

Methodology Note on the Human Life-Table Database (HLD)

by Vladimir M. Shkolnikov

With assistance from Evgeniy M. Andreev (Centre of Demography and Human Ecology, Moscow), Jacques Vallin and France Meslé (Institut national d'études démographiques, Paris), Carl Boe and John R. Wilmoth (University of California at Berkeley), Sigrid Gellers-Barkmann (Max Planck Institute for Demographic Research)

Introduction

Life tables describe the extent to which a generation of people (the life table cohort) dies off with age. Life tables are the most ancient and important tool in demography. They are widely used for descriptive and analytical purposes in demography, public health, epidemiology, population geography, biology and many other branches of science.

The Human Life-Table Database is a collection of population life tables for a multitude of countries and many years. Most of the HLD life tables are life tables for national populations, which have been officially published by national statistical offices. Some of the HLD life tables refer to certain regional or ethnic sub-populations within countries. Part of the HLD life tables are non-official life tables produced by researchers.

HLD includes the following types of data:

- complete life tables in text format;
- abridged life tables in text format;
- references to statistical publications and other data sources;
- scanned copies of the original life tables as they were published.

Three scientific institutions are jointly developing the HLD: [the Max Planck Institute for Demographic Research](#) (MPIDR) in Rostock, Germany, the [Department of Demography at the University of California at Berkeley](#), USA and the [Institut national d'études démographiques](#) (INED) in Paris, France. The MPIDR is responsible for maintaining the database. A big set of life tables were collected for and given to the HLD by Dr. Väinö Kannisto, a former United Nations advisor on demographic and social statistics. Professor J.W.Vaupel, Founding Director of the MPIDR provided general guidance to the HLD project.

Method of calculation

A life table is a rectangular matrix, showing changes in a standard set of life table functions (columns) across ages (rows). The conventional set of life table functions includes: probability of death within elementary age interval $[x, x+1)$ ${}_1q_x$, probability of survival from birth to exact age x l_x , number of deaths within the elementary age interval $[x, x+1)$ ${}_1d_x$, central death rate for the age interval $[x, x+1)$ ${}_1M_x$, number of person-years lived within the elementary age interval $[x, x+1)$ ${}_1L_x$, number of person-years lived after the exact age x T_x , and life expectancy at exact age x e_x . The first three functions are frequency (or intensity) measures since they show frequencies of

events (deaths or survival). The last three functions are duration measures since they show amounts of lifetime and are measured in person-years.

