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## Foreword

An important part of the activity of IIASA's Population Program is related to the development of data visualization techniques. The paper is devoted to the analysis of cause specific mortality data for Japan using the shaded contour map approach which was recently developed in the program by an international team of scientists.

Anatoli Yashin
Deputy Leader
Population Program

# Cause Specific Mortality in Japan: Contour Maps Approach

*B. Gambill*[1], *A. Yashin*[2], *J. Vaupel*[3], *Z. Nanjo*[4], *T. Shigematsu*[5]

## 1. Introduction

The fluctuating mortality history of Japan provides for a remarkably interesting study. Mosk (1979) divided modern Japanese demographic history into five periods. The earliest, encompassing the eighteenth and nineteenth centuries, is characterized by low mortality. The second period, which includes the late nineteenth and early twentieth centuries, demonstrates increasing mortality, while the third, running until the outset of World War II, is marked by slowly decreasing mortality rates. The final two periods span the post-war period and will be the focal point of our cause specific investigation of mortality among Japanese males. The rapid progress and changability of mortality during these periods is astonishing. Investigation of cause specific mortality provides some clues about the nature and future of total mortality in Japan, and perhaps, the rest of the Western World.

The method that we use for analyzing mortality trends is called "shaded contour maps." This is an effective means of representing thousands of demographical data simultaneously, either on a piece of paper or on the color monitor of a computer. Data which might be used in such an analysis are age and time specific demographical characteristics such as mortality, fertility, population, migration rates, etc.

We begin our discussion of mortality trends showing the map of Japanese male mortality from 1891 to 1982 and age categories 0 to 89. The contour map is compared with a three-dimensional plot of the mortality surface. Analyzing the map, one may like to look at different profiles of mortality through age or time. These profiles can be readily provided making the appropriate cuts through the demographical surface. Examples of such cuts are also shown. Maps of six cause specific mortality rates for Japanese males are presented, together with their proportions of total male mortality. The four maps of leading causes of death over age and time are presented at the end.

## 2. Male Mortality in Japan

The mortality rate in Japan declined steadily from the end of the 19th century until World War II. Right after the war major prograss was observed for ages from 5 to 40 years. Later, progress against mortality was achieved also for adults over 40 and younger children. The contour map in Figure 1a displays this progress even for elderly males. The lines on the contour map represent points of equal mortality. One would see these lines cutting the three-dimensional plot of male mortality (Figure 1b) by horizontal planes fixed on the respective mortality levels.

Figures 1c and 1d demonstrate vertical cuts in the three-dimensional mortality surface. In Figure 1c one can see the age specific mortality patterns observed in the years 1900, 1945 and 1980. One sees that the mortality rate among Japanese

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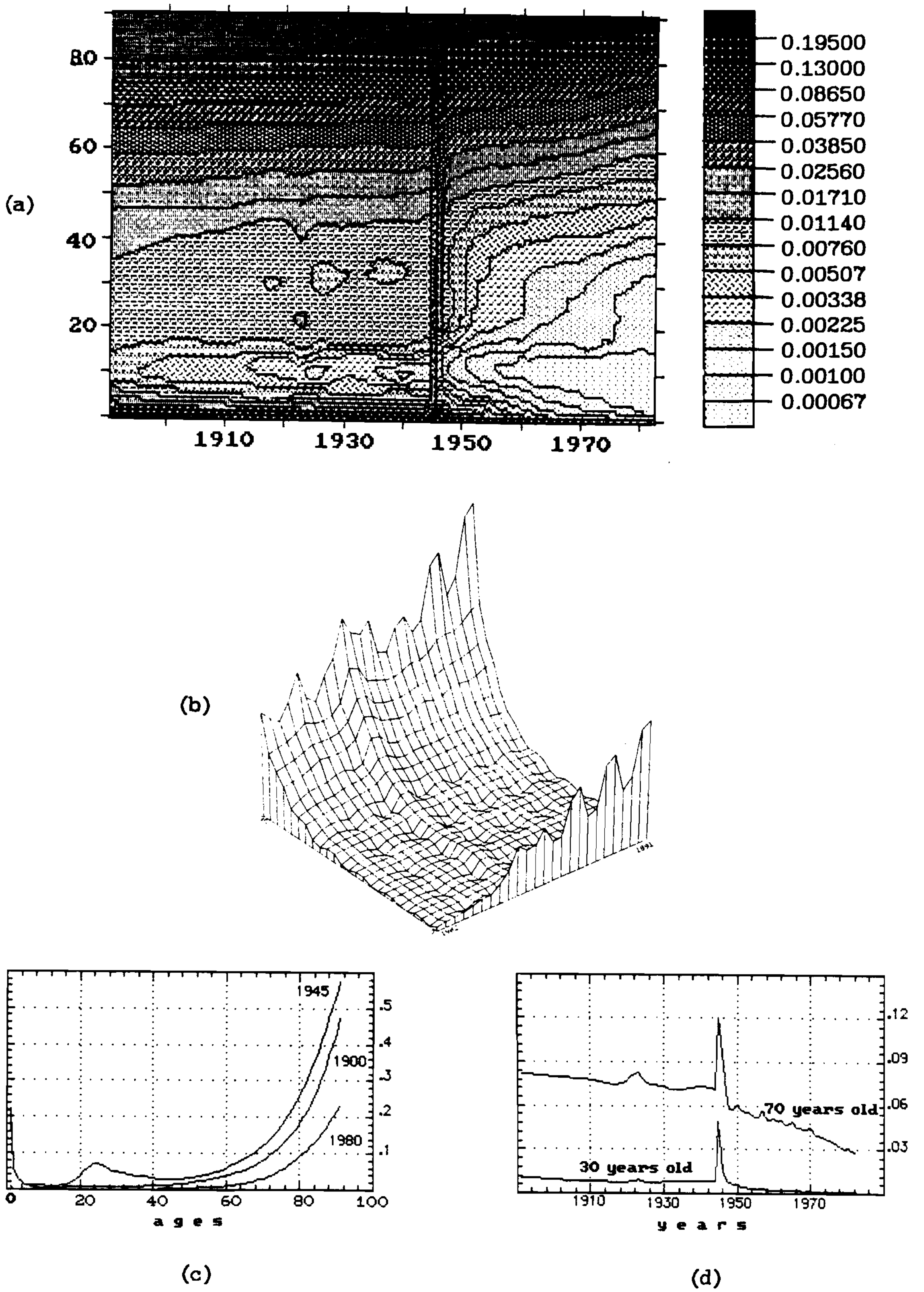



**FIGURE 1. Japanese male mortality from 1891 to 1982 and age 0 to 89: (a) contour map; (b) three-dimensional plot; (c) age profile; (d) time profile.**

males in 1945 was higher than in 1900 for all age groups, especially for the age group interval from 18 to 40. However, the mortality rate in 1980 is more than two times less than at the beginning of the century for all ages. In order to better understand the reasons for such significant changes, it is useful to look at the trends of cause specific mortalities after World War II.

