THE EXTENT OF CONTAMINATION, DETECTION, AND HEALTH SIGNIFICANCE OF HIGH ACCUMULATIONS OF RADIOACTIVITY IN SOUTHEASTERN GAME POPULATIONS[1]

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ABSTRACT

Specimens of various game species from Virginia, North Carolina, South Carolina, Georgia, Alabama, and Florida were analyzed for all gamma ray emitting radioisotopes by gamma ray spectrometry methods in a whole body counter. It was possible to determine radionuclide concentrations in the field with relatively simple gamma ray detecting equipment. The most important isotope was Cesium-137. Specimens from the Mountain, Piedmont, and Upper Coastal Plain regions were generally low; those from the Lower Coastal Plain region had significantly higher concentrations. Levels of contamination ranged from 250 picocuries per Kilogram in the Mountain region to 152,940 picocuries per kilogram in the Lower Coastal Plain region. Domestic commodities were much lower in radiation burden and were regularly analyzed for radionuclides as a comparison to levels found in game species.

At the present time it is not known what long term effects high radionuclide levels may have on the game species involved. An individual could consume twenty-eight pounds per year of a game animal containing 100,000 picocuries per kilogram of Cesium-137 without exceeding the limits recommended by the Federal Radiation Council.

Due to human dietary habits the present radionuclide levels in game species are not considered a serious public health hazard, but monitoring of this situation should be continued.

INTRODUCTION

Concentrations of radioisotopes in a food chain leading to man become of significance to public health when radiation from ingested nuclides approach the maximum permissible limits. This has been dramatically illustrated in the arctic food chain: lichen-caribou-man and lichen-reindeer-man. Witkamp (1966) points out that contrary to widespread belief higher than average levels of Cesium-137 and Strontium-90 accumulated by Alaskan Eskimos and Finnish Laplanders are not the result of higher fallout levels, but result from the closed economy and unique interplay of ecological conditions. Hanson (1966) states that arctic regions (60-70 degrees north latitude) receive one-half to one-fourth the fallout deposition of the more temperate regions (40-50 degrees north latitude).

Several factors are responsible for the unusually high concentrations of radionuclides in arctic ecosystems. The combination of the specific configuration of the vegetation on the wet, acidic, and poor substrata, together with the low temperatures, is primarily responsible for the high concentrations of long lived radionuclides in the tundra vegetation (Witkamp 1966).

Whicker (1965), in a study of mule deer *(Odocoileus hemionus)* in Colorado, and Pullen, Plummer, and Provost (1967), in a study of the whitetailed deer *(Odocoileus virginianus)* in the Piedmont of Georgia, found Cesium-137 whole body burdens to

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be much lower than those of caribou *(Rangifer caribou)* and reindeer *(Rangifer taradus)* in circumpolar regions. However, Jenkins, Monroe, and Golley (1967) found ^{137}Cs whole body burdens of bobcats *(Lynx rufus)* in the Coastal Plain of Georgia and South Carolina approaching those of caribou and reindeer in circumpolar regions.

The present report concerns a continuation of these recent investigations at the University of Georgia which indicate that a concentration phenomenon similar to that found in arctic regions does occur in some habitats in the Southeastern United States.

MATERIALS AND METHODS

Specimens were analyzed for all gamma emitting radioisotopes in a whole body counter by gamma spectrometry methods. The whole body counter was constructed from a low level background steel safe shielded by 6,000 pounds of lead and is large enough to accept animals up to seventy-five pounds in weight. Twenty gram warblers can also be counted in a smaller unit. The gamma rays are detected with ε 3 x 3 inch sodium iodide crystal and sorted by energy level into the 100 channels of a pulse height analyzer. Output was coupled into an automatic printout. Phantoms resembling cotton rats, rabbits, bobcats, and foxes were constructed of sugar with known amounts of ^{137}Cs and potassium. In preparing the phantoms the known amounts of liquid Cesium-137 in the form of cesium chloride were calibrated against Amersham standards using 100 minute counts. The results obtained on the phantoms were then compared with the biological specimens. The usual counts on biological materials in the whole body counters are 40 minutes in length.

A portable detection unit was constructed for use in analyzing domestic and "wild foods" stored in freezers throughout the state. The unit consisted of a 3 x 3 inch sodium iodide (thallium) crystal connected to a single channel pulse height analyzer. The crystal was shielded by a three hundred pound lead vault which could be broken into six components. The largest component weighted seventy-five pounds. A 100 volt outlet was the only necessity for operation.

