The objective in this chapter is to describe the data sets in this table using exploratory Data Analysis (EDA) so as to come up with summary statistics and identify regions with low, moderate, high and very high classifications for mortality and fertility.

Table 5.1

A Summary of Demographic Estimates: North Model

		Brass		Venka.	Coale		Reverse		Rele
	REGION	c_0	q(5)	North	M(avg)	F(avg)	b_{0-9}	Avg	Average
1.	KENYA	50.959	.16909	.05025	.05034	.04914	.04860	.04890	6.1986
2.	NAIROBI	58.234	.09982	.03690	.03607	.03595	.03633	.03616	4.4423
3.	CENTRAL	60.809	.09309	.04881	.04973	.04745	.04653	.04700	7.4406
4.	Kiambu	61.041	.08678	.04773	.04738	.04665	.04545	.04590	7.0443
5.	Kirinyaga	56.723	.10171	.04765	.04761	.04760	.04559	.04600	7.1985
6.	Muranga	60.230	.09935	.05162	.05143	.05052	.04941	.04986	7.7650
7.	Nyandarua	60.844	.09373	.05042	.04848	.04635	.04864	.04896	8.4108
8.	Nyeri	64.224	.06970	.04662	.04537	.04462	.04385	.04448	7.2173
9.	COAST	46.176	.20701	.04878	.04793	.04677	.04837	.04838	5.8355
10.	Kilifi	42.128	.24556	.05413	.05400	.05232	.05460	.05447	6.1047
11.	Kwale	44.119	.22357	.05161	.05124	.04981	.05181	.05170	6.2141
12.	Lamu	45.713	.20284	.06175	.05732	.05623	.05768	.05907	6.6086
13.	Mombasa	53.460	.14616	.03645	.03461	.03472	.03703	.03670	4.7132
14.	T.Taveta	53.127	.14837	.04831	.04783	.04669	.04610	.04664	6.7873

15.	Tana R.	46.509	.19817	.06304	.06054	.05923	.05779	.05921	6.9046
16.	EASTERN	55.122	.13986	.04999	.05029	.04968	.04822	.04857	6.8272
17.	Embu	57.182	.12459	.05136	.05162	.05059	.04906	.04949	7.2276
18.	Isiolo	51.618	.16713	.04512	.04467	.04384	.04497	.04476	5.6941
19.	Kitui	48.815	.18592	.05242	.05226	.05091	.04984	.05051	6.7965
20.	Machakos	55.745	.13169	.05104	.05111	.05006	.04879	.04931	7.0369
21.	Marsabit	52.885	.13859	.05352	.04940	.04882	.04819	.04952	5.4934
22.	Meru	58.381	.11960	.04685	.04728	.04634	.04651	.04640	6.7074
23.	N.EASTERN	51.117	.16402	.05051	.04953	.04855	.04599	.04713	6.1725
24.	Garissa	57.001	.10232	.06066	.05842	.05760	.05206	.05442	6.5183
25.	Mandera	50.337	.16424	.03946	.03793	.03686	.03876	.03888	5.8596
26.	Wajir	51.203	.16536	.05258	.05036	.04964	.04705	.04848	6.0291
27.	NYANZA	44.700	.23066	.05012	.05174	.04848	.04877	.04897	6.6793
28.	Kisii	54.878	.14507	.04127	.04086	.03982	.04190	.04161	5.8436
29.	Kisumu	42.093	.26345	.05779	.05831	.05621	.05609	.05634	7.8559
30.	Siaya	40.767	.26618	.05023	.05057	.04873	.04811	.04859	5.9365
31.	S.Nyanza	40.050	.27147	.05143	.05157	.04964	.04921	.04967	6.5160
32.	R.VALLEY	52.533	.15833	.05188	.05209	.05094	.05044	.05065	5.1729
33.	Baringo	47.077	.19412	.04855	.04751	.04619	.04791	.04795	7.0007
34.	Elgeyo M.	52.425	.14931	.03537	.03215	.02951	.03748	.03687	6.4091
35.	Kajiado	60.496	.09162	.05531	.05651	.05572	.05290	.05336	6.8286
36.	Kericho	57.049	.11814	.04716	.04646	.04544	.04763	.04731	7.6146
37.	Laikipia	59.410	.09884	.06377	.06522	.06425	.05728	.05891	7.5050
38.	Nakuru	56.109	.12537	.05603	.05311	.05260	.04951	.05120	7.4476
39.	Nandi	54.663	.13664	.04978	.04970	.04869	.04903	.04903	7.5131
40.	Narok	56.260	.12866	.05707	.05876	.05775	.05539	.05565	7.0814
41.	Samburu	58.704	.09819	.03891	.03513	.03426	.03983	.03947	5.9993
42.	T.Nzoia	53.982	.13976	.06979	.05385	.05227	.06248	.06421	7.7424
43.	Turkana	50.829	.17400	.03015	.02895	.02849	.03130	.03095	4.3935
44.	U.Gishu	57.714	.12023	.05185	.05048	.04968	.04976	.05015	7.2670
45.	W.Pokot	43.436	.23668	.07322	.07471	.07262	.06666	.06777	7.0938
46.	WESTERN	48.092	.19127	.05431	.05402	.05260	.05237	.05269	7.1303
47.	Bungoma	50.073	.16859	.05622	.05564	.05430	.05417	.05441	7.6814
48.	Busia	42.101	.25591	.05813	.05850	.05664	.05483	.05550	6.4954
49.	Kakamega	49.239	.18021	.05205	.05127	.04989	.05058	.05082	7.2060

Note: e_0 and q(5) are mortality estimates by Brass' techniques; Venk-North is the North Model estimates of birth rate by Venkatacharya and Teklu's method; Coale's M(avg) and F(avg) refers to male and female averages, respectively.

5.1.0 EXPLORATORY DATA ANALYSIS

An effective analysis of quantitative empirical data is a two stage process - an initial stage involving surveying and exploring the data using some quick and non-rigorous methods, and the second stage consisting of model building and hypothesis testing using the procedures of classical inferential statistics. The first stage is called Exploratory Data Analysis (EDA) and the second is called Confirmatory Data Analysis (CDA).

Tukey (1977) stated that EDA is detective in nature and examines the strength in the evidence. Tukey has developed a large and diverse array of intuitively sound and theoretically supportable tools for exploring data prior to the application of confirmatory tools. This study examines in detail the distribution of the estimates mortality and fertility in Kenya using EDA and attempts to explain the observed distributions in terms of the differences in socio-economic status, socio-cultural setting, environmental factors and their interactions.

Exploratory Data Analysis (EDA) was used to summarize the information about the distribution of the estimates of birth rate, total fertility rate and various mortality estimates. Two basic EDA display procedures were used, namely the Box-plot and the Stem-and-leaf display. From the displays, one can see how tightly cases cluster together, if there is some sequence(s) in which the estimates occur, and determine whether there are any extreme values. The numerical and graphical procedures of EDA introduced by Tukey (1977) were followed. In this form of analysis, the basic numbers that are easy to find and that tells something about a collection - a batch - of numbers as a whole are the two extremes (minimum and maximum) and the middle value, (Kim, no date). The middle value is called the median and is used as a measure of location. In addition to these numbers, the lower and upper quartiles add more information about the batch numbers; the range between them is called the midspread and measures dispersion.

The box-plot gives the median as a measure of central tendency, or location; the length of the box tells about the spread, or variability of the observations. Box-plots are particularly useful for comparing the distribution of values in several groups. The Stem-and-leaf display is similar to a histogram, but unlike the latter, provides more information about the actual values than does the histogram.

5.1.1 THE STEM - AND - LEAF DISPLAY

A stem-and-leaf display is a basic organizational procedure of EDA. Like a simple sorting of data values, the display organizes the values in numerical order; and facilitates the study of the shape, spread and distributional characteristics of empirical values. Unlike a sort and histogram, however, the stem-and-leaf display retains information on individual data and provides both a graphical summary and a convenient calculation of median and midspread (Sykes,1978). The plot is divided into two components - the leading digits called the stem, and trailing digits referred as the leaf.

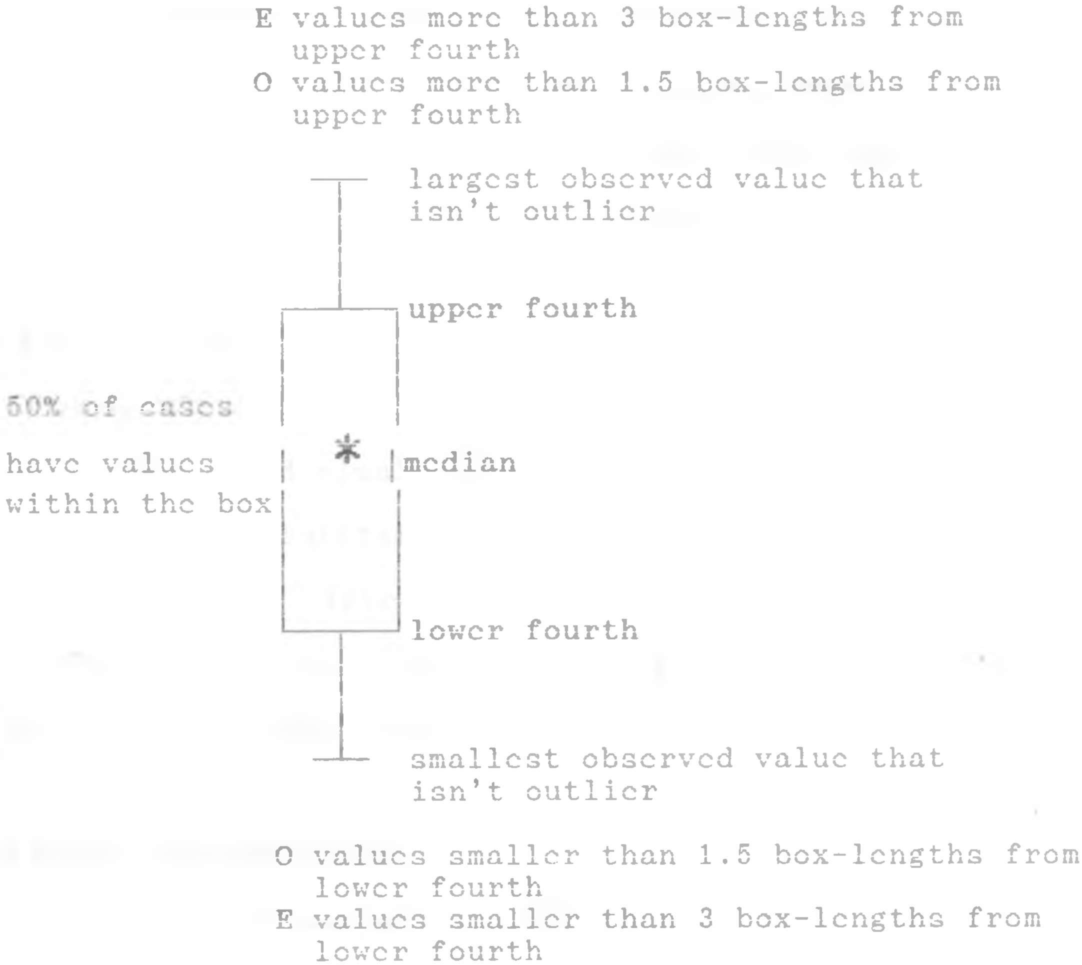
The display is usually presented in two formats depending on the extent to which the observations are crowded or on the number of cases considered. The options are to sub-divide the stem into two parts - one for leaves of 0 through 4, designated by "*"; and the other for leaves of 5 through 9, designated by "." . Alternatively, the stem can be sub-divided the stem into five parts, each of which representing two leaf values. The first, designated by "*" is for leaves of 0 and 1; the next, designated by "t" for leaves of 2's and 3's; "f" for 4's and 5's; "s" for 6's and 7's; and "." for 8's and 9's. The latter display format ensures a wider spread of the batch numbers.

5.1.2 THE BOX OR SCHEMATIC PLOT

Perhaps a better way of displaying the distribution of a set of numbers is the Box-plot. A box-plot is obtained by plotting the lower and upper quartile values of a batch of numbers and drawing a box to identify the length of the spread. Instead of plotting actual values, a box-plot displays summary statistics of the distribution. It plots the median, the 25th percentile, the 75th percentile, the mean and the k% trimmed mean, for some k. and the values that are far removed from the rest (extremes) as well as other measures of dispersion like the variance, standard deviation and skewness. An *asterix* in (or on) the box represents the location of the median, crosses at the end of the vertical line drawn outwards from the lower and upper quartiles are the last data points that lie within 1 (or 1.5) midspread(s) from the quartiles.

The original rule by Tukey was to put crosses at 1.5 midspreads from the quartiles. Numbers lying outside these crosses are called outliers, and outliers more than three times the midspread away from its ends are called "far out" observations (Sykes,1978). Box-plots are particularly useful for comparing the distribution of values in several groups. In our case it was very useful in comparing the birth rate obtained by the various reverse survival techniques. Figure 5.1 is an annotated sketch of a box-plot.

Figure 5.1
An Annotated sketch of a box-plot



<u>Source</u>:Marija J. Norusis, SPSS/PC+ V3.0 Update Manual. pp B-21.

The boundaries of the box are Tukey's hinges. The length of the box is the interquartile range (IQR) based on Tukey's hinges. Values more than 3 IQR's from the end of the box are labelled as extreme (E), and those more than 1.5 IQR's but less than 3 IQR's are labelled as outlier (O).

5.2.0 ANALYSIS USING THE STATISTICAL TECHNIQUE

In the following section, the study discusses the findings of the demographic estimation techniques of analysis in the light of the Exploratory Data Analysis organization procedures. This will enhance a quick and effective means by which a comparison can be made between the estimates. The procedures have been applied to all the fertility and mortality parameters estimated, but only summary estimates will be presented here for discussion. In both the box-plot and the stem-and-leaf display, the figures given in this work are the actual values of the estimates which may be rounded to a convenient number of decimal places. There were a total of 49 cases, each case representing a region, viz. 1 national level estimate, 8 provincial level estimates, and 40 district level estimates. The regions have been numbered 1 through to 49, in the summary table above (table 5.1).

