LIFE TABLES 1970 - 1972

SRI LANKA

Department of Census & Statistics
P. O. Box 563 Colombo

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Preface

This report contains abridged life tables as well as complete life tables for the three year period 1970-72. This updates the series of life tables that this Department has published for three year periods centred on the Census year since the Census of 1921.

The life tables were computed and the report prepared by Mr. Armindo Miranda and Ms. Berit Tvedt, Demographers of The Chr. Michelsen Institute, Bergen, Norway, in collaboration with Mr. T. Nadarajah, Assistant Director of Census & Statistics. Mr. Miranda's services were made available to this Department by The Chr. Michelsen Institute, through the Ministry of Planning for a period of about six weeks in January/February, 1977. Further work of computation, development of methodology and report writing was subsequently done by Ms. Tvedt at the institute in Bergen.

My thanks are due to Mr. Miranda, Ms. Tvedt and The Chr. Michelsen Institute as well as to the Ministry of Planning for the support given to the Department.

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17th February, 1978.

CONTENTS

List of Tables

List of Figures

List of Appendices

I. ABRIDGED LIFE TABLES FOR SRI LANKA 1970-72

1. INTRODUCTION

This paper contains abridged life tables for males and females for the three-year period 1970-72, as well as complete life tables (by single years of age) for the same period. As has been the usual practice, the period 1970-72 was chosen because a Census of Population was taken in 1971. The life tables are based on the deaths registered during the three-year period 1970-72 and the population by age and sex as at mid-year 1971 estimated from the population enumerated at the Census of 9th October 1971.

The previous publication on life tables, viz. "Life Tables, Ceylon 1962-67" published by the Department of Census and Statistics contained abridged life tables upto 1967. The estimated expectation of life for 1967 was 64.8 for males and 66.9 for females, i.e. slightly higher figures than those for 1970-72 obtained in this paper. Although we cannot completely rule out the hypothesis that mortality conditions might have been better in 1967, the reader should observe the fact that mortality estimates for a single calendar year distant from the latest census available are less reliable than mortality average estimates based on three year census-centered periods. In this report comparisons of expectation of life and mortality patterns are therefore made between the 1962-64 life tables and the 1970-72 life tables as such comparisons would be more reliable in indicating long term trends.

2. MAIN RESULTS

During the period 1970-72, expectation of life at birth is estimated at 64 years for males and nearly 67 years for females. Although new-born males as well as females experienced an increase in their expectation of life during the last intercensal period, the average length of life increased at a much faster pace for females who added nearly 3 years to their expectation of life in 1962-64.

Table 1. Expectation of life at birth - Sri Lanka

		1945-47	1952	1962-64	1970-72
Males	years	46.8	57.6	63.3	64.0
Females		44.7	55.5	63.7	66.8

As a consequence, one of the important mortality trends in Sri Lanka since Independence appears to have been the reversal of the advantage that males had over females in terms of expectation of life. In the years immediately prior to Independence, the sex differential in expectation of life at birth gave an advantage of about 5% to males. The advantage was gradually reduced and for the first time in 1962-64 women in Sri Lanka were enjoying an expectation of life slightly higher than their male counterparts. This trend was further consolidated during the sixties, probably in connection with a large set of sociological/ demographic changes, as suggested by an analysis of the age-specific mortality data.

Between 1962-64 and 1970-72, infant mortality was reduced by about 18%, both sexes benefitting from this improvement in the same proportions. The probability of death under age 1 is about 20% higher for males, and the gap between male and female infant mortality has remained stable in the past decade. Children between ages 1 and 5 also experienced a reduction of their mortality which declined by about one third for both sexes. The traditional pattern of higher female mortality is still observable between ages 1 and 10, possibly as a result of cultural preference for male children and relative neglect of young girls. Thus, there is still some scope for further increases in female expectation of life if young girls' mortality rates were at least brought down to the level already achieved by young boys.

Table 2. Infant and child mortality 1962-64 and 1970-72 - Sri Lanka

	Infant mortality (below age 1)		Child mortality (1-4)	
	1962-64	1970-72	1962-64	1970-72
Males	0.05974	0.05001	0.03106	0.02051
Females	0.04995	0.04181	0.03680	0.02412

The reasons for the slower growth of expectation of life at birth of males in comparison to females lie in the observed evolution of adult mortality rates. Females experienced in 1970-72 better mortality conditions at all ages in comparison to 1962-64, the decline of the mortality rates being particularly impressive and significant between ages 20 and 40. Males, on the contrary, seem to have experienced increased mortality rates between ages 20 and 60 during the last intercensal period. While some explanation can be provided for the favourable evolution of females' mortality pattern - by linking the higher chances of survival through child-bearing ages to the decline of fertility rates and therefore lesser exposure to the risk of maternal mortality - no such straightforward explanation can be provided for the observed increase in male mortality. The resurgence of malaria since 1968 seems so far to have had little direct impact on mortality: only 23 deaths caused by malaria were registered during the period 1970-72, although nearly 750,000 cases of the disease were detected. It is possible that wide-spread malaria morbidity offers a good play-ground for other lethal illnesses and could therefore be held responsible for the observed mortality increases even if the registration system does not record "malaria" as the decisive cause of death. But, since mortality increases are only observable for males and mostly within their active life-span ages, we cannot completely rule out the hypothesis that a new pattern of mortality is emerging for this population sub-group as a consequence of socio-economic changes in the society at large.

It is interesting to note that the present pattern of mortality in Sri Lanka is quite close to the pattern experienced by Scandinavian countries some decades ago, a pattern which was used as background material for the construction of Model "North" life tables in Coale and Demeny's "Regional Model Life Tables and Stable Populations". The main characteristic of Model "North" life tables is the high level of child mortality rates in relation to the level of infant mortality, yet with the clear difference that Scandinavian countries have no recorded experience of female overmortality at comparable levels of expectation of life. Apart from the comparative value of such similarities and dissimilarities (as is shown below in the construction of complete life tables for Sri Lanka) the fact that Sri Lanka's current mortality pattern is similar to life tables in other countries could be used to project possible trends of mortality decline in Sri Lanka.

3. ABRIDGED LIFE TABLES

Table 3. Abridged life tables for Sri Lanka: 1970-72

(a) MALES

Age	${}_nm_x$	${}_nq_x$	l_x	${}_nd_x$	${}_nL_x$	T_x	e^o_x	P_x
0	...	0.05001	100000	5001	95931	6403266	64.03	0.942920
1	0.00535	0.02051	94999	1949	375529	6307335	66.39	0.982713
5	0.00168	0.00834	93050	776	463310	5931806	63.75	0.993104
10	0.00109	0.00544	92274	502	460115	5468496	59.26	0.993458
15	0.00154	0.00765	91772	702	457105	5008381	54.57	0.990523
20	0.00228	0.01132	91070	1031	452773	4551276	49.98	0.988332
25	0.00242	0.01201	90039	1082	447490	4098503	45.52	0.987481
30	0.00262	0.01303	88957	1159	441888	3651013	41.04	0.983661
35	0.00398	0.01970	87798	1729	434668	3209125	36.55	0.977454
40	0.00515	0.02545	86069	2191	424868	2774457	32.24	0.968677
45	0.00760	0.03734	83878	3132	411560	2349589	28.01	0.956701
50	0.01013	0.04949	80746	3996	393740	1938029	24.00	0.937885
55	0.01563	0.07540	76750	5787	369283	1544289	20.12	0.911821
60	0.02143	0.10200	70963	7238	336720	1175006	16.56	0.872372
65	0.03373	0.15616	63725	9952	293745	838286	13.15	0.804303
70	0.05495	0.24253	53773	13042	236260	544541	10.13	0.711221
75	0.08467	0.34982	40731	14249	168033	308281	7.57	0.586046
80	0.13982	0.51258	26482	13574	98475	140248	5.30	0.297851
85	0.30901	1.00000	12908	12908	41773	41773	3.24	-

(b) FEMALES

Age	${}_nm_x$	${}_nq_x$	l_x	${}_nd_x$	${}_nL_x$	T_x	e^o_x	P_x
0	...	0.04181	100000	4181	96553	6683436	66.83	0.949494
1	0.00631	0.02412	95819	2311	377880	6586569	68.74	0.980413
5	0.00180	0.00895	93508	837	465448	6208689	66.40	0.993017
10	0.00100	0.00500	92671	463	462198	5743241	61.97	0.993942
15	0.00143	0.00712	92208	657	459398	5281043	57.27	0.991663
20	0.00192	0.00956	91551	875	455568	4821645	52.67	0.989530
25	0.00229	0.01139	90676	1033	450798	4366077	48.15	0.988103
30	0.00250	0.01241	89643	1112	445435	3915279	43.68	0.985785
35	0.00323	0.01605	88531	1421	439103	3469844	39.19	0.983551
40	0.00340	0.01686	87110	1468	431880	3030741	34.79	0.979550
45	0.00488	0.02412	85642	2065	423048	2598861	30.35	0.971580
50	0.00667	0.03283	83577	2744	411025	2175813	26.03	0.958891
55	0.01017	0.04967	80833	4015	394128	1764788	21.83	0.937855
60	0.01560	0.07528	76818	5782	369635	1370660	17.84	0.899008
65	0.02743	0.12881	71036	9150	332305	1001025	14.09	0.830601
70	0.04820	0.21599	61886	13367	276013	668720	10.81	0.746613
75	0.07064	0.30107	48519	14608	206075	392707	8.09	0.625151
80	0.12768	0.48039	33911	16291	128828	186632	5.50	0.309722
85	0.30482	1.00000	17620	17620	57804	57804	3.28	-

4. COMMENTS ON THE ENTRIES OF THE LIFE TABLES

Death rates (${}_nm_x$): Average age/sex-specific death rates observed in Sri Lanka during the period 1970-72, obtained by dividing the annual average registered deaths in each age group by the population in the corresponding age group as at mid 1971.

Mortality rates (${}_nq_x$): Probability at age x of dying before reaching age x+n. Infant mortality rates were computed by dividing the number of registered deaths under age 1, for each sex, in 1970, 1971 and 1972 by the number of births of each sex registered during the same period. Other mortality rates were computed from the corresponding death rates using the Reed-Merrel formulas[1]:

1) Shryock and Siegel, The Methods and Materials of Demography. Wash. D.C., U.S. Bureau of the Census, 1973. p.p. 866-867.

for age group 1-4

$$ {}_4q_1 = 1-e^{-4\,{}_4m_1\,(0.9806\,-\,2.079\,{}_4m_1)} $$

for age groups between 5 and 85

$$ {}_5q_x = 1-e^{-5\,{}_5m_x\,-\,{}_5m_x^2} $$

The probability of dying in the open interval "85 and over" is, by definition, equal to 1: ($q_{85+} = 1$).

Survivors at exact age (l_x): Number of survivors at age x out of an original cohort of 100,000

$$ l_0 = 100,000 $$

$$ l_{x+n} = l_x - {}_nd_x $$

Deaths (${}_nd_x$): Number of deaths between ages x and x+n out of an original cohort of 100,000

$$ {}_nd_x = l_x \cdot {}_nq_x $$

Person-years (${}_nL_x$): Number of person-years lived between ages x and x+n by an original cohort of 100,000 or number of persons living at any moment in the age group x, x+n out of an original cohort of 100,000. Between ages 5 and 84 the incidence of mortality within each age group is assumed to be evenly distributed and thus

$$ {}_5L_x = 5\,(l_x + l_{x+5})/2 $$

For ages below 5, such an assumption could obviously not be held since child mortality is actually concentrated in the early part of the age intervals. Separation factors, K_0 for age 0-1 and K_1 for the age group 1-4 were devised, ultimately linking the distribution of mortality within the age groups to the level of infant mortality:

$$ {}_1L_0 = K_0 \cdot l_0 + (1-K_0)l_1 $$

$$ {}_4L_1 = K_1 \cdot l_1 + (4-K_1)l_5 $$

The actual values of K_0 and K_1 were obtained using the formulas proposed by Coale and Demeny for model North life tables[1]:

	Males	Females
K_0	$0.0425 + 2.875\,{}_1q_0$	$0.05 + 3\,{}_1q_0$
K_1	$1.859 - 3.013\,{}_1q_0$	$1.733 - 1.627\,{}_1q_0$

For the last open ended age group

$$L_{85+} = \frac{d_{85+}}{m_{85+}}$$

Cumulated person-years (T_x): Number of person-years lived at age x and over by an original cohort of 100,000. (Column ${}_nL_x$ cumulated from the bottom).