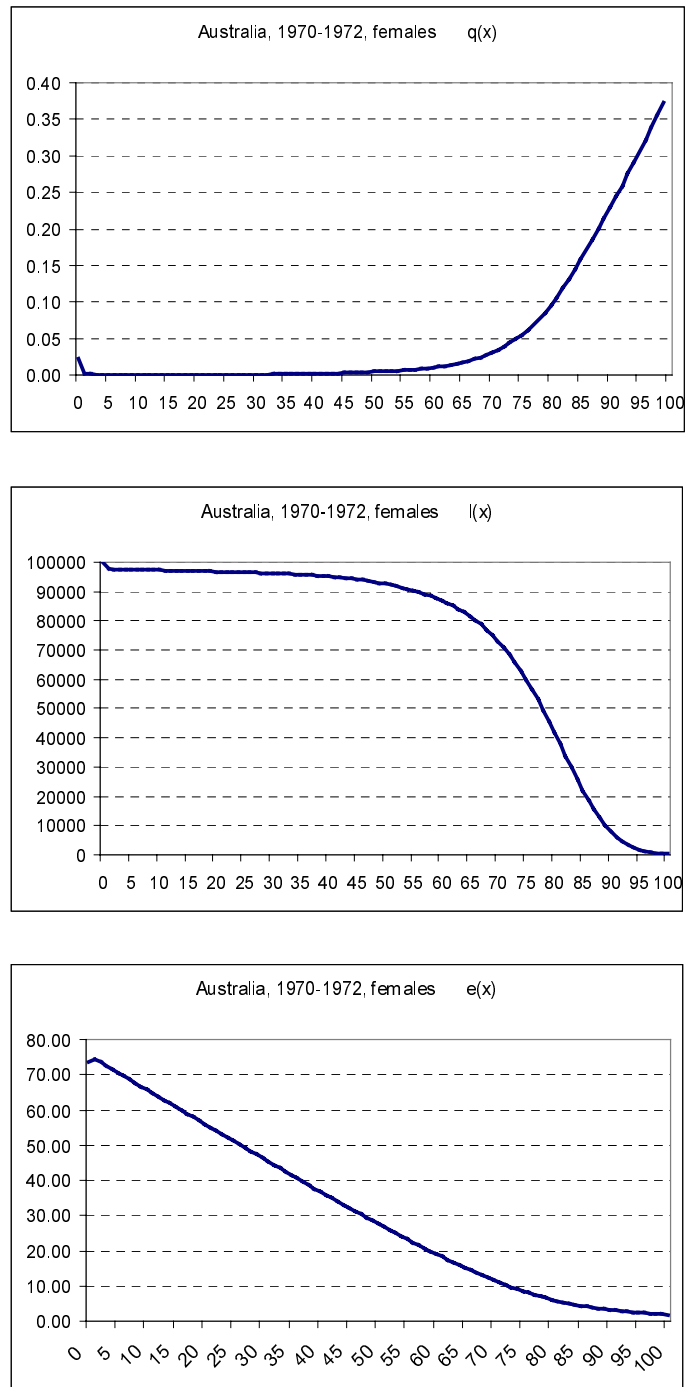


Figure 1. An example of life table functions: probability of death at age x , probability of survival to age x (from 100,000 at age 0), life expectancy at age x (in years).

Life tables differ with respect to the width of elementary age intervals. Complete life tables are based on one-year age intervals, while abridged life tables are based on wider age categories. Usually, these are age groups 0, 1-4, 5-9, 10-14, 20-24,

For a more detailed description of life tables and methods for their construction, see the textbooks by Preston, Heuveline, Guillot (2001), Keyfitz (1985) and Chiang (1984).

HLD mostly relies on published life tables. Life tables published in different countries and years represent a variety of methods for their calculation and presentation in print. They depend on both national and historical peculiarities and on the availability and quality of vital statistics.

The majority of the HLD life tables are *original, complete* life tables. Some users, however, might prefer abridged life tables as a shorter form of the complete ones. For this reason, the HLD presents also abridged life tables calculated from the complete ones.

Complete life tables are rarely available for developing countries and for the historical populations of today's developed countries. However, for some of them, there are abridged life tables. Therefore, the HLD includes *original, abridged* life tables.

Usually not all of the standard life table functions (columns) described above are shown in published life tables.

Almost all published life tables include the column of life expectancies e_x . It shows how many years an average individual at exact age x can expect to live after this age. In a *period life table*, life expectancy estimates correspond to age-specific intensities of death at age x and older ages observed in a given calendar year or during a short calendar period. In a *cohort life table*, life expectancy estimates correspond to age-specific intensities of death at age x and older ages observed for a birth cohort during a long calendar period.

Columns q_x and l_x are also published frequently. However, columns ${}_1d_x, {}_1M_x, {}_1L_x, T_x$ are omitted in many publications. Later on we will show that the absence of columns ${}_1T_x$ and ${}_1L_x$ causes certain difficulties for the computation of exact values of these functions.

The absence of life table parameters in publications is an important disadvantage since users might need some of the missing parameters. Therefore, the HLD provides to a user all of the standard life table columns.

There are different ways for the calculation of missing life table functions.

HLD provides six types of life tables computed from original, complete or abridged life tables by two methods. One method allows for the computation of missing life table functions from two original life table functions of frequency and duration. Life tables of types 1, 2, and 5 are computed by this method. Another method allows computing all life table functions from one original frequency function (life tables of types 3, 4, and 6).

Type 1: Complete life tables.

This type of the HLD life tables closely resembles to the original, published tables. The calculation procedure ensures that one frequency function (${}_1q_x$ or l_x) and one duration function (${}_1T_x, {}_1L_x$ or e_x) of the original, published life table are preserved

without changes. It means that all values of life expectancy e_x of the type 1 life table are exactly or almost exactly as in the original.

In the type 1 life table, one of the original columns l_x , ${}_1q_x$ or ${}_1d_x$, dependent on their availability, is taken as a frequency function and one of the columns T_x , ${}_1L_x$ or e_x is taken as a duration function for further calculations.

