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Selection and Use of Survival Ratios in Population Studies

By Everett S. Lee and Gladys K. Bowles

Assumptions underlying use of survival ratios in population studies have been examined repeatedly, but some uncertainty remains as to the best ratio for specific problems and as to the advisability of attempting to correct ratios for variations in mortality, in racial or ethnic composition, in rural-urban residence, and in other categories or classifications. In separate research projects,¹ and in collaboration, the authors and their colleagues² used survival ratios to estimate migration for various areas and residence groups and in computing replacement ratios for rural-farm males of working age. In this article the authors report results of their explorations during the course of this work.

IN SEVERAL TYPES of population analyses it is necessary to estimate the survivors of a given population group at the end of a specified period. This is usually done by applying survival ratios to specified groups or subdivisions of the population at the beginning of a period. Survival ratios in the main reflect mortality. They are commonly developed from life tables or by relating the population of a specified age group counted in one decennial census to the population counted in a group 10 years younger in the preceding census. The two types of ratios, generally labeled life table and census survival ratios, respectively, have application in specific types of population studies.

For approximately closed populations, census survival ratios tend to yield more reliable estimates of net migration than life table survival ratios, as Hamilton, Henderson, Price, Siegel, and others³

have demonstrated, and these ratios have been used in our historical migration studies. In other problems, such as the making of current estimates or projections, life table ratios were used.⁴ For example, in estimating entrants into and departures from the working-age group of rural farm males (defined as 25-69), we computed survivors to 1960 of males aged 15 to 24 in 1950, and deaths during the decade of males aged 25 to 59. We considered using 1940-50 census survival ratios but abandoned the idea because of changing mortality, changing patterns of misenumeration from census to census, and the apparently heavier underenumeration in 1940 than in 1950. Instead of 1940-50 census survival ratios, we used life table ratios based on a projection of 1950 ratios under a medium assumption of mortality. For some areas ratios resulting from high and low assumptions were applied also.

¹LEE, EVERETT S. NET INTERCENSAL MIGRATION, 1870-1940. VOL. I. INTRODUCTION AND SUMMARY TABLES. Univ. of Penn. Studies of Population Redistribution and Economic Growth, 1953. (Unpublished.)

U. S. AGRICULTURAL MARKETING SERVICE and U. S. BUREAU OF THE CENSUS. REPLACEMENT RATIOS AND RATES OF RURAL FARM MALES OF WORKING AGES, 1950-60. (In process.)

U. S. AGRICULTURAL MARKETING SERVICE. NET MIGRATION FROM THE FARM POPULATION, 1940-50. (In process.)

²Especially Helen R. White, formerly with the U. S. Department of Agriculture, and Anne S. Lee, University of Pennsylvania.

³HAMILTON, C. HORACE, and HENDERSON, F. M. USE OF SURVIVAL RATE METHOD IN MEASURING NET MIGRATION. Jour. Amer. Statis. Assoc. 39 (226): 197-206. 1944.

HENDERSON, F. M. AN ESTIMATE OF NET RURAL-URBAN MIGRATION IN THE STATE AND COUNTIES OF NORTH CAROLINA.

North Carolina State College, 1943. (Unpublished Master's thesis.)

PRICE, DANIEL O. ESTIMATES OF NET MIGRATION IN THE UNITED STATES, 1870-1940. Amer. Soc. Rev. 18 (1): 35-39.

SIEGEL, JACOB S., and HAMILTON, C. HORACE. SOME CONSIDERATIONS IN THE USE OF THE RESIDUAL METHOD OF ESTIMATING NET MIGRATION. Jour. Amer. Statis. Assoc. 47 (259): 475-500. 1952.

⁴NATIONAL RESOURCES COMMITTEE. POPULATION STATISTICS-2. STATE DATA (U. S. and State Life Tables, 1929-31). 1937.

U. S. DEPT. HEALTH, EDUC. AND WELFARE, NATIONAL OFFICE OF VITAL STATISTICS. STATE AND REGIONAL LIFE TABLES, 1939-41. 1948.