Expectation of life (e_x): Average number of years remaining to be lived at age x; obtained dividing T_x by l_x.

Probability of survival (P_x): Proportion of persons in each age group still alive 5 years later. P_0 represents, however, the proportion surviving in the age group 0-4 out of the respective cohorts at birth and P_1 is the probability of survival from age 0-4 to age 5-9.

$$P_0 = ({}_1L_0 + {}_4L_1) / 5l_0$$

$$P_1 = {}_5L_5 / ({}_1L_0 + {}_4L_1)$$

$$P_{80} = T_{85} / T_{80}$$

5. COMPLETENESS AND ACCURACY OF BASE DATA

a) Estimate of mid 1971 population by age and sex

Since the reference date of the population census was 9th October 1971, backward shifting of the population figures to mid 1971 was required prior to the computation of death rates. Unfortunately no straight-

1) Coale and Demeny, Regional Model Life Tables and Stable Populations. Princeton N.J., Princeton Univ. Press, 1966. p. 20.

forward method appeared to be methodologically acceptable, since data on external migration exist only as grand totals of emigrants and immigrants (no breakdown by age or sex) and digital preference/avoidance in age declaration at census was an obvious obstacle to the backward shifting of the population at the boundaries of the 5 year age groups. A two-step procedure was finally devised: the first step consisted in obtaining the total population of the island as at 1st July 1971 under the assumption of no-seasonal pattern of births, deaths and net-migration:

$$P_{1/7/71} = P_{9/10/71} + 100/365\ (\text{Deaths}_{71} - \text{Migration}_{71} - \text{Births}_{71})$$

The second step consisted in breaking down this grand total as at mid 1971 according to the age and sex structure interpolated from the 1963 and 1971 census pyramids, under the assumptions that (a) selective underenumeration/age-misreporting followed the same pattern in both censuses and (b) the deformation of the age/sex structure over time was a gradual process evenly distributed during the inter-censal period. As expected, the final results are very close to the structure shown by the 1971 census since only 3.3% of the observed changes between 1963 and 1971 are supposed to have occurred between mid 1971 and the 1971 census reference date.

Designating by p the proportion of persons of either sex in each age group

$$p_{1/7/71} = p_{9/10/71} - 100/3014\ (p_{8/7/63} - p_{9/10/71})$$

b) Deaths registered by age and sex

The annual number of deaths registered by age and sex in 1970, 1971 and 1972 was obtained from the Registrar General's Office. Age-unspecified deaths were not taken into consideration since they make a quite negligible proportion of the total deaths registered (between 2 and 3 per thousand).

c) Completeness and accuracy of census and vital registration data

The most important assumption underlying the computation of these life tables is that both census and vital registration data are affected by the same type of shortcomings (selective underenumeration or under-registration, inaccuracies in age reporting, etc.), and in the same proportions. Thus, although each source considered separately may be quite defective, their matching for the computation of death rates would yield far better results, making preliminary adjustments unnecessary. This is a very strong assumption indeed, and the reader might wish not to take it for granted. However, the assumption of mutually off-setting shortcomings is supported by the fact that mortality rate curves obtained without any smoothing display a quite standard shape, consistent with the life tables for previous census-centered periods and also quite close to one of the model life tables established by Coale and Demeny on the basis of Scandinavian mortality data around 1935.

The reader might also like to know what kind of shortcomings are present in the basic inputs of the life tables and to what extent they affect each source (census and registration) taken separately. These questions have been explored in previous publications.[1] As regards the registration system, a survey conducted in 1967 revealed that 1.3% of births and 5.5% of deaths had not been registered within the prescribed period for registration, which is 3 months. These estimates suggest a big improvement in the completeness of registration since the corresponding figures yielded by the 1953 check stood at 11.9% and 11.4% respectively. The suggested trend might still be currently operating. Moreover, it is possible that the ultimate proportion of registered events ends up closer to 100% if late registration is taken into account.

As regards the census, there are indications of inaccuracy in age reporting and incompleteness. The age distribution by single years of age shows a large degree of "heaping" due to digital preference. The analysis of age-specific sex-ratios also suggests that age-misreporting among women has noticeable effects even when considering five-year age groups. But it may be assumed that age reporting for death registration

1) Department of Census and Statistics: Life Tables Ceylon 1962-67, Colombo 1970, and A study of the extent of under-registration of births and deaths in Ceylon, Colombo 1970.

purposes would follow the same patterns of digital preference and age shifting observed in census data.

Census completeness can only be tentatively assessed for the lower age groups, checking the census count against the population expected from birth and death registration data pertaining to the corresponding cohorts. For the 1971 Census the following results were obtained:

Table 4. Census count and expected population - Sri Lanka 1971

	MALES			FEMALES		
Age	Census count	Number expected	Percent completeness	Census count	Number expected	Percent completeness
0	174,825	185,813	94.1	169,291	179,451	94.3
1	154,710	177,485	87.2	148,354	172,409	86.1
2	164,137	178,381	92.0	158,900	173,847	91.4
3	177,102	180,313	98.2	175,351	175,252	98.9
4	176,689	175,710	100.6	169,319	169,550	99.9

This figure suggest that census under-enumeration of young children, a typical feature of traditional societies, is still prevalent in Sri Lanka. Assuming that this age group is the most critical as regards selective omissions, an attempt was made to quantify the margin of error attached to the death rate of the age group 1-4 (the mortality rate for children under age 1 being customarily obtained without reference to a census count is not affected by census under-enumeration). The outcome of different assumptions regarding the quality of data (or of different methods of combining census and registration data) are shown in Table 5. It is reassuring to find that the most extreme assumptions have an impact on the final death rate estimates of only a few percentage points ($\pm$ 6%). The original assumption stands as an intermediate hypothesis, yielding results practically identical to those that would be obtained assuming complete registration of births and defective registration of deaths (at the level observed in 1967) and making no use of the census count for the computation of this particular death rate.

Table 5. Alternative estimates of mortality for age group 1-4

Assumption		Average deaths	Mid 71 popu- lation	Death rate	Life table deaths
Vital registration and census are identically defective in accuracy and completeness.	Males	3585	670,523	0.00535	1949
	Females	4101	649,924	0.00631	2311
Only registration of birhts and deaths is complete and accurate. Census figures discarded.	Males	3585	709,456	0.00505	1845
	Females	4101	690,903	0.00594	2178
Registration of deaths assumed 94,5% complete. Census complete and accurate.	Males	3794	670,605	0.00566	2060
	Females	4340	650,004	0.00668	2442
Vital registration assumed 94,5% complete for deaths and 98,7% complete for births. Census figures discarded.	Males	3794	716,515	0.00530	1931
	Females	4340	698,026	0.00622	2278
Registration of births 100% complete, registration of deaths 94,5% complete. Census figures discarded.	Males	3794	706,502	0.00537	1958
	Females	4340	688,348	0.00631	2310

II. COMPLETE LIFE TABLES FOR SRI LANKA 1970-72

6. INTRODUCTION AND BRIEF PRESENTATION OF THE INTERPOLATION PROCEDURES

The abridged life tables presented in the first section of this publication correspond to the immediate possibilities of mortality analysis offered by the statistical data made available by the Reigstrar General's Office: death statistics are given by 5-year age groups only (with the exception of ages 0 to 4) and the computation of complete life tables by single years of age must therefore be the outcome of some interpolation procedure. Since several alternatives could be envisaged to split the aggregate data, it is clear that the computation of complete life tables from the death statistics currently available introduces an element of subjective judgement. While abridged life tables are sensitive to the weaknesses of census and vital registration data, as discussed in the first section of this publication, complete life tables might in addition be criticized on the grounds of the interpolation methods adopted, for which there is no universally accepted practice. It is important therefore to describe in some detail the procedures used in the construction of the complete life tables.

The starting point for the interpolation presented in this section is the set of abridged life tables by 5-year age groups given above. The objective is to split the data pertaining to 5-year groups into single age data. This was done stepwise through specific procedures applied to life table variable ${}_nd_x$:

(i) ${}_5d_{85}$, ${}_5d_{90}$ and ${}_5d_{95}$ were computed using a simplifying hypothesis about the relative distribution of deaths above age 85.

(ii) $d_1,\dots, d_4$ were computed on the basis of model life table values.

(iii) $d_5,\dots, d_{99}$ were computed using an osculatory interpolation method.

(iv) $d_1,\dots, d_4$ were further adjusted to the series $d_5,\dots,d_{99}$ with the help of iterative methods.

(v) d_{90}, .., d_{99} were finally re-worked on an admittedly arbitrary basis, since it appeared that the basic interpolation routine had given less satisfying results for the terminal segment of the mortality rate series.

Using these procedures, a series of life table deaths by single years of age, d_x, was obtained for each sex, this series in turn determined the values of the other complete life table variables. In the following paragraphs the interpolation procedures are more closely presented and discussed. In a final section (section 13) an overall assessment of the complete life tables is given.

7. COMPUTATION OF $_5d_{85}$, $_5d_{90}$ AND $_5d_{95}$

Unlike abridged life tables which stop at age 85 - due to the fact that death statistics beyond that age limit are not made available by quinquennial age group by the Registrar General - the complete life tables for 1970-72 will cover the age span 0-99, following the model set by previous life tables for Ceylon[1]. This implies that, at a first stage, the aggregate number of deaths above age 85 (d_{85+}) will be split into 3 five-year age groups plus a remainder of deaths occuring beyond age 99.

From the abridged life tables we have:

$$d_{85+} = 12,908 \text{ for males}$$

$$d_{85+} = 17,620 \text{ for females}$$

and we want to obtain a data breakdown satisfying the condition:

$$_5d_{85} + {_5d_{90}} + {_5d_{95}} + d_{100+} = d_{85+}$$

The real distribution is unknown for 1970-72. We have chosen, without further analysis, to make comparisons with the published complete life tables for 1962-64. Under the assumption that the mortality pattern of people aged over 85 did not change during the last intercensal period, we can use the relative distribution of deaths established for 1962-64 as a key for the distribution of the aggregate figures for 1970-72

1) Department of Census and Statistics, Life Tables Ceylon 1962-67. Colombo 1970.

The life tables for Ceylon 1962-64 presented the following distribution of deaths above age 85:

Table 6. Aggregate number of deaths above age 85 - Ceylon 1962-64

	MALES		FEMALES	
Age	$_nd_x$	%	$_nd_x$	%
85-89	8,571	66.3	9,257	67.4
90-94	3,558	27.5	3,730	27.2
95-99	742	5.8	698	5.1
100+	57	0.4	42	0.3
85+	12,928	100.0	13,727	100.0

Applying the above percentage distribution to d_{85+} figures for 1970-72 we obtain the following table:

Table 7. Aggregate number of deaths above age 85 - Sri Lanka 1970-72

	MALES		FEMALES	
Age	%	$_nd_x$	%	$_nd_x$
85-89	66.3	8,558	67.4	11,876
90-94	27.5	3,550	27.2	4,793
95-99	5.8	749	5.1	899
100+	0.4	51	0.3	52
85+	100.0	12,908	100.0	17,620

The figures in table 7 will later be used in the course of the interpolation routine that generates the d_x-series.