Let us assume, first, that l_x and T_x are available from the original life table. Then all other life table functions can be computed in the following way

$${}_1d_x = l_x - l_{x+1}, {}_1q_x = {}_1d_x / l_x, {}_1L_x = T_x - T_{x+1}, e_x = T_x / l_x. \quad (1)$$

If ${}_1q_x$ is available from the published table instead of l_x , then l_x can be calculated from ${}_1q_x$:

$$l_0 = 100000, l_1 = l_0 - l_0 \cdot {}_1q_0, l_2 = l_1 - l_1 \cdot {}_1q_1, \dots, l_{x+1} = l_x - l_x \cdot {}_1q_x, \dots \quad (2)$$

If ${}_1d_x$ is available instead of l_x or ${}_1q_x$, then l_x and ${}_1q_x$ can be calculated from ${}_1d_x$:

$$l_0 = 100000, l_1 = l_0 - {}_1d_0, {}_1q_0 = {}_1d_0 / l_0, \dots \quad (3)$$

If ${}_1L_x$ is available instead of T_x , then T_x can be calculated from ${}_1L_x$:

$$T_x = \sum_{t \geq x} {}_1L_t. \quad (4)$$

Finally, if T_x and ${}_1L_x$ are not published in the original source, then it is still possible to compute T_x from e_x as $T_x = l_x \cdot e_x$. However, the values of T_x and especially their first differences ${}_1L_x$ resulting from such calculation are relatively imprecise since the values of e_x in most publications are given only with one or two decimal positions after the point. Figure 2 shows a comparison of ${}_1L_x$, calculated from the original, published T_x , with ${}_1L_x$ calculated from $T_x = l_x \cdot e_x$. In the latter case, ${}_1L_x$ values experience random fluctuations. At ages of low mortality (from 5 to 15) it can even result in values of ${}_1L_x$ higher than 100000.

This is an inevitable disadvantage of the type 1 complete life table where T_x or ${}_1L_x$ are not available. In such cases, these columns can be computed only approximately. The problem is more severe for small populations. It diminishes in abridged life tables with wider age intervals containing more deaths.

For the highest age ω , the published values of the life expectancy e_ω and of the probability of death q_ω are used for computation of other functions. If the last age interval is open ended, then ${}_\infty q_\omega = 1$ otherwise ${}_1q_\omega \leq 1$.