5.2.1 ESTIMATES OF MORTALITY

For the discussion of mortality estimates in this section, the study picked on the life expectancy at birth, e_0, and the probability of dying at exact childhood age 5, q(5). The stem - and - leaf display for the estimates is given in figure 4.2, and the box -plot in figure 4.3 below. Further to these, the extreme values for each set of estimates, namely the five highest and five lowest values in the batch, have been displayed. The stem-leaf also provides the frequency of cases in each leaf.

Fig.5.2

The Stem-Leaf plot of the Expectation of Life at birth

```
Valid cases:  49.0
Mean    52.3750  Std err  0.8838  Min   40.0498  Skewness -0.2910
Median 52.8846  Variance 38.275  Max   64.2235  S E Skew  0.3398
5%Trim 52.4711  Std dev   6.1867  Range 24.1737 Kurtosis -0.8004
                                   IQR    9.5310  S E Kurt  0.6681

   Frequency      Stem  &   Leaf
     2.00           4   *   00
     4.00           4   t   2223
     3.00           4   f   445
     3.00           4   s   667
     3.00           4   .   889
     7.00           5   *   0000111
     6.00           5   t   222333
     4.00           5   f   4455
     7.00           5   s   6667777
     4.00           5   .   8889
     5.00           6   *   00001
     0.00           6   t
     1.00           6   f   4

   Stem width:  10.0
   Each leaf:   1 case(s)
```

Extreme values

5 Highest	Case No.	Region	5 Lowest	Case No.	Region
64.223	8	Nyeri	40.050	31	S.Nyanza
61.041	4	Kiambu	40.767	30	Siaya
60.843	7	Nyandarua	42.093	28	Kisumu
60.809	3	CENTRAL	42.101	48	Busia
60.507	35	Kajiado	42.128	10	Kilifi

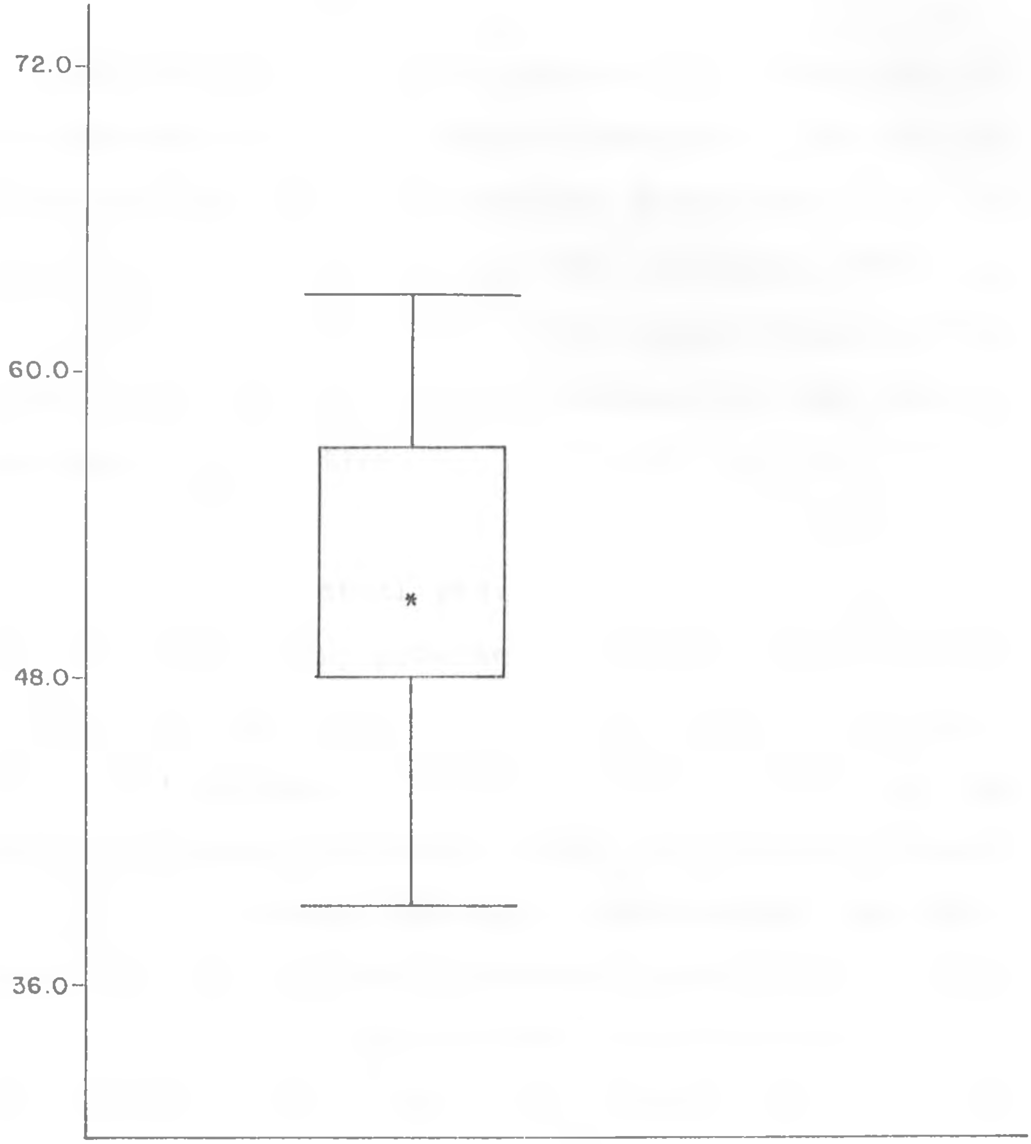
In the stem-leaf plot (fig 5.2), the stem is the second column, while the leaves are in the last column. Each leaf represents one case (region) whose estimate has been rounded to the nearest ones. The stem gives the range, in this case the first digit of each value; and the leaves give the second digit. The leaves are divided into five parts, '*' representing leaves of 0 and 1; 't' for leaves of 2 and 3; 'f' for leaves of 4 and 5; 's' for leaves of 6 and 7;

and '.' for leaves of 8 and 9. The frequency of cases represented in each stem is given in the first column. Thus, for example, in the first row, there are 2 cases, lying in the range 40-41. The exact values are 40.04978 and 40.76659, while the second row has 4 cases whose exact values are 42.09298, 42.10138, 42.12798, and 43.43599. The plot gives all these values in this order. They are the life expectancies for South Nyanza, Siaya, Kisumu, Busia, Kilifi, and West Pokot districts, respectively.

Other measures of statistical interest in figure 4.1 include the mean, median and 5% trimmed mean as measures of central tendency (or location), and measures of dispersion. The median life expectancy is 52.885, this value divides the batch into two equal parts; and the mean value is 52.373, nearly coinciding with the computed estimate for Kenya at national level. The 5% trimmed mean is the mean value of data when the lowest 5% and the highest 5%, are disregarded, that is, the mean of the 90% 'middle' values. Like the median, this measure of location is a robust one and is not affected by the extreme values. However, it makes better use of the data than the median because it is based on a large number of middle values.

The distribution shown on the stem-leaf plot in figure 4.1 appear to be bimodal, with the major peaks around the life expectancies in the 50's. If the aggregate distribution is visualized as the sum of the two component distributions, a mode in e_0's of early 50's is observed, which is where the life expectancy for Kenya lies. The general outlook is however one leaning towards 'high' life expectancies. This shows that many regions in Kenya have made some improvements in their mortality conditions.

Along with the stem-leaf display, the extremes, which are the five lowest and five highest observed e_0 values, have also been plotted. These statistics hold also for the box-plot (fig 5.3). With reference to table 5.1, these cases (regions) have been identified and matched accordingly. The maximum observed e_0 is 64.2 years and the lowest is 40.0 years, giving a range of 24.2. This implies that in the most prosperous district (Nyeri), people expect to live at least 24.2 years longer than in the district experiencing the highest mortality (South Nyanza).



K E Y

Number of cases 49

Median *

Figure 5.3 is a box-plot for the life expectancy for Kenya and all her provinces and districts. The figure emphasizes some of the observations made in the stem-leaf display. Furthermore, it has given more information about the spread of the estimates (IQR) and the relative position of the median. The lines (also called 'whiskers') from either side of the box terminate at the largest data point that is not an outlier.

It comes out clearly that Central province is at the top of the mortality scale in Kenya, the province's estimate being 60.809 years, only lower than her three districts - Nyeri (64.2235), Kiambu (61.041) and Nyandarua (60.844). At the bottom of the mortality spectrum are mainly districts in Nyanza province, namely South Nyanza (40.050), Siaya (40.767), and Kisumu (42.093), followed by Busia (42.101) in Western province and Kilifi (42.128) in Coast province. All these high mortality districts are lake- or sea-shore areas, prompting suspicion on the probable effects of the available expanse of water on mortality conditions.

The cases with low mortality, except for Kajiado (e_0 = 60.496) are highly agricultural areas, having good rainfall and fertile soils and bordering Kenya's largest urban centre of Nairobi. This suggests that a combination of city life and agricultural activities have a negative effect on mortality. The basis of this argument is wide and encompasses the entire array of environmental and socio-economic factors. When we look at Central province agriculturally, we can argue that her productive lands ensure not only good nutrition for the population, but also good enough income for the people. In general, this implies improved standards of living. Agriculture alone, however can not be held absolutely responsible for the low mortality in this province, since there are some other high agricultural potential areas (Kericho, Kisii, Bungoma, Kakamega, Trans Nzoia, Nakuru with cash and food crops) elsewhere which do not feature as low mortality areas. Therefore, we can also look at this area in terms of awareness of child health care practices and availability of health clinics within their reach. If this argument is tenable, then Kajiado district should not be within comparable rates with any of the districts in Central province, given the area's distance from better established urban centres and semi-arid conditions. The estimate for Kajiado is probably misplaced due to erroneous data obtained from this region as a result of their nomadic life styles.

The lake region and coastal districts have high mortality. A closer perusal of the estimates has indicated that death cases are more intense at infancy and early childhood. The areas share common features such as the sea-shore climate which is usually hot and dry, and large expanses of water that may provide breeding grounds for malarial disease agents and a variety of other water borne disease parasites. These conditions may have serious effects on the mortality conditions even where there is moderate medical attention.

Ocholla - Ayayo and Osiemo (1989) talks of certain socio-cultural dynamics of fertility change and differentials, and emphasizes that a population deeply rooted in her traditional beliefs and customs may show markedly different trends of fertility change. Reflected in mortality, this study suggests that certain socio-cultural beliefs and child-care practices in South Nyanza, Siaya, Kisumu and the Coastal districts could be the 'social disease' behind the high death rate in these areas. In this perspective, the districts which through Westernization (modernization or urbanization) have emancipated themselves from traditional values and norms, should, and indeed have lower mortality rates.

Fig 5.4

Stem-leaf plot for the probability of dying before exact age 5, q(5)

Valid cases : 49.0

Mean	0.1578	Std Err	0.0076	Min	0.0697	Skewness	0.5491
Median	0.1484	Variance	0.0028	Max	0.2715	S E skew	0.3398
5%Trim	0.1559	Std Dev	0.0531	Range	0.2018	Kurtosis	-0.5122
				IQR	0.0738	S E kurt	0.6681

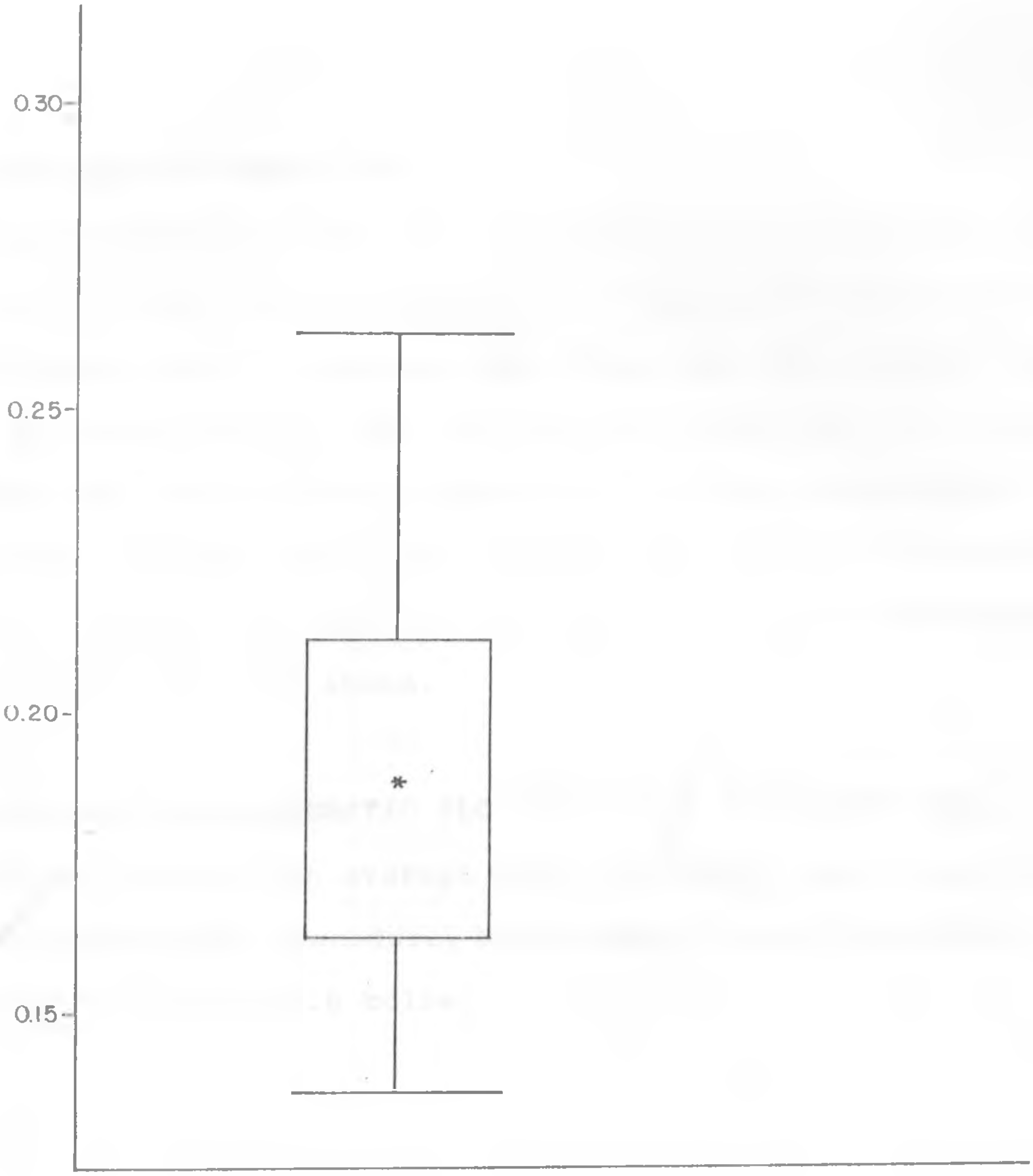
Frequency	Stem	&	Leaf
1.00	0	s	6
8.00	0	.	89999999
4.00	1	*	0011
11.00	1	t	22223333333
4.00	1	f	4445
7.00	1	s	6666667
4.00	1	.	8999
2.00	2	*	00
3.00	2	t	233
2.00	2	f	45
3.00	2	s	667

