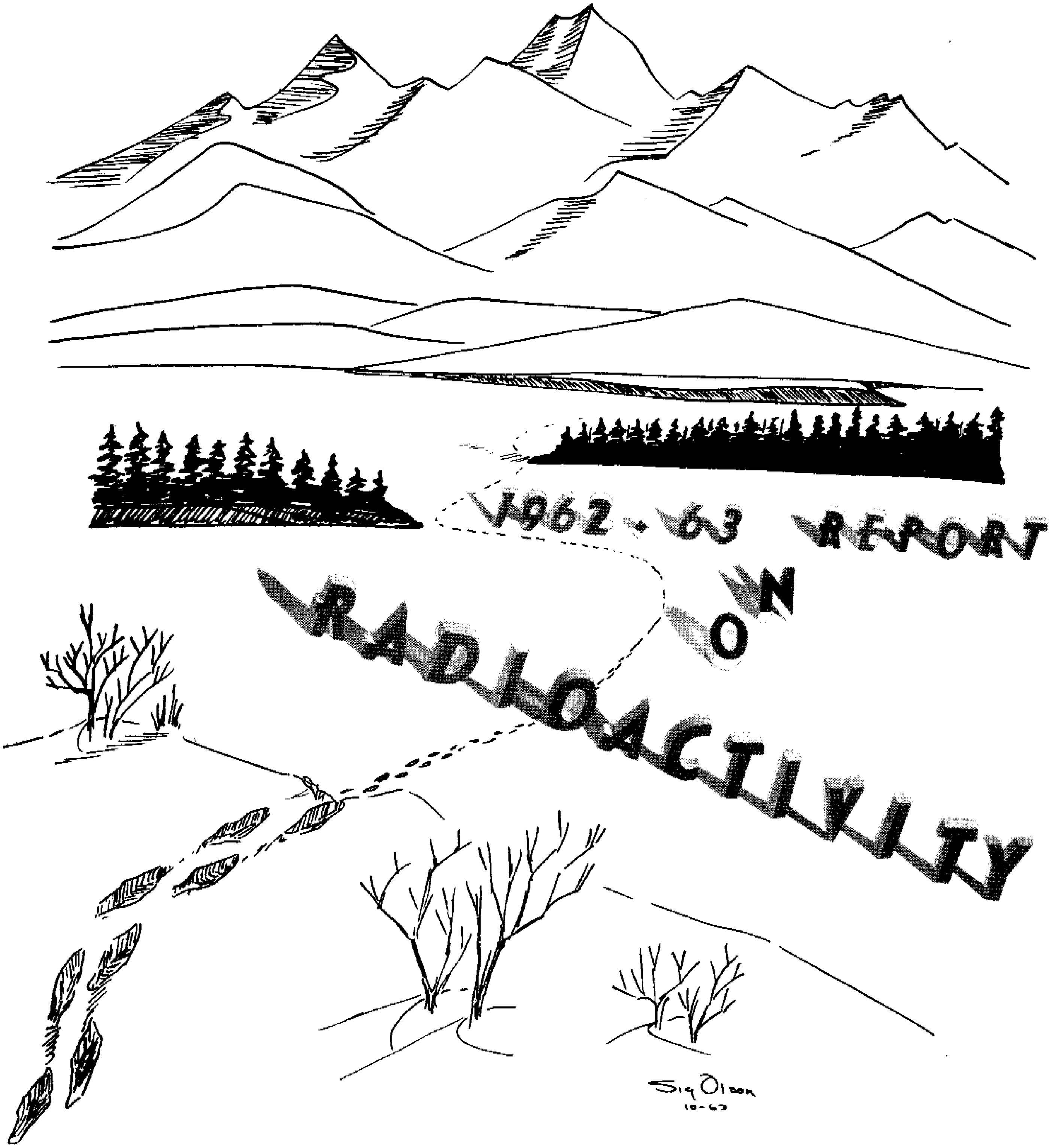
Frank Jones



ALASKA DEPARTMENT OF FISH AND GAME

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ALASKA DEPARTMENT OF FISH AND GAME
JUNEAU, ALASKA

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RADIOACTIVITY REPORT

by

Leslie A. Viereck

Volume IV
Annual Project Segment Report
Federal Aid in Wildlife Restoration
Project W-6-R-4, Work Plan L