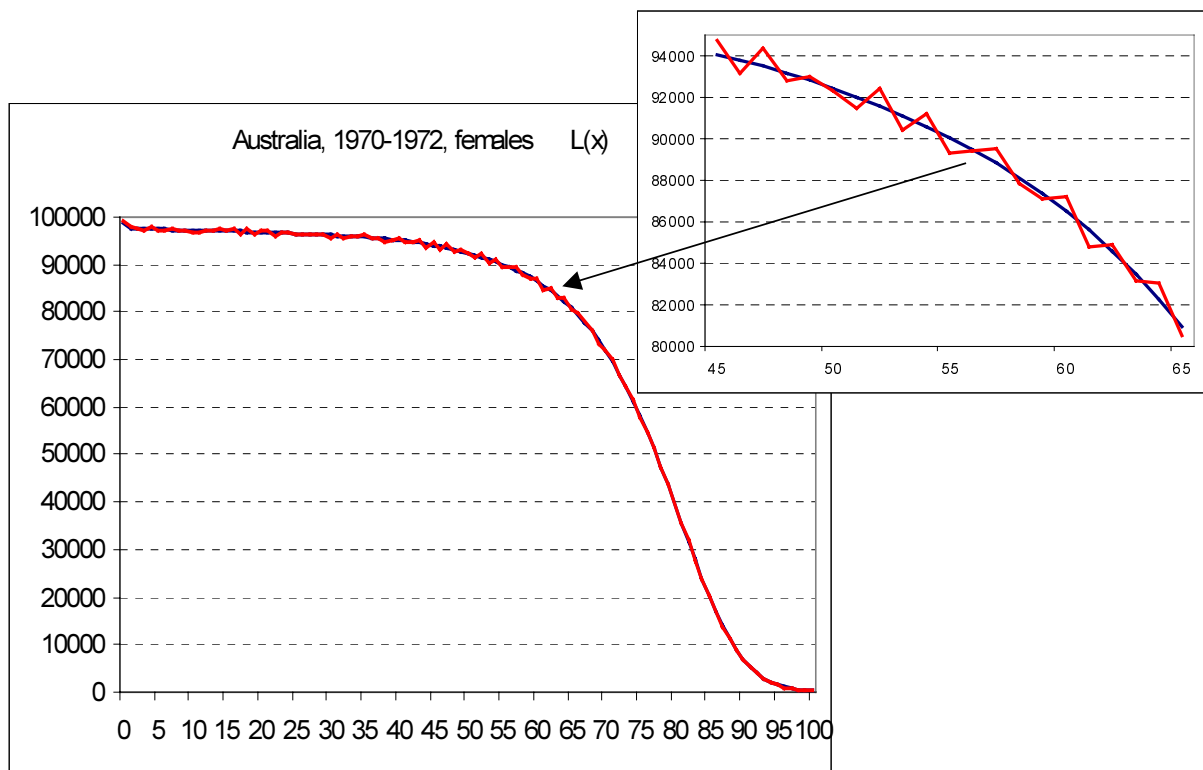


Figure 2. Comparison between ${}_1L_x$, calculated from the original, published T_x (blue curve) with ${}_1L_x$ calculated from $T_x = l_x \cdot e_x$ (red curve).

Type 3: Recalculated complete life tables.

Complete life tables of type 1 include two original, published life table functions and preserve the original values of e_x . However, methods for the life table computation have been changing with time and have been different in different countries. This concerns two major parts of the life table construction: calculation of the probabilities of death from the raw data on deaths and population at risk and transition from the probabilities of death to the duration measures. The HLD does not deal with the first issue because it relies on the published values of ${}_1q_x$ (or l_x or ${}_1d_x$). However, the HLD has to address the second issue by providing "recalculated" life tables of type 3, which are computed from only one frequency measure ${}_1q_x$ (or l_x or ${}_1d_x$) in a completely uniform way for all countries and all years. This means that period- or country-specific peculiarities of methods, originally used for the computation, are eliminated and that the type 3 life tables are comparable in respect to countries and calendar years.

A disadvantage of this approach is that the calculated values of life expectancy e_x are slightly different from the published ones.

The procedure to compute ${}_1L_x$ from ${}_1q_x$ begins from the calculation of l_x according to formula (2). For the first year of life we apply a formula very similar to that used in the Coale-Demeny model life tables:

$${}_1L_0 = \begin{cases} 0.35 \cdot l_0 + 0.65 \cdot l_{1,1}q_0 > 0.1 \\ (0.05 + 3 \cdot {}_1q_0) \cdot l_0 + (0.95 - 3 \cdot {}_1q_0) \cdot l_0 \cdot q_0 \leq 0.1 \end{cases} \quad (5)$$

For older ages, ${}_1L_x$ is computed by averaging neighboring values of l_x :

$${}_1L_x = \frac{1}{2} \cdot (l_x + l_{x+1}).$$

T_x is computed by applying (4) and $e_x = T_x / l_x$.

The simple method for the closing of the type 1 life tables can not be applied for closing the type 3 life tables because recalculated life tables are based on ${}_1q_x$ and the original value of e_ω can not be used.

First of all, we have to define which age is to be considered as the last age ω in the recalculated life table. Let age X be the last age, for which the value of ${}_1q_x$ is not missing. If ${}_1q_x = 1$, then the last age is defined as $\omega = X$ and ${}_\infty d_\omega = l_{X-1}$. If ${}_1q_x < 1$, then the last age is defined as $\omega = X + 1$ and ${}_\infty d_\omega = l_x$.

The last life expectancy at age ω is taken from the table of correspondence between e_ω and e_0 in appendix 1. In order to construct this table we used long series of life tables of France and Sweden from two data sources:

1) The Berkeley Mortality Database (<http://demog.berkeley.edu/wilmoth/mortality>) for the Swedish life tables in 1861-1995 and for the French life tables in 1899-1995.

2) Data files from the CD enclosed in the publication by Vallin and Meslé (2001) for the French life tables in 1806-1898.

