Consistent correction of census and vital registration data for Thailand, 1960–80

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PAPERS OF THE EAST-WEST POPULATION INSTITUTE

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ABSTRACT A new procedure for the simultaneous and consistent correction of two or more censuses and intercensal registered births and deaths is applied to Thailand's censuses of 1960, 1970, and 1980, and to registered births and deaths for the period 1960–80. The procedure begins with a set of preliminary correction factors that are inconsistent because they are derived from a variety of existing sources. The procedure then identifies the set of consistent correction factors that are "closest" to the preliminary factors.

The results show marked underenumeration of the 0–4 age group in each census, especially the 1960 census in which age rounding was apparently prevalent. Age exaggeration at the oldest ages is also indicated, at least in the 1970 and 1980 censuses. Birth registration completeness rose during 1960–80, from about 82 to 85 percent for males and from about 78 to 85 percent for females. Nevertheless, death registration completeness for both sexes hovered within the 61 to 67 percent range, declining slightly until the early 1970s, when it leveled off or began to rise. The age group 0–4 had the greatest underregistration of deaths, and underregistration at this age apparently increased throughout the period. Although life expectancy increased for both sexes during the period, female superiority in life expectancy also increased. The average number of years of life expectancy is estimated to have increased from 59.3 for females and 54.8 for males in 1960–65 to 65.2 for females and 58.1 for males in 1975–80.

The Thailand censuses of 1960, 1970, and 1980 and vital registration during the period 1960-80 have been the subject of various estimates of census undercount, adjusted census age–sex distributions, underregistration of births and deaths, intercensal life tables, and other demographic variables, many of which are mentioned below. However, these estimates, as a whole, contain many inconsistencies. The purpose of this paper is to provide a new, consistent set of estimates for these data, making selective use of the previous estimates.

To accomplish this purpose, a new procedure for the simultaneous and consistent correction of two or more censuses and intercensal registered births and deaths (Luther and Retherford 1986a, 1986b) is applied to Thailand's censuses of 1960, 1970, and 1980 and to the registered births and deaths for the intervening period of 1960–80. Specifically, for each sex the procedure provides estimates of (1) correction factors for intercensal registered births, (2) age-specific correction factors for intercensal registered deaths, (3) age-specific correction factors for the age distribution at each census, and (4) life tables for the intercensal periods, such that the corrected registered births and deaths, the corrected census age distributions, and the estimated life tables are mutually consistent. Furthermore, the corrected births satisfy a specified sex ratio. Consistency here means that the usual intercensal demographic balancing equations relating census age distribu-

tions, births, and deaths by age are exactly satisfied. Net international migration was negligible for the period 1960–80, so that it may be ignored. The volume of permanent immigration and emigration was small throughout this period. Temporary migration of contract workers to the Middle East began to increase in 1978, but it did not become substantial until after the 1980 census.

METHOD

The procedure begins with a set of preliminary correction factors that are not necessarily consistent. These preliminary correction factors are derived from previous estimates and by existing methods of demographic analysis, as detailed below. Starting from this set of preliminary correction factors and the demographic data themselves, the new procedure specifies a "best," or optimal, set of final consistent correction factors that is "closest" to the set of preliminary correction factors. The optimization procedure finds this closest set by use of the principle, from the mathematics of finite-dimensional vector spaces, that there exists in a hyperplane a unique point of minimum distance from a fixed point not in the hyperplane. The methodology is explained in Luther and Retherford (1986a, 1986b), the latter source gives details for the non-mathematically-inclined reader. It is shown in those sources that, by utilizing the concept of weighted distance, the procedure allows the analyst to weight the preliminary estimates according to the analyst's assessment of their accuracy. The use of "proportional weights," as described in the application of the procedure to South Korean data for 1970–80 (Luther and Retherford 1986a, 1986b), will spread the correction evenly over the preliminary correction factors. This is also appropriate for the Thailand application since we would assess all of the preliminary correction factors derived below to be of comparable accuracy.

The three-census application to Thailand given in this paper illustrates an important advantage of this procedure: that it may be used to correct consistently more than two censuses at a time, along with intercensal births and deaths. In contrast, most previous procedures correct just two censuses at a time (e.g., Demeny and Shorter 1968; Preston 1983), and that typically leads to inconsistent results for the intermediate censuses from the separate applications of the procedure. In particular, most previous analyses of Thailand data have involved just two successive censuses (e.g., Fulton 1979; Arnold and Phananiramai 1975; Pejaranonda, Arnold, and Hauser 1983).

Another advantage of the consistent correction procedure is that it allows the researcher great leeway in the amount and type of structure that is imposed. For example, one may require the final age-specific correction factors to be the same from census to census, as with the Demeny–Shorter technique (Demeny and Shorter 1968) and the "variable r" methods (Preston

1983). No such assumptions are made for the Thai application given here, however. This latter, more flexible approach, which is often more realistic and appropriate, was adopted for the Korean application as well (Luther and Retherford 1986a, 1986b). Or one may compromise and assume that the final correction factors follow some trend. As an example of a different type of restriction that the procedure allows, we have fixed the sex ratio for the corrected Thai births. In fact, the only conditions that must be satisfied by the restrictions involving the correction factors are that these restrictions be linear in the factors and hold when all factors are zero.

The procedure, however, has limitations. The primary one is that the final correction factors are sensitive to errors in the preliminary correction factors. Consequently, it is important to estimate the preliminary correction factors as accurately as possible.

In any case, the final correction factors given by the procedure yield consistent adjustments of the data. The degree to which these adjustments are actually corrections depends on the accuracy of the preliminary correction factors.

APPLICATION TO THAILAND, 1960–80

All censuses are treated as if they occurred on 1 April, although the 1960 census was taken on 25 April. The four five-year intercensal periods that will be frequently mentioned are those separated by 1 April of the years 1960, 1965, 1970, 1975, and 1980.

The input into the procedure, and specifically into the computer program (which may be obtained from the authors), consists of: (1) the 1960, 1970, and 1980 reported census age distributions by sex and five-year age groups (open-ended at age 70), given in Tables 1 and 2 in the next section, with each census age distribution uniformly premultiplied by a correction factor based on a census underenumeration estimate (the details of this premultiplication are given with the derivation of the preliminary correction factors in Appendix A); (2) total registered intercensal births by sex for each of the four five-year intercensal periods, given in Tables 5 and 6; (3) total registered intercensal deaths by sex and five-year age groups (open-ended at age 70) for each of the four five-year intercensal periods, again given in Tables 5 and 6; (4) l_0, l_5, and ${}_5L_0$ values by sex for each of the four five-year intercensal periods obtained from Coale–Demeny model North life tables (levels 16.825, 17.175, 17.525, and 17.875 respectively for males given in Appendix Table B.3, and 17.0, 17.6, 18.2, and 19.0 respectively for females given in Appendix Table B.4) in order to yield an estimate of the separation factor for deaths at ages 0–4 by sex for each of the four five-year intercensal periods; (5) a specified sex ratio at birth of 1.058 for each of the four five-year intercensal periods; and (6) estimated preliminary correction factors

for each of the demographic quantities listed in (1), (2), and (3). Because there are fifteen age groups (fourteen five-year age groups plus the open-ended one), for each sex there will be forty-five census correction factors (fifteen for each census) and sixty death correction factors (fifteen for each five-year intercensal period). If we add to this the four correction factors for births for each sex (one for each five-year intercensal period), we have a total of 109 correction factors for each sex. The preliminary correction factors are put into the computer program with male factors first and female factors following. The order of preliminary correction factors for each sex is births first (in chronological order), then censuses (youngest to oldest age group in first census, in second census, etc.), then deaths (youngest to oldest age group in first intercensal period, in second intercensal period, etc.).

Because registered births and deaths (by age) for Thailand are tabulated by calendar year, it was necessary to interpolate to obtain registered births and deaths for the four five-year intercensal periods. For example, registered births for the first five-year intercensal period, 1 April 1960 to 1 April 1965, include three-fourths of the births for 1960, all of the births for 1961–64, and one-fourth of the births for 1965. The same interpolation procedure was used for deaths by age group.

Coale-Demeny model North life tables have been used frequently in the analysis of Thai data, for example by Pejaranonda Arnold, and Choe (1985) and by Fulton (1979) after a careful study comparing the fit of the different Coale-Demeny (1966) model life table families to Thai mortality experience. We opted for such model tables rather than those resulting from the Surveys of Population Change (SPC) of 1964–67 and 1974–76 (Thailand, National Statistical Office 1969, 1978) because of the irregularity of some SPC ${}_5q_x$ values, probably due to the small sample size. At the mortality levels listed in (4) above, the Coale-Demeny model North tables are applied both for estimating separation factors for deaths at ages 0–4 and for deriving the preliminary correction factors for deaths. The one exception involves the later adult ages, where it was judged that the SPC life tables more accurately reflect Thai mortality experience during 1960–80; therefore the SPC life tables were employed for both sexes rather than the model North life tables in order to derive the preliminary correction factors for deaths for the 70+ age group for each of the four five-year intercensal periods.

