**Figure 8.37.** Estimates of I-131 thyroid doses for persons born on January 1, 1954 (Average diet; average milk consumption)

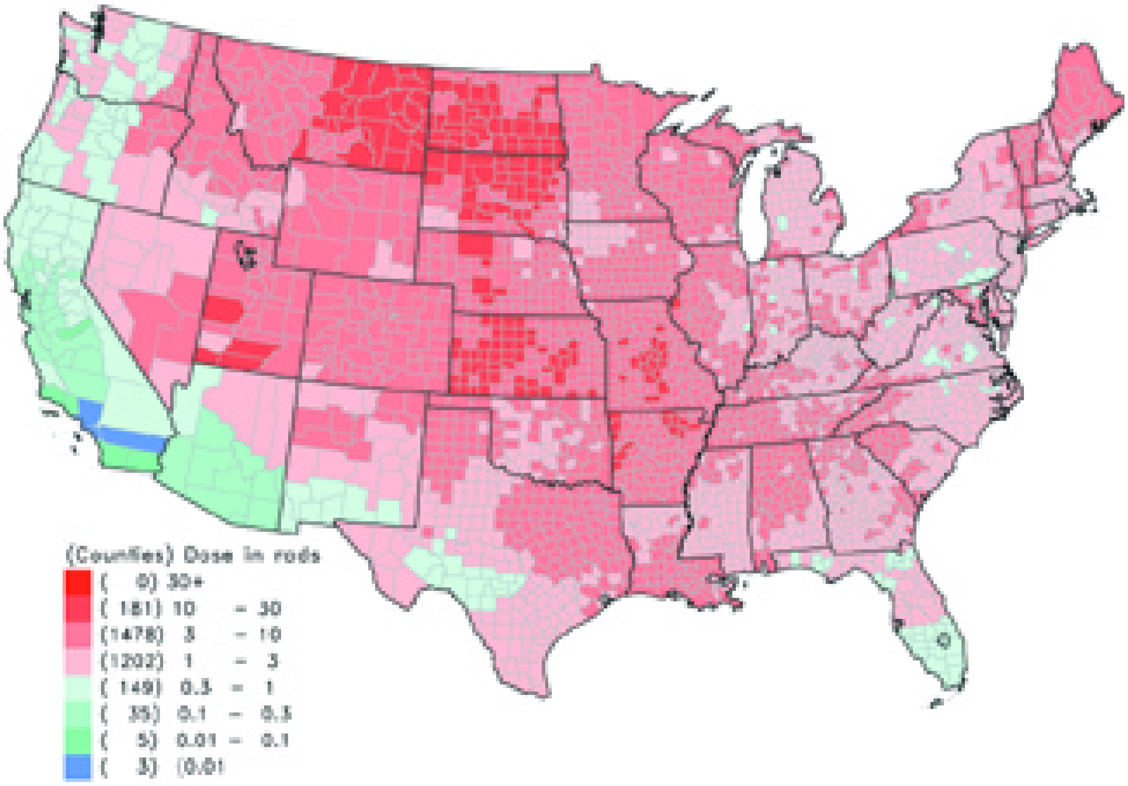



**Figure 8.38.** Estimates of I-131 thyroid doses for persons born on January 1, 1954 (Average diet; high milk consumption)

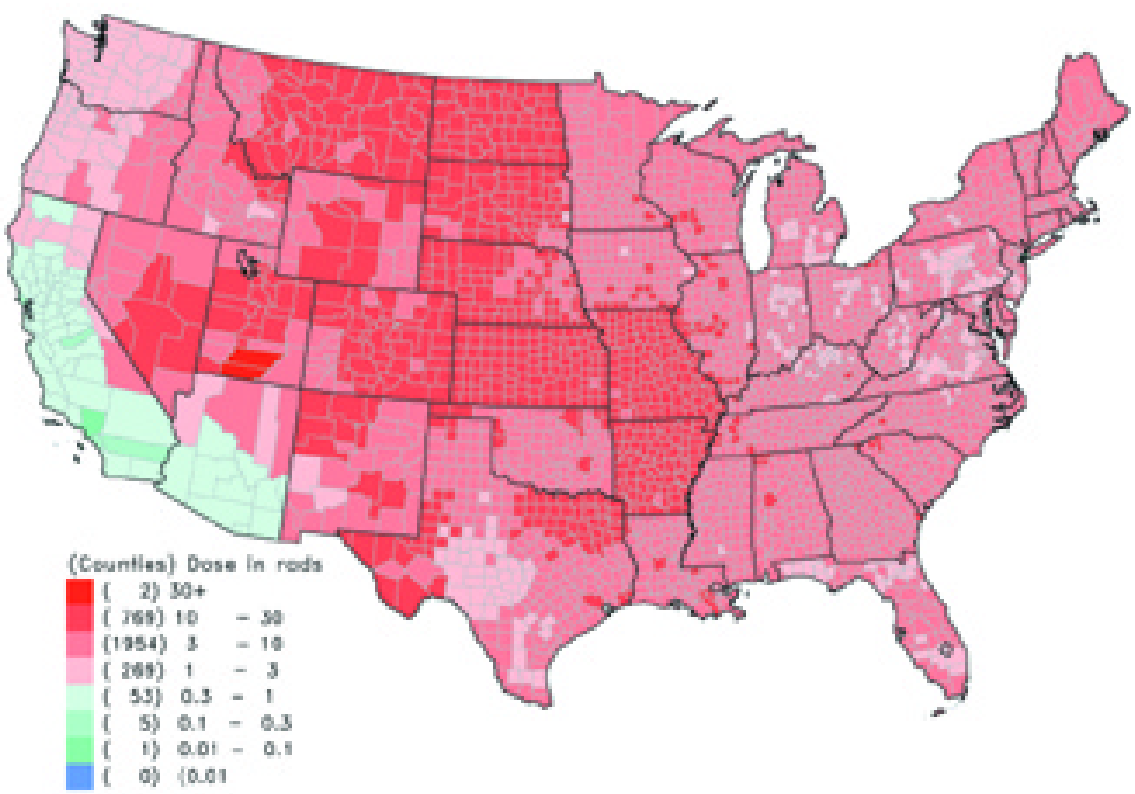


**Figure 8.39.** Estimates of I-131 thyroid doses for persons born on January 1, 1954 (Average diet; milk from "backyard cow")

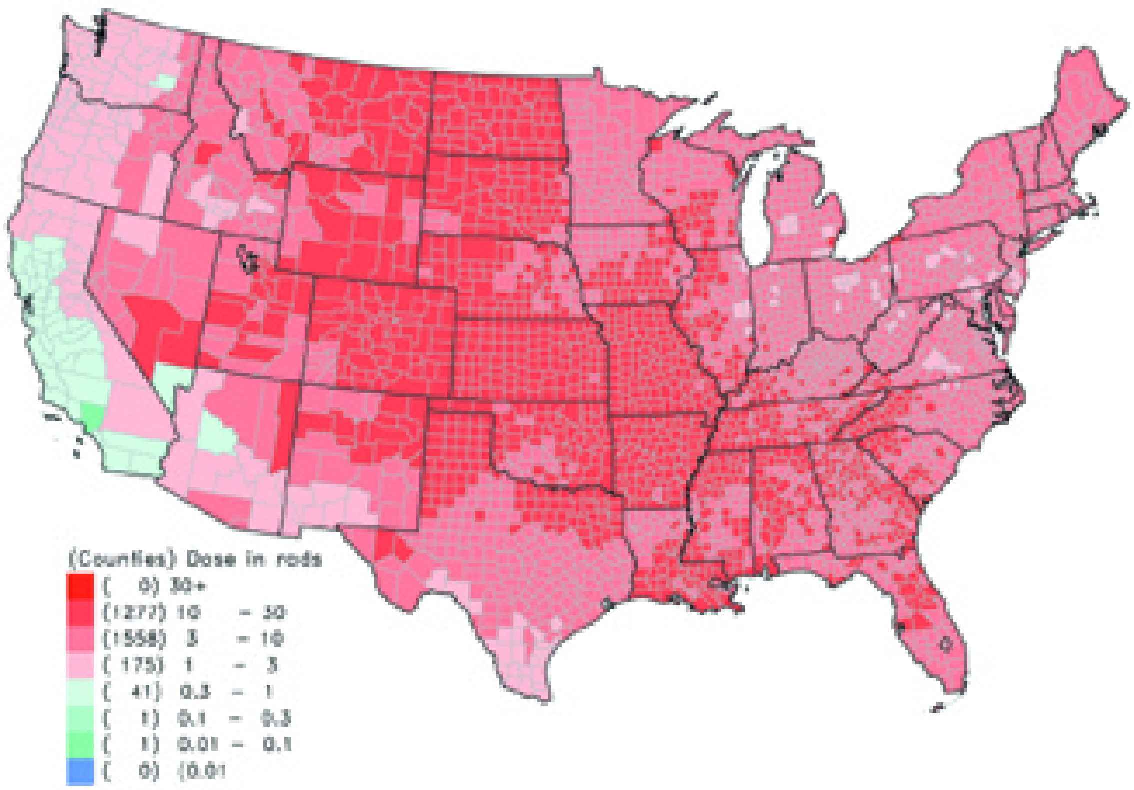



**Figure 8.40.** Estimates of I-131 thyroid doses for persons born on January 1, 1954 (Average diet; no milk consumption)

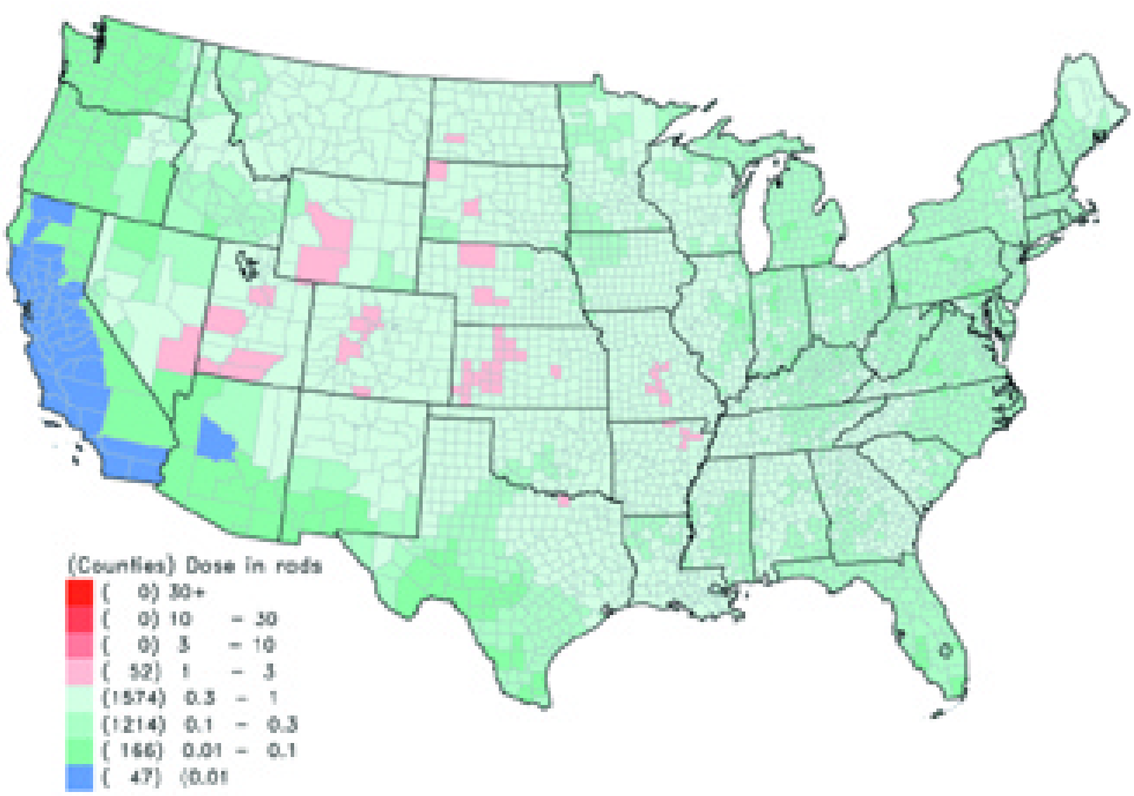


**Figure 8.41.** Estimates of I-131 thyroid doses for persons born on January 1, 1955 (Average diet; average milk consumption)

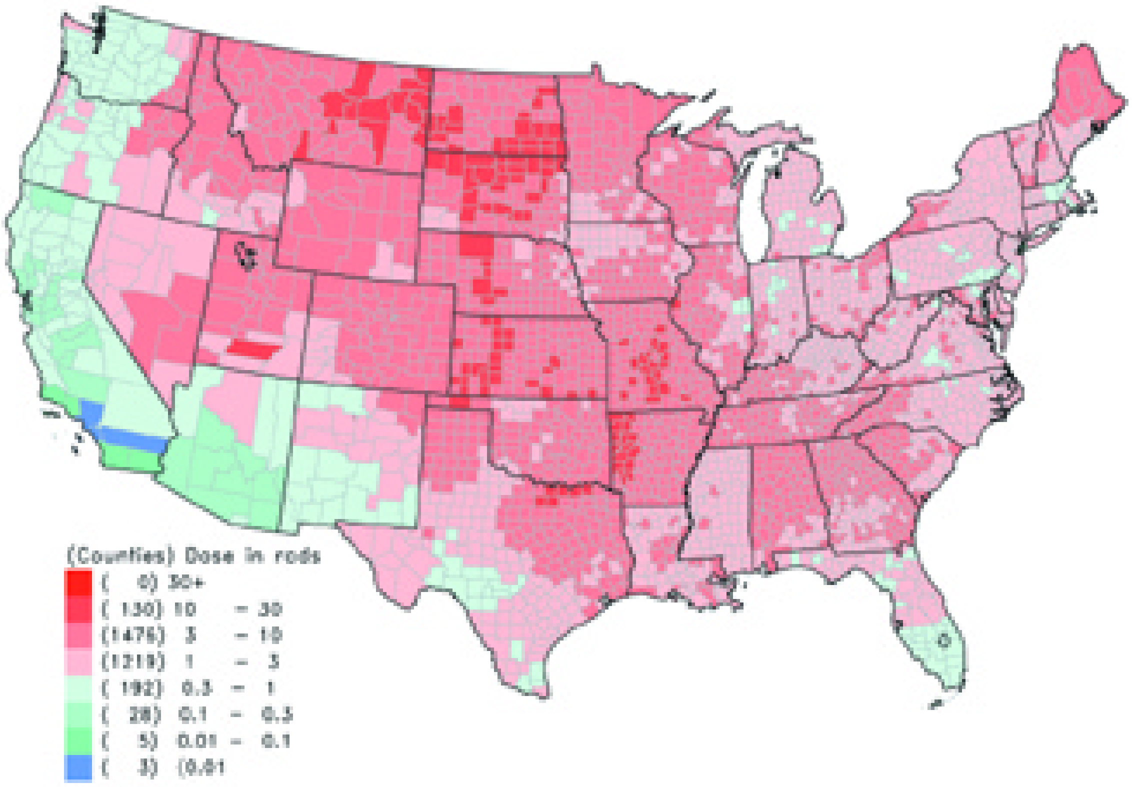



**Figure 8.42.** Estimates of I-131 thyroid doses for persons born on January 1, 1955 (Average diet; high milk consumption)