U. S. DEPT. HEALTH, EDUC. AND WELFARE, NATIONAL OFFICE OF VITAL STATISTICS. VITAL STATISTICS-SPECIAL REPORTS. Vol. 37, No. 12, NATIONAL SUMMARIES, ABRIDGED LIFE TABLES, UNITED STATES, 1950. 1953.

In deciding which ratios to use in various problems and the methods of application, we made several investigations, six of which are selected for discussion in this paper: (1) Differences in mortality among States; (2) differences in life table survival ratios between native and foreign-born whites; (3) comparison of estimated State life table survival ratios with actual State life table ratios; (4) differences in estimates of net migration resulting from use of "forward," "average," and "reverse" survival ratios; (5) differences obtained in estimated survivors when broad age groups instead of narrow ones were used; and (6) results obtained from using different assumptions about mortality.

Differences in Survival Among the States

To examine State differences in survival, we constructed 10-year survival ratios for each 5-year age-sex group from 0-4 through 60-64, and for the group 65 and over at the beginning of the decade from State and national life tables for whites for 1929-31 and 1939-41. Ratios for the States were then compared with those for the United States, age group by age group. Comparisons for 1939-41 for males are shown in figure 1.

For younger ages, variation from the national average was usually slight; but after age 35-39, differences widened in most States; for the upper age groups they become rather large. In 1939-41 no group of either sex below age 25 at the beginning of the decade differed from the national survival ratio by as much as 2 percent. Among 47 of the 48 States and the District of Columbia, the difference for females was less than 1 percent for all ages below 40 at the beginning of the decade. Not until ages 45-49 for males and 55-59 for females were there States in which the ratios were as much as 5 percent greater or less than the United States ratio. In only one State did a survival ratio for each sex for an age group differ as much as 10 percent from the national average.

State ratios for females varied much less from the national average than did those for males. No State ratio for females through age group 40-44 at the beginning of the decade differed by 2 percent or more from the ratio for the United States. But nine States had male survival ratios in this age range that differed from the national average by 2 percent. For females, of the 686

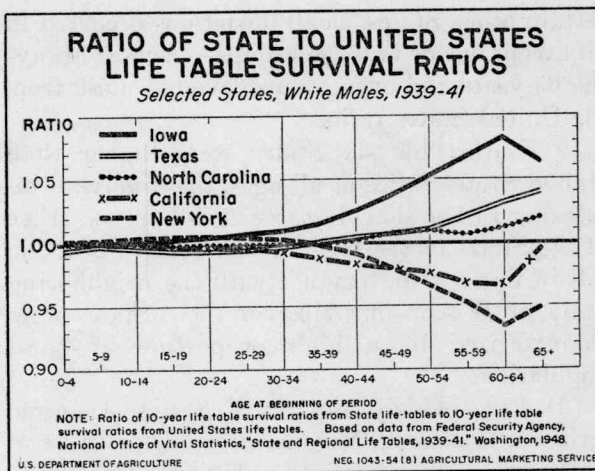


FIGURE 1.

State ratios—14 age groups for each State and the District of Columbia—498 were within 1 percent of the United States ratio. For males, only 437 of the State ratios fell in this category. In some States survival ratios were higher than the United States ratio for one sex, lower for the other. In California, for example, the survival ratios (1939-41) for males were lower than the United States ratio, especially for the older age groups. The ratios were approximately equal to or higher than the United States ratios for young and middle-aged females and were considerably higher for the older ages.

To show how State ratios departed from the national average States are grouped into the *five* following patterns for 1939-41. Most of the States fall into one of these groups. (Our discussion refers to the white male population; patterns for females are highly similar, although they deviate somewhat less from the United States ratio.)

