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ABSTRACT

Contour maps of Italian male and female mortality rates from age 0 to 79 and from 1870 to 1979 graphically display persistent global and prominent local patterns of mortality, simultaneously over age, by period, and for cohorts. The maps give demographers visual access to previously recognized features of the evolution of Italian mortality as well as focusing attention on some neglected features. Use of contour maps to display various kinds of mortality data, including mortality comparisons, may help demographers better understand the social and biological determinants of mortality.

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INTRODUCTION

Contour maps provide an intelligible and graphically striking means of summarizing large arrays of demographic data that are structured by age and time. Here we use contour maps to depict both the general development and the prominent local details of age-specific male and female mortality rates for Italy from 1870 to 1979. Contour maps permit demographers to visualize mortality surfaces from a different perspective than the usual graphs of mortality rates at selected ages over time or at selected times over age. This change in vantage point can highlight previously obscure patterns in the interaction of age, period, and cohort effects, and thus stimulate a deeper understanding of the evolution of mortality over age and time and its possible social and biological determinants. For example, the map of Italian male mortality shown in Figure 1 reveals a striking but unremarked pattern of high mortality for the cohorts who were in their early twenties during World War I.

CONTOUR MAP METHODS

Contour maps, which are widely used in depicting spatial patterns, can be readily adapted to represent any surface that is defined over two dimensions. Thus, as illustrated in Vaupel, Gambill and Yashin (1985), contour maps can summarize a variety of age-specific demographic data that vary over time, such as population size and rates of fertility, marriage, divorce, immigration, morbidity, and mortality.

Contour maps have been used only occasionally by demographers, perhaps because of the computational effort required and because of the lack of detailed data over long stretches of age and time. In a pioneering study, Delaporte (1941) published a set of contour maps that summarized mortality patterns in several European countries; Federici (1955) directed attention to Delaporte's work in her important survey of demographic methods. Recent advances in computers, including the development of powerful micro-computers, and the collection and publication of extensive arrays of demographic rates for single years of age and single years of time (e.g., Natale and Bernassola (1973), Vallin (1973), Heuser (1976) and Veys (1983)), may lead to greater use of demographic contour maps in the future.

The contour maps presented in this paper are all based on annual mortality rates, ${}_1q$, that are available for single years of age from 0 to 79 and for single years of time from 1870 to 1979. The data are discrete, but a surface is continuous: we defined the surface $q(x,y)$ by linearly interpolating between adjacent data points. The values of $q(x,y)$ give the height of the mortality surface over age x and time y.

The lines on a contour map connect adjacent points that are of equal height; these lines are sometimes called level lines or isograms. In Figure 2, one of the level lines represents a mortality rate of about 11 percent: the line starts in 1870 at age 28 and ends in 1979 at age 64, indicating that 64-year-old Italian women in recent years faced the same chance of mortality that 28-year-olds faced about a century ago.

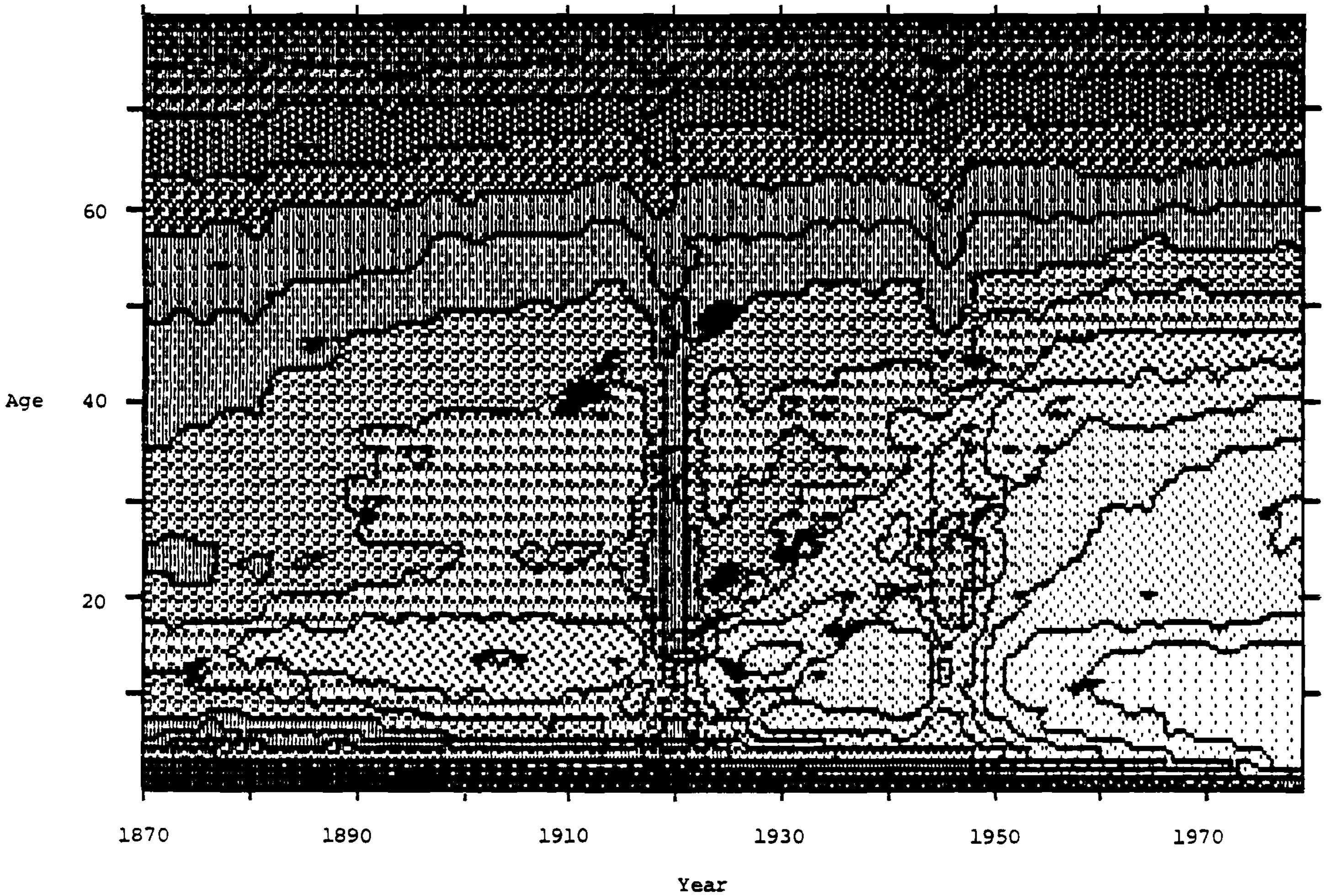
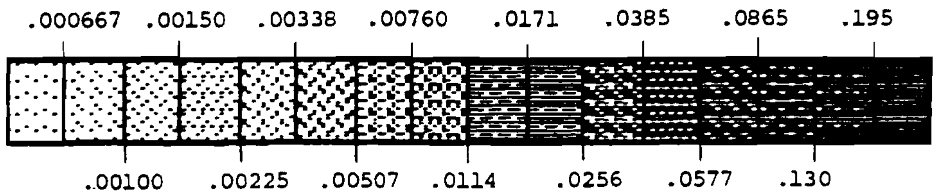