We may question the validity of the assumption implying that the mortality pattern for people aged 85 and over has been stable through the last intercensal period. From a theoretical point of view, we may argue that this pattern has most probably changed. If we take the distribution of deaths between ages 70 and 84 in the two sets of abridged life tables, we observe that the relative weight of the two first quinquennial age groups (70-74 and 75-79) in 1970-72 was less than in 1962-64 and that a slightly larger proportion of deaths occured in the age group 80-84 in the latter period.

Table 8. Percentage distribution of deaths for ages 70-84 - Ceylon 1962-64 and Sri Lanka 1970-72

	MALES		FEMALES	
AGE	1962-64	1970-72	1962-64	1970-72
70-74	32.7	31.9	31.6	30.2
75-79	35.2	34.9	35.4	33.0
80-84	32.1	33.2	33.0	36.8
70-84	100.0	100.0	100.0	100.0

In other words, those dying between ages 70 and 84 in 1970-72 had an expectation of life higher than those dying in the same age interval in 1962-64. We may therefore be tempted to extrapolate and conclude that a similar change in the mortality pattern could be assumed for the age group 85 and over.

From a practical point of view, however, we may equally observe that the background material for the computation of quinquennial death rates beyond age 85 is certainly less solid than the corresponding data for lower age groups. The distribution of deaths at age 85 and over is clearly tentative and its status should not be greatly affected by the simplifying assumption of stability of the mortality pattern over an eight-year period.

8. COMPUTATION OF d_1, ..., d_4

Standard interpolation formulas for the computation of deaths by single years of age would give results quite inadequate to describe actual mortality pattern for early childhood: standard formulas tend to produce gradual progressions from one interpolated value to the next one, while in reality there is a very sharp decrease of mortality after the first year of age.

Model life tables like those established by Coale and Demeny provide us with sets of d_1, ..., d_4 corresponding to given levels of survivors at age 1 (l_1) and age 5 (l_5) for each "regional" mortality pattern.[1)] The values of l_1 and l_5 being known from the abridged life tables the problem is thus to find a specific model life table fitting the data available for Sri Lanka in such a close way that one may adopt its model series d_1,..., d_4.

For males it appears that level 20 of Model North life tables is the obvious solution, since this particular table falls very close to the overall mortality pattern in Sri Lanka for 1970-72. For females, however, no model life table shows such a striking closeness to the observed data: there are instead two alternatives, namely level 19 and level 20 of Model North, both giving quite good approximations. Level 19 was finally chosen for reasons explained in section 10 below.

In order to obtain more refined values of d_1, ..., d_4, the deviations observed for l_1 and l_5 between the 1970-72 abridged life tables and the data pertaining to Model North were computed and subsequently used as a guide for the interpolation of the intermediate values l_2, l_3 and l_4.

In the following table, the values of l_x for x = 1 and x = 5 are those of the abridged life tables 1970-72, while the values of l_x' for x = 1, ..., 5 are those of the Model North life tables. The differences $l_1 - l_1'$ and $l_5 - l_5'$ are immediately established by comparison and the differences $l_x - l_x'$ for x = 2,3,4 are obtained by linear interpolation between $l_1 - l_1'$ and $l_5 - l_5'$.

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1) Coale and Demeny, Op.cit., p.p. 42-43.

Table 9. Survivors at early childhood ages - Sri Lanka 1970-72 and Model North life tables

	MALES			FEMALES		
Age x	Sri Lanka 1970-72 l_x	Model North level 20 l_x'	$l_x - l_x'$	Sri Lanka 1970-72 l_x	Model North level 19 l_x'	$l_x - l_x'$
1	94,999	95,115	-116	95,819	95,199	+620
2		94,378	- 72 } interp.		94,236	+681 } interp.
3		93,811	- 27 } values		93,583	+742 } values
4		93,355	+ 17 }		93,064	+803 }
5	93,050	92,989	+ 61	93,508	92,645	+863

As a result, we obtain the following series of l_x and d_x for Sri Lanka 1970-72, where l_x for x = 2, 3, 4 is computed by the formula $l_x = l_x' + (l_x - l_x')$ and d_x for x = 1, ..., 4 by the formula $d_x = l_x - l_{x+1}$:

Table 10. Survivors and deaths at early childhood ages - Sri Lanka 1970-72

	MALES		FEMALES	
Age x	l_x for 1970-72 based on Model North level 20	d_x	l_x for 1970-72 based on Model North level 19	d_x
0	100,000	5,001	100,000	4,181
1	94,999	693	95,819	902
2	94,306	522	94,917	592
3	93,784	412	94,325	458
4	93,372	322	93,867	359
5	93,050		93,508	

This distribution of deaths by single age in the first five-year age group is assumed to be representative of the actual distribution corresponding to the mortality conditions prevailing in Sri Lanka in 1970-72.

9. COMPUTATION OF d_5, ..., d_{99}

a) Choice of interpolation procedure

The ${}_nd_x$ variable, which was selected as the leading life table parameter to be interpolated, consists of aggregate data we wish to subdivide into fifths whose sum is consistent with the original aggregate amount. As a consequence, we have to use interpolation procedures devised for breaking down aggregates into fifths - as opposed to procedures which interpolate intermediate values between two given points to form a series of five values.

The interpolation method to be applied makes use of a special concept of "differences". By "leading differences" is meant the result obtained by subtracting from a given value the preceeding value in a series. Such differences can be of "1st-order", "2nd-order", etc. and may be expressed symbolically as follows:

Observed values: $x_1, x_2, ...$

1st-order differences: $\Delta x_1 = x_2 - x_1$

$\Delta x_2 = x_3 - x_2$

$\vdots$

2nd-order differences: $\Delta^2 x_1 = \Delta x_2 - \Delta x_1$

$\Delta^2 x_2 = \Delta x_3 - \Delta x_2$

$\vdots$

3rd-order differences: $\Delta^3 x_1 = \Delta^2 x_2 - \Delta^2 x_1$

$\Delta^3 x_2 = \Delta^2 x_3 - \Delta^2 x_2$

$\vdots$

etc.

Shryock and Siegel[1] suggest that the success of an interpolation method can be assessed by the analysis of leading differences in the resulting interpolated series: smaller leaps between consecutive differences (at an

1) Shryock and Siegel, Op. cit., p. 682.

appropriate level of differencing) indicate that the interpolation has been successful. This means that a good interpolation routine must generate a relatively even progression from any interpolated value to the next one.

The more usual analytical interpolation methods for subdividing aggregate data are presented in Shryock and Siegel's The Methods and Materials of Demography, chapter "Selected General Methods". The authors distinguish two principal classes of analytical procedures: the "osculatory interpolation methods" and the "mid-point and cumulation-differencing methods".

The second class of interpolation methods - which treat each quinquennial age group separately - have the disadvantage of producing series of interpolated values whose progression is not always smooth at the junction of contiguous age intervals. The osculatory interpolation methods, however, appear therefore in a sense more sophisticated because - being built on polynomials which partly overlap each other - they ensure smooth transitions across the borders of the age intervals.

Osculatory interpolation methods can be classified into two groups
a) those which reproduce the inputs, i.e. the sum of the interpolated values within a given age group equals the original group total and
b) those which modify the original data, the sum of the interpolated values becoming distinct from the aggregate input. These latter methods combine interpolation and a certain extent of smoothing/adjustment of rough data: they are particularly useful to deal with data one suspects to be partly defective, undesirable fluctuations being rooted out as the interpolated series becomes smoothed.

Among the modified osculatory methods available for aggregate data, Shryock and Siegel mention Grabill's formula based on Sprague coefficients and Beers' 6-term modified formula.[1] Beers' formula was finally selected for the interpolation of Sri Lanka life tables since Grabill's formula appeared to produce too drastic a smoothing of interpolated values at the cost of the original aggregate data. In fact, it seems desirable to conserve a certain degree of irregularity and even though the present input data are clearly defective up to a certain point, the incidence of age-specific death causes may be responsible for some unevenness in the shape of the mortality curves.

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1) Shryock and Siegel, Op. cit., p. 702.

In order to test this point, 1st-order differences were computed for single age mortality rates in Ceylon 1962-64 and USA 1959-61 life tables. It appears that the series of 1st-order differences in the life tables for Sri Lanka 1970-72 generated by Beers' formula is not more uneven than the corresponding series of 1st-order differences in the other life tables. Using Grabill's formula would imply both a larger loss of information as regards the original data and at the same time patterns of change in relation to the 1962-64 life tables which do appear suspect.

Thus, the choice of Beers' modified formula represents a compromise between the possibility of scrupulously respecting the original aggregate data and the alternative of undertaking an extensive smoothing which violate the original Census and Vital Registration data. The properties of Beers' formula are described below.

b) Beers' modified six-term formula

Beers' modified six-term formula which is an osculatory method that combines subdivision of the aggregate data with some smoothing of the interpolated series, can be expressed in its general form as follows:[1)]

$$V_{x+s} = U_x + s\Delta U_x + \frac{s(s-1)}{2}\Delta^2 U_{x-1} + \frac{(s+1)s(s-1)}{6}\Delta^3 U_{x-1} +$$

$$f(s)\Delta^4 U_{x-1} + f(1-s)\Delta^4 U_{x-2}$$

By splitting the aggregate values into five sub-values - that is, by interpolating for the interval between x and x+1 for x = 2, ..., n-3 and s = 0.0, 0.2, 0.4, 0.6 and 0.8 - the interpolated values V_{x+s} can be expressed as a function of s, the aggregate values U_x and the 1st- through the 4th-order differences of U_x.

Computation of d_5, ... d_{99} has, however, been carried out on the basis of a variation of this equation where Beers' formula is expressed in linear compound forms, in terms of coefficients that are applied to the original data. Adjusted for our purposes of inquiry, the coefficient equations for Beers' formula are as follows:[2)]

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1) Beers, Henry S.,"Modified Interpolation Formulas that minimize Fourth Differences". The Record of the American Institute of Actuaries, June 1944.

2) The equations have been arrived at on the basis of the chapter "Selected General Methods" in Shryock and Siegel's textbook.

Computation of $d_5, \ldots, d_9$:

$$d_{5+z} = a_{5+z,1} \cdot {}_5d_0 + a_{5+z,2} \cdot {}_5d_5 + a_{5+z,3} \cdot {}_5d_{10} + a_{5+z,4} \cdot {}_5d_{15} +$$

$$a_{5+z,5} \cdot {}_5d_{20} \qquad \text{for } z = 0,1, \ldots, 4$$

Computation of $d_{10}, \ldots, d_{89}$:

$$d_{y+z} = a_{y+z,1} \cdot {}_5d_{y-10} + a_{y+z,2} \cdot {}_5d_{y-5} + a_{y+z,3} \cdot {}_5d_y + a_{y+z,4} \cdot {}_5d_{y+5} +$$

$$a_{y+z,5} \cdot {}_5d_{y+10} \qquad \text{for } y = 10,15, \ldots, 85; \quad z = 0,1, \ldots, 4$$

Computation of $d_{90}, \ldots, d_{99}$:

$$d_{y+z} = a_{y+z,1} \cdot {}_5d_{75} + a_{y+z,2} \cdot {}_5d_{80} + a_{y+z,3} \cdot {}_5d_{85} + a_{y+z,4} \cdot {}_5d_{90} +$$

$$a_{y+z} \cdot {}_5d_{95} \qquad \text{for } y = 90,95; \quad z = 0,1, \ldots, 4$$

The equations can be interpreted as follows: Each aggregate value, ${}_5d_y$, for $y = 5,10, \ldots, 95$, is, by means of the interpolation procedures, broken down into five subvalues, d_{y+z}, for $y = 5,10, \ldots, 95$ and $z = 0,1,\ldots,4$. The sub-values in each 5-year group, except the first and the last two groups, are interpolated on the basis of the aggregate value in focus and the aggregate values for the two preceeding and two subsequent 5-year groups. Sub-values for the first 5-year group, $d_5, \ldots, d_9$, are computed from ${}_5d_0$ and the four subsequent aggregate values, and the sub-values for the last two 5-year groups, $d_{90}, \ldots, d_{99}$, are computed on the basis of the last five aggregate values. $a_{y+z,w}$, for $y = 5,10,\ldots,95$, $z = 0,1,\ldots, 4$ and $w = 1,2,., 5$ are the coefficient values that are applied to the separate aggregate values in the interpolation equations. The coefficient matrix has the following values:[1)]

1) Shryock and Siegel, Op. cit., p. 878.

