A refined method of estimating numbers of future births, based on age-parity specific rates, is used to obtain two series of birth projections for the period 1956–65.

Short Range Birth Projections

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ESTIMATES of the number of births that will occur during the next 10 years are of considerable importance for effective program planning in areas of public health, social welfare, economic activity, and community facilities. In response to the need for such data, various methods have been developed for estimating the number of future births on the basis of alternative assumptions as to fertility trends. These estimates are generally called projections. While they do not purport to predict the future, projections are usually designed to provide alternative birth series representing the range of reasonable possibility. A large element of judgment is, of course, involved, but a knowledge of fertility trends and an understanding of the current demographic situation are basic factors in the quality of the results.

Of the various methods for making birth projections, the one most widely accepted uses age-specific birth rates to measure fertility (*1*, *2*). This rate is defined as the number of births to mothers of specified age per 1,000 women in the corresponding age group. Time series of these fertility rates are extrapolated on the basis of alternative assumptions as to future trends. A parallel series of estimates of the projected female population in the reproductive ages is obtained by "aging" the present population the required number of years and adjusting for anticipated mortality and net immigration. The projected rates are then applied to the projected numbers of women to derive estimated numbers of births.

A logical refinement is introduced into the foregoing procedure by the substitution of the age-parity specific birth rate as the fertility measure. This rate is a birth probability, having as its denominator the number of women of specified age at the beginning of the year who are subject during the year to a birth of specified order. The numerator represents the number of these women who experience a birth of this order during the observation year. Thus the age-parity rate identifies the female population at risk of pregnancy not only in terms of the women's ages but also the order of birth to which they are subject. The age-specific rate, of course, does not take explicit account of this latter variable.

In the proposed method of projection the birth probabilities are extrapolated and applied to successive cohorts of women classified by age and parity. The end product is a series of birth frequencies classified by single years of age of mother and by birth order. We have applied this procedure experimentally to obtain two series of birth projections for the period 1956–65, based on available fertility data

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through 1955 and on alternative assumptions as to future fertility. All birth data are adjusted for under-registration.

Projection Series A

Age-parity specific birth rates for the period 1950–55 were furnished by Whelpton, together with figures showing the estimated distribution of the female population as of January 1, 1955, by single year of age and by parity. These data and a detailed discussion of their nature will be presented in his forthcoming fertility monograph, which revises and expands an earlier publication on the subject (*3*). The birth rates were formed into time series for each age-parity group and examined to determine their trends in recent years. There were about 240 such series, some of which are illustrated in figure 1. In general, the trend showed an upward movement during the 6-year period but at a declining rate.

Fertility Assumptions

For extrapolation purposes, various assumptions could, of course, be made as to the future direction of fertility trends. A reasonable possibility, however, was that these curves would level off by 1960 and remain at that level until 1965. This hypothesis formed the basis for series A, the first of two illustrative projections. A second series, series B, was also prepared, based on the assumption that the 1955 age-parity rates would remain the same in each of the years 1956–65 (fig. 2).

To apply systematically the fertility assumptions underlying series A, a second-degree equation was fitted to the 1950–55 age-parity rates, the curve of which would satisfy the following conditions:

1. Form a least-squares fit to the data for 1950–55.

2. Pass through the arithmetic mean of the 1954 and 1955 rates at the ordinate midway between those for the 2 years.

Figure 1. Age-parity rates for third births to women 25–29 years of age, United States, 1950–65.