Figure 1. Italian Male Mortality Rates, not smoothed, for ages 0 to 79 and years 1870 to 1979, with contours from .000667 to .195 at multiples of 1.5:



An important consideration in designing a contour map is how many different levels to use. The computer program that we employed to draw the maps, which was developed by Bradley Gambill under one of our (Vaupel's) supervision at Duke University and at the International Institute for Applied Systems Analysis, allows lines to be drawn at 15 levels, separating the surface into 16 tiers. Use of fewer lines sacrifices detail, whereas use of more lines makes the map less intelligible: 15 levels seems to be a reasonable compromise, although use of 10 or 20 levels might be considered. Delaporte draws lines at 19, 20, or 21 levels on his various maps of European mortality.

What specific elevations the contour lines should connect is a second important design decision. On mortality surfaces, where mortality rates might approach a minimum of the order of magnitude of 0.0001 and a maximum of close to 1, use of equally spaced lines—say at 0.01, 0.02, and so on up to 0.15--will result in a map where the contours are clumped together at the youngest and oldest ages, with a largely empty expanse in-between. It is more informative to spread the lines out more evenly. This can be done by placing the lines at constant multiples--e.g., each line representing a level 50 percent higher than the previous line. Alternatively, a convenient scale can be used: Delaporte places his lines at levels of mortality of 1, 2, 3, ..., 9, 10, 12, 15, 20, 30, 50, 100, 150, 200, 250, 300, 350, and 400 per thousand.

Demographers often work with transformations such as the log or logit, so it might seem reasonable to transform the surface $q(x,y)$ into the surface of, say, $\log q(x,y)$ and then to draw level lines at equal intervals on the transformed surface. If the transformation is monotonic, like the log or logit transformation, an identical contour map can be drawn by spacing the level lines at appropriately unequal intervals on the original surface. In the case of logarithms, the level lines should be at multiples of each other rather than being equally spaced.

An innovation in the computer program we used is the shading of regions according to the height of the surface, the shading varying from light to dark as the surfaces rises from low to high levels of mortality. Such shading, which is time-consuming to do by hand but easy with the help of a computer, makes the overall pattern of a mortality surface more immediately comprehensible, especially if the map is viewed at a distance, but the details of small peaks and pits