(1) In the first group of States the deviations from the United States ratio are small, not exceeding 2 percent in any age group except for the age group 65 and over at the beginning of the decade. This group comprises 11 States, 3 in New England (Maine, New Hampshire, Vermont), four in the South Atlantic Division (Delaware, Georgia, North Carolina, Virginia), two in the East North Central Division (Ohio, Michigan), and one each in the East South Central and Mountain States (Alabama, Montana). Montana had no age group among males in which variation from the United States ratio was as much as 1 percent. In

certain other States, small deviations occurred in all except one or two age groups. Almost always the 65-years-and-over group deviated most from the United States ratio.

(2) Ratios for six States were higher than United States ratios at all ages, the difference increasing rather sharply after age 30 or so. Five of the States of the West North Central Division fell in this group, together with the neighboring State of Wisconsin. Most of these States were characterized by a high proportion of rural population.

(3) Five widely separated States—Georgia, Arizona, Louisiana, Nevada, and California—had lower ratios than those of the United States at all ages with the difference increasing for ages above 30 to 34 years.

(4) For a contiguous block of southern New England and Middle Atlantic States—Connecticut, New Hampshire, Massachusetts, Rhode Island, New Jersey, New York, and Pennsylvania, the neighboring State of Maryland, and the District of Columbia—the State ratios were higher than the national average up to about age 25 or 35, and then usually fell increasingly below the United States ratio as age increased. All these are highly urban States and have a high proportion of foreign-born whites.

(5) In another group of States, in the South and West most of the ratios are below the national average for the younger age groups, but for the middle and upper age groups the State ratios are higher than that of the United States, the difference increasing with age. These States are Florida, West Virginia, Tennessee, Arkansas, Oklahoma, Texas, Colorado, Idaho, New Mexico, Utah, Oregon, and Washington. For the most part they have a large proportion of rural population.

For 1929–31, deviations of State ratios are not presented in this paper, but they were much greater than for 1939–41. In contrast to 437 of 686 State ratios for males that were within 1 percent of the national average in 1939–41, only 369 of 672⁵ fell in this category for 1929–31. Female ratios tended to be closer to the national average, with 443 of 672⁵ differing from United States ratios by less than 1 percent. As in 1939–41 deviations were relatively small for the younger age groups and large for older age groups. States

which had high ratios in the later period generally had high survival ratios in 1929–31.

Examination of State survival ratios could not be pushed back to a period earlier than 1929–31 because a much smaller number of States had life tables for earlier periods, and the only “national” life tables that exist cover varying aggregates of States. But through examination of survival ratios from 24 State life tables for 1919–20, we were able to confirm the impression gathered from the later life tables that differences in survival among the States tend to diminish with time.

Survival Ratios for Native and Foreign-Born Whites

Several States that had markedly low survival ratios for middle and upper age groups had a large proportion of urban population, or of foreign-born white, or of both. Most life tables for the United States and the States are based on total white population. To examine the commonly held assumption that foreign-born survival ratios are lower than those for native whites we constructed life tables for native whites and foreign-born whites for 1900–10, 1910–20, 1920–30, and 1930–40. These life tables were admittedly crude; no adjustments were made of population or mortality data, and they were based on the age-specific mortality rates of census years. For example, the 1900–10 table was based on the average of the mortality rates for 1900 and 1910.

But it was found that for the younger ages there was little difference between the two, and in several instances foreign-born ratios were larger than those for native whites, particularly for 1900–10. After group 30–34 at the beginning and group 40–44 at the end of the 10-year period, ratios for foreign born were markedly lower than those for native born. The greatest difference is observed in 1900–10 and at each later period the difference decreased (fig. 2).

Adjustment of National Life Table Survival Ratios

Often neither life table nor census data are available for a specific group for which survival ratios are required. In some instances, national survival ratios can be adjusted to account for variation in survival known or thought to exist

⁵ Life tables for Texas are not available for 1929–31.

