Cancer Surveillance Series: Changing Geographic Patterns of Lung Cancer Mortality in the United States, 1950 Through 1994

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Background: **Geographic surveys revealing variations in lung cancer mortality rates across the United States have prompted epidemiologic studies in high-risk communities. We have updated these maps to track the changing patterns and to provide further clues to the determinants of lung cancer.** ***Methods:*** **Age-adjusted race- and sex-specific lung cancer mortality rates from 1950 through 1994 were calculated for nine Census Divisions and 508 State Economic Areas of the United States.** ***Results:*** **Pronounced geographic variation in lung cancer rates was evident, with the patterns changing substantially over time. Among white males in the 1950s and 1960s, high rates were observed in urban areas of the northeast and north central states and in areas along the southeast and Gulf coasts. By the 1970s, the northern excess began to fade, with high rates starting to cover wider areas of the south. By the 1980s to the mid-1990s, clustering of elevated rates was prominent across the southeast and south central areas, with relatively low rates throughout much of the northeast. Among white females, little geographic variation was evident in the 1950s, but thereafter relatively high rates began to appear in clusters along the Atlantic and Pacific coasts. For both sexes, consistently low rates were seen in the mountain and the plains states. Rates among blacks were consistently elevated in northern areas and low across the south.** ***Conclusions:*** **The changing mortality patterns for lung cancer generally coincide with regional trends in cigarette smoking, indicating that public health measures aimed at smoking prevention and cessation should have a dramatic effect in reducing lung cancer rates. [J Natl Cancer Inst 1999;91:1040–50]**

The geographic patterns in cancer occurrence have provided important clues to the role of environmental or lifestyle factors that affect cancer risk. Atlases of cancer mortality in the United States for overlapping periods from 1950 through 1980 *(1–4)* have revealed substantial geographic variation in rates and identified high-risk areas where special studies have helped to elucidate carcinogenic exposures *(5,6)*. Because the variation in lung cancer has been especially marked over time and place *(7)*, we have updated the maps through 1994 and documented dramatic regional shifts in the geographic patterns of lung cancer mortality.

Materials and Methods

Data on all deaths among Americans from 1950 through 1994 with cancer as the underlying cause according to age, sex, and race were provided for the 3055 U.S. counties by the National Center for Health Statistics (Hyattsville, MD). We selected all deaths due to cancer of the lung, trachea, bronchus, or pleura. The International Classification of Disease codes included were 162–3 for the 6th and 7th revisions (for deaths occurring from 1950 through 1967) *(8,9)*, 162 and 163.0 for the 8th revision (from 1968 through 1978) *(10)*, and 162 and 163 for the 9th revision (from 1979 through 1994) *(11)*. Annual county-, age-, sex-, and race-specific mid-year population estimates on the basis of data from the U.S. Bureau of the Census (Suitland, MD) were aggregated to form the person-years at risk. Detailed population estimates were available for the entire 45-year period for whites but only from 1970 through 1994 for blacks (earlier detailed population estimates pertained only to the entire group of nonwhites). Death counts and rates were produced at the national level, the level of nine Census Divisions (*see* "Appendix" section), and the level of State Economic Areas (SEA), which are 508 individual counties or groups of counties defined by the U.S. Bureau of the Census to be relatively homogeneous in 1960 with respect to various demographic, economic, and cultural factors *(12)*. Data for all 50 states are presented, with Alaska and Hawaii each being considered a single unit for SEA purposes.

Age-adjusted (direct method, 1970 U.S. population standard) mortality rates per 100 000 person-years were calculated for the time periods from 1950 through 1959, from 1960 through 1969, from 1970 through 1979, from 1980 through 1989, and from 1990 through 1994 among whites and from 1970 through 1979, from 1980 through 1989, and from 1990 through 1994 among blacks *(13)*. To allow comparison of the rates of change by considering the slopes of the lines, figures presenting the trends by the Census Division were prepared by use of a log scale for the *y*-axis. The *y*-axis-to-*x*-axis ratio of one log cycle to 40 years was used uniformly in all figures; this results in an annual change in rate of 1% to be portrayed by a line with a slope of 10 degrees *(14)*. Prior to preparing the maps, we deemed rates for an SEA on the basis of sparse data to be unstable if *(a)* the observed number of deaths was fewer than six; *(b)* the observed number of deaths was fewer than 12 and the rate was not significantly different statistically from the national rate; or *(c)* the expected number of deaths was fewer than six and the rate was not significantly different statistically from the U.S. rate. For each race, sex, and time period, the stable SEA-level rates were ranked and partitioned into deciles, and maps were prepared with color codes that used shades of red and blue. Areas with rates based on sparse numbers of deaths were shaded gray.

Results

The numbers of lung cancer deaths and age-adjusted rates are shown in Table 1. The national age-adjusted lung cancer mortality rates among white males more than doubled from 1950 through 1959 to 1980 through 1989 before declining slightly from 1990 through 1994, when the age-adjusted rate was 71.7 per 100 000 person-years. Mortality rose over the 45-year period in all regions of the country, with the increases most pronounced in the East South Central states and least pronounced in the Mountain states (Fig. 1). The rates of increase among men gradually slowed over time, and in five of the nine Census Divisions, mortality declined in the most recent period, from 1990 through 1994. Lung cancer rates continued to increase from 1990 through 1994 in the Mountain, West North Central, West South Central, and East South Central Census Divisions.

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See "Notes" following "References."

Table 1. Lung cancer deaths and mortality rates by sex, race, and time period, United States, 1950 through 1994*

	Males		Females	
	No.	Rate†	No.	Rate†
Whites				
1950–1959	204 225	30.00	37 789	5.18
1960–1969	366 761	47.12	70 554	7.71
1970–1979	560 116	64.09	168 223	15.31
1980–1989	728 664	72.23	340 601	26.17
1990–1994	401 593	71.71	243 955	33.43
Blacks‡				
1970–1979	66 331	79.55	16 238	15.25
1980–1989	94 910	100.99	33 534	25.92
1990–1994	53 067	103.76	24 158	32.74

*Based on data from the National Center for Health Statistics and the U.S. Bureau of the Census.

