MEMORANDUM
RM-5115-TAB
DECEMBER 1966

THE POSTATTACK POPULATION OF THE UNITED STATES

Ira S. Lowry

PREPARED FOR:
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PREFACE

This Memorandum is one part of a study of the biological and environmental consequences of nuclear war. The RAND Corporation is conducting the study for the U.S. Atomic Energy Commission, Division of Biology and Medicine, Technical Analysis Branch (TAB).

The Memorandum presents quantitative estimates of damage to the U.S. population inflicted by a variety of simulated nuclear attacks on this country. It differs from most such studies in giving particular attention to the possibility of survival disparities among demographic components (age/sex/color) of the population at risk. It explores the implications of such disparities for both immediate post-attack recovery planning and for long-term patterns of demographic change.

The study should be of interest to persons concerned with post-attack recovery planning and to sociologists and demographers concerned with the impact of disaster on human societies.

SUMMARY

This Memorandum describes the demographic consequences of a set of five simulated nuclear attacks on the United States, and traces the demographic implications of initial damage into the years following such an event. The demographic variables examined include the size of the postattack population; its rate of growth in subsequent decades; its composition by age, sex, and color; and postattack patterns of fertility and mortality.

Because of the possible sensitivity of these variables to the configuration of initial damage, and because of the uncertainties of targeting, weapon effects, and human exposure and vulnerability, the simulated attacks and the models and parameters employed for damage assessment are described in considerable detail. The range of alternative outcomes from the five simulated attacks is increased to fifteen by variation of damage assessment parameters. In terms of total fatalities, these outcomes range from 2 to 62 percent of the preattack (1960) population.

The possibility of critical survival disparities is examined for such population characteristics as age, sex, and color, within the limitations imposed by a population representation that distinguishes urban, rural nonfarm, and farm residents of each state. Survival disparities could result either from differential exposure of various population components or from differential vulnerability among those exposed to a given weapon effect.

Although differential exposure (by age, sex, or color) within a local population is possible under rather special conditions of attack, the requisite targeting and timing strategies are implausible. Of greater relevance is the possibility of exposure disparities within the national population, due to broad spatial variations in population composition, e.g., as between urban and rural areas, or as among geographic regions of the United States.

Primarily because they occasion higher total exposure to weapon effects, the simulated attacks directed against cities produce greater exposure disparities among age/sex/color groups than do those directed

against nonurban targets. Females are relatively more exposed to prompt effects than are males, adults more than children, and nonwhites more than whites. Exposure to radioactive fallout is less consistent. In no case, however, are these exposure disparities large enough to be of much consequence for subsequent estimates of survival disparities within the national population.

For any given exposure to weapon effects, there is considerable evidence that human vulnerability varies with age, and possibly differs for males and females. For the present analysis, casualty data from the Hiroshima-Nagasaki bombings are extrapolated to provide estimates of differential vulnerability by age and sex, by level of exposure. Especially for severe exposures, much higher mortality rates are assumed for small children and old people than for persons between 10 and 49 years of age. Older females are assumed to be more vulnerable than males of corresponding ages.

These mortality schedules, specific to exposure level, are applied to the schedules of population by exposure level as generated by each attack. As would be expected from the absence of any striking disparities in exposure by age or sex, and from the U-shaped mortality schedules, all attacks result in disproportionately high survival of persons in the intermediate ages. The differences among attacks are only matters of degree in this respect. In general, the greater survival disparities are associated with the heavier attacks.

For the heaviest attack and least favorable sheltering assumption, only 38 percent of the preattack population survives. But nonwhites fare substantially better than whites in every age group for both sexes. White males fare better than white females at every age above 25 years; for nonwhites, the pattern by age and sex is similar but less regular. For both whites and nonwhites below 20 years, females have a slight edge on males. The highest survival rates are for young adults -- ages 25-29 for white males, 20-24 for white females -- and for nonwhites of both sexes aged 15-19.

Yet even for this extreme case, the changes in national population composition as a result of attack mortality are well within the range of recorded peacetime variations, and cannot be viewed as having

profound significance either for postattack manpower planning or for long-run demographic recovery. Since young adults consistently fare better than small children or aged persons, the surviving population would for a time have a higher marginal yield of manpower than did the preattack population.

Analysis of the factors influencing postattack fertility leads to the tentative conclusion that the number of births per thousand persons during the first five years postattack would be considerably lower than preattack. Long-term trends are uncertain, but there is no present evidence that attack-related fecundity impairments would be a significant constraint on these trends.

Mortality directly related to weapon effects, including single-dose radiation exposure, would not persist for more than two or three months postattack. Thereafter, the number of deaths per thousand persons would depend mostly on the degree of postattack social and economic disorganization. In the event of heavy organizational damage, the most likely result would be a temporary return to the mortality pattern of the nineteenth century, with especially high infant deathrates.

Using vital rate projections consistent with these general conclusions, the author projects the size and composition of the U.S. population over a 25-year postattack period, beginning with the surviving populations of each of the fifteen simulated attacks. A sixteenth case is similarly treated, comparable to the heaviest attack in number of survivors, but identical to the preattack population in component structure (i.e., no survival disparities by age, sex, or color).

The general conclusion from this exercise is that the size of the U.S. population would decline for a period of five to ten years postattack, and increase thereafter. The number of years required to regain preattack size would naturally vary with the extent of attack-related damage to the population, but the <u>rate</u> of increase is greatest in cases of heavy damage. With the sixteenth case used as a standard, it is shown that this peculiar consequence follows from the demographic selectivity of attack damage, rather than from

possibly inappropriate use of identical postattack vital rates for both light and heavy attacks.

A comparison of projected populations under low and high fertility assumptions, with and without attack survival disparities, reveals an important fact: estimates of the size of the nation's population, even 25 years after a nuclear attack, are much less sensitive to plausible variations in postattack fertility or to plausible disparities in component survival of the attack than they are to plausible variations in the number of fatalities at the time of the attack.

The projections also indicate that the age composition of the nation's population would change substantially over time. When the age distribution is summarized in a "dependency rate" (persons under 15 and over 64 years of age per hundred persons 15-64 years of age), examination of extreme cases indicates that the dependency rate would decline well below the preattack level of 67 per hundred. The period of decline ranges from five to fifteen years under alternative assumptions, and in one case the rate approaches a minimum of 45 per hundred. A low dependency rate is interpreted as being favorable to economic recovery.

Although the analysis indicates the likelihood of some changes in sex ratios and ethnic composition over the projection period, these changes are too small to have any definite implications for social organization or economic policy. Of the three demographic variables considered, the age distribution and its changes over time appear to have much greater significance for public policy.

ACKNOWLEDGMENTS

This Memorandum draws on numerous studies and materials outside my professional competence but essential to the development of its demographic themes. More expert colleagues at RAND and elsewhere have been generous with their advice and assistance, and I am most grateful to them.

Special acknowledgments are due to the following persons: Norman Hanunian, of RAND, who provided me with prepublication access to data on attack outcomes generated for use in his own study of the socio-economic impact of nuclear war; Bruce Goeller, also of RAND, who helped me interpret QUICK COUNT, the computer model employed for damage assessment; L. Wayne Davis and William L. Baker of the Dikewood Corporation, who provided me with data on age-dependent vulnerability to weapon effects; Peter G. Nordlie, S. D. Vestermark, Jr., and William Pendleton, of Human Sciences Research, Inc., whose work and thoughts on postattack demographic and social problems have been most stimulating, and with whom I periodically discussed my own research; and David M. Heer, whose book, After Nuclear Attack, is the most substantial inquiry into postattack demographic problems so far published, and whose findings provided a continuous check on my own.

I am also extremely grateful for the talented and unstinting assistance of Luita Booth Swales, a graduate student in biostatistics at the University of California, Los Angeles, and a consultant to RAND for this study. The data presented in Secs. IV to VI reflect long hours of work on her part, and her critique of the text saved me from several serious blunders.

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I. INTRODUCTION

This Memorandum explores the demographic consequences of a nuclear attack on the United States. The attack is treated as an acute bio-social stress on the human population, with heavy collateral damage to the resources of the social system. It is followed by a long period during which the environment is less favorable to human life than before the attack.

There have been many studies of the human casualties that might result from nuclear warfare. Computer simulations of hypothetical attacks have been used to generate estimates of the number of casualties to be expected from an attack of specified weight, targeting, and timing. Very few studies have inquired into the characteristics of survivors, and I know of only one that deals at much length with the longer-run demographic implications of such damage to the U.S. population.

This study was not meant to be concerned with the strategies of nuclear warfare nor with methods of assessing damage from nuclear attack. However, the starting point for an analysis of postattack demographic processes is necessarily an explicit assumption as to the damage suffered by the subject population and by its physical and social environment. If it were clear that damage could be adequately described in a single dimension -- say, the total number of fatalities -- we could reasonably proceed to explore the demographic implications of alternative levels of damage without specifying what sort of attack produced the damage.

It is possible, however, that deaths in nuclear war may be demographically selective, and that the relative damage to various components of the population may vary with the configuration of the attack. In conventional warfare, young adult males make up the largest age/sex group of casualties. What survival disparities, if any, would be characteristic of nuclear warfare? How are these disparities related to the configuration of the attack?

To throw some light on this issue, I have used RAND's attack simulator and damage-assessment model (QUICK COUNT) to appraise the

demographic consequences of five simulated attacks on the United States. Each attack assumes a different configuration of targets and weapons, and a different total explosive megatonnage. The implicit war scenario is that of a brief nuclear interchange terminated by a peace settlement. Although alternative sheltering cases are considered, I have not treated the possibility of preattack evacuation programs, which would substantially change the peacetime geographical distribution of our population.

These five attacks by no means cover the spectrum of possibilities, which is virtually infinite.* But they provide enough variety in targeting systems, weapons, and sheltering to allow us to distinguish between demographic consequences that are clearly sensitive to the attack configuration and those that are insensitive. Most important for our purposes is the question of survival disparities among demographic components of the same population subjected to alternative attacks.

The three steps in assessing the damage from each hypothetical attack are described in detail in Secs. II to IV of this Memorandum. Briefly, the sequence is as follows:

1. Estimating weapons effects (Sec. II). The explosion of a nuclear device produces a number of direct physical consequences. Prominent among them are the prompt effects, such as atmospheric pressure waves, and thermal and shortwave radiation from the fireball; and the delayed effects of radioactive debris, most of which falls to earth over a period of hours after the explosion.

Many kinds of uncertainty becloud our knowledge of the physical effects of megaton-range weapons, an uncertainty further compounded by lack of experience with the synergistic consequences of multiple detonations over a short time. Moreover, many of the acute stresses to which the population would be exposed are not direct, but are mediated by damage to the exposed environment, as in the case of self-sustaining fires ignited by thermal radiation from the original explosion.

Nonetheless, this study employs but a single set of parameters for estimating weapons effects. These effects are scaled to the

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*For example, we assume weapons to be detonated at ground level. Air-burst weapons would produce slightly different patterns of prompt effects, and negligible delayed fallout; but the data herein on fatalities from prompt effects provide rough estimates of the damage to be expected from corresponding attacks using air-burst weapons.

explosive megatonnage of the individual weapon, its fission/fusion ratio, and its height of burst. Furthermore, all weapons effects are represented by only two variables. Prompt effects are measured by blast overpressure as a function of distance from the point of delivery. Gamma radiation from local fallout is computed as a function of the time after burst required for fallout deposition. The geographic distribution of such fallout is determined by representative wind patterns.

2. Estimating exposure of the population to weapons effects (Sec. III). Given a specific attack and geotemporal pattern of weapons effects, the incidence of exposure in the subject population can be estimated by matching the geographic distribution of effects to that of population. The outcome of this correlation partly depends on the geographic detail with which weapons effects and population distributions are represented.

For this study, 3990 monitoring points were selected as the basis for exposure computations -- one point for each county, large city, or urbanized area of the conterminous United States. Each monitoring point represents a well-defined geographical area. The resident population of an area, as reported by the 1960 Census, is assumed to be spatially distributed around the monitoring point according to a circular Gaussian function whose parameters depend on the size of the area. Circular gradients of overpressure centered on the delivery point of each weapon are then overlaid on this population representation to determine the number of persons exposed to any specified level or range of prompt effects. For local fallout, the two-week integrated gamma-ray dosage (open-field conditions) is computed for each monitoring point and assigned to the entire population associated with that point.

3. Estimating the vulnerability of the exposed population (Sec. IV). Given a schedule of persons by type and level of exposure, the next step is to decide how the exposed persons will be affected. While reasonable estimates can be made of the vulnerability of the human body to a carefully defined stress applied under laboratory conditions, such determinations have limited relevance to the circumstance of a combination of stresses applied to a heterogeneous population in assorted microenvironments. For the present analysis, I have accepted two

conventional vulnerability functions, one binary and the other continuous. It is assumed that all persons exposed to 6+ psi overpressure will die from the direct and indirect effects of blast (including building collapse, flying debris, and secondary fires), or from other prompt effects (thermal or initial nuclear radiation) whose spatial distribution closely resembles that of overpressure. For exposure to radioactive fallout, I have used a continuous mortality function whose midlethal value is a two-week integrated dose of 900 roentgens, with mortality rates approaching 100 percent in the vicinity of 1400 roentgens, and approaching zero in the vicinity of 400 roentgens.

These vulnerability parameters determine the overall fatality rates for heterogeneous populations exposed to the indicated weapon effects. The major innovation of this study so far as damage-assessment methods are concerned is the use of mortality schedules specific to age and sex as well as to exposure. Section IV describes the construction of these schedules.

To maintain the study's focus on postattack events, it was necessary to accept single values for uncertain parameters in each step of damage assessment. The range of possible outcomes was extended, however, by applying a scalar parameter that is nominally a protection factor for exposure to radiation, but which could as easily be interpreted as a shift in weapon yields or in the vulnerability function so far as these pertain to radioactivity. (The scalar parameter does not affect blast yields, exposures, or vulnerabilities.) The open-field radiation doses reported by QUICK COUNT for each attack were reduced alternatively by factors of 1/3, 1/6, and 1/10 (Protection Factors of 3, 6, and 10) before estimating radiation fatalities. Thus a total of 15 distinct fatality lists were generated from five distinct attack configurations.

The complements of these fatality lists -- i.e., the corresponding lists of survivors for each case -- provide bases from which postattack demographic events can be projected. The lists of fatalities (and of survivors) are detailed for the nation as a whole in terms of age, sex,

and color,* a total of 60 components. A special attempt was made to evaluate the possibility of survival disparities of these components, either because of differential exposure to weapon effects, or because of differential vulnerability to these effects.

Sections V and VI take up the projection of postattack demographic events proper. Section V is devoted to an analysis of possible demographic trends in the years following the simulated attacks. The discussion focuses on four interrelated topics: the size and rate of growth of total population, its composition by age and sex, the incidence of births, and the incidence of deaths. In each case, I have tried to delimit the range of uncertainty within which speculation can reasonably be confined. In part these boundaries are indicated by biological properties of the species, in part by social institutions and human motivations that would persist into the postattack world, in part by the nature of the damage directly inflicted on our population by the simulated attack, and in part by the collateral damage to the human habitat.

Section VI presents some illustrative population projections covering a postattack period of 25 years. These illustrations are based on only a few of the possible configurations of assumptions regarding the characteristics of the attack, weapons effects, human vulnerability, biological and behavioral responses to chronic stress, and so on. The range of assumptions considered is wide enough, however, to indicate the sensitivity of results to alternative values of several key parameters.

To the policymaker of the postattack world, the population must be regarded as both a burden and a resource. The absolute size of that population is a measure of the number of people who must be fed and supplied with clothing and shelter. Given the total number of people, their distribution by age and sex is the primary indicator of the population's value as a source of manpower to support itself and to implement national policies. The crude birthrate (births per thousand population) is a measure of the rate of social investment in

*Although the color distinction (white and nonwhite) is genetically trivial, it is demographically relevant as an approximate cultural distinction that bears on vital rates and on labor-force characteristics.

manpower, while life expectancy is a fairly good indicator of the efficiency of this investment.

Section VII discusses the postattack population from the perspective of a government engaged in reconstructing the U.S. economic and social order. I have tried to indicate the major policy choices that must be made, and the pressures that are likely to guide the outcomes. Nothing therein should be read as a recommendation; it is intended to suggest what is likely to be done rather than what should be done.

I should like to comment on the kinds of evidence used in this Memorandum. Owing to the nature of the problem, none of this evidence is conclusive. The human race has no experience remotely comparable to full-scale nuclear warfare. Despite atmospheric tests, there are important gaps in our knowledge of the direct physical effects of megaton-range nuclear explosions. The most relevant experience of human vulnerability on which we can draw relates to disasters of much smaller scale -- tornadoes, volcanic eruptions, plague, famine, flood, even conventional warfare -- few of which involve levels of energy release as large as those possible with existing arsenals of nuclear weapons, and none of which offer a close parallel to the persistent and widely distributed radioactivity that is a byproduct of ground-burst nuclear devices. Even the Hiroshima-Nagasaki bombings involved energy releases of a lesser order of magnitude than those of the smallest of current weapons, and (since the two weapons were detonated in midair) produced negligible radioactive fallout. Moreover, devastating as they were to people and structures in the vicinity of the targets, these bombings lacked the synergistic effects of a simultaneous stress applied to an entire society.

Thus our conceptions of the biosocial consequences of nuclear war are necessarily extrapolations from physical, biological, and behavioral processes associated with disasters of a smaller order of magnitude and threatening the biosocial system with a different package of specific stresses. And much of the available case material relates to societies other than our own, whose members may well respond somewhat differently to a given stress.

The connecting links among these fragments of empirical evidence, and our tentative conclusions about events in the postattack world, are provided by theories developed in a variety of disciplines. For the most part, these are "theories of the middle range," to use the phrase of Robert K. Merton, "adequate to account for selected aspects of a specified range of phenomena and subject to being consolidated with others of like kind into a more comprehensive set of ideas." He goes on to say:

> Such theories often enable us to anticipate phenomena which are at odds with common sense expectations. . . . It is only a matter of common sense, for example, to believe that the greater the loss experienced by families in a disaster, the more they will feel deprived. . . . But the theory of relative deprivation leads to quite other expectations. In this theory, self-appraisals [of deprivation] are seen as depending upon people's comparisons of their own situation with that of other people perceived as being of the same kind. The theory therefore leads us to anticipate that, under certain conditions, families suffering serious losses will feel <u>less</u> deprived than those suffering smaller losses. . . . Actual inquiry into the matter produces findings that are at odds with common sense expectations and in approximate accord with the theory of relative deprivation.*

Such middle-range theories underlie most of the conclusions presented in this study, and my research in turn suggests a few additions to the stock. For instance, common sense might lead one to suppose that a heavily damaged population would recover more slowly than a lightly damaged one. Demographic analysis of damage from nuclear attack and subsequent recovery suggests the opposite conclusion.

I have also come to believe that much would be gained from a theoretical formulation of the disaster problem that is at once more comprehensive and less detailed than the present study. My notion is that the events associated with disasters of various kinds can be

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*Robert K. Merton, introduction to Allen H. Barton, <u>Social Organization Under Stress: A Sociological Review of Disaster Studies</u>, Disaster Study Number 17, Disaster Research Group, Division of Anthropology and Psychology, National Academy of Sciences - National Research Council, Washington, D.C., 1963, pp. xxix-xxxvi.

crudely consolidated into a generalized index of environmental stress, either acute or chronic in its manifestation; and that there is enough commonality in human responses to stress to enable us to predicate the outcomes of certain broad demographic and social processes on such a generalized index of stress. I cannot yet show evidence that this approach would be fruitful for disaster research in general or for postattack research in particular; but the idea seems promising enough to bring to the attention of others in the field, and to illustrate in this study wherever possible.

II. FIVE SIMULATED ATTACKS

The quantitative background for this study is provided by analysis of the damage done to the U.S. population by each of five simulated nuclear attacks.* These attacks were chosen to display the range of outcomes associated with alternative target lists and alternative weapon-sizes; they also vary in total megatonnage delivered, but relative levels of damage are not reliably indicated by this measure.

The aggregate level of damage done to the U.S. population by each attack depends on exposure and vulnerability parameters as well as on weapon effects. However, our five attacks can be consistently ranked from least to greatest damage except for one reversal of rank which occurs under the assumption of full fallout protection for the population. The dominant order of relative damage (least to greatest) is indicated by the order in which the attacks are described in Table 1. Each attack is designated by a three-digit code number that identifies both the target list (first digit) and the size-of-weapon code (second and third digit). The target lists are summarized in unclassified detail.

The order of the attacks with respect to population damage reflects both the degree of collocation of explicit targets with dense clusters of population and the radius of damage from individual weapons. Thus, with identical but fewer weapons, Attack 203 destroys more people than does Attack 103 because most of the targets of Attack 103 are missile sites located in rural areas. Although Attacks 103 and 130 are directed against exactly the same targets, the latter employs larger weapons and thus does more damage to the population of areas adjacent to the

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*These attacks were designed by Norman Hanunian of The RAND Corporation for use in his forthcoming study (RM-5140-TAB, Dimensions of Survival: Postattack Survival Disparities and National Viability) which deals with possible survival disparities among various socioeconomic groups within the U.S. population as well as with survival disparities among nonhuman resources. Hanunian chose the parameters of weapons effects, devised the population representation, and had QUICK COUNT, RAND's damage assessment model, altered in order to separate calculation of ambient hazards from calculation of damage or casualties.

I have built my own analytic superstructure on Hanunian's data for three components of the U.S. population (urban, rural nonfarm, and farm residents). My analysis began with the "dose tapes" generated by QUICK COUNT for each attack. The treatment of exposure detail and the choices of vulnerability parameters are entirely my responsibility, although I have discussed my methods with Hanunian and other members of RAND's staff who are familiar with the operation of QUICK COUNT.

Table 1

SUMMARY DESCRIPTION OF FIVE SIMULATED NUCLEAR ATTACKS ON THE UNITED STATES

Attack Number	Rank Order of Population Damage	Total Explosive Megatonnage	No. of Weapons	Size of Individual Weapons	Target List
103	1	1020	1195	0.3 MT (Minuteman sites) 3.0 MT (other targets)	Military command centers Nuclear weapons storage USAF communications Naval communications Minuteman and Titan II sites
203	2	855	285	3.0 MT (all targets)	Military command centers Nuclear weapons storage USAF communications Civil communications Bomber bases Bomber dispersal fields Major port facilities
130	3	10,200	1195	3.0 MT (Minuteman sites) 30.0 MT (other targets)	Military command centers Nuclear weapons storage USAF communications Naval communications Minuteman and Titan II sites
599	4	3,000	30	100.0 MT (all targets)	30 largest urbanized areas
430	5	13,200	1225	3.0 MT (Minuteman sites) 30.0 MT (other targets) 100.0 MT (urbanized areas)	30 largest urbanized areas Military command centers Nuclear weapons storage USAF communications Naval communications Minuteman and Titan II sites

targets. And Attacks 599 and 430, aimed explicitly at 30 urban centers, do the greatest amount of damage to population.

Conspicuously absent from this set of attacks is one targeted explicitly on industrial facilities.* Since the destruction of industrial capacity would have little effect on the nation's counterstrike capability, such targets would have low priority unless the enemy envisaged protracted hostilities. However, both Attacks 599 and 430 would do considerable incidental damage to industrial facilities because such facilities are highly collocated with the explicit targets of these attacks.

WEAPONS EFFECTS**

The weapon assigned to each target is assumed to be detonated at ground level. All weapons are assumed to be delivered (i.e., not intercepted), but subject to random errors of delivery with respect to the coordinates of the designated target. The radius of the standard error of delivery is one nautical mile. The aiming point is the approximate centroid of population for the urbanized area.

Prompt effects of each weapon are described in terms of a radius about the point of detonation, covering an area subject to blast overpressure of 6+ pounds per square inch.*** For a surface-burst weapon

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*Hanunian's Target List 3 includes civil airfields, petroleum refineries, ports, and certain other industrial targets, as well as military targets. Because of technical difficulties with the dose tapes from a simulated attack on these targets, it could not be included in the present study.

**Full appreciation of the significance of the parameters of weapons effects requires familiarity with the damage assessment model in which they are employed. An overview of the mathematical and computational structure of QUICK COUNT is given in L. H. Wegner, QUICK COUNT: A General War Casualty Estimation Model, The RAND Corporation, RM-3811-PR, September 1963. A full exposition of the model is available in N. D. Cohen, The QUICK COUNT System: A Users' Manual, The RAND Corporation, RM-4006-PR, April 1964.

***The calculation could be made for any overpressure, but 6+ psi is the only value considered in the QUICK COUNT runs here reported.

whose yield is 1 megaton of energy, this radius is assumed to be 2.12 nautical miles (2.44 statute miles). The 6+ psi radii for other weapon-sizes (MT) are calculated as follows:

$$R_{6+psi} = (MT)^{.33} \times 2.12.$$

The basic parameter for the computation of local fallout doses is a measure of the radioactivity of weapon debris one hour after burst. For this study it is assumed that reaction products equivalent to one kiloton of total weapon-yield, if uniformly distributed over a square statute mile of the earth's surface, would deliver 800 roentgens per hour of gamma radiation to a point three feet above that surface. This dose diminishes over time at the rate ($t^{-1.2}$).

The principal variables reflected in this hypothetical one-hour dose rate are the fission/fusion mix of the nuclear reaction characteristic of the particular weapon (only fission products are radioactive) and the amount of natural shielding characteristic of the fallout surface (the more irregular the surface the greater the shielding). The figure of 800 $r/hr/kt/mi^2$ is consistent with several alternative combinations of fission fractions and terrain shielding that lie within the bounds of current weapons technology and empirical evidence of terrain shielding.

The spatial distribution of fallout particles from each weapon is determined by QUICK COUNT from a wind map and a model of the rate of deposition of particles from the cloud of radioactive debris raised by the explosion. Calculation of the dosage delivered to each monitoring point takes into account the time-pattern of the arrival of fission products at that point. Approximately 92 percent of the total radioactivity accounted for by the fallout deposition model arrives within 30 hours of burst.

Fallout distributions were computed for each of six wind patterns compiled from meteorological records for specific days of 1950-51. The dose rates assigned to each monitoring point for the present analysis are averages of those compiled for each of the six wind patterns.

Averaging, of course, tends to suppress extreme values or "hot spots" in the fallout map.

The appropriate mode for measurement of radiation dosage at monitoring points depends on the circumstances of exposure and on theories of organic response to radiation. Thus, depending on the circumstances of attack and on the organization of passive defense measures, one might assume open-field exposure for a brief period after the attack with subsequent sheltering; or one might assume initial sheltering followed by open-field exposures as the population emerges from shelter. With respect to vulnerability, the critical measurement might be the maximum dose rate, the total dose integrated over time, or some combination of the two.* In this study, fallout is measured in terms of the open-field gamma dose in roentgens delivered at each monitoring point over a period of 336 hours after burst, or the "two-week integrated dose."

POPULATION REPRESENTATION

The basic system of population representation employed in these simulated attacks is keyed to a list of 3990 monitoring points distributed over the conterminous United States (i.e., excluding Alaska, Hawaii, and overseas dependencies).

Every county and quasi-county in the conterminous United States is assigned a monitoring point whose location within the county is the center of mass of the county's population as determined by the Bureau of the Census from small-area data. An additional monitoring point is located at the nominal center of each municipality whose 1960 population exceeded 50,000. One city, New York, is represented by several monitoring points. In selected counties, an additional rural monitoring point is added to improve the representation of farm populations.

A well-defined population (P_{mp}) is associated with each monitoring point. This population is divided into urban, rural nonfarm, and farm

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*One QUICK COUNT option provides for the computation of a "maximum biological dose" which assumes that a portion of organic damage is reparable during protracted exposure.

residents as reported by the 1960 Census for the relevant civil division. Most counties contain but a single monitoring point, to which the entire population of the county is assigned. If the county contains an additional urban monitoring point, the population of the designated municipality is assigned to its monitoring point and subtracted from the county P_{mp}. If the county contains an additional rural monitoring point, the county's farm population is assigned to this point and subtracted from the county P_{mp}. Thus some P_{mp} are entirely urban residents, some are entirely farm residents, and some include all three components.

Each P_{mp} is represented as a circular Gaussian distribution centered on the monitoring point; a number of standard deviations were used, mostly $R_{mp}/1.8$ and $R_{mp}/2.0$, where R_{mp} is the radius of the circle whose area equals that of the relevant civil division. On a two-dimensional map, the circles described by monitoring-point radii would frequently overlap; indeed some would be completely contained in others. If a third dimension representing population density were added, each P_{mp} would appear as a low mound, hill, or peak, depending on the number of persons represented and the area of the civil division. The population of a low-density county would appear as a symmetrical mound whose base line was a circle in the vicinity of the county boundary and whose highest point was the location of the county monitoring point. If the county contained a medium-sized city, this would be represented by a more sharply peaked protuberance somewhere in the county mound.

The population of civil divisions is reported by the census at the place of residence. Especially during a normal weekday, most persons spend part of their time away from home, many traveling to adjacent civil divisions to work or shop. Our population representation does not distinguish the diurnal from the nocturnal population of a particular civil division, but such a distinction would in any case be lost in the generalization of all local populations as circular Gaussian distributions.

COMPUTATION OF EXPOSURES

The final step of QUICK COUNT's damage assessment is matching the map of weapons effects with the map of population. This is done in two steps, one for exposure to prompt effects and one for exposure to local fallout.

Persons located within the 6+ psi radius of each weapon are counted as exposed to prompt effects. Their number is computed by relating neighboring monitoring points to each point of burst and calculating the overlap of the 6+ psi radius of the weapon and the population radius of each such monitoring point. The fraction of P_{mp} residing in the area of overlap is computed by an approximation to numerical integration. For each monitoring point, combined exposure to all weapons (E_{mp}) is estimated by the formula:

$$E_{mp} = 1 - (1 - E_1)(1 - E_2) \ . \ . \ . \ (1 - E_n)$$

where (E_1, E_2, . . ., E_n) are the fractions of P_{mp} exposed to weapons (1, 2, . . ., n). In other words, exposures to different weapons are treated as independent events. If 80 percent of a population is exposed to 6+ psi from one weapon and 20 percent is exposed to 6+ psi from another weapon, E_{mp} = .84, and the total number of persons exposed is .84 P_{mp}.

Fallout exposures are more generalized. For each monitoring point, fallout dosage delivered by each weapon is independently calculated and summed over all weapons. The total dose is then assigned to the entire monitoring-point population.

These exposures are summarized for specified groups of monitoring points -- in this case, for each state and the District of Columbia -- separately for the urban, rural nonfarm, and farm populations. Such a statewide summary indicates the number of persons exposed to 6+ psi overpressure, and the number exposed to less than 6+ psi overpressure by dose-interval of radiation exposure. These summaries are the basis for my analysis of possible disparities in exposure and survival among age/sex/color components of the nation's population, as described in subsequent chapters.

The creators of QUICK COUNT make no claims for the reliability of its small-area exposure estimates. As its name implies, the model offers a relatively inexpensive way to estimate damage for large geographical areas within which local errors tend to be mutually offsetting. In working with state exposure summaries I am perhaps straining the credibility of the model; but in my analysis, these state summaries are used only to construct national aggregates for age/sex/color components of the population as these might be affected by broad geographical disparities in the preattack distribution of such population components and by similar broad geographical disparities in the severity of weapons effects.

III. EXPOSURE TO WEAPONS EFFECTS

From the dose tapes of five simulated nuclear attacks, summaries were prepared detailing for each state the number of persons exposed to 6+ psi overpressure and to various levels of gamma radiation from local fallout. Separate tables of exposure were constructed for the urban, rural nonfarm, and farm populations of each state (for short, U, R, and F).

There are several reasons for distinguishing among these three populations. For one thing, their spatial distributions and densities characteristically differ -- a fact used to advantage in compensating for the coarseness of QUICK COUNT's geographical representation of population. These populations also vary in education, skills, and incomes, a fact of relevance to the postattack economic and social structure. Finally, the demographic compositions of the three populations are usually somewhat different.

The present analysis is limited to demographic distinctions of age, sex, and color. Given exposure rates for each of the three populations, and assuming that all components of a given population are subjected to the same exposure, we can calculate the incidence of exposure for particular age/sex/color groups of each state's population, and -- by summary over the 48 states -- of the nation's population. To put it another way, we can determine whether it is reasonable to suppose that children and adults, males and females, whites and nonwhites would all be exposed to weapons effects to the same degree, or whether some such groups would be more exposed than others. We can also determine whether the configuration of the attack makes a substantial difference in such exposure disparities.

The analysis is based on exposure summaries for individual states -- rather than for the nation as a whole -- because region of residence is fully as significant as the urban/rural distinction in differentiating among population groups in the United States. The farm population of Illinois differs from the urban population of that state, but it also differs from the farm population of Alabama with respect to composition by age, sex, and especially color. Of course,

such geographic distinctions could be pursued ad infinitum, but the compilation of component detail for each monitoring-point population would not be possible without a major effort to retrieve unpublished and untabulated data from the files of the U.S. Census. Consequently, I have compiled the component detail separately for the U, R, F populations of each state.

The reader should note that such an analysis of exposure disparities glosses over differentials in the microenvironment of various population components at the instant of attack. Thus, if a surprise attack occurred during a normal weekday,* most adult males would be found in office buildings or industrial structures, most adult females in residential structures and retail stores, and most children in school buildings or on playgrounds. The shielding characteristics of these locations are substantially different.

Moreover, at some times of day there are substantial local concentrations of various population components within the civil divisions represented by our monitoring points. Thus a much larger proportion of young adults than of other residents of a large city will be found in its central business district during working hours.

Especially in view of these qualifications, we will do well to review some related studies of survival disparities before presenting the findings of this one.

RELATED STUDIES OF SURVIVAL DISPARITIES

I know of only one study** of disparities in exposure or survival of demographic components of the U.S. population that depends on differential sheltering for its results (although there are studies of regional differences in survival rates for the general population that reflect the regional availability of shelter spaces). Three published studies have considered the possibility that such disparities might arise because of local concentrations of particular components of the U.S. population.

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*Because of time zone differences, there is only a brief period each day during which the "typical" daytime population distribution is applicable to the entire nation.

**Hanunian, op. cit., Sec. III.

David Heer* has examined the demographic consequences of two nuclear attacks simulated by the National Resource Evaluation Center. Alternative day and night versions of these attacks were considered. One attack (1466 megatons) was directed at a mixture of military and industrial targets, and the other (1779 megatons) was directed primarily at military targets. NREC's estimates of total fatalities from these attacks are 30 and 18 percent of the U.S. population, respectively, with only minor differences in this respect between day and night versions.

NREC's damage assessment model employs nearly 44,000 monitoring points as compared to the 3990 used in our QUICK COUNT runs. But Heer's data consist of summaries of fatalities for each of four broad Census Regions, tabulated separately for residents of each Region's Standard Metropolitan Statistical Areas (SMSAs) and for non-SMSA residents. For each Census Region, Heer in turn compiled the 1960 age/sex distribution of three population groups: residents of central cities of SMSAs, suburban residents of SMSAs, and non-SMSA residents. NREC's fatality rates (night attacks) for the non-SMSA population of each Region were applied directly to each age/sex component of that population. Heer calculated separate nocturnal fatality rates for central city residents and suburban residents of each Region on the assumption that central city rates would be double suburban rates. The derived fatality rates were then applied to the age/sex distributions of each Region's central city and suburban residents. The number of nocturnal fatalities in each age/sex component was then summarized for each Census Region and for the United States as a whole.

These steps were repeated for the daytime attacks, using NREC's daytime fatality rates for SMSA and non-SMSA residents. For SMSA residents, Heer used Census data on place of work to estimate the daytime populations of central cities and suburbs, and also to estimate the age/sex composition of each population.

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*<u>After Nuclear Attack, A Demographic Inquiry</u>, Frederick A. Praeger, Inc., New York, 1965. The book is based on a study conducted for Human Sciences Research, Inc., under contract to the U.S. Office of Civil Defense.

Since NREC's fatality rates are based on vulnerability or damage functions as well as exposure tables, Heer's findings cannot be directly related to those to be presented later in this section. But NREC's damage functions did not discriminate among demographic components, so the resulting fatality rates can be interpreted as a sort of weighted exposure-index for each population for which a rate was reported. In Heer's report, then, survival disparities are dependent on either differential exposure of central city, suburban, and non-SMSA populations within each Census Region, or on differences in the demographic composition of these three groups, or both. With respect to age and sex, he concluded:

> After each attack there would be only very small changes in the distribution of the United States population by age and sex. These changes would be minute compared to the changes many nations have undergone in previous wars. After each attack the proportion of the total population under 15 years old would increase, with the largest increase--from 31.2 to 32.1 percent--coming after the daytime Holifield [1466 megaton] attack. The proportion of the total population 15 to 64 years old would decrease very slightly after each attack. The largest decrease--from 59.8 to 58.8 percent--would again follow the daytime Holifield attack. The proportion of the population 65 years old and over would change only after the daytime Holifield attack (from 9.0 to 9.1 percent).
>
> The two daytime attacks would differ from the two nighttime attacks with respect to their effects on the sex ratio. The ratio of males to females would decline very slightly after each daytime attack and increase slightly after each nighttime attack. The largest changes in each direction would occur after the two versions of the Holifield attack. Following the daytime Holifield attack, the ratio of males to females would decrease from .968 to .965; following the nighttime attack it would increase to .976.*

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*Ibid., p. 53. Heer's model appears remarkably insensitive to parametric changes. In a follow-up study, analysts at Human Sciences Research, Inc., recomputed survivors by age and sex after 1) changing the ratio of central-city and ring fatalities from 2:1 to 4:1; 2) reducing all area-wide survival rates by 25 percent; and 3) arbitrarily interchanging area-wide survival rates among the four Census Regions. The resulting age/sex distributions are virtually indistinguishable from the originals. They are shown in Human Sciences Research, <u>A Study of the Demography of Nuclear War</u>, HSR-RR-66/14-Pr, McLean, Virginia, May 1966, pp. 59-78.

A similar analysis was made of fatalities by race. Because of the pronounced regional and local residential differences in racial distribution, significant survival disparities were generated by Heer's method. In the extreme case, only 64 percent of all nonwhites survive, as compared to 71 percent of all whites. But since nonwhites constitute only a small fraction of the total population, this substantial survival disparity has very little effect on the racial balance of the national population. The white population constitutes 88.8 percent of the total before the attack, 89.8 percent after the attack.*

Heer's division of the exposed population into residents of central cities, SMSA suburbs, and non-SMSA territory of each Census Region parallels the division used in the present study, i.e., urban, rural nonfarm, and farm populations of each state. When the components of the U, R, and F populations are summed over the several states of a given Census Region, the structure of each (age/sex/color) closely approximates the structure of the corresponding population compiled by Heer's method. The numbers in each category do, however, differ as between the two methods, since non-SMSA territory includes urban and rural nonfarm residents as well as farm residents, while the SMSA suburbs contain rural nonfarm and farm residents as well as urban residents.**

Our methods diverge more significantly in that Heer worked from a single fatality rate for each of the three populations of each Census Region, while the present study begins with an array of exposures for each of the three populations of each state. Moreover, as the next section will explain, vulnerability to a given exposure is assumed in the present study to vary with age, whereas in Heer's study,

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*Ibid., p. 150 and Table 1.26.