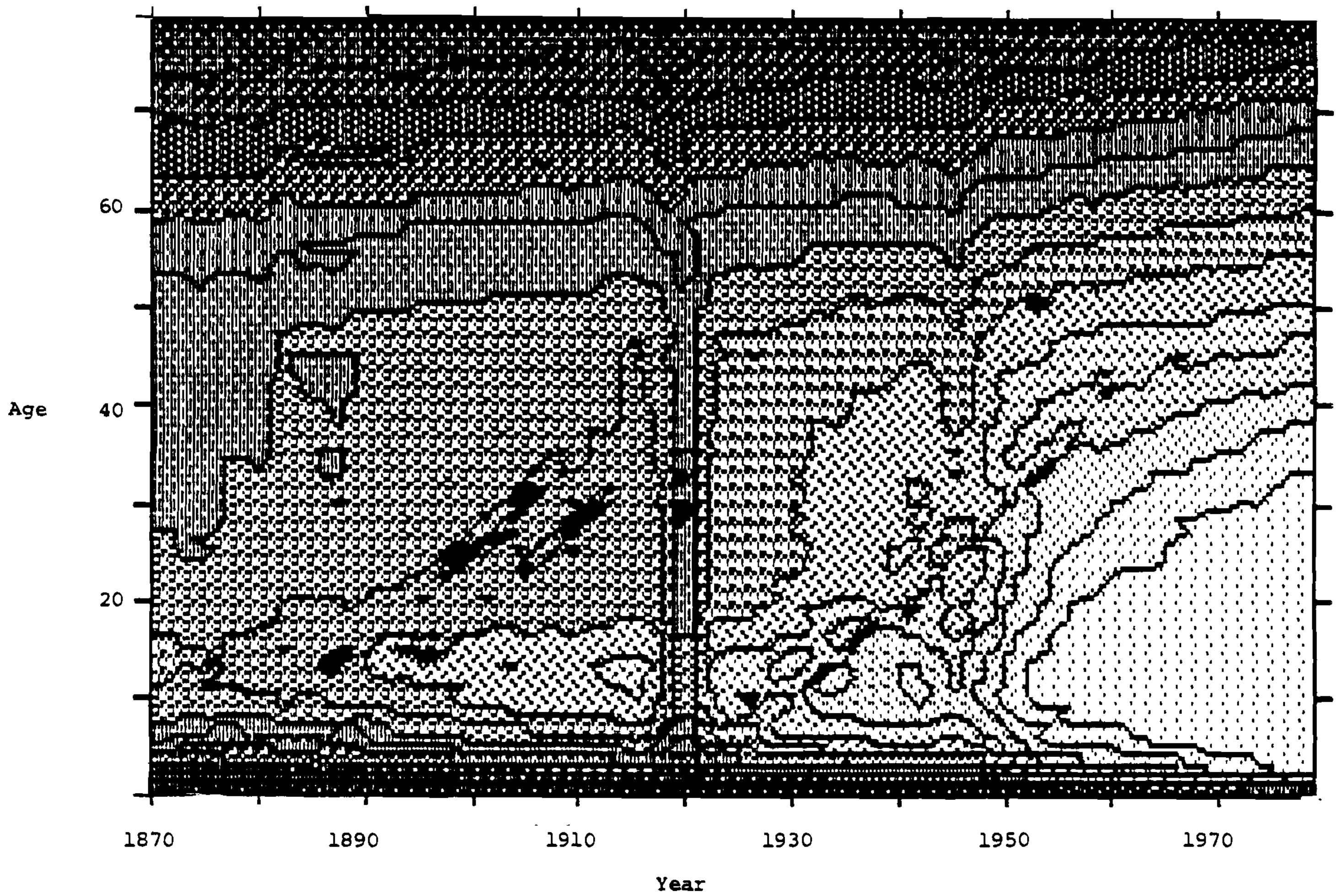
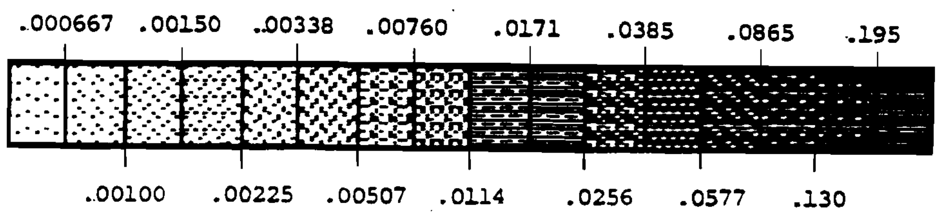


Figure 2. Italian Female Mortality Rates, not smoothed, for ages 0 to 79 and years 1870 to 1979, with contours from .000667 to .195 at multiples of 1.5:



and of the twists and turns of the contours lines are still there to be scrutinized at close range. Literature, critics note, can be profitably read at different levels of understanding; we suggest the reader view the maps in this paper at the two levels of 5 meters and 25 centimeters.

In Figures 1 and 2 some rough black blots are smeared across level lines. These represent virtual plateaus where the mortality surface is repeatedly crossing and recrossing a level line. To eliminate this kind of noise and to suppress the details of local fluctuations so that global patterns can be more clearly perceived, it may be useful to smooth a surface. Delaporte presented both raw and smoothed contour maps of mortality rates in various European countries: on his "adjusted" maps, Delaporte drew smooth contour lines based on his feeling for the data. We used a mechanistic, computer algorithm to produce the smoothed maps shown in Figures 3, 4, and 5. In each case the height of the surface at age x in year y was replaced by the average of the 25 heights in the 5 by 5 square of points from $x-2$ to $x+2$ and from $y-2$ to $y+2$. Use of this smoothing procedure cuts the contour map by two years on each edge, so that our smoothed maps range from age 2 to 77 and from 1872 to 1977.

A variety of alternative smoothing procedures might be used, including procedures that replace points by a weighted average of adjacent points, the weights diminishing with distance. For our purposes, however, the conceptual simplicity and computational convenience of straightforward averaging over a 5 by 5 square outweighed the advantages of more elaborate algorithms. We also produced maps, not shown in this paper, based on smoothing over an 11 by 11 square: on these maps, global patterns were somewhat clearer than on the maps smoothed on a 5 by 5 square but much interesting local detail was lost.

Contour maps can be used not only to analyze a mortality surface but also to compare two surfaces by computing a new surface that represents at every point either the difference in heights of the two surfaces or the ratio of the height of one surface to the other. Figure 5, for example, depicts the ratio of male to female mortality in Italy.