†Rate per 100 000 person-years, age-adjusted using the 1970 U.S. population distribution.

‡Prior to 1970, data for blacks were reported as part of nonwhite deaths, not separately.

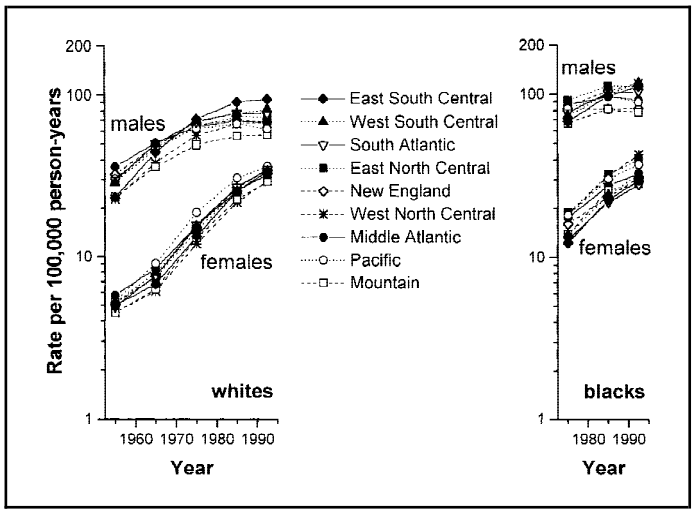

Fig. 1. Age-adjusted mortality rates for cancers of the lung, trachea, bronchus, and pleura by sex and Census Division, from 1950–1959 through 1990–1994. Based on data from the National Center for Health Statistics and the U.S. Bureau of the Census.

Although considerably lower than the rates among males, lung cancer rates among white females showed a steeper climb, with the national mortality rising sixfold, from 5.2 per 100 000 person-years in 1950 through 1959 to 33.4 in 1990 through 1994. The rates tripled by the 1970s and have doubled again since then. Mortality rose in each Census Division, with the most rapid increases from the 1960s to the 1980s. In recent years, rates were highest in the Pacific states and lowest in the Mountain states.

Rates among black males were higher than those among any of the other three groups, increasing 31%, from 79.5 per 100 000 person-years for the period from 1970 through 1979 to 101.0 for the period from 1980 through 1989 and to 103.8 for the period from 1990 through 1994. Rates continued climbing into the 1990s in five of the nine Census Divisions, but peaks during the period from 1980 through 1989 were apparent in the Middle Atlantic, East North Central, Mountain, and Pacific Divisions (Fig. 1). From 1990 through 1994, the highest rates were in the West North Central and West South Central Divisions. The national rates among black females were similar to those among white females, more than doubling, from 15.2 per 100 000 person-years for the period 1970 through 1979 to 32.7 for the period 1990 through 1994. The increases occurred over the entire time period in each Census Division, with rates from 1990 through 1994 being the highest in the East and West North Central Divisions.

Geographic variation in lung cancer mortality was pronounced in nearly all time periods. During the period from 1950 through 1959, rates among white males were elevated in urban areas of the northeast and along the south Atlantic and Gulf coasts (Fig. 2, A). Over time, however, the northeast excesses became less evident, as rates rose more rapidly in other areas of the country (Fig. 2, B–E). By the 1970s, many of the highest rates occurred in the southeast quadrant of the country, with broader coastal bands of high rates spreading inland and also along the Mississippi Valley. By the 1990s, virtually all of the rates in the highest decile occurred in the southeast quadrant. In contrast, rates in the North Central and Mountain areas remained low relative to the rest of the country, while rates in the northeast and far west approximated the national rate.

Among white females during the period from 1950 through 1959, geographic gradients were not pronounced (Fig. 3, A). Over time, however, elevated rates became apparent along the coastal areas of the southeast and the Gulf but not across the southeast quadrant as seen for males (Fig. 3, B–E). Rates also became elevated in the far western states, while they remained relatively low in the North Central and Mountain areas.

Lung cancer mortality rates among black males were relatively low across most of the southeast during the 1970s, with scattered areas of high rates across the northern tier, although not necessarily in urban areas (Fig. 4, A). The regional variation faded over time, although scattered high-rate areas were seen (Fig. 4, B–C). Among black females, rates were consistently low across the south from the 1970s through the 1990s and high in northern and western areas (Fig. 5, A–C).

DISCUSSION

The first atlas of cancer mortality in the United States, covering the white population from 1950 through 1969, revealed substantial geographic variation in lung cancer, with clusters of high-rate counties in northern urban and southern coastal areas *(1)*. When data were shown through 1980, there was a shift toward higher rates across the south among men and along the Atlantic and Pacific coastal areas among women *(3,7)*. The striking changes in the geographic patterns of lung cancer among white men are illustrated here in the updated maps covering the 45-year period from 1950 through 1994. During the period from 1990 through 1994, the rates among males in New Jersey, New York, and other parts of the northeast had gone from some of the highest in the nation to below the U.S. average, while the relatively low mortality previously seen in the mid-south (e.g., Kentucky, Tennessee, and Arkansas) and southeast gave way to some of the highest rates in the country. Although geographic shifts were less pronounced among white females, relatively high mortality rates along the Atlantic and Pacific coasts have become increasingly evident since the 1960s. The earlier maps for nonwhites in the 1950s and 1960s *(2,4)* revealed low rates across the south for both males and females, with scattered high rates in other areas, similar to the maps shown here for blacks in

