ANALYZING HEAD AND NECK CANCER INCIDENCE AND MORTALITY USING GEOGRAPHIC INFORMATION SYSTEMS

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ABSTRACT

Age-, race-, and gender-specific information for 20 major anatomical cancer sites of the head and neck was ascertained for the 46 South Carolina counties during 1979-1998 (mortality) and 1996-2000 (incidence). Over 80 age-adjusted analyses of head and neck cancer incidence and mortality rates by county were completed for major anatomical sites. Detailed maps presenting age-adjusted mortality and incidence rates, by quartile, at the county level were prepared using color-coding methods and three-dimensional displays, allowing rapid assessment of statistically significant geographic patterns. County-based indicators of health care access (including distribution of physicians, dentists, and general hospitals) were obtained, along with indicators of education, income, poverty, air emissions and water pollution. County-based survey results indicating use of alcohol, cigarettes, and smokeless tobacco (N = 223,663 respondents) also were obtained. Multiple regression models were used to describe possible factors associated with etiology of head and neck cancer in South Carolina.

INTRODUCTION

There will be 28,260 new cases and 7,230 deaths from cancers of the head and neck in the United States during 2004 (1). While cigarette and cigar smoking, smokeless tobacco, and alcohol are strongly associated with risk of most cancers of the head and neck (1), some cases cannot be accounted for solely by excessive use of tobacco and alcohol.

The purposes of this research were to identify data sources and obtain head and neck cancer mortality and incidence data at the county level for the 46 counties of South Carolina; identify and analyze data concerning lifestyle, social and demographic factors, access to medical care, and environmental factors; and develop GIS maps to examine associations between these factors and risk of cancers of the head and neck.

METHODS

Cancer Mortality Data by County. Age-, race-, and gender-specific mortality data were obtained for cancer sites in the head and neck for each of the 46 South Carolina counties during a 20-year period (1979-1998) (Table 1). The cancers were selected using relevant codes in the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) (2). The data were obtained from the Centers for Disease Control and Prevention county (CDC) mortality database (known as WONDER) (3).

Table 1. Head and neck cancer diagnoses and their International Classification of Diseases, Ninth Revision, codes for mortality data, 46 South Carolina counties, 1979-1998*

<u>Malignant neoplasm of</u>:

Lip (ICD-9-CM Code 140)
Tongue (ICD-9-CM Code 141)
Major salivary glands (ICD-9-CM Code 142)
Gum (ICD-9-CM Code 143)
Floor of mouth (ICD-9-CM Code 144)
Other and unspecified parts of mouth (ICD-9-CM Code 145)
Oropharynx (ICD-9-CM Code 146)
Nasopharynx (ICD-9-CM Code 147)
Hypopharynx (ICD-9-CM Code 148)
Other and ill-defined sites within the lip, oral cavity and pharynx† (ICD-9-CM Code 149)
Accessory sinuses, auditory tube, middle ear, and mastoid air cells (ICD-9-CM Code 160.1-160.9)
Bones of the skull, face and mandible (ICD-9-CM Code 170.0-170.1)
Eye (ICD-9-CM Code 190)

Other and ill-defined sites in the head, face and neck (ICD-9-CM Code 195.0)

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*Source: (2).
†Includes malignant neoplasms of Waldeyer's ring, unspecified sites in the pharynx, and ill defined sites.

Age-adjusted analyses of head and neck cancer mortality by county were performed for cancers of the head and neck, stratified by sex and race. The mortality rates were directly age-adjusted to the age distribution of the total 1970 U.S. population using the direct method (4). Whenever the sample size was sufficient, these analyses were used to identify possible associations of demographic, lifestyle, and environmental factors with incidence and mortality rates of head and neck cancer.

Mapping. Maps were made of mortality rates of major head and neck cancers by county, stratified by sex and race. The maps show age-adjusted mortality rates by quartile at the county level, using color-coding that allowed rapid assessment of geographic patterns of mortality from cancers of the head and neck. Statistical significance was estimated using the Poisson distribution (4). Automated mapping programs (ArcGIS 8.0 and BusinessMap, ESRI, Redlands CA) facilitated the process. Maps with three-dimensional extruded county boundaries (Figures 1-10) and color-coded isopleths (Figure 16) were created using two ArcGIS extensions, Arc Spatial Analyst and Arc 3D analyst. Two-dimensional maps (Figures 11-15) were created using BusinessMap.

Cancer Incidence Data by County. The South Carolina Central Cancer Registry of the South Carolina Department of Health and Environmental Control provided numerators and denominators that were used to calculate age-specific and age-adjusted incidence rates of cancers of the head and neck, according to sex, race (white or nonwhite), and county during a four-year period (1996-1999), for the cancers listed in Table 2. The registry began incidence data collection in 1996. The incidence rates were age-adjusted using the indirect method, providing standardized incidence ratios (SIR's) (4). Statistical significance was estimated using the Poisson distribution (4).

Table 2. Head and neck cancers and corresponding ICD-10 codes for incidence rates, 1996-1999*†

Malignant neoplasm of:

Lip (C00)
Base of tongue (C01)
Other and unspecified parts of tongue (C02)
Gum (C03)
Floor of mouth (C04)
Palate (C05)
Other and unspecified parts of mouth (C06)
Salivary glands (C07-08)
Tonsil (C09)
Oropharynx (C10)
Nasopharynx (C11)
Pyriform sinus (C12)
Hypopharynx (C13)
Other and ill-defined sites in the lip, oral cavity and pharynx (C14)

*Sources: (5, 6)
†Diagnoses were originally coded using the International Classification of Diseases for Oncology (ICD-O), then converted to ICD-10 codes for analysis.

Data on sociodemographic and environmental factors in South Carolina were obtained from a range of official sources at the national and state level. Data on access to health care by county, including the number of active physicians providing patient care in each county, was provided by an analysis performed by the American Medical Association. The distribution of general hospitals and other inpatient medical facilities by county was provided by an analysis performed by the American Hospital Association for this study. The number of dentists by county was obtained from the Health and Demographics Section of the Division of Research and Statistical Services (DRSS) of the State of South Carolina. A list of potential explanatory variables available at the county level for all 46 South Carolina counties is shown in Table 3.

Data were provided by the South Carolina Department of Alcohol and Other Drug Abuse Services on reported use of alcohol, cigarettes, and smokeless tobacco by teenagers, for use as a proxy measure of the overall level of use of alcohol, cigarettes and smokeless tobacco within each county (Table 4**)**. This proxy measure of tobacco and alcohol use was used since data on these exposures in adults were not collected by the state at the county level. The data included self-reported tobacco and alcohol use from a survey of students in grades 7-12 in all South Carolina counties. There were *N* = 223,663 respondents.