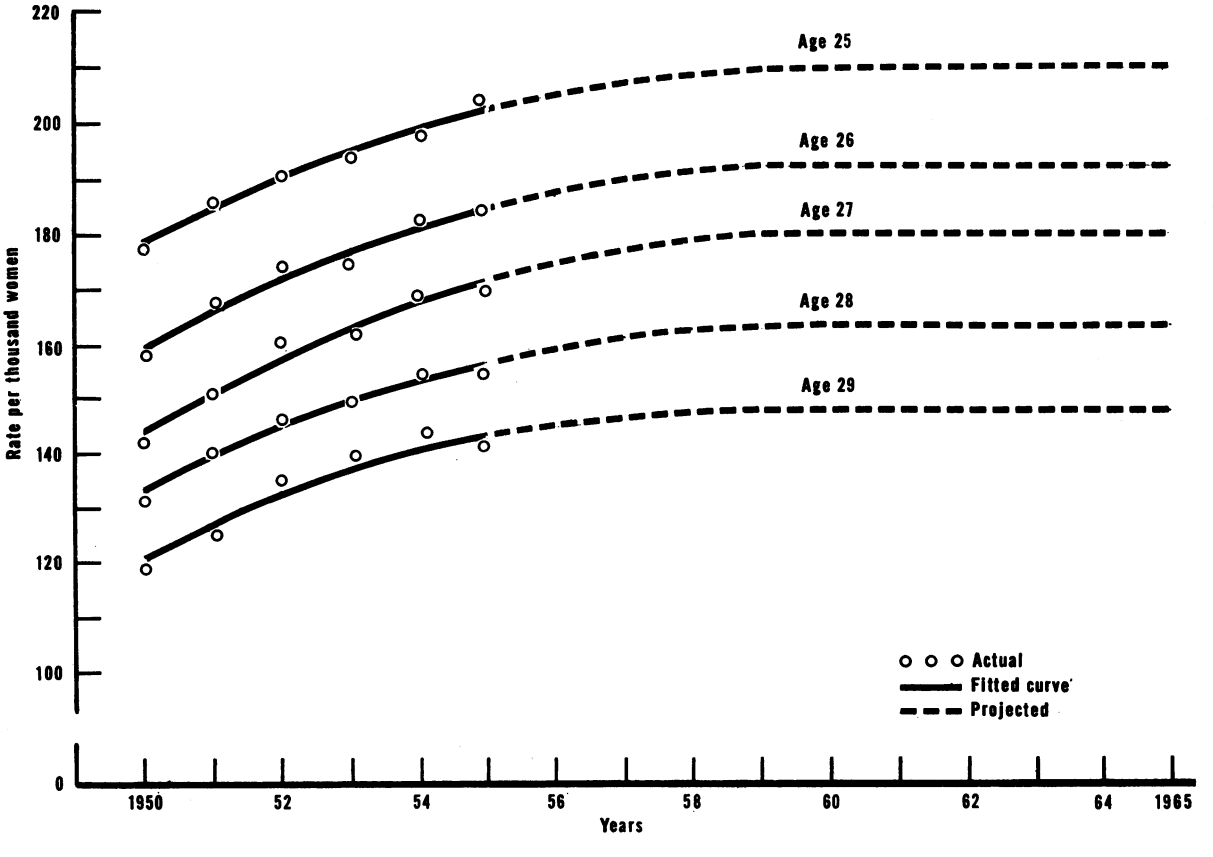
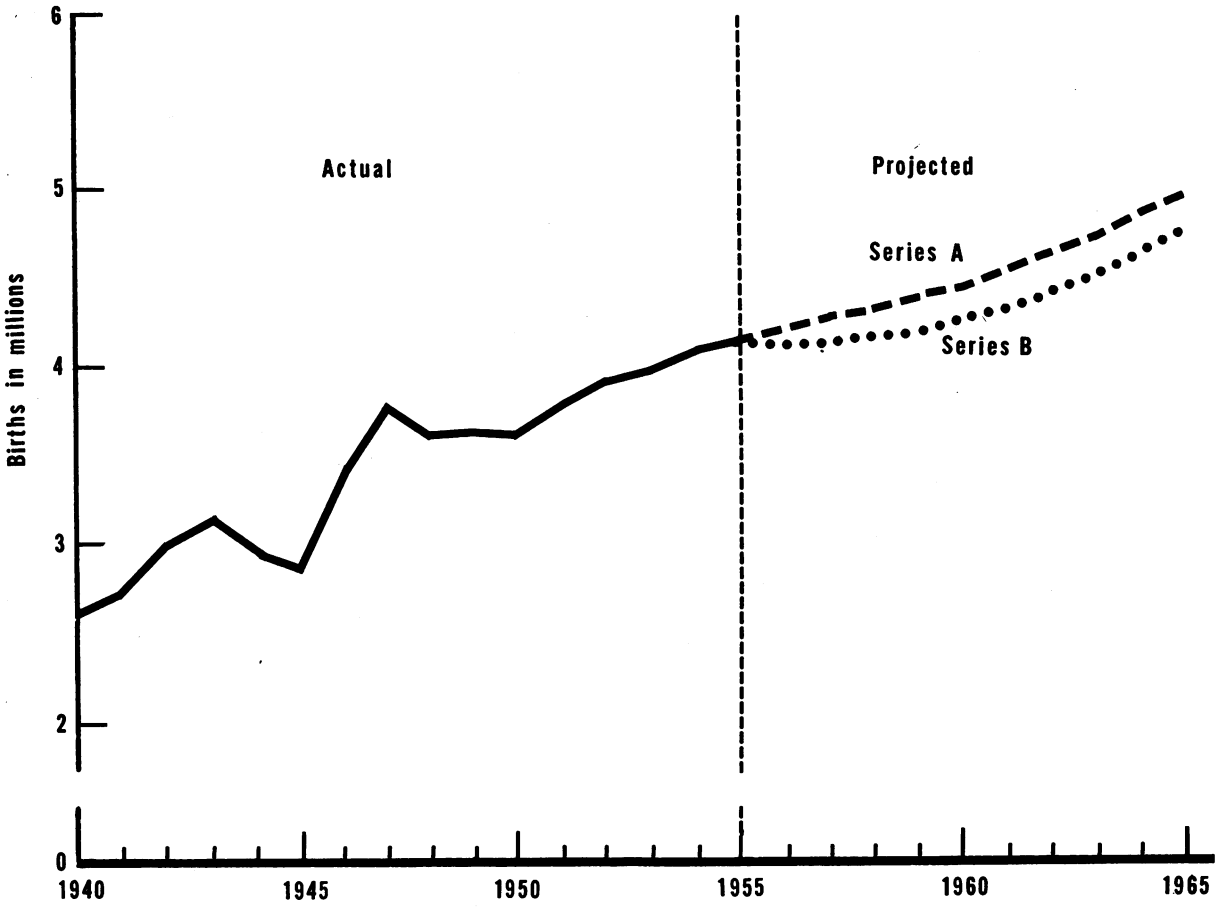