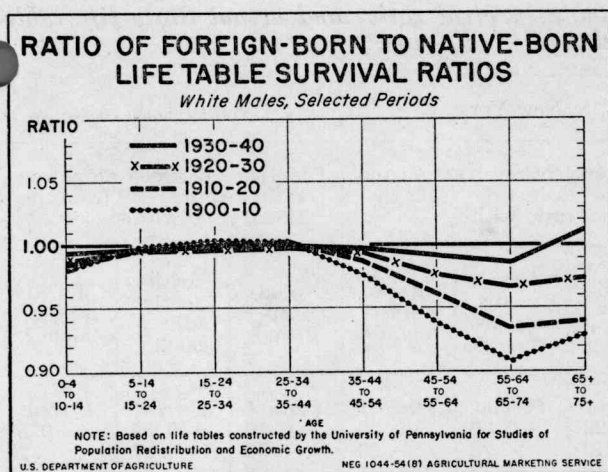


FIGURE 2.

between the national and a smaller group. For example, national survival ratios are sometimes adjusted for the State variations in survival discussed in the previous section.

We made a rough test of the effects of adjusting national survival ratios for State differences in survival. Estimates of the 10-year survival ratios for the States in 1939-41 were made by applying to the 1939-41 United States life table ratios adjustments based on differences between life table survival ratios for the United States and the States in 1929-31. Percentage differences between estimated survival ratios and actual ratios obtained from State life tables were computed when (1) no adjustment was attempted and the national life table ratios were used for the States; (2) adjustments representing the arithmetic difference between the 1929-31 State and national life table ratios were applied to 1939-41 national life table ratios; and (3) the ratios between 1929-31 State and national life table survival ratios were applied to the 1939-41 national life table survival ratios.

This was done for 20 States. For South Dakota and Arizona, States with the highest and lowest expectation of life at birth in 1930, and for New York, a State with medium life expectancy, results are shown in table 1. When no adjustment was made, the ratios were always too high for Arizona and too low for South Dakota. For some age groups, adjustments produced greater errors and for other age groups smaller errors than when no adjustments were made. Overcorrection is evident in many cases where the signs of the percentage errors change when the adjustments were made. Generally speaking, the results were better for the

younger age groups when no adjustment was made. For the middle and upper age groups, adjustments improved the correspondence with survival ratios computed from the 1939-41 State life tables for some States, but not for others. In view of these results the desirability of introducing such adjustments may be questioned. They were not made in computing replacement ratios for rural-farm males of working age. An influential factor in the decision not to make this adjustment for State variation in survival was the convergence over time of the survival ratios of the States, as was pointed out in a previous section.

Forward, Reverse, and Average Survival Ratios

Census survival ratios can be computed by three different methods. These are usually designated as "forward," "reverse," and "average." A forward census survival ratio is a fraction in which the numerator is the number of persons in an age-sex group of a closed population (one which is entered only by birth and left only by death) at a given census, and the denominator is the number 10 years younger at the preceding census. A reverse ratio, on the other hand, is obtained by inverting the fraction. The numerator is the number of persons in an age-sex group at a given census, and the denominator is the number 10 years older in the following census. Average ratios are obtained by combining the forward and the reverse ratios.

We experimented with reverse and average, as well as forward survival ratios. An example of our results (table 2) shows the percentage difference in the estimates of net migration for males for California and Vermont obtained by using the various types of survival ratios. For all age groups in California, net in-migration was indicated by all three methods; for all age groups in Vermont, net out-migration was estimated. The reverse method gave larger estimates of net in- or out-migration at any age than the forward method. The average method gave intermediate results. Differences in net migration using the three ratios are most striking for the oldest age groups. Theoretically, it may be better to use forward survival ratios for some States, average survival ratios for others, and reverse survival ratios for still others, but the extra work involved in using different types of ratios is not warranted by differ-

TABLE 1.—*Difference between estimated State life table survival ratios and actual State life table survival ratios¹ white males, selected States²*