**SMSAs are constructed of entire counties except in New England, where the building blocks are townships. Thus, while the residents of the outlying parts of an SMSA may be "metropolitan" in the sense of proximity to a metropolis, they are not necessarily "urban" in the sense of dwelling in cities.

the fatality rate given for each population was applied indiscriminately to all its components.

Another test of the possibility of survival disparities is reported in a publication of the U.S. Naval Radiological Defense Laboratory.* Estimates of survival disparities are presented for Santa Barbara County, California, following the detonation of a 100-megaton bomb at Vandenberg Air Force Base. The County's population is represented by 36 monitoring points, mostly census tracts or enumeration districts. For each such unit of area, population compositions by age/sex, education, and broad occupational categories were compiled from unpublished Census data.

Exposure and vulnerability are treated very simply in this analysis. All persons associated with monitoring points located within 30 miles of the point of detonation are assumed to be killed, and all those associated with monitoring points beyond that distance are assumed to survive. (As a matter of fact, there are no monitoring points at all situated in the annulus defined by radii of 17 and 30 miles, so the outcome would be unchanged for a much smaller weapon-radius.) Under this rule, 60 percent of the County's preattack population of 170,000 survive the explosion. The age/sex composition of the surviving population differs from that of the preattack population as shown in Table 2.

Although none of these survival disparities are spectacular, they are large enough to be significant when rescaled to the national level. However, there is considerable reason to question both the method of calculating survivals and the delineation of the population at risk.

Santa Barbara County is roughly rectangular, about 45 by 70 miles. The long dimension runs east to west. Vandenberg AFB, the target of NRDL's simulated attack, is close to the western boundary. A cluster of beach communities in the southeast corner accounts for more than half of the County's population; the largest of these is

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*W. Mostow, S. H. Cassidy, E. S. Shapiro, and D. Freund, <u>Demographic Response to Nuclear Attack in the State of California</u>, USNRDL-TR-803, San Francisco, December 1964.

the city of Santa Barbara. Between this urban cluster and Vandenberg, the terrain is mountainous and thinly populated.

If the radius required to embrace this cluster (70 miles) were swept northward into the adjacent County of San Luis Obispo, it would embrace an additional population of 81,000, of which about 15,000 are located within the 30-mile fatality radius. In other words, the boundaries chosen by NRDL to delineate the population at risk are

Table 2

SURVIVAL DISPARITIES IN SANTA BARBARA COUNTY FOLLOWING ATTACK ON VANDENBERG AIR FORCE BASE

	Percentage Distribution of Population by Age in Years					
Sex	0-14	15-34	35-44	45-64	65+	Total
Males						
Preattack	15.2	15.0	7.0	9.1	3.9	50.2
Postattack	13.4	12.7	6.5	10.0	5.4	48.0
Females						
Preattack	14.8	13.6	6.6	9.5	5.3	49.8
Postattack	13.2	13.0	6.7	11.7	7.4	52.0

SOURCE: USNRDL-TR-803, Table 7.a.

manifestly arbitrary with respect to their distance from the target and the radial asymmetry of the area embraced. To oversimplify only a little, the study shows that the personnel and dependents of a large Air Force Base constitute a different mixture from the population of the resort-and-retirement city of Santa Barbara. As one might expect, Table 2 shows relatively high survival rates for the elderly of both sexes, and for females as compared with males.

Another study of local survival disparities was made by Human Sciences Research. It is briefly described in a report to the Office of Civil Defense.* Five SMSAs (New Orleans, Albuquerque, San Jose, Providence, and Detroit) are each made the target of a single 10-megaton

*Human Sciences Research, op. cit., pp. 44-58.

weapon exploded so that "the fireball . . . touches the ground." Within each SMSA a systematic attempt is made to select points of detonation that would produce the greatest survival disparities for a night attack.

A continuous damage function is used to estimate survivors in each census tract of the SMSA by distance from ground zero.* The survival rate for a tract is then applied to each age/sex component of the tract population, and also to each major occupational group represented in the tract. By summarizing component survival across tracts, survival disparities for the SMSA are estimated. To test the value of small-area detail for this computation, total survivors by tract are summarized for the central city and SMSA ring, and the aggregated survival rates then applied to each component of the two aggregated populations.

The report does not present quantitative results of these experiments; it only says that "the analysis indicated that a shift in the point of detonation would affect the composition of the surviving population, that the effects of changing the point of detonation would vary from city to city, and that the tract-by-tract analysis is more sensitive to possible compositional changes in the population than the city-ring method."**

These findings suggest to me that survival disparities traceable to the lack of compositional uniformity among census tracts will disappear in national summaries of such small-area data. Weapons of megaton-range yields have destructive radii commensurable with those of most areas of high population density in the United States, and

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*Parameters of the damage function are not specified. It is "based on materials obtained from the Office of Civil Defense." Although the type of burst indicated implies local fallout -- which does not usually descend symmetrically about ground zero -- this fallout was either ignored as a source of casualties, or incorporated into the symmetrical damage function.

**Ibid., p. 53. Table I, p. 57, is entitled "Reduced Surviving Population Based on City by City Analysis." The population "reduced" appears to be that of the United States, but the sense in which the reduction derives from the five-city analysis is not explained.

it is hardly conceivable that, in a real attack, such weapons would be aimed with a view to generating survival disparities. Even if they were, delivery errors would probably foil this design.

For example, the 10-megaton weapons used in HSR's simulated attacks have a prompt-effects radius for 6+ psi of about 5 statute miles. Commonly used values for standard error of delivery of ICBMs are in the vicinity of 1 statute mile. Outside the range of heavy damage from prompt effects, radioactive fallout is unpredictably distributed. While disparities in the exposure of various components of the population of a particular city are clearly possible, it is very hard to conceive of a systematic bias of this nature for a large group of urban places subjected to simultaneous attack. If we are to find exposure disparities, I think we must look for variations in population composition on a grander geographical scale, and according to a system of classification that relates to strategically plausible patterns of targeting for a nuclear attack.

The central-city-suburban-ring dichotomy of the population of SMSAs is a distinction that has such relevance. An attack directed either against population per se or against civilian control and communication centers would certainly be targeted on central cities; even allowing for delivery errors, the suburbs would typically suffer distinctly less from prompt effects.

These considerations lead us back to an issue raised in Heer's study: whether it is important for the study of survival disparities to distinguish between day and night attacks. His evidence suggests that it is not, despite the well-known concentration of employed persons in central cities during working hours. For total U.S. casualties, the difference between day and night versions of his two simulated attacks is less than one percent, and the age/sex survival disparities generated by his methods are insignificant in either case.

The concentration of daytime population in the central city is evidenced by data from the 1960 census, which reports place of work by place of residence for employed persons living in SMSAs. In the Boston SMSA, 287,000 workers live in the central city, but 409,000 work there. Even in sprawling Los Angeles, the net influx of workers

to jobs within the city limits amounts to 12 percent of total employment in the city.* Casual observers of the metropolitan scene tend to be hypnotized by the most visible congregation of persons in the central business district, and to assume that the undeniably authentic instances of long-distance commuting are the rule rather than the exception. But metropolitan traffic studies have consistently revealed that most metropolitan residents do not go far from their homes in the course of their daily round of activities.

Of all daily trips from home, work trips are the longest; yet the average (and median) airline length of such trips is on the order of three to five miles even in our largest metropolitan areas, and well under three miles in the smaller ones. For example, a 1956 survey of Chicago travel patterns reported average lengths for work trips of 5.3 miles; social and recreational trips, 4.3 miles; shopping and school trips, 2.8 miles. In Pittsburgh, the median length of work trips in 1958 was less than three airline miles.**

These are distances commensurable with the radius of heavy destruction of a megaton-range weapon. It follows that, whether such a weapon is detonated at night when all members of a family are at home, or in the daytime when they are scattered, all are likely to be within range of its prompt effects. The principal <u>systematic</u> difference in exposures from day and night attacks is more likely to derive from the kind of sheltering available at places of work, schools, shops, and homes -- the various daytime locations of particular components of the urban population.

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*<u>U.S. Census of Population: 1960. Detailed Characteristics</u>, Reports PC(1) - 6D and 23D, Table 131.

**Chicago Area Transportation Study, <u>Final Report</u>, Vol. 1, <u>Survey Findings</u>, Chicago, December 1959, p. 38. Unpublished data from the files of the Pittsburgh Area Transportation Study, Pittsburgh, 1958. See also Wilbur Smith and Associates, <u>Future Highways and Urban Growth</u>, New Haven, February 1961, pp. 103-109.

EXPOSURE DISPARITIES IN THE QUICK COUNT ATTACKS

Unlike the studies described above, the present analysis* distinguishes exposure to weapons effects from vulnerability to weapons effects. Survival disparities might arise either because certain age/sex/color components of the U.S. population were more heavily exposed to weapons effects than were other such components, or because some components were more vulnerable than others to a given exposure, or for both reasons. By examining patterns of exposure rather than estimated fatalities, we are able to clarify the origins of potential survival disparities.**

Table 3 shows the exposure distribution of the total U.S. population for each of our five simulated attacks. For prompt effects, only one exposure class is defined: 6+ psi overpressure.*** Exposure to radiation from local fallout is shown in intervals of 1000 roentgens over the range of greatest interest; additional detail is shown for exposures below 1000 roentgens.

Perhaps the most significant difference in exposures revealed by Table 3 is the high proportion of the U.S. population exposed to prompt effects in Attacks 599 and 430 as compared with the other three. This difference is attributable to the use of 100-megaton weapons in those two attacks, targeted on the 30 largest concentrations of population in the United States. For a weapon of this yield, overpressures of 6+ psi are calculated to cover an area of 390 square miles (R_{6+psi} = 11.15 miles) around the point of detonation. By way of comparison, the land area of New York City is 310 square miles. Of all central cities in the United States, only Los Angeles and Oklahoma City have areas greater than 390 square miles. Of course, in no case are these cities literally circular in shape.

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*Like that of Hanunian, op. cit.

**Heer suggests age-dependent vulnerability as a possible source of survival disparities, but for lack of data does not treat the subject systematically. See After Nuclear Attack, pp. 53-55.

***By this point, the reader may be legitimately impatient for an interpretation of this prompt-effects parameter in terms of its damage-producing capability. The subject is treated in Sec. IV., pp. 41-43.

Table 3

PERCENTAGE DISTRIBUTION OF U.S. POPULATION BY EXPOSURE TO WEAPONS EFFECTS: FIVE SIMULATED ATTACKS, 1960

Exposure Category	Percentage of Total U.S. Population Exposed				
	Attack 103	Attack 203	Attack 130	Attack 599	Attack 430
Total, all categories	100.0	100.0	100.0	100.0	100.0
Prompt effects					
6+ psi overpressure	1.2	9.0	4.1	23.4	26.3
Local fallout					
30,000+ roentgens[a]			0.6		0.7
15,000 - 29,999		0.1	2.2		3.1
14,000 - 14,999		0.1	0.5		0.4
13,000 - 13,999			0.4		0.4
12,000 - 12,999		0.1	0.7		0.4
11,000 - 11,999		0.1	0.8		0.8
10,000 - 10,999			0.7	0.1	0.8
9,000 - 9,999	0.1	0.3	1.1	0.4	0.8
8,000 - 8,999	0.1	0.5	1.4	0.5	1.8
7,000 - 7,999	0.1	0.3	1.1	1.4	2.6
6,000 - 6,999	0.1	0.3	2.1	1.9	3.6
5,000 - 5,999	0.2	1.1	1.8	2.7	3.9
4,000 - 4,999	0.3	1.4	3.5	3.5	6.0
3,000 - 3,999	0.8	2.1	5.4	5.8	7.4
2,000 - 2,999	2.2	4.1	6.5	8.1	8.9
1,000 - 1,999	4.5	9.7	11.2	9.7	9.5
300 - 999	12.2	24.0	13.6	10.2	8.0
100 - 299	8.9	12.1	3.5	1.7	1.5
0 - 99	69.1	34.7	38.7	30.7	13.0

NOTE: Percentage exposed to local fallout excludes persons exposed to both local fallout and prompt effects.

[a]Two-week integrated dose.

Except for Attacks 130 and 430, significant fallout doses do not occur above 10,000 roentgens. The smaller weapons employed in Attacks 103 and 203 do not yield sufficient radioactive debris to create such hot spots, and Attack 599, which employs only 100-megaton weapons, masks the most probable location of high fallout doses by the wide radius of its prompt effects.

Persons not exposed to prompt effects are in fact heavily concentrated in the low fallout categories. For the lightest attack (103), only 8.5 percent of those not exposed to prompt effects receive doses of more than 1000 roentgens. The fraction increases, though not regularly, as we consider successively heavier attacks; at most, it is 69.3 percent for Attack 430.

It is apparent from the patterns of exposure shown in Table 3 that we can safely combine certain exposure categories where the frequencies are small. This is done in Tables 4-8, where exposure distributions are shown for five-year age groups by sex for each attack.

The principal conclusion to be drawn from these five tables is that no major disparities in exposure by age or sex can be generated by our method of computation. The largest difference between two rows of any table is to be found in Attack 599 (Table 8), where 20.9 percent of males, ages 15-19, are exposed to prompt effects, as compared with 24.6 percent of females, ages 60-64. Disparities as large as one percentage point are almost entirely confined to Attacks 599 and 430, the two that share as their principal targets the 30 largest urbanized areas of the nation. The data for Attack 599, which has no other targets, reflect in purest form the urban concentration of males 20-64 years of age, and of all adult females.*

To summarize, those attacks directed against cities produce greater exposure disparities among age/sex groups than those directed

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*In the central cities of U.S. metropolitan areas, 55.3 percent of all persons were between ages 20-64 in 1960. For the entire population classified by the Census Bureau as urban, the corresponding figure is 53.8 percent; and for all rural residents (both farm and nonfarm), the figure is 52.5 percent.

The ratio of males to females is well under unity for all ages above 20 years both in central cities and for the total urban population. In rural areas, the ratio is greater than .98 for ages 20-44, and greater than unity for all ages 40-74. Elderly females are especially concentrated in central cities; at ages 65-69 the ratio of males to females is .83, dropping to .54 for ages 85+.

For more detail, see U.S. Census of Population: 1960, Vol. 1, Part 1, Table 46.

CODING KEY FOR TABLES 4-8

Exposure Levels

1 = Total, all categories
2 = 6+ psi overpressure
3 = 30,000+ roentgens[a]
4 = 10,000 - 29,999
5 = 3,000 - 9,999
6 = 1,000 - 2,999
7 = 300 - 999
8 = 100 - 299
9 = 0 - 99

Age Code

1 = 0 - 4 years
2 = 5 - 9
3 = 10 - 14
4 = 15 - 19
5 = 20 - 24
6 = 25 - 29
7 = 30 - 34
8 = 35 - 39
9 = 40 - 44
10 = 45 - 49
11 = 50 - 54
12 = 55 - 59
13 = 60 - 64
14 = 65 - 69
15 = 70 - 74
16 = 75+
(rows 17 and 18 omitted)
19 = all ages

NOTE: Percentage exposed to local fallout excludes persons exposed to <u>both</u> local fallout and prompt effects.

[a]Two-week integrated dose.

Table 4

PERCENTAGE DISTRIBUTION OF AGE/SEX COMPONENTS OF THE U.S. POPULATION BY EXPOSURE TO WEAPON EFFECTS: ATTACK 103

Age Code	Percentage Distribution By Broad Exposure Level								
	1	2	3	4	5	6	7	8	9
					Males				
1	100.0	1.2	0.0	0.1	1.7	6.8	12.1	8.8	69.3
2	100.0	1.2	0.0	0.1	1.7	6.7	12.1	8.8	69.4
3	100.0	1.1	0.0	0.1	1.7	6.7	12.1	8.8	69.4
4	100.0	1.2	0.0	0.1	1.8	6.8	12.2	8.8	69.1
5	100.0	1.4	0.0	0.1	1.9	7.0	12.2	8.8	68.6
6	100.0	1.3	0.0	0.1	1.8	6.9	12.1	8.8	68.9
7	100.0	1.3	0.0	0.1	1.7	6.8	12.1	8.8	69.2
8	100.0	1.3	0.0	0.1	1.8	6.8	12.1	8.8	69.1
9	100.0	1.2	0.0	0.1	1.8	6.8	12.2	8.8	69.2
10	100.0	1.2	0.0	0.1	1.7	6.7	12.2	8.8	69.2
11	100.0	1.2	0.0	0.1	1.7	6.7	12.2	8.9	69.2
12	100.0	1.2	0.0	0.1	1.7	6.6	12.3	8.9	69.2
13	100.0	1.1	0.0	0.1	1.7	6.6	12.3	9.0	69.3
14	100.0	1.1	0.0	0.1	1.7	6.6	12.3	9.0	69.3
15	100.0	1.0	0.0	0.1	1.7	6.6	12.3	9.0	69.2
16	100.0	1.0	0.0	0.1	1.8	6.8	12.4	8.9	69.1
19	100.0	1.2	0.0	0.1	1.8	6.8	12.2	8.8	69.2
					Females				
1	100.0	1.2	0.0	0.1	1.7	6.8	12.1	8.8	69.3
2	100.0	1.2	0.0	0.1	1.7	6.7	12.1	8.8	69.3
3	100.0	1.1	0.0	0.1	1.8	6.7	12.1	8.8	69.4
4	100.0	1.2	0.0	0.1	1.7	6.7	12.1	8.9	69.2
5	100.0	1.3	0.0	0.1	1.7	6.8	12.1	8.9	69.1
6	100.0	1.3	0.0	0.1	1.7	6.8	12.1	8.8	69.2
7	100.0	1.3	0.0	0.1	1.7	6.8	12.1	8.8	69.2
8	100.0	1.3	0.0	0.1	1.8	6.8	12.1	8.8	69.1
9	100.0	1.3	0.0	0.1	1.7	6.7	12.2	8.9	69.1
10	100.0	1.2	0.0	0.1	1.7	6.7	12.2	8.9	69.1
11	100.0	1.2	0.0	0.1	1.7	6.7	12.3	9.0	69.0
12	100.0	1.2	0.0	0.1	1.7	6.7	12.3	9.0	69.0
13	100.0	1.2	0.0	0.1	1.7	6.7	12.3	9.1	68.9
14	100.0	1.2	0.0	0.1	1.7	6.7	12.3	9.1	69.0
15	100.0	1.2	0.0	0.1	1.7	6.8	12.4	9.1	68.8
16	100.0	1.2	0.0	0.1	1.8	7.0	12.4	9.0	68.6
19	100.0	1.2	0.0	0.1	1.7	6.7	12.2	8.9	69.1

Table 5

PERCENTAGE DISTRIBUTION OF AGE/SEX COMPONENTS OF THE U.S. POPULATION BY EXPOSURE TO WEAPON EFFECTS: ATTACK 203

Age Code	Percentage Distribution By Broad Exposure Level								
	1	2	3	4	5	6	7	8	9
Males									
1	100.0	8.8	0.0	0.4	5.9	13.6	24.0	12.1	35.1
2	100.0	8.6	0.0	0.3	5.8	13.5	23.9	12.2	35.7
3	100.0	8.4	0.0	0.3	5.8	13.4	23.9	12.3	35.9
4	100.0	8.3	0.0	0.4	5.7	13.4	23.7	12.3	36.2
5	100.0	9.0	0.0	0.4	6.2	13.8	23.7	12.0	34.9
6	100.0	9.3	0.0	0.4	6.4	14.0	24.0	11.9	34.1
7	100.0	9.2	0.0	0.4	6.3	14.0	24.0	12.0	34.1
8	100.0	9.2	0.0	0.4	6.4	14.1	24.0	12.0	34.0
9	100.0	9.1	0.0	0.4	6.3	14.0	24.0	12.1	34.2
10	100.0	8.9	0.0	0.4	6.2	13.9	24.0	12.1	34.5
11	100.0	8.9	0.0	0.3	6.1	13.9	24.1	12.1	34.5
12	100.0	8.9	0.0	0.3	6.1	14.0	24.2	12.2	34.4
13	100.0	8.9	0.0	0.3	6.0	13.9	24.1	12.2	34.5
14	100.0	8.7	0.0	0.3	5.9	13.7	23.9	12.3	35.2
15	100.0	8.6	0.0	0.3	5.8	13.6	23.7	12.3	35.6
16	100.0	8.5	0.0	0.3	5.6	13.4	23.6	12.4	36.3
19	100.0	8.8	0.0	0.4	6.0	13.7	23.9	12.1	35.0
Females									
1	100.0	8.9	0.0	0.4	5.9	13.6	24.0	12.1	35.1
2	100.0	8.7	0.0	0.3	5.8	13.5	23.9	12.2	35.6
3	100.0	8.5	0.0	0.3	5.8	13.5	23.9	12.2	35.7
4	100.0	8.8	0.0	0.3	5.8	13.5	24.0	12.3	35.3
5	100.0	9.5	0.0	0.4	6.1	13.9	24.2	12.0	34.0
6	100.0	9.2	0.0	0.4	6.2	13.9	24.1	12.0	34.1
7	100.0	9.2	0.0	0.4	6.3	14.0	24.2	12.0	33.9
8	100.0	9.3	0.0	0.4	6.5	14.1	24.1	12.0	33.7
9	100.0	9.2	0.0	0.4	6.4	14.1	24.1	12.1	33.7
10	100.0	9.2	0.0	0.4	6.3	14.0	24.2	12.1	33.9
11	100.0	9.2	0.0	0.3	6.2	14.1	24.3	12.2	33.8
12	100.0	9.2	0.0	0.3	6.2	14.1	24.3	12.2	33.8
13	100.0	9.3	0.0	0.3	6.2	14.1	24.2	12.2	33.7
14	100.0	9.3	0.0	0.3	6.2	14.1	24.1	12.2	33.9
15	100.0	9.4	0.0	0.3	6.1	14.0	24.0	12.1	33.9
16	100.0	9.4	0.0	0.4	6.1	14.0	23.9	12.2	34.1
19	100.0	9.1	0.0	0.4	6.1	13.8	24.1	12.1	34.4

Table 6

PERCENTAGE DISTRIBUTION OF AGE/SEX COMPONENTS OF THE U.S. POPULATION BY EXPOSURE TO WEAPON EFFECTS: ATTACK 130

Age Code	Percentage Distribution By Broad Exposure Level								
	1	2	3	4	5	6	7	8	9
					Males				
1	100.0	4.1	0.7	5.4	16.3	17.5	13.5	3.6	39.0
2	100.0	4.0	0.7	5.4	16.3	17.5	13.5	3.6	39.1
3	100.0	3.9	0.7	5.4	16.2	17.6	13.5	3.6	39.0
4	100.0	4.0	0.7	5.5	16.3	17.7	13.5	3.6	38.8
5	100.0	4.6	0.7	5.4	16.5	17.6	13.6	3.5	38.0
6	100.0	4.4	0.6	5.3	16.6	17.7	13.7	3.5	38.3
7	100.0	4.3	0.6	5.2	16.6	17.6	13.6	3.5	38.7
8	100.0	4.3	0.6	5.3	16.7	17.5	13.6	3.5	38.6
9	100.0	4.2	0.6	5.3	16.6	17.5	13.5	3.4	38.8
10	100.0	4.1	0.6	5.3	16.6	17.7	13.6	3.4	38.7
11	100.0	4.0	0.7	5.3	16.6	17.9	13.6	3.4	38.6
12	100.0	3.9	0.7	5.3	16.6	18.0	13.6	3.4	38.5
13	100.0	3.8	0.7	5.3	16.6	18.0	13.5	3.4	38.7
14	100.0	3.7	0.7	5.4	16.6	17.9	13.4	3.5	38.9
15	100.0	3.6	0.7	5.5	16.6	17.8	13.4	3.4	38.8
16	100.0	3.6	0.8	5.7	16.6	17.7	13.3	3.4	38.9
19	100.0	4.1	0.7	5.4	16.5	17.7	13.5	3.5	38.8
					Females				
1	100.0	4.1	0.7	5.4	16.3	17.5	13.5	3.6	39.0
2	100.0	4.0	0.7	5.4	16.3	17.5	13.5	3.6	39.1
3	100.0	3.9	0.7	5.4	16.2	17.6	13.5	3.6	39.0
4	100.0	4.0	0.7	5.4	16.2	17.7	13.5	3.6	38.9
5	100.0	4.3	0.6	5.2	16.4	17.7	13.6	3.5	38.6
6	100.0	4.3	0.6	5.2	16.4	17.7	13.7	3.5	38.5
7	100.0	4.2	0.6	5.2	16.5	17.7	13.6	3.5	38.6
8	100.0	4.3	0.6	5.2	16.6	17.6	13.6	3.5	38.6
9	100.0	4.2	0.6	5.2	16.6	17.7	13.6	3.4	38.6
10	100.0	4.1	0.6	5.2	16.6	17.9	13.7	3.4	38.5
11	100.0	4.1	0.6	5.3	16.6	18.0	13.7	3.4	38.3
12	100.0	4.0	0.6	5.3	16.7	18.1	13.6	3.4	38.2
13	100.0	4.0	0.6	5.3	16.8	18.1	13.6	3.4	38.2
14	100.0	3.9	0.7	5.3	16.8	18.0	13.6	3.4	38.3
15	100.0	4.0	0.7	5.4	16.9	17.9	13.5	3.4	38.2
16	100.0	4.0	0.7	5.6	17.0	17.8	13.4	3.3	38.2
19	100.0	4.1	0.6	5.3	16.5	17.7	13.6	3.5	38.7

Table 7

PERCENTAGE DISTRIBUTION OF AGE/SEX COMPONENTS OF THE U.S. POPULATION BY EXPOSURE TO WEAPON EFFECTS: ATTACK 430

Age Code	Percentage Distribution By Broad Exposure Level								
	1	2	3	4	5	6	7	8	9
Males									
1	100.0	25.6	0.8	6.0	26.0	18.7	8.1	1.5	13.3
2	100.0	24.9	0.8	6.0	26.1	18.9	8.2	1.6	13.5
3	100.0	24.3	0.8	6.1	26.2	19.1	8.4	1.6	13.6
4	100.0	23.8	0.8	6.2	26.0	19.3	8.5	1.6	13.8
5	100.0	25.7	0.8	6.1	25.5	18.8	8.3	1.6	13.3
6	100.0	26.8	0.7	5.9	25.8	18.3	8.0	1.5	12.9
7	100.0	26.8	0.7	5.9	26.2	18.1	8.0	1.5	12.8
8	100.0	26.9	0.7	5.9	26.2	18.0	8.0	1.5	12.8
9	100.0	26.5	0.7	5.9	26.3	18.1	8.0	1.5	12.9
10	100.0	26.2	0.7	6.0	26.4	18.2	8.0	1.5	12.9
11	100.0	26.3	0.7	6.0	26.5	18.1	8.0	1.5	12.9
12	100.0	26.5	0.7	6.0	26.6	18.0	7.9	1.5	12.7
13	100.0	26.5	0.8	6.0	26.8	17.9	7.8	1.5	12.7
14	100.0	25.7	0.8	6.1	26.7	18.2	8.0	1.6	13.0
15	100.0	25.3	0.8	6.2	26.7	18.3	8.0	1.6	13.1
16	100.0	24.4	0.8	6.4	26.9	18.6	8.1	1.6	13.2
19	100.0	25.7	0.8	6.0	26.2	18.5	8.1	1.5	13.2
Females									
1	100.0	25.6	0.8	6.0	26.0	18.7	8.1	1.5	13.3
2	100.0	25.0	0.8	6.0	26.0	18.9	8.2	1.6	13.5
3	100.0	24.5	0.8	6.0	26.2	19.1	8.3	1.6	13.5
4	100.0	25.1	0.8	6.0	26.0	19.0	8.3	1.5	13.4
5	100.0	27.1	0.7	5.8	25.7	18.4	8.0	1.5	12.8
6	100.0	26.8	0.7	5.8	26.0	18.3	8.0	1.5	12.8
7	100.0	26.9	0.7	5.8	26.2	18.2	8.0	1.5	12.7
8	100.0	27.1	0.7	5.9	26.2	18.0	8.0	1.5	12.7
9	100.0	27.1	0.7	5.9	26.3	18.0	7.9	1.5	12.6
10	100.0	27.0	0.7	5.9	26.3	18.1	8.0	1.5	12.6
11	100.0	27.1	0.7	5.9	26.4	18.0	7.9	1.5	12.5
12	100.0	27.2	0.7	5.9	26.4	17.9	7.8	1.5	12.5
13	100.0	27.4	0.7	5.9	26.5	17.8	7.8	1.5	12.4
14	100.0	27.2	0.7	6.0	26.4	17.9	7.8	1.5	12.4
15	100.0	27.2	0.7	6.1	26.4	17.8	7.8	1.5	12.4
16	100.0	26.9	0.8	6.3	26.6	17.9	7.8	1.5	12.3
19	100.0	26.3	0.7	5.9	26.2	18.4	8.0	1.5	12.9

Table 8

PERCENTAGE DISTRIBUTION OF AGE/SEX COMPONENTS OF THE U.S. POPULATION BY EXPOSURE TO WEAPON EFFECTS: ATTACK 599

Age Code	Percentage Distribution By Broad Exposure Level								
	1	2	3	4	5	6	7	8	9
Males									
1	100.0	22.7	0.0	0.2	15.9	18.0	10.4	1.7	31.1
2	100.0	22.0	0.0	0.2	15.9	18.1	10.5	1.8	31.6
3	100.0	21.4	0.0	0.2	15.9	18.2	10.7	1.8	31.9
4	100.0	20.9	0.0	0.2	15.6	18.1	10.9	1.9	32.4
5	100.0	22.5	0.0	0.2	15.7	17.8	10.6	1.8	31.4
6	100.0	23.8	0.0	0.2	16.2	17.7	10.2	1.7	30.3
7	100.0	23.9	0.0	0.2	16.6	17.8	10.0	1.6	30.1
8	100.0	23.9	0.0	0.2	16.6	17.8	10.0	1.6	30.0
9	100.0	23.6	0.0	0.2	16.6	17.8	10.0	1.7	30.2
10	100.0	23.3	0.0	0.2	16.5	17.8	10.1	1.7	30.5
11	100.0	23.5	0.0	0.2	16.5	17.7	10.0	1.7	30.5
12	100.0	23.8	0.0	0.2	16.5	17.6	9.9	1.6	30.4
13	100.0	23.8	0.0	0.2	16.7	17.7	9.7	1.6	30.4
14	100.0	23.0	0.0	0.2	16.4	17.7	9.9	1.7	31.1
15	100.0	22.6	0.0	0.1	16.3	17.8	10.0	1.7	31.4
16	100.0	21.7	0.0	0.2	16.3	18.0	10.2	1.8	31.9
19	100.0	22.8	0.0	0.2	16.2	17.9	10.3	1.7	31.0
Females									
1	100.0	22.7	0.0	0.2	15.9	18.0	10.4	1.7	31.2
2	100.0	22.1	0.0	0.1	15.8	18.0	10.5	1.8	31.5
3	100.0	21.7	0.0	0.2	15.9	18.1	10.7	1.8	31.7
4	100.0	22.2	0.0	0.2	15.7	18.0	10.6	1.8	31.5
5	100.0	24.1	0.0	0.1	15.9	17.6	10.3	1.7	30.2
6	100.0	23.8	0.0	0.1	16.2	17.7	10.2	1.7	30.3
7	100.0	24.0	0.0	0.2	16.5	17.7	10.0	1.6	30.0
8	100.0	24.1	0.0	0.2	16.6	17.7	9.9	1.6	29.8
9	100.0	24.2	0.0	0.2	16.6	17.7	9.9	1.6	29.8
10	100.0	24.1	0.0	0.1	16.5	17.6	10.0	1.7	30.0
11	100.0	24.3	0.0	0.1	16.5	17.5	9.9	1.6	30.0
12	100.0	24.5	0.0	0.2	16.4	17.5	9.8	1.6	30.0
13	100.0	24.6	0.0	0.2	16.6	17.5	9.7	1.6	29.9
14	100.0	24.4	0.0	0.2	16.5	17.5	9.8	1.6	30.1
15	100.0	24.4	0.0	0.2	16.5	17.5	9.8	1.6	30.0
16	100.0	24.1	0.0	0.2	16.6	17.8	9.8	1.6	30.0
19	100.0	23.4	0.0	0.2	16.2	17.8	10.2	1.7	30.5

against nonurban targets, and the disparities principally appear in the prompt-effects column. Females are relatively more exposed than males, and adults more than children. The findings with respect to age disparities are in full agreement with those reported by Heer (cited above, p. 20). His results with respect to disparate exposure by sex are mixed, but the only substantial difference he finds in his four attacks is unfavorable to females.

Table 9 displays patterns of exposure for whites and nonwhites under each of the five attacks. For the identically targeted Attacks 103 and 130, nonwhites are relatively more exposed than whites to prompt effects. This target list generally avoids cities -- where nonwhite populations are concentrated -- in favor of military installations and missile sites; but it does include command centers in the nation's capital and vicinity. Nearly 54 percent of the population of the District of Columbia is exposed to 6+ psi from Attack 103, and 98 percent from Attack 130. Such exposures of the nonwhite residents of the District, who comprise two percent of the total nonwhite population of the nation, easily account for the disparities noted, if the targeting system is otherwise nonselective with respect to ethnic groups.

For fallout exposures, the most obvious disparities appear in Attacks 430 and 599. In Attack 430, relatively fewer nonwhites than whites receive doses of 1000 roentgens or more. In Attack 599, nonwhites are relatively less exposed to doses of 3000 roentgens or more. The nonwhite inhabitants of our urban areas are typically concentrated in the central city. With the central cities blanketed by prompt effects, exposure to high fallout doses is most likely for those suburban areas where nonwhites are relatively scarce.

In none of the five attacks do the exposure disparities appear large enough to account for the survival disparity of 64:71 in favor of whites that Heer reported for his simulated night attack targeted primarily at cities. In fact, our city attacks seem to favor nonwhites. The difference in results, I believe, reflects in part a difference in the attacks themselves, and in part a difference in the method by which survival (Heer) and exposure (this study) were computed.

Table 9

PERCENTAGE DISTRIBUTION OF WHITES AND NONWHITES BY EXPOSURE TO WEAPONS EFFECTS: FIVE SIMULATED ATTACKS, 1960

Attack and Population Group	Total, All Categories	6+ psi Overpressure	Fallout Dose in Roentgens[a]						
			30,000+	10,000 to 29,999	3,000 to 9,999	1,000 to 2,999	300 to 999	100 to 299	0 to 99
Attack 103									
White	100.0	1.1		0.1	1.7	6.8	12.2	8.9	69.2
Nonwhite	100.0	2.3		0.1	1.8	6.7	11.7	8.7	68.7
Attack 203									
White	100.0	8.9		0.4	6.1	13.8	23.9	12.1	34.8
Nonwhite	100.0	9.4		0.3	5.9	13.9	24.5	12.2	33.9
Attack 130									
White	100.0	3.8	0.7	5.4	16.7	17.6	13.4	3.4	38.9
Nonwhite	100.0	6.1	0.5	4.6	15.1	18.2	14.6	4.0	36.8
Attack 599									
White	100.0	25.9	0.8	6.1	26.7	18.0	8.0	1.5	13.0
Nonwhite	100.0	26.6	0.6	4.9	22.3	21.7	9.0	1.4	13.4
Attack 430									
White	100.0	23.1		0.2	16.7	18.0	9.9	1.7	30.5
Nonwhite	100.0	23.4		0.1	12.3	16.6	12.6	2.2	32.8

NOTE: Percentages exposed to fallout doses exclude persons exposed to both fallout and prompt effects.

[a]Two-week integrated dose.

The attack that produced this substantial survival disparity for Heer targeted 110 weapons on 71 "concentrations of population and industry," expending a total of 567 megatons for this purpose. The individual weapons varied in size, but the largest was 10 megatons.* Applying our parameters of weapons effects, a 10-megaton weapon would yield 6+ psi overpressure over an area of 86 square miles, as compared with 390 square miles similarly covered by the 100-megaton weapons used in the QUICK COUNT attacks on 30 urbanized areas.

Assuming the weapons to be targeted on central cities in both cases, prompt-effects exposure from the 10-megaton weapon would be localized in that part of the urbanized area typically containing almost all of the urban nonwhite population; the white suburbs would be subjected only to fallout.

Furthermore, Heer's accounting system distinguishes central city from suburban populations, whereas the system used in the present study only distinguishes urban from nonurban populations. The central city category more clearly isolates nonwhite concentrations than does the urban category. Finally, Heer divides the reported fatality rate for SMSAs into separate rates for central cities and suburbs, assuming the former to be twice the latter. All these factors -- weapon size, accounting categories, fatality functions -- work against nonwhite survival in his study.

Despite the evidence presented by Human Sciences Research that it _is_ possible to target weapons on individual SMSAs so as to cause substantial disparities in the exposure of particular age/sex components of the SMSA's population, the results of the present study, combined with Heer's findings, militate against generalizing these local results to a national conclusion. The disparate exposure of whites and nonwhites seems more probable, but of insufficient magnitude for most plausible attacks to have significant consequences for

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*This is the attack described in pp. 12-55 of _Biological and Environmental Effects of Nuclear War_, Hearings before the Special Subcommittee on Radiation of the Joint Committee on Atomic Energy, 86th Congress, First Session, June 22-26, 1959. The figures cited are from pp. 12-13.

the composition of the surviving population. And while the possibility of large exposure disparities by age, sex, or color appears remote, this is definitely not true for some other population characteristics, particularly those associated with urban/rural residence.* But this study is limited to the analysis of demographic characteristics.

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*My colleague, Norman Hanunian, has investigated the prospects for survival disparities among various socio-economic groups as well as among nonhuman resources. Cf. Hanunian, op. cit.

IV. VULNERABILITY TO WEAPON EFFECTS

The final step in our program of damage assessment is to translate the exposure schedules presented in Sec. III into schedules of fatalities. In other words, we must specify how a given weapon-effect acts upon those exposed to it. Reasonable men can and do differ widely on this question, and the choice of vulnerability parameters has a decided effect on the final score of damage.*

For the population under attack, there is an important disjunction between the consequences of prompt effects and local fallout. The former is a package of severe biological stresses delivered at the instant of detonation. They include violent pressure waves of several seconds duration, intense thermal radiation, and also initial nuclear radiation (gamma rays and neutrons) emitted directly from the fireball. There have been enough tests of nuclear weapons to provide reasonable estimates of overpressures, heat, and shortwave radiation dosage by distance from the point of detonation. But these tests provide relatively little information about the direct biological consequences for humans of such stresses operating simultaneously, and even less about those consequences that are mediated by damage to the environment. These prompt but indirect consequences include injuries due to falling buildings, fires, flying fragments of rubble, secondary explosions of stored petrochemicals, etc. Beyond the moment of burst, we encounter more unknowns: the efficiency of rescue operations, and the ability of a confused and battered human throng to escape environmental dangers that are at least in principle avoidable.