Establishing the correspondence between e_ω and e_0 includes two steps:

1) For each interval of life expectancy at birth (<35, 35-39, 40-44,..., ≥80 for women and <35, 35-39, 40-44,..., ≥75 for men) the mean values of life expectancy at ages $\omega = 75, 76, \dots, 107$ are computed.

2) Some of these values experienced random fluctuations. These fluctuations were smoothed by the splines and the values of e_ω are extrapolated up to age $\omega = 120$ (see Appendix 1).

These model values are used in the type 3 life tables as the values of e_ω . Remaining duration functions are computed as ${}_\infty L_\omega = T_\omega = l_\omega \cdot e_\omega$.

Type 2: Abridged life tables computed from complete life tables

These abridged life tables are computed from the type 1 complete life tables. Their calculation is very simple.

For the elementary age interval $[x, x+n)$, the functions of the abridged life table are

$${}_n d_x = l_x - l_{x+n}, {}_n q_x = {}_n d_x / l_x, {}_n L_x = T_x - T_{x+n}, e_x = T_x / l_x. \quad (6)$$

Type 4: Abridged life tables computed from recalculated complete life tables

These abridged life tables are computed from the type 3 complete life tables. They are constructed by applying formula (6) to respective recalculated complete life tables.

Type 5: Abridged life tables

For some countries/time periods, complete life tables are unavailable, but abridged life tables exist. Type 5 of the HLD life tables is very close to the original, published abridged tables. The calculation procedure is similar to that for type 1 complete life tables. It ensures that one frequency function and one duration function of the original, published life table is preserved without changes in the type 1 table. Values of life expectancy e_x are exactly or almost exactly as those in the original tables.

In the type 5 life table, one of the original columns l_x , ${}_n q_x$ or ${}_n d_x$, dependent on their availability, is taken as a frequency measure. One of the columns T_x , ${}_n L_x$ or e_x is taken as a duration measure.

In an abridged life table, the length of the elementary age interval is n . After replacement of ${}_1 q_x$ by ${}_n q_x$, ${}_1 d_x$ by ${}_n d_x$ and ${}_1 L_x$ by ${}_n L_x$, formulae (1)–(4) are used for the calculation.

Type 6: Recalculated abridged life tables

In life tables of type 6, all functions have to be calculated from ${}_n q_x$. Transition from ${}_n q_x$ to ${}_n L_x$ is central for this calculation.

Formula (5) yields ${}_1 L_0$ for the first age group (age 0). For the second age group (1-4 years) another approximate relationship by Coale-Demeny (1983) is applied:

$${}_4 L_1 = k_1 l_1 + (1 - k_1) l_4,$$

where k_1

	Males	Females
$q_0 \leq 0.01$	$1.653 - 3.013 \cdot q_0$	$1.524 - 1.627 \cdot q_0$
$q_0 > 0.01$	1.352	1.361

For age groups 5-9, 10-14, ${}_5 L_x = \frac{1}{2} \cdot (l_x + l_{x+5})$.

Formats for data presentation

Images of published life tables are on the web in portable document format (.pdf) as shown in Figure 3.