Table 3. Demographic and environmental variables included in the South Carolina Counties Head and Neck Cancer study, 1979-1998

Poverty – Percent of population living at or below the poverty level*
Income – Median annual household income in dollars*
Rent – Median contract rent, dollars per month*
Education – (a) Percent with less than junior high school education, (b) Percent with junior high school education but not high school graduate, and (c) Percent high school graduate*
Race – Percent of population that was nonwhite*
Older adults – (a) Percent of population that was aged 65-74 years, and (b) Percent of population that was aged 75 years or older*
Hospital access – Number of short-term general hospital beds per 1,000 resident population†
Physician access – Number of active physicians engaged in direct patient care, per 1,000 population in 1990‡
Dentist access – Number of active dentists engaged in direct patient care, per 1,000 population in 1979 and 1988§
Volatile organic compounds – Annual air emissions of volatile organic compounds‖
Nitrogen oxides – Annual air emissions of nitrogen oxide‖
Carbon monoxide – Annual air emissions of carbon monoxide‖
Sulfur dioxide – Annual air emissions of sulfur dioxide ‖
Small particulates – Annual air emissions of particulate matter with diameter of less than 10 microns‖
Larger particulates – Annual air emissions of particulate matter with diameter of less than 25 microns‖
Ammonia – Annual air emissions of ammonia from industrial sources‖

*Source: (7)
†Source: American Hospital Association.
‡Source: American Medical Association.
§Source: State of South Carolina, Division of Research and Statistical Services, based on data on practicing dentists from Dental Licensing Board.
‖Source: United States Environmental Protection Agency AIR database. Air pollutants were measured in thousands of tons emitted per year. Web site: http://www.epa.gov/air/data/index.html

Table 4. Lifestyle variables and per capita state sales tax charged

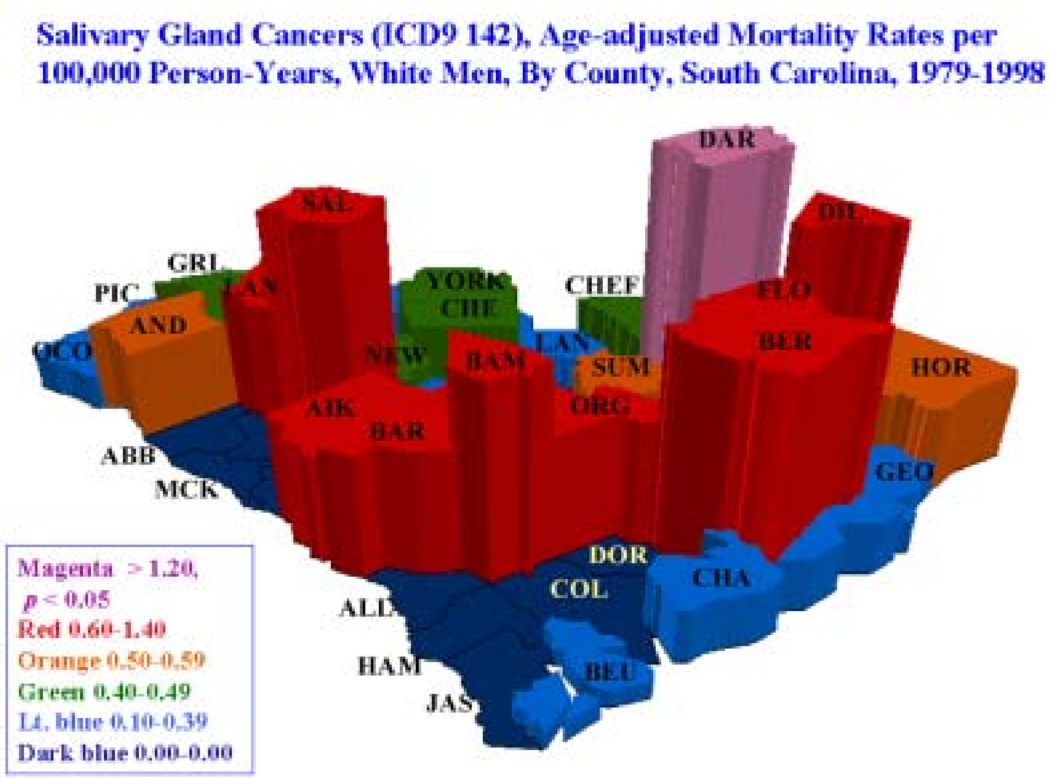
Percent of teenagers in each county who:
Smoked cigarettes*
Ever
During the past 30 days
Used smokeless tobacco*
Ever
During the past 30 days
Consumed alcohol*
Ever
During the past 30 days
More than one time per week during the past 30 days
State sales tax†
Per capita tax charged

* Source: State of South Carolina, Department of Alcohol and Other Drug Abuse Services 1989 survey data, students in grades 7-12.
† Source: State of South Carolina, Department of Finance, 1999.

RESULTS

Salivary gland cancers. Age-adjusted mortality rates from cancers of the salivary gland in white men tended to be markedly lower than expected in coastal areas and adjacent counties having direct water connections to the coast (Figure 1).