A small unit consisting of a six pound ratemeter (Victoreen Thyac) coupled to a 1¼ x 1½ inch sodium iodide crystal was used without lead shielding to determine approximate Cesium-137 levels of animals in the field and was particularly valuable for checking deer specimens. This unit is only slightly more sensitive than the usual radiation counter used for monitoring laboratories and for civil defense.

A wide variety of animals, plants, and animal products have been analyzed in our laboratory in order to establish levels of contamination and in standardizing methodology with our equipment. Our deer specimens have been checked against the results of two other laboratories in order to confirm the most unusual results—these were checked by the Savannah River Laboratory of the U. S. Atomic Energy Commission at Aiken, South Carolina and the Southeastern Radiological Health Laboratory, Public Health Service, Montgomery, Alabama.

Well over 2,000 mammals and around 1,000 birds have been counted as well as various lichens, mosses, grasses, beef, cheese, milk, and domestic animals. We have done some preliminary work with human radiation levels.

Bobcats, gray fox *(Urocyon cinereoargenteus),* cottontail rabbit *(Sylvilagus floridanus),* gray squirrel *(Sciurus carolinensis),* oppossum *(Didelphis virginianus),* and raccoon *(Procyon lotor)* were obtained during the course of related studies in South Carolina, Georgia, and Florida. These specimens were frozen in a position similar to the standard phantoms used.

Most of the whitetailed deer samples were obtained seasonally through the deer parasite study of the Southeastern Cooperative Wildlife Disease Study from each of the following states: Virginia, North Carolina, South Carolina, Georgia, Alabama, and Florida. In December 1967 seven deer samples were obtained through the cooperation of the Georgia Game and Fish Commission at their Waycross state Forest managed hunt. A sample of two to six pounds of hip muscle was taken from each deer and frozen until radio-analysis.

RESULTS

Whitetailed deer contained the highest ^{137}Cs levels of all species analyzed. Values ranged from as low as 250 pCi/Kg (picocuries per Kilogram) to *152,920*pCi/Kg of Cesium-137; by contrast all specimens of beef were less than 500 pCi/Kg. This means that the highest deer had over *300 times more* radiation body burden than domestic livestock.

The seasonal concentrations of ^{137}Cs for whitetailed deer are shown in Table 1. In general, the highest concentrations tend to occur in the late winter–early spring period and the lowest in the late spring-summer period. Seasonal highs in whitetailed deer from the mountain region occurred during the July–August period; whereas, the high concentrations of the Piedmont, Upper Coastal Plain, and Lower Coastal Plain regions occurred in the October 1967 to February 1968 period.

TABLE 1

Mean Cesium–137 concentration in picocuries per kilogram for 165 whitetailed deer collected in the Southeast, April 1967 to May 1968.

Location	*Collected*	*No.*	*Range*	*S.E.*	*Mean*
Blue Ridge Mountains					
Daniel Boone Game	May 1967	5	1,443- 2,937	276	1,904
Management Area, N.C.	Sept.	5	844- 11,838	1,709	7,414
	Nov.	5	1,764- 7,958	976	4,220
	Feb. 1968	5	<250- 3,220	459	1,315
	May	5	<250- 617	72	378
Mountains					
Choccolocca Game	May 1967	5	371- 760	70	516
Management Area, Ala.	Sept.	4	6,289- 13,709	1,402	9,105
	Oct.	5	4,116- 5,721	237	4,944
	Jan. 1968	5	613- 1,934	206	1,091
	April	5	<250- 994	123	533
Piedmont					
Forks Game Manage-	April 1967	5	499- 1,297	127	834
ment Area, S.C.	July	5	<250- 1,862	270	1,078
	Oct.	5	<250- 3,880	555	1,733
	Jan. 1968	5	2,323- 19,821	2,558	11,083
	May	5	<250- 250		<250
Upper Coastal Plain					
Fort A. P. Hill, Va.	April 1967	5	250- 672	100	260
	July	5	250- 1,151	193	596
	Oct.	5	3,459- 18,618	2,504	7,639
	Jan. 1968	5	2,026- 4,634	400	3,227
	April	5	250- 931	128	479
Lower Coastal Plain					
Fort Stewart, Georgia	May 1967	5	2,076- 9,330	1,030	5,594
	Aug.	5	12,380- 31,034	2,865	22,321
	Nov.	5	14,285- 54,818	6,347	31,009
	Feb. 1968	5	8,725- 30,864	3,538	18,811
	April	5	7,463- 17,751	1,579	12,345
Eglin AFB, Florida	May 1967	5	879- 15,815	2,665	5,577
	Aug.	5	2,486- 13,218	1,675	7,913
	Nov.	5	12,416- 29,513	2,683	24,018
	Feb. 1968	5	80,713-152,940	12,442	120,861
	Mar.	8	2,660- 77,060	8,042	41,111
	May	5	2,387- 7,543	733	4,968
Waycross State Forest, Ga.	Dec. 1967	5	28,247- 83,736	6,429	51,311
Big Cypress Swamp-					
Everglades, Fla.	Jan. 1968	5	2,321- 4,710	387	3,050

