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S. Bah

Abstract

The paper gives a critical review of South African life tables published since the 1920s. The life tables were constructed on the assumption that vital registration was complete among whites, coloureds and Asians. Over time, robust measures of the life tables such as under-five mortality rate and life expectancy at birth have to show internal and external consistency. In addition, derived measures such as entropy, *E*, which summarises the degree of convexity of the life table survivorship function, *l(x)*, and Anson's *U* also have to display such consistency. Against these criteria, the paper sets out to assess the validity of South African life tables published since the 1920s.

Introduction:

Life tables published for any census year are invariably judged against life tables of previous census years. In keeping along with this tradition, life table reports often include a historical table in which life expectancies of previous census years are compared with current life expectancies. As long as the life expectancies continue to rise, questions are not asked and the current life tables are accepted and quoted world-wide. Questions start getting asked only when life expectancies from current life tables are lower than those obtained from previous census years. In such a situation, it is often reasoned that something was either wrong with the current life tables or with the life tables of previous census years. In some countries though, there have been evidence of genuine reductions in life expectation resulting from rise in mortality. One such example was the case of Mauritius in the 1970s (Bah, 1992). In the case of other parts of sub-saharan Africa, there have been claims of reduction in life expectancies in the 1980s. For example, Hill (1987) groups several African countries such as Angola, Niger Nigeria, Mozambique, Ethiopia and Rwanda as belonging to those which experienced 'static or rising' mortality. Such experience of static or rising mortality is often a result of socio-political instability and interruptions in socio-economic development. On the other hand, claims for decline in life expectancies can also be disputed on the basis of questionable quality of past estimates. If analytical techniques were poor in the past and life expectancies had been inflated, a misleading picture may emerge. Current life tables, if correctly estimated, may appear to reflect slow-down of mortality decline. Arguments along similar lines have been presented by Ayeni (1985) in discussing levels and trends in infant and child mortality in Africa.

Against this background the paper looks at South African life tables published since the 1920s. The life tables were published separately for whites, coloureds and Asians[1]. The paper uses internal and external consistency checks to validate those life tables.

Methods and materials:

One of the data source used in the paper are published complete life tables for South Africa dating back to 1920. Since the life tables were published in terms of population group and gender, the analysis of South African life tables is also structured along those lines. The following methods were used:

1. Graphical assessment of survivorship curves

2. Computation of under-five mortality rate, q(5), defined as:

$$q(5)= 1-l(5),$$

where l(5) is the life table survivorship value at age 5 given that the radix l(0)=1

3. Computation of Entropy parameter, *H*, defined as defined as the weighted average of the logarithm of the life table survivorship function (*l(x)*):

$$H = \frac{-\int_0^{\omega} l(x)[\ln l(x)]dx}{\int_0^{\omega} l(x)dx}$$

Entropy refers to the information content or randomness of a distribution. It is used differently in different disciplines. Theil (1972) applied it to general probability density functions while Demetius (1976) applied it in the context of population biology. In Demography, the concept was first applied by Keyfitz (1977).

The usefulness of *H* lies in the fact that it gives the percentage change in life expectancy produced by a reduction of one per cent in the force of mortality at all ages. Keyfitz (1977) had shown that if mortality at all ages changes by 100δ the effect of this change on life expectancy will be as follows:

$$\Delta e(0)/e(0) \approx -H\delta$$

[1] The terms 'white', 'coloured' and 'Asian' are aparthied classifiers. As the paper takes a historical perspective and the life tables were published under these population groupings, the terms have been retianed.

After Keyfitz introduced *H*, it has been extended by several researchers. Goldman and Lord (1986) as well as Vaupel (1986) derived an alternative expression for *H*. Goldman and Lord (1986) proved that *H* is not bounded by 1.0 as had been previously assumed by some researchers. Goldman and Lord (1987) re-expressed *H* as follows:

$$H = \frac{\int_0^{\omega} d(x)e(x)dx}{e(0)}$$

Written this way, *H* can be viewed as the average years of future lifetime that are lost by observed deaths. Alternatively, the numerator of *H* can be viewed as the weighted average of life expectancies at age *x* (since $\int_0^w d(x)dx = 1$)

As life expectancy increases, the survivorship function assumes a more rectangular form and the values of *H* decrease. Thus, entropy *H* is a measure of the degree of rectangularity of the *l(x)* curve. Empirically derived correlation between e(0) and *H* have been found to be quite high (Keyfitz 1977). However, because *H* declines as e(0) increases, proportional declines in mortality produce smaller proportional increases in longevity at higher values of e(0) (Schoen, 1988).

For this paper, *H* was calculated using a numerical integration method due to Weddle.

4. Calculation of Anson's *U*, defined as the ratio of the survivorship in middle-adulthood (35-59) to the square of the survivorship in young adulthood (15-35):

$$U = \frac{{}_{25}p_{35}}{{}_{20}p_{15}{}^2} = \frac{l(15)^2 * l(60)}{l(35)^3}$$

This measure of rectangularity was recently proposed by Anson (1991).The measure has had limited testing unlike *H* which has been applied to life tables of different countries and has even been extended to handle analysis of causes of death (Nanjo, 1980). According to Anson, *U* differs from *H* in that it is independent of the level of mortality. Thus, the parameter *U* would not exhibit an ideal typical trend. However, ultimately, as mortality reaches its minimum, *U* must approach unity (Anson, personal communication). I venture to add that, if *U* is to exhibit any trend, it would be a very gentle sloping line with positive slope.

For the purpose of comparison, these measures had to be calculated for another country whose life tables were of high quality. Canadian life tables were chosen for this task. However, since I only had available with me, abridged life tables, the eight parameter Heligman-Pollard model was used to interpolate the abridged life tables to obtain complete life tables (Heligman and Pollard, 1980).

Results:

Figures 1 and 2 show the trend over time in the life table survivorship function *l(x)* against age, for white males and females respectively. Figures 3 and 4 show similar curves for coloured males and females respectively and Figure 5 and 6 show the similar curves for Asian males and females respectively. For each Figure, the trends show some peculiarity. For white males, the peculiarity occurs over the period 1946-1970. Survivorship up to age 40 is very high from 1946 onwards. The Also, the *l(x)* values for 1946, 1951 and 1970 are very close to each other with mortality crossover occurring around age 55. After the crossover, mortality in 1970 became heavier than mortality in either 1941 or 1951. For white females, no crossovers occur in the *l(x)* curves but survivorship up to around age 40 is exceedingly high from 1970 onwards. For coloured males, one peculiar feature is the convergence of the *l(x)* for 1936, 1951 and 1970 in the old ages. Another peculiarity is the crossover of the 1936 and 1946 *l(x)* curves around age 55. For coloured females, there is convergence of the *l(x)* curves for 1936 and 1946. Also an excess gain in survivorship was experienced during the period 1951-1970, especially over the age range 30-55. For Asian males, the *l(x)* curves are very peculiar. The 1946 *l(x)* curve has an uneven distribution, there is convergence between the 1951 and the 1970 *l(x)* curves, especially in the oldest ages. The survivorship values for 1980 and 1985 are very high and very close for ages less than 40. For Asian females, again, The survivorship values for 1980 and 1985 are very high and very close for ages less than 40 and they diverge appreciably age 40. 1946 *l(x)* curve has an uneven distribution, and there is convergence between the 1946 and the 1951 *l(x)* curves, especially in the oldest ages.

Tables 1 through 6 show the results of under-five mortality, q(5), entropy values and Anson's *U* for South Africa and, for comparative purposes, for Canada as well. From these results, Figures 7, 8 and 9 were drawn.