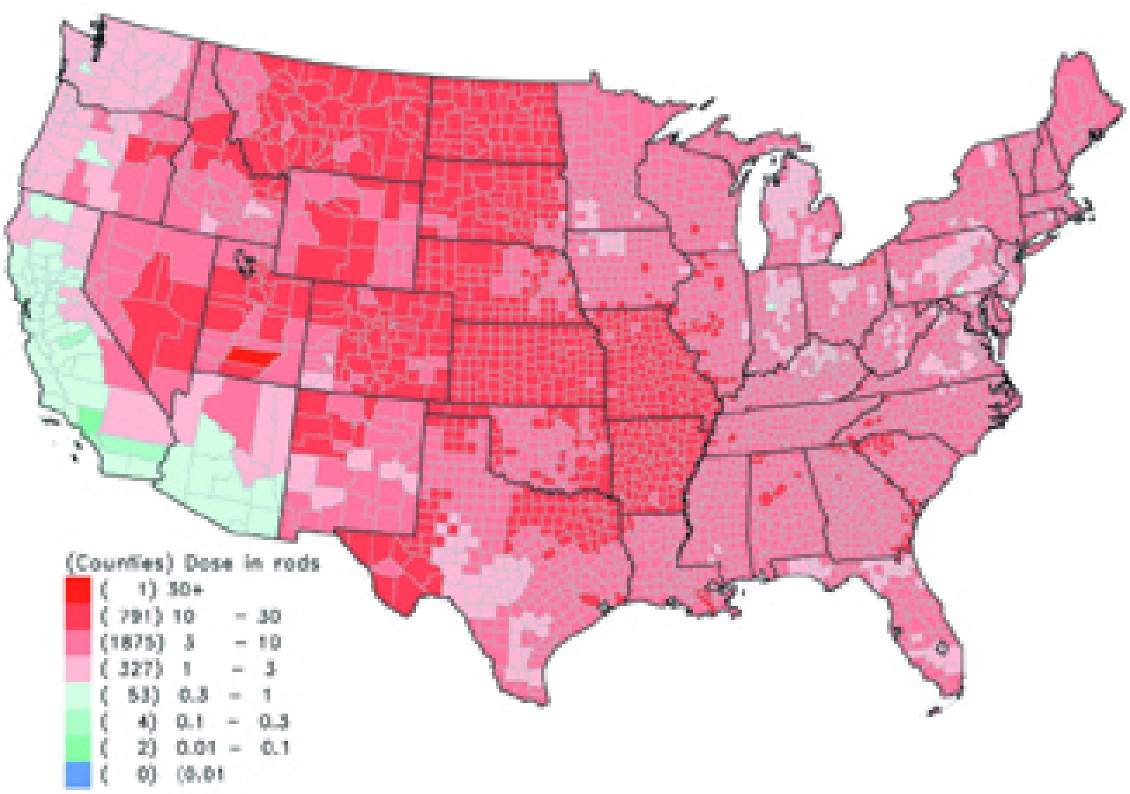


**Figure 8.43.** Estimates of I-131 thyroid doses for persons born on January 1, 1955 (Average diet; milk from "backyard cow")

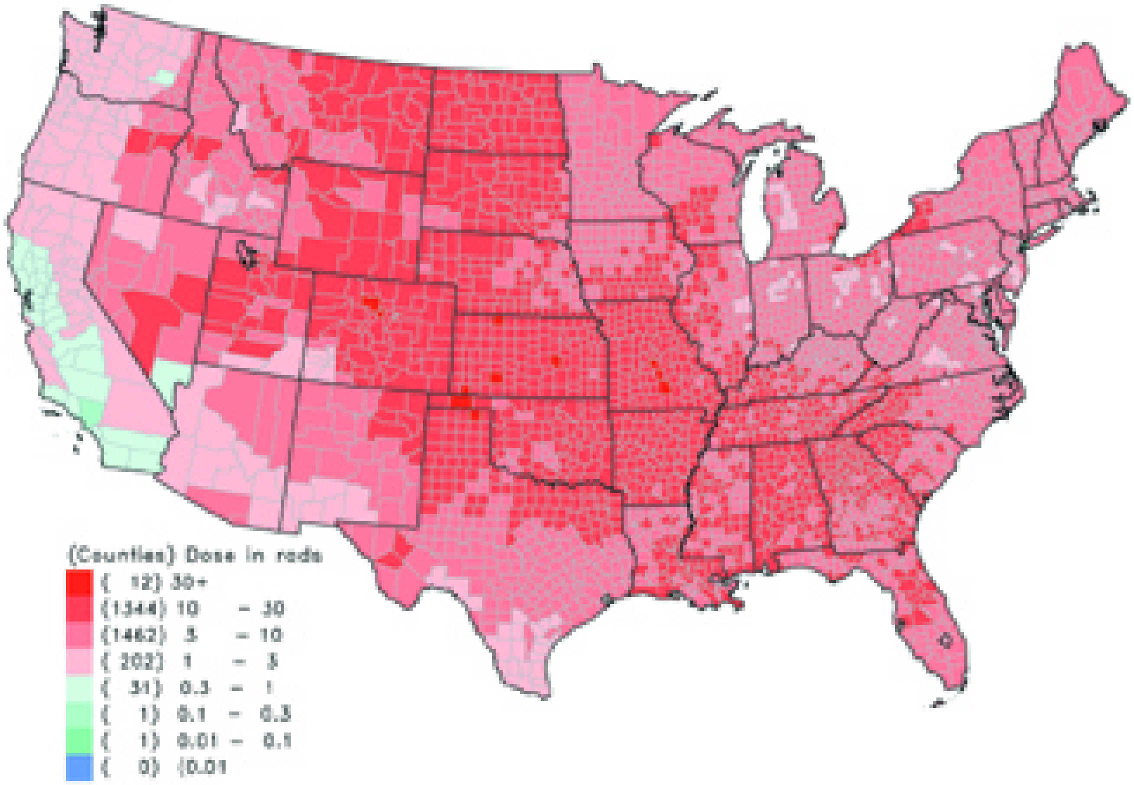



**Figure 8.44.** Estimates of I-131 thyroid doses for persons born on January 1, 1955 (Average diet; no milk consumption)

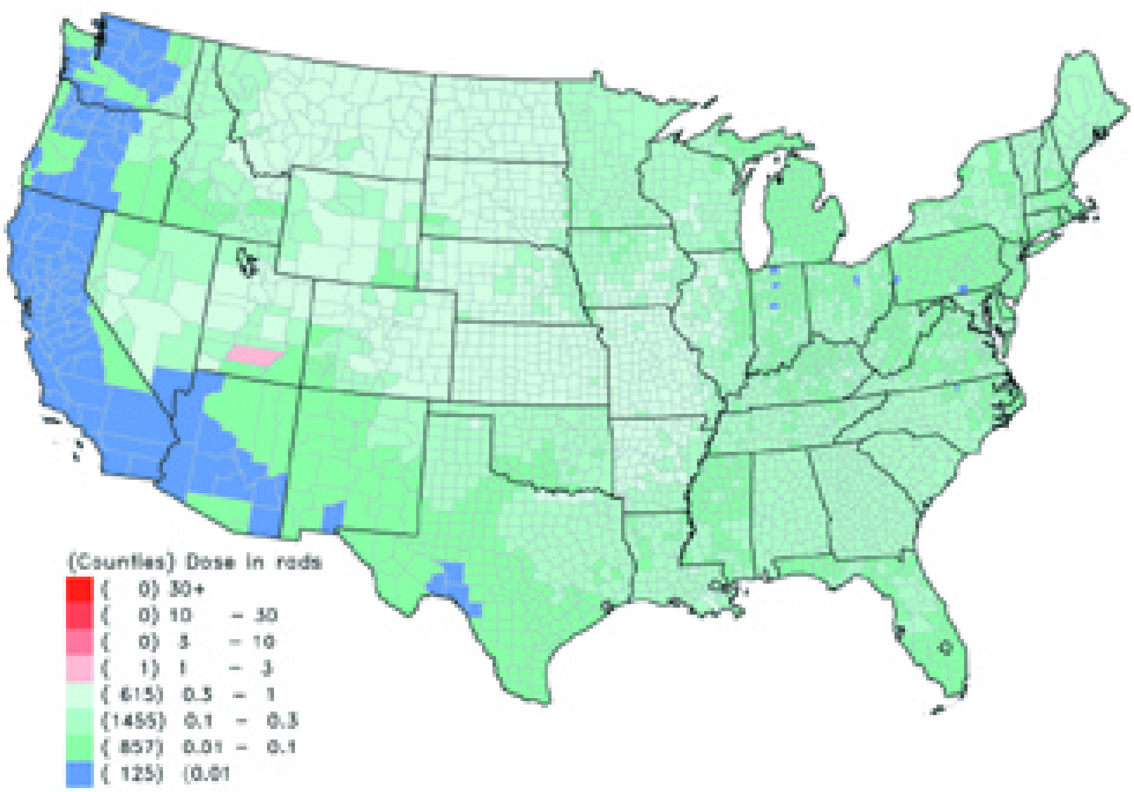


**Figure 8.45.** Estimates of I-131 thyroid doses for persons born on January 1, 1956 (Average diet; average milk consumption)

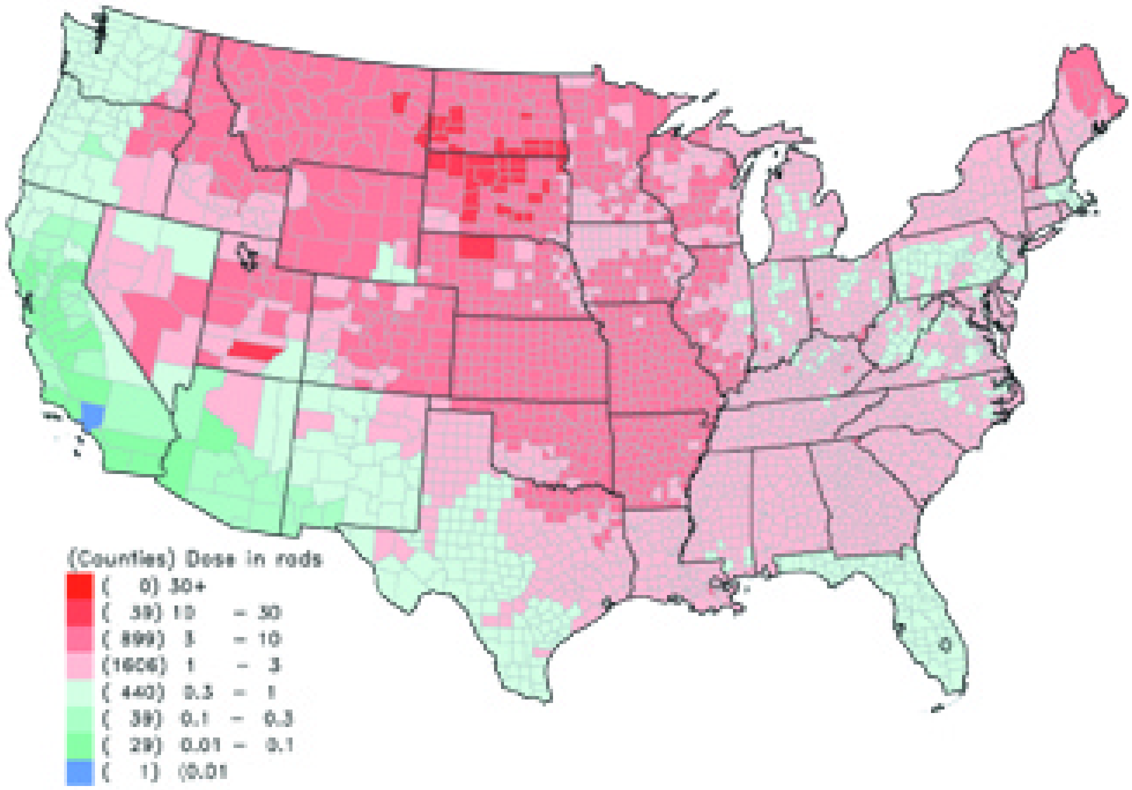



**Figure 8.46.** Estimates of I-131 thyroid doses for persons born on January 1, 1956 (Average diet; high milk consumption)

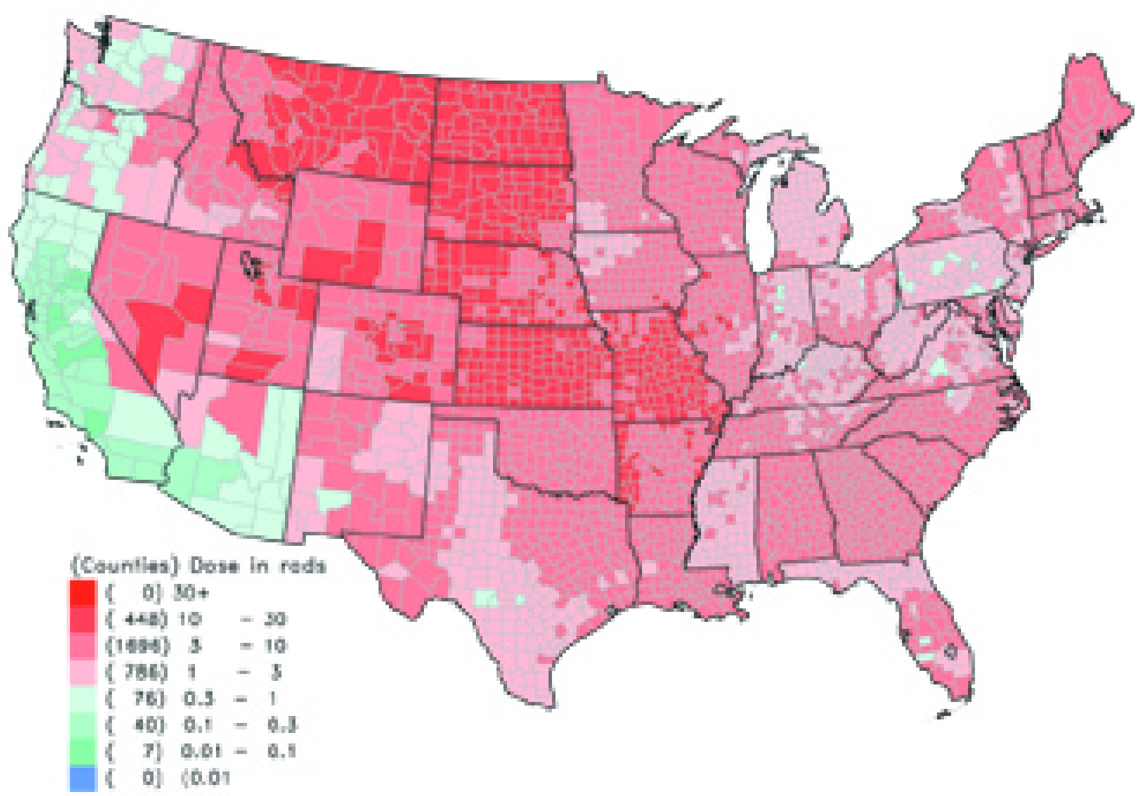


**Figure 8.47.** Estimates of I-131 thyroid doses for persons born on January 1, 1956 (Average diet; milk from "backyard cow")

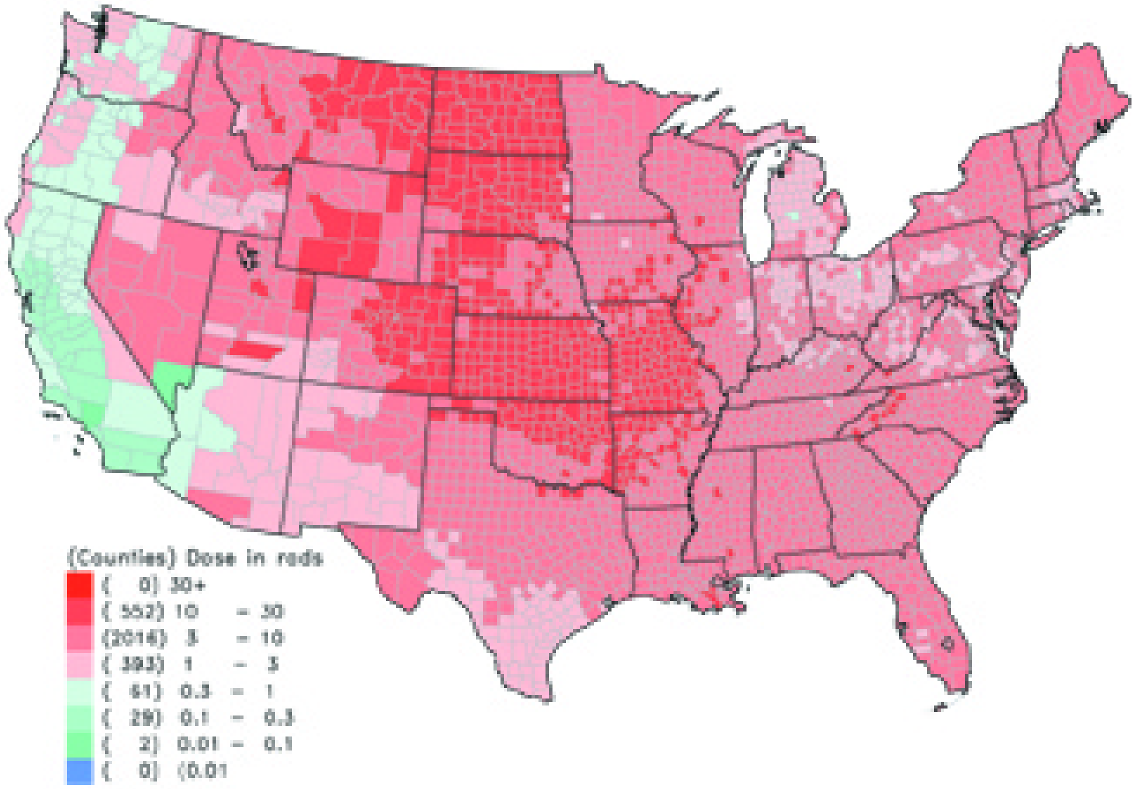



**Figure 8.48.** Estimates of I-131 thyroid doses for persons born on January 1, 1956 (Average diet; no milk consumption)