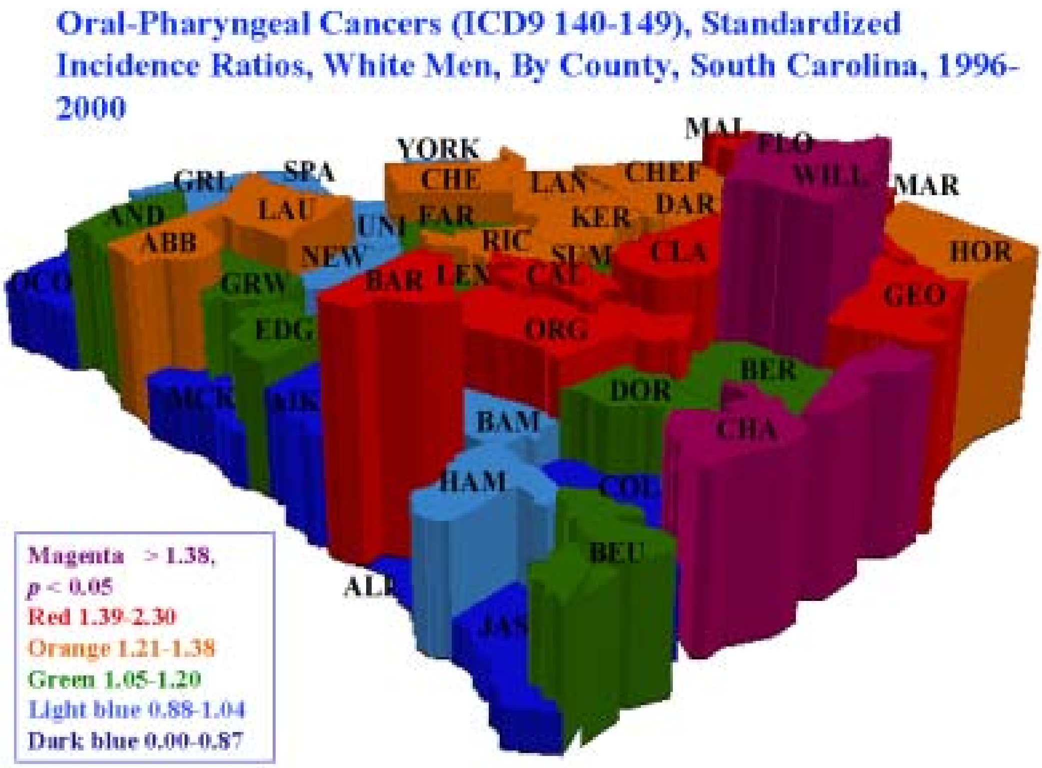
Figure 1



By contrast, they were highest in a band of inland counties, extending from Aiken, along the southwest inland boundary of the state, to a group of five counties on the northeast, including a statistically significantly high rate in one county, Darlington, that is identified by a magenta-colored bar. Rates were in the highest quintile in three nearby counties (Dillon, Florence and Berkeley). There were exceptions, including a few inland counties of small population size with low rates, and one northeastern coastal county, also of small population size, with a moderately high rate (Horry). The pattern was similar in other demographic groups, although the geographic distinctions were not as pronounced (not shown). A review of incidence data (not shown) revealed that SIR’s tended to be low in coastal counties, except for Charleston county.

Oral-Pharyngeal Cancers. SIR's were plotted for oral-pharyngeal cancers (ICD-9-CM codes 140-149). The favorable association of residence in a coastal county with salivary cancer rates was not present for oral-pharyngeal cancers (Figure 2)**.**

Figure 2



Most of the coastal counties that had low rates of salivary gland cancer had, by contrast, high SIR's for oral-pharyngeal cancers. Charleston, an exception, had a statistically significantly high SIR's for both salivary and oral-pharyngeal sites, although a low mortality rate for salivary cancer.

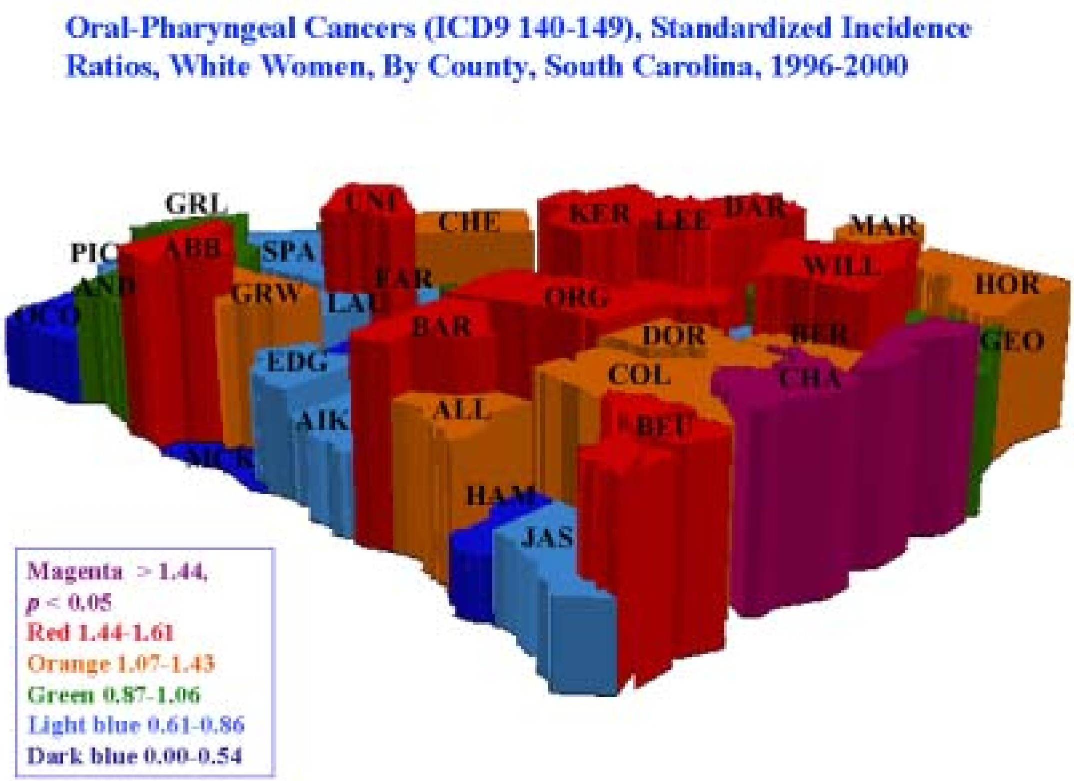
The apparent cluster of statistically significantly high SIR's from oral-pharyngeal cancers in the northeastern part of the state was located near the greatest tobacco-producing areas in the region (Figure 3), although high SIR's were not confined to these areas.

Figure 3

Tobacco-growing areas, South Carolina. Height and color denote annual tobacco harvest. The leading counties were Horry, Florence, Williamsburg; next were Darlington, Clarendon, Georgetown, and Sumner. Many counties (dark blue) reported no commercial tobacco harvest.

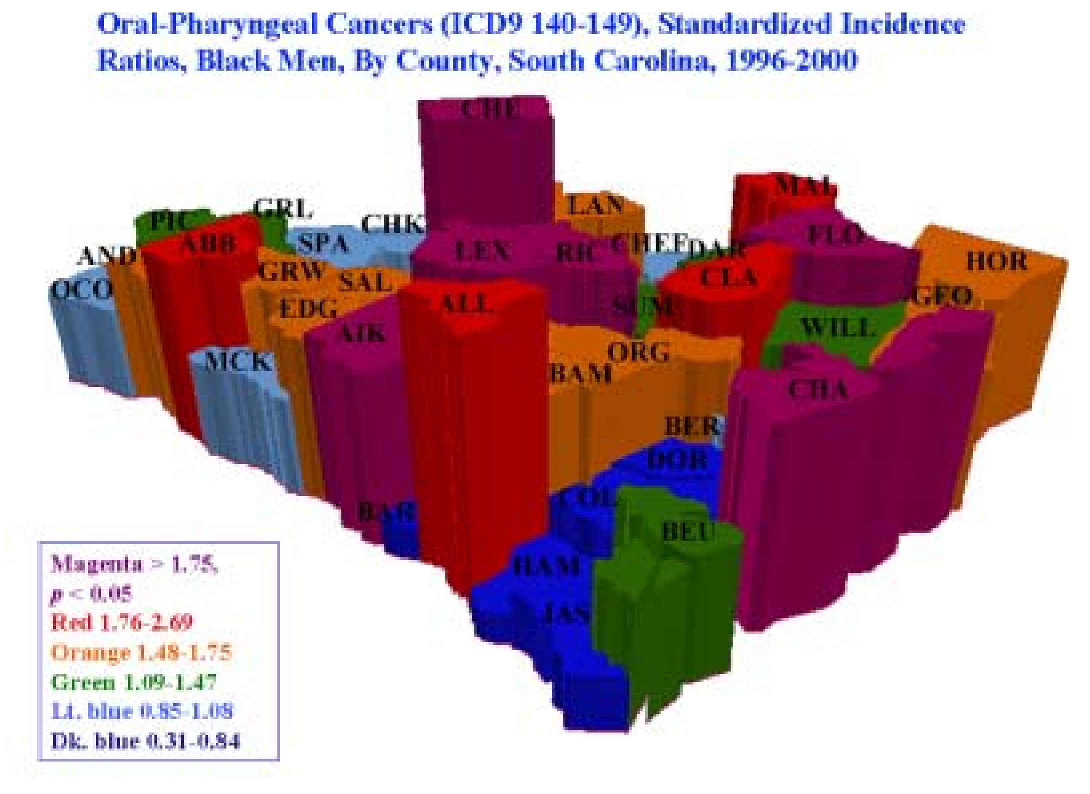
The pattern was somewhat similar in white women (Figure 4), with a statistically significantly high SIR in Charleston county and SIR’s in the top quintile in Williamsburg and several other counties spread throughout the state.