The predatory bobcat was the next highest species encountered. The ^{137}Cs levels ranged from 2,671 pCi/Kg to 97,724 pCi/Kg (Table 2). Concentrations in the bobcat exhibited much less seasonal variation than concentrations in whitetailed deer. Raccoon and opossum contained comparable levels of fallout materials; opossum ranged from 2,992 pCi/Kg to 29,057 pCi/Kg and raccon 2,891 pCi/Kg to 25,671 pCi/Kg (Table III). The gray fox contained greater concentrations (5,652 pCi/Kg to 42,438 pCi/Kg) than raccoon or opossum, but much less than levels found in the bobcat. Cottontail rabbits had levels from 250 pCi/Kg to 16,952 pCi/Kg (Table 4) and 141 gray squirrels analyzed in this laboratory (Wise 1968) contained from 407 pCi/Kg to 50,846 pCi/Kg.

Samples of the same species from different geographic regions contained different concentrations of ^{137}Cs. In all species the Lower Coastal Plain animals were much higher in ^{137}Cs accumulation than the Upper Coastal Plain, Piedmont, or Mountain regions. Gray squirrels collected from eight physiographic regions in Georgia increased in Cesium-137 levels in a direction from the Mountain region to the Coastal Island Region (Wise 1968). Cottontail rabbits as well as whitetailed deer, bobcats, opossum, raccoon, and gray fox also exhibited an increased accumulation in a direction from the Mountains to the Coastal region.

TABLE 2

Mean concentrations of Cesium--137 (pCi/Kg) in the bobcat of the Southeastern United States.

Location	*Date of Collection*	*No.*	*Range*	*S. E.*	*Mean*
Lower Coastal Plain of Georgia	Fall 1965 & 1966	14	3,495-36,344	2,710	12,562
	June 1967	2	32,592-45,191	4,454	38,891
	July 1967	6	27,833-97,512	11,475	66,378
	August 1967	5	26,357-76,783	8,492	50,206
	September 1967	3	52,620-97,724	12,094	82,241
	October 1967	2	51,300-72,816	7,607	62,058
	January 1968	1	----	--	28,837
	February	1	----	---	42,949
	March 1968	1	----	--	44,678
	May 1968	1	----	---	96,413
	June 1968	1	----	--	73,258
Upper Coastal Plain of South Carolina	Fall 1965 & 1966	16	2,713-41,958	2,469	15,183
	January 1968	10	8,238-62,090	5,109	24,450
	February 1968	3	7,623-14,011	1,508	10,696
	March 1968	4	5,739-8,622	521	7,320
	May 1968	2	2,671-8,843	2,182	5,757
	June 1968	2	5,672-10,614	1,748	8,143

Of particular interest is the concentration factor from one trophic level to another. Table 5 gives the trophic level Cesium-137 concentration factors for several southeastern game species. From rabbit to bobcat there was a 12.1 increase in concentration. The gray fox, an omnivore, exhibited a 5.7 increase over the levels found in cottontail rabbits; whereas, the whitetailed deer approaches the classic three times factor implied by other investigators. The increase from whitetail deer rumen contents (wet weight) to whitetail deer muscle was 3.3.

A large variety of domestic foods were analyzed to determine fall-out contamination levels entering the food web of man. These included such items as: beef, pork, cheese, milk, vegetables, and fruits. In all cases Cesium-137 levels were found to be less than 500 picocuries per kilogram.

A portable detecting unit was used in the spring of 1967 to analyze domestic and wild foods stored in freezers in an effort to determine human intake of radioactive

TABLE 3

Mean concentrations of ^{137}Cs (pCi/Kg) in selected omnivores of the Southeastern United States.