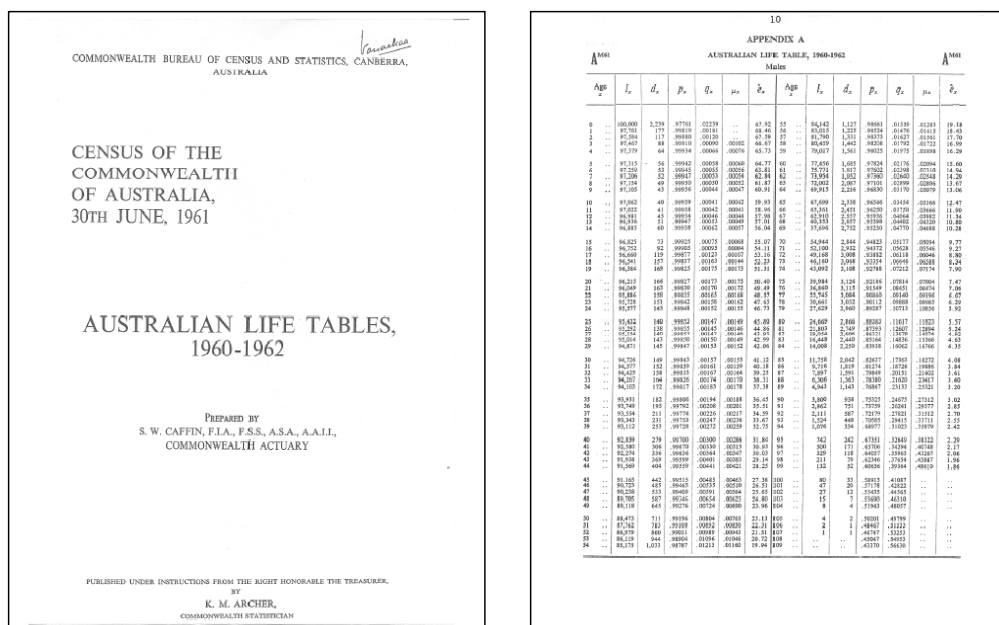


Figure 3. Presentation of the published Australian life table for the period 1960-62 in PDF format.

The HLD life tables are given in a tabular form as text files with comma-separated values. The following columns are given in each table:

- Country United Nations 4-digit country-code followed by two digits, which are used for the additional coding of ethnic groups or regions within a country (when needed)
- Year1 Beginning of the calendar period
- Year2 End of the calendar period
- TypeLT Type of HLD life table (see explanations in the section "Methods of calculation")
- Sex 1-males 2-females
- Age Lower limit of age interval (age x)
- AgeInt Length of age interval. Usually has values of 1, 4 or 5. Value 99 is used for the age group ω in recalculated life tables of types 3, 4 or 6 with $q_{\omega} = 1$
- m(x) Central death rate at age x

$q(x)$	Probability of death at age x
$l(x)$	Number of survivors to age x
$d(x)$	Death number at age x
$L(x)$	Number of person-years lived at age x
$T(x)$	Number of person-years lived after age x
$e(x)$	Life expectancy at age x

The columns of the original, published life table, which are used to produce HLD life tables of types 1, 2, 5 and 6, are marked by an asterisk e.g. " $l(x)^*$ ", " $e(x)^*$ ".

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APPENDIX 1

Correspondence between the levels of life expectancy at birth and the last life expectancy e_{ω} .

Males

Last age	Life expectancy at birth									
	-35	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75+
75	5.97	6.17	6.37	6.57	6.78	6.98	7.18	7.60	8.43	9.48
76	5.64	5.82	6.01	6.19	6.37	6.56	6.74	7.13	7.93	8.94