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*The current uncertainty in estimates of vulnerability to weapon effects is discussed in detail by M. E. Arnsten, <u>Sensitivity of Mortality Estimates to Uncertainties in Some Nuclear Damage Parameters</u>, The RAND Corporation, RM-4706-TAB, September 1966. In the present study, these substantial uncertainties are crudely reflected by scalar shifts in schedules of vulnerability to local fallout, holding constant the schedule of vulnerability to prompt effects (see p. 43). The discussion that follows is hardly adequate as a resume of the literature on human vulnerability to weapon effects, but it should enable the reader to follow the reasoning behind my treatment of vulnerability.

Prompt effects have a characteristic circular symmetry. Overpressure, thermal radiation, and initial nuclear radiation all tend to decline with distance from the point of detonation, although both pressure waves and radiation are subject to absorption, reflection, and scattering by obstacles of terrain and structure. At a given distance from ground zero, all three effects increase with the energy-yield of the explosion, but tend to be less compressed in time. Consequently, scaling prompt effects to weapon-yield can be rather complicated.

The simplification adopted by the creators of QUICK COUNT relates all prompt effects to overpressure. Thus, for a 20-megaton burst, initial nuclear radiation above the probable midlethal range for unsheltered persons extends about two miles from ground zero. For the same weapon, this distance corresponds to overpressure of about 40 psi. The thermal pulse from such a weapon will ignite almost all flammable materials within 10 to 15 miles of ground zero, depending on atmospheric visibility. Flash burns of midlethal severity to unsheltered persons have about the same range. These distances correspond to overpressures of 2.75 to 1.25 psi for a 20-megaton weapon.

Severe structural damage to reinforced concrete structures is associated with 9 to 8 psi; similar damage to brick buildings, with 4 to 3 psi; and to wood-frame buildings with 3 to 2 psi. Although medical estimates of midlethal values for primary blast injury (effects of pressure variation on the body) are in the range of 58 to 42 psi, midlethal damage from flying debris or bodily impact is believed to occur in the range of 6 to 3 psi.

Such estimates of lethality of course assume exposure to the indicated stress. Though we may be able to estimate the number of persons at a given distance from ground zero, and thus their general exposure in terms of overpressure, it does not follow that all are equally exposed to thermal radiation or to flying glass. On the other hand, even though we might be able to estimate a midlethal value for primary blast injuries, and another for initial nuclear radiation, we are still faced with the problem of estimating lethality for persons exposed to both stresses simultaneously.

For the present analysis, I shall assume that all persons within range of 6+ psi overpressure, regardless of sheltering, are fatally injured. In view of the indicated overpressure equivalents of specific types of damage (particularly thermal effects), the synergy of stresses, and the confusion and dysfunctional behavior that is likely among those who survive the immediate stress, this vulnerability parameter seems to me if anything conservative. Of course, one would expect to find some survivors within range of 6+ psi, and some prompt-effects fatalities beyond that range.* For the survivors, local fallout would become an acute danger within half an hour after burst. And my decision to ignore prompt-effects fatalities beyond $R_{6+\ psi}$ is at least partly compensated by the likelihood that the adjacent population will be exposed to lethal fallout.

Radiation from local fallout is measured in terms of the two-week integrated dose to an unsheltered person. I have assumed a midlethal value of 900 roentgens, with a standard deviation of 225 roentgens. In other words, mortality is assumed to approach 95 percent in the vicinity of 1350 roentgens, and to approach 5 percent in the vicinity of 450 roentgens. These figures may be compared to current estimates of midlethal values for acute doses (i.e., doses received during a single day) ranging from 300 to 900 roentgens. It is generally agreed that the same dose, delivered over a longer period, is less damaging.

However, the radiation threat from fallout does not commence at the instant of attack, and it is cumulative over time. It is quite feasible for the population at risk to take evasive action. Beyond the range of blast and fire hazards, even the shelter of frame houses or basements could reduce the effective exposure to levels in the

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*Assuming a uniform distribution of population, a circle may be drawn about ground zero such that the number of survivors inside the circle equals the number of fatalities outside. The radius of this circle is often called the weapon radius for prompt effects. For most types of damage, this radius approximately corresponds to the midlethal distance, i.e., the distance at which the probability of fatal injury is 50 percent. Overpressures in the vicinity of 6+ psi have been used on occasion as the criterion of weapon radius for prompt effects of megaton-range weapons.

range of one-half to one-tenth the open-field exposure. Special structures could provide much greater protection; for instance, the Office of Civil Defense currently requires a radiological protection factor of 40 for officially designated fallout shelters; that is, the shelter must reduce the inside exposure to one-fortieth the open-field exposure.

To allow for uncertainties in estimates of both the midlethal dosage and of shelter utilization, I have estimated fatalities from the lethality function described above after scalar transformation. The scalar is nominally described as a "protection factor," and the values chosen were 10, 6, and 3. Thus, for a protection factor of 10, the midlethal dose is shifted from 900 to 9000 roentgens, and the standard deviation from 225 to 2250 roentgens.

Three schedules of fatality rates corresponding to given open-field exposures are shown in Table 10. Because the schedule of exposures is not itself a continuous function, fatality rates corresponding to the midpoints of each exposure interval were applied to the populations counted in that interval for a given attack. The table shows fatality rates of 100 percent for those exposed to 6+ psi and also for those exposed to fallout greater than the midlethal dose plus three standard deviations, a level which varies with the assumed protection factor. For exposures less than the midlethal dose minus three standard deviations, the table shows minimal fatality rates of 0.9 percent. This figure is in fact the annual crude deathrate for the U.S. in 1960.

Thus, the three vulnerability schedules shown in Table 10 indicate 100-percent mortality for exposures greater than 15,000, 10,000 and 5000 roentgens, respectively, and minimal mortality for exposures less than 4000, 2000, and 1000 roentgens, respectively. The reader is free to choose from among these schedules; my own excursions into the literature leave me with no solid convictions.

In any case, the alternatives are well suited to <u>a fortiori</u> analysis. Applying each set of mortality rates in turn to exposure schedules provided by five simulated attacks yields a total of 15 possible outcomes, with fatalities ranging from 2 to 62 percent of

Table 10

CRUDE DEATHRATES AS A FUNCTION OF EXPOSURE TO WEAPON EFFECTS: THREE ALTERNATIVE SCHEDULES

Type of Exposure	Deaths per Thousand Persons Exposed		
	PF[a] = 10	PF = 6	PF = 3
Prompt effects			
6+ psi overpressure	1000	1000	1000
Local fallout			
30,000+ roentgens[b]	1000	1000	1000
15,000-29,999	1000	1000	1000
14,000-14,999	991	1000	1000
13,000-13,999	980	1000	1000
12,000-12,999	942	1000	1000
11,000-11,999	862	1000	1000
10,000-10,999	742	1000	1000
9,000-9,999	572	999	1000
8,000-8,999	396	983	1000
7,000-7,999	235	935	1000
6,000-6,999	131	815	1000
5,000-5,999	52	550	1000
4,000-4,999	35	258	991
3,000-3,999	9	79	884
2,000-2,999	9	35	364
1,000-1,999	9	9	35
300-999	9	9	9
100-299	9	9	9
0-99	9	9	9

NOTE: Persons exposed to local fallout exclude those exposed to both local fallout and prompt effects.

[a]Radiological Protection Factor.

[b]Two-week integrated dose to unsheltered persons.

the U.S. population. These results are shown in Table 11. Note that the national fatality rates are well spaced over the entire range, and exhibit fairly regular progressions of magnitude both down columns (alternative attacks) and across rows (alternative protection factors).

Death from weapon effects is not necessarily instantaneous, especially for the less exposed but injured. At Hiroshima, where lethal radiation occurred only at the instant of explosion, nearly all deaths attributable to the bombing took place within 30 days

thereafter.* In the present study, where fallout hazards are assumed, even exposure may be delayed for hours after the attack. I will interpret prompt mortality, as given by the figures in Table 11, to include a period of 90 days following attack. Vital rates for subsequent postattack time are discussed in Sec. V.

Table 11

FATALITIES FROM FIVE SIMULATED ATTACKS, ALTERNATIVE SHELTERING ASSUMPTIONS: CONTERMINOUS UNITED STATES, 1960

Attack	Radiological Protection Factor 10	6	3
	Thousands of Deaths		
103	4,232	5,160	8,492
203	19,035	22,630	31,436
130	22,220	33,135	52,086
599	44,834	54,668	75,783
430	63,406	81,451	110,249
	Percentage of Preattack Population		
103	2.4	2.9	4.8
203	10.7	12.7	17.6
130	12.5	18.6	29.2
599	25.1	30.6	42.5
430	35.5	45.6	61.8

DEMOGRAPHIC DISPARITIES IN VULNERABILITY TO WEAPON EFFECTS

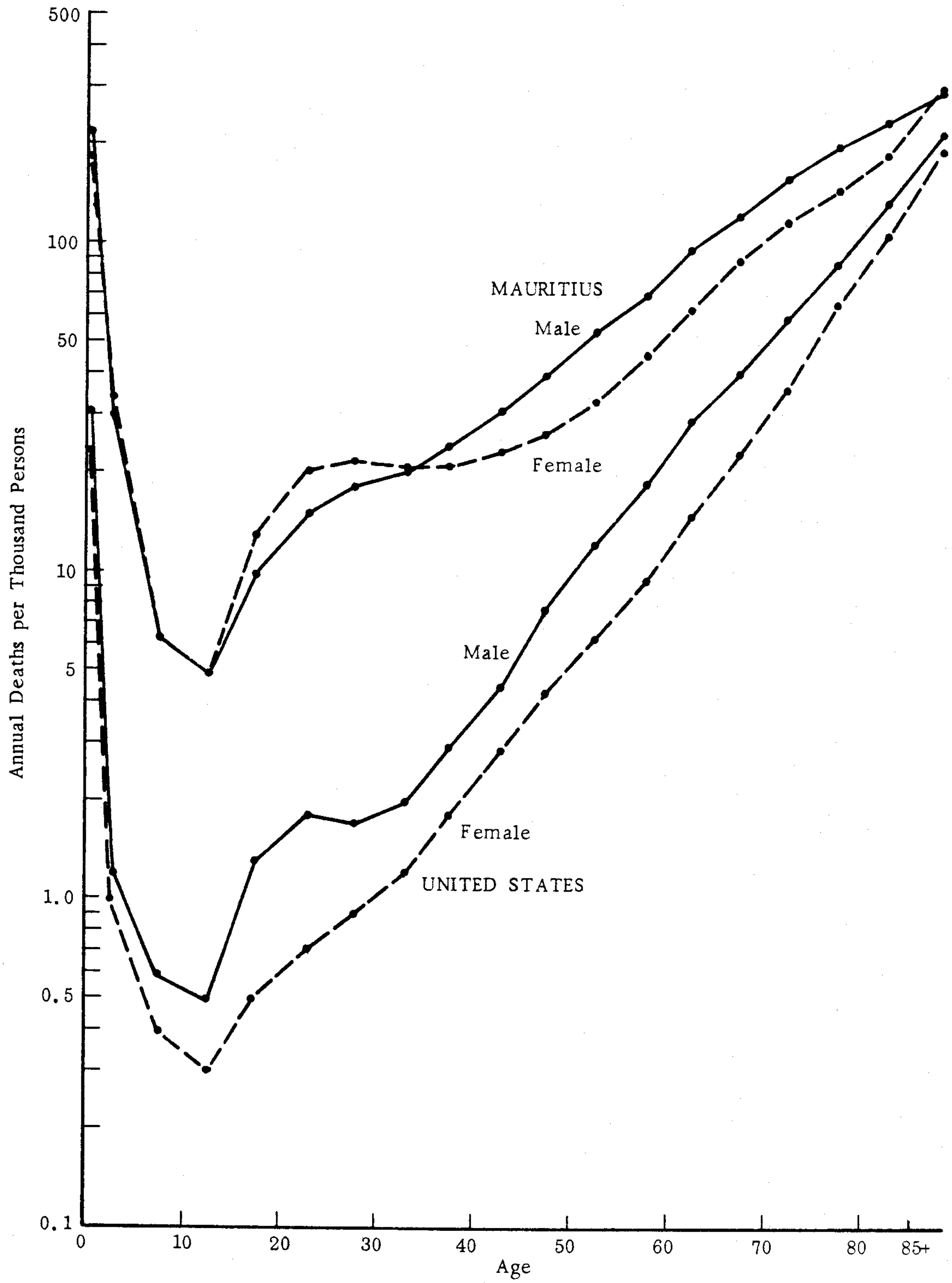
It is commonplace for the very young and very old of any species to be more vulnerable to environmental stresses than those in the prime of life. The case for innate differences in vulnerability of males and females is much less clear, except that pregnancy naturally reduces the ability of females to cope with extraordinary stresses.

*M. Ishida and I. Matsubayashi, "An Analysis of Early Mortality Rates following the Atomic Bomb: Hiroshima," Atomic Bomb Casualty Commission, Technical Report 20-61, Hiroshima-Nagasaki, 1961, Fig. 2 and Tables 1 and 2.

Figure 1 displays typical age-specific mortality functions for human males and females, drawn on log scale so as to emphasize detail in the vicinity of the minima of the functions. The two lower curves are for males and females of the United States in 1960. The two upper curves are for males and females of Mauritius, 1942-46. Mauritius at that time had a crude deathrate of about 21.6 persons per thousand per annum, as compared with 9.4 for the United States in 1960, and was therefore chosen as a contrasting example. Other nations and other social groups have higher crude deathrates than Mauritius -- as high as 30 per thousand -- but they do not keep records in enough detail to allow us to construct age-specific mortality functions.

The point of the comparison is twofold: On the one hand it exhibits the narrowness of the range of chronic mortality experience for human populations, and on the other hand it shows that mortality schedules for these fairly extreme cases quite clearly belong to the same family of functions. Thus infant deathrates (under 1 year) are always high relative to deathrates for children between 1 and 4 years of age, and minimum mortality is always achieved in the vicinity of ages 10-14. A minor plateau is often visible between ages 15-19 and 25-30. Thereafter, deathrates typically follow a rising log-linear path. Above age 40, female deathrates are usually lower than those for males; below that age, the relationship varies. For comparable age groups, the greatest variation among societies is in the deathrate for children; the values shown for Mauritius are nearly 10 times those for the United States; above ages 10-14, the difference steadily diminishes.

That the levels of the curves differ for Mauritius and the United States is indicative that the two populations either faced different levels of stress or (what amounts to the same thing) possessed differing abilities to cope with stress. In both cases, the stresses are chronic for the populations as wholes, although many of the individual deaths result from acute stresses. And in both cases, the chronic stresses are obviously far below the level which threatens extinction.



SOURCE: U.S. P.H.S., N.V.S.D., Vital Statistics of the United States, 1960, Vol. II, Part A.
U.N. Dept. of Econ. and Social Affairs, Population Bulletin of the United Nations, No. 6 (1962).

Fig. 1 -- Deathrates by age and sex: United States, 1960, and Mauritius, 1942-1946

What pattern of mortality by age and sex is appropriate for the extraordinary stresses of nuclear attack? In the analysis of Heer and Mostow, et al., it has been assumed that the crude fatality fraction for the population at risk applied to each of its components. This assumption has not gone unquestioned, but I am not aware of any attempt until recently to devise an alternative which takes account of age- or sex-dependent mortality. Hanunian* models age-dependence in human susceptibility by reference to various peacetime hazards which are assumed to represent the principal weapon effects and then synthesizes an overall relationship between age and the likelihood of death from nuclear attack. Here I apply my own insights to modeling both age and sex dependence. My ultimate objective in doing this is to show the extent to which this departure from the Heer-Mostow approach influences subsequent demographic events, such as population "recovery" in the postattack period.

MORTALITY BY AGE AND SEX FOR ACUTE STRESS

There are virtually no data on mortality differentials by age and sex under conditions of acute stress. For many localized disasters, it is possible to account for virtually all casualties, but their numbers are relatively small, and the age distribution of the population at risk is not known precisely enough to allow computation of age-specific rates of death or injury. Indeed, it is rare that the population at risk can be clearly defined.

H. J. Friedsam has published a brief demographic analysis of the casualties of Hurricane Audrey, which devastated the lower half of Cameron Parish, Louisiana, in 1957.** He cheerfully allows that "any number of criticisms might be directed against [his] procedure," but it is clearly the best that could be done with the meagre data available. Table 12 reproduces his computed indices of casualties for three age groups, by sex. Entries above 100 indicate greater than

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*Hanunian, op. cit.

**H. J. Friedsam, "Older Persons in Disaster," in George W. Baker and Dwight W. Chapman (eds.), Man and Society in Disaster, Basic Books, New York, 1962, pp. 164-168.

average casualty rates for the group, while entries below 100 indicate casualty rates below the average for the group. The four columns of the table have a striking consistency, with much higher values for those under 10 and those over 60 than for persons between 10 and 59 years of age. Sex differentials are less consistent.

Despite extensive surveys of the damage resulting from Allied bombing raids on German cities, data for civilian populations in World War II are equally scanty. R. K. Titmuss has reviewed the wartime mortality experience of the population of the United Kingdom, and offers data on the relative frequency by age and sex of casualties in London, but due to the confusion of wartime evacuation and population movements, the size and age/sex structure of the population at risk is unknown. Consequently, casualty rates were not calculated.*

Table 12

CASUALTY INDICES BY AGE AND SEX: WHITE PERSONS DEAD AND MISSING, HURRICANE AUDREY, CAMERON PARISH, LOUISIANA, 1957

	Dead		Missing	
Age Group	Male	Female	Male	Female
Under 10	117	124	153	125
10 to 59	63	64	57	71
60 and over	371	340	309	278

SOURCE: Friedsam, op. cit., p. 165.

NOTE: For each type of casualty, percentage distributions by age were computed. A similar percentage distribution was computed for the 1950 population of Cameron Parish. The index number is the ratio of the casualty percentage to the population percentage, multiplied by 100.

The most obviously relevant experience is that of the Hiroshima-Nagasaki bombings. At least two surveys of the casualties of these bombings produced records that could be used for the analysis of

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*Richard K. Titmuss, Problems of Social Policy, History of the Second World War, United Kingdom Civil Series, W. K. Hancock (ed.), H. M. Stationery Office and Longmans, Green, London, 1950, Appendix 8.

age/sex variations in short-term mortality,* but I have been unable to find any report of such an analysis except for a single chart showing deathrates by sex and distance from ground zero for Hiroshima.** Between 0.5 and 1.28 kilometers from ground zero, female deathrates are shown to be distinctly lower than male. Beyond that distance, no systematic differences are apparent.

Although I have been unable to gain access to the records of either of the principal casualty surveys, I have been fortunate in obtaining some relevant data from a less systematic file compiled by the Dikewood Corporation from various Hiroshima-Nagasaki source documents, primarily clinical records now in the custody of the Armed Forces Institute of Pathology. These casualty records, compiled by

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*Late in 1945, the Joint Commission for the Investigation of the Effects of the Atomic Bomb in Japan conducted a survey of casualties in Hiroshima and Nagasaki. Respondents were selected by area-sample from the returns of the Japanese Census of November 1945 (in itself an astonishing event!). These were people who 1) survived the bombing and 2) remained in the city or returned to the city by the census date. Respondents were asked to report on the fates of members of their families and friends who were in the city at the time of the bombing. Each person so listed by the respondent was to be described by name, relationship to respondent, age, location at the time of the bombing, and whether "killed, injured, or uninjured." (See facsimile of the questionnaire in A. W. Oughterson and Shields Warren, Medical Effects of the Atomic Bomb in Japan, McGraw-Hill Book Company, Inc., New York, 1956, Appendix D, p. 452.) The field work was directed by Capt. M. E. Habel, USA, and Dr. M. Masuyama of the Faculty of Medicine, Tokyo Imperial University. I have been unable to locate the records of this survey.

In August, 1946, a casualty survey of the residents of Hiroshima was conducted by the City Office under the direction of I. Matsubayashi. Its format, like that of the Joint Commission's survey, provides data for both casualties and survivors by age, sex, and location at the time of the bombing. It is a much larger sample, covering 143,000 persons as compared with the 20,500 (Hiroshima only) of the Joint Commission survey. The file is now in the possession of the Atomic Bomb Casualty Commission, excepting some 20,000 missing records.

**Medical Section, Special Committee for the Investigation of the Effects of the Atomic Bomb, National Research Council of Japan, Medical Report on Atomic Bomb Effects, 1953, Chart 3, p. 23. The chart is based on computations by M. Masuyama, from data gathered in the Joint Commission Survey.

Dikewood for a study of shelter effectiveness, cover over 35,000 persons who were present in the two cities at the time of the bombings. My analysis deals only with the 21,616 persons in that sample who were members of collocated groups. The records are based on survivors' reports of the identities and fates of those who were collocated with survivors. Thus each group of collocated persons shared a well-defined exposure, and for each such group the Dikewood file identifies those killed, those nonfatally injured, and those uninjured. For the individuals thus classified, age and sex are almost always reported.

Since the sample is fortuitous,* the proportions of individuals in the various categories -- age, sex, shielding, location with respect to ground zero -- do not necessarily reflect the corresponding proportions in the populations of Hiroshima and Nagasaki at the time of the bombings. In particular, there are few records for persons who were close to ground zero, because there were few survivors to report on such persons. There are only 5698 records for Nagasaki, a number precluding disaggregation for that city alone. But insofar as it is possible to disaggregate the Hiroshima sample of 15,918 persons into groups with comparable exposures, vulnerability differentials by age and sex can be discerned.

Figure 2 shows rates for total casualties, nonfatal injuries, and fatalities by age and sex for the entire sample. Each age/sex group of course includes persons exposed to varying kinds and intensities of weapon effects. A plausible proxy for average exposure of each group is its total casualty rate, in which case the proportion of total casualties that resulted in death is at least a crude measure of the group's vulnerability to weapon effects relative to other age/sex groups. The curves for total casualties suggest that males were typically more exposed to weapon effects than females, and that persons 20 to 49 years of age were more exposed than children or old people. While these exposure differentials may have been

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*The Dikewood Corporation has checked the distribution of the elements of its Hiroshima sample among small areas within the range of greatest interest, 1000 to 2000 meters from ground zero. Coverage was found to be quite systematic in this respect.

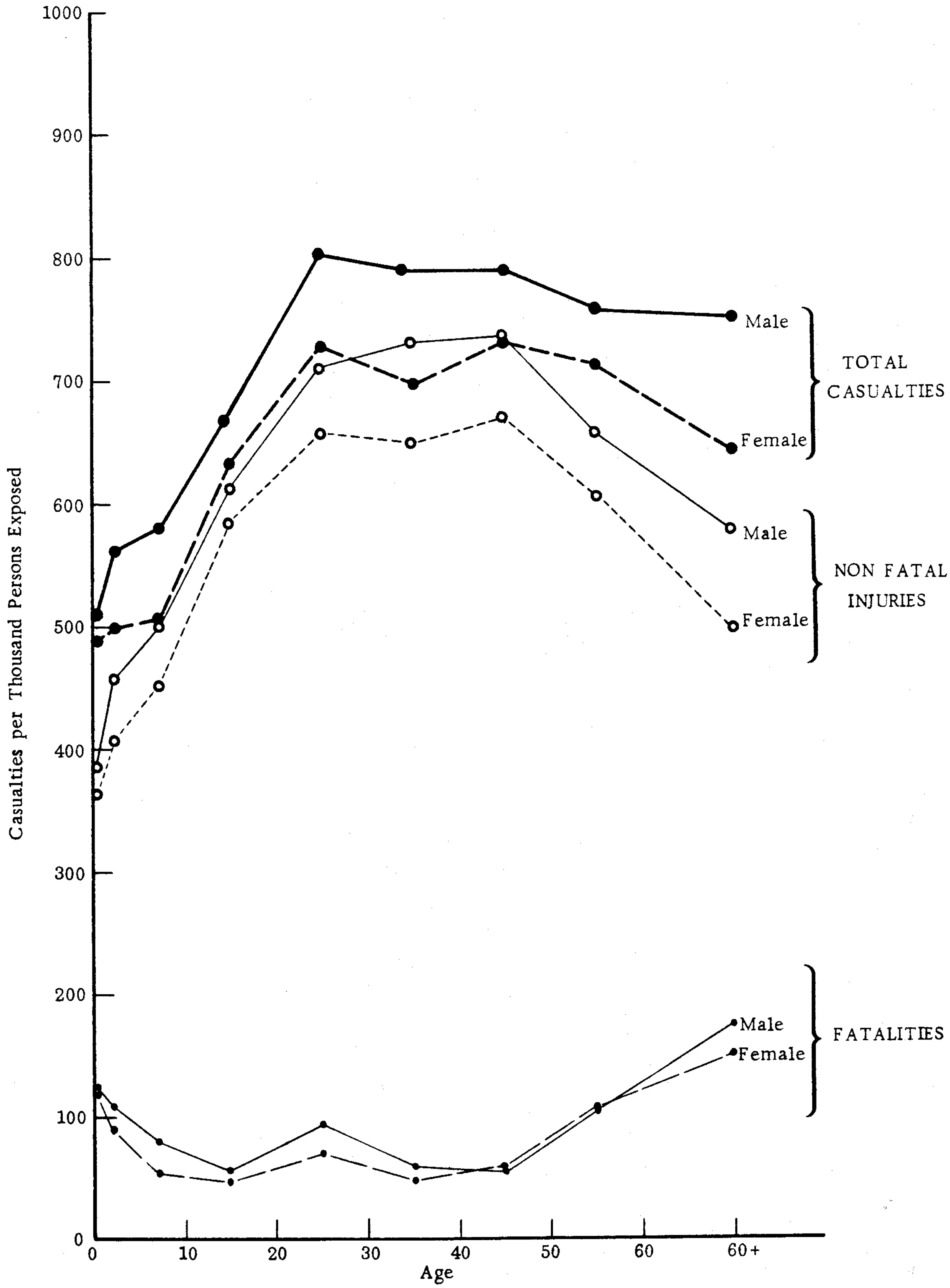


Fig. 2 -- Hiroshima/Nagasaki casualty rates by age and sex: all locations, all shielding categories

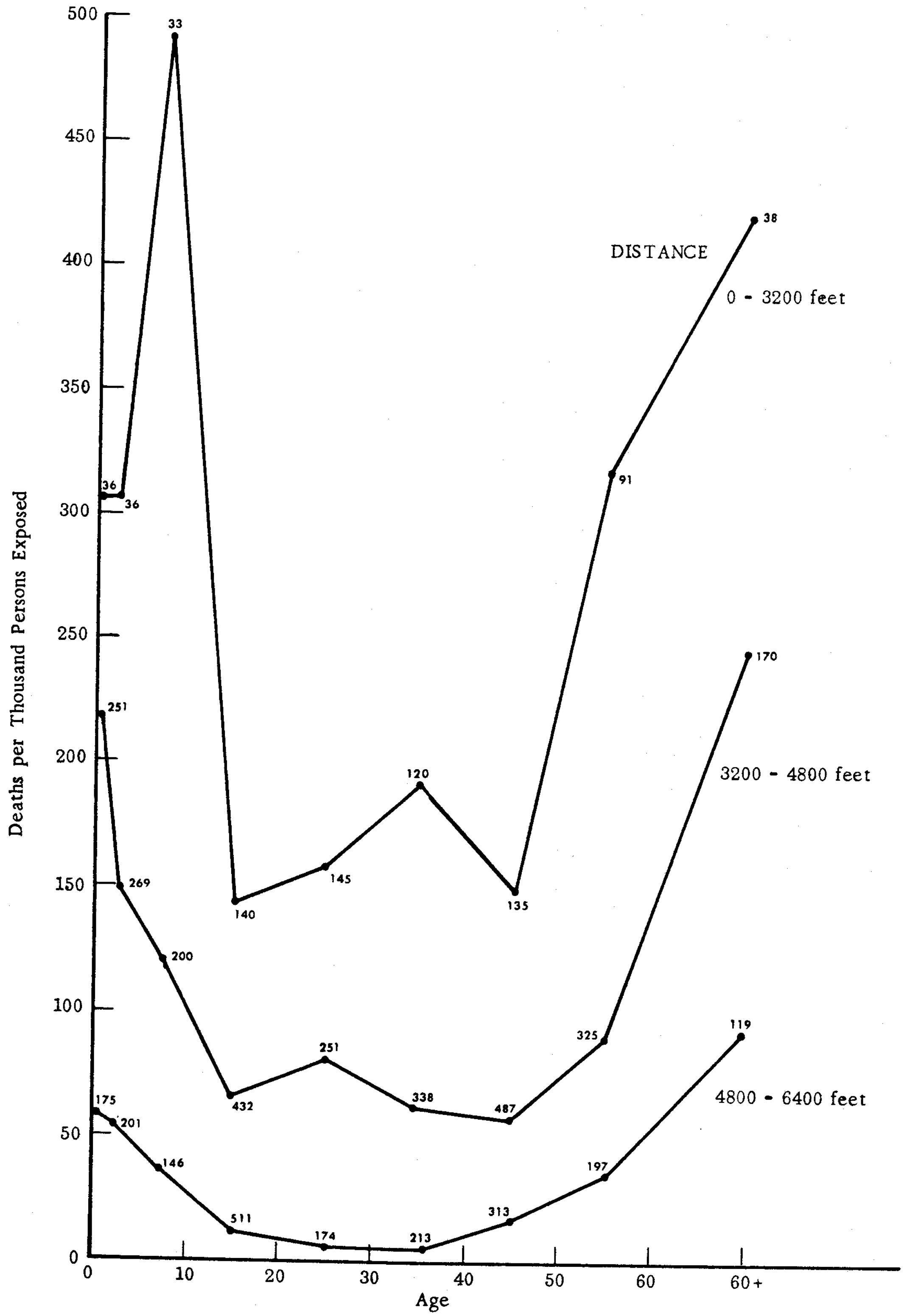
accidents of time, place, and culture, they seem quite reasonable for our own urban populations in cities of comparable size, assuming a 20-kiloton weapon exploded during a normal weekday.

If we may then interpret the rates for total casualties as approximate exposure schedules by age and sex, the issue of differential vulnerability is considerably clarified. In Fig. 2, the curves for nonfatal injuries follow those for "exposure," with the highest injury rates for ages 20 to 49 years. But the curves for fatalities are quite different. They show relatively high rates for children and old people, low rates for ages 20 to 49. Despite being least exposed, the young and the old appear to be most vulnerable. For any given age, fatality rates for males and females are similar, and with the possible exceptions of ages 40-49 and 50-59, the differences reflect only the characteristically greater "exposure" of males rather than differences in vulnerability.

Fatality rates are shown in greater detail for males and females of Hiroshima in Figs. 3 and 4. The sample is divided into three exposure groups, as indicated by distance from ground zero. All of these disaggregations (age, sex, city, location) have a price in that the number of cases forming the base for each rate are reduced. This number is shown beside each plotted point. Despite small statistical bases for some of the points, the curves have enough regularity of shape to allow some broad conclusions to be drawn.

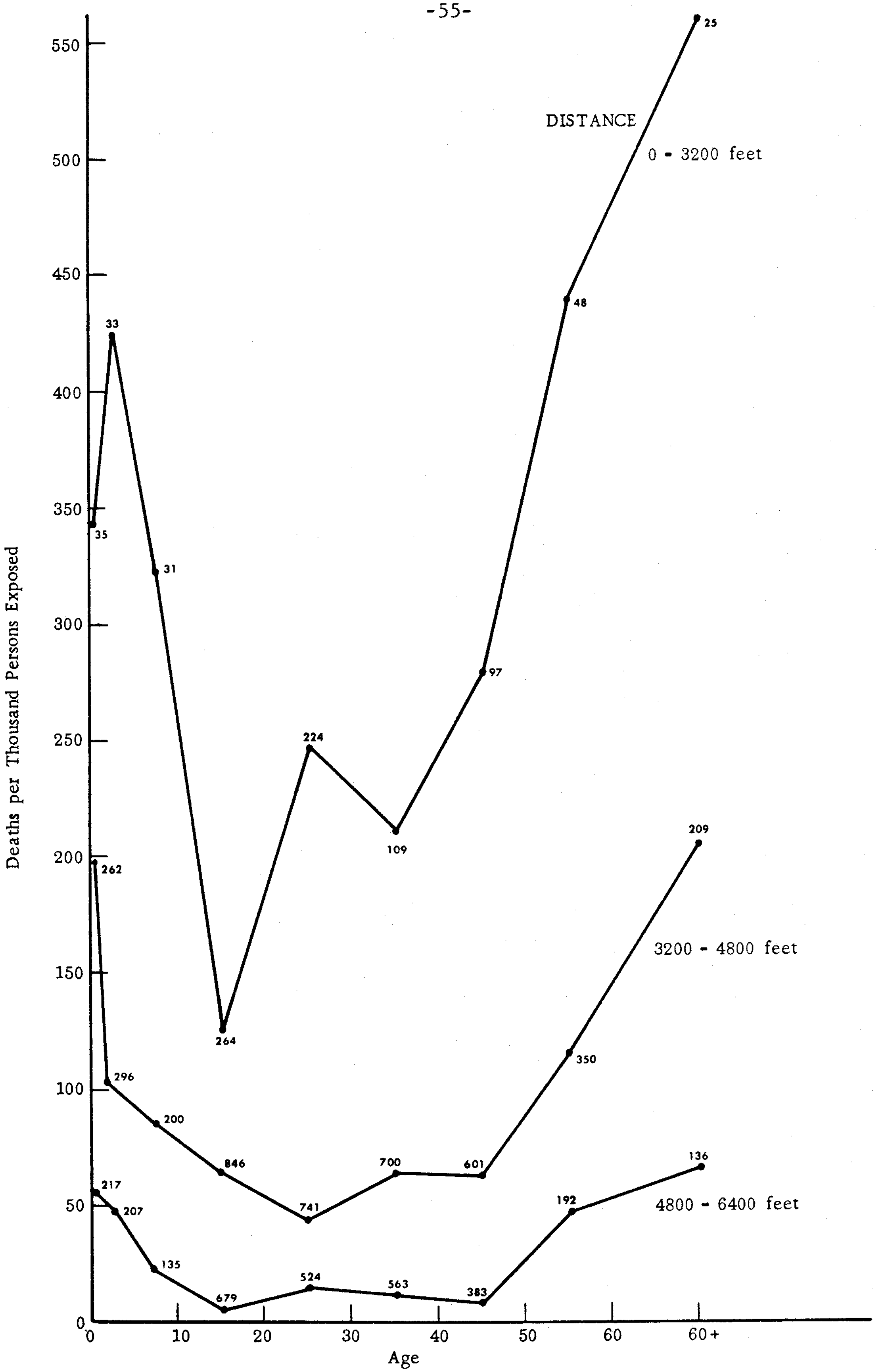
When exposure is thus crudely standardized for each age/sex group, the differences in vulnerability by age become much more distinct. On the other hand, there are no systematic differences in vulnerability by sex except for persons located within 3200 feet of ground zero. For this group, higher fatality rates for females are reported for all ages above 20 years.

Age differentials in vulnerability increase with exposure over the range covered by these data. Fatality rates for small children and for old people rise much more rapidly than rates for persons 10 to 49 years of age. Even though the number of cases is small for extreme age groups located within 3200 feet of ground zero, the similarity of values for the youngest and oldest and for males and females argues for the approximate validity of the illustrated rates. In all



NOTE: Number of persons exposed shown for each plotted point.

Fig. 3 -- Hiroshima fatality rates by age and distance from hypocenter: males, all shielding categories



NOTE: Number of persons exposed shown for each plotted point.

Fig. 4 -- Hiroshima fatality rates by age and distance from hypocenter: females, all shielding categories

exposure groups, there are erratic secondary peaks at various ages 20 to 49 years, but the irregularity of these peaks suggests sampling oddities rather than authentic vulnerability differences.

It is important to note the limited range covered by these mortality schedules. The lowest curves of the two figures correspond to crude deathrates in the neighborhood of 35 per thousand persons exposed. The highest curves correspond to crude deathrates in the vicinity of 300 per thousand persons -- far above any recorded chronic deathrates, but well below even the midlethal level that appears as a key parameter in most damage assessment models.

As compared to chronic rates, moreover, the curves are differently shaped. In Fig. 5, mortality rates for Hiroshima males, 4800-6400 feet from ground zero, are plotted on log scale together with the chronic rates for Mauritian males, 1942-46. Note that for the Hiroshima curve, the difference between minimum mortality and infant mortality is less pronounced than for Mauritians, but the drop in mortality after age 1 is not nearly so rapid. For this particular Hiroshima curve, the lowest mortality rate is for ages 30-39; other curves from this series show minima either at ages 10-19 or 20-30, but the statistical base in each case is too scanty to reach a firm conclusion about the "true" location of a minimum within the relatively flat middle range of the curves.* Finally, the rise in mortality among adults begins later but is much steeper for Hiroshima than for Mauritius.

MODEL MORTALITY SCHEDULES FOR QUICK COUNT ATTACKS

On the admittedly slim statistical basis of the Dikewood data for Hiroshima, I have prepared a set of model mortality schedules for use in estimating fatalities from nuclear attack. Each such schedule is specific to age and sex, and corresponds to a definite crude fatality rate. A selection of these schedules is shown in Fig. 6 for males and Fig. 7 for females; the corresponding crude fatality rate (F) is shown alongside each schedule.

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*Flat, that is, when plotted on natural rather than log scale. See Figs. 3 and 4.