Figure 2. Actual and projected numbers of births, United States, 1940–65.



3. Have a slope of zero in 1960.

The following general equation was used to fit the curves to each of the series of observed data:

$$v_x = ax^2 + bx + c$$

where v_x denotes the computed rate corresponding to the abscissa x (year−1950). Here a, b, and c are constants to be determined for each series in accordance with the conditions previously stated, which lead to the expressions:

$$a = \sum_{x=0}^{5} M_x \left(Y_x - \frac{Y_4 + Y_5}{2} \right) \div \sum_{x=0}^{5} M_x^2$$

$$b = -20a$$

$$c = 69.75a + \frac{Y_4 + Y_5}{2}$$

where Y_x is the observed rate in the year $1950+x$, and $M_x = x^2 - 2x + 69.75$.

Separate equations conforming to the conditions set forth above were computed for each of the series of age-parity rates and mathematically extrapolated to 1960. As a visual check on the goodness of fit, freehand curves were also plotted and extrapolated, and the results were compared with those obtained mathematically. In a few cases the freehand curve appeared to provide a more reasonable basis for projection purposes, and these were so used. But in general, the mathematical results were found to be suitable. Age-parity rates were then derived algebraically for each year 1956 to 1960, and the rates for the latter year were used also for the 1961–65 period.