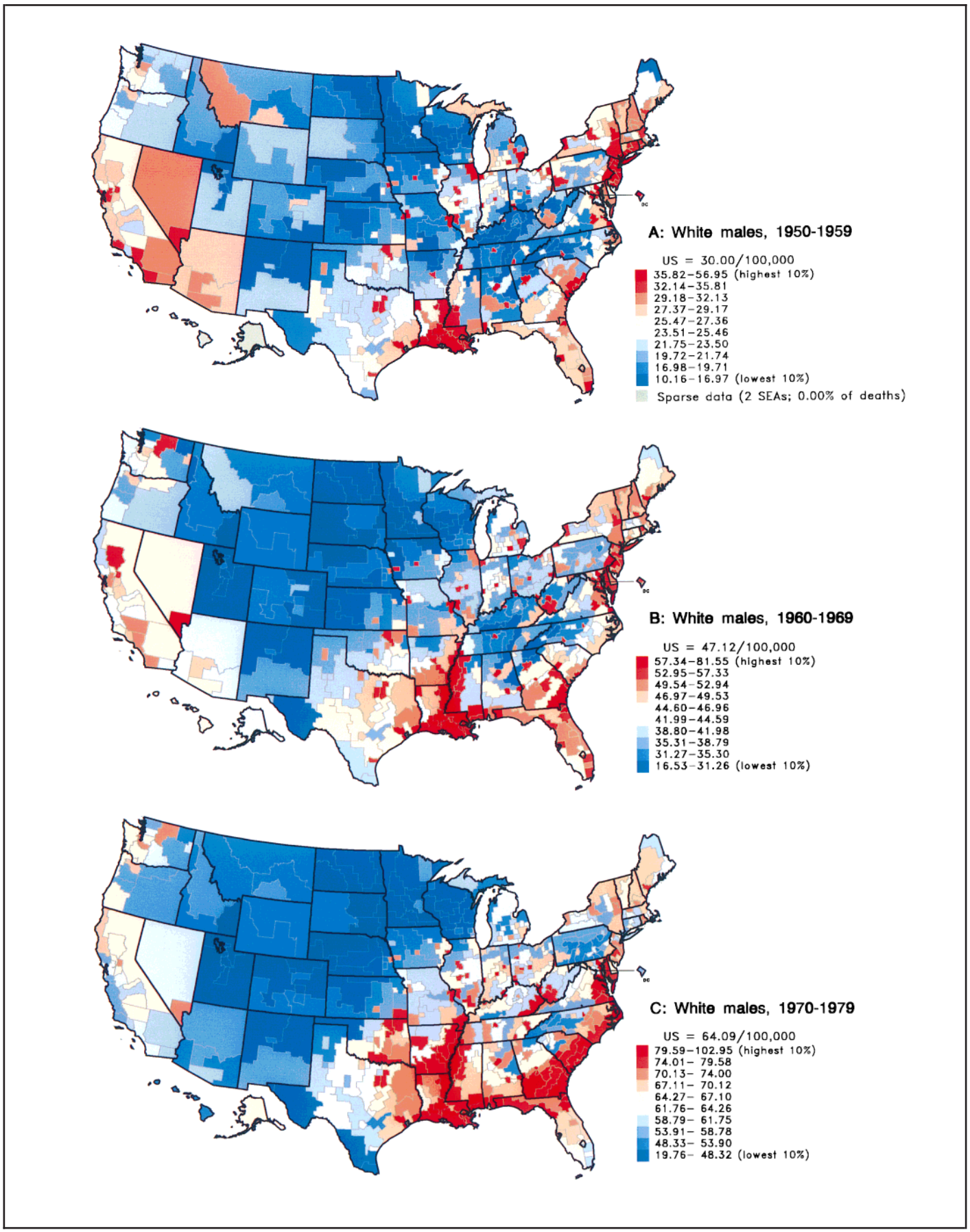

Fig. 2. Mortality rates by State Economic Area for cancers of the lung, trachea, bronchus, and pleura among white males (age-adjusted, 1970 U.S. population). **A** = 1950 through 1959, **B** = 1960 through 1969, **C** = 1970 through 1979. Based on data from the National Center for Health Statistics and the U.S. Bureau of the Census.