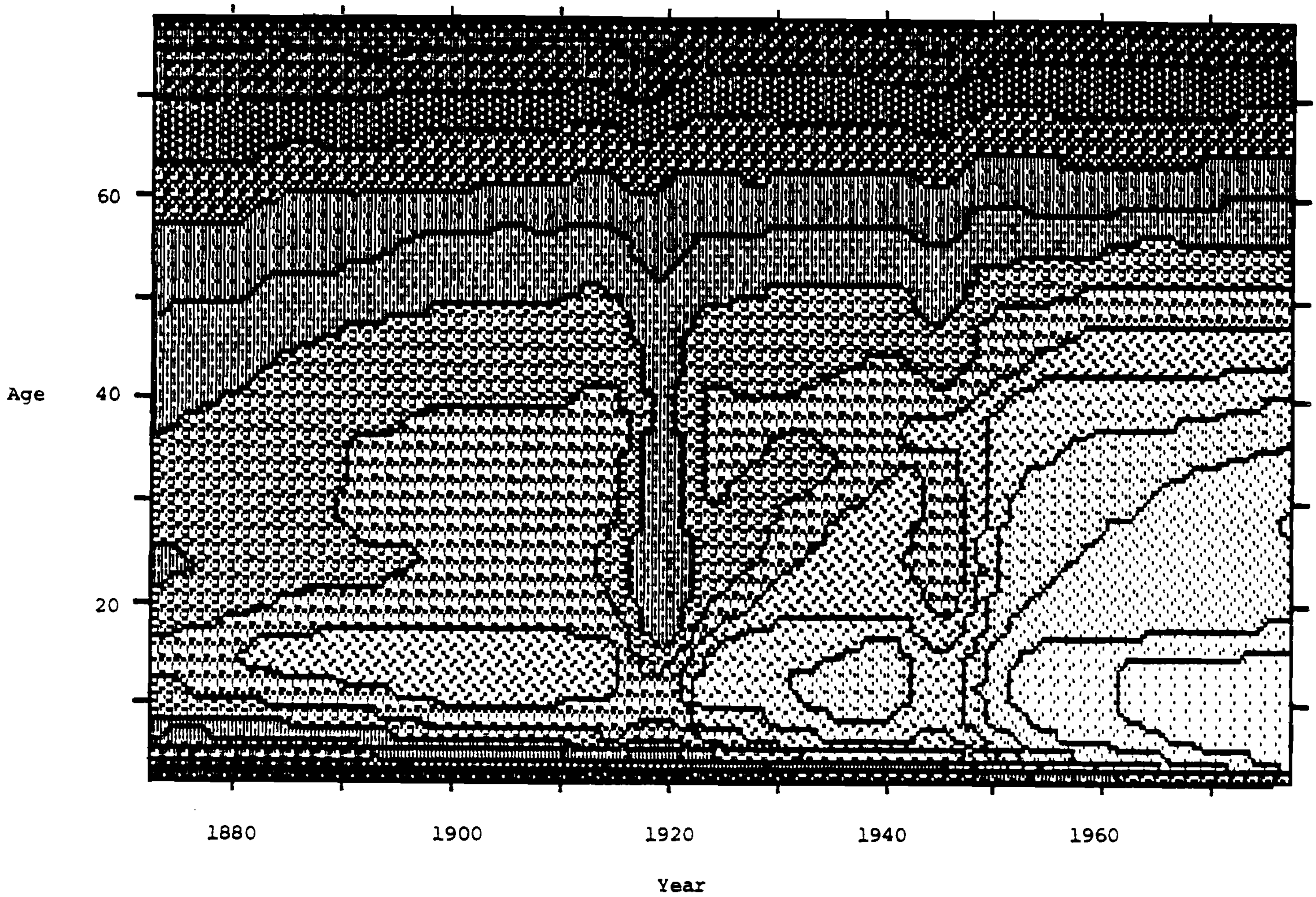
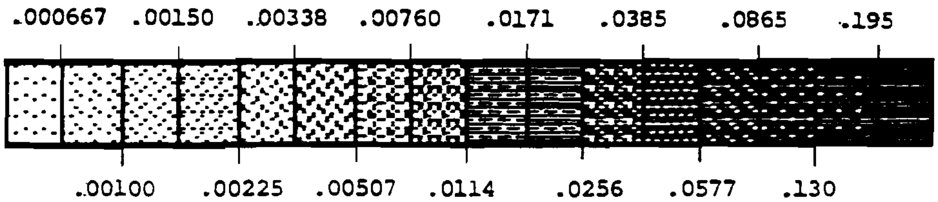


Figure 3. Italian Male Mortality Rates, smoothed on a 5 by 5 square for ages 2 to 77 and years 1872 to 1977, with contours from .000667 to .195 at multiples of 1.5:



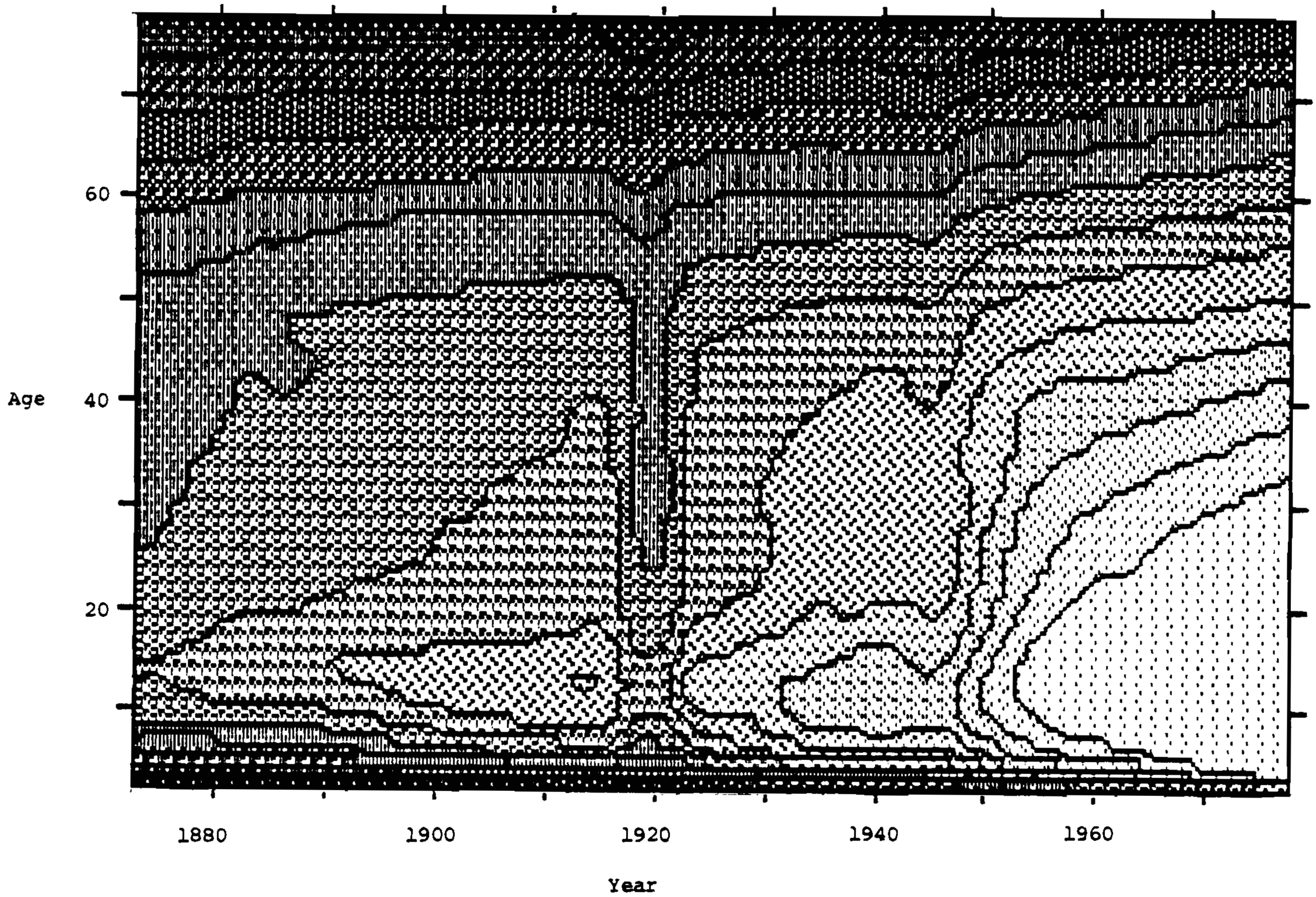
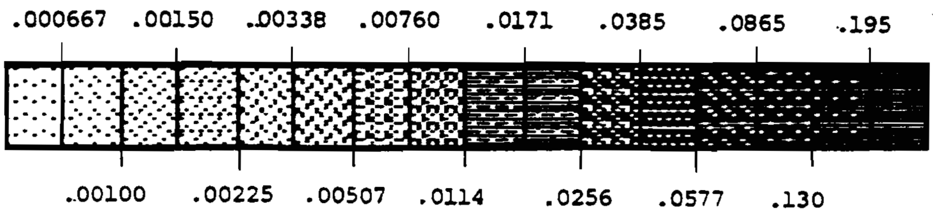


Figure 4. Italian Female Mortality Rates, smoothed on a 5 by 5 square for ages 2 to 77 and years 1872 to 1977 with contours from .000667 to .195 at multiples of 1.5:



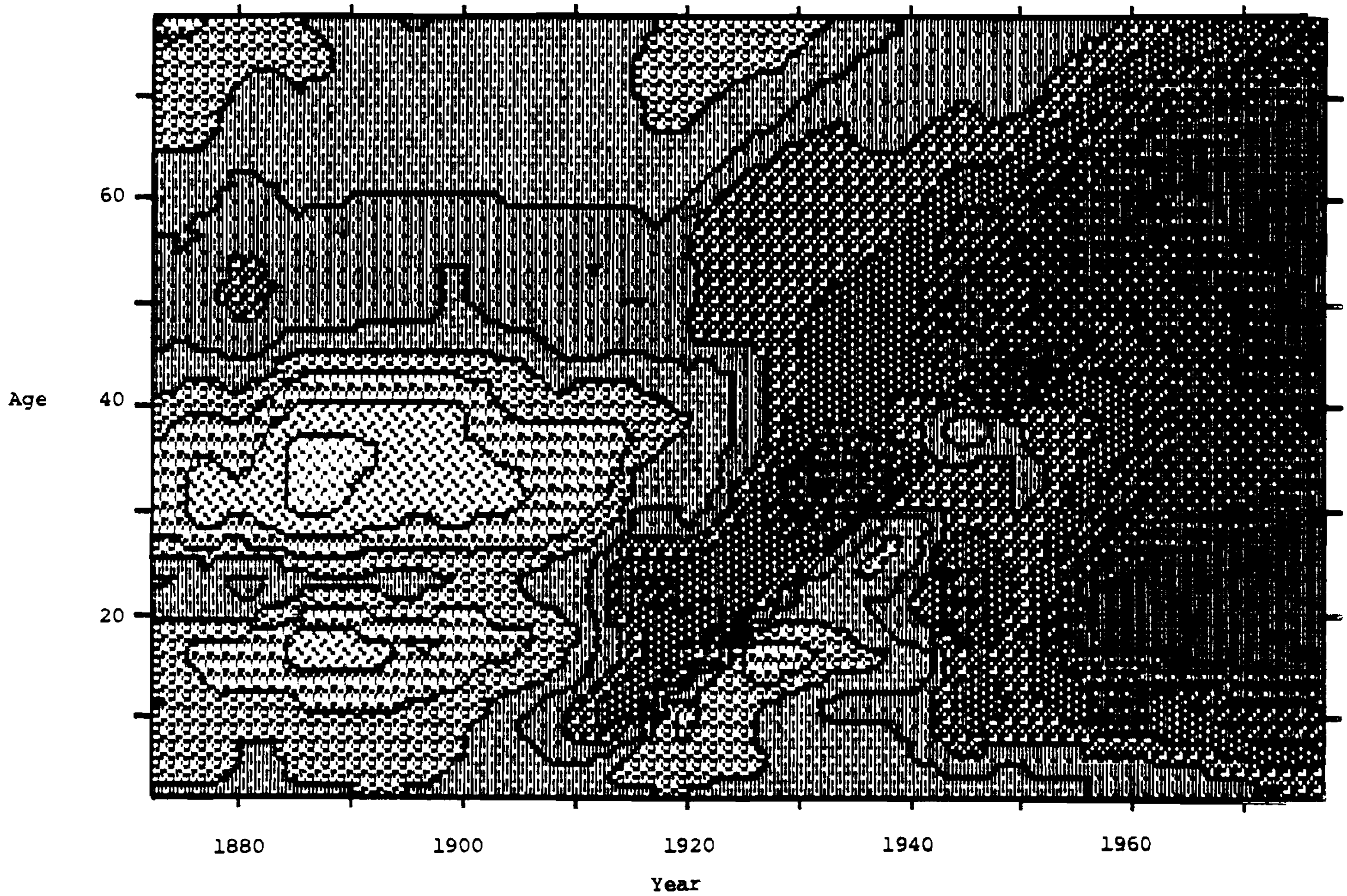
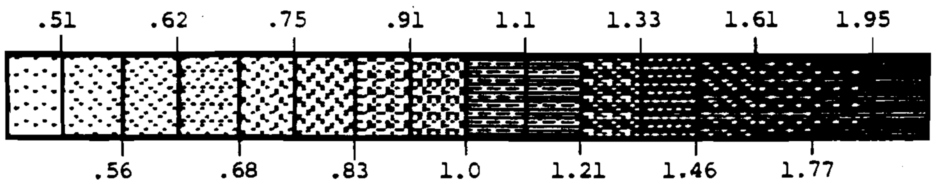


