Chapter 8

Estimated Thyroid Doses Resulting from Atmospheric Bomb Tests Conducted at the Nevada Test Site

CONTENTS: Examples of the estimates of thyroid doses due to exposure of the American people to ^{131}I from Nevada atmospheric bomb tests are presented, compared to average thyroid doses resulting from other sources of radiation exposure.

The dose calculation methods presented in **Chapters 6** and **7** were used to estimate thyroid doses resulting from the deposition of ^{131}I in fallout from the bomb tests considered in this analysis. As was described in **Chapter 3**, many atmospheric detonations, some cratering tests, and some tests during the underground testing era have been analyzed. Thyroid doses were calculated for the population of each county divided into 13 age groups, with adults subdivided by gender (i.e., including four fetal periods, four age intervals during the first year of life, four age intervals between ages 1 and 20, plus adults). The doses to one particular fetal age group (the fetus not yet 10 weeks old) have not been reported as they are very low in comparison to those of the other age groups because the thyroid of the fetus is not formed until about the 12^{th} week of gestation. Doses to the other 12 age groups were estimated for a variety of dietary habits pertaining to assumed milk sources and consumption patterns.

All of the ^{131}I fallout data used to make the dose estimates is contained in the Annexes and Sub-annexes to the report. There is an Annex for each test, which begins with a description of the test and contains the fallout deposition data that was obtained near the NTS and across the country in the form of maps. Detailed tabulations of the fallout data, day by day and county by county, are given in the corresponding Sub-annex. Estimates of time-integrated concentrations of ^{131}I in milk (see **Chapter 4**) due to fallout from that test are tabulated in the Annex for each of the counties and subcounties in the contiguous United States. The detailed milk concentration data were used to calculate thyroid doses from milk consumption as described in **Chapter 6**, using the consumption rates given in **Chapter 5**.

Included in the Annex also are the estimates of the time-integrated concentrations of ^{131}I in other foodstuffs (i.e., goats' milk, cottage cheese, eggs, leafy vegetables, air, and mothers' milk) that are discussed in **Chapter 7.** These estimates reflect the fallout ^{131}I distribution for the particular test and are tabulated for each county or sub-county. Estimated consumption rates for these other exposure routes also are given in **Chapter 7**, together with the dose calculation methods.

The estimated thyroid doses resulting from the fallout from a particular test are presented in the Sub-annex for that test. (Note that the dose units are rad; 1 rad = 1000 mrad.) Per capita doses due to milk consumption and for all exposure routes are listed for each county and sub-county. The values of the geometric mean, GM, and the geometric standard deviation, GSD, are provided for doses due to consumption of milk and for doses due to intakes of milk and other foodstuffs, and for airborne contamination. A summary map of the per capita dose from all pathways is included in the Annex for the test. Included in the same table are the estimated collective doses (the sum of the doses to all age and sex groups) for each county and sub-county. The geometric mean collective dose estimates are for milk consumption alone and for all exposure pathways combined. The geometric mean collective doses for the entire country are provided at the end of the tabulation.

Each Sub-annex continues with detailed dose estimates, listed by county, for each age (and sex) group, for which dose conversion factors were developed in **Chapter 6.** There are 13 such tables. Each contains geometric mean dose estimates and the associated measures of uncertainty (the GSDs) for four dietary regimes: average milk consumption, high milk consumption, consumption of milk from a backyard cow, and no milk consumption. These regimes are discussed in **Chapter 6** and below in **Section 8.1**. The first three provide a range of possible doses from milk consumption; the fourth is an estimate of the dose from intakes of other foods and inhalation of airborne contamination. (These doses are also expressed in rad.)

The dose estimates in the Sub-annexes have been computed using the methods appropriate for a multiplicative model of parameters that are log-normally distributed. The mathematical formulas and necessary assumptions for this approach have been presented in **Chapters 3, 4, 6**, and **7**. In the discussion that follows, a simpler calculational procedure is described that illustrates the main components of the methodology. Each component incorporates the detailed analyses performed in the earlier chapters, to which the reader is referred for details.

8.1. ESTIMATED THYROID DOSES

The magnitude of the thyroid dose received by a person from fallout after a bomb test at the NTS depends upon the person's age, location and dietary habits. As discussed in **Chapters 6** and **7**, the thyroid dose, D, resulting from an intake of ^{131}I in fallout from a particular exposure route following a given test can be estimated as the product of:

- The time-integrated ^{131}I concentration, IC, in milk (nCi d L^{-1}) or other foodstuff (nCi d kg^{-1}) ingested or in ground-level air (nCi d m^{-3}) inhaled.
- The consumption rate, CR, of milk (L d^{-1}) or other foodstuff (kg d^{-1}) or the breathing rate, BR (m^3 d^{-1}), during the weeks following the test considered.
- The thyroid dose conversion factor, DCF, appropriate for the age or sex (mrad per nCi).

For ingestion of milk or a particular foodstuff, the equation can be written:

$$D_{food} = IC_{food} \times CR_{food} \times DCF \qquad (8.1)$$

and for inhalation:

$$D_{inh} = IC_{air} \times BR \times DCF \qquad (8.2)$$

The total dose resulting from a given test is obtained by adding the estimated mean dose from inhalation and the estimated mean doses from ingestion of the foodstuffs considered (cows' milk, goats' milk, mothers' milk (for infants), cottage cheese, eggs, and leafy vegetables).

In the absence of person-specific data, only doses to representative groups of people can be estimated with reasonable accuracy. For this reason, the doses systematically estimated in this report are for specified age groups (and for adults, both sexes) and to other population groups deemed to have received relatively high or low doses, for each county and for each test. However, the manner in which doses to specific individuals can be estimated if information pertaining to the individual is available will be illustrated using examples in **Chapter 9**.

The data necessary to estimate doses are provided as follows:

- The estimated time-integrated ^{131}I concentrations, IC, in the four categories of milk identified in **Chapter 5** (milk consumed on the farm, produced and sold in the county, originating from another county of the same milk region, originating from another milk region), plus the maximum and the volume-weighted time-integrated concentrations in those four categories of milk, as well as the ^{131}I concentrations in milk from backyard cows, are found in the Annexes for each of the test series and for each of the tests and for each of the 3,094 counties and sub-counties of the contiguous United States.
- The estimated time-integrated average ^{131}I concentrations, IC, both in the other foodstuffs of interest and in ground-level air for each of the 3,094 counties and sub-counties of the contiguous United States also are given in the Annexes for each of the tests and for each of the test series.
- The estimated average consumption rates, CR, of milk appropriate for each of the 13 age and both of the adult sex groups by state are given in *Table 5.8* of **Chapter 5**. Estimates of daily milk consumption by "high-exposure" groups in each age and sex group are given in *Table 6.4* of **Chapter 6**. The average consumption rates for the other foodstuffs of interest and for breathing rates, BR, are given in *Table 7.4* of **Chapter 7.**
- The estimated average thyroid dose conversion factors, DCF, for the 14 age and sex groups are given in *Table 6.7* of **Chapter 6**.

Central estimates of thyroid doses (median doses) are presented in the Sub-annexes of this report for each nuclear test and for each of the 14 age and sex groups with the following consumption parameters:

- For the assessment of the estimated average dose to the population of milk drinkers of a given age and sex group in a given county:

  (a) Cows' milk: average consumption rate of milk drinkers with volume-weighted average time-integrated concentration of ^{131}I.

  (b) Other foodstuffs: average consumption rates with average time-integrated concentrations of ^{131}I.

  (c) Inhalation: average breathing rate with average time-integrated concentration of ^{131}I in ground-level air.

- For the assessment of the estimated average dose to the "high-exposure" group in the population of a given age and sex group in a given county:

  (a) Cows' milk: "high" consumption rate (95th percentile, (*Table 6.4*)) drinking milk in the category having the highest time-integrated concentration of ^{131}I.

  (b) Other foodstuffs: average consumption rates with average time-integrated concentrations of ^{131}I.

  (c) Inhalation: average breathing rate with average time-integrated concentration of ^{131}I in ground-level air.

- For the assessment of the estimated dose to the group in the population of a given age and sex group in a given county drinking milk from backyard cows:

  (a) Cows' milk: "high" consumption rate (95th percentile, (*Table 6.4*)) with the time-integrated concentration of ^{131}I in milk estimated for the backyard cow.

  (b) Other foodstuffs: average consumption rates with average time-integrated concentrations of ^{131}I.

  (c) Inhalation: average breathing rate with average time-integrated concentration of ^{131}I in ground-level air.

- For the assessment of the estimated average dose to the "low-exposure" group in the population of a given age and sex group in a given county:

  (a) Cows' milk: no consumption.

  (b) Other foodstuffs: average consumption rates with average time-integrated concentrations of ^{131}I.

  (c) Inhalation: average breathing rate with average time-integrated concentration of ^{131}I in ground-level air.

- For the assessment of the estimated average doses to the infants in the population of age 0-3 months, 3-6 months, and 6-9 months in a given county drinking mothers' milk:

  (a) Cows' milk: no consumption.

  (b) Mothers' milk: average consumption rate by the mother of milk having the volume-weighted average time-integrated concentration of ^{131}I.

  (c) Other foodstuffs: average consumption rates with average time-integrated concentrations of ^{131}I.

  (d) Inhalation: average breathing rate with average time-integrated concentration of ^{131}I in ground-level air.

A series of maps that illustrate the effects of location, age, and diet on the estimated thyroid doses (in rad) are provided for the convenience of the reader. These maps cover the contiguous United States, but the level of detail differs slightly from that in the Sub-annexes. The sub-counties in Nevada, Utah, California and Arizona are not shown separately in the maps; results for a population-weighted composite are shown. The five boroughs of the city of New York have also been combined, as have several small counties in Virginia. The resolution of the printed maps and ordinary visual acuity limit the level of detail that can be presented in the map format.

The maps illustrate the estimated thyroid doses (in rad) to persons who resided in the same county throughout the period (January 1951 through December 1970) when the tests considered in this analysis were conducted. The total doses were computed using the methods described in **Chapters 6** and **7**, as appropriate. The results shown reflect changes in the person's age during this time period, including associated changes in consumption rates and in the dose conversion factor.

Table 8.1 is a guide to the set of maps that is intended to help readers identify the maps of greatest interest to them, depending upon their dates of birth. The first four maps, *Figures 8.1* through *8.4*, show the estimated doses to males who were adults when testing began in 1951. There are clear differences as a function of the four milk consumption scenarios presented above.

For persons in this age group who drank milk, differences between the doses to men, shown in *Figures 8.1* through *8.3*, and those to women (not shown) are small. The doses to women are about 10% higher. For persons who did not drink milk, the doses shown in *Figure 8.4* for men also are about 10% lower than corresponding doses to women. Considering the uncertainties in the dose estimates and the width of the dose categories in this figure, differences of 10% are not significant and *Figures 8.1* through *8.4* may also be applied to women.

Other groups of maps show similar information about dose as a function of residence and milk consumption for persons of various ages during the period of interest.

Table 8.1. Index to maps of estimated thyroid doses (from all bomb test considered) to persons according to year of birth.

Birthdate	Age (y) when tests began [a]	Age (y) when tests ended [b]	Maps of thyroid doses
January 1, 1930	21	40	Figures 8.1-8.4
January 1, 1935	16	35	Figures 8.5-8.8
January 1, 1940	11	30	Figures 8.9-8.12
January 1, 1945	6	25	Figures 8.13-8.16
January 1, 1950	1	20	Figures 8.17-8.20
January 1, 1951	Newborn	19	Figures 8.21-8.24
January 1, 1952		18	Figures 8.25-8.28
April 1, 1952		18	Figures 8.29-8.32
January 1, 1953		17	Figures 8.33-8.36
January 1, 1954		16	Figures 8.37-8.40
January 1, 1955		15	Figures 8.41-8.44
January 1, 1956		14	Figures 8.45-8.48
January 1, 1957		13	Figures 8.49-8.52
January 1, 1958		12	Figures 8.53-8.56
January 1, 1959		11	Figures 8.57-8.60
January 1, 1960		10	Figures 8.61-8.64
January 1, 1962		8	Figures 8.65-8.68

[a] First test considered in this analysis was conducted in January 1951.
[b] Last test considered in this analysis was conducted in December 1970.

Figure 8.1. Estimates of I-131 thyroid doses for males born on January 1, 1930 (Average diet; average milk consumption)

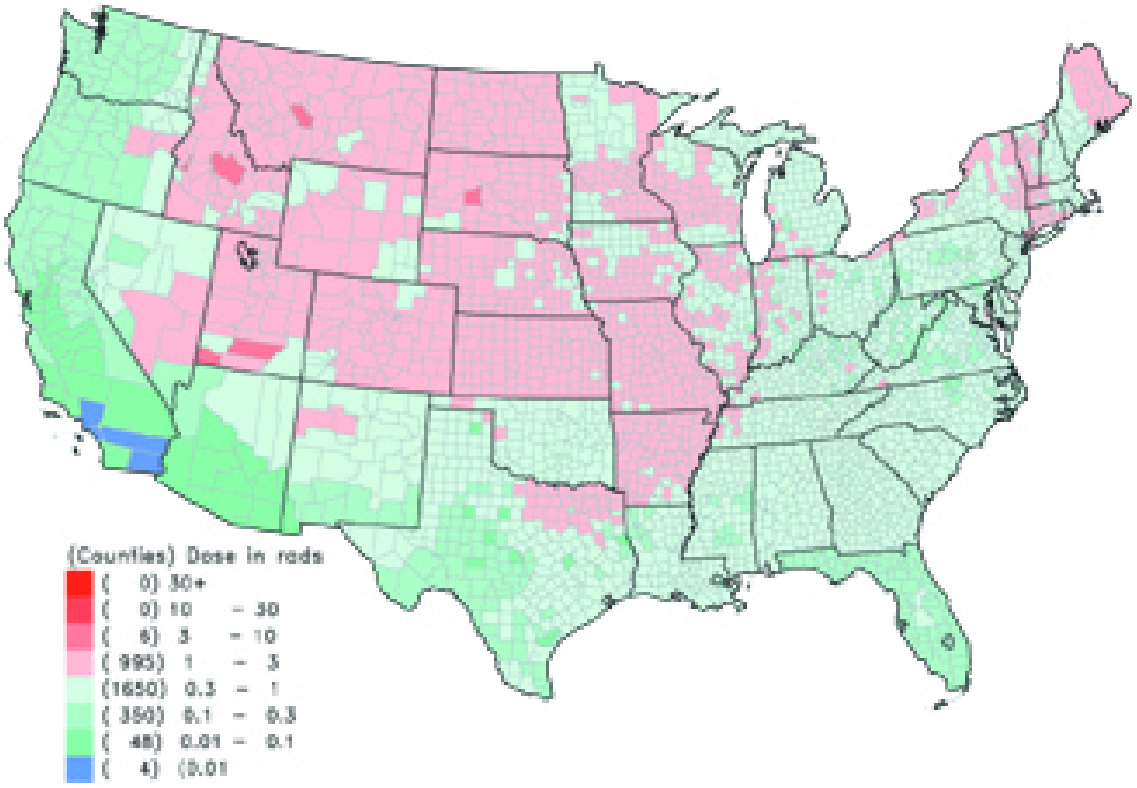

Figure 8.2. Estimates of I-131 thyroid doses for males born on January 1, 1930 (Average diet; high milk consumption)