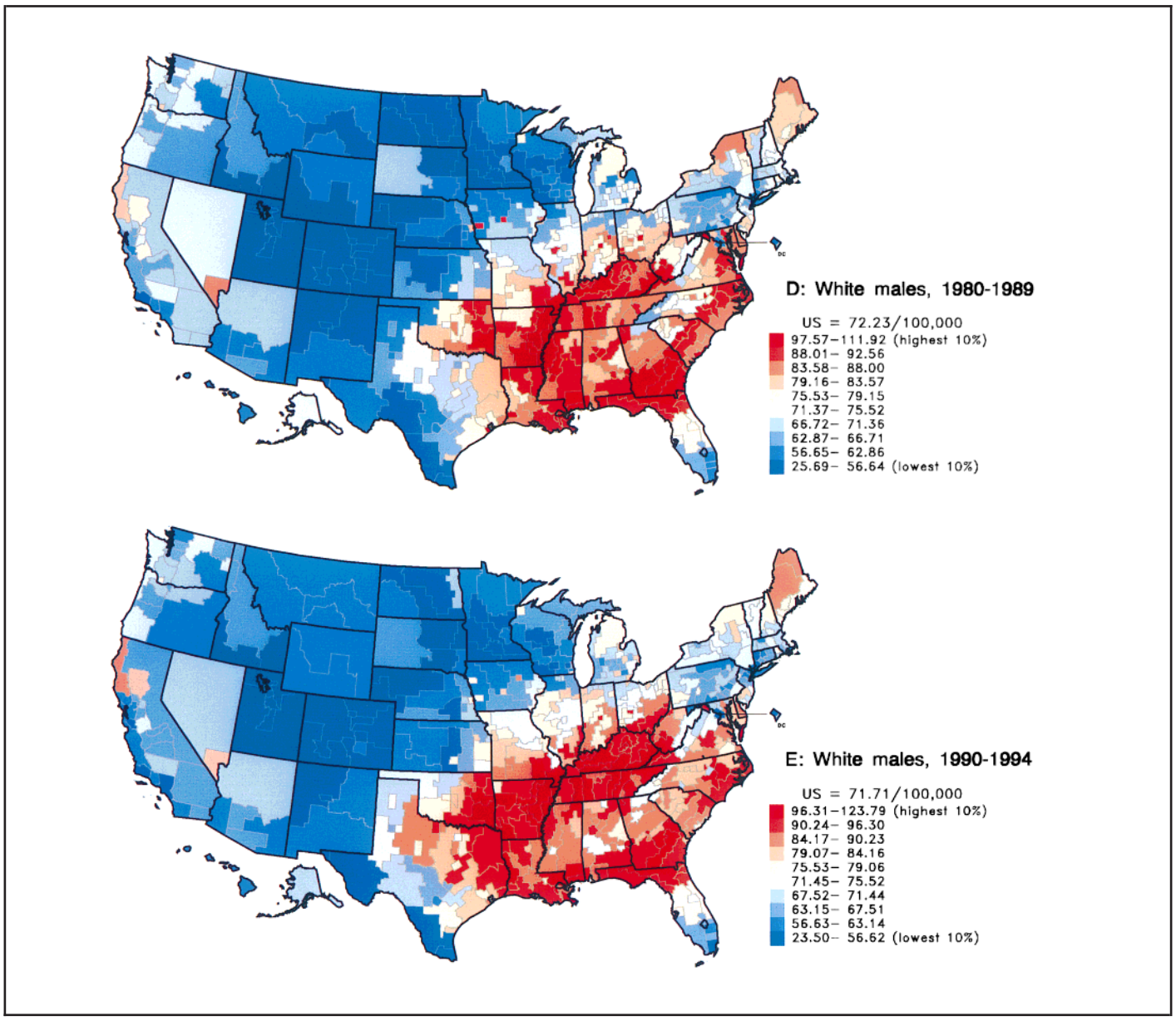

Fig. 2 (continued). Mortality rates by State Economic Area for cancers of the lung, trachea, bronchus, and pleura among white males (age-adjusted, 1970 U.S. population). **D** = 1980 through 1989, **E** = 1990 through 1994. Based on data from the National Center for Health Statistics and the U.S. Bureau of the Census.

the 1970s and 1980s. The geographic variation seen among blacks, however, has become less pronounced over this time period.

We present maps for which the rates have been ranked independently for each combination of race, sex, and time period. An alternative would be to combine the rates across time periods—and even, perhaps, across race or sex categories—before ranking and partitioning into deciles. However, because of the substantial increases in rates over time, this approach would result in mostly blue maps for early years and red maps for more recent years. Because of the much higher rates among males than among females, combining the data for both sexes would result in mostly red maps for males and blue maps for females. Maps combining the data for both races would be difficult to interpret because of the large areas with sparse data for blacks. The approach that we chose avoids these problems and enables clearer assessment of the geographic contrasts within each map.

Only limited data are available according to SEA on risk factors that have been associated with the distribution of lung cancer. Because cigarette smoking is the dominant cause of lung cancer in the United States *(15)*, we evaluated data from previous population surveys of smoking rates by area of residence. Although indicators of cigarette consumption at the state level, based on sales tax data, have been available for many years *(16)*, the earliest sex- and state-specific data we could find pertained to 1985, although even these data were not race specific *(17)*. Fig. 6, A (males) and B (females), plots the distribution of current smokers in 1985 by state *(17)*. Among white males, the patterns of smoking prevalence and lung cancer rates for 1990 through 1994 appear to be similar, with high-rate areas for both variables in the southeastern quadrant of the country. Among females, the concordance was less pronounced. Because estimates of the prevalence of smoking are weighted toward young and middle-aged adults and the mortality rates are dominated by deaths at generally older ages, the 1985 smoking patterns for both males and females may predict lung cancer mortality rates