Moreover, the life expectancy values (e_0) from the SPC life tables determined the levels of the model North life tables that were used. For example, the 1964–67 and 1974–76 SPC male life tables list e_0 values of 56.27 and

58.00 respectively. These values were assumed for the dates 1 April 1965 and 1 April 1975, which are encompassed by the respective SPCs. Model North levels of 17.0 and 17.7 were matched to these male e_0 values at these dates; accordingly, life tables for males for each of the four five-year intercensal periods were obtained by linear interpolation, taking the reference dates to be the midpoints of the five-year periods.

The same process was used to obtain a female life table for each five-year intercensal period, except that level 19 was used for the period 1 April 1975 to 1 April 1980 rather than 18.8 as would result from linear interpolation. The decision to use this higher level was based on evidence that life expectancy for females was accelerating in the 1970s, at least in relation to that for males (Hill 1979). Moreover, the results from using the lower figure of 18.8 contradicted preliminary evidence from the 1984–86 SPC that death registration completeness leveled off in the 1970s rather than continuing its earlier decline.

The preliminary correction factors for deaths by sex and by five-year intercensal period for the 70+ age group were obtained from the SPC life tables as follows. The SPC life tables for 1964–67 and 1974–76 were ascribed to the dates 1 April 1965 and 1 April 1975 respectively. Linear interpolation was performed, and again the reference dates were taken to be the midpoints of the five-year intercensal intervals.

The estimate of 1.058 as the true sex ratio at birth was based on the average of the values 1.055 and 1.062 obtained by the 1964–67 and 1975–76 SPCs. The same value of 1.058 was input for each of the five-year intercensal periods since there is no reason to expect the sex ratio at birth to vary from one five-year period to the next. The correction procedure then requires that the corrected registered births satisfy the specified sex ratio of 1.058 for each five-year intercensal period. This feature has been added to the correction procedure since its original description in Luther and Retherford (1986a, 1986b).

The complete details of the derivation of the preliminary correction factors are given in Appendix A. The reader who is interested in the mechanics, as well as the results, of the consistent correction procedure can refer to that appendix. As mentioned before, the more theoretical aspects of the methodology of the procedure are given in Luther and Retherford (1986a, 1986b).

Finally, it is worth noting that the cost of running the computer program for this application involving three Thai censuses and four five-year intercensal periods is only about $16.

PRINCIPAL FINDINGS

The principal findings are given in Tables 1-11, Figures 1-5, and Appendix Tables B.1-B.5.

Censuses

Tables 1-4 and Figures 1 and 2 present the final results for the censuses. In Figures 1 and 2 the final correction factors of Table 3 are compared with the corresponding preliminary correction factors given in Appendix Table B.2.

Especially striking is the high degree of underenumeration of the 0-4 age group for both sexes for all censuses, but especially for the 1960 census (Table 4). This is consistent with the observation of Chamratrithirong, Debavalya, and Knodel (1978), Panel on Thailand (1980), United Nations (1966), and others that the 0-4 age group was especially underenumerated in the 1960 census because of age rounding owing to the fact that the census question asked for ages of household members rather than dates of births. Thus the ages of children between exact ages 4½ and 5 were frequently rounded upward to age 5. This was less likely to occur in the 1970 and 1980 censuses, in which date of birth was asked rather than age.

If there was rounding to the nearest age at all ages in the 1960 census, then the count of, say, the 5-9 age group (exact ages 5 to 10) included some children between exact ages 4½ and 5 and excluded some between exact ages 9½ and 10. Suppose the extent of rounding was substantial and of similar proportions throughout the entire population. Since the total population between exact ages 4½ and 5 exceeds that between exact ages 9½ and 10, such rounding would tend to result in a relative overcount of the 5-9 age group and, for the same reason, those age groups above it. Thus for those age spans in which enumeration was relatively complete, slight overenumeration would appear. The results show this to be true for ages 20-49 for both males and females in the 1960 census (see Table 4). Since the 1960 census is believed to have given a relatively complete count for ages 5 and above (United Nations 1966), such slight overenumeration for some age groups is plausible.

On the other hand, the results imply that the 1970 census contained considerable underenumeration at ages 20-49 as well as at ages 50-69. Of course, the total population of the 1970 census was substantially more underenumerated than the 1960 census (see, e.g., Fulton 1979; Preston and Hill 1980; and Luther 1983 as well as Table 4).

Table 4 also indicates considerable age exaggeration at the older ages in both the 1970 and 1980 censuses, although the age exaggeration for males in 1970 was not sufficient to offset the general undercount. One cannot discern from the procedure, however, whether such age exaggeration occurred

Table 1. Reported and final corrected census age distributions and estimates of completeness for males: Thailand, censuses of 1960, 1970, and 1980

Age group	1960		1970		1980	
	Reported	Corrected	Reported	Corrected	Reported	Corrected
0-4	2,141,559	2,512,313	2,866,562	3,234,789	2,771,779	3,040,599
5-9	2,016,266	2,001,079	2,682,560	2,757,912	2,979,485	3,204,070
10-14	1,565,889	1,558,905	2,312,473	2,353,701	3,006,300	3,071,068
15-19	1,265,152	1,297,995	1,834,496	1,932,295	2,696,618	2,676,213
20-24	1,214,356	1,202,446	1,323,314	1,500,287	2,239,837	2,275,485
25-29	1,026,654	1,019,704	1,099,473	1,236,913	1,743,323	1,847,351
30-34	885,681	875,690	1,048,649	1,141,353	1,333,155	1,423,980
35-39	693,448	690,219	954,165	960,952	1,161,496	1,170,734
40-44	569,749	563,945	775,308	818,919	1,064,541	1,075,500
45-49	494,691	487,183	599,875	634,543	927,227	891,716
50-54	402,425	403,137	472,783	507,599	744,588	744,492
55-59	322,258	322,151	388,820	424,953	543,743	555,018
60-64	229,018	242,226	301,182	333,743	411,260	422,898
65-69	149,291	157,901	213,227	245,689	296,774	328,187
70+	177,685	187,933	250,973	267,276	408,481	395,896
Total	13,154,122	13,522,828	17,123,861	18,350,923	22,328,607	23,123,208
Completeness (%)	97.27		93.31		96.56	

Sources: Reported figures are from Thailand, Central Statistical Office (1962: table 3, p. 9); Thailand, National Statistical Office (1972: table 4, p. 12; 1983: table 4, pp. 22-23). Unknown ages are allocated proportionally.

Table 2. Reported and final corrected census age distributions and estimates of completeness for females: Thailand, censuses of 1960, 1970, and 1980

Age group	1960		1970		1980	
	Reported	Corrected	Reported	Corrected	Reported	Corrected
0–4	2,105,216	2,439,170	2,799,770	3,117,372	2,654,067	2,954,623
5–9	1,982,900	1,974,806	2,609,020	2,673,382	2,855,893	3,129,504
10–14	1,527,750	1,520,036	2,255,500	2,308,528	2,898,197	3,000,334
15–19	1,238,223	1,242,389	1,887,756	1,918,301	2,711,643	2,616,050
20–24	1,206,032	1,198,094	1,363,440	1,475,896	2,281,192	2,257,910
25–29	1,048,097	1,038,303	1,144,824	1,200,251	1,811,104	1,865,258
30–34	871,233	865,134	1,078,451	1,154,181	1,365,493	1,426,153
35–39	681,001	677,001	958,819	992,093	1,183,324	1,155,458
40–44	564,692	561,835	767,302	819,472	1,102,535	1,107,333
45–49	483,720	480,027	598,210	633,529	967,187	940,695
50–54	410,994	418,251	490,414	519,371	768,793	765,667
55–59	329,554	334,693	402,239	434,036	567,740	577,231
60–64	245,371	262,045	324,633	365,000	442,596	457,181
65–69	163,855	174,990	239,203	271,841	333,312	358,791
70+	245,099	261,755	353,933	347,895	552,857	522,357
Total	13,103,737	13,448,530	17,273,514	18,231,149	22,495,933	23,134,546
Completeness (%)	97.44		94.75		97.24	

Sources: Same as Table 1.

Table 3. Final correction factors: Thailand, censuses of 1960, 1970, and 1980

Age group	1960		1970		1980	
	Males	Females	Males	Females	Males	Females
0–4	1.173	1.158	1.129	1.113	1.097	1.113
5–9	.992	.996	1.028	1.025	1.075	1.096
10–14	.995	.995	1.018	1.024	1.021	1.035
15–19	1.026	1.003	1.053	1.016	.992	.965
20–24	.990	.993	1.134	1.083	1.016	.990
25–29	.993	.991	1.125	1.049	1.060	1.030
30–34	.989	.993	1.088	1.070	1.068	1.044
35–39	.995	.994	1.007	1.034	1.008	.977
40–44	.990	.995	1.056	1.068	1.010	1.005
45–49	.985	.992	1.058	1.059	.962	.973
50–54	1.002	1.018	1.073	1.059	1.000	.996
55–59	.999	1.016	1.092	1.079	1.020	1.017
60–64	1.058	1.068	1.109	1.125	1.029	1.033
65–69	1.058	1.068	1.152	1.136	1.105	1.076
70+	1.058	1.068	1.065	.983	.969	.945

Note: The entries here may be obtained by dividing the corrected population by the corresponding reported population in Tables 1 and 2.

in the 1960 census. With the choice of the same preliminary correction factors for the last three age groups in the first of the three censuses and the use of the "proportional weights," mentioned earlier, to spread the correction evenly, it can be shown that the procedure will necessarily yield the same final correction factors for those last three age groups in the first census. Thus the figures 1.058 for males and 1.068 for females for the 1960 census should be considered as the final correction factors (and, correspondingly, 94.5 percent for males and 93.6 percent for females as the final completeness estimates) for the combined 60+ age group rather than for the 60–64, 65–69, and 70+ age groups separately.

