SOME PROBLEMS AND METHODS OF MEASURING THE GROWTH OF AFRICAN NEGROID POPULATIONS.

A dissertation presented to Rhodes University for the degree of Doctor of Philosophy giving details of problems and methods of obtaining statistics of the more important demographic aspects of the African Negroid populations, that is the size of a population, its sex and age distribution, migration movements, births, deaths and rates of increase. I certify that this dissertation is entirely my own work and that it has not been submitted for a degree in any other university.

Salisbury,
Southern Rhodesia.
May, 1954.

C. A. L. Myburgh,
M.Com., F.S.S.

SUMMARY.

Chapter I: The Basic Requirements and Procedure.

Attention is drawn to the poor quality of the available demographic statistics of the African Negroid populations and the growing need for more and better statistics. The basic requirements are visualised as the answers to the following questions: (i) What is the present population? (ii) How fast is it growing? (iii) How does this rate of increase compare with that for other races and other areas? (iv) What are the factors accounting for the differences in the rate of growth between races and between areas? and (v) What is the future rate of growth likely to be?

In the more advanced countries the answer to the first question is obtained from population estimates based on population censuses or registers, migration statistics and birth and death records. These, particularly the migration and birth and death statistics, also provide some answers to the remaining questions. However, crude birth and death rates are affected by the sex and age composition of the population. Normally, the effects of the sex and age distribution are eliminated by calculating the total fertility and gross reproduction rates, standardised death rates, life tables and the net reproduction rates. These provide further answers to questions (ii) to (iv). In addition the net reproduction rate is often assumed to give an answer to the last question, but in fact it is nothing more than a standardised measure of the current rate of growth. Any attempt to predict the future rate of growth necessarily involves a considerable amount of guesswork.

The normal method of calculating life tables and the net reproduction rate requires details of the sex and age distribution of both the total population and the deaths together with particulars of the births by the ages of the mothers. In

the course of time various other measures of fertility and mortality have been evolved which do not require all these particulars. These are of special interest to African countries because of the great difficulties encountered in any attempt to arrive at the conventional measures of fertility and mortality. The substitute measures considered are the general fertility rate, the effective fertility rate, the replacement index, estimates based on detailed age distribution statistics, substitute life tables and estimates of total and net fertility obtained from returns of the number of children ever born and the number of these surviving.

Chapter II: Problems and Methods of Obtaining Population Totals.

The methods of obtaining figures of the total population are divided into three categories. These are (i) census enumerations, (ii) estimates based on tax registers and (iii) sample surveys.

In censuses of African Negroid populations, the results of a *de facto* enumeration can be very different from those of a *de jure* enumeration. This is because of the movements of migrant labourers. Theoretically a *de facto* census gives a more precise figure, but a *de jure* census may be required for administrative purposes and in some respects it can simplify the taking of a census. However, the customs of the people give rise to special problems in determining the *de jure* place of residence or domicile. Further problems, common to both *de facto* and *de jure* enumerations, arise from the suspicions and superstitions of the people. The suspicions are not entirely unfounded. The suspicions and superstitions tend to result in an under-enumeration of the population. Some indication of omissions can be obtained from an examination of the reported sex and age distribution. In addition to the problems arising from the suspicions, customs and superstitions of the people, there are certain administrative difficulties arising from the fact that the people are illiterate and the low density of population. There is usually a shortage of a sufficient number of suitable enumerators. In most cases where censuses have been undertaken these administrative difficulties have led to the use of an undesirably low standard of enumerator, the spreading of the census over a long period of time, or to the adoption of some form of group enumeration. It is suggested that the spreading of the enumeration over a long period is preferable to a reduction in the standard of the enumerators or the adoption of group enumeration.

In the past, estimates obtained from tax registers have under-stated the true position. These errors may be attributed to the arbitrary way in which the coefficients applied to the number of tax units were obtained. Errors in the tax registers due to tax evasion can be taken into consideration in a scientifically determined coefficient. Satisfactory coefficients can be obtained from reliable census enumerations or properly conducted sample enquiries. Population estimates obtained from tax registers are of use even where census or sample enquiries are held at regular intervals as they provide a basis for intercensal estimates.

Sample surveys are likely to produce better results than complete or census enumerations. The fact that a relatively small population is included in a sample means that a high standard of field officer or enumerator can be used. In addition more attention can be devoted to training the field staff and to developing techniques for overcoming the problems arising from the customs, suspicions and superstitions of the people. However, a sample enquiry cannot produce detailed figures for small geographical areas. There have been several early attempts at sampling, but none of these were scientifically designed. Modern techniques have been used since 1948. Some of the recent enquiries have not been adequately reported. Attention is drawn to three aspects of sampling, namely (i) the choice of the framework, (ii) the selection of the sample and (iii) the estimation of the sampling errors.

The frameworks used so far have adopted villages or headmen, enumeration areas and administrative sub-districts as basic units. Households or taxpayers are unsuitable basic units, but taxpayers may be used as second stage units and as supplementary information. In selecting the basic sampling units a method of systematic selection is suggested. It is suggested that the sample be divided into a number of sub-samples each selected in a systematic manner from a randomly selected starting point. Reasonably good estimates of the standard error for the sample as a whole can be obtained by comparing the results of the sub-samples.

<u>Chapter III: Problems and Methods of Obtaining Statistics on Migration Movements, Births, Deaths and the Age Distribution.</u>

In most parts of Africa the main inter-territorial movements of Negroid peoples are those of the temporary migrant workers. The main obstacle to obtaining reliable records of the inter-territorial migrations is the impossibility of setting up a sufficient number of emigration and immigration posts along the extensive land frontiers. The available information refers to partial counts in respect of the main routes and information obtained indirectly from administrative records of the inward or outward movements. Further information may be obtained from censuses and similar enquiries. Details of birthplace and length of residence are useful, but they may be biased. Some indication of emigration may be obtained from records of the numbers and whereabouts of absentees.

Most countries have at least a partial birth and death registration system, but generally these registers are still unsatisfactory. This state of affairs is attributed to (i) the public's lack of interest in a birth and death registration system, (ii) certain customs and superstions affecting registrations and (iii) administrative difficulties.

Although birth and death statistics are urgently required, the Negroid public has not yet developed a need for birth and death certificates. Compulsory registration is no solution to the problem unless a large staff can be employed to detect evasions and to enforce the law.

There are various customs and superstitions hampering the introduction of efficient birth and death registration systems. There is an initial period of secrecy and seclusion which delays birth registrations and gives an opportunity for hiding the deaths that occur in early infancy. The relative importance of the two sexes in the social system may affect the completeness of the registrations. Some indication of omissions in the birth registrations might be obtained by an examination of the sex ratio of the registered births. Amongst adults there are likely to be omissions in the death registrations because there is a common superstition that to refer to a dead person is likely to encourage that person's spirit to harm the living.

In view of the Negroid's lack of interest in a birth and death registration system and in view of the customs and superstitions of the people, a person cannot be expected to go out of his way to register a birth or a death. Consequently the main administrative difficulty in introducing an efficient birth and death registration system is that of establishing a sufficient number of registration centres. In some countries the tribal organisation has been used in the framework of the registration system, but so far the results obtained in this way have not been satisfactory.

In view of all the difficulties, the only hope of obtaining reliable birth and death statistics in a relatively short time seems to be by sampling. There are two alternative methods of approach. One is to obtain retrospective returns for the events which occurred during the twelve months, or other convenient period, preceding the date of an enquiry. The other is to establish registration systems in a number of small sample areas and to make every effort to obtain complete statistics for only these areas. The first method of approach has been adopted in conjunction with several sample surveys of the total population. It provides statistics immediately, but it does not introduce a permanent registration system and some of the figures obtained in this way have not been satisfactory. In view of this it is suggested that the second method of approach be adopted. This scheme will not produce statistics immediately, but with care it should provide reliable information long before it is possible to raise a complete national registration system to a satisfactory standard. It is suggested that each sample registration area be small enough for the deputy registrar to get to know his people sufficiently well to enable him to record the births and deaths from personal knowledge.

The basic difficulty in obtaining age particulars is the ignorance of the people of any system of measuring time in years. In the case of very young children age can be estimated by determining date of birth by reference to a primitive lunar calender or a calender of the seasonal agricultural activities and seasonal weather conditions. For older people ages have to be estimated by referring to certain features of physical and social development, the attainment of puberty, cronological tables of important local events, the age-set systems of certain tribes and the end of the childbearing period in the case of women. The age of puberty can be determined if some of the people for whom ages are known are divided into those under and those over puberty. Reasonably good estimates of the detailed age distribution can be obtained from a mathematical interpolation of the numbers in a few broad age groups.

Chapter IV: The Estimation of the Total Fertility Rate from the Average Number of Children Ever Born to Women Questioned.

It is shown that the average number of children ever born to the women questioned, including women still in the childbearing period, is related to the total fertility rate in terms of a simple function of the age distribution of the population and the distribution of the relative, as distinct from the absolute, values of the age specific fertility rates. This function may be used to obtain an estimate of a type of cohort total fertility rate.

Various estimates of the relative distribution of the age specific fertility rates of African Negroid populations are considered and it is concluded that the relative age specific fertility rates of the U.S.A. non-white population may be assumed to be applicable to African Negroid populations. Allowing for probable errors in the estimated age distribution, it is considered that the standard error of the differences between (i) estimates of the total fertility rate obtained by the formula referred to above and (ii) the actual figures, is about 7.5 per cent. of the estimates. The age distribution need be known only approximately. Information in respect of only three broad age groups is sufficient. Where no satisfactory information is available on the age distribution, the total fertility rate of an African Negroid population might be assumed to be equal to 1.47 times the average number of children ever born to all women aged 15 years and over. Such an estimate is likely to have a standard error of about 9.5 per cent.

A summary is given of an alternative method of approach developed by Brass. This refers to returns in respect of women up to the end of the childbearing period. It is suggested that these estimates also be based on the relative age specific fertility rates of the U.S.A. non-white population.

Chapter V: The Estimation of the Expectation of Life at Birth from the Ratio of Children Surviving to Total Children Ever Born.

The theoretical relationship between the expectation of life at birth and the ratio of children surviving to total children ever born is examined. This theoretical relationship includes a number of variables not likely to be known in practice. It is reduced to an empirical formula giving the expectation of life at birth in terms of (i) the proportion of the total children ever born who survive to the date of the enquiry, and (ii) the proportion of the total children ever born who were born in the twelve months preceeding the date of the enquiry. The latter may be estimated from the age distribution of the population.

This empirical formula contains three constants, the values of which are obtained from an examination of a number of theoretical figures in respect of populations other than African Negroid populations. The suitability of these constants for estimates in respect of African Negroid populations is examined. It is indicated that the constants give good estimates of the expectation of life at birth for populations with a high or a low expectation of life. The available life tables in respect of African Negroid populations do not appear to be very different from other life tables with a low expectation of life. Some adjustment to one of the constants is required when the returns in respect of some of the women under 50 years of age are not taken into consideration. It is estimated that the standard error of the difference between (i) estimates obtained from the empirical formula referred to above in respect of returns for all women aged 15 years and over, and (ii) the actual values is between 1.8 and 2.5 years.

As the returns of children ever born and the number of these still living in respect of African Negroid populations do not usually distinguish between males and females, the resulting estimate of the expectation of life at birth is usually an average for the two sexes. The relationship between the expectation of life at birth of males and females is examined. It is indicated that the expectation of life at birth of females is about 1.6 years above that for males and 0.8 years above the average for the two sexes.

Chapter VI: Further Consideration of Returns of the Total Number of Children Ever Born and the Number of These Still Living.

Estimates of the total fertility rate and the expectation of life at birth obtained from the formulae referred to previously may be biased because of reporting errors. The basic returns may be biased by the omission of some of the children that died in early infancy or the inclusion of still births. Biases might be introduced by the women refraining from reporting their first births or including adopted children. Some indication of reporting errors might be obtained by examining the sex ratio of the reported births and the apparent trends of mortality and fertility revealed by the returns in respect of women in successive quinquennial age groups. A general formula is given for the estimation of the expectation of life at birth from the returns in respect of women in any one age group. The relevant parameters for the quinquennial age groups between the ages of 30 and 74 years are determined. These parameters are based on the relative age specific fertility rates of the U.S.A. non-white population and may give biased estimates where the actual relative age specific fertility rates differ from these. However, this formula is intended to reveal the apparent trend in mortality rates rather than the absolute value of the expectation of life at birth. The total fertility rate, in respect of the women in any single quinquennial age group, may be estimated by applying an appropriate constant to the average number of children ever born to women in that age group. The appropriate constants obtained from the relative age specific fertility rates of the U.S.A. non-whites are given.

The theoretical relationship between the net reproduction rate, the gross reproduction rate, the relative age specific fertility rates and the appropriate life table probabilities is examined to arrive at a simple formula giving the net reproduction rate in terms of the gross reproduction rate and the expectation of life at birth. This formula has two parameters. Further examination reveals that one of these is a constant while the other is a function of the relative age specific fertility rates. Marked variations in the latter require an adjustment to the second parameter which affects the net reproduction rate by only 4 per cent.

An examination of the formulae for the total fertility rate, the expectation of life at birth and the net reproduction rate indicates that the standard error of the difference between (i) estimates of the net reproduction rate obtained by the methods referred to above and (ii) the actual values, is about 7 per cent. of the estimates.

A summary is given of an alternative method of estimating the net reproduction rate developed by Brass. This does not require a direct estimate of the expectation of life at birth, but such an estimate is easily obtained in arriving at the net reproduction rate.

Consideration is given to the conversion of the net reproduction rate to the standardised rate of natural increase. It is shown that the length of the generation implied in the net reproduction rate in the case of the relative age specific fertility rates of the U.S.A. non-whites is less than that for other distributions of the relative age specific fertility rates.

Finally attention is drawn to the compensating nature of certain reporting errors and biases. Although the estimates of the total fertility rate and the expectation of life at birth may be biased by errors in the reported number of children who have died, the resulting estimate of the net reproduction rate will be relatively free from bias. The various formulae referred to previously are combined and reduced to a single formula giving the net reproduction rate in terms of the average number of children still living per woman. However, errors in the returns of the children still living will give biased estimates of the total fertility rate, the gross reproduction rate, the expectation of life at birth and the net reproduction rate. Apart from these sources of bias, the use of the relative age specific fertility rates of the U.S.A. non-whites may give a downward bias to the total fertility rate, the gross reproduction rate and the net reproduction rate. However, there is a compensating downward bias in the length of the generation implied in the net reproduction rate, so that the resulting standard rate of natural increase is unbiased.

Chapter VII: Various Estimates of Fertility and Mortality for a Number of Countries.

The various formulae referred to above are applied to the available information regarding the total number of children ever born and the number of these still living. The countries concerned are considered in alphabetical order and wherever possible replacement indexes are also calculated. The countries dealt with are Angola, Bechuanaland, British East Africa, the Gold Coast, Mozambique, Nigeria with special reference to Lagos, the Rhodesia and Nyasaland Federation and Swaziland. The figures are then summarised and commented upon.

In general the exclusion of the returns for the older women has no significant effect on the estimates. It is suggested that the effect of the faulty returns of the older women has been exaggerated. The replacement indexes do not always agree with the other estimates of the net reproduction rate. There appears to have been a general downward trend in the level of fertility, but no change, or only a slight improvement, in mortality conditions. The figures indicate that there are marked territorial differences in the fertility and reproduction rates and also in the expectation of life at birth. The variations in mortality rates are attributed to variations in climatic and health conditions.

Chapter VIII: The Correlation Between Fertility on the one hand and Marriage Customs and the Proportion of Absentee Migrant Workers on the Otherhand.

An examination of the scanty information available indicates that there are marked territorial variations in the customary age at marriage. However, these variations are, at least partly, accounted for by variations in the definitions of the terms normally used in the analysis of the population by marital status. Of the countries for which figures are available, the highest mean age at marriage of women is found in the Union of South Africa. Here it is about 22 years which is only slightly less than the mean age at marriage of European women in the Union of South Africa. Negroid customs affecting the definitions of the terms never married, married and widowed are discussed.

Although variations in the definitions of these terms are likely to account for a large part of the territorial variations referred to above, it is to be expected that a more or less uniform system of classification is adopted within each country. However, even within each country there appear to be marked regional variations in marriage customs. In the Belgian Congo there is a significant correlation between the general fertility rate and the prevalence of polygamy. It would appear that an increase in polygamy leads to a reduction in fertility. The difference between the fertility in monogamous and polygamous households hides the fact that unmarried women have far fewer children than married women. In the Union of South Africa and Mozambique there is no significant correlation between the effective fertility rate and the proportion of women aged 15-44 years who have never married. The analysis for the Union of South Africa is distorted by urban conditions and that for Mozambique is distorted by reporting errors.

An analysis of the returns of the 1948 and 1950 sample surveys of Southern and Northern Rhodesia respectively reveals no relationship between the birth rate and the percentage of adult males away from home.

In conclusion it is suggested that variations in the incidence of polygamy cannot entirely account for the large territorial differences in fertility. Birth control cannot be an important factor. Apart from reporting errors, variations in diet and the incidence of malnutrition and various tropical and venereal diseases are other possible factors having an important effect on the level of fertility, but no reliable figures are yet available regarding these.

CONTENTS.

CHAPTER I

THE BASIC REQUIREMENTS AND PROCEDURE.

The Need for Better Demographic Statistics.

Most of the demographic statistics of Africa are no more than rough guesses. The United Nations classifies them as "poor", a classification shared only with the near and far east excluding south-central Asia and Japan.[1a] This unsatisfactory state of affairs is due mainly to the poor quality of the figures of the Negroid races of Africa. These people are the main inhabitants of Africa south of the Sahara, an area of over seven million square miles. In 1949 the total population of this area was estimated to be about 125 million, but about 60 million of these had not been counted by even a single census.[1b] Many of the censuses of the remaining 65 million are of doubtful accuracy.

In recent years there has been a considerable increase in world interest in Africa, particularly in the area inhabited by Negroids. The natural resources of Africa appear to have been little more than touched and there seems to be room for a considerable increase in the production of foodstuffs and raw materials. An improvement in the demographic statistics of Africa is urgently required to reveal the potential human resources available for the development of Africa, the extent to which these human resources are being improved by education and public health programmes and also to reveal the rate of growth of the population.

There is a growing consciousness of the tendency for the world demand for foodstuffs to outstrip the rate at which

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(1) 1949-50 Demographic Yearbook, United Nations:
(a) pp. 10-11.
(b) pp. 71-74.

the supplies are increasing. Improvements in the demographic statistics of Africa are required to assist in determining whether Africa will alleviate or aggravate the world shortage. In the interests of humanity it is necessary that sufficient food be produced or imported into Africa to meet not only the unknown natural increase of the indigenous population, but also to raise the general standard of nutrition and health of the people. It is generally recognised that the rate of development in Africa is handicapped by the low standard of health and education of the Negroids and plans for the improvement of these conditions are severely handicapped by insufficient demographic details. Edge states that[1] "Complete and dependable systems of human book-keeping ---- too often the unpopular 'Cinderella of Public Health' under the official title of 'Vital Statistics' ---- are as necessary to the medical officer wherever his work may lie, as is the microscope."

The statistics of particular interest to the public health worker are the birth, death and infant mortality rates, the expectation of life, and the causes of deaths. Where such information is available by geographical areas the medical officer is able to decide which areas should receive priority in the allocation and distribution of the limited resources available. A time series of such information will provide the medical offácer with an index of the improvement in public health brought about by his efforts. The education officer is also interested in the rate of growth of the population and its age distribution. Such information provides him with details of the size of the population he has to deal with. Literacy figures for two or more dates will provide some indication of the rate at which the influence of schools is spreading. There are numerious

(1) Edge, P. G. (1944), <u>Vital Statistics and Public Health Work in the Tropics</u>, Williams and Wilkins, Baltimore. p.59.

other fields in which information on special characteristics of the population are required, but the basic requirements are usually reliable statistics regarding the size of the present population and the factors affecting its rate of growth.

Basic Questions and Methods of Answering Them.

The basic demographic requirements may be visualised as the answers to the following questions:

(1) What is the present population?

(2) How fast is it growing?

(3) How does this rate of increase compare with that of other races and other areas?

(4) What are the factors accounting for the differences in the rate of growth between races and between areas?

(5) What is the future rate of growth likely to be?

Questions such as these have been studied by demographers in the more advanced countries for hundreds of years and various methods of answering them have been devised. The basis of answers to the first question is now normally the census of population. A census provides particulars of the population at a certain date. Estimates of the population at other than census dates are normally obtained by correcting the latest census figures by the subsequent number of births, deaths, immigrants and emigrants. In many countries such corrections to census figures are made as they are required by reference to birth and death registration figures and details of international migration movements. In some countries a continuous national register of the population is kept which provides a continuous record of the total population and sometimes also a record of the geographical and industrial distribution and various other characteristics of the people. The birth and death registers and immigration and emigration records furnish details of the additions and subtractions to be made to the national totals with a reasonable degree of reliability. However, reliable information on the internal movements of the population between areas, industries, occupations etc. is difficult to obtain --- much depends on the voluntary co-operation of the public.

In the absence of adequate records of births, deaths and international migration, current population estimates of the population may be based on a mathematical extrapolation of past census results, supplemented perhaps by other indications of population movement such as the number of taxpayers in the case of a primitive community. Estimates based on the number of taxpayers are common in Africa, but as pointed out in the previous section they are not yet very reliable.

One answer to the second question, that is "How fast is the population growing?" is provided by comparing the results of two censuses or by comparing two estimates. Assuming the census results or estimates are accurate, the difference between two such figures will indicate the net change in the population between the two dates to which the figures refer taking into consideration all the factors affecting population movement. This net change is the combined result of migration and natural increase. While such a figure is of value for some purposes, for other purposes it is necessary to divide the net change up into its component parts and to obtain separate figures of births, deaths, immigrants and emigrants. Such a breakdown of the overall net increase provides some answers to the questions "What are the factors accounting for the differences in the rate of growth between races and between areas?" and "What is the future rate of growth likely to be?" Further answers to these questions are provided by the detailed analysis of the births and deaths.

For comparative purposes it is customary to convert the number of births and deaths into crude birth and death rates.

An important factor accounting for some of the variations in these crude rates is variations in the sex and age composition of the populations. In a relatively young population the birth rate can be expected to be higher, and the death rate lower, than in a relatively old population. The effects of the sex and age distribution may be eliminated by calculating age specific birth and death rates . This requires details of the age distribution of the population, a record of births by the age of mothers and sometimes also by the age of fathers if age specific birth rates for the adult male population are required as well as age specific birth rates for the adult female population, and also a record of deaths by age at death.

A type of age specific death rate of special significance is the infant mortality rate. This generally takes the form of the number of children who die in a given year before they reach their first birthday per thousand births in that year. It gives some indication of the general level of mortality independent of the sex and age distribution of the population without resorting to an involved calculation. The infant mortality rate is a useful index of the general level of mortality simply because a relatively large proportion of all deaths occur in early infancy.

Sonnabend has suggested[1] that for the primitive races of Africa the infant mortality rate should be based on the deaths of children up to the age of three or four years instead of the more usual practice of using only deaths in the first year of life. The reason for this suggestion is evidence that there is no marked drop in the mortality of these primitive people until the third or fourth year of life whereas amongst Europeans there is a marked drop in infantile mortality sometime within the first twelve months. This peculiarity of the Negroid races

(1) Sonnabend, H. (1934) "Demographic Samples in the Study of Backward and Primitive Populations", South African Journal of Economics, Volume II, No. 3, p. 306.

is attributed to the widespread practice of weaning children abruptly at about the age of two or three years.

However, any departure from the customary method of calculating infant mortality rates is bound to lead to confusion. If the argument that infant mortality rates should be based on deaths up to the age at which there is a marked drop in infantile deaths is accepted, it would be quite reasonable for many countries to take into consideration only the deaths which occur in the first few months of life for the drop in mortality often occurs well before the end of the first year of life. In the case of the United States of America, Australia and New Zealand over 70 per cent. of the deaths in the first year now occur in the first month.[1] An examination of the probabilities of survival given in Tables E and H of the Appendix shows that relatively high mortality rates up to the age of four or five years are in any case to be expected where the expectation of life is relatively low so that Sonnabend's observations regarding heavy mortality after the first year of age are not peculiar to Africa. However, it is quite evident that although the infant mortality rate is a useful indication of the general level of mortality, it is necessary to use it with some caution since it takes no account of deaths over the age of one year. It is therefore desirable that the death rates for older age groups also be obtained wherever possible.

For comparative purposes age specific death rates, for individual years of age or for quinquennial age groups, for the two sexes may be used to calculate a standardised death rate for any convenient standard sex and age distribution.[2] However, details of the sex and age distribution of both the total population and the deaths under consideration are of

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(1) <u>1948 Demographic Yearbook</u>, United Nations Organisation, pp. 433-455.

(2) The age and sex distribution of the population of England and Wales in 1901 is the standard normally used.

greater value as the basis of a life table. A useful summary of a life table is provided by the complete expectation of life at birth. For the purpose of comparing ordinary death rates with a summary of a life table, the appropriate expectation of life at birth may be divided into the figure of 1,000. This gives the overall, or average, death rate per 1,000 persons of the appropriate life table population.

Age specific birth rates are normally summarised by calculating the total fertility rate. This may be visualised as the aggregate of the age specific fertility rates for each individual year of age from the beginning to the end of the childbearing period. For the purpose of calculating total fertility rates the childbearing period of women is normally assumed to be from the age of 15 years to the age of 49 years. The total fertility rate is normally obtained by summing the age specific fertility rates for quinquennial age groups and multiplying the result by five since there are five individual years in each quinquennial age group. Births to women under the age of 15 years and to women aged 50 years and over are usually included with the births to women aged 15-19 and 45-49 respectively. The gross reproduction is then obtained by correcting the total fertility rate by the sex ratio at birth. If the quinquennial age specific fertility rates are corrected by this ratio and by appropriate life table probabilities of surviving to the specified ages, five times the sum of these adjusted figures gives the net reproduction rate. This is a measure of the net rate of population growth. It differs from the crude rate of natural increase in two respects. In the first place the effects of variations in the sex and age distribution of the population are eliminated. In the second place the net reproduction rate reflects the standardised rate of growth over a generation, whereas the crude rate of natural increase reflects the rate of growth over a period of only one year. In recent years the net reproduction rate in Europe and America has fluctuated substantially. These fluctuations have given rise to much criticism of the net reproduction rate both as a forecast of the future rate of growth and as a standardised measure of the current net rate of growth.

It is sometimes convenient, but incorrect, to describe the net reproduction rate as the size of the next generation in terms of the present generation if the current levels of fertility and mortality remain unchanged. From this concept of the net reproduction rate it is only a short step to a consideration of this rate as a forecast of the future rate of population growth. However, a forecast is obviously of doubtful value when it is subject to large annual revisions. The recent fluctuations in the rates in Europe and America have therefore given rise to much criticism of the net reproduction rate as a forecast of the future rate of growth. However, these criticisms tend to overlook the fact that this rate is essentially a measure of the current rate of growth and not a forecast.(1) Lotka has stated(2) that "It should perhaps be made clear that when computations of this kind have been made in the past, they were not intended as forecasts. As I have stated elsewhere, rates of natural increase based upon survival and fertility rates for a particular calender year, are of interest not so much as forecasting instruments, as through the fact that they express an intrinsic property of the population, namely its current fundamental capacity for growth." Attention has also been drawn to the fact that, even assuming current levels of fertility and mortality remain

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(1) See Woofter T.J. (1949) "The Relation of the Net Reproduction Rate to Other Fertility Measures", Journal of the American Statistical Association, Vol. 44, p. 501.

(2) Lotka A.J. (1947) "Evaluation of Some Methods of Measuring Net Fertility with Special Regard to Recent Developments", Proceedings of the 25th. Session of the International Statistical Institute, Vol. III, p. 716.

unchanged, it may take at least two generations before the actual rate of increase approximates to the rate implied in the net reproduction rate.(1) In practice the actual rate of increase differs from that given by the net reproduction rate because of the difference between the sex and age distribution of the actual population and the hypothetical stable sex and age distribution. The latter is the sex and age distribution that would be attained, after at least two generations have elapsed, in a community which is free from migration movements and subject to a constant level of fertility and mortality. Any estimate of the future population or the future rate of growth is necessarily very rough since it has to be based on rather arbitrary assumptions regarding the future trends of all the basic factors governing the level of fertility and mortality.

The misunderstanding over the use of the net reproduction rate as a forecast of the future rate of growth has probably arisen from the fact that it is expressed as a measure of growth in terms of a generation and not in terms of a year. Much of this misunderstanding could possibly have been avoided had the calculations been taken a stage further, as explained by Dublin and Lotka(2) and the results published as a standardised rate of natural increase, in the form of so much per annum per 1,000 persons.

The main other criticisms of the net reproduction rate draw attention to the fact that while the total fertility rate

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(1) Glass D.V. (1940) Population Policies and Movements in Europe, Oxford University Press, p. 415. Kuczynski R.R. (1935) The Measurement of Population Growth, Sidgwick and Jackson, London, p. 228.

(2) Dublin L.I. and Lotka A.J. (1925) "On the True Rate of Natural Increase as Exemplified by the Population of the United States, 1920," Journal of the American Statistical Association, Vol XX, p. 305.

gives a measure of fertility which is independent of the sex and age composition of the population, it does not eliminate the effects of temporary fluctuations in other variables, particularly age at marriage and the spacing of births after marriage. It is well known that there is a tendency for marriages and births to be brought forward or postponed as a result of marked variations in the economic state of the community and as a result of a war. There is a growing opinion that the resulting fluctuations in births are of a rather temporary nature in that a rise in births due to the hastening of marriages and births in one year tend to be merely the bringing forward of some of the future births. Various refinements have been suggested to take account of these and other factors.(1)

These refinements are at present of little interest with regard to the African Negroid populations since the basic statistics are not yet available and are not likely to become available for many years to come. Even all the information required to calculate the conventional net reproduction rate, namely the age and sex distribution of both the total population and the deaths, and births by age of mother, are not yet generally available. Apart from the lack of statistics, it may be argued that the recently proposed refinements to the calculation of the net reproduction rate would lead to little or no improvement in the determination of the fundamental rate of growth of population in Africa because of the very early age of marriage of the women, the absence of any social stigma associated with illigimate births and the absence of any effective limitations on childbearing.

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(1) See for example Whelpton P. K. (1946) "Reproduction Rates Adjusted for Age, Parity, Fecundity and Marriage", Journal of the American Statistical Association, Vol. 41, p. 50, Hajnal J. "Analysis of Recent International Recovery in the Birth Rate", (1947) Population Studies, Vol. 1, p. 137 and Report of Royal Commission on Population (1949), (Cmd. 7695), Her Majesty's Stationery Office, London, pp. 60-99 & 241-259.

Although all the basic information required for the calculation of the conventional net reproduction rate is not yet generally available in respect of the African Negroid populations, there are several methods of obtaining what may be termed substitute total fertility, gross and net reproduction rates. The more useful of these are referred to in the following section.

Substitute Measures of Fertility and Mortality

The General Fertility Rate. This is obtained by dividing the total number of births in a specified year by the total number of women in the childbearing ages, usually taken as 15-44 years or 15-49 years. An approximation to the total fertility rate is normally obtained by multiplying the general fertility rate by the number of years covered by the women under consideration, that is by 30 for the 15-44 year age group and by 35 for the 15-49 year age group. Lorimer has examined the reliability of estimates of the total fertility rate obtained from the general fertility rate in respect of ninety populations.(1) He shows that on the average, the total fertility rate is 29.64 times the general fertility rate for the 15-44 year age group. This coefficient has a standard deviation of only 0.94. Less efficient estimates are obtained by taking 35 times the general fertility rate for the 15-49 year age group. This is because the age specific fertility rates for the last five years of the childbearing period are very much below the average for the whole of the childbearing period.

Although Lorimer's investigations are very encouraging, the possibility of a substantial bias should not be overlooked.

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(1) Lorimer F. Social and Cultural Conditions Affecting Fertility in Non-Industrial Societies, Appendix A: To be published shortly under the auspices of the International Union for the Scientific Study of Population and the United Nations Educational Social and Cultural Organisation.

The relationship between the total fertility rate and the general fertility rate for women aged 15-44 years may be expressed algebraically as

$$R = \frac{K.\sum_{s=15}^{49} r_s F_s}{\sum_{s=15}^{44} F_s}$$

R is the total fertility rate. $\sum_{s=15}^{49} r_s F_s$ is the number of births in the year under consideration, where r_s is the age specific fertility rate of women aged s years and F_s is the number of women aged s years. K is the coefficient to be applied to the general fertility rate to raise the latter to the total fertility rate. Therefore

$$K = \frac{R.\sum_{s=15}^{44} F_s}{\sum_{s=15}^{49} r_s F_s}$$

Putting $r_s = R X_s$ where X_s is the relative, as distinct from the absolute, age specific fertility rate at the age s years, this becomes

$$K = \frac{R.\sum_{s=15}^{44} F_s}{R.\sum_{s=15}^{49} X_s F_s} = \frac{\sum_{s=15}^{44} F_s}{\sum_{s=15}^{49} X_s F_s}$$

The value of K is therefore dependent on the age distribution of the population under consideration and the relative distribution of the age specific fertility rates. Where the population has an age distribution with relatively large numbers in the younger ages and relatively small numbers in the higher ages, together with relatively high age specific fertility rates in the younger ages and relatively low rates in the higher ages, the value of K will be somewhat smaller than the normally assumed figure of 30. For example, if the relative age specific fertility rates of the U.S.A. non-white population given in Table C of the Appendix are applied to the average age distribution of African Negroid populations given in Table A of the Appendix, the value of k is 26.8. For such such a population, thirty times the general fertility rate would over-estimate the total fertility rate by about 12 per cent.

Effective Fertility Rate or Fertility Ratio. This is obtained by dividing the number of children under a certain age, say under one year or under five years, by the total number of women aged 15-44 or 15-49 years. It differs from the general fertility rate in that the number of children still living is used in place of the number of births. Apart from the basic fertility of the population, this rate is greatly influenced by the accuracy with which the children have been enumerated and by the level of child mortality. The influence of mortality can be reduced by confining the calculation to the youngest group of children, that is those under one year of age. However, it is well known that censuses tend to understate the number of very young children and the effective fertility rate is normally based on the number of children under five years of age. This reduces, but does not eliminate, the influence of omissions in the number of very young children, but increases the influence of mortality. The latter might sometimes be allowed for by increasing the number of children, from information obtained from an appropriate life table, to obtain an estimate of the total number of births which have occurred during the past five years. A rough approximation to the general fertility rate may then be obtained from the estimated average number of births per year.

Replacement Index. The effective fertility rate is more usually converted into what is termed the replacement index or net reproduction ratio. This is in fact a type of net reproduction rate. It is obtained by dividing the effective fertility rate by the corresponding figure obtained from an appropriate life table. This extremely simple measure of the net reproduction rate has given some good results.[1] However, poor estimates of the net reproduction rate will be obtained if there is a substantial error in the effective fertility rate due to census omissions of the children and if the life table chosen for the estimate is not a reasonably good reflection of the actual mortality conditons. Glass has pointed out[2] that the replacement index will be the same as the net reproduction rate if the population has the same relative age distribution as the appropriate life table. If the actual population has a larger proportion of women in the younger ages of the childbearing period, and therefore a smaller proportion in the older ages, the replacement index will be higher than the net reproduction rate. Similarly if the actual population has a smaller proportion of women in the younger ages the replacement index will be lower than the net reproduction rate.

Estimates Based on Detailed Age Distribution Statistics. Where reasonably reliable information on ages can be obtained in a census, an analysis of the children under one year or under five years, by age of mother, can provide some indication of the age specific fertility rates.[3] The mothers of most children can be identified by referring to the particulars on each person's relationship to the head of the household and to the information on each person's name.

The two main weaknesses of such an analysis are firstly

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(1) See Lotka A.J. (1936) "The Geographic Distribution of Intrinsic Natural Increase in the United States, and an Examination of the Relationship Between Several Measures of Net Reproductivity", Journal of the American Statistical Association, Vol. 31, pp. 273-94.

(2) Glass D.V. (1940) Population Policies and Movements in Europe, Oxford University Press, p. 396.

(3) Population Census Methods, Population Studies No. 4, United Nations, (1949), pp. 30-35.

the general tendency for young children, particularly those under one year of age, to be under-enumerated and secondly the fact that the children who died before the census date will not be recorded. However, these understatements of the births should not seriously affect the relative distribution of the age specific rates, and this is in itself useful information even if no reliance can be placed on the total fertility rate obtained in this way. For example, knowledge of the relative distribution of the age specific fertility rates will be useful in the determination of any bias in an estimate of the total fertility rate obtained from the general fertility rate. The understatement in estimates of fertility obtained from relating children under one year to their respective mothers can, theoretically, be overcome by asking each woman how many children, including those that have died, she has had during the previous twelve months. Special questions on such births should help to obtain a complete enumeration of the living children under one year of age because of the additional attention paid to them. The practical application of this method of approach will be discussed in Chapter III.

Where the total number of births, but not births by age of mother, is known as well as the detailed age distribution of the female population, the total fertility rate may be estimated by a method often used by Kuzynski and Glass.(1) The age specific fertility rates for some other country are applied to the number of females in the appropriate age groups to obtain an estimate of what the total number of births would have been with these rates. The total fertility rate for these age specific fertility rates is then corrected by the ratio of

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(1) Glass D. V. Population Policies and Movements In Europe, Oxford University Press, London (1940), p. 387.

the actual births to the estimated births. This ratio makes allowance for the absolute difference between the total fertility rates of the population under consideration and the population to which the age specific fertility rates actually refer without any reference to possible differences in the relative distribution of the age specific fertility rates. Although all age specific fertility rates follow a similar pattern in that they rise to a peak sometime before the age of thirty five years and then decline again there are some marked variations.[1] A variation in the relative distribution of the age specific fertility rates used in the calculation will obviously affect the estimated number of births even if there is no change in the total fertility rate to which the age specific fertility rates actually refer. For example, if the rate for the 20-24 year age group is raised by say 25 births per thousand women and the rate for the 25-29 year age group reduced by a like amount the total fertility rate remains unchanged, but the estimated number of births would normally be increased since there are normally more women in the lower age group. A change in the estimated number of births will affect the correction factor used to estimate the total fertility rate of the country under consideration. Glass suggests that the effects of such variations are relatively small if the total fertility rate of the population under consideration is within about ten per cent. of that for the age specific fertility rates used as the basis of the estimate. However, there is always the possibility that the population under consideration is peculiar. The analysis of children under one or under five years by age of mother, referred to above should give a good indication of the appropriate distribution of the age specific fertility rates.

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(1) See Table C of Appendix for some details of the distribution of age specific fertility rates.

<u>Substitute Life Tables.</u> Although there are various substitute methods of estimating the total fertility rate, there is only one known method of compiling a life table where the normal proceedure, requiring detailed information of the sex and age distribution of both the total population and of deaths, cannot be applied. This substitute method of compiling a life table does not require any direct information at all on the deaths, but it does require information on the detailed sex and age distribution of the population at two successive census dates. The basic principle behind such a calculation is that in a closed community, that is one free of any immigration or emigration, the persons enumerated at the second date are the survivors of firstly the persons enumerated at the first date and secondly the persons born in the intercensal period. Excluding from the second census those ages which are affected by the births during the intercensal period, a crude measure of the probability of surviving the intercensal period may be obtained for any age by comparing the people at the first date with those a certain number of years (as determined by the intercensal period) older at the second date. In practice it is necessary to make adjustments for reporting errors in the age analyses. Details of these adjustments, the interpolation of the probabilities of dying and surviving single years and other technical points in the preparation of the life tables are given in the actuarial reports to the Indian life tables and by Mortara.[(1)]

Up to the present it has not been possible to apply this method to any African Negroid population. Except for the Union of South Africa satisfactory figures of the detailed age distribution are not yet available in respect of two census

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(1) <u>Methods of Using Census Statistics, Population Studies No. 7</u>, (1949), United Nations Organisation.

dates. In the case of the Union of South Africa migration movements distort the comparisons to such an extent that no satisfactory results can be obtained.[1] The effects of migration can theoretically be eliminated if adequate records of the sex and age of emigrants and immigrants are available, but by the time these are available for African Negroid populations, it will probably be possible to use the more conventional methods of calculating life tables. The migration complication might, however, sometimes be avoided by comparing the age analyses of only the home born population at two successive census dates. This would not be of any use where there is a substantial outward migration, but in certain countries, particularly in the Union of South Africa, outward migration seems to be negligible. It is unfortunate that the Union of South Africa has not already provided analyses of the age distribution of its home born population.

So far only two sets of life tables have been published for African Negroid populations, both of which refer to urban conditions. The first of these were obtained by the Government Statistician of Nigeria in 1931 and refer to Lagos in 1921-33. Kuczynski stated that[2] "the basic data used in computing these tables --- population by age, births, and deaths by age --- are all so inadequate that the results are by no means conclusive. Nor do they seem plausible." The second set of life tables are those obtained by Sadie[1] for the Witwatersrand in the Union of South Africa in 1945-47 and are also based on birth and death registration figures. The author of these is

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(1) Sadie J. L. (1951), "Differential Mortality in South Africa", <u>South African Journal of Economics</u>, Vol. 19, No. 4 p. 361.

(2) Kuczynski R. R. (1948), <u>A Demographic Survey of the British Colonial Empire</u>, Oxford University Press, London, Vol. I, p. 666.

not entirely satisfied with his calculations and "had great qualms in presenting them." Until more comprehensive and more reliable information on the mortality rates of African Negroid populations becomes available, any estimate of the net reproduction rate obtained from the substitute measures of fertility referred to above will necessarily contain a substantial element of guesswork. A new approach to the problem of estimating the net reproduction rate, which does not require an accurate estimate of the level of mortality, is referred to below.

Estimates of Total and Net Fertility Obtained from Returns of The Number of Children Ever Born and the Number of These Surviving. A common form of enquiring into the fertility of a population is by means of questions on the total number of children ever born to individual women. Amongst European communities these returns are often incomplete in that the single women, and sometimes also the widowed and divorced, are not required to answer the questions and sometimes married women are requested to confine their answers to existing marriages only. Amongst African Negroid populations, however, the questions are usually put to all females and cover previous as well as existing marriages, although in several cases the questions are confined to women passed the childbearing ages.

It is obvious that the number of children ever born to women passed the childbearing ages is a direct measure of a total fertility rate in respect of a cohort of women who have passed through the childbearing period. Where the questions have been put to women of all ages and where it can be safely assumed that the general level of fertility has remained unchanged over a long period of time, the returns may be used to measure the age specific fertility rates as well as the total fertility rate by a process of differencing. For example, if the women aged 15-19 years have averaged 200 births per 1,000 women and those aged 20-24 years have averaged 800 births per

1,000 women, the age specific fertility rate for the 15-19 age group is approximately 200 births per 1,000 women and that for the 20-24 age group is approximately 600 births (800 - 200) per 1,000 women. These are only approximate figures as no account is taken of the fact that the women in each age group have not all reached the end age of the group.

Where the basic information is collected by a qualified anthropologist or sociologist valuable details might also be obtained with regard to the age of each mother at the time of each birth, the date of each birth and the age and date of the death of each child.(1) If a sufficient number of cases can be investigated in this way it should be possible to make a detailed analysis of the age specific fertility rates for a number of years, provide some indication of life table probabilities, and examine the secular trends of fertility and mortality. However, such investigations can be undertaken only on a limited scale because there are few people qualified to undertake them and a considerable time has to be spent with each individual family in order to obtain all the necessary detail. This survey of methods of obtaining demographic statistics in Africa is primarily concerned with techniques that can be used on a large scale, by official statisticians using relatively unqualified field staff, to obtain no more than reasonably accurate statistics in a relatively short time. It is extremely doubtful that these large scale enquiries can go further than to obtain an approximate indication of each woman's age and

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(1) Lorimer F. Social and Cultural Conditions Affecting Fertility in Non-Industrial Societies, Appendix B --- To be published shortly under the auspices of the International Union for the Scientific Study of Population and the United Nations Educational Social and Cultural Organisation. Mitchell J. C. (1949) "An Estimate of Fertility in Some Yao Hamlets in Liwonde District of Southern Nyasaland", Africa, Vol. XIX No. 4, p. 293 and (1953) "An estimate of Fertility Among Africans on the Copperbelt of Northern Rhodesia", Rhodes-Livingstone Journal, No. 13 p. 18.

information on merely the total number of children ever born to each woman and the number of these still living. However, the relatively small scale and intensive demographic surveys undertaken by anthropologists and sociologists are to be encouraged as much as possible as a means of filling the gap in our knowledge of Africa, as a means of detecting errors in the results of large scale surveys and to show how these errors might be avoided.

Shaul has suggested a method of deriving the total fertility rate from the average number of children ever born to all women over puberty or aged 15 years and over.(1) This suggestion is examined and elaborated in Chapter IV. Although enquiries into the total number of children ever born usually also obtain particulars of the number of these who survive to the date of the enquiry, little use has so far been made of this information. The relationship between the proportion of the total children ever born who are still living and the complete expectation of life at birth is examined in Chapter V. This relationship would appear to be of particular interest to countries which have no other indication of mortality. Unfortunately returns of the total children ever born and the number of these still living are subject to various reporting errors. The most common of these is probably a tendency for women, particularly the older ones, to forget about children that died in early infancy. This leads to a downward bias in estimates of fertility and an upward bias in estimates of the survival rates. However, these biases tend to cancell out when the estimates of fertility and mortality are brought together to obtain an estimate of the net reproduction rate as developed in Chapter VI.

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(1) Shaul J.R.H. (1946), "Derivation of Total Fertility, Gross and Net Reproduction Rates from Census Statistics of Marriage Fertility", Journal of the Royal Statistical Society, Vol. CIX, Part III, p. 278.

CHAPTER II

PROBLEMS AND METHODS OF OBTAINING POPULATION TOTALS.

One of the first things one wants to know about the population of any country is the size of that population. It is desirable that this information be as up-to-date and as accurate as possible. As far as the Negroid populations of Africa are concerned, there are three basic methods that have been used to obtain this information, namely census enumerations, estimates based on tax registers and sample surveys. Estimates based on tax registers can normally be made annually, but censuses and sample surveys are undertaken far less frequently and their results soon become out of date. For dates other than those at which censuses and sample surveys are undertaken estimates have to be prepared from tax registers or on the basis of other supplementary information. In the more advanced countries extensive use is made of migration and vital statistics to bring census figures up-to-date. The collection of these figures will be considered in the next chapter. This chapter is confined to the three basic sources of population totals, namely census enumerations, estimates obtained from tax registers and sample surveys.

Census Enumerations.

De Facto and De Jure Definitions. A census of population is normally either a *de facto* or a *de jure* enumeration. In a *de facto* census each person is counted where he happens to be on census night, regardless of his normal place of residence, domicile, or abode. Visitors from other countries are included and residents on temporary visits to other countries are excluded. There is no ambiguity as to whether or not a particular person should be included and as to where each person should be enumerated. In a *de jure* census each person is allocated to his normal place of residence, abode or domicile, regardless of where he is on census night. Visitors from other countries are excluded and residents on temporary visits to other countries are included, either from information obtained from relatives who have remained behind or when they return. To the layman a de jure enumeration would appear to give a far more satisfactory figure than a de facto enumeration, but from the practical point of view the de facto principle is generally easier to apply and theoretically should give a more precise figure. In conducting a de jure enumeration various ambiguities arise in defining the terms usual or normal place of residence, abode or domicile.

In many countries a de facto census would probably give very nearly the same total as a de jure census because the number of residents who are omitted because they are temporarily outside the country concerned is often roughly balanced by the number of visitors from other countries who are included. However, this is often not the case with regard to African Negroid populations and in using figures of these people some care should be taken to ascertain whether they refer to the de facto or to the de jure population. In many parts of Africa, for administrative and fiscal purposes, the indigenous people are regarded as legally domiciled in their traditional rural areas. Large numbers of these people, particularly the adult males, leave their traditional homes for temporary employment in the money economy of their own or a neighbouring country. Although these migrant workers sometimes remain away from hbme for several years at a time, for some purposes they are still regarded as legally domiciled in their district of origin and are included with the population of that area. Figures of the population registered or domiciled in an area in this sense reflect a type of de jure enumeration. The extent to which de facto and de jure figures can differ is illustrated by the following figures for Southern Rhodesia and Basutoland. The 1951 census of Natives employed in Southern Rhodesia showed that out of a total of 530,203 employees 259,001 or nearly half were migrant workers from neighbouring territories.[1] On the other hand the 1936 census of Basutoland revealed that while there were 90,201 males between the ages of 15 and 50 years in the territory there were 78,604 males temporarily in the Union of South Africa.[2] Although *de facto* enumerations are to be preferred to *de jure* enumerations because of the ambiguities of definition introduced in attempting the latter, in some parts of Africa a *de jure* enumeration may simplify the work in other directions. This is illustrated by the following description of relevant aspects of the 1953 sample survey of the indigenous African population of certain districts in Southern Rhodesia.[3] Although this was a sample survey and not a complete census, the remarks made below are also applicable to census enumerations.