Figure 4



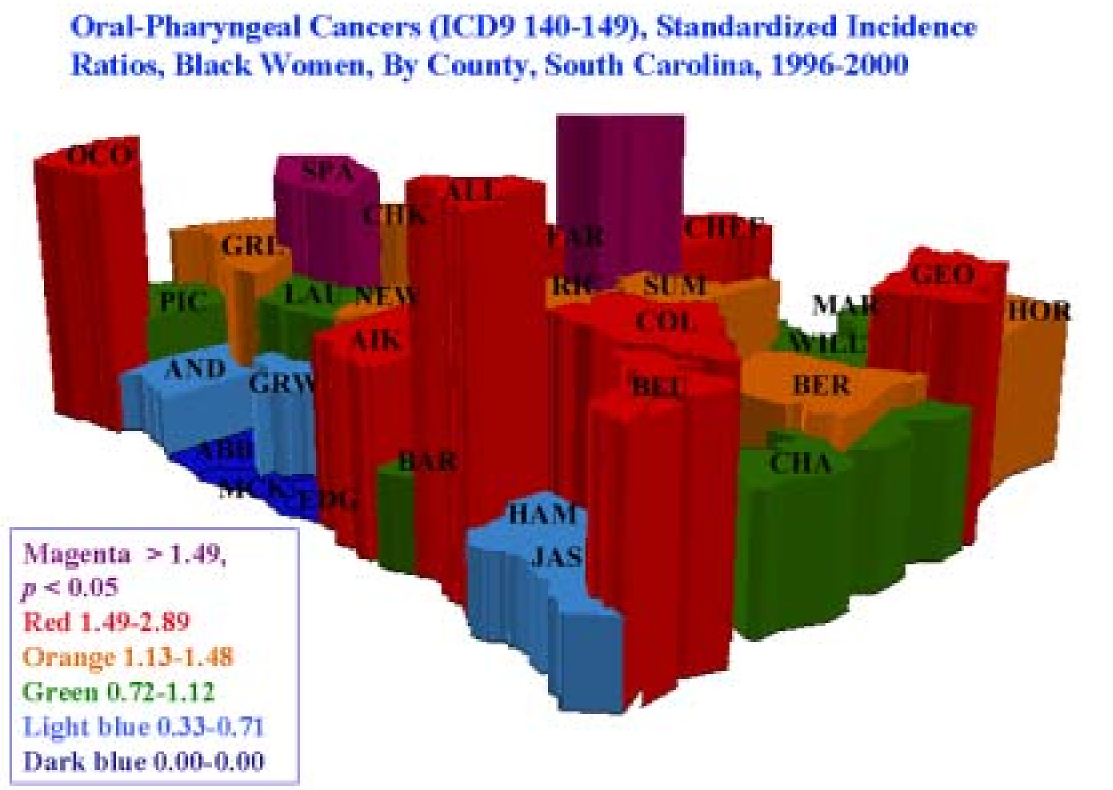
A similar pattern was present in black men, although with more significant localization to certain counties, including urbanized Charleston and Richland counties, in addition to Florence and three other inland counties (Aiken, Chester and Lexington) (Figure 5).

Figure 5



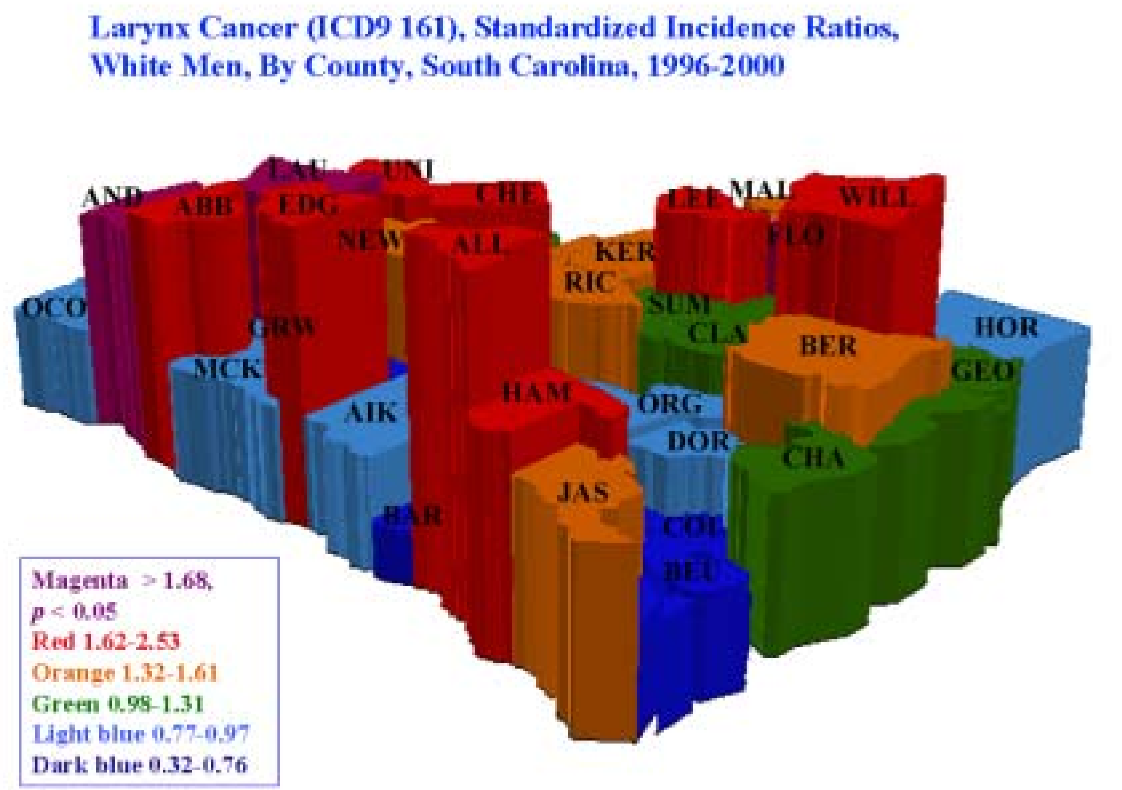
The pattern in black women had some characteristics in common with that of black men, although the counties that had statistically significantly high SIR's were different (Figure 6).