Figure 7 shows the trend in under-five mortality. Under-five mortality is a good indicator of improvements in health and socio-economic development, yet it is a more robust measure than either infant mortality rate or child mortality rate. The Figure shows a pairing of the rates for males and females of each population group with males having higher values than females. The under-five mortality was highest for coloureds and least for whites. The differentials in under-five mortality between whites and coloureds remained fairly constant between 1936 and 1951. The differentials between the two population groups started narrowing after 1951 and accelerated between 1970 and 1980. The differential between whites and Asians was narrowing down since 1946. Between 1951 and 1970 the differential between the two population groups narrowed at a rapid pace and by 1985, there was close convergence between the under-five mortality of both population groups.

Figure 8 shows entropy values for the different population gender groups. Again there is a pairing of the rates for males and females of each population group with males having higher values than females with the exception of Asians in 1946. The decline in entropy values is smooth for white females and coloured males followed by white males and Asian males. One peculiarity in the Figure is the Asian male-Asian female crossover in 1951. Another peculiarity in the Figure is the Asian female-white male crossover in 1970.

Figure 9 shows values for Anson's *U*. If any thing, Anson's *U* is expected to show a very gentle slope, asymptotically approaching unity. White males and females show high but normal trend in Anson's *U*. However, there are several peculiarities in the trend in Anson's *U* for other population-gender groups. Firstly, the values of *U* among coloured females are very high, approaching unity as early as 1936. Secondly, there are very wide differences between values of Anson's *U* for coloured males and coloured females. Thirdly, there is a marked drop in values of Anson's *U* between 1951 and 1970 and as a result, the trend of the values for coloured females cuts across three other trends. Fourthly, there is convergence in values of Anson's *U* for coloured males and Asian males. Lastly, there is divergence in values of Anson's *U* between Asian males and Asian females.

Before discussing these results, one needs to examine sets of yardsticks against which to compare. For this purpose, similar sets of figures have been constructed for national Canadian life tables (without breakdown into population groups). Figures 10 and 11 show the smooth progression in the l(x) curves over time. The rectangularity is increasing in a smooth manner. The trend in under-five mortality in Figure 11 and the trend in entropy values in Figure 12 show smooth decline with time. Lastly, the trend in Anson's U in Figure 14 show a very gradual increase tending towards unity.

Discussion:

Using the Figures from the Canadian life tables as references, ideally, one would expect that *l(x)* curves to be smooth and the levels of the curves to increase with time. One would also expect that the *l(x)* for a later census year should be higher than an earlier census year. One would not expect to see convergence or crossover for *l(x)* curve for the same population-gender group. Correspondingly, the *q(5)* values would show smooth decline over time and slow convergence between male and female values. One would also expect the entropy values to decline slowly with time and the Anson's *U* values to increase slowly with time.

Upon judging the Figures obtained from South African life tables, the closest set of Figures that approach the Canadian reference set are those for white males and females. The *l(x)* curves show relatively smooth progression (more for females than males). For the other sets of Figures for coloureds and Asians, there is marked deviation from the Canadian reference set. The convergence of *l(x)* values at old ages for coloured males suggests a lack of improvement in mortality in older ages. Gains in survivorship among children, youths and adults is not reflected in similar gains among the elderly. Alternatively, this could mean that old age mortality was overestimated in the more recent life tables compared to the earlier ones or that old age mortality was underestimated in the earlier life tables compared to the latter ones. For coloured females, the excess gain in survivorship among adults suggest serious underestimation of adult mortality. The trends in under-five mortality look realistic. The under-five mortality is higher for males than females for all the population groups. The decline in *q(5)* is fairly uniform for whites and coloureds. For Asians, the decline is rather rapid. One is not sure to what extent this rapid decline is real.

The trends in *q(5)* show smooth decline over time for both males and females. However for the entropy values, the trends for Asian females and coloured females show marked deviation from the Canadian reference set. Values in Anson's *U* exhibit a near stationary trend among whites (more so for females than males). For coloureds, the trend in Anson's *U* show a peculiar trend. For Asians, there is divergence in the trends of Anson's *U* values for males and females rather than pairing up.

It is evident that South African life tables are faced with several problems. The fact that Anson's *U* have been close to unity even way back in the 1920's suggest that mortality have been grossly under-estimated in the past. The sharp drop in both *U* and entropy values between 1950 and 1970 for coloureds suggest a forced correction in the trends life table values. In an unpublished report on the history of vital statistics in South Africa, Bah and Kleinschmidt (1997) identified five phases in the development of vital statistics in South Africa, namely: pre-1910, 1910-1962, 1963-1975, 1976-1990 and post-1991 phases. Of interest in this paper are the second, third and fourth phases, from 1910 to 1990. In that paper, it was reported that uniformity in birth and death registration throughout the union of South Africa was only achieved during the second phase, after the Act 17 of 1923. As such, the life table of 1921 could not have been representative of the whole union of South Africa. In the USA as well, vital registration data did not voer the entire United States until the Death Registration Area (DRA) was complete in 1933 (Haines and Preston, 1997). As such, mortality could have been grossly under-estimated then, as shown by the high *U* values, close to unity. During the third phase, a new act was passed concerning births and deaths registration, namely Act 81 of 1963. This Act required a death in an urban area should be registered within 48 hours while a death in rural areas should be registered within 14 days. This in itself is an implicit admission of the urban-rural differential in completeness in death registration.

Another interesting feature found in South African life tables is the phenomenon of mortality convergence and crossover. A recent review of the literature pertaining to this phenomenon was provided by Nam (1995). He generalized studies of mortality crossovers under nine points. In one of the points he observed that while mortality crossover could arise out of age misreporting in older ages, it could still arise in the absence of age misreporting. He observed further that mortality convergence and crossover was dynamic, that convergence and crossover would occur when two populations had dissimilar socio-economic characteristics. When, however, those two populations became more alike, convergence and crossover would decline and eventually disappear.

With the political policies of the past, it is hard to accept that the socio-economic characteristics of the different South African population groups were becoming more alike prior to the 1990s. This makes it highly questionable to accept the validity of the crossovers in the South African context.

Conclusion:

Even though the life table published in the 1920s and 1930s were meticulous and excellent pieces of work, they might have underestimated mortality by assuming completeness in vital registration. In those decades, techniques had not yet been developed to take account of incompleteness in death registration. In the decades that followed, authors of life tables used the earlier published life tables as benchmarks and hence the underestimation of mortality was handed down the generations. The life tables among whites showed the most plausible pattern in spite of their under-estimation of mortality. The life tables among coloureds showed the most irregular pattern.

Unless the historical set of life tables are reworked, they should not be used as benchmarks for judging contemporary life tables. Similarly, South African population projections based on life tables which underestimate mortality would have an upward bias. Such projections should not be used to judge the completeness of the 1996 population census of South Africa.

Table 1: Under five mortality (q5) values by population group and gender, RSA, 1921 - 1985

	white male	white female	coloured male	coloured female	Asian male	Asian female
1921	0.12363	0.11001				
1936	0.09235	0.07790	0.27790	0.26199		
1946	0.05324	0.04372	0.22976	0.21679	0.12893	0.12375
1951	0.04767	0.03786	0.22013	0.20283	0.11073	0.09882
1970	0.02955	0.02269	0.17706	0.16046	0.05338	0.04543
1980	0.02042	0.01587	0.09447	0.08343	0.03233	0.02466
1985	0.01460	0.01042	0.06799	0.06043	0.02217	0.01864

Table 2: Entropy values by population group and gender, RSA, 1921 - 1985

	white male	white female	coloured male	coloured female	Asian male	Asian female
1921	0.3220	0.2812				
1936	0.2658	0.2238	0.6043	0.5988		
1946	0.1972	0.1588	0.5462	0.5264	0.3656	0.3802
1951	0.1875	0.1388	0.4967	0.4691	0.2994	0.3008
1970	0.1743	0.1120	0.4083	0.3309	0.2232	0.1816
1980	0.1559	0.0963	0.3076	0.2302	0.1934	0.1360
1985	0.1382	0.0833	0.2634	0.1954	0.1762	0.1214