Except for a few thousand Africans who are recognised as permanent residents of the larger towns, every indigenous African in Southern Rhodesia is registered or legally domiciled in a rural African village or on a small African farm. Large numbers of these people, particularly the adult males, leave these rural areas for temporary employment in the money or European economy of Southern Rhodesia or the neighbouring territories. There is a growing tendency for the adult males to take their dependents with them, but at present the vast majority of the dependents remain in the rural African villages. The survey obtained figures of the *de facto* population of these villages and, in order to determine the total population legally domiciled

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(1) *1951 Census of Southern Rhodesia*, Government Printer, Salisbury, Southern Rhodesia, (1954), p. 116.

(2) Figures quoted by Kuczynski R.R. (1949), *A Demographic Survey of the British Colonial Empire*, Oxford University Press, Vol. II, p. 27.

(3) *Preliminary Report on Second Demographic Sample Survey of the Indigenous Population of Southern Rhodesia*, Central African Statistical Office, Salisbury, Southern Rhodesia, (1954).

in each district, particulars were also obtained of all absentees. Where an absentee has been away for a long time the particulars of his whereabouts and age are apt to be vague. If he left as a bachelor there is sometimes some doubt in the minds of the people being questioned as to whether or not he has taken up permanent residence elsewhere, whether or not he is married and if married, how many children he has. Information on the total number of persons domiciled in each district could be obtained by taking a de facto census of the whole country and analysing the returns by place of domicile. However, this would necessitate asking detailed questions on place of domicile, it would require a much larger field staff and it would lead to a considerable increase in the amount of analysis work to be done.

In determining a person's place of domicile, reference may be made to either where the person's family lives or, in the case of adult males, where he is registered for tax purposes. In many cases a man is registered where his family lives, but this is not always the case. Where the registers are not completely up-to-date they do not reflect recent movements. In some cases a movement may not be reported for several years. In the 1948 survey the enumeration was based on the place where each person, or his family, normally lives, but this resulted in some omissions. In the 1953 survey these omissions were reduced considerably, if not practically eliminated, by basing the enumeration on place of registration. Each field officer was supplied with a list of the taxpayers officially domiciled under each headman and the field staff was instructed to regard each taxpayer as domiciled in the village in which he was registered regardless of where he was actually living. In the case of other people, place of domicile was determined by place of registration of the male on whom they are dependent, or, if there was no such male, by reference to the place where the family lives. It is probable that women who have been absent for many years were missed altogether, but fortunately the women have not yet entered the money economy in large numbers.

Some of the customs of the people also have a bearing on the determination of place of domicile. In the case of polygamists the question arises as to with which wife the man should be enumerated, for each wife generally has a separate household. In some cases the wives live in different villages. Duplications and omissions were reduced to a minimum by regarding the husband as domiciled in the village in which he is registered. Where a man had several wives in this village care had to be taken to ensure that he was recorded only once. Although the women normally take up residence in their husband's village, cases were encountered where a woman was living with a man, but still regarded herself as a member of her parent's family, even if she had had children by the man with whom she was living. In general the women do not consider they have changed their place of domicile until the husband has completed or nearly completed the bridewealth or lobola payments and the children belong to their mother's family until these payments have been made. In questioning the woman's parents they will often regard her as an absentee from their home rather than as a member of her husband's family. This is probably a common custom amongst the southern Bantu. Junod refers to it with regard to the Thonga people who inhabit a large portion of Mozambique and also parts of the Union of South Africa and Southern Rhodesia.(1) A similar, but much stronger, view is held where a woman enters into a temporary marriage. Such temporary marriages or consensual unions are more common in the European economy than in the rural areas. To avoid ambiguity in the treatment of these cases the field staff was instructed to regard all women for whom lobola payments had not been completed as members of their parent's family for the purpose of obtaining the total or de jure population.

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(1) Junod H. A. (1927), The Life of a South African Tribe, MacMillan & Co., London, p. 120.

Another custom sometimes found in Southern Rhodesia and also reported by Junod[1] which has a bearing on de jure censuses is that of children being sent to the maternal grandparents shortly after they are weaned until they are approaching puberty. In view of the long-term nature of these movements, the children might be regarded as residents of the maternal grandparent's household which is often in a different village from that of the parent's household. However, the parents normally report these children as absentee members of their household. In the Southern Rhodesia survey the field staff was instructed to record them as de jure residents of the parent's household and to take care to regard them as only visitors to the grandparents.

Suspicions and Superstitions of the People. In taking any census it is desirable that the public concerned should appreciate the need for and objects of the census, for appathy and obstruction can greatly reduce the reliability of the results. By European standards the cultural level of most of the African Negroid people is very low. Relatively few of the people have had more than a very elementary education and the vast majority are quite illiterate and there is no obvious need for a census in the primitive economy and culture of the Negroids. Under these circumstances it is extremely difficult to get the people to appreciate the purpose and objects of an accurate enumeration. The problem is further complicated by a suspicion that there is some ulterior motive in census taking. Such suspicion is by no means unknown amongst the relatively well educated European populations. It is not surprising that it is very common amongst the primitive races of Africa. What is perhaps a natural suspicion

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(1) Junod H. A. (1927), The Life of a South African Tribe, MacMillan & Co., London, p. 61.

of government action is accentuated by the fact that in most parts of Africa the government is entirely or largely in the hands of Europeans who form only a small minority of the total population. These Europeans are often regarded as intruders who are primarily concerned with their own interests. The Negroids may often regard government action as a step taken to improve or consolidate the position of the Europeans at the expense of the Negroids. Unfortunately this suspicion of government action is not entirely unfounded. In Southern Rhodesia the compulsory movement of Negroids is still in progress.(1) Goldthorpe states that in East Africa "Forced labour has been raised for farms and plantations as well as for public work within the life time of many now living. Incomprehensible arrests and deportations are not unkown. Above all, fears that the Europeans may yet be contemplating settlements like these of the Kenya Highlands continue to be widespread."(2) Lord Hailey mentions numerious instances of compulsory work on public works and persuasive, if not compulsory, measures for the production of foodstuffs in the British, Belgian, French and Portugese colonies.(3)

Apart from the suspicions of the Negroids, difficulties arise from the traditional customs and superstitions of these people. Frazer reports that in Urundi-Ruanda the people are unwilling to mention the true names of children and adults to strangers because of a fear that this information will give the stranger a magical power over the persons concerned.(4)

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(1) Southern Rhodesia Government Gazette, Proclamations Nos. 4 to 16 of the 6th. February, 1953.

(2) Goldthorpe J. E. (1952) "Attitudes to the Census and Vital Registration in East Africa", Population Studies Vol. VI, p. 163.

(3) Lord Hailey, (1938) An African Survey, Oxford University Press, London, pp. 616-626 and 630-635.

(4) Frazer J. C. (1938) Native Races of Africa and Madagascar, Humphries & Co. London p. 234

This could be a serious difficulty in an enquiry in which it is necessary or desirable to record individual names. Goldthorpe reports that there appears to be a general belief in East Africa that it is unlucky to count people because it is likely to result in numericus deaths.[1] The report on the 1931 census in Nigeria refers to a superstition against the counting of women and children, it being believed that the women might run away and the children might die.[2] Such fears and beliefs are possibly encouraged by the activities of the Jehova witnesses since the Watch Tower followers are opposed to censuses on religious grounds. Opposition to village counts has been experienced in Southern Rhodesia in areas where the people have been influenced by these Watch Tower followers. In the Gold Coast a number of villages with a total population of about 20,000 had to be omitted from the 1948 census because of strong opposition to the census presumably because of either the traditional beliefs of the people or the influence of some alien religious belief.[3] Among many tribes there is also an initial period of seclusion and secrecy associated with the early life of a new born infant.[4] This period has been reported to last for as long as four months in the case of the Swazi of South Africa.[5] In some cases even the father may not see the child during this period. In other cases the infant is regarded as being an animal rather than a human being

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(1) Goldthorpe J. E. (1952) "Attitudes to the Census and Vital Registration in East Africa", Population Studies, Vol. VI, p. 163

(2) Census of Nigeria, 1931, Her Majesty's Stationery Office, London, Vol. II pp. 11-12.

(3) Census of Population, 1948: Report and Tables, (1950), Crown Agents for the Colonies, London. p. 9.

(4) Frazer J. G. (1938) Native Races of Africa and Madagascar, Humphries & Co., London , pp. 42, 44 and 93.

(5) Marwick B. A. (1940) The Swazi, Cambridge University Press, pp. 68 and 147.

until the umbilical cord has dropped off. The influence of these customs and beliefs is doubtless slowly being reduced by the infiltration of western civilization, contact with Europeans and as a result of the work of schools and missions. There are, however, still vast areas in Africa where these factors have made little or no impression on the traditional life of the indigenous population.

The suspicions of government action and the superstitions referred to above are factors which probably lead to some omissions even in the most carefully prepared census. Since the fears and superstitions affect some sections of the population more than others, they are also likely to lead to distortions in the sex and age distribution of the population. For example, if fears of forced labour are widespread it is to be expected that there will be a greater under enumeration of men than of women and children. On the other hand, it is to be expected that the men are less superstitious than the women because the men have probably been more influenced by European civilisation, schools, missions etc. The traditional superstitions of the people might therefore be expected to lead to a greater under enumeration of women, and possibly also children, than of the men. Under certain circumstances there might be an exaggeration of the population. This might occur where a small community, say a village or a small tribe, wishes to exaggerate its importance. Such exaggeration may be induced by a hope that the community concerned will thereby obtain more than its fair share of government assistance. However, on the whole there is more likelihood of under rather than over enumeration.

It is extremely difficult to determine to what extent the suspicions and superstitions referred to above affect the results of a census. Much depends on the success of pre-census propaganda, the training of field staff and the extent to which the enumerators are able to gain the confidence of the public. A check on the accuracy of a census might be made by undertaking a sample check immediately after the census using only the very best field staff. Such a sample survey might conveniently also obtain information on subjects not covered by the census. It is understood that the sample survey conducted in East Africa shortly after the 1948 census was designed to check the accuracy of the census and to provide additional information on ages and fertility. Up to the present no detailed report has been published.

Some indication of errors in a census may sometimes be obtained by examining the consistency of the results. One of the first subjects to be dealt with in a census, apart from population totals, is the sex and age composition of the population and this information may be used to check the accuracy of the enumeration of young children. It is well recognised that, in the absence of migration and abnormally large fluctuations in birth and death rates, it is to be expected that the largest number of persons at any individual year of age will be in the age group under one year. Thereafter the number of people at each individual year of age should decrease as age increases. The use of this general characteristic as a check on the omissions of young children may be illustrated by reference to the figures given in Table 1.

Table 1[1] Sex and Ages of Natives Under Five Years of Age in the Union of South Africa in 1946.

Age in Years	Males	Females	Total
0	75,716	80,917	156,633
1	100,197	104,984	205,181
2	110,353	116,130	226,483
3	114,429	120,059	234,488
4	113,653	118,775	232,428

(1) Seventh Census of The Union of South Africa, 7th., May, 1946, (1950), Government Printer, Pretoria. Vol. II, p. 283.

The number of children under one year of age is 24 per cent. lower than the number aged one year. This suggests a decline of 24 per cent. in the number of births between say 1945 and 1946 before any account is taken of the fact that relatively fewer of the 1945 births would have survived to the date of the census. The effect of mortality may be estimated by referring to an appropriate life table. The 1936 life table of the Coloured population of the Union of South Africa will be used here. This gives the total number of years lived in the first year of life as 88,023 for males and 89,652 for females from a radix of 100,000 births in each case.[1] Adjusting the number of children under one year of age by these values indicates that the 156,633 children enumerated under the age of one year are the survivors of 176,300 births. Similarly the appropriate life table figures for the age of one year indicates that the 205,181 children enumerated as one year of age are the survivors of 257,200 births. The apparent decline in the number of births is then 31.5 per cent. This very large decrease is a very strong indication that the census grossly under stated the number of children under one year of age. If it is assumed that the numbers aged one year are correct and if it is assumed that there was very little change in the birth rate, the 1936 life table of the Coloured population indicates that there should have been about 228,400 children under one year.[2] This is probably a conservative estimate for two reasons. In the first place the figures given in Table 1 indicate that there were also some omissions amongst the one and two year-olds and in the second place the 1936 life table

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(1) Sixth Census of the Union of South Africa, 1936, (1939), Government Printer, Pretoria, Vol. XI, pp. 5 and 7.

(2) Obtained by correcting the numbers aged one year by the life table ratio of the years lived in the first year of life to the years lived in the second year of life.

of the Coloured population is probably a conservative indication of Negroid mortality. According to this life table the expectation of life at birth is 40.18 years for males and 40.86 years for females, whereas Sadie has estimated that the Natives on the Witwatersrand have an expectation of life at birth of 35.7 years in the case of males and 37.1 years in the case of females.(1)

Further indications of census omissions might be obtained from an examination of the relative number of males and females in the younger age groups. At the time of birth there are normally about 106 males to every 100 females.(2) As a result of this there is normally a slightly larger number of males than females in the younger ages. An excess of females in the lower ages, as in Table I, indicates that the census omitted more males than females. From birth to the end of life, the mortality rates of males are generally slightly higher than those of females. The excess of males at birth therefore gradually gives way to a preponderance of females in the higher age groups. However, above the age of about fifteen years the sex and age distribution might be distorted by migration movements.

<u>Administrative Problems</u>. The main administrative problem in organising a large scale census in Africa is one of finding a sufficient number of reliable enumerators to complete the field work in a reasonably short time. Many areas are sparsely populated and the roads are generally poor and few and far apart,

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(1) Sadie J.L. (1951), "Differential Mortality in South Africa", <u>South African Journal of Economics</u>, Vol. 19, No.4, p. 361.

(2) See pp. 69-72 for further details.

so that the enumerators have to do a considerable amount of walking if they are to visit every dwelling. This, combined with the fact that the enumerators have to obtain the particulars by verbal questioning because of the illiterate population under consideration, means that each enumerator can deal with only a relatively small population. Consequently a relatively large number of enumerators is required if a census is to be completed in a short time. In most parts of Africa there is a very limited number of litterate and well educated people who can be used as reliable enumerators. The potential number of enumerators can be increased by lowering the acceptable standard, but this is likely to reduce the accuracy of the results. The desirable standard of enumerator is influenced by the number and detail of the subjects to be covered. A long complicated questionaire will require a higher educated and better trained enumeration staff than a short simple questionaire. Although there is a wide field of subjects on which information is required, a short simple questionaire is desirable both to keep the desirable standard of enumerator down to a minimum and to safequard against inaccuracies resulting from the public becoming confused, if not annoyed, by a large number of questions.

In general Europeans are likely to make better enumerators than members of the indigenous population because of their wider general knowledge, higher standard of education and perhaps higher standard of responsibility. However, the use of Europeans increases the cost of the enquiry, both because of the relatively high rates of pay that have to be offered and because of the necessity for providing them with suitable transport and camping equipment. Other disadvantages of using European enumerators are their lack of knowledge of the customs and superstitions of the people and the necessity of providing them with guides and interpreters. A well educated and responsible European enumerator may easily produce unsatisfactory results because he is not aware of local customs and superstitions or because of an unreliable interpreter. Amongst some tribes, for example the Matebele in Southern Rhodesia, the use of an interpreter reduces the Negroid's respect for an official and this could lead to poor results. Fortunately amongst other tribes the reverse is the case and an official gains prestige by using an interpreter even if it is known that he can converse fluently in the Native language.(1) Although Negroid enumerators are handicapped by a lower standard of education, a poorer general knowledge and less experience, they have a better knowledge of local languages, customs and superstitions. Provided care is taken to keep the scope of the enquiry within their grasp so that they fully understand what is required and provided they are properly trained, they should be able to produce satisfactory figures. In some cases they may even obtain better results than European staff. A comparison of the work of European and Native field staff was made in a pilot survey of Native Agriculture in Northern Rhodesia and it was found that the Native staff obtained the best results. This survey was suspected of being a disguised method of introducing contour ridges which are unpopular, and consequently the landholders tended to avoid drawing attention to out of the way and hidden fields. Because of their local knowledge, familiarity with Native life, suspicions etc. the Native team leaders were far more successful in obtaining the confidence of the population and made a more complete survey.(2)

Amongst European populations a census is invariably organised by dividing the whole country up into a large number of

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(1) Holleman J. F. Shona Customary Law, Oxford University Press, London, (1952), p. x.

(2) Pilot Sample Survey of Native Agriculture in Northern Rhodesia, 1950, Central African Statistical Office, Salisbury, pp. 1-3.

small enumeration areas and the enumeration is done by each enumerator making a personal visit to each dwelling within his particular enumeration area. Very detailed particulars of each person are recorded separately although it is convenient to group the people so that each household or family is enumerated on a separate form. Sufficient enumerators are usually appointed to complete the census in two or three weeks. By this standard the 1948 census of East Africa was an outstanding achievement. The whole area covered by the census was divided up into small enumeration areas as is normally done in taking a census of Europeans and the 17,576,000 Negroid population in Kenya, Uganda and Tanganyika was enumerated by some 25,000 enumerators in only one week![1] Perhaps in this case too much emphasis was placed on the need for a rapid enumeration. It is of considerable interest to note that the 1950 census of the United States of America, in which all the returns referred to the position on the Ist. of April, was spread over a period of three months.[2]

In the more advanced countries such as the United States most of the population is litterate and census taking is considerably simplified by the fact that the public usually fills in most of the census forms. If there is some delay in reaching some of the people, the position on the date of the census can be recalled without much difficulty. In Africa retrospective returns in respect of a past census date are not likely to be very reliable unless the people concerned are interviewed within a few days of the census date. The reason for this is the fact that the primitive African is not very familiar

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(1) Martin C. J. (1949) "The East African Population Census, 1948", Population Studies, Vol. III No. 3 p. 303 and (1953) "Some Estimates of the General Age Distribution, Fertility and Rate of Natural Increase of the African Population of British East Africa", Population Studies, Vol.VII, No.2

(2) United States Census of Population: 1950, United States Government Printing Department, Washington D. C. (1952), Vol. I, p. IX.

with the days of the week and the days of the month and the position on a certain day has to be ascertained by referring to the number of days that have passed rather than to the name of the day in a particular week or to a particular date. The difficulty of obtaining information in respect of a past census date may be circumvented by relating each return to the date of interview and using the average of these dates as the date of the census as a whole. Unless there is a substantial migration during the period of the census, the extension of the period of enumeration to perhaps up to two months should have little effect on the accuracy of the results, provided special attention is paid to the enumeration of visitors in a *de facto* census. The natural growth of the population contributes very little to the error in the returns. A rate of increase of 2.5 per cent. per annum, which is a high rate of growth, would amount to only approximately 0.4 per cent. over a period of two months. In a *de facto* census spread over a period of several weeks or months there is a danger of an appreciable downward bias resulting from the short-term movements of the people. Normally members of a household who are away on a temporary visit would not be enumerated at home, but would be enumerated with the family to whom they are paying a visit. Where a *de facto* census is spread over a period of weeks or months members of a household who are away on temporary visits are apt to be missed altogether, for they are likely to have returned home by the time an enumerator reaches the household they have been visiting. However, cases will occur in which visitors are found who were previously enumerated at home or with some other family. Although there may be a temptation to avoid duplicating persons who have already been enumerated, enumerators should be instructed to take care to make such duplications in order that the effect of the omissions referred to above may be cancelled out. In a *de jure* enumeration persons temporarily away from home would normally be included and visitors to the household being enumerated would normally be excluded. Errors of omission and duplication should therefore not arise in a *de jure* census except as a result of the complications arising from the application of *de jure* definitions, to which reference has already been made.

The official reports on censuses usually omit to give details of the time taken and the method of enumeration used. However, it is to be expected that in most cases a shortage of enumerators has necessitated spreading the work over a much longer period than the week required for the East African census and often also to the adoption of some form of collective or group enumeration. In the case of the 1948 census of the Gold Coast the enumeration was spread over a period of six weeks.[1] Three and a half months were required for the 1945 census of Nyasaland and group enumeration had to be resorted to. The inhabitants of each village were called together, sorted into a small number of groups by sex and age and a simple count taken of each group.[2] It is understood that in the Union of South Africa and Mozambique the inhabitants of several villages are sometimes called together for a census. However, in these cases the particulars of each individual are recorded separately, the people being called together merely to save the enumerator the time required to visit each individual dwelling.

Although the calling together of the people, for either collective or individual enumeration, reduces the time required to enumerate the population, especially where the dwellings are

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(1) *The Gold Coast Census of Population, 1948: Report and Tables*, The Crown Agents for the Colonies, London, (1950), pp. 1, 2, 8 and 9.

(2) *Report on the Census of 1945*, Government Printer, Zomba, (1946), pp. 1-2.

difficult to get to or are scattered over a wide area, it is likely to result in some omissions. Persons who are unable to attend the gathering because of illness, having to attend to the live-stock or guard the crops from wild animals, etc. can easily be under reported. Where the fears, suspicions and superstitions referred to previously are widespread, it is probable that full advantage is taken of the opportunity for under-statement. There is also the probability that the inhabitants of isolated dwelling and villages which are not known to exist before the census will not be called to the central meeting place.

Estimates Obtained From Tax Registers.

Direct taxation of the indigenous population usually takes the form of a personal tax on males over the age of about fourteen to sixteen years, or a tax on dwellings. For the purpose of collecting these taxes a tax register is compiled which records the taxable units by chiefs, headmen, villages or other convenient administrative units. These registers are used extensively as the basis of population estimates.

A common form of estimation is to multiply the number of taxable units by an arbitrarily determined coefficient. The so called censuses of the Sierra Leone Protectorate are nothing more than crude estimates obtained in this way. In the 1931 census in this part of Africa some attempt was made to obtain a satisfactory coefficient. A number of "representative" villages were arbitrarily chosen by each District Commissioner and counts were taken in these villages to determine the coefficient. These counts covered between two and twenty five per cent. of the district populations.[1] A similar method has been used in East Africa for many years. In this case the 1948

(1) Kuczynski R. R. (1948) A Demographic Survey of the British Colonial Empire, Oxford University Press, London, Vol. I pp. 32-34.

census provided a check on the accuracy of these estimates and it revealed a twenty per cent. under-statement.[1] In Southern Rhodesia the same method has been in use since 1901 and, for the Colony as a whole, the estimates based on taxpayers were less than three per cent. above the results of the 1948 sample survey.[2] However, the second survey carried out in 1953 revealed that the 1948 enquiry omitted a large number of the adults.[3]

In a number of other countries the tax registers are extended to record the total population of each village or other convenient unit. In Northern Rhodesia the Provincial Administration obtains these particulars by village counts conducted by the District Commissioners and Officers in the course of their normal tours within their districts. These counts are, however, not made at regular intervals. In adding up the village figures to arrive at district and national totals no allowance is made for the natural growth of population in the villages which have not been visited for a long time. Nor is the dates of the counts taken into consideration. The figures published for any particular date reflect the date at which the recorded village totals are added up rather than the date at which the basic information was obtained. It is therefore not surprising that the 1950 sample survey revealed that these estimates under-stated the total population by approximately nine per cent.[4] This survey also obtained details of the

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(1) Methods of Estimating Total Population for Current Dates, Manuals on Methods of Estimating Population, Manual I, United Nations, (1952), p. 21.

(2) Shaul J.R.H. and Myburgh C.A.L. (1949), "Provisional Results of the Sample Survey of the African Population of Southern Rhodesia", Population Studies, Vol. III, No.3, p.274.

(3) Preliminary Report on the Second Demographic Sample Survey of the Indigenous Population of Southern Rhodesia, Central African Statistical Office, Salisbury, S. Rhodesia, (1954).

(4) 1950 Demographic Sample Survey of the African Population of Northern Rhodesia, Central African Statistical Office, (1952)

rate of natural increase and is the basis of the population estimates prepared by the Central African Statistical Office. In the French colonies a system whereby each village is visited at regular three, or four, yearly intervals is in operation, but so far no check of these counts has been made by either a census or a sample survey. In the Belgian Congo the tax registers have been extended to a form of national population register with the issue of identity cards to each person. The population figures obtained from these registers are checked periodically by investigations in a number of arbitrarily chosen "representative" villages.[1] Population estimates based on tax or population registers are generally thought to be unsatisfactory and this view is supported by the few cases in which it has been possible to check the figures by comparison with census or sample survey results. Although the Belgian Congo has kept a check on its population register by a crude form of sampling, the fact that it has taken steps[2] to introduce more scientific sample enquiries indicates that the results obtained so far are not entirely satisfactory.

Any observed errors in estimates obtained by applying a coefficient to the number of taxable males or dwellings may be attributed to the careless way in which the coefficients are obtained rather than to any basic weakness in the principles involved. It must be admitted that the number of units actually registered for tax is probably less than the number of units legally liable to taxation, for some evasion is inevitable. However, this can be taken into consideration in arriving

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(1) Lord Hailey (1938), An African Survey, Oxford University Press, p. 121 and Demographie Conglaise:1950, Service des A.I.M.O., du Gouvernement General, Leopoldville.

(2) See Neesen V. (1952) "Un Nouvel Echantillon de la Population du Ruanda Urundi" and d'Arianoff A. (1952) "Premieres realisations dans le domaine des Statistiques demographiques au Ruanda Urundi", Bulletin Mensuel des Statistiques du Congo Belge, No. 21.

at the coefficient to be applied to the number of taxable units actually on the registers. What is required is the relationship between the total population and the actual number of units registered for taxation and not the theoretical relationship between the total population and the number of units theoretically liable to the taxes. An accurate census of the whole country or a comprehensive sample survey can be used to obtain reliable coefficients. Estimates obtained from tax registers are of considerable value even if censuses are held regularly. No country can expect to take a census every year, but annual estimates are required for many purposes and the tax registers are an obvious source of such estimates, particularly where little or nothing is known about migration movements and the magnitude of the births and deaths. The main weakness with the coefficients used in the past is that they have been guessed or at the best obtained from arbitrarily selected, and therefore invariably biased, samples.

A factor to be taken into consideration in estimating the total population from the number of registered taxable units is the effect of the evolution of time on the reliability of the coefficients. A change in taxation policy will require a revision of the coefficients. The cofficients may get out-of-date by a change in the extent of tax evasion. In some cases the number of units appearing on the registers may also be subject to an artificial seasonal movement. For example, in Southern Rhodesia the registers are brought up-to-date in June and July of each year. Thereafter deletions, due to deaths and exemptions, are made as they occur, but no additions are made until the following June and July. A coefficient calculated on the position in early August is likely to give a substantial under-statement of the population if applied to the numbers on the registers say six months later. This source of error can be quite appreciable, perhaps up to four per cent., because of the high birth and death rates found in Africa. There may also be seasonal movements of the population to and from labour markets which would affect estimates of the <u>de facto</u> population although the movements of migrant labourers would not affect the <u>de jure</u> position. Over a number of years changes in the age composition of the population, particularly in the ratio between total population and adult males, may be large enough to introduce a significant bias.

<u>Sample Enquiries.</u>

The main problems of obtaining population figures in Africa may be very briefly summarised as follows:

(1) Owing to the illiterate nature of the population, the poor means of communications and the shortage of enumeration staff, a properly conducted census is often out of the question. If a census is taken it has to use an undesirably low standard of enumerator, group enumeration may have to be used and the actual enumeration may have to be spread over a long period of time.

(2) The African's suspicions of government action and the inherent superstitions of the people are likely to give a downward bias to the results of exen a properly conducted census.

These difficulties can be reduced by conducting a sample enquiry. The fact that only a small part of the population is to be included in the survey immediately alleviates the first group of problems listed above. Further, considerably more time and effort can be devoted to the training of the enumerators, who will in any case be of a relatively high standard because only a limited number will be required, and more attention can be paid to the second group of problems. The use of sampling techniques introduces a new element of error, called the sampling error, the magnitude of which depends on the design and size of the sample. This error is, however, measurable from the sample. Provided care is exercised in designing and selecting the sample, the sampling error should be unbiased, that is to say the sample result will have just as much chance of being above the true figure as it has of being below it and the sampling error shows by how much the sample result can be expected to differ from the true figure. It is well recognised that under favourable conditions the total error from a sample, that is the sampling error plus the reporting errors in the returns, can be less than the errors in the returns of a complete enumeration.(1) These favourable conditions are probably to be found in demographic studies of the indigenous populations of Africa. Another important consideration is the fact that a sample enquiry is likely to be very much more economical than a complete census because it will cover only a relatively small section of the total population. Because of the relatively small number of returns to be analysed it is also to be expected that the results of a sample enquiry will be obtained in a far shorter time than the results of a complete census. It is now common practice for countries with large populations to obtain the first results of a complete census from a sample of the census returns, so that the first results of the more important characteristics of the population can be released in the shortest possible time.

The main disadvantage of a sample is that it cannot provide the detailed geographical distribution provided by a census. This detail is required for administrative purposes and the administrator has to choose between sample results which are relatively free from bias, but lacking in detail, and detailed geographical figures which are almost certain to contain an unknown downward bias. It should be remembered that the detail

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(1) See Manuals on Methods of Estimating Population, Manual I, (1952), United Nations, New York, p. 44.

available from a sample is largely a function of the size of the sample, so that a good deal of satisfactory detail, for example figures by administrative districts, can be obtained from a large sample. However, at the same time it must be remembered that every increase in the size of the sample will tend to introduce more of the bias obtained in a complete enumeration.

There are several early examples of crude forms of sampling in African demographic studies. Reference has already been made to the attempts to obtain improved coefficients for the purpose of estimating the total population from the number of tax units, by conducting counts in "representative" villages in connection with the 1931 census of the Sierra Leone Protectorate and the estimates in the Belgian Congo. Another example is the "Intensive Census" in Northern Nigeria in 1931, in which detailed counts were carried out in "specially selected" villages, covering four per cent. of the total population, to ascertain various characteristics of the population.[(1)(a)] There are also several examples of early attempts at sampling in the study of the fertility of women. Medical "censuses" covering 0.1 per cent. of the populations in Northern and Southern Nigeria were held in 1930-31.[(1)(b)] In the Gold Coast in 1931 each Medical and Health Officer was instructed to question a hundred "old women" taken "haphazardly" regarding the births and deaths of their children[(1)(c)] and a similar enquiry was conducted in Nyasaland in 1926 by District Commissioners.[(2)]

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(1)(a) Kuczynski R. R. (1948) A Demographic Survey of the British Colonial Empire, Oxford University Press, London, Vol. I p. 564.

(1)(b) Ibid. p. 677 (1)(c) Ibid. p. 467

(2) Nyasaland Protectorate: Report on the Census of 1926, Government Printer, Zomba, p. xxi.

Unfortunately these early enquiries produced figures of doubtful accuracy, mainly because the units included in the samples were not selected in a random manner. The units included in a sample should be chosen without any reference to personal opinions as to their "representativeness" and regardless of the physical difficulties likely to be encountered in obtaining the returns. If this principle is not adhered to the results are almost bound to be biased. The weakness of the early attempts at sampling may be attributable to the inexperience of the people attempting them and the fact that most of the development of modern sampling theory and technique has taken place in very recent years. The first general reference book on the application of sampling techniques to human populations was not published until 1949(1) Three other major works have appeared since then.(2)

The application of modern sampling techniques to demographic studies in Africa began in 1947. In that year Shaul drew up a plan for an extensive sample survey in Southern Rhodesia(3) and the present writer undertook a pilot survey.(4) A large scale sample survey was held in Southern Rhodesia in 1948.(5) In the same year sampling techniques were used in

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(1) Yates F. (1949) Sampling Methods for Censuses and Surveys, Charles Griffin & Co. London.

(2) Deming W. E. (1950) Some Theory of Sampling, Cochran W. G. (1953) Sampling Techniques, Hansen M. Hurwitz W. and Madow W. (1953) Sample Survey Methods and Theory, (two vols.), all published by Wiley & Sons, New York and Chapman & Hall, London.

(3) Shaul J. R. H. (1947) Proposals for a Sample Census of the African Population of Southern Rhodesia, Central African Statistical Office, Salisbury, Southern Rhodesia.

(4) Shaul J. R. H. and Myburgh C. A. L. (1948) "A Sample Survey of the African Population of Southern Rhodesia", Population Studies Vol II, No. 3, p.339.

(5) Demographic Sample Survey of the African Population of Southern Rhodesia, (1951), Central African Statistical Office, Salisbury, Southern Rhodesia.

British East Africa[1] and the Gold Coast.[2] This was followed by a sample survey in Northern Rhodesia in 1950[3] and pilot surveys in the Sudan in 1951-52[4] and in Ruanda Urundi in 1952.[5] A second survey of Southern Rhodesia is being undertaken over the years 1953-55. It is unfortunate that no adequate reports have been published on the 1948 samples in East Africa and the Gold Coast. The need for detailed reports has been emphasised by the United Nations Organisation and this body has prepared a detailed plan for the guidance of reporters. Attention is drawn to the need for giving details of the sample framework, the design of the sample, the methods of selecting the sample, the sampling errors and any biases there may be in the results.[6] Detailed reports on these aspects of a sample survey provide information for the assesment of the reliability of sample, and they are also of considerable value to persons planning similar surveys at a subsequent date.

The need for adequate reports of sample surveys in Africa is accentuated by the peculiarities of the tribal, administrative and social organisation of the people and their customs, superstitions and suspicions. Although several text books are now available on the theory of sampling as applied to human populations, the practical application of this theory is considerably assisted by an examination of the detailed reports regarding the methods used to meet the peculiarities of African conditions. A sample survey may be regarded as a count or

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(1) Martin C.J. (1949) "The East African Population Census, 1948", Population Studies, Vol. III No. 3 p. 303.

(2) Gold Coast Census of Population, 1948. Report and Tables, (1950) Crown Agents for the Colonies, London.

(3) 1950 Demographic Sample Survey of the African Population of Northern Rhodesia, (1952), Central African Statistical Office, Salisbury, Southern Rhodesia.

(4) Harvie C.H. (1950) "A Sample Census in the Sudan", Population Studies, Vol IV No. 2 p. 241.

(5) Neesen V. (1952) "Un Nouvel Echantillon de la Population du Ruanda-Urundi", Bulletin Mensuel des Statistiques du Congo Belge et du Ruanda-Urundi Vol. 3 No. 21.

(6) The Preparation of Sample Survey Reports, United Nation, New York, Statistical Papers Series C, No. 1 (Revised) (1950)

or census of certain specially selected areas or groups of people, so that the practical problems of census taking referred to in a previous section are also encountered in a sample enquiry, although on a smaller scale. Some practical aspects of choosing the sample framework, selecting the sample units and calculating sampling errors are discussed below.

<u>Sample Framework</u>. The first requirement in conducting a sample survey is an accurate and comprehensive framework. This is a complete list of all the units, areas or groups of people in the population to be sampled. Unless practically every person, known or unknown, can be fitted into such a framework the sample will be biased because certain people have no chance of being included in the sample. The framework of the samples that have been undertaken in Africa to date have varied with local conditions.

As far as population totals are concerned, it is desirable, in the interests of efficiency, that the basic sampling units be as small as possible, for the efficiency of a sample, as measured by its sampling error, generally increases as the size of the unit decreases.(1) In demographic studies the smallest possible unit is the individual, but if a framework of individuals can be compiled there is no need to take a sample to ascertain the total population. The next smallest possible unit is the household or dwelling. In Africa, taxable adult males might be used to identify households and as stated previously a record of dwellings is sometimes kept for tax purposes. However, a framework of taxpayers or dwellings is not likely to be complete because there is bound to be some tax evasion. Taxpayers or dwellings are also not entirely satisfactory as the basis for a sample because they are scattered over the whole country and a sample of such units will require the field staff to undertake a considerable amount of travelling. Although the sampling errors can be expected to be relatively

(1) This generalisation is not entirely true for samples designed to obtain vital statistics and attributes of the population. See pp. 79-80 and Deming W.E. (1950) <u>Some Theory in Sampling</u>, Wiley and Sons, New York and Chapman and Hall, London, pp. 189-212.

small, apart from elements of bias, the scattered nature of units will necessitate using a large field staff and will raise the cost of the survey to a relatively high figure. A basic unit somewhat larger than a household or dwelling is therefore desirable for a single stage sample or for the first stage of a multi-stage sample. Taxpayers have, however, been used to select second-stage units in sample enquiries in the Sudan. Further particulars of this are given later.(1) Taxpayers can also be used as a control and as the basis for ratio sampling. It is well known that the coefficient of variation of ratios is generally less than that of absolute values.

In many parts of Africa the next largest cluster of people is the village. The village headman is normally recorded in the tax registers and it is a relatively simple matter to compile a list of these for use as a sample framework. However, such a framework may not cover the whole country and in the areas to which it does refer it is possible that the registers do not record all the villages. The sample surveys conducted in Southern and Northern Rhodesia are based on a framework of villages. In both these territories certain areas are set aside for European occupation and in general the registered villages are not situated in the European areas, although there are large numbers of Negroids in the European areas as temporary migrant workers. In Southern Rhodesia the surveys have been confined to the registered villages, the Native population in the European areas as a whole being obtained by recording the population absent from the registered villages. In the 1950 survey in Northern Rhodesia supplementary information on the *de facto* population of the main European towns and the European farms was obtained from supplementary sample enquiries using dwellings and farms as basic sampling units. In Southern

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(1) see pp. 51-2.

Rhodesia the registers of villages are revised annually and are considered to be complete. The 1950 survey of Northern Rhodesia could not be undertaken until the Provincial Administration had brought the registers up-to-date by extensive tours undertaken by the District Commissioners and Officers.

Omissions of villages from the tax registers are probably groups of people, including taxpayers, who have broken away from an older parent village which is recorded. If there are many of these new villages the registers would have to be revised before they could be used as a framework for a sample. If the number of new villages is small they might be treated as offshoots of the parent villages and the lists of taxpayers used to ensure that they are not omitted. The tax registers may also be out of date in that some of the registered villages may have completely disintegrated and ceased to exist. The inhabitants of the disintegrated villages may have attached themselves to other villages or they may be living as isolated family units. Provided there are not many of these cases, the field staff could be required to track down the people concerned using the lists of taxpayers as a control. Where a large number of the people live in isolated family units rather than in physical villages, the adoption of this method of enumeration will result in a considerable increase in the travelling time required to conduct the survey and there are likely to be many omissions. Although it is common practice for the tax units to be recorded by so-called village headmen, in some parts of Africa the inhabitants live in scattered family units and not in physical villages. This is general in the Eastern part of Africa and each of the three territories which have undertaken sample surveys under these conditions have used a different type of framework.

In British East Africa the problem of sampling a scattered population was met by using the enumeration areas used for the

1948 census as the basic sampling units. Ordinary census enumeration areas were also used as the basis of the 1948 sample survey in the Gold Coast, but this was because of the unsatisfactory state of the registers of villages and not because the population lives in scattered family units.(1) The use of enumeration areas as the basis of a sample ensures that everyone is included in the framework since every part of the country is covered by the subdivision into enumeration areas. However, the delimitation of a country into enumeration areas requires a considerable amount of preparatory work and it is likely to be a relatively inefficient basis for a sample because there is likely to be a wide range in the total population of the enumeration areas. The efficiency of the sample might be increased by stratifying the areas by size of population and by obtaining the required figures from ratio estimates. For the latter purpose the population of each enumeration area at the date of a previous census might be used(2) or the number of tax units in each enumeration area might be obtained.

In the southern provinces of the Sudan the practical difficulties arising from a dispersed population were met by a combination of multi-stage and a form of cluster sampling.(3) In the first stage of the sample a number of tribal headmen were selected at random. In the second stage one taxpayer for each headman was selected from the known taxpayers and particulars were then obtained for his family and a predeter-

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(1) Gold Coast Census of Population, 1948. Report and Tables (1950), Crown Agents for the Colonies, London. p. 9

(2) For an example of such a survey see Jessen R.J., Blythe R.H. and others (1947) "On a Population Sample for Greece", Journal of the American Statistical Assoc., Vol. 42, No. 239 p. 357

(3) Harvie C.H. (1950) "A Sample Census in the Sudan", Population Studies, Vol. IV, No. 2, p. 241.

mined number of the families nearest to the selected taxpayer, regardless of whether they were represented on the tax registers or not. The number of families counted under each headman was proportionate to the number of his taxpayers. In the course of the survey the number of taxpayers actually enumerated was recorded separately and the sample was designed to determine the ratio between total population and the known number of taxpayers.

The use of the list of taxpayers for selecting the cluster of people for the second stage of a sample may give biased results because families with more than one taxpayer, for example a family with a father and grown up but unmarried sons, have a greater chance of selection than families with only one taxpayer. However, the number of families with more than one taxpayer is likely to be small. If the individual dwellings are out of sight of one another, either because they are scattered over a very wide area or because they are hidden in forrests, the field officer will have difficulty in locating the required dwellings. If he has to be guided by the headman the latter is given an opportunity of not disclosing the families who have evaded taxation.

A two stage system of sampling has also been adopted in Urandi-Urundi, the third territory in which a sample enquiry has been undertaken in an area with a scattered population.(1) In this case the first stage was a sample of sub-districts, the smallest administrative unit. Within each of these units the population lives in individual family units clustered on the thousands of hills found in this part of Africa. Groups

(1) Neesen V. (1952) "Un Nouvel Echantillon de la Population du Ruanda-Urundi" and d'Arianoff A. (1952) "Premieres realisations dans le domaine des Statistiques demographiques au Ruanda Urundi", Bulletin Mensuel des Statistiques du Congo Belge et du Ruanda-Urundi, Vol. 3, No. 21.

of two or three hills were used as the basis of the second stage of the sample.

<u>Selecting the Sample.</u> The units included in a sample should be chosen at random, without any reference to personal opinions as to the representativeness of the units. Experience has shown that if personal opinions are allowed to influence the selection, the sample is very likely to be biased and misleading. In practice the selection of a large truely random sample, such as one in which each unit included in the sample is selected by reference to a table of random sampling numbers, is a lengthy operation. The selection of the sample can be simplified by making a systematic instead of a truely random selection. Provided care is exercised with a systematic selection it can, for practical purposes, be regarded as equivalent to a random selection. Apart from the time and work saved in selecting the sample, a systematic selection can be used to obtain reasonably good estimates of the sampling errors in a relatively short time. This aspect of systematic samples will be considered in the following sub-section.

In its simplest form a systematic selection is made as follows: Suppose a sample of one nth of all the villages in a district is required. A list of all the villages is compiled, the villages being arranged alphabetically, geographically or in any other convenient order. The first village for the sample is selected at random from the first n villages on the list. Thereafter every nth village from this point is chosen. This simple method of selection is not entirely satisfactory, for there may be some cyclical fluctuation in the frame, not necessarily an obvious one, which may lead to a biased sample. This objection may be overcome by adopting Tukey and Youden's suggestion[1] of selecting a num-

(1) See Deming W.E. (1950) <u>Some Theory of Sampling.</u> Wiley and Sons, New York, and Chapman and Hall, London, pp. 96 and 352-55.

ber of sub-samples in a like manner, each with a random starting point, with the sum of the sub-samples equivalent to the desired sample. Thus if a sample of one nth of the units is required ten sub-samples, each of which is one tenth of the required size, may be chosen. The starting point for each would then be selected at random from the first 10n villages on the list and from each of these points every (10n)th village would then be selected.

The procedure outlined above is satisfactory when all the units are roughly the same size, but when there is a substantial variation in the size of the units a further modification is desirable. When the variability of the units is large, a random sample of these units can give biased results. As far as possible each unit's chance of selection should be proportionate to its size. For example, a unit with a population of 1,000 persons should have ten times as much chance of being selected as a unit with a population of only 100. This principle may be introduced by weighting each unit according to its size and making the selection on the basis of the weights. The framework may be visualised as a list of units in which each unit is repeated a sufficient number of times to raise its chance of selection to correspond to its size.

The detailed application of relating each unit's chance of selection to its size introduces an appreciable amount of work. A simpler approach is to divide the framework into a number of strata by the size of the units and making an independent selection from each stratum with each stratum's sampling fraction roughly proportionate to the average size of its units. If the sample is used to determine ratios and not absolute values, the possibility of a bias being introduced because units of varying size are given an equal chance of selection is reduced, unless the ratios are correlated with the size of the units. In ratio sampling it may in fact be preferable to stratify the units by characteristics other than size in order to increase the efficiency of the sample. This is probably the case in sampling for the ratio between the total population and the number of taxpayers, unless there is reason for thinking that this ratio is correlated with size of unit. The main purpose of stratifying a sample is to increase the efficiency of the sample by reducing the variability within each stratum. The important factors accounting for the variability in the ratio between total population and the number of taxpayers are such factors as distance from registration centres, accessibility of the units, racial or tribal variations etc. rather than variations in the size of the units.

The principles of sub-sampling outlined above may be used to check the quality of the field work. If the sub-samples are divided equally amongst the available field staff the consistency of the results provides a check on the reliability of the work of the individual field officers. Since each sub-sample covers the whole universe being sampled, differences between the work of any two field officers may be attributed to only two factors, namely pure chance variations between the results of two samples and variations due to differences in the standard of work. If a particular field officer produces results which differ from those of other field officers by more than can be reasonably expected by chance, there is a strong indication that his work is below the standard of the others. This system of checking the quality of the field work was used in the 1948 survey in Southern Rhodesia. The sample in each district was divided into two or three sub-samples and each field officer was allocated one sub-sample in each of three or four districts, so that his work could be checked against that of at least three other field officers. Unfortunately the field staff objected strongly to this system of checking their work and it has not been used again. Owing to the low density of population, there were numerous cases where a few isolated villages had to be enumerated by two or more field officers, each of whom had to make a special journey to that area. The field staff objected strongly to this duplication of travelling time, particularly as the time spent in enumerating a village was generally much less than that required to get to the village.

Sampling Errors: A knowledge of the sampling errors of at least the main results of a sample is always desirable, as the sampling errors are a simple and direct indication of the degree of confidence that can be attached to the results. The formulae usually given for the calculation of these errors are normally complicated functions taking into consideration the exact design of the sample. The application of these formulae usually involves a considerable amount of work. For practical purposes all that is required is a reasonably good estimate of the sampling error and this can be obtained with very little effort if the sample has been selected in a number of separate parts or sub-samples as outlined in the previous sub-section.

A sampling error is normally regarded as a measure of the extent to which the sample results might differ from the true figures. However, it may also be regarded as a measure of the variation in the results of a number of samples of equal size, the same design and taken from a common population at the same time. The standard error of a sample may therefore be obtained by comparing the results of the sub-samples which make up that sample. Since there will be only a few sub-samples as against hundreds, perhaps thousands, of units in the sample as a whole, this method of approach results in a considerable saving of time and work. The work may be reduced to a very simple calculation by estimating the standard error from the range of the results of the sub-samples.

from the range of the results of the sub-samples.

For example, take the variance formula[1]

$$V(r) = \frac{(1-f)\, n \sum_{s=1}^{n} (Y_s - r X_s)^2}{\left[\sum_{s=1}^{n} X_s\right]^2 (n-1)} \quad \ldots\ldots\ldots\ldots (1)$$

where $V(r)$ = required variance

$r = \sum_{s=1}^{n} Y_s \div \sum_{s=1}^{n} X_s$

f = sampling fraction

n = number of units in the sample

Y_s = number of persons with a particular characteristic in the s th unit in the sample (s = 1, 2, 3 .... n)

X_s = total population of the s th unit in the sample.

This formula involves a considerable amount of work since it necessitates calculating the value of $(Y_s - r X_s)^2$ or of Y_s^2, $Y_s X_s$ and X_s^2 for each unit in the sample. Where the sample is made up of a number of sub-samples selected in the manner described previously, the required variance may be estimated from the formula

$$V(r) = \frac{(1-f)\, n' \sum_{s=1}^{n'} (Y'_s - r X'_s)^2}{\left[\sum_{s=1}^{n'} X'_s\right]^2 (n'-1)}$$

$$= \frac{(1-f)\, n' \sum_{s=1}^{n'} \left[X'_s (r'_s - r)\right]^2}{\left[\sum_{s=1}^{n'} X'_s\right]^2 (n'-1)} \quad \ldots\ldots\ldots (2)$$

where n' = number of sub-samples

X'_s = total population in the s th sub-sample (s = 1, 2, 3 ..... n')

Y'_s = total number of persons with a particular characteristic in the s th sub-sample

$r'_s = Y'_s \div X'_s$

and $V(r)$, f and r remain as before. This introduces a considerable saving in work as all the units in each sub-sample are taken together and not treated separately. In formula (2) the X'_s values, in this case the total populations in the sub-

(1) See Yates F. (1949), Sampling Methods for Censuses and Surveys, Charles Griffin & Co., London, p. 213.

samples, are weights applied to the $(r'_s - \bar{r})$ values. Where all these weights are approximately the same, they may be replaced by their mean, $\bar{x}'$. Formula (2) then becomes

$$V(\bar{r}) = \frac{(1-f)\, n'\, \bar{x}'^2 \sum_{s=1}^{n'} (r'_s - \bar{r})^2}{(n'\bar{x}')^2 (n'-1)}$$

$$= \frac{(1-f) \sum_{s=1}^{n'} (r'_s - \bar{r})^2}{n'(n'-1)} \quad \text{.............. (3)}$$

Where all the x'_s values are approximately the same, the value of $\bar{r}$, which is the weighted average of the r'_s values, will be close to the straight average of the r'_s values. Further, the variance of $\bar{r}$ should not be very different from the variance of the straight average of the r'_s values. Consequently a further approximation may be introduced by adopting Mantel's method of estimating the standard error of a mean from the range[1] and putting

$$V(\bar{r}) = \frac{(1-f)(\text{range of the values of } r'_s)^2}{k^2} \quad \text{....... (4)}$$

where the range of the values of r'_s is simply the fifference between the highest and lowest values and k is a parameter, varing with the number of sub-samples used, which experience has shown to give unbiased estimates of the standard error of the mean when applied to the range. The values of k for the normal distribution for from from six to ten sub-samples are as follows:[1]

Number of Sub-samples	Value of k
6	6.2
7	7.2
8	8.1
9	8.9
10	9.7

(1) Mantel M. (1951), "Rapid Estimation of Standard Errors of Means for Small Samples", The American Statistician, Vol. 5, No. 4, p. 26.