(Printed January 1964)

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FEDERAL AID IN WILDLIFE RESTORATION

STATE: Alaska

PROJECT NO.: W-6-R-4 TITLE: Alaska Wildlife Investigations

WORK PLAN: L TITLE: Wildlife Data Collections

JOB NO.: 2

PERIOD COVERED: July 1, 1962 to June 30, 1963

ABSTRACT

A report titled "Report on radioactive materials in the lichen-caribou-human food chain in Alaska" was compiled from published and unpublished data. The following is an abstract of that report:

The importance of the concentration of fallout materials in the arctic food chain has only recently been realized and consequently there have been few studies made to date. In Scandinavia, a large group of scientists are working on the problem, but their information is only now becoming available. In Alaska, most of the investigations have been made in connection with the Project Chariot studies. The Alaska Department of Fish and Game has helped in the collection of samples but these samples have not been analyzed by the California laboratories to which they were sent. The Arctic Health Research Center in Anchorage collected a few samples in scattered areas in Alaska and the analyses of these samples were reported in Science in April of 1962. Programs for sampling radioelements in caribou and lichens have recently been initiated by the Alaska Department of Fish and Game, the Alaska Division of Public Health, and the Arctic Health Research Center at Anchorage.

The amount of available information on this problem is small, but the results of sampling in all of the northern areas including Alaska, Canada, Greenland, and Northern Scandinavia are similar, indicating that the concentration of fallout materials in the lichen-caribou-human food chain is quite similar throughout the northern region.

The data from these samples show that:

1. Lichens have concentrations of strontium-90 and cesium-137 of from 10 to 100 times that of most other plants from either temperate or northern regions. The effects of these concentrations on the lichens are not known.

2. Caribou and reindeer have concentrations of strontium-90 in meat and bones that are about 25-30 times that found in meat in the average U.S. diet. Cesium-137 levels are from 3-300 times that found in beef. Effects of these concentrations on the caribou and reindeer are completely unknown.

3. Strontium-90 in bone in caribou-eating Alaskan Eskimos is being laid down at about four times the rate of that of the average U.S. citizen.

4. Reindeer-eating Lapps were found to have whole body counts of cesium-137 of about 20 times that of control groups from southern Norwegian cities.

5. Inland Alaskan Eskimos at Anaktuvuk in the summer of 1962 had whole body counts of cesium-137 averaging 421 nanocuries and a few individuals had whole body counts of 800 nanocuries. This is approximately 50-100 times the concentration of cesium-137 in people of temperate latitudes.

RECOMMENDATIONS

Because of the limited data it is nearly impossible to recommend anything except further study. For further work I would recommend:

1. That data from all samples that have been taken previously be made available;

2. That specific studies be made on the concentration of radioelements in different lichen species in different geographic areas and under different ecological conditions;

3. Initiation of a continuous program of sampling caribou for radioelements in different herds throughout Alaska. These amounts might be correlated with amounts of concentrations in lichens in different areas. It is especially important to follow changes in cesium-137 and strontium-90 as the result of further atomic testing;

4. That wolf bones, of which the Alaska Department of Fish and Game has many, be measured for strontium-90 content because this animal is close to the caribou in the food chain. Amounts of radioactive materials in wolf bones and meat may be correlated with amounts in humans and serve as a useful guide;

5. That there be an extensive program of measuring strontium-90 and cesium-137 in white and native populations and in their diets in all areas in Alaska. Detailed studies should be made so that food intake can be correlated with radioelement amounts. These measurements should also be made on a continuous basis so that they can serve as safeguards should fallout increase greatly in Alaska;

6. Making one agency in Alaska responsible for organizing and conducting these studies with the cooperation of all other state and federal agencies. Data should be made available immediately to any agency concerned with the problem.