Table3: Anson's *U* by population group and gender, RSA, 1921 - 1985

	white male	white female	coloured male	coloured female	Asian male	Asian female
1921	0.85983	0.92830				
1936	0.84732	0.89935	0.86692	0.99110		
1946	0.83806	0.89237	0.81380	0.96989	0.79303	0.82505
1951	0.84515	0.90127	0.81556	0.95171	0.76788	0.82266
1970	0.83220	0.89957	0.74503	0.82312	0.71880	0.80154
1980	0.86192	0.91502	0.75590	0.83145	0.74199	0.84897
1985	0.88425	0.92365	0.78767	0.83820	0.78784	0.87254

Table 4: Under-five mortality, q(5), Canada, 1951 - 1981

	Canadian Males	Canadian females
1951	0.04998	0.04018
1956	0.03973	0.03201
1961	0.03431	0.02709
1966	0.02919	0.02322
1971	0.02330	0.01815
1976	0.01729	0.01467
1981	0.01308	0.01010

Table 5 Entropy values for Canada, 1951-1981

	Canadian Males	Canadian females
1951	0.2193	0.1808
1956	0.1992	0.1608
1961	0.1910	0.1503
1966	0.1869	0.1438
1971	0.1811	0.1360
1976	0.1728	0.1227
1981	0.1591	0.1153

Table 6: Anson's *U* for Canada, 1951 - 1981

	Canadian Males	Canadian females
1951	0.87956	0.91715
1956	0.89090	0.92226
1961	0.89126	0.92617
1966	0.89366	0.92900
1971	0.89592	0.93274
1976	0.90162	0.94090
1981	0.91594	0.94522

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Disclaimer

The view expressed in this paper are mine, as a professional demographer, and do not necessarily reflect the views of the CSS.

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Fig 1: Life table l(x) values for white male, RSA, 1921-1985