Mantel has calculated the most efficient value of k for cases where the number of units used is less than six and greater than ten, but these are not likely to be required in the type of work under consideration here. Grubbs and Weaver have shown (1) that where more than ten units are being used more efficient estimates are obtained by dividing the units into two or more groups and using the ranges of each of these groups.

Although formulae (2), (3) and (4) given above refer to the variance of a ratio or proportion, it requires a change only in the notation to convert them into formulae for the variance of an average. For example for the variance of the average population per village all that is required is a change in the notation of r'_s and $\bar{r}$ to

r'_s = average population per village in the sth sub-sample

$$\bar{r} = \sum_{s=1}^{n} X_s \div n$$

Where a ratio or an average has been calculated an estimate of a total absolute number, such as the total population of the district or country, may be obtained from this ratio or average simply by multiplying the ratio or average by the appropriate total in respect of the district or country as a whole. For example, the total population of a district may be obtained by multiplying the average population per village by the total number of villages in the district. Similarly the total population may be obtained by multiplying the ratio of total population to taxpayers obtained in a sample by the the total number of taxpayers in the district. The standard error of the estimated total may be obtained by multiplying the standard error of the ratio or average by the same figure

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(1) Grubbs F. E. and Weaver C. L. (1947) "The Best Unbiased Estimate of Population Standard Deviation Based on Group Ranges", Journal of the American Statistical Association, Vol. 42, No. 238, p. 224.

used to obtain the total population.

The efficiency of the formulae given above is illustrated by the following example: The 1950 sample demographic survey of Northern Rhodesia included a sample of 108 villages in the Fort Jameson district. The sample was stratified by tribal areas and the total population was estimated from the ratio of taxpayers to population. The coefficient of variation of the estimated ratio was 0.0349. To compare this result with estimates obtained from formulae (2) to (4), the villages were divided into ten sub-samples in a systematic manner in the order in which they were enumerated. The first village went to the first sub-sample, the second village went to the second sub-sample and so on. Formulae (2) to (4) gave the following results:

Formula	coefficient of variation of ratio
(2)	0.036
(3)	0.041
(4)	0.038

The differences between these three coefficients of variation and the original value of 0.0349, which was based on formula (1), is sufficiently small to be ignored for most practical purposes. This is inspite of the fact that in this case the number of taxpayers in each sub-sample, the basis of the weights used in formula (2), varied quite substantially, namely from 215 to 404. The calculations on the basis of formula (4) took only about ten per cent. as long as the original calculations. This method of calculating variances also gave very good results in a sample analysis of the 1951 census of the European population of Southern Rhodesia.[1]

(1) A Method of Obtaining Preliminary Results of a Census of a Small Population by Sampling, Central African Statistical Office, Salisbury, Southern Rhodesia, (1953).

CHAPTER III

PROBLEMS AND METHODS OF OBTAINING STATISTICS ON MIGRATION MOVEMENTS, BIRTHS, DEATHS AND THE AGE DISTRIBUTION.

The need for reliable records of international migration, birth and death statistics and the age composition of a population is almost as great as the need for a reliable census or estimate of the total population. Apart from their use to arrive at, or to check, population estimates, records of the migration movements, births and deaths are essential for a study of the causes of population movement and growth, both in respect of the past and as a basis for estimates of future movements. Knowledge of the age composition of the population is of fundamental importance in the detailed study of birth and death rates and is also of considerable value in all social and economic studies.

Migration Movements.

Migration movements are of two types, namely internal and international migration. Internal migration is often of considerable local interest, but it is extremely difficult to measure because of the absence of restrictions on the internal movements of a country's population. International migration is primarily of national interest and the collection of statistics on international migration is facilitated by the restrictions normally imposed on persons moving from one country to another. Outside Africa international population movements are normally divided into two broad groups, namely the purely temporary movements of tourists, business executives etc., and the more permanent movements of immigrants and emigrants. Because of the purely temporary nature of the former, demographic studies are primarily concerned with the movements of migrants and often ignore the other movements. Although the distinction between migrant and other movements varies from country to country it is generally recognised that the term "immigrant" should refer to people intending to remain in the country for more than twelve months, including residents of that country who return after having been away for more than a year. Similarly it is recognised that the term "emigrant" should refer to persons leaving a country for an intended period of over twelve months.(1)

Amongst the African Negroid races the number of persons going from one country to another on short term tourist, holiday or business visits is probably negligible because of the low standard of living and income level of the people. The movement of permanent migrants, that is persons intending to make a permanent change in their country of residence, is probably quite significant, but in most parts of Africa the major portion of the Negroids moving from country to country are what might be termed temporary migrants. Unlike the average European migrant, these temporary Negroid migrants have every intention of returning home again. They are predominantly adult males in search of temporary employment in the money economy and they normally leave their wives and children at home. In the case of the Union of South Africa and Southern Rhodesia there are labour agreements with neighbouring territories which provide for the repatriation of migrant workers within a specified period. In terms of the Union-Mozambique labour convention, persons recruited in Mozambique for work in the Union of South Africa must be repatriated within eighteen months of their departure from Mozambique.(2) In Southern Rhodesia an agreement with Northern Rhodesia and

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(1) See Problems of Migration Statistics, (1949), Population Studies No. 5, and International Migration Statistics, (1953), Statistical Papers Series M/20, United Nations, New York.

(2) Official Yearbook of the Union of South Africa, No. 25, (1949), Government Printer, Pretoria, p. 504.

and Nyasaland provides for the repatriation of adult males within two years of their departure from home, unless they are accompanied by their dependents.[1]

The main obstacle to obtaining reliable records of inter-territorial movements of Negroid people is the impossibility of establishing emigration and immigration posts along the whole of the land frontiers of a country. In a few cases head counts of the total inward and outward movements have been attempted along the main migration routes. However, because it is a simple matter for the indigenous people to cross from one country to another almost anywhere along the international boundaries, these figures are incomplete. If there is any fear of government intervention in the plans of the people, many migrants will obviously avoid any check points which have been established. Examples of the type of information that is obtained are given below.

In Uganda head counts of the movements along the two main routes are made. Kuczynski has estimated[2] that in 1937 entry at other points amounted to 20 per cent. or more of the immigrants using the two main routes. In Southern Rhodesia counts are made of the inward and outward movements of people taking advantage of the free services supplied by the government. Free transport, food and accomodation is provided to and from points well inside Northern Rhodesia and Nyasaland. Inspite of the obvious incentives to take advantage of these facilities, it is reported that only 70 per cent. of the migrants are believed to use these free services.[1]

A number of countries have direct or indirect information of migration in only one direction. Thus in Southern Rhodesia

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(1) Official Yearbook of Southern Rhodesia, No. 4, (1952), Government Printer, Salisbury, p. 217.

(2) Kuczynski R.R. (1949) A Demographic Survey of the British Colonial Empire, Oxford University Press, London, Vol. II, pp. 244-5.

all Negroids seeking work in the money economy have to produce a registration certificate before they can be employed. Figures are available of the number of registration certificates issued to migrant workers from neighbouring territories.(1) Details of persons visiting Southern Rhodesia without seeking employment and of the dependents of those seeking employment are not obtained, but the number of these is not considered to be great. In Gambia records are kept of the number of people coming in from neighbouring territories for the purpose of farming for a temporary period of one or two years.(2) In the case of Basutoland(3) and Bechuanaland(4) records are kept of permits issued by the local District Commissioners to persons leaving for visits to, or employment in, neighbouring territories, but it seems likely that unrecorded movements are quite substantial. If there is the slightest difficulty or inconvenience in obtaining a permit there are bound to be many cases where the permits are not obtained because of the ease with which Negroids can cross international boundaries without any documents. The mere fact that a special visit, or detour, has to be made to an official may be sufficient reason for not obtaining a permit.

Further information on migration can be obtained from censuses and similar enquiries. Countries which have a large foreign born Negroid population normally obtain details of the birthplace, or country of origin, of the people whenever a census is taken. In a few cases this information has been

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(1) Official Yearbook of Southern Rhodesia, No. 4 (1952), Government Printer, Salisbury, p. 176.

(2) Kuczynski R.R. (1948) A Demographic Survey of the British Colonial Empire, Oxford University Press, London, Vol. I, pp. 333-7.

(3) Official Yearbook of the Union of South Africa, No. 25, (1949), Government Printer, Pretoria, pp. 1279-80

(4) ________ p. 1301.

supplemented by questions on lenght of residence, which should throw some light on the duration of stay of the temporary migrant workers. (Information on birthplace and length of residence might also be used to study internal migration.) An indication of emigration may be obtained from information collected in the home country on the number and whereabouts of absentees.

Particulars regarding birthplace and length of residence are not likely to be accurate if there is some incentive for the public to make false statements. Kuczynski believed(1) that the particulars obtained in the 1944 census in Bathurst, Gambia, are misleading. The census was used to allocate housing priorities, first priority being given to the home born and subsequent priorities being related to the length of residence of the foreign born. There was an obvious incentive for people to declare themselves as born in Bathurst and for those who did not do this to overstate their length of residence. Apart from any incentive for the public to make false statements, it is difficult to obtain reliable figures on length of residence because the primitive Negroid is not very familiar with the European system of measuring time. In many cases the Enumerators will have to estimate a person's length of residence by reference to such factors as the seasons of the year, how many winters or summers have passed, etc. It may be possible to choose a small number of well known events which could be used to determine maximum periods of residence. Apart from the Bathurst survey, the only other occasion on which any attempt has been made in a census to obtain information on the length of residence of Negroids is the 1948 census of the Gold Coast.(2)

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(1) Kuczynski R.R. (1948) A Demographic Survey of the British Colonial Empire, Oxford University Press, London, Vol. I, pp. 316-17.

(2) Gold Coast Census of Population, 1948, Report and Tables, (1950), Crown Agents for the Colonies, London, p. 17.

In this case particulars were obtained in respect of persons with a residence of (i) under one year, (ii) from one to five years and (iii) over five years.

Birth and Death Statistics.

Most countries in Africa have some system for the registration of the births and deaths of the indigenous population, either in respect of certain proclaimed areas, usually the main urban areas, or the country as a whole. In the case of the British possessions in West Africa some of these registers have been in operation for very many years. Sierre Leone started a register in 1801, Gambia in 1845, Lagos in 1892 and part of the Gold Coast in 1912.(1) Kuczynski has made a detailed study of the reliability of the information available in respect of the British colonies in Africa and he has shown that these records are, generally, unsatisfactory. This state of affairs may be attributed to three factors, namely

(1) The public's lack of interest in a birth and death registration system,

(2) The customs and superstitions of the people which interfere with birth and death registration systems, and

(3) Administrative difficulties encountered in setting up a sufficient number of registration centres.

Lack of Public Interest. A system for registering births and deaths serves two purposes. In the first place it provides the population with a permanent record and proof of births and deaths. In the second place it provides the administrative authorities with statistics of these vital events. The pro-

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(1) Kuczynski R.R. (1948), A Demographic Survey of the British Colonial Empire, Oxford University Press, Vol. I, p. 5.

vision of statistics is largely a by product of the arrangements for providing the public with a permanent record of the births and deaths, for the accuracy of the statistics depends primarily on the completeness of the birth and death registrations. The completeness of the registrations in turn depends largely on the extent to which the public requires and takes advantage of a system which provides a permanent record of the births and deaths. A birth certificate is basically proof of a person's age. In the more highly developed countries proof of age is often required on such occasions as a person's entry into a school, entry into certain fields of employment, the taking out of an insurance policy and in applying for a pension. Proof of death, in the form of a death certificate, is required by insurance companies before they will meet life insurance claims, and it is usually required in the settlement of deceased estates. In the more advanced countries reasonably complete records of deaths are obtained by making it illegal for a person to be burried before a death certificate has been completed, and the cause of death recorded, by a medical practitioner. Although the registration of births is also generally theoretically compulsory, the completeness of the birth registers depends primarily on the public's appreciation of the need for registering births. In many cases a baptismal certificate may be acceptable proof of age where a birth certificate cannot be produced and even in advanced countries there are probably some people who go through life without ever requiring any proof of their age.

Amongst Negroid populations there is as yet no widespread need for birth and death certificates in the every day life of the community. Generally little voluntary effort is made to take advantage of what birth and death registration facilities have been provided. Compulsory measures are not likely to lead to much improvement, unless a large reliable staff is employed to detect evasions and enforce the law. As a result of the influence of schools and missions and an improvement in the standard of literacy of the population, interest in birth and death certificates is increasing. In the vicinity of a school or mission it is not uncommon to find some people keeping records of the dates of birth of their children even if a system of registration is not available. However, it is still true to say that in most parts of Africa the population has no interest whatsoever in recording births and deaths. There is no need for death certificates except in the urban areas where it is normally required before burial can take place. While some Negroids can now appreciate the usefulness of a birth certificate, it is doubtful that any of them see any useful purpose in the registration of deaths.

Customs and Superstitions of the People. In view of the great interest Negroids have in procreation, it is surprising that there are some tribes who do not understand the rudiments of conception. Both in Nigeria and East Africa[1] there are tribes who ascribe conception to mysterious magico-religious agencies. Such people believe that no mention or record of the births should be made as this is likely to bring harm or death to the children. Reference has already been made to the widespread practice of concealing an infant from all except a small number of people for anything up to several months after birth.[2] This initial period of secrecy, besides delaying registration, gives ample opportunity for the practise of infanticidal customs. These practices obviously affect the accuracy of both the birth and the death registrations. It is well known that in the early days many tribes had infanticidal customs and it is probable that these have not yet died out completely.

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(1) Census of Nigeria, 1931, Her Majesty's Stationery Office, London, Vol. II pp. 12-13 and Goldthorpe J.E. (1952) "Attitudes to the Census and Vital Registration in East Africa", Population Studies, Vol. VI, p. 163.

(2) see pp. 29-30.

Another factor which might affect the accuracy of the birth and death registrations is the relative importance of the two sexes in the social system. Amongst matrilineal tribes the considerable importance of females might lead to fewer omissions in the records of the females than of the males. In matrilineal societies each couple desires to have one or two sons to continue the family lineage, but after that more sons tend to become a liability whereas all daughters are an asset. The daughters bring in bride-wealth whereas the sons have to be provided with the bride-wealth required for their marriages. It is therefore possible that even in patrilineal societies there is likely to be less omission in the female births.

Some indication of a tendency to omit more male than female births or vice versa may be obtained from the sex ratio of the reported births. Normally, there should be a slight preponderance of males and any marked departure from the normal sex ratio is a prima facie indication that the births have not been fully recorded. Lorimer has stated(1) that extensive investigations amongst all races under all climatic conditions for which accurate data are available have shown that amongst live births there are generally about 105 males per 100 females and that in only a few cases are there variations from this average by as much as 4 per cent. The League of Nations reported(2) that the female live births fluctuated around 48.5 per cent. of total live births. This corresponds to a ratio of 106 males per 100 females.

In any population some fortuitous variations from the normal position are bound to occur. The magnitude of these

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(1) Lorimer F. Social and Cultural Conditions Affecting Fertility in Non-Industrial Societies, Appendix A. (To be published shortly).

(2) 1942/44 Statistical Year-book, League of Nations, Geneva.

may be determined from the standard error of the sex ratio as given by

$$\sqrt{\frac{pq}{n}}$$

where p is the proportion of females, q is the proportion of males and n is the total number of births under consideration. If the difference between the observed proportion of female births and the normal of .485 is less than twice the standard error it may be purely fortuitous, but if it is as high as three times the standard error it is practically certain that it is not fortuitous.

It is possible that an abnormal sex ratio is a reflection of some peculiarity of the population under consideration. McMahon and Pugh have shown(1) that the proportion of male births decreases as the age of the mother, and the number of previous births, increases. Lowe and McKeown have suggested(2) that these variations in the sex ratio are due to variations in the composition and incidence of abortions, miscarriages and still births. These investigations give possible explanations of significant variations from the normal sex ratio. For example, a high proportion of male births might be due to a high proportion of first births. The relatively low proportion of male births often reported for primitive peoples might be due to a relatively small proportion of first births and a high incidence of miscarriages and still births. However, before such explanations can be considered it is necessary to make quite sure that the returns being studied are complete and that the observed departures from the normal position are not due to reporting errors.

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(1) McMahon B. and Pugh T.E. (1953) "Influence of Birth Order and Maternity Age on the Human Sex Ratio at Birth", British Journal of Preventive and Social Medicine, Vol. VII, No. 2, p. 83.

(2) Lowe C.R. and McKeown T. (1951) "Secular Changes in the Sex Ratio", British Journal of Preventive and Social Medicine, Vol. V, No. 2, p.91.

Apart from errors arising from the omission of large numbers of one or the other of the sexes, a departure from the normal sex ratio may be due to a departure from the ideal definition of a live birth. The recommended definition[1] covers all births which show any sign of life at the moment of birth, including infants that die very shortly after birth. The normal ratio of 105 or 106 males per 100 females refers to live births in this sense. Departures from this definition can lead to a higher proportion of males. It is well known that there is a marked preponderance of males amongst abortions, still births, premature births and deaths in early infancy. The sex ratio at conception has been estimated to be as high as 170 males per 100 females![2] Owing to the heavy mortality of the male sex, the sex ratio normally falls to about 105 or 106 males per 100 females amongst live births and the proportion declines to less than 100 males per 100 females late in life. If the recorded births include a large proportion of still births, the sex ratio will tend to exceed the normal ratio for live births. Amongst African Negroid populations it is more likely that the recorded births exclude some of the children that died shortly after birth. This will lead to only a very small, if not a negligible, reduction in the proportion of males.

In theory it is to be expected that the errors referred to above will be reduced by keeping a separate record of still births. This will draw attention to the fine distinction between live and still births. The still birth figures are of interest to the medical authorities, but they are not likely to be reliable because of the difficulty of distinguishing between still births on the one hand and abortions and mis-

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(1) Principles for a Vital Statistics System, (1953), Statistical Papers, Series M, No.19, United Nations, p. 6.

(2) Baird D. (1950) Combined Textbook of Obstetrics and Gynaecology, (5th. edition), E. &. I. Livingstone, Edinburgh. p. 86.

carriages on the other hand. In practice it is probably impossible in many parts of Africa to improve the birth registrations by keeping a separate record of still births. This is because the still births are not readily reported as they are attributed to breaches of sexual taboos.(1) It is probable that some of the deaths in very early infancy are also attributed to breaches of these taboos. Amongst the older women in Southern Rhodesia and at least also amongst the Swazi of South Africa(2) another factor contributing to the omission of children that die in early infancy is a custom of not regarding a child as a human being until the navel string has dropped off. Amongst the Zulus of South Africa a child is not regarded as human until the age of puberty.(3)

Errors in the birth records due to the omission of children who die in early infancy will obviously also affect the records of deaths, particularly the infant deaths used in calculating the infant mortality rate. Fortunately when the births and deaths are combined to obtain the natural increase these errors cancel out. Amongst the death records of the older people omissions are likely to occur because there is a common superstition that to refer to a dead person will offend that person's spirit which might consequently harm the living.(4)

Administrative Difficulties. In general the normal administrative staff of an African country is only a very small frac-

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(1) Mitchell J.C. (1949) "An Estimate of Fertility of Some Yao Hamlets in Liwonde District of Southern Nyasaland", Africa, Vol. XIX, No. 4, p. 293 and Ashton H. (1952), The Basuto, Oxford University Press, p. 28.

(2) Marwick B.A. (1940) The Swazi, Cambridge University Press, pp. 68 and 144.

(3) Krige E.J. (1950) The Social System of the Zulus (2nd. Ed.) Shuter and Shooter, Pietermaritzburg, p.88.

(4) Goldthorpe J.E. (1952) "Attitudes to the Census and Vital Registration in East Africa", Population Studies, Vol. VI, p. 163, Fraser J.C. (1938) Native Races of Africa and Madagascar, Humphries & Co., London, p. 308, Mitchell J.C. (1949) in Africa Vol. XIX, No.4, p.293 and Ashton H. (1952) The Basuto, Oxford University Press, p. 113. Also Bullock C. (1927), The Mashona, Juta & Co., Cape Town, p. 269.

tion of the total population and consequently each administrative centre is responsible for a very large area. In view of the Negroid's lack of interest in birth and death registrations and the fears, superstitions and customs discouraging registration, a Negroid cannot be expected to go far to register a birth or a death. It therefore becomes necessary to establish numerous local registration posts.

In most countries it has not been possible to find the staff to cover more than a fraction of the total population. In most cases the registration system is confined to a small number of proclaimed registration areas where administrative staff is already available. The main towns are often chosen as the first registration areas. Here a relatively large population is concentrated into a small area and administrative staff is readily available. Complete registration of deaths is relatively easy to achieve in urban areas because steps can be taken to ensure that (i) all burials are made in proclaimed cemeteries and (ii) a person is not buried until his death has been registered. The maternity centres, hospitals, doctors, nurses and health inspectors may also be used to encourage and enforce registriation and to obtain reliable records of the cause of death.

However, there is the probability that the births and deaths registered in such areas are influenced by the movements of pregnant women and the sick into or from these areas. The presence of maternity centres and hospitals may tend to attract the pregnant and the sick from the neighbouring rural areas, but on the other hand the suspicions and customs of the people may work in the opposite direction. A record of the usual place of residence will help to eliminate any bias resulting from the attractions of the maternity centres and hospitals, but a bias in the opposite direction cannot be measured. Apart from these considerations, urban birth and death statistics cannot be regarded as representative of the country as a whole because they are biased by the urban conditions. In particular the birth and death rates will be influenced by the peculiar sex and age distribution of the population. In general there will be a marked preponderance of males of working age. The value of urban birth and death registrations would be increased considerably if they could be used to obtain an indication of the age specific fertility and mortality rates. These rates can provide measures of fertility and mortality which are independent of the sex and age composition of the population. In order to calculate these rates it will be necessary to determine the sex and age distribution of the urban population and the deaths and also the age distribution of the mothers of the registered births. In view of the scanty information at present available, such an analysis should be of value even if the ages are estimated only very roughly.

In a number of countries the administrative difficulty of finding sufficient staff to maintain the registers is met, either in certain proclaimed registration areas or over the whole country, by making use of the tribal organisation of the indigenous population. An outstanding example of this is the system in operation in Uganda. Kuczynski describes it[1] as "the most outstanding example of birth and death registration established by native authorities." The people report their births and deaths to their landlord, who passes the information on to the Gombolola chief. The latter renders a quarterly return to the Saza chief. These quarterly reports go from the Saza chief to the District Commissioner, to the Provincial Commissioner and finally to the Director of Medical Services. Theoretically the reports are checked at each stage of their

(1) Kuczynski R.R. (1949) A Demographic Survey of the British Colonial Empire, Oxford University Press, Vol. II, pp. 112 and 271.

progress to the Director of Medical Services, but in practice the checking is often neglected and the returns for many areas are faulty. As Kuczynski pointed out, the accuracy of these returns could be improved if they were checked more conscientiously. However, there are also the customs and superstitions referred to in the previous sub-section to contend with.

The Uganda system could not be applied to an area where no literate person can be found to fill in the returns. In Mozambique an attempt has been made to deal with the problem of illiteracy by requiring the village headmen to make regular verbal reports to their nearest District Commissioner. This system has not yet produced satisfactory results. For the years 1945-52 the registered births fluctuated erratically between 33,621 and 50,185 and the registered deaths ranged from 30,533 to 39,118.(1) Assuming that the population increased at a compound interest rate between the 1940 and 1950 censuses, the annual rate of natural increase was 11.5 per 1,000, whereas the registered births and deaths give an average rate for the 1945-52 period of only 1.3 per 1,000!

<u>Sampling</u>. In view of the various difficulties referred to in the previous sub-sections, it seems very unlikely that many African countries will be able to obtain reliable figures of births and deaths, from birth and death registers for large areas, in a reasonably short time. Under these circumstances the only hope of getting reasonably satisfactory vital statistics in the near future is by sampling. However, the extension and improvement of the normal birth and death registration system should be encouraged as much as possible to hasten the day when these records will reach a satisfactory state of completeness. There are two methods of approach that might be adopted in sample

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(1) Figures supplied to the author by the Director of Statistical Services, Lourenco Marques.

enquiries. In the first place the enquiries might only obtain statistics and not be concerned with the establishment of a registration system. In the second place a sample of small areas might be selected and an intensive drive made in these areas to establish an efficient registration system providing a permanent record of births and deaths as well as supplying reliable statistics.

The first method of approach produces statistics immediately and has been used in the 1948 sample surveys in Southern Rhodesia and East Africa, in the 1950 sample survey in Northern Rhodesia and is being used in sample surveys at present being undertaken in Southern Rhodesia and the Sudan. The framework used as the basis for these samples has been referred to previously.(1) The vital statistics sections of these surveys takes the form of obtaining retrospective particulars of the number of births and deaths that occurred during the twelve months preceeding the date of the interviews. Incidentally this method of approach can also be used to check the accuracy of a birth and death registration system.(2) Unfortunately the results of these surveys have not been entirely satisfactory. The East African results are of very doubtful accuracy.(3) In Southern Rhodesia reasonable birth and infant mortality rates have been obtained, but the overall death rate for 1953 is surprisingly low.(4) Some of the 1950 birth and

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(1) See pp. 49-53.

(2) Sekar C.C. and Deming W.E. (1949), "On a Method of Estimating Birth and Death Rates and the Extent of Registration", Journal of the American Statistical Association, Vol. 44, p. 101.

(3) Martin C.J. (1953), "Some Estimates of the General Age Distribution and Rate of Natural Increase of the African Population of British East Africa", Population Studies, Vol. VII, No. 2, p. 181.

(4) Preliminary Report on the Second Sample Demographic Survey of the Indigenous Population of Southern Rhodesia, Central African Statistical Office, Salisbury, (1954).

death rates obtained in Northern Rhodesia are extraordinarily high and the infant mortality rates are high in relationship to the crude death rates.

There are two types of bias that might occur in enquiries of this type. Firstly there are the errors arising from the customs and superstitions referred to previously and secondly errors might arise because the period under consideration is not properly understood by the public, so that the returns in fact refer to a period of less, or more, than a year. The errors arising from the customs and superstitions of the people are not likely to be eliminated altogether. The best that can be expected is for them to be reduced to a minimum. Advance publicity, particularly word of mouth publicity by local official on every convenient occasion, on the objects and purpose of the enquiry, careful training and instruction of the field staff and unhurried field work can all help to reduce the errors.

Since the vast majority of the indigenous peoples of Africa have only a very vague idea of the measurement of time, unsatisfactory results are to be expected if they are simply asked to state the number of births and deaths that occurred during the previous twelve months. Instead, it is necessary for the field staff to ascertain as best they can when the last event occurred and from this decide whether or not it should be included and whether or not further questioning is necessary. For this purpose they might be supplied with lists of the main characteristics of the seasonal agricultural activities and the seasonal weather conditions by months, so that the date of each birth and death can be estimated. In some cases the indigenous people have a lunar calender which could be of assistance. A record of the births and deaths in a period of less than a year is likely to give more accurate returns, particularly if the beginning of the period is fixed by some well known event. However, the returns of the deaths, and possibly also the returns of the births, would then be influenced by seasonal factors. The complication arising from seasonal fluctuations might be met by repeating the enquiry say two or three times to obtain returns for a full year, but obviously this would result in a considerable increase in the cost of the survey.

In view of the difficulties and weaknesses of the sample surveys referred to above, it is suggested that another approach be adopted and an attempt made to establish permanent registers in a number of sample areas. The maintenance of a permanent birth and death registration system in the sample areas will be a relatively expensive method of obtaining statistics, but provided a serious attempt is made to get complete registration it should produce really satisfactory figures. To begin with there might be only one such registration area, with a population of perhaps between 300 and 5000, but in the first instance the objective should be to cover the whole country on a sample basis. Reliable estimates for the whole country will not be available until the whole country has been covered in this way. The various sample registration areas should be decided upon at an early stage and the collection of the returns expanded as rapidly as possible until the whole country is covered by a sample network. After this stage has been reached the sample could be expanded to provide say provincial as well as national figures. By the gradual addition of further registration areas the scheme could be expanded until the whole country is covered by a permanent registration system. This is a long term project, but reliable national figures should be available shortly after the initial stage of covering the whole country by a sample of small registration areas has been reached.

It is suggested that the basic sample units, that is the registration areas, be small enough for the appointed local registrar to become quite intimate with the people under his control. The unpopularity of the registration system should not be increased by prosecutions for failure to register births and deaths. It is suggested that in the first instance it should be the local registrar's duty to make regular and frequent visits to all the families in his area to detect and record the births and deaths. He should take note of the women who are obviously pregnant and also of the illnesses of the people, so that he has advance notice of the births and deaths. At a later stage these duties might be reduced gradually and the public required to report their births and deaths to him at his office. This would be an opportunity for expanding the registration area to cover new ground.

An unfortunate feature of any scheme for obtaining birth, death and infant mortality rates by sampling is the fact that a relatively large population has to be included in the sample in order to obtain an acceptable standard error. This is because the standard error depends largely on the number of births and deaths included in the sample and even the highest rates give a relatively small number of births and deaths for any given population. For example, a birth and death rate of 70 and 25 per 1,000 persons respectively and an infant mortality rate of 200 per 1,000 births give only 70 births, 25 deaths and 14 infant deaths for every 1,000 of the total population. The size of the required sample depends on the maximum standard error that can be accepted, the design of the sample and the variability between the sampling units.

For many purposes a standard error much in excess of 5 per cent. of the relevant rates is not likely to be acceptable. The rates are not likely to change rapidly and unless relatively small standard errors are obtained the gradual changes which are taking place will not become apparent for

for some time. Further, the variance of the rate of natural increase, which is the birth rate less the death rate, is the sum of the variances of the birth and death rates.[1]

It has been stated previously[2] that in designing a sample it is generally desirable to use the smallest possible unit as the basic sampling unit because the smallest unit generally gives the smallest standard error. This is true for samples designed to estimate population totals, but it is not entirely true for samples designed to obtain vital statistics. Standard errors generally decrease as the size of the basic unit decreases because of a reduction in the variability between the basic sampling units. However, under certain circumstances the variability between the basic units increases with a reduction in their size and this is the case with vital statistics where the basic unit is small. Where the units are small villages, say with an average population of fifty persons, there will be numerous cases in which there are no infant deaths to be recorded, so that the infant mortality rate may be as low as nought. There will be cases where there is one birth and one infant death, giving an infant mortality rate of 1,000. Cases might even occur where there is no birth but an infant death, the latter being a child born the previous year which died in the current year before its first birthday. The infant mortality rates of individual villages will therefore range from nought to infinity! There will also be a marked variability in the village birth and death rates. If the basic sampling unit is increased to groups of villages, small enumeration or registration areas, the extreme rates will disappear and the efficiency of the sample will increase. However, it

(1) Yates F. (1949) Sampling Methods for Censuses and Surveys, Charles Griffin & Co., London, p. 196, formula (7.5c).

(2) See p. 48.

is to be expected that after a certain point is reached further increases in the size of the basic unit will lead to a reduction in efficiency because of the increasing importance of regional differences in fertility and mortality. In a sample designed primarily to produce vital statistics, such as the sample of registration areas suggested above, special attention can be given to the relationship between the size of the basic unit and the variability of the vital statistics. In the samples so far used to provide vital statistics in Africa the design of the sample has been primarily concerned with the most efficient, or most convenient, unit with regard to estimates of the total population.

Estimating Ages.

The basic difficulty in obtaining age particulars of the Negroid populations is the ignorance of the people of any system of measuring time in years. In areas where schools and missions have been established for some time quite a large proportion of the people will have quite a good knowledge of their date of birth or age. However, Goldthorpe reports(1) that in parts of East Africa the indigenous population have a superstitious objection to stating their correct age even when they knew it. This might be overcome by asking for date or year of birth rather than age. In the case of adults it sometimes happens that a person knows the date or year of birth, but cannot calculate his present age. It is therefore suggested that a question on present age be asked only when a person cannot state his year of birth.

In all African countries there are at least some areas, or sections of population, where many of the indigenous people have not the vaguest idea of their date of birth or age.

(1) Goldthorpe J.E. (1952) "Attitudes to the Census and Vital Registration in East Africa", Population Studies, Vol.VI, p. 163.

Nevertheless details of the quinquennial age distribution, or figures for individual years of age, have been published for censuses in Angola, Mozambique, Sierre Leone Colony, the Union of South Africa, Basutoland, Bechuanaland and for Lagos in Nigeria. Similar information was obtained in the 1931 sample enquiry in Northern Nigeria and in the 1948 sample surveys in East Africa and the Gold Coast. In all these cases the enumerators or field officers must have had to estimate the ages of a considerable proportion of the population, particularly amongst the adults, but there is very little or no indication in the official reports as to how these estimates were made. In the Sierre Leone Colony, where details of the age distribution date back to 1891, it appears that the enumerators were instructed to enter on the forms what they considered to be a reasonable age.[1] In the 1948 sample fertility survey in the Gold Coast the field officers were instructed to "enter the age as nearly as can be ascertained either by enquiry or from the woman's appearance...... If a woman was married before the end of the first big war (1918) she can be assumed to be more than 45 now. Any other known event which can be associated with date of marriage can be used in a similar manner to estimate age. Assume in each such case that the woman was at least 15 years old when married."[2] Instructions such as these are vague and are bound to lead to very rough, if not misleading, age statistics. Better results are likely to be obtained by estimating ages from the physical and social changes that take place in the life of the people and from a cronological table of well known events. Some details are given below. To obtain accurate figures of the detailed age distri-

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(1) Kuczynski R.R. (1948) A Demographic Survey of the British Colonial Empire, Oxford University Press, Vol. I, p.174.

(2) Gold Coast Census of Population, 1948, Report and Tables, (1950), Crown Agents for the Colonies, London, p. 414.

bution of a population the field staff has to spend quite an appreciable time questioning each person and some preliminary research work is necessary before the detailed instructions can be prepared. Apart from the work involved this might be considered impracticable in certain cases where a poor standard of enumerator has to be used. In such cases it is suggested that more satisfactory results would be obtained if a concentrated effort is made to obtain reliable figures for a small number of broad age groups. The detailed age distribution could then be interpolated from these figures and, provided care is exercised with the classification of the borderline cases, these interpolated figures are likely to be at least as good as the detailed figures based on very rough estimates of each person's age. A method of interpolating the detailed age distribution from particulars in respect of three broad age groups is outlined at the end of this section.

Ages of Children. Several attempts have been made to ascertain the number of children under one year of age by reference to the ability to walk, it being assumed that the infants who cannot walk are under one year of age. This method seems to be based on the experience of child development amongst Europeans. In the case of the 1945 census of Nyasaland(1) and the 1948 census of the Gold Coast(2) it is reported that the use of this yardstick resulted in an over-statement of the number of children under one year of age. It would appear that the Negroid custom of a mother carrying her infant on her back for more than the child's first year of life was overlooked, either in the instructions to the field staff or by the field staff. The latter tended to assume that all children being

(1) Nyasaland Protectorate, (1946) Report on the Census of 1945, Government Printer, Zomba, p. 11.

(2) Gold Coast, (1950) Census of Population, 1948, Report and Tables, Crown Agents for the Colonies, London, p. 13.

carried by their mothers were still unable to walk, without enquiring about the child's ability to walk. It is to be expected that a mother finds it convenient to carry a child for some time after it has taken its first uncertain steps. This practice may also retard the child's development, so that Negroid children do not in fact start walking as early as European children. A more satisfactory method of obtaining the number of children under one year would appear to be to attempt to determine each child's age in months from the date of birth and from this decide whether or not it should be recorded as under one year. If the mother cannot state in what month a child was born reference may be made to the primitive lunar calender found in some areas,[2] or a calender of the seasonal agricultural activities and weather conditions may be compiled for the use of the enumerators.

For the older children this method of approach is not likely to be very satisfactory because of the relatively long period of time that has elapsed since the date of birth. Reference might then be made to typical activities of children of different ages. For example in a medical survey in East Africa[1] boys not trusted to herd goats and girls unable to carry water were classified as under six years of age. Boys herding goats but not trusted with cows and girls able to carry water in small tins were allocated to the six to eight age group. Boys herding cows alone and girls able to carry water and pound maize were classified as nine to twelve years. Similar characteristics of various age groups which might be used in estimating ages are referred to in various anthropological studies. A general tendency for children to be weaned at the age of about two years is often mentioned. The herding of goats by

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(1) Kuczynski R.R. (1949) A Demographic Survey of the British Colonial Empire, Oxford University Press, Vol. II, pp. 143-4.
(2) For example see Stayt. H.A. (1931), The Bavenda, Oxford University Press, p. 228.

boys from the age of four to the age of six is mentioned by Krige[1] and Marwick[2]. Junod[3] refers to Thonga boys being promoted to the herding of oxen at about ten or eleven. Ashton mentions that the Basuto boys do not normally start wearing any clothing until the age of about seven.[4] Talbot[5] states that in Nigeria girls are not allowed palm-wine until they are about ten years of age.

A rough estimate of the age of a child might also be obtained from an examination of the teeth. Amongst European children the first teeth usually appears before the ninth month[6] and at twelve months there are usually six to eight teeth. There are twenty temporary or deciduous teeth altogether and they have normally all appeared by the age of two and a half years. There is then a break of about four years before the permanent teeth start appearing. The first permanent molars, which appear behind the temporary teeth, are commonly called the six year old molars because they erupt at this age. By this time a child has lost one or more of its temporary front teeth and the first permanent front teeth also make an appearance at the age of six years. Thereafter permanent teeth appear at more or less regular intervals until the age of about twelve years. There are then no further teeth until the wisdom teeth come out. The most easily recognised stage in tooth development is the stage at which one or more of the front teeth

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(1) Krige E.J. (1950) The Social System of the Zulus, (2nd. edition), Shuter and Shooter, Pietermaritzburg, p. 76.

(2) Marwick B.A. (1940) The Swazi, Cambridge University Press, p. 149.

(3) Junod H.A. (1927) The Life of a South African Tribe, (revised edition) MacMillan & Co., London, Vol. I., p. 62.

(4) Ashton H. (1952) The Basuto, Oxford University Press, p.33.

(5) Talbot P.A. (1923) Life in Southern Nigeria, MacMillan & Co., London, p. 225.

(6) McNiell K. (1951) The Health of the Child, Shuter and Shooter, Pietermaritzburg, pp. 142-3.

has fallen out. Amongst European children the first tooth is lost at the age of five or six years. Before any attempt is made to estimate the ages of Negroid children from their teeth, it is advisable that a study be made of the peculiarities of the particular population under consideration. Disease and malnutrition may retard the development of the teeth. Bennett has suggested[1] that the order and dates of eruption are subject to racial variations.

Puberty, or the Division Between Children and Adults. Amongst Negroid races the division between childhood and adulthood is normally made at, or shortly after, the age of puberty. The attainment of adulthood is well recognised by the Negroid races and in many cases one or more ceremonies are performed in recognition of a person's entry into the adult age group. Circumcision and clitoridectomy often takes place at this time. In some cases there are obvious indications that a person has reached adulthood. For example the Bris in Uganda and the Sudan are tattooed,[2] the Basutos have their noses bored,[3] the Thonga have their ears pierced,[4] the Bagesu have four teeth removed,[5] and in West Africa the teeth are sometimes filed[6] as a sign of adulthood. Even where there is no recognition of the attainment of adulthood in the form of some ceremony or other, as in the case of the Mashona in Southern Rhodesia, indirect questions on the attainment of puberty, such as "have you grown up?" or "are you fully grown?" are readily understood and answered without much bashfulness or reticence. However, direct questions on such factors as nocturnal emissions and the onset of the menses are resented.

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(1) Bennett N. (1931), The Science and Practice of Dental Surgery, Oxford University Press, Vol. I, pp. 45, 46, and 63.

(2) Frazer J.C. (1938), Native Races of Africa and Madagascar, Humphries & Co., London, p. 329.

(3) ———————— p. 99.

(4) Junod H.A. (1927), The Life of a South African Tribe, MacMillan & Co., London, p. 95.

(5) Roscoe J. (1924), The Bagesu, Cambridge University Press.

(6) Talbot F.A. (1923), Life in Southern Nigeria, MacMillan & Co., London, p. 215.

It is often assumed that the Negroid races reach puberty at an earlier age than the European races because of the tropical climates in which most of them live. However, Ellis has found[1] that the mean age of menarche was 14.4 years amongst Nigerian school girls as compared with 13.73 years amongst girls in Great Britain. An experienced medical officer in Nyasaland has also stated[2] that Negroid girls develop slower than European girls, but no figures are given. Apart from these considerations the division between children and adults referred to above probably often occurs later than the age of puberty amongst Europeans because it tends to be based on general physical development rather than a biological indication of puberty.

The average age at which a person is accepted as an adult should be known, so that the division between children and adults can be defined in years. It does not matter whether it is fourteen, fifteen or any other age, but it is important that it should be known. In most countries there are bound to be quite a significant number of persons up to the age of twenty of twenty five who know their age. These may be used to give a very simple estimate of the mean age at which the people are accepted as adults. All that is required is the number of these people at each year of age who fall into (i) the child and (ii) the adult age groups. The basic formula is[3]

$$\bar{y} = a + \sum_{s=a}^{n} x_s \quad \text{..................} \quad (5)$$

where $\bar{y}$ is the mean age at which a person changes from the child to the adult group, a is the youngest age at which

(1) Ellis R.W.B. (1950) "Age of Puberty in the Tropics", British Medical Journal, Vol. I, p. 85.

(2) Nyasaland Protectorate: (1946) Report on the Census of 1945, Government Printer, Zomba, p. 12.

(3) Hajnal J. (1953) "Age at Marriage and Proportions Marrying", Population Studies, Vol. VII, No.2, p. 111.

some of the people are in the higher group, x_s is the proportion of the persons known to be aged s years who are still in the younger group. s ranges from a to n, where n is the youngest age at which $x_s = 0$. The application of this formula is illustrated by the following calculations in respect of a sample survey carried out in certain districts in Southern Rhodesia in 1953.

The population included in this survey was classified into males and females under and over puberty. In addition actual age was recorded where this was known. These cases produced the following figures:

Proportion of Persons of Each Age Who Were Under Puberty: Southern Rhodesia 1953 Sample Survey.

Age in Years	Proportion of Persons Classified as Under Puberty	
	Males	Females
0–12	1.00	1.00
13	1.00	.97
14	.97	.80
15	.84	.36
16	.40	.10
17	.24	.05
18	.08	.02
19	.03	.01
20 and over	.00	.00

In the case of males $a = 14$ and $\sum_{s=a}^{n} x_s = 2.56$, so that the mean age of puberty is 16.56 years. Similarly in the case of females the mean age of puberty is $13 + 2.31$ or 15.31 years.

This method of estimating a mean age is likely to give biased results if there is any reason for believing that the reported ages are influenced by the division between children and adults under consideration. For example if a male should normally start paying tax at the age of eighteen years and taxpayers is used as a criterion of adulthood, it is likely that persons over eighteen years who have evaded taxation will tend to state that they are not older than seventeen.

Age Of Adults. The social and physical changes referred to previously in connection with the estimation of the ages of children may also be used to estimate the ages of the older people, that is those in the adult age group, if a cronological table of well known events is available. If a person's age at the time of some cronicled past event is estimated from the type of information given previously, his present age may be obtained by adding to this estimate the number of years that have elapsed since the event occurred. Unfortunately considerable difficulty is likely to be encountered in dating more than a few widely known events. Events which are well known to Europeans are not necessarily suitable. For example, a royal visit, or the outbreak of a war, is not likely to be well remembered by primitive people in remote areas who have no personal interest in such matters. Epidemics, droughts, destruction of crops by pests and similar disasters are likely to be useful if they have not been frequent. If they have been frequent, there is likely to be confusion over which particular epidemic or drought etc. is under consideration when the people are being questioned. The deaths of very popular, or unpopular, local chiefs might also be used.

In the case of adult males estimates of age might sometimes also be assisted by the age-set system of the people. Amongst some tribes all the youths who go through an initiation ceremony together, about the age of puberty, form what is termed an age-set. Each age-set is given a distinctive name. If the dates of the formation of the age-sets are known, a man's age can be estimated simply by asking him what age-set he belongs to. Amongst the Kikuyu of East Africa, a new age-set is formed each year.[1] In such a case considerable difficulty is likely to be encountered in dating all the age-sets, but once this has been done it should be possible to get a fine age classification of the population. More generally there is an interval of from about three to about seven years between the age-sets, or recognisable sub-divisions of broad age-sets. Because of the smaller numbers involved, the dating of the formation of the age-sets is then somewhat simplified.

Broad Age Groups and the Interpolation of the Detailed Age Distribution. Many African countries have so far attempted to divide their Negroid population into only a small number of very broad age groups. A division into children and adults is invariably attempted. Sometimes the children and adults are su-divided into two or three smaller groups. This considerably simplifies the work of the field staff. Provided care is taken with the allocation of the borderline cases and provided the divisions between the broad age groups are accurately known, a reasonably good interpolation of the detailed age distribution may be made from these particulars.

The age at which the division between children and adults is made varies from country to country and ranges from thirteen to eighteen years. The division is presumably based on some convenient indication of the end of childhood and the beginning of adulthood, such as the attainment of puberty, the attainment of marriageable age in the case of females and the age at which males are registered as taxpayers. It

(1) Middleton J. (1953), The Kikuyu and Kamba of Kenya, International African Institute, pp. 33-4.

is probable that the reported age division is only a very approximate one, often based on little more than guesswork. Where this is the case the particulars on age could be improved by determining the mean age at which the people pass from the one age group to the other by the simple method given by formula (5).[1] The same principle could be used to determine the sub-divisions of the children. However, it can probably not be used for the sub-divisions of the adults because it is unlikely that many of the adults will know their ages.

The adults are quite frequently divided into those under and over the age of fourty five or fifty. Normally no indication is given as to how this is done, but in the case of females an obvious basis for such a division is the age of menopause. To some extent this is assisted by the fact that the Negroid people sometimes have special terms for women past the childbearing period.[2] However, reference to the end of the childbearing period is not likely to give a very precise age division because the borderline cases will not be able to give a precise answer to a question on the menopause and in any case difficulty will be experienced in determining the mean age to which the division refers. According to Pearl[3] the mean age at menopause varies from population to population and ranges from 44.0 to 49.4 years with an average of 46.4 years.

Although the division somewhere about menopause may not be very precise, it is of considerable demographic value because it gives some idea of the size of the childbearing pop-

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(1) see pp. 87-89.

(2) Mitchell J.C. (1949) "An Estimate of Fertility of Some Yao Hamlets in Liwonde District of Southern Nyasaland, Africa, Vol. XIX, No. 4, p. 293, and Krige N.J. (1950) The Social System of the Zulus, (2nd. edition), Shuter and Shooter, Pietermaritzburg, p.32.

(3) Pearl R. (1939) The Natural History of Population, London, pp. 46-56 and Appendix.

ulation. However, in order that the users of the figures may not be misled, it is desirable that some indication be given as to how the age division was made. A statement to the effect that the women in the age group "over 45 years" in fact refer to those reported to be passed menopause indicates the roughness of the figures and gives some indication as to the direction of any bias in the published age division. For example, in this case the demographer could assume that these women might in fact be aged 50 years and over. On the other hand if it is stated that the women in the age group "over 50" refers to women passed menopause, the demographer is warned that the figures might in fact refer to women aged 45 years and over. If no explanation is given as to how the age division was made, one hesitates to make an assuption as to what age group the figures might relate to because there might be some special reason for the wording used. For example the phrase "over 45" might be preferred to "over 50" because all the borderline cases are included in the higher age group, or the phrase "over 50" might be used to indicate that all the borderline cases are included in the lower age group.