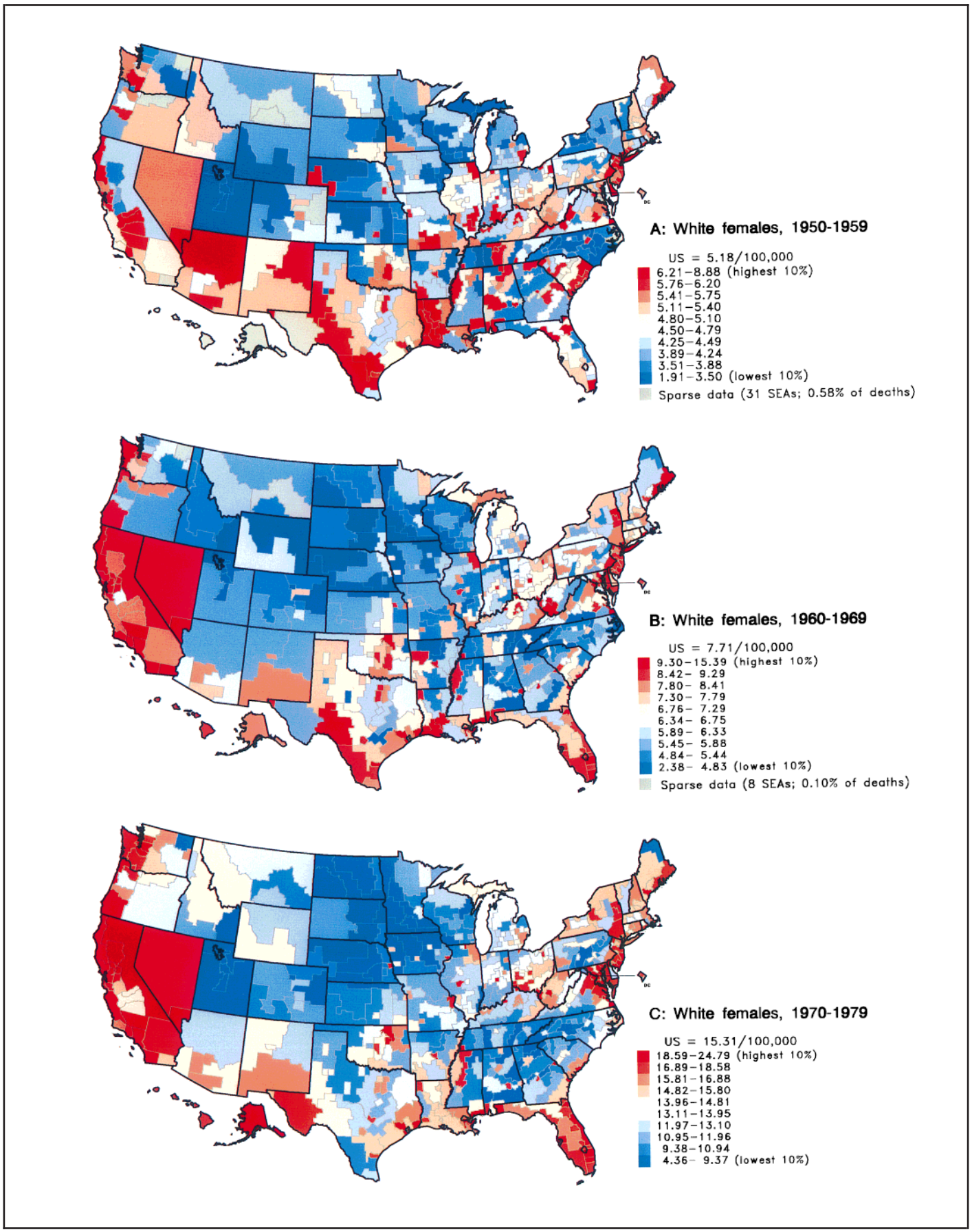

Fig. 3. Mortality rates by State Economic Area for cancers of the lung, trachea, bronchus, and pleura among white females (age-adjusted, 1970 U.S. population). **A** = 1950 through 1959, **B** = 1960 through 1969, **C** = 1970 through 1979. Based on data from the National Center for Health Statistics and the U.S. Bureau of the Census.

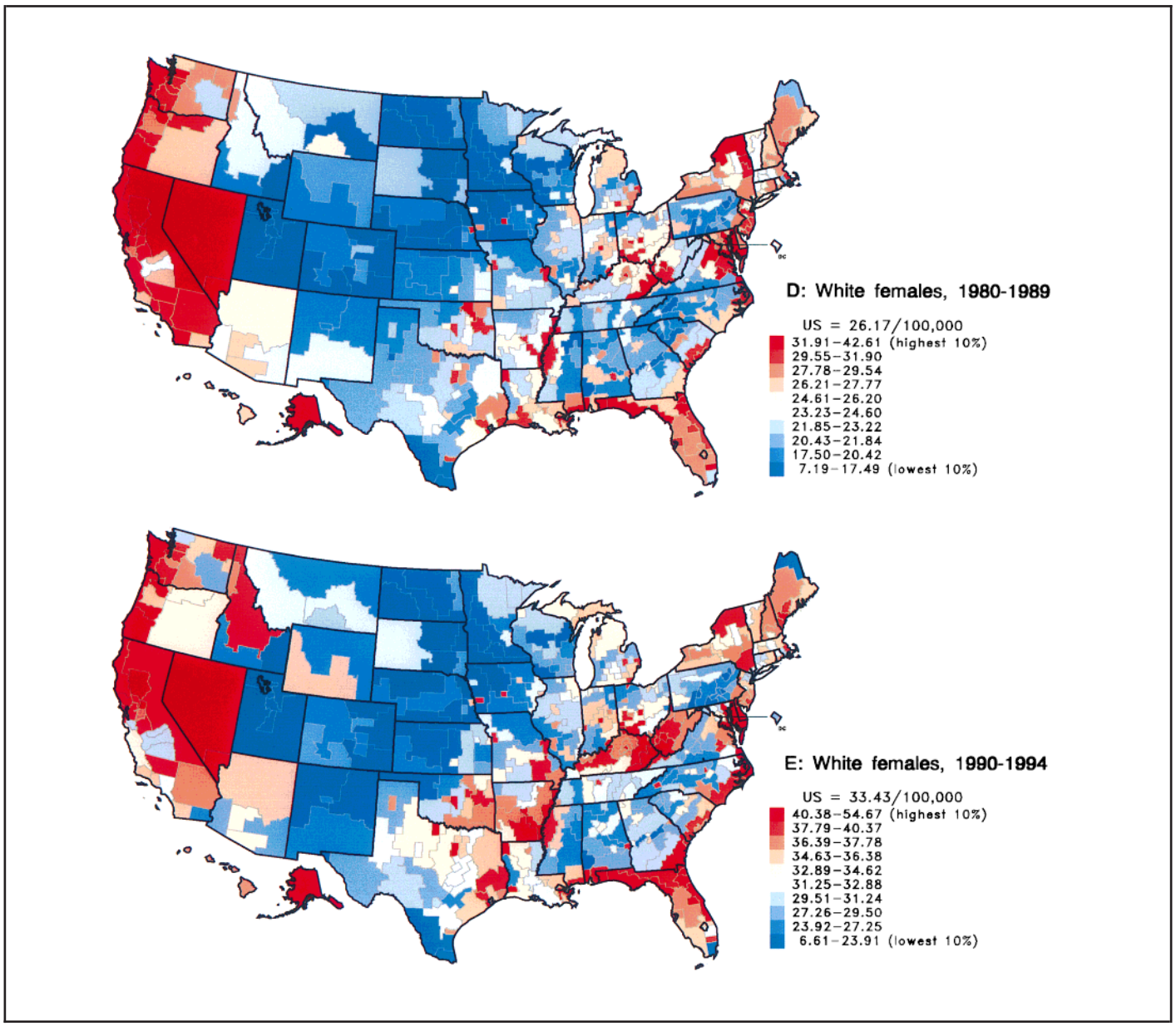

Fig. 3 (continued). Mortality rates by State Economic Area for cancers of the lung, trachea, bronchus, and pleura among white females (age-adjusted, 1970 U.S. population). **D** = 1980 through 1989, **E** = 1990 through 1994. Based on data from the National Center for Health Statistics and the U.S. Bureau of the Census.

in the decades to come. Formal statistical evaluation of the potential associations between the SEA-specific lung cancer mortality rates and the state-specific prevalences of smoking is beyond the scope of this analysis.