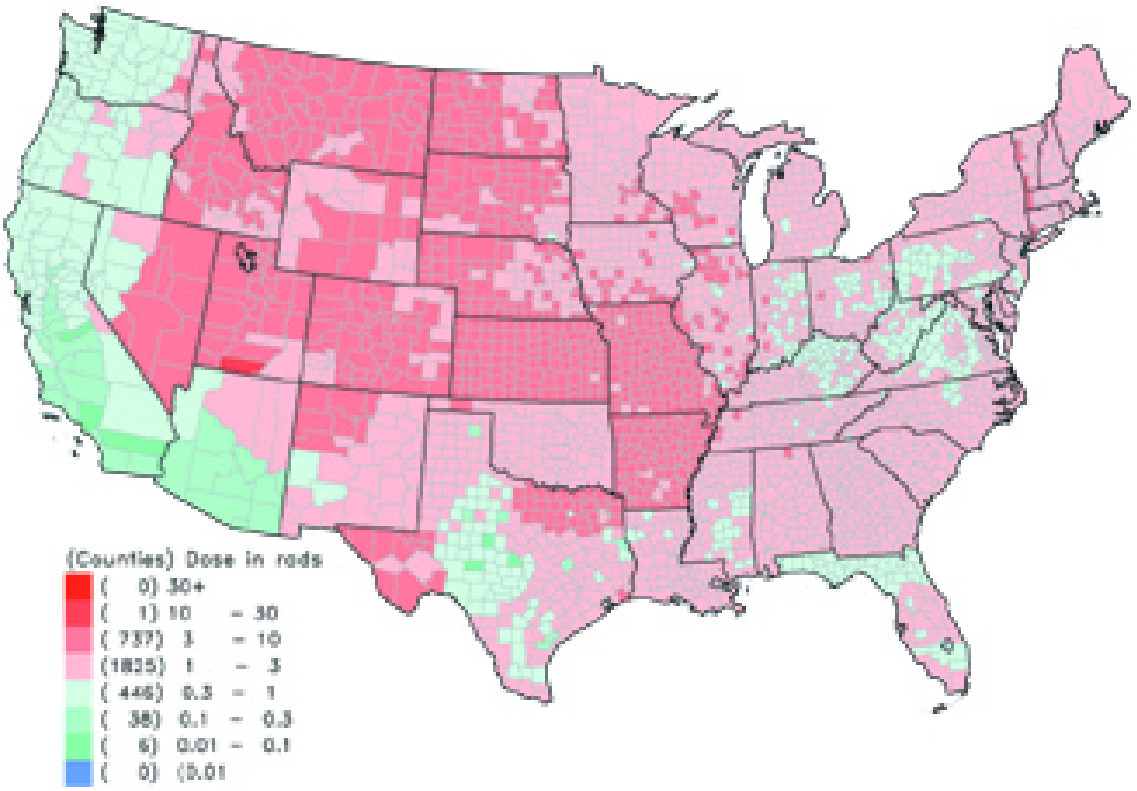

Figure 8.3. Estimates of I-131 thyroid doses for males born on January 1, 1930 (Average diet; milk from "backyard cow")

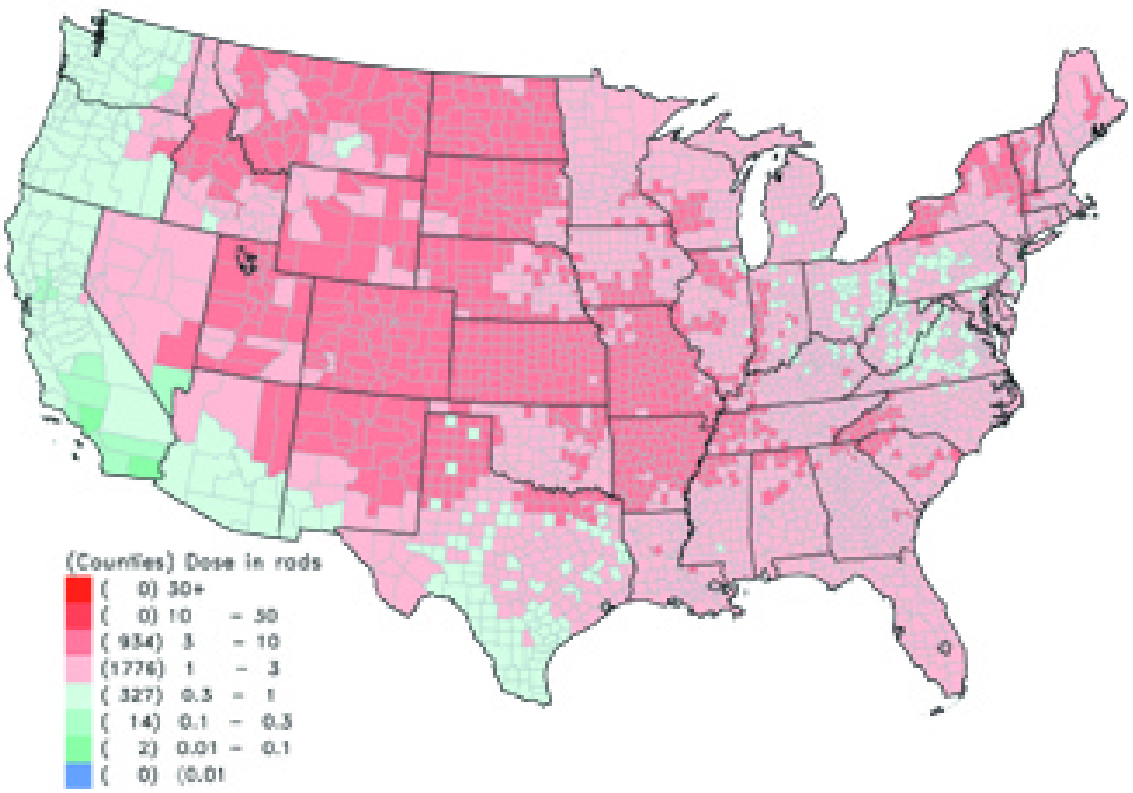

Figure 8.4. Estimates of I-131 thyroid doses for males born on January 1, 1930 (Average diet; no milk consumption)

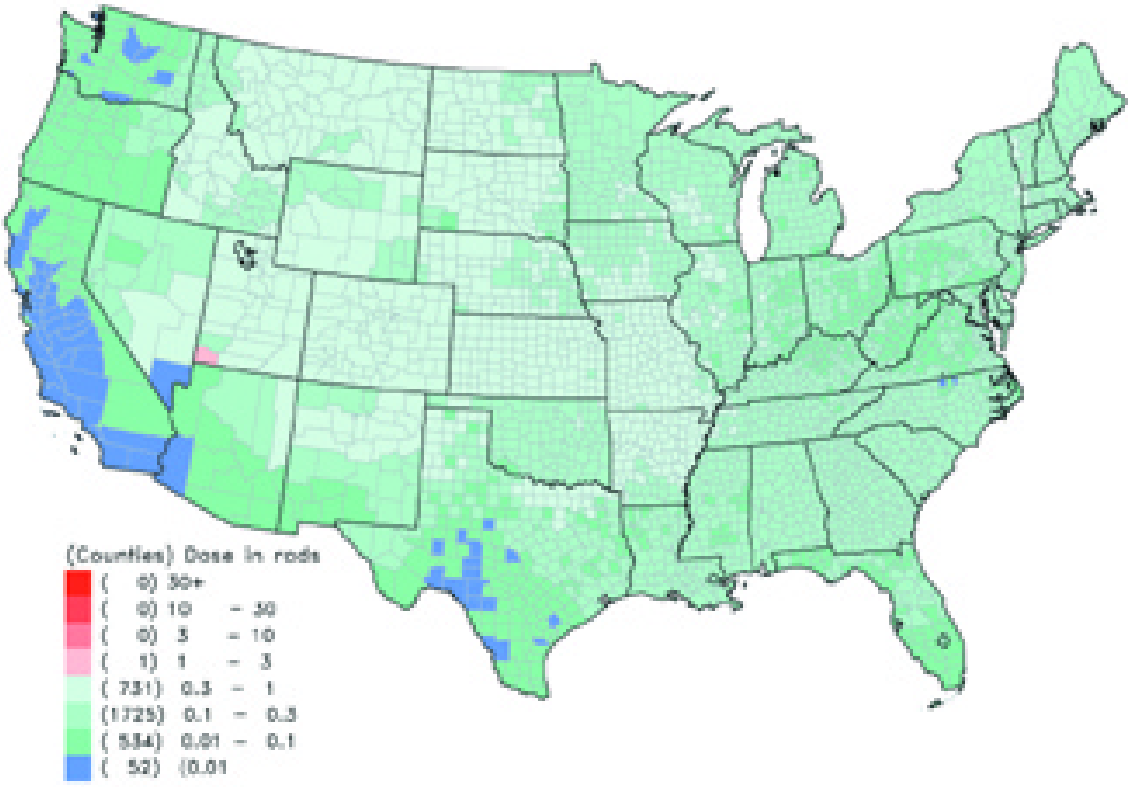

Figure 8.5. Estimates of I-131 thyroid doses for persons born on January 1, 1935 (Average diet; average milk consumption)

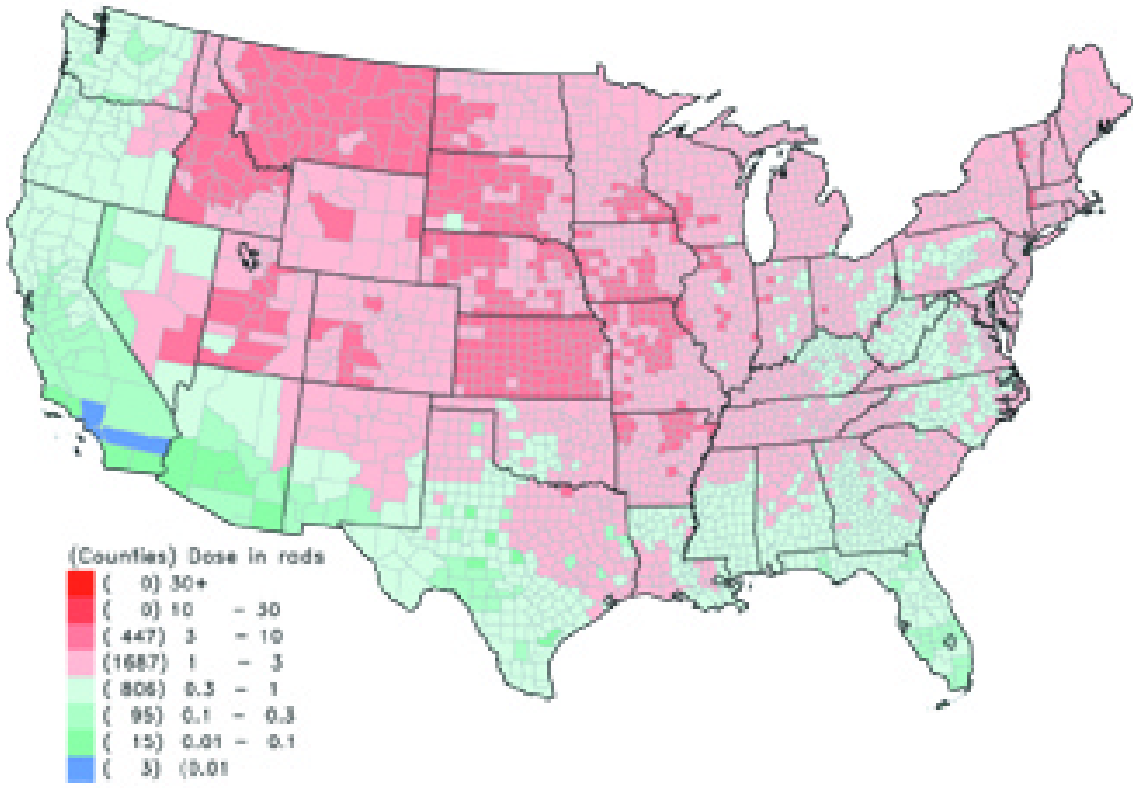

Figure 8.6. Estimates of I-131 thyroid doses for persons born on January 1, 1935 (Average diet, high milk consumption)

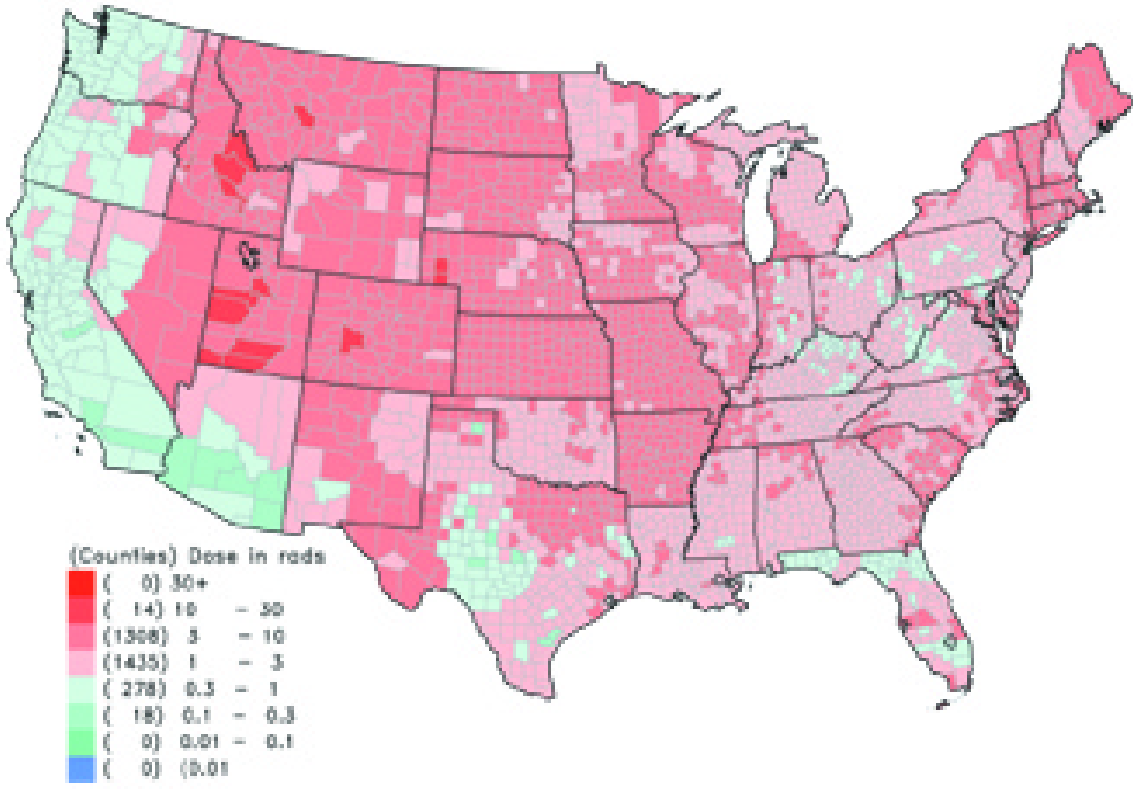

Figure 8.7. Estimates of I-131 thyroid doses for persons born on January 1, 1935 (Average diet; milk from "backyard cow")