Given particulars in respect of three or more broad age groups, estimates of the numbers in smaller age groups may be obtained from an estimate of the cumulative frequency distribution. It is well known that the number of persons at any particular age is always slightly less than the number at the preceeding age, unless there have been changes in the birth and death rates and large migration movements to upset what might be termed the normal age distribution. For the normal age distribution the relationship between age and the total number of persons under that age may be approximated to a function of the form

$$Y_x = a + bx + cx^2 \quad \ldots\ldots\ldots\ldots\ldots \quad (6)$$

where Y_x is the total population under the age of x years and a, b and c are constants. Since there will be no persons under the age of nought years, the value of a is nought. The values of b and c may be obtained from any two known points on the cumulative frequency distribution. For example, the 1946 census of Swaziland[1] revealed that 48.7 per cent of the indigenous females were under 18, 35.3 per cent. were aged 18 to 50 and the remaining 16.0 per cent were over 50. There were therefore 48.7 per cent. under 18 and 84.0 (48.7 + 35.3) per cent. under 51. Therefore we have

$$48.7 = 18b + 18^2c \text{ and}$$

$$84.0 = 51b + 51^2c$$

These two simultaneous equations give 3.29 and −.0321 as the values of b and c respectively, so that the cumulative frequency distribution is estimated to be

$$Y_x = 3.28x - .0321x^2$$

An estimate of Y_x can now be obtained for any value of x. The estimated percentage of the total female population in any age group is then merely the difference between the value of Y_x for (i) the age at the lower limit of the age group under consideration and (ii) the age next above the upper limit under consideration. For example, when $x = 15$, $Y_x = 42.0$ and when $x = 20$, $Y_x = 52.8$, so that 42 per cent. of the population is under 15 years of age and 52.8 per cent. is under 20 years of age. Therefore 10.8 per cent. (52.8 − 42.0) is in the 15-19 year age group. Estimates for all the quinquennial age groups between the ages of fifteen and fourty nine years for the Negroid females in Swaziland and a number of other countries are given in Table A of the Appendix.

This is only a very rough method of estimating the detailed age distribution. It assumes that there have been

(1) Swaziland Census, 1946, Swaziland Government, Mbabane, (1950), p. 2.

no marked fluctuations in birth and death rates and no marked migration movements to affect the age distribution. Although it will be shown later(1) that there is reason for believing that the birth rate of the African Negoid populations has in general been declining, there is no reason for believing that it has at any time changed suddenly. It is likely that famines, tribal wars and epidemics have resulted in a fluctuating death rate, but the influence of these fluctuations on the age distribution may be ignored. Famine and epidemic deaths affect the people of all ages more or less equally. Deaths resulting from tribal warfare will affect mainly the able bodied males of the time of the war, but as far as the present population is concerned, they are likely to affect the age distribution of only the very old people. However, it is known that large migration movements are taking place, particularly amongst the adult males, and because of this formula (6) is not likely to give very satisfactory estimates of the age distribution of the male population, unless the immigrant population is excluded and the absentee population included.

From the demographic point of view, the age distribution of the adult female population is of particular interest and fortunately the age distribution of these people is not likely to be greatly affected by the present day migration movements. An advantage of this method of estimation is that the estimates are free from the rather erratic fluctuations often found where an attempt is made to estimate the age of each individual. These erratic fluctuations are generally an indication of reporting errors rather than a reflection of migration movements and variations in the birth and death rates.

Apart from the other considerations, the reliability of estimates obtained by means of formula (6) depends on the accuracy of the classification of the population into broad age groups. It is desirable that the ages at which the broad

(1) See pp. 109 and 205.

age groups are separated be known as accurately as possible. A minimum of three broad age groups is required, but a larger number is an advantage. For four groups formula (6) can be expanded by the addition of the term dx^3, but for more than four groups the addition of further terms leads to cumbersome calculations. For more than four groups a simpler method of approach is to fit formula (6), with or without the addition of a fourth term, to the known information by the method of least squares. Formula (6) should be used with considerable caution in estimating the population in an age group above the highest age used in obtaining the values of the constants, as an extrapolated figure is never as reliable as an interpolated one.

Some indication of the accuracy of this method of estimation is provided by the figures given in Table II in respect of the 1946 Native female population of the Union of South Africa.

Table II: Comparison Between Estimates Obtained from Formula (6) and Reported Figures, 1946 Native Female Population of Union of South Africa.

Age Group (Years)	Percentage of Total Population		Difference between the two sets of figures as percentage of the reported figures.
	Reported Figures(1)	Estimate based on total population aged 0-14, 15-49 & 50 and over.	
0 - 4	14.1	14.0	(+) 0.7
5 - 9	13.4	12.8	(+) 4.6
10 - 14	10.9	11.6	(-) 6.4
15 - 19	10.2	10.4	(-) 1.9
20 - 24	8.7	9.3	(-) 6.9
25 -29	8.1	8.1	....
30 - 34	7.1	7.0	(+) 1.4
35 - 39	5.6	5.8	(-) 3.6
40 - 44	5.1	4.7	(+) 7.9
45 - 49	3.9	3.4	(+)12.8

(1) Seventh Census of the Population of the Union of South Africa, 1946, Government Printer, Pretoria, (1950), Vol. II, pp. 283-4.

Assuming that the reported figures are correct, the estimates differ from the true figures by much less than 10 per cent. except in the case of the 45-49 year age group where there is a difference of 12.8 per cent. Both sets of figures are slightly biased by the omission of some of the young children.[1] The reported figures for individual years of age[2] reveal a considerable clustering at ages ending in an even number and also at ages ending in a five in the ages from twenty five onwards. This clustering at certain ages is a definite indication of reporting errors. These reporting errors affect the estimates based on formula (6) only in so far as they affect the totals of the 0 - 14, 15 - 49 and 50 and over age groups. As far as the reported figures are concerned, the reporting errors probably affect the totals for each quniquennial age group and except for the 45 -49 age group, the estimated figures might well be nearer the truth than the reported figures. In the case of the 45 - 49 year age group the estimated figure is so very much lower than the reported figure that it appears to have a definite downward bias. A bias in this age group is not surprising in view of the fact that it is at the end of the interpolated series. Although some bias is to be expected in the last of the interpolated figures, it will not necessarily always be in the same direction. A bias in the last one or two age groups must be balanced by an equal absolute bias in the opposite direction in the younger age groups. However, the bias in the younger age groups will be relatively small because of the relatively large numbers in the younger age groups.

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(1) see pp.31-2.

(2) Seventh Census of the Population of the Union of South Africa, 1946, Government Printer, Pretoria, Vol. II, pp pp. 283-4.

CHAPTER IV

THE ESTIMATION OF THE TOTAL FERTILITY RATE FROM THE AVERAGE NUMBER OF CHILDREN EVER BORN TO WOMEN QUESTIONED.

Basic Formulae.

For pratical purposes it is normally assumed that the reproductive period of women starts at the fifteenth birthday and ends at the fiftieth birthday. Reported births to women below or above these ages are invariably relatively insignificant and often they may be attributed to the faulty reporting of the mother's age.[1] In calculating age specific fertility rates it is usual to relate all births to women under the age of 20 years to the number of women aged 15-19 years and to relate all births to women aged 45 years and over to the number of women aged 45-49 years. In enquiries which have obtained particulars of the total number of children ever born to each women, the average number of children ever born to women aged 50 years and over is a direct measure of the total fertility rate in respect of a cohort of women which has actually passed through the whole of the childbearing period. However, this measure of the total fertility rate suffers from the following weaknesses:

(i) It is apt to understate the true position because there is generally a tendency for the older women to forget the children who died in infancy.

(ii) The estimates relate to the fertility experience of the distant past.

(iii) There may be some unkown correlation, positive or negative, between fecundity and longevity.

(iv) The estimates are based on a relatively small number

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(1) Kuczynski R.R. (1935) The Measurement of Population Growth, Sidgwick & Jackson, London, pp. 23-7 and 107-10.

of returns and are therefore likely to be subject to relatively large fortuitous errors.

The first three of these weaknesses can to some extent be reduced by excluding the very old women, say those aged sixty years and over, but such action would tend to exaggerate the fourth weakness. Far more satisfactory results are likely to be obtained if the relatively large number of women still within the childbearing period are taken into consideration. The complication arising from the fact that these women have not yet completed their reproductive history is considered below.

Let F_s = females aged s years at the date of the enquiry (s = 15, 16, 17.......... t),

$\sum_{s=15}^{t} F_s = M_t$ = total number of females aged 15 to t years inclusive,

A_s = total number of children ever born to the F_s females,

$\sum_{s=15}^{t} A_s = C_t$ = total number of children ever born to the M_t females,

r_s = average specific fertility rate (per female) at the age s years (here s = 15, 16, 17 .... 49 since r_{50} and higher values are assumed to be nil),

$\sum_{s=15}^{49} r_s = R$ = average total fertility rate, per female.

Then, when t is greater than 48, approximately

$$A_{15} = F_{15} r_{15} \qquad = F_{15}(R - r_{16} - r_{17} - \cdots r_{49})$$

$$A_{16} = F_{16}(r_{15} + r_{16}) \qquad = F_{16}(R - r_{17} - r_{18} - \cdots r_{49})$$

etc. up to $A_{49} = F_{49}(r_{15} + r_{16} + r_{17} + \cdots r_{49}) = F_{49} R$ and

$$A_{50} = F_{50}(r_{15} + r_{16} + r_{17} + \cdots r_{49}) = F_{50} R$$

$$A_{51} = F_{51}(r_{15} + r_{16} + r_{17} + \cdots r_{49}) = F_{51} R$$

etc. up to $A_t = F_t(r_{15} + r_{16} + r_{17} + \cdots r_{49}) = F_t R$

Adding all these lines together the approximations cancel out getting

$$\sum_{s=15}^{t} A_s = R \sum_{s=15}^{t} F_s - r_{16} F_{15} - r_{17}(F_{15} + F_{16}) - \cdots - r_s(F_{15} + F_{16} + F_{17} + \cdots F_{s-1}) - \cdots - r_{49}(F_{15} + F_{16} + F_{17} + \cdots F_{48}).$$

$$\therefore \; C_F = RM_F - \sum_{s=16}^{49} r_s (F_{15} + F_{16} + F_{17} --- F_{s-1})$$

$$\therefore \; \frac{C_F}{M_F} = R - \frac{\sum_{s=16}^{49} r_s (F_{15} + F_{16} + F_{17} --- F_{s-1})}{M_F}$$

Let $\dfrac{(F_{15} + F_{16} + F_{17} --- F_{s-1})}{M_F} = T_s$ ....(7)

and $r_s = RX_s$ then

$$\frac{C_F}{M_F} = R\left(1 - \sum_{s=16}^{49} X_s T_s\right) \qquad ....(8)$$

The values of X_s reflect only the relative differences in the specific fertility rates, the sum of all the values of X_s being equal to unity. The values of T_s are functions of the age distribution.

Normally age specific fertility rates are calculated in quinquennial age groups and the rates for each quinquennial age group is in fact a weighted average of the age specific fertility rates for the individual years within that age group. For practical purposes it may be assumed that

$$\sum_{s=16}^{49} X_s T_s = \sum_{s=1}^{7} X'_s T'_s$$

where X'_s is the weighted average relative age specific fertility rate for the s th quinquennial age group, (s = 1 for the 15-19 year age group) and

$$\left.\begin{array}{l} T'_1 = T_{16} + T_{17} + T_{18} + T_{19} \\ T'_2 = T_{20} + T_{21} + T_{22} + T_{23} + T_{24} \\ T'_3 = T_{25} + T_{26} + T_{27} + T_{28} + T_{29} \\ \text{etc.} \end{array}\right\} \qquad ....(9)$$

Formula (8) may then be re-written as

$$\frac{C_F}{M_F} = R\left(1 - \sum_{s=1}^{7} X'_s T'_s\right) \qquad ....(10)$$

so that $R = \dfrac{C_F}{M_F} \div \left(1 - \sum_{s=1}^{7} X'_s T'_s\right)$ .... (11)

In some cases it may be convenient, or because of faulty returns in respect of the older women it may be desirable, to confine the estimate to women up to an age below 49 years. Where the age of the oldest woman under consideration is the end of one of the normal quinquennial age groups, such as 39 or 44, the total fertility rate may still be estimated from formula (11). However, to allow for the fact that the oldest women under consideration has not reached the end of the child-bearing period, less than seven values of X'_s and T'_s should be used. For example, when women up to the age of 39 years are considered, only five values should be considered. Nevertheless, the X'_s values used in such a calculation should be the same as the ones which would have been used had the women up to the end of 49 years or older been under consideration; that is to say it is only necessary to leave out an appropriate number of the higher values of X'_s and not necessary to make any changes to the absolute values of the remainder.

The calculation of the T'_s values may be simplified by assuming that there is an equal number of persons at each individual year of age within each quinquennial age group. Then

$$\left.\begin{aligned} F_{15} = F_{16} = F_{17} = F_{18} = F_{19} &= \text{(say)} \ \frac{F'_1}{5} \\ F_{20} = F_{21} = F_{22} = F_{23} = F_{24} &= \text{(say)} \ \frac{F'_2}{5} \\ &\text{etc.} \end{aligned}\right\} \quad \ldots\ldots\ldots \ (12)$$

where F'_1 , F'_2 etc. are the number of females in the 15-19 year, 20-24 year age groups etc. From formulae (7) and (12)

$$T_{16} = \frac{F_{15}}{M_F} = \frac{F'_1}{5M_F}$$

$$T_{17} = \frac{F_{15}+F_{16}}{M_F} = \frac{2F'_1}{5M_F} \quad \text{and similarly}$$

$$T_{18} = \frac{3F'_1}{5M_F} \quad \text{and} \quad T_{19} = \frac{4F'_1}{5M_F}$$

But $T'_1 = T_{16} + T_{17} + T_{18} + T_{19}$

Therefore $T'_1 = \dfrac{F'_1 + 2F'_1 + 3F'_1 + 4F'_1}{5M_F} = \dfrac{2F'_1}{M_F}$

Similarly $T'_2 = T_{20} + T_{21} + T_{22} + T_{23} + T_{24}$

$$= \frac{F_{15}+F_{16}+ \cdots F_{19}}{M_F} + \frac{F_{15}+F_{16}+\cdots F_{20}}{M_F} + \cdots$$

$$\cdots\cdots \frac{F_{15}+F_{16}+\cdots F_{23}}{M_F}.$$

$$= \frac{5F'_1}{5M_F} + \frac{5F'_1+F'_2}{5M_F} + \frac{5F'_1+2F'_2}{5M_F} + \cdots \frac{5F'_1+4F'_2}{5M_F}.$$

Therefore

$$T'_2 = \frac{25F'_1 + 10F'_2}{5M_r} = \frac{5F'_1 + 2F'_2}{M_r}$$

and in general

$$T'_s = \frac{5(F'_1 + F'_2 + \cdots F'_{s-1}) + 2F'_s}{M_r} \qquad \ldots\ldots\ldots\ldots(13)$$

The bias resulting from the assumption that there is an equal number of persons at each individual year of age within each quinquennial age group may be examined by studying the results obtained from two extreme age distributions. For this purpose the 1940 females of Nicaragua are chosen as a population with a very rapid decline in the numbers at successive ages and the 1936 females of France are chosen as an example of the other extreme.(1) The relative age distributions of these two populations are as follows:

Table III: Age Distribution of Females in Nicaragua (1940) and France (1936)

Age in years	Percentage of total female population	
	Nicaragua	France
Under 15	42.1	23.6
15-19	10.7	5.2
20-24	8.7	6.9
25-29	7.6	7.7
30-34	6.2	7.7
35-39	6.0	7.5
40-44	4.9	6.8
45-49	3.6	6.5
50 and over	10.2	27.9

In the case of Nicaragua there is a fairly steady and rapid decline in the proportion at each successive age group and the numbers aged 45-49 years represent only 33.7 per cent. of the numbers aged 15-19 years. In the case of France the percentage in each age group rises to a peak in the 25-34 year age groups and then declines very gradually with the numbers aged 45-49

(1) See Table B of Appendix for details of the age distributions in various countries.

years 25 per cent. greater than the numbers aged 15-19 years. The percentage at each individual year of age for the ages from fifteen to forty-nine inclusive for these two countries were interpolated from a large scale free hand ogive of the above figures. These estimates were then used to obtain values of T'_s in terms of formulae (7) and (9). The effect of using formula (13) in place of formulae (7) and (9) may be studied by examining the values of $\sum_{s=1}^{7} X'_s T'_s$ obtained from the two sets of T'_s values for each country. The X'_s values used for this purpose are the figures for Nicaragua and France given in Table C of the Appendix. The two sets of figures are as follows:

Estimates of $\sum_{s=1}^{7} X'_s T'_s$ for Nicaragua and France.

Formulae on which T'_s values are based	Value of $\sum_{s=1}^{7} X'_s T'_s$ (1)	
	Nicaragua	France
Formulae (7) and (9)	.414	.212
Formula (13)	.411	.213

(1) These figures are in respect of all females aged 15 years and over. The exclusion of some of the older women, for example those aged 55 years and over, would result in all the figures rising as a result of a reduction in the common denominator of formulae (7) and (13).

The simplified method of calculating the values of T'_s as given by formula (13) results in a downward bias of only 0.7 per cent. in Nicaragua and an upward bias of only 0.4 per cent. in France.

In addition to the age distribution, it is necessary to know, or estimate, the distribution of the relative age specific fertility rates before the total fertility can be estimated from formula (11). An analysis of the young children, such as those under one or under five years of age, by age of mother, would provide a reasonably good indication of the relative age specific fertility rates. Since only the surviving children are considered, the total fertility rate obtained in this way will be understated by the number of children who have died. It is unlikely that these omissions will affect the relative distribution of the age specific fertility rates, as there is no reason for thinking that there is any marked correlation between the infant death rates and the age of mother. If the distribution of the relative age specific fertility rates is unknown and cannot be estimated it is necessary to assume that the distribution for some other country, or the average for a number of countries, is applicable to the population under consideration. Details of the relative age specific fertility rates for thirty populations, and the average of these rates, are given in Table C of the Appendix.

The age distributions of the females in these populations are given in Table B of the Appendix. Since the total fertility rates for these countries are known, it is possible to calculate theoretical values of the ratio of total children ever born to women questioned from formula (10). These values may then be used in formula (11), in conjunction with the actual age distribution and the average instead of the actual relative age specific fertility rates, to obtain estimates of the total fertility rate. A comparison of the actual and the estimated total fertility rates will indicate the magnitude of the errors in the estimated figures due to the use of an assumed instead of the actual distribution of the relative age specific fertility rates. Comparative figures for the thirty populations are given in Table IV on page 104. The variance of the difference between these estimates and their actual values may be assumed to be given by the formula[1]

$$V(R) = \frac{\sum_{s=1}^{n} (Y_s - Y_s')^2}{n} \quad \ldots\ldots\ldots\ldots \quad (14)$$

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(1) Ezekiel M. (1947) Methods of Correlation Analysis, (2nd. edition), Wiley & Sons, New York and Chapman & Hall, London, p. 133. Note: A slight downward bias arising from the absence of any adjustment for the number of cases under consideration may here be ignored.

where $V(R)$ is the required variance, Y_s and Y'_s are the actual and estimated s th values and n is the number of cases under consideration.

Table IV: Comparison of Estimated and Actual Total Fertility Rates.[1]

Country	Estimated value of $\frac{C_r}{M_r}$	Total Fertility Rate	
		Actual	Estimated
Australia	1.46	2.16	2.16
Belgium	1.50	2.10	2.12
Bulgaria	2.37	3.50	3.61
Canada	1.86	2.83	2.84
Chile	2.61	4.67	4.43
Czechoslovakia	1.70	2.50	2.54
Denmark	1.59	2.22	2.27
England and Wales	1.31	1.84	1.85
Estonia	1.41	1.97	1.92
Finland	1.42	2.09	2.03
France	1.60	2.04	2.10
Germany	1.58	2.21	2.20
Hungary	1.77	2.42	2.51
Italy	1.95	2.93	2.82
Jamaica	2.46	3.64	3.91
Japan	2.66	4.40	4.18
Latvia	1.77	2.40	2.40
Netherlands	1.82	2.95	2.76
New Zealand	1.44	2.12	2.11
Nicaragua	2.41	4.10	4.14
Norway	1.35	2.14	2.00
Peru	2.20	3.64	3.58
Poland	2.10	3.53	3.38
Portugal	2.05	3.18	3.04
Scotland	1.53	2.20	2.16
Sweden	1.32	1.83	1.84
Switzerland	1.56	2.17	2.13
Union of S. Africa (Europeans)	2.03	3.04	3.10
U. S. A. whites	1.51	2.10	2.22
non-whites	1.65	2.33	2.64

(1) In respect of all women aged 15 years and over.

The standard error of the estimates given in Table IV, as given by formula (14), is 0.12 which is equivalent to a coefficient of variation of 0.045. There is a wide range in the distribution of the relative age specific fertility rates of the countries considered here. The age of peak fertility in most cases, and also in the average distribution, occurs in the 25-29 year age group, but in several cases it occurs in the 20-24 year age group and in one case, that is in Chile, it is as late as the 30-34 year age group. In the latter case the estimated total fertility rate is .24 below the actual rate. At the other extreme the estimated figure for the U. S. A. non-whites, where the age of peak fertility is in the 20-24 year age group, is .31 above the true figure.

Application of Formula (11) to African Negroid Populations.

In obtaining an estimate of the total fertility rate of an African Negroid population from formula (11), it is necessary to bear in mind the probability that the returns of the total number of children ever born, in respect of at least the older women, are faulty. These errors have a direct bearing on the most suitable value of M_p to be used as the basis of the estimate. However, these errors will not be considered until Chapter VI, as they also affect the estimates of the expectation of life at birth which are dealt with in Chapter V. Apart from these reporting errors, the accuracy of an estimate of the total fertility rate depends on the choice of appropriate relative age specific fertility rates and also on the reliability of the age distribution figures used as a basis for the estimate. These two points are considered below.

Relative Age Specific Fertility Rates of African Negroid Populations. No attempt has yet been made to calculate age specific fertility rates of an African Negroid population from birth registration statistics. However, some indication of the distribution of the relative age specific fertility rates may be obtained by examining those censuses which have details of the total number of children ever born by age of mother. The available information is as follows:

Table V: Average Number of Children Ever Born by Age of Woman.(1)

Country	Date	Average Number of Births per Female up to the following Age Group							
		15-19	20-4	25-9	30-4	35-9	40-4	45-9	Over 49
Angola	1940	.07	1.05	2.02	2.72	3.34	3.74	3.99	4.07
Gold Coast	1948	.59	1.59	2.60	3.71	4.68	5.36	6.14	6.56
Mozambique	1940	.34	1.23	2.11	2.86	3.40	3.65	3.59	3.49
Nigeria	1931	.69	1.76	2.92	3.52	4.22	4.27	4.32	4.35
Lagos	1950	.23	0.87	1.50	1.90	2.35	2.70	2.90	3.30
Tanganyika	1948	.47	1.69	2.63	3.44	4.03	4.34	4.50	4.40
Uganda	1948	.09	1.25	2.38	3.50	4.44	5.00	5.38	4.80

(1) Source: Censo Geral de Populaçao 1940, Imprensa Nacional, Luanda, Angola, Vol. III p. 3 and Vol. XI p. 107. Census of Population, 1948, Government Printer, Accra, Gold Coast, (1950), p. 396. Censo da Populaçao em 1940, Imprensa Nacional, Lourence Marques, Mozambique, (1945), Vol. V pp. iv and v. Census of Nigeria, 1931 Vol V pp. 39-43 and Vol. VI pp. 46-9. Population Census of Lagos, 1950, Government Printer, Kaduna, Nigeria, (1951) p. 55. C.J. Martin (1953) "Some Estimates of the General Age Distribution, Fertility and Rate of Natural Increase of the African Population of British East Africa", Population Studies, Vol. VII, No. 2, p. 181.

Note: In order to obtain comparable figures it has been necessary to interpolate some of the published information. The figures for Nigeria for the ages from forty upwards were interpolated from the figures for the lower age groups and the fact that the average number of births to all women aged forty years and over was 4.30. The figures above 24 years for Lagos were interpolated from the averages of 1.74 for the 25-34 age group, 2.60 for the 35-44 age group, 2.96 for the 45-54 age group and 3.30 for females aged 55 years and over. The figures for Tanganyika and Uganda refer to the average number of births to women aged 17, 22, 27, 32, 37, 42, 47 and 45 years and over.

The differences between these averages may be used as a very rough indication of the age specific fertility rates. For example, in Angola the age specific fertility rate for the 15-19 year age group may be taken as .07, the rate for the

20-24 year age group may be taken as (1.05 - .07), or .98, the rate for the 25-29 year age group becomes (2.02 - 1.05), or .97 etc. The age specific fertility rates obtained in this way have been converted into relative rates in Table VI.

Table VI: Estimated Relative Age Specific Fertility Rates For Certain African Populations —— Based on Table V.

Country	Date	Age Group							
		15-9	20-4	25-9	30-4	35-9	40-4	45-9	Total[1]
Angola	1940	.004	.050	.048	.036	.030	.020	.012	.200
Gold Coast	1948	.002	.036	.036	.040	.034	.024	.028	.200
Mozambique	1940	.018	.050	.050	.042	.030	.014	-.004	.200
Nigeria	1931	.032	.050	.054	.028	.032	.002	.002	.200
Lagos	1950	.016	.044	.044	.028	.030	.024	.014	.200
Tanganyika	1948	.020	.054	.042	.036	.026	.014	.008	.200
Uganda	1948	.004	.042	.042	.042	.036	.020	.014	.200
Average		.014	.047	.045	.036	.031	.017	.010	.200

(1) The total is .200 and not 1.000 as there are five individual years in each quinquennial age group.

This method of estimation has several weaknesses. In the first place the use of figures by quinquennial age groups tends to hide reporting errors. Mortara[2] has drawn attention to a tendency for the average number of children ever born to be biased downwards in the case of women reported to be of an age ending in a nought or a five. Reporting errors of this nature can be detected, and the information adjusted accordingly, where figures are available for individual years of age. Unfortunately the particulars under consideration here are generally available only by broad age groups.

A more serious objection to the calculations made above is the implied assumption that fertility has remained constant for at least the past thirty five years. Where the level of fertility has in fact been rising, the rates for the lower age

(2) See Methods of Using Census Statistics, Population Studies No. 7, United Nations, (1949).

groups will be over-estimated and the rates for the higher age groups will be under-estimated. Where fertility has been falling the position is reversed and the rates for the lower age groups will be under-estimated while those for the older ages will be over-estimated. The relative age specific fertility rates given in Table C of the Appendix for the 15-19 age group range from .004 to .045 and those for the 45-49 age group range from .001 to .007. Compared with these figures, those in Table VI for the 15-19 year age group appear rather low in the Gold Coast and the figures for the 45-49 age group are very high in Angola, the Gold Coast, Lagos and Uganda. In these four cases there is, therefore, an indication that the level of fertility has been declining. The negative rate in the 45-49 age group in Mozambique suggests that here the level of fertility has been rising, but this suggestion is not supported by an unduly high rate in the 15-19 year age group. The figures for the ages 15-19 and 45-49 in Nigeria and Tanganyika are not inconsistent with an assumption of constant fertility.

Kuczynski's examination of medical reports(1) indicates that a rising incidence of venereal diseases has generally led to a reduction in the level of fertility. Although no satisfactory figures are available to support the statements, there is a widespread opinion amongst medical officers that in many African countries there was at one time a rise in the prevalence of these diseases and that this led to a fall in birth rates. If this is the case it seems likely that in some

(1) Kuczynski R.R. <u>A Demographic Survey of the British Colonial Empire</u>, Oxford University Press, Vol. I, (1948) and Vol. II, (1949), various sections on fertility.

areas the downward trend in fertility has been arrested, if not reversed, because of an improvement in medical services in recent years.

Another indication of secular changes in the level of fertility may be obtained by comparing the average number of births in the 45-49 year age group with the average for the older women. If fertility has remained constant, it is to be expected that the figure for women aged 45-49 will be about the same, possibly very slightly lower because all of these have not quite passed through the whole of the childbearing period, than the figure for the older women. Where the figure for the older women is substantially greater than that for the 45-49 year age group, as in the case of the Gold Coast and Lagos in Table V, there is an indication that the level of fertility has been declining. On the other hand, when the figure for the older women is the smaller of the two, as in Mozambique, Tanganyika and Uganda, there is a suggestion that there has been an upward trend in the level of fertility. However, this suggestion that fertility has been rising in Mozambique, Uganda and Tanganyika is not supported by an unduly high relative age specific fertility rate in the 15-19 year age group. The suggestion that fertility has been rising in Mozambique is supported by the negative rate for women aged 45-49 years, but in Uganda the rate for the 45-49 year age group suggests that fertility has been falling. These inconsistencies might be accounted for by reversals in the trends of fertility or by reporting errors. The detection of the latter will be considered in Chapter VI.

In view of the above indications of varying levels of fertility and the possibility that the figures are distorted by reporting errors, the figures quoted in Table VI cannot be accepted as a reliable indication of the relative age specific fertility rates of African Negroid populations. Further information on these rates may be obtained from the investigations of Mitchell, Brass and the French colonial authorities.

In 1951 Mitchell[1] examined a sample of 5,785 women in the copperbelt towns of Northern Rhodesia and obtained age specific fertility rates from detailed questions regarding their age and childbearing history during the preceding five years. Brass[2] quotes figures of the average number of children (i) under one year and (ii) under five years, by age of women, in respect of an East African Medical survey of 2,051 females in Tanganyika. In 1951-2 the French authorities made a detailed study of mother's age in respect of approximately 180,000 births in the maternity centres in the French colonies in Africa and in Madagascar.[3] The latter may be converted into relative age specific fertility rates by assuming that the age distribution of the Negroid population of these French possessions is the same as the average age distribution given in Table A of the Appendix and assuming that the mothers attending the maternity centres are a random sample of all mothers. The relative age specific fertility rates obtained from Mitchell's figures, the East African Medical survey and the French particulars are compared with various other rates in Table VII on page 111.

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(1) Mitchell J.C. (1953), "an Estimate of Fertility Among Africans on the Copperbelt of Northern Rhodesia," Rhodes-Livingstone Journal, No. 13, p. 18.

(2) Brass W. (1953), "Derivation of Fertility and Reproduction Rates," Population Studies, Vol. VII, No. 2, p. 137.

(3) Documents and Statistiques, No. X, (1953), Ministère de la France D'outre-mer Service des Statistiques, Paris.

Table VII: Comparison of Various Relative Age Specific Fertility Rates

Population	Age Group							
	15-9	20-4	25-9	30-4	35-9	40-4	45-9	Total
N. Rhodesia Copperbelt(1)	.043	.047	.037	.027	.021	.008	.017	.200
East Africa Medical Survey(2)	.067	.053	.036	.022	.015	.006	.001	.200
French Colonies in Africa	.039	.062	.061	.025	.011	.001	.001	.200
Madagascar	.042	.064	.055	.023	.013	.003	.000	.200
Average from Table VI	.014	.047	.045	.036	.031	.017	.010	.200
U.S.A. non-whites (1940)	.045	.059	.041	.029	.018	.007	.001	.200
Average from Table C of Appendix	.012	.048	.054	.044	.028	.012	.002	.200

(1) Mitchell's total fertility rate was reduced from 4.365 to 4.281 and his rate for the 15-19 year age group was raised from 0.172 to 0.183. The original total fertility rate included five times the rate for the 13-14 year age group instead of only twice this figure. The rate for the 13-14 year age group has here been included with the 15-19 year age group to conform with normal practice: the rates for the 13-14 and 15-19 age groups were combined in the ratio of 2:5.

(2) Based on returns in respect of children under 5 years of age. It is assumed that these children were on the average two and a half years old, so that the ages of the women were reduced by two and a half years to reflect the age distribution at the time of the births.

The copperbelt distribution has a peculiar rise in the 45-49 year age group, but this is of doubtful significance because of the very small number of women in the last two age groups in this survey. There were only 2.2 and 0.6 per cent. of the women aged 15-49 years in the 40-44 and the 45-49 year age groups respectively. A larger sample might well have reversed the position of the rates for the last two age groups. The rates given above for the French colonies and Madagascar are probably biased because of an error regarding the age distribution of the total population from which the mothers came. It is to be expected that the maternity centres are visited by a larger proportion of the young mothers than the older ones.

In spite of the weaknesses of the Copperbelt and French Colonial figures, they are perhaps more satisfactory than those given in Table VI since they are free from any bias due to any secular trend in the general level of fertility. The rates for non-whites in the U.S.A. are given in Table VII as they correspond quite closely to the figures for the Copperbelt, East Africa and the French colonies. In the absence of any further information on the subject, the figures for the U.S.A. non-white population seem to be a reasonable approximation to the distribution in respect of African Negroid populations. The fact that this U.S.A. population contains a considerable element of Negroes of African descent might be an important factor accounting for the similarity referred to above.

There is such a marked difference between the rates for the U.S.A. non-whites and the average for the thirty populations listed in Table C of the Appendix that the use of the latter distribution for estimating the total fertility rate of African Negroid populations is bound to give a biased estimate. The extent of this bias may be estimated by applying the two distributions of the relative age specific fertility rates to the values of T_s' obtained from the average age distribution of African Negroid populations given in Table A of the Appendix. When all women aged fifteen years and over are considered, the value of $\sum_{s=1}^{7} X_s' T_s'$ for the U.S.A. rates comes to .319. The corresponding figure for the average distribution given in Table C of the Appendix is .413. The use of the higher, in place of the lower, figure in formula (11) — see page 99 — has the effect of raising the estimated total fertility rate by 16 per cent.

The available evidence indicates that the distribution of the relative age specific fertility rates of African Negroid populations is close to that of the U.S.A. non-whites and it is suggested that estimates of the total fertility rates of

African Negroid populations be based on the relative age specific fertility rates of the U.S.A. non-white population unless there is strong evidence that these rates are unrepresentative of the population under consideration. The standard error of such an estimate may be assumed to be the same as that previously calculated for estimates based on the average relative age specific fertility rates of the populations listed in Table C of the Appendix. This is 4.5 per cent of the estimate. This would allow for a considerable variation between the actual and the assumed distribution of the relative age specific fertility rates. The figures given in Table VII for the Copperbelt, East Africa and the French Colonies suggest that there is very little variation in the relative age specific fertility rates of African Negroid populations. This suggests that the standard error of an estimated total fertility might well be less than 4.5 per cent. of the estimate, provided the age distribution is known accurately.

<u>Age Distribution of Negroids</u>. In estimating the total fertility rate of an African Negroid population it is very difficult to determine accurately the age distribution. It is impossible to measure precisely the effects of errors in the reported age distribution on an estimate of the total fertility rate, but some indication of the possible magnitude of the error in the estimated total fertility rate due to this factor is desirable.

For this purpose let us assume that the actual age distribution may differ from the reported age distribution by as much as the age distributions given in Table B of the Appendix differ from the average of these distributions. The range of these age distributions has been given in Table III —— see page 101. At the one extreme there is Nicaragua with a very rapid decrease in the numbers at each successive quniquennial age group and at the other extreme there is France with a rise in the numbers at each successive age group up to the 25-34 year age groups followed by a slow decrease in numbers thereafter. If the total fertility rates of all these populations are estimated from their average age distribution and the average of their relative age specific fertility rates instead of from the actual figures, the standard error of the estimates, as given by formula (14) on page 103, is 9.5 per cent. As stated previously, if the actual age distributions are used as a basis for the estimates, the latter have a standard error of 4.5 per cent. The use of the average instead of the actual age distributions therefore raises the standard error by a further 5.0 per cent. of the estimated total fertility rates. It seems very unlikely that the differences between the actual and the reported age distributions of African Negroid populations will be as great as the departures from the average age distribution of the populations considered above. Therefore it seems unlikely that the reporting errors in the age classification of African Negroid populations will raise the standard error of an estimate of the total fertility rate from 4.5 to 9.5 per cent. A standard error of about 7.5 per cent. might be taken as a likely figure.

Where the age distribution is known only in a small number of broad age groups, the values of T_i' required to estimate the total fertility rate may be obtained from an estimate of the detailed age distribution based on formula (6) given on page 92. An indication of the possible error introduced by this method of estimation may be obtained by comparing the values of T_i' for the two age distributions given in Table II on page 95 in respect of the 1946 Native female population of the Union of South Africa. The one set of figures gives the reported age distribution and the other set gives estimates based on formula (6). When all women aged fifteen years and over are considered, the two series of the T_i' values are as follows:

T'_s Values for Native Females in South Africa in 1946.

Value of s	Value of T'_s	
	Based on reported age distribution	Based on interpolated age distribution
1	0.33	0.34
2	1.11	1.15
3	1.80	1.86
4	2.42	2.48
5	2.95	3.01
6	3.39	3.45
7	3.76	3.79
Total	15.76	16.08

If the values of T'_s obtained from the reported age distribution are applied to the relative age specific fertility rates of the 1940 U.S.A. non-white population, formula (11) gives $R = 1.44 \frac{C_F}{M_F}$. The corresponding calculation for the estimated age distribution gives $R = 1.46 \frac{C_F}{M_F}$, so that the latter estimate of the total fertility rate would be only about one per cent higher than one based on the reported age distribution. For practical purposes an error of one per cent. may be ignored.

Where there is insufficient information from which to obtain estimates of the detailed age distribution, a rough indication of the total fertility rate might be obtained by using the average of the age distributions given in Table A of the Appendix. If this age distribution is applied to the relative age specific fertility rates of the U.S.A. non-white population formula (11) reduces to

$$R = 1.47 \frac{C_F}{M_F}$$

where M_F refers to all women aged fifteen years and over. Such an estimate is likely to have a standard error in the neighbourhood of the 9.5 per cent. referred to above in respect of estimates of the total fertility rate of the thirty populations listed in Tables B and C of the Appendix when the estimates are based on the average age distribution and the average relative age specific fertility rates of these populations.

An Alternative Approach.

Another method of estimation has been developed recently by Brass.(1) Changing the notation to conform with that used above, Brass' formula for the total fertility rate becomes

$$C_p = R M_p \left[\frac{n-m}{n} + \frac{p}{2n} \left\{ m(n-m) - 40 \right\} \right] \quad \ldots\ldots\ldots (15)$$

M_p is the number of women aged 15 to p years (With this formula p does not exceed 50). C_p is the total number of children ever born to the M_p women. R is the total fertility rate. n is the number of years in the childbearing period under consideration. m is the weighted average of the ages to which the age specific fertility rates, for the whole of the reproductive period that is 15-49 years, refer. (For the purpose of calculating m the 15th. birthday is taken as 0.) p is a function of the age distribution of the women under consideration as given by the formula

$$p = \frac{2\left[\sum_{s=p'+1}^{p} F_s - \sum_{s=15}^{p'} F_s \right]}{M_p (p-14)} \quad \ldots\ldots\ldots\ldots\ldots (16)$$

where F_s is the number of females at the age of s years, p is the age of the oldest woman under consideration and p' is the mid-point between 14 and p. For example when p is 44 p' is 29.

Brass states that the best estimates obtained from formula (15) are those in respect of women aged 15-44 years, but other age groups may be used. The values of C_p, M_p, n and p vary with the age group under consideration, but m remains unchanged and always refers to the whole of the child-

(1) Brass W. (1953) "Derivation of Fertility and Reproduction Rates", Population Studies, Vol. VII, No. 2, p. 137.

bearing period, that is 15-49 years. The estimate of the total fertility rate is sensitive to variations in m and it is desirable that this variable be estimated as accurately as possible. The value m may be regarded as an index of the distribution of the age specific fertility rates. Where this distribution is known, or can be estimated from an analysis of young children, such as those under one or under five years, by age of mother, the value of m can be obtained by weighting the difference between 15 and the mid-point of each quinquennial age group by the appropriate relative age specific fertility rate. Theoretically the weighted average age of each quinquennial age group should be used instead of the mid-point of the age group.(1) The use of the mid-point of the age group gives a downward bias when the age specific fertility rates are rising, but there is a corresponding upward bias in the higher age groups, where the specific fertility rates decline as age rises. In practice the upward and downward biases may be assumed to cancel out when the whole distribution is taken into consideration and when the age groups under consideration are as small as those for five year age groups.

Brass suggests various alternative methods of estimating m for cases where the distribution of the age specific fertility rates by quinquennial age groups is not known. In the first place an estimate might be obtained from specific fertility rates for as few as two broad age groups. In the second place various estimates may be obtained from the formula

$$m = 16{\cdot}2 - 38\frac{f}{R} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (17)$$

where f is the proportion of the total fertility rate, R, experienced in the 15-19 year age group. The value of f may be obtained from an analysis of children under one year of age and R may be approximated by nC/W where C/W

(1) Kuczynski R.R. (1938), "The Analysis of Vital Statistics: II Birth and Death Statistics", Economica, Vol. V (New Series), No. 19, p. 289.

is the effective fertility rate or the ratio of children under one year of age to the women in the childbearing period, that is women aged 15-44 years or some other convenient period, and n is the number of years in the childbearing period under consideration. If the number of children under one is not available Brass suggests that R might be taken as the average number of children ever born to women over 45 or 50 years and f obtained from the average number of children ever born to women aged 15-19 years by comparison with known distributions of fertility.

Brass admits that his alternative methods of estimating m are only rough ones. The possibility of a biased estimate cannot be over emphasised. An estimate obtained from age specific fertility rates for as few as two broad age groups is almost bound to be biased. The errors arising from the use of the mid-points of the age groups instead of the weighted average age of the broad age groups are not likely to cancel out when only two or three age groups are considered. The dangers of estimating the total fertility rate, which is required in formula (17), from the effective and general fertility rates have already been mentioned.(1) Of particular significance, as far as African Negroid populations are concerned, is Brass' statement that formula (17) does not fit the distribution of the age specific fertility rates of the U.S.A. non-white population, for it has been indicated above that this distribution approximates closely the distributions in respect of the African Negroid populations. An estimate based on the relationship between the average number of children ever born to women aged 15-19 years and the average number of children ever born to women past the childbearing period is dangerous because of the possible influence of secular trends in the level of fertility. As far as the African Negroid populations

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(1) See pp. 11-13.

are concerned, it would seem advisable to estimate the value of m from the age specific fertility rates of the U.S.A. non-white population, where an estimate cannot be made from an analysis of the young children by age of mother. For the 1940 rates of the U.S.A. non-whites given in Table C of the Appendix the value of m is 11.

CHAPTER V

THE ESTIMATION OF THE EXPECTATION OF LIFE AT BIRTH FROM THE RATIO OF CHILDREN SURVIVING TO TOTAL CHILDREN EVER BORN.

Most of the enquiries which have recorded particulars of the total number of children ever born have also obtained particulars of the number of these children who have survived up to the date of the enquiry. While the particulars of the total number of births have been used quite extensively, relatively little use has so far been made of the information regarding the number of survivors. This is probably largely due to the fact that up to the present no study has been made of the various elements of mortality summarised by these figures. It will be shown below that the ratio of survivors to total births can be used to estimate the complete expectation of life at birth. For many purposes the expectation of life at birth is the most useful figure in a life table, for it is a summary of the whole life table and it is a useful age standardised index of mortality.

Derivation of Basic Formulae.

Let C_x = children born in the twelve months ended x years before the date of the enquiry. ($x = 0, 1, 2 \ldots n$)

$\sum_{x=0}^{n} C_x = C_t$ = total live births of all women up to the age of t years at the date of the enquiry.

S_x = survivors of the C_x children.

P_x = probability of living x years six months.

$\sum_{x=0}^{n} S_x = S_t$ = total number of the C_t births surviving to the date of the enquiry.

Then, assuming that the births are spread evenly throughout each year,

$$S_x = P_x C_x \quad \text{and} \quad \sum_{x=0}^{n} S_x = \sum_{x=0}^{n} P_x C_x$$

Therefore $$\frac{S_F}{C_F} = \frac{\sum_{x=0}^{n} P_x C_x}{\sum_{x=0}^{n} C_x}$$

Let $$\frac{C_x}{\sum_{x=0}^{n} C_x} = W_x$$

Then $$\frac{S_F}{C_F} = \sum_{x=0}^{n} P_x W_x \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (18)$$

$$= n'\bar{P}\bar{W} + n'\rho\sigma_P\sigma_W \quad \ldots\ldots\ldots\ldots\ldots (19)$$

where $n' = n+1$ (because P_x and W_x range from 0 to n), $\bar{P}$ and $\bar{W}$ are the means and σ_P and σ_W are the standard deviations of the P_x and W_x distributions respectively. ρ is the correlation between the P_x and W_x distributions. However, the sum of the W_x distribution is unity, so that $n'\bar{W} = 1$. Therefore

$$\frac{S_F}{C_F} = \bar{P} + n'\rho\sigma_P\sigma_W \quad \ldots\ldots\ldots\ldots (20)$$

Now $$\bar{P} = \frac{\sum_{x=0}^{n} P_x}{n'} = \frac{\sum_{x=0}^{n} L_x}{n' l_0}$$

where L_x is the number of survivors of l_0 persons born x years six months ago and l_0 is the life table radix at the age of nought years.

Since the formulae given above deal with the children of women alive at the date of the enquiry, n' will be less than the end of the life table, say N. Therefore

$$\frac{\sum_{x=0}^{n} L_x}{n' l_0} = \frac{\sum_{x=0}^{N} L_x - \sum_{x=n'}^{N} L_x}{n' l_0}$$

$$= \frac{T_0}{n' l_0} - \frac{T_{n'}}{n' l_0}$$

where T_0 and $T_{n'}$ are the life table populations above the ages of 0 and n' respectively. However,

$$T_0 = l_0 e_0^0 \quad \text{and} \quad T_{n'} = l_{n'} e_{n'}^0$$

where e_0^0 and $e_{n'}^0$ are the expectations of life at birth and at the age of n' years respectively and $l_{n'}$ is the life table survivors at exact age n' years. Therefore

$$\frac{\sum_{x=0}^{n} L_x}{n' l_0} = \frac{l_0 e_0^0}{n' l_0} - \frac{l_{n'} e_{n'}^0}{n' l_0}$$

and $\bar{P} = \frac{e_0^o}{n'} - \frac{l_{n'} e_{n'}^o}{n' l_0}$

Substituting this value of $\bar{P}$ in formula (20) gives

$$\frac{S_t}{C_t} = \frac{e_0^o}{n'} - \frac{l_{n'} e_{n'}^o}{n' l_0} + n' \rho \sigma_P \sigma_W$$

Therefore $e_0^o = n' \frac{S_t}{C_t} + \frac{l_{n'} e_{n'}^o}{l_0} - n'^2 \rho \sigma_P \sigma_W$ ....(21)

Determination of Empirical Formulae.

Although formula (21) expresses the theoretical relationship between (i) the ratio of children still living to total children ever born, (ii) the expectation of life at birth and (iii) various other factors, it cannot be used directly to provide an estimate of the expectation of life at birth. The only component part of this formula which is likely to be known is the ratio of children still living to total children ever born. However, formula (21) may be used as the basis for determining an empirical formula from which to estimate the expectation of life at birth. Values of the component parts of this formula may be obtained for a number of theoretical cases and these may be used to arrive at the required empirical formula.

The two fundamental factors determining the values of the various parts of formula (21) are the life table probabilities and the distribution, over time, of the total births to the women alive at the date of an enquiry. Life table probabilities are readily available for a number of countries, but the required figures of births are not available for any country. The normal figures of births are not suitable because the births for past years include the children of women who have since died. However, theoretical values of the required births may be calculated from the formula

$$C_x = \sum_{s=15}^{49} r_s F_{s+x}$$ .... (22)

where C_x is the number of children born in the twelve months ended x years before the date of the enquiry, r_s is the age specific fertility rate of women when they are s years of age and F_s is the number of women at the age of s years in the most recent year under consideration. Values of c_x for $x = 0$, 4, 9 etc. were obtained directly from formula (22) in respect of the age distributions given in Table D of the Appendix. Intermediate values had to be obtained by interpolation, as details of the age distribution by single years were not available. The interpolation was made by plotting the values c_0, c_4, c_9 etc. on a large scale graph and reading off the intermediate values from a free hand curve joining these points. The appropriate age specific fertility rates are given in Table C of the Appendix. In a few cases where the age specific fertility rates are not known, the calculations were based on the average values given in Table C of the Appendix. An element of secular change was introduced by basing the calculations for each country on a random selection of one of the following arbitrary assumptions:

(i) the general level of fertility remained constant throughout the period under consideration,

(ii) the level of fertility increased at the rate of three per cent. every five years,

(iii) the level of fertility decreased by three per cent. every five years.

Appropriate values of p_x, the probability of surviving to the age of x years six months, were then interpolated from the figures given in Table E of the Appendix. This table gives the probability of surviving to the exact age of 1, 2, 3, 4 and 5 years and every fifth year thereafter.

The estimation of the value p_0 is complicated by the fact that mortality in the first six months of life is much heavier than in the second six months. To take account of this fact use was made of the figures given in Table F of the Appendix which gives the infant mortality rates in the first six and the first twelve months of life. The value of P_0 was obtained from the formula

$$P_0 = \frac{I_6}{I_{12}} (1 - P_1')$$

where I_6 and I_{12} are the infant mortality rates for the first six and the first twelve months respectively and P_1' is the probability of surviving to the exact age of one year.