Figure 6



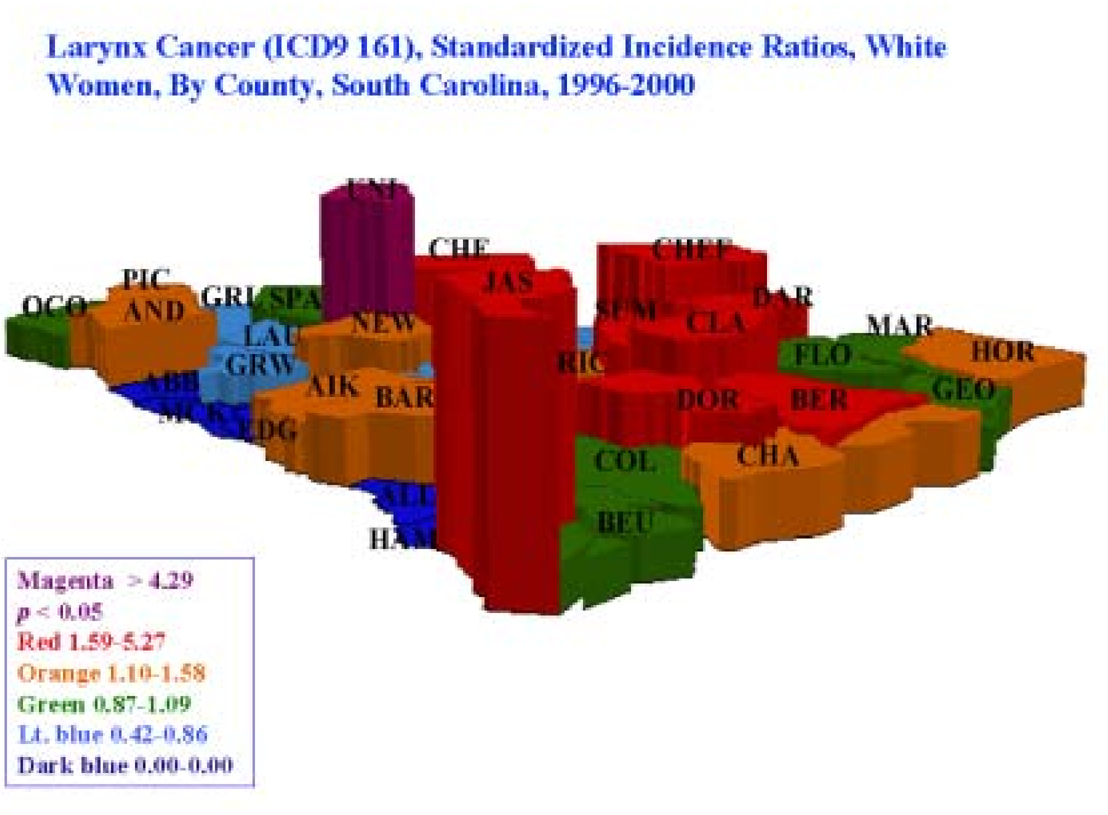
Laryngeal cancers. SIR's for cancer of the larynx (ICD-9-CM code 161) in white men tended to cluster somewhat in the major tobacco-growing regions (Figure 7). However there were statistically significant high SIR's in two counties of the foothill region adjoining the Appalachian Mountains, Anderson and Laurens.

Figure 7



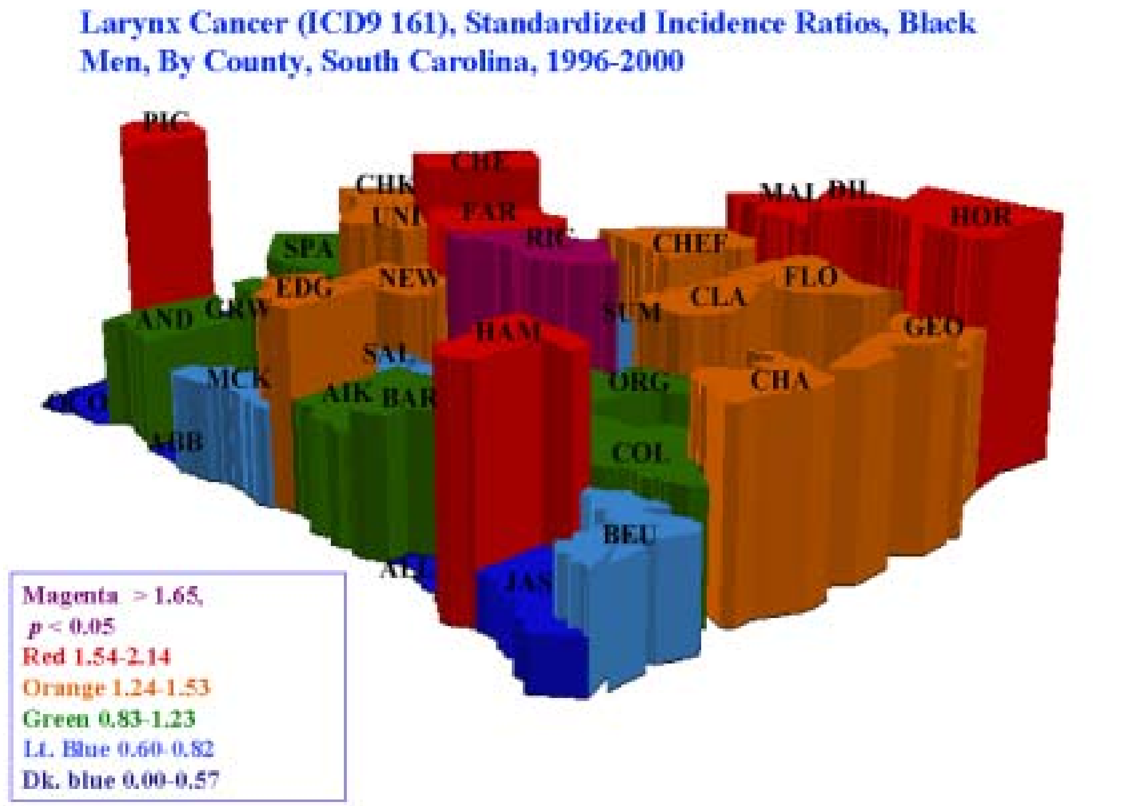
The pattern was somewhat different in white women, who had a statistically significantly high SIR in Union county, in the Appalachian foothills, and a nonsignificantly high SIR in the southernmost coastal county, Jasper (Figure 8).