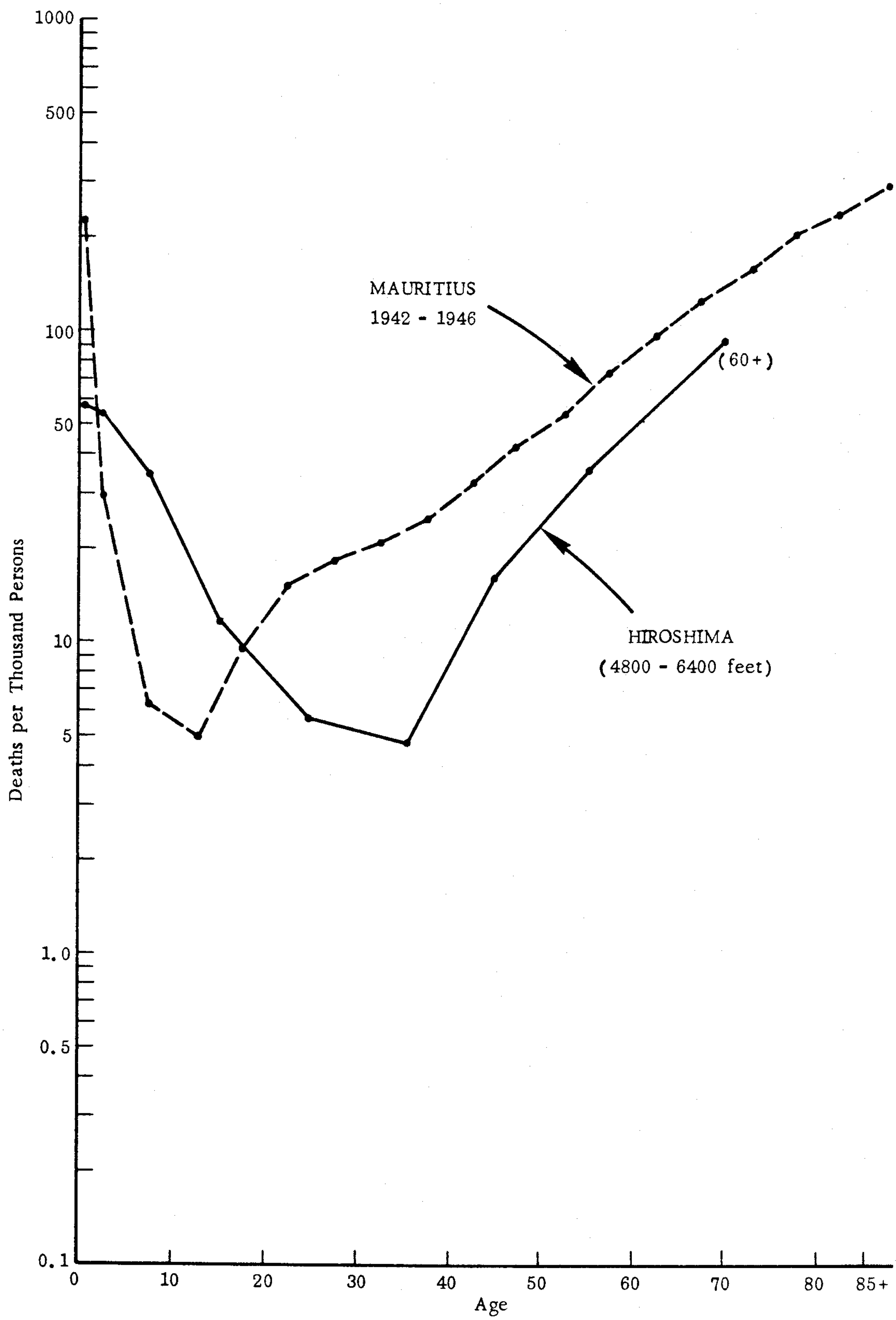

Fig. 5 -- Hiroshima fatality rates and Mauritian annual deathrates for males, by age

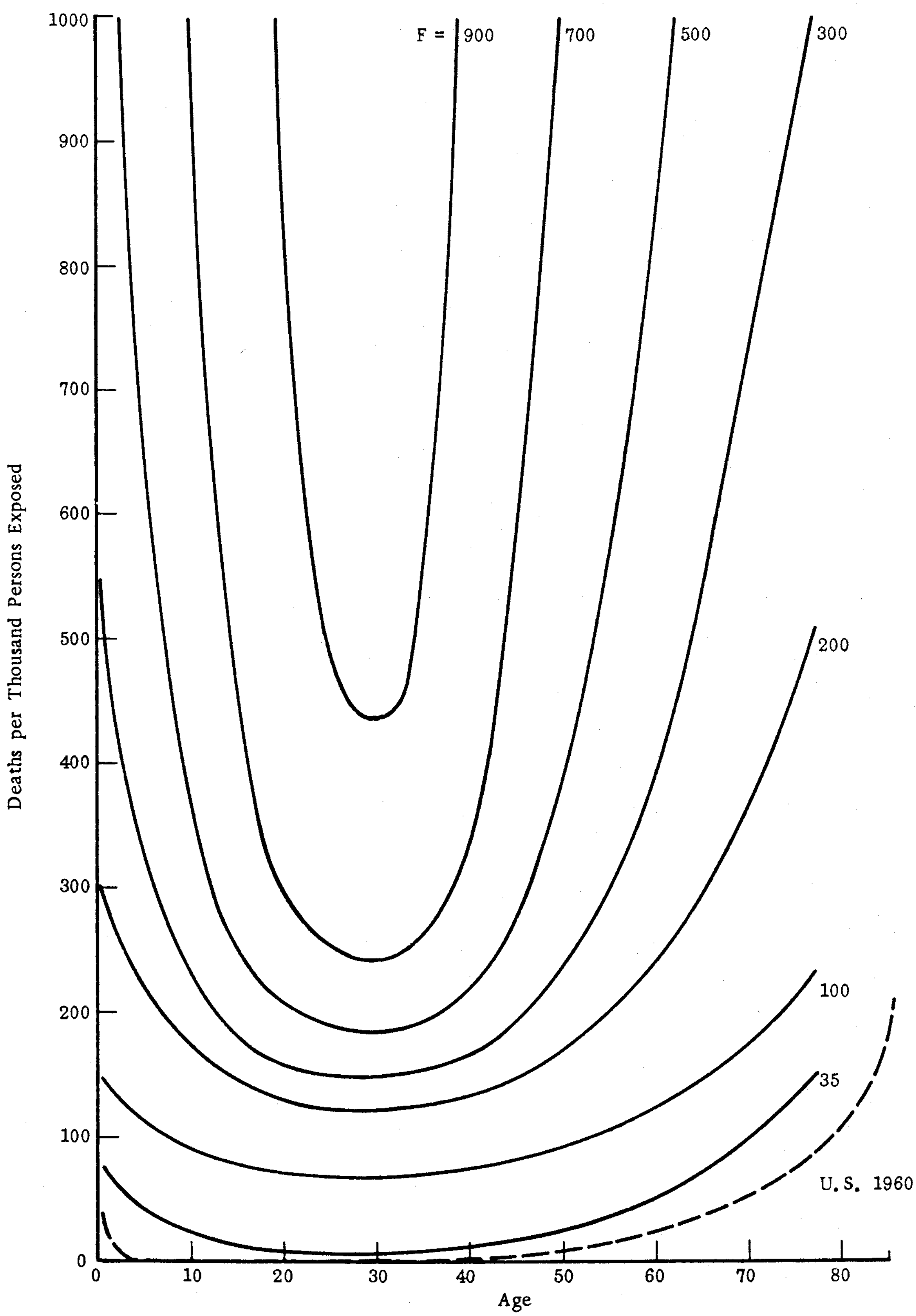

Fig. 6 -- Model mortality schedules by age for males, selected crude fatality rates

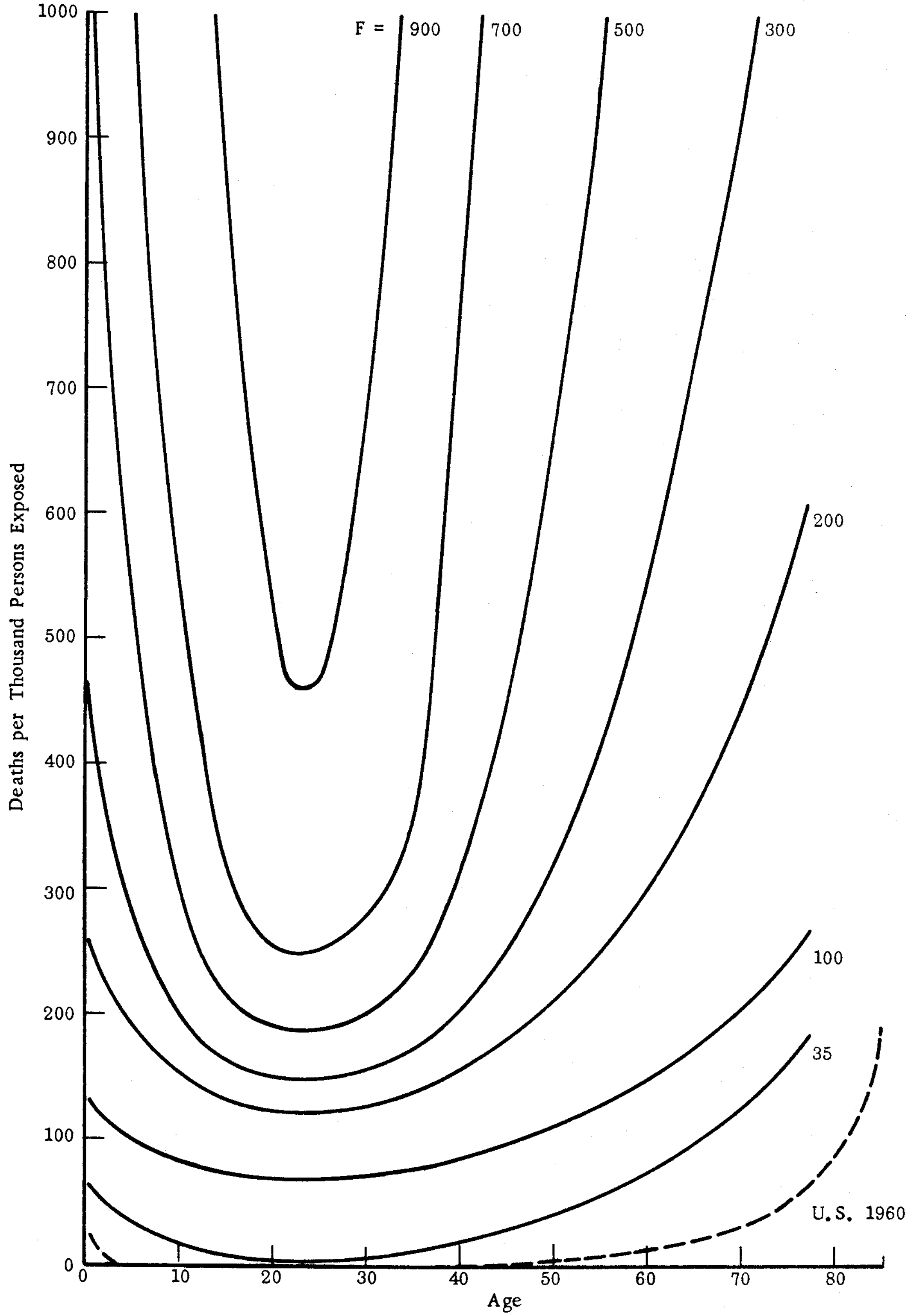

Fig. 7 -- Model mortality schedules by age for females, selected crude fatality rates

The schedule labeled "F = 35" is based on Hiroshima fatality rates for persons located 4800-6400 feet from ground zero, the lowest curves in Figs. 3 and 4. These observed rates were fitted graphically to obtain the smooth curves, F = 35. The latter were then translated upward for higher levels of mortality. The translation was made by the following formula:

$$M'_x = M_x + c + M_x^{\alpha c} ,$$

where M_x = deathrate for age x, read from the model function, F = 35,

M'_x = deathrate for age x at a higher level of mortality,

c = an arbitrary constant,

α = .1, a fitted parameter.

By advancing the value of <u>c</u> in small increments, a series of schedules of M'_x were generated for age-groups under 1 year, 1-4 years, and by 5-year increments to 75+ years, with separate values for males and females. Each such schedule was then applied to a standard population (distributed by age and sex) to calculate the crude fatality rate implied by the given set of values of M'_x. The standard population is that of the conterminous United States in 1960 -- i.e., the population at risk in our five simulated attacks.

The schedules selected for display in Figs. 6 and 7 correspond to crude fatality rates ranging from 35 to 900 deaths per thousand persons.* At the bottom of each figure is also shown the schedule of annual age-specific deathrates for the United States in 1960.

The formula for the translation of the base schedule of M_x contains a single fitted parameter α, which was effective in modifying the shapes of successively higher M'_x schedules to the pattern suggested by the Hiroshima data for 3200-4800 feet and 0-3200 feet. Figures 8 and 9 compare the model mortality schedules with the empirical ones for these cases.

The reader will recall that three schedules relating crude fatality rates and exposure to weapon effects were selected for <u>a fortiori</u> analysis of the demographic outcomes of our five attacks.

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*For the convenience of readers who may wish to use these functions, they are tabulated in Table 25 for a more complete set of F-values.

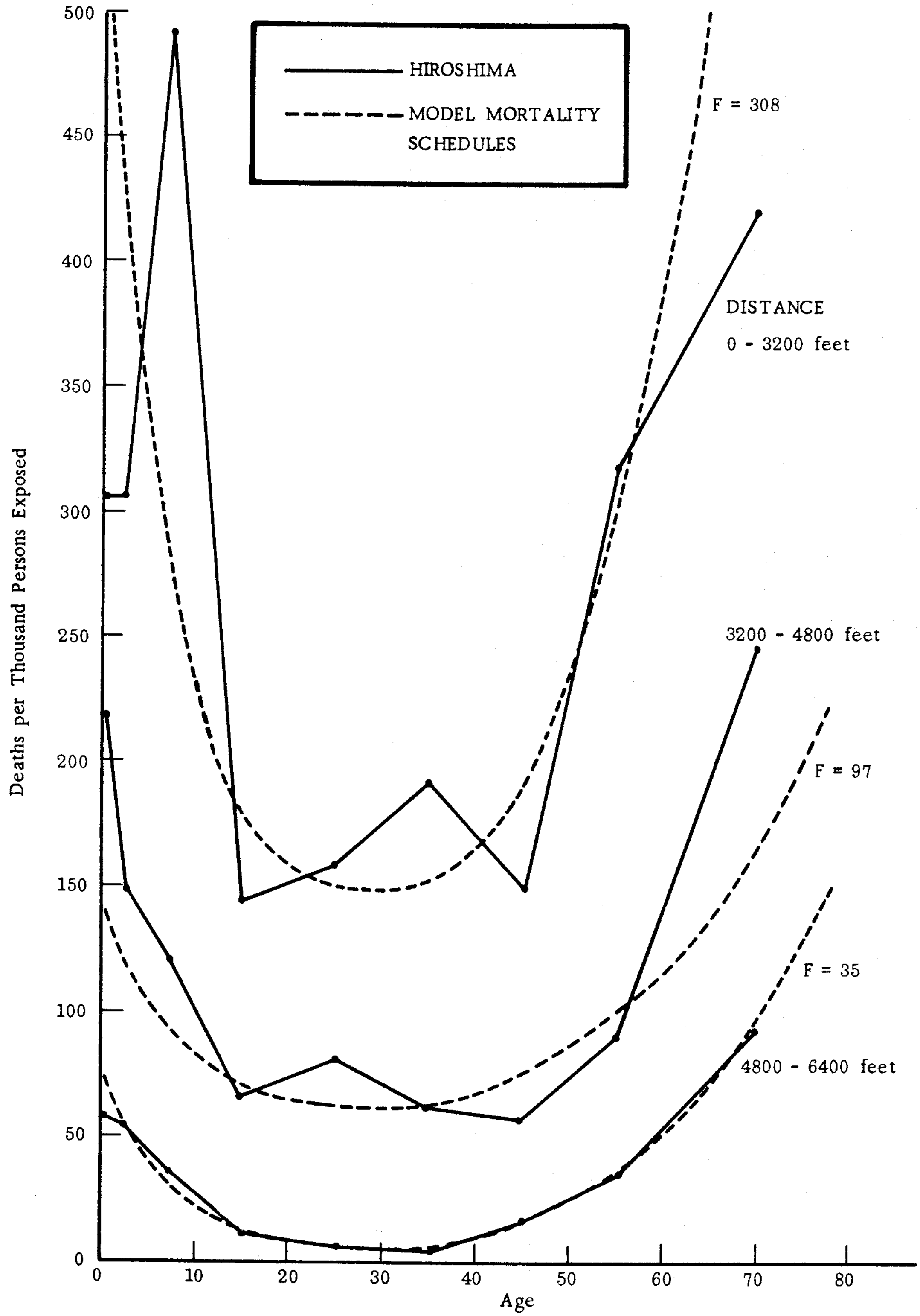

Fig. 8 -- Deathrates by age for males: Hiroshima and model mortality schedules

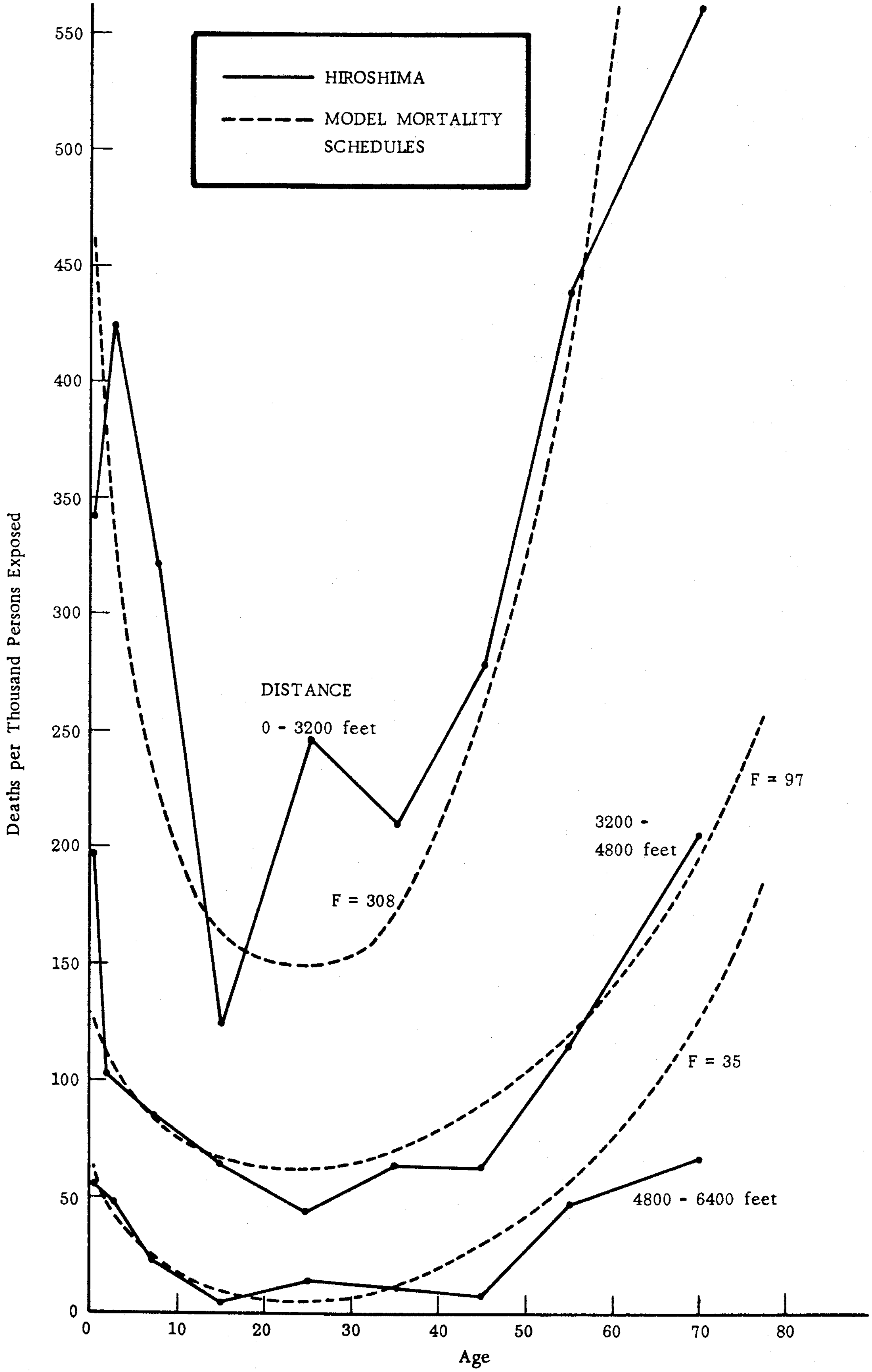

Fig. 9 -- Deathrates by age for females: Hiroshima and model mortality schedules

Reading the appropriate crude fatality rate for each exposure from Table 10, I selected the corresponding model mortality schedule -- in other words, translated the crude rate into a set of rates detailed by age and sex.

For each simulated attack, estimates had already been prepared of the number of persons by age, sex, and color who were exposed to each of 20 levels of weapon effects (Sec. III). The appropriate model mortality schedule was applied to the population of each such exposure group. Identical rates by age and sex were applied to whites and nonwhites, but since the two groups differ in age/sex composition, a given set of age/sex-specific fatality rates usually corresponds to slightly different crude fatality rates by color. For persons subjected to minimal exposures under a given protection factor, U.S. annual mortality rates for 1960, specific to age, sex, and color, were used in preference to a downward translation of the Hiroshima curves. Since attack-mortality is here treated as including all deaths within three months of attack, the use of annual rates for minimally exposed persons effectively quadruples these peacetime deathrates.

Summing fatalities across all exposure groups, I then calculated totals by age, sex, and color for the nation. The procedures described above were repeated for each of the five simulated attacks under each of the three alternative sheltering assumptions, a total of 15 cases. In each case, estimated fatalities by age, sex, and color were subtracted from the corresponding component of the preattack population to yield a schedule of three-month survivors. A detailed table of survivors for each case is presented in the Appendix, Table 26.

An overview of the results is presented in the form of a population pyramid for each attack, Figs. 10-14. The outer pyramid represents the preattack population, the inner pyramids show the shrinkage of this population as a result of the attack under each of three sheltering assumptions. Disproportionate reduction in the lengths of any two bars representing different age groups indicates a survival disparity, the combined effect of disparate exposure and disparate vulnerability.

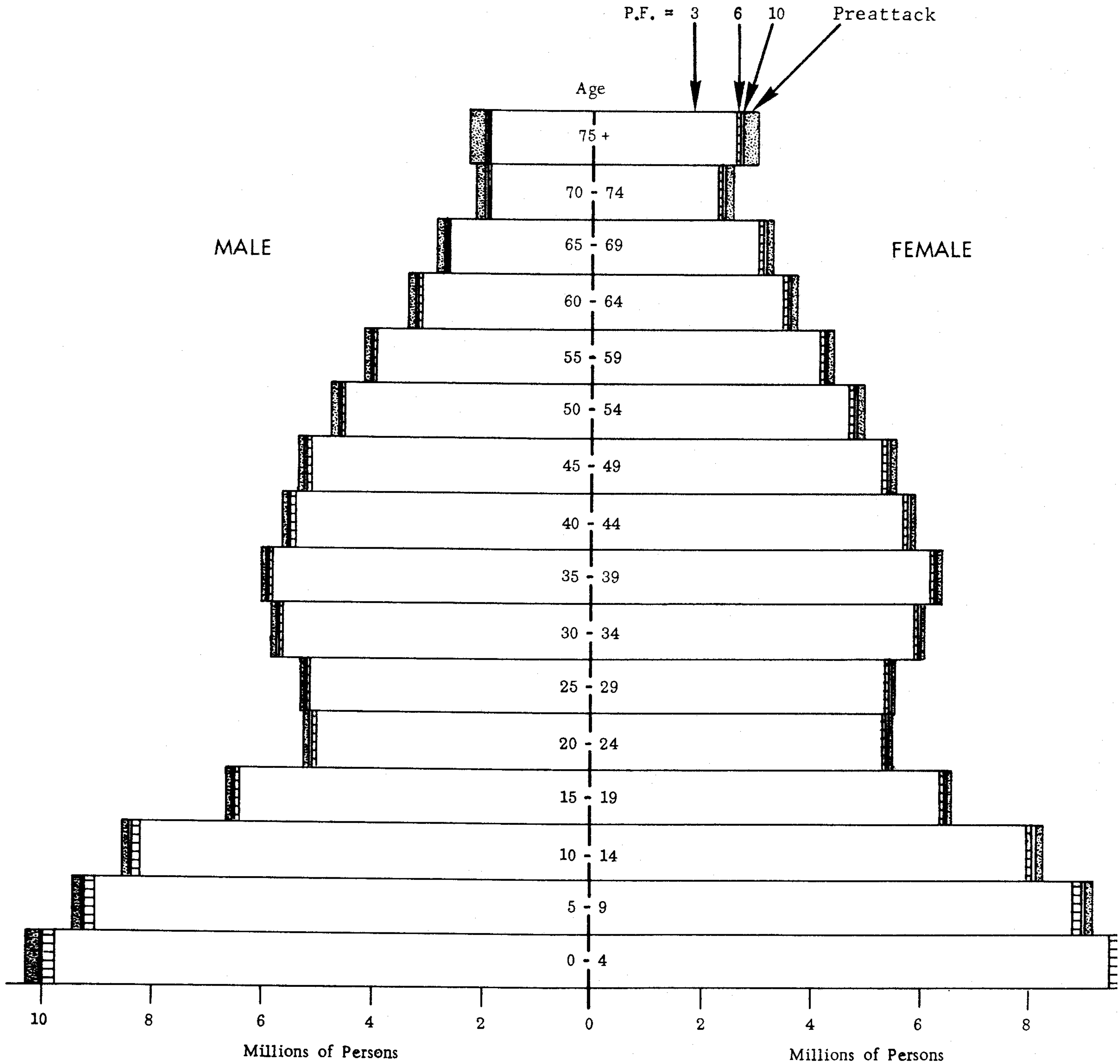

Fig. 10 -- Population pyramids for survivors of Attack 103, alternative sheltering assumptions

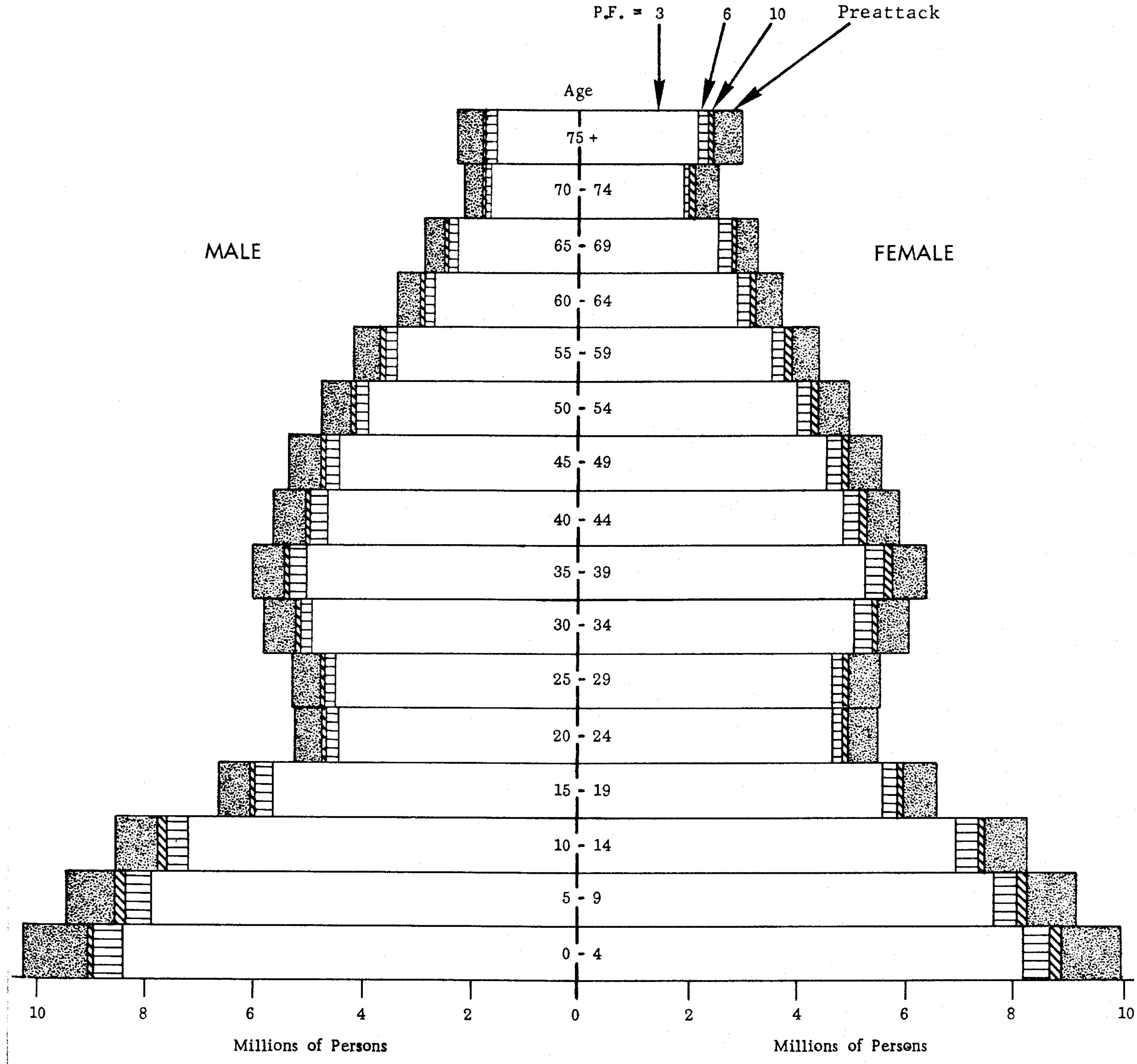

Fig. 11 -- Population pyramids for survivors of Attack 203, alternative sheltering assumptions

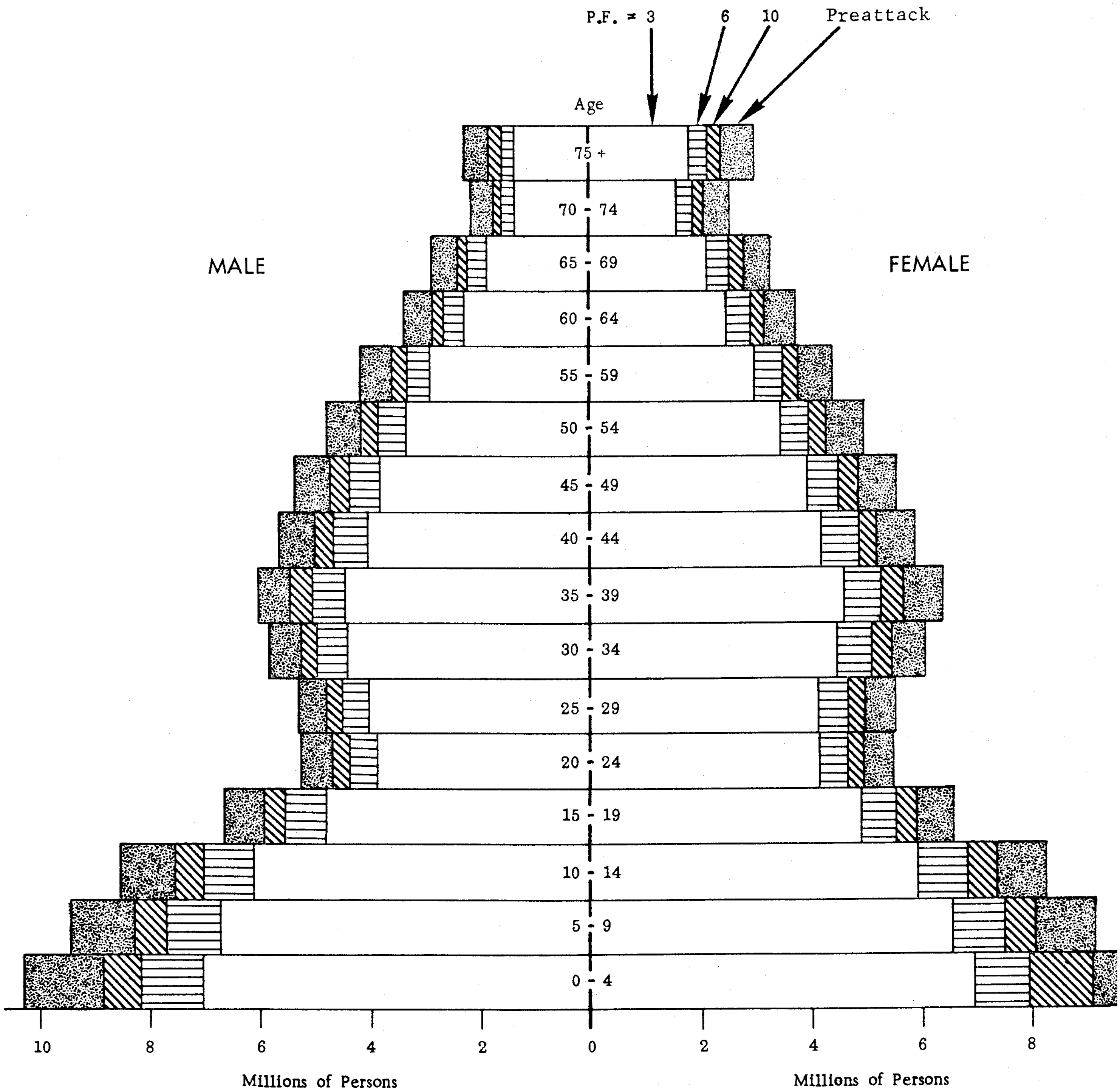

Fig. 12 -- Population pyramids for survivors of Attack 130, alternative sheltering assumptions

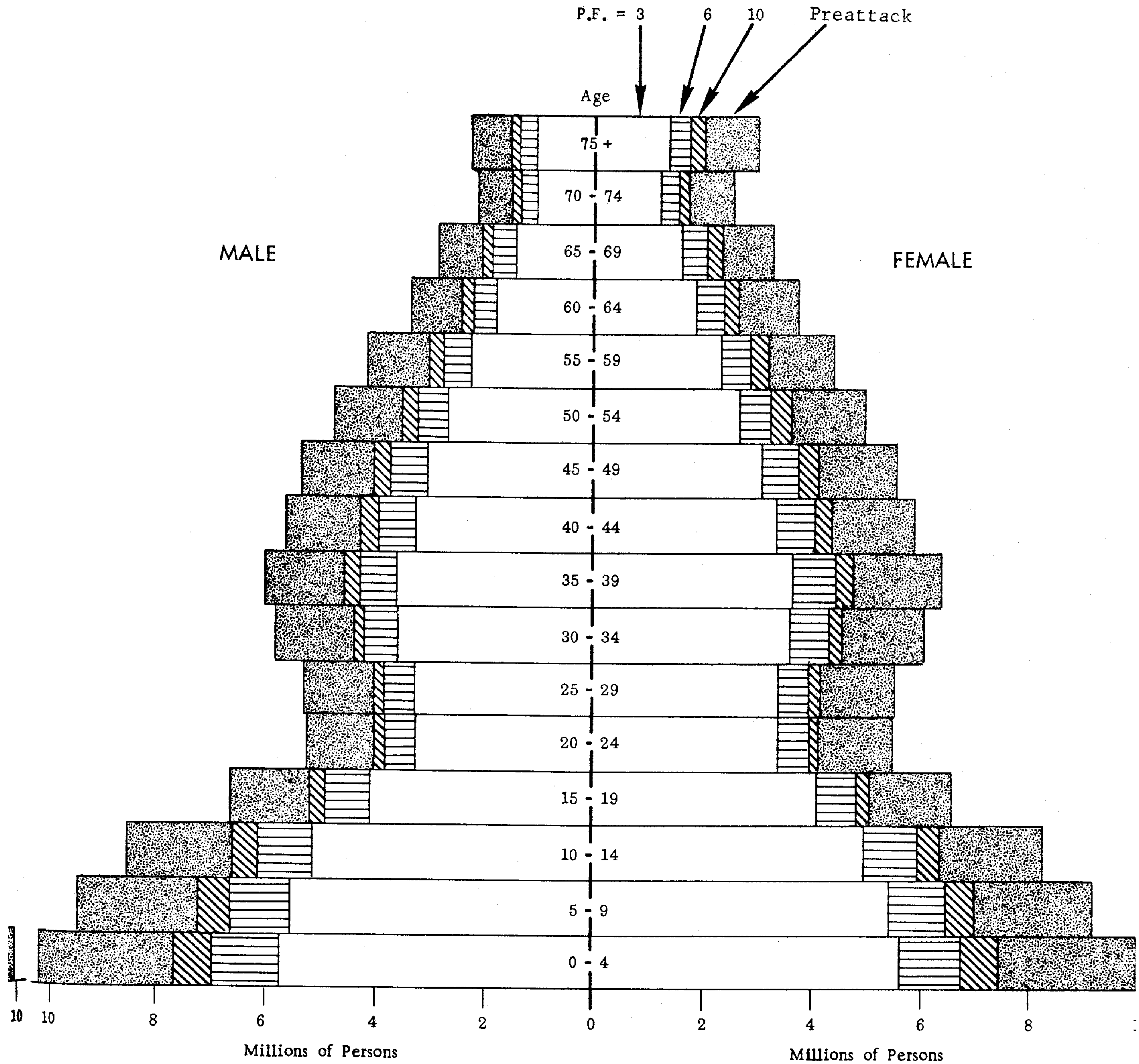

Fig. 13 -- Population pyramids for survivors of Attack 599, alternative sheltering assumptions

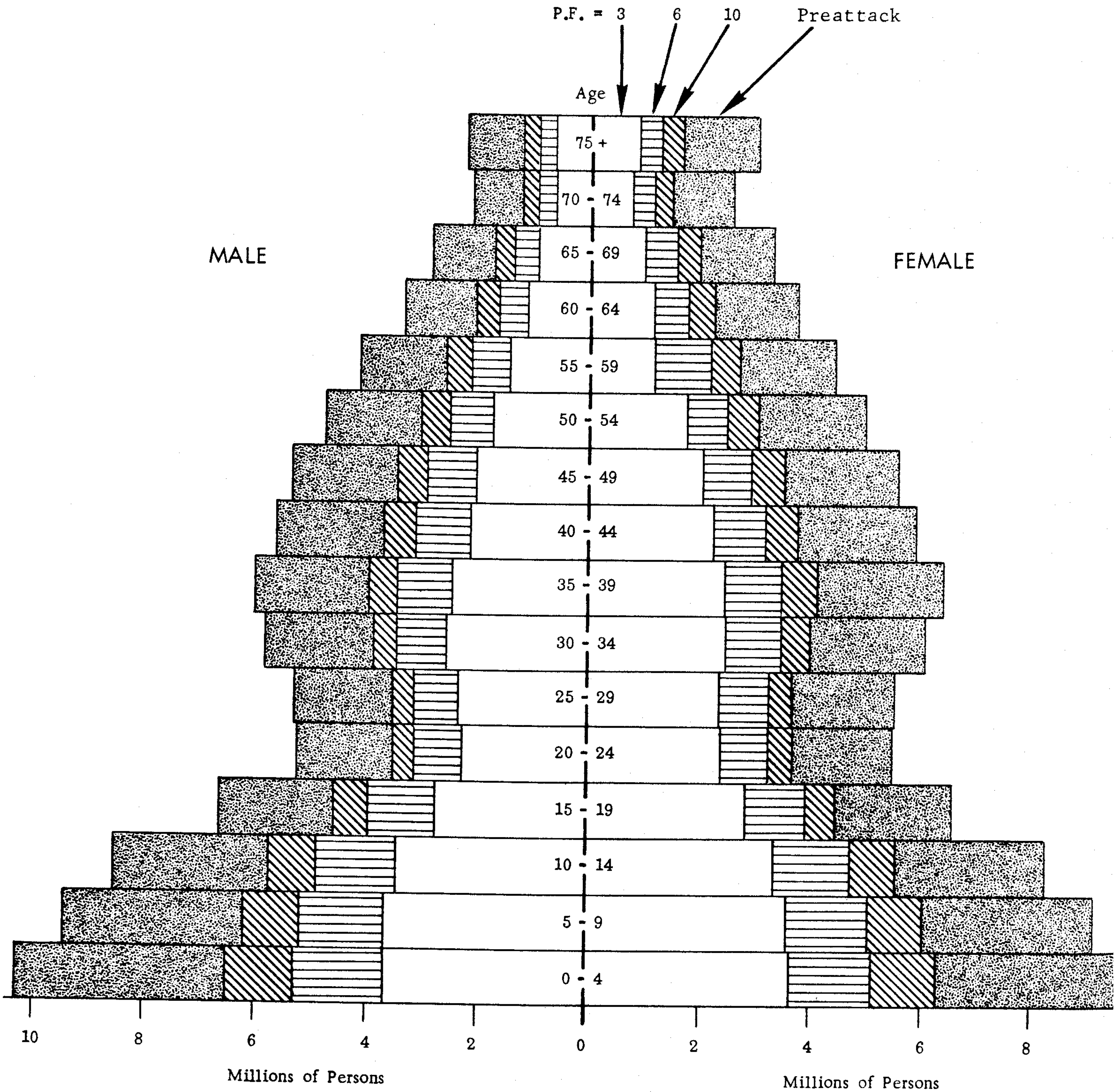

Fig. 14 -- Population pyramids for survivors of Attack 430, alternative sheltering assumptions

As one might expect from the absence of any striking disparities in exposure by age or sex (see Sec. III) and from the U-shaped mortality functions applied to exposed populations, all of the pyramids show disproportionately high survival of persons in the intermediate ages. The differences among attacks in this respect are only matters of degree. For any one attack, the same pattern of survival disparities by age is manifested under all three sheltering assumptions, again with differences of degree only. In general, the greater disparities are associated with the heavier attacks and with the lower protection factors.