Stem width : 0.1
Each leaf : 1 case(s)

Extreme values

5 Highest	Case No.	Region	5 Lowest	Case No.	Region
0.2792	31	S. Nyanza	0.0712	8	Nyeri
0.2746	30	Siaya	0.0887	4	Kiambu
0.2687	28	Kisumu	0.0946	35	Kajiado
0.2640	48	Busia	0.0951	3	CENTRAL
0.2543	10	Kilifi	0.0959	7	Nyandarua

It was mentioned earlier that the mortality indices based on the Brass estimation procedure are related, as is again indicated in these plots. Life expectancy and the probability of dying at exact age 5 are inversely related, hence the distribution of q(5) estimates is skewed to the right as opposed to that of life expectancy. In the same tune, the cases appearing as high extremes in e_0 plots turn out to be low extremes in the q(5) plots. All the extreme cases in e_0 plots are duplicated for the q(5) plots, except that some regions switch positions. The plot is trimodal at leaves of 8 and 9 of stem 0; leaves of 2 and 3 of stem 1, and leaves 6 and 7 of stem 1.



<u>K E Y</u>

Number of cases 49.00

Median *

5.2.2 ESTIMATES OF FERTILITY

The EDA procedures were applied also for fertility parameters under the general reverse survival equations, Coale and Venkatacharya's methods and the Rele's approach approximations. The results shown in the following tables are the average values for the Rele's method and the reverse survival based on 'reverse resurrection' of the 0-9 year old population. The displays for results of extending the reverse projection equation by Coale (1981) and Venkatacharya & Teklu (1987) are also shown.

5.2.3 STEM-LEAF AND SCHEMATIC PLOT FOR TOTAL FERTILITY RATE

Let us first examine the average total fertility rate obtained by the Rele's estimation procedure, North model. We have presented the plots below in figure 5.6 below.

Fig. 5.6

Stem-Leaf and Schematic Plots of Rele's TFR estimates

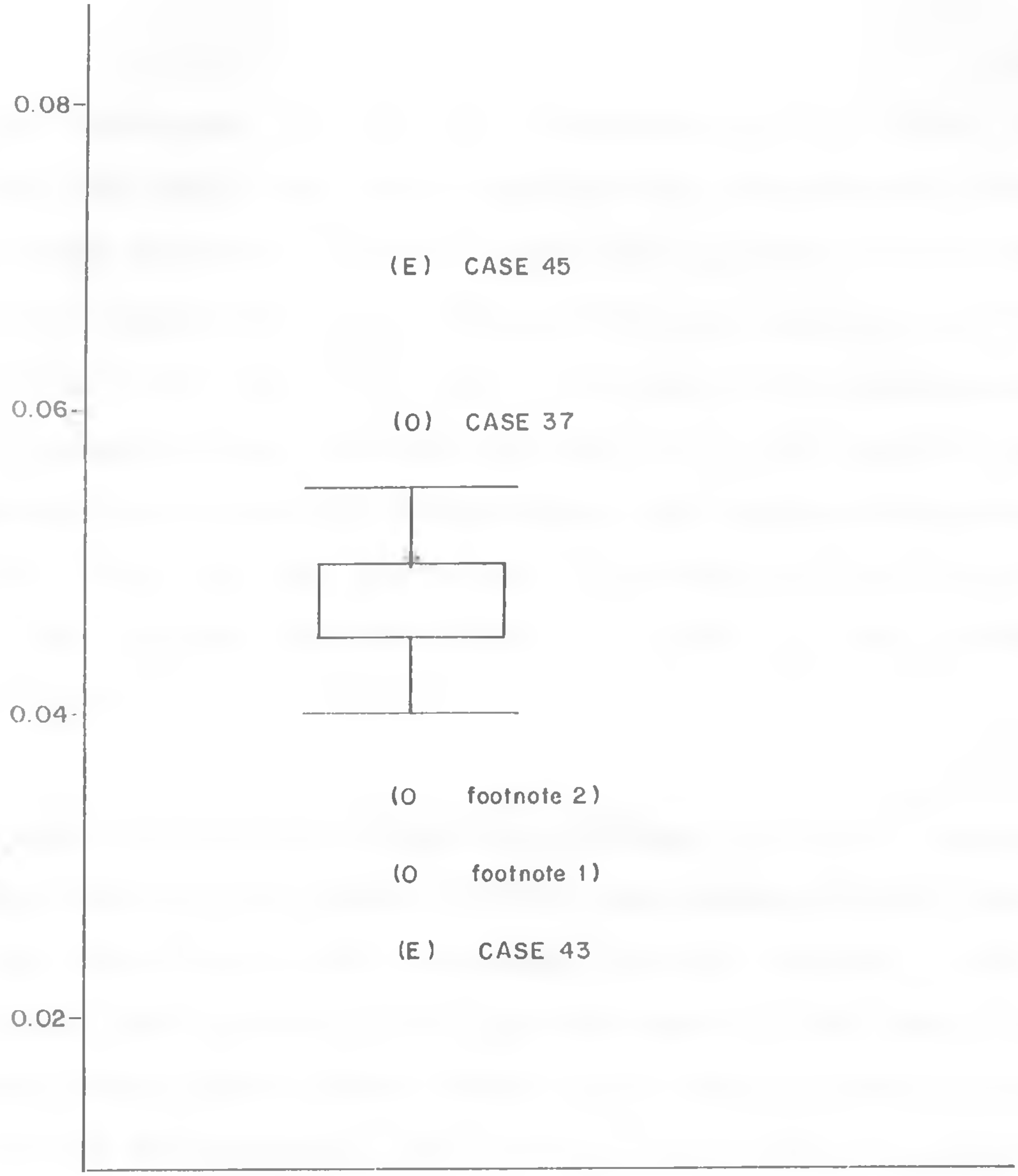
```
Valid cases :  49.0
Mean      6.643  Std Err  0.1249  Min    4.394  Skewness -.7248
Median    6.797  Variance 0.7642  Max    8.411  S E Skew  .3398
5% Trim   6.687  Std Dev  0.8742  Range  4.017  Kurtosis  .4819
                                  IQR    1.156  S E Kurt  .6681

Frequency    Stem &  Leaf
   2.00        4  f  44
   1.00        4  s  7
   1.00        5  *  1
   0.00        5  t
   1.00        5  f  4
   1.00        5  s  6
   5.00        5  .  88899
   4.00        6  *  0111
   1.00        6  t  2
   4.00        6  f  4455
   5.00        6  s  66777
   3.00        6  .  889
   7.00        7  *  0000011
   4.00        7  t  2222
   4.00        7  f  4455
   5.00        7  s  667777
   0.00        7  .
   0.00        8  *
   0.00        8  t
   1.00        8  f  4

Stem width :  1.0
Each Leaf : 1 case(s)
```

Extreme Values

5 Highest	Case No.	Region	5 Lowest	Case No.	Region
8.411	7	Nyandarua	4.394	43	Turkana
7.765	6	Muranga	4.442	2	NAIROBI
7.742	42	T. Nzoia	4.713	13	Mombasa
7.704	28	Kisii	5.173	32	R.VALLEY
7.681	47	Bungoma	5.493	21	Marsabit



<u>K E Y</u>

Number of cases	49.00
Median	*
Outlier	(O)
Extreme	(E)

<u>Footnotes</u>

(1) Case 13, Case 34, Case 41

(2) Case 2, Case 25

A remarkable skewness to the left (heaping to the right) is evidenced by the stem-leaf plot, meaning that most regions have relatively high fertility levels; relatively in the sense of the inter-regional comparison within Kenya. The mean and median TFRs are respectively 6.64 and 6.80, but it is noted that the greatest number of estimates fall between 6.5 and 7.7. The highest and lowest TFRs are 8.41 and 4.39 in Nyandarua and Turkana districts, respectively. That is, the fertility of persons in the highest fertility area nearly doubles that of persons in the lowest fertility region.

Extremely high fertility are observed in Nyandarua (8.41), Muranga (7.77), Trans Nzoia (7.74), Kisii (7.704) and Bungoma (7.68); while observed low fertilities are in Turkana (4.39), Nairobi (4.44), Mombasa (4.71), Rift Valley (5.17), and Marsabit (5.49). What can be observed in this case is that districts of Central province are leading in these TFR estimates. The low fertility districts in Rift Valley may be treated with reservation given the normadic nature of the population, particularly in Turkana[6] and Marsabit, and inter- and intra-provincial migration in the districts. Nairobi and Mombasa's low fertility values can be attributed to their being basically urban areas. Ocholla - Ayayo and Osiemo (1989) observed that the urban fertility may be lower because of the strain placed

[6] Turkana and Elgeyo Marakwet District infact recorded negative population growth rate over the period 1969-1979.

on parents in providing education facilities, nourishment and bedspace for their children. Other possibilities are that urban women are self-selected in terms of standards of education, which is inversely related to fertility (Ominde, et al. 1983). Low urban fertility can also be explained in terms of availability, knowledge and freedom of use of contraceptives, most women in these areas having been emancipated from the traditional ways of life which places stigma on users of contraceptives. Weller and Bouvier (1981), observes that loyalty to traditional laws is likely to diminish as one moves further away from the traditional chiefs both in distance and psychologically.

5.2.4 STEM-LEAF AND SCHEMATIC PLOTS OF BIRTH RATE

A reverse projection of the 0-9 year old population has been observed to have a desirable property, that it is not very much affected by age shifting and misreporting. Further, the projection does not go very far into the past and provides estimates which on average refer to a time 5 years before the enumeration time. On this background, the study plotted stem-leaf and box-plot for the estimates based on this age group to enhance the revelation of fertility levels within Kenya and comparison with the picture provided by the plots of Rele's estimates discussed above.

Fig 5.8

Stem-Leaf and Schematic Plots of Reverse Survival Birth Rates

Valid cases : 49.0

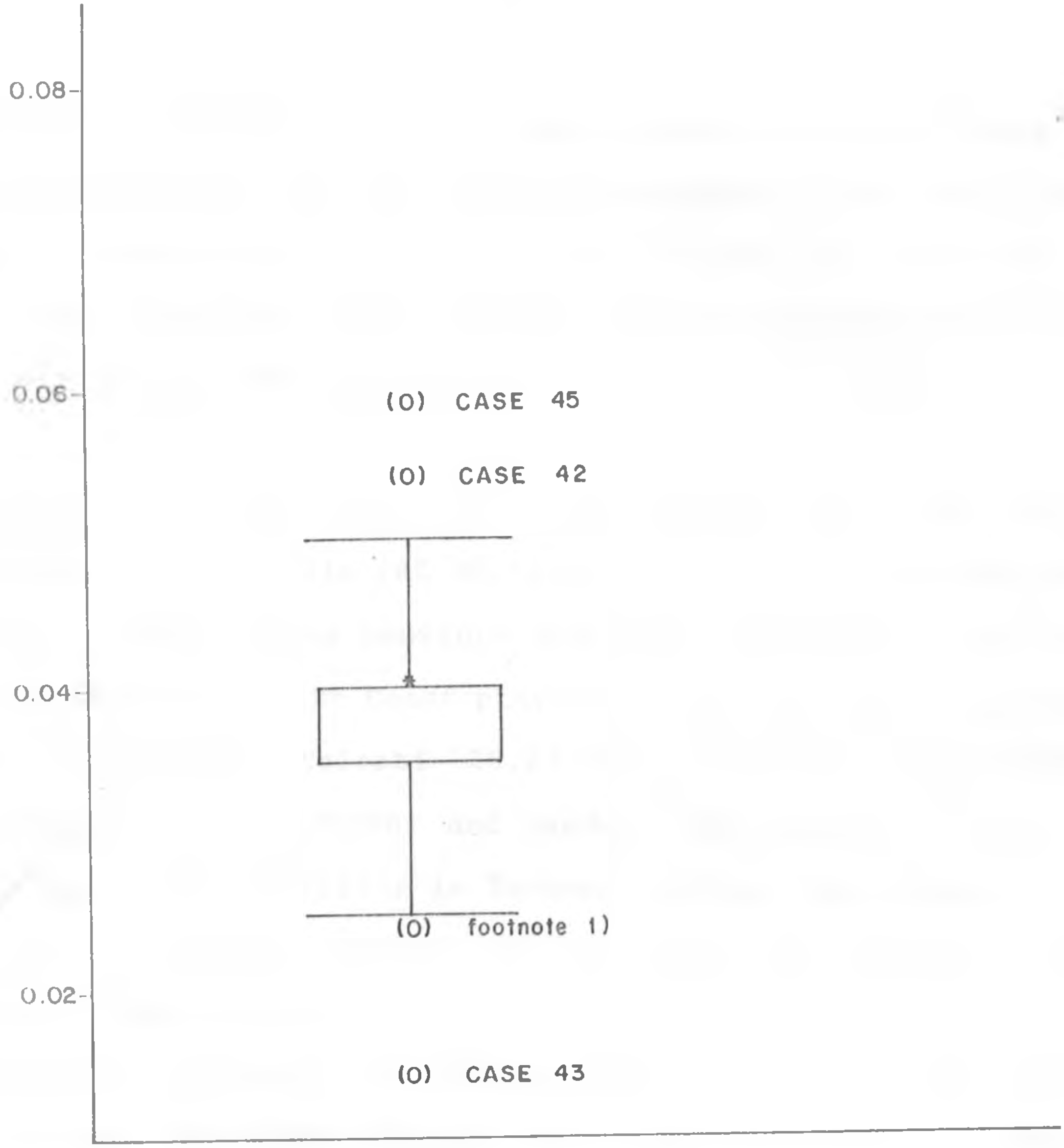
Mean	0.0487	Std Err	0.0009	Min	0.0313	Skewness	-.0642
Median	0.0488	Variance	0.0000	Max	0.0667	S E Skew	.3389
5% Trim	0.0487	Std Dev	0.0065	Range	0.0354	Kurtosis	1.1704
				IQR	0.0062	S E Kurt	.6631