WORK PLAN SEGMENT REPORT
FEDERAL AID IN WILDLIFE RESTORATION

STATE: Alaska

PROJECT NO.: W-6-R-4 TITLE: Alaska Wildlife Investigations

WORK PLAN: L TITLE: Wildlife Data Collections

JOB NO.: 2

PERIOD COVERED: July 1, 1962 to June 30, 1963

OBJECTIVES

To obtain a general description of the range of the important game animals as a basis for determining utilization of the range and the feasibility of transplants.

To aid other departmental biologists in their own range of studies by the collection and identification of plant specimens.

To compile a report on the problem of concentration of radioactive materials in the lichen-caribou-human food chain in Alaska.

TECHNIQUES

Work on general range requirements of Alaskan big game mammals was limited to literature review.

One plant collection was identified through the use of keys and the University of Alaska Herbarium.

All available published and unpublished material was reviewed and a report compiled. Samples collected by other Alaska Department of Fish and Game biologists were processed and sent to the AEC Laboratory at Las Vegas for strontium-90 and cesium-137 analysis.

FINDINGS

A report concerning the problem of radioelements in northern food chains was compiled and has been revised below:

REPORT ON RADIOACTIVE MATERIALS IN THE LICHEN-CARIBOU-HUMAN FOOD CHAIN IN ALASKA

Introduction

We are all aware that as a result of nuclear weapons tests fission products have been introduced into the atmosphere and that most of these fission products eventually become part of our environment at the earth's surface. The accumulation of these isotopes in plants and soil has made them available to the human diet and many fission products are now found within the human body. There is now evidence that these materials tend to concentrate under certain conditions that occur in northern regions.

The most important of fallout isotopes, because of their long half life, are strontium-90 and cesium-137. Strontium-90, with a half life of 28 years, acts in a similar manner to calcium in metabolism and is therefore found primarily in bones. Strontium-90 emits high speed electrons (beta particles) upon decay and it is thus termed a beta emitter. Cesium-137, with a half life of 27 years, acts in a manner similar to potassium. It becomes distributed more or less uniformly in soft tissues throughout the body and irradiates the whole body with penetrating gamma rays (similar to x-rays).

Two other isotopes, carbon-14 (half life of 5,600 years) and iodine-131 (half life of 8 days), may be of importance within the arctic food chain, but because of the very short half life of iodine and the relatively low concentrations of carbon-14, we cannot readily ascertain their importance. To my knowledge, no published material exists on the importance of these two radioelements in arctic areas.

A tremendous amount of information is available on worldwide distribution of fallout and on amounts of radioactive elements in various diets and people in temperate regions. It has been shown that fallout is heaviest in north temperate latitudes and less toward the equator and the poles. Thus the cumulative amounts to July 1, 1960 in millicuries per square mile (see definition of terms, appendix) were 59.5 for central United States (Lat. 30-40°N), 44.0 for northern United States and Canada (40-50°N), 25.2 for southern Alaska (50-70°N), and 26.8 for northern Alaska (60-70°N) (Kulp and Schulert, 1962). In central and northern Alaska there has been relatively less fallout than in more southerly latitudes, in spite of the fact that the Russians have been conducting many of their tests in the Arctic. However, high concentrations of iodine-131 reported for milk from the Palmer area for the year ending October 1962 indicate that Alaska has been receiving unusually high amounts of fallout from the 1961-62 series of atomic tests.

It was soon realized during the studies of fallout that special situations might exist where more than normal amounts of radioactive materials might be taken up into the diet. Peoples of many countries that derive most of their food from plants and very little from milk and meat might be expected to have higher amounts of strontium-90 than people in countries where milk is extensively used. Likewise, people in areas of heavy rainfall could be expected to ingest more fallout products than those in areas of low precipitation. But of more or less complete unpredictability was the discovery that people in northern latitudes that depend to a large extent on caribou and reindeer meat may, in effect, have the largest amounts of fallout isotopes of any peoples in the world.