Table 11. Interpolation coefficients based on the Beers' modified formula.

For y = 5: $a_{5+z,w}$

z \ w	1	2	3	4	5
0	+ 0.0486	+ 0.1831	− 0.0329	+ 0.0021	− 0.0009
1	+ 0.0203	+ 0.1955	− 0.0123	− 0.0031	− 0.0004
2	+ 0.0008	+ 0.1893	+ 0.0193	− 0.0097	+ 0.0003
3	− 0.0108	+ 0.1677	+ 0.0577	− 0.0153	+ 0.0007
4	− 0.0159	+ 0.1354	+ 0.0972	− 0.0170	+ 0.0003

For y = 10, 15,..., 85 : $a_{y+z,w}$

z \ w	1	2	3	4	5
0	− 0.0160	+ 0.0973	+ 0.1321	− 0.0121	− 0.0013
1	− 0.0129	+ 0.0590	+ 0.1564	+ 0.0018	− 0.0043
2	− 0.0085	+ 0.0260	+ 0.1650	+ 0.0260	− 0.0085
3	− 0.0043	+ 0.0018	+ 0.1564	+ 0.0590	− 0.0129
4	− 0.0013	− 0.0121	+ 0.1321	+ 0.0973	− 0.0160

For y = 90: $a_{90+z,w}$

z \ w	1	2	3	4	5
0	+ 0.0003	− 0.0170	+ 0.0972	+ 0.1354	− 0.0159
1	+ 0.0007	− 0.0153	+ 0.0577	+ 0.1677	− 0.0108
2	+ 0.0003	− 0.0097	+ 0.0193	+ 0.1893	+ 0.0008
3	− 0.0004	− 0.0031	− 0.0123	+ 0.1955	+ 0.0203
4	− 0.0009	+ 0.0021	− 0.0329	+ 0.1831	+ 0.0486

For y = 95: $a_{95+z,w}$

z \ w	1	2	3	4	5
0	− 0.0012	+ 0.0054	− 0.0410	+ 0.1506	+ 0.0862
1	− 0.0011	+ 0.0059	− 0.0351	+ 0.0969	+ 0.1334
2	− 0.0005	+ 0.0032	− 0.0146	+ 0.0216	+ 0.1903
3	+ 0.0006	− 0.0027	+ 0.0205	− 0.0753	+ 0.2569
4	+ 0.0022	− 0.0118	+ 0.0702	− 0.1938	+ 0.3332

Computation of the equations involves routine calculations suitable for computer processing. Appendix 1 includes a programme in FORTRAN which has been used for the interpolation procedure and which, for the entered values of the coefficient matrix and ${}_5d_x$ for $x = 0,5, \ldots, 95$ for each sex, prints out the interpolated sub-values, $d_5, \ldots, d_{99}$.

10. ADJUSTING THE SERIES FOR AGES 0-4 TO THE SERIES FOR AGES 5-99

$d_5, \ldots, d_{99}$ have been, as explained in the previous section, interpolated on the basis of Beers' modified formula, while $d_0, \ldots, d_4$ are estimated from values given in model life tables. Beers' formula assures smooth transitions between consecutive interpolated values. However, as the series $d_0, \ldots, d_4$ is affixed to the series $d_5, \ldots, d_{99}$, a smooth transition would be coincidental between the values d_4 and d_5, that is at the junction of the two interpolated series.

In dealing with this issue we will lay aside the variable d_x and instead focus on single age mortality rates, q_x, as we have greater understanding of its properties than of the properties of d_x and thus, the assessment of the assumptions undertaken is made easier. The relationship between d_x and q_x is $q_x = \frac{d_x}{l_x}$. As with d_x, the transitions between consecutive values of q_x in the interpolated series ought to be smooth for the interpolation to be successful.

The properties of q_x are characterized by a high infant mortality rate, and after a substantial reduction in the value of q_x following the first year, one usually finds gradually decreasing values throughout the childhood years until mortality rates begin to rise usually at about the teen-age period. It is also characteristic that during the years of declining values of q_x, the rate of decline decreases with increasing age. With respect to the differences of q_x, this implies negative values of Δq_x and positive values of $\Delta^2 q_x$. These characteristics should be present also in the complete life tables for Sri Lanka.

As q_x now stands, the attachment of the series $q_0, \ldots, q_4$ to the series $q_5, \ldots, q_{99}$ creates a discontinuity at the transition from

q_4 to q_5, as Δq_4 has a much lower value than the adjacent 1st-order differences. This is caused by the use of the aggregate value ${}_5d_0$ in the interpolation equations for calculation of d_5, d_6,... , producing unacceptable results for the derived values q_5, q_6, ... d_0, which is of a completely different magnitude than the subsequent values of d_x, composes such a large portion of ${}_5d_0$ that ${}_5d_0$ cannot represent the values of the interpolated series without adjustment. We therefore face the following problem:

Given q_0, ..., q_4 based on the model life tables and given the interpolation method that calculates d_5, ..., d_{99}, from which q_5, ..., q_{99} can be computed, find a value ${}_5d_0 = f(d_0, ..., d_4)$ which, when entered into the interpolation equations, will provide a series d_5, ..., d_{99} where the following assumptions are fulfilled for derived series q_5, ..., q_{99}:

i) Continuity is maintained for the transition from q_4 to q_5 when q_0, ..., q_4 is attached to q_5, ..., q_{99}. In addition, the smooth decline in q_x continues past age four, with steadily diminishing changes in q_x until approximately the teen-age years - i.e., negative Δq_x-values and positive $\Delta^2 q_x$-values for these age groups. This is assumed to apply for both sexes.

ii) For the 5 - 9 age group, the values of q_x for 1970-72 are less than the corresponding values for 1962-64. This is assumed to apply for both sexes. The assumption seems reasonable as the aggregate number of male deaths for ages five to nine, ${}_5d_5$, came to 1213 in 1962-64 as opposed to 776 in 1970-72, while for females they came to 1047 in 1962-64 as opposed to 837 in 1970-72, and it seems unlikely that the relative distribution of single age deaths within the five-year group has changed significantly during the eight year-period.

To find a suitable value of ${}_5d_0$ we have through iteration tried various functions of d_0, ..., d_4. It seems that for males ${}_5d_0 = 5 \times d_2$ provides an aggregate value that fulfills the above demands.

We recall that, for males, q_0, ..., q_4 is based on the mortality pattern in Model North level 20. For females, the choice is between level 19 and level 20 in Model North. However, with level 20 as basis for females, finding a value of ${}_5d_0$ that fulfills both the above mentioned demands simultaneously is impossible. On the other hand with level 19 as basis, we find through iteration that, as with males, $_5d_0 = 5 \times d_2$ provides an acceptable solution in which the two demands are fulfilled simultaneously also for females.

Thus, the considerations above result in the following $_5d_0$ values:

$$_5d_0 = 5 \times d_2 = 5 \times 522 = 2610 \qquad \text{for males}$$

$$_5d_0 = 5 \times d_2 = 5 \times 592 = 2960 \qquad \text{for females}$$

As the $_5d_x$ values for x = 5,10, ..., 80 are obtained from the abridged life tables and $_5d_{85}$, $_5d_{90}$ and $_5d_{95}$ are computed as described in the first section of this paper on interpolation, the distribution of the aggregate number of deaths by five-year age groups is determined. These values, which are used in the Beers' formula for computing the interpolated values of single age deaths between ages 5 and 99, are as follows:

Table 12. Aggregate number of deaths for ages 0-99 - Sri Lanka 1970-72

Age x	Males $_5d_x$	Females $_5d_x$	Age x	Males $_5d_x$	Females $_5d_x$
0	2,610	2,960	50	3,996	2,744
5	776	837	55	5,787	4,015
10	502	463	60	7,238	5,782
15	702	657	65	9,952	9,150
20	1,031	875	70	13,042	13,367
25	1,082	1,033	75	14,249	14,608
30	1,159	1,112	80	13,574	16,291
35	1,729	1,421	85	8,558	11,876
40	2,191	1,468	90	3,550	4,793
45	3,132	2,065	95	749	899

11. ADJUSTMENT OF d_{90}, ... d_{99}

In life tables, the variable q_x for upper age groups characteristically features accelerating value increments, i.e., both positive Δq_x- and $\Delta^2 q_x$-values. However, use of the chosen interpolation formula on the above data produces results that, for females age 96 on and for men age 97 on, do not meet these conditions. Beers' formula distributes deaths between ages 90-99 in an unfortunate manner, as the resulting q_x-values first rise unusually rapidly and then decline for the final ages. It is therefore reasonable to manipulate the interpolated series and redistribute the d_x-values within the last 10-year age interval so as to attain a smoother and more plausible progression of the variable q_x for the higher ages. Such a redistribution should be carried out in keeping with the following conditions:

i) The aggregate number of deaths within the 10-year interval remains substantially unchanged.

ii) q_x-values for 1970-72 do not differ very much from corresponding values for 1962-64, as far as this is consistent with the mortality pattern that is built into the 1970-72 abridged life tables.

iii) Both Δq_x- and $\Delta^2 q_x$-values are positive.

Through iteration - experimenting with alternative assumptions for the values of $\Delta^2 q_x$ for ages 89 on - we have arrived at a set of values d_{90}, ..., d_{99} which, for each sex, satisfactorily fulfills these conditions. The resulting values are presented in the complete life tables.

12. CONSTRUCTION OF THE COMPLETE LIFE TABLES FOR SRI LANKA 1970-72

The series derived from the above process is assumed to reflect mortality conditions in Sri Lanka in 1970-72, and forms the basis for construction of the complete life tables, building upon the following relationships:

1) $l_o = 100.000$

2) $l_x = l_{x-1} - d_{x-1}$ $\quad x = 1,\ldots, 99$

3) $q_x = \frac{d_x}{l_x}$ $\quad x = 0,\ldots, 99$

4a) $K_o = 0.0425 + 2.875\ q_o$ $\quad$ for males

4b) $K_o = 0.05 \ + 3\ q_o$ $\quad$ for females

5) $L_o = K_o l_o + (1-K_o)l_1$

6) $L_x = 0.5\ l_x + 0.5\ l_{x+1}$ $\quad x = 1,\ldots, 98$

7) $L_{99+} = \frac{l_{99}}{m_{99}}$

8) $T_x = \sum_{y=x}^{99} L_y$ $\quad x = 0,\ldots, 99$

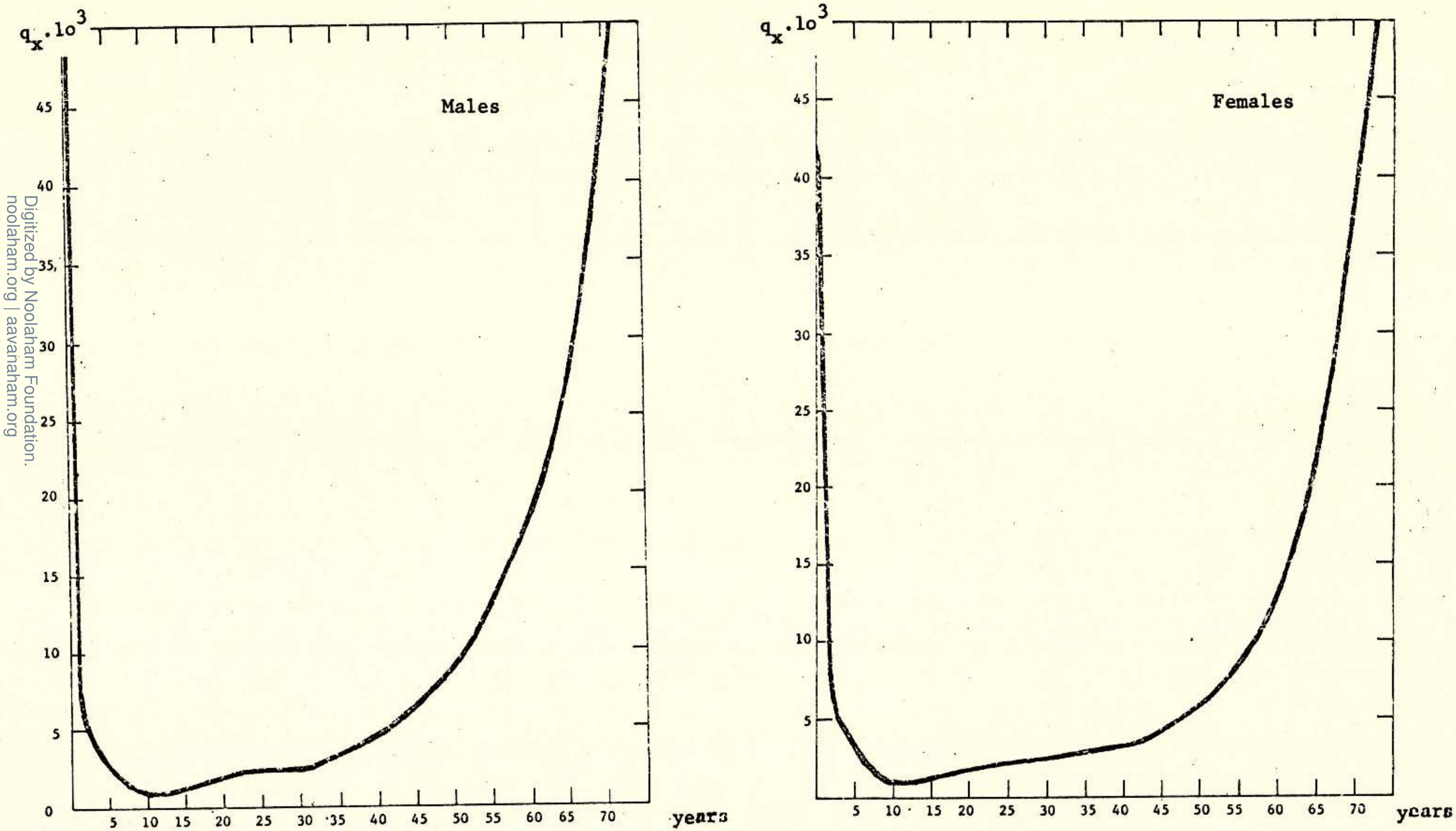
9) $e_x = \frac{T_x}{l_x}$ $\quad x = 0,\ldots, 99$

10) $P_o = \frac{L_o}{l_o}$

11) $P_x = \frac{L_x}{L_{x-1}}$ $\quad x = 1,\ldots, 98$

Definition of the variables is presented in the first part of this paper in connection with the construction of the abridged life tables. On the basis of the above-noted relationships, a FORTRAN programme has been constructed for computing and printing out the complete life tables for the entered values of $d_0, \ldots, d_{99}$ and K_0 for each sex. The programme is found in Appendix 2 and the print-out of the complete life tables by single years of age for Sri Lanka 1970-72 is given in Appendix 3. In Fig. 1 the resulting mortality rates are presented graphically.

Fig. 1 Single age mortality rates, Sri Lanka 1970-72



13. ASSESSMENT OF THE INTERPOLATION WORK PERFORMED

The acceptability of the complete life tables depends inter alia on the degree to which the following demands are met:

i) Closeness to the mortality pattern present in the abridged tables for 1970-72.

ii) Plausible mortality shift between 1962-64 and 1970-72.

iii) Consistent pattern of mortality in relation to Model North level 20 for males and level 19 for females.

a) Comparisons with the abridged life tables for Sri Lanka 1970-72

In order to compare mortality patterns in the complete life tables with the abridged life tables 1970-72, the number of deaths in each five-year group from the complete tables have been aggregated and the corresponding mortality rates have been computed. In the table below, these mortality rates plus those from the abridged tables are presented side-by-side and the differences between them have been computed.

Table 13. Mortality rates by 5-year age groups, abridged and complete life tables - Sri Lanka 1970-72

Age	Males			Females		
	$_nq_x \cdot 10^3$ based on		% changes in $_nq_x \cdot 10^3$	$_nq_x \cdot 10^3$ based on		% changes in $_nq_x \cdot 10^3$
	abridged life tables	complete life tables		abridged life tables	Complete life tables	
0	50.01	50.01	0.0	41.81	41.81	0.0
1	20.51	20.51	0.0	24.12	24.12	0.0
5	8.34	8.84	-6.0	8.95	9.50	-6.1
10	5.44	5.09	6.4	5.00	4.71	5.8
15	7.65	7.68	-0.4	7.12	6.91	2.9
20	11.32	10.98	3.0	9.56	9.54	0.2
25	12.01	11.95	0.5	11.39	11.24	1.3
30	13.03	13.54	-3.9	12.41	12.78	-3.0
35	19.70	19.12	2.9	16.05	15.42	3.9
40	25.45	26.02	-2.2	16.86	17.48	-3.7
45	37.34	36.54	2.1	24.12	23.63	2.0
50	49.49	50.66	-2.4	32.83	33.12	-0.1
55	75.40	73.85	2.1	49.67	49.03	1.3
60	102.00	103.42	-1.4	75.28	76.25	-1.3
65	156.16	157.19	-0.7	128.81	130.71	-1.5
70	242.53	241.15	0.6	215.99	211.53	2.1
75	349.82	352.43	-0.7	301.07	308.96	-2.6
80	512.58	503.58	1.8	480.39	471.68	1.8
85+	1.000.00	1.000.00	0.0	1.000.00	1.000.00	0.0

The differences in the mortality rates for the two sets of life tables are caused by the use of an osculatory interpolation method which provides a smooth series of interpolated values for the complete life tables. Beers' modified formula has, however, resulted in only minor discrepancies in the mortality rates for most age groups, as we can see from the table above. The closeness of the two tables should be considered good - especially since the observed differences alternate between positive and negative values, which suggests the absence of systematic variations between the mortality patterns for the two tables.

In comparing the variable e_x for the two sets of life tables, we find a variation of approximately 0.2-0.3 years for most age groups of both sexes. The expectation of life is slightly higher when based upon the complete tables. This difference, which also is reflected in the values of some other variables in the life tables (T_x and P_x), is caused by the fact that the mortality pattern assumed for ages 85 and over in the complete life tables is not fully consistent with the pattern built into the abridged life tables for the last age segment.

b) Comparisons with the life tables for Ceylon 1962-64

For dealing with the issue of whether the interpolation and smoothing undertaken has provided a more plausible shift in mortality pattern between 1962-64 and 1970-72 we have, for both sexes, computed the differences:

$${}_nq_x^{\,1970-72\ (C)} - {}_nq_x^{\,1962-64} \quad \text{and}$$

$${}_nq_x^{\,1970-72\ (A)} - {}_nq_x^{\,1962-64}$$

for $x = 0,1,5,10, \ldots, 80$

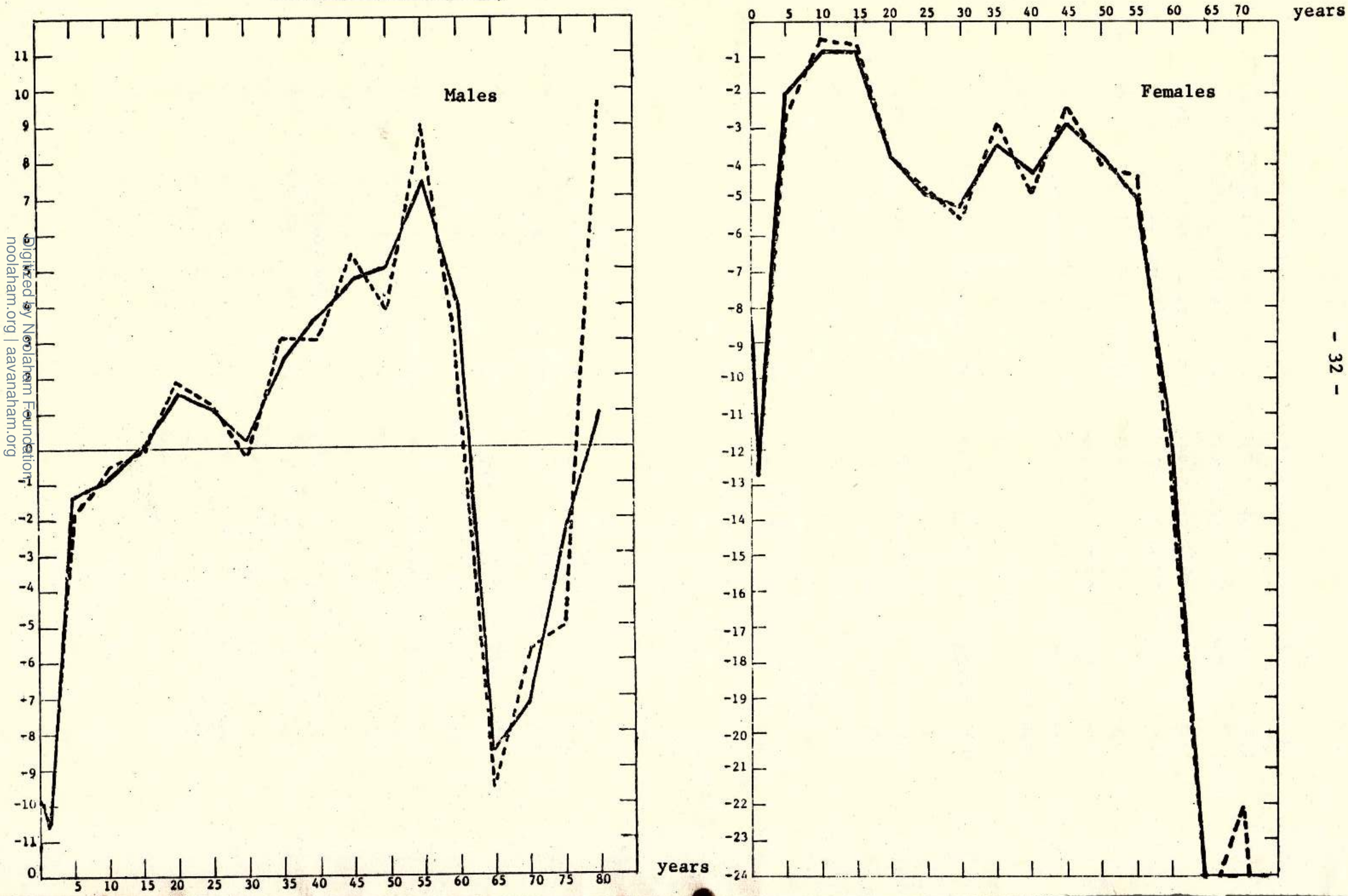
Here ${}_nq_x^{\,1970-72\ (C)}$ represents the mortality rates arrived at by summarizing the deaths within each aggregate age group from the complete life tables for 1970-72, ${}_nq_x^{\,1962-64}$ are the corresponding values for 1962-64, and ${}_nq_x^{\,1970-72\ (A)}$ are the mortality rates from the original abridged life tables for 1970-72. The differences ${}_nq_x^{\,1970-72} - {}_nq_x^{\,1962-64}$ give the changes in mortality rates in the eight-year period.