Figure 5. Ratio of Italian Male to Female Mortality Rates, smoothed on a 5 by 5 square, for ages 2 to 77 and years 1872 to 1977, with contours centered on 1.0 at multiples of 1.1:



DATA

The maps in this paper are based on life table data for single year cohorts born from 1790 to 1978 (Natale and Bernassola (1973) supplemented by Caselli (forthcoming)). These life tables give the standard probabilities of death, i.e., for each age the probability that a person born in a particular calendar year and alive at exact age x will die before his or her x+1-st birthday. As is well known, this type of probability refers to events that affect each single year cohort at each age in two successive calendar years; for a discussion of this, see Vallin (1973) or Wunsch and Termote (1978).

Standard calculations yield period life tables for two consecutive years from a diagonal reading of the cohort life tables. From our data, this allowed computation of period life tables from 1869-70 to 1978-79. For convenience in constructing mortality surfaces, we assumed that each ${}_1q$ calculated by this method described the height of the mortality surface at integer age x and at a time y halfway through the two-year period which we took to be January 1, 1870 for the 1869-70 period and so on. Thus our maps run from January 1, 1870 to January 1, 1979.

We were able to check some aspects of the quality of the underlying data by scrutinizing the contour maps produced from the data. Wherever there was an island on the map—i.e., a local peak or depression on the mortality surface—one of us (Caselli) looked at historical records and previous demographic analyses to try to account for the abnormality. Based on this research we believe that there are plausible explanations for the local patterns shown on the maps, some of which are discussed below, although we realize that plausibility by no means guarantees veracity and that some of the patterns may be artifacts of the procedures used to collect and process mortality and population statistics.

We also took a close look at the small black blemishes isolated from contour lines on the unsmoothed maps, because these dark spots indicate outliers--very localized peaks or pits--that might be due to erroneous data values. Consider, for instance, the black spot in Figure 1 at about age 54 and year 1878: it turned out that this blemish was indeed produced by an error made in transcribing the Italian mortality data to a computer tape. (The error was corrected, but we left the spot as an illustration.) On the other hand, the mark at about age 20 in 1962 represents a point where the mortality surface barely crosses a contour level, like the top of a sea mount that appears as a small island just rising above the level of the surrounding ocean.

LOCAL PATTERNS AND FLUCTUATIONS

Figures 1 and 2 present contour maps of Italian male and female mortality rates. The maps, which are not smoothed and based on data for single years of age and time, convey an image of persistent if somewhat jagged trends with some islands and peninsulas of relatively high or low mortality. Some of the variability may be essentially random noise and some is undoubtedly due to the procedures used to estimate the mortality rates. For the major fluctuations, however, it is possible to establish meaningful links with external events and developments.

The serious crises in mortality due to the two World Wars can easily be traced on the maps in the dark shafts of high mortality penetrating younger ages. These shafts, especially in the years 1916-1918 and somewhat less dramatically in the period 1915-1920, may be interpreted as a high but narrow mountain of mortality that suddenly confronts a population with levels of mortality that in normal times would be first encountered at much older ages. During these years during and immediately after World War I, women as well as men experienced risks of death from the age of 15 that they would have had to confront only from the age of 50 or 60 in the absence of war.

For the male cohorts most directly involved in the First World War, a diagonal spur of high mortality indicates serious negative repercussions of the war on mortality for another 10 to 15 years. This is not surprising in light of a study by Gini and Livi (1924): out of the five and a half million Italian males who survived military service in World War I, about 85 percent were invalids at the end of the conflict. A third were both ill and wounded and more than half were ill although not wounded.

Women also had to pass through extremely high levels of mortality in this period, although they were less directly involved in the war. As Mortara (1925) discusses, the epidemic of Spanish influenza in Italy and the disastrous economic and nutritional conditions resulting from the war caused more than 600 thousand female deaths in 1918, compared with a mean of around 330 thousand in preceding and subsequent years. This experience appears to have had some negative effect on the survival of the cohorts of females who were young adults at the end of the war, somewhat delaying progress in reducing mortality rates.