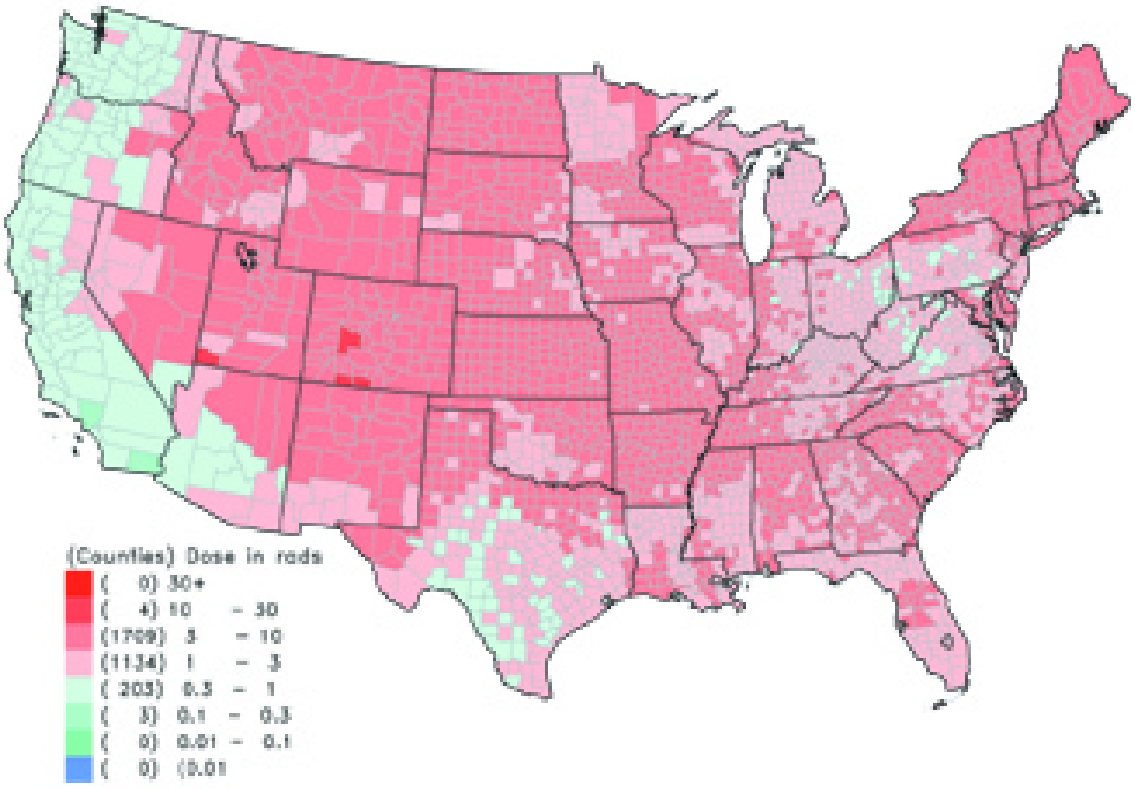

Figure 8.8. Estimates of I-131 thyroid doses for persons born on January 1, 1935 (Average diet; no milk consumption)

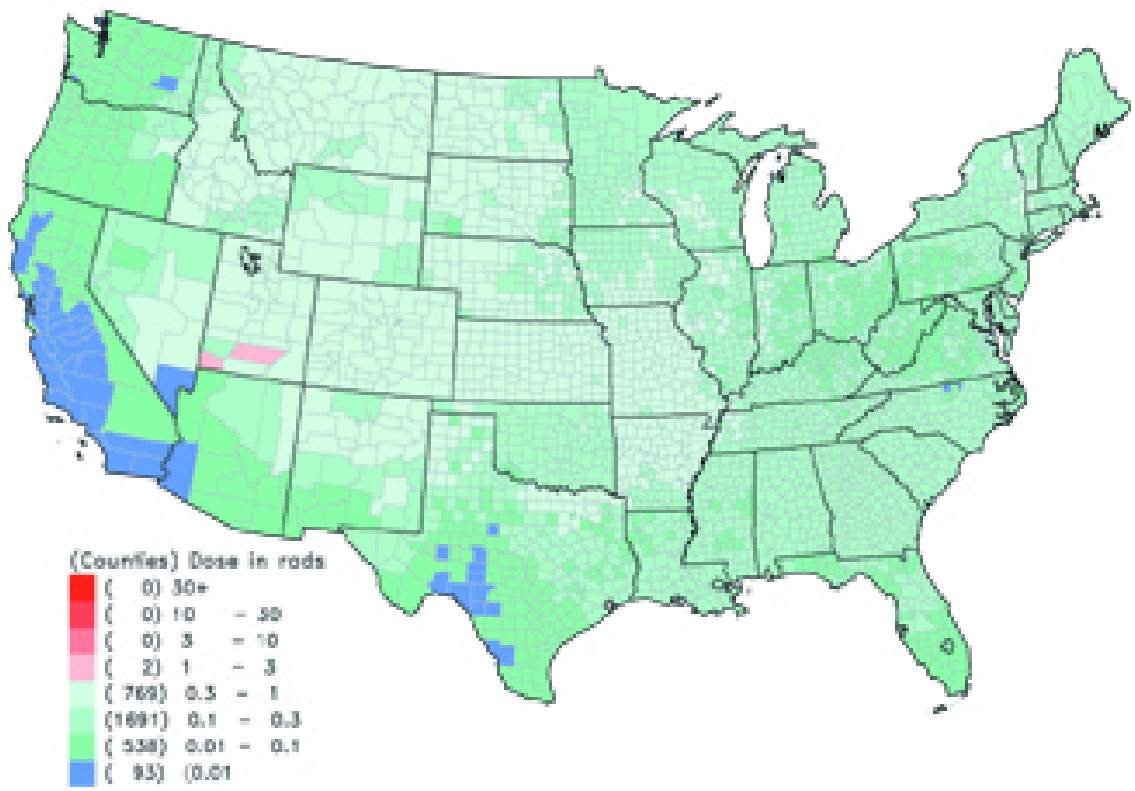

Figure 8.9. Estimates of I-131 thyroid doses for persons born on January 1, 1940 (Average diet; average milk consumption)

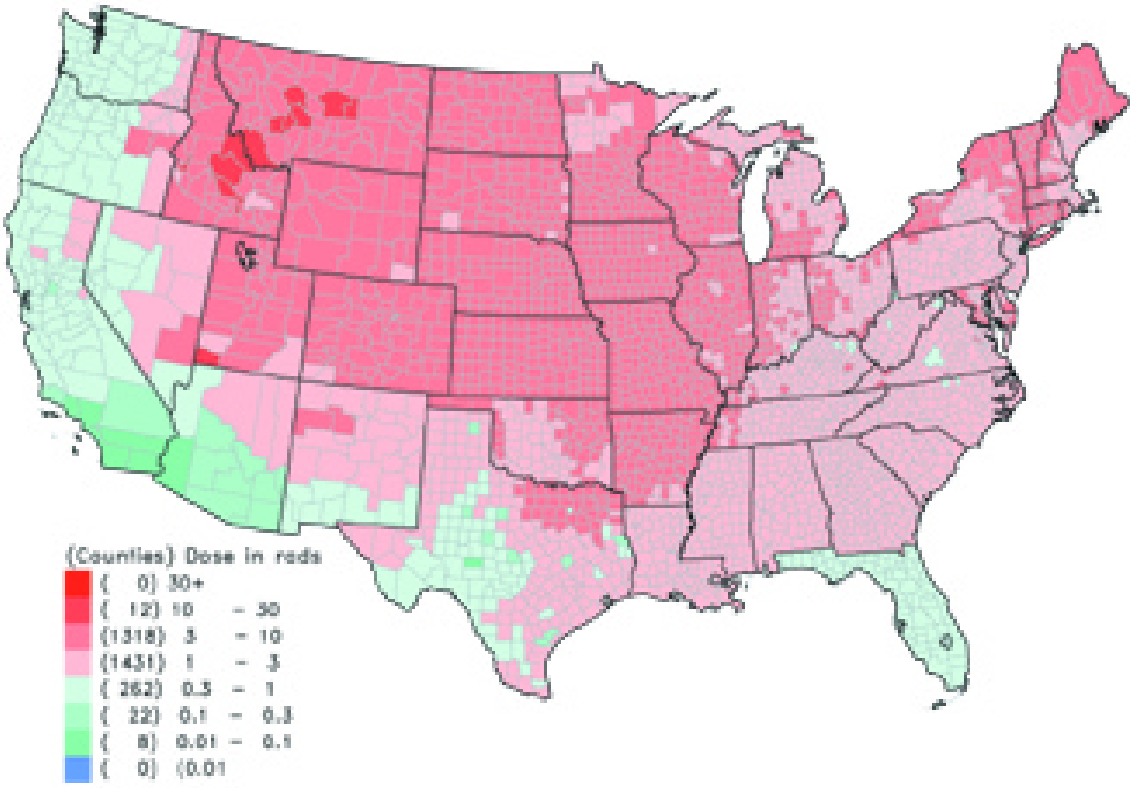

Figure 8.10. Estimates of I-131 thyroid doses for persons born on January 1, 1940 (Average diet; high milk consumption)

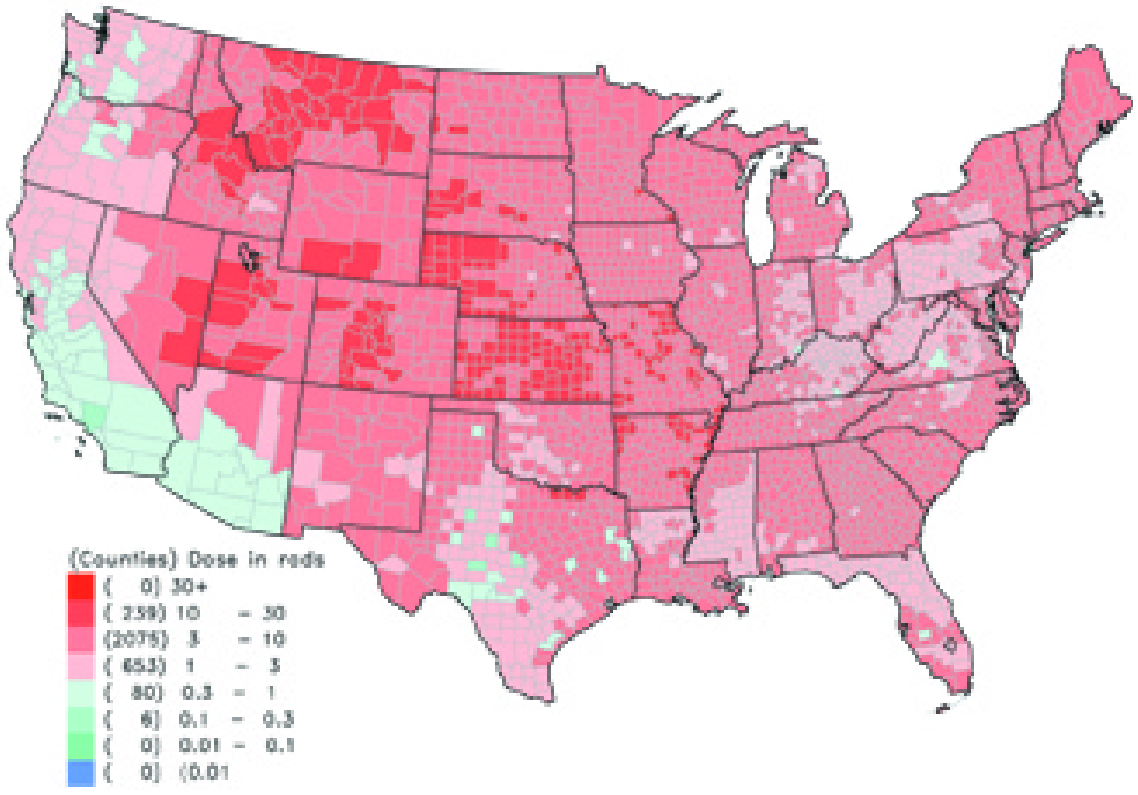

Figure 8.11. Estimates of I-131 thyroid doses for persons born on January 1, 1940 (Average diet; milk from "backyard cow")

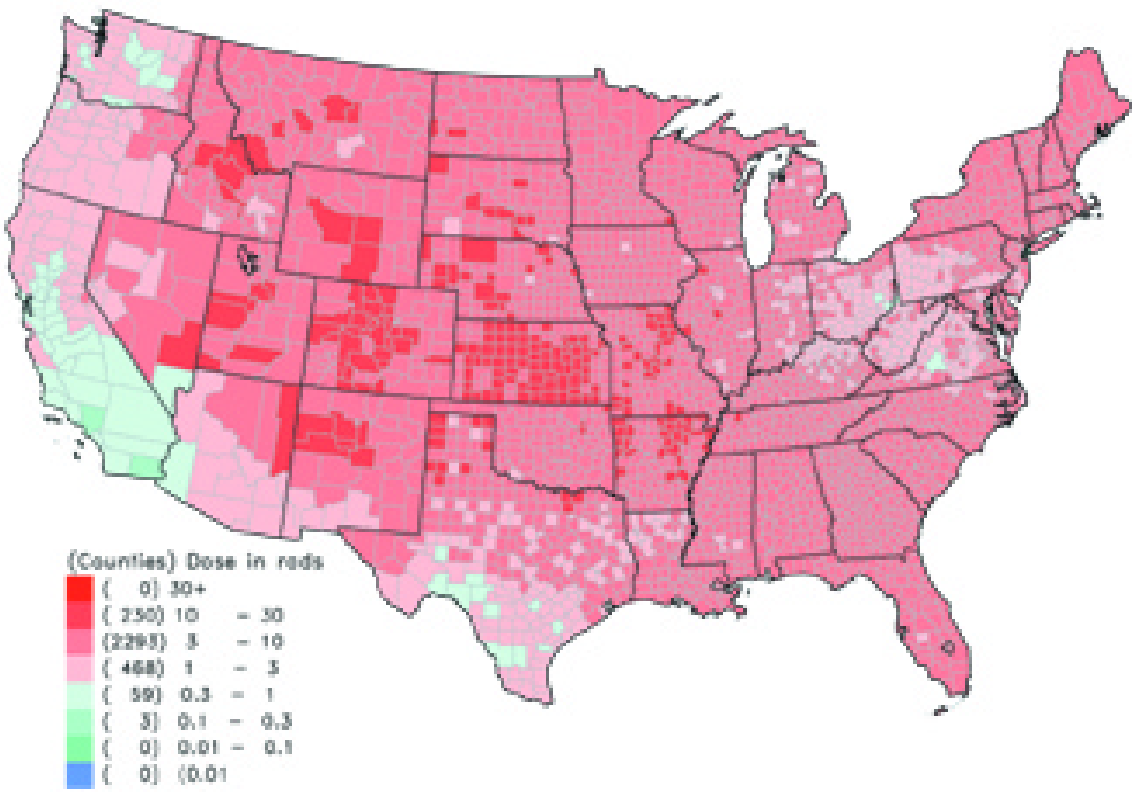

Figure 8.12. Estimates of I-131 thyroid doses for persons born on January 1, 1940 (Average diet; no milk consumption)