Cohort Survival

The next step in the projections was the application of the projected rates successively each year to the numbers of women of corres-

Table 1. Series A birth projection results for the United States, 1956–65 [1]

Year	Total	Live birth order							
		1	2	3	4	5	6	7	8 and over
	Number in thousands								
1955 [2]	4,104	1,138	1,104	800	462	249	139	80	132
1956	4,204	1,147	1,100	818	491	270	151	87	139
1957	4,287	1,164	1,094	828	511	288	163	94	146
1958	4,341	1,151	1,094	835	529	304	174	101	154
1959	4,385	1,135	1,090	840	544	319	185	108	164
1960	4,446	1,148	1,079	844	556	332	196	116	175
1961	4,538	1,189	1,075	846	567	345	206	123	187
1962	4,630	1,220	1,083	848	577	356	216	130	200
1963	4,735	1,256	1,098	853	586	367	225	137	213
1964	4,856	1,298	1,121	862	594	377	234	144	226
1965	4,994	1,345	1,150	875	604	387	243	150	240
	Rate per 1,000 women 15–44 years old [3]								
1955 [2]	116.2	32.2	31.3	22.6	13.1	7.1	3.9	2.3	3.7
1956	118.6	32.4	31.1	23.1	13.9	7.6	4.3	2.5	3.9
1957	120.2	32.6	30.7	23.2	14.3	8.1	4.6	2.6	4.1
1958	120.5	31.9	30.3	23.2	14.7	8.4	4.8	2.8	4.3
1959	120.7	31.2	30.0	23.1	15.0	8.8	5.1	3.0	4.5
1960	121.6	31.4	29.5	23.1	15.2	9.1	5.4	3.2	4.8
1961	123.2	32.3	29.2	23.0	15.4	9.4	5.6	3.3	5.1
1962	123.6	32.6	28.9	22.6	15.4	9.5	5.8	3.5	5.3
1963	124.5	33.0	28.9	22.4	15.4	9.7	5.9	3.6	5.6
1964	125.8	33.6	29.0	22.3	15.4	9.8	6.1	3.7	5.9
1965	127.6	34.4	29.4	22.4	15.4	9.9	6.2	3.8	6.1

[1] Based on assumption that 1950–55 trends in age-parity specific rates will level off by 1960.
[2] Actual.
[3] Rates based on Whelpton's population estimates, which differ slightly from those prepared by the Bureau of the Census and used in National Office of Vital Statistics publications.

ponding parity and age. The method used was that of cohort survival. This refers to the shifting of a population at a given date forward in time, making allowances in each age cohort for attrition due to mortality and for adjustments in its parity composition. As each cohort advances from one year to the next, its parity distribution changes to reflect its fertility experience in the previous year. The process involves an iterative series of successively linked computations.

Mortality and Migration

Mortality projections were needed to compute the proportion of each population cohort surviving from one year to the next during the 1956–65 period. The necessary survival factors were furnished by Thomas N. E. Greville, assistant chief actuary, Social Security Administration. They reflect assumptions of "medium" mortality during the 10-year period, that is, a moderate continuation of the presently declining mortality trends.

Account was taken separately of the number of births to the net immigrant population during the 1956–65 period. Estimates were obtained from the Bureau of the Census of female immigrant population projections by age for the 1957–60 and 1961–65 periods. From these data estimates of annual net immigration were derived. The cohort survival method was used to obtain the age distribution of each year's complement of immigrant females in each of the remaining years of the projection period. To the cumulative totals of immigrant females in each year 1956–65 were then applied the age-specific fertility rates derived for the general population. The contribution of immi-

grants to the total number of births during the projection period is small. For 1960, births to immigrants represent only 1.7 percent of the estimated total, and for 1965 less than 3 percent.