Frequency	Stem	&	Leaf
1.00	3	*	1
1.00	3	t	
1.00	3	f	
3.00	3	s	677
2.00	3	.	89
1.00	4	*	1
1.00	4	t	3
4.00	4	f	4555
8.00	4	s	66667777
14.00	4	.	88888889999999
4.00	5	*	0011
2.00	5	t	22
4.00	5	f	4445
4.00	5	s	6777
0.00	5	.	
0.00	6	*	
1.00	6	t	2
0.00	6	f	
1.00	6	s	7

Stem width : .0
Each leaf : 1 case(s)

Extreme Values

5 Highest	Case No.	Region	5 Lowest	Case No.	Region
0.06666	45	W.Pokot	0.03130	43	Turkana
0.06248	42	T.Nzoia	0.03633	2	NAIROBI
0.05768	12	Lamu	0.03703	13	Mombasa
0.05779	15	Tana R.	0.03748	34	Elgeyo M.
0.05728	37	Laikipia	0.03876	25	Mandera



K E Y

Number of cases	49.00
Median	*
Outlier	(O)

Footnotes

(1) Case 13 , Case 2

The stem-leaf plot for these estimates show a similar trend of skewness to the plot for Rele's method estimates - that more rates are on the higher side. The modal range of birth rate is 45-49, in other words, most sub-regions in Kenya have birth rates between 45 and 49 births per 1000 population.

The highest extreme cases in these plots are West Pokot (66.66/1000), Trans Nzoia (62.48/1000), and Laikipia (57.28/1000) districts of Rift Valley province and Lamu (57.68/1000) and Tana River (57.79/1000) in the Coast province. The lower side comprises Turkana (31.30/1000), Nairobi (36.33/1000), Mombasa (37.03/1000), Elgeyo Marakwet (37.48/1000) and Mandera (38.76/1000). There is consistency in low fertility in Turkana, Nairobi and Mombasa when this plot is checked against the previous one. Estimates for Mandera and Elgeyo Marakwet districts in Rele's plots are below the mean of all the estimates, but are not quite as low as is portrayed in these plots. The high extremes are strangers in the plot except for Trans Nzoia which also featured in the Rele's plots.

Plots for estimates by Venkatacharya and Teklu's approach and Coales's extension approach are displayed below. There is no marked deviation from the plots discussed in the foregoing sections.

Fig. 5.10

Stem-leaf Plot of Venkatacharya and Teklu's method estimates

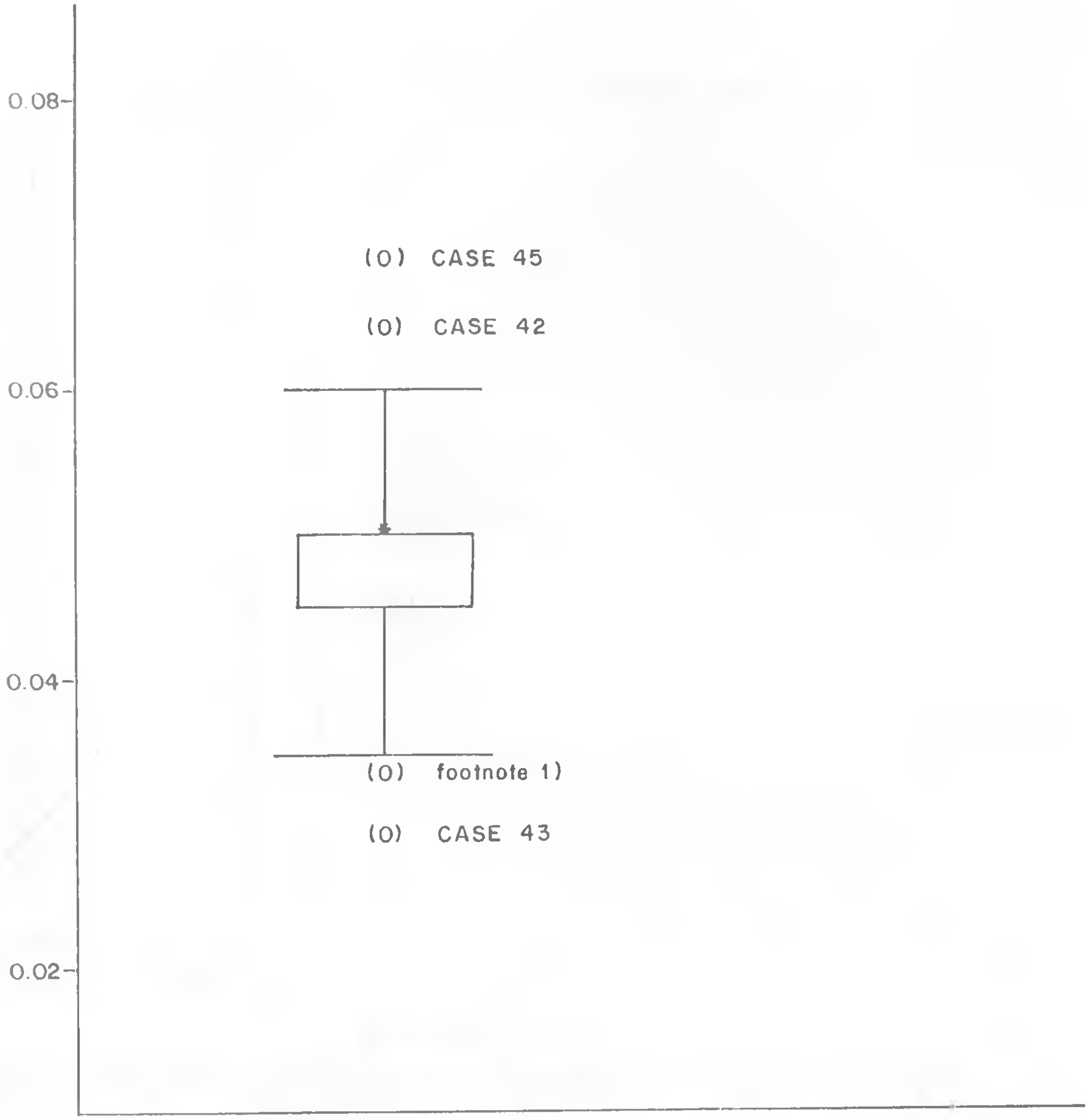
```
Valid cases :    49.0
Mean     0.0510  Std Err  0.0012  Min    0.0302  Skewness 0.0630
Median   0.0510  Variance 0.0001  Max    0.0732  S E Skew 0.3398
5% Trim  0.0509  Std Dev  0.0082  Range  0.0431  Kurtosis 1.2023
                                  IQR    0.0071  S E Kurt 0.6681

 Frequency       Stem  &   Leaf
   1.00            3   *   0
   0.00            3   t
   1.00            3   f   5
   1.00            3   s   6
   2.00            3   .   89
   1.00            4   *   1
   0.00            4   t
   1.00            4   f   5
   5.00            4   s   66777
   6.00            4   .   888899
  12.00            5   *   000001111111
   4.00            5   t   2223
   3.00            5   f   445
   4.00            5   s   6677
   1.00            5   .   8
   2.00            6   *   01
   2.00            6   t   33
   0.00            6   f
   0.00            6   s
   0.00            6   .
   1.00            7   *   0
   1.00            7   t   3

Stem width : 0.0
Each Leaf : 1 case(s)
```

Extreme values

5 Highest	Case No.	Region	5 Lowest	Case No.	Region
0.07321	45	W. Pokot	0.03015	43	Turkana
0.06979	42	T. Nzoia	0.03537	34	Elgeyo M.
0.06377	37	Laikipia	0.03647	13	Mombasa
0.06304	15	Tana R.	0.03690	2	NAIROBI
0.06175	12	Lamu	0.03891	41	Samburu



<u>K E Y</u>

Number of cases	49.00
Median	*
Outlier	(O)

Footnotes

(1) Case 13, Case 2, Case 34

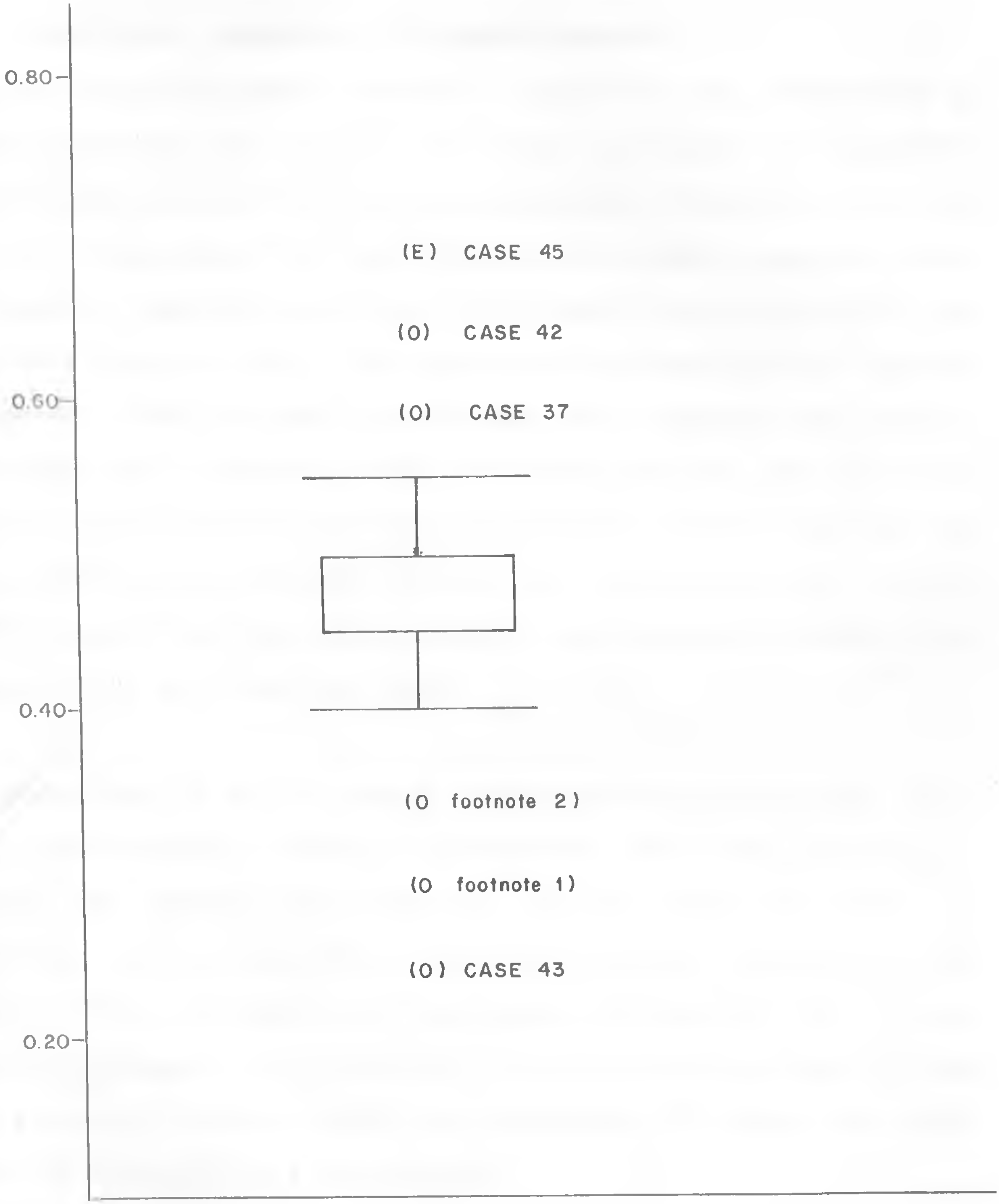
Fig. 5.12
Stem-leaf Plot of Coale's method estimates

Frequency	Stem	&	Leaf
1.00	2	.	9
1.00	3	*	1
0.00	3	t	
1.00	3	f	5
2.00	3	s	67
0.00	3	.	
1.00	4	*	0
0.00	4	t	
3.00	4	f	445
7.00	4	s	6677777
7.00	4	.	8999999
11.00	5	*	00000000111
4.00	5	t	2333
1.00	5	f	4
4.00	5	s	6677
3.00	5	.	889
0.00	6	*	
0.00	6	t	
1.00	6	f	5
0.00	6	s	
0.00	6	.	
0.00	7	*	
0.00	7	t	
1.00	7	f	4

Stem width : 0.0
Each leaf : 1 case(s)

Extreme values

5 Highest	Case No.	Region	5 Lowest	Case No.	Region
0.07367	45	W. Pokot	0.02872	43	Turkana
0.06474	37	Laikipia	0.03083	34	E. Marakwet
0.05989	15	T. River	0.03467	13	Mombasa
0.05826	40	Narok	0.03470	41	Samburu
0.05801	24	Garissa	0.03601	2	NAIROBI



<u>K E Y</u>

Number of cases	49.00
Median	*
Outlier	(O)
Extreme	(E)

Footnotes

(1) Case 13, Case 34, Cas

(2) Case 2, Case 25

5.2.5 FERTILITY - MORTALITY INTERRELATIONSHIPS

The EDA procedures have provided a tool for easy comparison of batches, and we now want to use this to examine the possible relationship between fertility and mortality. It has been observed that the 'replacement' of dead children often makes couples be more procreative, implying a positive relationship between mortality and fertility (Shultz, 1973). The child survival hypothesis of Johnson and Meyer, (1986) focuses on the attitudinal change and suggests that there is a threshold level of child mortality that has to be attained before parents can have confidence in child survival and hence seriously consider the family size control measures. Preston (1978) pointed out that shorter birth intervals have usually been observed when an infant had died.