Because smoking acts at both early and late stages of lung carcinogenesis *(18)*, the relevant data on smoking for lung cancer occurring during the period from 1990 through 1994 would be smoking prevalences for this time period and for time periods 10, 20, and 30 or more years earlier. Limited data from the 1950s indicate that regional differences in smoking patterns among males were small, although smoking was more common in urban than in rural areas, and the percentage of heavy smokers was greatest in the Northeast *(19)*. However, by the late 1970s, the prevalence of current smokers was highest among men under age 65 years in the South, with little difference at older ages *(20)*. By the mid-1980s, it was clear that the South led the nation at all ages in the percentage of adult males who smoked *(21)*. Therefore, the smoking trends fit well with the early excess of lung cancer among white men in urban areas, particularly in the North, and the recent emergence of elevated mortality across broad stretches of the South. Smoking data were not specific enough to correlate with the patterns of lung cancer seen along the southeast coast. However, smoking habits including the use of hand-rolled cigarettes were found to contribute to the high rates in southern Louisiana, especially among Cajuns *(22)*. Among black males, the prevalence of smoking in 1985 was lowest in the South *(21)*, coinciding with the low rates of lung cancer among southern black men.

Among females in the 1950s, the prevalence of current smokers was highest in the West and lowest in the South *(19)*. By the 1980s, however, white women in the West, in both the Pacific and the Mountain states, had the lowest percentage of current smokers among all regions *(21)*. Thus, the lung cancer patterns among white women, particularly the Pacific coastal excess, are consistent with the high smoking rates in earlier years, but the recent shifts in smoking prevalence are not yet reflected in the

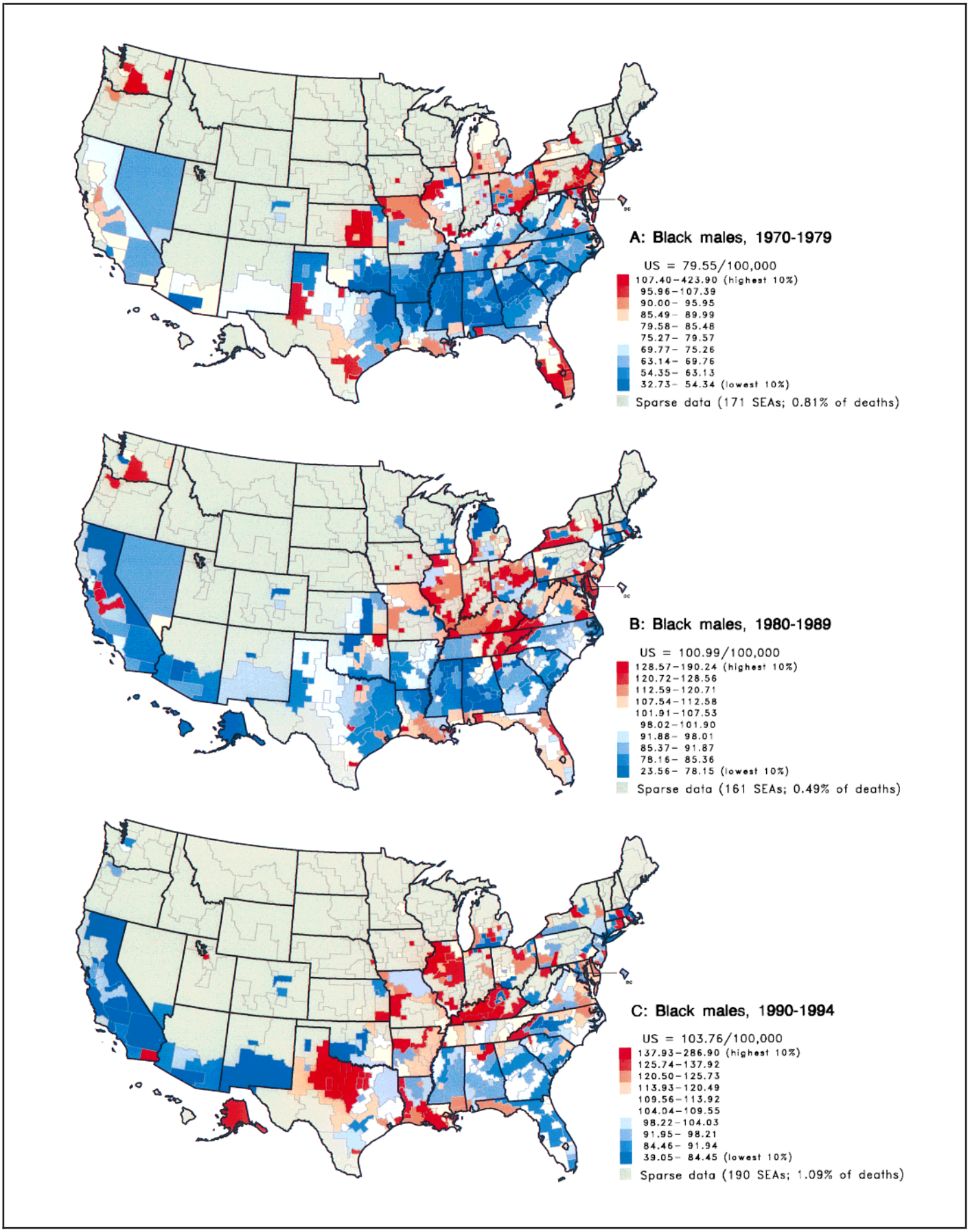

Fig. 4. Mortality rates by State Economic Area for cancers of the lung, trachea, bronchus, and pleura among black males (age-adjusted, 1970 U.S. population). **A** = 1970 through 1979, **B** = 1980 through 1989, **C** = 1990 through 1994. Based on data from the National Center for Health Statistics and the U.S. Bureau of the Census.