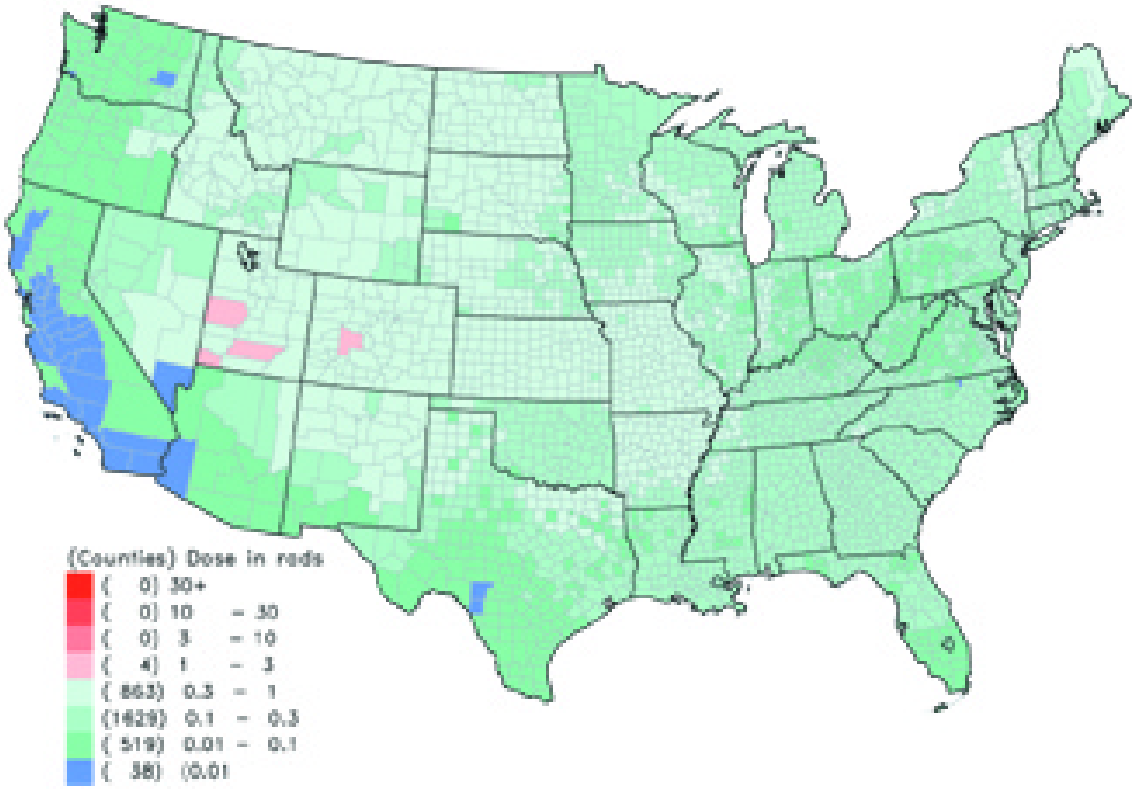

Figure 8.13. Estimates of I-131 thyroid doses for persons born on January 1, 1945 (Average diet; average milk consumption)

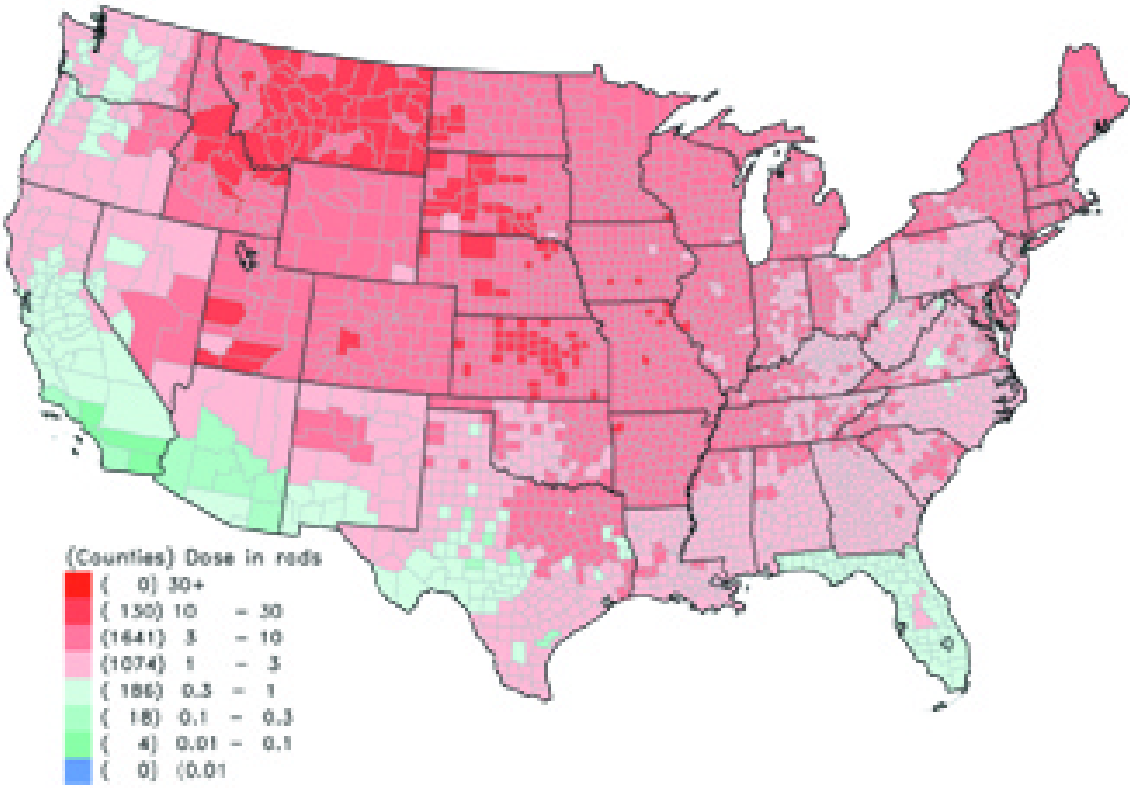

Figure 8.14. Estimates of I-131 thyroid doses for persons born on January 1, 1945 (Average diet; high milk consumption)

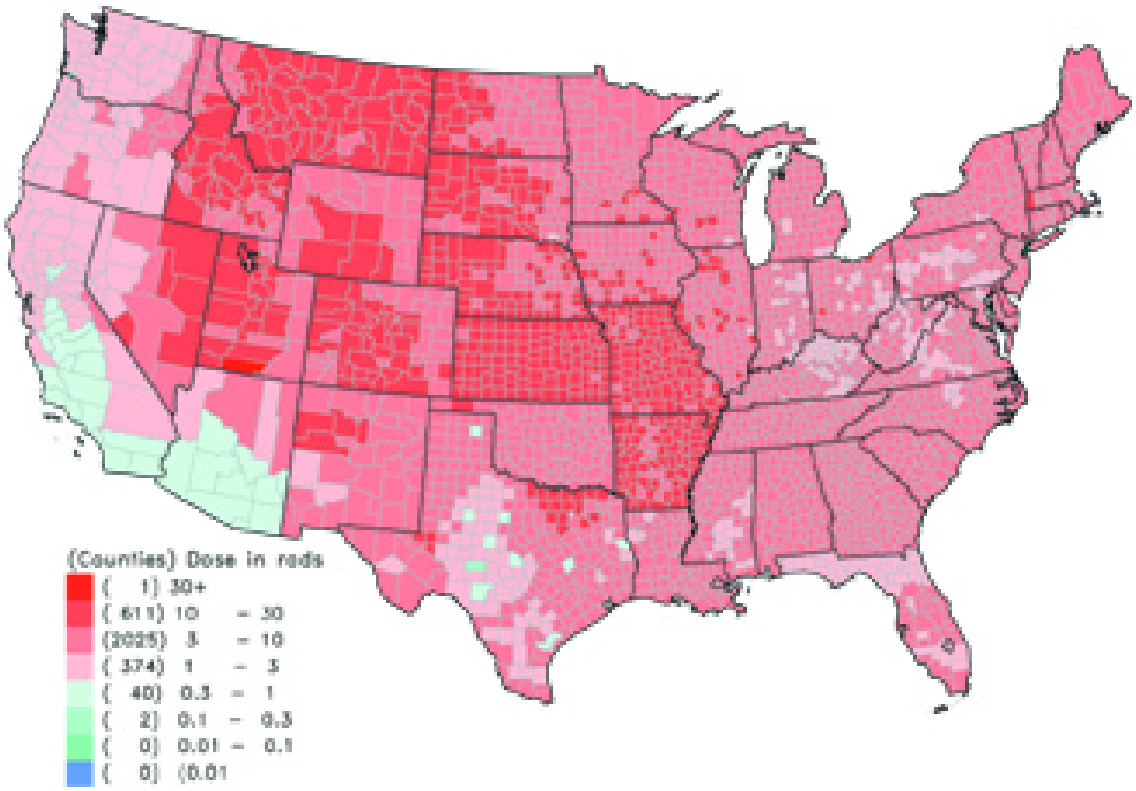

Figure 8.15. Estimates of I-131 thyroid doses for persons born on January 1, 1945 (Average diet; milk from "backyard cow")

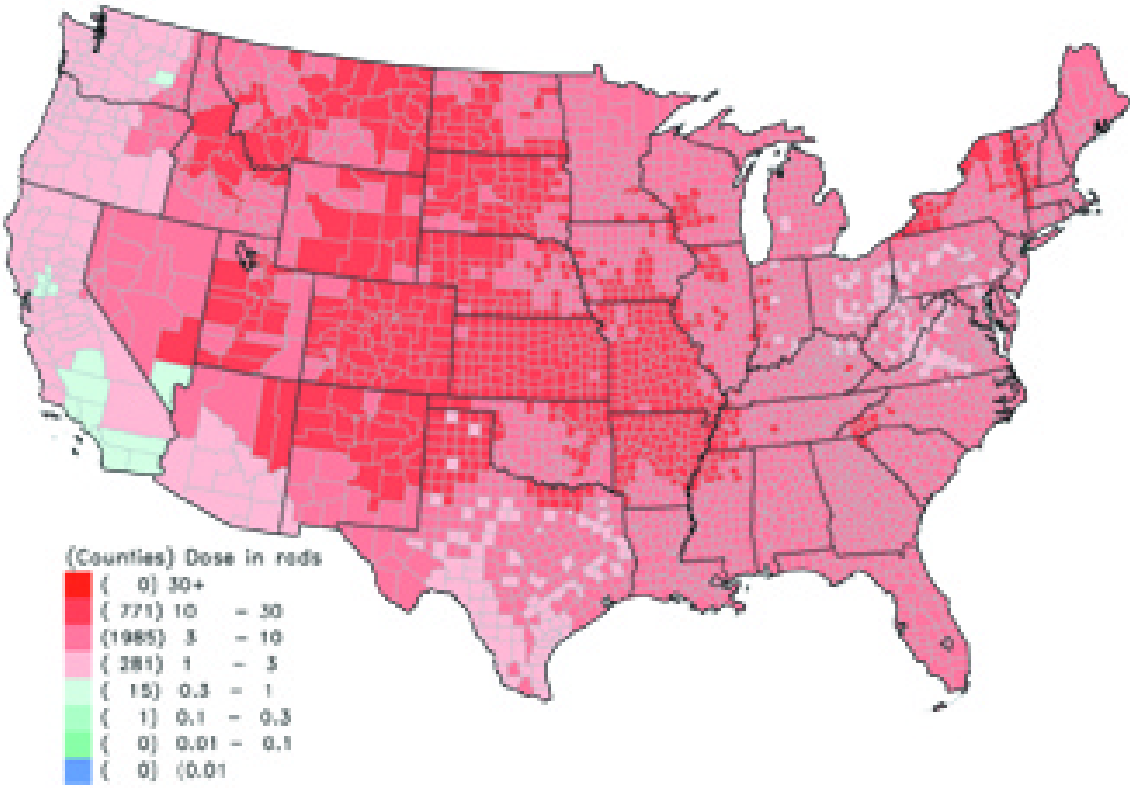

Figure 8.16. Estimates of I-131 thyroid doses for persons born on January 1, 1945 (Average diet; no milk consumption)