Location	*Date of Collection*	*No.*	*Range*	*S. E.*	*Mean*
Opossum					
Lower Coastal Plain (Ga.)	May 1967	3	2,992-17,914	3,747	8,871
Upper Coastal Plain (S.C.)	Jan. 1968	5	6,240-27,853	3,724	12,065
Lower Coastal Plain (Fla.)	March 1968	14	11,474-29,057	1,049	19,372
Raccoon					
Lower Coastal Plain (Ga.)	May 1967	6	15,762-25,671	1,447	20,571
Upper Coastal Plain (S.C.)	Jan. 1968	5	2,891- 5,766	521	3,979
Lower Coastal Plain (Fla.)	March 1968	11	3,015-22,215	1,606	10,994
Gray Fox					
Lower Coastal Plain (Ga.)	May 1967	9	11,914-52,438	4,125	28,795
Upper Coastal Plain (S.C.)	Jan. 1968	17	5,652-20,009	983	8,326

TABLE 4

Whole body burden of Cesium—137 (pCi/Kg) in cottontail rabbits collected during 1966 and 1967.

Location	*Sample*	*Minimum*	*Maximum*	*S. C.*	*Mean*
Lower Coastal Plain	18	525	16,952	845	5,010
Upper Coastal Plain	145	<100	4,371	51	785
Piedmont	142	<100	2,701	34	586
Mountains	20	174	1,063	37	379

TABLE 5

Increase of Cesium—137 concentration (pCi/Kg) from one tropic level to the next higher one.

Lower Level	Mean (pCi/kg)	Higher Level	Mean	Ratio of Increase
Cottontail rabbit (18)	5,010	Bobcat (23)	60,392	12.1
Cottontail rabbit (18)	5,010	Gray fox (9)	28,794	5.7
Deer rumen contents (8)	12,303	Deer muscle (8)	41,111	3.3

materials. Field values double checked in more reliable equipment indicated field analysis was within plus or minus 15 per cent of the true value. By using a small ratemeter approximate Cesium-137 concentrations to as low as 15,000 pCi/Kg could be determined.

DISCUSSION

The seasonal variation in radiation accumulation has been noted by other investigators. Whicker (1965) found the greatest concentrations in mule deer on the summer range. He attributed this to the greater deposition at the higher summer range elevations. Whitetailed deer in the Southeast generally contain greater

concentrations in the winter when new growth foods are scarce and the more persistent vegetation must be utilized. Becuase the Southeast does not have drastic seasonal changes, other interactions of the environment may bring about concentration. An example could be drought conditions in the summer killing back much of the more palatable materials; therefore, other tougher more long-lived foods are utilized which have accumulated more fallout from aerial deposition. These conditions would interact indirectly to cause unusual uptake of radioactive materials in carnivorous species of the southeast.

The exact mechanisms for differential uptake in different regions are not known at this time. The high water table, low concentrations of plant nutrients, and long-lived plant species are characteristic of the Lower Coastal Plain and may in part be the factors causing the higher concentrations of ^{137}Cs in this area.

Pendleton *et al.* (1965) imply that contamination levels in Alaskan, Eskimos, and Finnish Laplanders can be predicted using a trophic level increase of three for cesium-137. They compared the trophic level increase between four cougars *(Felis concolor)* and several mule deer, and found an increase ratio of Cesium-137 of three times for cougars. Hanson *et al.* (1964) measured the level in carnivores from northern Alaska to illustrate the concentration of Cesium-137 among terminal members of the terrestrial food web. Red fox *(Vulpes fulva)* and wolf *(Canis lupus)* samples contained concentrations two to three times those in caribou from the same region.

In our laboratory whitetailed deer muscle concentrations were 3.3 times higher than their respective rumen concentrations (both on a wet weight basis); however, when bobcats and gray foxes were compared to their prey, the cottontail rabbit, concentrations factors of 12.1 and 5.7 respectively were found. Due to various ecological factors, such as food preference and consistency, abundance, and habitat of the prey, a relationship is difficult to determine at this time for the difference in radioactivity in predator and prey species. The fact that gray foxes have a lower concentration factor than bobcats is probably tied in with their more omnivorous food habits.

It is of public health significance when high concentrations of radioactive materials are found in game species. This is further complicated by the concentration factor differences at various trophic levels and even between degrees of predation (the predatory bobcat and the omnivorous gray fox).

The Federal Radiation Council (1965) considers an average whole body burden of 1,000 nanocuries (Nc) of Cesium–137 to be a safe level for the general population. In general adults today in the U. S. contain around 10-15 Nc. The FRC also recommends that the whole body burden of an individual in the general population not exceed 3,000 Nc whole body burden of Cesium-137. A standard man with a whole body burden of 1,000 Nc of ^{137}Cs would have 14,286 pCi/Kg. It is probable that an individual could exceed the FRC recommendations through above average consumption of some game species from certain habitats of the Southeast. A person could consume 28 pounds per year or 7 pounds per three months of a specimen containing 100,000 pCi/Kg of ^{137}Cs and not exceed recommendations of the FRC. However, some deer have been counted in this study that exceeded 152,000 pCi/Kg.