## 3. Six Causes of Death over Age and Time

Figures 2–7 present pictures of cause specific mortality among the male population in Japan from 1947 to 1982 and age 0 to 89. Each figure contains two contour maps: map (a) represents mortality due to one particular cause; map (b) designates this particular cause as a proportion of total male mortality. Map (a) was drawn using lines that begin at 0.0000667 and increase to 0.0195 at intervals of fifty percent. These lines are exactly one-tenth of the lines normally used to draw total mortality maps. The darkest areas of map (b) correspond to approximately one-third of total male mortality at the corresponding age and time.

Tuberculosis is the subject of Figure 2. The progress made against this infectious disease that was at one time largely responsible for mortality among young males in Japan is instantly clear. The rate of mortality from tuberculosis was at its highest point from 1947 to 1950 at ages 20 to 33. At these points, and others around them, it accounted for almost one-third of all Japanese male mortality. By the 1970s and 1980s it was almost non-existent at similar ages.

Additionally, notice that mortality from tuberculosis follows diagonal lines over the 35 year period. The pattern indicates that the percentage of people who die from tuberculosis is nearly constant at all ages throughout the cohort. Because tuberculosis is a chronic disease, we might explain this phenomenon through debilitation. With exposure to tuberculosis now nearly negligible, deaths at older ages along the cohort line are probably due to infection at earlier ages, when exposure was much greater. Since each cohort suffered different levels of exposure at younger ages, the rate of mortality that each cohort carries with it is different. Figure 2b illustrates that a constant rate of tuberculosis mortality over the life of the cohort leads to a decrease in the proportion of people succumbing to tuberculosis in the cohort direction.

Another peculiarity of the map is that the rate of mortality from tuberculosis was greater in 1982 at ages above 70 than it was in 1947 for similar age groups. Though cause of death statistics are not available for the period before 1947, Shigematsu and Yanagawa (1983) and Okubo (1981) mention that tuberculosis played a major role in mortality among men in their twenties during the pre-war period. If this is true, one would believe that selection might be responsible for the curious increase in tuberculosis mortality at older ages. A high rate of exposure to tuberculosis would mean that all but the most robust individuals would contract the disease at younger ages. As a result, there would be fewer "weak" individuals remaining to be afflicted at older ages. Now that exposure to the disease is very low, these weaker, more susceptible individuals are living to older ages and contracting the disease later in life.

This point however does not get any support from the data. Indeed, individuals aged 70 and above in 1982 lived their twenties in the 1920s and 1930s when TB was most prevalent in Japan and they cannot be regarded as "weaker" who escaped from TB infection. On the other hand, those aged 70 and above in 1947 lived their twenties in the 1890s when TB was less prevalent than in the early 1900s. Their early life exposure to the disease was relatively low compared with the experiences of similar ages in 1982. The high TB mortality of similar ages in 1982 is regarded as residuals of the high rates at their younger age rather than selection.

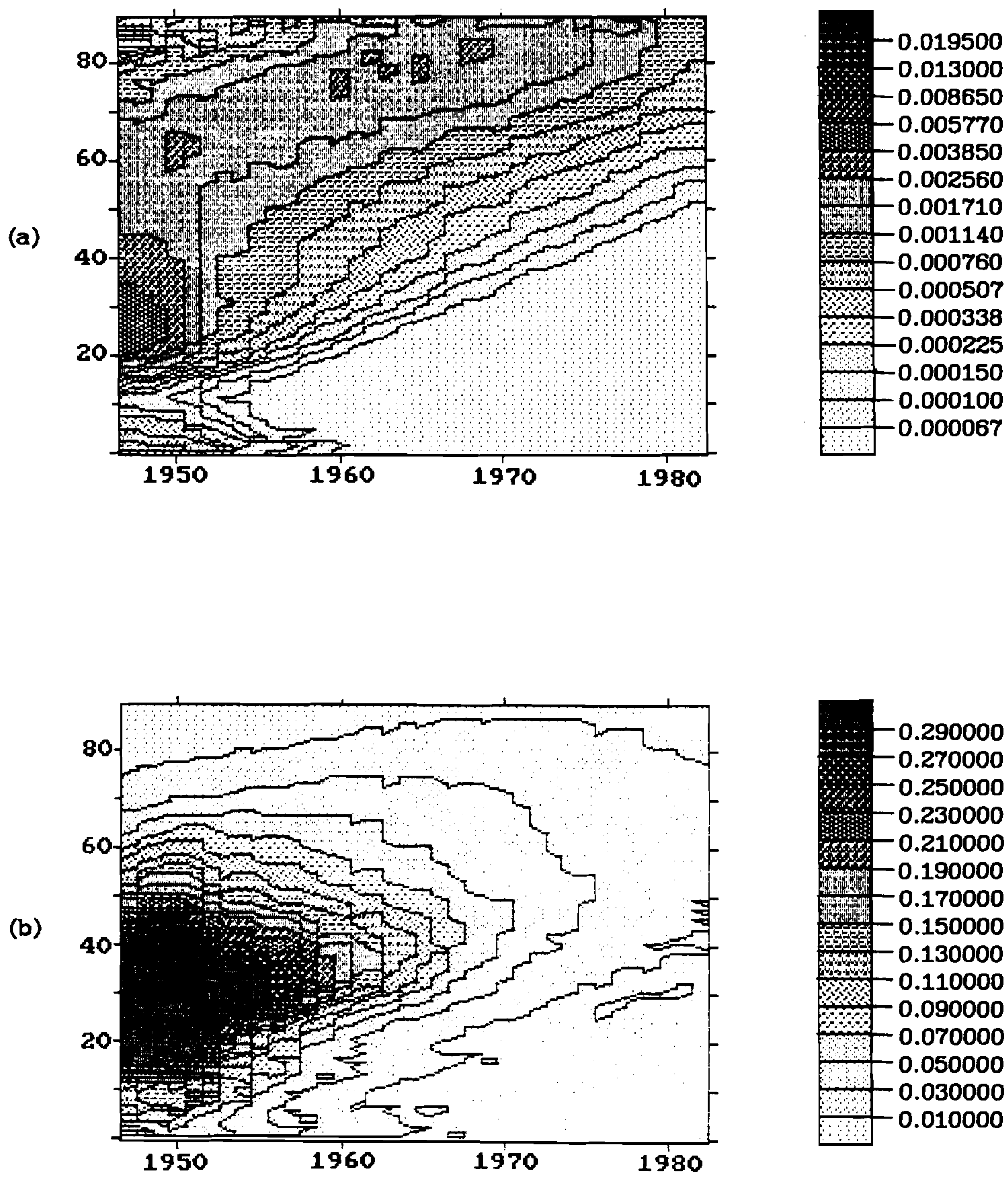



FIGURE 2. (a) Mortality rates from tuberculosis for Japanese males from 1947 to 1982 and age 0 to 89. (b) Tuberculosis as a proportion of total mortality for Japanese males from 1947 to 1982 and age 0 to 89.