77	5.32	5.49	5.66	5.82	5.99	6.16	6.32	6.69	7.45	8.40
78	5.02	5.17	5.32	5.47	5.62	5.77	5.92	6.27	6.99	7.91
79	4.74	4.87	5.01	5.14	5.27	5.41	5.54	5.87	6.55	7.42
80	4.47	4.59	4.71	4.83	4.95	5.06	5.18	5.49	6.13	6.95
81	4.21	4.32	4.42	4.53	4.63	4.74	4.84	5.12	5.73	6.52
82	3.97	4.06	4.15	4.24	4.33	4.43	4.52	4.78	5.36	6.11
83	3.74	3.82	3.90	3.98	4.06	4.14	4.22	4.46	5.00	5.71
84	3.52	3.59	3.66	3.73	3.80	3.87	3.94	4.16	4.67	5.33
85	3.32	3.38	3.44	3.50	3.56	3.62	3.68	3.88	4.36	4.99
86	3.12	3.18	3.23	3.28	3.33	3.38	3.43	3.62	4.07	4.66
87	2.92	2.97	3.03	3.08	3.13	3.18	3.23	3.40	3.80	4.31
88	2.73	2.78	2.83	2.89	2.94	3.00	3.05	3.20	3.54	3.98
89	2.55	2.61	2.66	2.72	2.77	2.83	2.88	3.02	3.31	3.68
90	2.39	2.45	2.50	2.56	2.61	2.67	2.73	2.85	3.09	3.39
91	2.24	2.30	2.36	2.41	2.47	2.53	2.58	2.69	2.88	3.13
92	2.09	2.15	2.21	2.27	2.33	2.39	2.45	2.55	2.71	2.91
93	1.95	2.02	2.08	2.14	2.20	2.26	2.32	2.41	2.54	2.70
94	1.84	1.90	1.96	2.02	2.08	2.14	2.20	2.28	2.39	2.51
95	1.72	1.78	1.84	1.90	1.97	2.03	2.09	2.16	2.24	2.33
96	1.62	1.69	1.75	1.81	1.88	1.94	2.00	2.07	2.13	2.19
97	1.50	1.56	1.63	1.69	1.75	1.81	1.87	1.94	2.00	2.06
98	1.38	1.44	1.50	1.56	1.62	1.68	1.74	1.80	1.86	1.93
99	1.26	1.32	1.38	1.44	1.50	1.55	1.61	1.67	1.73	1.79
100	1.19	1.24	1.29	1.35	1.40	1.45	1.50	1.56	1.61	1.66
101	1.12	1.16	1.21	1.26	1.30	1.35	1.39	1.44	1.49	1.53
102	1.09	1.13	1.16	1.19	1.23	1.26	1.29	1.33	1.36	1.39
103	1.04	1.07	1.10	1.13	1.16	1.19	1.21	1.24	1.27	1.30
104	0.99	1.02	1.04	1.07	1.10	1.13	1.15	1.18	1.21	1.24
105	0.94	0.96	0.99	1.02	1.04	1.07	1.09	1.12	1.14	1.17
106	0.89	0.91	0.93	0.96	0.98	1.01	1.03	1.06	1.08	1.11
107	0.83	0.86	0.88	0.90	0.93	0.95	0.97	0.99	1.02	1.04
108	0.78	0.80	0.82	0.85	0.87	0.89	0.91	0.93	0.95	0.98