The concentration of strontium-90 and cesium-137 in this food chain is brought about by the following circumstances which are peculiar to northern regions. One of the main sources of winter food for caribou is the lichen, a type of plant that occurs extensively in northern regions. Unlike most plants the lichen obtains water and nutrients directly from the atmosphere rather than from the soil. Because of this, the fallout material is not diluted with soil minerals but occurs in high concentration in the lichens.

In winter these lichens provide an important food for the arctic caribou herds. The fallout materials in the lichens are ingested by the caribou and accumulate in the bones and meat. The caribou and reindeer, in turn, provide the main food source for many inland Eskimos in arctic Alaska and an important source of protein for many coastal natives. The strontium-90 and cesium-137 are thus transferred from the air to lichens, then to caribou, and ultimately to humans. Concentrations of both strontium-90 and cesium-137 have been shown to be many times higher in some Alaskan Eskimos than they are in the general population in the rest of the United States. The same accumulations have been reported in the reindeer-eating Lapps in northern Scandinavia.

I would like to emphasize that most data presented are a result of sampling done previous to the 1961-1962 Russian tests and the 1962 American tests which could easily alter the data presented here by many fold as could future tests.

History of Publication and Work

Much of the published information regarding the radioactive food chain in the Arctic has come from countries other than the United States. In 1958 Hvinden reported that concentration of strontium-90 in reindeer bones in Norway was much higher than that found in the bones of sheep grazing in the same area and related this to the possibility that the reindeer diet consisted primarily of the radioelement-rich lichens. Gorham (1959) found that lichens from Canada had much higher accumulations of radioactive fallout than did angiosperms of the same area and suggested that this was due to the fact that lichens obtained most of their moisture and nutrients directly from the air rather than from the soil.

Alaska: In 1959 work in the Alaska arctic was begun in connection with Project Chariot. During the first summer's work, as reported in Progress Reports in December 1959 and June 1960 (Davis et al, 1959, 1960), workers from the Hanford Laboratory confirmed the findings that lichens did have high amounts of radioelements, but they did not take samples of caribou. In the summer of 1960 and continuing through the winter, samples of caribou meat were taken in the Cape Thompson area and other areas in western arctic Alaska by Hanford Laboratory personnel and by Peter Lent and Dr. W. O. Pruitt, both of whom were working on caribou studies connected with Project Chariot. In a summary by the Committee on Environmental Studies for Project Chariot (1962) the Hanford Laboratory personnel reported on the results of their radioelement analysis of vegetation, birds, and mammals. The summary included data on strontium-90 and cesium-137 levels in 35 caribou from northwest Alaska. In May 1963 a short report on iodine-131 in thyroids of caribou collected in conjunction with Project Chariot studies was published (Hanson, Whicker, and Dahl, 1963). During the summer of 1962 Hanford Laboratory personnel visited several Alaskan Eskimo villages and made whole body counts of the gamma emitters of most of the Eskimo and white inhabitants. The results of this sampling have been made available in an unpublished report (Palmer, et al, 1962) and in the Project Chariot's Environmental Committee Report (1962).

In April 1962 S. R. Schulert reported on strontium-90 concentrations in caribou and humans in Alaska. The data on caribou were obtained from a few antlers and one sample of meat and stomach contents near Anaktuvuk and two caribou near Shungnak. The bones of Eskimos were obtained primarily from the native hospital in Anchorage and no attempt was made to correlate the strontium-90 results with past histories or diets of the individuals. All but three of the individuals tested were over 20 years old. The results of Schulert's work, however meager the data may be, were similar to that which has been found in the Scandinavian countries. Schulert found that caribou meat contained 10-20 times the amount of strontium-90 found in domestic cattle and that the Eskimos' samples had four times more strontium-90 than the average for the population in the North Temperate Zone.