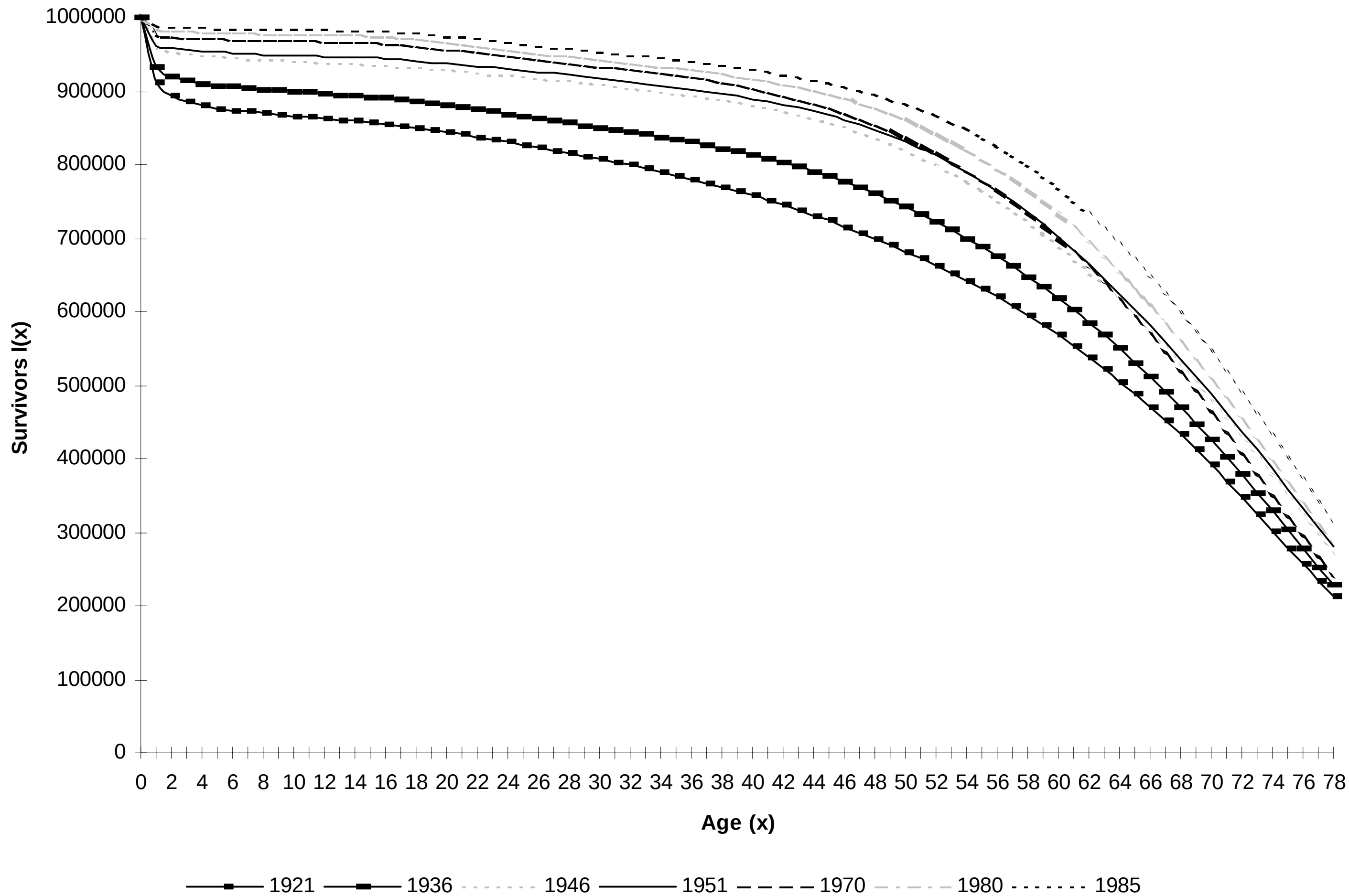

Fig 2: Life tables l(x) values for white females, RSA, 1921-1985

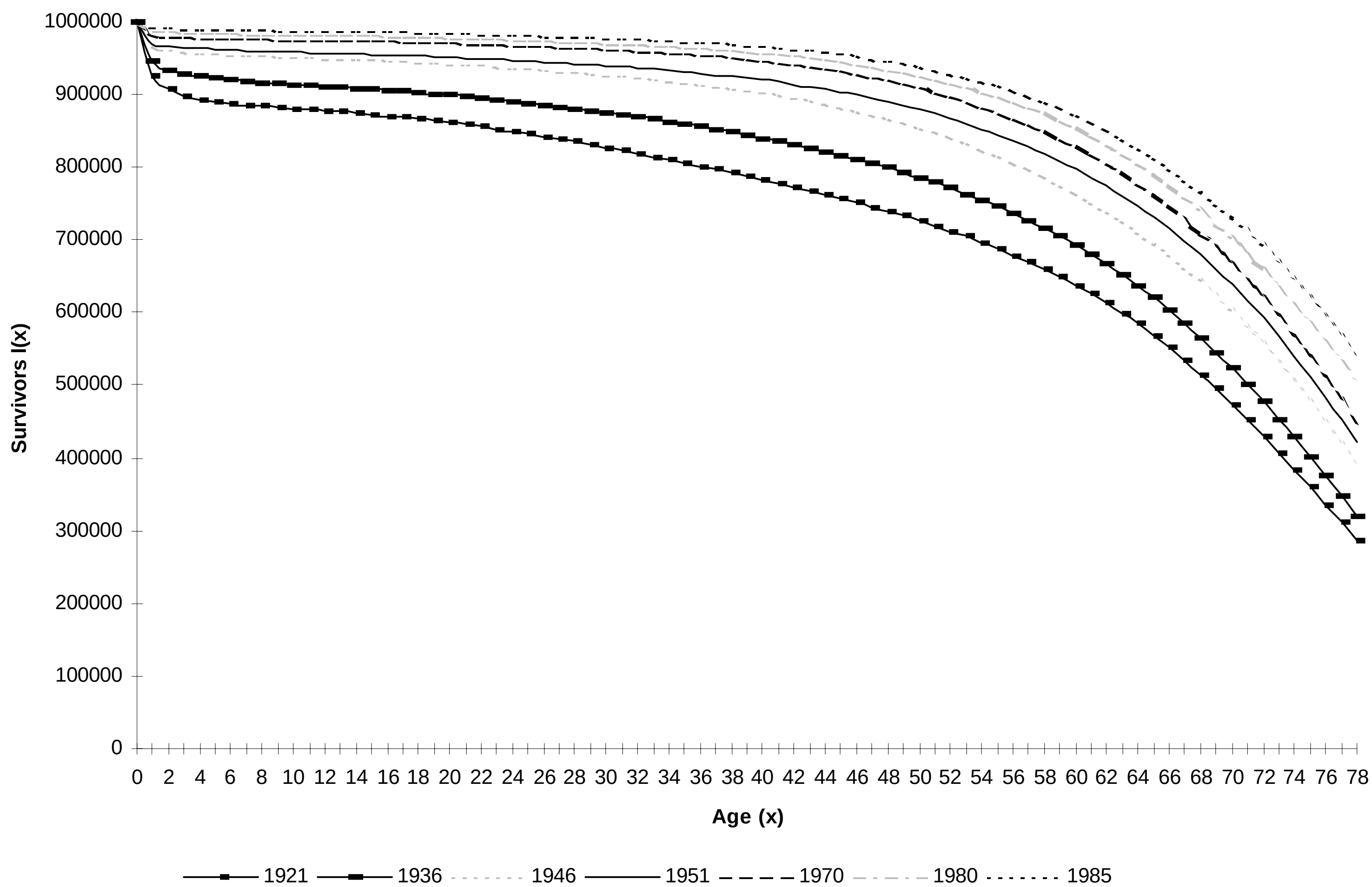

Fig 3: Life table l(x) values for coloured males, RSA, 1936-1985

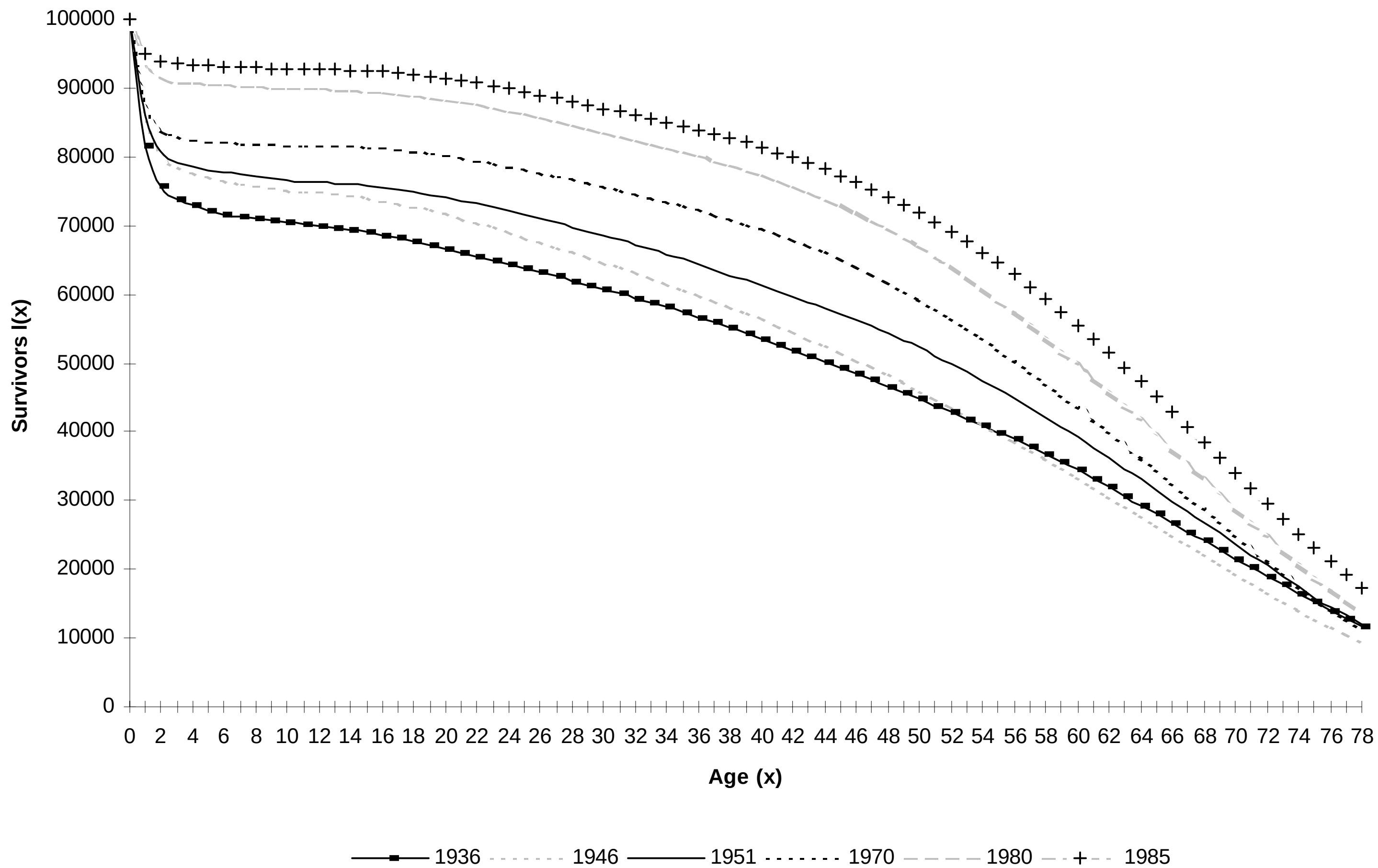