The remaining values of P_x were interpolated from a large scale free hand curve joining the probabilities of surviving to the exact ages given in Table E of the Appendix. The aggregates of the interpolated figures for the ages 5-29, 30-59 and 60-74 were checked from the information on the expectation of life at the ages of 5, 30, 60 and 75 given in Table G of the Appendix. The derivation of this check is as follows:

Let P_x = probability of surviving to the age of x years six months.

P_x' = probability of surviving to exact age of x years.

l_x = life table population at exact age of x years.

L_x = life table population in the x th. age of life, that is persons on the average aged x years six months.

T_x = life table population above the exact age of x years.

$\mathring{e}_x$ = expectation of life at exact age of x years.

Then
$$\sum_{x=a}^{b} P_x = \frac{\sum_{x=a}^{b} L_x}{l_0}$$

$$= \frac{\sum_{x=a}^{N} L_x - \sum_{x=b+1}^{N} L_x}{l_0} \quad \text{(where } N \text{ is the end of the life table)}$$

$$= \frac{T_a - T_{b+1}}{l_0} = \frac{\mathring{e}_a l_a - \mathring{e}_{b+1} l_{b+1}}{l_0}$$

$$= \mathring{e}_a P_a' - \mathring{e}_{b+1} P_{b+1}'$$

Having obtained the individual values of P_x, these were then multiplied by their appropriate W_x values and the results summed to obtain the ratio of children surviving to total births as given by formula (18). The average value of p_x was then calculated and the value of $n'\bar{\rho}^{c}\bar{p}^{c}\bar{W}$ obtained from formula (20). The value of $n'^2\bar{\rho}^{c}\bar{p}^{c}\bar{W}$ was obtained by multiplying this result by the value of n' as determined by the W_x distribution. For practical purposes it was assumed that n' is determined by the point at which the value of W_x fell below .0005.

The remaining unknown in formula (21) is the value of $\frac{L_{n'}e^{o}_{n'}}{l_0}$. Values of this variable, for $n' = 60, 65, 70$ and 75 were calculated directly from the information given in Tables E and G of the Appendix. These were then plotted on a graph and any required intermediate value read off from a free hand curve joining these points. These, and the values of the other component parts of formula (21), in respect of a number of countries are given in Table VIII.

Table VIII: Values of the Variables in Formula (21) For Certain Countries. (1)

Population	Trend of Fertility (2)	W_0	$\frac{S_F}{C_F}$	e^{o}_{0}	n'	$\frac{e^{o}_{n'}L_{n'}}{l_0}$	$n'^2\bar{\rho}^{c}\bar{p}^{c}\bar{W}$
Belgium	C	.025	.724	48.8	71	2.76	5.33
British Honduras	R	.046	.778	49.0	71	3.71	9.94
Canada	C	.032	.872	62.1	72	4.38	5.08
Denmark	F	.022	.800	56.2	74	2.88	5.87
England & Wales	F	.019	.793	53.4	73	2.84	5.37
Finland	R	.034	.729	48.1	70	3.15	6.09
France	F	.017	.702	48.7	75	1.53	5.49
Hawaii	F	.034	.782	47.3	73	1.49	11.30
Iceland	R	.036	.780	53.1	73	3.05	6.96

(1) In respect of all women aged fifteen years and over.

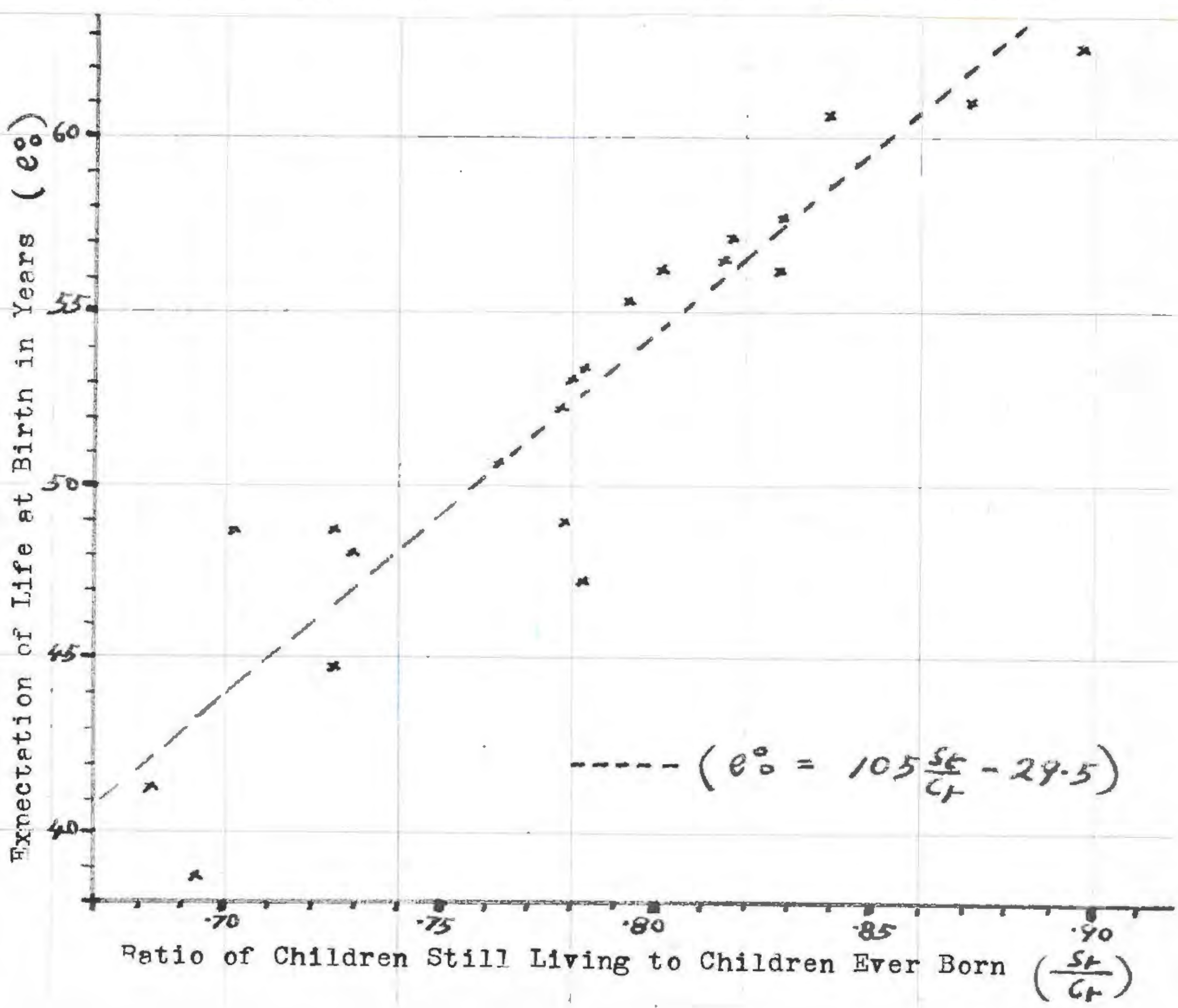
(2) The symbol "C" reflects an assumption of constant fertility, "R" represents an assumption of rising fertility and "F" represents an assuption of falling fertility.

Table VIII Continued.

Population	Trend of fertility	W_0	$\frac{S_t}{C_t}$	e_0^0	n'	$\frac{e^0_{n'} l_{n'}}{l_0}$	[illegible]
Jamaica	C	.039	.682	41.4	71	2.29	9.30
Japan	R	.043	.725	44.8	68	3.19	7.61
Netherlands	C	.031	.782	53.4	70	3.87	5.21
New Zealand	C	.033	.839	60.6	71	4.55	3.60
Northern Ireland	C	.030	.827	56.1	71	3.62	6.27
Norway	F	.025	.828	57.7	73	3.87	6.11
Scotland	R	.028	.816	56.4	71	3.69	5.24
S. Rhodesia (Europeans only)	C	.032	.897	62.6	69	5.70	5.01
Sweden	C	.025	.814	57.0	74	3.12	6.42
Switzerland	F	.021	.777	52.2	75	1.56	7.72
Trinidand	R	.045	.692	38.8	66	2.30	9.18
United States of America	C	.028	.762	50.7	76	1.62	8.83

Chart I.

Values of the Expectation of Life at Birth in Terms of the Ratio of Children Still Living to Children Ever Born.



To begin our examination of formula (21) let us study the relationship between the expectation of life at birth and the ratio of children surviving to total children ever born. These values have plotted in Chart I. This suggests that formula (21) may be approximated to

$$e_0^o = a + b\frac{sr}{cr} \qquad \text{............ (23)}$$

putting $\quad e_0^o - a - b\frac{sr}{cr} = 0$

and differentiating with regard to a and b in turn leads to the following equations for obtaining the best values of a and b by the method of least squares:

$$a = \overline{e_0^o} - b\left(\overline{\frac{sr}{cr}}\right)$$

$$b = \frac{\sum \frac{sr}{cr}\cdot e_0^o - n\,\overline{e_0^o}\left(\overline{\frac{sr}{cr}}\right)}{\sum\left(\frac{sr}{cr}\right)^2 - n\left(\overline{\frac{sr}{cr}}\right)^2}$$

where $\overline{e_0^o}$ = average of all the e_0^o values.

$\left(\overline{\frac{sr}{cr}}\right)$ = average of all the $\frac{sr}{cr}$ values.

n = number of cases under consideration.

$\sum$ denotes summation over all the n values.

Applying these formulae to the relevant values in Table VIII leads to the formula

$$e_0^o = 105\frac{sr}{cr} - 29.3 \qquad \text{........... (23 a)}$$

This formula does no more than convert the ratio of children still living to total children ever born into a more commonly used expression. The resulting estimate of the expectation of life at birth can be expected to contain an appreciable bias if the W_x distribution for a particular population differs greatly from the average of the W_x distributions of the populations considered in Table VIII. It is to be expected that a more efficient estimate would be obtained if the W_x distribution could be taken into consideration. The W_x distributions of the populations considered in Table

VIII are illustrated in Chart II, where the two extreme and an intermediate distribution are shown.

Chart II.

Illustration of the W_x Distribution: The Proportion of the Total Children Ever Born Who Were Born x Years Before the Date of the Enquiry.

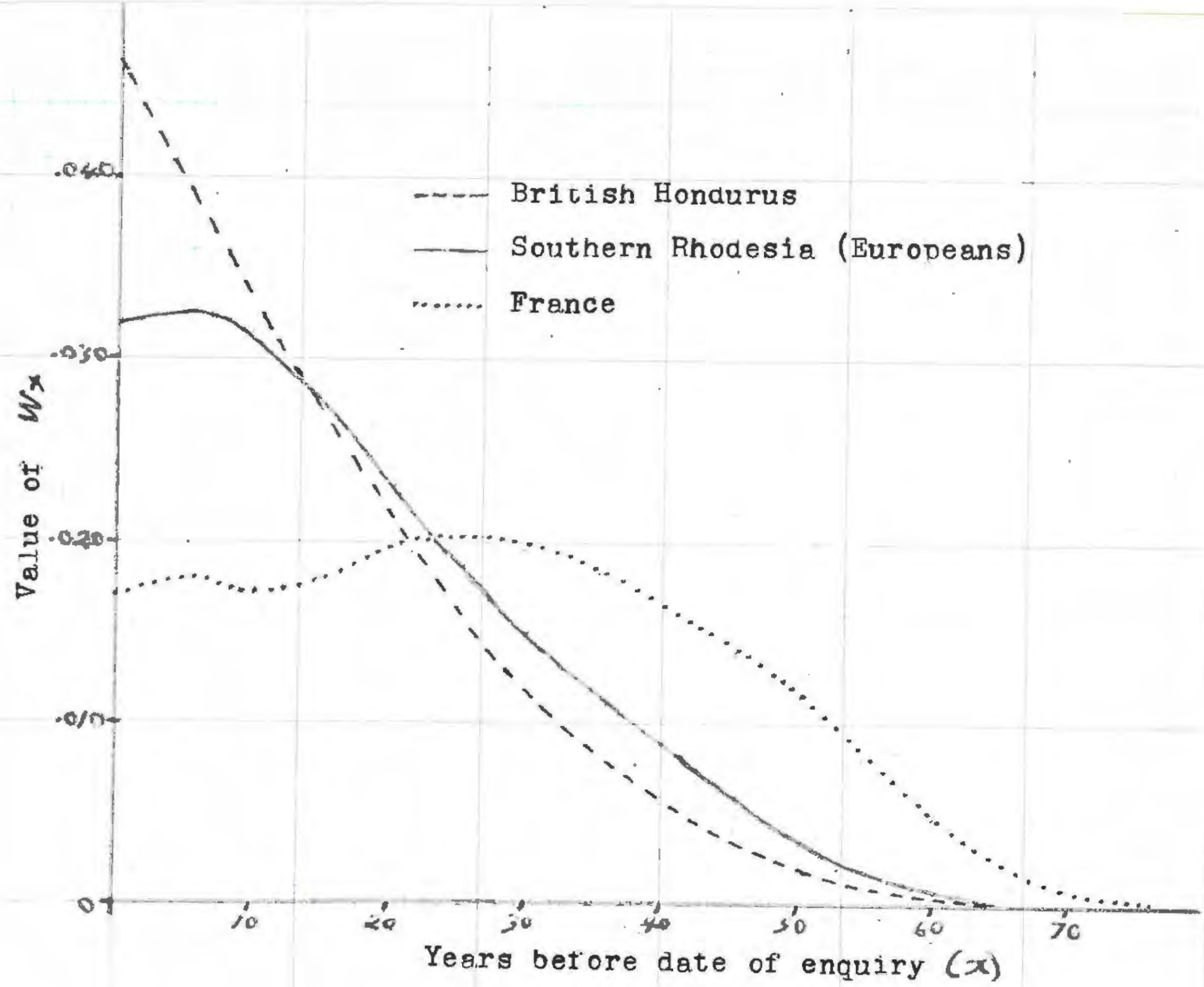
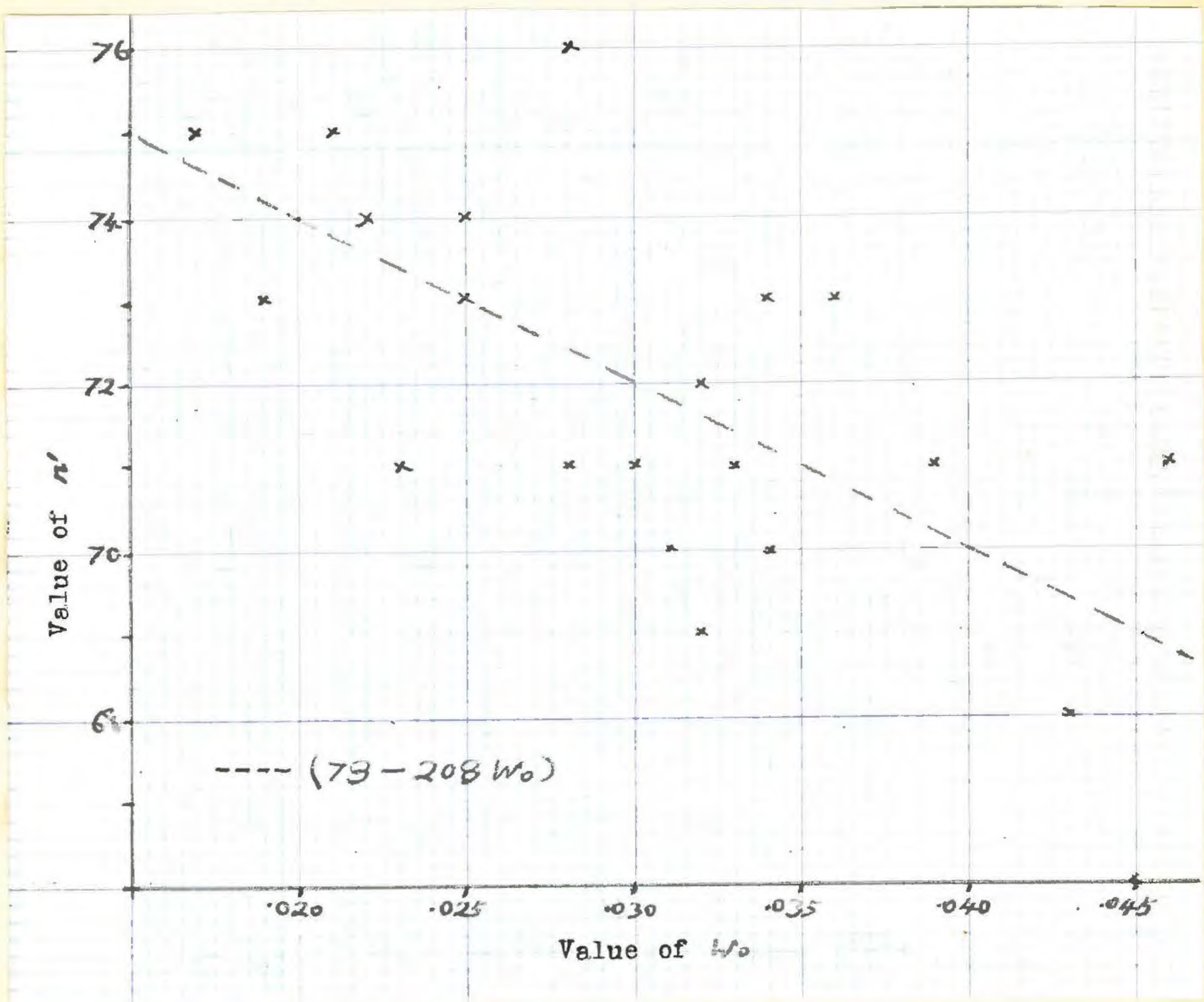


Chart II shows that the value of W_x with the greatest variability is that of W_0. The range of values decreases as x increases until it is insignificant when x is 65 or over. Since, by definition, the sum of all the W_x values is unity, it would appear that the value of W_0 may be used as an index of the whole W_x distribution. The relationship between the values of W_0 and n' is illustrated in Chart III.

Chart III.

The Relationship Between n' and W_o.



The correlation coefficient between n' and W_o, as given by Spearman's Rank Correlation Coefficient,[1] is — .68. The value of Student's t[2] for this coefficient is 4.0. For nineteen degrees of freedom the value of Student's t is 3.9

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(1) As given by the formula $\dfrac{1/6\,(n^3-n)-(T_x+T_y)-\Sigma(d^2)}{[1/6\,(n^3-n)-2T_x]^{1/2}\,[1/6\,(n^3-n)-2T_y]^{1/2}}$ where n is the number of cases under consideration, $\Sigma(d^2)$ is the sum of the squares of the differences between the ranks of the two distributions, $T_x = \sum_{j=1}^{n} \frac{1}{12}[(x_j)^3 - x_j]$, $T_y = \sum_{j=1}^{n} \frac{1}{12}[(y_j)^3 - y_j]$, x_j and y_j are the number of cases tied at the jth. rank of the first and second distributions respectively. (see Yule G.U. and Kendall M.G. (1950), An Introduction to the Theory of Statistics, (14th. edition), p. 265.

(2) As given by the formula $t = r\sqrt{n-2}/\sqrt{1-r^2}$, where r is the correlation coefficient and n is the number of cases under consideration. (see Yule and Kendall p. 455)

(3) Yule and Kendall p. 667.

at the 0.1 per cent. level of significance and 2.1 at the 5.0 level of significance. The correlation coefficient of — .68 may, therefore, be regarded as definitely significant. Since it is desirable to reduce formula (21) to a simple function, it is convenient to assume that the relationship between n' and W_o takes the form

$$n' = a + bW_o$$

Applying the method of least squares in a similar manner to that used in formula (23) gives 78 and — 208 as the best values of a and b respectively. Substituting $a - bW_o$ for n' in formula (21) gives

$$e_o^o = (a - bW_o)\frac{S_t}{C_t} + \frac{e_{n'}^o l_{n'}}{l_o} - n'^2 \rho \sigma_P \sigma_W \quad \ldots\ldots\ (24)$$

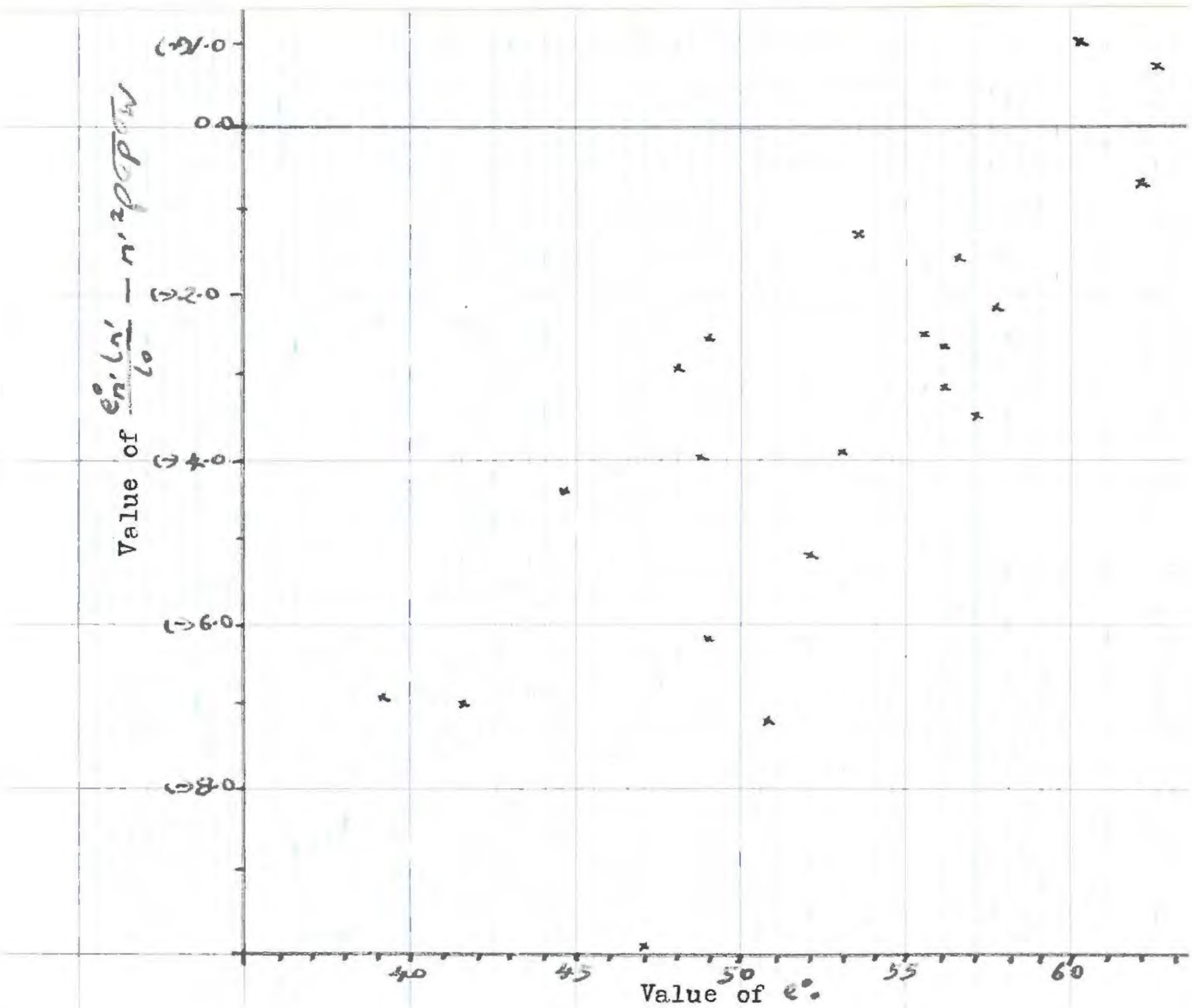
The remaining unknowns in this formula are the values $\frac{e_{n'}^o l_{n'}}{l_o}$ and $n'^2 \rho \sigma_P \sigma_W$. The correlation coefficients, as given by Spearman's Rank Correlation Coefficient, between these two variables taken together on the one hand and $\frac{S_t}{C_t}$, e_o^o and W_o on the other hand, together with the value of Student's t, are as follows:

Correlation between $\frac{e_{n'}^o l_{n'}}{l_o} - n'^2 \rho \sigma_P \sigma_W$ and the following values	Correlation Coefficient	Student's t
$\frac{S_t}{C_t}$	(+) .72	4.5
e_o^o	(+) .81	6.0
W_o	(−) .24	1.1

The correlation coefficient for W_o is of doubtful significance as the appropriate value of Student's t is below the 5.0 per cent. level of significance. However, the coefficients for $\frac{S_t}{C_t}$ and e_o^o are highly significant as the appropriate values of Student's t are above the 0.1 level of significance. It would appear that the coefficient for $\frac{S_t}{C_t}$ is lower than that for e°_0 because the value of $\frac{S_t}{C_t}$ is influenced by the W_x distribution and the latter appears to have no significant correlation with $\frac{e^\circ_{n'} l_{n'}}{l_0} - n'^2 \rho \sigma_p \sigma_w$. The relationship between $\frac{e^\circ_{n'} l_{n'}}{l_0} - n'^2 \rho \sigma_p \sigma_w$ and e°_0 is illustrated in Chart IV.

Chart IV.

The Relationship Between $\frac{e^\circ_{n'} l_{n'}}{l_0} - n'^2 \rho \sigma_p \sigma_w$ and e°_0.



It may be assumed that the relationship between these two variables takes the form

$$\frac{e^\circ_{n'} l_{n'}}{l_0} - n'^2 \rho \sigma_p \sigma_w = c + d e^\circ_0$$

Substituting this in formula (24) gives

$$e^\circ_0 = (a - bW_0) \frac{S_t}{C_t} + c + d e^\circ_0$$

Therefore $e^\circ_0 (1 - d) = a . \frac{S_t}{C_t} - bW_0 \frac{S_t}{C_t} + c$

and $e^\circ_0 = \frac{a}{(1-d)} . \frac{S_t}{C_t} - \frac{b}{(1-d)} W_0 \frac{S_t}{C_t} + \frac{c}{(1-d)}$

For practical purposes this may be written as

$$e_0^o = a'\frac{S_t}{C_t} + b' W_0 \frac{S_t}{C_t} + c' \qquad \text{.............} \quad (25)$$

Taking the terms on the right hand side to the left hand side and differentiating with regard to a', b' and c' in turn gives the following equations for obtaining the best values of these constants by the method of least squares:

$$\sum\left(\frac{S_t}{C_t}\right)e_0^o - a'\sum\left(\frac{S_t}{C_t}\right)^2 - b'\sum W_0\left(\frac{S_t}{C_t}\right)^2 - c'\sum\left(\frac{S_t}{C_t}\right) = 0$$

$$\sum W_0\left(\frac{S_t}{C_t}\right)e_0^o - a'\sum W_0\left(\frac{S_t}{C_t}\right)^2 - b'\sum W_0^2\left(\frac{S_t}{C_t}\right)^2 - c'\sum W_0\left(\frac{S_t}{C_t}\right) = 0$$

$$\sum e_0^o - a'\sum\left(\frac{S_t}{C_t}\right) - b'\sum W_0\left(\frac{S_t}{C_t}\right) - nc' = 0$$

Applying these equations to the relevant values in Table VIII —— see page 125 —— gives

$$e_0^o = 101{\cdot}2\,\frac{S_t}{C_t} - 273{\cdot}5\, W_0 \frac{S_t}{C_t} - 20{\cdot}2 \qquad \text{..........} \quad (25\ a)$$

Estimates obtained by means of formula (25 a) are likely to be more efficient than those obtained from formula (23 a) because the W_x distribution is taken into consideration in addition to the ratio of the children still living to the total children ever born. The improvement in efficiency may be measured by comparing the respective standard errors of the two methods of estimation. The standard error, as given by formula (14) on page 103, for estimates obtained from formula (23 a) in respect of the twenty one populations listed in Table VIII is 2.3 years. The corresponding figure for estimates obtained from formula (25 a) is 1.8 years. These standard errors are equivalent to coefficients of variation of .044 for formula (23 a) and .034 for formula (25 a).

Although formula (25 a) gives the more efficient estimate it requires details of the proportion of the total number of children ever born who were born during the twelve months preceding the date of the enquiry. In many cases records of the births in the past twelve months are either not available or very unreliable. However, the value of W_0 may be estimated from the age distribution of the women under consideration and also from the number of children under one year of age.

The value of W_0 may be estimated from the age distribution of the female population by assuming that the level of fertility has remained constant throughout the period under consideration. By definition

$$W_0 = \frac{C_0}{\sum_{x=0}^{n} C_x} \qquad \text{where} \qquad C_x = R_x \sum_{s=15}^{49} X_s F_{s+x}$$

R_x is the appropriate total fertility rate for the x th. year and X_s and F_s are the relative age specific fertility rate and the number of females respectively at the age of s years. If fertility has remained constant throughout the period under consideration

$$W_0 = \frac{\sum_{s=15}^{49} X_s F_s}{\sum_{s=15}^{49} X_s F_s + \sum_{s=15}^{49} X_s F_{s+1} + \sum_{s=15}^{49} X_s F_{s+2} + \text{-----} \sum_{s=15}^{49} X_s F_{s+n}}$$

The value of the numerator may be obtained by applying appropriate relative age specific fertility rates to the age distribution. The denominator may be written as

$$X_{15} \sum_{s=15}^{t} F_s + X_{16} \sum_{s=16}^{t} F_s + X_{17} \sum_{s=17}^{t} F_s + \text{----} + \sum_{s=49}^{t} F_s$$

where t is the age of the oldest women under consideration. If it is assumed that there is an equal number of persons at each individual year of age within each quinquennial age group

$$F_{15} = F_{16} = F_{17} = F_{18} = F_{19} = \text{(say)} \quad F_1' \div 5$$

$$F_{20} = F_{21} = F_{22} = F_{23} = F_{24} = \text{(say)} \quad F_2' \div 5$$

etc. and $\sum_{s=15}^{19} F_s = F_1'$, $\sum_{s=16}^{19} F_s = \frac{4}{5} F_1'$, $\sum_{s=17}^{19} F_s = \frac{3}{5} F_1'$ etc.

The denominator may then be written as

$$X_{15}\sum_{s=1}^{t'}F'_s + X_{16}\left[\frac{4}{5}F'_1 + \sum_{s=2}^{t'}F'_s\right] + X_{17}\left[\frac{3}{5}F'_1 + \sum_{s=2}^{t'}F'_s\right] +$$

$$X_{18}\left[\frac{2}{5}F'_1 + \sum_{s=2}^{t'}F'_s\right] + X_{19}\left[\frac{1}{5}F'_1 + \sum_{s=2}^{t'}F'_s\right] + \ldots\ldots$$

$$X_{45}\sum_{s=7}^{t'}F'_s + X_{46}\left[\frac{4}{5}F'_7 + \sum_{s=8}^{t'}F'_s\right] + X_{47}\left[\frac{3}{5}F'_7 + \sum_{s=8}^{t'}F'_s\right] +$$

$$X_{48}\left[\frac{2}{5}F'_7 + \sum_{s=8}^{t'}F'_s\right] + X_{49}\left[\frac{1}{5}F'_7 + \sum_{s=8}^{t'}F'_s\right]$$

, where t' is the appropriate quinquennial age group corresponding to t'.

Replacing the X_s values for the individual years by the weighted average of these rates by quinquennial age groups, this becomes

$$X'_1(3F'_1 + 5\sum_{s=2}^{t'}F'_s) + X'_2(3F'_2 + 5\sum_{s=3}^{t'}F'_s) + \ldots X'_7(3F'_7 + 5\sum_{s=8}^{t'}F'_s)$$

where X'_1, X'_2 ...... X'_7 are the weighted average relative age specific fertility rates for the age groups 15-19, 20-24, 25-29........45-49. Therefore, when t is greater than 48

$$W_0 = \frac{\sum_{s=1}^{7}X'_sF'_s}{X'_1(3F'_1 + 5\sum_{s=2}^{t'}F'_s) + \ldots X'_7(3F'_7 + 5\sum_{s=8}^{t'}F'_s)} \quad \ldots\text{(26i)}$$

and similarly when t is less than 49 and coincides with the end of one of the normal quinquennial age groups

$$W_0 = \frac{\sum_{s=1}^{t'}X'_sF'_s}{X'_1(3F'_1 + 5\sum_{s=2}^{t'}F'_s) + \ldots X'_{t'}(3F'_{t'})} \quad \ldots\text{(26ii)}$$

where t' is the appropriate quinquennial age group corresponding to t.

Another indication of the proportion of the total children ever born who were born in the twelve months preceeding the date of the enquiry may be obtained from the ratio of the children enumerated as under one year to the total number of children ever born. It should, however, be remembered that the children enumerated as under one year are only the survivors of the births during the previous twelve months. In some cases there will also be a substantial under enumeration of the children under one year. If the infant mortality rate is known, or can be estimated, a correction can be made for the children who have died. As the average age of the children enumerated as under one year will be six months, ignoring any seasonal movement in the births, a correction is required only for mortality during the first six months of life. A method of detecting the under enumeration of the children under one year of age has been outlined in Chapter II.

Application of Formulae to African Negroid Populations.

Apart from the effect of reporting errors, which will be discussed in Chapter VI, an estimate of the expectation of life at birth of an African Negroid population obtained from formula (23 a) is likely to be biased because it is to be expected that the W_x distributions of these people are quite different from the average distribution of the populations used in arriving at this formula. The W_x distribution is a function of the relative age specific fertility rates, the trend of fertility and the age distribution of the population. In the previous chapter it was indicated that there is a marked difference between the distribution of the relative age specific fertility rates of African Negroid populations and most other populations. A comparison of the averages of the age distributions given in Tables A and B of the Appendix shows that African Negroid populations have a larger proportion of young persons, and a smaller proportion of old persons, than the other populations. Formula (25 a) takes account of the W_x distribution, but in most cases it will be necessary to estimate the value of W_0. This obviously introduces an additional source of error. Further the constants given in formula (25 a) are based on the mortality experience of non-African-Negroid populations and might require adjustment for the peculiarities of the African Negroid populations. Finally the constants are in respect of estimates based on returns from all women aged fifteen years and over and they might require adjustment for estimates where the returns for the older women are excluded because they are thought to be faulty. These aspects of the formula are considered below.

Estimation of W_0. It has been suggested that where the number of births during the twelve months preceeding the date of the enquiry is either not available or unreliable, the value of W_0 to be used in formula (25 a) may be obtained from formula (26 i) or (26 ii). This gives an estimate of W_0 based on the assumptions (i) that there is an equal number of persons at each individual year of age within each quinquennial age group and (ii) that the level of fertility has remained unchanged throughout the period under consideration. In the case of the African Negroid populations it is also necessary to make some assumption regarding the distribution of the relative age specific fertility rates. In the previous chapter it was suggested that the rates of the U.S.A. non-white population are appropriate. In addition it is necessary to bear in mind that the reported age distribution may contain various errors and in some cases it may be necessary to estimate the quinquennial age distribution from particulars in respect of only a small number of broad age groups.

The affects of all these factors on the efficiency of the estimate of W_0 may be examined by comparing the theoretical results obtained in respect of the 1946 Native female population of the Union of South Africa on various asdumptions. Table A of the Appendix shows that the age distribution of these females is typical of the African Negroid populations and full details are available of the distribution by individual years of age. A number of estimates of the value of W_0 for this population are given in Table IX on page 137.

Comparing estimates 1a and 2a it is evident that the assumption of an equal number of persons at each individual year of age within each quinquennial age group results in an over-estimate of .002 or about 5 per cent. Since the age dis-

Table IX: Various Estimates of w_0 in Respect of the 1946 Native Population of the Union of South Africa.(1)

Basis of Calculation	Value of w_0
1. Relative age specific fertility rates of U.S.A. non-white population applied to figures by individual years of age:	
a. Assuming constant fertility	.039
b. Assuming fertility declined by one per cent. per annum.	.035
2. Assuming equal number of persons within each quinquennial age group and using relative age specific fertility rates of	
a. U.S.A. non-white population	.041
b. Average population as given in Table C of Appendix.	.043

(1) In respect of all women aged fifteen years and over.

tribution of all African Negroid populations, as far as females are concerned, is roughly the same[1] this may be assumed to be a constant bias and allowed for in all estimates of w_0 obtained from formula (26 i).

Comparing estimates 1a and 1b, the assumption of constant fertility leads to an upward bias of .004 or roughly 10 per cent. if fertility has in fact declined by one per cent. per annum. A decline of one per cent. per annum is equivalent to a fall of about 40 per cent. in fifty years. Comparing estimates 2a and 2b it appears that the use of relative age specific fertility rates as far apart as those of the U.S.A. non-white population and the average given in Table C of the Appendix affects the estimate of w_0 by .002 or about 5 per cent.

The significance of these variations on estimates of the expectation of life at birth may be judged by examining formula (25 a). The relevant term is $-273.5\, w_0 \frac{S_F}{C_F}$. An

(1) See Table A of Appendix.

error of 10 per cent., say .004 in the value of w_0 would affect the estimate of the expectation of life at birth by $1.09 \frac{s_f}{c_f}$. Where f refers to all women aged fifteen years and over as in this case, the value of $\frac{s_f}{c_f}$ will range from about .567 for an expectation of life at birth of 30 years to about .857 for an expectation of life at birth of 60 years.(1) An error of 10 per cent. in the value of w_0 will therefore affect the estimate of the expectation of life at birth by between about 0.6 and 0.9 years.

Where the detailed age distribution of the female population is not known and cannot be estimated, it is suggested that an estimate of w_0 be obtained by applying the relative age specific fertility rates of the U.S.A. non-white population to the average age distribution of African Negroid populations as given in Table A of the Appendix. An estimate obtained in this way might be assumed to have a standard error of about the same magnitude, say 2.5 years, as the standard error of estimates obtained from formula (23 a) in respect of the non-African-Negroid populations considered previously.(2)

<u>Suitability of Constants of Formula (25 a)</u>. So far it has been assumed that the constants given in formula (25 a) are applicable to African Negroid populations. These constants are based on life tables with an average expectation of life at birth of 52.47 years, but it is to be expected that the average expectation of life of the African Negroid populations is somewhat lower than this. It is therefore necessary to examine to what extent these constants have to be adjusted for populations with a relatively low expectation of life at birth. For this it is assumed that the w_x distribution obtained by applying the relative age specific fertility rates of the U.S.A. non-white population to the age distribution of the 1946

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(1) Estimated from formula (23 a) on p. 127.

(2) See p. 132.

Native females in the Union of South Africa is typical of the African Negroid populations. This distribution was applied to the life table probabilities of life tables with an expectation of life at birth of under 40 years, given in Table H of the Appendix, to obtain theoretical values of the ratio of children still living to total children ever born. These figures, the resulting estimates of the expectations of life at birth and the actual expectations of life are given in Table X.

Table X: Test of Possible Bias in Estimates Obtained from Formula (25 a) in Respect of Populations with a Low Expectation of Life at Birth.

Country	Estimated Value of $\frac{S_F}{C_F}$ (1)	Expectation of life at birth		Estimate minus actual figure
		Actual (years)	Estimated (years)	
British Guiana	.605	32.4	34.5	(+) 2.1
Brazil	.640	37.4	37.6	(+) 0.2
Chile	.608	37.7	34.7	(-) 3.0
Guatemala	.625	37.1	36.3	(-) 0.8
India	.479	24.0	23.1	(-) 0.9
Mauritius	.626	33.8	36.2	(+) 2.4
Mexico	.578	34.1	32.0	(-) 2.1
Trinidad	.675	38.8	40.7	(+) 1.9
U.S.S.R. (in Europe)	.548	33.4	29.3	(-) 4.1

(1) In respect of all women aged fifteen years and over. These values were obtained by the technique outlined on pp. 122 - 125 using the age distribution of the 1946 Native female population of the Union of South African, the 1940 relative age specific fertility rates of the U.S.A. non-white population and the particulars given in Tables H and I of the Appendix.

The estimated values of the expectation of life at birth are, on the average, 0.5 years below the true figures. However, as there are only nine cases, this cannot be regarded as a significant bias. The standard error of these differences is 2.2 years and this suggests that an estimate obtained for a population with a low expectation of life at birth has a larger standard error than one in respect of a population with a high expectation of life at birth.

Although formula (25 a) appears to give unbiased estimates in respect of populations with high and low values of the expectation of life at birth, a bias may be introduced in estimates in respect of African Negroid populations, as a result of some peculiarity in the distribution of African Negroid life table probabilities. Sonnabend has suggested[1] that there is an unusually marked rise in mortality rates at the age of three or four years because of the abrupt weaning of children. Life tables have been prepared for African Negroid people in Lagos in 1931[2] and on the Witwatersrand in 1946.[3] Unfortunately in the latter case the published figures give only the expectations of life at certain ages, so that a detailed comparison with other life tables cannot be undertaken. However, the expectation of life at comparable years of age for various life tables may be reduced to a common level by dividing each set of figures by the appropriate expectation of life at birth. The two extreme distributions of the life tables referred to in Table X are those for Russia in Europe and Mauritius. These and the average distribution of the nine life tables referred to in Table X are compared with the corresponding figures for the Lagos and Witwatersrand life tables in Table XI on page 141.

Except for the two ages of one and eighty in Lagos, all the figures for the African Negroid populations fall within the range of the other figures. The Lagos figures are below the average distribution of the nine life tables referred to

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(1) Sonnabend H. (1934) "Demographic Samples in the Study of Backward and Primitive Populations", South African Journal of Economics, Vol. II, No. 3, p. 306

(2) Census of Nigeria, 1931 Vol I, pp. 80-85.

(3) Sadie J.L. (1951) "Differential Mortality in South Africa", South African Journal of Economics, Vol. 19, No. 4, p. 361.

Table XI: Comparison of Life Tables of African Negroid Populations and Other Populations with a low Expectation of Life.

Age (years)	Expectation of life at specified age divided by expectation of life at birth.					
	Witwatersrand 1946		Lagos 1931 (males)	Russia (upper limit)	Mauritius (lower limit)	Average for Table X
	Males	Females				
1	1.22	1.22	1.15	1.31	1.18	1.22
2	1.41	1.35	1.30	1.42	1.23	1.31
5	1.44	1.37	1.27	1.51	1.21	1.34
10	1.36	1.29	1.17	1.45	1.10	1.25
20	1.15	1.10	.98	1.23	.89	1.04
30	.92	.90	.81	1.02	.77	.87
40	.72	.71	.64	.81	.63	.70
50	.53	.52	.48	.61	.46	.53
60	.38	.37	.33	.42	.31	.37
70	.26	.26	.20	.29	.21	.25
80	.17	.17	.11	.23	.14	.15

in Table X, but the Witwatersrand figures are above the average. Although the life tables of the African Negroid populations are very rough ones and although they refer to urban conditions, the available evidence gives no indication that formula (25 a) will give a biased estimate of the expectation of life at birth of African Negroid populations if the basic returns are reliable.

Adjustment of Formula (25 a) for the Exclusion of Faulty Returns. The constants given in formula (25 a) are based on the assumption that the returns for all women aged fifteen years and over are taken into consideration. In practice, particularly with African Negroid populations, the returns in respect of the older women are likely to be faulty because of a tendency for these women to omit some of their children who died in early infancy. The exclusion of these faulty returns might give a biased estimate of the expectation of life, if an appropriate adjustment is not made to the constants. Fresh formulae with revised constants could be determined, by the method used previously, for the exclusion of the returns in respect of women over various ages. However, a simpler approach is to examine to what extent formula (25 a) will give biased estimates and then determine what adjustment is necessary to the estimates obtained from formula (25 a).

For this purpose the relative age specific fertility rates of the U.S.A. non-white population were applied to the average age distribution of Negroid populations, as given in Table A of the Appendix, to obtain estimates of the distribution over time of the total children ever born to African Negroid women up to the ages of (i) 34 and (ii) 49 years. These distributions were then applied to the life table probabilities, used in arriving at formula (25 a), to obtain theoretical values of the ratio of children still living to total children ever born. The values of these ratios for the various life tables are given below.

Table XII: Theoretical Values of the Ratio of Children Still Living to Total Children Ever Born in Respect of an Average African Negroid Population.

Life table used as basis of calculation (1)		Ratio of Children still living to total children ever born	
Country	Expectation of life at birth (years)	Women aged 15-34 years	Women aged 15-49 years
Belgium	48.8	.817	.797
British Honduras	49.0	.823	.801
Canada	62.1	.930	.918
Denmark	56.2	.884	.866
England & Wales	55.4	.874	.860
Finland	48.1	.826	.798
France	48.7	.827	.804

(1) See Tables E and G for further details.

Table XII Continued

Life table used as basis of calculation		Ratio of Children still living to total children ever born	
Country	Expectation of life at birth (years)	Women aged 15-34 years	Women aged 15-49 years
Hawaii	47.3	.870	.844
Iceland	53.1	.863	..844
Jamaica	41.4	1779	.742
Japan	44.8	.810	.778
Netherlands	53.4	.851	.833
New Zealand	60.6	.929	.918
Northern Ireland	56.1	.908	.894
Norway	57.7	.916	.900
Scotland	56.4	.890	.874
S. Rhodesia (Europeans)	62.6	.937	.927
Sweden	57.0	.906	.885
Switzerland	52.2.	.882	.867
Trinidad	38.8	.779	.748
U.S. A.	50.7	.855	.835
Average	52.4	.865	.844

The values of W are .095 for the women aged up to 34 years and .057 for the women aged up to 49 years. Using these values and the ratios given above in formula (25 a) results in an average under-estimate of the expectation of life at birth of 7.6 years when women up to the age of 34 years are considered, but an under-estimate of only 0.3 years when women up to 49 years are considered. For practical purposes the bias of 0.3 years at the age of 49 years is small enough to be ignored, but the bias becomes substantial when the returns for women aged 34 years and over are excluded. It is convenient to assume that there is a linear relationship between the magnitude of the bias and the age of the oldest woman under consideration. It may be assumed that formula (25 a) gives a downward bias of about 0.5 for each year by which 49 exceeds the age of the oldest woman under consideration. With adjustments on this basis, the standard error, as given by formula (14) on page 103, of estimates obtained from formula (25 a), rises from 1.8 years when women of all ages are under consideration to 2.8 years when women over

49 years are excluded and to 3.5 years when women over 34 years are excluded. Because of the small numbers involved, the returns for women above the age of about 70 years contribute very little to the overall ratio of children ever born to women questioned. Consequently, it may be assumed that the standard error of estimates obtained from formula (25 a) is 1.8 years when women over 59 years are included or excluded and that it increases by about o.05 for each year by which 69 exceeds the age of the oldest woman under consideration. It should be borne in mind that the exclusion of women younger than about 40 years is undesirable because the expectation of life at birth is then estimated on the mortality experience in respect of less than the first 25 years (40 minus the beginning of the childbearing period) of life.

The Relationship Between the Expectation of Life at Birth of Males and Females.

In general males are subject to higher mortality rates than females, so that the expectation of life of females is generally higher than that for males and higher than that for for the two sexes taken together. As the customary net reproduction rate relates female births to their mothers, it is based on the mortality experience of females. Separate estimates of the expecthtion of life at birth of males and females can be obtained from the formulae given previously, provided the returns of the total children ever born and the number of these still living distinguish between males and females. Where, as is often the case amongst African Negroid populations, the sexes are not shown separately, the resulting estimate of the expectation of life is an average for the two sexes. The use of this average as an indication of the appropriate life table to be used to obtain a net reproduction rate may give a slightly biased estimate of the net reproduction rate, unless the fact that the expectation of life at birth of females is usually above that for the two sexes is taken into consideration. In the case of countries with relatively low mortality rates the expectation of life at birth of females has been as much as 6.5 years above that for males in the case of Finland. Amongst the countries with heavy mortality rates the figure for females has been as high as 5.8 years above that for males in the case of Egypt.(1)

The fact that males are subject to higher mortality rates than females is attributed to two factors. In the first place males are biologically weaker than females,(2) a fact invariably reflected in the relatively heavy mortality rates for males during the first few years of life. In the second place males are generally exposed to greater occupational hazards. Amongst primitive peoples the occupational hazards of males may not be as great as they are in the more developed countries, but the females are possibly subject to relatively heavy maternal mortality rates because of the crude methods employed in primitive midwifery.(3) These factors will tend to bring the expectations of life of males and females closer together than is the case amongst the advanced communities. There will be a further tendency for the figures to come together if a primitive race regards the males as more important than females, for more attention is then likely to be paid to an ailing male than to a sick female. However, if the female is the predominant sex the position will tend to be reversed, so that the effect of a reduction in the occupational hazards of males and an increase in the maternity risks of females is counter-balanced by the fact that greater care is taken of females. There is also the possibility that the relative biological weakness

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(1) 1951 Demographic Yearbook, United Nations, Table 29.

(2) Hamilton J.B. (1948) "The Role of Testicular Secretions as Indicated by the Effects of Castration in Man and by Studies of Pathological Conditions and the Short Lifespan Associated with Maleness," Proceedings of Laurention Hormone Conference, Academic Press, New York, Vol. III, p. 257.