Shigematsu and Yanagawa (1983) point out that a reduction in death from tuberculosis was the largest contributor to the decline of mortality in Japan after 1950. The rapid and almost complete eradication of tuberculosis is largely the result of improved economic conditions, the development and use of the BCG (Bacillus Calmette-Guerin) innoculation, and a massive public health program implemented in the early post-war period. The Japanese economic prosperity of the 1950s most certainly played a role in reducing death from tuberculosis in that country. A preventative innoculation that gained acceptance and use in Europe and the United States during the 1930s and 1940s was not widely available in Japan until the late 1940s and early 1950s. The TB Prevention Law employed it and wide scale x-raying as effective measures in reducing mortality from tuberculosis.

It is worth mentioning, however, that BCG, public health programs, and economic prosperity alone are not enough to explain the rapid decline in TB mortality in Japan from the 1950s onward, when economic reconstruction had only started and could not be regarded as prosperous. During this time, the improvement in medical treatment – especially the introduction of effective chemotherapy, anti-TB drugs – certainly played an important role in the decline in TB mortality.

Figure 3 displays total and proportional malignant neoplasm mortality. From Figure 3a it is apparent that the rate of death from cancer has increased significantly only at ages greater than 70. Figure 2b illustrates, however, that malignant neoplasms have assumed a much greater role in determining the rate of total mortality at each age. In 1947, only 15 percent of all deaths between the ages 50 and 65 resulted from cancer. In 1982, this proportion more than doubled to greater than 31 percent. Even more striking is that among ten year old males, only about one percent of all deaths resulted from cancer in 1947. By 1982 this number had increased approximately 30 times so that over 31 percent of mortality at age 10 was directly the result of some form of cancer.

The pictures provide a remarkable illustration of how much total mortality has declined relative to mortality from malignant neoplasms. In 1982, malignant neoplasms were responsible for at least 11 percent of the deaths at each age. In 1947, this was true only for ages 43 to 71. Though maligant neoplasm mortality rates have not increased at most ages, the increasing proportion results from a decrease in the mortality rates for other causes of death. In other words, the probability that any healthy person will die from cancer at a particular age is not increasing, but the probablity that death will result from cancer at some age is.

Projecting current rates of progress against cancer mortality, Owen and Vaupel (1985) predict that a male born in the U.S. in 1984 has a 67 percent chance of eventually succumbing to cancer, though his life expectancy is increased from those born in years before him. The Lexis maps of malignant neoplasm rates lead us to believe that results will be similar for Japanese males. As other causes of death are eliminated and natural selection becomes less important in the aging process, people will likely live longer but eventually die from cancer, leading to higher rates of neoplasm mortality at older ages.

Looking at Figure 4 we see a similar picture for heart disease in Japan. For all ages less than 70, the rate of mortality from heart disease remained constant or decreased from 1947 to 1982, though increased, as expected, with age. As a proportion of total mortality, however, heart disease increased over age and time. In Figure 4a there is evidence of post-war progress against heart disease mortality at ages less than 40. For Japanese males in their eighties from 1960 to 1982, the probability of death from heart disease was around 0.2.

When compared with other countries in the western world, Japanese mortality from heart disease is relatively low, especially at older ages. Kono and Takahashi (1985) explain that cultural and behavioral eating patterns may be responsible for