It is obvious from Figs. 10-14 that for many of the 15 cases considered, survival disparities, though present, are slight. Any of the three outcomes of Attack 103, for instance, could have been quite satisfactorily approximated by a scalar reduction in all population components. The only manifest error would have been an overestimate of survivors above age 75. Our time will be better spent in the examination of some more extreme case.

None will serve better than Attack 430, PF = 3. This is the heaviest attack, and under this least-favorable sheltering assumption only 38 percent of the nation's people survive. Survival rates detailed by age, sex, and color are shown in Table 13. Clearly some groups fare much better than others. Only 26.7 percent of white females over age 75 survive the attack, as compared with 49.1 percent of nonwhite females 15-19 years of age.

Nonwhites fare substantially better than whites in every age group for both sexes. White males fare better than white females at every age above 25 years; for nonwhites, the pattern by age and sex is similar but not so regular. For both whites and nonwhites below 20 years, females have a slight edge on males. Reading down each column of the table confirms the impression gained from the graphic representation: the highest survival rates are reported for young adults -- ages 25-29 for white males, 20-24 for white females, and 15-19 for nonwhites of both sexes.

From the schedules of survivors relegated to Table 25 in the Appendix, the reader can construct similar tables of survival rates

for any of the other 14 cases. He will find the same general pattern, with less drastic disparities among components of the population. However, the survival advantage of nonwhites appears only for the two attacks targeted in large cities -- 599 and 430; and in these cases, the advantage is substantial only for the least-favorable sheltering assumption.

Table 13

SURVIVAL RATES BY AGE, SEX, AND COLOR:
ATTACK 430, PF = 3

Age	Survivors as Percentage of Corresponding Preattack Component			
	White Males	White Females	Nonwhite Males	Nonwhite Females
75+	28.1	26.7	33.5	32.9
70-74	29.5	28.4	33.7	33.8
65-69	31.4	29.1	35.7	34.4
60-64	33.5	30.6	36.6	34.7
55-59	36.3	33.1	38.8	37.1
50-54	36.9	34.9	40.3	39.0
45-49	37.9	36.3	41.2	42.1
40-44	38.4	37.1	40.1	40.1
35-39	41.0	37.9	41.9	39.8
30-34	43.9	40.3	44.6	41.7
25-29	44.0	42.7	45.6	44.0
20-24	43.1	43.2	47.2	46.3
15-19	40.6	42.6	47.7	49.1
10-14	39.6	39.8	46.0	46.1
5-9	38.2	38.7	43.3	44.0
0-4	35.1	36.2	39.1	40.4
Total	38.1	37.2	42.4	42.0

In my opinion, it would require considerable ingenuity to compose a plausible attack which would produce greater disparities for the nation as a whole, even allowing considerable latitude in the choice of the parameters of weapon effects and vulnerability functions. The arithmetic of disparity is such that only heavy attacks can be expected to produce large survival disparities. To be "heavy" in the demographic sense, an attack must be targeted in large cities because that is

where large numbers of people are gathered. And in our cities as elsewhere, the population is rather thoroughly mixed by age and sex. With respect to the three demographic characteristics considered in this study, the only massive local concentrations are of urban whites and nonwhites. Small weapons targeted on central cities should reduce the disparities of survival by color shown in Table 13 because of the local concentrations of nonwhites in central cities. Indeed, Heer's calculations for one such attack reversed the outcome shown here for a large-weapon attack on our cities; he calculated higher survival rates for whites than for nonwhites.

We may now ask what significance should be attached to these survival disparities, the largest produced by our method of analysis. There are two readily distinguishable issues.

One pertains to the composition of the surviving population, which is shown graphically in Figs. 10-14. Of particular interest to short-term recovery planning is the available manpower and its complement, the dependency burden. Findings on this score are presented in Sec. V.

The second issue pertains to the long-run demographic consequences of what is practically an instantaneous alteration of the age/sex composition of our nation's population. The reproductive capacity of a human population depends to a large extent on the age distribution of its female members. Disproportions in survival by sex could influence the birthrate, or even place a strain on the social norms governing sexual liaisons. Chronic mortality could vary considerably, depending on the age structure of the surviving population. These matters are also treated in Sec. V., with quantitative illustrations in Sec. VI.

V. POSTATTACK POPULATION CHANGES

Having finally completed an assessment of the demographic damage resulting from a variety of simulated nuclear attacks on the United States, we can now turn to an analysis of the surviving populations: What would be their characteristics? How would these populations change over time? I have selected four topics for examination: the size and rate of growth of the postattack population, its distributions by age and sex, postattack fertility, and postattack mortality.

Data on the size and composition of the postattack population emerge directly from the damage-assessment model. Indeed, we have thus generated 15 alternative schedules of 3-month survivors, each related to an assumed targeting system and weapon-mix as well as to an assumed configuration of weapon effects, sheltering, and human vulnerability. This embarrassment of riches is shown in full component detail in the Appendix, Table 26. But we have yet to deal with the question of how the size and component structure of such a population might change over postattack time, and what significance such changes may have for public policy.

Rates of birth and death in the years following the attack are the principal parameters of such changes. We will explore possible variations in the incidence of natality and mortality in the postattack population, relating these variations to changing size and component structure both as cause and effect.

Most of all, I propose to emphasize, as in the case of damage assessment, the uncertainties of any preattack estimates of values for these variables. Despite these uncertainties, there is much to be learned from quantitative treatment; especially, the examination of quasi-extreme cases helps to bound the plausible.

THE SIZE OF THE POSTATTACK POPULATION

Chief among our present uncertainties about the nature of the postattack population is simply the number of survivors of the attack itself. While we can (or think we can) make fair estimates of the capability of the enemy, we cannot be sure of either his intentions or strategy, nor of the effectiveness of our own countermeasures. And,

as we have seen, even given the explosive megatonnage and targeting of an attack, there remain great uncertainties about exposure to weapon effects and the vulnerability of those exposed.

The fifteen cases examined in Sec. IV yielded surviving populations that varied in size from 68.2 to 174.2 million persons, out of a pre-attack population of 178 million. As shown by Table 14, the number of survivors is sensitive to assumed protection against radioactive fallout. High protection factors not only substantially increase the number of survivors for a given attack, they also narrow the differences in this number as among alternative attacks. For persons outside the range of heavy damage from prompt effects, fallout protection well above the levels assumed in this analysis could be provided by specialized sheltering structures; the principal difficulty is to locate these shelters so they can be reached in a matter of minutes. Even following a no-warning attack, survivors of prompt effects have a brief period of grace before local fallout reaches lethal concentrations.

It is also important to recall that our estimates of damage were based on the 1960 population of the conterminous United States, 178 million persons. If the attack had occurred in 1965, this number would have been 193 million; by 1970, the population at risk will be about 209 million; by 1975, about 226 million.* If the attacks described in this study occurred at these later dates, casualty rates would probably not be greatly changed, though possibly more sensitive to sheltering assumptions.** Assuming no change in casualty rates, both the number

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*Postcensal estimate for 1965 by U.S. Bureau of the Census, Current Population Reports, Series P-25, No. 327, February 1966. Projections for 1970 and 1975 from Current Population Reports, Series P-25, No. 286, July 1964, Table 4. A slight decline in fertility after 1965 is assumed.

**Since 1960, most of the growth in our nation's population has occurred on the fringes of large metropolitan areas; central cities have grown very little -- indeed some have lost population. (See Current Population Reports, Series P-25, No. 330, March 1966.) Thus, for attacks targeted on central cities, a smaller proportion of the metropolitan population is likely to be within range of prompt effects and a larger proportion within range of heavy fallout.

of fatalities and the number of survivors would be greater. For the lightest attack on the 1960 population, I estimated 174.2 million survivors; applying the same fatality rate to the projected population for 1970 leaves 204 million survivors. For the heaviest attack, the corresponding figures are 68.2 million and 80 million. Thus the date of attack offers greater uncertainty in the number of survivors for small attacks than for large attacks.

Table 14

TOTAL SURVIVORS OF FIVE SIMULATED ATTACKS, ALTERNATIVE SHELTERING ASSUMPTIONS: CONTERMINOUS UNITED STATES, 1960

Attack	Radiological Protection Factor		
	10	6	3
	Thousands of Survivors		
103	174,232	173,303	169,972
203	159,429	155,834	147,028
130	156,243	145,329	126,378
599	133,630	123,796	102,681
430	115,058	97,013	68,215
	Percentage of Preattack Population		
103	97.6	97.1	95.2
203	89.3	87.3	82.4
130	87.5	81.4	70.8
599	74.9	69.4	57.5
430	64.5	54.4	38.2

Given the number of survivors, the size of the postattack population would change thereafter in a pattern defined by the ratio of births to deaths, and it might be further affected by migration into or out of the United States. It is hard to imagine a reason for migration into a country laid waste by nuclear war. Emigration of survivors is more probable, assuming that some other parts of the world are relatively undamaged. Such emigration, if not prevented by the governing authorities, would of course further reduce the size of the U.S. population.

Even without emigration, the nation's population would probably shrink in size for a period of five to ten years during which deaths exceeded births. Under the most extreme fertility and mortality rates considered in Sec. VI, this shrinkage is modest -- a decline of less than five percent.

For any given set of vital rates, the period of postattack population decline would be shorter for heavy attacks than for light ones; and subsequent growth would be more rapid for the heavier attacks, although from a smaller base. These results follow from the demographic selectivity of attack mortality. A heavy attack tends especially to eliminate the elderly; thus the surviving population would be younger, more fertile, and more resistant to the chronic stresses of the postattack environment.

Given parameters of fertility, mortality, and migration, it is not difficult to calculate the years necessary for population "recovery," the return to preattack size. Quite aside from the uncertainties of estimates for these parameters, population recovery in this sense is not a good measure of societal viability or even a relevant goal of public policy. The biological vigor of a population is better expressed as the intrinsic rate of growth implied by current patterns of fertility and mortality. The quality of social life and the problems of domestic policy are better expressed by per capita indices, of which the most general is the ratio of resources to people. It is only when we consider the position of our nation in the postattack world order that the absolute size of our population is a relevant indicator, and even then its significance is heavily qualified by the ratio of resources to people.*

Moreover, there is every reason to believe that this ratio would itself be a major influence on the rate of population growth over the

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*See S. G. Winter, Jr., Economic Viability After Thermonuclear War: The Limits of Feasible Production, The RAND Corporation, RM-3436-PR, August 1963; Fred Cottrell, Energy and Society, McGraw-Hill Book Company, Inc., New York, 1955; Katherine Organski and A.F.K. Organski, Population and World Power, Alfred A. Knopf, New York, 1961.

years following a nuclear war. I would expect postwar fertility to vary directly, and mortality to vary inversely, with the standard of living -- say, Gross National Product per capita.* Since it is not at all clear that people and inanimate resources are equally vulnerable to weapon effects, it is conceivable that a heavy attack might leave the survivors with more resources per capita than would a light attack. On the other hand, a heavy attack would cause greater damage to the organizational structure by which resources are transformed to human ends. With respect to the postattack standard of living, this is the more critical determinant for the short run.

AGE/SEX DISTRIBUTION OF THE POSTATTACK POPULATION

It is fairly clear that exposure to weapon effects will be about the same for all age groups in the population, and for both sexes, at least if fallout exposure is measured by open-field dose rates in the environs of the population at risk. For prompt effects, differential exposure rates by age and sex are likely to occur only if the radius of heavy damage is substantially less than the radius of daily travel patterns. Our population is thoroughly mixed by age and sex at the household level; during a normal work/school day, household members disperse into clusters that tend to be age- or sex-specific. But a weapon whose antipersonnel effects embrace this daily range of household movement will impinge on all groups more or less equally. The attacks most likely to discriminate in terms of age or sex would be 1) a day attack targeted on central cities, using airburst (no-fallout) weapons that are small by present standards, or 2) a small-weapon attack targeted exclusively on military installations, such as Attack 103 of the QUICK COUNT series. The latter kind of attack is light by definition in terms of the number of persons seriously exposed to weapon effects; consequently, even substantial disparities of exposure by age and sex within the small number of persons affected would reflect only dimly in any computation of casualties for the nation as a whole.

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*These relationships are explored below under the headings, "Postattack Fertility" and "Postattack Mortality."

The demographic effects of conventional warfare are quite different in this respect. Males of military age have traditionally been exposed to much greater risks of death than has the population at large. Thus, World Wars I and II brought about marked changes in the age distribution of males (and consequently in the sex ratios for certain age groups) for countries that were heavily involved. A general nuclear war, should it occur, would not have this effect.

We have also seen that vulnerability to weapon effects at a given level of exposure varies with age and sex. Children and old people are much more vulnerable than those in the prime of life, and females over 25 years are more vulnerable than males. When survivors are computed by means of model mortality functions reflecting this age/sex variation in vulnerability, some striking survival disparities emerge for the heavier attacks. Yet these disparities result in only modest changes in component structure of the population at risk.

Preattack and postattack age distributions are compared in Table 15 for all fifteen survival schedules generated by our damage assessment model. For each case, the table shows the percentage distribution of the total population by sex for four broad age groups. To assist the reader in making comparisons, corresponding age distributions for the preattack population are given in the first two columns of each section of the table.

The 15 cases represented in the table offer little contrast either among themselves or with respect to the preattack figures. The largest shifts in age/sex composition come after Attack 430, PF = 3. The percentage of persons over 65 years declines from 9.0 to 6.9 as a result of the attack, and the percentage of persons 40-64 declines from 26.8 to 25.3. The age group 15-39 increases from 33.2 to 36.4 percent of the total. Under 15 years of age, there is little change. These then are the unspectacular implications of the striking survival disparities shown for the same case in Table 13.

These minor changes in age structure at least result in a population slightly better adapted to the presumptive rigors of postattack life. Persons over 65 and under 15 are usually counted as economic

Table 15

COMPOSITION OF SURVIVING POPULATIONS BY BROAD AGE GROUPS AND SEX: FIVE ATTACKS, THREE SHELTERING ASSUMPTIONS

Age	Percentage of Total Population							
	Preattack		PF = 10		PF = 6		PF = 3	
	Male	Female	Male	Female	Male	Female	Male	Female
Attack 103								
65+	4.1	4.9	3.8	4.8	3.8	4.8	3.7	4.6
40-64	13.0	13.8	13.1	13.8	13.1	13.8	13.0	13.6
15-39	16.3	16.9	16.5	16.9	16.5	16.9	16.5	17.0
0-14	15.9	15.3	15.9	15.5	15.9	15.5	15.8	15.5
Total	49.2	50.8	49.2	50.8	49.2	50.8	49.2	50.8
Attack 203								
65+	4.1	4.9	3.8	4.7	3.8	4.6	3.7	4.5
40-64	13.0	13.8	13.0	13.6	13.0	13.5	13.0	13.5
15-39	16.3	16.9	16.5	16.9	16.5	17.0	16.5	17.3
0-14	15.9	15.3	16.0	15.5	15.9	15.4	16.0	15.4
Total	49.2	50.8	49.3	50.8	49.3	50.7	49.3	50.7
Attack 130								
65+	4.1	4.9	3.7	4.6	3.7	4.6	3.7	4.4
40-64	13.0	13.8	12.9	13.5	12.9	13.5	12.9	13.4
15-39	16.3	16.9	16.8	17.3	16.8	17.3	17.1	17.6
0-14	15.9	15.3	15.8	15.4	15.7	15.4	15.8	15.4
Total	49.2	50.8	49.2	50.8	49.3	50.7	49.3	50.7
Attack 599								
65+	4.1	4.9	3.7	4.6	3.7	4.4	3.4	4.2
40-64	13.0	13.8	12.9	13.5	12.8	13.1	12.7	12.9
15-39	16.3	16.9	16.6	17.0	17.1	17.4	17.4	17.7
0-14	15.9	15.3	16.1	15.6	16.0	15.5	16.0	15.6
Total	49.2	50.8	49.4	50.6	49.6	50.4	49.7	50.3
Attack 430								
65+	4.1	4.9	3.7	4.4	3.4	4.1	3.2	3.7
40-64	13.0	13.8	12.9	13.3	12.7	12.9	12.7	12.6
15-39	16.3	16.9	17.1	17.4	17.8	17.9	18.0	18.4
0-14	15.9	15.3	16.0	15.5	15.7	15.4	15.8	15.6
Total	49.2	50.8	49.5	50.5	49.7	50.3	49.9	50.1

NOTE: Distributions may not add exactly to totals because of rounding.

dependents who contribute little to the social product and draw heavily on social resources. In 1960, there were about 67 such dependents for every 100 persons in the economically active ages, 15-64. As a result of Attack 430, PF = 3, the dependency rate is reduced to 62 per 100. And among those of working age, the distribution shifts in favor of the younger adults, 15-39.

Thus the largest survival disparities that were produced by my methods of damage assessment cannot be represented as having profound demographic significance. Compositional changes of the magnitudes indicated above are commonplace in peacetime demographic processes. For example, in 1945, there were only 43 dependents per 100 persons in the economically active ages.

We have seen that the exact year of an assumed attack is important to estimates of the size of the surviving population. This does not seem to be the case for the broad age distributions indicated in Fig. 15. In 1965, the dependency rate as defined above was still 67 per 100, and population projections for 1970 and 1975* indicate only a slight decline to 65 per 100. In 1960, 77 percent of the dependents were children (under 15 years), a proportion that also persists to 1975.

I have already suggested a postattack period of continued decline in population. The vital rates associated with such a decline would have the effect of further reducing the relative size of the dependent age groups -- e.g., under 15 and over 64 years. Thus during the period of postattack population decline, the manpower-yield of our population should increase. When the population began to grow once more, this yield would drop as an inverse function of the rate of growth.

If out-migration from the United States were to occur on a substantial scale, it would almost certainly lower the manpower-yield of the remaining (nonmigrant) population. For fairly obvious reasons, migration under stress is selective; young adults and especially young adult males are particularly mobile.

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*U.S. Bureau of the Census, Current Population Reports, Series P-25, No. 286, July 1964, Table 4.

POSTATTACK FERTILITY

For analysis of the patterns and determinants of childbearing in a population, it is important to distinguish between the physiological capacity of women to conceive and bear children (fecundity) and the actual frequency of live births (fertility).

There is of course no rigorous way to estimate the average fecundity of women from puberty to menopause, given the social norms that limit sexual intercourse to a portion of that period, and the immemorial availability of contraceptive methods. There are cases on record of women who have borne as many as 20 children. Allowing for the interruptions in fecundity necessarily associated with pregnancy and lactation, one student has estimated that, if women were married at age 16, if the marriage lasted 30 years before either spouse became sterile, if every pregnancy ended with a birth, and if all babies were nursed, the average number of births per couple would be 15.* However, this computation does not allow for the incidence of genetic or functional subfecundity among these women, nor for the usual marked reduction in fecundity with age and number of previous births. "There are few large groups in which the average number of births per couple reaches 7. Among groups whose members marry young and let nature run its course with respect to childbearing, the most prolific known at present are the Hutterites, with 10.4 births per couple, and older women who married young in rural Quebec, with 10.0."**

Whatever the biological limits, American women today are far from realizing their potential. In the Census of 1910, women who had reached age 50 (i.e., menopause) between 1885 and 1890 reported an average of 5.0 live births each. Those who had ever been married averaged 5.4 live births. The average number of children ever born to the most

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*A. F. Gutmacher, "Fertility of Man," Fertility and Sterility, Vol. 3, No. 4, 1952, pp. 288-289.

**Ronald Freedman, Pascal K. Whelpton, and Arthur A. Campbell, Family Planning, Sterility, and Population Growth, McGraw-Hill Book Company, Inc., New York, 1959, pp. 19-20.

recent cohort of women to reach 50 years of age is about 2.3; for married women, 2.4. Cohorts not yet at menopause are doing better: women 30-34 years of age in 1960 had already accumulated 2.7 live births per woman.*

Both historically and in the contemporary world, declining family size is associated with the complex of variables usually subsumed under "economic development": industrialization, urbanization, increasing per capita income, more education, and so on.** But the trend may not be irreversible, as evidenced by the data cited in the preceding paragraph.

Investigation of family-planning practices in the United States reveals a rather widespread pattern of two-stage decision-making. The first decision pertains to the desired size of the completed family. Although some couples revise this decision from time to time, and many are unable to achieve the exact number of children desired, on a statistical basis family-planning goals are both stable and virtually achievable.*** For successive cohorts of women who have reached menopause, changes in average completed family size are slow and extremely regular, the only measure of fertility that does not exhibit highly erratic fluctuations.****

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*Wilson H. Grabill, Clyde V. Kiser, and Pascal K. Whelpton, The Fertility of American Women, John Wiley and Sons, New York, 1958, Table 9; U.S. National Center for Health Statistics, Natality Statistics Analysis, United States, 1962, Government Printing Office, Washington, D.C., 1964, Table 13.

**See "Economic and Social Factors Related to Differences in Levels of Fertility" in United Nations Department of Economic and Social Affairs, Population Bulletin of the United Nations, No. 7, 1963, New York, 1965, pp. 134-151.

***Freedman, Whelpton, and Campbell, op. cit., pp. 257-270. From interviews with 731 wives, ages 35-39 (near the end of childbearing), the authors conclude that only 8 percent had more children than were wanted, and only 15 percent expected more than were wanted. Underachievement was more common: 32 percent both had and expected fewer than were wanted (Table 8-7).

See also Judith Blake, "Ideal Family Size among White Americans: A Quarter of a Century's Evidence," Demography, Vol. 3, No. 1, 1966, pp. 154-173; Ronald C. Freedman, Lolagene C. Coombs, and Larry Bumpass, "Stability and Change in Expectations about Family Size: A Longitudinal Study," Demography, Vol. 2, 1965, pp. 250-275.

****Pascal K. Whelpton and Arthur A. Campbell, Fertility Tables for Birth Cohorts of American Women, Part I, Annual and Cumulative Birth Rates, by Age, by Order of Birth for All Women in Cohorts of 1876 to

Given the first decision, the timing of conceptions in fulfillment of this goal is a mixture of accident and choice.* The choices seem to be highly sensitive to social and economic disturbances. When the family is under stress, conception tends to be postponed. When the stresses ameliorate, the couple tends to make up for lost time by more frequent conception. Some of these stresses are of course purely familial or personal in origin. Others are imposed by the social milieu, for instance joblessness due to economic recession. Stresses of the latter type can cause sharp fluctuations in the annual crop of births, not only because of regulated conception among the already-married, but also because of postponed marriage. In Fig. 15, the annual number of births per thousand females 15-44 years of age -- the "total fertility rate" -- is plotted for the United States, 1909-63. It is not hard to match the major economic and social crises of that period to peaks and troughs in this series.

As the notion of planned families implies, births are not randomly distributed among females 15-44 years of age. The age of peak fertility for American women has always been 20 to 24 years, and about 60 percent of all births in any calendar year are to women between 20 and 29 years of age. Figure 16 shows age-specific fertility rates for selected years, 1930-60. Note that age differentials persist as the general level of fertility shifts up and down.

Thus age composition of the female population is, like social stress, a significant determinant of the size of the annual crop of children. The total fertility rate plotted in Fig. 15 reflects variations in female age distribution as well as responses to stress. The crude birthrate, whose denominator is the entire population, is even more sensitive to shifting age distribution.

Bearing in mind these peacetime fertility patterns, let us now consider the postattack situation. It is obvious that the events associated with the attack and its aftermath could impinge directly on all the fertility determinants we have discussed: fecundity,

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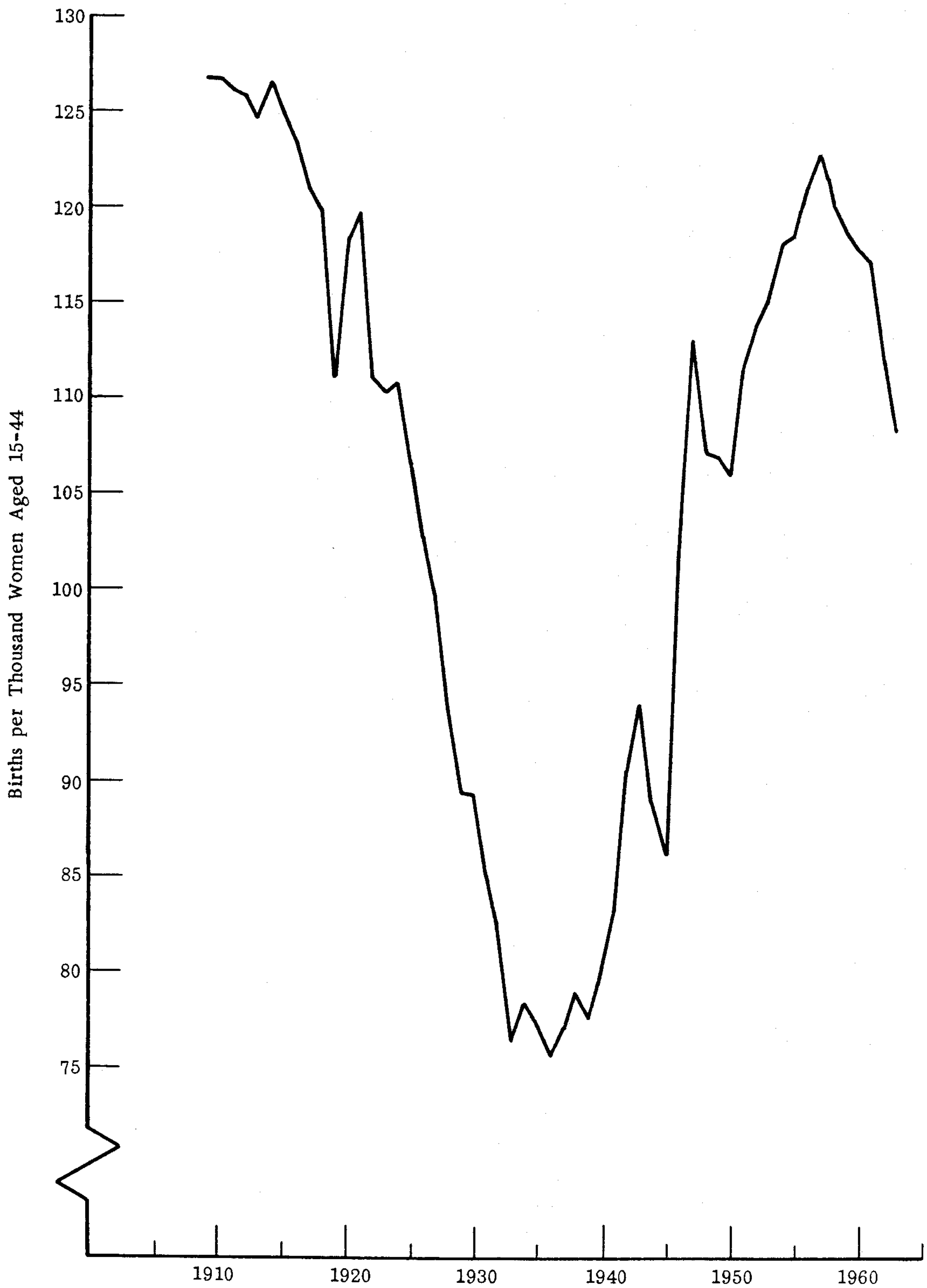
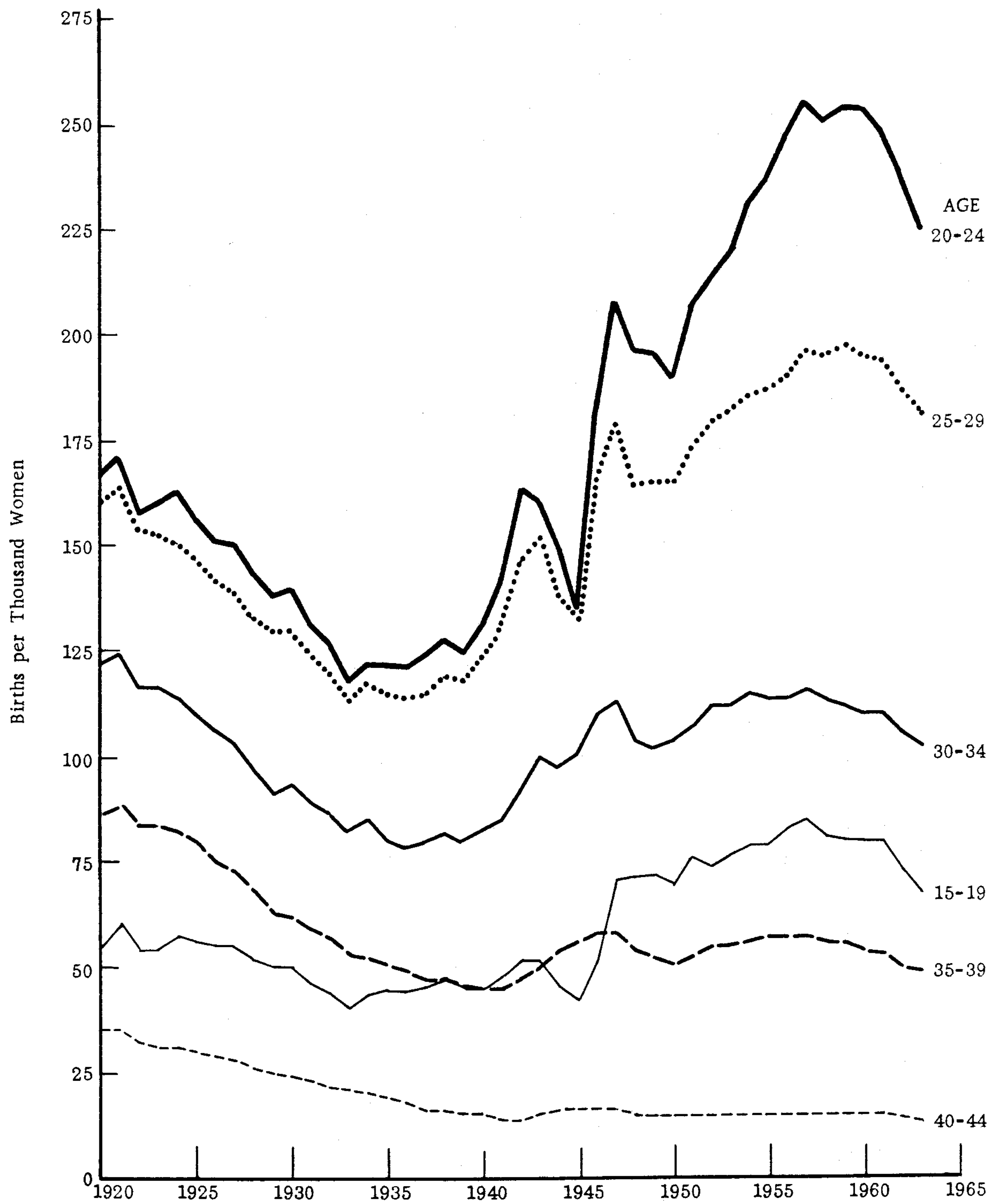
1943, Vital Statistics -- Special Reports, Vol. 51, No. 1, January 1960, National Office of Vital Statistics, U.S. Department of Health, Education and Welfare, Table 4.

*Freedman, Whelpton, and Campbell, op. cit., Chaps. 3-5.



SOURCE: Vital Statistics of the United States, 1963.

Fig. 15 -- Annual births per thousand women 15-44 years of age: United States, 1909-1963



SOURCE: 1920-1939, National Office of Vital Statistics
1940-1963, Vital Statistics of the United States, 1963

Fig. 16 -- Annual births per thousand white women by age: United States, 1920-1963

family planning goals, timing of births, age composition of the female population. The crude birthrate after attack is thus the resultant of a variety of forces some of which may favor higher fertility, others lower fertility.

During the first nine months following an attack, the birthrate would result from preattack conceptions. My computations of survival disparities indicate that female age groups most likely to be pregnant are also the age groups most likely to survive the attack.* Even so, the incidence of abortion and stillbirth among pregnant women exposed to weapon effects would certainly be higher than preattack rates. The fetal deathrate was only 10 percent for a sample of 98 pregnant survivors of the Nagasaki bombing, all located within 600 feet of ground zero; on the other hand, one report on the Hiroshima bombing insists that "all, or nearly all" pregnant survivors located within 3000 feet of ground zero subsequently had miscarriages.**

It is important to recall in this connection that exposures which would result in fetal damage are also very likely to be fatal to the mother. All factors considered, it seems reasonable to expect the crude birthrate for these first nine months -- i.e., births per thousand survivors -- to be not far below preattack, say 80 percent of the latter value. For an attack in 1960 this estimate implies 18 or 19 births per thousand survivors for the first year.

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*Compare Fig. 16 and Table 13 of Sec. IV. I found no evidence that young adult females would be less exposed than others to weapon effects; their relatively high rate of survival derives from the low fatality rates assigned to these ages by my model mortality schedules. (See Fig. 7.) In constructing these schedules, I was tempted to raise fatality rates for young adult females because it seemed reasonable to expect that the high incidence of pregnancy for these ages would reflect in greater vulnerability. However, the Dikewood data on which the schedules are based offered no clear warrant for this supposition.

**David Heer, After Nuclear Attack, pp. 317-319, summarizes the conflicting evidence. The sources of the data cited above are: James Yamazaki, Stanley Wright, and Phyllis Wright, "Outcome of Pregnancy in Women Exposed to the Atomic Bomb in Nagasaki," American Journal of Diseases in Children, April 1954, pp. 448-463; United States Strategic Bombing Survey, The Effects of Atomic Bombs on Health and Medical Services in Hiroshima and Nagasaki, Washington, D.C., 1947, p. 53.

Thereafter I would expect the crude birthrate to decline further. For one thing, sublethal radiation exposure is known to cause temporary sterility in both men and women for as much as two years. Acute doses sufficient to cause permanent sterility would under most circumstances be fatal.*

Long-term reductions in fecundity are also likely. A careful study of Hiroshima/Nagasaki survivors exposed at 900 feet or less from ground zero has yielded no evidence of reduction in the number of offspring, or of higher rates of fetal mishap, congenital malformation, or neonatal mortality. However, these were survivors of brief exposures rather than persons subjected to the chronic irradiation that would be a feature of the postattack environment we have assumed. There is evidence both from occupational exposure of humans and laboratory exposure of mammals that chronic irradiation reduces fecundity.**

Even under the extravagant assumption of a 50-percent reduction in conjugal fertility, it is clear that persons still in their twenties at the time of attack could easily achieve families of preattack size simply by abandoning contraceptive measures. We have already seen that the number of children currently borne by American women is far below their potential. Consequently, we must look to social rather than physiological factors as determinants of the postattack birthrate.

One such factor that would tend to reduce fertility might be termed the "widow problem." The incidence of widowhood among survivors is difficult to estimate on an aggregative basis. For groups

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*M. Tsuzuki, "Atomic Bomb Injury: Delayed Radiation Effects," Japanese Journal of Clinical and Experimental Medicine, Vol. 37. No. 4, 1960, p. 517; National Academy of Sciences, National Research Council, The Biological Effects of Atomic Radiation, Washington, D.C., 1960, Long-Term Effects of Ionizing Radiations from External Sources, Washington, D.C., 1961, pp. 23-24.

**J. V. Neel and W. J. Schull, The Effect of Exposure to the Atomic Bombs on Pregnancy Termination in Hiroshima and Nagasaki, Publication No. 461, National Academy of Sciences, National Research Council, Washington, D.C., 1956. Further investigation is in progress under the auspices of the Atomic Bomb Casualty Commission. For occupational exposure, see S. H. Macht and P. S. Lawrence, "National Survey of Congenital Malformations Resulting from Exposure to Roentgen Radiation," American Journal of Roentgenology, Vol. 73, 1955, pp. 442-466.

exposed to a common degree of risk, the binomial expansion provides an approximate model. For such a group, widowhood reaches a maximum of 25 per 100 married couples exposed when the risk of death is 50 percent.* These widows are not barred from ever again having children, but they are not all likely to remarry immediately. We can expect several years of sharply lowered fertility among widows, and possibly a lower completed fertility.

Among couples both of whose members survive, I would also expect fewer births during the first postattack years. The period would be one of considerable social and economic stress, and even persons who retained their preattack size-of-family goals would be inclined to postpone conception in hope of easier circumstances to come. Some couples who had completed their planned families before the attack, but lost children in the attack, might resume conception. Because of higher chronic infant mortality rates, more births would be needed, on the average, to reach a given completed family size. So not all indicators point to lower fertility.

On balance, I would anticipate a period of about five years during which birthrates would be considerably lower than preattack. I cannot guess how much lower. The lowest rates on record for the United States occurred in 1933 and 1936, with 76 births per thousand females 15-44 years of age, or 18 births per thousand total population, as compared with values of 120 and 25 respectively during the late 1950's. These minima occurred during the depths of the Great Depression, certainly a time of severe stress on our population. Even greater and more complex stresses would follow a heavy nuclear attack.

What would happen in the following decades is even less clear. If we assume that a successful reconstruction program is under way, and that conditions of life are steadily improving, I would expect

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*David Heer, After Nuclear Attack, pp. 56-85, makes extensive and interesting use of the binomial expansion for estimating the incidence of family fragmentation. Because of the frequent collocation of family members, the binomial expansion's assumption of independent probabilities of death for each family member is not met, but the method provides a useful upper bound to the possibilities of family fragmentation.

fertility to increase. How rapidly it would increase, and to what peak, is beyond forecasting. Despite the probability that fecundity will be slightly below the preattack level for many years, it is clear from the figures cited earlier that families several times as large as preattack families are biologically feasible. The unanswerable question concerns family-planning goals in this altered environment.