(3) Dublin L.I. et. al. (1949) Length of Life, Ronald Press, New York, p. 129. Census of India, Paper No.2, Life Tables 1951, Manager of Publications, Delhi, (1954), p. 25.

of the male sex referred to above is exaggerated rather than improved under primitive conditions.

Table XIII: Differences Between Male and Female Expectations of life: Countries with an Expectation of Life at Birth of Less than 40 years.[1]

Country	Date	Expectation of life at birth		Excess of females over males
		Males	Females	
British Guiana	1910-12	29.9	32.4	2.5
Chile	1930	35.4	37.7	2.3
Guatemala	1939-41	36.0	37.1	1.1
India	1891-01	23.6	24.0	0.4
Mauritius	1942-46	32.3	33.8	1.5
Mexico	1930	32.4	34.1	1.7
Trinidad	1900-03	36.7	38.8	2.1
U.S.S.R.	1896-97	31.4	33.4	2.0

(1) 1951 Demographic Yearbook, United Nations, pp. 526-39.

In table XIII the expectation of life at birth of females is, on the average, 1.7 years above that for males. For African Negroid populations there are only three sets of figures available at present. Amongst the 1946 Native population of the Witwatersrand the expectations of life at birth were 35.7 for males and 37.1 for females.[1] In Southern Rhodesia in 1953 the figures were 46.3 for males and 47.9 for females.[2] In Northern Rhodesia the 1950 figures were 35.0 for males and 36.9 for females.[2] For these three sets of figures the females have an average expectation of life at birth of 1.5 years above that for males. In the absence of any further information on the subject, it will be assumed that the expectation of life at birth of African Negroid females is 0.8 years, that is about half the average differences referred to above, higher than the average for the two sexes obtained from formula (25 a). Similarly it will be assumed that the expectation of life at birth of the males is 0.8 years above the average for the two sexes.

(1) Sadie J.L. (1951), "Differential Mortality in South Africa," South African Journal of Economics, Vol. 19, No. 4, p. 361.

(2) Figures obtained from formula (25a) for the 1950 and 1953 Demographic sample surveys of Northern and Southern Rhodesia respectively. For further details see pp. 200-203.

CHAPTER VI

FURTHER CONSIDERATION OF RETURNS OF TOTAL CHILDREN EVER BORN AND NUMBER OF THESE STILL LIVING.

In applying the formulae developed in the two previous chapters to primitive races it is necessary to bear in mind that biases are likely to be introduced by reporting errors in the basic returns. Adjustments to the formulae for the exclusion of the faulty returns of the older women have already been given. Methods of detecting reporting errors are discussed below. This leads to a consideration of methods of detecting secular trends in fertility and mortality. Finally consideration is given to the estimation of the net reproduction rate and the standard rate of natural increase.

Reporting Errors.

Sources of Error. It is well known that returns of the total children ever born are apt to omit at least a few of the children who have died.[1] Children who die shortly after birth are especially likely to be omitted, particularly in the returns for the older women. Such omissions result in an under-statement of the ratio of children ever born to women questioned and an over-statement of the ratio of children still living to children ever born. Consequently the total fertility rate will tend to be under-estimated and the expectation of life at birth will tend to be over-estimated. Somewhat similar errors would result from any departure from the ideal definition of the term "live-birth", that is a birth which shows

(1) Kuczynski R.R. (1935) The Measurement of Population Growth, Sidwick & Jackson, London, pp. 79-80. 1949-50 Demographic Yearbook, United Nations, p. 19.

any sign of life at the moment of birth.[1] On the one hand, the births and deaths may be inflated by the inclusion of still-births and on the other hand the returns might be deflated by a general exclusion of children that died within a a few days, or perhaps a few weeks, of birth. In view of the customs and superstitions referred to in Chapter III, it seems likely that, amongst African Negroid populations, there is a tendency for some children that die in early infancy to be excluded.

Mortara has drawn attention[2] to a tendency for women who report their ages in round numbers, that is ages ending in a nought or a five, to be particularly prone to under-state their total births. The implication is that persons who forget their age are also apt to forget their children who have died. Errors due to this factor might not be important amongst the African Negroid populations because the ages are normally estimated by the field officers, so that errors in the age distribution are a reflection of the field officers' work rather than a reflection of mis-statements by the public. Figures of the total children ever born to women of each individual year of age are available for all ages only in the case of the 1948 sample survey in the Gold Coast.[3] These are summarised in Table XIV on page 149.

This table begins with ages ending in five since the child-bearing period starts at fifteen. Normally the number of women in each age group should decline steadily from a maximum for ages ending in five to a minimum for ages ending in four. The average number of children per woman should show a slight,

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(1) Principles for a Vital Statistics System, (1953) Statistical Papers Series M. No. 19, United Nations, p. 6.

(2) Methods of Using Census Statistics, (1949) Population Studies No. 7, United Nations, p. 44.

(3) Gold Coast Census of Population, 1948, Crown Agents for the Colonies, London (1950), p. 395.

Table XIV: Number of Women, and Number of Children Ever Born to Them, by End Ages: 1948 Sample Survey in Gold Coast.

Ages ending in the following digits	Number of Women	Total Children ever born	Average number of children per woman
5	3,666	13,472	3.67
6	2,699	8,988	3.23
7	2,032	6,310	3.10
8	3,508	12,185	3.47
9	2,765	9,214	3.33
0	5,199	21,035	4.11
1	1,593	5,150	3.23
2	2,146	8,270	3.86
3	1,277	4,729	3.70
4	1,630	5,540	3.40

but steady, rise from ages ending in five to ages ending in four. The actual figures given in the table above suggest that the field officers over-stated the number of women in ages ending in 5, 8, 0, 2 and 4. The average number of births to women of these ages appears to be over-stated rather than under-stated.

Another source of error has been mentioned by Edge.[1] He states that some women refrain from including their first born because of a fear of bringing misfortune upon this child. A third party, that is the husband or another woman, would, however, give a correct return. On the other hand You Poh Seng[2] refers to a tendency for adopted children to be included in some areas. Where a man marries a second time after his first wife's death, the living wife sometimes tends to in-

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(1) Edge P.G. (1944) Vital Statistics and Public Health Work in the Tropics, Williams & Wilkins, Baltimore, p. 30.

(2) You Poh Seng (1949) "Practical Problems in Sampling for Social and Demographic Inquiries in Undeveloped Countries", Population Studies, Vol. III, No. 2, p. 170.

clude the children of the first wife with her own, as they all have a common father. A similar position may arise where one of the wives of a polygamist has died.

Detecting Errors. The reporting errors referred to above are likely to affect the returns for certain age groups more than others. Thus the omission of children that died in early infancy will tend to be most marked in the returns in respect of the older women. Similarly a tendency to include adopted children might be most pronounced amongst the older women. On the other hand a tendency to omit the first born will affect the returns of the younger women more than those of the older women, since the younger women will have a relatively large proportion of first births. Consequently such errors will tend to be reflected in an analysis of the returns by quinquennial age groups. For example, if the older women have omitted some of their children that died in early infancy, their total fertility rate will tend to be lower than that of the younger women and at the same time the survival rates of the children of the older women will tend to be overstated. However, an examination of the returns by quinquennial age groups for the purpose of detecting reporting errors is complicated by the fact that the average number of births, and the survival rates of the children, are affected by the ages of the women and also by secular trends in the level of fertility and mortality. These factors are considered in the following sections.

A further indication of reporting errors might be obtained if the sex ratio of each group of children is available. As explained in Chapter III, amongst live births, females are normally about 48.5 per cent. of total births. Any marked departure from this normal proportion of females, either in the returns for women of all ages or in the returns for women of only some age groups, is an indication of reporting errors.

Secular Trends of Mortality.

The survival rates in respect of the children of women of different ages may be affected by three factors, namely reporting errors, the fact that the age to which the children survive increases with the age of their mothers, and secular trends in the general level of mortality. If the effect of the ages of the mothers is eliminated, the remaining variations may be due to either reporting errors or a secular trend in mortality rates. The choice between these two explanations of variations in figures standardised for the age factor is largely a matter for personal judgement. It seems likely that mortality rates have declined in the more recent years because of a reduction in the number of deaths due to tribal wars and starvation and also as a result of improvements in medical services. An apparent deterioration in mortality rates is, therefore, prima facie evidence that the returns are faulty. Further evidence of reporting errors might be obtained from an examination of the apparent trend of fertility and an examination of the sex ratio of the total children ever born. The omission of children that died in early infancy is likely to be reflected in (i) an apparent deterioration in mortality rates and (ii) an apparent improvement in the level of fertility, as the age of the women increases.

The effects of the variable age factor on the survival rates may be eliminated by converting each survival ratio into an estimate of the expectation of life at birth taking due consideration of the age factor. The survival ratio of the children of the women of any specified age is a function of the various dates of birth of the children and the appropriate life table. The various dates of birth may be estimated by applying appropriate age specific fertility rates to the women under consideration. Assuming that there has been no change in the general level of fertility of the particular group of women in question, the survival ratio may be expressed in terms of the life table probabilities and the age specific fertility rates as follows:

Let F_s = women aged s years at the date of the enquiry.

C_s = total number of children ever born to the F_s women.

$X_{s'}$ = relative age specific fertility rate at the age s' years, (s' = 15, 16, 17 .... 49) and $\sum_{s'=15}^{49} X_{s'} = 1$

R = total fertility rate.

P_x = probability of surviving to the age of x years six months, it being assumed that the births for any one year are spread evenly throughout that year.

S_s = survivors of the C_s children.

When the women under consideration are under fifty years of age

$$C_s = R.F_s (X_{15} + X_{16} + X_{17} + ---- X_s)$$

$$S_s = R.F_s (P_0 X_s + P_1 X_{s-1} + P_2 X_{s-2} + ----- P_{s-15} X_{15})$$

$$\therefore \frac{S_s}{C_s} = \frac{(P_0 X_s + P_1 X_{s-1} + P_2 X_{s-2} + ---- P_{s-15} X_{15})}{(X_{15} + X_{16} + X_{17} + --- X_s)} \quad \text{........ (27)}$$

and similarly when the women under consideration are over 49 years of age

$$\frac{S_s}{C_s} = \frac{P_{s-49}X_{49} + P_{s-48}X_{48} + \cdots P_{s-15}X_{15}}{X_{15} + X_{16} + X_{17} + \cdots X_{49}}$$

$$= P_{s-49}X_{49} + P_{s-48}X_{48} + \cdots P_{s-15}X_{15} \qquad \ldots\ldots (28)$$

Where the age of the women under consideration coincides with the end of one of the normal quinquennial age groups, the calculation of the survival ratio may be simplified. The relative age specific fertility rates for the quinquennial age groups, which are the weighted average of the rates for the individual years within each age group, may be substituted for the rates for the individual years. For example, when women aged 34 years are considered, formula (27) reduces to

$$\frac{S_s}{C_s} = \frac{X'_4(P_0 + P_1 + P_2 + P_3 + P_4) + X'_3(P_5 + P_6 + P_7 + P_8 + P_9) \text{ etc.}}{X'_1 + X'_2 + X'_3 + X'_4}$$

where X'_1 , X'_2 etc. are the relative age specific fertility rates for the age groups 15-19, 20-24 years, etc.

The change in the survival ratio, due to a rise in the age of the women, may be determined from formulae (27) and (28) for any given life table if the distribution of the relative age specific fertility rates is known. The relationship between the survival ratio, age of women and the expectation of life at birth may be estimated by calculating a number of theoretical values for various ages and various life tables and then determining the relationship between these variables. Values in respect of women aged 34, 54 and 74 years are given in Table XV and plotted in Chart V.

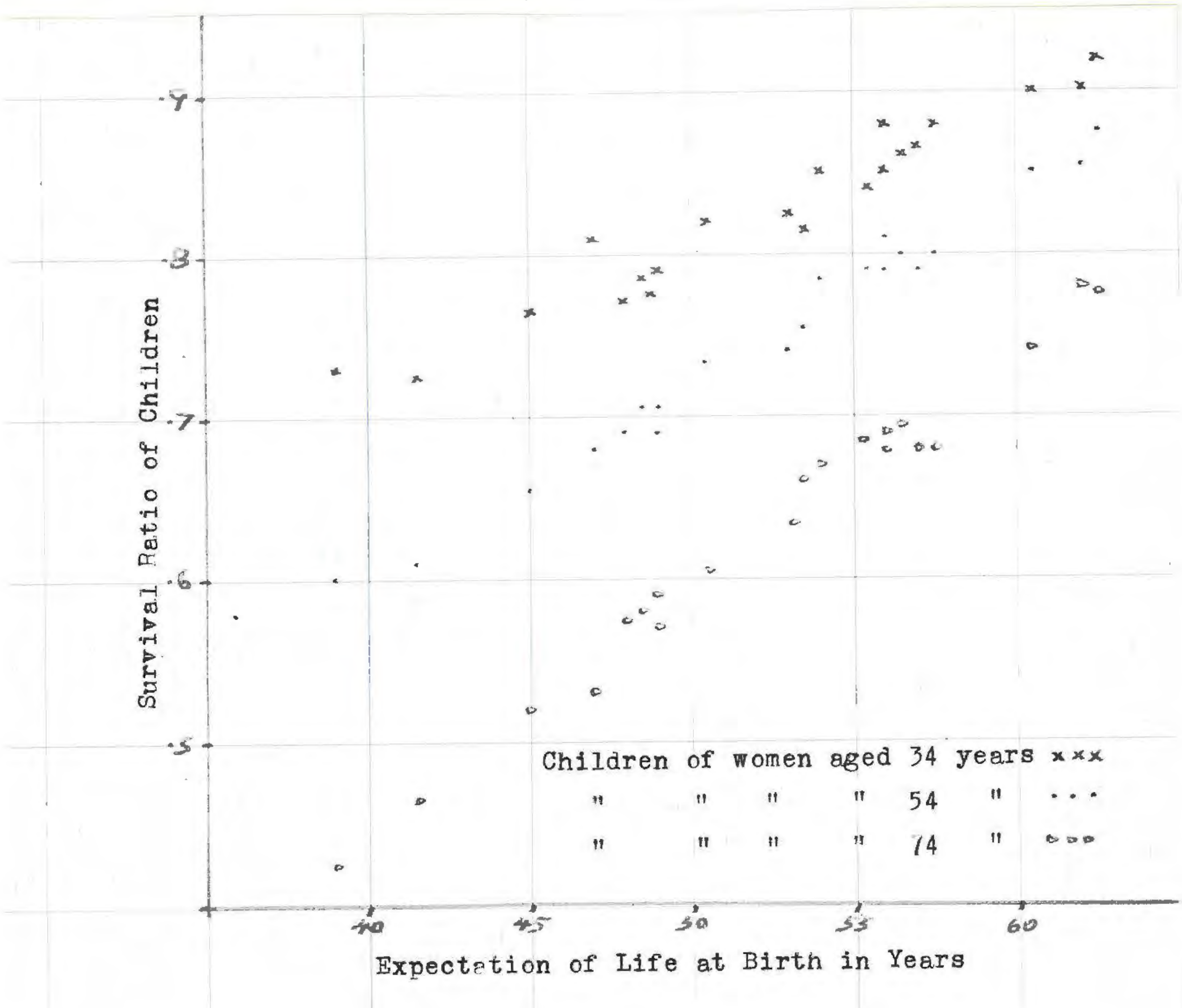
Table XV: Survival Ratio of Children of Women Aged 34, 54 and 74 years.[1]

Expectation of life at birth (years)	Survival Ratio when mothers' are at the following ages:		
	34 years	54 years	74 years
48.8	.778	.706	.592
49.0	.790	.690	.570
62.1	.902	.855	.767
56.2	.850	.788	.686
55.4	.841	.790	.685
48.1	.776	.686	.574
48.7	.788	.705	.585
47.3	.811	.679	.531
53.1	.824	.739	.635
41.4	.723	.613	.466
44.9	.766	.655	.520
53.4	.815	.757	.658
60.6	.899	.852	.742
56.1	.877	.809	.683
57.7	.882	.796	.679
56.4	.860	.801	.695
62.6	.917	.874	.776
57.0	.864	.788	.682
53.9	.849	.784	.668
38.8	.732	.598	.424
50.7	.817	.736	.605

(1) Obtained by applying the relative age specific fertility rates of the U.S.A. non-white population to the life table probabilities as estimated for examining formula (21). For details of the method of estimating these life table probabilities see pp. 123-4.

Chart V.

Relationship Between the Survival Ratio of the Children of Women aged 34, 54 and 74 years and the Expectation of Life at Birth.



The figures plotted in Chart V suggest a function of the form

$$e^{\circ}_{\circ} = x_s + y_s \frac{S_s}{C_s} \qquad \text{.........} \; (29)$$

where x_s and y_s are parameters which vary with the value of s, the age of the women under consideration. This is similar to formula (23) on page 127 and proceeding as before the following values of x_s and y_s are obtained by the method of least squares: When $s = 34$, $x_s = -64.3$ and $y_s = +141.3$. When $s = 54$, $x_s = -10.6$ and $y_s = +84.3$. When $s = 74$, $x_s = +9.1$ and $y_s = +68.9$. Intermediate values of x_s and y_s may be obtained by interpolating these figures. Assuming that the relationship between (i) x_s and s and between (ii) y_s and s takes the form

$$x_s = a + bs + cs^2$$

$$y_s = a' + b's + c's^2$$

the figures given above produce two sets of three simultaneous equations for the values of x_s and y_s. These give

$$x_s = -233.8 + 6.425s - 0.0425s^2$$

$$y_s = 333.8 - 7.426s + 0.0520s^2$$

Values of x_s and y_s for the mid-points of the quinquennial age groups between the ages of 35 and 74 years are then as follows:

<u>Table XVI: Various Values of x_s and y_s for use in Formula (29).</u>

Quinquennial Age Groups	x_s	y_s
35-39	(-) 47.5	(+) 128.4
40-44	(-) 37.2	(+) 111.7
45-49	(-) 24.1	(+) 98.1
50-54	(-) 14.5	(+) 87.2
55-59	(-) 4.8	(+) 77.7
60-64	(+) 1.8	(+) 72.9
65-69	(+) 6.4	(+) 69.9
70-74	(+) 10.6	(+) 69.1

For the purpose of judging the time factor with regard to secular trends, reference may be made to the weighted average date of the births of each group of women. With constant fertility, the weight for each year is determined only by the distribution of the relative age specific fertility rates. For the relative age specific fertility rates of the U.S.A. non-white population the weights for the births to women aged 34, 54 and 74 years are as follows:

Table XVII: Relative Weights for Determining Weighted Average Date of Birth of Total Children Ever Born to Women aged 34, 54 and 74 years.

Births in the following years prior to date of enquiry.	Relative weight[1] in respect of children of Women of the following Ages:		
	34 years	54 years	74 years
0- 4	.029	—	—
5- 9	.041	.001	—
10-14	.059	.007	—
15-19	.045	.018	—
20-24	.—	.029	—
25-29	—	.041	.001
30-34	—	.059	.007
35-39	—	.045	.018
40-44	—	—	.029
45-49	—	—	.041
50-54	—	—	.059
55-59	—	—	.045.

(1) Relative age specific fertility rates taken in reverse. For example in the case of women aged 34 years the weight for the years 0 - 4 is the relative age specific fertility rate for the age group 30-34 years, the weight for 5-9 years is the rate for the 25-29 year age group and so on.

Assuming that the births which occurred 0 - 4 years before the date of the enquiry are centred at 2.5 years, that those which occurred 5 - 9 years before the enquiry are centred at 7.5 years and so on, the average date of birth of the children of the women aged 34 years is 11 years before the date of the enquiry. Similarly the children of the women aged 54 and 74 years were on the average born 29 and 49 years before the date of the enquiry. These dates should not be confused with the average date of the mortality rates under consideration. The latter is a function of the numbers surviving to each age of life, that is a function of the appropriate life table as well as a function of the age specific fertility rates.

The standard errors, as measured by formula (14) on page 103 and the figures given in Table XV, of estimates obtained from formula (29), are 2.1 years for returns in respect of women aged 34 years, 0.9 years when women aged 54 years are considered and 0.8 years for women aged 74 years. For practical purposes it may be assumed that the standard error is 0.9 years for the returns of women aged 49 years or over and that it increases by $\frac{2.1 - 0.9}{49 - 34}$, that is by 0.08, for each year by which 49 exceeds the age of the oldest women under consideration. These standard errors should be taken into consideration when figures for two or more age groups are being compared, as otherwise an improvement in the efficiency of the estimates, associated with a rise in the age of the women, may be mistaken for a secular trend in mortality rates.

The standard errors given above are significantly lower than those given on page 144 for estimates obtained from formula (25 a). Estimates obtained from the latter formula have a standard error of 1.8 years when all women up to the age of 74 years are considered, 2.8 years when the returns of women aged 50 years and over are omitted and 3.5 years when the returns of women over 34 years are excluded. Although the standard errors given above for formula (29) are smaller than these, formula (25 a) will give the better estimates of the expectation of life. Apart from the fact that formula (29) uses the returns for only a small group of women, the absolute value of the expectation of life may be biased. For example, if the figures given in Table XV are revised on the basis of the average relative age specific fertility rates given in Table C of the Appendix, the estimates obtained from the parameters given above lead to an upward bias of about three years. On the other hand, as shown on pages 137-140, estimates obtained from formula (25 a) are not affected to any significant extent by variations in the relative age specific fertility rates, as these are taken into consideration by the value of w_0 , the proportion of the total number of children ever born who were born in the twelve months preceeding the date of the enquiry. Although the estimates obtained from formula (29) may be biased by the extent to which the actual relative age specific fertility rates differ from those of the U.S.A. non-white population, any such bias is not likely to have a marked effect on the apparent trend of the mortality rates since all the estimates will be affected to about the same extent. Formula (29) is intended to reflect only the trend of mortality rates and it is not intended to give an unbiased estimate of the absolute level of the expectation of life at birth.

Secular Trends of Fertility.

An indication of secular trends of fertility, or reporting errors in the returns of the total children ever born, may be obtained by using some suitable distribution of the relative age specific fertility rates in conjunction with the average number of children ever born to women in successive age groups. In Chapter IV it was suggested that the relative age specific fertility rates of the U.S.A. non-white population are close to those of African Negroid populations. If the general level of fertility is assumed to have remained constant, in so far as each group of women is concerned, the average number of children ever born to women in a particular age group may be converted into a total fertility rate by taking account of the level to which this average is likely to rise by the time the women under consideration reach the end of the childbearing period. The appropriate corrections to be made for the relative age specific fertility rates of the U.S.A. non-white population are given in Table XVIII.

Table XVIII: Relationship Between Relative Age Specific Fertility Rates and Their Aggregates: U.S.A. non-White Population.

Age Group (years)	Relative Age Specific Fertility rate	Cumulated figures	Correction Factor to be applied to average number of births to estimate Total Fertility[1]
15-19	.045	.045	4.45
20-24	.059	.104	1.92
25-29	.041	.145	1.38
30-34	.029	.174	1.15
35-39	.018	.192	1.04
40-44	.007	.199	1.01
45-49	.001	.200	1.00

(1) 0.200 divided by cumulated figures.

The use of the correction factors given above for women under the age of 25 years is not likely to give very satisfactory estimates of the total fertility rate because such women have experienced only up to half of their child-bearing history. For age groups above the age of 49 years the average number of children ever born is a direct measure of the total fertility rate. Some indication of the weighted average date to which the births of each group of women refer has already been given on page 157.

The method outlined above is obviously only a very rough one. The apparent trend will be affected by the extent to which the actual relative age specific fertility rates differ from the assumed rates. A further indication of the trend of fertility might be obtained by estimating the actual distribution of the age specific fertility rates, as indicated on pages 166-7, and judging if these are reasonable. If the distribution of such estimates appears abnormal it will be apparent that the level of fertility has been changing. The departures from the normal will indicate whether fertility has been declining or rising. If fertility has been rising the rates for the younger age groups will appear to be very high and the rates for the older age groups will appear to be low. If fertility has been falling the rates for the younger ages will tend to be low while those for the older ages will appear to be high.

In examining an apparent change in the level of fertility it is necessary to bear in mind that the apparent changes may be a reflection of reporting errors. The choice between these two alternatives is largely a matter for personal judgement. As indicated in Chapter IV, there is a general opinion amongst medical officers that there has been a decline in fertility as a result of a rising incidence of venereal diseases, but in some areas it is likely that in the more recent years such a downward trend has been arrested, if not reversed, by an increase in health services. The most likely source of error is the omission of children that died in early infancy, particularly in the returns for the older women. These errors are likely to be reflected in an average number of births per woman which decreases as the age of the women increases. In order to decide whether or not an apparent trend in fertility is due to reporting errors, it is desirable to refer also to the apparent trend in mortality.(1)

Estimation of Gross and Net Reproduction Rates.

The Gross Reproduction Rate is normally obtained by multiplying the total fertility rate by the ratio of female births to total births. Amongst live births there is normally a ratio of about 485 females for every 1,000 births. Where no information is available from the returns of the total children ever

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(1) See pp. 151-2.

born, because the published figures refer to the two sexes taken together, the gross reproduction rate may be obtained by assuming a ratio of 485 females per 1,000 births. There is a tendency to use this normal ratio when published figures show an abnormal ratio. There is no objection to this where the observed departure from the normal position can be attributed to a chance variation, but where reporting errors give rise to an abnormally high proportion of females the use of the observed sex ratio gives a more satisfactory estimate of the gross reproduction rate. For example, if an observed high proportion of females is due to the omission of some of the male births, the use of the biased sex ratio will help to offset the downward bias in the gross reproduction rate resulting from the bias in the total fertility rate. However, the use of a sex ratio which reflects an abnormally small proportion of females will exaggerate a downward bias in the total fertility rate. For example, if the total fertility rate and the sex ratio contain a down-ward bias because of the omission of some of the female births, the use of the observed ratio will accentuate the downward bias in the gross reproduction rate resulting from the downward bias in the total fertility rate.

Derivation of Formula for Estimating the Net Reproduction Rate. The normal method of calculating a net reproduction rate may be visualised as follows: The age specific fertility rates are corrected by the ratio of female births to total births and these corrected rates are multiplied by the appropriate life table probabilities of surviving to the various ages to which the age specific fertility rates refer. The sum of all these corrected figures gives the net reproduction rate. This may be expressed algebraically as

$$_nR = {}_gR \sum_{s=15}^{49} X_s P_s \qquad \text{............ (30)}$$

$_nR$ is the net reproduction rate, $_gR$ is the gross reproduction rate, X_s is the relative age specific fertility rate at the age of s years and P_s is the life table probability of a female surviving to the age of s years six months.

The net reproduction rate is therefore a function of the gross reproduction rate, the distribution of the relative age specific fertility rates and the appropriate life table probabilities. The latter are summarised by the expectation of life at birth, although this does not indicate the detailed distribution of the life table probabilities. The relationship between the expectation of life at birth and the correction factor to be applied to the gross reproduction rate may be examined by applying appropriate relative age specific fertility rates to various life tables. Some relevant figures, based on the age specific fertility rates of the U.S.A. non-white population, are given in Table XIX. These are plotted in Chart VI.

Table XIX: Relationship Between $\sum_{s=15}^{49} X_s P_s$ and the Expectation of Life at Birth.(1)

Expectation of Life at Birth	$\sum_{s=15}^{49} X_s P_s$	Expectation of Life at birth	$\sum_{s=15}^{49} X_s P_s$
48.8	.718	53.4	.766
49.0	.710	60.6	.859
62.1	.865	56.1	.823
56.2	.798	57.7	.811
55.4	.799	56.4	.812
48.1	.699	62.6	.883
48.7	.719	57.0	.801
47.3	.710	52.2	.795
53.1	.755	38.8	.623
41.4	.630	50.7	.752
44.8	.676		

(1) For details of life tables see Tables E and G of Appendix.

Chart VI.

Relationship Between $\sum_{s=15}^{49} X_s P_s$ and the Expectation of Life.

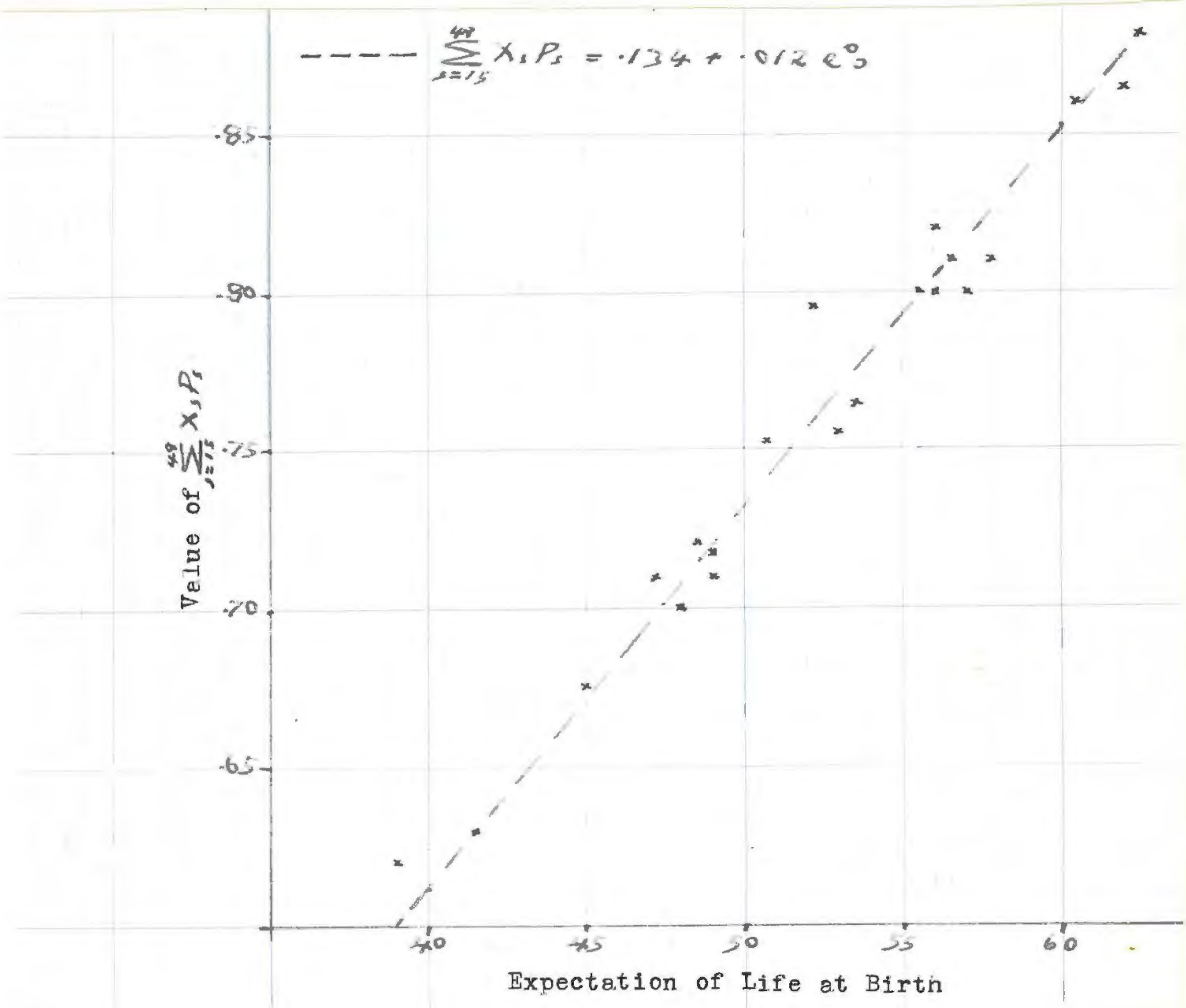

Chart VI suggests a relationship of the type

$$\sum_{s=15}^{49} X_s P_s = a + b e^{o}_{o}$$

so that formula (30) becomes .

$$_nR = {_g}R(a + b e^{o}_{o}) \quad \ldots\ldots\ldots\ldots\ldots (31)$$

The values of a and b obtained by the method of least squares from the figures given in Table XIX give

$$\sum_{s=15}^{49} X_s P_s = \cdot 134 + \cdot 012\, e^{o}_{o} \quad \ldots\ldots\ldots\ldots (31\ a)$$

There are two possible sources of bias in estimates of the net reproduction rate obtained from these constants. Firstly there may be a marked difference between the relative distribution of the appropriate life table probabilities of African

Negroid and other populations. Secondly there is the possibility that the relative age specific fertility rates of the U.S.A. non-white population are not applicable to a particular population.

It has been indicated on pages 140-1 that the available evidence indicates that there is no significant difference between the distribution of life table probabilities of African Negroid and other populations with a low expectation of life at birth. If the relative age specific fertility rates of the U.S.A. non-white population are applied to the life tables with expectations of life at birth of less than forty years referred to in Table XI on page 141, the resulting values give

$$\sum_{s=15}^{49} X_s P_s = \cdot 138 + \cdot 012\, e_0^{\circ} \quad \ldots\ldots\ldots\ldots \text{(31 b)}$$

This is very similar to formula (31 a). In both cases the regression coefficient is .012 and the value of a increases only from .134 to .138. The difference between formulae (31 a) and (31 b) would, therefore, affect the estimates of the net reproduction rate by only .004 of the gross reproduction rate. For practical purposes this is a negligible difference. It may be concluded that variations in mortality conditions have no significant effect on the value of the constants.

The effect of the distribution of the relative age specific fertility rates on the value of the constants may be examined by substituting the average distribution given in Table C of the Appendix for the distribution of the U.S.A. non-whites The resulting revision to the figures given in Table XIX leads to the expression

$$\sum_{s=15}^{49} X_s P_s = \cdot 094 + \cdot 012\, e_0^{\circ} \quad \ldots\ldots\ldots\ldots \text{(31 c)}$$

The regression coefficient remains unchanged at .012, but the value of a is reduced to .094. Although there is a marked difference between the relative age specific fertility rates of the U.S.A. non-white population and the average distribution given in Table C of the Appendix, this difference affects estimates of the net reproduction rate by only about .04 of the gross reproduction rate.

Table XX: Gross and Net Reproduction Rates and Expectations of Life at Birth of Females of Various Countries.(1)

Country	Period	Reproduction Rates		Expectation of Life at Birth (years)
		Gross	Net	
Australia	1920-22	1.517	1.319	63.31
Austria	1931-32	0.865	0.714	58.53
Belgium	1941	0.804	0.672	59.79
Bulgaria	1926.27	2.217	1.446	46.64
Czechoslovakia	1929-32	1.204	0.939	55.18
Denmark	1931-35	1.036	0.932	63.80
England & Wales	1937	0.883	0.782	64.40
France	1928-33	1.088	0.905	59.02
Finland	1931-35	1.178	0.956	58.69
Germany	1933	0.800	0.698	58.53
Hungary	1930-31	1.338	1.011	51.34
Ireland	1940-42	1.422	1.192	61.00
Italy	1935-37	1.425	1.131	57.49
Latvia	1929-32	1.093	0.890	60.10
Netherlands	1942	1.305	1.196	67.20
New Zealand	1921-22	1.442	1.291	65.43
Norway	1930-31	1.036	0.890	63.84
Poland	1931-32	1.705	1.250	51.40
Scotland	1938	1.074	0.932	59.50
Sweden	1936-40	0.873	0.796	66.92
Switzerland	1943	1.169	1.054	64.60
Union of S. Afr.	1940	1.495	1.346	66.08
U.S.A. — whites	1942	1.270	1.189	68.61

(1) 1942/33 Statistical Year Book, League of Nations, Geneva. pp. 56-7, 82-5.

Further values of the constants may be obtained by fitting formula (31) to the figures given in Table XX by the method of least squares. This gives

$${}_nR = {}_gR(.091 + .012\, e^{\circ}_{o}) \quad \ldots\ldots\ldots \text{(31 d)}$$

The regression coefficient is again .012. The value of a, that is .091, differs only slightly from the .094 given in formula (31 c). This is not surprising as the average relative age specific fertility rates given in Table C of the Appendix is largely a reflection of the experience of the populations listed in Table XX.

It is evident from the figures given above that the value of b in formula (31) is constant and equal to .012. The value of a varies slightly with the distribution of the relative age specific fertility rates. As indicated in Chapter IV the relative age specific fertility rates of the African Negroid populations appears to be close to that of the U.S.A. non-white population, so that the best value of a to use for the African Negroid populations seems to be the .134 given in formula (31 a). This would give an upward bias of not more than 4 per cent. if the actual distribution of the relative age specific fertility rates is in fact near the average distribution given in Table C of the Appendix.

<u>Standard Error of Estimates</u>. Some indication of the standard error of an estimate obtained from formula (31) may be obtained by comparing the net reproduction rates given in Table XX with the coresponding estimates obtained from the constants given in formula (31 d). The variance of the difference between these figures, as given by formula (14) on page 103, is .0004. This gives a standard error of .02. The average net reproduction rate is 1.023 so that the coefficient of variation is approximately .02. In the absence of any further information, this might be assumed to be the coefficient of variation of an estimate in respect of an African Negroid population based on the constants given in formula (31 a), not taking into consideration the variance of the estimated gross reproduction rate

and the variance of the expectation of life at birth. The total variance of an estimate obtained from formula (31) may be expressed algebaically as

$$V(nR) = V(a.{}_yR) + V(b.e^\circ_0.{}_yR)$$

where the symbol V stands for variance . For practical purposes it may be assumed[1] that

(i) $$V(a.{}_yR) = a^2 V({}_yR) + ({}_yR)^2 V(a) \quad \text{and}$$

(ii) $$V(b.e^\circ_0.{}_yR) = b^2(e^\circ_0)^2 V({}_yR) + ({}_yR)^2 b^2 V(e^\circ_0) + ({}_yR)^2(e^\circ_0)^2 V(b)$$

Then $$V(nR) = a^2 V({}_yR) + ({}_yR)^2 V(a) + b^2 (e^\circ_0)^2 V({}_yR) + ({}_yR)^2 b^2 V(e^\circ_0) + ({}_yR)^2 (e^\circ_0)^2 V(b).$$

$$= \left[({}_yR)^2 V(a) + ({}_yR)^2 (e^\circ_0)^2 V(b)\right] + a^2 V({}_yR) + b^2 (e^\circ_0)^2 V({}_yR) + ({}_yR)^2 b^2 V(e^\circ_0) \quad \ldots\ldots\ldots (32)$$

But $\left[({}_yR)^2 V(a) + ({}_yR)^2 (e^\circ_0)^2 V(b)\right]$ is the variance of formula (31) not taking into consideration the variances of the gross reproduction rate and the expectation of life at birth. It has been suggested that this may be assumed to be .0004 and that, for African Negroid populations, a should be taken as .134 and b should be taken as .012. Therefore, for African Negroid populations,

$$V(nR) = .0004 + .134^2 V({}_yR) + .012^2 (e^\circ_0)^2 V({}_yR) + .012^2 ({}_yR)^2 V(e^\circ_0).$$

$$= .0004 + V({}_yR)\left[.134^2 + .012^2 (e^\circ_0)^2\right] + .012^2 ({}_yR)^2 V(e^\circ_0). \quad \ldots\ldots\ldots\ldots (32\ a)$$

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(1) Yates F. (1949) Sampling Methods for Censuses and Surveys, Charles Griffin & Co., London, p. 198.

It has been suggested on page 114 that, when all women aged 15 years and over are considered, the coefficient of variation of the total fertility rate may be assumed to be .075. This may be assumed to be the coefficient of variation of the gross reproduction rate, so that the variance of the latter may be taken as $.075^2 (gR)^2$. On page 132 it was suggested that the coefficient of variation of the expectation of life is between .034 and .044. Taking it as .04, the variance of the expectation of life becomes $.04^2 (e^\circ_0)^2$. Substituting these variances in formula (32 a) gives

$$V(nR) = \cdot 0004 + (gR)^2 \left[\cdot 000101 + \cdot 00000104 (e^\circ_0)^2 \right]$$

To illustrate the magnitude of the variance, let us assume that the gross reproduction rate is 2.0 and that the expectation of life is 40. Formula (31 a) then gives the net reproduction rate as 1.23. The variance becomes .00764. The standard error is therefore .0864. The coefficient of variation is then .07.

Alternative Formula. Brass[1] has developed an alternative approach for estimating the net reproduction rate. He shows that

$$nR = R \cdot a \cdot l(m+c) \quad \ldots\ldots\ldots\ldots\ldots \ (33)$$

nR is the required net reproduction rate. R is the total fertility rate as given by formula (15) on page 116. a is the correction factor to be applied to the total fertility rate to reduce it to the gross reproduction rate. $l(m+c)$ is the probability of surviving to the age $(m+c)$ years. c is the beginning of the childbearing period, that is the beginning of the 15th. year of age. m is the mean age to which the age specific fertility rates, for the whole of the reproductive period, refer when the beginning of the 15th. year of age is taken as 0.

Before the value of $l(m+c)$ can be obtained, it is necessary to determine the value of $l(n-m)$, the probability of surviving to the age of $(n-m)$ years. n is the number of years in the reproductive period under consideration, that is $t - 14$,

(1) Brass W. (1953) "Derivation of Fertility and Reproduction Rates", Population Studies, Vol. VII, No. 2, p. 137.

where t is the age of the oldest woman under consideration. (Brass does not consider cases where t exceeds 49 years.) The value of $l_{(n-m)}$ is obtained from the formula

$$\frac{S_t}{C_t} = q + k(1-q) \qquad \text{............ (34)}$$

where C_t is the total children ever born to the women under consideration and S_t is the number of these children surviving to the date of the enquiry. q is merely an abreviation for $l_{(n-m)}$ and k is a parameter that varies with the range of the ages of the women under consideration. Excluding the experience of the U.S.A. non-white population Brass has calculated that the average values of k are 0.09 for women aged 15-39 years, 0.13 for women aged 15-44 years and 0.16 for women aged 15-49 years. He suggests that these values be used when m is about 15. In the case of the U.S.A. non-whites Brass' value of m is ~~12.3~~ 11 and the values of k are 0.15 for women aged 15-39 years, 0.19 for women aged 15-44 years and 0.22 for women aged 15-49 years.

The values of k need be known only approximately, but where m is much lower than 15 it is necessary to use a value of k somewhat larger than the average for the appropriate age group in order to avoid obtaining a biased estimate. The values given above for the U.S.A. non-white population are probably suitable for African Negroid populations.

Having obtained the value of $l_{(n-m)}$ from formula (34), it is necessary to estimate $l_{(m+c)}$. Where $(m+c)$ and $(n-m)$ are very close to 30 and 15 respectively, the value of $l_{(m+c)}$ may be obtained from the formula

$$l_{(30)} = -0.197 + 1.17\, l_{(15)} \qquad \text{.......... (35)}$$

However, $(n-m)$ and $(m+c)$ are not likely to be near 15 and 30 in the case of African Negroid populations, as in most cases m will be less than 15. Brass states that in such cases it is necessary to estimate the value of $l_{(m+c)}$ by referring to published life tables in which (i) the value of $l_{(n-m)}$ agree closely with the estimate given by formula (34) and (ii) the relationship between $l_{(30)}$ and $l_{(15)}$ agrees closely with formula (35). When an appropriate life table has been found, this will automatically provide a rough estimate of the expectation of life at birth.

The Standardised Rate of Natural Increase.

The net reproduction rate is a useful standardised measure of the rate of population growth, but as it reflects the rate of growth in terms of a generation, it is not as simple a conception as an annual rate of increase. In comparing the net reproduction rates for a number of countries there is the complication that the length of the generation to which the rates refer may vary from country to country. The complications arising from the fact that the net reproduction rate reflects the rate of growth in terms of a vague generation can be eliminated by reducing it to the standardised rate of natural increase. This is the annual rate of growth that will eventually be attained given constant fertility and mortality rates and a population free from migration.

Theoretically the determination of the standardised rate of natural increase is a complicated calculation.(1) However, Kuczynski states that the following formula gives good estimates, that is estimates with an error of only up to one per cent.(2)

$$r = \sqrt[\frac{R_1}{R_0}]{R_0} - 1 \qquad \text{.........} \quad (36)$$

r is the standard rate of natural increase. R_0 is the net reproduction rate. R_1 is the sum of the terms constituting the net reproduction rate, each multiplied by the years of age at confinement. The ratio $\frac{R_1}{R_0}$ may be regarded as the length of the generation implied in the net reproduction rate. It is a weighted average of the years of age at confinement, the weights being a function of the relative age specific fertility rates and the appropriate relative life table probabilities. The actual as opposed to the relative values of the specific fertility rates and life table probabilities are irrelevant since the general level of fertility and mortality affect the numerator and denominator equally.

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(1) Dublin L.I. and Lotka A.J. (1925) "On the True Rate of Natural Increase", Journal of the American Statistical Association, Vol. XX, No. 151, p. 305.

(2) Kuczynski R.R. (1938) "The Analysis of Vital Statistics", Economica, Vol. V (New Series), No. 19, p. 289.

For the purpose of determining the length of a generation of African Negroid populations, the relative age specific fertility rate of the U.S.A. non-white population have been applied to the life tables used previously in the analysis of the expectation of life at birth. The resulting figures are given below.

Table XXI: Estimation of the Length of an African Negroid Generation.[1]

Expectation of Life at Birth (years)	Length of Generation (years)	Expectation of Life at Birth (years)	Length of Generation (years)
48.8	25.7	53.4	25.8
49.0	25.7	60.6	25.9
62.1	25.9	56.1	25.8
56.2	25.8	57.7	25.7
55.4	25.9	56.4	25.9
48.1	25.7	62.6	25.9
47.3	25.4	57.0	25.7
48.7	25.7	52.2	25.8
53.1	25.8	38.8	25.4
41.4	25.5	50.7	25.7
44.8	25.6		

(1) For details of the appropriate life tables see Tables E and G of the Appendix.

Although the expectation of life at birth of these life tables ranges from 38.8 to 62.6 years, the estimated length of a generation has a range of only 0.5 years, that is from 25.4 to 25.9 years. Therefore, for practical purposes the influence of the life table on the length of the generation may be ignored and the length of a generation reflecting the distribution of the age specific fertility rates of the U.S.A. non-white population may be assumed to be approximately 26 years. For the average relative age specific fertility rates given in Table C of the Appendix the average generation is about 29 years. The net reproduction rate of an African Negroid population therefore probably reflects a faster annual rate of increase than the same net reproduction rate for other populations. The standardised rates of natural increase for various values of the net reproduction rate, when a generation is taken to be 26 years, are as follows:

Table XXII: Relationship Between the Net Reproduction Rate and the Standardised Rate of Natural Increase When a Generation is Taken to be 26 Years.

Net Reproduction Rate	Standardised Rate of Natural Increase (Per cent. per annum)	Net Reproduction Rate	Standardised Rate of Natural Increase (Per cent. per annum)
1.1	0.4	1.6	1.8
1.2	0.7	1.7	2.1
1.3	1.0	1.8	2.3
1.4	1.3	1.9	2.6
1.5	1.6	2.0	2.9

The standardised rate of natural increase may be broken down into its component parts, that is the corresponding standardised birth and death rates. A close approximation to the theoretical standardised birth rate may be obtained by dividing the net reproduction rate by the expectation of life at birth.[1] The corresponding standardised death rate is simply the difference between the standardised birth rate and the standardised rate of natural increase.[1] These standardised birth and death rates are the rates that will ultimately prevail in a community which is free from migration movements and which is subject to a constant level of fertility and mortality for at least two or three generations. This standardised death rate differs from the life table death rate referred to on page 7. The life table rate refers to a stationery population, that is one in which the births and deaths are equal, whereas the standardised death rate referred to here is one for a population which is increasing or decreasing at a constant rate.

Compensating Biases.