The results of these computations are presented graphically in fig. 2. As one can see from the figures, the smoothing has evened the differences considerably, to this extent the interpolated life tables represent a more likely shift in mortality rates between 1962-64 and 1970-72 than do the abridged tables. In order to document this further, we have computed the mean square of differences:

Fig. 2. **Differences in mortality rates, complete and abridged life tables 1970-72 to life tables 1962-64**

——— $_nq_x^{1970-72(C)} - {_nq_x^{1962-64}}$

- - - - - $_nq_x^{1970-72(A)} - {_nq_x^{1962-64}}$



$$s^2(C) = \frac{1}{m} \sum_x ({}_nq_x^{1970-72(C)} - {}_nq_x^{1962-64})^2$$

$$s^2(A) = \frac{1}{m} \sum_x ({}_nq_x^{1970-72(A)} - {}_nq_x^{1962-64})^2$$

for $x = 0,1,5,10, \ldots,80$

$m = 18$, i.e. number of age groups

Low value of s^2 indicate a high degree of conformity between the two series. When $s^2 = 0$, the two series are identical. We find the following results for s^2:

	$s^2(C)$	$s^2(A)$
Males	26.70	33.98
Females	251.07	259.45

For both males and females, $s^2(C) < s^2(A)$, thus indicating that the complete life tables provide better conformity with the 1962-64 life tables.[1)]

c) Comparisons with the model life tables

To assess the conformity with the model life tables, we have used the following differences:

---

1) In the table above we notice that s^2 is much larger for females than for males. This can also be seen from the figures as, on the whole, greater differences can be noted for females than for males. This indicates that females have experienced greater changes in mortality conditions than males in the eight-year period, but this has no significance for the assessment of the interrelationships of $s^2(C)$ to $s^2(A)$ for the female population.

$${}_{n}q_{x}^{\,1970-72(C)} - {}_{n}q_{x}^{\,level\ y} \quad \text{and}$$

$${}_{n}q_{x}^{\,1970-72(A)} - {}_{n}q_{x}^{\,level\ y}$$

for y = 19 for females and y = 20 for males

x = 0,1,5,10, ..., 75

Here, ${}_{n}q_{x}^{\,level\ y}$ represents the mortality rates for Model North level y = 19 alternatively 20. The results of the calculations are presented in fig. 3. In addition, the mean square of differences has been computed:

$$s^2(C) = \frac{1}{m}\sum_{x}\left({}_{n}q_{x}^{\,1970-72(C)} - {}_{n}q_{x}^{\,level\ y}\right)^2$$

$$s^2(A) = \frac{1}{m}\sum_{x}\left({}_{n}q_{x}^{\,1970-72(A)} - {}_{n}q_{x}^{\,level\ y}\right)^2$$

for y = 19 and 20

x = 0,1,5,10, ...,75

m = 17

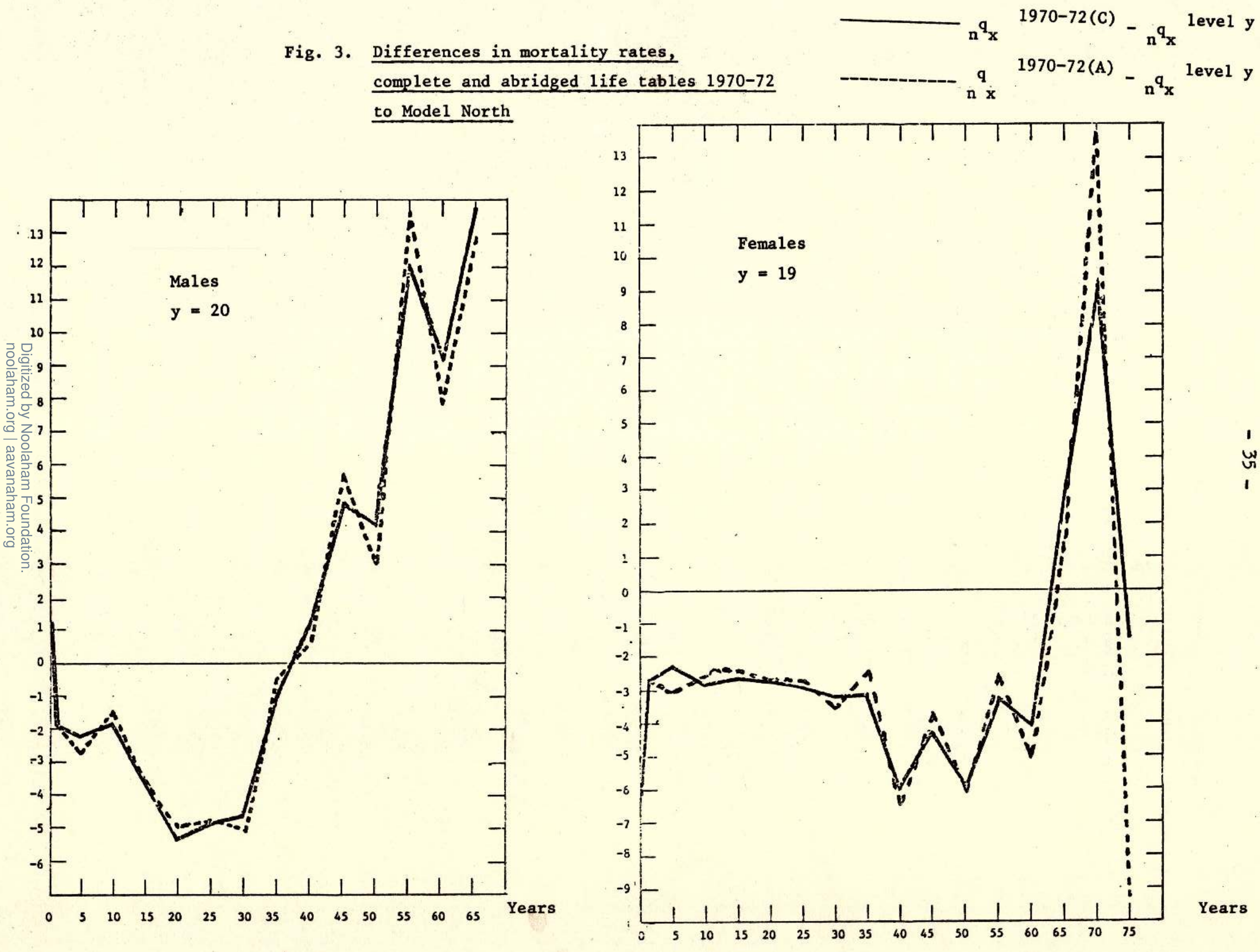
We obtain the following values of s^2:

	$s^2(C)$	$s^2(A)$
Males	96.32	92.85
Females	18.37	29.59

In this case, we find that for females, the interpolation and smoothing undertaken has produced a marked improvement - i.e. the complete life tables correspond more favourably with the model life tables than the abridged tables do. For males, we find that assessment from the values of s^2 indicates a less close correspondence to the model life tables for the complete than for the abridged life tables. However, if we consider the individual differences for males, we find that for most age groups the complete life tables furnish the closest approximation to the model life tables. On the other hand, the single difference of

$$\left({}_{5}q_{75}^{\,1970-72(C)} - {}_{5}q_{75}^{\,level\ 20}\right)$$

Fig. 3. Differences in mortality rates, complete and abridged life tables 1970-72 to Model North



is by itself so large that its removal from the expression of s^2 reverses the conclusion so that $s^2(C) < s^2(A)$ which indicates that the poor correspondence for the higher ages for males disturbes an overall picture that otherwise would have been satisfactory.

Appendix 1 - <u>Interpolation of single age deaths based on the Beers' modified formula</u>

```
C           PROGRAM TO READ THE INTERPOLATION COEFFICIENT MATRIX
C           FROM THE USER'S TERMINAL AND STORE IT ON A DISK FILE.
C           THE ROUTINE'SEARCH' IS A MACHINE-DEPENDENT ROUTINE
C           WHICH OPENS A FILE CALLED COEFMA ONTO WHICH THE MATRIX
C           IS WRITTEN, - STORED COLUMNWISE.
C
C
      REAL COEFMA (4,5,5)
      INTEGER Y,W,Z
      CALL SEARCH (2,'COEFMA', 1,0)
C           Y REPRESENTS THE NUMBER OF THE 4 ARRAYS.
C           W REPRESENTS THE COLUMN-NUMBER IN THE Y'TH ARRAY.
C           Z REPRESENTS THE ROW-NUMBER IN THE Y'TH ARRAY.
      DO 10 Y = 1,4
      DO 10 W = 1,5
      DO 10 Z = 1,5
      READ(1,1) COEFMA(Y,W,Z)
 10   CONTINUE
C
C           WRITE THE MATRIX OUT ON THE DISK FILE.
C

      WRITE (5,1) COEFMA
 1    FORMAT (F8,4)
      CALL EXIT
      END


C           INTERPOLATION OF SINGLE AGE DEATHS BASED ON THE BEERS' MODIFIED
C           FORMULA. FILE-UNIT 1 IS THE USER'S TERMINAL, FILE-UNIT 9
C           IS A DISK FILE UNIT WHERE THE RESULTS ARE WRITTEN.
C           THE OTHER FILES ARE INPUT DATA-FILES.
C           S. BERVEN CMI JUNE 1977
C           ======================
C

      INTEGER GRMAT(20),MATRIX(20),VECTOR(20),NAME(3)
      INTEGER *4  IDO
      REAL  COEFMA (4,5,5), MAS
      DATA GRMAT/ 1,1,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,16,16/
      DATA VECTOR/ 0,1,2,2,2,2,2,2,2,2,2,2,2,2,2,2,2,2,3,4/
      IDO = 0
      WRITE(1,3)
 3    FORMAT ('WHICH SEX IS TO BE INTERPOLATED (MASCULIN OR FEMININ) ')
C
C           INPUT NAME OF THE FILE CONTAINING THE DATA TO BE INTERPOLATED
C
      READ(1,4) (NAME(I), I=1,3)
 4    FORMAT (15A2)
      IF (NAME(1). EQ.2HMA) IHEAD=1
      IF(NAME (1). EQ.2HFE) IHEAD=0
C
C           OPEN FILES NAME & COEFMA FOR READING. THE FILE NAMED
C           FIL20 IS A FILE WHERE THE RESULTS ARE PLACED TO BE HANDLED
C           BY ANOTHER ROUTINE.
```

Appendix 1, contd.

```
C           THE FILE COEFMA CONTAINS THE DATA FOR THE INTERPOLATION COEFFICIENT
C           MATRIX.  THIS MATRIX SHOULD BE STORED ON DISK AND READ EACH TIME
C           THE PROGRAM RUNS.
C           THE SYSTEM SUBROUTINE 'SEARCH' OPENS FILES NAMES
C           AND COEFMA FOR READING ONLY, THE FILE FIL20 FOR WRITING
C           ONLY.
C
      CALL SEARCH (1,NAME,2,0)
      CALL SEARCH (1,'COEFMA',4,0)
      CALL SEARCH (2,'FIL20', 5,0)
      MAS = 0 . 0
      READ(6,1) MATRIX
      READ(8,2) COEFMA
 1    FORMAT (I10)
 2    FORMAT (F8.4)
      I10 = 0
      I11 = 5
      DO 100 I1=2,20
      DO 100 I2=1,5
      I7=GRMAT (I1)
      DO 50 I3=1,5
      I6=VECTOR (I1)
      MAS=MAS+MATRIX(I7) *COEFMA (I6,I3,I2)
 50   I7=I7+1
C
C           CALL TO PRINTOUT ROUTINE
C
      CALL PRINT(MAS,I10,IHEAD,IDO,I11)
 100  CONTINUE
      WRITE (1,55) IDO
 55   FORMAT(5X,'TOTAL NUMBER OF DEATHS FOR AGES 5-99:', I7)
C
C           CLOSE ALL FILES BEFORE EXIT
C
      CALL SEARCH(4,0,2,0)
      CALL SEARCH(4,0,4,0)
      CALL SEARCH(4,0,5,0)
      CALL EXIT
      END


C           PRINT-OUT ROUTINE FOR THE BEERS' INTERPOLATION. THIS
C           ROUTINE ALSO SUMS UP THE TOTAL NUMBER OF SINGLE AGE DEATHS
C           FOR AGES 5-99 IN THE VARIABLE IDO.
C
C           S. BERVEN CMI JUNE 1977
C           ========================
C
      SUBROUTINE PRINT (MAS,I10,IHEAD,IDO,I11)
      INTEGER *4  IDO
      REAL  MAS
      IF(I10.NE.0) GO TO 10
C
C           PRINT HEADING. FORMAT STMT. NO 1 CONTAINS TOP-OF-FORM PARAMETER.
C
```