Age group		Arizona			New York			South Dakota		
		Difference between actual and ratio estimated from national ratio with—			Difference between actual and ratio estimated from national ratio with—			Difference between actual and ratio estimated from national ratio with—		
1940	1950	No adjustment ³	Arithmetic adjustment ⁴	Ratio adjustment ⁵	No adjustment ³	Arithmetic adjustment ⁴	Ratio adjustment ⁵	No adjustment ³	Arithmetic adjustment ⁴	Ratio adjustment ⁵
Years	Years	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
0-4	10-14	0.62	-1.54	-1.56	-0.23	-0.30	-0.30	-0.16	0.54	0.54
5-9	15-19	.25	-.99	-1.00	-.19	-.23	-.23	-.08	.17	.17
10-14	20-24	.83	-1.52	-1.54	-.35	-.22	-.21	-.08	.58	.58
15-19	25-29	1.27	-2.97	-3.01	-.48	-.24	-.24	-.21	.78	.79
20-24	30-34	1.49	-5.26	-5.35	-.47	-.29	-.29	-.51	.50	.51
25-29	35-39	2.12	-6.79	-6.92	-.36	-.43	-.43	-.76	.40	.42
30-34	40-44	3.07	-6.13	-6.27	-.18	-.66	-.67	-1.08	.91	.94
35-39	45-49	4.03	-4.01	-4.14	.23	-.97	-.99	-1.76	1.54	1.59
40-44	50-54	4.92	-2.28	-2.38	.95	-1.42	-1.45	-2.92	1.82	1.89
45-49	55-59	4.79	-2.34	-2.41	1.99	-2.00	-2.04	-4.30	1.69	1.75
50-54	60-64	3.88	-3.24	-3.29	3.37	-2.41	-2.45	-5.86	.61	.66
55-59	65-69	3.30	-4.02	-4.11	5.19	-2.03	-2.12	-7.30	-.68	-.60
60-64	70-74	3.43	-4.45	-4.60	7.11	-.81	-.97	-7.95	.51	.68
65+	75+	1.75	-.91	-.96	5.34	-1.94	-2.08	-6.84	2.17	2.34

¹Basic data for the estimated and actual State life table survival ratios are from FEDERAL SECURITY AGENCY, NATIONAL OFFICE OF VITAL STATISTICS, STATE AND REGIONAL LIFE TABLES, 1939-41, and NATIONAL RESOURCES COMMITTEE, POPULATION STATISTICS—2. STATE DATA. Washington, D. C., 1948 and 1937, respectively.

²The three States above were selected for illustration on the basis of expectation of life at birth for white males in 1929-31. Arizona with 48.08 years, South Dakota with 64.38 years, were lowest and highest in expectation of

life, respectively, and New York with 57.84 years was about midway between these two extremes.

³Estimated by assuming the 1939-41 United States survival ratio to be the same as the 1939-41 State survival ratio.

⁴Estimated by adding the difference between the 1929-31 United States survival ratio and the 1929-31 State survival ratio to the 1939-41 United States survival ratio.

⁵Estimated by multiplying the 1939-41 United States survival ratio by the ratio of the 1929-31 State survival ratio to the 1929-31 United States survival ratio.

ences obtained. Furthermore, intelligent choice of different ratios for different States presumes *a priori* knowledge of migration patterns in the States.

Age Groupings and Mortality Assumptions

We also explored the effect of using survival ratios applied to different age groupings. In computing replacement ratios—ratio of number of entrants into selected working ages per 100 departures through death or retirement from these ages during a specified decade—we applied survival ratios computed for broad, modified broad, and detailed (5-year) age groups. For the working age group 25-69, survival ratios for the following groups were developed: *Broad age groups*—15-24 and 25-59; *Modified broad age groups*—15-24,

25-44, and 45-59; *Detailed age groups*—each 5-year age group 15-19 through 55-59.

Differences in replacement ratios from almost none to nearly 8 percent were observed among the various age groupings among the experimental areas. Some of these are shown in table 3. The determining factor in the resulting estimation of entrants and departures that form the ratio is the age structure of the rural-farm male population, particularly among the older ages, where the differential in survival changes markedly from age group to age group. In North Carolina, for example, 41,619 entrants and 18,536 departures were obtained by using the detailed age grouping, and 41,576 entrants and 19,480 departures were obtained using the broad age groups. The percentage difference in the resulting replacement

ratios was 5.3. As some differences as large as 8 percent were obtained, we decided to use a detailed age breakdown throughout computations of the replacement ratios.