The reporting errors likely to be encountered in returns of the total children ever born and the number of these still living may be divided into two groups, namely those affecting

(1) Dublin L.I. and Lotka A.J. (1925), "On the True Rate of Natural Increase", Journal of American Statistical Assoc., Vol. XX, p. 305.

the children still living and those affecting the children who have died. As indicated previously, the number of children still living might be under-stated as a result of the influence of superstitions and suspicions regarding a count of children. It might be over-stated by the inclusion of adopted children. These errors will lead to a bias in the total fertility rate, the expectation of life at birth and the net reproduction rate. As far as the children who have died are concerned, it is likely that they are, at least to some extent, under-stated as a result of the omission of children that died in early childhood. These omissions will lead to a downward bias in the estimated total fertility rate. At the same time the expectation of life will be over-stated because of the under-statement of the proportion of children who have died. When the estimates of the total fertility rate and the expectation of life are brought together to arrive at the net reproduction rate, the over-statement in the expectation of life more or less balances the downward bias in the total fertility rate. These compensating errors considerably reduce any objection there may be to the inclusion of the returns from the older women. Although the estimates of the total fertility rate and the expectation of life at birth are likely to be biased, the estimate of the net reproduction rate should be unbiased, unless there are errors in the returns in respect of the children still living. The formulae developed previously may be combined and reduced to one formula giving the relationship between the net reproduction rate and the average number of children still living per woman questioned. Using the constants given for African Negroid populations in respect of returns from all women aged 15 years and over we have

$$R = \frac{C_r}{M_r} \div \left[1 - \sum_{s=1}^{7} X'_s T'_s\right]$$

$$e^o_0 = 101.2 \frac{S_r}{C_r} - 273.5\, W_0 \frac{S_r}{C_r} - 20.2$$

$$nR = gR(.134 + .012\, e^o_0)$$

Let $gR = a \frac{C_r}{M_r}$ where $a = a' \div \left[1 - \sum_{s=1}^{7} X'_s T'_s\right]$ and a' is the proportion of the total births who are females. Then

$$nR = a\frac{C_F}{M_F}\left[\cdot134 + \cdot012\left(101\cdot2\frac{S_F}{C_F} - 273\cdot5\,W_0\frac{S_F}{C_F} - 20\cdot2 + 0\cdot8\right)\right]$$

Note. The constant 0.8 has been added to provide a formula based on the returns for the two sexes taken together. This constant reflects the extent to which the expectation of life of females is likely to exceed that for the two sexes taken together. (see pp. 144-6)

Simplifying this we get

$$nR = a\frac{C_F}{M_F}\left[\cdot134 + 1\cdot214\frac{S_F}{C_F} - 3\cdot283\,W_0\frac{S_F}{C_F} - \cdot099\,a\frac{C_F}{M_F}\right]$$

$$= a\frac{C_F}{M_F}\frac{S_F}{C_F}(1\cdot214 - 3\cdot283\,W_0) - \cdot099\,a\frac{C_F}{M_F}$$

$$= a\frac{S_F}{M_F}(1\cdot214 - 3\cdot283\,W_0) - \cdot099\,a\frac{C_F}{M_F} \quad\ldots\ldots\ (37)$$

Let us now determine the extreme limits of $\frac{C_F}{M_F}$ in terms of $\frac{S_F}{M_F}$. Assuming that W_0 is .040, which is the value suggested for use in connection with African Negroid populations when the true figure is not known and cannot be estimated, and taking the expectation of life at birth as 25 years for the lower limit and 55 years for the upper limit, the following figures are obtained. For the lower limit formula (25 a) on page 132 gives the value of $\frac{S_F}{C_F}$ as .5, so that $\frac{C_F}{M_F}$ is twice $\frac{S_F}{M_F}$. Similarly for the upper limit $\frac{C_F}{M_F}$ is 1.2 $\frac{S_F}{M_F}$. It may be assumed that $\frac{C_F}{M_F}$ is between 1.2 and 2.0 of $\frac{S_F}{M_F}$, say 1.6 plus or minus 0.4 of $\frac{S_F}{M_F}$. If this value is used in formula (37)

$$nR = a\frac{S_F}{M_F}(1\cdot214 - 3\cdot283\,W_0) - 1\cdot6\times\cdot099\,a\frac{S_F}{M_F}$$

$$= a\frac{S_F}{M_F}(1\cdot056 - 3\cdot283\,W_0) \quad\ldots\ldots\ldots\ldots\ldots\ (37a)$$

If $\frac{C_F}{M_F}$ could be as low as 1.2 or as high as 2.0 of $\frac{S_F}{M_F}$ this formula will have an additional standard error of not more than about 4 per cent. and possibly only about 2 per cent.

A further compensation of biases occurs when the net reproduction rate is reduced to the standardised rate of natural increase. Although the available evidence indicates that the relative age specific fertility rates of the U.S.A. non-white population are applicable to African Negroid populations, there is the possibility that the use of these rates sometimes results in an under-estimate of the total fertility rate. It has been shown on page 112 that the use of the average relative age specific

cific fertility rates given in Table C of the Appendix in place of those of the U.S.A. non-white population raises the total fertility rate by 16 per cent. As indicated on page 166, this substitution leads to an adjustment of one of the constants of the formula for the net reproduction rate which has the effect of reducing the net reproduction rate by 4 per cent. The net rise in the net reproduction rate is therefore 12 per cent. However, the length of the generation reflected in the age specific fertility rates of the U.S.A. non-white population is 12 per cent. less than that reflected in the average distribution given in Table C of the Appendix. Consequently when the net reproduction rate based on the relative age specific fertility rates of the U.S.A. non-white population is reduced to the standardised rate of natural increase the downward bias in the net reproduction rate is offset by a corresponding downward bias in the assumed length of the generation to which the rate refers.

CHAPTER VII

VARIOUS ESTIMATES OF FERTILITY AND MORTALITY FOR A NUMBER OF COUNTRIES.

The formulae developed in Chapters IV to VI will now be applied to the available information obtained in censuses or large scale sample surveys of the African Negroid populations. The countries concerned will be dealt with in alphabetical order. It will be assumed that the relative age specific fertility rates given in Table C of the Appendix for the U.S.A. non-white population are applicable to all the countries under consideration.

Wherever possible estimates of the total fertility and net reproduction rates, for the returns in respect of women aged 15-44 years, will also be obtained from the formulae developed by Brass and outlined on pages 116-9 and 169-70. To obtain these net reproduction rates it is necessary to make appropriate estimates of the probability of surviving to the mean age to which the age specific fertility rates refer. For the rates of the U.S.A. non-whites given in Table C of the Appendix the mean age is 26 years. Formula (34) will provide an estimate of $l_{(19)}$, that is the probability of surviving to the age of 19. An estimate of $l_{(26)}$, that is the probability of surviving to the age of 26, will be obtained from the life table probabilities given in the 1951 Demographic Yearbook of the United Nations. In each case a life table will be selected which (i) has a value of $l_{(20)}$ close to the value of $l_{(19)}$ given by formula (34) and (ii) fits formula (35). The required value of $l_{(26)}$ will be obtained from a linear interpolation of the values of $l_{(25)}$ and $l_{(30)}$.

In addition, replacement indexes will be calculated wherever possible. These replacement indexes will be based on the effective fertility rates obtained by dividing the number of children under five by the number of women aged 15-44 years, and the coresponding effective fertility rates given by the 1942-6 life tables for Mauritius and the 1936 life tables of the Coloured population of the Union of South Africa. These life tables have been chosen arbitrarily, but it is thought that they should give a good indication of the actual replacement indexes as they have low expectations of life. In the case of the Mauritius life tables the expectation of life at birth of females is 33.8 years and the effective fertility rate is .494. In the case of the Coloured population of the Union of South Africa the expectation of life at birth of females is 40.9 years and the effective fertility rate is .438.

Angola.

The following figures give the apparent trends of fertility and mortality revealed by the 1940 census.

Table XXIII: Apparent Trends of Fertility and Mortality: Angola 1940 Census.[1]

Age of women (years)	Average Number of children ever born.	Total Fertility Rate (2)	Survival Ratio of children	Expectation of life at birth. (years) (3)	Average date to which births refer. (years before census)
25-29	2.02	2.8	.659		6
30-34	2.72	3.1	.634		11
35-39	3.34	3.5	.621	32	16
40-44	3.74	3.8	.590	29	20
45-49	3.99	4.0	.559	31	25
50 and over	4.07	4.1	.495		

(1) Based on figures given in Censo Geral de Populaçao, 1940, Imprensa Nacional, Luanda, (1947), Vol XI p. 107 and Vol. III p. 3.

(2) Determined by the method outlined on pages 159-61.

(3) As given by formula (29).

These figures suggest that there has been a downward trend in fertility, but no significant trend in mortality. The apparent downward trend in fertility may be exaggerated by the fact that the estimates are based on the relative age specific fertility rates of the U.S.A. non-white population. However, the relative age specific fertility rates given on page 107, based on the assumption of constant fertility, are unreasonable. In particular the rate of .004 for the 15-19 year age group is as low as the lowest given in Table C of the Appendix and the rate of .012 for the 45-49 year age group is extraordinarily high. The distribution of these relative age specific fertility rates becomes more reasonable only if it is assumed that the level of fertility has been declining. Consequently although the estimates of the total fertility rate given in Table XXIII may exaggerate the downward trend in fertility it is impossible to adjust them to reflect a constant or an upward trend without accepting an unreasonable distribution of the relative age specific fertility rates. It is unfortunately not possible to make a further examination of the apparent trends of fertility and mortality and reporting errors, as the returns for the women aged 50 years and over are not broken down by quinquennial or any other age groups and no particulars are available regarding the sex ratio of the births. The available figures regarding the age distribution are as follows:

Table XXIV: Reported Age Distribution: 1940 Census of Angola.

Age (in years)	Males	Females	Persons
0	49,479	55,160	104,639
1	38,340	41,535	79,875
2	65,339	69,532	134,871
3	57,673	59,826	117,463
4	57,295	58,579	115,874
0 - 4	268,090	284,632	552,722
5	54,905	54,265	109,170
6	60,073	58,445	118,518
7	54,832	50,734	105,566
8	57,309	52,022	109,331
9	43,594	36,977	80,571
5 - 9	270,713	252,443	523,156

Table XXIV Continued

Age (in years)	Males	Females	Persons
10-14	214,234	180,988	395,222
15-19	137,400	148,896	286,296
20-24	132,684	162,903	295,587
25-29	150,129	193,490	343,619
30-34	119,867	158,870	278,737
35-39	124,529	151,534	276,063
40-44	93,727	124,802	218,529
45-49	65,462	77,580	143,042
50 and over	141,983	182,138	324,121
Not stated	5,092	4,213	9,305
Total	1,723,910	1,922,489	3,646,399

The clustering at the even ages in the younger ages may be smoothed out by taking the averages for 1 and 2 years, 3 and 4 years etc. The figures, to the nearest 1,000, are then 105,000 aged 0, followed by averages of 107,000 for ages 1 and 2, 117,000 for ages 3 and 4 years, 112,000 for ages 5 and 6 and 107,000 for ages 7 and 8 years. There is then a strong indication of omissions in the number of children under 3 years of age. Taking 117,000 as a conservative estimate of the number of persons at each of the first three years of life,there were apparently 12,000 children under 1 year, 10,000 aged 1 year and 10,000 aged 2 years missed in the census. Amongst the older people the relatively low number of females aged 15-19 years and the relatively high number of females aged 25-29 years indicate reporting errors of significance in fertility studies. However, the available information gives no obvious indication as to how these apparent errors may be corrected and no attempt will be made to adjust these figures.

Allowing for the apparent under-enumeration of children aged under three years referred to above, the replacement index based on the Mauritius life table is 1.26 and that based on the South African Coloured life table is 1.42. The children under three years of age omitted from the age distribution figures are likely to have been omitted from the returns in respect of the total children ever born and the number of these still living. Allowing for this factor the total number of children ever born rises to 2,319,000 for women aged 15-49 years and to 3,068,000 for all women aged 15 years and over. The number of surviving children rises to 1,448,000 for women aged 15-49 years and to 1,818,000 for all women aged 15 years and over. The estimates of fertility and mortality obtained from formulae (11), (25a) and (31) are then as follows:

Some Estimates of Fertility and Mortality: Angola 1940.

Characteristic	Based on Returns in Respect of Women aged	
	15-49 years	15 years and over
Total Fertility Rate	3.42	3.56
Gross Reproduction Rate (1)	1.66	1.73
Expectation of life at birth of females (years)	35.9	34.7
Net Reproduction Rate	0.95	0.95

(1) Assuming 485 females per 1,000 births.

These estimates are reasonably consistent with one another, but the apparent trend of fertility referred to previously seems to continue past the age of 49 years. The fact that the expectation of life at birth for the children of women aged 15-49 years is slightly higher than that for the children of all women aged 15 years and over suggests there has been a slight improvement in mortality rates, but the difference between these two figures is not significant. The fact that the estimates of the expectation of life used in determining the net reproduction rates are significantly higher than those given in Table XXIII is attributed to the difference in the methods of calculation. The estimates given in Table XXIII are likely to be biased. They are intended to reveal any apparent trend in mortality rather than the absolute level of the expectation of life.

Some further estimates of fertility and mortality may be obtained from Brass' formulae, that is formula (15) on page 116 and formula (33) on page 169. For women aged 15-44 years the value of ρ is — 0.01. The average number of children ever born to women aged 15-44 years is 2.1, so that the total fertility rate given by formula (15) is 3.34. The ratio of children surviving to children ever born is .628 so that the value of $l(19)$ given by formula (34) is .541. The most appropriate life table for arriving at the net reproduction rate is that for males in Mexico in 1930 with an expectation of life at birth of 32.4 years. This gives a net reproduction rate of 0.85.

Bechuanaland.

Questions on the total number of children ever born and the number of these still living, in respect of married women, were asked in the 1946 census of Bechuanaland. According to information supplied by the High Commissioner, there were 48,102 married women in 1946 of whom 41,532 had 160,400 total births and 41,903 had 125,363 children still living. Since the 41,532 women referred to in the analysis of total births and the 41,903 women referred to in the analysis of children still living include women with no children, it would appear that some of the returns were excluded because they contained obvious errors. Assuming that the women excluded from these two analyses had the same average experience as the others it is estimated that the 48,102 married women had a total of 185,800 births of whom 143,800 were still living at census date. As the married women represent only 51 per cent. of the total female population aged 15 years and over, and as the widowed, divorced and some the single women have also had children, the total number of children ever born to the total population is appreciably higher than 105,800. Estimates of the total fertility rate based on[1] the latter figure will, therefore, be an under-statement of the true position, but it is impossible to make a reasonably accurate estimate of the children born to the widowed, divorced and single women. The recorded age distribution of the population is as follows:

Table XXVI: Sex and Age Distribution of Native Population of Bechuanaland: 1946 Census.

Age (in years)	Males	Females	Persons
0	2,280	2,418	4,698
1	2,518	2,548	5,066
2	3,445	3,351	6,796
3	3,425	3,526	6,951
4	3,585	3,569	7,154
0–4	15,253	15,412	30,665
5–9	18,296	17,949	36,245
10–14	20,193	19,312	39,505
15–19	16,244	16,024	32,268
20–24	12,286	14,270	26,556
25–29	10,968	12,106	23,074
30–34	9,417	10,757	20,228
35–39	9,904	9,514	19,418
40–44	6,632	7,124	13,756
45–49	7,179	6,213	13,392
50–54	4,421	4,676	9,097
55 and over	13,896	13,060	26,956
Unspecified	807	788	1,595
Total	145,550	147,205	292,755

The figures for the first three quinquennial age groups suggest that there has been a decline in the birth rate during the past ten to fifteen years. However, the very marked rise from 4,698 persons under one to 6,796 persons aged two years indicates that there was a substantial under-enumeration of children under two years of age. It seems likely that the number of children under one was at least 6,500 with about the same number aged one year.

Ignoring the unknown children of the widowed, divorced and single women, the 185,800 children ever born average 1.96 children per female aged 15 years and over. According to formula (11) this is equivalent to a total fertility rate of 2.87. Assuming that female births are 48.5 per cent. of total births, the gross reproduction rate comes to 1.39. Owing to the omission of the children of the widowed, divorced and single women and some of the children under two years of age, this is an under-estimate of the true gross reproduction rate.

For the married women the number of children still living represent .774 of the total children ever born. Assuming constant fertility over time, the number of children born in the twelve months preceeding the date of the census is estimated to be .040 of the total children ever born. Using this figure in formula (25 a) gives the expectation of life of the two sexes taken together as 49.7 years. This is probably an over-estimate as it is to be expected that the survival rate of the children of the widowed and divorced women is less than the .774 of the children of the married women. The children of the widowed and divorced women have probably survived to an older age than the children of the married women, since the average age of the widowed and divorced women is probably higher than that of the married women. If the expectation of life of the two sexes is 49.7 years that for females is about 50.5 years. Formula (31) then gives the net reproduction rate as 1.03.

Allowing for the apparent under-enumeration of children under two years of age, the effective fertility rate is .484. For the Mauritius and South African Coloured life tables the replacement indexes are then 0.98 and 1.11 respectively. These figures are in reasonable agreement with the previous estimate of the net reproduction rate. However, this agreement is surprising as the estimated net reproduction rate takes no account of the children of the widowed, divorced and single women and the apparent under-enumeration of children under two years of age. It is to be expected that the replacement indexes should be appreciably higher than the net reproduction rate. The agreement between the figures might be an indication of reporting errors. If the possibility of reporting errors is ruled out, the figures are consistent only if it is assumed that there has been a marked decline in the level of fertility in recent years, for the replacement indexes refer to a more recent period than the net reproduction rate.

British East Africa.

Returns of the total children ever born and the number of these still living were obtained in a sample survey held in Kenya, Tanganyika and Uganda in 1948. Unfortunately no detailed report on this investigation has appeared to date. However, some relevant particulars have been published by the United Nations(1) and by Martin.(2) The available figures on the total number of children ever born to women of various ages and the apparent trends of fertility and mortality are given in Table XXVII on page 186.

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(1) Additional Information on the Population of Tanganyika, Reports on the Population of Trust Territories, No. 2 Supplement, United Nations, (1953).

(2) Martin C.J. (1953), "Some Estimates of the General Age Distribution, Fertility and Rate of Natural Increase of the African Population of British East Africa", Population Studies, Vol. VII, No.2 p. 181.

Table XXVII: Trends of Fertility in East Africa: 1948 Sample Survey.

Age of Women (years)	Average Number of Children ever born.		Estimated Total Fertility Rate.(1)	
	Tanganyika	Uganda	Tanganyika	Uganda
27	2.63	2.38	3.6	3.3
32	3.44	3.50	4.0	4.0
37	4.03	4.44	4.2	4.6
42	4.34	5.00	4.4	5.1
47	4.50	5.38	4.5	5.4
45 and over	4.40	4.80	4.4	4.8

(1) Estimated as explained on pages 159-61.

The figures for the women up to the age of 47 years indicate that the level of fertility has been declining. The relative age specific fertility rates obtained on the assumption that the level of fertility remained constant are given in Table VI on page 107. In the case of Tanganyika the rate of .008 for the women aged 47 years is rather high, the highest figure in Table C of the Appendix being .007 for Chile and Peru. In the case of Uganda the rate of .004 for the women aged 17 years is extraordinarily low and the rate of .014 for women aged 47 years is remarkably high. A more normal distribution can be obtained only if it is assumed that fertility has been declining. The apparent downward trend in fertility reflected in the returns for women up to the age of 47 years is reversed when the returns for the latter are compared with those for all women aged 45 years and over. This reversal of the trend indicates that the returns for women aged 45 years and over are faulty. It seems likely that they have omitted some of the children who were born .

The overall average number of children ever born to women aged 16 to 45 years is given as 2.6 for Tanganyika, 2.7 for Uganda and 3.2 for Kenya. If it is assumed that the age distribution of the sample population is the same as that given for these territories in Table A of the Appendix, the estimated total fertility rates, as given by formula (11), are 4.4 for Tanganyika, 4.6 for Uganda and 5.9 for Kenya.

The available information regarding the number of children still living takes the form of figures of the proportion of the children of women aged 18-22, 23-27, 33-37 and 43-47 who have died. These figures may be converted into survival ratios by subtracting them from unity. The resulting survival ratios and some estimates of the expectations of life at birth are given in the following table:

Table XXVIII: Survival Ratios and Estimates of the Expectations of Life at Birth: East African 1948 Survey.

Age of Women (years)	Survival Ratio of Children		Expectation of Life at Birth (1)	
	Tanganyika	Uganda	Tanganyika	Uganda
18-22	.733	.713		
23-27	.719	.693		
33-37	.695	.611	35	23
43-47	.646 (2)	.534	37 (3)	25

(1) As given by formula (29).
(2) It is reported that it is thought that the proportion of children who have died should be at least .375. In other words the survival ratio should be about .625.
(3) This reduces to 35 if the survival ratio is taken to be .625.

With only two estimates of the expectations of life it is impossible to draw any conclusions as to the apparent trend in mortality rates. Although estimates of the expectation of life obtained from formula (29) might be biased, it is necessary to use the figures given above as a rough indication of the level of mortality because in this case no estimates can be obtained from formula (25 a). The figures given in Table XXVIII suggest that the expectation of life at birth is about 35 years in Tanganyika and about 24 years in Uganda. Assuming that female births are 48.5 per cent. of total births, the net reproduction rates given by formula (31) are 1.21 in Tanganyika and 0.97 in Uganda.

Gold Coast.

At the time of the 1931 census in the Gold Coast an attempt was made to obtain representative returns of the total children ever born and the number of these still living in respect of women past the childbearing period. Each medical and health officer was required to question a hundred old women taken haphazardly. On the average these women had 5.32 live born children of whom 60 per cent. survived to the date of the enquiry. However, Kuczynski's examination of these returns (1) shows that the variability between the figures obtained by various officers working in common districts is too great for these figures to be regarded as reliable.

Another attempt to obtain information of the total number of births and the number of children still living was made in conjunction with the 1948 census. (2) Every fortieth enumerator's district was selected and the enumerators were instructed to obtain returns for ever female aged fifteen years or over. The enumerators were required to report each woman's age, how many births, including still births, she had ever had, and how many of these children were still living. The reported figures and estimates of the trend of fertility and mortality are given in Table XXIX on page 189.

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(1) Kuczynski R.R. (1948), A Demographic Survey of the British Colonial Empire, Oxford University Press, Vol. I, p. 468.

(2) Census of Population, 1948: Report and Tables, Crown Agents for the Colonies, London, (1950), pp. 35-7 and 396.

Table XXIX: Results of 1948 Fertility Enquiry in the Gold Coast and Apparent Trends of Fertility and Mortality.

Age of Women (years)	Women ques-tioned	Births per Woman (1)	Fertility Rate (2)	Survival Ratio	Expecta-tion of life at birth (years) (3)	Approx. to which births refer (years before census) (4)
15–19	3,356	.59		.79		
20–24	3,727	1.59		.77		
25–29	4,734	2.60	3.6	.72		6
30–34	4,051	3.70	4.3	.66		11
35–39	3,426	4.68	4.9	.62	32	15
40–44	2,260	5.36	5.4	.60	30	20
45–49	2,374	6.14	6.1	.56	31	24
50–54	1,076	6.36	6.4	.52	31	29
55–59	529	6.83	6.8	.53	36	34
60–64	512	6.54	6.5	.50	38	39
65–69	251	6.65	6.7	.53	44	44
70–74	219	6.71	6.7	.48	42	49
75–79	108	6.56	6.6	.50		54
80 and over	116	6.78	6.8	.45		

(1) Including still births.
(2) As estimated by the method described on pages 159–61.
(3) As given by formula (29)
(4) As estimated by the method described on pages 156–8.

These figures suggest that there was a marked downward trend in the total fertility rate during the thirty years preceeding the census. There was apparently no significant change in the level of mortality during this period, but prior to about 1918 there appears to have been a decline in the expectation of life at birth. The extent of the decline in fertility as estimated in Table XXIX might be exaggerated if the actual relative age specific fertility rates are somewhat different from those of the U.S.A. non-white population on which the estimates given above are based. However, no reasonable change in the assumed relative age specific fertility rates will convert the estimates given above into rates which suggest a constant or rising level of fertility. Estimates of the relative age specific fertility rates in the Gold Coast based on the assumption of a constant level of fertility have been given in Table VI on page 107. These rise to a peak in the 30-34 year age group and the only country listed in Table C of the Appendix which has the peak level of fertility as late as this is Chile. The Gold Coast rate of .028 for the 45-49 year age group is very much higher than the highest recorded rates of .007 in Chile and Peru. It must, therefore, be assumed that the relative age specific fertility rates obtained on the assumption of constant fertility are unreasonable and that there has in fact apparently been a downward trend.

The census report states that the relatively small numbers of women questioned in the younger ages, that is 15 to 25 years, suggests that "enquiries were not pressed in the case of unmarried women." However, the average number of births per woman in the 15-19 and 20-24 year age groups are a long way from being unreasonably high. This suggests that the under-enumeration of women under 25 years covered a relatively large proportion of the single as well as the married women.

The apparent rise in the expectation of life at birth in the returns for women over the age of 54 years suggests that the returns for the older women are faulty. The observed trend might be explained by a tendency for the older women to forget to report children that died in early infancy. It is to be expected that such omissions would lead to a total fertility rate which decreases with a rise in the age of the women, but this is not the case in the Gold Coast. It is possible that the expected trend in the total fertility rate is hidden by a continuation of the trend in the younger ages, that is a level of fertility which rises as the age of the women increases. Another possible explanation of the relatively high expectation of life for the children of the older women is that the latter have included the adopted children who are living, but forgotten to include the corresponding children who have died. This might account for the high level of fertility of women aged 55 years and over, but it would not account for the high fertility of women aged 45-54 years. Further, if it is assumed that the older women have included adopted children, it is to be expected that the level of fertility would continue to rise from the age of 55 years onwards, unless the trend of fertility is reversed at this point. On the published information it is impossible to decide whether or not the returns for the older women are appreciably biased. Estimates of fertility and mortality including and excluding the returns in respect of women aged 50 years and over are given below:

Some Estimates of Fertility and Mortality: Gold Coast 1948

Characteristic	In Respect of Returns of Women of the following ages	
	15-49	15 years and over
Total Fertility Rate	4.86	5.11
Gross Reproduction Rate (1)	2.36	2.48
Expectation of life at birth of females (years)	37	38
Net Reproduction Rate	1.37	1.47

(1) Assuming 485 females per 1,000 births.

The age distribution of the females included in the sample is distorted by the apparent omission of some of the women under 25 years. However, this factor should not affect the estimates given above, for these are based on the actual age distribution of the sample. The use of a more normal age distribut ion would give biased estimates as the average number of births and the number of these still living given by the sample are distorted by the peculiar age distribution. The estimated expectation of life of 37 years used to arrive at the net reproduction rate for women aged 15-49 years is significantly higher than the figures given previously for women up to the age of 54 years. However, the previous figures are intended to show the trend of the mortality rates rather than the absolute expectation of life. They are based on formula (29) which may give biased estimates of the absolute level of the expectation of life.

For the women aged 15-44 years, the average number of children ever born to each woman is 2.94 and the ratio of children still living to children ever born is .664. From this formula (15) gives the total fertility rate as 4.66 and formula (34) gives .585 as the value of $l_{(49)}$. The most appropriate life table for obtaining the net reproduction rate from formula (33) is that for males in Chile in 1930. This has an expectation of life at birth of 35.4 years and gives a net reproduction rate of 1.26.

No satisfactory estimate of fertility may be obtained from the age distribution. Apart from the detailed age distribution obtained in the sample for females aged 15 years and over, the only figures on ages obtained in the census were the number of persons aged under one year, one to sixteen years, sixteen to forty five years and forty five years and over. There were 337,626 children under one year and 893,188 females aged 16-45 years. Without making any adjustment for the children that died in the first six months of life, these figures give a general fertility rate of .378 and a total fertility rate of 10.1! There was obviously a gross over-statement of the children under one year of age.

Mozambique.

Information on the total number of children ever born and the number of these still living was obtained in the 1940 census of the indigenous population of Mozambique. The total number of children ever born were divided into males and females, but in the reported figures of the children still living the two sexes are combined. The results of this enquiry and the apparent trends of fertility and mortality are given in the following table:

<u>Table XXX: Summary of 1940 Census Returns of Mozambique Regarding Total Number of Children Ever Born, Number of These Still Living and Resulting Trends of Fertility and Mortality.</u>[1]

Age of women (years)	Number of women	Children per woman	Total Fertility Rate (2)	Sex Ratio of Births (Females per 1,000 births)	Survival Ratio of Children.	Expectation of life at birth (3)	Date to which births refer (years before census) (4)
15-19	178,190	0.3		492	.821	-	
20-24	209,608	1.2		497	.779		
25-29	327,825	2.1	2.9	494	.775		6
30-34	197,966	2.9	3.3	485	.763		11
35-39	240,445	3.4	3.5	481	.730	46	16
40-44	99,173	3.7	3.7	478	.707	43	20
45-49	100,661	3.6	3.6	470	.667	41	25
50-54	42,747	3.6	3.6	473	.641	41	29
55-59	79,231	3.5	3.5	456	.591	41	34
60-64	43,227	3.5	3.5	457	.586	45	39
65-69	38,559	3.4	3.4	474	.563	46	44
70-74	13,815	3.3	3.3	457	.532	47	49

(1) <u>Censo da População em 1940</u>, Imprensa Nacional, Lourenco Marques, (1945) Vol. V, pp. iv-v.

(2) Estimated as described on pp.159-61.

(3) As given by formula (29).

(4) Estimated as described on pp. 156-7.

The apparent rise in the total fertility rate from about 49 years before census date to about 20 years before census date suggests that the returns for the higher ages have an increasing proportion of omissions. The apparent downward trend in fertility since about 1920 might be exaggerated because the estimates of the total fertility rate are based on the relative age specific fertility rates of the U.S.A. non-white population. The relative age specific fertility rates for Mozambique given on page 107 and based on the assumption of constant fertility, are not unreasonable if the negative rate for the 45-49 year age group is ignored. The rate for this age group appears to have been affected by the reporting errors referred to above. As the rates up to the age of 44 years are not unreasonable, it is possible that the level of fertility has not changed much during the past thirty five years.

The difference between the estimates of the expectations of life of the children of women aged 35-39, 40-44 and 45-49 years are not significant, but they indicate an improvement in mortality rates in the more recent years. This is possibly a reflection of the reduction in tribal wars, famines etc. and an improvement in medical services associated with the infiltration of western civilisation. The fact that the estimates of the expectations of life of the children of women aged 60 years and over are significantly higher than the estimates for the children of the younger women supports the previous indication that the returns for the older women are faulty.

A further indication of reporting errors is the peculiar trend in the sex ratio of the births. The number of females per 1,000 births declines with an increase in the age of the mothers. The total children ever born are reported to include still-births. Since there is generally a marked preponderance of males amongst still-births, it is to be expected that the proportion of females would be somewhat lower than the normal average, amongst live-births, of 485 per 1,000 births. Further, since the older women can be expected to have forgotten some of their still-births, it is to be expected that the proportion of females would increase from something less than 485 per 1,000 births amongst the younger women to somewhere about 485 per 1,000 births amongst the older women. The fact that the actual trend is in the opposite direction suggests that very few still-births were included in the returns. The high proportion of females amongst the children of women aged 15-29 years, an average of 494 per 1,000 births, suggests that these women omitted some of the male births. A possible, though perhaps an improbable, explanation of the peculiarities of the returns of the older women is that these omitted some of the daughters that had died. It is difficult to visualise why this should be the case, but it would account for the low proportion of female births, the relatively high expectation of life and the upward trend of the total fertility rate. It would also lead to an abnormally large differance between the estimates of the expectation of life of the male and female children, but as the surviving children are not divided by sex there is no means of testing this.

There are also some apparent errors in the age distribution of the female population within the childbearing ages. There is a peculiar rise in the number at successive age groups from the age of 15-19 years to the 25-29 year age group and evidently some clustering in the 25-29, 35-39 and 45-49 year age groups. However, there is insufficient information available to attempt any correction to these figures. The reported figures give the following fertility and mortality rates:

<u>Some Estimates of Fertility and Mortality: Mozambique 1940.</u>

Characteristic	Returns in Respect of Women Aged	
	15-49 years	15 years and over
Total Fertility Rate	3.46	3.47
Gross Reproduction Rate (1)	1.68	1.68
Expectation of life at birth of females (years)	46.0	44.8
Net Reproduction Rate	1.15	1.13

(1) Assuming 485 ~~births~~ females per 1,000 births.

For women aged 15-44 years the number of children ever born per woman is 2.2. Formula (15) raises this to a total fertility rate of 3.58. The ratio of children still living to children ever born is .751. Formula (34) reduces this to .693 for the value of $l(9)$. The 1925-28 life table for females in Bulgaria, with an expectation of life at birth of 46.6 years, gives the value of $l(20)$ as .698 and closely fits formula (35). The value of $l(26)$ is estimated to be .673 giving a net reproduction rate of 1.17.

The particulars of children that are available refer only to the under 1, 1-4, 5-9 and 10-14 year age groups. The figures are 346,353, 709725, 767,603 and 369,598 respectively. Accepting the numbers reported under five years as correct, the effective fertility rate is .841. This gives replacement indexes of 1.70 and 1.92 on the basis of the Mauritius and South African Coloured life tables respectively. The fact that these figures are so very much higher than the net reproduction rates given previously could be an indication that there have been substantial omissions in the returns in respect of children ever born and the number of these still living, but it might be an indication that the reported number of children under five years is a gross over-statement of the true position. The figure of 1,056,078 children under five years of age does seem to be rather high in comparison with the figures for the higher quinquennial age groups.

In view of the peculiar age distribution of the females aged 15 years and over, it is of interest to note that if the average age distribution given in Table A of the Appendix is used in place of the reported age distribution the estimates for all women aged 15 years and over are not significantly different from those given previously. The total fertility rate rises from 3.47 to 3.65, the gross reproduction rate rises from 1.68 to 1.77, the expectation of life at birth of females drops slightly from 44.8 to 44.6 years and the net reproduction rate rises slightly from 1.13 to 1.19.

Nigeria.

During the period 1930-32 two rough samples were taken in Nigeria which obtained reproductive histories of women of various ages. In the first enquiry, the so-called "Intensive" census of the Northern provinces in 1930-1, information was obtained on the number of children still living to women of various ages. In the second enquiry, the "Medical" censuses of the northern and southern provinces in 1930-2, particulars were obtained of the total number of children ever born, including still-births. The figures are summarised below:

Table XXXI: Summary of Relevant Results of Intensive and Medical Censuses of Nigeria.(1)

Intensive Census: Northern Province: 1930-1			Medical Censuses: Northern and Southern Provinces: 1930-2		
Age of Women (years)	Number of Women	Average Number of Children Still Living	Age of Women (years)	Number of Women	Average Number of Children Ever Born
15-19	22,033	0.53	15-19	1,035	0.7
20-29	41,557	1.52	20-24	1,262	1.8
30-39	29,463	2.40	25-29	1,041	2.9
40-49	18,814	2.63	30-34	902	3.5
50-59	11,375	2.40	35-39	787	4.2
60 and over	12,674	2.06	40 and over	2,277	4.3
Total	135,916	1.83	Total	7,304	3.0

(1) Based on figures quoted by R.R. Kuczynski; Demographic Survey of the British Colonial Empire, Vol. I, pp. 676 and 681.

From a rough interpolation of the age distribution, formula (37a) gives the net reproduction rate as 1.3 for the "Intensive" census. For the Medical censuses the total fertility, including still-births, is estimated to be 4.3 in respect of all women aged 15 years and over.

No further fertility enquiries appear to have been undertaken in Nigeria until the 1950 census of Lagos. A summary of these particulars and the apparent trends of fertility and mortality are given below:

Table XXXII: Apparent Trends of Fertility and Mortality in Lagos Municipality in 1950.(1)

Age of Women (years)	Number of Women	Average Number of Children.	Total Fertility Rate (2)	Survival Ratio of children	Expectation of life at birth (years) (3)	Average date to which births refer (years before census) (4)
15–19	10,979	0.2		.86		
20–24	13,337	0.9		.84		
25–34	22,718	1.7	2.2	.80		9
35–44	10,773	2.6	2.7	.77	48	18
45–54	5,231	3.0	3.0	.70	46	27
55–64	2,581	3.2	3.2	.63	47	37
65 and over	2,971	3.4	3.4	.57		

(1) Based on figures given in Population Census of Lagos, 1950, Government Printer, Kaduna: p. 55.

(2) Estimated as outlined on pp. 159–61.

(3) As given by formula (29).

(4) Estimated as outlined on pp. 156–8.

The estimates of fertility and mortality given above indicate that there has been a downward trend in fertility. There is also a slight indication of an upward trend in the expectation of life, but the differences between the relevant figures in Table XXXII are not significant. The average number of children born to all women aged 15 years and over is 1.68. Formula (11) raises this to a total fertility rate of 2.64. Assuming that females are 48.5 per cent. of total births, this is equivalent to a gross reproduction rate of 1.28. For all women aged 15 years and over the number of children still living represent

.750 of the total number of children ever born. According to formula (25a) the expectation of life at birth of the two sexes combined is then 45.6 years. Assuming that the expectation of life at birth of females is 0.8 years above this, formula (31) gives the net reproduction rate as 0.89.

For the women aged 15-44 years the average number of children ever born is 1.41. From formula (15) this is estimated to be equivalent to a total fertility rate of 2.59. The value of $l(14)$, as given by formula (34), is .746. The appropriate life table is that for females in Belgium in 1891-1900 with an expectation of life at birth of 48.8 years. The net reproduction rate obtained from formula (33) is then 0.92.

Further estimates of the net reproduction rate may be obtained from the age distribution of the Lagos population. The figures of children up to the age of nine years are as follows:

Age Distribution of Children Under
10 Years of Age: Lagos 1950.

Age	Persons
0	7,998
1	3,317
2	5,367
3	5,216
4	5,443
5	5,097
6	4,530
7	4,470
8	4,603
9	4,086

These figures reveal a clustering of the population at the even numbers. The averages for the ages 0 and 1, 2 and 3, 4 and 5 etc. are 5,658, 5,292, 5,270, 4,500 and 4,344 respectively. From this it is estimated that there were 27,170 children under five years of age. This figure differs only very slightly from that of 27,341 reported in the census and there is no evidence that any of the children under five years of age were omitted from the enquiry. The number of women aged 15-44 years is reported as 68,589. An examination of the figures for individual years of age does not indicate any marked error in this figure. The effective fertility rate is .399. This is equivalent to replacement indexes of 0.81 on the basis of the Mauritius life table and 0.91 on the basis of the South African Coloured life table.

Rhodesia and Nyasaland Federation.

In the area covered by the recently formed federation of the Rhodesias and Nyasaland questions on the total number of children ever born were asked for the first time in the 1926 census of Nyasaland.[1] Each District Commissioner was requested to question a hundred women "not likely to have any further children, but who on the other hand, were not so old as to have forgotten the details." A total of 2,159 women were questioned altogether and on the average they had had 6.32 children.

Questions on the total number of children ever born and the number of these still living were put to women of all ages in the demographic sample surveys held in Southern Rhodesia in 1948 and 1953 and in Northern Rhodesia in 1950.[2] The 1948 and 1950 surveys of Southern and Northern Rhodesia respectively covered the whole of these territories, but the 1953 survey covered a little less than half of Southern Rhodesia. The remainder of this Colony is being covered in 1954-5. In the 1948 and 1950 surveys the only information obtained on ages were figures of the population (i) under one year, (ii) aged one year and over, but under puberty and (iii) over puberty. In

(1) Census of 1926, Government Printer, Zomba, pp. xxi to xxii.

(2) Demographic Sample Survey of the African Population of S. Rhodesia, (1951): Demographic Sample Survey of the African Population of N. Rhodesia, (1952): Preliminary Report on Second Demographic Sample Survey of the Indigenous Population of S. Rhodesia, (1954): All published by the Central African Statistical Office, Salisbury. These reports do not give details of the total number of children ever born and the numbers still living —— The relevant figures given here have been extracted from the original returns by the present author.

the 1953 survey males over puberty were divided into those under and over 35 years of age and the females over puberty were divided into three groups, namely (i) under 35, (ii) 36 and over, but not past menopause and (iii) past menopause.

In the 1948 survey of Southern Rhodesia the average number of children ever born to women over puberty was 4.51, but this is considered to be a biased figure. The returns indicated that only 50.5 per cent. of the female population was over the so-called age of puberty. This is a surprisingly low figure and it would appear that either the division at puberty was in fact based on some characteristic of physical or social development that normally takes place some time after the biological age of puberty, or that large numbers of the adult females were omitted from the survey. The 1953 survey of portion of Southern Rhodesia revealed that 57.4 per cent. of the females were over puberty and on the average these had had 3.62 children each. These figures indicate that the 1948 survey omitted quite a large number of the adult women and overstated their average number of children. In view of these discrepencies the Southern Rhodesia estimates of total fertility and the net reproduction rate will be confined to the results of the 1953 survey. The age of puberty has been estimated to be 15.3 years. (see page 88). Taking this figure and assuming that the mean age of menopause is 45 years, the following estimate of the age distribution is obtained by the method described on pages 90-6.

<u>Estimated Age Distribution of Females: 1953 Sample Survey of Southern Rhodesia.</u>

Age Group	% of total	Age Group	% of total
0 -14	45.9	35-39	4.1
15-19	11.2	40-44	2.5
20-24	9.5	45-49	1.0
25-29	7.6	50 plus	12.2
30-34	6.0		

Although the 1953 survey divided the females over puberty into three broad age groups, details of the number of children ever born and the number of these still living are available only for all ages taken together. The 1950 survey of Northern Rhodesia gives only the same detail as the 1948 survey of Southern Rhodesia. The number of females over puberty is 59.5 per cent. of the total female population. This is not an unreasonable figure. In the demographic surveys in the Rhodesias separate records were kept of the total number of births that had occurred in the twelve months preceeding the dates of the enquiries, so that the values of b/ρ to be used in formula (25a) are known and do not have to be estimated. The total fertility, gross and net reproduction rates and the expectations of life at birth for the two Rhodesias are given in the following table:

<u>Some Estimates of Fertility and Mortality in the Rhodesias</u>

Characteristic	Southern Rhodesia 1953	Northern Rhodesia 1950
Total Fertility Rate(1)	5.70	5.86
Gross Reproduction Rate(2)	2.84	2.91
Expectation of life at birth of females (years)(3)	47.9	36.9
Net Reproduction Rate	2.01	1.68

(1) For Northern Rhodesia the estimate is based on the age distribution given in Table A of the Appendix.

(2) Based on observed sex ratios.

(3) As given by formula (25a) using returns for female children. The corresponding estimates for males are 46.3 years in Southern Rhodesia and 35.0 years in Northern Rhodesia.

Bearing in mind the possible standard errors of the estimates, the difference between the two total fertility rates is not significant, but there is a significant difference between the expectations of life in Southern and Northern Rhodesia. The difference between the two net reproduction rates is also significant. The relatively high expectation of life in Southern Rhodesia is in reasonable agreement with the figure of 46.6 years for females obtained from the 1948 returns. (The probable bias in the 1948 average number of children ever born to females over puberty, to which reference was made above, is not considered to have affected the ratio of children still living to total children ever born, so that this estimate for 1948 is not considered to be biased.) The difference between the Southern and Northern Rhodesia expectations of life is to some extent supported by the observed infant mortality rates. The infant mortality rate was 259 per 1,000 births in Northern Rhodesia in 1950, but only 131 in Southern Rhodesia in 1948. For the areas common to the 1948 and 1953 surveys in Southern Rhodesia the infant mortality rate was 120 and 123 respectively.

Swaziland.

Questions on the total number of children ever born and the number of these still living were asked for the first time in the 1946 census of Swaziland. It is estimated that the total number of births to all women was approximately 161,190 and that approximately 119,930 of these survived to census date.[1] These figures are not analysed by age of mother, so that it is not possible to examine the apparent trends in the fertility and mortality rates. The available information on the sex and age distribution of the population is given below:

Table XXXIII: Sex and Age Distribution of 1946 African Population of Swaziland.

Age Group	Males	Females	Persons
Under 1	4,495	4,867	9,362
1-12	29,958	27,731	57,689
13-17	14,008	12,884	26,892
18-50	32,909	33,006	65,915
Over 50	6,514	14,897	21,411
Total	87,884	93,385	181,269

(1) Swaziland Census, 1946; Assuming cases of "9 and over" children refer to an average of 10 children.

An interpolation of the age distribution of the adult female population is given in Table A of the Appendix. The average number of children ever born to all women aged 15 years and over is estimated to be 2.99. From this formula (11) gives the total fertility rate as 4.50. Assuming the ratio of female births to total births is 485:1,000, this reduces to a gross reproduction rate of 2.19. The ratio of children surviving to total children ever born is .744. Formula (25 a) gives an estimated expectation of life at birth, for the two sexes combined, of 46.8 years. Assuming that the expectation of life of females is 0.8 years higher than this, formula (31) gives a net reproduction rate of 1.55.

In the census report, the number of children under one year of age is used as a rough measure of fertility.[1] The number of women aged 15-44 years is assumed to be roughly six sevenths of the number aged 15-50 years and the children under one year are divided by this figure to get a ratio of 33 surviving children per 100 women. It is stated that "unless the rate of infant mortality was very high they" (i.e. figures of this order of magnitude) "do not indicate a high degree of fertility." This is a very misleading statement. A ratio of this nature is a rough general fertility rate and a general fertility rate of .33 is equivalent to a total fertility rate of 8.8 on the basis of the relative age specific fertility rates of the U.S.A. non-white population.[2] This is a phenomenally high rate which would be even higher if it is based on any other relative age specific fertility rates and if account is taken of the infant mortality rate. The number of children reported to be under one year of age is obviously an exaggeration of the true position.

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(1) Swaziland Census, 1946, p. viii.

(2) See pp. 11-12.

Summary.

The various estimates of fertility and mortality made in the previous sections are summarised in the following table:

TABLE XXXIV.- SUMMARY OF VARIOUS ESTIMATES OF THE TOTAL FERTILITY RATE, THE EXPECTATION OF LIFE AT BIRTH AND THE NET REPRODUCTION RATE.

COUNTRY	DATE OF EN-QUIRY	TOTAL FERTILITY RATE			TREND OF FER-TILITY (a)	EXPECTATION OF LIFE AT BIRTH (YEARS)			TREND OF MOR-TALITY (a)	NET REPRODUCTION RATE			REPLACEMENT INDEX	
		Formula (11)		Formula (15)		Formula (25a) Children of Women Aged		Used in Formula (33)		Formula (34)		Formula (33)	Expectation of Life at Birth (Years)	
		Women Aged								Women Aged				
		15 Years and Over	15-49	15-44		15 Years and Over	15-49			15 Years and Over	15-49	15-44	33.8 (b)	40.9 (c)
Angola	1940	3.6	3.4	3.3	D	35	36	32	C	1.0	1.0	0.9	1.3	1.4
Bechuanaland	1946	2.9(d)				51(d)				1.0(d)			1.0	1.1
East Africa :														
Tanganyika	1948		4.4(e)		D		35(f)				1.2(e)			
Uganda	1948		4.6(e)		D		24(f)				1.0(e)			
Kenya	1948		5.9(e)											
Gold Coast	1948	5.1(g)	4.9(g)	4.7(g)	D	38(g)	37(g)	35(g)	C	1.5	1.4	1.3		
Mozambique	1940	3.5(g)	3.5(g)	3.6(g)	D(?)	45(g)	46(g)	47(g)	U(?)	1.1	1.2	1.2	1.7	1.9
Nigeria :														
"Intensive" Census	1930-1									1.3(h)				
"Medical" Census	1930-2	4.3(g)												
Lagos	1950	2.6		2.6	D	46		49	U(?)	0.9		0.9	0.8	0.9
Rhodesia :														
Southern	1953	5.7				48				2.0				
Northern	1950	5.9				37				1.7				
Swaziland	1946	4.5				48				1.6				

(a) The abreviation "D" refers to a downward trend, "U" refers to an upward trend and "C" indicates no apparent upward or downward trend.
(b) 1942-6 life table for Mauritius.
(c) 1936 life table for Coloured population in the Union of South Africa.
(d) Excluding the children of widowed, divorced and single women.
(e) In respect of women aged 16-45 years.
(f) Rough estimate obtained from formula (29): possibly biased.
(g) Purporting to include still-births.
(h) From formula (37a).

Bearing in mind that estimates obtained from formula (11) have a standard error of about 7.5 per cent.[1] the exclusion of the returns of women over the age of 49 years has no significant effect on the estimated total fertility rate, although there appears to be a slight reduction. Thus in Angola there is a drop from 3.6 to 3.4 and in the Gold Coast there is a drop from 5.1 to 4.9, but in Mozambique there is no change. The exclusion of returns in respect of women over 49 years appears to raise the estimate of the expectation of life at birth slightly. Thus in Angola there is a rise of one year and the same in Mozambique, but in the Gold Coast there is a decline of one year. However, these variations are again not significant as the estimates of the expectation of life at birth have a standard error of about 2.5 years.(1) When the estimates of the total fertility rate and the expectation of life are brought together to obtain the net reproduction rate there is no difference between the figures in respect of women aged 15-49 and all women aged 15 years and over in Angola; the rise in the expectation of life is offset by the decrease in the total fertility rate. In the Gold Coast, where there is a drop in both the total fertility rate and the expectation of life, the net reproduction rate decreases from 1.5 to 1.4. In Mozambique, where there is no difference between the two total fertility rates but a slight rise in the expectation of life, the net reproduction rate rises from 1.1 to 1.2. The estimates of the net reproduction rate have a standard error of about 7 per cent.(2)

Comparing the total fertility rates obtained by Brass' method (formula (15)) with those obtained from formula (11) it will be noticed that formula (15) gives a slightly lower figure in Angola and the Gold Coast, but a slightly higher figure in Mozambique. The observed differences are, however, far from being significant. In Lagos the two formula give the same result. When the total fertility rates obtained from formula (15) are reduced to a net reproduction rate by the method advo-

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(1) See p. 138.
(2) See p. 169.

cated by Brass (formula (33)), the figure is slightly lower than that obtained from formula (31) in Angola and the Gold Coast, but in Mozambique and Lagos the two estimates are the same. It will be noticed that the life table used with Brass' method has an expectation of life appreciably lower than that obtained from formula (25a) in the case of Angola, a slightly lower figure in the Gold Coast and higher figures in Mozambique and Lagos. The differences in Angola and Lagos may be significant, but they are in opposite directions. These comparisons indicate that the two methods of estimating the total fertility and net reproduction rates are about equally efficient. However, Brass' method is of limited value as it has not been possible to use it in Bechuanaland, East Africa, the "Intensive" and "Medical" censuses in Nigeria, the Rhodesias and Swaziland.