As Figures 1 and 2 indicate, the preliminary and final correction factors for the censuses agree quite well except at the late ages. This shows that a considerable degree of consistency is already present with the determination of the preliminary correction factors (see Appendix A).

Vital registration

The vital registration results are given in Tables 5–8 and in Figures 3 and 4, in which preliminary and final correction factors for deaths are compared.

Table 4. Completeness estimates (percentages): Thailand, censuses of 1960, 1970, and 1980

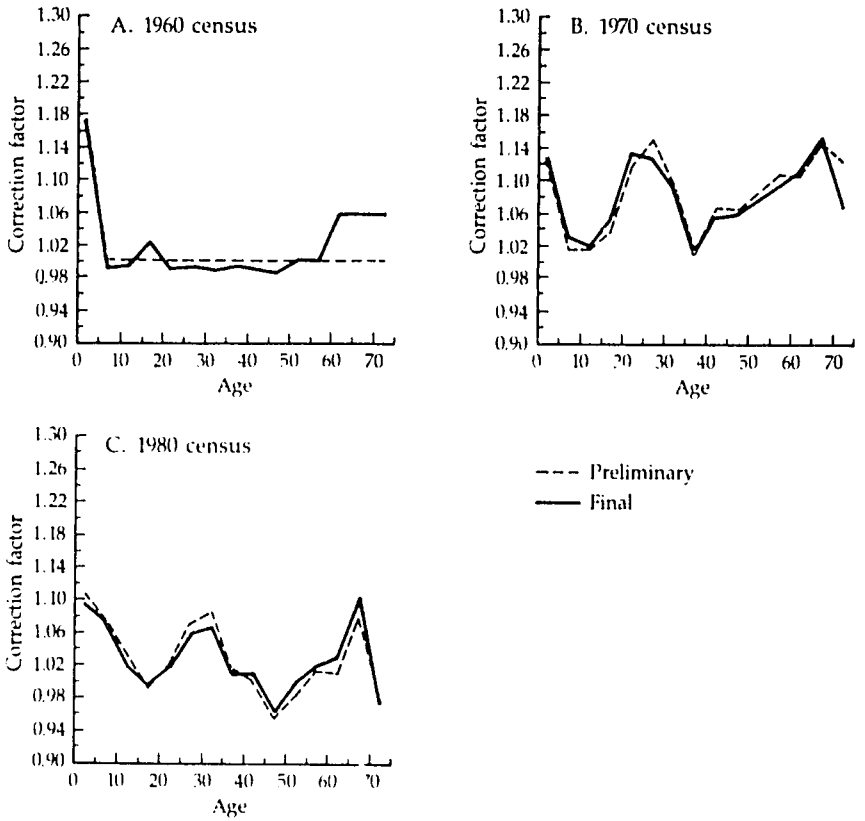
Age group	1960		1970		1980	
	Males	Females	Males	Females	Males	Females
0–4	85.3	86.4	88.6	89.8	91.2	89.8
5–9	100.8	100.4	97.3	97.6	93.0	91.2
10–14	100.5	100.5	98.2	97.7	97.9	96.6
15–19	97.5	99.7	95.0	98.4	100.8	103.6
20–24	101.0	100.7	88.2	92.3	98.4	101.0
25–29	100.7	100.9	88.9	95.3	94.3	97.1
30–34	101.1	100.7	91.9	93.5	93.6	95.8
35–39	100.5	100.6	99.?	96.7	99.2	102.4
40–44	101.0	100.5	94.7	93.6	99.0	99.5
45–49	101.5	100.8	94.5	94.4	104.0	102.8
50–54	99.8	98.2	93.2	94.4	100.0	100.4
55–59	100.1	98.4	91.6	92.7	98.0	98.3
60–64	94.5	93.6	90.2	88.9	97.2	96.8
65–69	94.5	93.6	86.8	88.0	90.5	92.9
70+	94.5	93.6	93.9	101.7	103.2	105.8

Note: The entries here are the reciprocals (expressed as percentages) of the entries of Table 3. Alternatively, they may be obtained by dividing the reported population by the corresponding corrected population in Tables 1 and 2.

The birth registration results are in reasonable agreement with those of the United Nations (1976), U.S. Bureau of the Census (1978), Hill (1979), and others. (See table 7 of Panel on Thailand 1980 for a good summary of estimates of birth registration completeness prior to 1976.) The upward trend, as well as the level, of the estimates of the completeness of birth registration is also consistent with a preliminary birth completeness estimate of about 89 percent for the combined sexes from the first year of the 1984–86 SPC (subject to change).

The death registration results also compare quite well with other estimates. (Again, table 7 of Panel on Thailand 1980 gives a good summary of estimates of death registration completeness.) The results indicate a decrease in death registration completeness during the 1960s and early 1970s and a slight upturn in the late 1970s on the whole—an upturn for males and a leveling off for females (Tables 5 and 6). This trend and the level are consistent with the results of the 1964–67 and 1974–76 SPCs and a preliminary finding of the first year of the 1984–86 SPC, which gives an estimate of about 76 percent completeness for death registration of both sexes combined (subject to change).

Figure 1. Preliminary and final correction factors for males: Thailand, censuses of 1960, 1970, and 1980



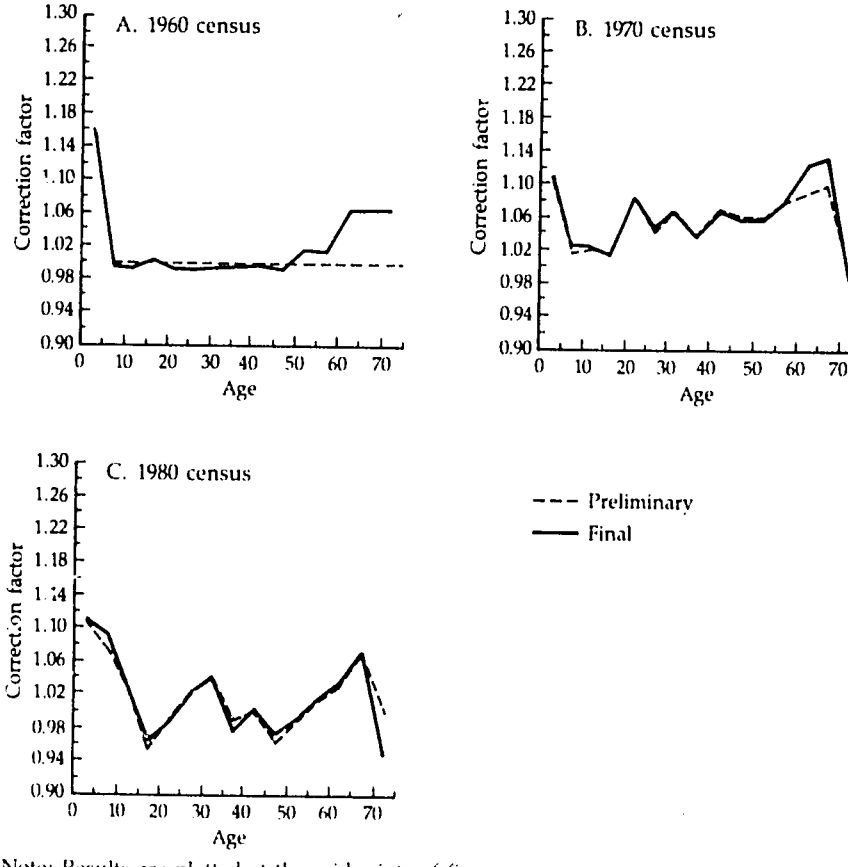
Note: Results are plotted at the midpoints of five-year age groups.

It is not surprising that the results indicate greatest underregistration of deaths at the youngest and oldest ages, and especially at ages 0-4 (Table 8). It is somewhat surprising, however, that death registration completeness at ages 0-4 declined steadily and substantially during the period 1960-80. This trend is present in the preliminary correction factors as well.

Another interesting feature of the results, especially evident from inspection of Figure 3, is the high degree of underregistration of male deaths at ages 20-29 for all five-year intercensal periods. This trend also emerges for females (Figure 4), but only after 1970.

The preliminary and final correction factors for deaths show considerable agreement except at the late ages, as was true for the censuses (Figures 3 and 4). Thus the preliminary correction factors as a whole reflect a considerable degree of consistency, although less so at the late ages.

Figure 2. Preliminary and final correction factors for females: Thailand, censuses of 1960, 1970, and 1980



Note: Results are plotted at the midpoints of five-year age groups.