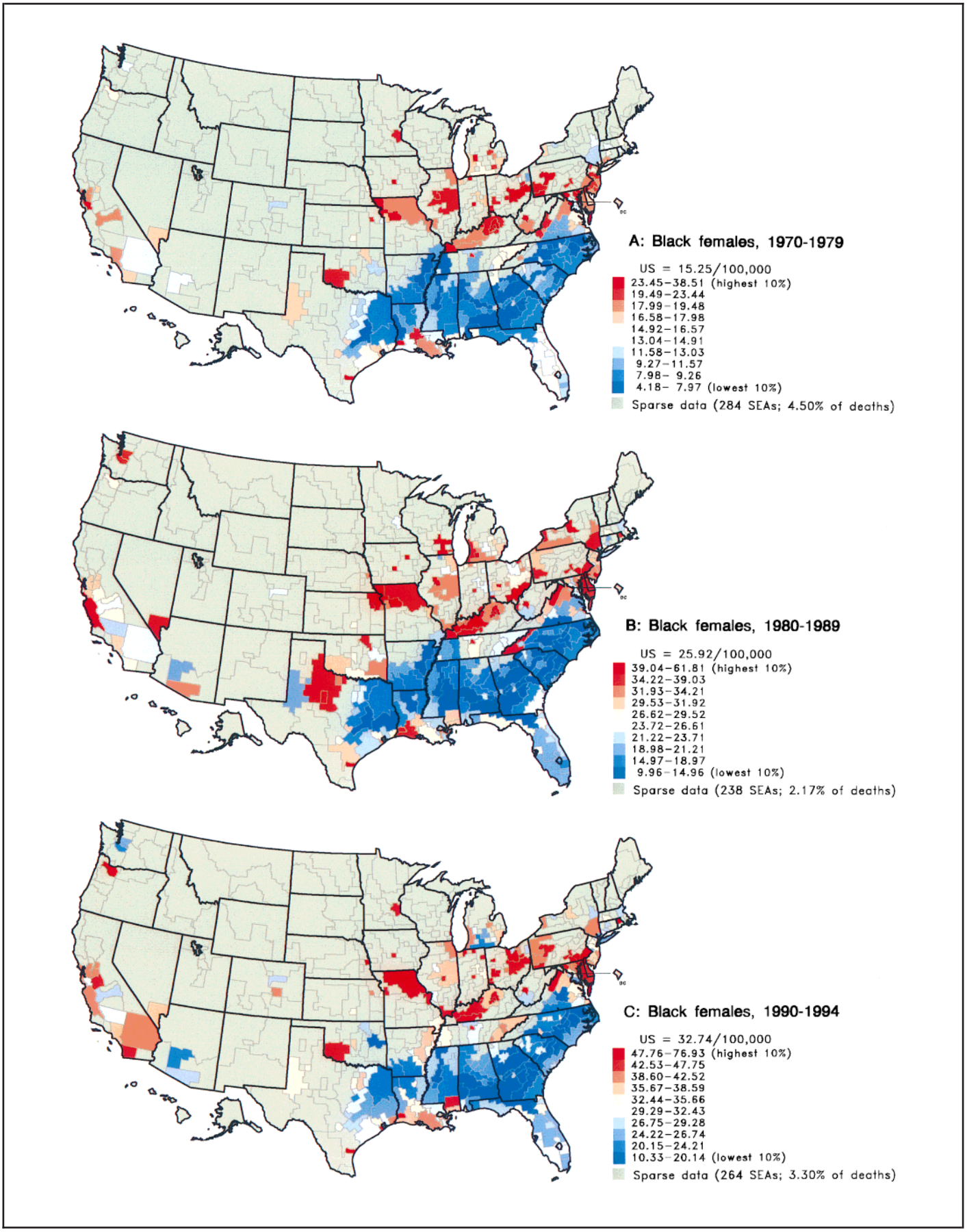

Fig. 5. Mortality rates by State Economic Area for cancers of the lung, trachea, bronchus, and pleura among black females (age-adjusted, 1970 U.S. population). **A** = 1970 through 1979, **B** = 1980 through 1989, **C** = 1990 through 1994. Based on data from the National Center for Health Statistics and the U.S. Bureau of the Census.