POSTATTACK MORTALITY

Section III glanced briefly at chronic patterns of mortality by age and sex for the United States and Mauritius (Fig. 1 and associated text). My purpose there was to provide a contrast for mortality patterns under the acute biological stresses of a nuclear attack. For the years following such an attack, it is virtually certain that conditions would be less favorable to human life than at present, but the stresses would be diffuse and persistent rather than brief and highly specific as they would be during the attack itself. It is appropriate, therefore, to speak of the survivors of the attack as a population faced with chronic stresses, and more severe ones than those impinging on the preattack population.

In the past, the American people have also faced higher levels of chronic stress than at present. Granted that the particular configuration of postattack stresses would be different from those of former times, it is nevertheless useful to review the historical mortality experience of our population. We can thus identify analogues and precedents that will clarify the prospects for postattack mortality.

Although records are not adequate to allow close estimates of age/sex-specific mortality schedules for the United States around 1880, they would undoubtedly fit very closely to the Mauritius data plotted in Fig. 1. The earliest published schedules, based on death registrations in 10 states in 1900, are shown in Fig. 17 for males only. Similar schedules, based on improved records, are shown for 1920, 1940, and 1960.

To each of these schedules of annual age-specific deathrates there corresponds a mathematical expectation of life at birth for persons exposed to the indicated age-specific rates as their birth-cohort passes through successive age brackets. Life expectancy for American males increased from 46 to 67 years between 1900 and 1960; for females, from 48 to 73 years.

The sources of this rise in life expectancy are easily inferred from Fig. 17, and can be confirmed by analyzing records of deaths by specific causes. During the interval covered, there have been dramatic advances in the technology of disease control, which reflect most clearly in the reduction of infant and childhood mortality. The epidemic and chronic infectious deseases that impinge most heavily before middle age have been almost eliminated as a cause of death by medical advances in their prevention and treatment, and by improvements in public sanitation. Better diets, improved domestic sanitation, and the virtual elimination of child labor have also played a role in reducing mortality among the young. Relatively little progress, however, has been made in arresting the degenerative processes of old age. Life expectancy for both sexes combined reached 70 years about a decade ago, and has not significantly changed since. Barring some major breakthrough in gerontology, it is unlikely to increase much in the future; deathrates for young people are already negligible. A recent United Nations publication comments that, "indeed, even if all deaths before middle age . . . were eliminated, the result would be to add only a few years to the expectation of life."*

With this background, we may consider the effects of nuclear attack on U.S. mortality patterns. First, we may note that preattack rates would be much the same whatever year we chose for a simulated attack. The attack itself would kill a great many people immediately. Survivors of prompt effects would include a large number of people with mechanical injuries, burns, and radiation sickness. Many of

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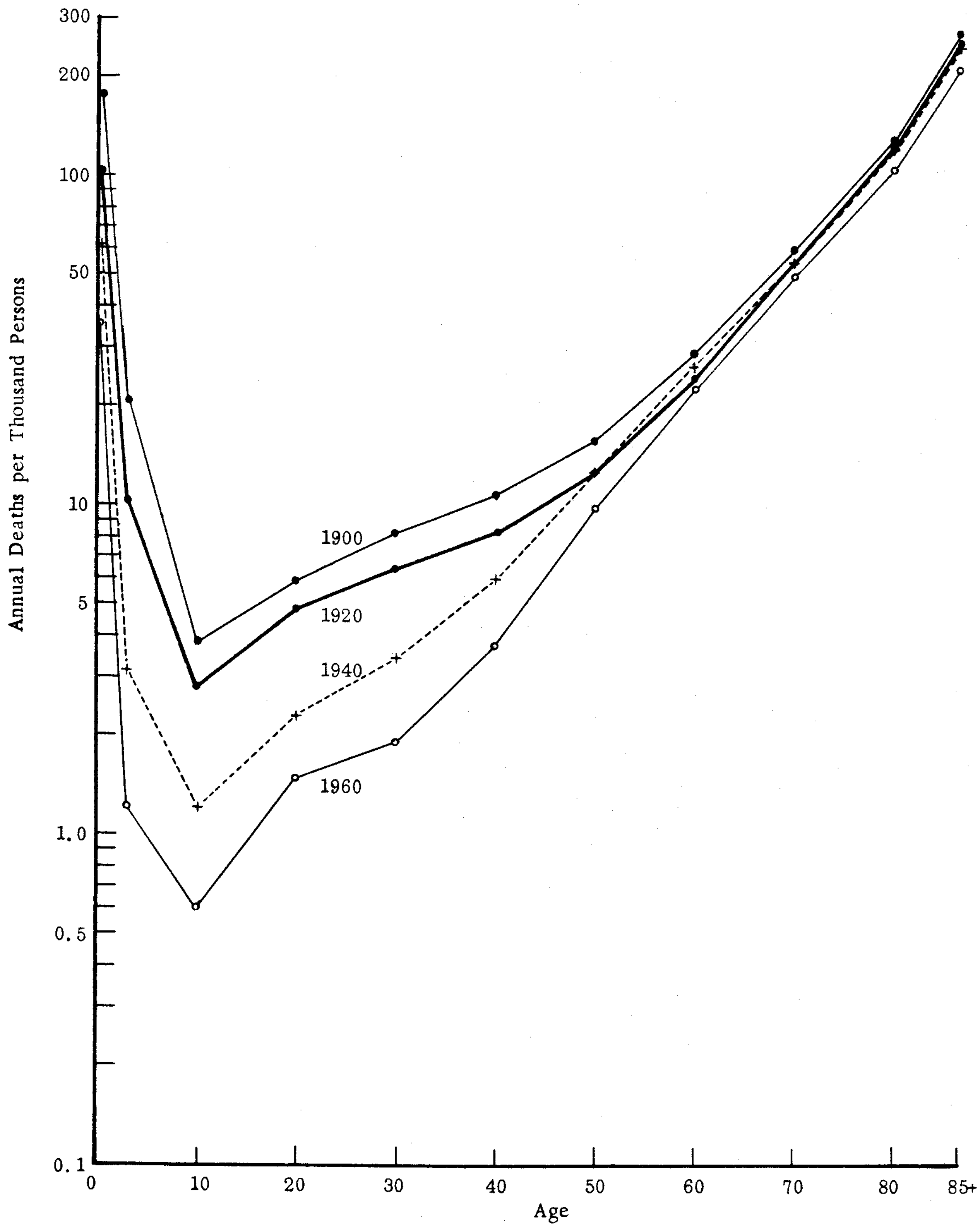
*United Nations Department of Social and Economic Affairs, <u>Population Bulletin of the United Nations</u>, No. 6, 1961, p. 11.



SOURCE: Historical Statistics of the United States
Vital Statistics of the United States, 1960

Fig. 17 -- Annual deaths per thousand males by age: United States, selected years, 1900-1960

these injured persons would die during the first few weeks postattack; some could be saved by intensive medical care, but for others there would be no real hope.

If we exclude the chronic irradiation due to fallout, there is little reason to expect that mortality directly related to weapon effects will persist significantly beyond the three-month period I have allowed for that purpose. Public discussion of delayed mortality from exposure to nuclear weapons has focused on three issues: The incidence of lethal or crippling genetic mutations; the incidence of malignant neoplasms, especially leukemia; and "life-shortening" -- all conceived as the consequences of irradiation. On the evidence to date, the issues are of greater interest to radiobiologists than to demographers.

I have already mentioned the findings from a study of births to parents one or both of whom were exposed to initial nuclear radiation from the Hiroshima/Nagasaki bombs. The data file was closed in 1954, nine years after the exposures. Records of 71,000 births to such couples revealed no statistically significant excess of stillbirths, neonatal mortality, or genetic malformation.*

There have been many studies of the incidence of malignant neoplasms among A-bomb survivors. Leukemia quite clearly occurs more often than in unexposed populations, but its incidence is nonetheless insignificant for demographic computations. For instance, the Life-Span Study, to be discussed at greater length below, found that the 10-year incidence of leukemia among persons exposed at locations within 600 feet of ground zero at Hiroshima and Nagasaki was about 18-20 cases per hundred thousand exposed -- a figure which would reflect in an annual crude deathrate as a change of .02 per thousand persons.

The Life-Span Study of nearly 100,000 survivors of the Hiroshima/Nagasaki bombings fails to detect any demographically significant delayed mortality for the period 1950-59. Only for persons located within 425 feet of ground zero were deaths during that period clearly

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*Neel and Schull, op. cit., pp. 192-204.

in excess of expectations for unexposed Japanese. Age/sex-specific mortality rates for the entire group located within 1200 feet of ground zero fit very well to corresponding rates for the entire Japanese population of 1955.*

Life-shortening effects of the Hiroshima/Nagasaki exposures cannot be fully evaluated for many years. But the evidence on excess mortality to 1960 is sufficient to satisfy a demographer that the effect of single-dose exposure is unimportant to his computations beyond the first few months postattack.

We cannot so easily dismiss the consequences of chronic irradiation for a population whose habitat has been blanketed by fallout particles including many radionuclides with long lives. But neither are we able at this time to say much about the consequences of such chronic irradiation for long-term mortality. The entire ecosystem is implicated, for such radionuclides enter food chains of which man is a member, and certain ones accumulate in human tissues. So in addition to increased background radiation, our population would face the hazard of internal emitters.

I am not competent to evaluate the population damage from this source. However, it seems to me to offer the possibility of a distinctive change in traditional age patterns of mortality. My reasoning is as follows: Over time, background radiation would decay rapidly, so that successive cohorts of postattack births would be exposed to lesser doses from external sources. Thus radiation-induced disease should decline over time among the younger age groups. At the same time, everyone would be accumulating the long-lived radionuclides (e.g., strontium 90) in his body; the longer the exposure, the greater the accumulation, so that radiation-induced disease among older people should increase over time. But the scale of effects may or may not be noticeable in the broader context of a stressful environment.

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*Gilbert W. Beebe, Morihiro Ishida, Seymour Jablon, and Mitsuru Yamasaki, "Studies in the Mortality of A-Bomb Survivors," published in three parts, Radiation Research: Part 1, Vol. 16, pp. 253-280, 1962; Part 2, pp. 423-445, 1964; Part 3, Vol. 25, pp. 25-52, 1965.

On present evidence, I am inclined to believe that the principal source of mortality change in the postattack population would not be radiation but social and economic disorganization -- reflected in shortages of food, clothing, shelter, fuel, and medical care, disorganization of public sanitation measures, contamination of water supplies, and so on. The entire population would be exposed to such stresses, but the very young and the very old would be least able to cope with them. Fragmentation of families would also have adverse consequences for the young and old, whose health requires the devoted attention best provided by family members. The stresses here considered are not too unlike those that we have known in the past, stresses whose amelioration has accounted for much of the historical reduction in mortality.

The most reasonable expectation, it seems to me, is a temporary return to the mortality patterns of the nineteenth century, with much higher deathrates for children and shorter life expectancy. In this connection, the postwar experience of Europe would be instructive, but detailed data for heavily damaged populations simply do not exist. The few available estimates of crude deathrates for the year following the termination of hostilities seem consistent with the view expressed above. David Heer summarizes these data:

> The U.S. Bureau of the Census, on the basis of various statements by Soviet officials, has calculated that the crude death rate per thousand in the USSR in 1947 was 22.0 and in 1948, 16.1. Official figures for East Germany and East Berlin show a death rate there of 22.9 per thousand in 1946 and 19.0 per thousand in 1947. The estimated USSR rates for the immediate postwar period may be compared with the USSR death rate of 18.1 per thousand in 1940 and 7.2 per thousand in 1960; those for East Germany with the rate of 12.7 per thousand for all of Germany in 1940 and that of 13.3 per thousand for East Germany in 1960.*

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*After Nuclear Attack, p. 313.

Assuming a successful socio-economic reconstruction, I would expect very rapid improvements in mortality from the immediate postattack period. Since we would retain our preattack knowledge of public health and medical techniques, the principal limitations on mortality improvements would be 1) resource shortages and 2) irreversible effects of exposure to radiation.

Finally, I should note that after the first few years, the chronic crude deathrate among survivors may actually be slightly lower for heavy attacks than for light ones. The reason for this perversity is simply that a heavy attack does more to eliminate the weaker elements of the population by weapon effects; thus the survivors would be the more vigorous, better able to cope with postattack chronic stresses.

VI. ILLUSTRATIVE POPULATION PROJECTIONS

Section V confined the discussion of postattack population changes to general trends or patterns in population size, component structure, fertility, and mortality. Since these variables are interdependent, it will be helpful to illustrate their interactions by quantitative projections of the postattack population over a period long enough for implicit trends and patterns to become manifest.

To make such a projection, it is necessary to specify the exact size of the initial population of survivors, and to describe its composition in exact detail. We must also select explicit values for the parameters of change, i.e., vital rates. It should be abundantly clear at this point that no one can make such exact specifications from the data available prior to the postulated attack. Therefore, the results of a quantitative projection of postattack population can be no more than illustrative. Illustrations are not without value, of course, though they often mislead because most of us overgeneralize from special cases. My illustrations will support generalization only to the extent that very different "exact" assumptions produce results that have common features of demographic significance.

I have prepared such projections for each of the 15 surviving populations tabulated in the Appendix, Table 26, plus a sixteenth surviving population that is yet to be described. In each case, two alternative configurations of vital rates were used, so that a total of 32 projection sets were produced. Each set consists of a schedule of the U.S. population by age, sex, and color at five-year intervals, 1960 to 1985, for a total of some 200 pages of data.

The reader will be spared this deluge of numbers.* Instead, I will describe the projection model and the configurations of vital rates that were selected, provide the briefest of statistical summaries of the projections, and discuss the general results and their implications. Two cases of special interest will be presented in greater detail.

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*The full set of tables is on file at The RAND Corporation, and will be made available to qualified persons on request. It may be of interest to students of postattack manpower problems.

THE PROJECTION MODEL

It was feasible to make so many alternative projections only because demographic processes are readily adaptable to computer modeling. The projections described here were made with the help of GPOP, a flexible machine program compiled by the author.* The program accepts a description of an initial population, detailed by five-year age groups, sex, and color. This population is modified over subsequent five-year intervals by events of three kinds: aging, deaths, and births. Thus, in the absence of mortality, the initial population of ages 10-14 years in 1960 would become the population of ages 15-19 years in 1965. In the model, their numbers are in fact reduced by the application of five-year survival rates that reflect annual deathrates specific to age, sex, and color. Births during each quinquennium are computed by applying annual birthrates to the population of females between 15 and 44 years of age; these birthrates are specific to five-year age groups within this fecund period, and also to color. Computation of deaths and births is done separately for whites and nonwhites, primarily because of substantial differences in vital rates for these two groups -- at least in the preattack environment.

Thus, changes over time in the size and composition of any given initial population are determined by the programmer's choice of a time-series of values for five-year survival rates specific to age, sex, and color, and annual birthrates specific to mother's age and color. The present projections are divided into two series that share a common set of survival rates, but differ with respect to assumed birthrates. The birthrates selected for Series I are lower than those selected for Series II throughout the projection period. Although I have indicated that postattack emigration from the United States is quite plausible, for these projections I have assumed that neither emigration nor immigration occurs.

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*For an earlier use of the algorithm see Ira S. Lowry, Metropolitan Populations to 1985: Trial Projections, The RAND Corporation, RM-4125-RC (DDC No. AD 605247), September 1964. The program has since been revised and generalized; final documentation is under way.

The status of the population -- its size and distribution by age, sex, and color -- is then summarized for every fifth year, and various measures of fertility and mortality during the preceding quinquennium are computed. For example, the computed crude deathrate reflects not only the age-specific survival rates used as parameters, but also the age structure of the population to which these parameters were applied; it can therefore be calculated only ex post.

FERTILITY ASSUMPTIONS

Birthrates for Series I and Series II projections are shown in Tables 16 and 17. The entries in the tables are averages both for the five-year age groups indicated in the column headings and the five-year intervals indicated in the row stubs. To compute births from these rates for each quinquennium, GPOP multiplies them by the total number of woman-years of exposure to each rate during the quinquennium; the latter figure is calculated as part of the algorithm of aging the population.

In both series, birthrates for nonwhite women are consistently higher than those for white women, a differential that reflects the American experience and is in fact the main justification for the separate treatment of white and nonwhite populations in this study. Differential fertility is greatest at ages 15-19, where the nonwhite birthrate is roughly double the white rate. Perhaps the best measure of the overall differential, one that is independent of the current age structures of the white and nonwhite populations, is the completed fertility implied by the age-specific rates for any given quinquennium, i.e., their sum across age brackets. On this basis, nonwhite fertility at various dates ranges from 123 to 131 percent of white fertility.

The Series I birthrates are based on the recorded performances of American women between 1932 and 1957. Annual age-specific rates such as those shown for white women in Fig. 16, p. 84, were smoothed and averaged to produce the entries in Table 16, with the time-scale shifted to the period 1960-85. Thus birthrates for five years after the simulated 1960 attacks correspond to the lowest ever experienced in the United States; thereafter the rates gradually increase,

levelling off in 1985 at values very close to those that prevailed immediately before the simulated attacks.

This series reproduces the response of American families to the economic stresses of the Great Depression and the subsequent recovery.* As a pattern it seems reasonable for the stresses of nuclear war and subsequent economic reconstruction. One feels less confidence in the absolute values assumed; still lower rates are certainly conceivable

Table 16

POSTATTACK BIRTHRATES BY AGE AND COLOR OF MOTHER: PROJECTION SERIES I

Time Period	Age of Mother and Births per 1000 Women					
	15-19	20-24	25-29	30-34	35-39	40-44
White						
1960-65	42.0	120.0	114.0	80.0	49.0	17.0
1965-70	49.0	139.0	126.0	84.0	45.0	15.0
1970-75	58.0	167.0	147.0	103.0	47.0	15.0
1975-80	69.0	200.0	170.0	112.0	52.0	14.0
1980-85	80.0	236.0	188.0	116.0	56.0	15.0
Nonwhite						
1960-65	107.0	155.0	111.0	82.0	58.0	22.0
1965-70	125.0	170.0	116.0	83.0	54.0	20.0
1970-75	142.0	197.0	135.0	96.0	56.0	21.0
1975-80	161.0	233.0	172.0	111.0	63.0	21.0
1980-85	172.0	282.0	220.0	135.0	75.0	22.0

in the face of the greater stresses of nuclear war. So the Series I assumption of "low" postattack fertility is at best a quasi-extreme that can be justified as having a concrete historical precedent.

Series II birthrates are based on those recorded for the United States in 1960. These are reduced by an average of 20 percent for the first five years postattack, then restored to the 1960 level

*The smoothing procedure applied to the original data eliminates the fluctuations associated with World War II.

for the remainder of the projection period. The pattern certainly implies minimal disruption of preattack modes of life and familial values, and is probably more appropriate to a light attack than to a heavy one. This quasi-extreme will be called the "high" fertility assumption.

Table 17

POSTATTACK BIRTHRATES BY AGE AND COLOR OF MOTHER: PROJECTION SERIES II

Time Period	Age of Mother and Births per 1000 Women					
	15-19	20-24	25-29	30-34	35-39	40-44
White						
1960-65	63.5	202.2	155.9	87.7	43.2	11.8
1965-70	79.4	252.8	194.9	109.6	54.0	14.7
1970-75	79.4	252.8	194.9	109.6	54.0	14.7
1975-80	79.4	252.8	194.9	109.6	54.0	14.7
1980-85	79.4	252.8	194.9	109.6	54.0	14.7
Nonwhite						
1960-65	126.6	235.4	171.7	108.5	59.4	17.6
1965-70	158.2	294.2	214.6	135.6	74.2	22.0
1970-75	158.2	294.2	214.6	135.6	74.2	22.0
1975-80	158.2	294.2	214.6	135.6	74.2	22.0
1980-85	158.2	294.2	214.6	135.6	74.2	22.0

MORTALITY ASSUMPTIONS

Survival rates in both Series I and Series II projections are based on model life-tables prepared by the United Nations Department of Economic and Social Affairs.* These life-tables were prepared for use in population projections for nations undergoing rapid change

*Originally published as Age and Sex Patterns of Mortality, Model Life-Tables for Under-Developed Countries, United Nations Publication ST/SOA/Series A/22, New York, 1955. My source is Manuals on Methods of Estimating Population, Manual III, Methods for Population Projections by Sex and Age, United Nations Publication ST/SOA/Series A/25, New York, 1956, pp. 70-81.

in mortality conditions; in this respect they are therefore quite appropriate for our purposes.

The model life-tables are keyed to a progression of values of intrinsic life expectancy at birth. Thus for a life expectancy of 40 years, there is a schedule of annual age-specific deathrates for males and another for females according to which a cohort of live births subjected to these rates over time would average 40 years of life per person.

In the formal sense, any given life expectancy is consistent with a variety of schedules of component-specific annual deathrates. Examining 157 such schedules of deathrates for different nations and periods, the United Nations demographers concluded that, regardless of time or place, "life tables corresponding to an identical expectation of life at birth bear a close similarity."* Consequently, it is possible to select model schedules of component-specific deathrates for any level of mortality and to associate such schedules with a progression of values for life expectancy.

To simulate improvement in mortality conditions over time, we select a series of increasing values for life expectancy. The corresponding annual deathrates by age and sex are then used to compute another life-table function, survival rates by age and sex for five-year intervals -- i.e., the probability that a person of age (x) will survive to age (x + 5). Such survival rates are the mortality parameters applied to the postattack populations in the present study.

It may not be clear to the reader that each value for life expectancy is computed from deathrates current at a particular time. If mortality conditions are changing, no one individual is exposed to this set in its entirety; rather his risks at successive ages are defined by rates drawn from the progression of schedules. Thus the survivors of our simulated attacks reap the benefits of improved mortality conditions over time, but the youngest survivors and persons born after the attack benefit the most.

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*Population Bulletin of the United Nations, No. 6, 1962, United Nations Publication ST/SOA/Series N/6, New York, 1963, p. 152.

Mortality for the first three months postattack was included in our damage-assessment computation. For the population projections, we begin with survivors to mid-1960. For the first 12 months thereafter, I have assumed an intrinsic life expectancy of 40 years for whites (a level that was reached in the United States about 1880), and 35 years for nonwhites (a level reached about 1908). The crude deathrates comprising our only mortality data for Eastern Europe at the end of World War II are also approximately consistent with these values for intrinsic life expectancy, although exact comparisons are impossible.

From this postattack low, mortality conditions are assumed to improve rapidly for the first few years, then at a decreasing rate. By 1985, life expectancy for whites has reached its preattack level; for nonwhites, it is higher than preattack. The projected paths of change are shown in Fig. 18. The five-year survival rates corresponding to the plotted life expectancies are detailed in the Appendix, Table 27, by year, age, sex, and color.

As with birthrates, the white/nonwhite differentials assumed for these projections reflect the American experience. In 1960, life expectancy for whites was 70.6 years; for nonwhites, 63.6 years. So far as can be determined, the differences arise from social and economic circumstances of the two groups rather than from genetic factors. Since the skills and education of survivors would not be altered by the attack, it seems reasonable to suppose that these white/nonwhite differences would persist into the postattack world. (We can readily imagine, however, that the relative earning power of various skills would change as a consequence of changes in the pattern of output requirements and of resource availability.) The assumed postattack differential of five years is less than preattack, and is maintained until 1980. Thereafter, as life expectancy for whites approaches its presumptive ceiling, the differential narrows.

It is hard to define this assumed pattern of postattack mortality as either "high" or "low." The postwar experience of Eastern Europe, to which our pattern roughly corresponds, followed wartime population losses and destruction of resources that would be considered light

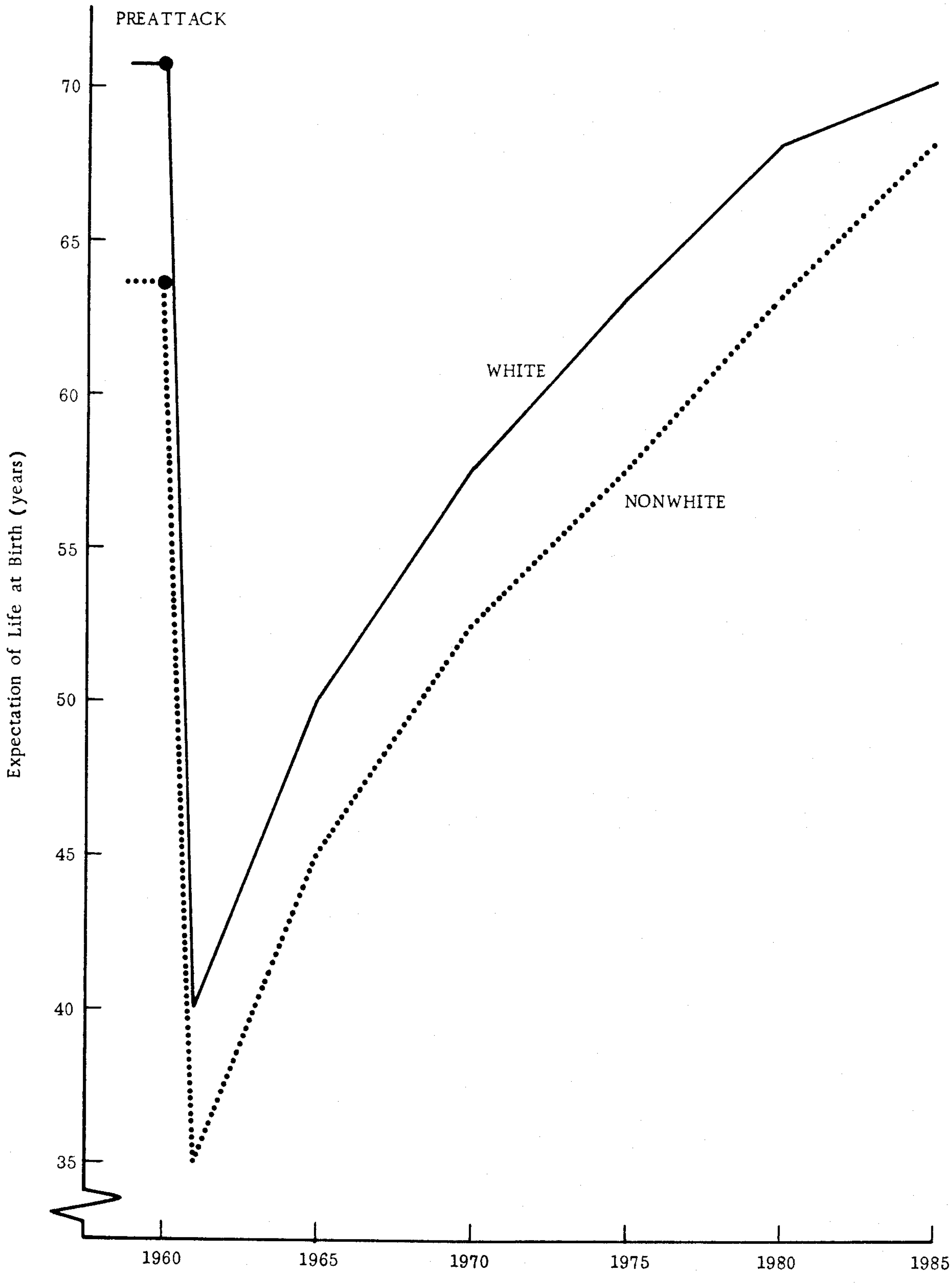


Fig. 18 -- Postattack trends in life expectancy by color, 1960-1985

according to the standards of nuclear warfare. Yet it is not clear that heavier damage would unfavorably alter the ratio of surviving people to surviving resources; and because of the role of scientific knowledge in control of disease, there is reason to expect rapid improvements in mortality conditions even following heavy attacks -- once the initial disorganization of society were repaired. Finally, there is great uncertainty about the long-run consequences of chronic irradiation for human life.

PROJECTION SERIES I

Postattack population projections under the low-fertility assumption are summarized in Table 18 for each of the 15 schedules of survivors tabulated in the Appendix, Table 26. Table 19 shows quinquennial growth rates for the same cases.

The differences among rows of Table 18 reflect variations both in size and in component structure of the initial populations of three-month survivors. The differences among rows of Table 19 reflect only the variations in component structure. In order to test the long-run demographic significance of the survival disparities estimated by my methods of damage assessment, I prepared projections for a sixteenth case, for which the initial population was created by reducing all components to 38.2 percent of their preattack figures. In other words, population damage from this attack involved no survival disparities. As measured by the total number of three-month survivors, this case is virtually identical with Attack 430, PF = 3, the case revealing the largest disparities in component survival.

The projections of total population for the first 15 cases do not differ greatly except in absolute numbers of persons. In each case, the first five years postattack is a period of declining population, and the second five years is one of virtually no change. The first period of growth is 1970-75, when all 15 populations recover their immediate postattack sizes. Thereafter the growth rate increases to nearly two percent per annum by 1985.*

*From 1950 to 1965, the annual rate of population growth in the United States fluctuated between 1.8 and 1.3 percent per annum.

Table 18

POSTATTACK POPULATION SUMMARIES, PROJECTION SERIES I:
16 SURVIVING POPULATIONS, 1960-85

Attack No. and Protection Factor	Survivors, Mid-1960	Midyear Populations in Thousands				
		1965	1970	1975	1980	1985
Attack 103						
PF = 10	174,232	167,300	167,507	174,516	187,599	203,959
PF = 6	173,303	166,438	166,662	173,651	186,666	202,937
PF = 3	169,972	163,399	163,739	170,668	183,470	199,450
Attack 203						
PF = 10	159,429	153,159	153,429	159,932	171,983	187,014
PF = 6	155,834	149,828	150,196	156,632	168,445	183,149
PF = 3	147,028	141,595	142,128	148,345	159,595	173,560
Attack 130						
PF = 10	156,243	150,410	150,892	157,372	169,157	183,828
PF = 6	145,329	140,072	140,645	146,750	157,731	171,382
PF = 3	126,378	122,113	122,841	128,312	137,970	149,945
Attack 599						
PF = 10	133,630	128,537	128,957	134,637	144,955	157,727
PF = 6	123,796	119,528	120,288	125,811	135,465	147,331
PF = 3	102,681	99,551	100,517	105,367	113,590	123,651
Attack 430						
PF = 10	115,058	111,036	111,685	116,778	125,747	136,789
PF = 6	97,013	94,190	95,200	99,814	107,487	116,834
PF = 3	68,215	66,581	67,562	71,004	76,554	83,927
Scalar Damage[a]	68,216	65,307	65,261	67,904	72,943	79,281

[a]Each population component reduced to 38.2 percent of preattack number.

Although the differences in growth rates among the 15 cases are small, the pattern is typical: the heavier the damage from the attack itself, the more rapid is the recovery. In part this result is a consequence of the arbitrary application of the same set of vital rates to both light and heavy attacks, when it is somewhat more reasonable to expect lower age-specific fertility and higher age-specific mortality for the heavier attacks. But the association of faster recovery with greater initial damage cannot be attributed solely to this source. It also results from the greater demographic selectivity of the heavier attacks.

Table 19

QUINQUENNIAL RATES OF GROWTH, PROJECTION SERIES I: 16 SURVIVING POPULATIONS, 1960-85

Attack No. and Protection Factor	Survivors, Mid-1960, (thousands)	Percentage Change				
		1960-65	1965-70	1970-75	1975-80	1980-85
Attack 103						
PF = 10	174,232	-4.0	0.1	4.2	7.5	8.7
PF = 6	173,303	-4.0	0.1	4.2	7.5	8.7
PF = 3	169,972	-3.9	0.2	4.2	7.5	8.7
Attack 203						
PF = 10	159,429	-3.9	0.2	4.2	7.5	8.7
PF = 6	155,834	-3.9	0.2	4.3	7.5	8.7
PF = 3	147,028	-3.7	0.4	4.4	7.6	8.8
Attack 130						
PF = 10	156,243	-3.7	0.3	4.3	7.5	8.7
PF = 6	145,329	-3.6	0.4	4.3	7.5	8.7
PF = 3	126,378	-3.4	0.6	4.5	7.5	8.7
Attack 599						
PF = 10	133,630	-3.8	0.3	4.4	7.7	8.8
PF = 6	123,796	-3.4	0.6	4.6	7.7	8.8
PF = 3	102,681	-3.0	1.0	4.8	7.8	8.9
Attack 430						
PF = 10	115,058	-3.5	0.6	4.6	7.7	8.8
PF = 6	97,013	-2.9	1.1	4.8	7.7	8.7
PF = 3	68,215	-2.4	1.5	5.1	7.8	9.6
Scalar Damage[a]	68,216	-4.3	-0.1	4.1	7.4	8.7

[a]Each population component reduced to 38.2 percent of preattack number.

This conclusion follows from comparison of projections for Attack 430, PF = 3, with the case of scalar damage immediately beneath it. Since both attacks result in the same number of fatalities, the three-month survivors for these two cases differ only in composition. When scalar damage is assumed, the postattack shrinkage of population is greater and recovery is slower than when survival disparities are assumed. By 1985, the difference in projected populations for these two cases amounts to 4.6 million persons, or 5.9 percent of the smaller number. This difference is one measure of the long-term demographic significance of the largest survival disparities generated by my damage-assessment model.

The pattern of growth rates exhibited by all the attacks is best understood by comparing crude rates of birth and death over the projection period. Since the relationships between these rates do not differ greatly among attacks, they are plotted in Fig. 19 only for the lightest attack (103, PF = 10), the heaviest attack (430, PF = 3), and the scalar case. (The figure shows data for both Series I and Series II. The data for Series II, and its contrast with Series I, are discussed below under the heading, "Projection Series II.") Crude birthrates and crude deathrates reflect both the assumed incidence of fertility and mortality for each population component, and also the component structure of the population at risk. The difference (plus or minus) between the crude birthrate and the crude deathrate is, identically, the rate of population growth or decline.

Note that crude deathrates for the lightest attack and for the scalar case are very close for corresponding periods. Despite the demographic selectivity of damage in Attack 103, the number of fatalities is so small that the preattack component structure of the population is virtually unaltered as a result of the attack. In this respect, the population of three-month survivors resembles that of the scalar case; consequently, the assumed component-specific survival rates result in very nearly the same crude deathrates. The same comments apply to birthrates.

As between these two cases and the demographically selective heavy attack, initial crude rates for both births and deaths are quite different but converge over time. By 1985, all three cases show very nearly the same rates. This result illustrates the homeostatic properties often noted for human populations. Component structures of the populations of survivors, visibly different at the extremes of the age distribution, are much closer after 25 years of exposure to a common set of component-specific rates of birth and death. When the two populations have achieved approximately the same component structures, the application of a given set of component-specific vital rates thereafter naturally yields virtually the same crude rates for both cases.

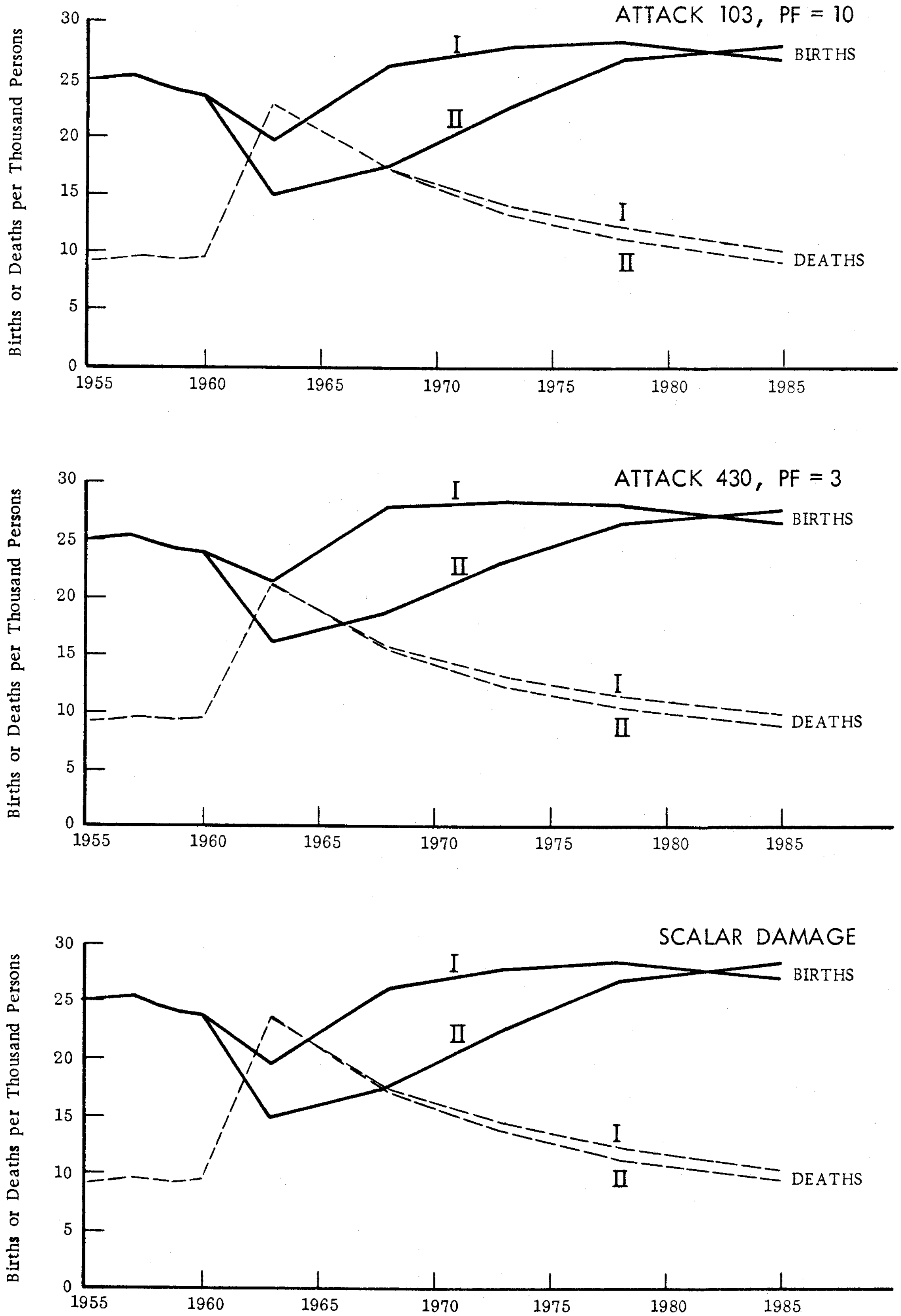


Fig. 19 -- Crude rates of birth and death for three surviving populations: Projection Series I and II, 1960-1985

PROJECTION SERIES II

Projections for the high-fertility assumption are summarized in Tables 20 and 21. Most of the discussion of Projection Series I, above, applies to these projections as well; we need only note the ways in which the second series contrasts with the first.

Because of the assumption of rapid return to preattack fertility, the period of postattack population decline is shorter for all attacks in Series II than for corresponding attacks in Series I. By 1970, all 16 cases show larger populations than in 1960. The same pattern of more rapid recovery from heavy attacks is exhibited, and the explanation offered is still supported by the data for the scalar case.

We can again measure the long-term demographic significance of survival disparities by comparing the 1985 projection for a demographically selective attack (430, PF = 3) with that for the scalar damage case, which had the same number of three-month survivors. Under the high-fertility assumption, these two populations differ by 4.8 million in 1985, as compared with 4.6 million under the low-fertility assumption of Series I. Since the 1985 populations are larger for the high-fertility case, the relative difference is less -- 5.4 percent as compared with 5.9 percent for Series I.