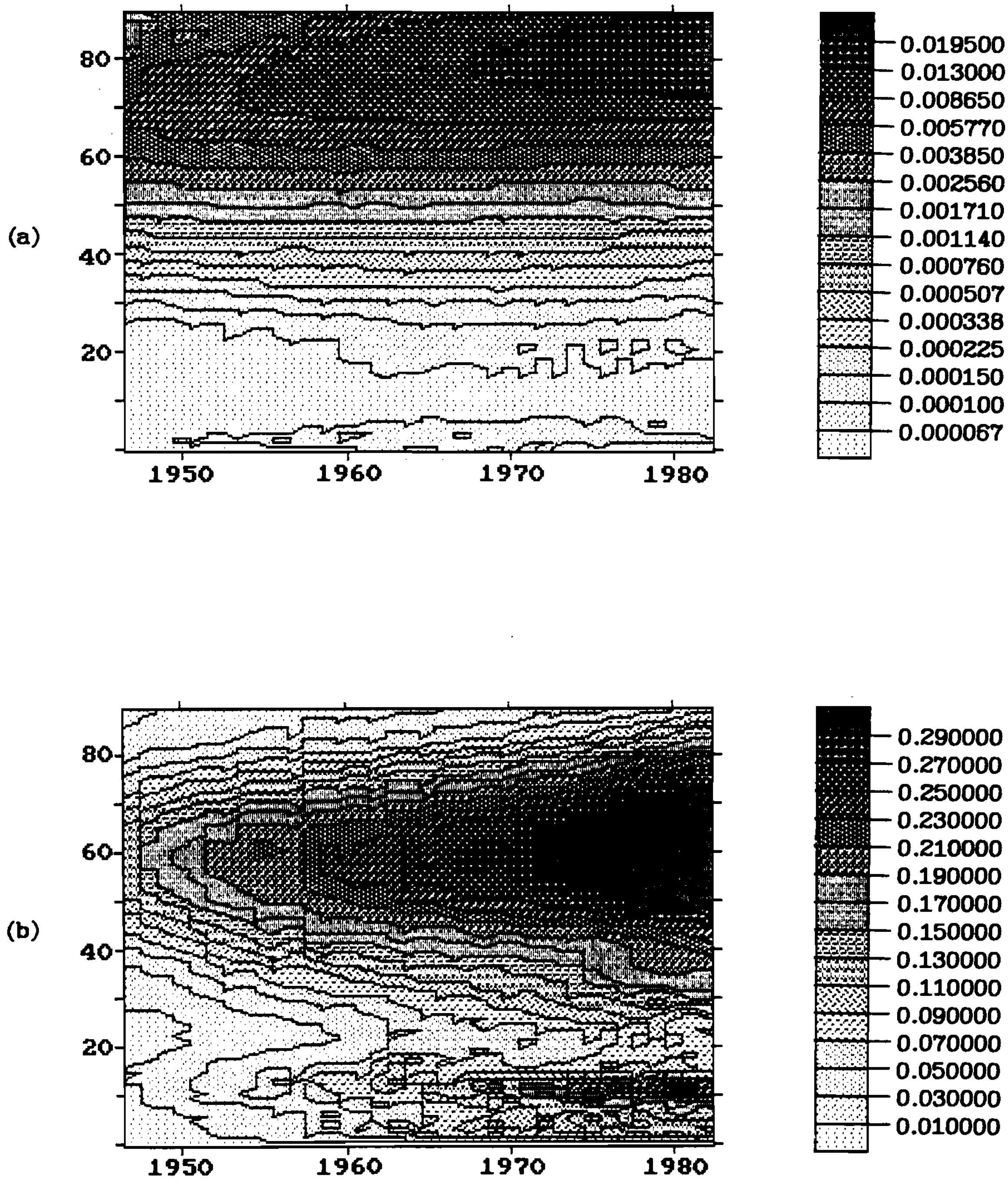
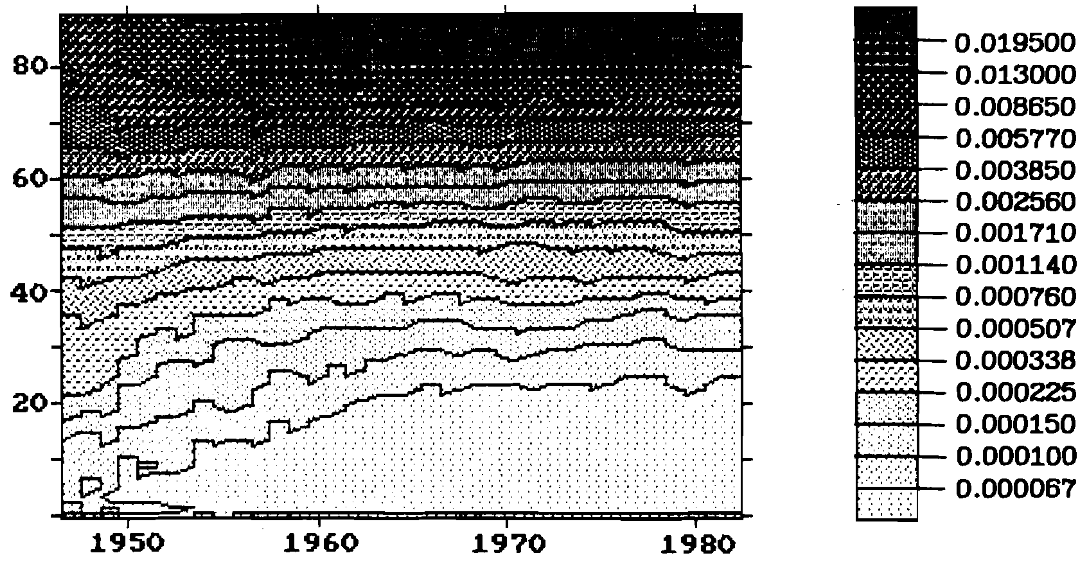



FIGURE 3. (a) Mortality rates from cancer for Japanese males from 1947 to 1982 and age 0 to 89. (b) Cancer as a proportion of total mortality for Japanese males from 1947 to 1982 and age 0 to 89.

(a)

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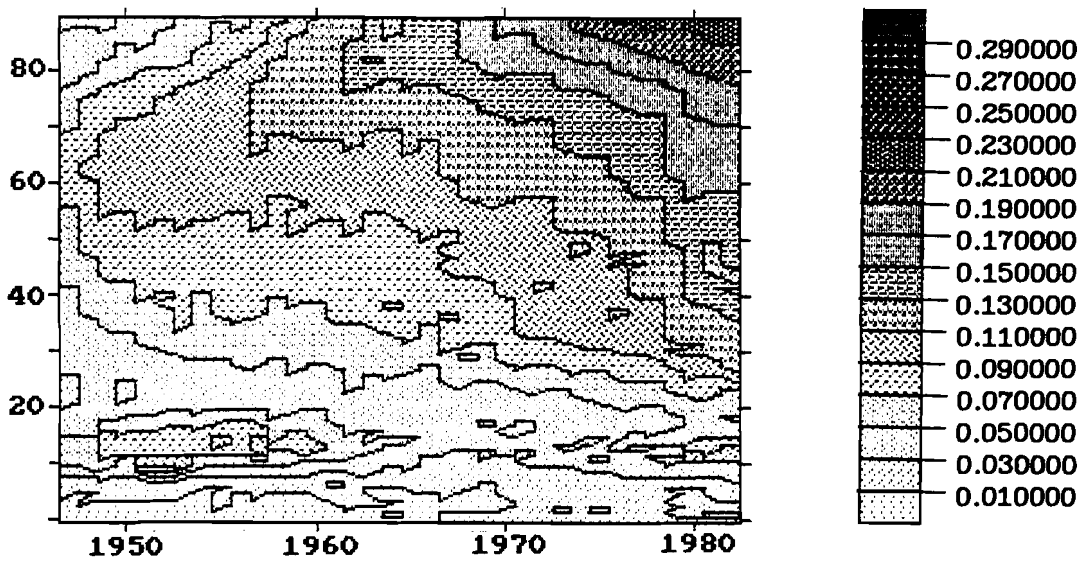



FIGURE 4. (a) Mortality rates from heart disease for Japanese males from 1947 to 1982 and age 0 to 89. (b) Heart disease as a proportion of total mortality for Japanese males from 1947 to 1982 and age 0 to 89.

the advantaged position of the Japanese males. The fat and overall caloric input of Japanese males has not reached the level of their peers in the west. In blue-skinned fish, they also consume more eicosapentaenoic acid which many biologists and physicians believe prevents coagulation in human blood vessels and therefore lessens the risk of myocardial infarction. Perhaps a contributing factor is selection. A comparison with other western data shows that Japanese males suffer greater rates of heart disease mortality from birth until their thirties, but then less mortality from heart disease at middle and older ages. If those born with weaker cardiovascular systems die early in life, we would expect the mortality rate to be less at older ages. A more careful analysis of diseases by type in child- and in adult-hood is needed, however, to justify this idea.

Figure 4b reveals that the proportion of total mortality that results from heart disease increases with successive cohorts. For a Japanese male who died at age 80 in 1950, the probability that his death resulted from heart disease was around 0.05. This probability thirty years later was 0.21, an increase of 400 percent. Comparisons of proportional mortality at other ages would reveal a similar, though perhaps less drastic, pattern. The map provides additional indications of a shift from exogeneous to endogeneous mortality.