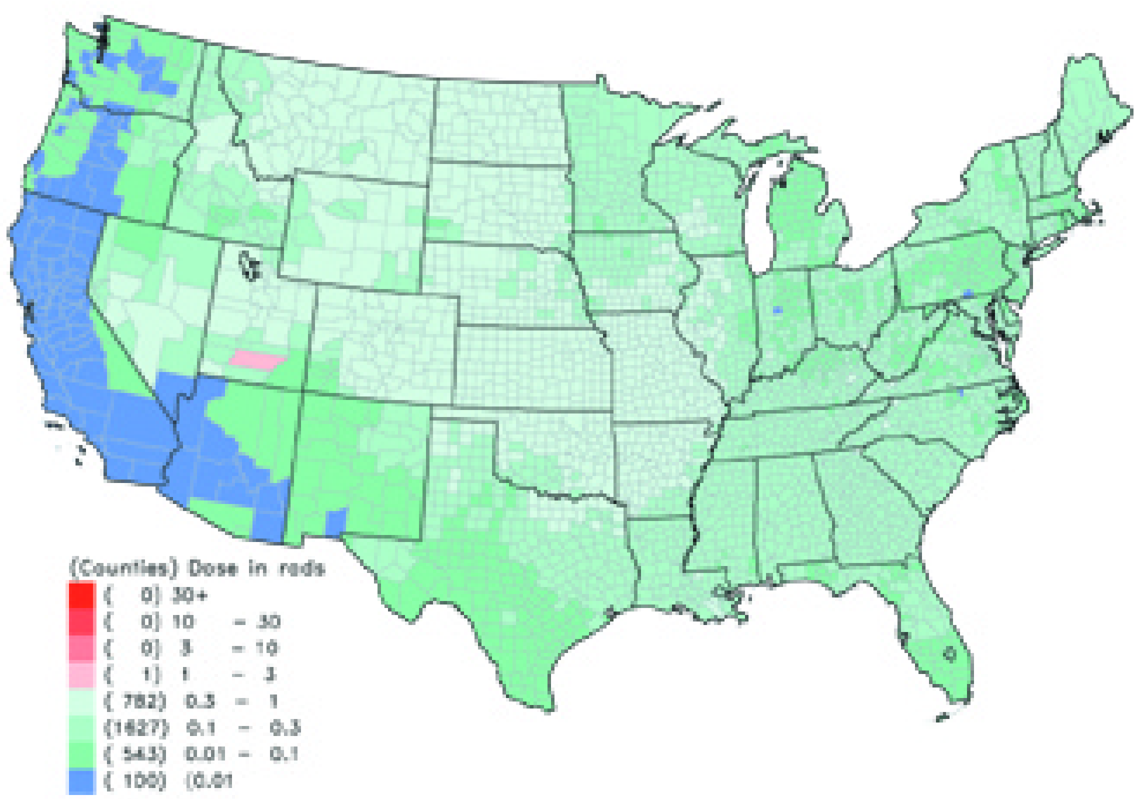


**Figure 8.49.** Estimates of I-131 thyroid doses for persons born on January 1, 1957 (Average diet; average milk consumption)

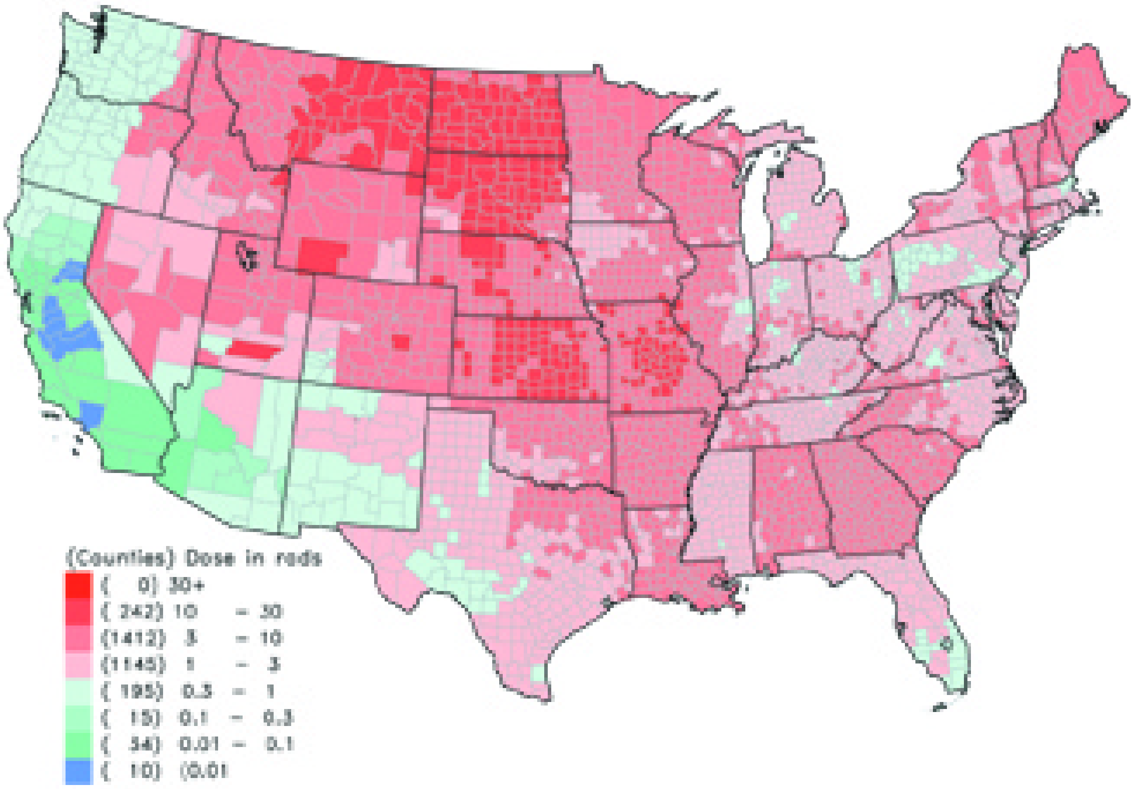



**Figure 8.50.** Estimates of I-131 thyroid doses for persons born on January 1, 1957 (Average diet; high milk consumption)

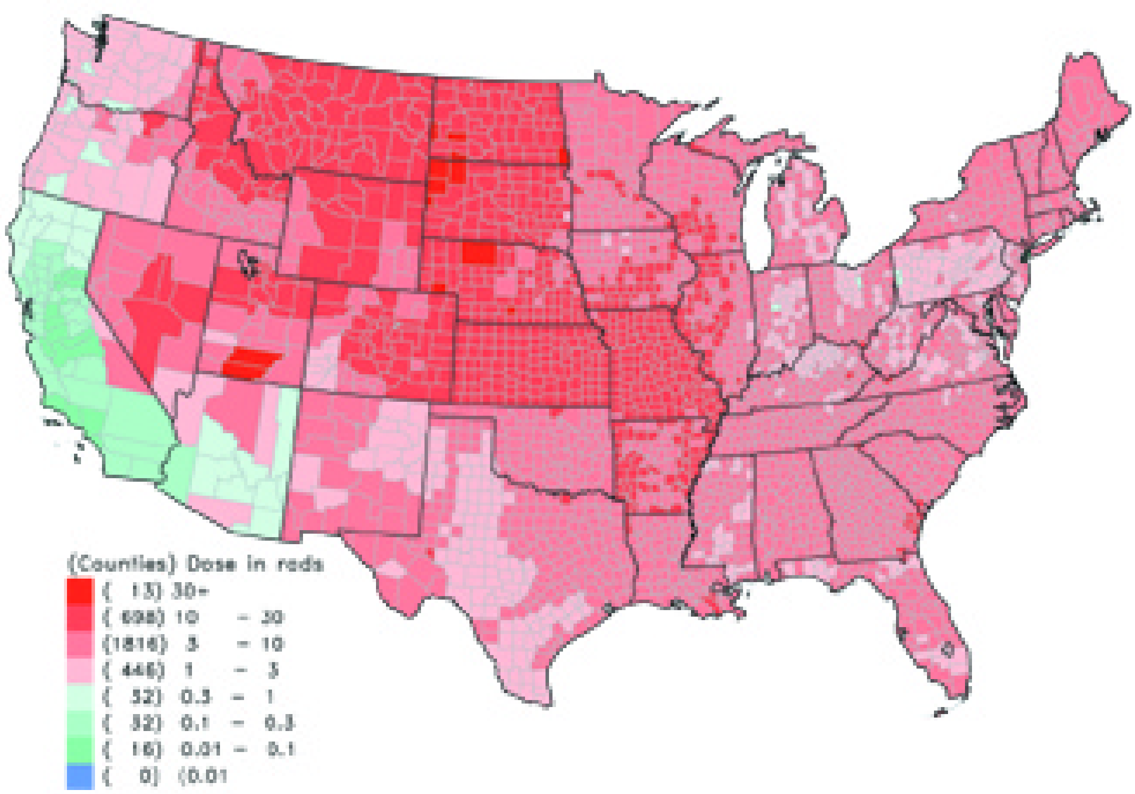


**Figure 8.51.** Estimates of I-131 thyroid doses for persons born on January 1, 1957 (Average diet; milk from "backyard cow")

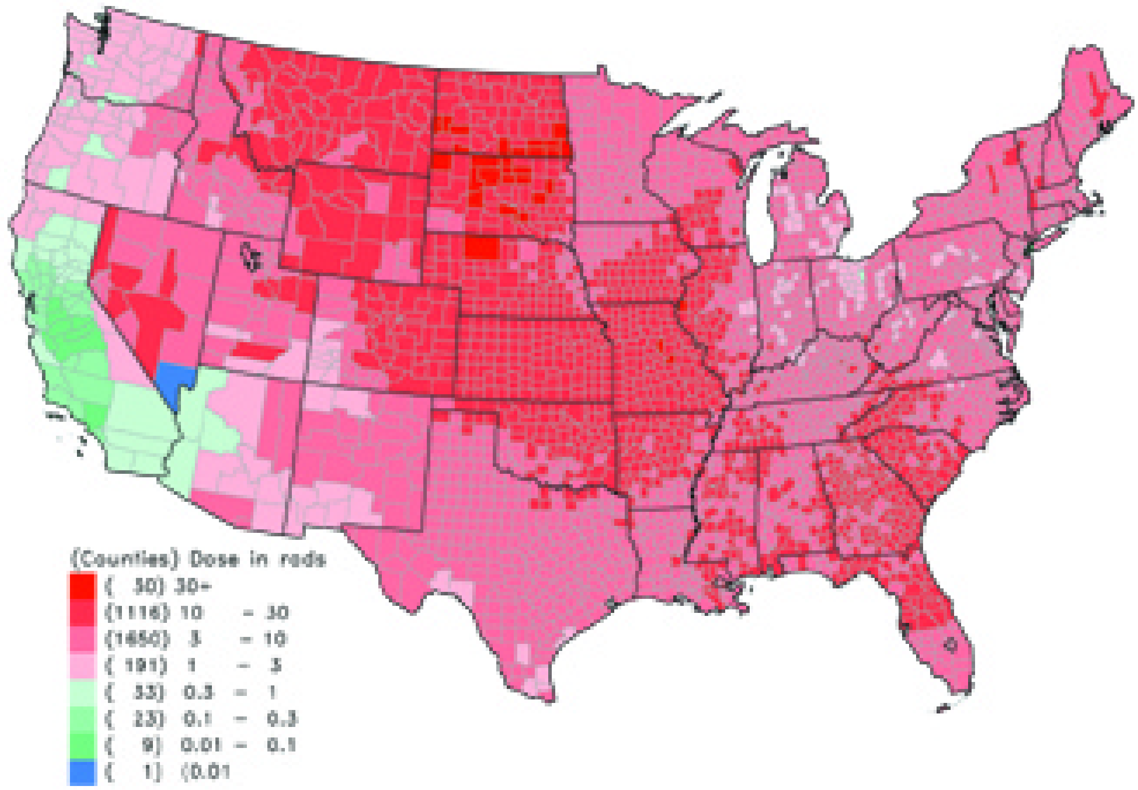



**Figure 8.52.** Estimates of I-131 thyroid doses for persons born on January 1, 1957 (Average diet; no milk consumption)

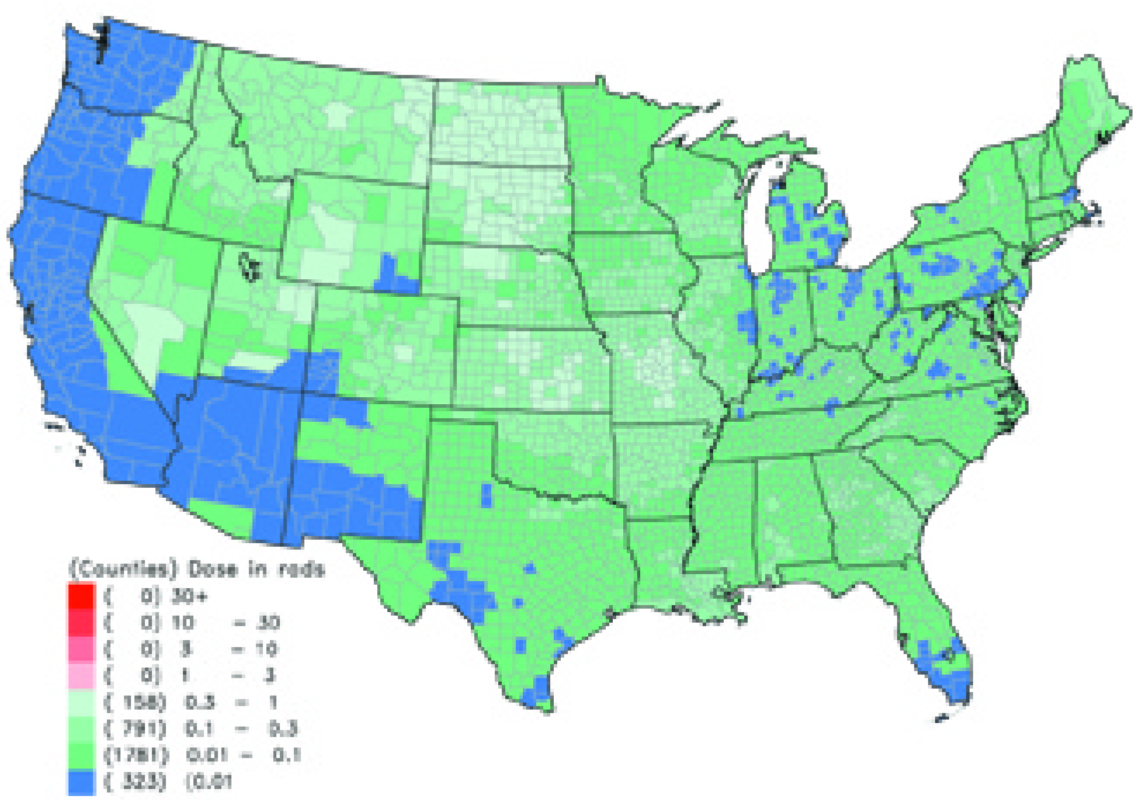


**Figure 8.53.** Estimates of I-131 thyroid doses for persons born on January 1, 1958 (Average diet; average milk consumption)