The comparison of the estimates in themselves may not make sense since they measure different parameters, the idea here is to compare the general distribution of the sets of values as reflecting upon a possible inter-relationship between the two measures. One can comment on the shapes portrayed by the various fertility estimates in relation to the plot of the estimates of the expectation of life at birth, or estimates of infant and child mortality rates for all sub-regions.

Fig 5.14

Stem-Leaf Plots for Child Mortality Rate and Birth Rate based on the 0-4 year old Population

Valid cases : 49.0

Child mortality

Frequency	Stem	&	Leaf
1.00	0	s	6
8.00	0	.	88999999
4.00	1	*	0011
11.00	1	t	22223333333
4.00	1	f	4445
7.00	1	s	6666667
4.00	1	.	8999
2.00	2	*	00
3.00	2	t	233
2.00	2	f	45
3.00	2	s	667

Birth rate

Frequency	Stem	&	Leaf
1.00	3	*	0
0.00	3	t	
0.00	3	f	
2.00	3	s	67
2.00	3	.	88
5.00	4	*	00111
6.00	4	t	222233
9.00	4	f	444555555
10.00	4	s	6666677777
4.00	4	.	8888
6.00	5	*	000011
1.00	5	t	3
2.00	5	f	45
0.00	5	s	
0.00	5	.	
0.00	6	*	
1.00	6	t	3

Stem width : 0.1
Each leaf : 1 case(s)

The same format of stem and leaf display has been used for these estimates to enhance the study of their relative distributions. It is clear that the display for birth rate is fairly normally distributed, and widely spread, implying the sort of diversity that exists in the estimates of Kenyan fertility at sub-regional level. On the other hand are nearly equally wide-spread estimates of child mortality, which is skewed to the right. The right skew in the latter shows that more estimates are on the lower side of the scale, whereas the fairly normal distribution shows that the mean of the estimates is approaching the middle.

Distributionwise therefore, there is an indication that fertility follows mortality. This observation follows the assumption that mortality and fertility have tended to decline in the recent past, in line with UN (1972) observation that Kenya is in her second phase of the demographic transition. The curve presented by the fertility estimates can thus be visualized as moving with a lag on that of mortality in the same direction. All the other stem-leaf plots of fertility show similar trends of variation, being skewed to the left and thus the suggestion of this thesis that there is a lag of fertility decline on the decline of mortality in Kenya when looked into at sub-regional level.

With the help of figure 4.6, the study conveniently placed the regions of Kenya into four fertility categories. The first category of fertility considered as 'low' includes TFRs upto 5.1. The next category is considered moderate and takes all cases with TFR between 5.2 and 6.1, followed by the high and very high, respectively, covering fertility brackets of 6.2 to 7.7 and over

7.7. According to the stem and leaf plot for the reverse survival birth rates, we can also sub-divide the regions into categories of low (upto 39/1000), moderate (40-49/1000), high (50-60/1000) and very high (above 60/1000) birth rates, and compare the resulting list with the one obtained by the same categorization for Rele's estimates. Similarly, the probabilities of dying at exact age five were categorized into the same categories, to enhance observation of fertility-mortality inter-relationships. The summary of this presentation is in table 5.2.

Table 5.2
Categorizing of Birth Rates, Total Fertility Rates and Probabilities of dying at exact age 5

Birth rates	Total Fert. Rate	Probability of at exact age 5
LOW	LOW	LOW
NAIROBI 36.33	NAIROBI 4.44	Kiambu 86.78
Mombasa 37.03	Mombasa 4.71	CENTRAL 93.09
Mandera 38.76	R. VALLEY 5.17	Nyandarua 93.73
E. Marakwet 37.48	Turkana 4.39	Nyeri 69.70
Samburu 39.83		Kajiado 91.62
Turkana 31.3	MODERATE	NAIROBI 99.82
	COAST 5.84	Muranga 99.35
MODERATE	Kilifi 6.10	Laikipia 98.84
KENYA 48.6	Isiolo 5.69	Samburu 98.19
CENTRAL 46.53	Marsabit 5.49	
Kiambu 45.45	N. EASTERN 6.17	MODERATE
Kirinyaga 45.59	Mandera 5.86	Kirinyaga 101.71
Muranga 49.41	Wajir 6.03	EASTERN 139.86
Nyandarua 48.64	Kisumu 5.84	Embu 124.59
Nyeri 43.85	Siaya 5.94	Machakos 131.69
COAST 48.37	Samburu 6.00	Marsabit 138.59
Taita Taveta 46.1		Meru 119.60
EASTERN 48.22	HIGH	Garissa 102.32
Embu 49.06	CENTRAL 7.44	Kisii 145.07
Isiolo 44.97	Kiambu 7.04	Kericho 118.14
Kitui 49.84	Kirinyaga 7.20	Nakuru 125.37
Machakos 48.79	Nyeri 7.22	Nandi 136.64
Marsabit 48.19	Lamu 6.61	Narok 128.66

Meru 46.51	Kwale 6.21	Trans Nzoia 139.76
N.EASTERN 45.99	Taita Taveta 6.79	U. Gishu 120.23
Wajir 47.05	Tana River 6.90	Mombasa 146.16
NYANZA 48.77	EASTERN 6.83	Taita Taveta 148.3
Kisumu 41.9	Embu 7.23	E. Marakwet 149.31
Siaya 48.11	Kitui 6.80	
S. Nyanza 49.21	Machakos 7.04	HIGH
Baringo 47.91	Meru 6.71	KENYA 169.09
Kericho 47.63	Garissa 6.52	Tana River 198.17
Nakuru 49.51	NYANZA 6.68	Isiolo 167.13
Nandi 49.05	S. Nyanza 6.52	Kitui 185.92
U. Gishu 49.76	Baringo 7.00	N. EASTERN 164.02
	E. Marakwet 6.41	Mandera 164.24
HIGH	Kajiado 6.83	Wajir 165.36
Kilifi 54.6	Kericho 7.61	RIFT VALLEY 158.33
Kwale 51.81	Laikipia 7.51	Baringo 194.12
Lamu 57.68	Narok 7.08	Turkana 174.00
T. River 57.79	Nandi 7.51	WESTERN 191.27
Garissa 52.06	Nakuru 7.45	Bungoma 168.59
Kisii 56.09	U. Gishu 7.27	Kakamega 180.21
R. VALLEY 50.44	W. Pokot 7.09	COAST 207.01
Kajiado 52.9	WESTERN 7.13	Lamu 202.84
Laikipia 57.28	Bungoma 7.68	
Narok 55.65	Busia 6.50	VERY HIGH
WESTERN 52.37	Kakamega 7.21	Kilifi 245.56
Bungoma 54.17	KENYA 6.20	Kwale 223.57
Kakamega 50.58		NYANZA 230.66
Busia 54.83	VERY HIGH	Kisumu 263.45
	Muranga 7.77	Siaya 266.18
VERY HIGH	Nyandarua 8.41	S. Nyanza 271.47
Trans Nzoia 62.48	Kisii 7.86	W. Pokot 236.68
West Pokot 66.66	Trans Nzoia 7.74	Busia 255.91

* Figures per 1000 population.

In this table, the Birth rate, Total Fertility Rate and the Probability of dying at exact age 5 have been sub-divided into various categories. The idea behind this was to attempt to observe the fertility performance in relation to the prevailing mortality conditions of a region. The estimates of the indicator of mortality used for these purposes, q(5) have also been sub-divided into the low, moderate, high and very high categories. These groups represent the probabilities of up to 102/1000, 103-149/1000, 150-

207/1000 and over 207/1000, respectively.

A number of areas fall in similar categories, for instance, Trans Nzoia and West Pokot districts are found to fall in the 'very high' category with respect to both fertility and mortality. Whereas this may hold in many cases, there are some cases whose values present pictures far from this observation. Kisii jumps from moderate mortality estimates to high birth rate estimates and very high total fertility rate estimates. In the Western province, most of the districts are having either high or very high fertility and mortality. In contrast, Nairobi and Central provinces are either in the low or moderate categories for the mortality and fertility estimates.

The general picture is that high fertility areas tend to have high mortality also, and vice versa. The sub-divisions are however arbitrarily based on the stem and leaf plots of the estimates by different methods, and a different criterion of sub-dividing the estimates will not necessarily present the same views. The disparities in the birth rate and total fertility rate can be attributed to the deference in the routes taken to reach the estimates, and the extent of sensitivity of the methods to age structure and age mis-statement errors.

A better means of the sub-dividing the sets can be achieved by expressing the actual observed estimates into more characters in the stem-leaf plot, instead of using the unit decimal place representation. For instance, if q(5) were expressed into three decimal places, and all the leaves of 0 through to 9 are combined in one stem, the figure below emerges.

Fig 5.15
The Stem and Leaf Plot of q(5) Estimates when expressed in three places of decimal

Frequency	Stem	&	Leaf
1.00	7	:	0
1.00	8	:	7
6.00	9	:	234899
3.00	10	:	012
1.00	11	:	8
5.00	12	:	00559
3.00	13	:	279
6.00	14	:	005689
1.00	15	:	8
6.00	16	:	445679
1.00	17	:	4
2.00	18	:	06
3.00	19	:	148
2.00	20	:	27
0.00	21	:	
1.00	22	:	3
2.00	23	:	17
1.00	24	:	6
1.00	25	:	6
2.00	26	:	36
1.00	27	:	1

Stem width : 0.0
Each Leaf : 1 case(s)

More clearer pictures also emerge when similar representations are used for the birth rates and total fertility rates. The plots are given in the appendices 10 and 11, for birth rates based on the age group 0-9 years expressed into four places of decimal, and total fertility rate at two places of decimal. For the case of birth rate, however, the classification slightly deviates from the previous one. Turkana (31.3/1000) now appear conspicuously as a low outlier, while Trans Nzoia (62.3/1000) and West Pokot (66.7/1000) become high outliers. The rest of the regions fit into three categories of low (36-42/1000), moderate (43-52/1000), and high (53-58/1000). On the plot for total fertility rate, Nyandarua district (8.41) comes out to be detached from the rest of the regions. A scatter is observed from the values between 4.00 and 5.69, most of the estimates falling between 5.84 and 7.86. The plots however, consume a lot of space and needs more care in their construction.

chapter six

SUMMARY AND CONCLUSIONS

6.0.0 SUMMARY OF FINDINGS

This study set out to estimate the fertility schedule for Kenya using the age-sex structure approach. In particular the stable based Reverse Survival method, and its extensions by Coale (1981) and Venkatacharya & Teklu (1987) were applied to the 1979 census data to estimate birth rate, and Rele's method (1967) to estimate the total fertility rate. The study was considered to be necessary given the historically unprecedented need for more demographic estimates as a prerequisite to the acceleration of the speed of social and economic development. The basic underlying assumption was that the modernization process may have had an influence on the demographic parameters, and that appropriate development policies may be instituted once one knows the forces behind the stagnation of these measures at undesirable rates.

To apply these techniques some mortality parameters and a life table were required. Hence there was need to estimate the mortality schedules also. For mortality estimates, the Coale-Trussell's method (1975) for mortality estimation was used along with the Coale-Demeny regional model life tables for the North and West families. The measures of interest were the probability of dying at exact age x, q(x) for x = 2, 3 and 5, while from the life table the infant mortality rate (IMR, ${}_1q_0$), child mortality rate (${}_4q_1$), life expectancy at birth (e_0), and the total person years lived in the age interval [x,x+n) denoted by ${}_nL_x$ for some x and n were deduced. The scope was to have the estimates at national, provincial and district levels. Some of the estimates of fertility and mortality were explored by using the Exploratory Data Analysis procedures.

The results of mortality estimation showed that there is a substantial variation between the regions. The districts in Nyanza province have shown the poorest performance with respect to mortality reduction, their rates still being quite high especially at infancy, resulting to a very low expectation of life at birth. Other high mortality areas include Coast and Western provinces. On the other end of mortality measurement are Nairobi and Central provinces. Central province enjoys the highest expectation of life, in particular, Nyeri district has the highest e_0, (64.22 years) but this still ranks low on the international comparisons. At national level, IMR = 99.78/1000, CMR = 70.84/1000 and e_0 = 50.94 years on the North model. The West model indices are respectively 110.58/1000, 56.43/1000 and 51.31 years. Looking at Kenya's life expectancy against that of South Nyanza (40.05 years) and Nyeri (64.22 years) districts, we notice that the national value lies just close to the average of these two. Therefore, it is clearly the duty of the high mortality regions to improve in their living conditions and child care practices in order to improve the country's mortality levels. Otherwise, Kenya is still far from comfortable mortality conditions.

The reverse survival techniques have given birth rates for Kenya which range between 45 and 50 births per 1000 population, referring to different periods of reverse projection. The estimates seem to rise from the reverse projection of the youngest age group, 0-4 years, to nearly constant values when reverse projection is carried on 0-9 and 0-14 year old populations. The 5-9 year age group overestimates birth rate. What should be considered the best estimates are obtained by reverse surviving 0-14 year age group, 49.82 births per 1000 population, given the minimal error incurred. This is evident from the fact that these values are close enough to the arithmetic mean of the estimates for all the age groups that have been considered (48.89 births per 1000 population). The preference given to this estimate is based on the observation that developing nations have serious problems of misreporting of ages especially at infancy and early childhood. Therefore, cummulation of ages to encompass all the childhood ages tends to 'correct' for the shifting and misreporting between age groups 0-4, 5-9 and 10-14 years. The age group 0-9 also give reliable estimates (48.6/1000) because it brings together the two age groups most affected by shifting and misreporting.