Figure 8



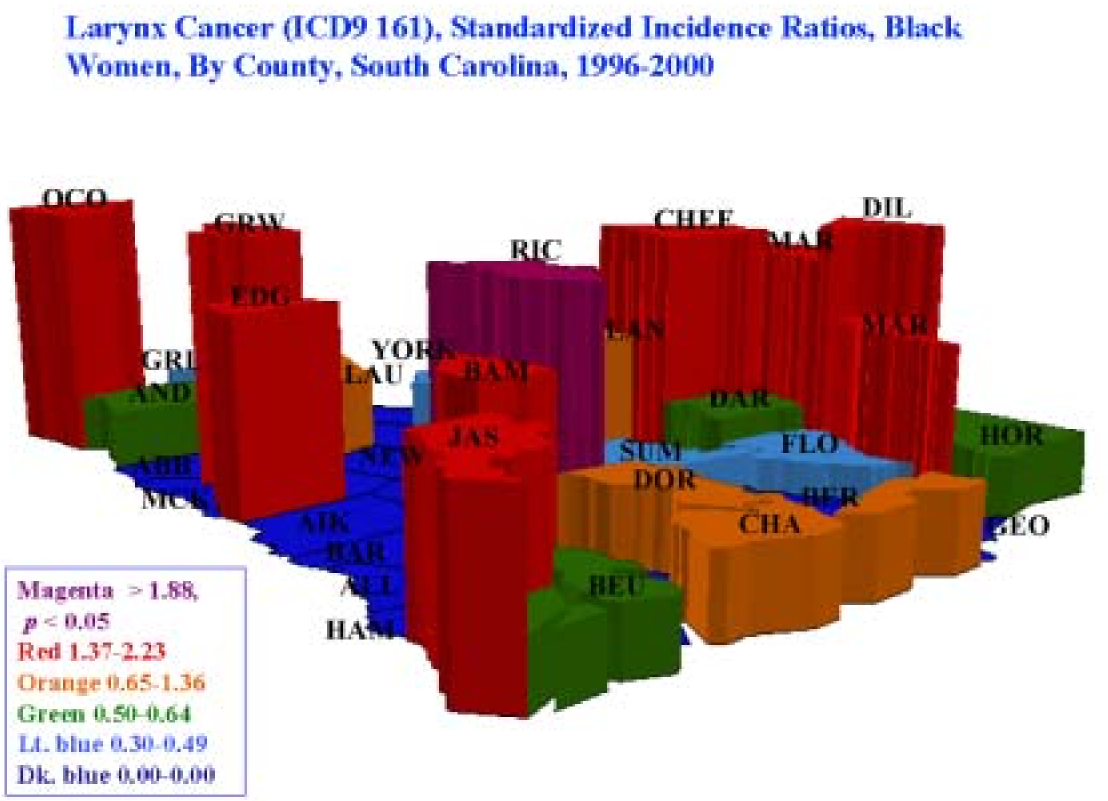
The pattern in black men (Figure 9) was suggestive of some degree clustering in the major tobacco-growing counties, especially Horry county. The SIR was statistically significantly high only in Richland county, site of the state capital.

Figure 9



SIR's in black women (Figure 10) were similar to those in black men. Black women and men had statistically significantly high SIR's in Richland county, and tended to show clustering of high SIR's in major tobacco-growing counties.

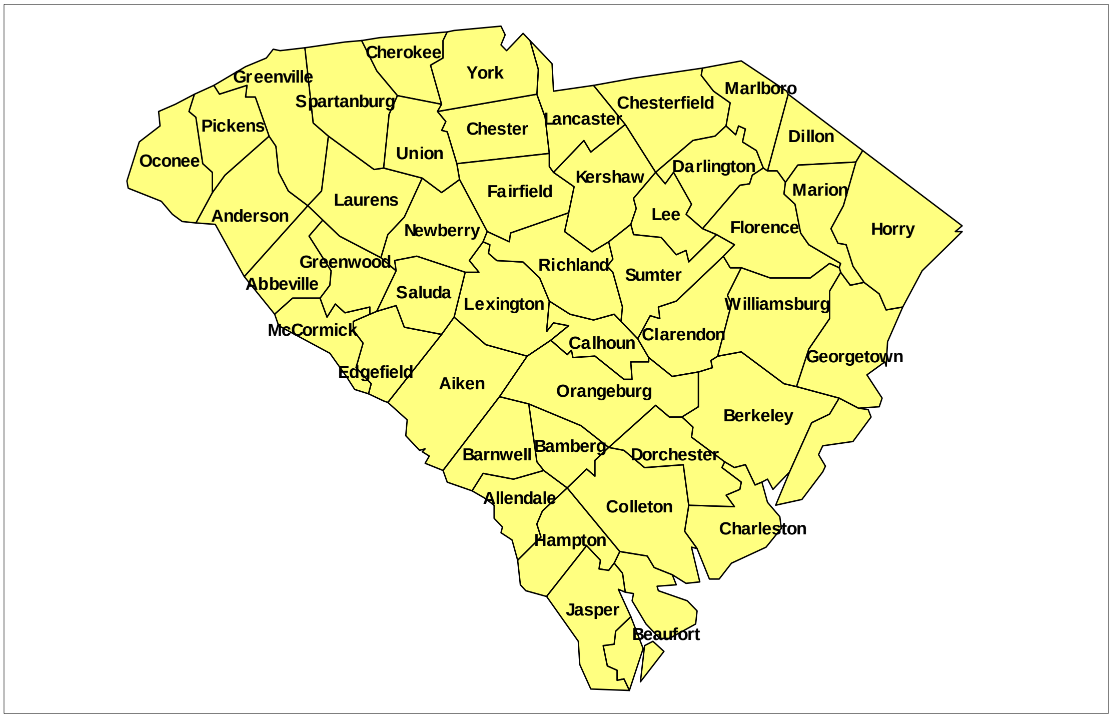
Figure 10



A base map showing county boundaries (Figure 11) may be helpful in interpreting the other maps.