Variations in mortality from 1935 to 1948, peaking in the years of the Second World War, are apparent on the maps. The increase in the risk of death is notably less marked than the increase during the First World War. World War II resulted in about half as many deaths among soldiers as World War I and substantially less debilitation among surviving soldiers. Furthermore, although the civilian population was directly involved in the Second World War, it was decimated neither by the war itself nor by a major epidemic: Spanish influenza resulted in 274 thousand deaths in 1918 alone, whereas less than 150 thousand civilian deaths attributable to the war occurred in the entire period 1940-1945.

The variable and often unfavorable mortality rates suffered by young males, especially between ages 20 and 25, can be traced across Figure 1. As analyzed by Mortara (1912), Gini (1932), and Federici (1940, 1941, and 1959), the male mortality curve in some periods not only increases steeply at these ages but also reaches a local maximum; the reasons include reckless behavior, violent conflicts, and unfavorable living conditions and life styles resulting from socioeconomic disruptions. Islands and peninsulas denoting prominent local maximums of mortality for males in their early twenties occur around 1870-75, 1880, 1890-95, 1905-12, 1914-25, 1938-48, and 1976-79. From 1920 to 1935 the diagonal spur of high mortality, which, as indicated above probably resulted from debilitation during and immediately after the war, implies local maximums in period mortality at ages increasing from 20-25 in 1920-25 to 30-35 in 1930-35. The reappearance after 1975 of a prominent local maximum in male mortality rates between ages 20 and 25 is, as discussed by Caselli and Egidi (1984), principally due to the persistence of high rates of accidental and other violent causes of death among these young males.

PERSISTENT TENDENCIES

The contour maps in Figures 3 and 4 are smoothed versions of the maps shown in Figures 1 and 2; as discussed above, the smoothing was done on a five by five square. The smoothing, by reducing random noise and variations of short duration and small magnitude, makes general patterns in the evolution of Italian mortality more apparent.

For instance, Figure 3, compared with Figure 1, provides a clearer and more striking impression of the effects of the two World Wars and the lingering cohort effect among the cohorts who were in their early twenties during the First World War. An analysis of French mortality by Vallin (1973) indicates that higher rates of mortality for the males most directly affected by World War I can be detected in France; a recent study by Horiuchi (1983) indicates that a similar pattern, centered on the birth years 1901 and 1902, appears for Germany and Austria but not for Sweden and Japan, two countries that were not deeply involved in the First World War. It would be interesting to display male mortality data from various countries on contour maps to gain visual access to the relative strength of this cohort effect in different countries.

Clearly evident in Figures 3 and 4 is the persistent progress, interrupted only temporarily by the two World Wars, in reducing mortality rates at all ages but most dramatically before age 50. As discussed by Bellettini (1981) and Del Panta (1984), the introduction of public health reforms by the first governments of the Kingdom of Italy played an significant role in the progress in reducing mortality rates at the end of the 19th century. Progress, however, is evident even before these reforms, suggesting the importance of improvements in living conditions and personal hygiene. Ample statistical documentation of these effects can be found in Di Comite (1974).

The slow progress made in reducing mortality rates among younger women in the period up until the First World War stands in marked contrast to the rapid progress in reducing mortality rates for these women after the Second World War. The drastic recent reduction in the risk of death from complications of pregnancy and child birth, due, in part, to reductions in fertility, plays a key role in the progress made after 1945; earlier progress was also associated with a reduction in the risk of death from various infectious diseases such as tuberculosis.

Among teenagers considerable resistance to a decline in mortality is apparent to the very end of the last century for females compared with males. Biological differences and differences in social roles help account for this. Reductions in the labor-market participation of young boys, which, as Felloni (1961) discusses, was a consequence of social progress following industrialization, allowed an improvement in health conditions that particularly benefitted young boys already active in work outside the household. Female children and teenage girls continued to labor at the demanding tasks of domestic life; under existing hygienic, sanitary, and nutritional conditions, this certainly did not lighten the physical stress following menarche.

In addition to the striking progress in reducing female death rates before age 50, Figure 4 reveals systematic if less dramatic trends in reducing female mortality at older ages. For males, however, mortality rates after age 50 have fallen slowly and even show signs, at least since 1910, of more or less leveling off. This stagnation, particularly during the last 30 to 40 years, is discussed at length by Egidi (1984); related patterns in France are described by Vallin (1983) and an increase in mortality rates among Japanese men 35 to 55 years old is documented by Okuro (1981). If the evidence of persistent progress in reducing female mortality were not available, one might be inclined to think that little or nothing could be gained in the struggle against death at older ages. An important research task is to disentangle the lingering effects on male mortality of debilitating events, like the First and Second World Wars, from period effects associated with current patterns of economic activity, environmental conditions, and styles of behavior.

SEX DIFFERENTIALS

In Figure 5 a contour map is presented of the ratio of male to female mortality in Italy; the map is smoothed on a five by five square so that, as on Figures 3 and 4, each point on it represents the average of the surrounding 25 points. The overall picture, which reveals the evolving levels of this classic index of excess male mortality, is striking but no surprise. The light areas in the 19th century in the decade of age between 10 and 20 and again between 30 and 40 depict the substantial female disadvantage, discussed above, in adolescence and in the later childbearing years: the disadvantage is less in the decade from 20 to 30 because of the elevated male mortality at these ages. These light areas are transformed in less than a century into the black mountain of excess male mortality from ages 10 to 35 and especially ages 15 to 30, attributable largely to violent causes of death.