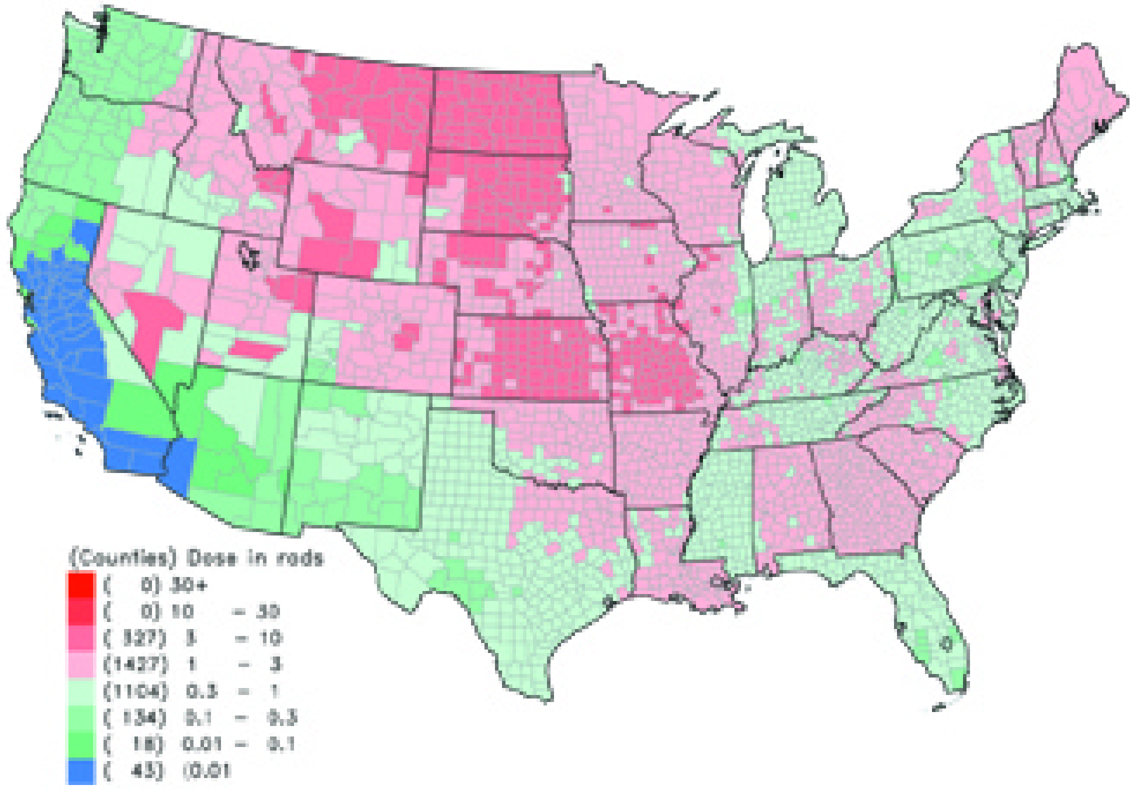



**Figure 8.54.** Estimates of I-131 thyroid doses for persons born on January 1, 1958 (Average diet; high milk consumption)

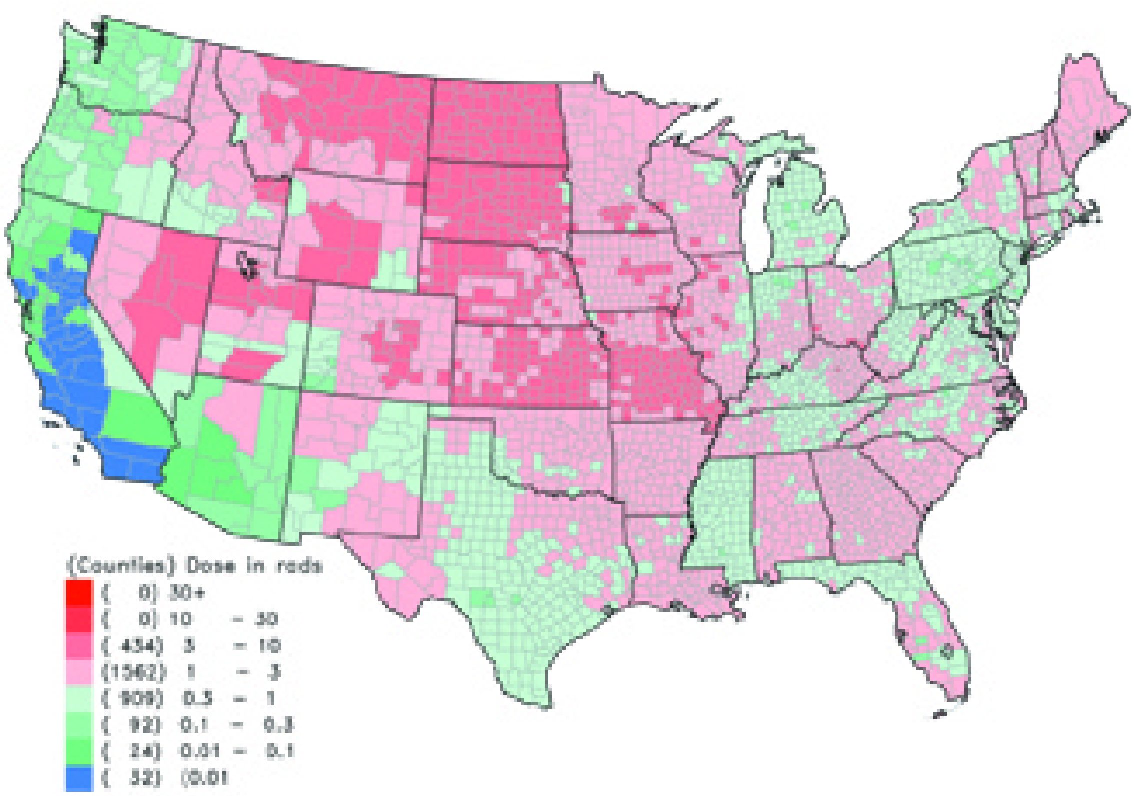


**Figure 8.55.** Estimates of I-131 thyroid doses for persons born on January 1, 1958 (Average diet; milk from "backyard cow")

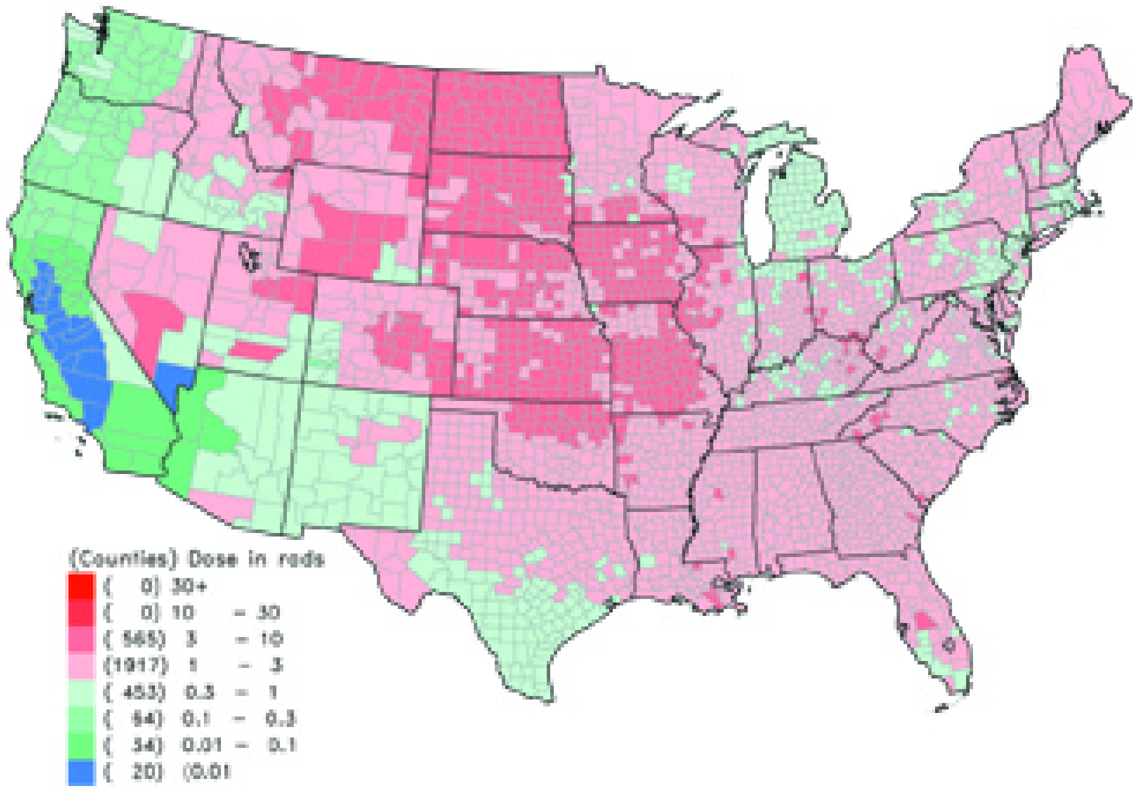



**Figure 8.56.** Estimates of I-131 thyroid doses for persons born on January 1, 1958 (Average diet; no milk consumption)

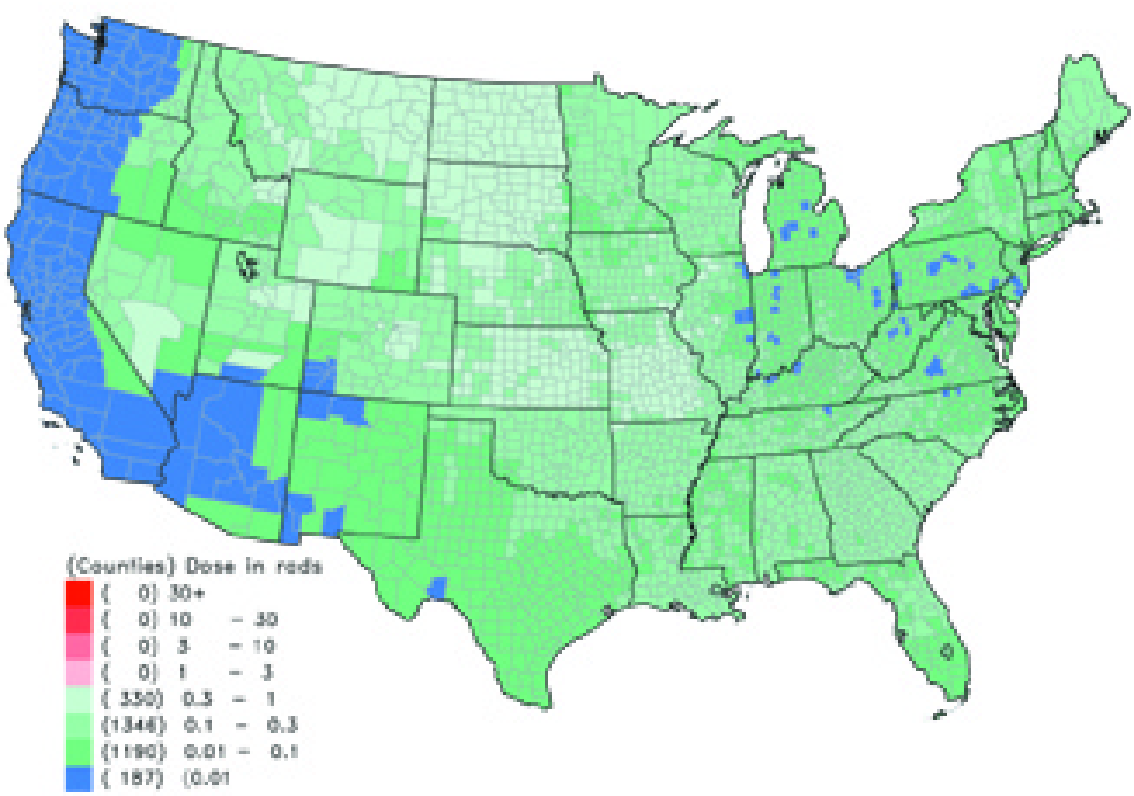


**Figure 8.57.** Estimates of I-131 thyroid doses for persons born on January 1, 1959 (Average diet; average milk consumption)

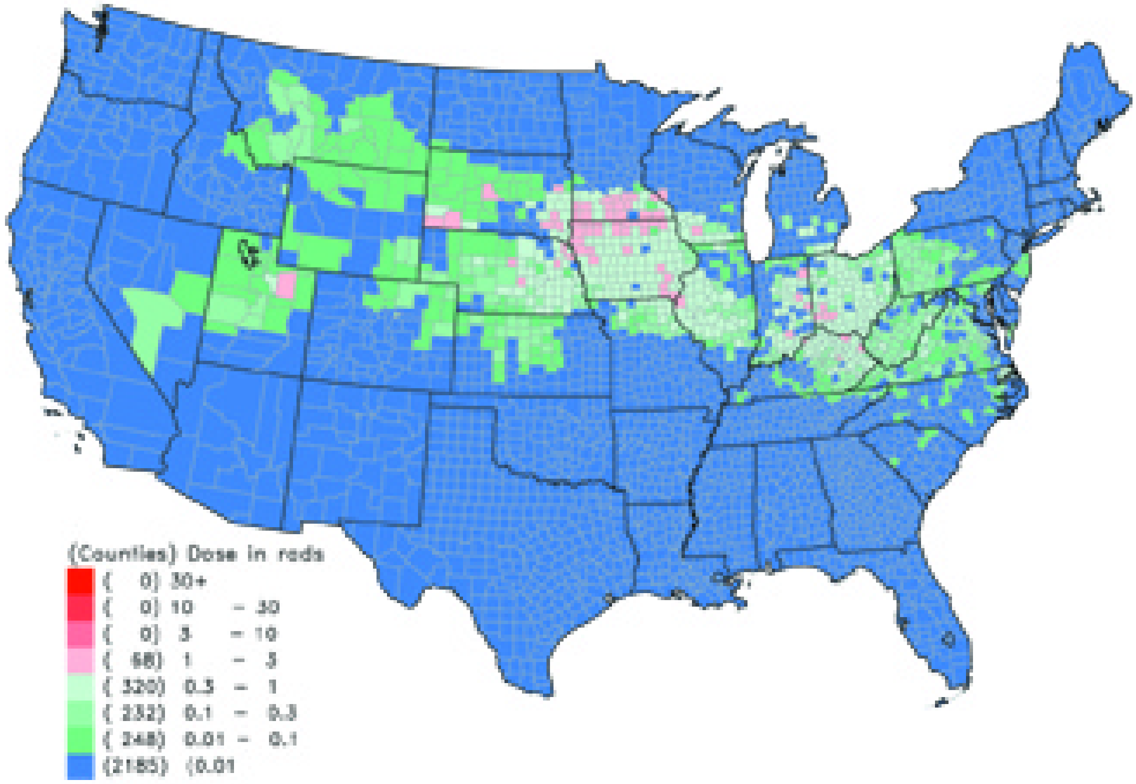



**Figure 8.58.** Estimates of I-131 thyroid doses for persons born on January 1, 1959 (Average diet; high milk consumption)