Figure 11

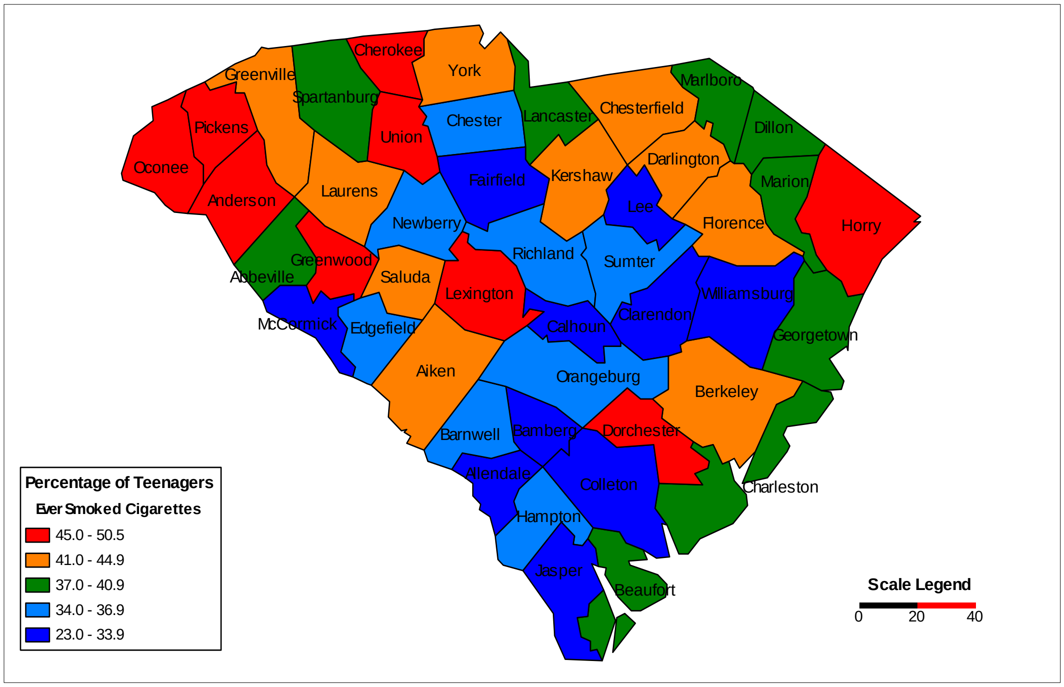
Counties of South Carolina



The counties with the highest teenage smoking rates included Horry, the county with the largest tobacco crop (Figure 12), but the rates also tended to be high in several inland counties where tobacco was not produced. Teenage tobacco use tended to be lower than average in coastal counties, apart from Horry.

Figure 12

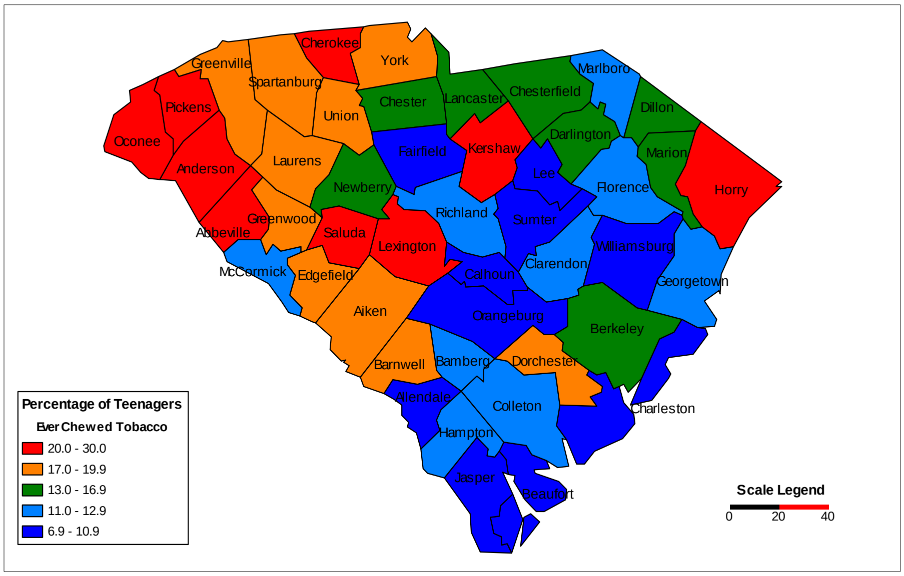
Percentage of teenagers who ever smoked cigarettes, South Carolina



Teenage use of smokeless tobacco tended to be lower than average in coastal counties, with the prominent exception of Horry county (Figure 13). It tended to be relatively high in a cluster of four counties in the northeast corner of the state.

Figure 13

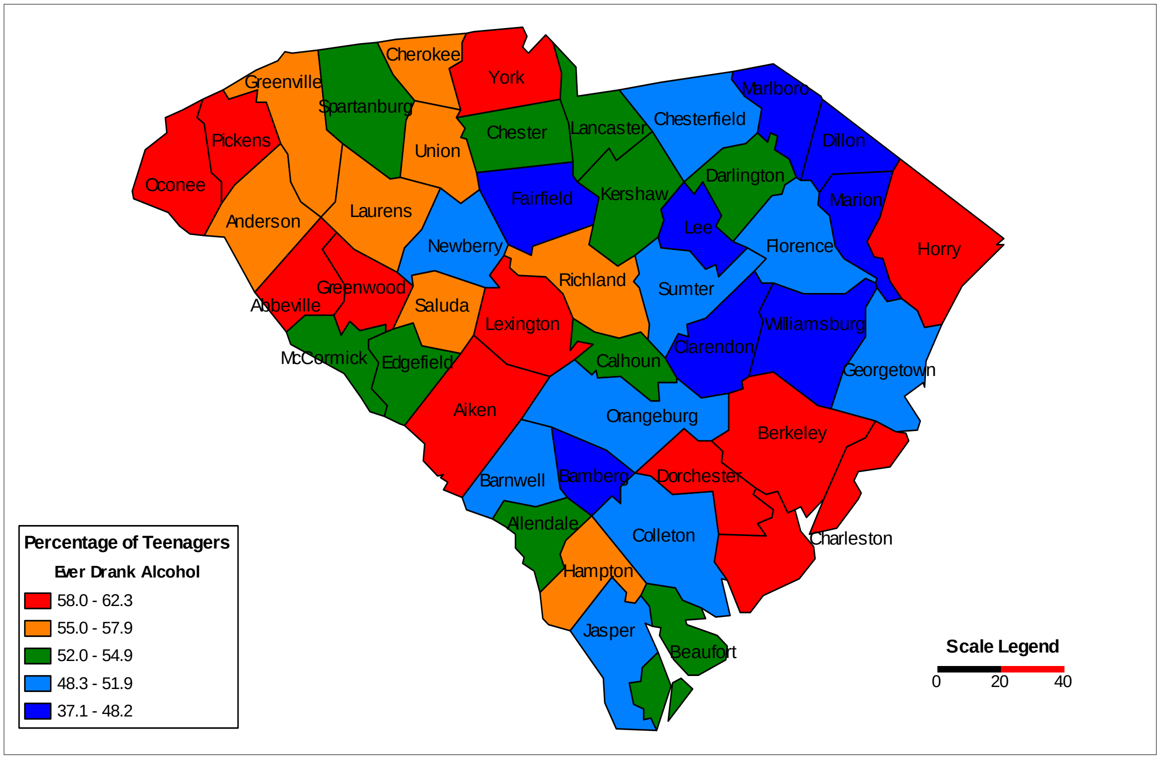
Percentage of teenagers who ever used smokeless tobacco, South Carolina



Alcohol use tended to be higher than average in three counties centered on Charleston, several counties in the northwestern part of the state, and several counties in other areas, including Horry (Figure 14).