Fig 4: Life table l(x) values for coloured females, RSA, 1936-1985

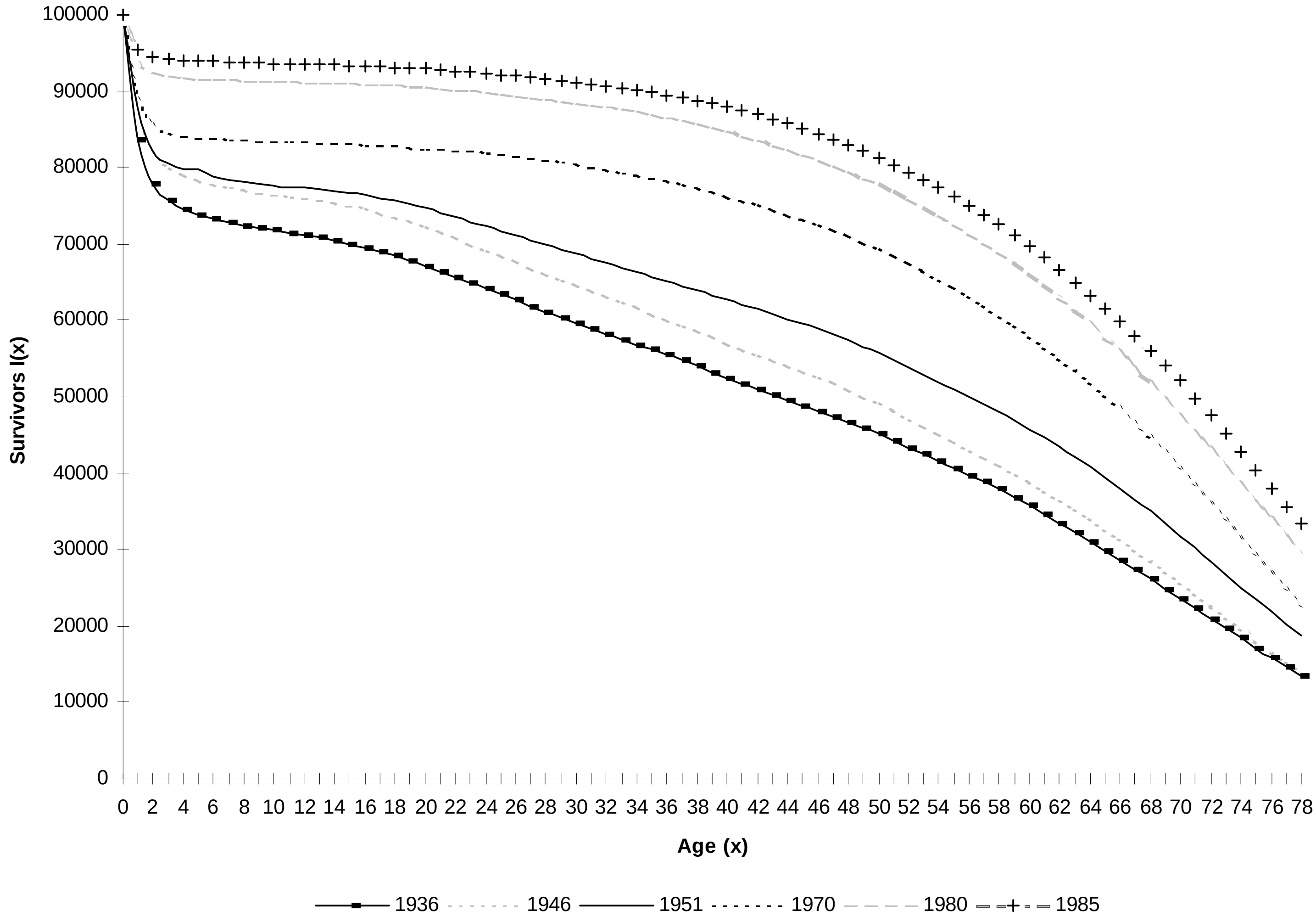

Fig 5: Life tables l(x) values for Asian males, RSA, 1946-1985

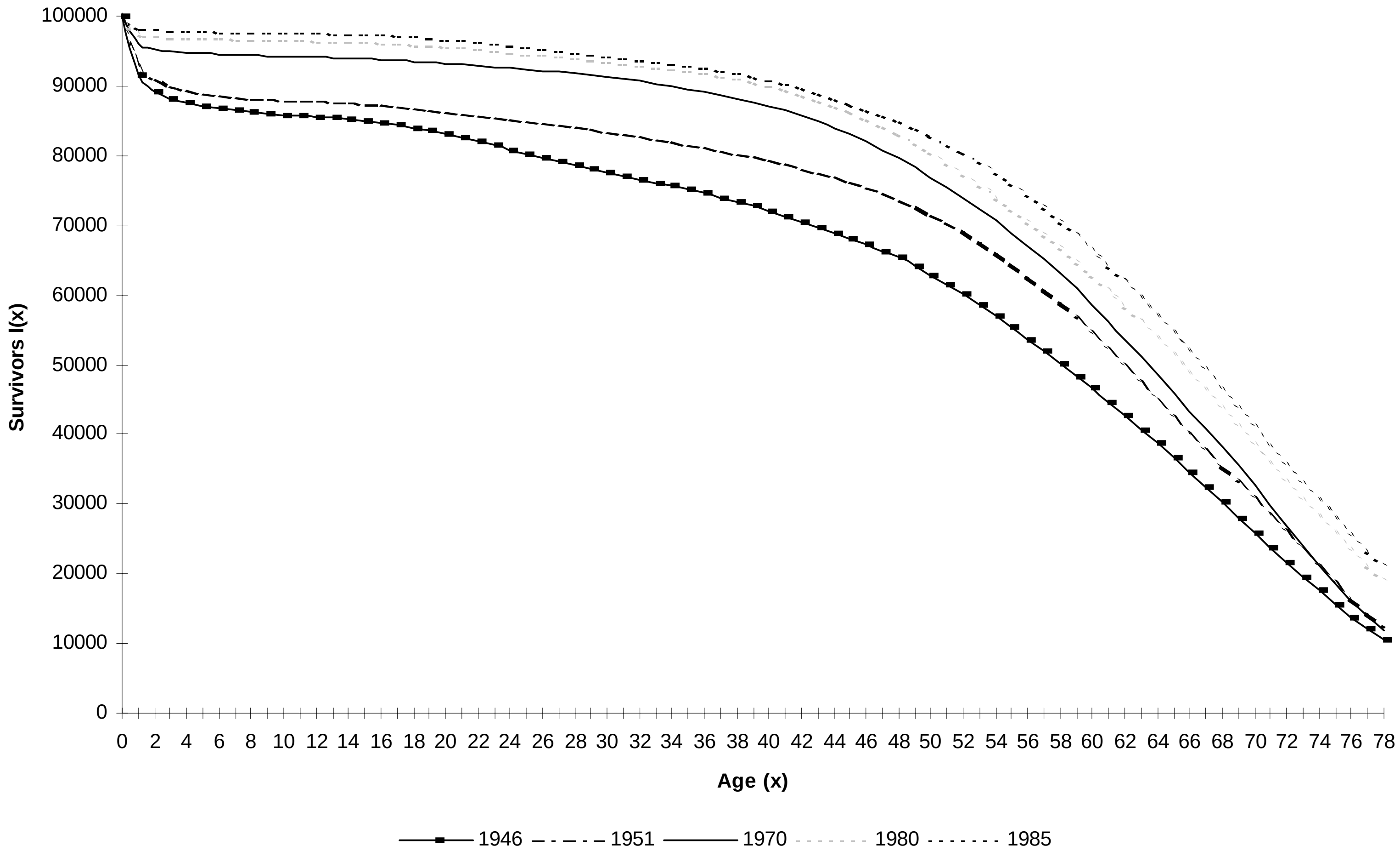