In connection with the replacement ratios project, we observed variation in the ratios when survival ratios assuming different levels of mortality for the 1950-60 decade were used. Survival ratios to the midpoint of the decade were developed by assuming that average annual rates of decrease in 5-year death rates between 1939-41 and 1950 would prevail for 1950-60. We used two times this medium rate for the high assumption and half of it for the low. The high, medium, and low ratios were applied to detailed age data for rural farm males of all States. New Hampshire, a State with low replacement ratio 1940-50; Iowa, a State with medium replacement ratio 1940-50; and North Carolina, a State with high replacement ratio 1940-50, were chosen for illustration in table 3. Replacement ratios ranged from no appreciable difference to a difference of 4 percent when medium and high mortality levels were assumed. Between medium and low assumptions the range was from almost 2 percent to about 10 percent.

TABLE 2.—*Difference between estimates of net migration of white males using average and reverse census survival ratios from estimates using forward census survival ratios, selected States, 1930-40*¹

Age group		California		Vermont	
		Difference between forward and—		Difference between forward and—	
1930	1940	Average	Reverse	Average	Reverse
<i>Years</i>	<i>Years</i>	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>
0-4	10-14	0.88	1.76	0.91	1.66
5-9	15-19	1.44	2.88	1.44	2.89
10-14	20-24	3.10	6.19	3.09	6.17
15-19	25-29	2.67	5.34	2.65	5.35
20-24	30-34	1.75	3.50	1.75	3.50
25-29	35-39	.39	.78	.33	.65
30-34	40-44	1.27	2.53	1.48	2.66
35-39	45-49	4.39	8.78	4.00	8.00
40-44	50-54	4.13	8.26	4.76	7.94
45-49	55-59	8.89	17.79	8.00	18.00
50-54	60-64	13.23	26.45	13.54	26.04
55-59	65-69	13.70	27.40	13.60	27.45
60-64	70-74	24.90	49.80	24.74	50.00
65+	75+	83.94	167.89	83.87	167.94
All ages--	-----	3.90	7.81	10.03	20.08

¹ Based on data from 1940 and 1950 Censuses of Population.

TABLE 3.—*Replacement ratios*¹ *for rural-farm working-age males, using specified age groups and different mortality assumptions, selected States, 1950-60*

State and color	Replacement ratios based on—									
	A. Age groups					B. Mortality assumptions				
	Broad	Modi- fied	5-year	Percentage dif- ference between 5-year and—		High	Me- dium	Low	Percentage dif- ference between medium and—	
				Broad	Modi- fied				High	Low
				<i>Percent</i>	<i>Percent</i>				<i>Percent</i>	<i>Percent</i>
New Hampshire.....	95	94	93	2. 2	1. 1	94	95	97	—1. 1	2. 1
Iowa.....	132	133	133	— . 8	0	135	136	140	— . 7	2. 9
North Carolina:										
White.....	168	171	172	—2. 3	— . 6	174	176	180	—1. 1	2. 3
Nonwhite.....	213	222	225	—5. 3	—1. 3	231	238	251	—2. 9	5. 5
Combined.....	181	185	186	—2. 7	— . 5	190	193	199	—1. 6	3. 1

¹ The replacement ratios in this table are preliminary and are shown for illustrative purposes only. Ratios in Part A differ somewhat from those in Part B. Survival ratios used for the replacement ratios in Part A are from preliminary life table data supplied by the National Office of Vital Statistics. Survival ratios used for the replacement

ratios in Part B are as indicated in the above text. Data are from the forthcoming cooperative study of the U. S. Agricultural Marketing Service and the U. S. Bureau of the Census, REPLACEMENT RATIOS AND RATES OF RURAL-FARM MALES OF WORKING AGES, 1950-60.