Figure 5 presents maps of cerebrovascular mortality. Figure 5a shows that cerebrovascular mortality rates decreased by 10 to 20 percent at most ages from the mid-1960s to 1982, though the rates at middle and upper ages are high relative to mortality from other causes. For Japanese males, the probability of dieing from cerebrovascular disease at any age above 80 was close to 0.02, while it was less than seven in 100,000 for all ages less than 31 throughout the period.

Figure 5b shows the great proportion of death attributable to cerebrovascular mortality, especially at older ages from 1960 to 1980. Though Figure 5a elucidated the fact that mortality from cerebrovascular causes is decreasing, we now see that the rate of decrease has not kept pace with reductions in total mortality. Kono and Takahashi (1985) suggest that the salty food typical of the traditional Japanese diet could be one factor in making cerebrovascular mortality disproportionately high relative to other countries and other causes. They point out that the changing pattern of diet toward less salty food and more protein and fat is partly responsible for the reduction in rate and proportion of mortality that is apparent in the maps and believe the continuing trend will lead to great reductions in future mortality.

The diagonal patterns of Figure 5b are an interesting feature of that Lexis map. Strong evidence of debilitation can be discerned through close scrutiny. For cohorts born before between 1890 and 1910, the mortality from cerebrovascular disease resulted in diagonal lines perpendicular to the cohort. The pattern indicates that the rate of mortality varied from age to age and from cohort to cohort, with later cohorts experiencing a smaller proportion of mortality from cerebrovascular disease. We even see a decline in mortality at older ages along these cohorts.

For males born after 1910, however, cerebrovascular mortality remains relatively constant over the cohort, but varies from one cohort to the next. Year of birth determines the almost constant proportion of death that results from this cause, possibly an artifact of debilitation. Okubo (1981) suggests that the malnutrition and lack of protein-rich food during the pre-war and post-war years left adolescents of the period with weaker blood vessel tissue, making them more susceptible to cerebral hemorrhage. Assuming this is true, we might expect mortality to be constant over a cohort as birth year and variable exposure lead to different levels of mortality for each of the birth groups, and the endogeneous condition results in constant rate of mortality with age.

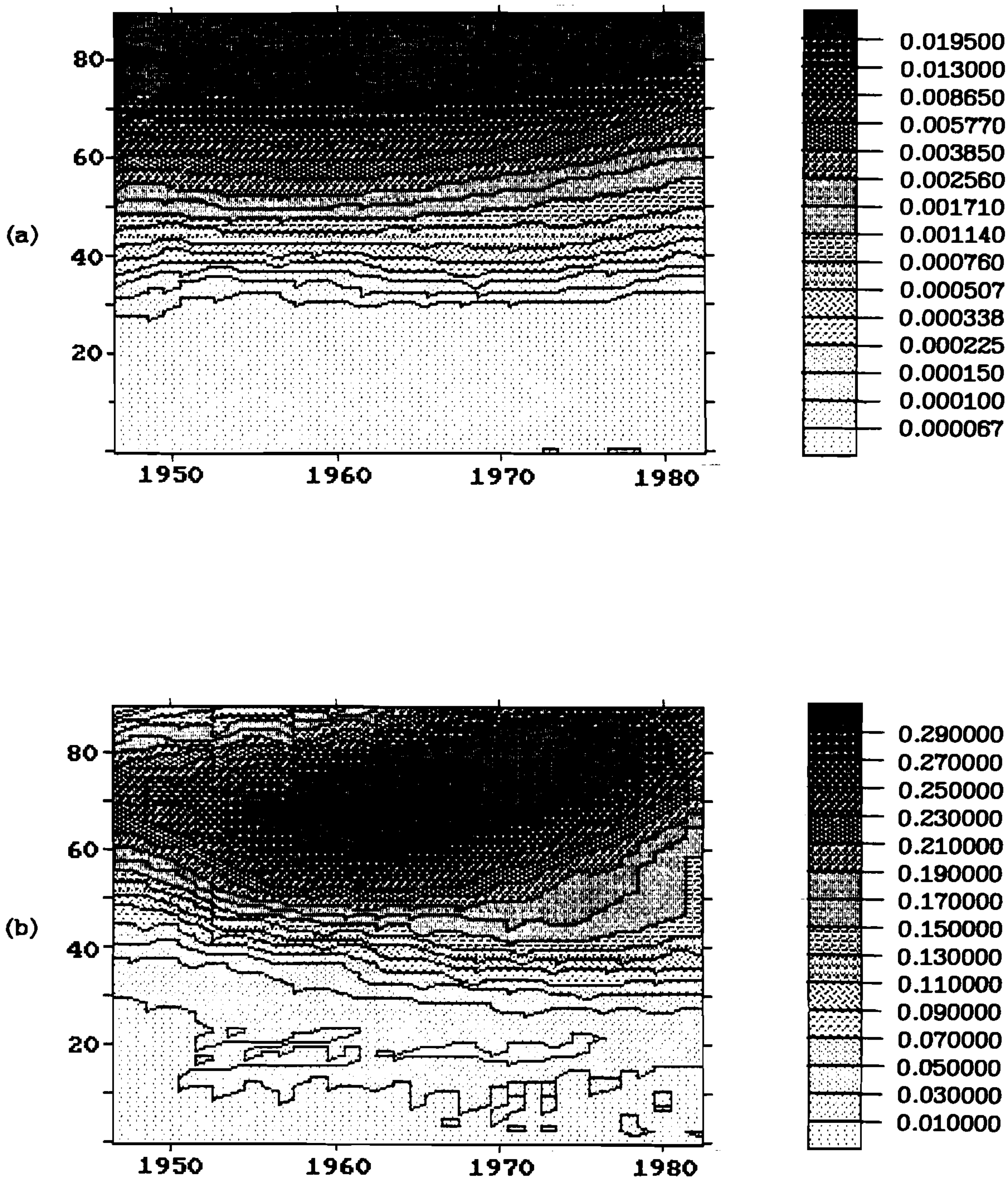



FIGURE 5. (a) Mortality rates from cerebrovascular disease for Japanese males from 1947 to 1982 and age 0 to 89. (b) Cerebrovascular disease as a proportion of total mortality for Japanese males from 1947 to 1982 and age 0 to 89.