Life tables

The intercensal life tables for the four five-year intercensal periods, which are derived from the results of the consistent correction procedure, are given in Tables 9 and 10, and the life table death probabilities for the extreme periods 1960–65 and 1975–80 are shown in Figure 5. The life tables are computed directly from corrected deaths and population by age, as detailed in Appendix C where precise formulas are given. The calculations use the estimated midcensus age-sex distributions of Table 11 produced by the consistent correction procedure, which pertain to 1 April 1965 and 1975, and the corrected data given in Tables 1, 2, 5, and 6.

Table 5. Registered and final corrected intercensal births and deaths and estimates of registration completeness for males: Thailand, 1960–65, 1965–70, 1970–75, and 1975–80

Births deaths and age group	1960–65		1965–70		1970–75		1975–80	
	Reported	Corrected	Reported	Corrected	Reported	Corrected	Reported	Corrected
Births	2,630,151	3,194,788	2,944,493	3,562,746	3,050,797	3,628,987	2,811,543	3,318,567
Completeness (%)	82.33		82.65		84.07		84.72	
Deaths								
0–4	224,812	406,581	191,302	419,457	161,667	408,795	114,808	353,137
5–9	33,206	53,298	32,834	56,786	30,189	60,236	26,830	58,212
10–14	17,047	24,933	18,345	27,943	18,979	30,080	18,725	32,687
15–19	15,724	26,229	19,579	31,394	24,350	36,402	28,405	40,395
20–24	17,496	30,348	19,474	34,681	25,213	42,108	34,247	49,555
25–29	17,153	30,488	18,667	30,907	21,261	33,789	28,100	41,822
30–34	18,542	27,638	20,938	30,441	22,404	31,309	25,424	34,895
35–39	20,504	26,835	23,819	28,938	26,012	32,171	28,646	32,365
40–44	21,800	25,428	25,539	30,134	29,430	32,950	34,024	35,861
45–49	25,879	25,898	27,100	28,957	31,377	34,913	37,724	37,489
50–54	29,031	30,362	31,720	32,409	33,649	37,130	39,701	43,501
55–59	30,562	31,804	34,254	35,791	36,937	39,127	39,933	43,506
60–64	32,972	35,689	38,825	40,830	42,805	47,027	47,810	49,641
65–69	29,125	35,765	36,553	44,602	42,954	51,940	47,423	57,736
70+	76,276	106,767	96,868	138,106	116,912	164,488	135,619	182,003
Total	610,129	918,063	635,817	1,011,375	664,139	1,082,462	687,419	1,092,807
Completeness (%)	66.46		62.87		61.35		62.90	

Sources: Registered births: Thailand, National Statistical Office (n.d.: No. 30, 1972-73, table 29, p. 84; n.d.: No. 32, 1976–80, table 23, p. 95; 1982). Registered deaths: Thailand, Ministry of Public Health, Division of Vital Statistics (1962, 1965, 1968, 1972, 1977, 1983).

Table 6. Registered and final corrected intercensal births and deaths and estimates of registration completeness for females: Thailand, 1960–65, 1965–70, 1970–75, and 1975–80

Births/deaths and age group	1960–65		1965–70		1970–75		1975–80	
	Reported	Corrected	Reported	Corrected	Reported	Corrected	Reported	Corrected
Births	2,363,132	3,019,648	2,715,779	3,367,435	2,855,596	3,430,045	2,668,218	3,136,641
Completeness (%)	78.26		80.65		83.25		85.07	
Deaths								
0–4	179,043	326,591	156,281	322,376	128,101	299,387	87,644	230,302
5–9	28,697	44,300	28,574	44,230	26,629	43,815	22,848	36,716
10–14	13,666	22,003	14,417	23,249	15,082	23,511	14,225	22,567
15–19	12,699	20,210	14,951	23,460	17,026	25,134	17,742	24,770
20–24	17,128	20,309	16,315	22,608	17,126	26,552	17,607	27,821
25–29	17,818	22,999	16,064	21,149	14,373	23,553	14,539	26,578
30–34	18,996	22,721	18,593	23,368	16,417	21,450	14,281	22,803
35–39	19,399	21,737	20,059	23,332	19,252	24,170	16,822	21,778
40–44	18,638	20,457	19,886	23,534	21,014	25,873	21,218	26,299
45–49	17,435	19,517	19,035	21,216	20,562	24,908	23,301	26,455
50–54	18,896	22,208	21,055	23,738	22,454	26,417	24,628	30,375
55–59	20,050	24,879	22,003	26,519	24,353	28,759	25,672	30,896
60–64	22,149	29,241	27,055	32,896	28,673	35,524	31,768	38,309
65–69	21,484	32,793	26,940	38,687	31,284	43,940	33,738	47,897
70+	80,530	128,951	103,983	155,187	122,355	171,486	140,629	205,244
Total	506,628	778,916	525,211	825,548	524,701	844,480	506,662	818,809
Completeness (%)	65.04		63.62		62.13		61.88	

Sources: Same as Table 5.

Table 7. Final correction factors for registered births and deaths: Thailand, 1960–65, 1965–70, 1970–75, and 1975–80

Births deaths and age group	1960–65		1965–70		1970–75		1975–80	
	Males	Females	Males	Females	Males	Females	Males	Females
Births	1.215	1.278	1.210	1.240	1.190	1.201	1.180	1.176
Deaths								
0–4	1.809	1.824	2.193	2.063	2.529	2.337	3.076	2.628
5–9	1.605	1.544	1.729	1.548	1.995	1.645	2.170	1.607
10–14	1.463	1.610	1.523	1.613	1.585	1.559	1.746	1.586
15–19	1.668	1.591	1.603	1.569	1.495	1.476	1.422	1.396
20–24	1.735	1.186	1.781	1.386	1.670	1.550	1.447	1.580
25–29	1.777	1.291	1.656	1.317	1.589	1.639	1.488	1.828
30–34	1.491	1.196	1.454	1.257	1.397	1.307	1.373	1.597
35–39	1.309	1.121	1.215	1.163	1.237	1.255	1.130	1.295
40–44	1.166	1.098	1.180	1.183	1.120	1.231	1.054	1.239
45–49	1.001	1.119	1.069	1.115	1.113	1.211	.994	1.135
50–54	1.046	1.175	1.022	1.127	1.103	1.177	1.096	1.233
55–59	1.041	1.241	1.045	1.205	1.059	1.181	1.089	1.203
60–64	1.082	1.320	1.052	1.216	1.099	1.239	1.038	1.206
65–69	1.228	1.526	1.220	1.436	1.209	1.405	1.217	1.420
70+	1.468	1.601	1.426	1.492	1.407	1.402	1.342	1.459

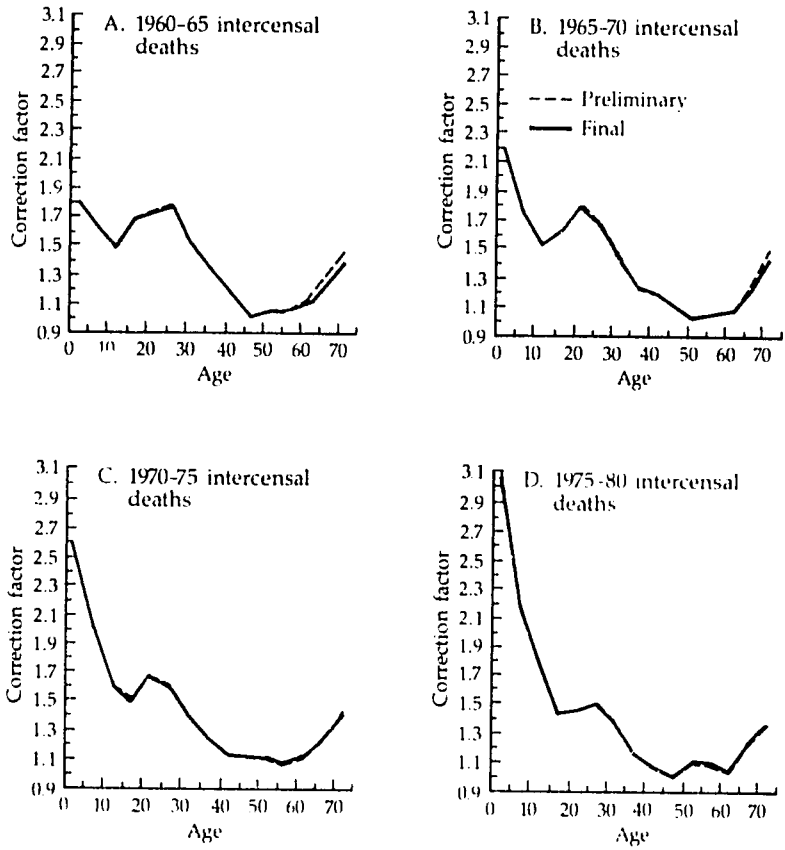
Note: The entries here may be obtained by dividing the corrected births or deaths by the corresponding reported births or deaths in Tables 5 and 6.