Appendix 1, contd.

```
      WRITE (1,1)
1     FORMAT ('
             ','
    *
      IF (IHEAD.EQ.0)  WRITE (1,2)
      IF (IHEAD.EQ.1)  WRITE (1,4)
2     FORMAT (//,15X, 'DEATHS BY SINGLE AGE',/,15X,
    * 20 ('='),//,18X,'  AGE : FEMININ',/, 18X,' - - - - - -:- - - - - - - - -')
4     FORMAT (//,15X, 'DEATHS BY SINGLE AGE',/,15X,
    * 20 ('='),//,18X,'  AGE : MASCULIN',/,18X,' - - - - - -:- - - - - - - - -')
10    IMAS = INT (MAS+0.5)
      WRITE (9,61) IMAS
61    FORMAT (I10)
      WRITE (1,3) I11,IMAS
      IDO=IDO+IMAS
3     FORMAT (19X,I3,'    :     ',I6)
15    MAS = 0.0
      I10 = I10+1
      I11 = I11+1
      IF (I10.EQ.25) I10=0
      RETURN
      END
```

Appendix 2. Construction of complete life tables based on the entered variable d_x

```
C
C          CONSTRUCTION OF COMPLETE LIFE TABLES, BASED ON THE
C          ENTERED VARIABLE  D.
C                                X
C          READ DATA FROM FILE-UNIT 5.
C          FILE UNIT 1 IS THE USER'S TERMINAL.
C          S. BERVEN CMI JUNE 1977
C          =======================
C
C
      DOUBLE PRECISION L (100),D(100),R(100),T(100),
     * Q(100),E(100),P(100),K,M(100),A1,A2
      INTEGER*2  FILNAM (3), TEXT (9)
      INTEGER*4  UI (100),LX,RX,TX
      DATA TEXT/2HFE,2HMA,2HLE,2HS ,2H19,2H70,2H-1,
     * 2H97,2H2 /
      WRITE (1,1)
C
C          INPUT NAME OF DATAFILE (MASCULIN OR FEMININ).  THE SYSTEM
C          SUBROUTINE 'SEARCH' WILL OPEN THE FILE FOR READING ONLY.
C
 1    FORMAT ('WHICH DATAFILE')
      READ (1,2) (FILNAM (I), I=1,3)
 2    FORMAT (3A2)
C
C          OPEN DATAFILE NAMED CONTENTS OF FILNAM FOR READING
C
      CALL SEARCH (1,FILNAM,1,0)
C
C          THE DATA ARE FOR SPECIAL REASONS STORED AS INTEGERS, AND
C          MUST BE CONVERTED TO FLOATING POINT REAL NUMBERS.
C
      DO 9  I=1, 100
      READ (5,3) UI(I)
      D(I) = FLOAT (UI (I) )
 9    CONTINUE
 3    FORMAT (I10)
      L(1) = 100000.
      Q(1) = D(1) / L(1)
      DO 10 I=2, 100
      L(I) = L(I-1) -D(I-1)
      Q(I) = D(I) /L(I)
      M(I) = (2*Q(I) ) / (2-Q(I) )
 10   CONTINUE
C
C          CHECH WHETHER MASCULIN OR FEMININ AND COMPUTE K ACCORDINGLY.
C          THIS IS CARRIED OUT BY CHECKING THE FIRST TWO LETTERS OF THE
C          NAME OF THE DATAFILE.
C
      IF(FILNAM(1). EQ.2HFE) K=0.05+3.0*Q(1)
      IF(FILNAM(1). EQ.2HMA) K=0.0425+2.875*Q(1)
      R(1) = K*L (1) + (1-K) *L (2)
      DO  20  I=2,99
      R(I)=0.5*L (I) +0.5*L (I+1)
 20   CONTINUE
      R(100)=L(100) /M(100)
      DO 30 I=1,100
      T(I) = 0.
```

Appendix 2, contd.

```
      DO 25 J=I,100
      T(I)=R(J)+T(I)
 25   CONTINUE
      E(I)=T(I) /L(I)
 30   CONTINUE
      P(1)=R(1) /L(1)
      DO 40 I=2,99
      P(I)=R(I) /R(I-1)
 40   CONTINUE
C
C          THIS ROUTINE CANNOT HANDLE THE CONTENTS OF THE ELEMENT
C          P(100), THEREFORE THIS ELEMENT IS SET EQUAL TO 0.0
C
      P(100) = 0.0
C
C          PRINT OUT RESULTS
C
      IF(FILNAM(1).EQ.2HMA)  TEXT(1) =2H
 100  CONTINUE
      I2=20
      DO 150  I1=1,100
      IF (I2.NE.20) GO TO 110
      I2=0
 105  WRITE (1,4) (TEXT(I), I=1,9)
C
C          FORMAT - STMT.  NO 4 CONTAINS TOP-OF-FORM PARAMETER.
C
 4    FORMAT (' 214','
     *                                        ',//,'
     *                               ',/,
     * 15X,'COMPLETE LIFE TABLES FOR SRI LANKA - ',9A2,/,15X,54('-'),//,
     * 5X,74 ('-'),/,5X,
     * 'AGE:PROBABILI-:SURVIVORS :NUMBER OF:YEARS   :CUMULATED : EXPEC-:',
     * 'PROBABILI - :',/, 8X,
     * ':TY OF DYI - :AT EXACT   :DEATHS    :LIVED    :PERSON-    :TATION:',
     * 'TY OF     :',/,8X,
     * ':NG BETWEEN : AGE X      :BETWEEN   :BETWEEN  :YEARS      :OF LI-:',
     * 'SURVIVAL  :',/,8X,
     * ':AGES X AND: ',10X,':AGES X    : AGES X    :LIVED AT     :FE AT :',
     * 10X,':',/,8X,
     * ':X+1',7X,':',10X,':AND X+1  :AND X+1  :AGE X AND  :AGE X :',10X,
     *':',/,8X,':',10X,':',10X,':',9X,':',8X,':OVER        :',6X,':',
     * 10X,':',/,5X,74 ('-'),/,6X,'X ',
     * ,':    Q     :     1     :     D     :     L     :     T     :     E     :'
     * ,'   P    :',/,8X,
     * ,':     X     :     X     :     X     :     X     :     X     :',
     * ,'    X    :    X    :',
     * /,5X,74 ('-') )
 110  CONTINUE
      A1=FLOAT (I1)
      A1=A1/5
      A2=FLOAT (INT(A1) )
      I=I1-1
C
C          L(I),R(I) & T(I) MUST BE CONVERTED TO INTEGERS BEFORE
C          PRINTOUT.
C
      LX=INTL (L (I1) )
      RX=INTL (R (I1) )
```

Appendix 2, contd.

```
      TX=INTL (T( I1) )
      WRITE (1,5)I,Q(I1),LX,UI(I1),RX,TX,E(I1),P(I1)
      IF (A1.EQ.A2) WRITE (1,6)
 5    FORMAT (5X,I3,': ',F7.5,' : ',I7,' : ',I4,' : ',I6,' : ',
     * I8,' : ',F5.2,' :',F8.6,' : ')
      I2=I2+1
 150  CONTINUE
 6    FORMAT (/)
C
C          CLOSE THE DATA-FILE BEFORE EXIT
C
      CALL SEARCH (4,0,1,0)
      CALL EXIT
      END
```

Appendix 3.

COMPLETE LIFE TABLES FOR SRI LANKA - MALES 1970 - 1972.

AGE	PROBABILITY OF DYING BETWEEN AGES X AND X+1	SURVIVORS AT EXACT AGE X	NUMBER OF DEATHS BETWEEN AGES X AND X+1	YEARS LIVED BETWEEN AGES X AND X+1	CUMULATED PERSON-YEARS LIVED AT AGE X AND OVER	EXPECTATION OF LIFE AT AGE X	PROBABILITY OF SURVIVAL
X	Q X	1 X	D X	L X	T X	E X	P X
0	0.05001	100000	5001	95930	6419613	64.20	0.959306
1	0.00729	94999	693	94652	6323682	66.57	0.986677
2	0.00554	94306	522	94045	6229030	66.05	0.993582
3	0.00439	93784	412	93578	6134985	65.42	0.995034
4	0.00345	93372	322	93211	6041407	64.70	0.996078
5	0.00272	93050	253	92923	5948196	63.92	0.996916
6	0.00211	92797	196	92699	5855272	63.10	0.997584
7	0.00164	92601	152	92525	5762573	62.23	0.998123
8	0.00131	92449	121	92388	5670048	61.33	0.998525
9	0.00109	92328	101	92277	5577660	60.41	0.998799
10	0.00098	92227	90	92182	5485382	59.48	0.998965
11	0.00094	92137	87	92093	5393200	58.53	0.999040
12	0.00098	92050	90	92005	5301107	57.59	0.999039
13	0.00105	91960	97	91911	5209102	56.65	0.998984
14	0.00114	91863	105	91810	5117190	55.70	0.998901
15	0.00125	91758	115	91700	5025380	54.77	0.998802
16	0.00139	91643	127	91579	4933679	53.84	0.998680
17	0.00153	91516	140	91446	4842100	52.91	0.998542
18	0.00169	91376	154	91299	4750654	51.99	0.998392
19	0.00185	91222	169	91137	4659355	51.08	0.998231
20	0.00200	91053	182	90962	4568217	50.17	0.998074
21	0.00212	90871	193	90774	4477255	49.27	0.997939
22	0.00223	90678	202	90577	4386481	48.37	0.997824
23	0.00231	90476	209	90371	4295904	47.48	0.997731
24	0.00237	90267	214	90160	4205532	46.59	0.997660
25	0.00240	90053	216	89945	4115372	45.70	0.997615
26	0.00240	89837	216	89729	4025427	44.81	0.997599
27	0.00240	89621	215	89513	3935698	43.91	0.997598
28	0.00239	89406	214	89299	3846185	43.02	0.997604
29	0.00241	89192	215	89084	3756886	42.12	0.997598
30	0.00245	88977	218	88868	3667801	41.22	0.997570
31	0.00253	88759	225	88646	3578933	40.32	0.997508
32	0.00268	88534	237	88415	3490287	39.42	0.997394
33	0.00287	88297	253	88170	3401871	38.53	0.997229
34	0.00309	88044	272	87908	3313701	37.64	0.997023
35	0.00334	87772	293	87625	3225793	36.75	0.996786
36	0.00360	87479	315	87321	3138167	35.87	0.996531
37	0.00387	87164	337	86995	3050846	35.00	0.996267
38	0.00411	86827	357	86648	2963850	34.14	0.996011
39	0.00435	86470	376	86282	2877202	33.27	0.995770

Appendix 3, contd.