Fig 6: Life tables l(x) values for Asian females, RSA, 1946-1985

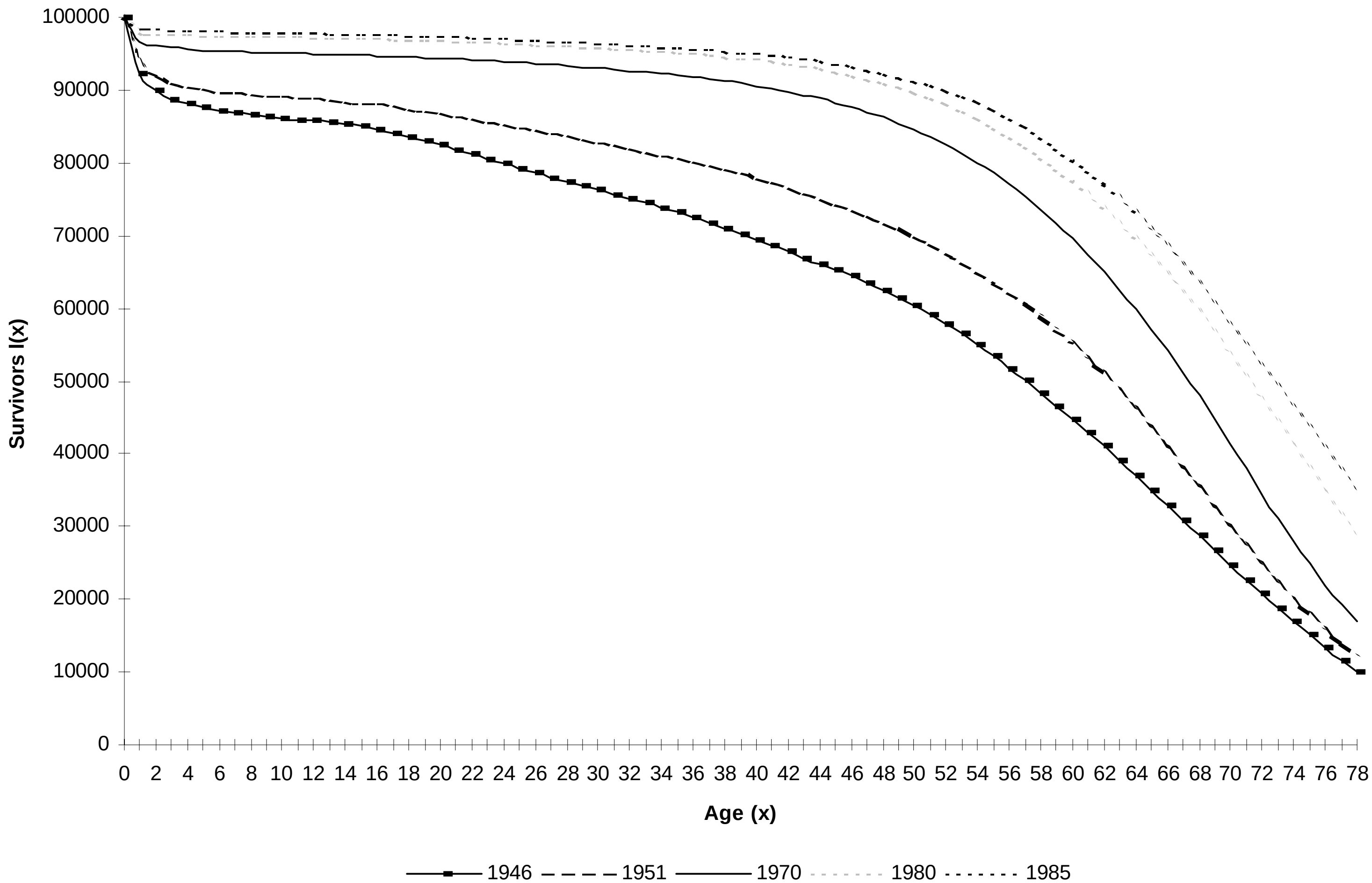

Fig 7: Trends in under-five mortality, q(5), RSA, 1921-1985

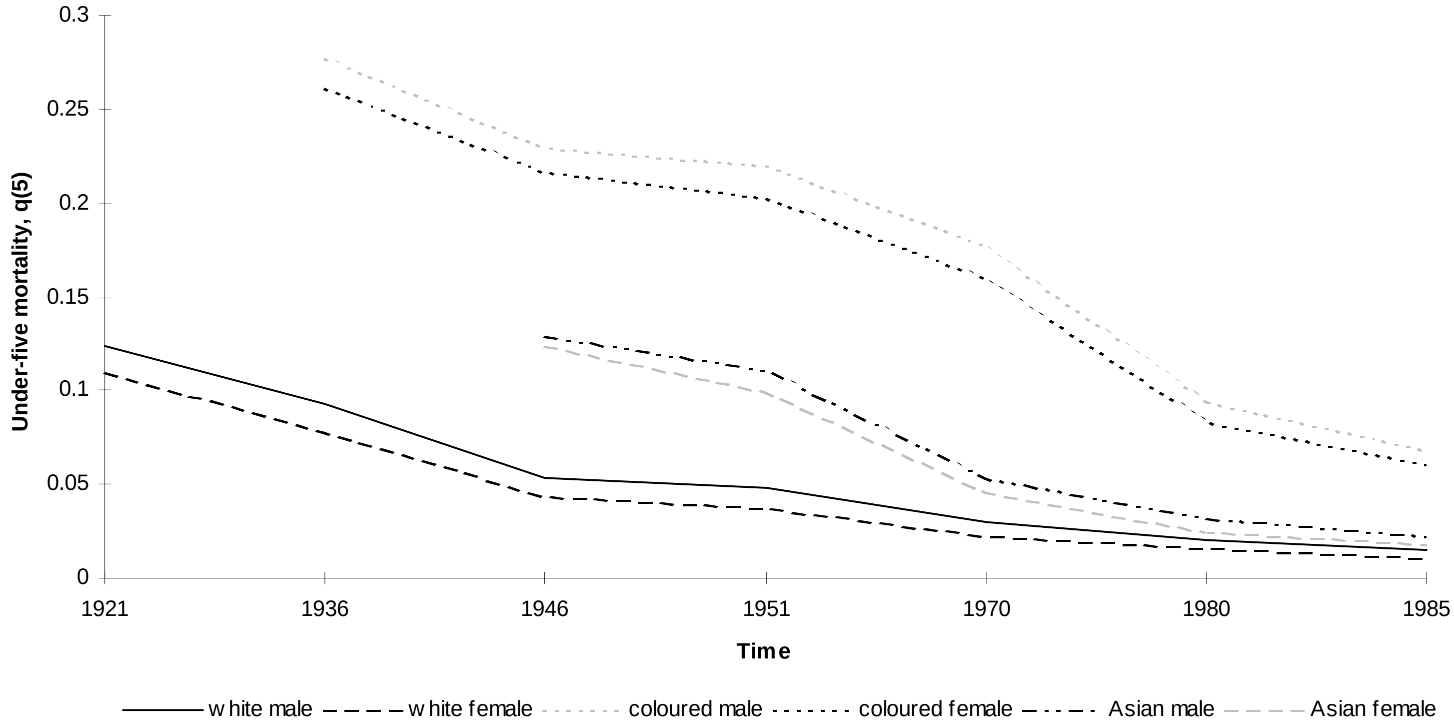

Fig 8: Trends in entropy values, RSA, 1921-1985

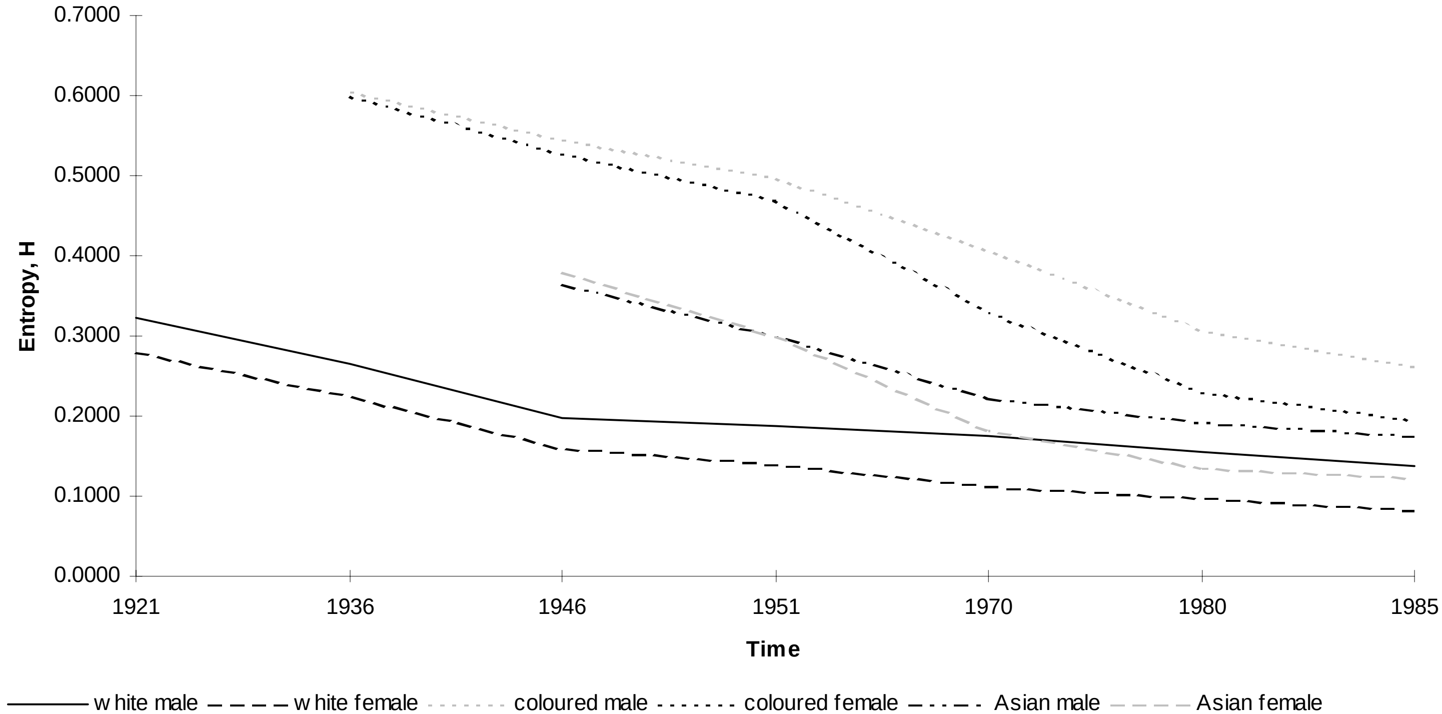