Figure 6a displays the age-specific mortality from suicide for Japanese males. Perhaps the most noticable feature of the map is the high area of mortality at ages 20 to 25 between 1952 and 1960. This region represents the mortality of men born from 1928 to 1940 – those who were children and adolescents during World War II. Following the map in the cohort direction, the mortality rates drop substantially at ages after the high region. Selection might be one cause of the cohort effect, since it appears over age in only the cohort, not the period, direction. Notice, however, that the region of high suicides at ages 42 to 57 from 1979 to 1982 corresponds to the same cohort that suffered a high suicide rate in its twenties. This does not support the selection idea. Throughout the period, suicide after age 70 appears to follow an age rather than cohort pattern, with some progress made over time.

Suicide mortality is strongly influenced by social and economic conditions in the community. The high rate of suicide mortality in the 1950s was brought about by the social conditions that were very difficult and competitive in the course of economic reconstruction from the chaos after the War. The decline in suicide mortality follows both cohort and period directions so the explanation by selection only is not completely suitable.

Figure 6b – proportional mortality from suicide – illustrates dramatically the suicide among young people throughout the period. The peak that appears first chronologically corresponds to the local maximum discussed earlier. More striking, however, is the high proportional mortality among men less than 40 throughout the 1970s and early 1980s. Over time, suicide was responsible for an increasing proportion of mortality among men between the ages of 30 and 50. After an ititial surge in the early 1950s, progress against suicide mortality at most ages seems to have kept pace with progress against total mortality, and even surpassed it at various ages and times. Hishunuma (1981) expects the trend to change, however, predicting that suicide rates in 2010 will be 50 percent higher than in 1978.

Figure 7a is a Lexis map of mortality rates from accidents among Japanese males. The global minumum falls around age 10 or 11 over the latest years of the map, while the maximum is at the highest ages from 1960 to 1982. A noticable feature of the map is the decreasing rate of mortality from accidents at almost all ages from the early 1970s to 1982. The decrease followed peak mortality from accidents in the year 1970. The patterns exhibited are a fine example of the effect of technology on demography. While increasing trends were perhaps attributable to the introduction of modern technology, it is noticable that the lowest mortality from accidents occurred in the latest years of the map, after an initial adjustment to the effects of science on daily life. A detailed analysis shows that the largest contributor to the increase of accident mortality after the War was the rapid progress of motorization in Japan. The decreasing trend after 1970 has resulted from the improvement of road conditions and facilities and of traffic systems and regulations.

Figure 7b displays the proportion of mortality attributable to accidents among males in Japan. For males less than 30, accidents have accounted for more than 31 percent of nearly all mortality since 1959. The one striking exception is around age 10 and in infancy, where the proportion is much lower. From Figure 7a, we see that this results not only from progress against total mortality, but also from a decrease in the rate of accident mortality among these age groups. The rapid increase in the proportion around 1957, however, is probably an artifact only of progress against infectious disease mortality, such as tuberculosis, that was once responsible for a great proportion of mortality among young men and children (see Figure 2b).

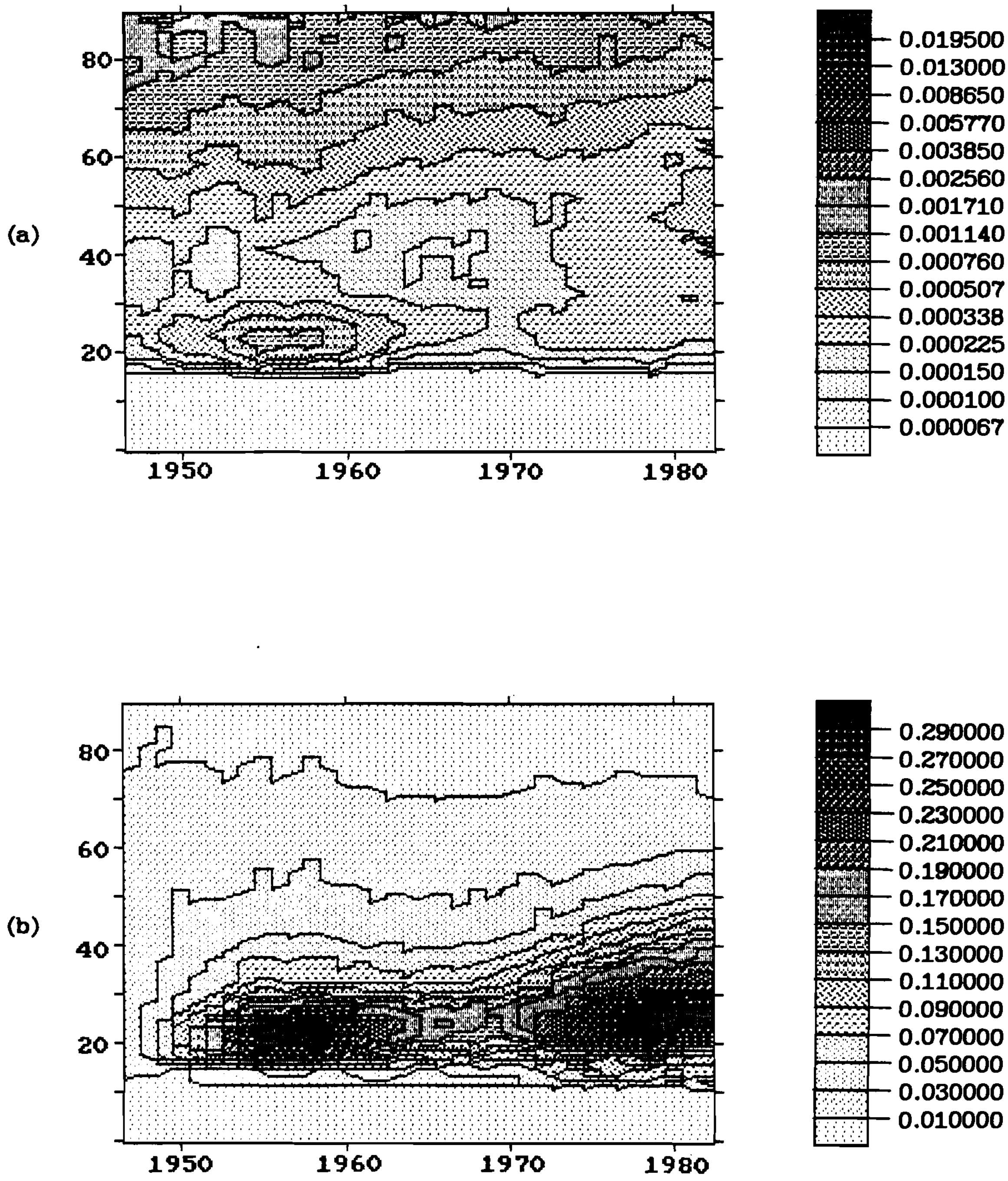
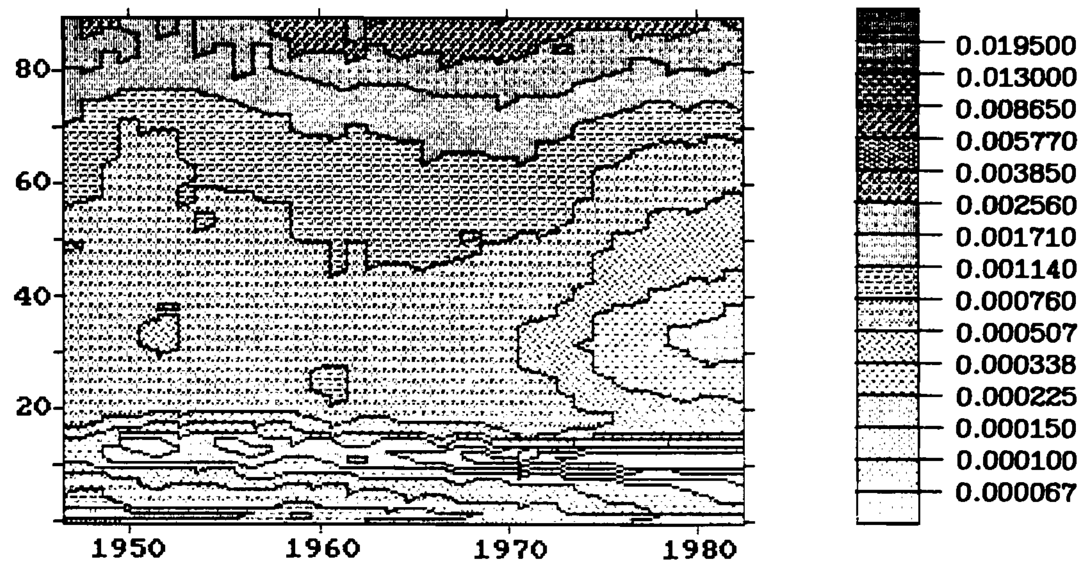