R. L. Rausch of the Public Health Laboratory at Anchorage and personnel of the Alaska Department of Fish and Game have taken many caribou and some wolf samples for analysis of radioelements. Dr. Kermit Larson of the University of California, to whom the samples were sent for analysis, has written that the analysis of these samples has been deferred because of some samples from the Nevada test site that had higher priority.

Recently several studies of radioelements in the northern food chain have been initiated. The Alaska Department of Fish and Game has collected samples and sent them to the AEC Laboratory at Las Vegas. The Alaska Department of Health and Welfare has announced the initiation of a sampling program for caribou and reindeer. In addition the U. S. Public Health Service's Arctic Health Research Laboratory has received $100,000 for a program of radioecology studies in Alaska.

Scandinavia: As mentioned above, the Scandinavian countries have been interested in the problem of radioactive food chains in the arctic since at least 1958. In June of 1961 Liden published a paper showing that cesium-137 levels in Lapp people were high, primarily as a result of the large amounts of reindeer meat in their diets. He found that the cesium-137 burden in Swedish Laplanders was 20-40 times as high as a control group in Lund, Sweden.

In the fall of 1961 the International Atomic Energy Agency called together a group of scientists that were interested or actively involved in the radioactive food chain problem in Scandinavia. This meeting was named "The First Expert Meeting on the RIS (Radioactivity Investigations in Scandinavia)." The meeting was called primarily to discuss present research and the extent of current knowledge of the problem. No new data were presented but a review of the problem was given in the abstract of the meeting. A second meeting, called "The Second Northern Meeting on Radioactive Food Chains," was held in Helsinki in April 1-3 of 1962. Biologists and physicists working on any segment of the problem were present at the meeting and presented the results of their research. Only a brief abstract of each paper has been sent to interested people and these abstracts do not represent published material. Much of the material presented at this conference has been recently published in a paper titled Cs^{137} and Potassium in People and Diets - A Study of Finnish Lapps". (Miettinen, et al, 1963). A third symposium was held at Lund, Sweden in May 1963. Results of this meeting are not yet available.

In the U.S. the problem of radioactive food chains in the Arctic has been reviewed by Commoner (1961), by Pruitt (1962), and by Pruitt and Viereck (1961). In May of 1962, Kulp and Schulert published a mimeographed three volume work on the present status of knowledge of strontium-90 in man and his environment (Kulp and Schulert, 1962). This is a good summary of much that is known at present about strontium-90 and other fallout products in man and in diets. The material on Alaskan caribou and Eskimos is reviewed, but no new data are presented. The Committee on Environmental Studies (1962) has recently published a good discussion of the problem.

The above mentioned papers and reports, published and unpublished, are the main sources for the data and discussion that follows. A selected bibliography is given at the end of this report.

Results

Table 1 summarizes all data that I have found for radioelement analysis of caribou samples in the Arctic. A few points should be discussed.

Table 1. Amounts of Sr^{90} and Cs^{137} in caribou and reindeer. (Data for Alaska is for caribou -- That for Greenland and Scandinavia is for reindeer)