Adjustment of First-Birth Estimates

An analysis of first-birth and marriage figures during the postwar period shows a high linear correlation (.96) between the two variables, with a lag of 1 year. It is believed that, if this relationship is utilized, some further refinement is introduced into the projections of first births for 1956–58. Since annual marriage data are presently available only through 1957, it is not possible to carry out the adjustment of first-birth projections beyond 1958.

The following regression equation for the relationship between marriages (X) in year M and first births (Y) in year $M + 1$ was derived for the period 1948–55:

$$Y - 668{,}000 + 0.3128X$$

The adjustment of first births by single years of age of mother in the original projections to the estimate of first births based on marriages was made on a pro rata basis. The revised figures differed only slightly from those obtained by the use of parity rates; the amount of adjustment averaged about 1 percent per year for the 3 years.

Table 2. Cumulative birth rates [1] for cohorts of women surviving to 1955 and 1965, continental United States

Age (years)	1955 rate	1965			
		Series A projection		Series B projection	
		Rate	Percent increase over 1955	Rate	Percent increase over 1955
15–19	96	95	−1.0	100	4.2
20–24	865	967	11.8	923	6.7
25–29	1,718	2,163	25.9	2,062	20.0
30–34	2,194	2,889	31.7	2,821	28.6
35–39	2,318	3,054	31.8	3,006	29.7
40–44	2,263	2,889	27.7	2,866	26.6
45–47	2,233	2,646	18.5	2,638	18.1

[1] Number births per 1,000 women.

NOTE: Data for 1955 based on actual figures; data for 1965 derived from birth projections.

Table 3. Estimated percent childless among cohorts of women surviving to 1955, 1960, and 1965 [1]

Age (years)	1955	Series A projection		Series B projection	
		1960	1965	1960	1965
15–19	92.2	91.9	92.3	92.0	92.0
20–24	50.1	46.2	46.2	48.2	48.2
25–29	24.2	19.4	17.5	20.0	19.2
30–34	15.7	13.7	11.1	13.8	11.4
35–39	17.1	11.6	10.1	11.8	10.4
40–44	20.7	15.9	10.7	15.9	10.9
45–47	22.5	20.0	13.7	20.0	13.7

[1] 1955, actual; 1960 and 1965, projected.

Results

On the basis of series A assumptions, total live births increase from 4,104,000 in 1955 to 4,446,000 in 1960, and then climb more rapidly to reach a figure of 4,994,000 in 1965 (table 1). First births, after an initial rise from 1,138,000 in 1955 to 1,164,000 in 1957, drop off slightly in 1958 and 1959. Thereafter, however, the number climbs steadily to 1,345,000 in 1965.

Second births decline for the first 6 years of the projection period (from 1,104,000 in 1955 to 1,075,000 in 1961), then turn upward during the next 4 years, and by 1965 number 1,150,000. All higher-order births increase consistently during the 10-year span. The following figures show the relative increase of birth-order frequencies from 1955 to 1965 implied by projection series A:

Live birth order	*Percent increase*
Total	21.7
First	18.2
Second	4.2
Third	9.4
Fourth	30.7
Fifth	55.4
Sixth	74.8
Seventh	87.5
Eighth and over	81.8

An interesting aspect of this birth projection technique is that it permits the derivation of cumulative fertility rates and estimates of the

percentage of women at various ages who are childless. The cumulative fertility rate is the number of births per 1,000 survivors of each cohort. This measure is useful in relation to questions regarding the extent to which family size is increasing. For example, table 2 shows that in 1955, women aged 45–47 years had a cumulative fertility rate of 2,233 births per 1,000. The corresponding age group, according to the fertility assumptions of series A, will have a rate of 2,646 per 1,000 in 1965.

It is recognized, of course, that the foregoing figures represent the extension of current high levels of fertility. These high levels may be due to the fact that relatively more women are marrying, are doing so at a younger age, and are completing their families earlier in life. To the extent, therefore, that the current situation is attributable to these factors, the result may be primarily a change in the timing and spacing of children in relation to the mother's age and the duration of marriage rather than a large increase in the total number of children she will ultimately bear.