Postattack growth rates are higher for Series II than Series I, but convergence between the two series is evident toward the end of the projection period. The principal force for convergence is that, by 1985, the component-specific birthrates for the low-fertility Series I are approaching those for the high-fertility Series II (see Fig. 19). Although identical sets of component-specific deathrates are used in the two series, crude deathrates diverge over time. This is because the high-fertility population develops a younger age structure, with relatively more persons in age brackets for which the incidence of mortality is low.

Comparing projected populations under low and high fertility assumptions, with and without attack survival disparities, reveals an important fact: the size of the nation's population, even 25 years after a nuclear attack, is much less sensitive to plausible variations in postattack fertility or to plausible disparities in component survival

Table 20

POSTATTACK POPULATION SUMMARIES, PROJECTION SERIES II:
16 SURVIVING POPULATIONS, 1960-85

Attack No. and Protection Factor	Survivors, Mid-1960 (thousands)	Midyear Population in Thousands				
		1965	1970	1975	1980	1985
Attack 103						
PF = 10	174,232	171,264	179,305	192,656	209,825	228,959
PF = 6	173,303	170,387	178,413	191,708	208,788	227,820
PF = 3	169,972	167,295	175,316	188,448	205,238	223,937
Attack 203						
PF = 10	159,429	156,794	164,260	176,594	192,394	209,967
PF = 6	155,834	153,405	160,843	172,994	188,471	205,671
PF = 3	147,028	145,008	152,266	163,900	178,620	194,961
Attack 130						
PF = 10	156,243	154,033	161,634	173,830	189,273	206,462
PF = 6	145,329	143,476	150,709	162,139	176,522	192,531
PF = 3	126,378	125,126	131,710	141,836	154,466	168,521
Attack 599						
PF = 10	133,630	131,601	138,119	148,747	162,232	177,147
PF = 6	123,796	122,456	128,986	139,134	151,720	165,612
PF = 3	102,681	102,051	107,903	116,641	127,326	139,110
Attack 430						
PF = 10	115,058	113,737	119,730	129,119	140,816	153,733
PF = 6	97,013	96,584	102,250	110,532	120,501	131,485
PF = 3	68,215	68,326	72,657	78,713	85,902	93,833
Scalar Damage[a]	68,216	66,845	69,838	74,942	81,569	88,984

[a]Each population component reduced to 38.2 percent of preattack number.

of the attack than to plausible variations in the number of fatalities at the time of the attack.

No matter on which attack we base our projections, the high-fertility assumption yields a population in 1985 that is about 112 percent of the corresponding population under the low-fertility assumption. The most extreme case of survival disparities yields a population for 1985 that is about 106 percent of the corresponding population for the scalar damage case. But as among alternative attacks, the largest number of three-month survivors is 255 percent of the smallest, and projections to 1985 for these two cases narrow the ratio only to 243 percent under the most favorable circumstances for convergence.

Table 21

QUINQUENNIAL RATES OF GROWTH, PROJECTION SERIES II: 16 SURVIVING POPULATIONS, 1960-85

Attack No. and Protection Factor	Survivors, Mid-1960 (thousands)	Percentage Change				
		1960-65	1965-70	1970-75	1975-80	1980-85
Attack 103						
PF = 10	174,232	-1.7	4.7	7.4	8.9	9.1
PF = 6	173,303	-1.7	4.7	7.5	8.9	9.1
PF = 3	169,972	-1.6	4.8	7.5	8.9	9.1
Attack 203						
PF = 10	159,429	-1.7	4.8	7.5	8.9	9.1
PF = 6	155,834	-1.6	4.8	7.6	8.9	9.1
PF = 3	147,028	-1.4	5.0	7.6	9.0	9.1
Attack 130						
PF = 10	156,243	-1.4	4.9	7.5	8.9	9.1
PF = 6	145,329	-1.3	5.0	7.6	8.9	9.1
PF = 3	126,378	-1.0	5.3	7.7	8.9	9.1
Attack 599						
PF = 10	133,630	-1.5	5.0	6.9	9.1	9.2
PF = 6	123,796	-1.1	5.3	7.9	9.0	9.2
PF = 3	102,681	-0.6	5.7	8.1	9.2	9.3
Attack 430						
PF = 10	115,058	-1.1	5.3	7.8	9.1	9.2
PF = 6	97,013	-0.4	5.9	8.1	9.0	9.1
PF = 3	68,215	0.2	6.3	8.3	9.1	9.2
Scalar Damage[a]	68,216	-2.0	4.5	7.3	8.8	9.1

[a]Each population component reduced to 38.2 percent of preattack number.

PROJECTED COMPONENT STRUCTURES

The component structure of the postattack population changes over time as the three-month survivors age, die, and are replaced by new cohorts of births. Because of the many relevant dimensions of component detail, it is difficult to display these changes so that significant patterns are easily grasped. For any given case -- i.e., any schedule of three-month survivors -- we have data for each of 15 age groups, for each of four sex/color groups, for each of two projection series, for each of six points in time.

To avoid overwhelming the reader with indigestible detail, I propose to consider only two extreme cases, and for the most part to

treat dimensions of age, sex, and color separately rather than in cross-classification. Some features of demographic interest will consequently escape notice, but the main sequences of postattack demographic changes can be displayed to greater advantage.

The two cases to be considered are Attack 430, PF = 3, which produced the greatest three-month survival disparities among population components; and the scalar damage case, in which the population of three-month survivors has precisely the same component structure as the preattack population. Although both cases represent heavy attacks (only 38 percent of the preattack population survives) they are extremes with respect to component structure. The remaining 14 cases -- for which surviving populations are detailed in the Appendix, Table 26 -- fall between these two with respect to compositional changes caused by the attack and also by demographic events over the ensuing 25 years.

In this spectrum of patterns, the lightest attack is virtually indistinguishable from the scalar damage case. As the attacks increase in weight -- that is, in number of fatalities -- component structures of the surviving populations, both immediately and in the longer run, come more and more to resemble those of the heaviest attack taken as our examplar. With so many dimensions to be considered, there are unavoidable minor exceptions to this generalization, but my review of the full set of data reveals none of major significance.

PROJECTED AGE DISTRIBUTION

Table 22 displays the projected changes in age distribution, 1960-85, for our two extreme cases under both low-fertility and high-fertility assumptions. Full detail by five-year age intervals and by sex for these four alternatives is tabulated in the Appendix, Table 28.

The principal differences between the survival-disparity case (Attack 430, PF = 3) and the scalar damage case is that the former begins at three months postattack with an age structure more heavily weighted with persons 15-39 years of age, the group least vulnerable

Table 22

COMPOSITION OF PROJECTED POSTATTACK POPULATIONS BY BROAD AGE GROUPS: ATTACK 430, PF = 3, AND SCALAR DAMAGE CASE, PROJECTION SERIES I AND II

Age	Percentage of Total Population						
	1960 Preattack	1960 Postattack	1965	1970	1975	1980	1985
			Attack 430, PF = 3, Series I				
65+	9.0	7.0	6.1	6.0	6.0	6.3	6.3
40-64	26.8	25.2	26.5	27.1	26.5	24.9	23.9
15-39	33.2	36.5	38.4	40.2	41.4	38.6	36.2
0-14	31.2	31.3	28.9	26.5	26.1	30.3	33.6
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0
			Attack 430, PF = 3, Series II				
65+	9.0	7.0	5.9	5.5	5.5	5.6	5.6
40-64	26.8	25.2	25.8	25.3	23.9	22.2	21.3
15-39	33.2	36.5	37.5	37.4	37.2	36.4	37.4
0-14	31.2	31.3	30.8	31.8	33.4	35.9	35.8
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0
			Scalar Damage, Series I				
65+	9.0	9.1	7.8	7.4	7.1	7.1	7.0
40-64	26.8	26.8	27.6	27.6	26.2	24.1	22.8
15-39	33.2	33.2	35.5	38.4	41.6	39.1	36.6
0-14	31.2	31.1	29.0	26.5	25.1	29.9	33.7
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0
			Scalar Damage, Series II				
65+	9.0	9.1	7.6	6.9	6.4	6.4	6.2
40-64	26.8	26.8	27.0	25.8	23.7	21.5	20.2
15-39	33.2	33.2	34.6	35.8	37.7	36.7	37.5
0-14	31.2	31.1	30.8	31.3	32.1	35.4	35.9
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

NOTE: Distributions may not add exactly to totals because of rounding.

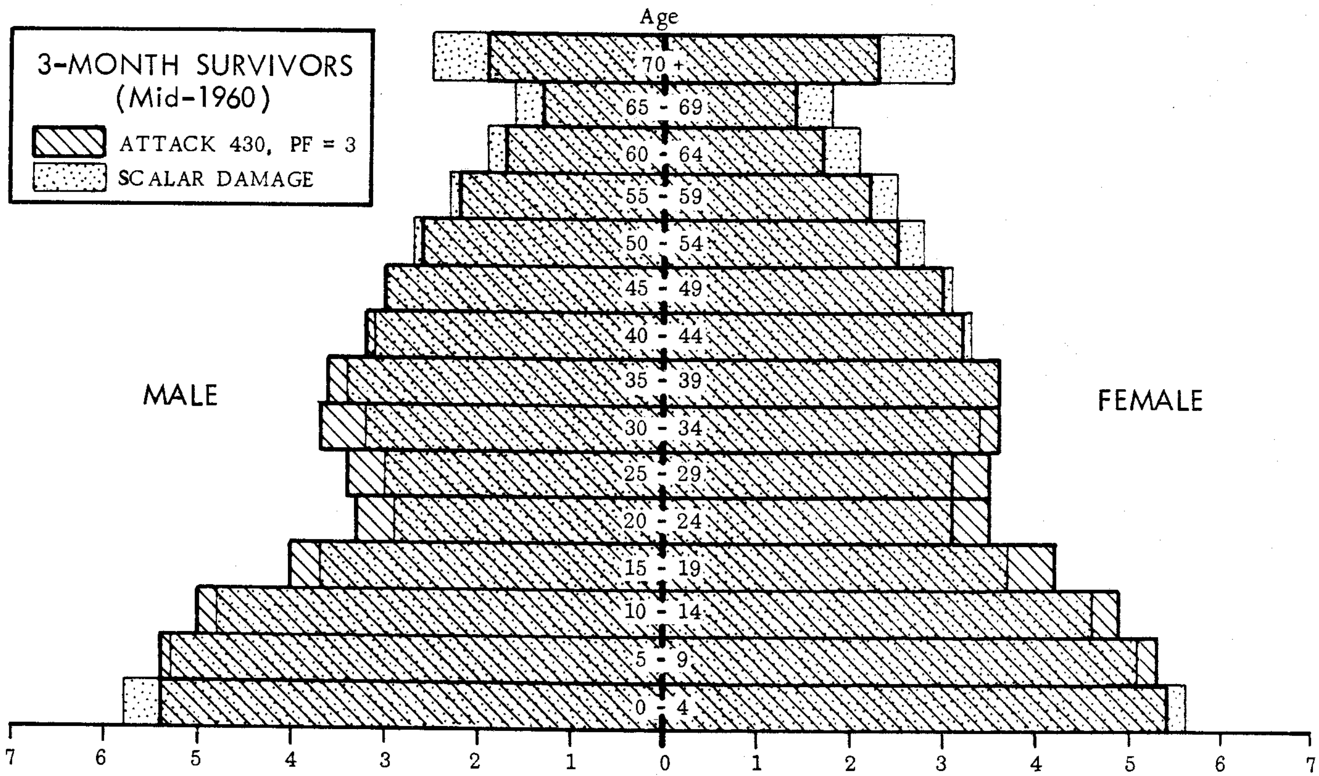
to weapon effects. The scalar case, on the other hand, reflects without modification the preattack age structure with its peculiar shortage of persons 20-29 years of age, a feature that resulted from the small cohorts of births during the 1930s. These initial differences are displayed in the upper half of Fig. 20, about which more will be said below.

The principal difference between Series I and Series II, given either population of three-month survivors, lies in the rate of increase in the annual cohort of births, which in turn reflects in the share of total population included in the age bracket 0-14 years. For Series I, this share declines for a period of 15 years postattack, but at the end of 25 years has surpassed its preattack level. For Series II, the age group 0-14 years declines only for 5 years, 1960-65, and has surpassed its preattack value by 1970.

All four alternatives shown are influenced by the rapid improvement in mortality conditions assumed for both Series I and II. The rate of decline in annual deathrates over postattack time is inversely related to age, a fact that at first tends to lower the average age of the population. If our projection period extended beyond 25 years, and age-specific birthrates stabilized as they do in Series II, we would begin to see the long-run consequences of declining deathrates among the young: more people surviving to the older ages.

One feature of particular interest was briefly noted earlier: the convergence over time of initially different age structures. This is illustrated in Fig. 20 for the survival-disparity case and the scalar damage case, Projection Series I. The top half of the figure superimposes the age/sex pyramid of survivors of the scalar damage case on that of Attack 430, PF = 3, to show the differences in age structure that are most marked at the upper extreme of the age-distribution. The bottom half of the figure is a similar overlay for 1985, when the two pyramids are nearly congruent. Such differences as remain are to be found in the middle of the age distribution.

This process of convergence follows from the fact that the two populations were subjected to a common set of vital rates. Differences between the two cases at the top of the pyramid, quite apparent



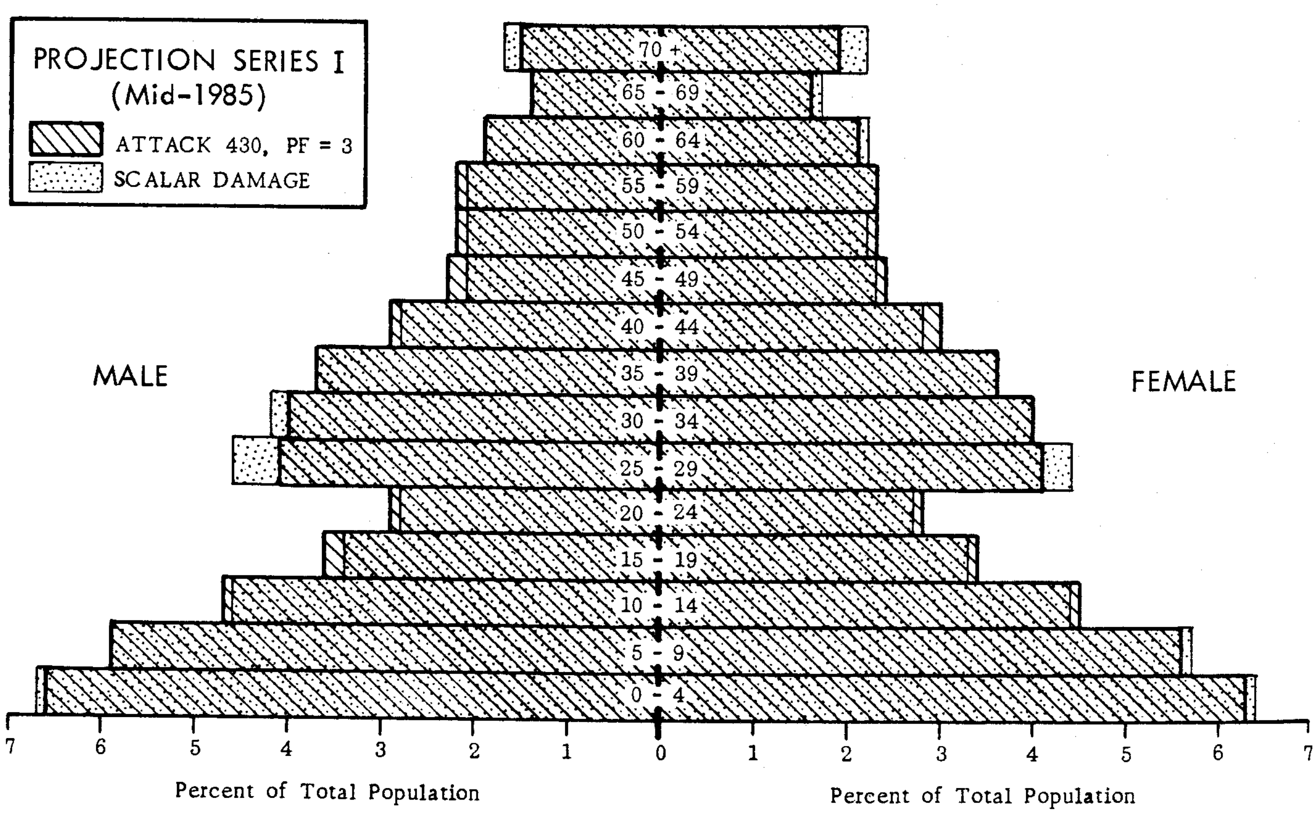


Fig. 20 -- Convergence of two dissimilar population structures: postattack population pyramids, 1960 and 1985

in 1960, disappear as the tenants of these age brackets die. At the bottom of the pyramid, new cohorts of postattack births account, by 1985, for all age groups 0-24 years. Although persons 25 years of age and older are all survivors of the attacks, the initial differences between the two survival patterns have been somewhat attenuated by interim mortality.

The socio-economic significance of a population's component structure is perhaps best reflected by dividing the population into those who are physically and mentally capable of useful work and those constitutionally dependent on others for their support. Age is the most relevant criterion for this division, though sex, education, and health also enter the picture. A reasonable approximation to the desired measure is obtained by counting those between 15 and 64 years of age as able-bodied persons eligible for productive work, and counting those under 15 and over 64 as dependents. Figure 21 shows the time-trend of the number of dependents per hundred labor-force eligibles calculated in this way. The top half of the figure shows values for the survival-disparity case under both the low-fertility and high-fertility assumptions. The bottom half shows similar values for the scalar damage case.

In all four cases, the dependency rate diminishes during the first few years postattack, and in no case does it reach the pre-attack level of 67 per hundred until the period 1975-80. Thus the postattack age structure is generally favorable to economic reconstruction, somewhat more so for the case of survival disparity than for the case of scalar damage.

The dependency rate is much more sensitive to the postattack fertility assumption than it is to the alternative initial age structures. Under the low-fertility assumption of Series I, the dependency rate falls for a period of 15 years, in both cases approaching the historic low for the United States.* Under the high-fertility

*In 1945, the dependency rate thus computed was 43 per hundred. Oddly, the influence of this age structure on postwar economic development has not received scholarly attention, so far as I know.

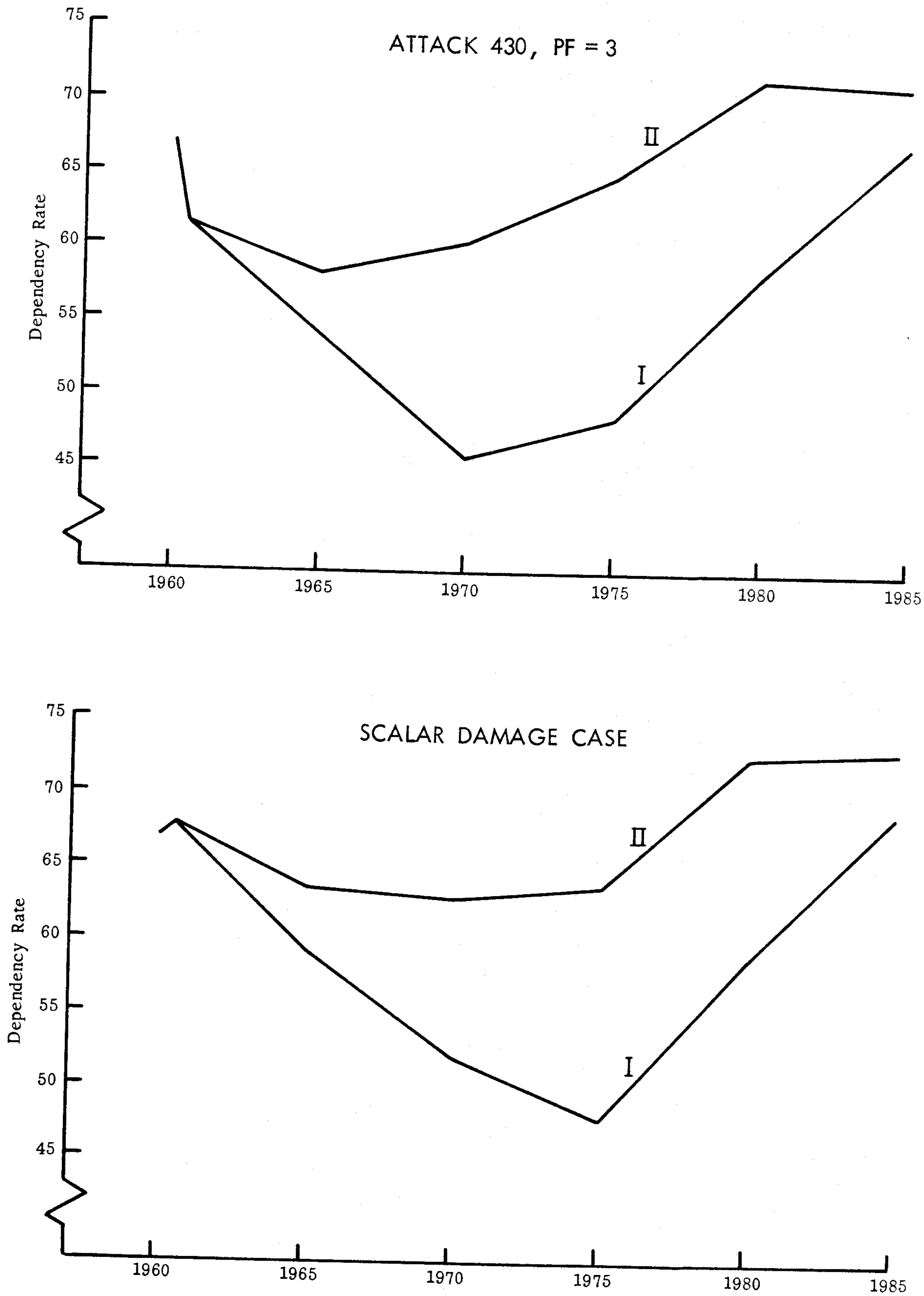


Fig. 21 -- Projected dependency rates: Attack 430, PF = 3 and scalar damage case, Projection Series I and II, 1960-1985

assumption, the dependency rate drops below 60 per hundred only briefly for the survival-disparity case, and not at all for the scalar damage case.

PROJECTED SEX RATIOS

The ratio of males to females in the postattack population would change over time for two reasons. One is that females have a greater life expectancy than males, a differential that increases as mortality conditions gradually return to the preattack pattern. The other is that the sex ratio at birth always favors males.* The two factors are partially offsetting, but most human populations have a slight overall excess of females.

Table 23 shows the number of males per thousand females for the survival-disparity case and for the scalar damage case under both fertility assumptions, 1960-85. Prior to the simulated attacks, the U.S. population contained more females than males, with the excess of females concentrated in the upper age brackets; among the young, there were more males than females. For Attack 430, PF = 3, the assumption of greater vulnerability at the extremes of the age-distribution reduces the differential between the numbers of male and female survivors. The scalar damage case, of course, reproduces the preattack sex ratio in the population of three-month survivors.

Although the same pattern of sex differentials in mortality applies to all four series shown in Table 23, the series differ among themselves in the composition of their initial populations, and also in the importance of postattack births as a source of change in the sex ratio. Yet the range of variation overall is not great. The lowest value of the sex ratio, 994.1 males per thousand females,

*The projection model requires separate sex ratios at birth (live male births per 1000 live female births) for whites and nonwhites. For both Series I and Series II projections, the values used were 1056 for whites and 1021 for nonwhites, unchanged for the entire projection period, 1960-85. These figures are averages of annual values for a period of 20 years preattack; the year-to-year variation is small for whites; though the variation is larger for nonwhites, this is more likely due to reporting errors than to "true" changes.

Table 23

PROJECTED SEX RATIOS: ATTACK 430, PF = 3, AND SCALAR DAMAGE CASE, PROJECTION SERIES I AND II

Projection Series	Males per Thousand Females						
	Preattack 1960	Postattack 1960	1965	1970	1975	1980	1985
Attack 403, PF = 3							
I	969.2	994.1	995.5	995.8	995.7	997.1	998.8
II	969.2	994.1	996.8	999.4	1000.6	1002.3	1004.7
Scalar Damage Case							
I	969.2	969.2	975.5	980.2	983.8	989.0	995.1
II	969.2	969.2	977.1	984.5	989.7	995.0	1000.4

occurs among survivors of Attack 403. The highest value, 1004.7, occurs in 1985 for the same case under the high-fertility assumption.

Although these summary measures may conceal larger disparities in the sex ratios of particular age groups, such disparities would need to be much larger than those found for the total population in order to have significance for the social structure or for the institution of monogamy. Examination of the detailed age/sex distributions of these projected populations (Appendix, Table 28) does not show such radical disparities.

PROJECTED ETHNIC COMPOSITION

In 1960, the Bureau of the Census classified 11.2 percent of the nation's population as nonwhite. The targeting of our five simulated attacks tended to favor nonwhite survival, but not significantly so except in the case of the heaviest attacks and lowest protection factors. After Attack 430, PF = 3, nonwhites make up 12.4 percent of all survivors.

Table 24

PROJECTED ETHNIC COMPOSITION: ATTACK 430, PF = 3, AND SCALAR DAMAGE CASE, PROJECTION SERIES I AND II

Population Group	Percentage of Total Population						
	Preattack 1960	Postattack 1960	1965	1970	1975	1980	1985
Attack 430, PF = 3, Series I							
White	88.8	87.6	87.3	86.9	86.4	85.9	85.0
Nonwhite	11.2	12.4	12.7	13.1	13.6	14.2	14.9
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Attack 430, PF = 3, Series II							
White	88.8	87.6	87.2	86.6	86.0	85.4	84.7
Nonwhite	11.2	12.4	12.8	13.4	13.9	14.6	15.3
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Scalar Damage Case, Series I							
White	88.8	88.8	88.4	88.0	87.6	87.0	86.4
Nonwhite	11.2	11.2	11.6	12.0	12.4	13.0	13.6
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Scalar Damage Case, Series II							
White	88.8	88.8	88.4	87.8	87.2	86.7	86.1
Nonwhite	11.2	11.2	11.6	12.2	12.7	13.3	13.9
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

NOTE: Distributions may not add exactly to totals because of rounding.

Projections for all cases, including the scalar damage case, indicate further shifts in the ethnic composition of the U.S. population. Table 24 shows the projections for Attack 430, PF = 3, and for the scalar damage case, under both the low-fertility and high-fertility assumptions. Both assumptions postulate continuation of the historically greater fertility of nonwhites as compared with whites. It is therefore not surprising that the percentage of nonwhites in the total population increases over time for both Series I

and Series II. As compared with preattack levels, the largest relative increase in the nonwhite population occurs for Attack 430, PF = 3. By 1985, the Series II projection for this case shows nonwhites constituting 15.3 percent of the total population.

VII. POSTATTACK POPULATION POLICIES

The demographic trends and patterns discussed in the two preceding sections were specifically selected for their relevance to issues the United States Government would face in the years following a nuclear war. This brief concluding section will suggest how demographic considerations would enter into recovery planning, and how Governmental policies might in turn affect demographic trends. For purposes of this discussion, I assume the reconstitution of legitimate civil authority in the United States following the termination of a nuclear war.

The members of such a postattack Government might view the nation's people in any of three ways: as economic burdens who require food, clothing, and shelter; as economic resources who provide the manpower and skills needed to operate the national economy and implement national policies; or as clients who are valued in and for themselves. In fact, all three views could coexist -- or conflict -- both in the minds of people in authority and among Government agencies with differing direct responsibilities.

This multiplicity of views would not be peculiar to the postattack world; it is implicit in all organized society. But under the more severe stresses of the postattack environment, the conflicts among these views would be greatly sharpened. Difficult choices, involving both ethical values and cause-and-effect relationships, would be forced upon the managers of postattack society. Furthermore, all three views would be conditioned by a time-dimension; ends and means would have to be considered not only for the day but for the next year and for a decade thence.

The fundamental goal of any legitimate government is to insure the survival of the society it governs; it may fail to do so by miscalculation, but not by design. Applying this premise to the management of the domestic economy during a period of great stress suggests a policy of maximizing the positive difference between total production and private consumption, in order to provide an economic surplus that could be used for the implementation of public purposes. Depending on

the international environment, public priorities might go either to restoring the nation's military strength or to rebuilding the industrial plant. Whichever the goal, the relevant view of the nation's population is as both resource and burden. Its "client" value would be at a discount.

Survivors then in their productive years -- roughly 15 to 64, by present standards -- would clearly be the most valuable segment of the postattack population. They would have to be kept in good health and encouraged to produce their utmost, to go where they were needed, to transfer their skills from frivolous to serious occupations. Providing them with bare subsistence consistent with health might not be enough to motivate them as producers; individually and collectively, the labor force would be in a strong position to exact preferential treatment at the hands of the Government. Furthermore, it would be impossible to limit preferential treatment to labor-force members alone, for the working members of society would insist on transferring some part of their personal advantages to members of their families who were not directly contributing to output.

Policymakers would presumably have to draw the line somewhere, however, in making such concessions, and those most likely to suffer are people with little or no productive potential: old people, chronic invalids, and the insane. Old people suffer the special disadvantage of being easily identified as a group and therefore subjected to categorical treatment. In the short run, of course, neither extreme of the age distribution would have value as a source of manpower; but children, at least, are tomorrow's workers. On the other hand, not even a long-run view bestows value as a <u>resource</u> on the elderly members of society. In a literate community, the elderly do not even serve their prehistoric function as repositories of traditional wisdom. Since the amount of care and attention necessary to sustain life increases with age, this drain on national resources could significantly affect recovery planning. In this sense at least, a community under stress would be better off without its old and feeble members. Yet those who made public policy would certainly be accustomed to thinking that all people, including the aged and the infirm, were intrinsically valuable.

The easiest way to implement a morally repugnant but socially beneficial policy is by inaction. Under stress, the managers of postattack society would most likely resolve their problem by failing to make any special provision for the special needs of the elderly, the insane, and the chronically ill. Instead of Medicare for persons over 65, for example, we might have Medicare for persons under 15. Instead of pensions, we might have family allowances. To be sure, the Government would not be able -- nor would it be likely to try -- to prevent the relatives and friends of old people from helping them; but overall, the share of the elderly in the national product would certainly drop.

Public policy toward surviving children would probably be more generous. The nearer these are to labor-force age, the greater their present value as producers, and the less costly it would be to protect them either as clients or as social capital. But one can imagine public policy toward maternity passing through two phases. In the immediate postattack period, the primary goal being to maximize the economic surplus, children would have no short-run value. Since it is easier to reject public responsibility for the individual welfare of the unborn than of persons already living, an antinatal policy would be the most plausible way to reduce the short-run dependency rate and free women for labor-force participation.

Of course it would be easier to proclaim an antinatal policy than to enforce it. But as an avowedly temporary expedient, it would probably accord anyway with the private inclinations of potential parents in a stressful environment. Voluntary compliance would most likely be widespread.

Once the most extreme pressures were removed, however, the policymakers would have to recognize that an antinatal policy heavily discounts the value of manpower 15 to 20 years hence. As recovery got under way, a pronatal policy would probably replace the antinatal; and the more critical issue would become the question of extended education versus early entry into the labor force.

Assuming that other parts of the world were in better shape, emigration would offer a serious challenge to Governmental authority. For individuals and family groups, beginning over again in South

America might be a much more attractive prospect than an austere existence in a radioactive United States. Because emigration requires both imagination and means, it would appeal disproportionately to the most vigorous and valuable members of postattack society. Yet to a Government that felt responsible for the survival of our society, such emigration would be nothing less than desertion.

I think it may be assumed that the object of Government policy under these circumstances would be to prevent emigration. The least satisfactory way of doing so would be a flat prohibition, particularly if it were delayed until the emigration flow were well under way. This strategy would undermine the morale of those who had contemplated emigration, and impel them to view the Government as adversary and jailer.

An alternative strategy for preventing emigration would be to involve the potential emigrants in the process of reconstruction, to give them a stake in the emerging society, to keep them sufficiently preoccupied so that the alternative of emigration would not crystallize in their minds. The success of such a strategy would depend very much on how long it would take the Government to develop an aggressive program of reconstruction. Personnel policies would also be important. On the one hand, there would be many surviving organizations, both public and private, with vacant offices. On the other hand, there would be many surviving officers whose organizations had been virtually destroyed. The dispossessed -- those deprived of their preattack power-bases -- would be most tempted to emigrate. Assuming that their talents were still socially valuable, their temptation would be reduced by shuffling them quickly into new positions of commensurate status. Since it is probable that the casualty rate would be higher among the organizational elite, it might be possible to give nearly everyone a promotion.

APPENDIX

Table 25

MODEL MORTALITY SCHEDULES FOR NUCLEAR ATTACK, BY AGE AND SEX, FOR SELECTED CRUDE FATALITY RATES

Deaths per 1000 Persons Exposed

Age in Years	F = 35		F = 52		F = 103		F = 149		F = 198	
	Male	Fem.	Male	Fem.	Male	Fem.	Male	Fem.	Male	Fem.
Under 1	75	62	92	79	148	134	214	194	300	267
1-4	55	45	72	62	126	115	182	166	247	221
5-9	32	25	49	42	100	92	145	133	187	170
10-14	18	12	34	29	83	77	121	112	151	139
15-19	10	7	26	23	74	70	108	103	133	125
20-24	6	5	23	22	70	68	102	100	124	121
25-29	5	6	21	22	68	69	99	101	121	123
30-34	5	8	21	24	68	72	99	104	121	128
35-39	8	15	24	32	71	80	104	116	127	145
40-44	12	24	28	41	76	91	111	132	137	167
45-49	20	34	37	51	86	102	125	148	157	192
50-54	30	48	47	64	98	118	141	170	182	227
55-59	42	64	59	81	112	136	162	196	214	271
60-64	60	85	77	102	132	159	190	230	260	328
65-69	82	110	99	127	157	187	226	269	321	396
70-74	112	142	130	159	190	222	273	318	403	485
75+	150	185	167	202	230	268	331	385	508	607

	F = 258		F = 308		F = 336		F = 396		F = 460	
Under 1	421	363	550	463	637	529	874	707	1000	970
1-4	330	287	414	350	468	391	613	497	824	647
5-9	233	206	275	237	300	256	363	300	448	358
10-14	178	161	200	178	212	187	241	207	275	229
15-19	153	143	167	156	175	162	192	175	210	190
20-24	142	138	154	150	160	155	173	167	186	179
25-29	138	140	149	152	154	158	166	171	178	184
30-34	138	146	149	160	154	166	166	181	178	196
35-39	145	170	158	189	164	199	178	223	193	251
40-44	159	202	175	232	184	250	204	292	225	346
45-49	187	241	212	286	226	313	259	382	301	476
50-54	225	297	264	366	287	410	344	525	421	689
55-59	276	370	335	473	373	542	470	726	606	1000
60-64	352	468	446	622	509	728	675	1000	920	1000
65-69	456	591	604	815	704	971	982	1000	1000	1000
70-74	604	757	835	1000	997	1000	1000	1000	1000	1000
75+	800	992	1000	1000	1000	1000	1000	1000	1000	1000

Table 25 -- continued

Age in Years	F = 491 Male	F = 491 Fem.	F = 550 Male	F = 550 Fem.	F = 622 Male	F = 622 Fem.	F = 662 Male	F = 662 Fem.	F = 700 Male	F = 700 Fem.
Under 1	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
1-4	964	744	1000	1000	1000	1000	1000	1000	1000	1000
5-9	501	393	638	480	946	668	1000	850	1000	1000
10-14	295	242	342	271	438	324	524	369	635	424
15-19	220	197	241	212	279	237	310	256	346	276
20-24	193	185	208	198	232	218	249	232	267	247
25-29	184	190	197	204	216	226	230	242	244	259
30-34	184	204	197	221	216	250	230	272	244	297
35-39	200	267	216	304	244	377	264	440	286	520
40-44	237	378	264	459	314	633	356	800	407	1000
45-49	325	535	384	688	506	1000	620	1000	770	1000
50-54	469	797	590	1000	860	1000	1000	1000	1000	1000
55-59	694	1000	925	1000	1000	1000	1000	1000	1000	1000
60-64	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
65-69	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
70-74	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
75+	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000

Age in Years	F = 757 Male	F = 757 Fem.	F = 804 Male	F = 804 Fem.	F = 853 Male	F = 853 Fem.	F = 901 Male	F = 901 Fem.	F = 948 Male	F = 948 Fem.
Under 1	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
1-4	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
5-9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
10-14	970	576	1000	815	1000	1000	1000	1000	1000	1000
15-19	440	325	576	387	847	493	1000	690	1000	1000
20-24	311	280	364	317	454	373	613	463	870	591
25-29	276	298	311	344	364	419	446	547	560	745
30-34	276	357	311	439	364	587	446	881	560	1000
35-39	340	752	412	1000	537	1000	779	1000	1000	1000
40-44	546	1000	761	1000	1000	1000	1000	1000	1000	1000
45-49	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
50-54	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
55-59	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
60-64	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
65-69	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
70-74	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
75+	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000

SOURCE: Based on data from Hiroshima-Nagasaki bombings compiled by the Dikewood Corporation. See Sec. IV for derivation. Values for crude fatality rates are derived by application of component-specific rates to U.S. population of 1960.