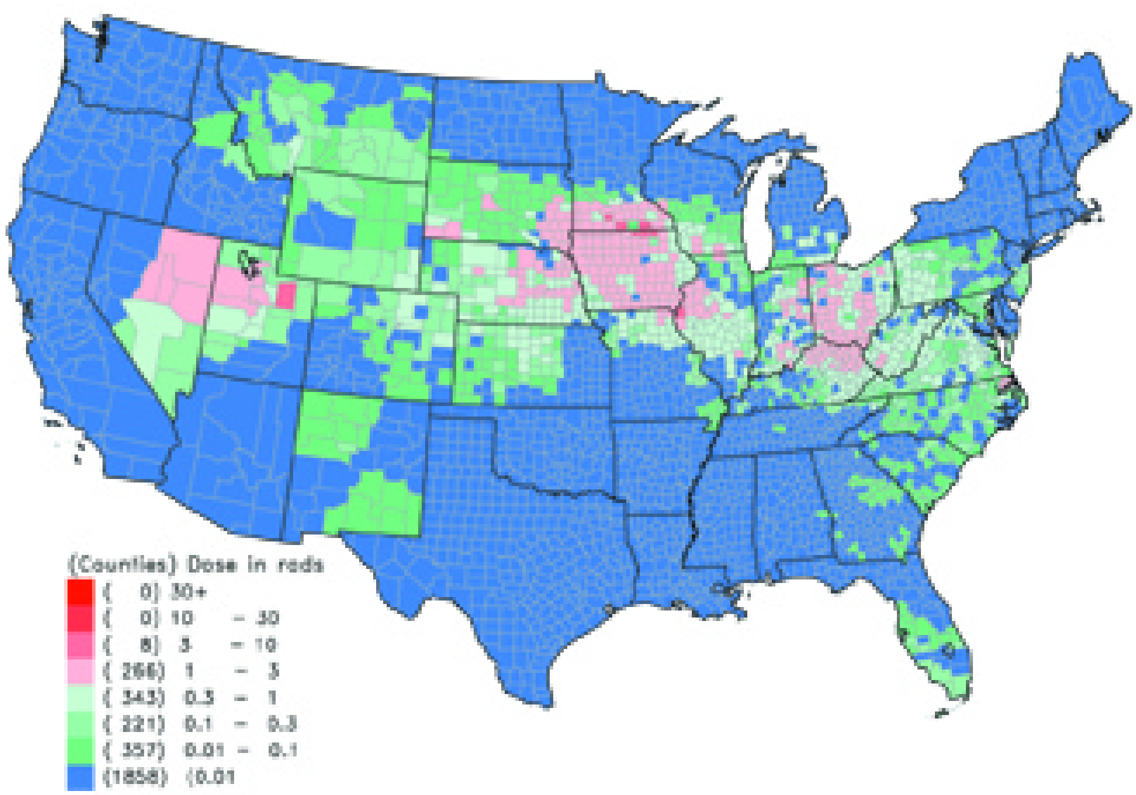


**Figure 8.59.** Estimates of I-131 thyroid doses for persons born on January 1, 1959 (Average diet; milk from "backyard cow")

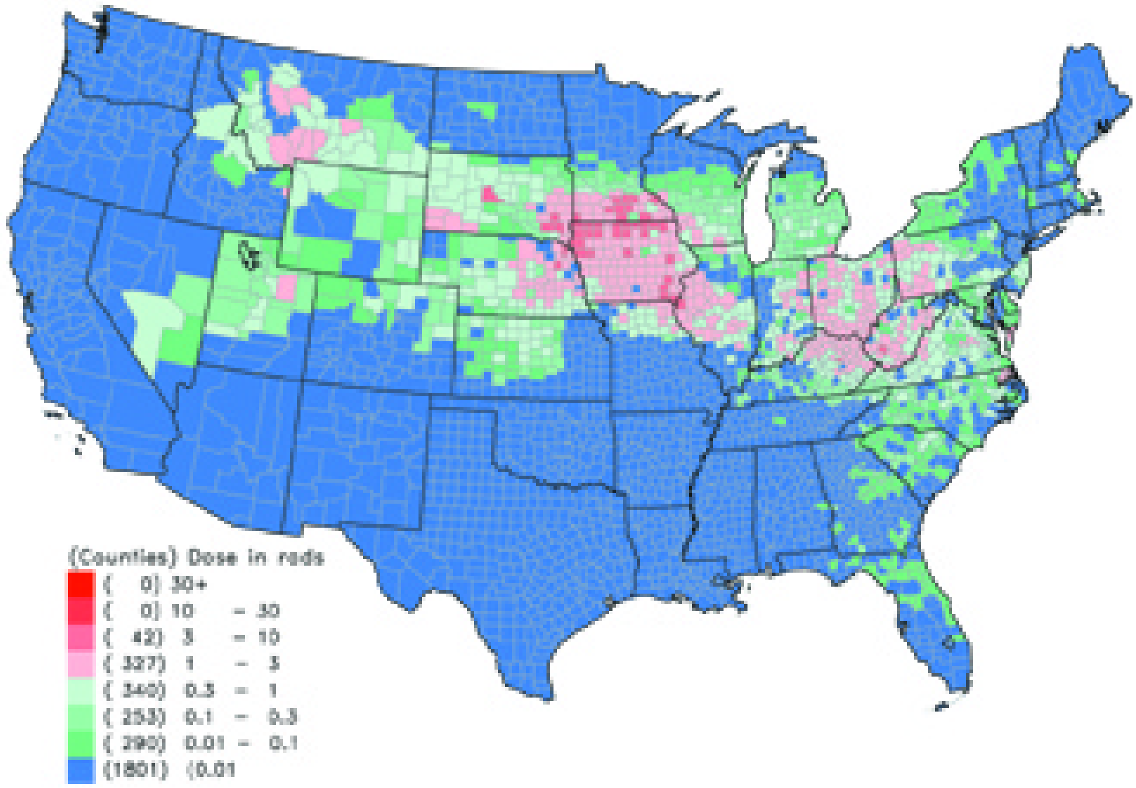



**Figure 8.60.** Estimates of I-131 thyroid doses for persons born on January 1, 1959 (Average diet; no milk consumption)

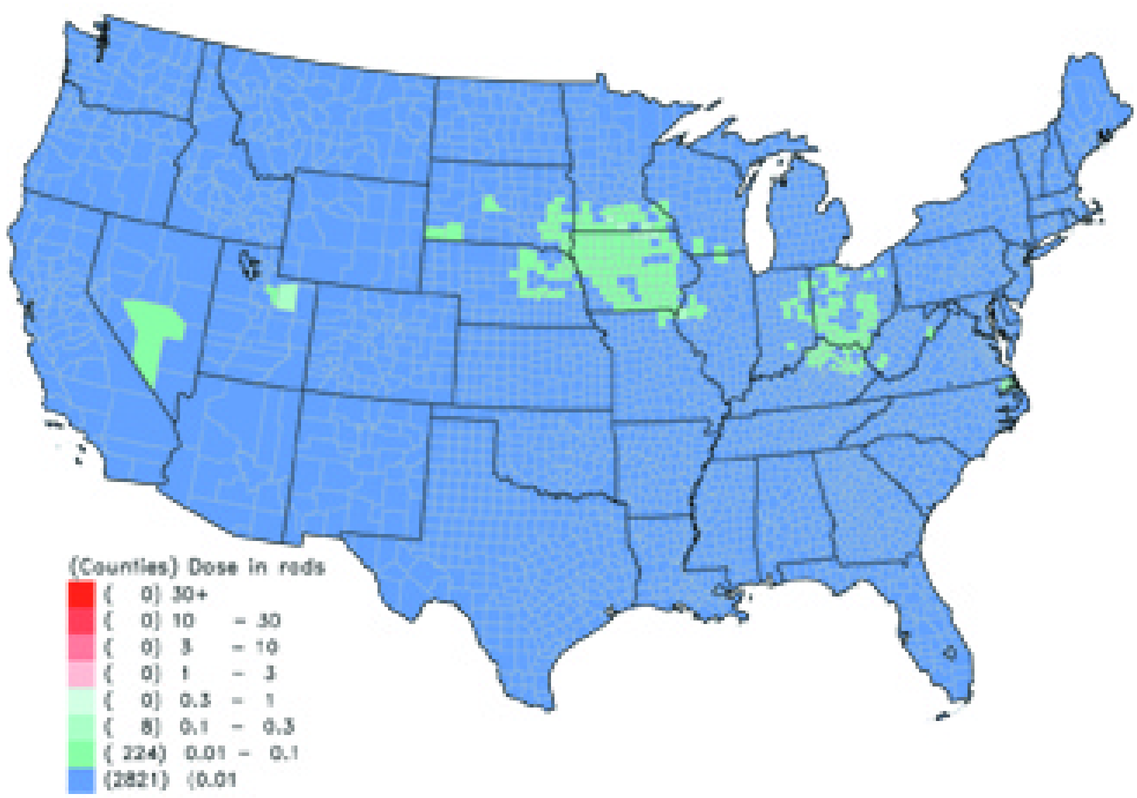


**Figure 8.61.** Estimates of I-131 thyroid doses for persons born on January 1, 1960 (Average diet; average milk consumption)

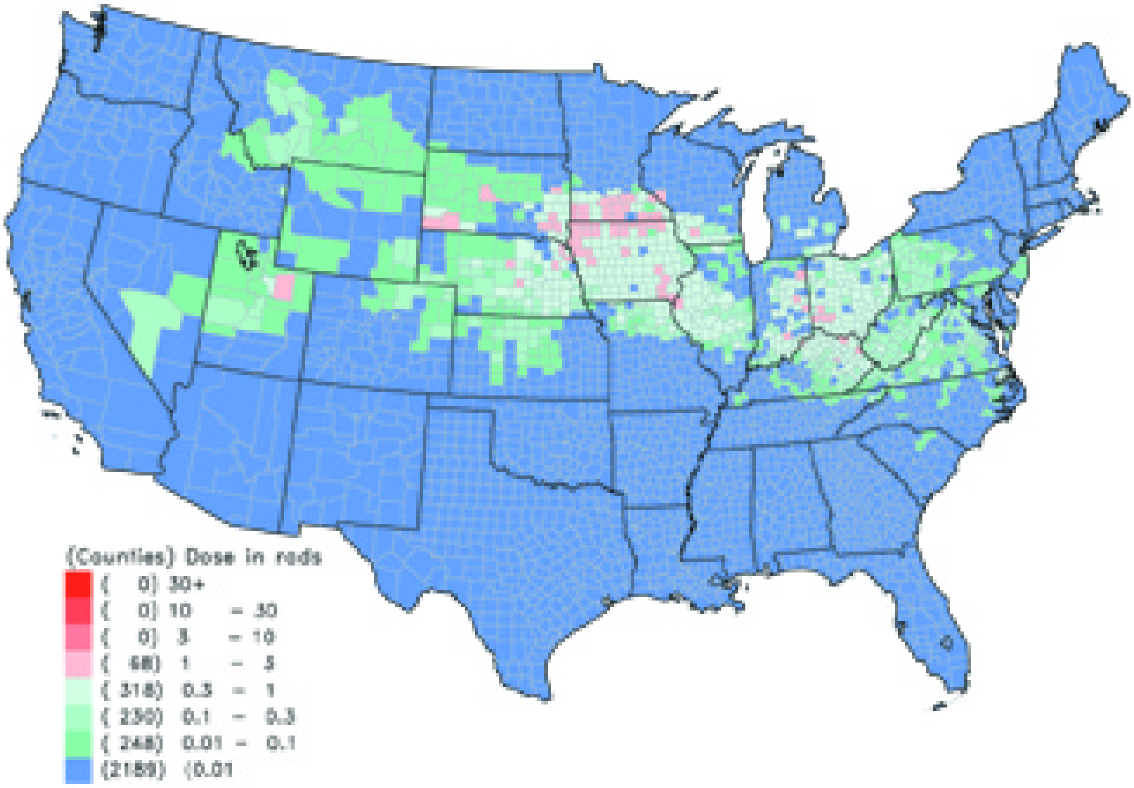



**Figure 8.62.** Estimates of I-131 thyroid doses for persons born on January 1, 1960 (Average diet; high milk consumption)

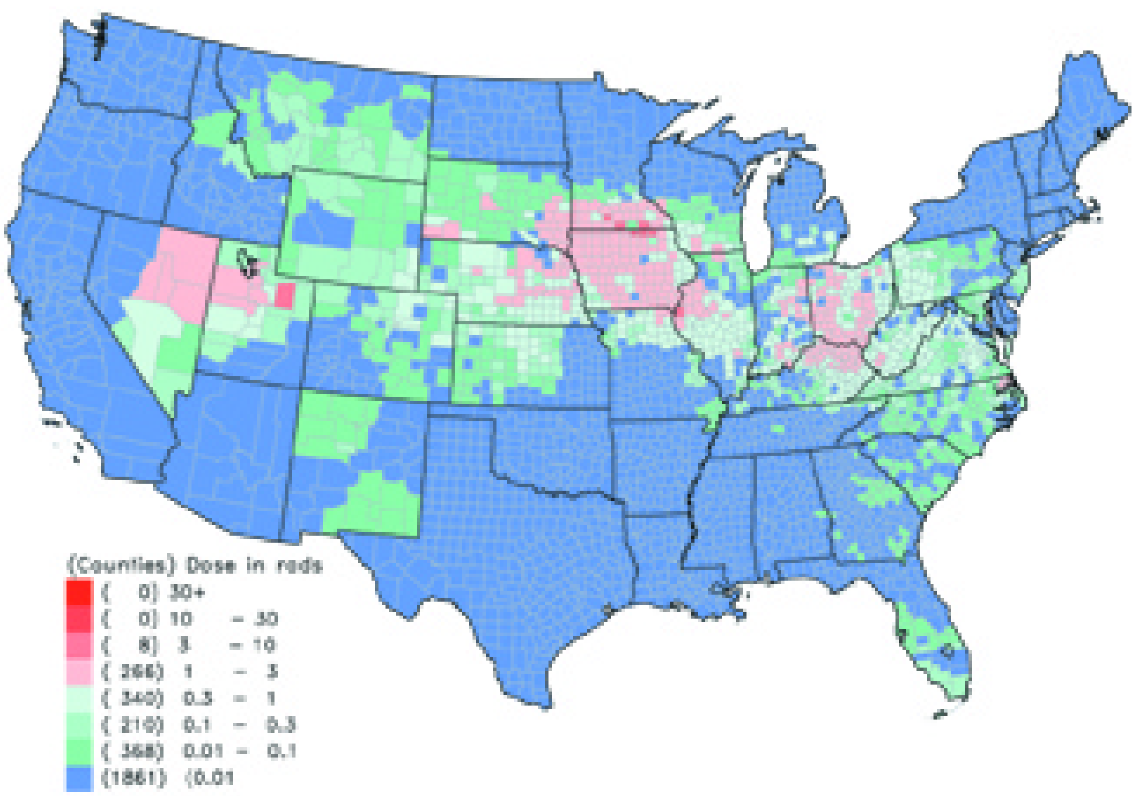


**Figure 8.63.** Estimates of I-131 thyroid doses for persons born on January 1, 1960 (Average diet; milk from "backyard cow")

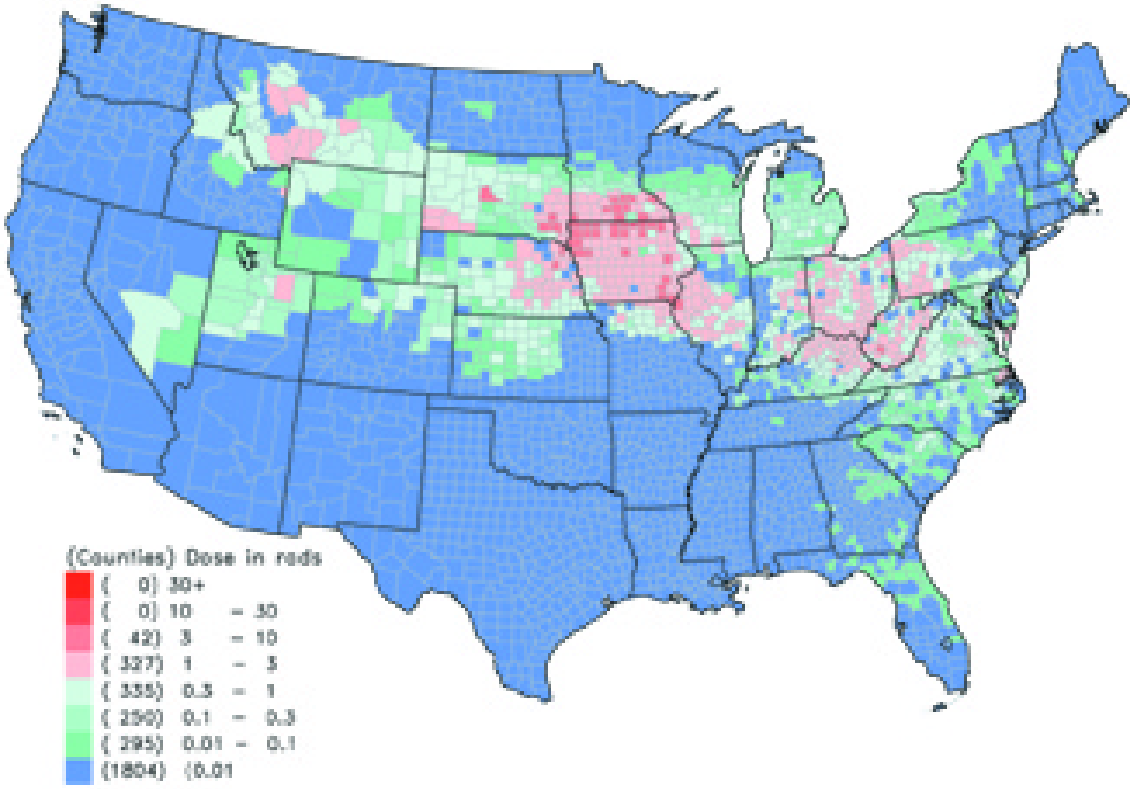



**Figure 8.64.** Estimates of I-131 thyroid doses for persons born on January 1, 1960 (Average diet; no milk consumption)