Fig 9: Trends in Anson's *U*, 1921-1985

Fig 10: Life table l(x) values, Canadian males, 1951-1981

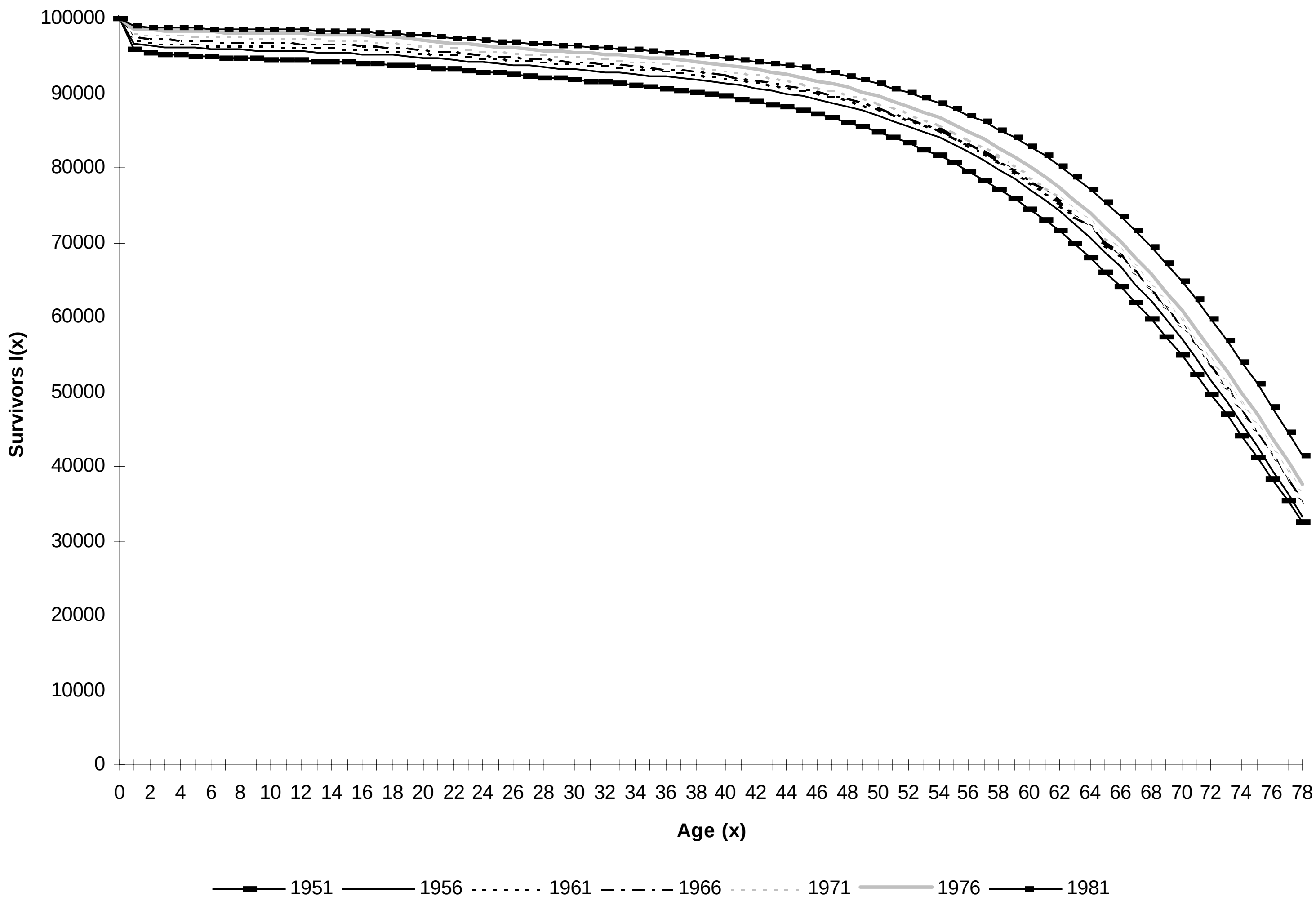

Fig 11: Life table l(x), Canadian females, 1951-1981

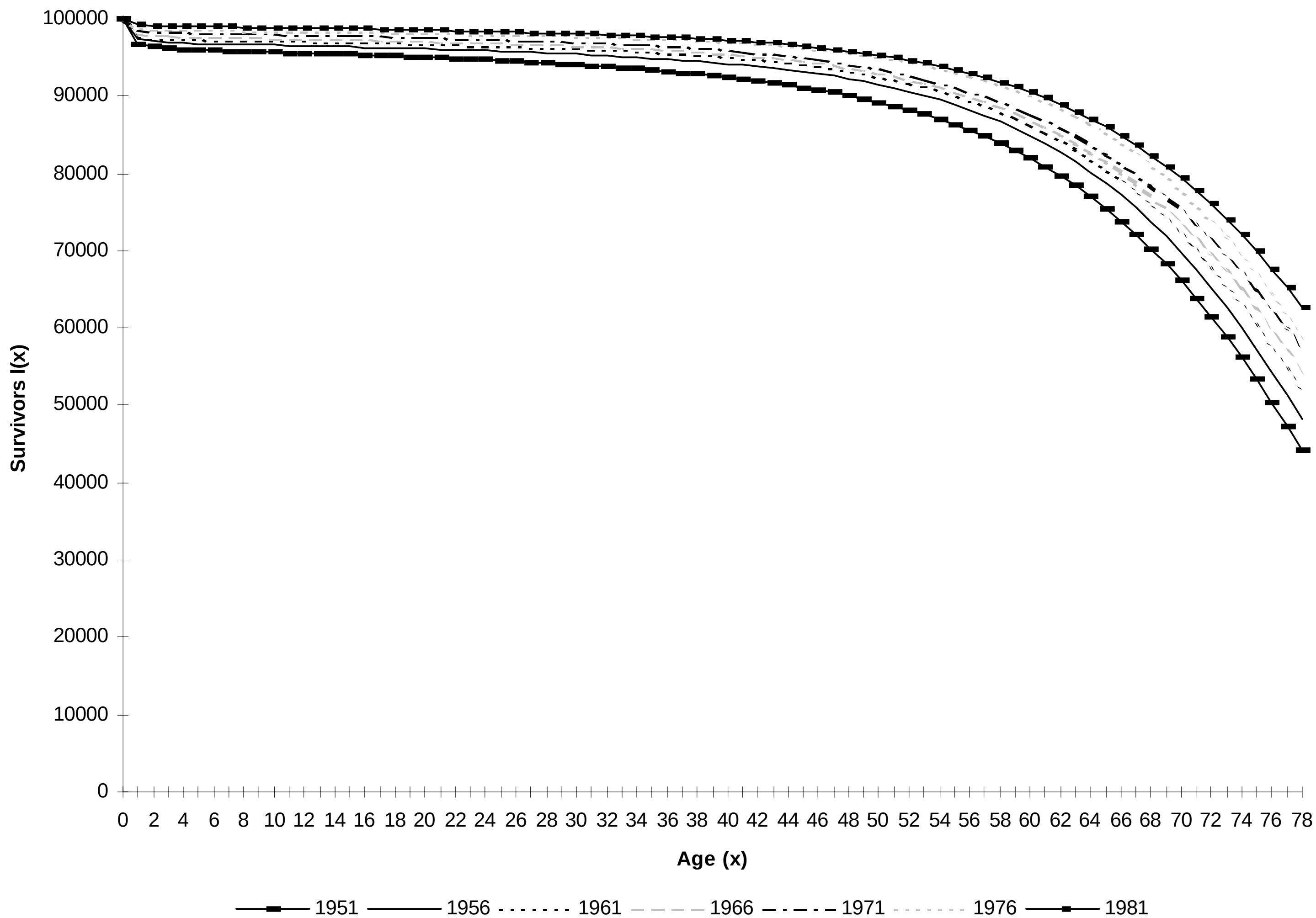