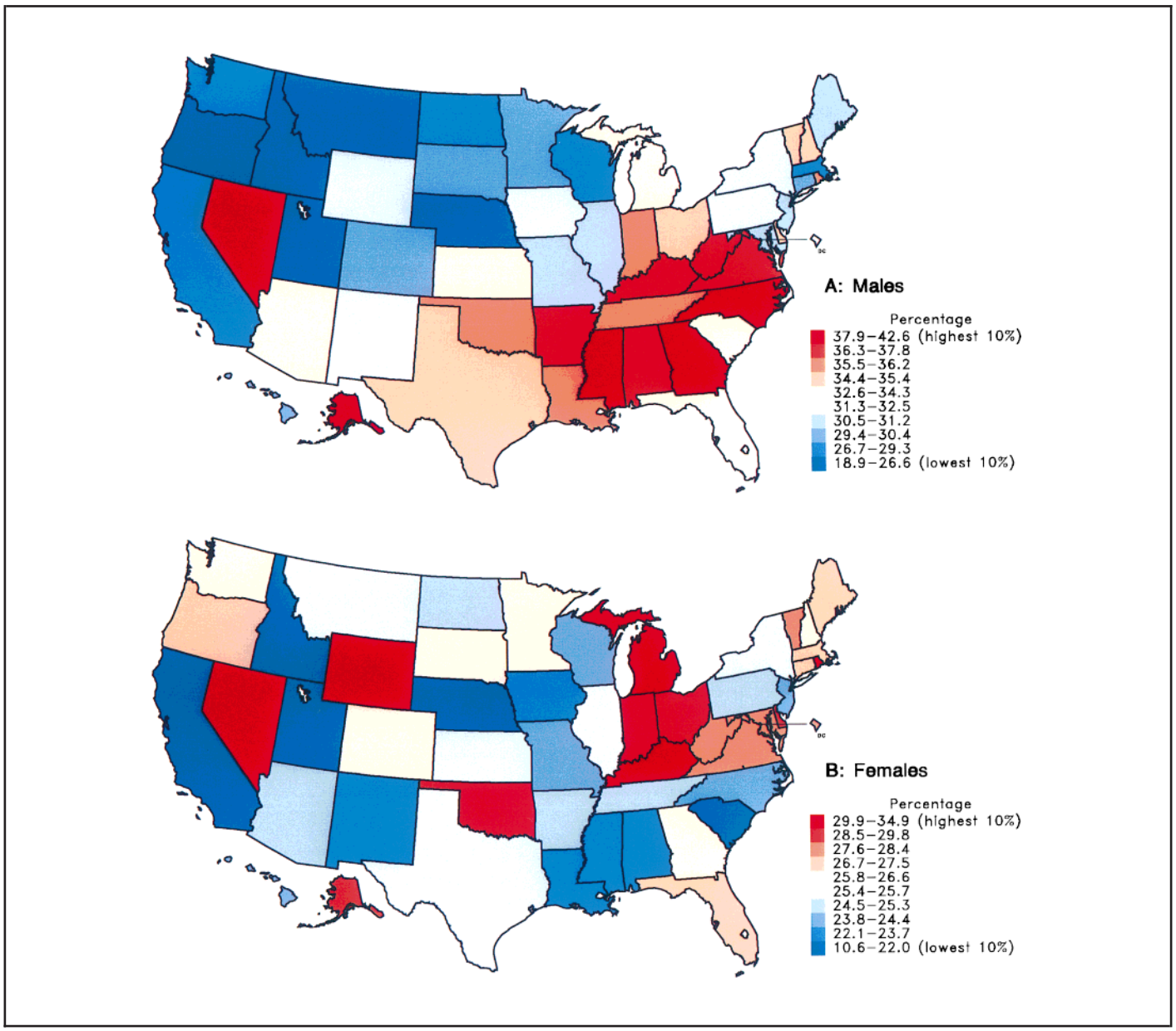

Fig. 6. Percentage of adults 20 years of age and older smoking cigarettes by state, 1985. **A** = males and **B** = females. Based on data from Shopland et al. *(17)*.

lung cancer patterns. Among black females, however, the 1985 prevalence of smoking was highest in the North Central region and lowest in the South, thus resembling the distribution of lung cancer.

Although smoking patterns largely account for the regional variation in lung cancer mortality, the early maps *(1,3)* and subsequent correlation studies also suggested a relation to certain occupational exposures *(23,24)* and prompted a series of case–control studies in high-risk areas, particularly along the southern seaboard. In the 1970s and early 1980s, studies in coastal Georgia *(25)*, Tidewater Virginia *(26)*, northeast Florida *(27)*, and southern Louisiana *(28)* revealed an excess risk of lung cancer associated with work in shipyards, primarily during World War II. Asbestos exposure appeared to be the major hazard, especially since clusters of mesothelioma were also observed in certain coastal areas *(29,30)*. In the more recent maps, the coastal excess of lung cancer among men was less pronounced, perhaps because of a diminished effect of wartime asbestos exposures in shipyards, since risk of lung cancer is known to decline following cessation of asbestos exposure *(18)*. Indeed, a case–control study of lung cancer in northeast Florida during the 1990s found no significant excess risk associated with prior work in shipyards *(31)*. It is possible that the recent clustering of high lung cancer rates among females in coastal areas may be partly related to asbestos exposures associated with the shipbuilding industry in view of synergistic effects with smoking, although few women worked in the industry and the high rates extended to coastal areas without shipyards.

Correlation studies have also revealed elevated rates of lung cancer among males and females residing in counties with arsenic-emitting smelters *(32)*, prompting case–control studies raising the possibility that there are carcinogenic effects of neighborhood as well as occupational exposure to inorganic arsenic *(33)*. Further epidemiologic studies in high-risk areas should continue to generate insights into occupational and other environmental determinants of lung cancer.

The geographic patterns of lung cancer may also be useful in targeting health planning and prevention programs. Lung cancer has become the second leading cause of death (following heart disease) among U.S. men and the third leading cause of death (following heart and cerebrovascular diseases) among U.S. women *(34)*, thus accounting for hundreds of thousands of premature deaths. The changing patterns of smoking prevalence and subsequent lung cancer rates should help identify target populations where anti-tobacco research and control programs are especially needed to reduce the enormous toll of this preventable disease. In particular, the study of high-risk populations affords a special opportunity for behavioral studies to understand the determinants of smoking and to develop the most effective measures aimed at smoking cessation.

APPENDIX. Census divisions and states

New England
Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont

Middle Atlantic
New Jersey, New York, and Pennsylvania

South Atlantic
Delaware, District of Columbia, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, and West Virginia

East North Central
Illinois, Indiana, Michigan, Ohio, and Wisconsin

East South Central
Alabama, Kentucky, Mississippi, and Tennessee

West North Central
Iowa, Kansas, Missouri, Minnesota, Nebraska, North Dakota, and South Dakota

West South Central
Arkansas, Louisiana, Oklahoma, and Texas

Mountain
Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, and Wyoming

Pacific
Alaska, California, Hawaii, Oregon, and Washington

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NOTES

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