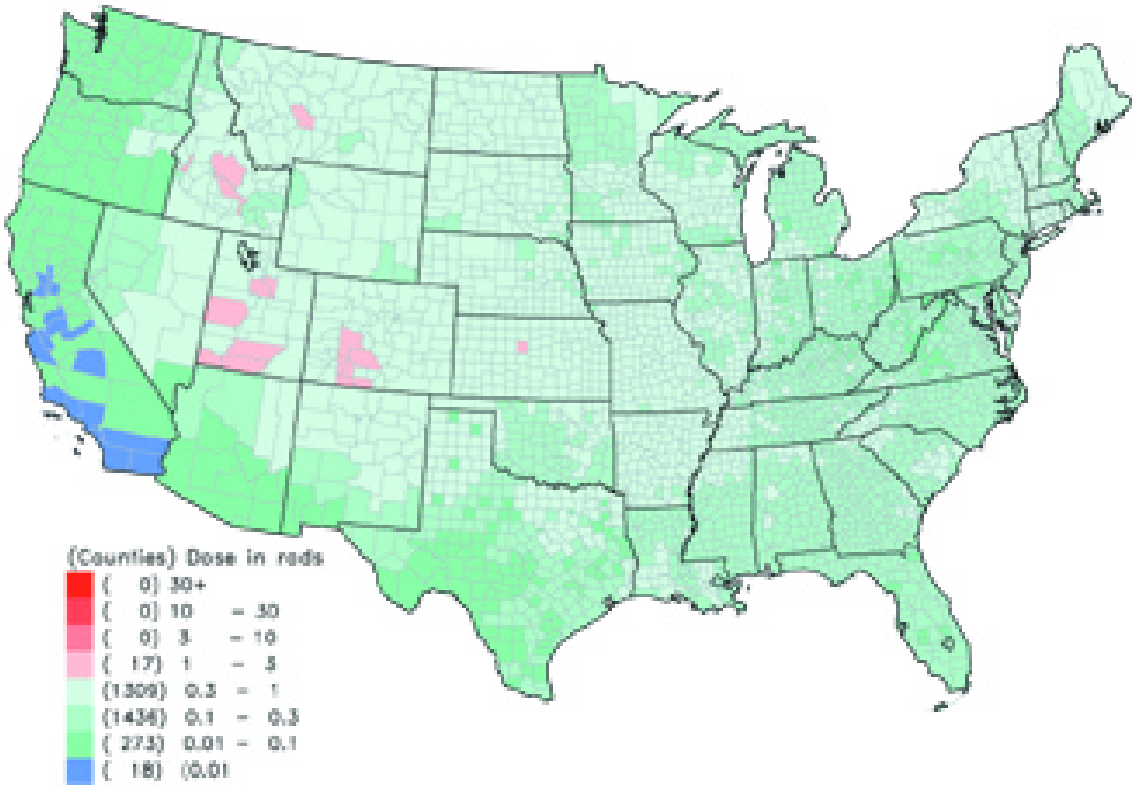

Figure 8.17. Estimates of I-131 thyroid doses for persons born on January 1, 1950 (Average diet; average milk consumption)

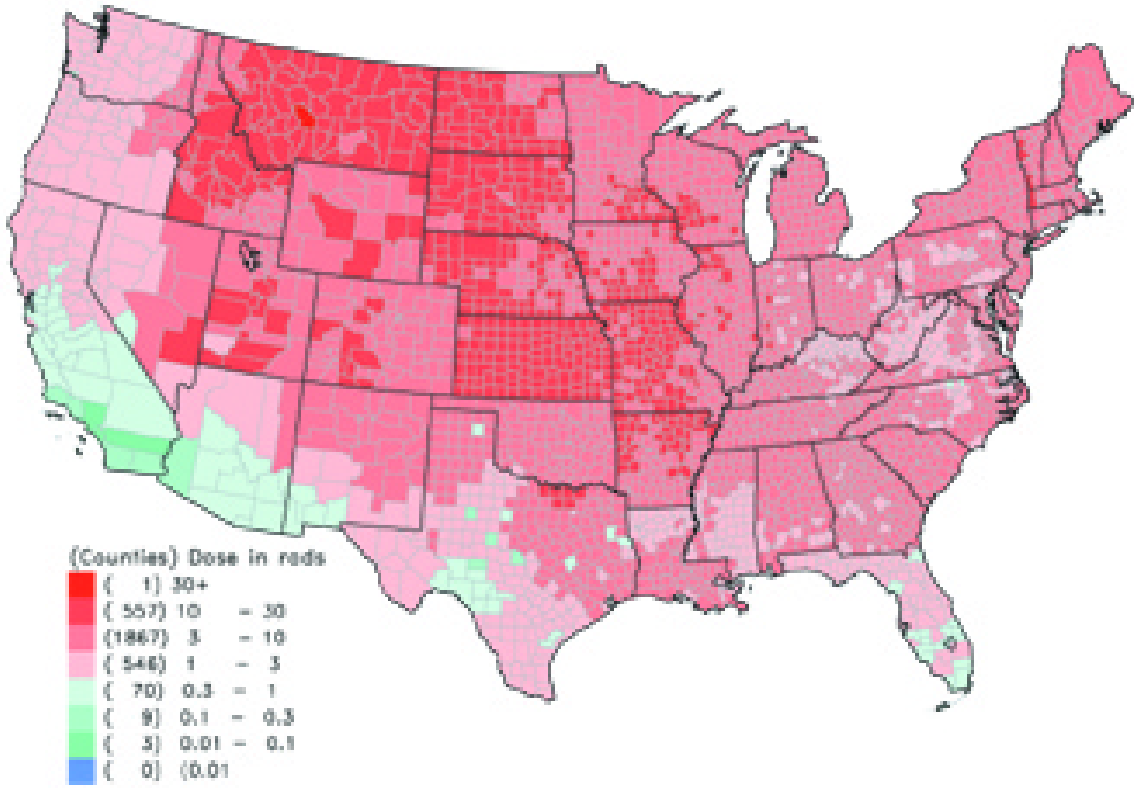

Figure 8.18. Estimates of I-131 thyroid doses for persons born on January 1, 1950 (Average diet; high milk consumption)

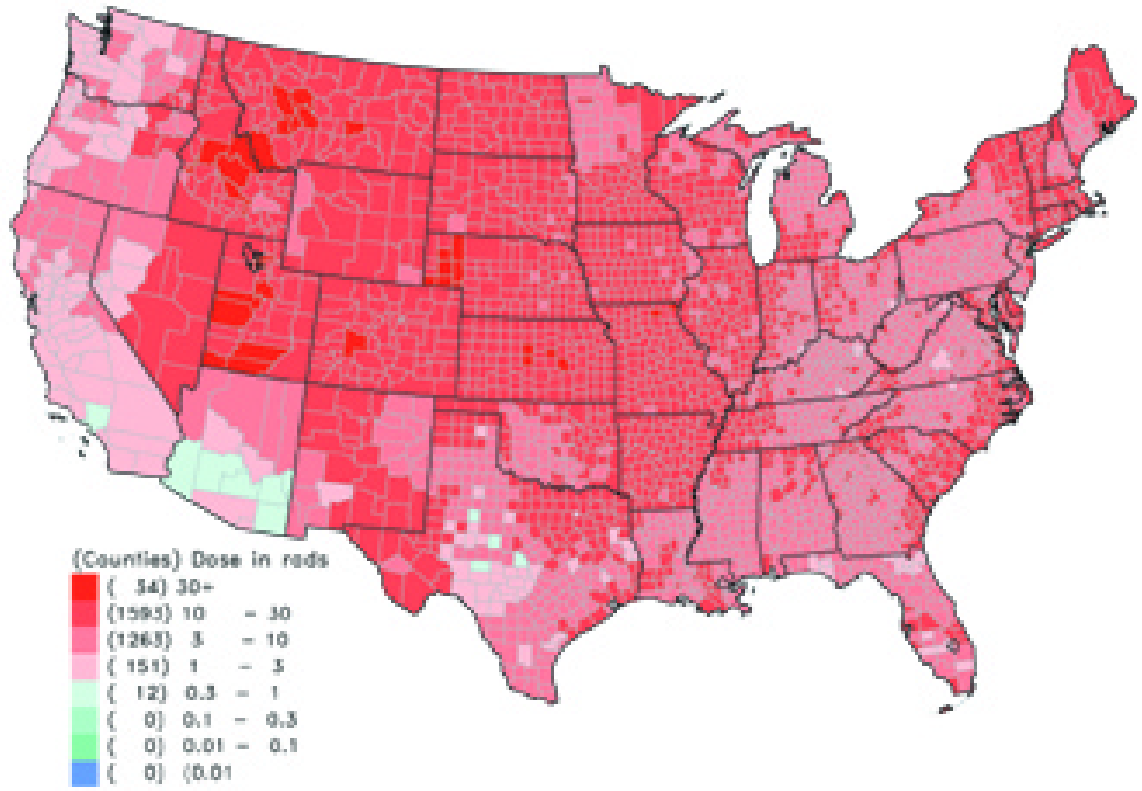

Figure 8.19. Estimates of I-131 thyroid doses for persons born on January 1, 1950 (Average diet; milk from "backyard cow")

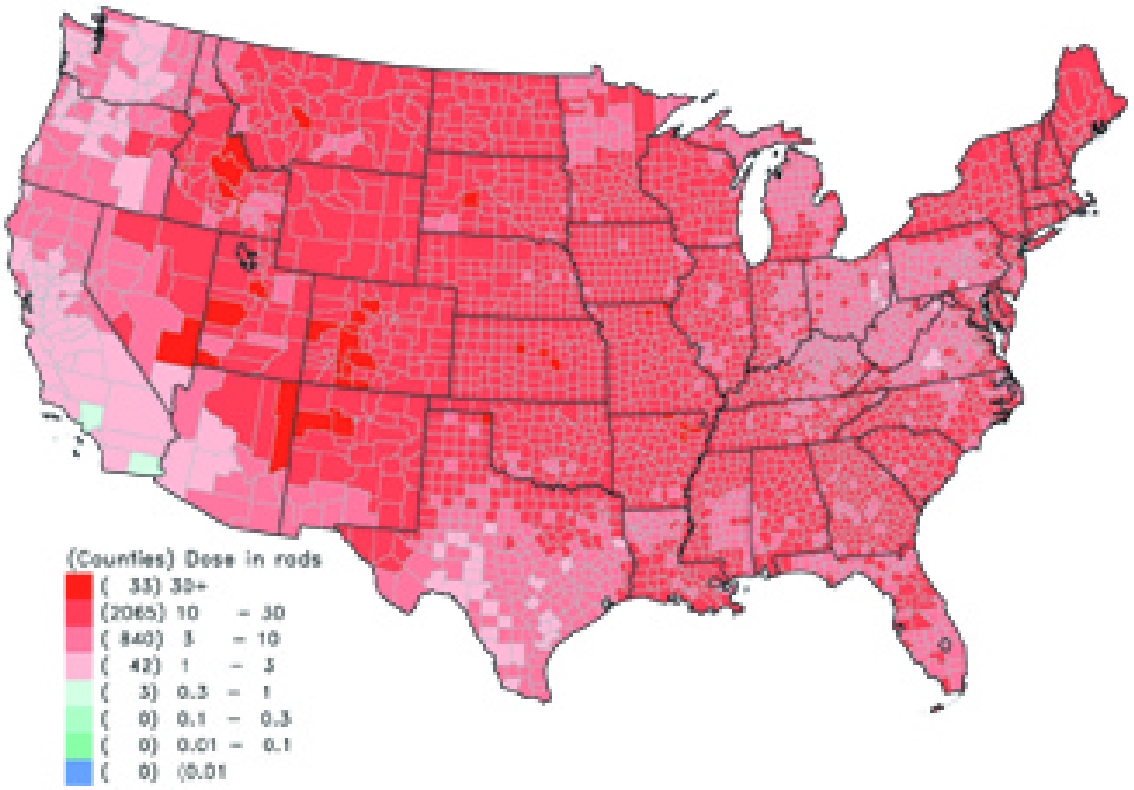

Figure 8.20. Estimates of I-131 thyroid doses for persons born on January 1, 1950 (Average diet; no milk consumption)

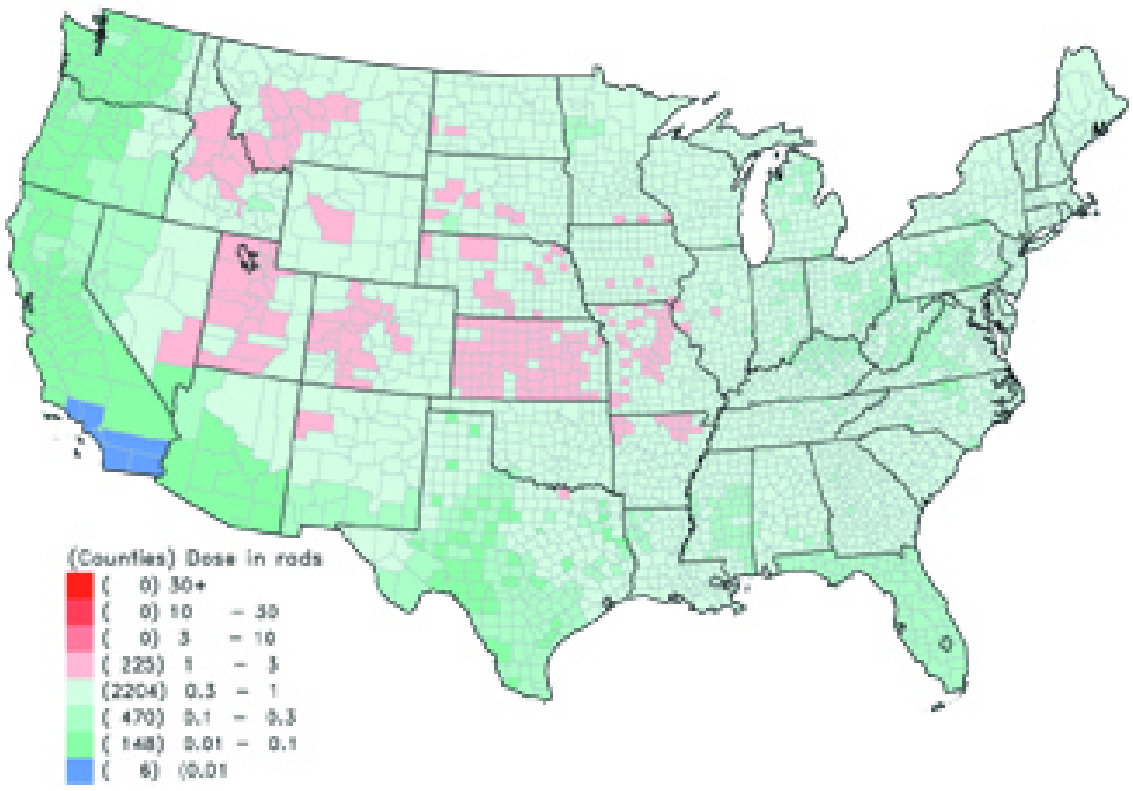

Figure 8.21. Estimates of I-131 thyroid doses for persons born on January 1, 1951 (Average diet; average milk consumption)