Table 26

PREATTACK POPULATION AND SURVIVORS OF FIVE SIMULATED ATTACKS, ALTERNATIVE SHELTERING ASSUMPTIONS, BY AGE, SEX, AND COLOR; CONTERMINOUS UNITED STATES, 1960

Age	White		Nonwhite		Total	
	Male	Female	Male	Female	Male	Female
	Preattack Population					
75+	2,108,760	2,865,806	171,830	202,354	2,280,590	3,068,160
70-74	1,971,297	2,338,362	161,836	179,388	2,133,133	2,517,750
65-69	2,634,648	3,029,227	242,067	267,759	2,876,715	3,296,986
60-64	3,096,527	3,416,769	277,502	302,231	3,374,029	3,719,000
55-59	3,768,952	3,982,072	398,821	417,242	4,167,773	4,399,314
50-54	4,307,365	4,455,913	436,858	461,771	4,744,223	4,917,684
45-49	4,840,186	4,980,436	509,497	554,854	5,349,683	5,535,290
40-44	5,080,245	5,287,564	539,352	605,466	5,619,597	5,893,030
35-39	5,444,555	5,694,680	610,393	691,996	6,054,948	6,386,676
30-34	5,198,951	5,365,141	606,577	712,820	5,805,528	6,077,961
25-29	4,705,715	4,825,520	592,788	680,874	5,298,503	5,506,394
20-24	4,625,741	4,808,535	611,134	683,396	5,236,875	5,491,931
15-19	5,874,268	5,762,279	782,668	795,392	6,656,936	6,557,671
10-14	7,472,847	7,173,863	1,046,941	1,039,099	8,519,788	8,212,962
5- 9	8,171,022	7,856,329	1,266,094	1,265,214	9,437,116	9,121,543
0- 4	8,831,539	8,483,042	1,448,651	1,443,116	10,280,190	9,926,158
Total	78,132,618	80,325,538	9,703,009	10,302,972	87,835,627	90,628,510
	Survivors of Attack 103, Protection Factor = 10					
75+	1,830,336	2,545,144	151,427	181,694	1,981,763	2,726,838
70-74	1,830,066	2,220,603	147,712	166,496	1,977,778	2,387,099
65-69	2,494,500	2,920,482	224,398	252,324	2,718,898	3,172,806
60-64	2,971,539	3,321,356	259,743	285,576	3,231,282	3,606,931
55-59	3,652,818	3,892,413	379,156	398,818	4,031,974	4,291,231
50-54	4,201,425	4,368,249	417,181	443,201	4,618,606	4,811,450
45-49	4,744,896	4,894,316	489,733	535,020	5,234,629	5,429,336
40-44	4,994,663	5,204,554	520,149	584,877	5,514,813	5,789,432
35-39	5,361,350	5,611,162	590,184	670,047	5,951,535	6,281,208
30-34	5,124,900	5,292,158	587,657	691,789	5,712,557	5,983,947
25-29	4,636,606	4,760,763	574,859	661,651	5,211,465	5,422,414
20-24	4,552,229	4,742,183	594,455	665,284	5,146,684	5,407,466
15-19	5,794,418	5,689,505	764,869	777,135	6,559,287	6,466,640
10-14	7,379,554	7,086,296	1,022,867	1,015,745	8,402,421	8,102,041
5- 9	8,063,026	7,755,281	1,235,176	1,234,682	9,298,202	8,989,963
0- 4	8,655,432	8,327,477	1,394,654	1,393,479	10,050,086	9,720,956
Total	76,287,752	78,631,937	9,354,222	9,957,815	85,641,974	88,589,753

Table 26 -- continued

Age	White		Nonwhite		Total	
	Male	Female	Male	Female	Male	Female
	Survivors of Attack 103, Protection Factor = 6					
75+	1,818,106	2,522,804	149,957	179,629	1,968,063	2,702,432
70-74	1,817,871	2,201,909	146,481	164,864	1,964,352	2,366,773
65-69	2,479,627	2,898,540	222,811	250,196	2,702,437	3,148,737
60-64	2,954,868	3,298,945	258,068	283,465	3,212,936	3,582,410
55-59	3,633,109	3,867,590	376,883	396,106	4,009,992	4,263,696
50-54	4,179,857	4,341,797	414,947	440,389	4,594,804	4,782,186
45-49	4,720,916	4,867,266	487,337	532,081	5,208,253	5,399,347
40-44	4,970,525	5,176,866	517,787	581,949	5,488,312	5,758,815
35-39	5,337,666	5,581,853	587,758	666,872	5,925,423	6,248,725
30-34	5,106,591	5,269,052	585,653	688,977	5,692,244	5,958,029
25-29	4,619,499	4,742,133	572,787	659,198	5,192,286	5,401,330
20-24	4,532,161	4,724,727	591,966	662,918	5,124,126	5,387,645
15-19	5,767,111	5,666,008	761,387	773,987	6,528,497	6,439,995
10-14	7,341,200	7,050,916	1,017,680	1,010,887	8,358,880	8,061,803
5- 9	8,017,476	7,713,240	1,228,040	1,228,024	9,245,516	8,941,263
0- 4	8,599,491	8,275,484	1,385,041	1,384,204	9,984,531	9,659,688
Total	75,896,068	78,199,126	9,304,582	9,903,743	85,200,649	88,102,868
	Survivors of Attack 103, Protection Factor = 3					
75+	1,760,668	2,437,026	144,847	173,652	1,905,515	2,610,679
70-74	1,759,656	2,127,316	141,349	159,219	1,901,005	2,286,535
65-69	2,409,599	2,800,982	215,974	241,784	2,625,573	3,042,766
60-64	2,886,764	3,198,924	251,501	274,542	3,138,265	3,473,466
55-59	3,561,215	3,770,861	368,626	385,849	3,929,841	4,156,710
50-54	4,103,446	4,249,311	406,465	430,574	4,509,911	4,679,885
45-49	4,638,963	4,773,872	478,067	521,251	5,117,030	5,295,122
40-44	4,886,451	5,083,209	508,376	570,801	5,394,827	5,654,010
35-39	5,261,559	5,485,907	578,730	654,904	5,840,289	6,140,811
30-34	5,045,172	5,191,444	578,064	678,249	5,623,236	5,869,692
25-29	4,562,854	4,681,266	565,257	650,158	5,128,111	5,331,425
20-24	4,468,227	4,666,316	583,198	654,115	5,051,425	5,320,432
15-19	5,667,106	5,589,111	747,282	762,396	6,414,388	6,351,507
10-14	7,215,176	6,932,562	998,473	992,485	8,213,649	7,925,048
5- 9	7,865,927	7,574,591	1,202,903	1,204,016	9,068,830	8,778,607
0- 4	8,394,618	8,096,952	1,349,824	1,352,385	9,744,443	9,449,337
Total	74,487,398	76,659,645	9,118,936	9,706,381	83,606,335	86,366,025

Table 26 -- continued

Age	White		Nonwhite		Total	
	Male	Female	Male	Female	Male	Female
Survivors of Attack 203, Protection Factor = 10						
75+	1,671,666	2,293,678	140,586	167,859	1,812,252	2,461,537
70-74	1,668,989	2,003,092	136,562	153,502	1,805,550	2,156,594
65-69	2,275,607	2,640,596	207,344	232,588	2,482,951	2,873,184
60-64	2,711,724	3,007,403	238,609	262,156	2,950,333	3,269,559
55-59	2,337,418	3,534,955	348,333	366,027	3,685,751	3,900,982
50-54	3,845,196	3,975,254	383,411	407,172	4,228,607	4,382,426
45-49	4,346,549	4,461,958	450,086	490,895	4,796,634	4,952,853
40-44	4,572,011	4,747,883	476,967	535,711	5,048,978	5,283,594
35-39	4,905,329	5,122,521	539,619	612,824	5,444,948	5,735,345
30-34	4,692,106	4,840,327	538,663	633,136	5,230,769	5,473,463
25-29	4,241,284	4,355,825	528,081	606,545	4,769,366	4,962,370
20-24	4,172,818	4,326,487	550,816	612,480	4,723,634	4,938,967
15-19	5,342,451	5,222,785	715,040	723,446	6,057,491	5,946,231
10-14	6,789,696	6,516,499	951,958	944,445	7,741,654	7,460,944
5- 9	7,390,561	7,110,705	1,143,131	1,143,380	8,533,692	8,254,085
0- 4	7,893,322	7,600,813	1,285,018	1,284,868	9,178,340	8,885,681
Total	69,856,725	71,760,777	8,634,223	9,177,033	78,490,947	80,937,811
Survivors of Attack 203, Protection Factor = 6						
75+	1,622,719	2,208,111	137,115	162,888	1,759,834	2,370,998
70-74	1,620,636	1,932,613	133,358	149,398	1,753,994	2,082,011
65-69	2,214,204	2,555,297	203,018	226,997	2,417,222	2,782,294
60-64	2,637,766	2,917,146	233,123	256,025	2,870,889	3,173,172
55-59	3,248,905	3,431,788	340,189	357,420	3,589,095	3,789,208
50-54	3,756,076	3,860,465	375,250	397,726	4,131,326	4,258,191
45-49	4,252,231	4,348,242	441,159	480,288	4,693,391	4,828,530
40-44	4,477,764	4,636,219	467,826	524,544	4,945,590	5,160,763
35-39	4,810,635	5,007,739	529,604	600,331	5,340,239	5,608,070
30-34	4,619,228	4,748,872	530,593	621,969	5,149,821	5,370,841
25-29	4,174,378	4,281,625	520,142	596,901	4,694,520	4,878,525
20-24	4,098,744	4,259,042	542,359	604,047	4,641,104	4,863,089
15-19	5,246,636	5,136,027	705,249	714,068	5,951,885	5,850,094
10-14	6,651,075	6,389,281	936,077	929,519	7,587,151	7,318,800
5- 9	7,214,888	6,952,749	1,120,028	1,122,058	8,334,916	8,074,807
0- 4	7,669,633	7,386,621	1,253,440	1,253,897	8,923,073	8,640,518
Total	68,315,516	70,051,833	8,468,530	8,998,076	76,784,046	79,049,908

Table 26 -- continued

Age	White		Nonwhite		Total	
	Male	Female	Male	Female	Male	Female
Survivors of Attack 203, Protection Factor = 3						
75+	1,507,390	2,039,337	128,104	151,650	1,635,494	2,190,987
70-74	1,494,092	1,773,582	123,690	138,428	1,617,782	1,912,010
65-69	2,053,279	2,338,661	189,328	209,911	2,242,607	2,548,572
60-64	2,471,316	2,686,049	218,489	236,879	2,689,805	2,922,928
55-59	3,063,979	3,199,917	320,201	333,507	3,384,179	3,533,424
50-54	3,544,184	3,628,701	353,051	373,473	3,897,235	4,002,175
45-49	4,014,066	4,094,178	415,048	451,128	4,429,114	4,545,306
40-44	4,223,154	4,366,299	438,999	491,945	4,662,153	4,858,244
35-39	4,566,676	4,718,396	500,047	562,539	5,066,723	5,280,935
30-34	4,410,501	4,501,078	504,954	586,444	4,915,455	5,087,521
25-29	3,985,008	4,082,464	495,265	567,090	4,480,273	4,649,554
20-24	3,905,506	4,066,618	516,549	576,088	4,422,055	4,642,706
15-19	4,969,388	4,900,728	669,938	683,203	5,639,326	5,583,931
10-14	6,301,625	6,051,740	887,773	881,496	7,189,399	6,933,236
5-9	6,828,640	6,582,313	1,058,697	1,061,513	7,887,337	7,643,826
0-4	7,206,157	6,973,049	1,174,504	1,180,148	8,380,661	8,153,198
Total	64,544,958	66,003,107	7,994,637	8,485,443	72,539,594	74,488,547
Survivors of Attack 130, Protection Factor = 10						
75+	1,594,658	2,195,382	131,648	157,442	1,726,306	2,352,825
70-74	1,600,486	1,926,048	128,915	144,971	1,729,400	2,071,018
65-69	2,191,430	2,546,642	196,892	221,260	2,388,322	2,767,902
60-64	2,629,680	2,906,650	229,263	250,446	2,858,943	3,157,096
55-59	3,247,691	3,429,161	336,190	352,319	3,583,881	3,781,480
50-54	3,761,069	3,871,230	372,118	393,098	4,133,187	4,264,329
45-49	4,266,751	4,367,559	439,199	477,484	4,705,950	4,845,043
40-44	4,521,374	4,669,009	469,207	524,094	4,990,581	5,193,103
35-39	4,884,609	5,065,628	535,457	603,886	5,420,066	5,669,514
30-34	4,710,352	4,823,573	536,789	628,569	5,247,142	5,452,142
25-29	4,254,983	4,357,476	524,689	603,296	4,779,672	4,960,772
20-24	4,138,278	4,349,070	540,308	608,200	4,678,586	4,957,269
15-19	5,243,813	5,187,814	692,989	707,737	5,936,801	5,895,551
10-14	6,642,287	6,408,345	920,647	918,688	7,562,935	7,327,033
5-9	7,190,788	6,944,606	1,102,868	1,106,281	8,293,655	8,050,887
0-4	7,631,729	7,364,738	1,231,361	1,234,303	8,863,090	8,599,042
Total	68,509,974	70,412,929	8,388,540	8,932,073	76,898,514	79,345,002

Table 26 -- continued

Age	White		Nonwhite		Total	
	Male	Female	Male	Female	Male	Female
Survivors of Attack 130, Protection Factor = 6						
75+	1,460,867	1,984,147	121,269	144,002	1,582,136	2,128,149
70-74	1,473,946	1,755,309	119,421	133,598	1,593,367	1,888,907
65-69	2,029,822	2,338,631	183,435	205,237	2,213,257	2,543,867
60-64	2,432,431	2,683,997	212,967	233,134	2,645,397	2,917,131
55-59	3,007,106	3,165,752	312,359	327,577	3,319,465	3,493,329
50-54	3,493,506	3,574,548	346,950	365,420	3,840,456	3,939,968
45-49	3,967,732	4,050,600	410,479	445,656	4,378,211	4,496,255
40-44	4,210,185	4,337,307	439,230	489,724	4,649,415	4,827,031
35-39	4,570,433	4,700,775	503,814	563,564	5,074,247	5,264,339
30-34	4,434,005	4,515,282	508,200	591,739	4,942,204	5,107,021
25-29	4,003,694	4,090,656	496,794	569,705	4,500,488	4,660,362
20-24	3,877,663	4,089,761	509,818	576,329	4,387,480	4,666,090
15-19	4,900,567	4,861,796	652,177	668,132	5,552,744	5,529,927
10-14	6,173,965	5,960,075	860,787	859,862	7,034,752	6,819,937
5-9	6,673,891	6,452,783	1,028,939	1,033,514	7,702,829	7,486,297
0-4	7,050,689	6,803,155	1,143,854	1,146,308	8,194,543	7,949,463
Total	63,760,498	65,364,571	7,850,491	8,353,500	71,610,987	73,718,069
Survivors of Attack 130, Protection Factor = 3						
75+	1,233,080	1,678,601	102,410	122,620	1,335,490	1,801,222
70-74	1,231,829	1,469,161	100,155	112,839	1,331,984	1,581,999
65-69	1,714,431	1,944,061	156,127	172,716	1,870,559	2,116,778
60-64	2,091,692	2,250,495	184,863	198,001	2,276,555	2,448,496
55-59	2,613,013	2,706,617	274,054	283,575	2,887,067	2,990,191
50-54	3,036,298	3,095,829	304,351	320,376	3,349,649	3,416,205
45-49	3,447,788	3,515,393	360,691	391,664	3,808,479	3,907,057
40-44	3,642,564	3,763,491	383,968	430,030	4,026,532	4,193,521
35-39	4,008,050	4,080,340	444,846	494,227	4,452,895	4,574,567
30-34	3,940,897	3,943,281	454,173	521,028	4,395,069	4,464,309
25-29	3,557,295	3,619,586	443,870	507,622	4,001,165	4,127,207
20-24	3,421,666	3,628,313	453,384	515,270	3,875,050	4,143,583
15-19	4,232,284	4,290,477	570,959	595,971	4,803,242	4,886,448
10-14	5,382,257	5,182,285	759,032	756,904	6,141,289	5,939,189
5-9	5,814,521	5,621,199	905,830	910,531	6,720,351	6,531,731
0-4	6,079,363	5,909,589	994,924	1,005,439	7,074,287	6,915,027
Total	55,447,026	56,698,715	6,893,636	7,338,812	62,340,661	64,037,526

Table 26 -- continued

Age	White		Nonwhite		Total	
	Male	Female	Male	Female	Male	Female
Survivors of Attack 599, Protection Factor = 10						
75+	1,400,494	1,867,035	122,818	143,851	1,523,312	2,010,886
70-74	1,386,201	1,626,521	117,554	131,040	1,503,755	1,757,560
65-69	1,886,131	2,150,015	177,341	198,419	2,063,472	2,348,434
60-64	2,240,084	2,452,562	199,539	219,842	2,439,624	2,672,404
55-59	2,766,136	2,899,177	290,134	304,942	3,056,270	3,204,119
50-54	3,206,452	3,276,644	320,433	338,889	3,526,885	3,615,533
45-49	3,641,966	3,696,271	374,976	408,132	4,016,943	4,104,403
40-44	3,836,242	3,947,056	393,080	440,165	4,229,321	4,387,221
35-39	4,115,557	4,278,584	439,813	499,209	4,555,370	4,777,793
30-34	3,936,234	4,056,234	438,717	515,090	4,374,952	4,571,324
25-29	3,564,045	3,661,213	434,713	495,574	3,998,759	4,156,788
20-24	3,547,465	3,622,347	468,156	507,568	4,015,621	4,129,915
15-19	4,583,336	4,428,679	626,561	624,292	5,209,897	5,052,971
10-14	5,784,032	5,549,071	822,255	813,992	6,606,286	6,363,063
5- 9	6,252,076	6,016,854	972,549	973,224	7,224,625	6,990,078
0- 4	6,609,383	6,374,317	1,079,267	1,079,474	7,688,650	7,453,791
Total	58,755,833	59,902,578	7,277,906	7,693,702	66,033,739	67,596,279
Survivors of Attack 599, Protection Factor = 6						
75+	1,247,302	1,626,132	113,981	132,197	1,361,284	1,758,329
70-74	1,239,848	1,429,694	109,159	120,988	1,349,007	1,550,681
65-69	1,696,653	1,907,372	165,110	183,993	1,861,763	2,091,364
60-64	2,017,482	2,190,009	184,492	203,516	2,201,975	2,393,525
55-59	2,506,312	2,601,601	268,901	282,125	2,775,212	2,883,726
50-54	2,946,750	2,949,586	300,175	314,138	3,246,925	3,263,724
45-49	3,373,668	3,374,772	353,097	381,344	3,726,764	3,756,116
40-44	3,582,102	3,635,162	371,628	412,742	3,953,730	4,047,904
35-39	3,889,299	3,964,678	419,171	469,155	4,308,470	4,433,833
30-34	3,777,780	3,829,338	423,501	491,417	4,201,281	4,320,754
25-29	3,422,745	3,495,331	420,282	477,160	3,843,027	3,972,491
20-24	3,382,449	3,474,030	451,560	491,535	3,834,009	3,965,565
15-19	4,323,573	4,208,144	602,960	603,437	4,926,533	4,811,581
10-14	5,373,236	5,181,598	782,698	777,393	6,155,934	5,958,991
5- 9	5,736,159	5,555,162	915,967	920,378	6,652,126	6,475,539
0- 4	5,954,666	5,753,487	1,002,393	1,003,393	6,957,059	6,756,880
Total	54,470,023	55,176,092	6,885,074	7,264,908	61,355,097	62,441,001

Table 26 -- continued

Age	White		Nonwhite		Total	
	Male	Female	Male	Female	Male	Female
Survivors of Attack 599, Protection Factor = 3						
75+	974,819	1,274,404	98,157	114,087	1,072,975	1,388,490
70-74	955,267	1,104,625	92,389	103,050	1,047,656	1,207,675
65-69	1,328,819	1,457,387	140,926	155,536	1,469,744	1,612,924
60-64	1,625,490	1,697,650	158,352	171,634	1,783,842	1,869,284
55-59	2,058,666	2,086,549	233,423	241,845	2,292,089	2,328,393
50-54	2,420,497	2,415,316	260,436	273,283	2,680,932	2,688,598
45-49	2,772,564	2,767,088	305,684	330,731	3.078,248	3,097,819
40-44	2,929,833	2,976,810	317,792	354,952	3,247,625	3,331,762
35-39	3,250,496	3,250,273	360,933	400,552	3,611,429	3,650,825
30-34	3,222,013	3,176,683	370,572	422,017	3,592,585	3,598,700
25-29	2,927,957	2,961,002	369,785	416,948	3,297,742	3,377,949
20-24	2,880,823	2,959,587	400,094	434,778	3,280,917	3,394,366
15-19	3,572,958	3,564,155	534,769	541,667	4,107,728	4,105,822
10-14	4,459,228	4,287,384	695,259	688,773	5,154,486	4,976,156
5- 9	4,756,534	4,604,894	808,235	812,559	5,564,769	5,417,452
0- 4	4,852,326	4,749,174	870,727	879,394	5,723,053	5,628,568
Total	44,988,287	45,332,976	6,017,531	6,341,804	51,005,818	51,674,780
Survivors of Attack 430, Protection Factor = 10						
75+	1,158,117	1,519,205	103,441	120,707	1,261,558	1,639,912
70-74	1,151,255	1,333,273	99,444	110,688	1,250,700	1,443,961
65-69	1,577,127	1,776,775	151,132	168,745	1,728,259	1,945,520
60-64	1,893,266	2,038,374	171,136	187,198	2,064,402	2,225,572
55-59	2,353,760	2,434,778	250,504	262,031	2,604,264	2,696,808
50-54	2,749,371	2,776,451	278,556	293,251	3,027,926	3,069,702
45-49	3,136,998	3,157,047	327,743	355,389	3,464,741	3,512,436
40-44	3,332,109	3,389,692	345,937	384,382	3,678,047	3,774,074
35-39	3,602,219	3,701,188	389,057	438,295	3,991,276	4,139,482
30-34	3,479,517	3,552,392	391,206	456,401	3,870,723	4,008,793
25-29	3,145,340	3,222,441	387,356	440,971	3,532,696	3,663,412
20-24	3,101,465	3,196,092	415,843	453,411	3,517,308	3,649,503
15-19	3,991,290	3,889,439	556,010	557,210	4,547,300	4,446,649
10-14	4,997,738	4,822,150	723,572	720,225	5,721,311	5,542,376
5- 9	5,345,154	5,165,076	847,803	851,542	6,192,957	6,016,618
0- 4	5,570,777	5,396,974	928,815	933,031	6,499,592	6,330,005
Total	50,585,501	51,371,345	6,367,555	6,733,476	56,953,056	58,104,821

Table 26 -- continued

Age	White		Nonwhite		Total	
	Male	Female	Male	Female	Male	Female
Survivors of Attack 430, Protection Factor = 6						
75+	908,657	1,150,700	86,054	97,990	994,711	1,248,690
70-74	915,970	1,033,428	83,475	91,470	999,445	1,124,898
65-69	1,269,758	1,401,653	127,972	141,392	1,397,729	1,543,045
60-64	1,521,064	1,627,285	143,429	157,224	1,664,493	1,784,510
55-59	1,906,601	1,950,093	210,877	219,711	2,117,477	2,169,804
50-54	2,281,658	2,229,530	239,085	246,380	2,520,743	2,475,911
45-49	2,639,498	2,597,508	283,987	303,407	2,923,485	2,900,915
40-44	2,838,375	2,830,846	301,745	330,570	3,140,120	3,161,416
35-39	3,131,067	3,112,582	344,578	377,347	3,475,645	3,489,929
30-34	3,113,075	3,082,889	355,694	404,227	3,468,768	3,487,116
25-29	2,815,174	2,850,123	352,847	397,516	3,168,020	3,247,639
20-24	2,735,750	2,851,950	375,703	413,470	3,111,452	3,265,420
15-19	3,458,100	3,407,918	498,789	504,114	3,956,889	3,912,032
10-14	4,222,008	4,100,416	635,737	635,844	4,857,744	4,736,261
5- 9	4,435,597	4,329,139	732,619	741,295	5,168,216	5,070,434
0- 4	4,496,155	4,360,361	784,487	788,545	5,280,641	5,148,906
Total	42,688,504	42,916,420	5,557,075	5,850,502	48,245,579	48,766,922
Survivors of Attack 430, Protection Factor = 3						
75+	592,106	764,775	57,513	66,570	649,619	831,345
70-74	581,707	665,709	54,502	60,589	636,209	726,298
65-69	827,557	882,531	86,354	92,126	913,911	974,656
60-64	1,037,420	1,047,025	101,635	104,865	1,139,055	1,151,890
55-59	1,335,638	1,319,670	154,648	154,936	1,490,287	1,474,607
50-54	1,589,484	1,557,220	176,253	180,265	1,765,737	1,737,486
45-49	1,835,215	1,810,641	209,852	223,455	2,045,067	2,034,096
40-44	1,949,977	1,963,345	219,667	242,496	2,169,643	2,205,840
35-39	2,227,044	2,159,232	255,705	275,736	2,482,749	2,434,967
30-34	2,280,229	2,162,324	270,415	297,414	2,550,645	2,459,738
25-29	2,070,066	2,061,383	270,167	300,196	2,340,233	2,361,580
20-24	1,994,063	2,075,000	288,313	316,513	2,282,376	2,391,513
15-19	2,382,982	2,455,659	373,446	390,467	2,756,428	2,846,126
10-14	2,961,028	2,853,286	481,386	479,290	3,442,415	3,332,576
5- 9	3,122,035	3,038,318	548,836	556,448	3,670,871	3,594,766
0- 4	3,104,246	3,068,935	566,850	582,553	3,671,096	3,651,488
Total	29,890,794	29,885,051	4,115,546	4,323,918	34,006,340	34,208,970

SOURCES: Preattack population summarized from U.S. Bureau of the Census, U.S. Census of Population: 1960, Vol. I, Characteristics of the Population, Table 37, for individual states and the District of Columbia. See Secs. II, III, and IV for derivation of surviving populations.

Table 27

FIVE-YEAR SURVIVAL RATES FOR POSTATTACK POPULATION PROJECTIONS, BY AGE, SEX, AND COLOR: 1960-1985

Probability of Surviving for Five Years

Age in Years	Mid-1960		Mid-1965		Mid-1970	
	Male	Fem.	Male	Fem.	Male	Fem.
Whites						
0-4	.9098	.9105	.9445	.9463	.9648	.9669
5-9	.9725	.9707	.9834	.9828	.9893	.9895
10-14	.9729	.9701	.9827	.9819	.9884	.9886
15-19	.9612	.9587	.9741	.9745	.9824	.9838
20-24	.9530	.9500	.9688	.9694	.9789	.9807
25-29	.9494	.9456	.9673	.9674	.9781	.9792
30-34	.9437	.9419	.9644	.9654	.9760	.9777
35-39	.9336	.9372	.9580	.9622	.9711	.9749
40-44	.9180	.9290	.9467	.9556	.9617	.9691
45-49	.8964	.9140	.9294	.9437	.9469	.9589
50-54	.8664	.8910	.9045	.9252	.9250	.9433
55-59	.8249	.8538	.8678	.8949	.8919	.9175
60-64	.7660	.7967	.8141	.8459	.8423	.8743
65-69	.6820	.7145	.7367	.7710	.7698	.8059
70+	.4770	.4976	.5440	.5214	.5483	.5726
e_o, both sexes[a]	40.0 years		50.0 years		57.6 years	

Age in Years	Mid-1975		Mid-1980		Mid-1985	
0-4	.9765	.9791	.9867	.9892	.9908	.9925
5-9	.9924	.9932	.9949	.9962	.9963	.9972
10-14	.9914	.9925	.9941	.9956	.9955	.9967
15-19	.9871	.9891	.9913	.9935	.9935	.9952
20-24	.9847	.9869	.9898	.9920	.9924	.9940
25-29	.9840	.9858	.9891	.9909	.9916	.9929
30-34	.9822	.9842	.9874	.9893	.9897	.9913
35-39	.9779	.9814	.9835	.9866	.9860	.9886
40-44	.9696	.9759	.9759	.9814	.9786	.9835
45-49	.9558	.9668	.9632	.9731	.9664	.9754
50-54	.9356	.9529	.9441	.9609	.9481	.9637
55-59	.9044	.9298	.9148	.9402	.9198	.9437
60-64	.8573	.8903	.8702	.9036	.8765	.9083
65-69	.7881	.8259	.8042	.8429	.8119	.8490
70+	.5631	.5890	.5759	.6028	.5820	.6078
e_o, both sexes[a]	63.2 years		68.2 years		70.2 years	

For footnotes, see next page.

Table 27 -- continued

Age in Years	Mid-1960 Male	Mid-1960 Fem.	Mid-1965 Male	Mid-1965 Fem.	Mid-1970 Male	Mid-1970 Fem.
Nonwhites						
0-4	.8868	.8870	.9287	.9300	.9518	.9537
5-9	.9651	.9627	.9785	.9773	.9856	.9852
10-14	.9666	.9628	.9783	.9764	.9848	.9843
15-19	.9532	.9495	.9681	.9671	.9772	.9778
20-24	.9434	.9387	.9615	.9606	.9725	.9735
25-29	.9381	.9322	.9592	.9577	.9712	.9718
30-34	.9301	.9265	.9551	.9550	.9686	.9700
35-39	.9170	.9204	.9473	.9513	.9628	.9669
40-44	.8980	.9110	.9342	.9439	.9523	.9606
45-49	.8734	.8942	.9150	.9304	.9359	.9493
50-54	.8406	.8688	.8877	.9098	.9121	.9318
55-59	.7964	.8285	.8488	.8761	.8767	.9030
60-64	.7355	.7682	.7924	.8230	.8244	.8559
65-69	.6492	.6830	.7116	.7443	.7487	.7832
70+	.4506	.4719	.5009	.5220	.5312	.5540
e_o, both sexes[a]	35.0 years		45.0 years		52.5 years	

Age in Years	Mid-1975 Male	Mid-1975 Fem.	Mid-1980 Male	Mid-1980 Fem.	Mid-1985 Male	Mid-1985 Fem.
0-4	.9648	.9669	.9765	.9791	.9867	.9892
5-9	.9893	.9895	.9924	.9932	.9949	.9962
10-14	.9884	.9886	.9914	.9925	.9941	.9956
15-19	.9824	.9838	.9871	.9891	.9913	.9935
20-24	.9789	.9807	.9847	.9869	.9898	.9920
25-29	.9781	.9792	.9840	.9858	.9891	.9909
30-34	.9760	.9777	.9822	.9842	.9874	.9893
35-39	.9711	.9749	.9779	.9814	.9835	.9866
40-44	.9617	.9691	.9696	.9759	.9759	.9814
45-49	.9469	.9589	.9558	.9668	.9632	.9731
50-54	.9250	.9433	.9356	.9529	.9441	.9609
55-59	.8919	.9175	.9044	.9298	.9148	.9402
60-64	.8423	.8743	.8573	.8903	.8702	.9036
65-69	.7698	.8059	.7881	.8259	.8042	.8429
70+	.5483	.5726	.5631	.5890	.5759	.6028
e_o, both sexes[a]	57.6 years		63.2 years		68.2 years	

SOURCE: Manuals on Methods of Estimating Population, Manual III, Methods for Population Projections by Sex and Age, United Nations Publication ST/SOA/Series A/25, New York, 1956, pp. 70-81. Values for ages 0-69 from Table IV; values for ages 70+ computed from Table III.

[a] e_o = life expectancy at birth.

Table 28

POPULATION PROJECTIONS FOR ATTACK 430, PF = 3, AND SCALAR DAMAGE CASE: PERCENTAGE DISTRIBUTIONS BY AGE AND SEX, 1960-1985

Age in Years	Postattack 1960		1965		1970		1975		1980		1985	
	Male	Fem.	Male	Fem.	Male	Fem.	Male	Fem.	Male	Fem.	Male	Fem.
Attack 430, PF = 3; Series I												
70+	1.9	2.3	1.7	1.9	1.5	1.7	1.5	1.7	1.5	1.8	1.5	1.9
65-69	1.3	1.4	1.2	1.3	1.3	1.4	1.3	1.5	1.4	1.6	1.4	1.6
60-64	1.7	1.7	1.8	1.8	1.8	1.9	1.9	2.1	1.8	2.1	1.9	2.1
55-59	2.2	2.2	2.2	2.3	2.3	2.5	2.3	2.5	2.4	2.5	2.2	2.3
50-54	2.6	2.5	2.7	2.8	2.7	2.8	2.8	2.9	2.7	2.7	2.2	2.3
45-49	3.0	3.0	3.0	3.1	3.2	3.2	3.1	3.0	2.6	2.7	2.3	2.4
40-44	3.2	3.2	3.5	3.4	3.4	3.3	2.9	3.0	2.6	2.8	2.9	3.0
35-39	3.6	3.6	3.6	3.5	3.2	3.2	2.9	3.1	3.2	3.4	3.7	3.6
30-34	3.7	3.6	3.3	3.4	3.1	3.3	3.5	3.7	4.1	4.0	4.0	4.0
25-29	3.4	3.5	3.3	3.4	3.8	3.9	4.5	4.3	4.4	4.3	4.1	4.1
20-24	3.3	3.5	4.0	4.1	4.8	4.6	4.8	4.7	4.5	4.5	2.9	2.8
15-19	4.0	4.2	5.0	4.8	5.2	5.1	4.9	4.9	3.2	3.1	3.6	3.4
10-14	5.0	4.9	5.4	5.3	5.2	5.2	3.5	3.7	3.9	3.8	4.7	4.5
5-9	5.4	5.3	5.4	5.4	3.7	3.6	4.3	4.1	5.2	4.9	5.9	5.6
0-4	5.4	5.4	3.8	3.7	4.5	4.3	5.6	5.3	6.4	6.1	6.6	6.3
Total	49.9	50.1	49.9	50.1	49.9	50.1	49.9	50.1	49.9	50.1	50.0	50.0
Attack 430, PF = 3; Series II												
70+	1.9	2.3	1.6	1.9	1.4	1.6	1.4	1.6	1.3	1.6	1.4	1.7
65-69	1.3	1.4	1.2	1.2	1.2	1.3	1.2	1.3	1.2	1.4	1.2	1.4
60-64	1.7	1.7	1.7	1.8	1.7	1.8	1.7	1.9	1.6	1.8	1.7	1.9
55-59	2.2	2.2	2.2	2.2	2.2	2.3	2.1	2.2	2.1	2.2	2.0	2.1
50-54	2.6	2.6	2.6	2.7	2.5	2.6	2.6	2.6	2.4	2.4	2.0	2.1
45-49	3.0	3.0	2.9	3.0	3.0	3.0	2.8	2.7	2.3	2.4	2.1	2.2
40-44	3.2	3.2	3.4	3.4	3.2	3.1	2.6	2.7	2.3	2.5	2.6	2.7
35-39	3.6	3.6	3.5	3.4	3.0	3.0	2.6	2.8	2.9	3.0	3.3	3.2
30-34	3.7	3.6	3.3	3.3	2.9	3.1	3.2	3.3	3.6	3.5	3.6	3.5
25-29	3.4	3.5	3.2	3.3	3.5	3.7	4.0	3.9	3.9	3.9	3.6	3.6
20-24	3.3	3.5	3.9	4.0	4.5	4.3	4.4	4.3	4.0	4.0	3.5	3.4
15-19	4.0	4.2	4.9	4.7	4.8	4.7	4.4	4.4	3.9	3.7	5.0	4.8
10-14	5.0	4.9	5.2	5.1	4.9	4.8	4.3	4.1	5.5	5.2	5.6	5.4
5-9	5.4	5.3	5.2	5.2	4.7	4.5	6.0	5.8	6.2	5.9	6.1	5.9
0-4	5.4	5.4	5.1	4.8	6.6	6.3	6.8	6.5	6.7	6.4	6.5	6.2
Total	49.8	50.2	49.9	50.1	50.0	50.0	50.0	50.0	50.0	50.0	50.1	49.9

Table 28 -- continued

Age in Years	Postattack 1960		1965		1970		1975		1980		1985	
	Male	Fem.	Male	Fem.	Male	Fem.	Male	Fem.	Male	Fem.	Male	Fem.
Scalar Damage Case; Series I												
70+	2.5	3.1	2.2	2.6	1.9	2.3	1.8	2.2	1.7	2.2	1.7	2.2
65-69	1.6	1.8	1.4	1.6	1.4	1.7	1.5	1.7	1.5	1.7	1.4	1.7
60-64	1.9	2.1	1.9	2.1	1.9	2.2	2.0	2.3	1.9	2.2	1.9	2.2
55-59	2.3	2.5	2.3	2.5	2.4	2.7	2.4	2.7	2.3	2.6	2.1	2.3
50-54	2.7	2.8	2.8	2.9	2.7	3.0	2.8	3.0	2.4	2.7	2.1	2.2
45-49	3.0	3.1	3.0	3.2	3.1	3.3	2.8	3.0	2.4	2.5	2.1	2.3
40-44	3.2	3.3	3.3	3.5	3.1	3.2	2.6	2.8	2.4	2.6	2.8	2.8
35-39	3.4	3.6	3.2	3.4	2.8	3.0	2.7	2.8	3.1	3.1	3.7	3.6
30-34	3.2	3.4	3.0	3.1	2.8	3.0	3.4	3.4	4.0	3.9	4.2	4.0
25-29	3.0	3.1	2.9	3.1	3.6	3.6	4.4	4.3	4.6	4.4	4.6	4.4
20-24	2.9	3.1	3.7	3.7	4.7	4.5	5.0	4.8	5.0	4.9	2.8	2.7
15-19	3.7	3.7	4.8	4.6	5.3	5.1	5.5	5.3	3.1	2.9	3.4	3.3
10-14	4.8	4.6	5.4	5.2	5.8	5.6	3.3	3.2	3.7	3.6	4.6	4.4
5-9	5.3	5.1	5.9	5.7	3.5	3.3	3.6	3.9	5.0	4.8	5.9	5.7
0-4	5.8	5.6	3.6	3.4	4.3	4.1	5.5	5.2	6.5	6.2	6.7	6.4
Total	49.2	50.8	49.4	50.6	49.5	50.5	49.5	50.5	49.7	50.3	49.9	50.1
Scalar Damage Case: Series II												
70+	2.5	3.1	2.1	2.6	1.8	2.2	1.6	2.0	1.5	1.9	1.5	1.9
65-69	1.6	1.8	1.4	1.6	1.4	1.6	1.3	1.5	1.3	1.6	1.2	1.5
60-64	1.9	2.1	1.9	2.1	1.8	2.0	1.8	2.0	1.7	2.0	1.7	2.0
55-59	2.3	2.5	2.3	2.4	2.3	2.5	2.1	2.4	2.1	2.4	1.8	2.1
50-54	2.7	2.8	2.7	2.9	2.6	2.8	2.5	2.8	2.2	2.4	1.8	2.0
45-49	3.0	3.1	2.9	3.1	2.9	3.1	2.5	2.7	2.1	2.2	1.9	2.0
40-44	3.2	3.3	3.2	3.4	2.9	3.0	2.4	2.5	2.2	2.3	2.5	2.5
35-39	3.4	3.6	3.1	3.3	2.7	2.8	2.4	2.5	2.8	2.8	3.3	3.2
30-34	3.2	3.4	2.9	3.0	2.7	2.8	3.1	3.0	3.6	3.5	3.7	3.6
25-29	3.0	3.1	2.9	3.0	3.4	3.3	4.0	3.9	4.1	4.0	4.1	4.0
20-24	2.9	3.1	3.6	3.6	4.4	4.2	4.5	4.4	4.5	4.4	3.3	3.2
15-19	3.7	3.7	4.7	4.5	4.9	4.8	5.0	4.8	3.7	3.5	4.8	4.6
10-14	4.8	4.6	5.3	5.1	5.4	5.2	4.0	3.9	5.2	5.0	5.5	5.3
5-9	5.3	5.1	5.7	5.5	4.4	4.2	5.7	5.5	6.1	5.8	6.2	5.9
0-4	5.8	5.6	4.6	4.3	6.2	5.9	6.7	6.4	6.8	6.5	6.6	6.3
Total	49.2	50.8	49.4	50.6	49.6	50.4	49.7	50.3	49.9	50.1	50.0	50.0

SOURCES: Preattack population and survivors of Attack 430, PF = 3, are tabulated in Table 26. Postattack 1960 population for scalar damage case derived by reducing each component to 38.2 percent of its preattack value. Projections to 1985, and vital rates assumed for Series I and II, are described in Sec. VI.

NOTE: Distributions may not add exactly to totals because of rounding.