The diagonal swath of excess male mortality running roughly along the life line of the cohort born around 1900 reflects the sufferings of the males who were children or of fighting age during the First World War, young adults during the difficult years between the wars, and 40 to 50 years old at the end of the Second World War. The black slant of excess mortality around age 60 in 1960 dramatizes the continuing disadvantage faced by the males in this cohort. The decline in relative mortality after this age may be due to the death of the most frail or debilitated members of the cohort, i.e., due to selection.

Compared with the cohort born in 1900, the male cohort born in 1910 experienced less excess mortality at every age up until age 60 or so. The cohort born in 1920, on the other hand, suffered substantial excess mortality, although less than that suffered by the 1900 cohort, including heavy mortality during the Second World War. This perhaps provides some indirect evidence of some debilitation occurring during the World War II among the males most directly involved. The relatively favorable experience of the 1910 male cohort, and, equivalently, the relatively unfavorable experience of the 1910 female cohort, deserves further attention.

Finally, it might be noted that the males between the ages of 45 and 70 in 1975 experiencing high excess mortality are the males who were born between 1905 and 1930, who experienced World War I or II or both, and who were the main agents of the modern era of reconstruction and industrial development in Italy.

The black mountain of excess male mortality in middle age in recent years may be attributable in part to these events and hence be a temporary phenomenon rather than evidence that there are intrinsic, biological reasons preventing the decrease in male mortality after 50 years of age. However, since both male and female children born in the first decade of the twentieth century suffered from the privations of the First World War during their period of growth, it would appear that the female population is better able to cope with such adverse circumstances.

CONCLUSION

The contour maps presented in this paper clearly and efficiently display both persistent global and prominent local patterns of mortality, simultaneously over age, by period, and for cohorts. Italian mortality has been carefully studied by a series of talented and perceptive analysts, so it is no surprise that most of the patterns apparent on the contour maps have been previously recognized and discussed. The maps highlight some of these patterns in such a visually revealing manner, however, that what was understood before can now be **seen**. Furthermore, the maps focus attention on some neglected aspects of the evolution of Italian mortality. Efforts to better understand the social and biological determinants of mortality could benefit from more careful attention to some of the prominent features of the contour maps, including the following:

- A series of dark islands and peninsulas punctuate Figures 1 and 5 over time at ages of roughly 20 to 25. These can perhaps be explained by reckless behavior, various violent conflicts, and various social and economic disruptions that afflict men more than women.
- The consequences of World War I and the accompanying influenza epidemic that raged around 1918 were more dramatic in Italy than the consequences of World War II. Especially prominent in Figures 1, 3 and 5 is the high mortality, during the 1920's and early 1930's, among the cohort of males who were in their early twenties during the First World War. This effect is probably due to debilitation resulting from illness and injury.

-- The extraordinarily rapid progress against childhood mortality after the Second World War is dramatically displayed in Figures 3 and 4. This progress is undoubtedly due to improved social and economic conditions and better health care, as well as the beneficial effects of a decreasing birth rate, but the relative importance of these various factors deserves further study.

-- The persistent pattern of progress in reducing female mortality rates in the early adult ages, clearly shown in Figure 4, is perhaps also associated with the decline in fertility rates and in the risk of death in childbearing, as well as the virtual elimination of fatal infectious diseases, like tuberculosis, that took a heavy toll among young adults.

Attention to other patterns, including the slow rate of progress in reducing mortality at older ages among men compared with women, and the resumption, after World War I and again after World War II, of the fairly regular and persistent trends apparent in most of the contour lines before World War I, might also deepen understanding of the social and biological determinants of mortality.

Additional contour maps may help demographers in four promising and important directions of research on mortality:

First, much can be learned by decomposing mortality rates into cause-specific rates. Contour maps could be used to display patterns in mortality from various causes of death, as well as to compare patterns from different causes, much as male and female patterns were compared in Figure 5.

Second, it would be useful to compare the evolution of Italian mortality with the evolution of mortality in various Italian regions and in various other countries, such as France, Belgium, and Sweden, for which extensive mortality data is available. Again, contour maps could be profitably employed in making these comparisons.

Third, patterns of fertility and of nuptiality could be studied using contour maps and comparisons could be made of these patterns with mortality patterns. Not only do fertility, nuptiality, and mortality interact with each other, but various social and biological factors affect each of these demographic phenomenon, in differing degrees and sometimes in opposite directions.

Comparisons of different kinds of demographic rates could shed light on the importance on both the internal and external interactions.

Fourth, models need to be developed that relate measures of external variables to observed mortality rates. Appropriate models would allow decomposition of mortality patterns into the effects of (1) aging, (2) persistent progress against mortality over time, (3) shocks and disasters like the 1918 influenza epidemic, (4) cohort effects due to selection resulting from to heterogeneity in frailty, and (5) debilitation of cohorts due to illness, injury, inadequate nutrition, etc. Such models would be valuable not only for explanation of past patterns but also in forecasting future patterns and in evaluating policy alternatives. Contour maps, by efficiently summarizing many numbers in a compact space and by revealing both strong global and local mortality patterns, can stimulate thinking about the kinds of external variables that may be important. Furthermore, the fit of a model to the data can be displayed by using comparative contour maps (like Figure 5); seeing where a model fits poorly may help the analyst develop a more accurate model.

Tufte, in his lucid exposition of *The Visual Display of Quantitative Information* (1983), concludes that graphic designs should give "visual access to the subtle and difficult, that is, the revelation of the complex". Demographic surfaces—which may be defined over nearly a century of age and more than a century of time, comprising close to ten thousand data points that may vary, as in the case of mortality surfaces, over four orders of magnitude—are complex; contour maps are a striking, efficient, and clear means of giving demographers visual access to them.

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