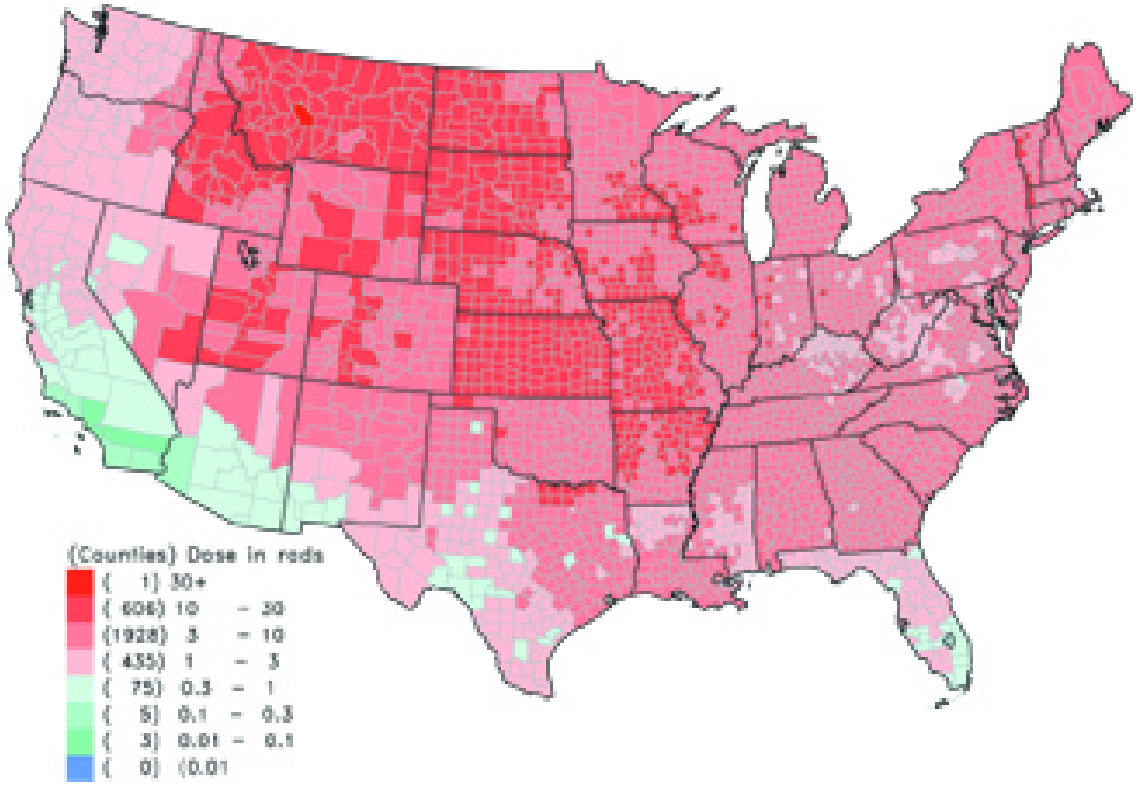

Figure 8.22. Estimates of I-131 thyroid doses for persons born on January 1, 1951 (Average diet; high milk consumption)

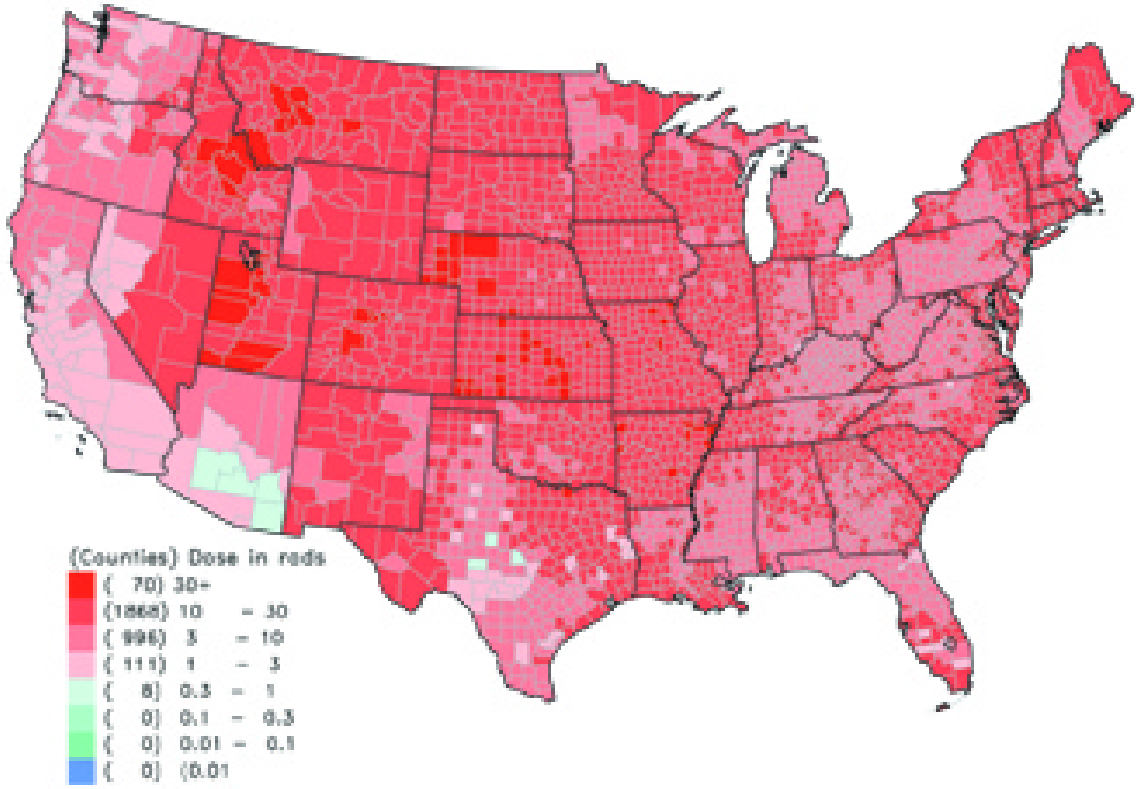

Figure 8.23. Estimates of I-131 thyroid doses for persons born on January 1, 1951 (Average diet; milk from "backyard cow")

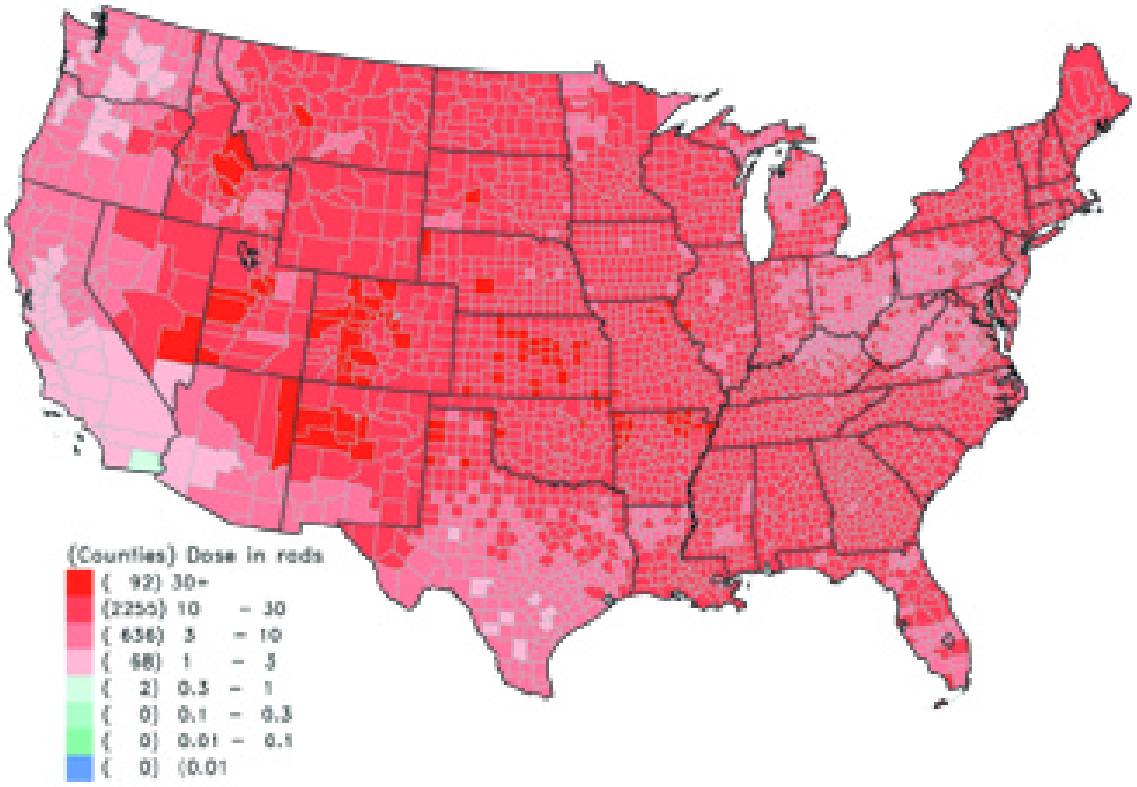

Figure 8.24. Estimates of I-131 thyroid doses for persons born on January 1, 1951 (Average diet; no milk consumption)

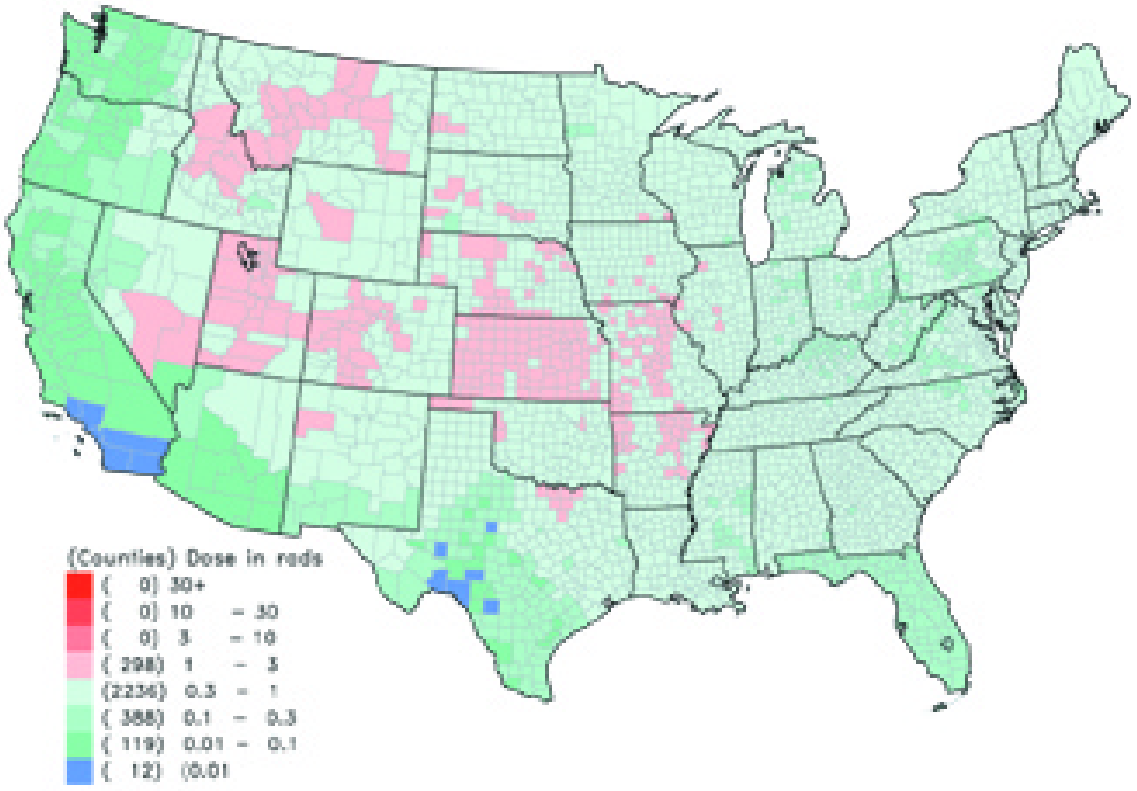

Figure 8.25. Estimates of I-131 thyroid doses for persons born on January 1, 1952 (Average diet; average milk consumption)

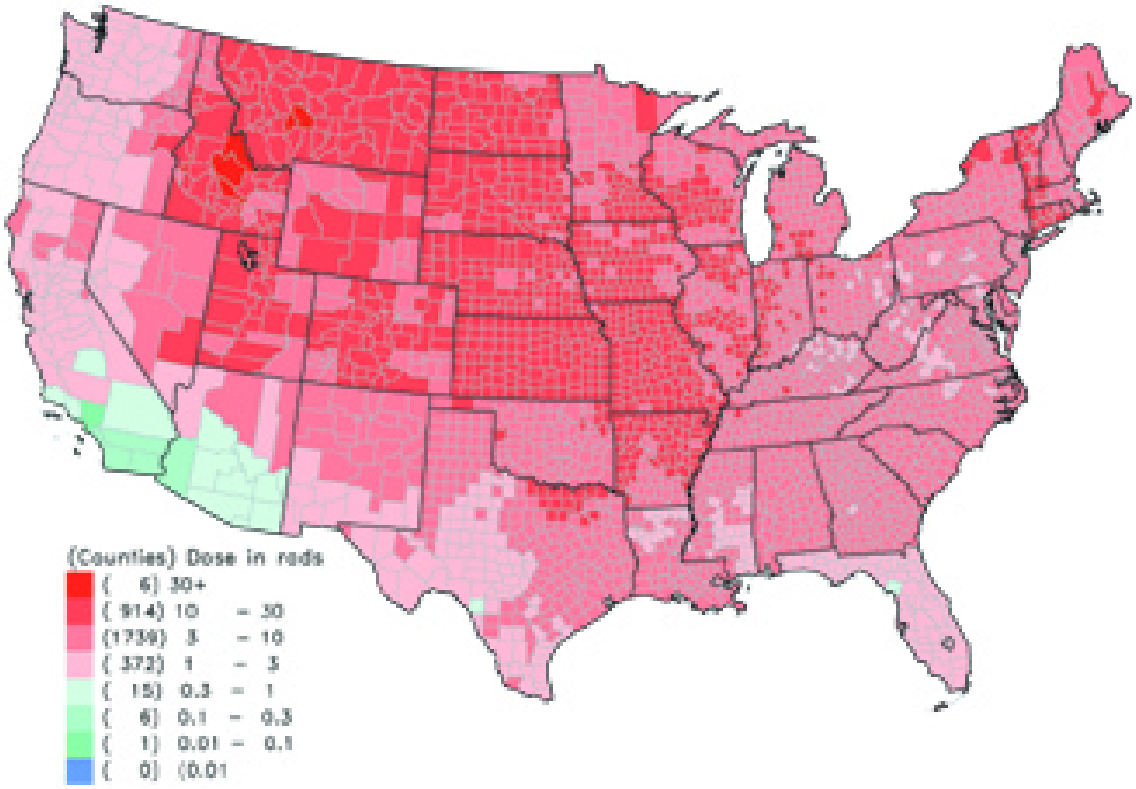

Figure 8.26. Estimates of I-131 thyroid doses for persons born on January 1, 1952 (Average diet; high milk consumption)