Table 3 shows the estimated percentages of women who were childless at specified ages in 1955 and the corresponding percentages in 1965, based on series A projections. According to these figures, a much smaller proportion of the women surviving to the end of their childbearing period will be childless in 1965 than is presently the case. In 1955, 23 percent of the women reached the end of their reproductive span without having a live birth. For women reaching age 45 years in 1965, the corresponding proportion would be 14 percent. The latter figure is only partially dependent upon the birth assumptions of series A. The women who will reach ages 45–47 years in 1965 had already experienced such high first-birth rates by 1955, at which time they were aged 35–37, that only 15 percent were still childless. Hence, regardless of their fertility experience during the next 10 years, they will have a substantially lower rate of childlessness in 1965 than the corresponding age group a decade earlier.

It is possible to compare series A projections for 1956 and 1957 with figures now available for these years. Insofar as the totals are concerned, the projected figures are within 0.3

Table 4. Comparison of projected birth figures [1] for 1956 with final tabulated data for that year

Classification	Number of live births		Percent difference [2]
	Projected	Actual	
Total	4, 204, 000	4, 218, 000	0. 31
Birth order			
First	1, 147, 000	1, 166, 000	−1. 6
Second	1, 100, 000	1, 109, 000	−. 8
Third	818, 000	821, 000	−. 4
Fourth	491, 000	483, 000	+1. 7
Fifth	270, 000	263, 000	+2. 7
Sixth	151, 000	149, 000	+1. 3
Seventh	87, 000	87, 000	0
Eighth and over	139, 000	139, 000	0
Age of mother (years)			
10–14	7, 000	7, 000	0
15–19	515, 000	530, 000	−2. 8
20–24	1, 314, 000	1, 342, 000	−2. 1
25–29	1, 142, 000	1, 144, 000	−. 2
30–34	756, 000	736, 000	+2. 7
35–39	370, 000	362, 000	+2. 2
40–44	94, 000	92, 000	+2. 2
45 and over	5, 000	5, 000	0

[1] Projections based on assumption that 1950–55 trends in age-parity rates will level off by 1960. Both projected and actual numbers adjusted for under-registration.

[2] Actual figure is base in computation.

NOTE: For 1957 only provisional figures are available. The 1957 total, according to these figures, is 4,301,000, or only 0.3 percent higher than the projected total of 4,287,000.

Table 5. Series B birth projection results for the United States, 1956–65 [1]

Year	Total	Live birth order							
		1	2	3	4	5	6	7	8 and over
	Number in thousands								
1955 [2]	4,104	1,138	1,104	800	462	249	139	80	132
1956	4,111	1,117	1,075	802	480	265	149	86	137
1957	4,121	1,107	1,052	801	496	271	159	92	144
1958	4,159	1,108	1,034	798	508	294	167	98	152
1959	4,201	1,118	1,024	794	517	306	177	104	161
1960	4,259	1,137	1,022	791	524	316	187	110	171
1961	4,330	1,162	1,028	791	530	325	195	117	182
1962	4,418	1,196	1,041	793	536	333	203	123	193
1963	4,518	1,232	1,061	800	542	340	210	129	205
1964	4,633	1,274	1,086	810	548	347	217	134	217
1965	4,762	1,320	1,116	824	556	354	223	139	229
	Rate per 1,000 women 15–44 years old [3]								
1955 [2]	116.2	32.2	31.3	22.6	13.1	7.1	3.9	2.3	3.7
1956	116.0	31.5	30.3	22.6	13.6	7.5	4.2	2.4	3.9
1957	115.5	31.0	29.5	22.5	13.9	7.6	4.5	2.6	4.0
1958	115.4	30.7	28.7	22.1	14.1	8.2	4.6	2.7	4.2
1959	115.7	30.8	28.2	21.9	14.2	8.4	4.9	2.9	4.4
1960	116.5	31.1	28.0	21.6	14.3	8.6	5.1	3.0	4.7
1961	117.6	31.5	27.9	21.5	14.4	8.8	5.3	3.2	4.9
1962	117.9	31.9	27.8	21.2	14.3	8.9	5.4	3.3	5.2
1963	118.8	32.4	27.9	21.0	14.2	8.9	5.5	3.4	5.4
1964	120.0	33.0	28.1	21.0	14.2	9.0	5.6	3.5	5.6
1965	121.7	33.7	28.5	21.0	14.2	9.0	5.7	3.6	5.9