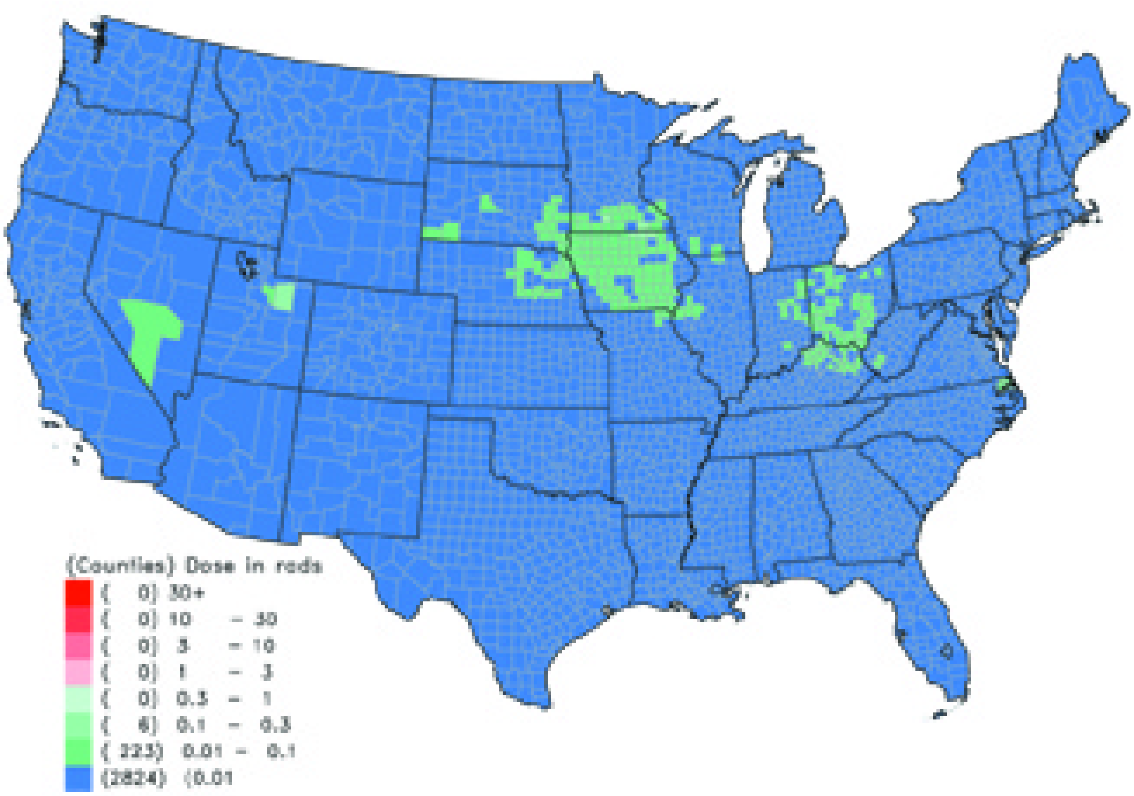


**Figure 8.65.** Estimates of I-131 thyroid doses for persons born on January 1, 1962  (Average diet; average milk consumption)

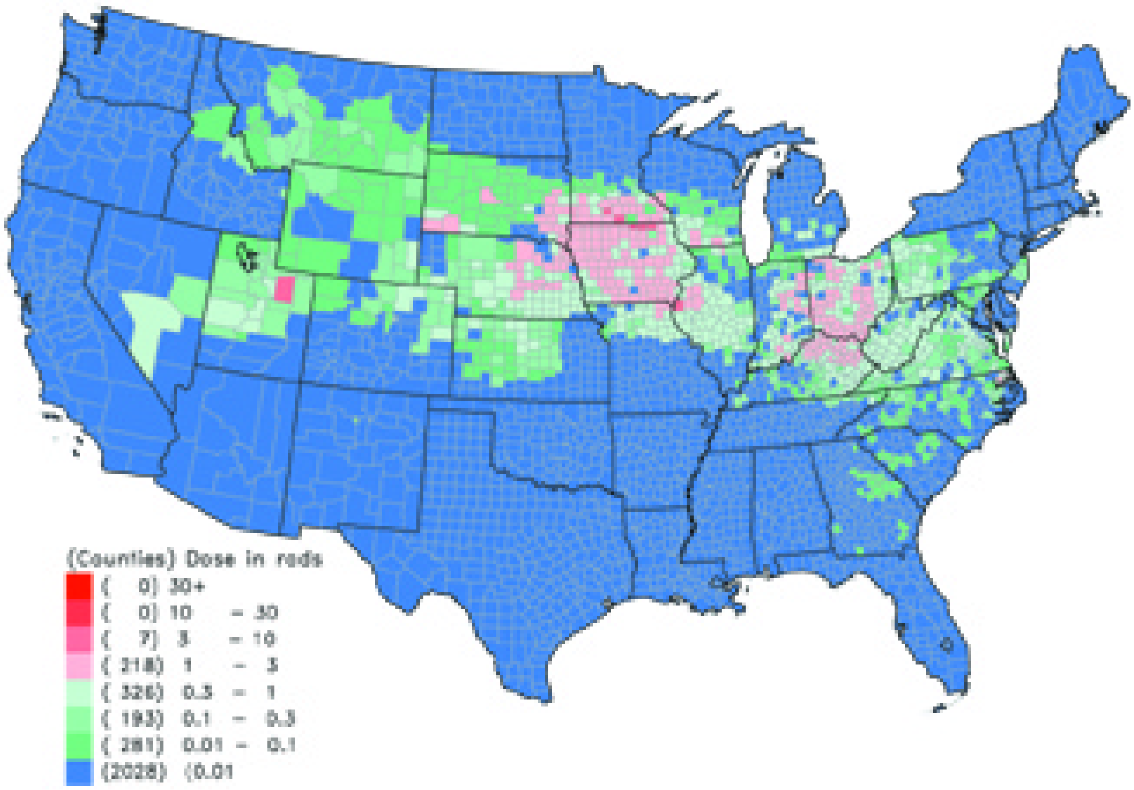



**Figure 8.66.** Estimates of I-131 thyroid doses for persons born on January 1, 1962  (Average diet; high milk consumption)

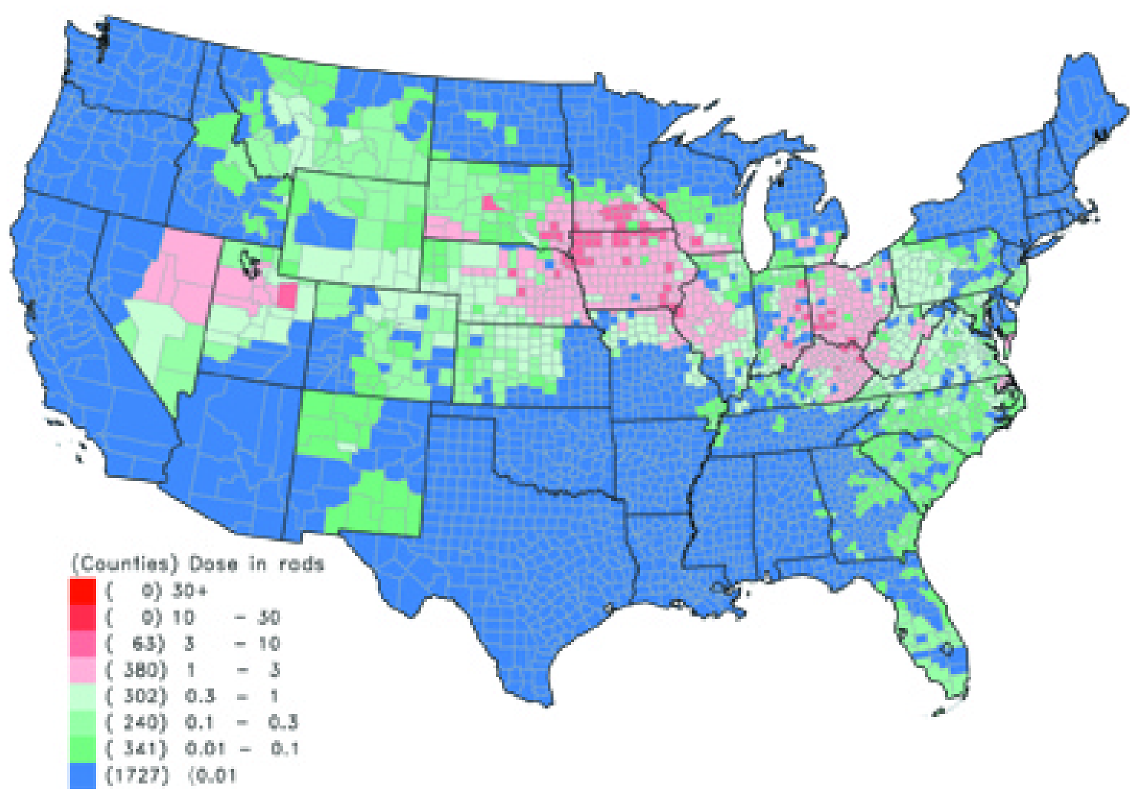


**Figure 8.67.** Estimates of I-131 thyroid doses for persons born on January 1, 1962 (Average diet; milk from "backyard cow")

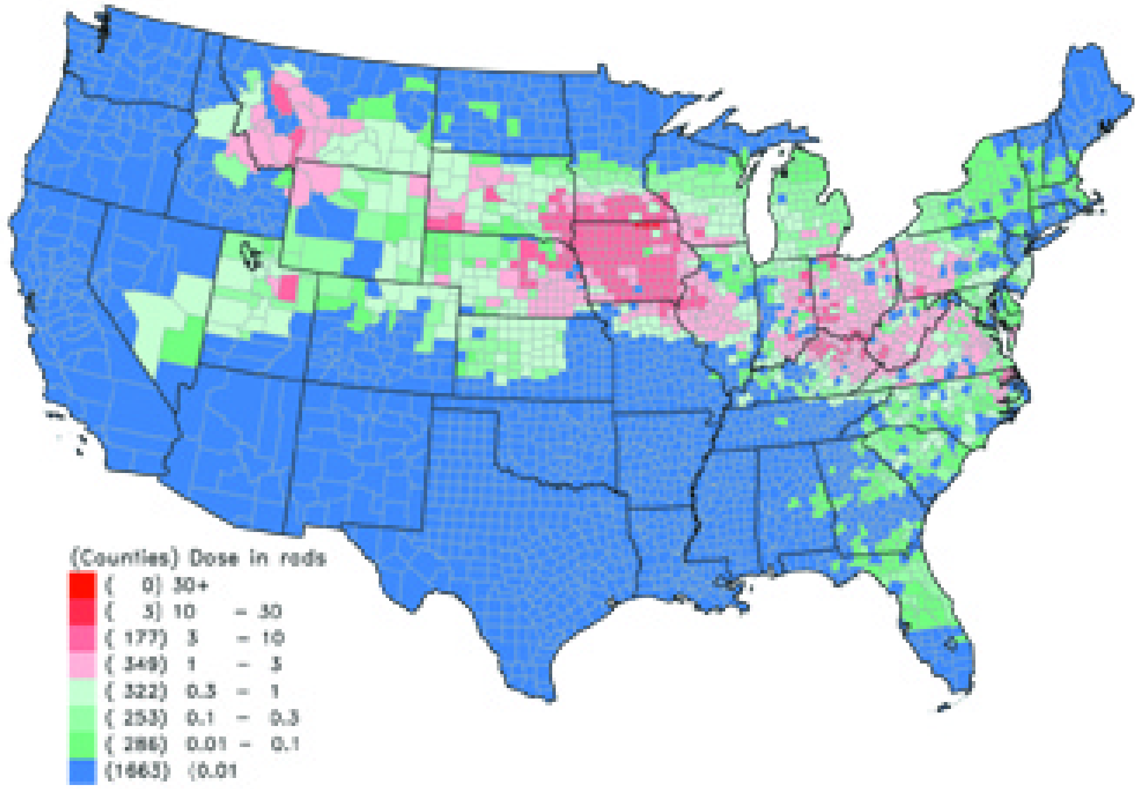
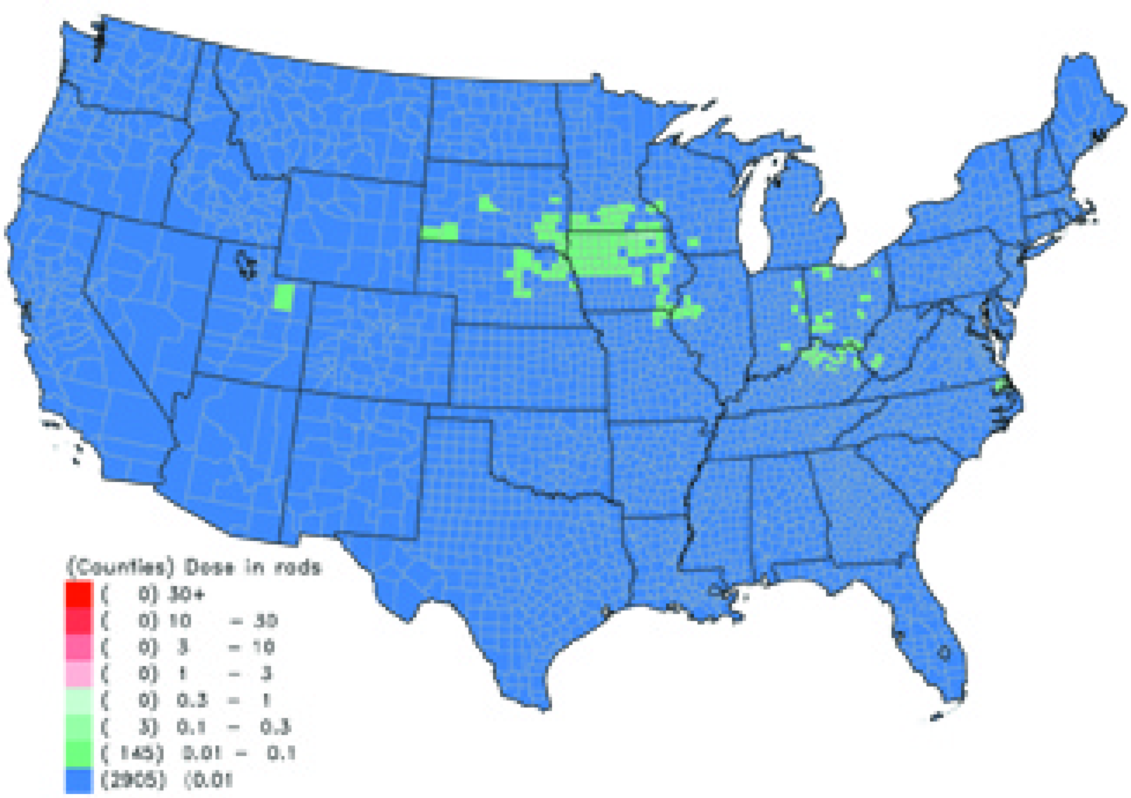



**Figure 8.68.** Estimates of I-131 thyroid doses for persons born on January 1, 1962 (Average diet; no milk consumption)



*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.