Table 8. Completeness estimates (percentages) for death registration: Thailand, 1960–65, 1965–70, 1970–75, and 1975–80

Age group	1960–65		1965–70		1970–75		1975–80	
	Males	Females	Males	Females	Males	Females	Males	Females
0–4	55.3	54.8	45.6	48.5	39.5	42.8	32.5	38.1
5–9	62.3	64.8	57.8	64.6	50.1	60.8	46.1	62.2
10–14	68.4	62.1	65.7	62.0	63.1	64.1	57.3	63.1
15–19	60.0	62.9	62.4	63.7	66.9	67.8	70.3	71.6
20–24	57.6	84.3	56.1	72.2	59.9	64.5	69.1	63.3
25–29	56.3	77.5	60.4	75.9	62.9	61.0	67.2	54.7
30–34	67.1	83.6	68.8	79.6	71.6	76.5	72.8	62.6
35–39	76.4	89.2	82.3	86.0	80.8	79.7	88.5	77.2
40–44	85.8	91.1	84.7	84.5	89.3	81.2	94.9	80.7
45–49	99.9	89.4	93.5	89.7	89.8	82.6	100.6	88.1
50–54	95.6	85.1	97.8	88.7	90.7	85.0	91.2	81.1
55–59	96.1	80.6	95.7	83.0	94.4	84.7	91.8	83.1
60–64	92.4	75.8	95.1	82.2	91.0	80.7	96.3	82.9
65–69	81.4	65.5	82.0	69.6	82.7	71.2	82.2	70.4
70+	71.4	62.5	70.1	67.0	71.1	71.3	74.5	68.5

Note: The entries here are the reciprocals (expressed as percentages) of the entries of Table 7. Alternatively, they may be obtained by dividing the reported deaths by the corresponding corrected deaths in Tables 5 and 6.

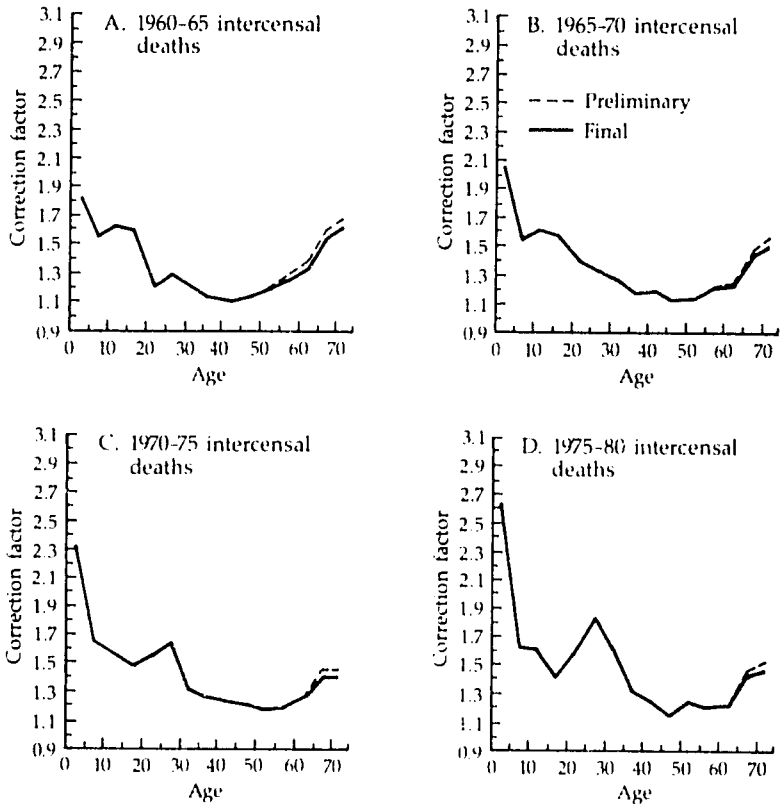
Figure 3. Preliminary and final correction factors for intercensal registered deaths for males: Thailand, 1960–65, 1965–70, 1970–75, and 1975–80



Notes: Results are plotted at the midpoints of five-year age groups. For births, the preliminary and final correction factors are: 1960–65, 1.234 and 1.215; 1965–70, 1.220 and 1.210; 1970–75, 1.199 and 1.190; 1975–80, 1.179 and 1.180.

The life tables generally show mortality improvements with time, as one would expect. The improvements are more substantial for females than males (Figure 5). The improvement in life expectancy is greatest for the youngest age group, in accordance with the pattern in most countries. Both the ${}_5q_0$ estimates, based on marked underregistration of deaths at ages 0–4, and the life expectancy estimates agree quite well with those given by the SPCs for 1964–67 and 1974–76, and by Rungpitarangsi (1974) for 1960 and 1970. Moreover, the widening gap between male and female life expectancies during the period 1960–80 is consistent with the conclusions of Hill (1979:34–35) and the results of the SPCs.

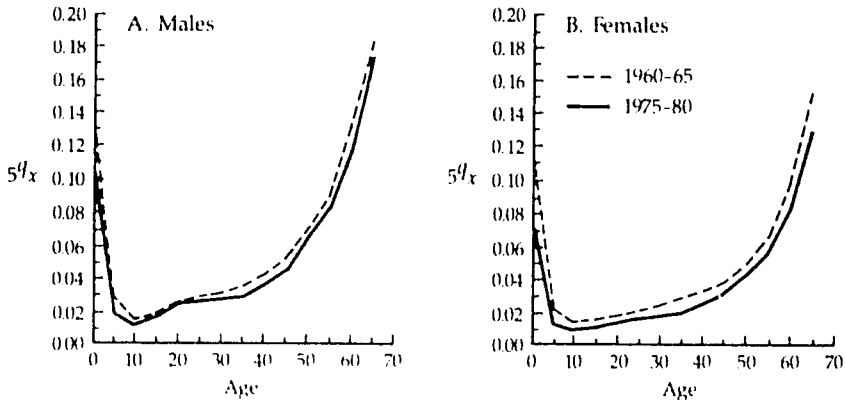
Figure 4. Preliminary and final correction factors for intercensal registered deaths for females: Thailand, 1960–65, 1965–70, 1970–75, and 1975–80



Notes: Results are plotted at the midpoints of five-year age groups. For births, the preliminary and final correction factors are: 1960–65, 1.300 and 1.278; 1965–70, 1.250 and 1.240; 1970–75, 1.211 and 1.201; 1975–80, 1.174 and 1.176.

Finally, comparison of the 1960–65 and 1965–70 male life tables reveals a possible slight anomaly in the results. The T_{70} value decreases a bit whereas the l_{70} value increases. This means that proportionately more people survived to age 70 according to the 1965–70 life table than according to the 1960–65 one, but that the greater number lived fewer person-years thereafter. This reversal may be real. Another possibility is that the SPC life tables do not reflect the mortality experience of males accurately at the oldest ages. This reversal is slight, however, compared with a more pronounced reversal of this same type that results for females when one uses model North life tables rather than the SPC life tables to determine the prelimi-

Figure 5. Corrected life table probabilities of dying, ${}_5q_x$: Thailand, 1960–65 and 1975–80



nary correction factors for the 70+ age group. It was primarily on this basis that the SPC life tables were chosen to determine the preliminary correction factors for the 70+ age group.

SUMMARY AND CONCLUSION

This paper has applied a new procedure for the simultaneous and consistent correction of two or more censuses and intercensal registered births and deaths to the three Thai censuses of 1960, 1970, and 1980, and to the registered births and deaths for the intervening period 1960–80. The results reveal marked underenumeration of the 0–4 age group in each census and especially in the 1960 census, in which age rounding was apparently prevalent. There is also an indication of age exaggeration at the oldest ages, at least in the 1970 and 1980 censuses.

The results also indicate that birth registration completeness rose during 1960–80, whereas death registration completeness declined slightly until the early 1970s and then leveled off or began to rise. The greatest underregistration of deaths was at ages 0–4, and the registration completeness for deaths at this age appears to have decreased throughout the period.

Life expectancy rose for both males and females, at an average of about one-fifth year per year for males and two-fifths year per year for females between 1960 and 1980. Thus female superiority in life expectancy increased during the period, from about 4.5 years in 1960–65 to about seven years in 1975–80.

Finally, it should be noted that these results are reasonably consistent with previous estimates. The results of this paper, however, have the advantage of providing consistent corrections for multiple sets of data involving more censuses and intercensal periods than in previous studies.