109	0.73	0.75	0.77	0.79	0.81	0.83	0.85	0.87	0.89	0.91
110	0.68	0.70	0.71	0.73	0.75	0.77	0.79	0.81	0.83	0.85
111	0.63	0.64	0.66	0.68	0.69	0.71	0.73	0.75	0.76	0.78
112	0.57	0.59	0.60	0.62	0.64	0.65	0.67	0.68	0.70	0.72
113	0.52	0.54	0.55	0.56	0.58	0.59	0.61	0.62	0.64	0.65
114	0.47	0.48	0.49	0.51	0.52	0.53	0.55	0.56	0.57	0.59
115	0.42	0.43	0.44	0.45	0.46	0.47	0.49	0.50	0.51	0.52
116	0.36	0.37	0.38	0.40	0.41	0.42	0.43	0.44	0.45	0.46
117	0.31	0.32	0.33	0.34	0.35	0.36	0.36	0.37	0.38	0.39
118	0.26	0.27	0.27	0.28	0.29	0.30	0.30	0.31	0.32	0.33
119	0.21	0.21	0.22	0.23	0.23	0.24	0.24	0.25	0.25	0.26
120	0.16	0.16	0.16	0.17	0.17	0.18	0.18	0.19	0.19	0.20

Females

Last age	Life expectancy at birth										
	-35	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80+
75	6.02	6.30	6.58	6.86	7.14	7.42	7.70	7.98	8.57	10.10	11.94
76	5.71	5.96	6.21	6.47	6.72	6.97	7.23	7.48	8.04	9.49	11.24
77	5.39	5.63	5.86	6.09	6.32	6.55	6.78	7.01	7.53	8.91	10.57
78	5.10	5.31	5.52	5.73	5.94	6.15	6.36	6.56	7.05	8.35	9.92
79	4.82	5.01	5.20	5.39	5.57	5.76	5.95	6.14	6.59	7.81	9.29
80	4.55	4.72	4.89	5.06	5.23	5.40	5.57	5.74	6.16	7.30	8.69
81	4.30	4.45	4.60	4.76	4.91	5.06	5.21	5.36	5.75	6.81	8.11
82	4.05	4.19	4.32	4.46	4.60	4.73	4.87	5.01	5.36	6.35	7.57
83	3.82	3.94	4.06	4.19	4.31	4.43	4.55	4.68	5.00	5.92	7.05
84	3.59	3.70	3.81	3.92	4.04	4.15	4.26	4.37	4.67	5.52	6.55
85	3.38	3.48	3.58	3.68	3.78	3.88	3.98	4.08	4.35	5.14	6.09
86	3.18	3.27	3.36	3.45	3.54	3.63	3.72	3.81	4.06	4.78	5.66
87	2.96	3.05	3.15	3.24	3.33	3.42	3.51	3.60	3.83	4.44	5.18
88	2.76	2.86	2.95	3.04	3.13	3.23	3.32	3.41	3.61	4.12	4.74
89	2.58	2.67	2.76	2.86	2.95	3.04	3.13	3.23	3.40	3.83	4.34
90	2.41	2.50	2.59	2.68	2.78	2.87	2.96	3.05	3.21	3.56	3.98
91	2.25	2.34	2.43	2.52	2.62	2.71	2.80	2.89	3.03	3.32	3.65
92	2.10	2.19	2.28	2.37	2.46	2.55	2.64	2.73	2.86	3.09	3.35
93	1.96	2.05	2.14	2.23	2.32	2.41	2.50	2.59	2.70	2.89	3.10
94	1.82	1.91	2.00	2.09	2.18	2.27	2.36	2.45	2.56	2.70	2.87
95	1.70	1.79	1.88	1.97	2.06	2.15	2.23	2.32	2.42	2.53	2.66
96	1.60	1.69	1.77	1.86	1.95	2.03	2.12	2.21	2.30	2.40	2.51
97	1.50	1.59	1.67	1.75	1.84	1.92	2.01	2.09	2.18	2.27	2.36
98	1.40	1.48	1.57	1.65	1.73	1.81	1.89	1.97	2.06	2.14	2.22
99	1.31	1.39	1.47	1.54	1.62	1.70	1.78	1.85	1.93	2.01	2.08
100	1.22	1.29	1.37	1.44	1.51	1.59	1.66	1.73	1.80	1.88	1.95
101	1.13	1.20	1.27	1.34	1.40	1.47	1.54	1.61	1.68	1.75	1.81

102	1.08	1.14	1.21	1.28	1.34	1.41	1.47	1.54	1.60	1.67	1.73
103	1.03	1.09	1.15	1.21	1.28	1.34	1.40	1.46	1.53	1.59	1.65
104	0.98	1.04	1.09	1.15	1.21	1.27	1.33	1.39	1.45	1.51	1.57
105	0.92	0.98	1.04	1.09	1.15	1.20	1.26	1.32	1.37	1.43	1.48
106	0.87	0.93	0.98	1.03	1.09	1.14	1.19	1.24	1.30	1.35	1.40
107	0.82	0.87	0.92	0.97	1.02	1.07	1.12	1.17	1.22	1.27	1.32
108	0.77	0.82	0.86	0.91	0.96	1.00	1.05	1.10	1.14	1.19	1.24
109	0.72	0.76	0.81	0.85	0.89	0.94	0.98	1.02	1.07	1.11	1.15
110	0.67	0.71	0.75	0.79	0.83	0.87	0.91	0.95	0.99	1.03	1.07
111	0.62	0.65	0.69	0.73	0.77	0.80	0.84	0.88	0.92	0.95	0.99
112	0.57	0.60	0.63	0.67	0.70	0.74	0.77	0.80	0.84	0.87	0.91
113	0.51	0.54	0.58	0.61	0.64	0.67	0.70	0.73	0.76	0.79	0.82
114	0.46	0.49	0.52	0.55	0.57	0.60	0.63	0.66	0.69	0.71	0.74
115	0.41	0.44	0.46	0.49	0.51	0.54	0.56	0.59	0.61	0.64	0.66
116	0.36	0.38	0.40	0.43	0.45	0.47	0.49	0.51	0.53	0.56	0.58
117	0.31	0.33	0.35	0.36	0.38	0.40	0.42	0.44	0.46	0.48	0.49
118	0.26	0.27	0.29	0.30	0.32	0.33	0.35	0.37	0.38	0.40	0.41
119	0.21	0.22	0.23	0.24	0.26	0.27	0.28	0.29	0.31	0.32	0.33
120	0.15	0.16	0.17	0.18	0.19	0.20	0.21	0.22	0.23	0.24	0.25