Figure 14

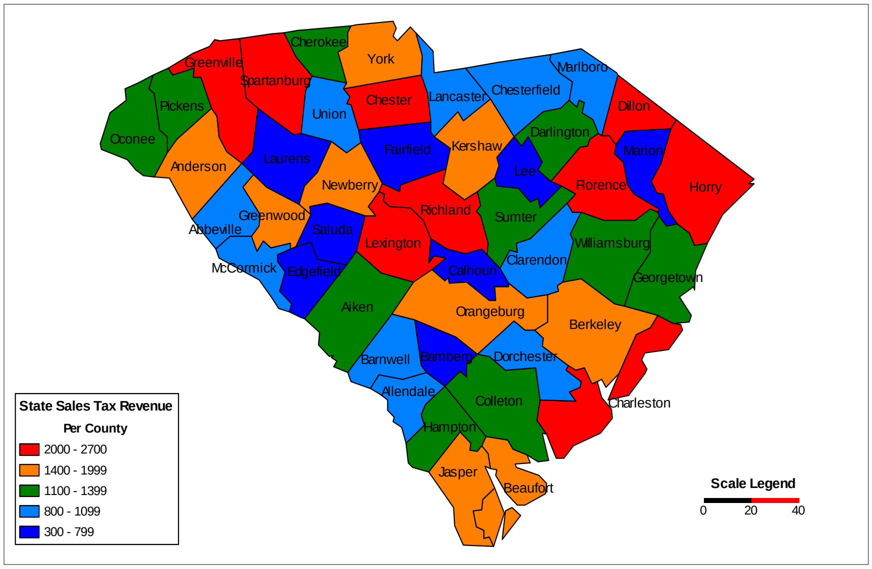
Percentage of teenagers who ever used alcohol, South Carolina



Per capita sales tax receipts identified Charleston and Richland, the two major urbanized counties, as having higher than average levels of consumer spending, along with several other counties dispersed throughout the state (Figure 15).

Figure 15

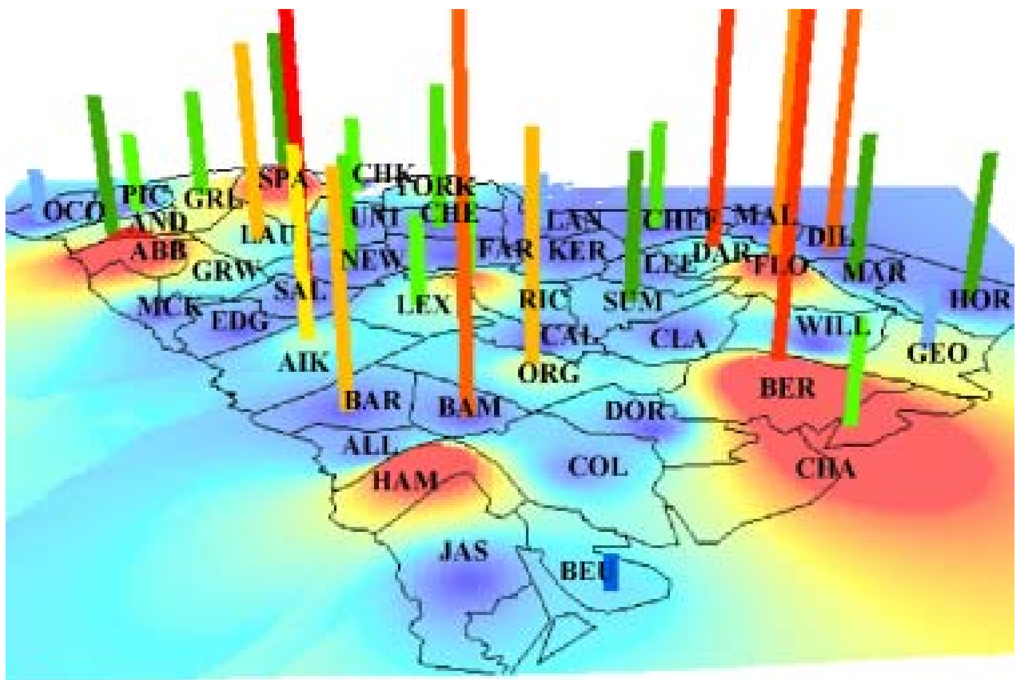
Sales tax receipts, dollars per capita, South Carolina



Finally, there appeared to be a possible geographical linkage of airborne ammonia emissions from industrial sources with death rates from salivary gland cancer in white men (Figure 16).

Figure 16

Ammonia emissions from industrial sources (surface peaks and valleys) and age-adjusted death rates from salivary gland cancer, white men, South Carolina



By contrast, there was no geographical association between such ammonia emissions and other oral-pharyngeal cancers as a group, or with non-industrial airborne emissions of ammonia, and no association was present in other demographic groups (not shown).

DISCUSSION

Automated mapping using GIS for analysis of incidence and mortality data was practical and useful for identifying areas with the highest incidence and mortality rates of salivary gland cancers. Mortality data were available from an authoritative source, the CDC, and incidence data were available from a geographically-based cancer registry that was part of a state government. Similar cancer registries exist in a number of other states, and many currently are being implemented throughout the U.S.

The geographic distributions of oral-pharyngeal and laryngeal cancers were distinctly different from that of salivary cancer. A tendency toward clustering of high rates of oral-pharyngeal and laryngeal cancers appeared to be present in some tobacco-growing counties, although high rates also occurred in some non-tobacco growing areas. Efforts to prevent teenagers from adopting tobacco and intake of excessive amounts of alcohol should be targeted to the counties with the largest populations, and, if feasible, those with the highest rates of oral-pharyngeal and laryngeal cancers.

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REFERENCES

1. American Cancer Society. Cancer facts and figures, 2004. Atlanta: American Cancer Society; 2004.
2. United States Department of Health and Human Services. Physician ICD-9-CM: International Classification of Diseases, Ninth Revision, Clinical Modification. Salt Lake City: Medicode; 2000.
3. Centers for Disease Control and Prevention. WONDER database: http//: wonder.cdc.gov. Accessed May 2004.
4. Lilienfeld D, Stolley P. Foundations of epidemiology, third ed. New York: Oxford; 1994.
5. World Health Organization. International Statistical Classification of Diseases and Related Health Problems, tenth revision. Geneva: WHO; 1992.
6. World Health Organization. ICD-O International Classification of Diseases for Oncology. Geneva: World Health Organization; 1990.
7. U. S. Bureau of the Census. Statistical abstract of the United States, 1990. Washington DC: Government Printing Office; 1990.

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