The total fertility rates by Rele's method varied from 4.39 in Turkana district to 8.4 in Nyandarua district. Extremely high fertility are observed in Nyandarua (8.41), Muranga (7.77), Trans

Nzoia (7.74), Kisii (7.70) and Bungoma (7.68); while observed low fertilities are in Turkana (4.39), Nairobi (4.44), Mombasa (4.71), Rift Valley (5.17), and Marsabit (5.49). What can be observed in this case is that districts of Central province are leading in these TFR estimates. The low fertility districts in Rift Valley may be treated with reservation given the normadic nature of the population in Turkana and Marsabit, whereas for Nairobi and Mombasa, it is due to the urban life environments.

The exploratory data analysis procedures were applied for some sets of estimates of mortality and fertility. The idea was to use the EDA displays to categorize the cases into low, moderate, high and very high. In terms of fertility, Central province districts came out as either high or very high fertility areas, while Nairobi, Mombasa and Turkana fall in the low category. On mortality, however, most Central province districts fall in the low category. Highest mortality conditions were observed in Coastal districts of Kilifi, Kisumu district in Nyanza, and Busia and Bungoma in Western province.

Comparing the various reverse survival methods used in this thesis, we find that birth rates based on the reverse survival of the 0-4 year age group gave lowest figures, while those based on the reverse survival of the 5-9 year age group were highest. The reverse survival procedure was extended for the age group 0-15 by Coale (1981) and Venkatacharya & Teklu (1987). These three sets of estimates are reasonably close, though the initial technique tends to give relatively lower values.

The results of this work have also been compared with those of past works by Osiemo (1986), who used the Gompertz Relational model (1978) and the Coale-Trussell technique (1974) for fertility estimation. Both the techniques are based on the children ever born and births last year, which is a different approach from the techniques applied in this thesis. We find that our results are generally lower, than the two techniques, but closer to those based on the Gompertz relational approach. However, when the sex ratio at birth was adjusted to a fixed average value of 1.05 for all the areas, the results fell somewhere between the two approaches used by Osiemo, but still nearer to the Gompertz relational model.

6.1.0 LIMITATIONS OF THE REVERSE SURVIVAL TECHNIQUES

Estimation of demographic parameters is more often than not met with a snag because most methods and models applied use different underlying assumptions. Therefore, even when the same set of data are used in estimation, the results may be difficult to reconcile, or even compare, because the approaches to the estimations and the time to which the estimates refer do not usually coincide. The reverse survival techniques assume that the subject population is closed to migration, a condition that is far fetched in the case of Kenya, particularly within her sub-regions. Despite this limitation, the study was carried to attempt the estimation of birth rates for the country at district and provincial levels by applying the method.

At all levels of analysis, the furthest the study could be carried was the district level. This may imply that the results obtained are only averages that tell something about the district and might hide certain desirable properties within the subject region as well as at national level. Out of the data on the 1979 census, it proved to be quite difficult to extract data that would enable analysis by the important population characteristics such as marital status, or level of education, to mention a few. Consider a differential, say marital status. The data available at district level provided information regarding children as belonging to a specific category of women, say married, but failed to give the facility by which the study could identify a relevant portion of the total population for use as the base population with respect to this particular differential. The results in this work are thus limited to district, provincial and national level total populations. On these regions, we may take the differences in estimates to reflect on the extent of socio-economic development, environmental differences, institutional settings, differences in age - sex distribution of the population, patterns and typology of migration and differences in traditions and customs, but only in general.

6.2.0 CONCLUSIONS

The interpretation of the estimates of birth rate by the reverse survival techniques has to be done with caution, since, apart from the assumption of closure, it produces estimates that refer to different points in time. The assumption on closure to migration can be expected to hold at national level, but may not hold comfortably at district level. It is common knowledge, for instance that the current urbanization problem in Kenya is primarily due to mass movement from the rural areas into the major urban centres of Nairobi, Mombasa, Kisumu and Nakuru. Depending on the extent of in and/or out movement therefore, it is expected that the estimates of the regions holding these urban centres are distorted in some fashion. On the other hand, areas experiencing excessive loss of population due to out-migration also have their estimates distorted. It is therefore expected that only the national level estimates are nearest to the prevailing measurements.

The study has shown that the age-sex distribution approach to fertility estimation, under the reverse survival procedures can be used comfortably as fertility indicators. The results have been shown to be lower, in general, to the children ever born and births last year approach used by Osiemo in 1986. They are however much lower than the Coale-Trussell approach which has been found to be overestimating fertility. The best estimates of birth rate by this approach are those based on the reverse projection of the 0-15 year age group, and to a reasonable extent, the reverse survival of the

0-9 year age group. This is simply because the age groups are wide enough to minimize the likely errors of age mis-reporting or mis-statement and shifting.

In terms of computational ease, the reverse survival techniques are recommended, in particular, its extension by Venkatacharya & Teklu (1987), which can be performed quite quickly by use of a hand calculator. The extension by Coale (1981) may be a lot more tedious because it involves references to model life tables and the use of stable population parameters. The latter method is more involving also in terms of the number of interpolations and extrapolations especially where the observed values fall outside the required range.

The descriptive statistical analysis technique used to describe the estimates of fertility and mortality obtained in this work proved quite useful in determining measures of statistical interest, as well as displaying the distributional characteristics of the sets. Further, it can be concluded that exploratory data analysis provides an easy tool for grouping the sets into different categories, which need not be arbitrary.

6.3.0 RECOMMENDATIONS FOR FURTHER RESEARCH

There is need for more research to be carried out on the interrelationship between fertility, mortality and migration, in view of the difficulties met in the analysis using the reverse survival techniques. Specifically, the following areas should be looked into;

(i) development of models to include the migration component, as this is very likely to affect the estimates of fertility when it is not assumed to be minimal;

(ii) measurement of population portion that can be used as base populations for the various differentials and hence obtaining relevant proportions for estimation of birth rates;

(iii) advancement of further work to find the suitability of Rele's method on smaller administrative regions, such as the Divisions in the Kenyan context;

(iv) improvements on the quality of data collected so that comparison can be done without fear of discrepancies arising from deficiency in one method of analysis, that does not affect the other;

(v) carrying out more studies on the effects of socio-economic, environmental and institutional factors on fertility.

appendices

Appendix 1

Calculation of Mortality Level: West Model

x	q(x)	p(x)	lower l(x)	upper l(x)	lower level	actual level
1	.1153582	.8846418	.87087	.88476	13	13.99149
2	.1313641	.8686359	.85753	.87421	14	14.66582
3	.1439669	.8560331	.84547	.86388	14	14.57377
5	.1713258	.8286742	.80881	.83174	13	13.86630
10	.1942919	.8057081	.79185	.81658	14	14.56038
15	.2152371	.7847629	.77939	.8054	13	13.20657
20	.2615507	.7384493	.73385	.76204	12	12.16315

Appendix 2

Life Table for the Republic of Kenya: West Model

Age x	nqx	npx	l(x)	ndx	nLx	Tx	e(x)
0	.1105805	.8894195	100000	11058.05	92259.36	5130631.	51.30631
1	.0564330	.9435670	88941.95	5019.261	342215.8	5038372.	56.64787
5	.0173219	.9826781	83922.69	1453.702	415979.2	4696156.	55.95812
10	.0130336	.9869664	82468.98	1074.870	409657.7	4280177.	51.90044
15	.0189981	.9810019	81394.11	1546.337	403104.7	3870519.	47.55281
20	.0258487	.9741513	79847.78	2063.960	394079.0	3467414.	43.42531
25	.0287370	.9712630	77783.82	2235.274	383330.9	3073335.	39.51125
30	.0326769	.9673231	75548.54	2468.694	371571.0	2690005.	35.60631
35	.0379896	.9620104	73079.85	2776.274	358458.6	2318434.	31.72466
40	.0454954	.9545046	70303.57	3198.490	343521.6	1959975.	27.87874
45	.0559347	.9440653	67105.08	3753.502	326141.7	1616453.	24.08839
50	.0753113	.9246887	63351.58	4771.090	304830.2	1290312.	20.36747
55	.1013712	.8986288	58580.49	5938.373	278056.5	985481.5	16.82269
60	.1460983	.8539017	52642.12	7690.922	243983.3	707425.0	13.43838
65	.2063317	.7936683	44951.20	9274.859	201568.8	463441.7	10.30989
70	.2983628	.7016372	35676.34	10644.49	151770.5	261872.9	7.340239
75+	1.000000	0.000000	25031.85	25031.85	110102.4	110102.4	4.398493

Appendix 3

Mortality Estimates at Provincial and District levels.
West Model

Region	e_0	level	$_1q_0$	$_4q_1$	$_5q_0$	q(2)	q(5)
			Index of mortality				
KENYA	51.306	14.369	0.11058	0.05643	0.16701	0.13136	0.14397
NAIROBI	58.160	17.339	0.07481	0.03158	0.10639	0.09397	0.10174
CENTRAL	60.648	18.419	0.06283	0.02394	0.08677	0.06768	0.09515
Kiambu	60.875	18.518	0.06177	0.02327	0.08504	0.07107	0.08871
Kirinyaga	57.540	17.070	0.07784	0.03355	0.11140	0.08260	0.13411
Muranga	59.808	18.054	0.06677	0.02643	0.09320	0.06906	0.10155
Nyandarua	60.676	18.431	0.06270	0.02385	0.08655	0.06832	0.09589
Nyeri	63.857	19.819	0.04814	0.01484	0.06298	0.04944	0.07124
COAST	46.447	12.350	0.13869	0.07891	0.21760	0.17480	0.21342
Kilifi	42.417	10.677	0.16448	0.09776	0.26223	0.20803	0.25425
Kwale	44.423	11.515	0.15128	0.08835	0.23963	0.18812	0.23005
Lamu	45.564	11.993	0.14394	0.08317	0.22711	0.20007	0.20868
Mombasa	53.447	15.297	0.09897	0.04796	0.14693	0.11793	0.15022
Taveta	53.300	15.233	0.09975	0.04851	0.14826	0.11747	0.15212
T. River	46.881	12.525	0.13612	0.07683	0.21295	0.18053	0.20425
EASTERN	55.198	16.056	0.08972	0.04152	0.13124	0.10012	0.14332
Embu	57.237	16.939	0.07953	0.03455	0.11408	0.08485	0.12713
Isiolo	51.110	14.283	0.11165	0.05724	0.16890	0.12642	0.17261
Kitui	48.964	13.449	0.11780	0.07300	0.19079	0.14838	0.19116
Machakos	55.849	16.338	0.08641	0.03927	0.12568	0.00988	0.13485
Marsabit	53.018	15.112	0.10124	0.04957	0.15080	0.13015	0.14307
Meru	58.247	17.377	0.07438	0.03131	0.10568	0.07495	0.12258
N. EASTERN	51.446	14.429	0.10982	0.05586	0.16568	0.13634	0.16785
Garissa	57.057	16.861	0.08027	0.03516	0.11542	0.13141	0.10529
Mandera	50.745	14.126	0.11365	0.05873	0.17238	0.14800	0.16779
Wajir	51.557	14.477	0.10921	0.05541	0.16462	0.13276	0.16884
NYANZA	45.032	11.770	0.14736	0.08557	0.23294	0.17376	0.23687
Kisii	54.827	15.895	0.09166	0.04285	0.13451	0.09802	0.14889
Kisumu	41.682	10.332	0.17012	0.10178	0.27190	0.18822	0.26871
Siaya	41.198	10.168	0.17278	0.10370	0.27648	0.20887	0.27465
S. Nyanza	40.471	9.866	0.17787	0.10733	0.28519	0.21423	0.27921
R. VALLEY	53.027	15.115	0.10119	0.04953	0.15073	0.11510	0.15712
Baringo	47.467	12.761	0.13264	0.07405	0.20669	0.17090	0.19963
Elgeyo M.	52.602	14.918	0.10364	0.05130	0.15494	0.12567	0.15391
Kajiado	60.157	18.205	0.06514	0.02539	0.09053	0.07414	0.09459
Kericho	56.959	16.818	0.08076	0.03549	0.11625	0.09092	0.12141

Laikipia	59.246	17.810	0.06949	0.02816	0.09766	0.07716	0.10155
Nakuru	56.094	16.443	0.08517	0.03843	0.12360	0.09720	0.12872
Nandi	54.630	15.810	0.09270	0.04357	0.13628	0.10899	0.14107
Narok	56.103	16.448	0.08512	0.03840	0.12352	0.09396	0.13238
Samburu	58.614	17.536	0.07259	0.30150	0.10274	0.08992	0.10081
T. Nzoia	54.001	15.537	0.09603	0.04590	0.14193	0.11327	0.14422
Turkana	51.018	14.243	0.11216	0.05761	0.16978	0.13245	0.17908
U. Gishu	56.862	16.776	0.08126	0.03582	0.11707	0.09130	0.12382
W. Pokot	43.800	11.255	0.15529	0.09122	0.24650	0.18695	0.24394
WESTERN	48.458	13.167	0.12681	0.06934	0.19615	0.15276	0.19648
Bungoma	50.341	13.952	0.11591	0.06047	0.17638	0.14126	0.17302
Busia	42.496	10.710	0.16394	0.09737	0.26131	0.19761	0.26400
Kakamega	50.348	13.954	0.11587	0.06043	0.17631	0.14377	0.18492