Extremely high levels in game species used as food are not normally found until after the hunting season is over. In addition cooking ordinarily causes a loss of 10-40% in discarded juices. The high utilization of domestic foods (most of which contain less than 200 pCi/Kg of ^{137}Cs) greatly reduces the hazards of "wild" food consumption. Because we are not closely associated with or dependent upon the natural environment for our foods the contamination of our food web with ^{137}Cs from wild foods is not alarming.

A simple single channel gamma analyzer was used to determine fallout contamination of the human food web by analysis of "wild" foods stored in freezers in different locations. It has had limited use at the present time but greater future use is anticipated. In addition a small relatively inexpensive gamma detecting ratemeter (Victoreen Thyac with 1¼ x 1½ inch sodium iodide probe – $580) was used to determine approximate levels of contamination. This instrument may well be

invaluable in the future for on-the-spot analysis at checking stations at managed hunts. If the specimen registers a high radiation count a sample could then be taken for further analysis by more accurate equipment.

Surveillance work as outlined here will be continued. The present levels, although exceeding the arctic levels in Reindeer and Caribou, are not considered a public health hazard since sportsmen are not as dependent on wildlife for food as are some groups in the far north. We have some evidence that concentrations of radionuclides in wildlife are still increasing in spite of the relatively inactive atomic testing programs around the world.

SUMMARY

Specimens of various game species from Virginia, North Carolina, South Carolina, Georgia, Alabama, and Florida were analyzed for Cesium-137 by gamma spectrometry methods. Concentrations of ^{137}Cs in specimens from the Mountain, Piedmont, and Upper Coastal Plain were generally much lower than those from the Lower Coastal Plain Region. The highest specimen counted was a whitetailed deer with 152,940 pCi/Kg. Seasonal highs generally occurred in the late winter – early spring period, but complex factors of the environment may interact in some cases to cause the highs in periods other than the late winter period.

Domestic commodities were frequently analyzed for Cesium-137 and generally contained less than 250 pCi/Kg. At the present time it is not known what long term effects high radionuclide levels will have on the game species involved. An individual could consume twenty-eight pounds per year of a game animal containing 100,000 pCi/Kg of Cesium-137 without exceeding the limits recommended by the Federal Radiation Council. Due to human dietary habits the present reaionuclide levels in game species are not considered a serious public health hazard, but monitoring of this situation should be continued.

LITERATURE CITED

Federal Radiation Council. 1965. Background material for the development of radiation protection standards. Protective action guides for strontium-89, strontium-90, and Cesium-137. Report No. 7. Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 44 p.

Hanson, W. C., H. E. Palmer, and B. F. Griffin. 1964. Radioactivity in northern Alaskan Eskimos and their foods, summer 1962. Health Physics 10:421-429.

Hanson, W. C. 1966. Radioecological concentration processes characterizing arctic ecosystems, p. 183-190. Radioecological concentration processes. Proceedings of an International Symposium held in Stockholm. Pergamon Press, Oxford and New York.

Jenkins, J. H., J. R. Monroe, and F. B. Golley. 1967. Fallout cesium accumulation and excretion in selected predators and prey in the Southeast. Paper presented at the Second National Symposium on Radioecology. University of Michigan, Ann Arbor. In press.

Pendleton, R. C., M. L. Steward, R. D. Lloyd, and C. W. Mays. 1965. A trophic level effect on Cesium-137 concentration. Health Physics 11:1503-1510.

Pullen, T. M., Jr., G. L. Plummer, and E. E. Provost. 1967. Strontium-90, Cesium-137, and other fallout radionuclides in the food chain of a whitetailed deer population in the Georgia Piedmont. Bull. Ga. Acad. Sci. 25(1):26-42.

Whicker, F. W. 1965. Factors influencing the accumulation of fallout Cesium-137 in mule deer. Ph.D. Dissertation. Colorado State University, Fort Collins. 124 p.

Wise, John S., Jr. 1968. The whole body burden of Cesium-137 in the gray squirrel in seven physiographic provinces. M.Sc. Thesis. University of Georgia, Athens. 24 p.

Witkamp, M. 1966. Biological concentrations of ^{137}Cs and Sr-90 in arctic food chains. Nuclear Safety 9(1):52-62.