X	Q X	1 X	D X	L X	T X	E X	F X
40	0.00460	86094	396	85896	2790920	32.42	0.995526
41	0.00488	85698	418	85489	2705024	31.56	0.995262
42	0.00521	85280	444	85058	2619535	30.72	0.994958
43	0.00559	84836	474	84599	2534477	29.88	0.994604
44	0.00602	84362	508	84108	2449878	29.04	0.994196
45	0.00648	83854	543	83582	2365770	28.21	0.993752
46	0.00695	83311	579	83021	2282187	27.39	0.993288
47	0.00742	82732	614	82425	2199166	26.58	0.992815
48	0.00788	82118	647	81794	2116741	25.78	0.992351
49	0.00836	81471	681	81130	2034946	24.98	0.991882
50	0.00889	80790	718	80431	1953816	24.18	0.991378
51	0.00950	80072	761	79691	1873385	23.40	0.990806
52	0.01023	79311	811	78905	1793693	22.62	0.990137
53	0.01107	78500	869	78065	1714788	21.84	0.989354
54	0.01203	77631	934	77164	1636722	21.08	0.988452
55	0.01308	76697	1003	76195	1559558	20.33	0.987449
56	0.01415	75694	1071	75158	1483363	19.60	0.986390
57	0.01522	74623	1136	74055	1408204	18.87	0.985318
58	0.01629	73487	1197	72888	1334149	18.15	0.984248
59	0.01739	72290	1257	71661	1261261	17.45	0.983166
60	0.01855	71033	1318	70374	1189599	16.75	0.982034
61	0.01985	69715	1384	69023	1119225	16.05	0.980803
62	0.02135	68331	1459	67601	1050202	15.37	0.979405
63	0.02309	66872	1544	66100	982601	14.69	0.977789
64	0.02512	65328	1641	64507	916501	14.03	0.975908
65	0.02748	63687	1750	62812	851993	13.38	0.973716
66	0.03021	61937	1871	61001	789181	12.74	0.971176
67	0.03328	60066	1999	59066	728180	12.12	0.968279
68	0.03668	58067	2130	57002	669113	11.52	0.965048
69	0.04042	55937	2261	54806	612111	10.94	0.961484
70	0.04443	53676	2385	52483	557305	10.38	0.957615
71	0.04876	51291	2501	50040	504821	9.84	0.953452
72	0.05337	48790	2604	47488	454781	9.32	0.948991
73	0.05829	46186	2692	44840	407293	8.82	0.944239
74	0.06350	43494	2762	42113	362453	8.33	0.939184
75	0.06916	40732	2817	39323	320340	7.86	0.933762
76	0.07535	37915	2857	36486	281016	7.41	0.927855
77	0.08232	35058	2886	33615	244530	6.98	0.921300
78	0.09014	32172	2900	30722	210915	6.56	0.913937
79	0.09890	29272	2895	27824	180193	6.16	0.905686

Appendix 3, contd.

X	Q_X	l_X	D_X	L_X	T_X	E_X	P_X
80	0.10854	26377	2863	24945	152368	5.78	0.896530
81	0.11891	23514	2796	22116	127423	5.42	0.886573
82	0.12994	20718	2692	19372	105307	5.08	0.875927
83	0.14157	18026	2552	16750	85935	4.77	0.864650
84	0.15381	15474	2380	14284	69185	4.47	0.852776
85	0.16641	13094	2179	12004	54901	4.19	0.840416
86	0.17948	10915	1959	9935	42896	3.93	0.827648
87	0.19317	8956	1730	8091	32961	3.68	0.814353
88	0.20772	7226	1501	6475	24870	3.44	0.800334
89	0.22376	5725	1281	5084	18394	3.21	0.785190
90	0.24122	4444	1072	3908	13310	3.00	0.768610
91	0.26038	3372	878	2933	9402	2.79	0.750512
92	0.28067	2494	700	2144	6469	2.59	0.730992
93	0.30268	1794	543	1522	4325	2.41	0.710121
94	0.32614	1251	408	1047	2802	2.24	0.687685
95	0.35113	843	296	695	1755	2.08	0.663801
96	0.37843	547	207	443	1060	1.94	0.638129
97	0.40588	340	138	271	617	1.82	0.611048
98	0.43564	202	88	158	346	1.71	0.583026
99	0.46491	114	53	188	188	1.65	0.000000

Appendix 3, contd.

COMPLETE LIFE TABLES FOR SRI LANKA - FEMALES 1970 - 1972

AGE:	PROBABILITY OF DYING BETWEEN AGES X AND X+1	SURVIVORS AT EXACT AGE X	NUMBER OF DEATHS BETWEEN AGES X AND X+1	YEARS LIVED BETWEEN AGES X AND X+1	CUMULATED PERSON-YEARS LIVED AT AGE X AND OVER	EXPECTATION OF LIFE AT AGE X	PROBABILITY OF SURVIVAL
X	Q_X	1_X	D_X	L_X	T_X	E_X	P_X
0	0.04181	100000	4181	96552	6702885	67.03	0.965525
1	0.00941	95819	902	95368	6606332	68.95	0.987732
2	0.00624	94917	592	94621	6510964	68.60	0.992167
3	0.00486	94325	458	94096	6416343	68.02	0.994452
4	0.00382	93867	359	93687	6322247	67.35	0.995659
5	0.00302	93508	282	93367	6228560	66.61	0.996579
6	0.00232	93226	216	93118	6135193	65.81	0.997333
7	0.00176	93010	164	92928	6042075	64.96	0.997960
8	0.00136	92846	126	92783	5949147	64.08	0.998440
9	0.00108	92720	100	92670	5856364	63.16	0.998782
10	0.00093	92620	86	92577	5763694	62.23	0.998996
11	0.00088	92534	81	92493	5671117	61.29	0.999098
12	0.00090	92453	83	92411	5578623	60.34	0.999113
13	0.00096	92370	89	92325	5486212	59.39	0.999069
14	0.00105	92281	97	922232	5393886	58.45	0.998993
15	0.00116	92184	107	92130	5301654	57.51	0.998894
16	0.00126	92077	116	92019	5209523	56.58	0.998790
17	0.00138	91961	127	91897	5117504	55.65	0.998680
18	0.00150	91834	138	91765	5025607	54.72	0.998558
19	0.00162	91696	149	91621	4933842	53.81	0.998436
20	0.00173	91547	158	91468	4842220	52.89	0.998325
21	0.00183	91389	167	91305	4750752	51.98	0.998223
22	0.00192	91222	175	91134	4659447	51.08	0.998127
23	0.00201	91047	183	90955	4568312	50.18	0.998036
24	0.00209	90864	190	90769	4477357	49.28	0.997950
25	0.00216	90674	196	90576	4386588	48.38	0.997874
26	0.00222	90478	201	90377	4296012	47.48	0.997808
27	0.00226	90277	204	90175	4205634	46.59	0.997759
28	0.00231	90073	208	89969	4115459	45.69	0.997716
29	0.00234	89865	210	89760	4025490	44.79	0.997677
30	0.00239	89655	214	89548	3935730	43.90	0.997638
31	0.00246	89441	220	89331	3846182	43.00	0.997577
32	0.00254	89221	227	89107	3756851	42.11	0.997498
33	0.00266	88994	237	88875	3667744	41.21	0.997396
34	0.00279	88757	248	88633	3578868	40.32	0.997271
35	0.00293	88509	259	88379	3490235	39.43	0.997140
36	0.00304	88250	268	88116	3401856	38.55	0.997019
37	0.00313	87982	275	87844	3313740	37.66	0.996919
38	0.00319	87707	280	87567	3225895	36.78	0.996841
39	0.00324	87427	283	87285	3138328	35.90	0.996785

Appendix 3, contd.

X	Q X	1 X	D X	L X	T X	E. X	P X
40	0.00328	87144	286	87001	3051043	35.01	0.996741
41	0.00335	86858	291	86712	2964042	34.13	0.996684
42	0.00347	86567	300	86417	2877329	33.24	0.996592
43	0.00364	86267	314	86110	2790912	32.35	0.996447
44	0.00386	85953	332	85787	2704802	31.47	0.996249
45	0.00413	85621	354	85444	2619015	30.59	0.996002
46	0.00444	85267	379	85077	2533571	29.71	0.995711
47	0.00476	84888	404	84686	2448494	28.84	0.995398
48	0.00509	84484	430	84269	2363808	27.98	0.995076
49	0.00543	84054	456	83826	2279539	27.12	0.994743
50	0.00579	83598	484	83356	2195713	26.27	0.994393
51	0.00618	83114	514	82857	2112357	25.42	0.994014
52	0.00665	82600	549	82325	2029500	24.57	0.993585
53	0.00718	82051	589	81756	1947174	23.73	0.993088
54	0.00778	81462	634	81145	1865418	22.90	0.992520
55	0.00844	80828	682	80487	1784273	22.07	0.991891
56	0.00916	80146	734	79779	1703786	21.26	0.991204
57	0.00994	79412	789	79017	1624007	20.45	0.990455
58	0.01077	78623	847	78199	1544989	19.65	0.989648
59	0.01171	77776	911	77320	1466790	18.86	0.988760
60	0.01278	76865	982	76374	1389469	18.08	0.987759
61	0.01403	75883	1065	75350	1313095	17.30	0.986599
62	0.01549	74818	1159	74238	1237745	16.54	0.985242
63	0.01720	73659	1267	73025	1163506	15.80	0.983661
64	0.01917	72392	1388	71698	1090481	15.06	0.981821
65	0.02149	71004	1526	70241	1018783	14.35	0.979679
66	0.02421	69478	1682	68637	948542	13.65	0.977164
67	0.02727	67796	1849	66871	879905	12.98	0.974278
68	0.03069	65947	2024	64935	813033	12.33	0.971041
69	0.03442	63923	2200	62823	748098	11.70	0.967475
70	0.03833	61723	2366	60540	685275	11.10	0.963660
71	0.04232	59357	2512	58101	624735	10.53	0.959713
72	0.04637	56845	2636	55527	566634	9.87	0.955698
73	0.05043	54209	2734	52842	511107	9.43	0.951645
74	0.05455	51475	2808	50071	458265	8.90	0.947561
75	0.05899	48667	2871	47231	408194	8.39	0.943291
76	0.06407	45796	2934	44329	360963	7.88	0.938547
77	0.07006	42862	3003	41360	316634	7.39	0.933035
78	0.07720	39859	3077	38320	275273	6.91	0.926500
79	0.08567	36782	3151	35206	236953	6.44	0.918738

Appendix 3, contd.

X	Q_X	l_X	D_X	L_X	T_X	E_X	P_X
80	0.09545	33631	3210	32026	201746	6.00	0.909662
81	0.10644	30421	3238	28802	169720	5.58	0.899332
82	0.11853	27183	3222	25572	140918	5.18	0.887855
83	0.13171	23961	3156	22383	115346	4.81	0.875293
84	0.14597	20805	3037	19286	92963	4.47	0.861658
85	0.16102	17768	2861	16337	73677	4.15	0.847095
86	0.17676	14907	2635	13589	57339	3.85	0.831798
87	0.19361	12272	2376	11084	43750	3.57	0.815630
88	0.21170	9896	2095	8848	32666	3.30	0.798313
89	0.23138	7801	1805	6898	23817	3.05	0.779624
90	0.25250	5996	1514	5239	16919	2.82	0.759440
91	0.27532	4482	1234	3865	11680	2.61	0.737736
92	0.29957	3248	973	2761	7815	2.41	0.714489
93	0.32527	2275	740	1905	5053	2.22	0.689842
94	0.35244	1535	541	1264	3148	2.05	0.663780
95	0.38129	994	379	804	1884	1.90	0.636220
96	0.41138	615	253	488	1079	1.76	0.607209
97	0.44199	362	160	282	591	1.63	0.577277
98	0.47525	202	96	154	309	1.53	0.546099
99	0.50943	106	54	155	155	1.46	0.000000