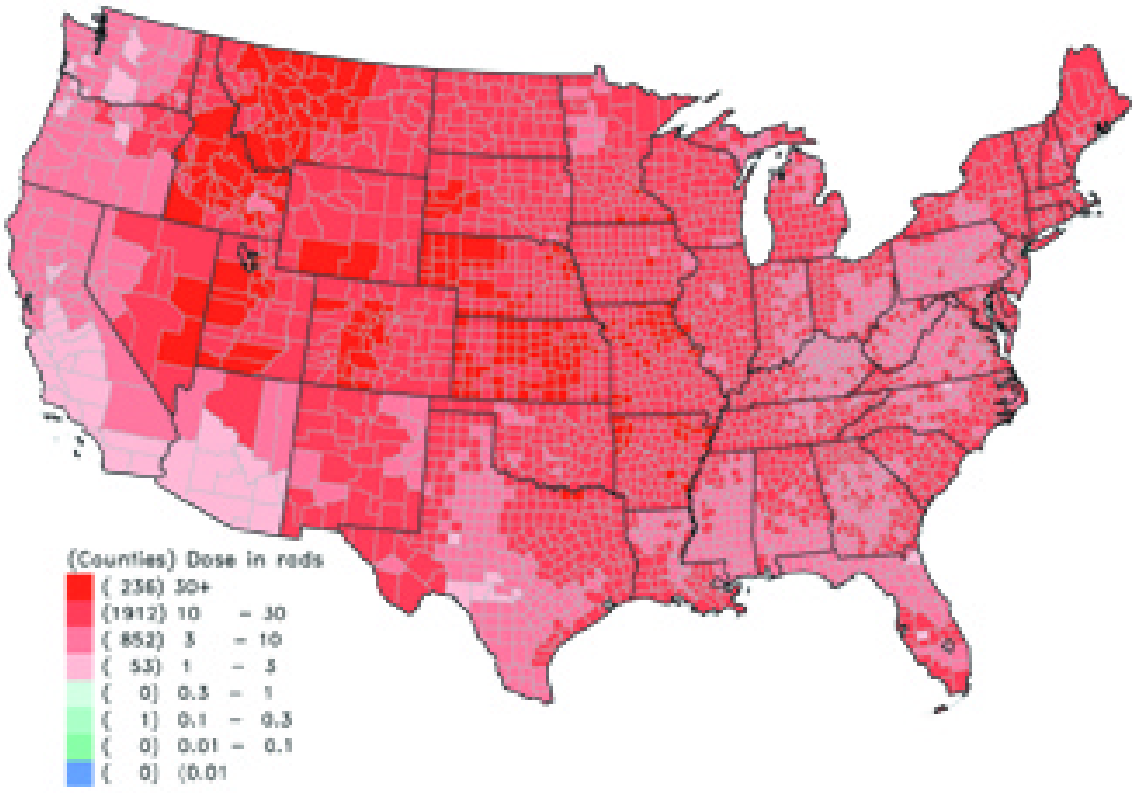

Figure 8.27. Estimates of I-131 thyroid doses for persons born on January 1, 1952 (Average diet; milk from "backyard cow")

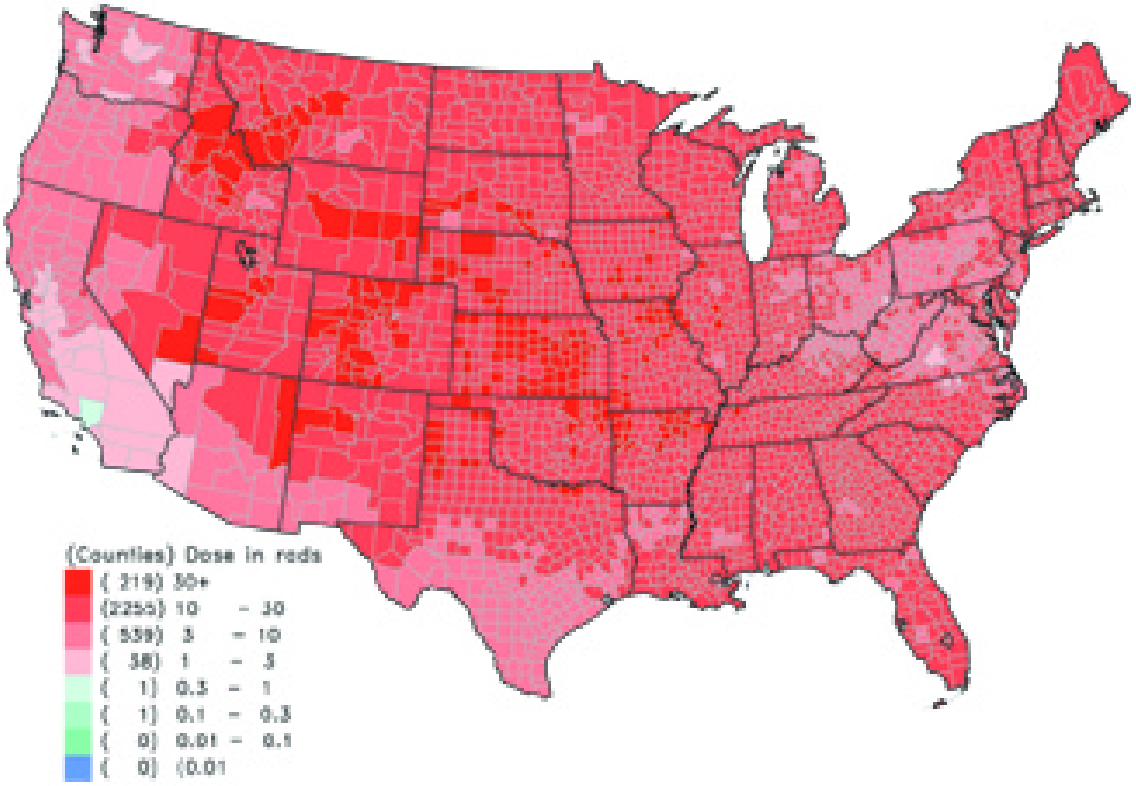

Figure 8.28. Estimates of I-131 thyroid doses for persons born on January 1, 1952 (Average diet; no milk consumption)

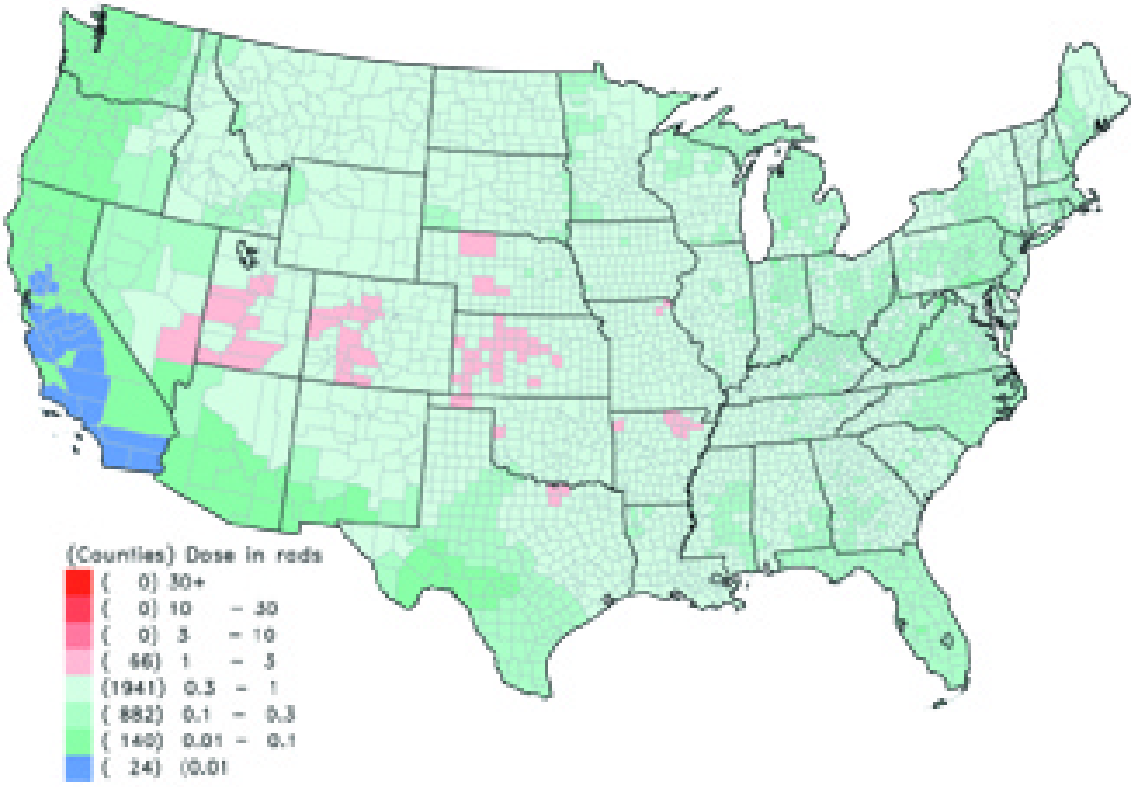

Figure 8.29. Estimates of I-131 thyroid doses for persons born on April 1, 1952 (Average diet; average milk consumption)

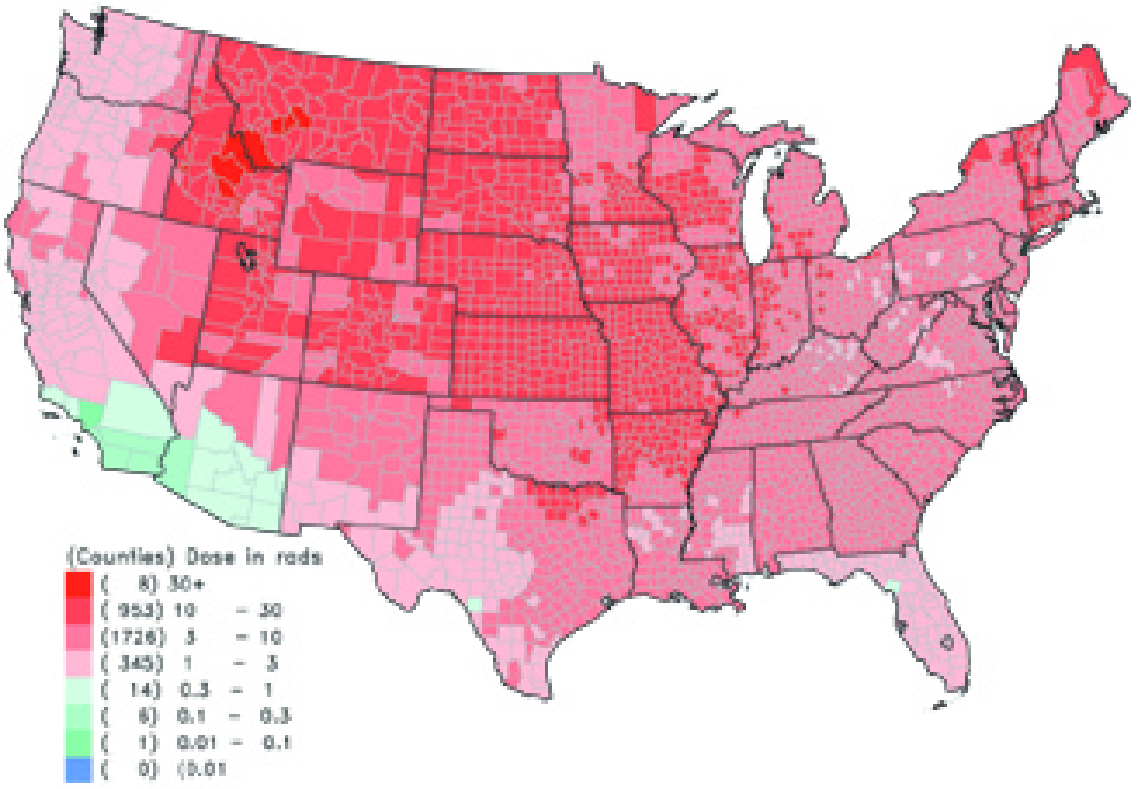

Figure 8.30. Estimates of I-131 thyroid doses for persons born on April 1, 1952 (Average diet; high milk consumption)

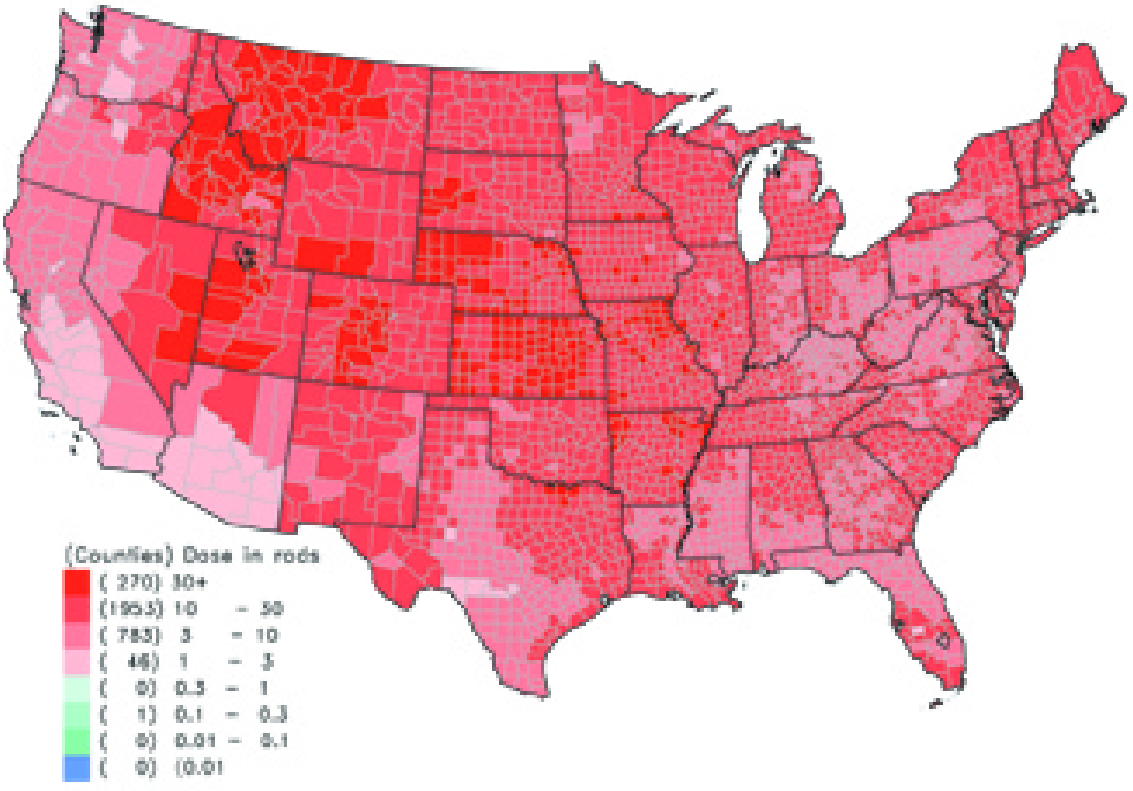

Figure 8.31. Estimates of I-131 thyroid doses for persons born on April 1, 1952 (Average diet; milk from "backyard cow")