In all the estimates given in Table XXXIV there are certain sources of bias which should be borne in mind. All the total fertility rates are based on the relative age specific fertility rates of the 1940 U.S.A. non-white population. Although the analysis in Chapter IV indicates that it is reasonable to assume that these rates are applicable to African Negroid populations, there is a possibility that, in some cases, the use of these rates leads to biased estimates of the total fertility, gross and net reproduction rates. However, as shown on pages 175-6, any bias in the net reproduction rate resulting from the use of the relative age specific fertility rates of the U.S.A. non-whites disappears when the net reproduction rate is converted into the standardised rate of natural increase. It should be noted that this does not necessarily apply to estimates of the standardised rate of natural increase obtained from the replacement indexes, as the latter are not based on the specific fertility rates of the U.S.A. non-whites. The estimates of the total fertility rate and the expectation of life at birth might be biased because of reporting errors in the basic returns. The errors normally associated with the returns for the older women seem to have very little effect on the estimates. The importance of these errors appears to have been exaggerated in the past. Large errors in the returns for the older women have little effect on the estimates because the number of old women is such a small fraction of the total population, particularly amongst populations like the African Negroid people which have what is sometimes described as an immature or emergent age distribution. Departures from the ideal definition of the term "live-birth" are another source of error, but again the resulting bias appears to be small. Still-births are reported to be included in the returns for the Gold Coast, Mozambique and the "Medical" census in Nigeria, but they do not appear to have affected the results to any significant extent. The compensating nature of the biases resulting from many reporting errors leads to a relatively unbiased estimate of the net reproduction rate.

If the replacement indexes are compared with the other estimates of the net reproduction rate, it will be noticed that the replacement indexes are appreciably higher than the other figures in Angola and Mozambique, but in Bechuanaland and Lagos all the figures are in reasonable agreement with one another. The discrepency between the Angola figures is inexplicable. In Mozambique the replacement indexes are possibly on the high side because of an over-statement of the number of children under five years of age and the other estimates of the net reproduction rate possibly contain a downward bias, as in this case there is some indication that the actual relative age specific fertility rates may be nearer the averages given in Table C of the Appendix than those of the U.S.A. non-white population. In Bechuanaland the agreement between the figures is surprising since the estimated net reproduction rate does not take into consideration the children of the single, widowed and divorced women.

As far as the apparent trends of fertility and mortality are concerned, the detailed analysis indicates a general decline in fertility in the more recent years, but no change, or a slight improvement, in mortality conditions. A more definite improvement in mortality conditions might have become evident had it been possible to examine the mortality rates in the very recent years.

The figures given in Table XXXIV reveal some marked variations from country to country. The net reproduction rates range from 0.9 in Lagos and possibly also in Angola to 2.0 in Southern Rhodesia. The total fertility rates range from 2.6 in Lagos to 5.9 in Northern Rhodesia. The expectation of life at birth of females, as given by formula (25 a), ranges from 35 years in Angola to 48 years in Southern Rhodesia and Swaziland. (The figure of 51 years for Bechuanaland is not considered as it refers to the children of only the married women). To some extent the observed regional variations in fertility and mortality are no doubt due to undetected reporting errors, but marked variations in the mortality rates are to be expected because of the wide range of climatic and health conditions in Africa. For example, the fact that the expectation of life is very much higher in Southern Rhodesia than it is in Northern Rhodesia is not surprising when it is borne in mind that Southern Rhodesia has a relatively larger public health service and at the same time has a relatively small area covered by swamps and tsetse fly. Variations in the incidence of various diseases, particularly venereal diseases, are likely to account for some of the variations in the total fertility rates. These rates might also be affected by variations in marriage customs and the magnitude of the exodus of migrant labourers. These two aspects of fertility are considered in the following chapter.

CHAPTER VIII

THE CORRELATION BETWEEN FERTILITY ON THE ONE HAND AND MARRIAGE CUSTOMS AND THE PROPORTION OF ABSENTEE MIGRANT WORKERS ON THE OTHER HAND.

Amongst European countries variations in the total fertility rate may be attributed to a wide range of factors, such as variations in the customary age of marriage of women, the ultimate size of family desired, religious and economic conditions etc. Amongst African Negroid populations it is quite frequently assumed that variations in these factors are very small, so that they are not likely to lead to marked variations in fertility. A popular view is that an African Negroid woman normally gets married shortly after she has reached the age of puberty and that she has a pregnancy every three or four years for the whole of the childbearing period. Further, it is often assumed that even if a woman does not get married shortly after reaching puberty she nevertheless has children because of the absence of any social stigma associated with illegitimacy. Although it is generally thought that variations in the customary age at marriage have little bearing on birth rates, it is sometimes stated that polygamy and the movement of migrant labour has a detrimental effect on the birth rate.(1) The validity of these views is examined below.

Marriage Customs.

Some indication of variations in the customary age at marriage is provided by figures of the relative proportions of women in various age groups who have never married. The

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(1) For example see Kuczynski R.R. (1939), The Cameroons and Togoland, pp. 150 and 450-6; (1949), A Demographic Survey of the British Colonial Empire, Vol. II, pp. 482, 495-500.

available figures are given in Table XXXV.

Table XXXV: Proportions of Women in Various Age Groups Who Have Never Married or Who are Single.

Age Group (years)	Percentage of Total Women in Each Age Group Who Have Never Marriedor Who are Single		
	Mozambique 1940[1]	Lagos 1950[2]	Union of South Africa 1936[3]
15-19	37.7	64.1	91.5
20-24	15.0	20.5	43.4
25-29	10.9	8.7	17.3
30-34	9.3		8.4
35-39	9.7	13.4	5.0
40-44	9.9		3.4
45-49	11.3	35.7	2.7
50 and over	10.4		2.6

(1) Censo da Populaçao em 1940, Imprensa Nacional, Lourenco Marques, (1945), Vol. II, p. 26.

(2) Population Census of Lagos, 1950, Government Printer, Kaduna, (1951), p. 54.

(3) Sixth Census of the Population of the Union of South Africa, 1936, Government Printer, Pretoria, (1942), Vol. IX, p. 45.

The Mozambique figures are reported to refer to the "never Married", but the upward trend in the figures from the age of 34 years is a definite indication that the figures include some of the widowed and divorced women in the older age groups. The figures for Lagos are reported to refer to "single" women including the widowed and divorced persons and persons of unknown marital status. This accounts for the relatively high proportions in the ages above 34 years. The figures for the Union of South Africa refer to the never married and appear to be free from any reporting errors as far as the widowed and divorced women are concerned.

Owing to the variations in the treatment of the widowed and divorced women noted above, it is impossible to draw any conclusions from Table XXXV except in so far as the 15-19 year age group is concerned. This age group is probably free from any inconsistencies arising from the variations in the treatment of the widowed and divorced women. The proportion of the women in this age group who have never married ranges from 37.7 per cent. in Mozambique to 91.5 per cent. in the Union of South Africa. This wide range suggests that there is a marked variation in the mean age of marriage.

In the sixty-seven countries outside Africa for which figures are available, the proportion of women in the 15-19 year age group who have never married ranges from 12.7 per cent. in India to 99.3 per cent. in Switzerland.(1) There are twenty-nine countries with a proportion which is less than the 91.5 per cent. quoted above for the Native population of the Union of South Africa. These include the U.S.A., most of South America and Asia, Bulgaria, Hungary, Yugoslavia and Russia. The detailed distribution for Natives in the Union of South Africa given in Table XXXV is similar to that of the European females in the Union of South Africa. It is of interest to note that the mean age at marriage, as given by formula (5) on page 87 with appropriate changes in notation, is 22.0 years for the Natives and 22.5 years for the Europeans. The mean age at marriage of the Negroid females in Mozambique and Lagos cannot be calculated because of the inclusion of the widowed and divorced women, but it is obvious that in both cases it is appreciably less than the age of 22 years

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(1) 1949-50 Demographic Yearbook, United Nations, pp. 214-21.

in the Union of South Africa, unless there is a substantial difference in the meaning of the term "married" in the three sets of figures.

Apart from variations in the treatment of the widowed and divorced persons, the wide range of the figures quoted in Table XXXV may be due to variations in the local meaning of the term "married". Amongst European communities the usual terms used in an analysis of the population by marital status have well known and legally defined meanings. The application of these terms to the African Negroid populations is complicated by the local customs of the people.

From the demographic point of view it is desirable that the term married be used to cover cases where a man and woman cohabit as man and wife, regardless of the local social or legal conception of the term. It is well known that amongst African Negroid people the process of getting married is spread over a much longer period than is the case amongst European races. Experimental field work in Southern Rhodesia has shown that young girls sometimes tend to be reported as married as soon as some preliminary arrangement, not necessarily something as definite as betrothal, has been made. On the other hand, women who are cohabiting with a man sometimes state that they are not married, even if they have had children by the man, because of various reasons. In the first place they may have entered into a purely temporary alliance with the man. In the second place the man may not have completed the lobola payments. In the third place they may wish to hide the fact that they are married because the marriage has not been registered, or reported to the local Native Commissioner. The third reason for not declaring their true status is common in polygamist households, as polygamists are taxed more than monogenists. Martin(1) has drawn attention to the fact that in parts of East African a women is not regarded as married until she has given birth to a child. Amongst the older women ambiguities arise in the classification of widows. When a married man dies it is usual for his widow to become the wife of one of his relatives. This inflates the number of polygamist households. If care is not exercised in questioning the people there is a danger that what for lack of a better term may be described as "inherited" wives will be classified as widows instead of as married women. From the demographic point of view it is desirable that the term widow be confined to women who are in the transition stage between the death of their husband and the time when they become the wife of another man, together with widows in the real sense of the word. The latter are widows who have refused to cohabit with another man; in many cases they will be women past the childbearing period. Where a man is taxed for each additional wife, the desired distinction between widowed and married women may be complicated by the fact that "inherited" wives are not taxable. In such a case there is likely to be a tendency on the part of the people concerned to report "inherited" wives as widows to conform with their normal practice in their dealings with officials.

Although variations in the definitions of the terms single, married, widowed etc. can be expected to exaggerate the differences between countries with regard to the analysis of the population by marital status, it is to be expected that a more or less uniform system of classification is adopted within each country. However, even within countries

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(1) Martin C.J. (1953) "The collection of Basic Demographic Data in Under-Developed Territories"; A paper submitted to the 1953 (Rome) session of the Internation Statistical Institute.

there is evidence of marked variations in marriage customs. In the Union of South Africa the proportion of women aged 15-44 years who were classified as never married in 1936 ranged from 29.3 per cent. in Benoni to 54.6 per cent. in Pretoria. In Mozambique the figures ranged from 3.7 to 38.0 per cent. In the Belgian Congo, of the women aged 20-45 years in 1950, the proportion never married ranged from 5 to 26 per cent. and the proportion in polygamous households ranged from 10 to 57 per cent.(1)

These local variations in marriage customs are not likely to have much affect on the local fertility rates if, as is generally thought to be the case, the unmarried women have children almost as frequently as the married ones. However, this does not appear to be the case in the Belgian Congo. In 1950 the Belgian Congo aurthorities undertook a crude large scale sample survey covering all parts of their territory. They paid special attention to the differences between the fertility of married and unmarried women and between women in polygamous and monogamous households. Although the absolute figures may be biased because the sample was not selected in a scientific manner, the relative differences between the fertility rates of the single and married women and between the polygamous and monogamous households are probably reasonably accurate. The main results of this aspect of the enquiry are summarised in Table XXXVI on page 216.

This shows that the illigitimate fertility rate was less than a third of the legitimate fertility rate and that the fertility rate in polygamous households was verymuch

(1) For details of these figures see Table XXXVI on page 216, Table XXXVII on page 219 and Table XXXVIII on page 220.

Table XXXVI: Summary of 1950 Belgian Congo Demographic Enquiry.[1]

District	Percentage of Women Aged 20-45		General Fertility Rates: (births per 1,000 women aged 15-45 years)				
	Never Married.	Polygamists	Legitimate	Illegitimate	Monog. House-Holds	Polyg. House-holds	All women
Moyen-Congo	18	36	201	?	228	115	141
Du LacLeopoldville	20	38	166	69	185	133	141
Du Kwango	15	41	226	31	246	196	179
Bas-Congo	26	27	242	46	264	173	170
De L'Equateur	16	29	120	42	125	102	97
Congo-Ubangi	7	39	128	27	144	103	121
La Tshuapa	8	43	71	35	94	47	66
Stanleyville	5	44	115	47	132	90	107
Kibali-Ituri	9	45	152	50	164	123	127
L'uele	13	48	76	32	90	58	70
Kivu	9	41	217	47	245	170	180
Maniema	6	57	82	?	110	91	88
Haut-Katanga	25	10	275	102	293	171	216
Tanganika	16	38	168	61	173	147	138
Lualaba	17	29	190	68	207	150	154
Haut-Lomami	13	43	181	54	157	90	113
Kasai	5	47	162	57	211	106	148
Sankuru	7	50	113	?	150	81	102
Kabinda	6	45	177	?	179	14	132
Average	13	40	161	51	179	114	131

(1) Demographic Conglaise, 1950, Service des A.I.M.O. du Gouvernement General, Leopoldville. The general fertility rates refer to the number of births per 1,000 women of each group, the legitimate and illegitimate rates being based on births to married and unmarried women respectively per 1,000 women in each category.

lower than that in monogamous households. It is therefore to be expected that a reduction in the proportion of unmarried women leads to a rise in fertility and that an increase in polygamy leads to a fall in fertility. The figures quoted in Table XXXVI give — 0.55 for the correlation[1] between the general fertility rate for all women and the proportion of women in polygamous households. However, instead of the expected negative correlation between the general fertility rate for all women and the proportion of women never married, there is a positive correlation of 0.45. The values of Student's t[2] are 2.7 for the correlation coefficient of — 0.55 and 2.1 for the correlation coefficient of 0.45. These values of t correspond to the 1.6 and five per cent. levels of significance. The observed correlation between the general fertility rate and the proportion of women who are not married is therefore probably significant while the correlation between the general fertility rate and the proportion of women in polygamous households is definitely significant. The observed correlation between the general fertility rate and the proportion of women never married implies that fertility increases with a rise, instead of a fall, in the proportion not married. This peculiar state of affairs is accounted for by a very high negative correlation (a coefficient of — 0.92) between the proportion never married and the proportion in polygamous households. In other words the variations in the proportions never married are an inverse reflection of the extent of

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(1) As given by Spearman's rank correlation coefficient — see footnote (1) on page 129 for formula.

(2) As given by formula in footnote (2) on page 129.

polygamy. The difference between the fertility of women in (i) monogamous and (ii) polygamous, households is more than sufficient to offset the difference between the fertility of (i) single and (ii) married women.

The Belgian Congo figures support the general view that polygamy has a detrimental effect on the level of fertility, but the Culwicks (1) found no relationship between fertility and polygamy in the Ulanga area of East Africa. Although the latter survey is probably the more reliable one from the point of view of the reliability of the returns, as the Culwicks are trained investigators, the results of the Belgian Congo survey are more acceptable in that they refer to a much larger population. The Culwicks' conclusions are based on the returns of 2,374 women aged 15 years and over, whereas there were about 75,000 to 80,000 women aged 15 to 45 years in the Belgian Congo investigation. The general view that polygamy has a detrimental affect on the level of fertility is sometimes explained by statements to the effect that the level of fertility is relatively low in polygamous households because polygamy increases the sterility due to venereal diseases and sexual excess. Another consideration may be the fact that polygamous households include most of the "inherited" wives who are normally the older, and therefore the less fertile, women. There is also the possibility that "inherited" wives are not treated quite the same as other wives.

There is no further information available on the relationship between polygamy and fertility, but in the

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(1) Culwick A.T. and G.M. (1938 and 1939), "A Study of Population in Ulanga, Tanganyika", The Sociological Review, Vol. 30 No. 4 and Vol. 31 No. 1, pages 365 and 25 respectively.

case of the Union of South Africa and Mozambique it is possible to examine the correlation between the effective fertility rate and the proportion of married women. The relevant figures are given in Tables XXXVII and XXXVIII below.

Table XXXVII: Percentage of Women Aged 15-44 years Who have Never Married and Effective Fertility Rate In the Municipal Areas of the Union of South Africa in 1936.(1)

Municipal Area	Effective Fertility Rate (children aged 0-4 per 1,000 women aged 15-44)	Percentage Women Aged 15-44 Never Married
Cape Town	413	32.3
East London	315	42.0
Kimberly	432	51.8
Port Elizabeth	4533	44.3
Durban	330	3599
Pietermaritzberg	271	41.4
Pretoria	274	54.6
Johannesburg	253	37.4
Randfontein	387	40.6
Krugersdorp	398	39.3
Roodepoort	409	38.2
Germiston	359	34.3
Boksburg	409	34.1
Benoni	405	29.3
Brakpan	389	33.0
Springs	372	34.1
Nigel	382	34.1
Bloemfontein	340	41.5

(1) Sixth Census of the Union of South Africa, 1936, Government Printer, Pretoria, (1939), Vol. XI, pp. 48-62.

Table XXXVIII: Effective Fertility Rate and Percentage of Women Aged 15-44 Who Have Never Married in Twenty Rural Areas of Mozambique in 1940.(1)

District	Effective Fertility Rate (children aged 0-4 per 1,000 women aged 15-44)	Percentage Women Aged 15-44 Never Married
Mrracuene	629	13.8
Magude	1027	14.0
Machopes	667	6.8
Inarrime	627	3.7
Pebane	819	33.8
Alto Molocue	1030	22.4
Milange	885	12.6
Mutarara	1032	13.3
Macanga	1143	9.2
Mogovolas	810	12.6
Ribaue	642	24.4
Memba	712	13.7
Amaramba	1040	6.7
Iurio	907	11.5
Mucojo	535	15.0
Tungue	683	13.1
Govuro	712	8.3
Buzi	815	8.5
Chimoio	1055	9.0
Gorongoza	769	38.0

(1) A sample of twenty rural areas selected from the particulars given in Censo da Populaçao em 1940, Imprensa Nacional, Lourenco Marques, (1945), Vol. III.

The correlation, as given by Spearman's rank correlation coefficient, between the effective fertility rate and the proportion of the women aged 15-44 years who have never married comes to only — 0.19 in the Union of South Africa and — 0.12 in Mozambique. These coefficients are far from being significant. The figures suggest that marked variations in the proportion of the women aged 15-44 who have never married have no affect on fertility. A similar analysis of the proportion of women aged 15-24 and 15-44 who are married revealed no significant improvement in the correlation coefficients. However, the figures for the Union of South Africa are distorted by urban conditions. It is to be expected that there is a relatively lax standard of morals in such areas. The figures for Mozambique are distorted by the fact that some of the widowed and divorced women appear to be included with the never married.[1]

Proportion of Absentee Husbands.

In many parts of Africa it is common for large numbers of the adult males to leave their wives in the rural African villages for several years at a time while they are earning money wages in the European or money economy of their own or a neighbouring country. For several decades there has been a belief in Northern Rhodesia that these long-term temporary absences of the males have a detrimental effect on the birth rate.[2] The sample surveys held in Southern Rhodesia in 1948 and in Northern

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(1) See comments on p. 211.

(2) See Kuczynski R.R. (1949), A Demographic Survey of the British Colonial Empire, Oxford University Press, Vol. II, pp. 482, 493-500.

Rhodesia in 1950 provide some statistical evidence that the birth rate is not affected by these long-term temporary absences of the adult males. A systematic sample of ever third village included in the original surveys has been re-analysed to determine the correlation between (i) the proportion of the adult males who are absent from home and (ii) the number of births per hundred women during the twelve months preceeding the date of the enquiry. The basic figures are summarised in Table XXXIX.

Table XXXIX: Relationship Between Proportion of Adult Males Who are Absent and the Birth Rate: 1948 and 1950 Surveys of Southern and Northern Rhodesia Respectively.

Percentage of Adult Males Absent from Home	Births per 100 Women over Puberty	
	Southern Rhodesia 1948	Northern Rhodesia 1950
Under 20	26.5	16.7
20-22.4	33.3	23.4
22.5-24.9	14.8	13.4
25.0-27.4	22.8	13.7
27.5-29.9	21.9	20.9
30.0-32.4	26.5	12.7
32.5-34.9	15.1	20.2
35.0-37.4	9.9	17.8
37.5-39.9	16.2	19.5
40.0-42.4	18.1	14.0
42.5-44.9	17.0	16.9
45.0-47.4	23.6	14.6
47.5-49.9	26.3	11.9
50.0-52.4	17.9	20.2
52.5-54.9	19.0	13.6

Table XXXIX Continued.

Percentage of Adult Males Absent from Home	Births per 100 Women over Puberty	
	Southern Rhodesia 1948	Northern Rhodesia 1950
55.0-57.4	16.6	18.8
57.5-59.9	17.0	17.6
60.0-62.4	18.5	18.3
62.5-64.9	13.2	15.0
65.0-67.4	15.4	13.4
67.5-69.9	17.0	13.1
70.0-72.4	21.9	19.1
72.5-74.9	6.2	14.7
75.0-77.4	24.0	16.9
77.5-79.9	16.7	15.6
80 and over	19.7	14.5

The correlation between the birth rate and the proportion of the adult males who are absent is — 0.25 in Southern Rhodesia and — 0.12 in Northern Rhodeisa. The values of Student's t are 1.3 in Southern Rhodesia and 0.6 in Northern Rhodesia. These low values of Student's

indicate that there is no significant correlation between the birth rate and the proportion of adult males who are absent, although in both cases the observed correlation is in the right direction in that it is negative. It would appear that the males do not stay away for a period long enough to materially affect the birth rate. It is of interest to note that Mithcell reports[1] that women

(1) Mitchell J.C. (1949) "An Estimate of Fertility of Some Yao Hamlets in Liwonde District of Southern Nyasaland", Africa, Vol. XIX, No.4, p. 293.

are known to ask their husbands to return when their children have been weaned, that is when they require an addition to the family. Although there is no evidence that the temporary absences of the husbands has any significant effect on the birth rate, they encourage adultery and have an undesirable social effect on family life.(1)

Conclusion.

The scanty information at present available indicates that there are marked local variations in the customary age at marriage, but that these variations do not affect the birth rate. There is some evidence that polygamy leads to a reduction in the birth rate, but the long-term temporary absences of husbands appear to have no effect on the level of fertility. It seems unlikely that variations in the incidence ofpolygamy are sufficient to account entirely for the marked regional differences in fertility noted in the previous chapter. In view of the Negroids' basic tribal interest in producing children, it seems unlikely that birth control has anything to do with the observed variations in fertility. This aspect has been examined by Lorimer(2) and he states that there is clear evidence of effective birth control amongst the indigenous races of Africa only in the case of the Hottentots and Bushmen. The remaining possible explanations of the wide range of fertility rates in Africa, apart from reporting errors, are variations in diet and variations in the incidence of malnutrition, various tropical and venereal diseases, but no figures are yet available regarding this aspect of fertility.

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(1) See Read M. (1942) "Migrant Labour in Africa and its Effects on Tribal Life", International Labour Review, Vol. XLV, No. 6, p. 605. Schapera I. (1947) Migrant Labour and Tribal Life, Oxford University Press. Barnes J.A. (1951) "Marriage in a Changing Society", Rhodes-Livingstone Papers, No. 20.

(2) Lorimer F. Social and Cultural Conditions Affecting Fertility in Non-Industrial Societies, to be published shortly.

APPENDIX

Table A: Age Distribution of African Negroid Female Populations.

Country and Date	Percentage of total female population in the following age groups								
	0-14	15-19	20-24	25-29	30-34	35-39	40-44	45-49	50 & over
(A) Countries with detailed figures (1)									
Angola: 1940	37.3	7.8	8.5	10.1	8.3	7.9	6.4	4.0	9.7
Basutoland: 1946	33.8	10.9	8.2	8.5	7.0	5.3	5.4	5.2	15.7
Bechuanaland: 1946	36.0	10.9	9.8	8.3	7.3	6.5	4.9	4.2	12.1
Mozambique: 1940	39.9	6.7	7.9	12.4	7.5	9.1	3.7	3.8	9.0
Nigeria: Northern Provinces:1931	39.8	9.7	9.3	8.1	7.6	5.4	5.6	3.1	11.4
Lagos: 1950	34.4	10.5	12.7	13.4	8.4	6.4	3.9	3.0	7.3
Sierra Leone Colony:1931	29.9	9.0	9.5	11.7	7.0	6.2	4.9	5.8	13.0
Union of S.Africa: 1946	39.7	10.2	8.7	8.1	7.1	5.6	5.1	3.9	11.6
(B) Figures interpolated from details for Broad Age Groups (2)									
Belgian Congo: 1950	36.6	10.1	9.1	8.1	7.0	5.9	5.0	3.8	14.4
Gold Coast: 1948	40.4	10.8	9.6	8.3	7.0	5.9	4.4	3.3	10.3
Kenya: 1948	45.7	11.8	10.0	8.3	6.8	4.9	3.1	1.6	7.8
Nigeria: Northern Region:1952	39.7	10.8	9.6	8.4	7.1	5.9	4.7	3.7	10.1
Rhodesia: Southern: 1953	45.9	11.2	9.5	7.6	6.0	4.1	2.5	1.0	12.2
Northern: 1950	39.6	9.9	9.5	7.8	6.9	5.4	4.5	3.7	12.7
Swaziland: 1946	42.2	11.2	9.2	7.6	6.1	4.3	2.9	1.2	15.3
Tanganyika: 1948	39.9	11.0	9.9	8.8	7.6	6.5	5.3	4.2	6.8
Uganda: 1948	38.7	10.8	9.6	8.7	7.6	6.5	5.4	4.4	8.3
(C) Average for all Countries									
	38.8	10.2	9.4	9.1	7.2	6.0	4.6	3.6	11.1

(1) Censo Geral da Populacao 1940, Imprensa Nacional, Luanda, Angola (1941) Vol. III, p.3. Basutoland and Bechuanaland figures supplied by the High Commissioner for Basutoland, Bechuanaland and Swaziland. Censo da Populacao em 1940, Imprensa Nacional, Lourenco Marques, (1945), Vol. III, p. 8. Figures for Nigeria: Northern Provinces and Sierra Leone Colony based on information given by Kuczynski R.R. (1948), A Demographic Survey of the British Colonial Empire, Oxford University Press, Vol. I, pp. 175 and 609. Population Census of Lagos, 1950, Government Printer, Lagos (1951), p.31. Seventh Census of the Union of South Africa, Government Printer, Pretoria, (1950), Vol. II, p.283.

P.T.O.

(2) Northern Rhodesia figures interpolated by J. C. Mitchell, from various published and unpublished sources, and given in a cycostyled statement. Southern Rhodesia figures from p.201. Other figures interpolated by the method described on p.p.92-93 from the particulars given in the following publications: Demographic Congolaise, 1950, Service des A.I.M.O. du Gouvernement General, Leopoldville. Census of Population 1948, Government Printer, Accra, Gold Coast, (1950). Population Census of the Northern Region of Nigeria, 1952, Bulletin No. 1, p.1, The Government Statistician, Lagos, (1953). Swaziland Census, 1946, Swaziland Government, Mbabane, (1950), p.2 . East African Quarterly Economic and Statistical Bulletin, High Commission Printer, Nairobi, No. 19, (1953), p.3. Note: As explained on pp. 90-6, the figures for the 45-49 year age group are very rough and subject to a relatively large margin of error.

TABLE 8: Age Distribution of Females used in Analysis of Fertility[1]

Country	Date	Percentage of Total in the following Age Groups[2]								
		0-14	15-19	20-24	25-29	30-34	35-39	40-44	45-49	50 & over
Australia	1933	27.4	9.3	8.8	7.8	7.3	7.3	6.9	6.1	19.0
Belgium	1930	22.6	7.9	8.5	8.7	8.2	7.4	6.7	6.4	23.6
Bulgaria	1934	35.0	7.2	9.3	8.8	7.7	6.4	5.1	5.1	15.4
Canada	1941	28.1	9.9	9.2	8.5	7.3	6.5	5.9	5.4	19.2
Chile	1930	36.6	11.1	9.8	8.8	6.6	6.3	5.0	4.1	11.7
Czechoslovakia	1930	25.2	9.0	9.6	9.0	8.2	6.9	6.1	5.5	20.3
Denmark	1940	23.4	8.4	8.3	8.3	8.2	7.5	7.0	6.1	22.6
England & Wales	1931	22.6	8.3	8.6	8.3	7.8	7.3	6.9	6.6	23.6
Estonia	1934	21.6	6.3	8.4	8.3	8.1	7.4	6.7	6.5	26.6
Finland	1940	24.8	8.6	7.8	8.3	8.4	7.4	6.7	5.8	22.0
France	1936	23.6	5.2	6.9	7.7	7.7	7.5	6.8	6.5	27.9
Germany	1939	20.6	9.8	5.4	8.6	8.8	8.3	7.6	6.7	24.2
Hungary	1939	25.7	9.4	5.6	8.9	8.2	7.7	7.0	5.8	21.2
Italy	1936	29.6	7.0	9.0	8.4	7.3	6.7	6.0	5.6	20.4
Jamaica	1949	35.0	10.0	8.3	8.4	7.9	6.9	5.6	5.0	12.8
Japan	1935	36.6	9.5	8.8	7.4	6.5	5.7	4.7	4.4	16.2
Latvia	1939	22.9	5.4	8.2	8.5	8.3	7.6	6.6	6.2	26.3
Netherlands	1930	29.9	9.3	9.0	8.3	7.4	6.6	5.8	5.2	18.6
New Zealand	1936	25.2	8.8	9.0	8.3	7.3	6.9	6.5	6.4	21.4
Nicaragua	1940	42.1	10.7	8.7	7.6	6.2	6.0	4.9	3.6	10.2
Norway	1930	27.3	9.2	8.6	8.2	7.7	6.6	5.8	5.1	21.5
Peru	1940	40.6	9.3	8.5	8.1	6.2	6.2	4.5	4.0	12.5
Poland	1931	32.1	9.5	10.4	9.1	7.7	6.0	5.2	4.5	15.5
Portugal	1940	30.1	9.4	7.9	7.8	7.2	6.6	5.7	5.1	19.9
Scotland	1931	25.7	8.7	8.6	8.0	7.4	6.8	6.3	6.0	22.5
Sweden	1940	19.8	8.0	8.2	8.4	8.4	7.8	7.1	6.5	25.7
Switzerland	1941	21.1	7.6	7.4	7.7	8.4	8.1	7.6	6.7	25.4
Union of S.Africa[3]	1941	30.2	9.1	8.8	8.8	8.4	6.8	5.7	5.3	16.9
U.S.A. - whites	1940	24.2	9.3	8.9	8.5	7.9	7.3	6.7	6.3	21.0
non-whites	1940	29.8	10.3	9.8	9.3	7.9	7.9	6.3	5.2	13.7
Average		28.0	8.7	8.5	8.4	7.7	7.0	6.2	5.6	19.9

(1) The figures for Jamaica, Nicaragua and Peru were obtained from Table 4 of the 1951 Demographic Yearbook of the United Nations The other figures were obtained from Table 3 of the 1942/44 Statistical Yearbook of the League of Nations.

(2) The figures do not always add up to exactly 100.0 because unknown ages are excluded.

(3) Europeans only.

Table C: Relative Age Specific Fertility Rates used in Analysis of Fertility[1]

Country	Date	Relative Specific Fertility Rate in the following Age Groups (2)							Total Fertility Rate
		Under 20	20-24	25-29	30-34	35-39	40-44	45 & over	
Australia	1932-34	.012	.046	.056	.045	.028	.012	.001	2.157
Belgium	1939	.009	.052	.060	.043	.026	.009	.001	2.097
Bulgaria	1934-35	.015	.057	.055	.034	.023	.010	.003	3.501
Canada	1941	.011	.049	.057	.043	.028	.011	.001	2.828
Chile	1930-32	.014	.038	.045	.046	.033	.017	.007	4.668
Czechoslovakia	1930-31	.012	.054	.056	.041	.026	.010	.001	2.503
Denmark	1940	.012	.053	.060	.043	.023	.008	.001	2.216
England & Wales	1938	.008	.050	.061	.045	.026	.009	.001	1.841
Estonia	1931-34	.007	.043	.055	.047	.032	.014	.002	1.967
Finland	1940	.007	.043	.055	.044	.032	.017	.002	2.088
France	1936	.013	.059	.058	.039	.022	.008	.001	2.040
Germany	1936	.006	.048	.062	.047	.026	.009(3)	.002(3)	2.212
Hungary	1936	.018	.057	.054	.038	.023	.009	.001	2.420
Italy	1935-37	.006	.039	.055	.048	.035	.015	.002	2.925
Jamaica	1948	.026	.062	.046	.033	.024	.008	.001	3.642
Japan	1937	.004	.039	.058	.046	.036	.015	.002	4.396
Latvia	1939	.008	.047	.058	.046	.029	.011	.001	2.404
Netherlands	1930-31	.004	.031	.056	.052	.038	.017	.002	2.952
New Zealand	1936	.008	.045	.062	.047	.027	.010	.001	2.115
Nicaragua	1940	.009	.054	.054	.042	.034	.005	.002	4.099
Norway	1930-31	.004	.033	.052	.050	.038	.020	.003	2.142
Peru	1940	.014	.046	.049	.040	.030	.014	.007	3.636
Poland	1931-32	.007	.041	.054	.047	.033	.015	.003	3.525
Portugal	1940-41	.007	.040	.053	.045	.035	.017	.003	3.175
Scotland	1938	.009	.048	.058	.046	.029	.009	.001	2.202
Sweden	1940	.012	.048	.056	.044	.028	.011	.001	1.832
Switzerland	1941-42	.004	.037	.064	.054	.030	.010	.001	2.172
Union of S. Africa(4)	1941	.012	.053	.056	.041	.027	.010	.001	3.039
U.S.A. - whites	1940	.020	.059	.056	.038	.020	.006	.001	2.096
non-whites	1940	.045	.059	.041	.029	.018	.007	.001	2.325
Average		.012	.048	.054	.044	.028	.012	.002	

(1) The figures for Jamaica, Nicaragua and Peru were obtained from Table 8 of the 1951 Demographic Yearbook of the United Nations. The other figures are from Table 11 of the 1942/44 Statistical Yearbook of the League of Nations.

(2) Absolute specific fertility rates divided by Total Fertility Rate.

(3) In the original table only one rate is given for the age group 40 years and over. This has been split as shown on the basis of the average distribution of the other countries.

(4) Europeans only.

Table D: Age Distribution of Females Used in Analysis of Expectation of Life at Birth[1]

Country	Date	Percentage of Total in the following Age Groups:															
		Under 15	15-19	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85 & over
Belgium	1950	20.4	7.1	7.4	7.8	5.3	7.1	7.5	7.5	6.9	6.0	5.2	4.5	3.5	2.3	1.2	0.5
Br. Honduras	1946	37.5	10.7	8.9	7.7	7.0	6.5	5.2	4.6	3.5	2.8	2.2	1.4	1.0	0.6	0.3	0.2
Canada	1950	29.3	8.1	8.4	8.2	7.7	6.9	6.0	5.3	4.7	4.2	3.6	2.9	2.1	1.4	0.8	0.5
Denmark	1949	25.4	6.7	7.0	7.6	7.3	7.5	7.1	6.6	5.9	5.1	4.4	3.6	2.7	1.7	← 1.3 →	
England & Wales	1950	20.7	6.1	6.7	7.4	6.8	7.6	7.5	7.1	6.5	5.8	5.2	4.5	3.6	2.4	1.2	0.6
Finland	1949	26.8	7.5	7.8	7.8	7.1	7.6	7.2	6.2	5.4	4.5	4.0	3.2	2.4	1.5	0.6	0.5
France	1950	20.7	7.0	7.4	7.5	4.9	6.5	7.1	7.1	6.6	6.0	5.4	4.8	3.9	2.7	1.5	0.8
Hawaii	1950	33.1	8.9	10.1	11.4	8.2	6.4	4.7	4.7	4.2	← 4.9 →			← 3.4 →			
Iceland	1949	29.6	8.7	8.3	7.8	6.8	6.3	5.8	5.2	4.9	4.4	3.5	2.6	2.4	1.7	1.2	0.7
Jamaica	1949	35.0	10.0	8.3	8.4	7.9	6.9	5.6	5.0	3.4	2.9	2.1	1.9	← 2.5 →			
Japan	1950	34.1	10.0	9.2	7.9	6.7	6.3	5.4	4.7	3.9	3.2	2.8	2.3	1.8	1.0	← 0.6 →	
Netherlands	1950	28.6	7.8	7.8	7.9	6.9	6.9	6.6	6.0	5.3	4.5	3.8	3.1	2.4	1.5	0.8	0.3
New Zealand	1949	27.0	6.8	7.3	7.7	7.4	7.3	6.6	5.8	5.2	4.7	4.5	4.0	2.9	← 2.8 →		
N. Ireland	1950	26.8	7.9	8.3	8.1	7.4	6.7	6.3	5.6	4.8	4.4	4.2	3.6	2.9	1.8	0.8	0.4
Norway	1946	21.9	7.0	8.1	8.5	7.9	7.5	7.1	6.7	5.8	4.9	4.2	3.5	2.8	1.9	1.3	0.7
Scotland	1950	23.8	7.2	7.3	7.0	5.7	7.0	7.3	7.0	6.3	5.6	4.8	4.0	3.1	2.1	1.2	0.6
S. Rhodesia	1946	29.0	7.1	6.9	7.7	9.2	9.0	7.4	5.9	4.8	4.1	3.2	2.6	1.6	0.9	0.3	0.1
Sweden	1948	22.1	6.1	6.9	7.9	7.6	7.9	7.5	6.9	6.2	5.5	4.8	3.9	3.0	1.9	1.1	0.6
Switzerland	1949	22.3	6.8	7.2	7.5	6.7	7.6	7.7	7.2	6.4	5.5	4.7	4.0	3.2	1.9	0.9	0.4
Trinidad	1950	39.3	8.2	8.4	8.2	7.4	6.2	5.8	4.3	3.5	2.4	2.0	1.5	1.6	0.7	0.3	0.2
U.S.A.	1950	26.9	6.9	7.7	8.1	7.7	7.4	6.7	6.1	5.5	4.9	4.1	3.1	2.3	1.5	0.8	0.4

(1) Source: 1951 Demographic Yearbook of the United Nations: Table 4.

Table E: Probability of Surviving to Specified Ages (Females), Used in Analysis of Expectation of Life at Birth[1]

Country	Date of Life Table	Age in Years																		
		1	2	3	4	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75
Belgium	1891-1900	.858	.824	.808	.798	.790	.773	.762	.747	.725	.702	.677	.651	.622	.592	.553	.503	.437	.349	.241
Br. Honduras	1944-1948	.885	.853	.843	.837	.832	.812	.797	.773	.741	.706	.669	.633	.596	.556	.513	.466	.410	.337	.247
Canada	1930-1932	.931	.921	.916	.913	.910	.902	.895	.885	.870	.854	.836	.816	.794	.768	.733	.684	.617	.526	.407
Denmark	1901-1905	.896	.879	.872	.867	.864	.851	.839	.823	.805	.786	.764	.740	.714	.684	.648	.602	.538	.451	.337
England & Wales	1910-1912	.902	.874	.862	.855	.850	.836	.828	.817	.804	.790	.772	.750	.723	.689	.645	.587	.512	.417	.301
Finland	1901-1910	.887	.848	.828	.814	.803	.772	.751	.728	.705	.680	.656	.629	.602	.574	.539	.493	.431	.350	.248
France	1898-1903	.864	.836	.822	.812	.805	.786	.772	.752	.727	.701	.674	.646	.617	.581	.545	.494	.427	.341	.235
Hawaii	1919-1920	.903	.881	-	-	.848	.837	.812	.771	.723	.669	.619	.576	.539	.498	.455	.401	.325	.247	.163
Iceland	1901-1910	.895	.870	.857	.849	.843	.825	.807	.785	.760	.733	.710	.686	.661	.637	.599	.556	.491	.415	.301
Jamaica	1910-1912	.822	.770	-	-	.736	.714	.696	.672	.640	.606	.572	.535	.497	.460	.420	.371	.314	.254	.189
Japan	1899-1903	.859	.828	.807	.793	.783	.762	.746	.717	.682	.649	.616	.583	.551	.518	.479	.430	.367	.287	.197
Netherlands	1900-1909	.882	.852	.839	.832	.827	.813	.803	.789	.773	.755	.734	.711	.686	.657	.621	.573	.505	.412	.298
New Zealand	1901-1905	.931	.921	.916	.912	.909	.900	.892	.881	.864	.845	.825	.801	.775	.744	.704	.652	.582	.491	.372
N. Ireland	1925-1927	.927	.907	.898	.892	.888	.877	.867	.851	.830	.807	.781	.754	.723	.683	.633	.569	.488	.391	.285
Norway	1901-1902) 1910-1911)	.933	.917	.909	.904	.899	.883	.868	.845	.818	.791	.763	.735	.706	.677	.642	.600	.545	.471	.373
Scotland	1920-1922	.917	.892	.880	.874	.869	.857	.848	.835	.819	.800	.778	.754	.728	.696	.654	.598	.523	.429	.315
S. Rhodesia	1935-1937	.954	.941	.933	.929	.926	.918	.913	.903	.890	.872	.854	.836	.810	.775	.737	.690	.614	.511	.383
Sweden	1901-1910	.924	.904	.895	.888	.883	.865	.850	.831	.808	.784	.760	.735	.709	.680	.646	.604	.547	.469	.365
Switzerland	1910-1911	.896	.878	.871	.866	.862	.850	.839	.822	.802	.780	.758	.733	.705	.670	.626	.566	.486	.381	.256
Trinidad	1900-1903	.845	.796	-	-	.756	.728	.707	.677	.635	.590	.546	.505	.465	.418	.368	.313	.249	.176	.107
U.S.A.	1900-1902	.887	.859	.846	.838	.831	.814	.803	.786	.761	.734	.705	.674	.641	.604	.559	.502	.432	.347	.250

(1) Based on Table 28 of the 1951 Demographic Yearbook of the United Nations.

Table F: Female Infant Mortality Rates (Per 1,000 Female Births) by Age at Death, Used in Analysis of Expectation of Life at Birth. (1)

Country	Date	Under one year	Under six months
Belgium	1938	69.2	55.5
Br. Honduras	1945	139.1	108.1
Canada	1936	58.8	48.9
Denmark	1936	57.6	45.5
England & Wales	1936	50.4	40.7
Finland	1936	59.1	47.7
France	1936	58.4	42.5
Hawaii	1936	67.3	48.8
Iceland	1936	39.2	33.7
Jamaica (a)	1944	98.8	71.9
Japan	1936	109.1	83.4
Netherlands	1936	34.2	27.9
New Zealand	1936	28.9	25.1
N. Ireland	1936	67.5	54.5
Norway	1936	37.1	31.9
Scotland	1936	71.9	56.1
S. Rhodesia	-	(b)	(b)
Sweden	1936	37.5	30.9
Switzerland	1936	40.4	35.0
Trinidad	-	(c)	(c)
U.S.A.	1936	50.5	42 4

(1) Source: Table 21 of the 1951 Demographic Yearbook of the United Nations.

(a) Both sexes combined.

(b) Not required as complete life table was readily available.

(c) Assumed to be the average of the remaining countries.

Table 6: Expectation of Life of Females at Specified Ages, Used in Analysis of Expectation of Life at Birth.(1)

Country	Date of Life Table	Expectation of Life at the following ages								
		0	10	20	30	50	60	65	70	75
Belgium	1891-1900	48.84	52.78	44.44	36.96	21.87	14.78	11.63	8.87	6.73
Br. Honduras	1944-1948	48.97	49.95	42.18	35.69	22.55	15.94	12.77	9.97	7.65
Canada	1930-1932	62.10	58.72	49.76	41.38	24.79	17.15	13.72	10.63	7.98
Denmark	1901-1905	56.20	55.80	47.5	39.6	23.8	16.3	13.0	10.0	7.5
England & Wales	1910-1912	55.35	55.91	47.10	38.54	22.51	15.48	12.36	9.58	7.29
Finland	1901-1910	48.10	51.74	44.54	37.30	22.31	15.08	11.87	9.00	6.68
France	1898-1903	48.69	51.53	43.59	36.44	21.64	14.58	11.47	8.72	6.50
Hawaii	1919-1920	47.27	44.09	37.39	32.29	20.10	13.69	11.27	9.03	7.39
Iceland	1901-1910	53.1	54.0	46.5	39.4	23.8	16.6	13.4	10.5	8.5
Jamaica	1910-1912	41.41	47.48	40.10	33.90	21.42	15.31	12.59	9.98	7.57
Japan	1899-1903	44.85	48.34	41.06	34.84	21.11	14.32	11.35	8.77	6.61
Netherlands	1900-1909	53.4	55.4	46.9	38.8	22.9	15.5	12.3	9.4	7.0
New Zealand	1901-1905	60.55	57.13	48.23	40.06	24.0	16.64	13.32	10.31	7.78
N. Ireland	1925-1927	56.11	53.73	45.22	37.42	22.18	15.55	12.69	10.20	8.08
Norway	1901-1902) 1910-1911)	57.70	55.08	47.34	40.24	25.30	17.85	14.38	11.24	8.49
Scotland	1920-1922	56.35	55.53	46.82	38.63	22.79	15.64	12.48	9.65	7.23
S. Rhodesia	1935-1937	62.57	58.05	48.88	40.41	24.04	16.35	13.03	10.15	7.68
Sweden	1901-1910	56.98	55.58	47.66	40.20	24.74	17.19	13.69	10.53	7.81
Switzerland	1910-1911	53.89	53.17	44.74	36.88	21.17	14.01	10.90	8.18	5.92
Trinidad	1900-1903	38.75	42.60	35.41	29.88	17.99	12.31	9.83	7.84	6.32
U.S.A.	1900-1902	50.70	51.94	43.60	36.30	21.84	15.21	12.22	9.59	7.34

(1) Source: Table 29 of the 1951 Demographic Yearbook of the United Nations.

Table H: Probability of Surviving to Specified Ages (Females) in Respect of Life Tables with an Expectation of Life at Birth of Under 40 years.(1)

Country	Date of Life Table	Expectation of Life at Birth (Years)	Probability of Surviving to the following ages																		
			1	2	3	4	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75
British Guiana	1910-1912	32.4	.793	-	-	-	.695	.665	.655	.611	.560	.503	.459	.411	.363	.314	.261	.207	.154	.105	.062
Mauritius	1942-1946	33.8	.828	.773	.749	.736	.728	.706	.688	.645	.582	.522	.469	.422	.376	.330	.280	.225	.164	.105	.058
Guatamala	1939-1941	37.1	.854	.766	.716	.689	.675	.647	.633	.616	.591	.562	.531	.498	.462	.420	.373	.317	.255	.188	.121
Mexico	1930	34.1	.803	.716	.671	.646	.631	.597	.581	.561	.535	.507	.477	.447	.416	.383	.344	.300	.243	.182	.113
Trinidad	1900-1903	38.8	.845	.796	-	-	.756	.728	.707	.677	.635	.590	.546	.505	.465	.418	.368	.313	.249	.176	.107
Brazil(2)	1920	37.4	.807	.749	.723	.710	.702	.681	.668	.646	.610	.573	.534	.494	.451	.405	.354	.300	.241	.181	.122
Chile	1930	37.7	.766	.691	.670	.662	.657	.641	.628	.604	.575	.546	.517	.488	.457	.426	.391	.347	.293	.234	.165
India	1891-1901	24.0	.741	.677	.636	.608	.586	.527	.489	.452	.412	.371	.330	.289	.249	.209	.170	.133	.096	.061	.031
U.S.S.R.	1896-1897	33.4	.742	.673	.635	.612	.595	.558	.542	.526	.507	.486	.464	.440	.414	.386	.351	.307	.252	.187	.125

(1) Source: 1951 Demographic Yearbook, United Nations, pp. 512-39

(2) Both sexes

Table I: Female Infant Mortality Rates (per 1,000 female births), by age at Death in Respect of Countries with an Expectation of Life at Birth of Under 40 years.[1]

Country	Date	Under one year	Under six months
British Guiana		(2)	(2)
Mauritius	1936	129.8	108.0
Guatamala	1946	106.2	75.1
Mexico	1936	123.1	83.0
Trinidad	1942	108.5	72.4
Brazil		(2)	(2)
Chile	1936	245.5	194.0
India	1936	161.0	126.2
U.S.S.R.		(2)	(2)

(1) Source: 1951 Demographic Yearbook, United Nations, Table 21.

(2) Assumed to be the same as the average of the other countries.

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