Appendix 4

Estimates of Total Fertility Rate by Rele's method
West model

		CWR1	CWR2	CWR3	CWR4	MEAN
		Time Reference Total Fertility Rates				
REGION	SRB	t-2.5	t-2.5	t-7.5	t-7.5	t-5
KENYA	0.988095	5.784365	5.892080	6.173067	6.919882	6.192349
NAIROBI	0.986976	4.434504	4.725051	4.111824	4.502453	4.443458
CENTRAL	0.995994	6.705738	6.732352	8.256308	8.096106	7.447626
Kiambu	1.016121	6.367927	6.459516	7.690302	7.687004	7.051187
Kirinyaga	0.983545	6.544088	6.575097	7.824764	7.784599	7.182137
Muranga	0.994526	6.799911	6.765734	7.987130	7.782294	7.333767
Nyandarua	0.982043	7.557037	7.552673	9.360983	9.204967	8.418915
Nyeri	0.983834	6.275369	6.291076	8.301313	8.064887	7.233161
COAST	0.975233	5.654698	5.737021	5.666692	6.220797	5.819802
Kilifi	0.940660	5.816644	5.842066	6.229179	6.463354	6.087810
Kwale	0.978116	5.929860	5.994564	6.213785	6.644380	6.195647
Lamu	0.972148	6.090875	6.206114	6.947195	7.229509	6.618423
Mombasa	0.999106	4.702438	4.891241	4.442897	4.927108	4.740921
T. Taveta	0.987881	6.169649	6.137567	7.169283	7.659970	6.784117
T. River	1.052203	6.481363	6.606266	6.981079	7.535464	6.901043
EASTERN	1.010896	6.407537	6.459814	7.099867	7.335446	6.825666
Embu	1.019658	6.804714	6.833611	7.587729	7.679901	7.226488
Isiolo	1.037426	5.756951	5.907587	5.294896	5.852988	5.703105
Kitui	1.003608	6.260136	6.317275	7.047882	7.518316	6.785902
Machakos	1.017609	6.440113	6.499515	7.556570	7.643356	7.034888
Marsabit	0.976769	5.358548	5.469216	5.360988	5.775809	5.491152
Meru	1.006976	6.460516	6.495434	6.883503	7.000962	6.710103

N. EASTERN	1.056338	5.607027	5.832005	6.287313	6.940673	6.166754
Garissa	1.042316	5.748508	5.961989	7.043062	7.315609	6,517292
Mandera	1.039745	5.427704	5.635081	5.894188	6.453804	5.852694
Wajir	1.082617	5.471741	5.715454	6.127746	6.777071	6.023003
NYANZA	0.976641	6.369478	6.330764	6.774822	7.154935	6.657499
Kisii	0.985931	7.277967	7.594523	8.101849	8.570774	7.886278
Kisumu	0.947490	5.667817	5.640732	5.856443	6.212932	5.844481
Siaya	0.946392	5.721081	5.535414	6.236001	6.155860	5.912089
S. Nyanza	1.003347	6.092497	6.061478	6.889148	6.917497	6.490155
R. VALLEY	0.996543	4.517653	4.755407	5.332498	6.207478	5.203259
Baringo	0.997635	6.644639	6.665456	6.962762	7.620752	6.973402
Elgeyo M.	0.989566	6.038827	6.019229	6.503769	7.061422	6.405811
Kajiado	0.950654	6.510565	6.589817	7.119702	7.148322	6.842101
Kericho	0.994876	7.162249	7.238500	7.872996	8.192536	7.616570
Laikipia	0.977633	7.148869	7.186124	7.837132	7.862298	7.508605
Nakuru	1.025165	6.988013	7.101128	7.639566	8.062807	7.447878
Nandi	0.992527	7.229022	7.253578	7.530810	8.041913	7.513830
Narok	0.973863	7.039445	7.030909	6.939002	7.329732	7.084772
Samburu	0.987013	5.849006	5.802270	6.094001	6.258404	6.000920
T. Nzoia	0.996054	7.569227	7.588172	7.569823	8.240559	7.741945
Turkana	0.977672	3.752193	3.919540	4.563767	5.328939	4.391109
U. Gishu	1.030374	6.809609	6.912875	7.524465	7.893802	7.282187
W. Pokot	0.967506	7.558893	7.555766	6.429695	6.735802	7.070039
WESTERN	0.950291	6.896273	6.855705	6.966616	7.697550	7.104036
Bungoma	1.003474	7.606214	7.631985	7.248412	8.214788	7.675349
Busia	0.985651	6.333091	6.258015	6.565152	6.727984	6.471060
Kakamega	0.959070	6.850321	6.795253	6.967920	7.882814	7.124077

Note : CWR1, CWR2, CWR3, and CWR4 respectively refer to the child-woman ratios P_{0-4}/W_{15-44}, P_{0-4}/W_{15-49}, P_{5-9}/W_{20-49}, and P_{5-9}/W_{20-54}.

Appendix 5

Estimates of Birth Rate by the Reverse Survival method and its Extensions on various age groups

	Birth Rates based on Reverse projection of						
	0-4	0-9	0-14	5-9	Mean	b_1	b_2
	Reference Time Birth Rates						
AREA	t-2.5	t-5	t-7.5	t-7.5	t-7.5	t-7.5	t-7.5
KENYA	0.04592	0.04778	0.04867	0.04952	0.04797	0.04751	0.04878
NAIROBI	0.03671	0.03628	0.03639	0.03499	0.03609	0.03738	0.03614
CENTRAL	0.04384	0.04648	0.04814	0.04921	0.04692	0.04945	0.04875
Kiambu	0.04300	0.04539	0.04707	0.04782	0.04583	0.04835	0.04703
Kirinyaga	0.04325	0.04522	0.04663	0.04721	0.04558	0.04792	0.04705
Muranga	0.04651	0.04946	0.05102	0.05250	0.04987	0.05241	0.05136
Nyandarua	0.04657	0.04859	0.04972	0.05064	0.04888	0.05108	0.04802
Nyeri	0.04056	0.04382	0.04601	0.04735	0.04444	0.04725	0.04503
COAST	0.04587	0.04831	0.04800	0.05068	0.04821	0.04944	0.04747
Kilifi	0.05071	0.05458	0.05324	0.05868	0.05430	0.05491	0.05322
Kwale	0.04870	0.05174	0.05075	0.05484	0.05151	0.05231	0.05065
Lamu	0.04863	0.05787	0.06105	0.06891	0.05911	0.06290	0.05693
Mombasa	0.03725	0.03702	0.03595	0.03634	0.03664	0.03696	0.03499
T. Taveta	0.04237	0.04600	0.04757	0.04997	0.04648	0.04891	0.04729
T. River	0.05081	0.05764	0.06196	0.06528	0.05892	0.06381	0.06029
EASTERN	0.04548	0.04814	0.04925	0.05085	0.04843	0.04852	0.04979
Embu	0.04676	0.04897	0.05060	0.05107	0.04935	0.05199	0.05110
Isiolo	0.04499	0.04521	0.04475	0.04484	0.04494	0.04602	0.04420
Kitui	0.04539	0.04981	0.05177	0.05469	0.05042	0.05315	0.05169
Machakos	0.04498	0.04869	0.05028	0.05267	0.04915	0.05176	0.05061
Marsabit	0.04294	0.04819	0.05304	0.05389	0.04952	0.05421	0.04827
Meru	0.04588	0.04647	0.04623	0.04673	0.04633	0.04749	0.04684
N. EASTERN	0.04166	0.04585	0.04966	0.05044	0.04690	0.05108	0.04911
Garissa	0.04420	0.05197	0.05976	0.06108	0.05425	0.06141	0.05806
Mandera	0.03824	0.03861	0.03877	0.03895	0.03864	0.03988	0.03742
Wajir	0.04192	0.04689	0.05169	0.05242	0.04823	0.05316	0.05013
NYANZA	0.04787	0.04868	0.04927	0.04929	0.04878	0.05077	0.04935
Kisii	0.05550	0.05660	0.05744	0.05740	0.05674	0.05926	0.05726
Kisumu	0.04194	0.04188	0.04072	0.04165	0.04155	0.04185	0.04035
Siaya	0.04571	0.04802	0.04932	0.05043	0.04837	0.05089	0.04986
S. Nyanza	0.04756	0.04914	0.05049	0.05066	0.04946	0.05212	0.05076
R. VALLEY	0.04805	0.05020	0.05093	0.05217	0.05034	0.05237	0.05125
Baringo	0.04663	0.04778	0.04771	0.04881	0.04773	0.04913	0.04693
Elgeyo M.	0.03881	0.03742	0.03484	0.03602	0.03677	0.03582	0.02722
Kajiado	0.04908	0.05291	0.05462	0.05672	0.05333	0.05611	0.05618

Kericho	0.04772	0.04760	0.04652	0.04711	0.04724	0.04780	0.04530
Laikipia	0.05058	0.05725	0.06292	0.06450	0.05881	0.06464	0.06551
Nakuru	0.04297	0.04946	0.05524	0.05666	0.05108	0.05677	0.05276
Nandi	0.04778	0.04900	0.04911	0.04991	0.04895	0.05048	0.04928
Narok	0.05187	0.05539	0.05635	0.05876	0.05559	0.05791	0.05833
Samburu	0.04088	0.03978	0.03874	0.03856	0.03940	0.03943	0.03474
T. Nzoia	0.08828	0.08475	0.08018	0.08065	0.08346	0.08243	0.05294
Turkana	0.03039	0.03125	0.02969	0.03208	0.03085	0.03054	0.02878
U. Gishu	0.04707	0.05002	0.05149	0.05293	0.05038	0.05291	0.05108
W. Pokot	0.06343	0.06654	0.07195	0.06800	0.06748	0.07417	0.07407
WESTERN	0.05070	0.05224	0.05341	0.05352	0.05247	0.05497	0.05339
Bungoma	0.05336	0.05405	0.05531	0.05410	0.05421	0.05690	0.05503
Busia	0.05215	0.05473	0.05710	0.05703	0.05525	0.05889	0.05783
Kakamega	0.04852	0.05004	0.05074	0.05143	0.05018	0.05220	0.05062

Appendix 6

An Extrapolation Example - the Case of Lamu District

For Lamu district, the following data was used in the analysis on the West model.

Age grp	i	FP(i)	CEB(i)	CD(i)	P(i)	D(i)	k(i)
15-19	1	2097	715	117	0.340963	.1636364	1.064951
20-24	2	1869	3604	705	1.928304	.1956160	1.022781
25-29	3	1553	5707	1057	3.674823	.1852111	.9771114
30-34	4	1256	6243	1317	4.970541	.2109563	.9892273
35-39	5	905	5345	1227	5.906077	.2295603	1.007349
40-44	6	849	4680	1161	5.512367	.2480769	.9951265
45-49	7	533	3170	808	5.947467	.2548896	.9875862
50-54	8	712	3471	1053			

P(1)/P(2) = 0.1768203 P(2)/P(3) = 0.5247338

Mean mortality level = 11.99271

Age x	l(x) level 11	l(x) level 12	Actual l(x)
0	1	1	1
1	.8408	.85617	.8560580
5	.76173	.78503	.7848601
10	.74139	.76632	.7661383
15	.72647	.75255	.7523599
20	.70642	.73385	.7336500
25	.68028	.70935	.7091381
30	.65222	.68299	.6827657
35	.62154	.65403	.6537931
40	.588	.62211	.6218613
45	.55092	.58642	.5861612
50	.51015	.54648	.5462152

55	.46076	.49743	.4971627
60	.40311	.43911	.4388476
65	.33196	.36605	.3658015
70	.25212	.28221	.2819906
75+	.16699	.19068	.1905073

Life Table for Lamu District: West Model

Age x	nqx	npx	l(x)	ndx	nLx	Tx	e(x)
0	.1439420	.8560580	100000	14394.20	89924.06	4556444.	45.5644
1	.0831694	.9168306	85605.80	7119.781	323199.8	4466520.	52.1754
5	.0238538	.9761462	78486.01	1872.188	387749.6	4143320.	52.7905
10	.0179842	.9820158	76613.83	1377.838	379624.5	3755570.	49.0194
15	.0248682	.9751318	75235.99	1870.984	371502.5	3375946.	44.8714
20	.0334110	.9665890	73365.00	2451.196	360697.0	3004443.	40.9520
25	.0371894	.9628106	70913.81	2637.239	347975.9	2643746.	37.2811
30	.0424341	.9575659	68276.57	2897.254	334139.7	2295770.	33.6245
35	.0488408	.9511592	65379.31	3193.181	318913.6	1961631.	30.0038
40	.0574085	.9425915	62186.13	3570.013	302005.6	1642717.	26.4161
45	.0681486	.9318514	58616.12	3994.605	283094.1	1340711.	22.8727
50	.0898043	.9101957	54621.52	4905.248	260844.5	1057617.	19.3626
55	.1172958	.8827042	49716.27	5831.512	234002.6	796772.8	16.0264
60	.1664498	.8335502	43884.76	7304.608	201162.3	562770.2	12.8238
65	.2291156	.7708844	36580.15	8381.084	161948.0	361608.0	9.88536
70	.3244198	.6755802	28199.06	9148.334	118124.5	199659.9	7.08037
75+	1.000000	0.00000	19050.73	19050.73	81535.44	81535.44	4.27991

Children population under age 15 by age groups

Age	Male	Female	Total
0	733	754	1487
0-4	3526	3690	7216
5-9	3491	3431	6922
10-14	2378	2155	4533
0-9	7017	7121	14138
0-14	9395	9276	18671

Tot.pop.	21633	20666	42299
Total pop. in 1969			22000
Growth rate, r(t) =			.0653721

Sex Ratio at Birth .9721485

Child-woman ratio (CWR)

P(0-4)/W(15-44)	.8460546
P(0-4)/W(15-49)	.7962922
P(5-9)/W(20-49)	.9938263
P(5-9)/W(20-54)	.9016543

Estimation of Total Fertility Rate by Rele's method.

The above data and computations for the mortality estimates were then used to estimate total fertility rate for the district of Lamu

For Lamu District, e(o) = 45.56444 years

	Total Fertility Rate at e_0		
	40	50	45.56444
	6.286865	5.934647	6.090876
	6.403961	6.048406	6.206115
	7.740929	6.314489	6.947195
	7.519154	6.998625	7.229509
Average TFR	6.987727	6.324042	6.618424

Estimation of Birth Rate by the Reverse Survival Methods

The following are the proportions of the population at various childhood ages.

C(4) = .1705950 c(5-9) = .1636445

C(10) = .3342396 C(15) = .4414052

l(o) = 100000 r(t) = .0653721

For the persons aged 0-4 years the birth rate is

$$b_0 = C(4)\exp(2.5r(t))*l(o)/{}_5L_0$$

$$= 0.0486254$$

Similarly, for persons aged 0-9 and 0-14 years respectively, the birth rates are

$$b'_0 = C(10\exp(5r(t))l(o)/{}_{10}L_0$$

$$= 0.0578692$$

and

$$b''_0 = C(15)\exp(7.5r(t))l(o)/{}_{15}L_0$$

$$= 0.0610524$$

For the persons aged 5-9 years, we use the proportion of the population in the age group, i.e

$$b_5 = c(5-9)\exp(7.5r(t))l(o)/{}_5L_5$$

$$= 0.0689098$$

Extension by Venkatacharya and Teklu (1987)

In this extension of the Reverse Survival technique, estimation equation is given by;

$$b_v = C(15)\exp(7.5r(t))l(o)/[u + vl(5)],$$

where u and v are constants. For the West model u and v are respectively equal to 0.365 and 14.599.