**Table 8.2.** Estimated collective thyroid doses to the U.S. population for each test series

| Series | Dates | Collective thyroid dose (Person rad) | Percent of total |
|---|---|---|---|
| Ranger | Jan.-Feb. 1951 | $1.6 \times 10^5$ | 0.04 |
| Buster-Jangle | Oct.-Nov. 1951 | $7.4 \times 10^6$ | 2 |
| Tumbler-Snapper | April-June 1952 | $1.1 \times 10^8$ | 29 |
| Upshot-Knothole | March-June 1953 | $8.9 \times 10^7$ | 24 |
| Teapot | Feb.-May 1955 | $4.1 \times 10^7$ | 11 |
| Plumbbob | May-Oct. 1957 | $1.2 \times 10^8$ | 32 |
| Hardtack II | Sept.-Oct. 1958 | $1.6 \times 10^2$ | $< 0.0$ |
| "Underground era" | 1961-1970 | $9.1 \times 10^6$ | 2 |
| Total | | $3.8 \times 10^8$ | 100 |

**Figure 8.69.** Estimates of I-131 thyroid doses resulting from the test series Ranger (January - February 1951)

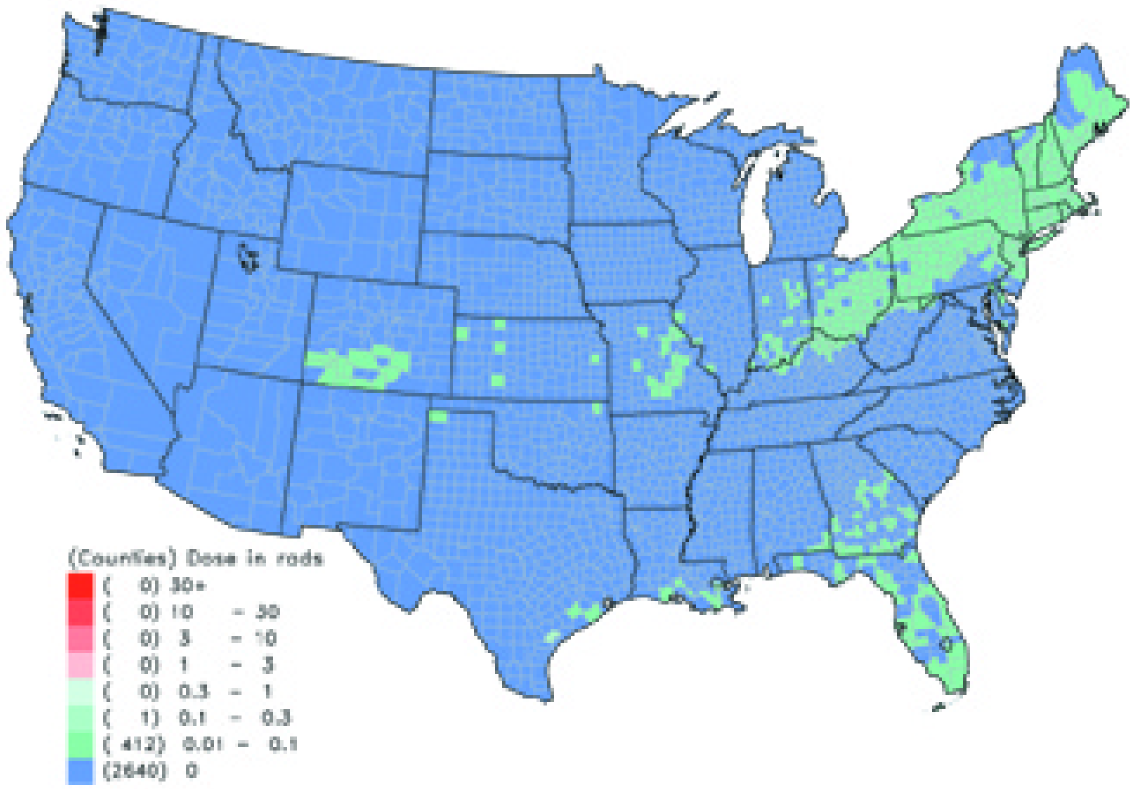



**Figure 8.70.** Estimates of I-131 thyroid doses resulting from the test series Buster-Jangle (October - November 1951)

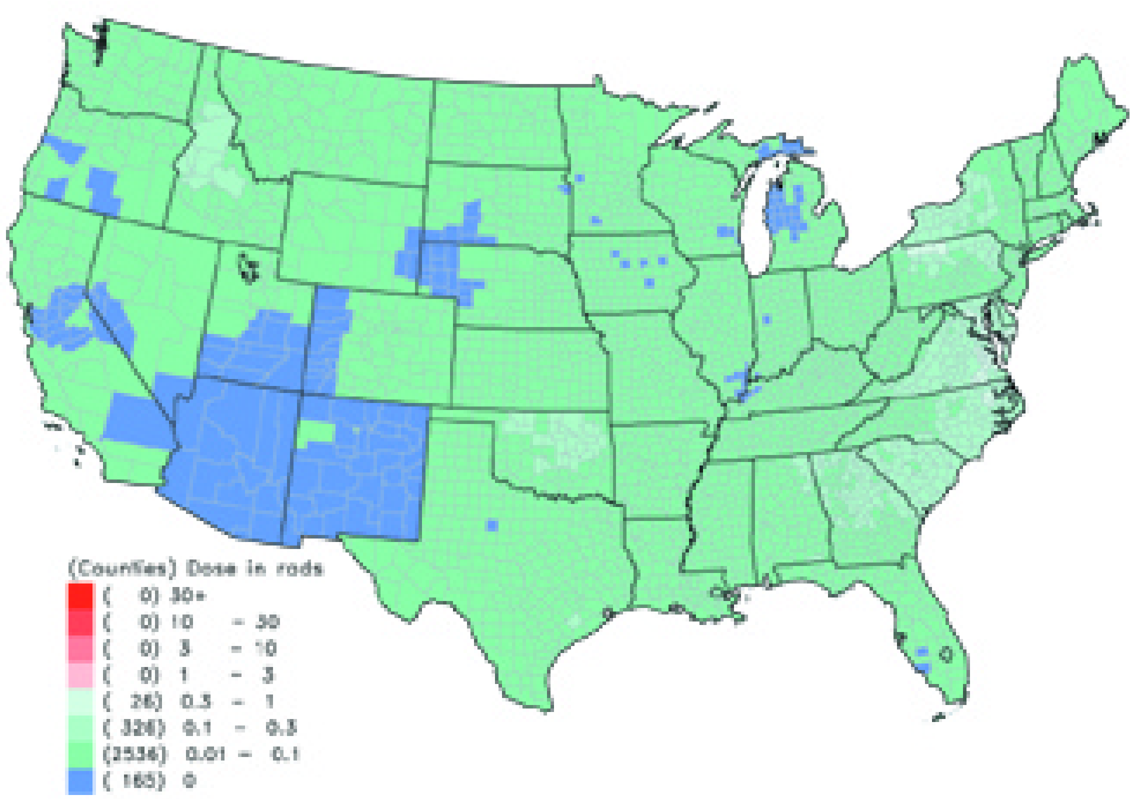


**Figure 8.71.** Estimates of I-131 thyroid doses resulting from the test series Tumbler - Snapper (April - June 1952)

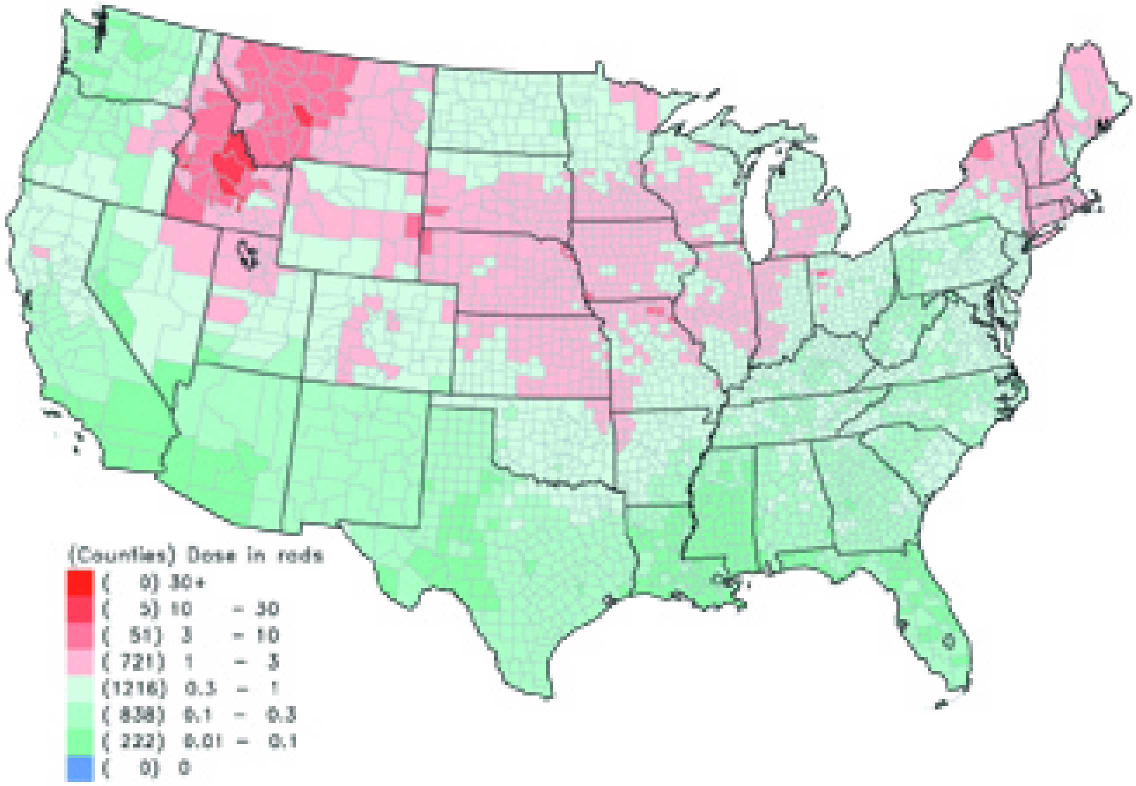



**Figure 8.72.** Estimates of I-131 thyroid doses resulting from the test series Upshot - Knothole (March - June 1953)

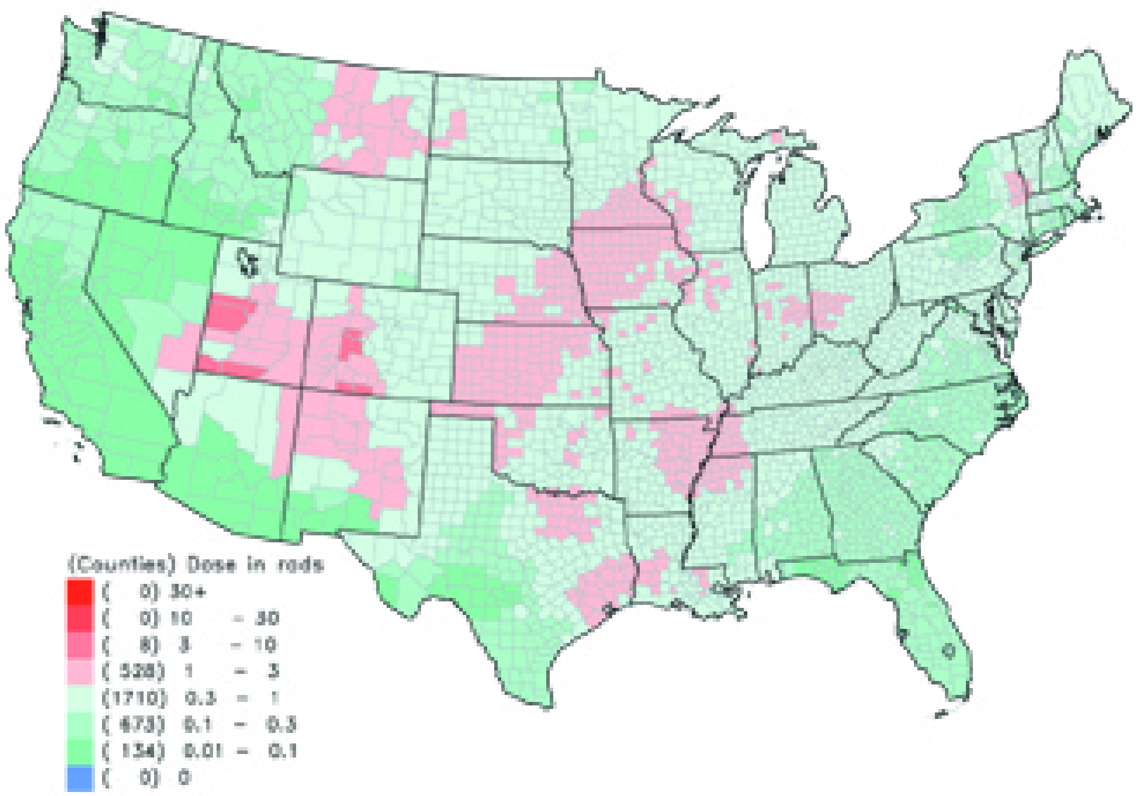


**Figure 8.73.** Estimates of I-131 thyroid doses resulting from the test series Teapot (February - May 1955)

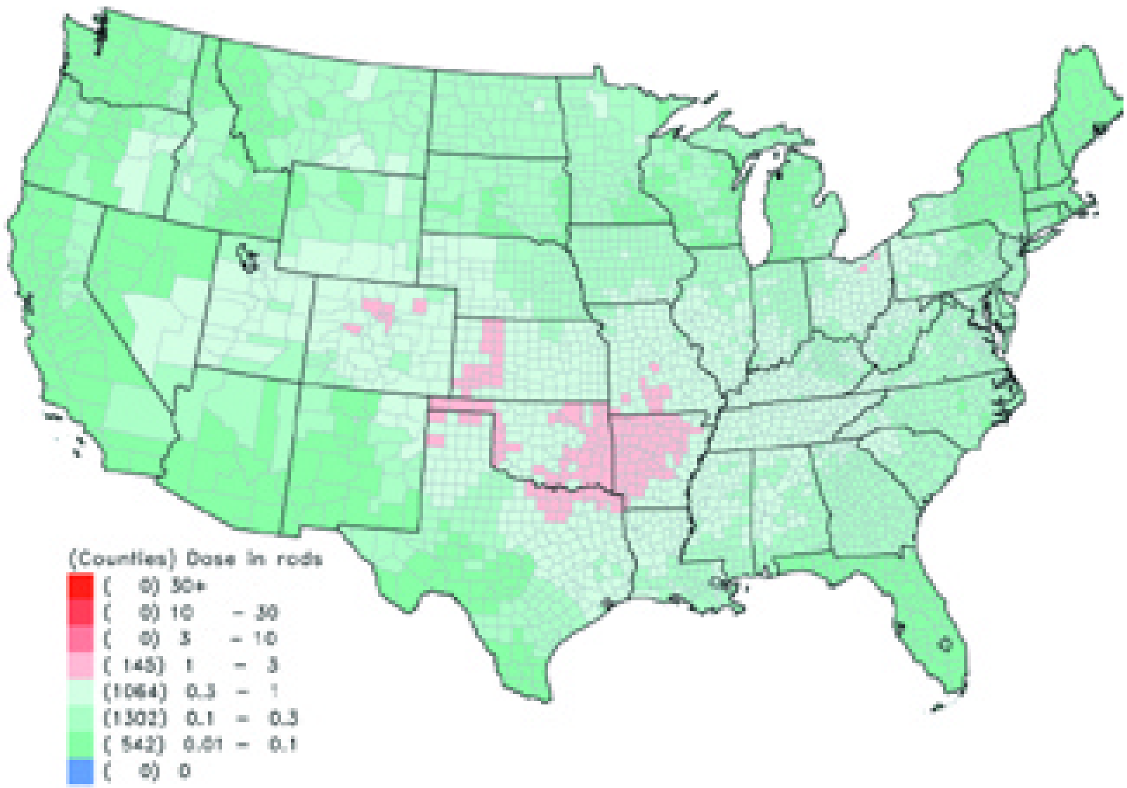



**Figure 8.74.** Estimates of I-131 thyroid doses resulting from the test series Plumbbob (May - October 1957)

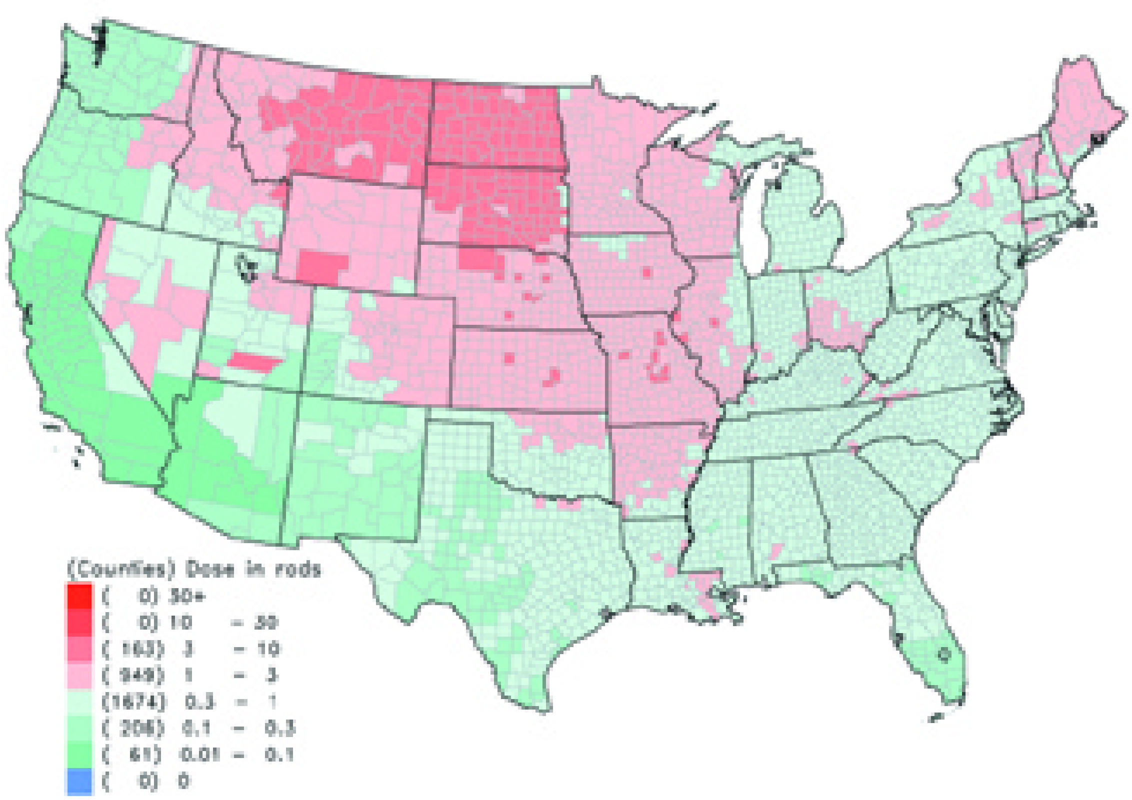


**Figure 8.75.** Estimates of I-131 thyroid doses resulting from the test series Hardtack - Phase II (September - October 1958)

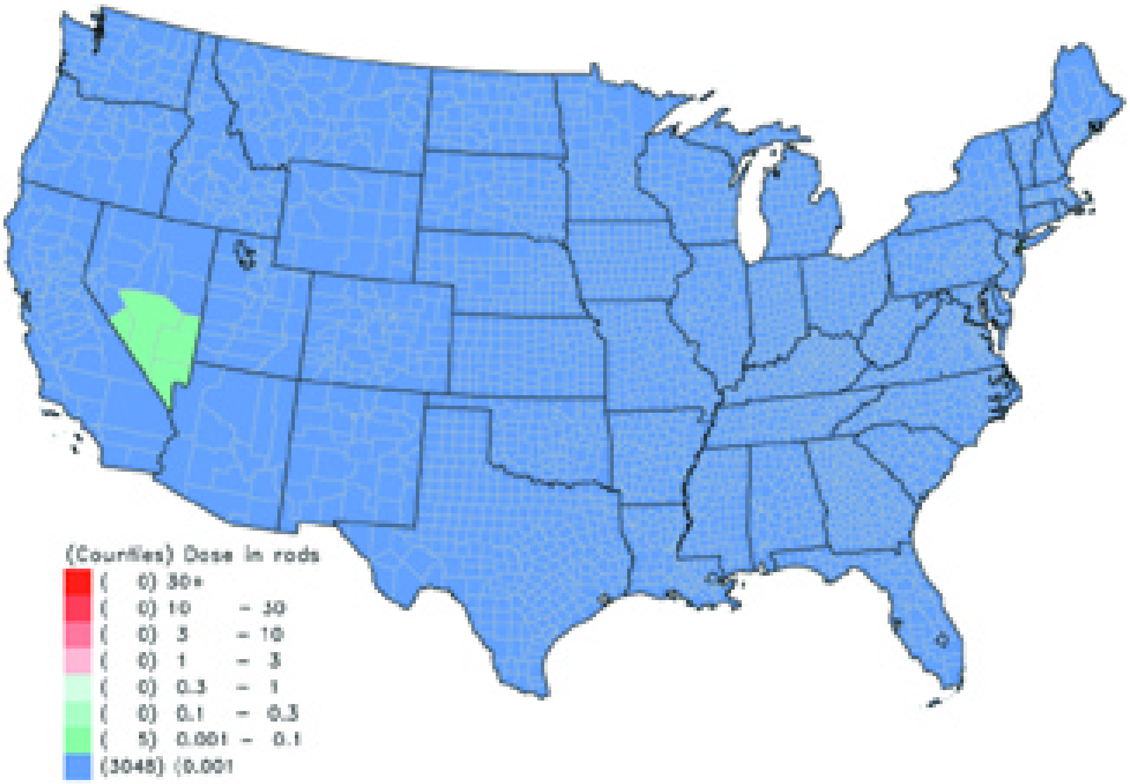
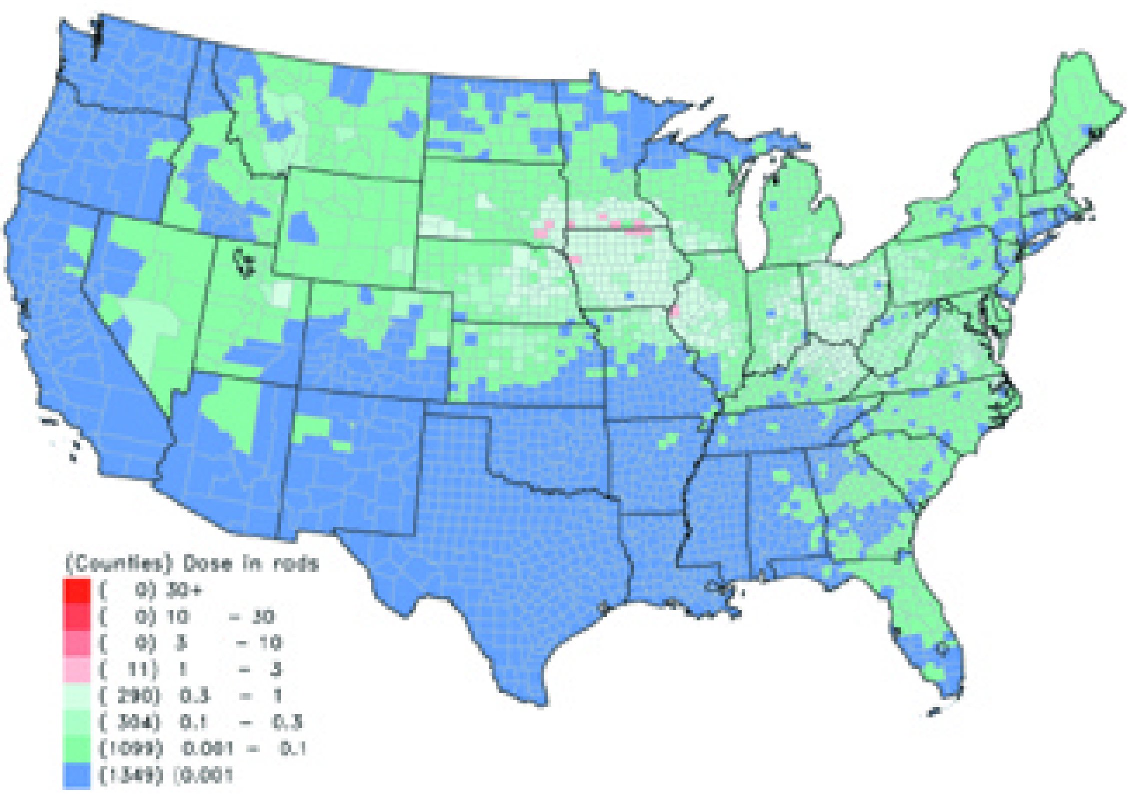



**Figure 8.76.** Estimates of I-131 thyroid doses resulting from the test series Underground Era (1961 - 1970)



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.

The next set of maps *Figures 8.5* through *8.8* is for persons who were 16 years old when testing began at the NTS in 1951 and who were teenagers or young adults during the period of highest fallout. *Figures 8.9* through *8.16* provide dose estimates for those persons who were ages 11 and 6, respectively, at the start of the testing program in 1951. Persons born in 1950-1957 or later years were young children throughout the highest fallout years (1952-1957) and received generally higher doses. Those born in 1958 and in later years were, generally speaking, exposed to lower amounts of $^{131}$I and received lower doses than those born earlier in the decade. Of course, this generality must be tempered by consideration of the county of residence because the general pattern does not apply universally.

## 8.2. ESTIMATED COLLECTIVE THYROID DOSES

The estimated collective thyroid dose received by the population of the entire U.S., CD(US), from $^{131}$I deposition after a given test can be calculated as the sum of average doses, D, over the population, POP, in each age and sex group, k, and each county, i:

$$CD\,(US) = \sum_{i,k} D\,(i,k) \times POP\,(i,k) \qquad (8.3)$$

As an example collective dose for Simon for all exposure routes is estimated to be about 2 x $10^7$ person rad.

The total collective dose to the population of the United States from all atmospheric bomb tests detonated at the Nevada Test Site is estimated to be about 4 x $10^8$ person rad (*Table 8.2*). The estimated per capita thyroid dose is about 2 rad. The greatest contribution to the total collective thyroid dose is estimated to have been due to the tests of the Plumbbob series (32%), followed by the tests of the Tumbler-Snapper series (29%) and the tests of the Upshot-Knothole series (23%). The collective doses for each test, total and by county, are tabulated in the Sub-annex for that test.

The per capita doses estimated to have been received by the populations of each county as a result of the test series Ranger, Buster-Jangle, Tumbler-Snapper, Upshot-Knothole, Teapot, and Plumbbob are shown in *Figures 8.69* through *8.76*. The data are presented in tabular form in the Sub-annexes, along with the collective doses. Per capita doses for the population of each county of the contiguous U.S. are presented, for each test, in the form of a map in the Annex for that test.

## 8.3. OTHER SOURCES OF THYROID DOSES

The internal thyroid doses from $^{131}$I in NTS fallout that are calculated in this report are the main component of the total thyroid doses that the American people received from fallout from testing at the NTS. Other exposure routes such as external irradiation contributed somewhat to the thyroid dose from $^{131}$I resulting from NTS fallout. Using information from UNSCEAR (1977) the per capita thyroid dose is estimated to be about 0.05 rad for the population of the U.S.

Other radioactive isotopes of iodine (e.g., $^{133}$I and $^{132}$I) also were present in NTS fallout and irradiated the thyroid, but their physical half-lives are such that the resulting doses were much lower, by a factor of 10 or more, than those delivered by $^{131}$I. The per capita thyroid dose due to exposure to these iodine isotopes is estimated, using information from UNSCEAR (1997), to be at most 0.2 rad to the population of the U.S. A large number of radionuclides other than the radioactive isotopes of iodine, such as $^{137}$Cs and $^{90}$Sr, contributed to the thyroid dose from NTS fallout. However, because they do not concentrate in the thyroid, the thyroid doses from these radionuclides is not large. The per capita thyroid dose from these other radionuclides is estimated, using information from UNSCEAR (1977), to be about 0.02 rad to the population of the U.S.