Fig 12: Trends in under-five mortality q(5), Canada, 1951-1981

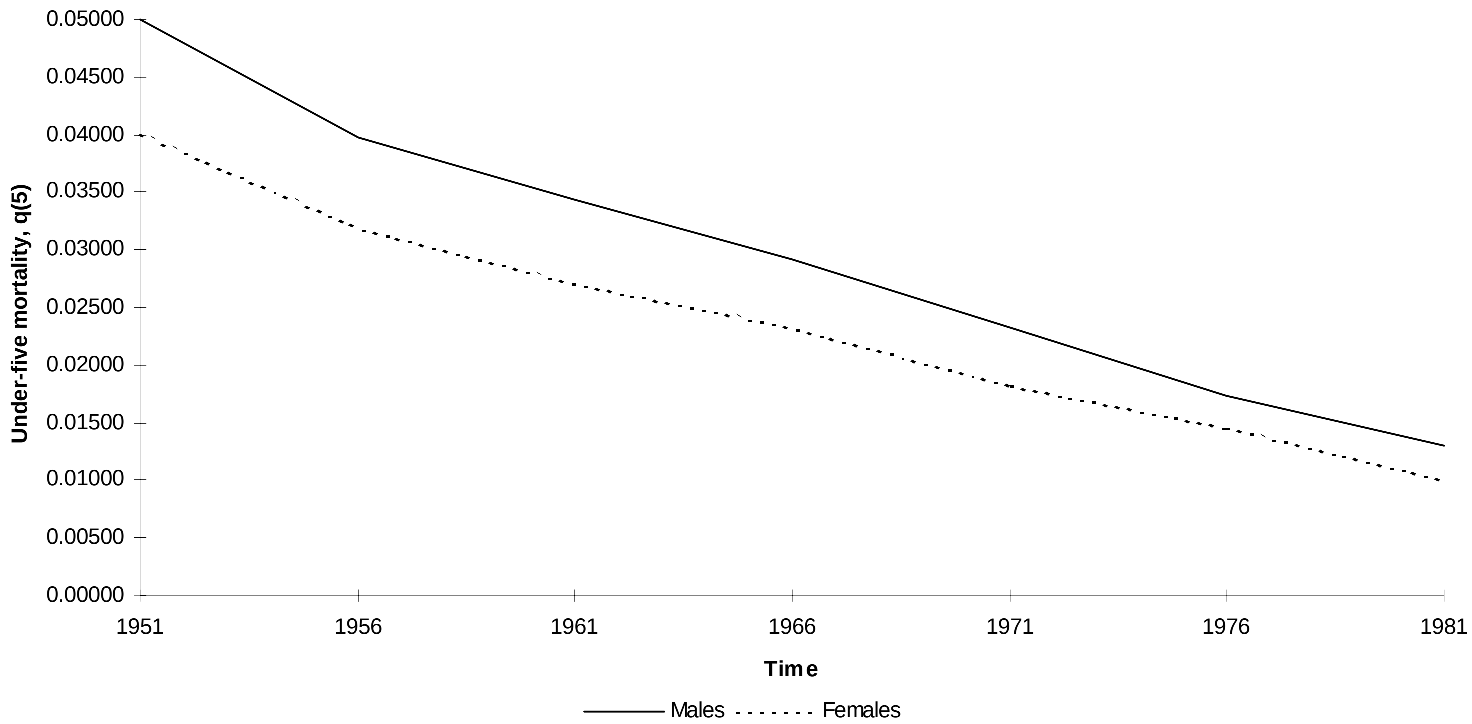

Fig 13: Trends in entropy values, Canada, 1951-1981

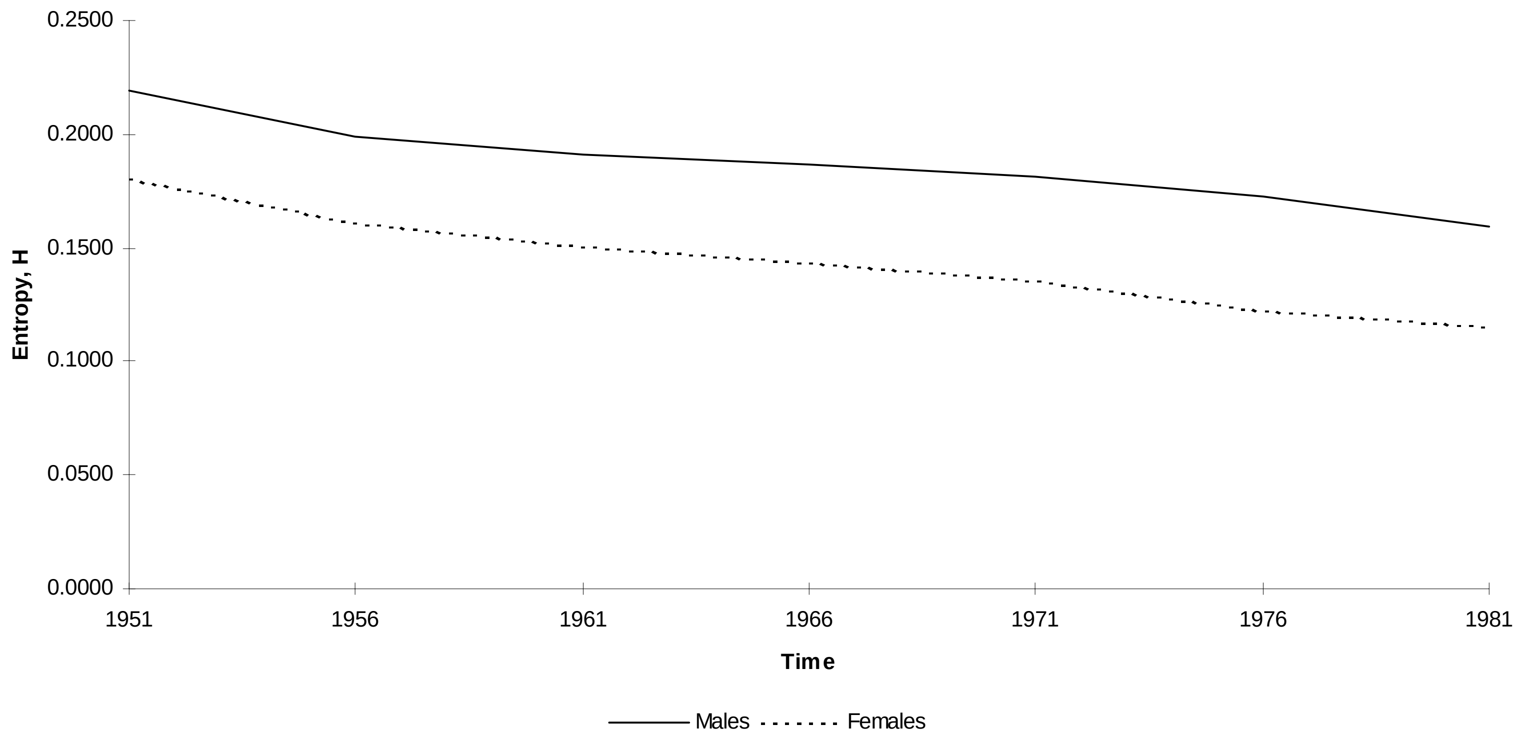

Fig 14: Trends in Anson's *U*, Canada, 1951-1981