Using this model, we have

$$b_T = 0.0629003$$

Extension by Coale (1981)

The equation in this case is

$$b_c = b_s.\exp[7.5(r(t)-r_s)]$$

where b_c is the birth rate due to Coale, b_s and r_s are the stable population birth and growth rates respectively. The first step is to identify these stable population parameters, based on C(15) and l(5) that correspond to the study population.

Mortality level corresponding to l(5) = 12.26435

Females
West Model

Level 12	observed range		factor	extrapolated range	
growth rates	.045	.05	3	.065	0.07
proportions	.5557	.5851	4	.6733	.7027
birth rates	.06349	.06907		.08581	.09139

Level 13					
growth rates	.045	.05	3	.065	0.07
proportions	.5508	.5805	4	.6696	.6993
birth rates	.06135	.06681		.08319	.08865

	Level 12		Level 13		Level 12.26435		
i	$C_i(15)$	$b_{i(s)}$	$C'_i(15)$	$b'_{i(s)}$	$C^*_i(15)$	b*i(s)	$r_{i(s)}$
1	.6733	.08581	.6696	.08319	.6723219	.0851174	.065
2	.7027	.09139	.6993	.08865	.7018012	.0906657	.070

C(15) = 0.4414052 b_s = 0.0416567 r_s = 0.0258341

Therefore, the birth rate by the given equation is

$$b_c(FW) = 0.0560362$$

Males
West Model

Level 12	observed range		factor	extrapolated range	
growth rates	.045	.05	3	.065	0.070
proportions	.5593	.5882	4	.6749	.7038
birth rates	.06567	.07135		.08839	.09407

Level 13					
growth rates	.045	.05	3	.065	0.070
proportions	.5543	.5834	4	.6707	.6998
birth rates	.06315	.06868		.08527	.09080

	Level 12		Level 13		Level 12.26435		
i	$C_i(15)$	$b_{i(s)}$	$C'_i(15)$	$b'_{i(s)}$	$C^*_i(15)$	$b^*i(s)$	$r_{i(s)}$
1	.6749	.08839	.6707	.08527	.6737897	.0875652	0.065
2	.7038	.09407	.6998	.0908	.7027426	.0932056	0.070

$C(15) = 0.4414052 \quad b_s = 0.0422941 \quad r_s = 0.0248685$

The birth rate for the West model males is

$$b_\wedge(MW) = 0.0573071$$

Another approximation for C(15) is obtained by further decomposing the age interval 0-15 into 0-4, 5-9 and 10-14 as follows :

$$C(15) = b_s[{}_5L_0.\exp(-2.5r_s) + {}_5L_5.\exp(-7.5r_s + {}_5L_{10}.\exp(-12.5r_s]/l(o)$$

$$= 0.4089005$$

and $b_s = C(15).\exp(7.5r(t))/{}_{15}L_0$

$$b'_\wedge(FW) = 0.0585566$$

similarly,

$$C(15) = 0.4179463$$

and

$$b'_\wedge(MN) = 0.0578077$$

Appendix 7

Estimated Growth Rates of the Regional Populations during the period 1969-1979, assuming Exponential Growth

Region	Population 1969	Population 1979	Growth Rate
KENYA	10943000	15327061	.0336920
NAIROBI	509000	827775	.0486293
CENTRAL	1676000	2345833	.0336231
Kiambu	467000	686290	.0384971
Kirinyaga	217000	291431	.0294906
Muranga	445000	648333	.0376330
Nyandarua	177000	233302	.0276184
Nyeri	36100	486477	.0298312
COAST	944000	1342794	.0352382
Kilifi	308000	430986	.0335976
Kwale	206000	288363	.0336344
Lamu	22000	42299	.0653721
Mombasa	247000	341148	.0322928
T. River	51000	92401	.0594312
T. Taveta	111000	147597	.0284955
EASTERN	1907000	2719851	.0355046
Embu	179000	263173	.0385426
Isiolo	30000	43478	.0371058
Kitui	343000	464283	.0302764
Machakos	707000	1022522	.0368997
Marsabit	52000	96856	.0621982
Meru	597000	830179	.0329724
N.EASTERN	246000	373787	.0418355
Garissa	64000	127067	.0685831
Mandera	95000	105601	.0105791
Wajir	86000	139319	.0482419
NYANZA	2122000	2643956	.0219917
Kisii	675000	869512	.0253219
Kisumu	401000	482327	.0184661
Siaya	383000	474516	.0214260
S. Nyanza	663000	817601	.0209599
R. VALLEY	221000	3240402	.2685290
Baringo	162000	203792	.0229504
E. Marakwet	159000	148868	-.006584
Kajiado	86000	149005	.0549633
Kericho	479000	633348	.0279319
Laikipia	60000	134524	.0807398

Nakuru	291000	633348	.0777697
Nandi	209000	299319	.0359176
Narok	125000	210306	.0520250
Samburu	70000	76908	.0094115
T. Nzoia	124000	140803	.0127080
Turkana	165000	142702	-.014519
U. Gishu	191000	300766	.0454059
W. Pokot	82000	158652	.0659994
WESTERN	1323000	1832663	.0325868
Bungoma	345000	503935	.0378903
Busia	200000	297841	.0398242
Kakamega	783000	1030887	.0275042

Appendix 8

Proportions Under Various Exact Childhood Ages

Region	0-4	0-9	0-14	5-9
KENYA	.185515	.348093	.483459	.162577
NAIROBI	.148545	.256794	.339559	.108249
CENTRAL	.187201	.361369	.513206	.174167
Kiambu	.182491	.348319	.491620	.165827
Kirinyaga	.182825	.350501	.499716	.167676
Muranga	.195566	.374586	.524232	.179020
Nyandarua	.201862	.389362	.554607	.187499
Nyeri	.178287	.355250	.517210	.176962
COAST	.174927	.327520	.439610	.152593
Kilifi	.186799	.356348	.469722	.169548
Kwale	.182960	.345741	.459129	.162780
Lamu	.170595	.334239	.441405	.163644
Mombasa	.151810	.273233	.363308	.121422
Tana R.	.183093	.347918	.475719	.164825
T. Taveta	.174122	.345523	.493892	.171500
EASTERN	.186290	.355126	.494040	.168836
Embu	.192857	.361853	.505306	.168995
Isiolo	.177860	.318758	.426008	.140898
Kitui	.179804	.355675	.505635	.175871
Machakos	.184448	.358602	.502043	.174153
Marsabit	.162488	.304658	.423979	.142169
Meru	.193179	.355926	.485488	.162747
N. EASTERN	.163199	.316747	.457939	.153547
Garissa	.168871	.329951	.475662	.161080
Mandera	.161068	.309826	.448641	.148758
Wajir	.161751	.314041	.454740	.152290

NYANZA	.186223	.347164	.490008	.160941
Kisii	.206936	.381321	.533364	.174385
Kisumu	.178792	.335353	.462512	.156562
Siaya	.171413	.328303	.469078	.156890
S. Nyanza	.177176	.333636	.477151	.156460
R. VALLEY	.192324	.352611	.490140	.165937
Baringo	.185051	.348291	.484936	.163240
Elgeyo M.	.173167	.332798	.467213	.159631
Kajiado	.198067	.368404	.494245	.170337
Kericho	.201681	.370062	.501821	.168381
Laikipia	.194835	.364968	.500275	.170133
Nakuru	.159363	.297557	.406895	.138194
Nandi	.194702	.358962	.488499	.164260
Narok	.205187	.379062	.503433	.173875
Samburu	.183011	.343774	.482421	.160764
T. Nzoia	.205870	.376158	.511913	.170288
Turkana	.136620	.284958	.415923	.148337
U. Gishu	.190294	.356068	.486754	.165773
W. Pokot	.218485	.375526	.506700	.157042
WESTERN	.198157	.366728	.510751	.168572
Bungoma	.209257	.376815	.519291	.167557
Busia	.189302	.346725	.481270	.157423
Kakamega	.195288	.367499	.515017	.172211

Appendix 9

The Four Types of Child-Woman Ratios used in the Rele's Method of Fertility Estimation

Region	Sex Ratio at Birth	$P_{(0-4)}/W_{(15-44)}$	$P_{(0-4)}/W_{(15-49)}$	$P_{(5-9)}/W_{(20-49)}$	$P_{(5-9)}/W_{(20-54)}$
KENYA	.988	.825021	.775102	.957557	.892074
NAIROBI	.987	.667068	.647209	.628373	.610245
CENTRAL	.996	.994379	.929011	1.201309	1.106411
Kiambu	1.016	.938725	.88379	1.112962	1.041874
Kirinyaga	.984	.961247	.897318	1.159858	1.048446
Muranga	.995	1.057049	.981772	1.232465	1.129014
Nyandarua	.982	1.122378	1.04026	1.136521	1.266107
Nyeri	.984	.954473	.888921	1.23864	1.131515
COAST	.975	.790908	.738676	.831480	.779805
Kilifi	.941	.808094	.748125	.855996	.801054
Kwale	.978	.817158	.761796	.871033	.819526
Lamu	.972	.846054	.796292	.993826	.901654
Mombasa	.999	.682803	.648023	.673939	.641898
T. River	1.052	.870625	.818995	.979295	.909308
T. Taveta	.988	.886573	.816365	1.091453	1.000395

EASTERN	1.011	.918306	.858326	1.057449	.959439
Embu	1.020	.979107	.914273	1.108798	1.013906
Isiolo	1.037	.801596	.757543	.809996	.735855
Kitui	1.004	.87179	.813653	1.063549	.945989
Machakos	1.018	.923035	.863867	1.114584	1.000618
Marsabit	.978	.778569	.730674	.833686	.758051
Meru	1.007	.942583	.879202	1.010334	.937097
N.EASTERN	1.056	.776373	.742396	.942832	.865958
Garissa	1.042	.824514	.788549	1.022684	.954219
Mandera	1.040	.755854	.720415	.897400	.808200
Wajir	1.083	.750041	.718888	.908456	.835611
NYANZA	.977	.878516	.807989	.958029	.886946
Kisii	.986	.976136	.947077	1.063324	1.032649
Kisumu	.947	.840843	.772599	.909544	.837518
Siaya	.946	.787922	.701758	.835507	.754176
S. Nyanza	1.003	.810791	.743717	.882440	.819225
R. VALLEY	.997	.648072	.620508	.834194	.792949
Baringo	.998	.917835	.853599	1.022030	.951247
E. Marakwet	.990	.864777	.796903	.997817	.917458
Kajiado	.951	.985738	.928053	1.062367	.997132
Kericho	.995	1.038876	.978662	1.164325	1.092541
Laikipia	.978	1.058605	.992765	1.153404	1.074557
Nakuru	1.025	.995561	.941284	1.120664	1.053097
Nandi	.993	1.036422	.969184	1.132518	1.057015
Narok	.974	1.027526	.956192	1.047465	.9826141
Samburu	.987	.867542	.795827	.9064516	.8487678
T. Nzoia	.966	1.077746	1.008456	1.140498	1.076567
Turkana	.978	.551592	.518125	.7248570	.6899834
U. Gishu	1.030	.972888	.918035	1.096791	1.033883
W. Pokot	.968	1.033236	.962327	.8938117	.8315533
WESTERN	.950	.978583	.904387	1.067956	.9912183
Bungoma	1.003	1.058564	.990522	1.114590	1.043681
Busia	.986	.857952	.783682	.8818982	.8154119
Kakamega	.959	.978388	.902210	1.107113	1.024604

Appendix 10

Stem-Leaf Plot of Estimates of Total Fertility Rate
for values expressed to two places of decimal

Frequency	Stem	&	Leaf
1.00	43	:	9
1.00	44	:	4
0.00	45	:	
0.00	46	:	
0.00	47	:	1
0.00	48	:	
0.00	49	:	
0.00	50	:	
1.00	51	:	7
0.00	52	:	
0.00	53	:	
1.00	54	:	9
0.00	55	:	
1.00	56	:	9
0.00	57	:	
3.00	58	:	446
1.00	59	:	4
2.00	60	:	03
2.00	61	:	07
2.00	62	:	01
0.00	63	:	
1.00	64	:	1
3.00	65	:	022
2.00	66	:	18
2.00	67	:	19
3.00	68	:	033
1.00	69	:	0
5.00	70	:	04489
1.00	71	:	3
5.00	72	:	01237
0.00	73	:	
2.00	74	:	45
2.00	75	:	11
2.00	76	:	18
2.00	77	:	47
1.00	78	:	6
0.00	79	:	
0.00	80	:	
0.00	81	:	
0.00	82	:	
0.00	83	:	
1.00	84	:	1
0.00	82	:	

Stem width : 1.0
Each Leaf : 1 case(s)

Appendix 11

Stem-Leaf Plot of Estimates of Birth Rate based on the 0-9 year age group for values expressed to four places of decimal

Frequency	Stem	&	Leaf
1.00	31	:	3
0.00	32	:	
0.00	33	:	
0.00	34	:	
0.00	35	:	
1.00	36	:	3
2.00	37	:	05
1.00	38	:	8
1.00	39	:	8
0.00	40	:	
1.00	41	:	9
0.00	42	:	
1.00	43	:	9
0.00	44	:	
3.00	45	:	056
4.00	46	:	0155
3.00	47	:	169
7.00	48	:	1224688
7.00	49	:	0124588
2.00	50	:	46
1.00	51	:	8
3.00	52	:	149
0.00	53	:	
3.00	54	:	268
1.00	55	:	4
1.00	56	:	1
3.00	57	:	378
0.00	58	:	
0.00	59	:	
0.00	60	:	
0.00	61	:	
1.00	62	:	3
0.00	63	:	
0.00	64	:	
0.00	65	:	
1.00	66	:	7

Stem width : 0.0
Each Leaf : 1 case(s)

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