Nuclear weapons tests were also conducted at sites other than NTS. Some were conducted by the United States; other countries also conducted tests that caused fallout in the United States. The per capita thyroid dose from those tests is estimated to be about 1 rad to the population of the U.S. (WHO 1983).

Natural background radiation (external and internal exposure) contributes about 0.1 rad per year to the thyroid dose (NCRP 1987), or about 0.8 rad from 1951 to 1958.

Some populations may have been exposed to multiple sources of radioiodine. Iodine-131 was used in the 1950s for diagnosis and treatment of thyroid disease, and numerous patients received thyroid doses from these medical procedures. The $^{131}$I fallout doses from the NTS to the most highly exposed groups could have been a non-trivial addition to the medical dose from diagnostic procedures. Therapeutic doses are much higher and the fallout contribution would be a small addition to the thyroid doses of persons who received such $^{131}$I treatments.

Other populations around weapons production facilities were exposed to both fallout $^{131}I$ and facility releases. At Hanford, Washington, the largest releases occurred in 1945 although there were also elevated releases in December 1949 and the summer of 1951 (TSP 1994). Persons exposed as infants to those releases would have still been children (7-12 years of age) during the years of highest NTS fallout. Summary doses for the Hanford releases are given in a report of the Technical Steering Panel (TSP 1994). The capability for individual dose assessment for persons exposed to those releases is being developed. Estimates of thyroid doses to persons exposed to both sources of $^{131}I$ would depend upon the date of birth habits, and residence history of the individual.

Radioiodine releases also occurred at the Oak Ridge Site (Tennessee), and the Savannah River Site (South Carolina). Among these, the releases at Oak Ridge were larger. The estimation of doses received by the local populations from releases at these facilities is currently underway.

## 8.4. SUMMARY

- Estimates of average thyroid doses resulting from the deposition of $^{131}I$ on the ground after an atmospheric bomb test are calculated for the population of each county, subdivided into 14 age and sex categories and according to dietary habits.The population groups in each age and sex group and in each county of the contiguous U.S. for which average thyroid doses are estimated in this report for each nuclear weapons test of interest are:

  (a) those drinking milk with average diets,

  (b) those with a high consumption of fresh cows' milk,

  (c) those drinking milk from backyard cows,

  (d) those drinking no cows' milk, and

  (e) infants drinking mothers' milk.

In addition, average per capita and collective doses estimated to have been received by the entire population of each county of the contiguous U.S. are provided for each test.

- Example results illustrate the fact that, for people with the same average diet, estimated thyroid doses from $^{131}I$ in NTS fallout are more important for people born near the beginning of the tests because estimated average doses to persons who were infants or children at that time are up to about 10 times higher than are the estimated doses to adults.

- Average thyroid doses are also sensitive to the type of diet that is assumed.

- The total collective dose to the population of the United States from all atmospheric bomb tests detonated at the Nevada Test Site is estimated to be about $4 \times 10^8$ person rad. The estimated per capita thyroid dose is about 2 rad. The greatest contribution to the total collective thyroid dose is estimated to have been due to the tests of the Plumbbob series (32%), followed by the tests of the Tumbler-Snapper series (29%) and the tests of the Upshot-Knothole series (23%).

- The estimated thyroid doses from $^{131}I$ reported here are the most important component of the thyroid doses due to fallout from the Nevada bomb tests. Other radionuclides in the fallout may also have contributed about 10% to the per capita dose.

- Some groups of people received thyroid doses from other sources (in addition to the 0.1 rad $y^{-1}$ from natural background radiation). This category includes persons who lived near nuclear facilities that released large amounts of $^{131}I$ (e.g., the Hanford plant) and persons who were given $^{131}I$ in the course of medical diagnosis or treatment of disease.

## REFERENCES

NCRP. National Council on Radiation Protection and Measurements. Ionizing radiation exposure of the population of the United States. NCRP Report No. 93. Bethesda, MD; 1987.

TSP. Technical Steering Panel of the Hanford Environmental Dose Reconstruction Project. Summary: radiation dose estimates from Hanford radioactive material releases to the air and the Columbia River. Olympia, WA; 1994.

UNSCEAR. United Nations Scientific Committee on the Effects of Atomic Radiation. Sources and effects of ionizing radiation. New York; 1977.

WHO. World Health Organization. Environmental Health Criteria 25. Selected radionuclides: Tritium, Carbon-14, Krypton-85, Strontium-90, Iodine, Caesium-137, Radon, Plutonium. Geneva; 1983.