**FIGURE 6. (a) Mortality rates from suicides for Japanese males from 1947 to 1982 and age 0 to 89. (b) Suicides as a proportion of total mortality for Japanese males from 1947 to 1982 and age 0 to 89.**

(a)

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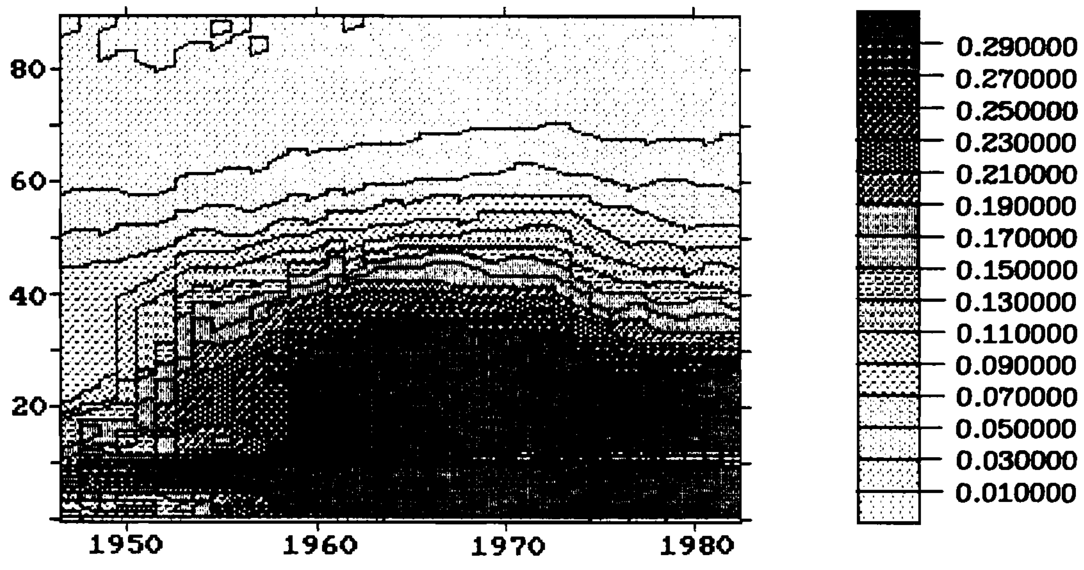



FIGURE 7. (a) Mortality rates from accidents for Japanese males from 1947 to 1982 and age 0 to 89. (b) Accidents as a proportion of total mortality for Japanese males from 1947 to 1982 and age 0 to 89.

## 4. Leading Causes of Death

Figures 8 and 9 illustrate a ranking for nine major causes of death from 1947 to 1982 and age 0 to 89. Unlike other Lexis maps presented to this point, the third variable is discrete and the surface discontinuous. For these maps, the level represents the particular cause at each age, time and rank for the six leading causes of death. From these, we see clearly how the composition of total mortality has changed substantially over the 35 year period under study. We did not include "other" as a cause of death, and some important causes, such as cirrosis of the liver, will not appear because the data was not available to us.

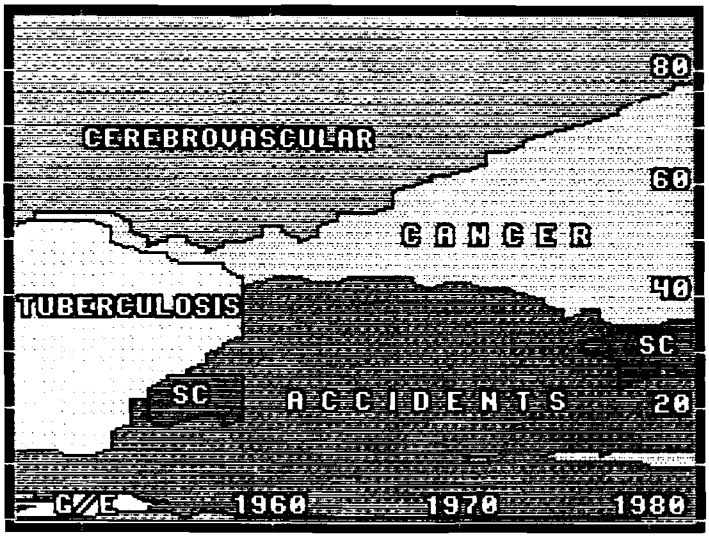
Figure 8a displays leading causes of death over age and time. Notice that four causes completely dominate the map. Tuberculosis, once a major cause of death for males 12 to 52, has been replaced by accidents, cancer, and, in some small areas, suicide. Cerebrovascular disease was consistantly the leading cause of death for those aged greater than 78, but by 1982 malignant neoplasms replaced it as the leading cause among middle-aged Japanese males. Overall, accidents seem to occupy the greatest area of the map, though suicides and cancer were beginning to replace it as the major cause of death by 1982.