Source	Location	Date	Sr^{90} #	Sr^{90} Dpm/kg wet wt.	Sr^{90} Dpm/g ash	Sr^{90} pc/g Ca	Sr^{90} pc/g wet wt.	Sr^{90} pc/g dry wt.	Cs^{137} #	Cs^{137} pc/gK	Cs^{137} pc/g dry wt.	Cs^{137} pc/g wet wt.
MEAT												
Schulert (1962)	Anaktuvuk Pass	Nov. 1959	1?	16.0		160						
	Shungnak	Mar. 1961	1		3.3	162						
	Shungnak	Feb. 1961	1		1.3	146						
Chariot Environmental Committee (1962)	Cape Thompson	Aug. 1960	5				0.0037	0.013	5			0.72
	Colville	Aug. 1960							3			2.0
	Colville	Oct. 1960	3				0.0097	0.039	4			9.7
	Colville	Nov. 1960	3				0.0076	0.029	2			8.9
	Cape Thompson								1			3.7
	Colville	Feb. 1961	2				0.0060	0.022	1			15
	Cape Thompson								1			1.7
	Cape Thompson	Mar. 1961	7				0.0088	0.038	7			1.0
	Cape Thompson	Apr. 1961	2				0.013	0.056	2			0.75
	Colville	May 1961	1				0.027	0.010	1			8.2
	Colville	June 1961	5				0.0047	0.020	5			5.6
	Colville	July 1961	3				0.0061	0.024	4			0.64
	Colville	Aug. 1961	4				0.0066	0.024	4			0.90
	Cape Thompson	Aug. 1961							2			1.3
	Colville	Sept 1961	4				0.0077	0.030	4			4.6
	Colville	Oct. 1961	3				0.0077	0.031	3			6.5
	Colville	Nov. 1961	6				0.0093	0.068	6			19
	Colville	Dec. 1961	5				0.0096	0.038	5			26

Table 1. (Continued)

			Sr^{90}						Cs^{137}			
Source	Location	Date	#	Dpm/kg wet wt.	Dpm/g ash	pc/g Ca	pc/g wet wt.	pc/g dry wt.	#	pc/gK	pc/g dry wt.	pc/g wet wt.
Lindell (1962)	Northern Scandinavia	Sept 1961										
	Lappland								7			12-14
	Norbotten								2			15-19
	Vasterbotten								1			3
	Jamtland								11			2-20
	Norrafinland								1			9
Virkkunen et al (1962)	Finland	?							?			20
Aarkrog (1962)	Greenland	1961							10	1940		11-12
Liden (1961)	N. Sweden	1961							1			28
Miettinen et al (1963)	Finland	1960							1			35.3
		Mar. 1961							1	4500	65.1	18.0
		Sept 1961							1	2670	31.1	7.4
		Oct. 1961							1	4980	58.0	15.5
		Oct. 1961							1	6160	60.0	16.0
OTHER FOODS												
Kulp and Schulert (1962)	Average meat in Eastern US diet	1961				5.4						
Liden (1961)	Beef--Lund, Sweden	1961							?			0.1

Table 1. (Continued)

Source	Location	Date	Sr^{90} #	Dpm/kg wet wt.	Dpm/g ash	pc/g Ca	pc/g wet wt.	pc/g dry wt.	Cs^{137} #	pc/gK	pc/g dry wt.	pc/g wet wt.
Farmer (1960)	Nevada Cattle	1960							14			0.59
Kulp and Schulert (1962)	All foods US diet	1956-1961								16-41		
Schulert (1962)	Milk U.S.	1957-1961				7.8-15.7				22-83		
CARIBOU AND REINDEER BONES												
Schulert (1962)	Shungnak	Mar. 1961										
	Backbone		1		136	177						
	Legbone		1		179	180						
	Shungnak	Feb. 1961										
	Backbone		1		121	140						
	Legbone		1		150	175						
Davis et al (1961)	N.W. Alaska	1960										
	Ogotoruk Creek								1		.35	
	Kisimilowk Creek								5		.17	
	Cape Thompson								10		.70	
	Noatak River								6		1.0	
	Kobuk River								1		.53	

Table 1. (Continued)

Source	Location	Date	#	Sr^{90} Dpm/kg wet wt.	Dpm/g ash	pc/g Ca	pc/g wet wt.	pc/g dry wt.	Cs^{137} #	pc/gK	pc/g dry wt.	pc/g wet wt.
Hardy and Klein (1960)	Northwest Territory, Canada	Jan. 1959	1			84.9						
			1			91.6						
	Steese Highway	Oct. 1958	1			133						
Virkkunen et al (1962)	Finland	1961?	8			232						
Aarkrog (1962)	SW Greenland	1961	1*			278						
	SW Greenland	1961	1*			318						
Hvinden (1958)	N. Norway	1956										
	Sør Trondelay		1?			120						
	Sør Trondelay		1?			120						
	Hallingdal		1?			120						
	Hallingdal		1?			40						
OTHER BONES												
Hvinden (1958)	Sheep bones N. Norway	1956	14			17						
USAEC (1960)	Cattle bones Nevada Test Site	1957-1959	?			Max. 44.8 Min. 5.6						

* Chosen because of high Cs^{137} amounts in the meat.