[1] Based on assumption that rates in 1956–65 will remain at 1955 level.
[2] Actual.
[3] Rates based on Whelpton's population estimates, which differ slightly from those prepared by the Bureau of the Census and used in National Office of Vital Statistics publications.

percent of the official counts (table 4). With regard to birth order, the largest difference in 1956 was 2.7 percent, and the unweighted average difference for all birth orders, ignoring signs, 1.1 percent. The situation was similar with respect to age of mother. The largest difference was 2.8 percent, and the average difference, 1.5 percent. Virtually all the projected birth-order and age-of-mother totals for 1956 correctly reflected the direction of the true change from 1955. National data for 1957 by age of mother and birth order have not yet been tabulated. It is recognized, of course, that 1- or 2-year projections, however made, are much more apt to approximate the actual counts than projections 5 or 10 years ahead.

Projection Series B

A second projection, series B, was computed on the basis of the fertility assumption that the age-parity birth probabilities during the period 1956–65 would be the same as in 1955. The mortality and migration assumptions are the same as in series A. The results are shown in tables 2, 3, and 5.

Series B births in 1956 and 1957 are below the numbers actually occurring in these years, and present indications are that they will fall short of 1958 experience. Should there be a downturn in fertility during the remaining years of the projection period, however, series B projections may provide a closer approximation of the birth situation during the first half of the 1960 decade than series A. In addition to its usefulness as a "low" series in bracketing possible future natality experience, series B serves two other purposes. It throws light on the question of the extent to which population and parity factors would result in a rise in the number of live births despite a

leveling off of the fertility rate as such, and it is useful in demonstrating the practical differences between projection results based on age-parity rates and those based on age-specific rates.

Comparison of Methods

For the purpose of comparing the two methods of estimating births, another projection, series C, was made for the 1956–65 period. Series C parallels series B in all respects except the method of measuring fertility. In series B, age-parity rates were used; in series C, age-specific rates. In both series, however, fertility was assumed to be the same in each year during the period 1956–65 as in 1955.

Table 6, which presents a comparison of the results of series B and series C projections, shows that there is an initially small but gradually widening gap between the total numbers of births obtained by the two methods, with series B yielding the larger numbers. By 1960, there is a difference of 2.5 percent, and by 1965 this gap widens to 4.8 percent. Differences for the individual age-of-mother groups are even greater. In 1965, for example, the projected number of births to mothers 30–34 years of age is 10 percent greater than the number obtained by the age-specific rate method. At ages 35–39 years, the difference is 18 percent. It should be emphasized that these differences are a function of the specific assumptions of population composition and fertility in this particular situation. They are not necessarily the maximum differences that could result from the use of the alternative methods.

Conclusion

As stated at the outset, the illustrative projections presented here are not predictions. No effort has been made to prognosticate trends in the social, psychological, and economic variables affecting fertility. The parity-rate method of birth projection, like the age-specific rate method, is essentially a mechanism for translating assumptions of future fertility into numbers of births. The significant difference between the two methods is that the use of parity rates provides a greater degree of fidelity in the resultant translation.

The age-parity rate is, of course, not the ultimate refinement in fertility measurement. If adequate child-spacing and marriage-duration data were available, the additional use of these variables would permit further delineation as to fertility risk status, and probably would improve the stability of the time-series data forming the basis of fertility projections.