Table 9. Derived intercensal life tables for males: Thailand, 1960–65,

	1960–65			1965–70		
Age_x	$_5q_x$	l_x	$_5L_x$	$_5q_x$	l_x	$_5L_x$
0	.13134	100,000	450,391	.12092	100,000	453,974
5	.02417	86,866	429,551	.02192	87,908	435,061
10	.01426	84,766	421,154	.01298	85,981	427,369
15	.01850	83,557	414,243	.01821	84,865	420,906
20	.02428	82,012	405,215	.02493	83,319	411,837
25	.02760	80,020	394,964	.02536	81,243	401,200
30	.02932	77,812	383,707	.02832	79,182	390,700
35	.03470	75,530	371,773	.03163	76,939	378,991
40	.04091	72,909	357,698	.04034	74,506	365,798
45	.04945	69,927	341,421	.04861	71,500	349,523
50	.06846	66,469	321,707	.06514	68,024	329,600
55	.08833	61,918	296,902	.08657	63,593	305,116
60	.12764	56,449	265,801	.12435	58,088	273,699
65	.18392	49,244	226,597	.18223	50,865	233,161
70	1.00000	40,187	402,083	1.00000	41,596	388,500
e_0			54.83			55.65

Table 10. Derived intercensal life tables for females: Thailand, 1960–65,

	1960–65			1965–70		
Age_x	$_5q_x$	l_x	$_5L_x$	$_5q_x$	l_x	$_5L_x$
0	.11149	100,000	458,300	.09845	100,000	462,870
5	.02048	88,851	440,093	.01757	90,155	447,079
10	.01283	87,031	432,705	.01097	88,572	440,639
15	.01478	85,915	426,697	.01386	87,600	435,339
20	.01665	84,645	419,739	.01678	86,386	428,649
25	.02065	83,236	412,152	.01764	84,937	420,975
30	.02405	81,518	403,078	.02141	83,438	413,010
35	02858	79,557	392,721	.02530	81,652	403,513
40	.03328	77,283	380,483	.03184	79,586	392,296
45	.03766	74,711	366,947	.03572	77,052	378,913
50	.04953	71,898	350,999	.04761	74,299	363,195
55	.06658	68,336	331,241	.06224	70,761	343,319
60	.09863	63,786	304,460	.09428	66,357	317,479
65	.15376	57,495	268,423	.14460	60,101	280,542
70	1.00000	48,654	538,142	1.00000	51,411	559,210
e_0			59.26			60.87

1965-70, 1970-75, and 1975-80

	1970-75			1975-80		
Age_x	${}_5q_x$	l_x	${}_5L_x$	${}_5q_x$	l_x	${}_5L_x$
0	.11320	100,000	455,822	.10458	100,000	458,119
5	.02039	88,680	439,156	.01826	89,542	443,680
10	.01187	86,872	431,966	.01129	87,907	437,209
15	.01713	85,841	425,865	.01613	86,915	431,320
20	.02488	84,371	417,213	.02372	85,513	422,960
25	.02492	82,272	406,660	.02533	83,485	412,752
30	.02637	80,221	395,959	.02642	81,370	401,925
35	.03079	78,106	384,948	.02802	79,221	390,702
40	.03720	75,701	371,905	.03540	77,001	378,691
45	.04867	72,885	356,495	.04397	74,275	363,731
50	.06556	69,338	336,258	.06369	71,009	344,967
55	.08426	64,792	311,000	.08230	66,486	319,893
60	.12437	59,337	279,474	.11683	61,014	288,159
65	.18057	51,957	238,038	.17419	53,886	247,646
70	1.00000	42,575	403,076	1.00000	44,499	464,938
e_0			56.54			58.07

1965-70, 1970-75, 1975-80

	1970-75			1975-80		
Age_x	${}_5q_x$	l_x	${}_5L_x$	${}_5q_x$	l_x	${}_5L_x$
0	.08777	100,000	465,904	.07226	100,000	470,985
5	.01531	91,223	452,843	.01186	92,774	461,165
10	.00950	89,826	447,141	.00801	91,674	456,653
15	.01199	88,973	442,430	.01011	90,940	452,559
20	.01590	87,906	436,469	.01343	90,021	447349
25	.01778	86,509	429,060	.01617	88,812	440,920
30	.01823	84,970	421,016	.01754	87,376	433,416
35	.02262	83,421	412,696	.01887	85,844	425,213
40	.02878	81,534	402,287	.02517	84,224	416,178
45	.03480	79,187	389,823	.03029	82,104	404,827
50	.04616	76,432	374,032	.04395	79,617	390,341
55	.06060	72,904	354,164	.05666	76,118	370,668
60	.08893	68,486	327,937	.08596	71,805	344,588
65	.13898	62,396	292,240	.13159	65,633	307,631
70	1.00000	53,724	643,952	1.00000	56,996	701,129
e_0			62.92			65.24

Table 11. Estimated midcensus age distributions for males and females: Thailand, 1965 and 1975 (1 April)

Age	1965		1975	
	Males	Females	Males	Females
0-4	2,877,805	2,767,810	3,308,346	3,196,146
5-9	2,396,066	2,342,268	3,116,518	3,029,976
10-14	1,961,963	1,941,655	2,712,754	2,639,719
15-19	1,533,324	1,498,930	2,320,461	2,284,206
20-24	1,269,707	1,222,129	1,893,040	1,892,458
25-29	1,172,027	1,176,440	1,462,338	1,450,844
30-34	990,641	1,015,443	1,204,364	1,177,749
35-39	848,454	842,905	1,109,613	1,131,371
40-44	664,088	655,904	928,391	967,072
45-49	538,282	541,848	784,987	794,082
50-54	459,053	459,164	598,521	607,866
55-59	372,054	394,707	469,471	491,783
60-64	288,405	307,633	381,876	401,894
65-69	206,500	231,028	284,260	325,268
70+	221,184	291,397	322,508	426,281
Total	15,799,553	15,689,261	20,897,448	20,816,715

Note: These are the estimated midcensus age-sex distributions given by the consistent correction procedure.

APPENDIX A. DERIVATION OF THE PRELIMINARY CORRECTION FACTORS

Births

A linear increase was assumed in the birth registration completeness of both sexes combined, from 78 percent on 1 April 1960 to 86 percent on 1 April 1980. This agrees quite well with the estimates of the U.S. Bureau of the Census (1978) and Hill (1979). We should note that the latter estimates are based on the Ministry of Public Health (MOPH) registration figures, whereas ours are based on the Ministry of Interior (MOI) figures, which are larger in most years; see the corrigenda sheet of Hill (1979) for a comparison of these figures through 1974. A sex ratio at birth of 1.058 for each five-year intercensal period was also used to help calculate the preliminary correction factors for births by sex.

From this assumption regarding birth registration completeness, it follows that the average birth registration completeness for the combined sexes was 79, 81, 83, and 85 percent for the successive five-year intercensal periods. The calculation of the preliminary correction factors for male and female births for the first five-year intercensal period will be shown in detail for illustrative purposes.

Let k_m and k_f be the preliminary correction factors for numbers of male and female registered births B_m and B_f respectively for the five-year period. Then k_mB_m and k_fB_f denote the estimated true numbers of male and female births. Assuming a 1.058 sex ratio at birth, one has

$$k_mB_m = 1.058k_fB_f \tag{1}$$

Assuming, moreover, 79 percent birth registration completeness for 1960–65, one may equate two different expressions of the true number of births for the combined sexes as follows:

$$k_mB_m + k_fB_f = (B_m + B_f)/(.79) \tag{2}$$

Since $B_m = 2{,}630{,}151$ and $B_f = 2{,}363{,}132$ are known, they may be substituted into equations (1) and (2). These equations then represent a system of two linear equations in the two unknowns, k_m and k_f, which may be solved simultaneously to yield the values of k_m and k_f.

The same process may be used to find the preliminary correction factors for registered births for the other five-year intercensal periods. The values obtained for the successive periods are 1.234, 1.220, 1.199, and 1.179 for males and 1.300, 1.250, 1.211, and 1.174 for females. They are recorded in Appendix Table B.5.

Censuses

The preliminary correction factors for censuses are derived directly from the following corrected census age-sex distributions obtained from outside sources: (1) For the 1960 census, the correction given in United Nations (1966); (2) for the 1970 census, the correction of the 0–4 and 5–9 age groups in Arnold and Phananiramai (1975), and of the other age groups in Fulton (1979); and (3) for the 1980 census, the correction given by Pejaranonda, Arnold, and Hauser (1983). We use the final census report (Thailand, National Statistical Office 1983) rather than the Advance Report (Thailand, National Statistical Office 1981) for the corrected female 1980 census population age 70+: 552,900 rather than 562,900. These "preliminarily corrected" census age-sex distributions are recorded in Appendix Table B.1; and the resulting preliminary correction factors, obtained by dividing these preliminarily corrected populations by the corresponding reported populations from Tables 1 and 2, are given in Appendix Table B.2.

A certain amount of consistency is built into the preliminary correction factors for censuses by the use of the census corrections above, each of which is derived in part from the preceding census correction. However, the preliminary correction factors for births are derived independently; and to an extent, the same may be said for the preliminary correction factors for deaths (see below).

As with Pejaranonda, Arnold, and Hauser (1983), we have opted for the Fulton (1979) corrections of the 1970 census age-sex distributions rather than those of Arnold and Phananiramai (1975). The preliminarily corrected census age-sex distributions of Appendix Table B.1, which have been used for deriving the preliminary correction factors for censuses, are used to calculate total population preliminary correction factors for each sex at each census. The reciprocals of these factors in turn yield census underenumeration estimates by sex for each census. The total population preliminary correction factors are given in the last row of Appendix Table B.2.