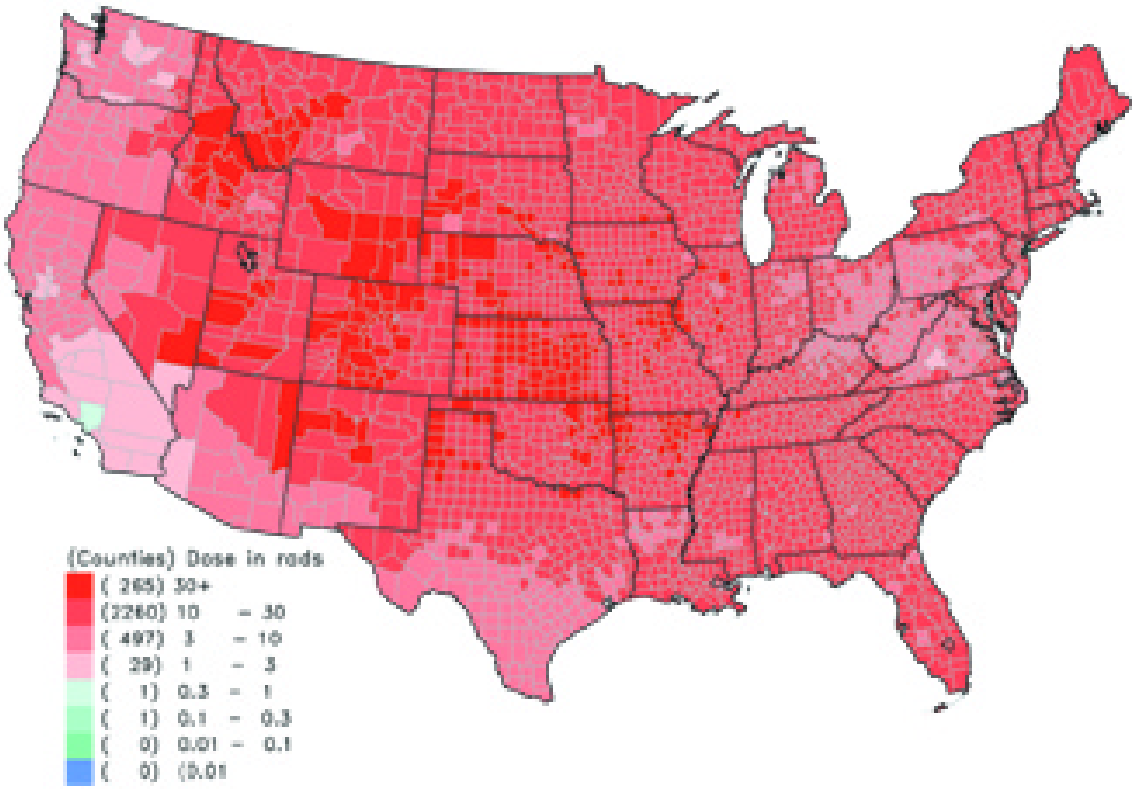

Figure 8.32. Estimates of I-131 thyroid doses for persons born on April 1, 1952 (Average diet; no milk consumption)

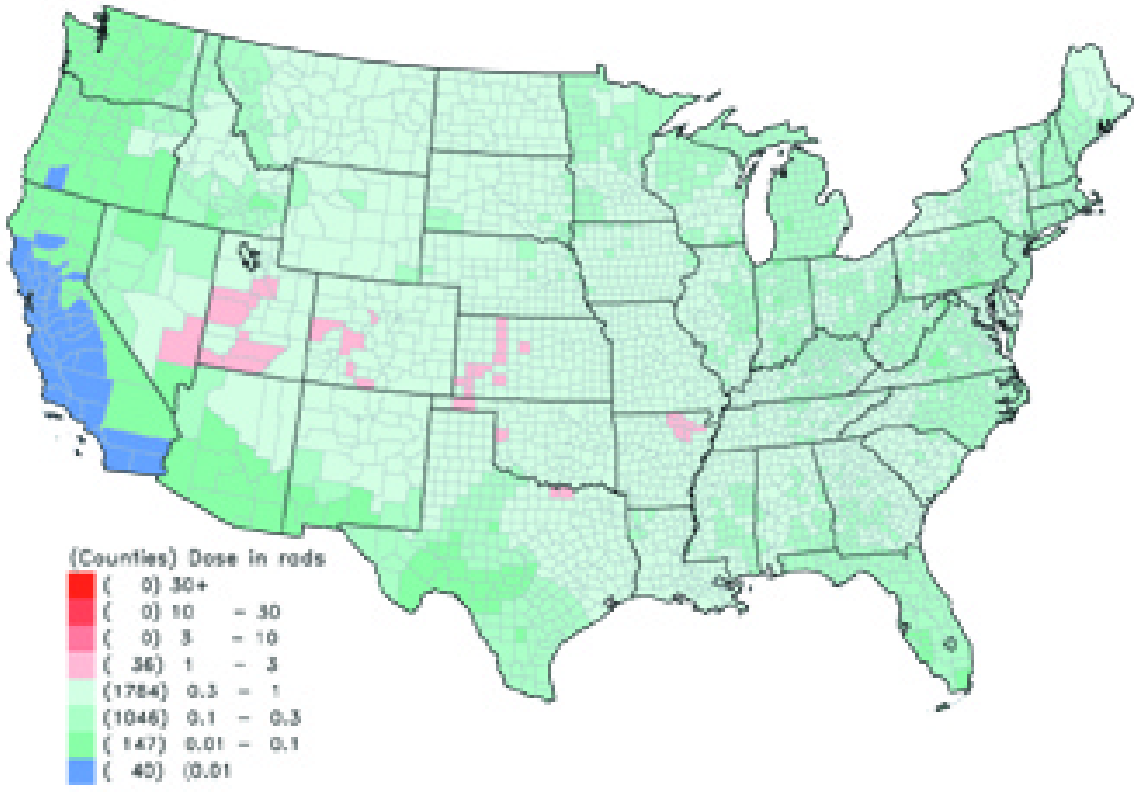

Figure 8.33. Estimates of I-131 thyroid doses for persons born on January 1, 1953 (Average diet; average milk consumption)

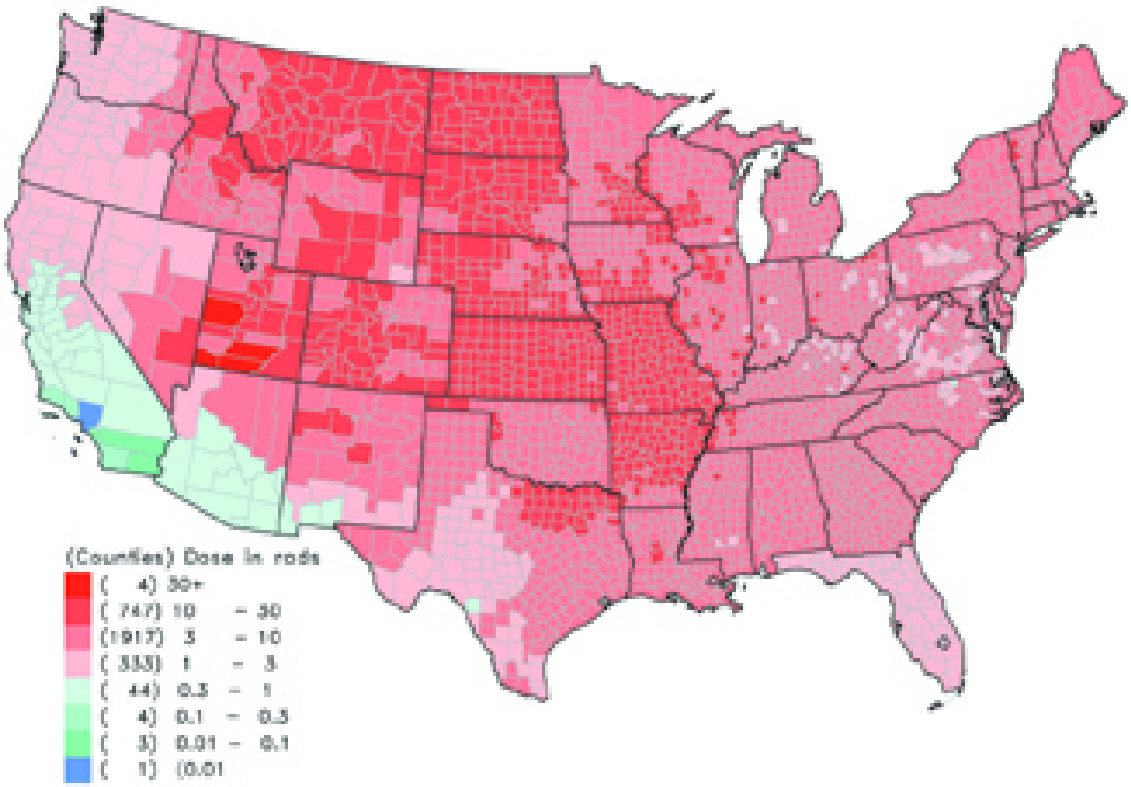

Figure 8.34. Estimates of I-131 thyroid doses for persons born on January 1, 1953 (Average diet; high milk consumption)

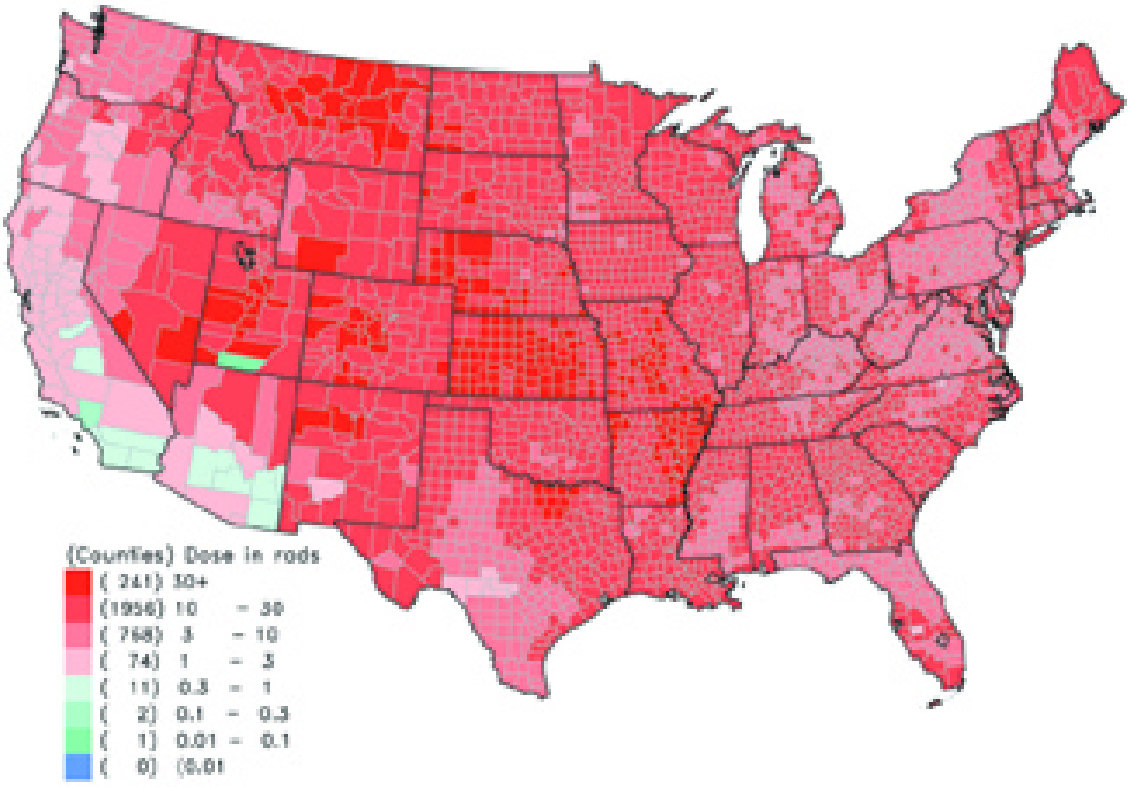

Figure 8.35. Estimates of I-131 thyroid doses for persons born on January 1, 1953 (Average diet; milk from "backyard cow")

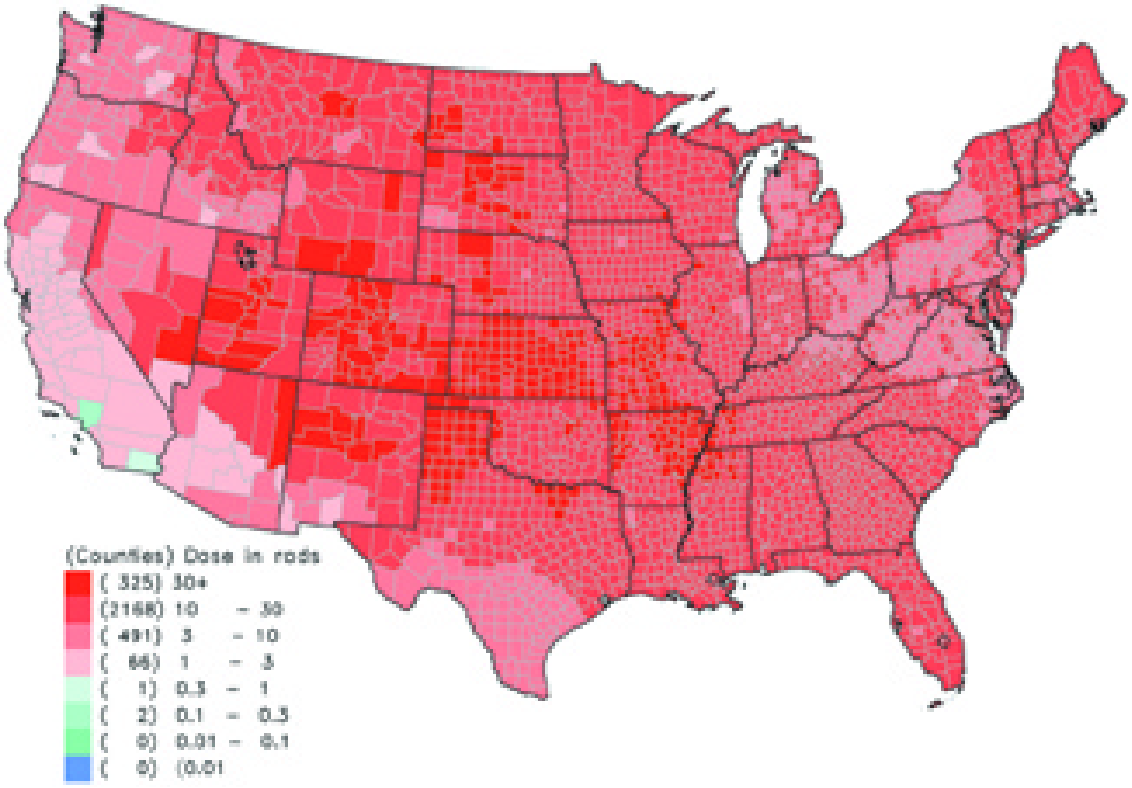

Figure 8.36. Estimates of I-131 thyroid doses for persons born on January 1, 1953 (Average diet; no milk consumption)