Table 6. Comparison of series B and series C for 1956, 1960, and 1965

[Numbers in thousands]

Age of mother (years)	1956			1960			1965		
	Series B	Series C	Percent difference	Series B	Series C	Percent difference	Series B	Series C	Percent difference
Total	4, 111	4, 088	+0. 6	4, 259	4, 155	+2. 5	4, 762	4, 545	+4. 8
10–14	6	6	0	7	7	0	8	9	−11. 1
15–19	505	506	−. 2	596	599	−. 5	739	737	+. 3
20–24	1, 283	1, 275	+. 6	1, 346	1, 331	+1. 1	1, 632	1, 610	+1. 4
25–29	1, 121	1, 117	+. 4	1, 062	1, 038	+2. 3	1, 112	1, 072	+3. 7
30–34	735	731	+. 5	738	708	+4. 2	717	651	+10. 1
35–39	363	356	+2. 0	402	372	+8. 1	426	360	+18. 3
40–44	92	91	+1. 1	101	94	+7. 4	120	100	+20. 0
45 and over	5	5	0	6	6	0	7	6	+16. 7

NOTE: Series C is base for computation of percent difference. A + sign indicates that the series B figure is the larger.

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Cockroaches as Vectors

Recent publication of Medical and Veterinary Importance of Cockroaches by Lewis M. Roth and Edwin R. Willis (Smithsonian Publication No. 4299, 1957) has raised the question as to whether the cockroach is being neglected as a vector of infectious disease. It is well that the question is raised, because conventional assumptions in public health work deserve periodic appraisal and challenge. That the authors make no solid case for more energetic suppression of the cockroach as a disease vector does not detract from the utility of their work as a compendium of information that was formerly scattered to the far ends of the library shelves.

Cockroaches are recognized as mechanical transmitters of various pathogens, and because of this and their general obnoxious characteristics they have been and will continue to be the object of individual and community control efforts. The data presented only confirm this situation.

Roth and Willis have outlined the habits, habitats, and dispersal of cockroaches and the association of cockroaches with viruses, bacteria, fungi, protozoa, and helminths. They review bites and allergic responses, accidental invasion of man, cockroaches as human food, cockroaches in medicine and folklore, and diseases incorrectly attributed to cockroaches. They compare the significance of cockroaches and flies. Especially useful is their annotated list of pathogenic organisms and their reported association with cockroaches.

The authors undertake to prove that cockroaches are highly dangerous potential vectors of disease. But the association of cockroaches with pathogens is yet to be adequately evaluated.

Epidemiologists do not consider that reports of the presence of pathogenic organisms on cockroaches is evidence that the species is a natural vector. Neither is survival of the pathogens after experimental inoculation in cockroaches proof that roaches are experimental vectors. Ecologic associations need to be demonstrated to support such a claim.

The work of Marcel Graffar and Simone Mertens (Ann. Inst. Pasteur, Paris, 79: 654–660, 1950) cited by Roth and Willis is the most persuasive study reported. These workers observed that during an epidemic of food poisoning new infections of *Salmonella typhimurium* occurred in spite of quick isolation of patients, the absence of healthy carriers, and the lack of detectable contact except through cockroaches. It was observed that cockroaches overran the nursery at night and *S. typhimurium* was isolated from cockroaches in the vicinity of the infants. The epidemic was checked immediately when the nursery was disinfected with DDT. The epidemiological data cited do not definitely incriminate cockroaches even in this instance.

Structural and ecologic adaptations of cockroaches which are conducive to their potential as disease vectors are widely recognized. One may well speculate as to why they are not more prominent as conveyors of pathogens. New evidence or reinterpretations of present evidence may eventually shed the necessary light.

—Melvin H. Goodwin, Jr., Ph.D., *Chief, Phoenix Field Station, Communicable Disease Center, Public Health Service*