The reported census age-sex distributions (given in Tables 1 and 2) are uniformly premultiplied by these total population preliminary correction factors of Appendix Table B.2 before being put into the computer. For example, each female five-year age group is premultiplied by 1.051 for the 1970 census and by 1.025 for the 1980 census. To compensate, each preliminary correction factor given in Appendix Table B.2 must be divided accordingly before it is put into the computer. This will insure that each input census age-sex group population multiplied by the corresponding input preliminary correction factor still yields the preliminarily corrected census age-sex group population of Appendix Table B.1. Thus, for example, each preliminary correction factor for females must be divided by 1.051 for the 1970 census, and by 1.025 for the 1980 census, before being put into the

computer. In particular, the input preliminary correction factors for females of ages 0–4 for the 1970 and 1980 censuses are 1.104/1.051 = 1.050 and 1.110/1.025 = 1.083 respectively. These adjustments of the reported census age-sex distributions, as well as of the preliminary correction factors for the censuses, must be put into the computer program to get appropriate census underenumeration levels in the final results (output). This is true because the computer program is written so that for the last census (the 1980 one in our case), there is equality between the total input population for both sexes combined and the total output (corrected) population for both sexes combined. This equality was incorporated into the computer program to obtain more control over the census underenumeration levels in the final results.

Finally, except for the 0–4 age group, in which underenumeration is very evident because of age rounding (see section on principal findings), all preliminary correction factors for both sexes for the 1960 census were chosen to be 1, on the basis of United Nations (1966). First of all, the opposing effects of age rounding partially compensate in all age groups except 0–4 and 70+, and the effect is relatively small on the 70+ age group. Second, other than for the 0–4 age group, the 1960 census count appears to be fairly complete and accurate by five-year age groups (United Nations 1966). Moreover, this choice was made simply for lack of better evidence.

Deaths

Coale-Demeny model North life tables were used to determine the preliminary correction factors for deaths for all age groups below 70. The levels used were based on the e_0 values of the 1964–67 and 1974–76 SPC life tables, as described in the section on application of our method to Thailand, 1960–80. The life tables corresponding to these levels for males and females are given in Appendix Tables B.3 and B.4 respectively.

For the 70+ age group the SPC life tables were used rather than model tables. That is, the preliminary correction factors for deaths for the 70+ age group were derived from life tables obtained from the SPC life tables by an interpolation process described in the section on application of the method.

The 1960–65 and 1970–75 preliminary correction factors for deaths were derived from the life tables by a forward survival method involving the 1960 and 1970 preliminarily corrected census age-sex distributions. Similarly, the 1965–70 and 1975–80 factors were derived by a reverse survival method involving the 1970 and 1980 preliminarily corrected census age-sex distributions. The preliminarily corrected census age-sex distributions are given in Appendix Table B.1, and the preliminary correction factors for deaths are given in Appendix Table B.5.

More precisely, the forward survival formula used for the periods 1960-65 and 1970-75 to calculate the preliminary correction factor for deaths (h_a) at age a to $a + 5$ is

$$h_a = \left(\frac{P_{a-5} \cdot {}_5l_a}{{}_5L_{a-5}}\right)\left(\frac{l_a - l_{a+5}}{l_a}\right)\Big/ D_a$$

$$= \frac{5(l_a - l_{a+5})P_{a-5}}{{}_5L_{a-5}\ D_a} \qquad (3)$$

where l_a denotes life table survivors at exact age a; ${}_5L_a$ denotes life table person-years lived between exact ages a and $a + 5$; D_a denotes the number of registered deaths of age a to $a + 5$ for the period; and P_a denotes the preliminarily corrected population of the age group a to $a + 5$ for the census immediately preceding the period in question (the 1960 census for the period 1960-65 and the 1970 census for the period 1970-75).

The rationale behind formula (3) is as follows. In the first line of formula (3), the first factor in the numerator gives the number of those age $a - 5$ to a in the preliminarily corrected census population at the beginning of the period who have survived to attain age a during the period, based on the life table used for the period. The second factor in the numerator is the life table probability of dying between age a and $a + 5$ for the period. Thus the numerator, which is the product of these two factors, gives an estimate of the true number of deaths between ages a and $a + 5$ for the period. When divided by D_a, the registered number of deaths between ages a and $a + 5$ for the period, this yields the estimated (preliminary) correction factor for deaths for this age group.

Similarly, the reverse survival formula used for the periods 196- 70 and 1975-80 is

$$h_a = \left(\frac{P_a \cdot {}_5l_a}{{}_5L_a}\right)\left(\frac{l_a - l_{a+5}}{l_a}\right)\Big/ D_a$$

$$= \frac{5(l_a - l_{a+5})P_a}{{}_5L_aD_a} \qquad (4)$$

where the notation is as above except that P_a is the preliminarily corrected population of the age group a to $a + 5$ for the census immediately following the period in question.

Formula (4) is the same as formula (3) except for the first factor in the numerator. In both formulas, this first factor estimates the true number of people who have attained age a during the period. In formula (4), the number who have attained age a during the period is obtained by reverse survival of those aged a to $a + 5$ in the preliminarily corrected census

population at the end of the period rather than by forward survival of those aged $a - 5$ to a in the preliminarily corrected census population at the beginning of the period, as in formula (3).

Clearly the forward survival formula for 1960–65 and 1970–75 is not applicable for the age group 0–4. However, its natural analogue is

$$h_0 = \frac{(l_0 - l_5)B}{l_0 D_0} \tag{5}$$

where B denotes the estimated true number of births for the period and the other notation is as before. Equation (5) is used to determine the preliminary correction factor for deaths at ages 0–4. B is obtained by using the preliminary correction factors for births determined above to estimate the true number of births. For example, the preliminary correction factor for deaths for females of ages 0–4 for the period 1960–65, given in Appendix Table B.5, is

$$h_0 = \frac{(100{,}000 - 89{,}462)\ (1.300)\ (2{,}363{,}132)}{(100{,}000)\ (179{,}043)} = 1.808$$

Here, 89,462 is the l_5 value from the Coale–Demeny model North level 17.0 female life table.

Special formulas are needed also for the preliminary correction factor for deaths for the 70+ age group. The approximate reverse survival formula that is used may be obtained from equation (4) by letting $a = 70$ and $a + 5$ be an age beyond which anyone lives. Hence it is the same as equation (4) with $a = 70$; l_{a+5} set equal to 0; P_a and D_a replaced by the preliminarily corrected census population P_{70+} and registered deaths D_{70+} respectively; and ${}_5L_a$ replaced by T_{70}, the life table person-years lived above age 70. Thus

$$h_{70} = \frac{5l_{70}\ P_{70+}}{T_{70}\ D_{70+}} \tag{6}$$

As before, P_{70+} refers to the census immediately following the period in question.

For example, the value of h_{70} for males for the period 1965–70 is

$$h_{70} = \frac{5(43{,}881)\ (280{,}900)}{(428{,}383)\ (96{,}868)} = 1.485$$

(Recall that the interpolated SPC life tables are used for the 70+ age group.)

If census and death registration data and SPC life tables for five-year age groups beyond age 70 are available, as is true for some periods, one may use a more precise formula than equation (6) for h_{70}. This formula would consist of a sum with terms like equation (4) for the five-year age

groups and equation (6) for the open-ended age group. However, it was found that this more cumbersome formula yielded correction factors that differed little from those given by formula (6).

The reverse survival equation (6) was used to determine h_{70} not only for the periods 1965-70 and 1975-80, but also for the periods 1960-65 and 1970-75 after forward surviving the age group 65+ preliminarily corrected population of the 1960 and 1970 censuses to 1965 and 1975 respectively. It can be shown that the same result is obtained by using the forward survival formula

$$h_{70} = \frac{5l_{70}\ P_{65+}}{T_{65}\ D_{70+}}$$

where P_{65+} is the preliminarily corrected population of the age group 65+ for the census immediately preceding the period in question.

APPENDIX B. TABLES

Table B.1. Preliminarily corrected census age-sex distributions: Thailand, 1960, 1970, and 1980

Age group	1960		1970		1980	
	Males	Females	Males	Females	Males	Females
0–4	2,517,000	2,448,000	3,219,100	3,090,100	3,074,700	2,945,500
5–9	2,016,300	1,982,900	2,725,400	2,644,500	3,208,900	3,083,900
10–14	1,565,900	1,527,800	2,350,100	2,300,700	3,103,700	2,975,700
15–19	1,265,200	1,238,200	1,904,900	1,919,400	2,672,900	2,587,500
20–24	1,214,400	1,206,000	1,475,000	1,480,000	2,283,800	2,265,600
25–29	1,026,700	1,048,100	1,263,200	1,192,300	1,866,600	1,862,800
30–34	885,700	871,200	1,147,400	1,153,900	1,447,200	1,421,600
35–39	693,400	681,000	965,700	996,200	1,178,700	1,172,900
40–44	569,700	564,700	826,100	821,400	1,063,100	1,105,100
45–49	494,700	483,700	637,800	635,800	884,600	931,100
50–54	402,400	411,000	512,500	519,800	732,200	761,100
55–59	322,300	329,600	430,200	434,600	552,100	573,900
60–64	229,000	245,400	332,400	353,900	416,400	456,400
65–69	149,300	163,900	244,400	263,200	321,100	357,400
70+	177,700	245,100	280,900	354,000	400,100	552,900
Total	13,529,700	13,446,600	18,315,100	18,159,800	23,206,100	23,053,400

Sources: For 1960: United Nations (1966). For 1970: Arnold and Phananiramai (1975: table 11), for ages 0–4 and 5–9; Fulton (1979: tables 17, 18), for ages 10+. For 1980: Pejaranonda, Arnold, and Hauser (1983: table 11).