Among the second leading causes of death displayed in Figure 8b, suicide stands out as a major factor in mortality among males 17 to 43. Notice also that cerebrovascular disease and malignant neoplasms together are the primary causes of death among males aged 50 to 80. Heart disease becomes a factor in determining mortality for males aged greater than 80 after 1950. In the late 1940s and early 1950s, accidents were second to tuberculosis as a cause of death among males aged 12 to 41.

As the rankings progress, the patterns become more complex as different causes play different roles in determining the makeup of mortality. One interesting feature of the maps, however, is that diagonal effects become striking. Notice the diagonal patterns of tuberculosis in the maps representing the third and sixth leading causes of death. Also apparent are particular cohorts that carry a cause specific mortality with them. They can be seen by looking in the bottom corner of the fourth and fifth cause maps.

Taken together, the cause of death maps displayed in Figures 2–9 provide an interesting decomposition of mortality. They give demographers, medical scientists, and policy makers some idea of how progress against cause mortality might change the structure of mortality and population in Japan. Indeed, the maps contain information about changing trends in cause specific mortality that could provide important clues about mortality structure in the future.

(a)

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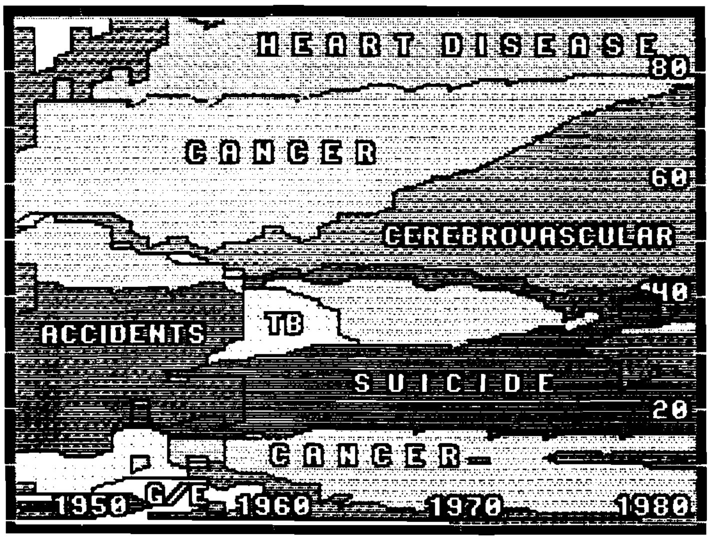
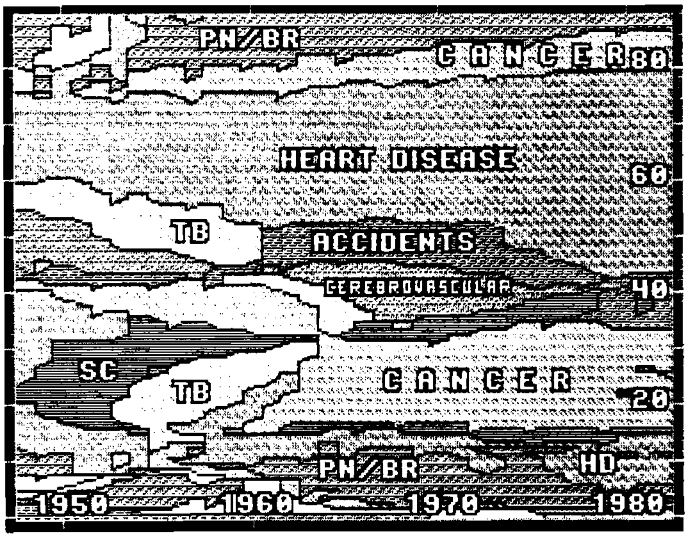



FIGURE 8. (a) First leading causes of death for Japanese males from 1947 to 1982 and age 0 to 89. (b) Second leading causes of death for Japanese males from 1947 to 1982 and age 0 to 89.

(a)

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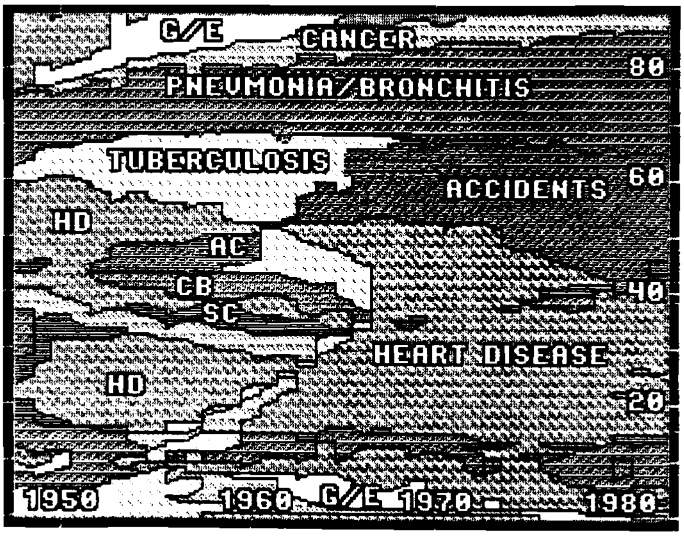


FIGURE 9. (a) Third leading causes of death for Japanese males from 1947 to 1982 and age 0 to 89. (b) Fourth leading causes of death for Japanese males from 1947 to 1982 and age 0 to 89.

**REFERENCES**


Hishunuma, Shigekazu (1981) Mortality Trends in Japan and their Possible Causes. *Medical Aspects of Mortality Statistics*. Stockholm: Almquist & Wiksell International, pp. 121–140.

Kono, Shigemi and Shigesato Takahashi (1985) *Mortality Trends in Japan: Why Has the Japanese Life Expectancy Kept on Increasing*? Informal Meeting I.5, Reversals in Declining Mortality, IUSSP Florence Center.

Mosk, Carl (1979) The Decline of Marital Fertility in Japan. *Population Studies* 33:19–38.

Okubo, Masakazu (1981) *Increase in Mortality of Middle-Aged Males in Japan*. NUPRI Research Paper. Nihon University, Tokyo, Japan.

Owen, John and James W. Vaupel (1985) An Exercise in Life Expectancy. *American Demographics* 7(11):37–39.

Shigematsu, Itsuzo and Hiroshi Yanagawa (1983) *Social and Economic Policies and their Effects of Mortality in Japan*. Presented at the Seminar on Social Policy, Health Policy and Mortality Prospects, Institute National d'Etudes Demographiques.