Table B.2 Preliminary correction factors: Thailand, censuses of 1960, 1970, and 1980

Age group	1960		1970		1980	
	Males	Females	Males	Females	Males	Females
0-4	1.175	1.163	1.123	1.104	1.109	1.110
5-9	1.000	1.000	1.016	1.014	1.077	1.080
10-14	1.000	1.000	1.016	1.020	1.032	1.027
15-19	1.000	1.000	1.038	1.017	.991	.954
20-24	1.000	1.000	1.115	1.085	1.020	.993
25-29	1.000	1.000	1.149	1.041	1.071	1.029
30-34	1.000	1.000	1.094	1.070	1.086	1.041
35-39	1.000	1.000	1.012	1.039	1.015	.991
40-44	1.000	1.000	1.066	1.071	.999	1.002
45-49	1.000	1.000	1.063	1.063	.954	.963
50-54	1.000	1.000	1.084	1.060	.983	.990
55-59	1.000	1.000	1.106	1.080	1.015	1.011
60-64	1.000	1.000	1.104	1.090	1.012	1.031
65-69	1.000	1.000	1.146	1.100	1.082	1.072
70+	1.000	1.000	1.119	1.000	.979	1.000
Totals	1.029	1.026	1.070	1.051	1.039	1.025

Note: The preliminary correction factors for censuses are calculated by sex and age group by dividing the corrected populations of Table B.1 by the corresponding reported populations given in Tables 1 and 2.

Table B.3. Coale-Demeny model North life tables for determining preliminary correction factors for registered deaths for males: Thailand, 1960-65, 1965-70, 1970-75, and 1975-80

	1960-65		1965-70		1970-75		1975-80	
Age_x	l_x	${}_5L_x$	l_x	${}_5L_x$	l_x	${}_5L_x$	l_x	${}_5L_x$
0	100,000	451,433	100,000	453,753	100,000	456,072	100,000	458,392
5	87,541	432,926	88,170	436,320	88,799	439,715	89,428	443,109
10	85,630	425,476	86,358	429,240	87,087	433,005	87,815	436,769
15	84,561	419,212	85,338	423,207	86,115	427,201	86,892	431,197
20	83,124	410,557	83,945	414,811	84,766	419,065	85,587	423,319
25	81,099	400,354	81,979	404,908	82,860	409,461	83,740	414,015
30	79,043	389,843	79,984	394,698	80,925	399,553	81,866	404,408
35	76,895	378,588	77,896	383,754	78,897	388,921	79,898	394,087
40	74,541	365,789	75,607	371,291	76,672	376,793	77,738	382,295
45	71,774	350,638	72,910	356,490	74,045	362,341	75,181	368,193
50	68,480	331,681	69,686	337,847	70,891	344,013	72,097	350,179
55	64,192	307,805	65,453	314,239	66,714	320,672	67,975	327,106
60	58,931	277,125	60,243	283,736	61,555	290,347	62,867	296,958
65	51,919	236,908	53,251	243,480	54,583	250,051	55,915	256,623
70	42,844	412,342	44,141	429,776	45,438	447,210	46,735	464,644

Note: Model North male life table levels are 16.825, 17.175, 17.525, and 17.875 for 1960-65, 1965-70, 1970-75, and 1975-80 respectively. SPC male life tables for 1964-67 and 1974-76, linearly interpolated, were used to determine preliminary correction factors for registered deaths for the age group 70+ for each five-year intercensal period.

Source: Coale and Demeny (1966).

Table B.4. Coale-Demeny model North life tables for determining preliminary correction factors for registered deaths for females: Thailand, 1960–65, 1965–70, 1970–75, and 1975–80

Age$_x$	1960–65		1965–70		1970–75		1975–80	
	l_x	$_5L_x$	l_x	$_5L_x$	l_x	$_5L_x$	l_x	$_5L_x$
0	100,000	459,370	100,000	462,864	100,000	466,359	100,000	470,935
5	89,462	443,154	90,425	448,401	91,388	453,648	92,645	460,502
10	87,800	436,542	88,936	442,444	90,072	448,346	91,556	456,060
15	86,817	431,191	88,042	437,535	89,267	443,879	90,866	452,179
20	85,660	424,759	86,973	431,559	88,286	438,360	90,004	447,268
25	84,244	417,186	85,652	424,489	87,059	431,792	88,904	441,372
30	82,630	408,648	84,144	416,517	85,658	424,386	87,645	434,726
35	80,829	399,064	82,463	407,560	84,097	416,057	86,245	427,241
40	78,797	388,007	80,562	397,135	82,327	406,262	84,651	418,301
45	76,406	375,313	78,292	385,051	80,179	394,759	82,669	407,593
50	73,732	359,785	75,729	370,217	77,726	380,449	80,368	394,013
55	70,263	340,249	72,359	351,013	74,455	361,776	77,237	376,091
60	65,837	313,593	68,047	324,895	70,256	336,198	73,199	351,290
65	59,600	276,099	61,912	287,767	64,223	299,435	67,317	315,098
70	50,839	526,812	53,195	562,554	55,551	598,297	58,722	647,334

Note: Model North female life table levels are 17.0, 17.6, 18.2 and 19.0 for 1960–65, 1965–70, 1970–75, and 1975–80 respectively. SPC female life tables for 1964–67 and 1974–76, linearly interpolated, were used to determine the preliminary correction factors for registered deaths for the age group 70+ for each five-year intercensal period.

Source: Same as Table B.3.

Table B.5. Preliminary correction factors for registered births and deaths: Thailand, 1960-65, 1965-70, 1970-75, and 1975-80

Births deaths and age group	1960-65		1965-70		1970-75		1975-80	
	Males	Females	Males	Females	Males	Females	Males	Females
Births	1.234	1.300	1.220	1.250	1.199	1.211	1.179	1.174
Deaths								
0-4	1.799	1.808	2.194	2.045	2.534	2.325	3.088	2.624
5-9	1.604	1.543	1.724	1.537	2.001	1.637	2.177	1.596
10-14	1.460	1.609	1.522	1.612	1.587	1.556	1.751	1.578
15-19	1.682	1.594	1.601	1.568	1.503	1.478	1.424	1.393
20-24	1.746	1.187	1.795	1.388	1.685	1.549	1.455	1.582
25-29	1.773	1.286	1.667	1.318	1.602	1.645	1.503	1.827
30-34	1.485	1.191	1.449	1.252	1.396	1.313	1.385	1.603
35-39	1.304	1.117	1.209	1.158	1.228	1.250	1.128	1.301
40-44	1.162	1.095	1.175	1.180	1.108	1.224	1.045	1.234
45-49	.991	1.116	1.064	1.112	1.102	1.206	.982	1.128
50-54	1.042	1.183	1.012	1.124	1.093	1.173	1.085	1.228
55-59	1.044	1.260	1.041	1.213	1.040	1.178	1.079	1.200
60-64	1.113	1.364	1.055	1.235	1.092	1.264	1.019	1.203
65-69	1.287	1.596	1.251	1.480	1.219	1.459	1.211	1.445
70+	1.459	1.671	1.485	1.562	1.417	1.456	1.352	1.514

Note: Preliminary correction factors for registered births and deaths are determined as described in Appendix A.

APPENDIX C. FORMULAS FOR DERIVING THE LIFE TABLES

The following formulas were used to calculate the intercensal abridged life table for five-year age groups for the five-year period beginning 1 April of the year 1960 + 5(i-1) (i = 1,2,3,4):

$$ {}_5L_0 = (P_{i+1,0}/B)(5l_0) $$

$$ {}_5L_{a+5} = {}_5L_a(P_{i+1,a+5}/P_{i,a}) $$

$$ T_{75} = ({}_5L_{70}\ P_{i+1,75+})/(P_{i,70+} - P_{i+1,75+}) $$

where ${}_5L_a$ = life table person-years lived between ages a and a + 5; T_{75} = person-years lived after age 75; $P_{i,a}$ = corrected age a to a + 5 population on 1 April of the year 1960 + 5(i-1), i = 1,2,3,4,5 (see Tables 1, 2, and 11); B = corrected births in the five-year period; and l_a = life table survivors at exact age a. The second of these three formulas was applied iteratively.

All three formulas result from equating the survival ratios of the life table to those of the corrected data. In particular, the third is obtained by solving for T_{75} in

$$ T_{75}/({}_5L_{70} + T_{75}) = P_{i+1,75+}/P_{i,70+} $$

which equates the survival ratio of the life table with that of the corrected data for the open-ended age group.

Then

$$ l_{a+5} = ({}_5L_a/5)(1 - D_a^*/P_{,a}) $$

where D_a^* denotes the corrected number of deaths during the five-year period occurring before exact age a + 5 to those aged a to a + 5 at the beginning of the period.

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