Table 1. (Continued)

Source	Location	Date	#	Sr^{90} Dpm/kg wet wt.	Dpm/g ash	pc/g Ca	pc/g wet wt.	pc/g dry wt.	Cs^{137} #	pc/gK	pc/g dry wt.	pc/g wet wt.
Schultz and Longhurst (1961)	Deer bones California	1952-1960	49			Max. 72.1 Min. 0.5						
CARIBOU AND REINDEER ANTLERS												
Schulert (1962)	Anaktuvuk River	1959	1?	9450	238	281						
	Anaktuvuk River	1959	1	6480	146	170						
	Tolugak Creek	1959	1	6400	143	170						
	Alaska	1958	1?		98.4	106.1						
Foreman, Roberts and Lilly (1961)	Alaska	1958	1		105							
	Alaska	1958	1		162							
	Alaska	1958	1		145							
	Alaska	1958	1		64							
	Alaska	1957	1		73.3							
Davis (1961)	N.W. Alaska	1960										
	Ogotoruk Creek								1		.29	
	Kisimilowk Creek								3		.39	
	Cape Thompson								9		.48	
	Noatak								3		.50	

Table 1. (Continued)

Source	Location	Date	Sr^{90} #	Dpm/kg wet wt.	Dpm/g ash	pc/g Ca	pc/g wet wt.	pc/g dry wt.	Cs^{137} #	pc/gK	pc/g dry wt.	pc/g wet wt.
Larson, K. Personal letter	Anaktuvuk	Oct. 1959	13			128.1						
	Glenn Highway	Oct. 1959	1			128						
	Gulkana River	Sept 1955	1			36.7						
	Denali Highway	Sept 1956	1			51.7						
OTHER ANTLERS												
Schulert (1962)	California deer antlers	1958			6.81	8.05						
Larson, K. Personal letter	Moose Fairbanks, Alaska	1958	1			8.9						
RUMEN												
Schulert (1962)	Anaktuvuk River	Nov. 1959	1?	7880	245	1264						
	Shungnak	Mar. 1961	1?		300	3444						
	Shungnak	Feb. 1961	1?		231	2968						
Davis (1961)	N.W. Alaska	1960										
	Ogotoruk Creek								2		16	
	Kissimilowk Creek								8		14	
	Cape Thompson								4		22	
	Noatak River								9		21	

Meat: The Alaskan data for strontium-90 consist of samples from one or more caribou from Anaktuvuk, two from Shungnak, and 35 caribou from northwest Alaska. The 35 samples reported by the Project Chariot Environment Committee are not directly comparable with most figures for strontium-90 because calcium amounts are not given. The specimens from Anaktuvuk and Shungnak contained about 25-30 times the amount of strontium-90 that is found in the meat eaten by the average U.S. citizen.

There are presently more data available on the amounts of cesium-137 in caribou and reindeer meat than there are on strontium-90 amounts. Amounts of cesium-137 in caribou and reindeer vary from 1-35 picocuries per gram of meat while at the same time beef from Sweden had less than 0.1 picocurie per gram wet weight and Nevada cattle were reported to have 0.59 picocurie per gram wet weight (Farmer, 1960). The variation in caribou and reindeer is expected for there is a marked fluctuation of cesium-137 in other animals and man with time, the peaks usually following several months after fallout peaks. This is due in large part to the fact that cesium-137 has a biological half life of approximately 140 days (Anderson, G.C., et al, 1961).

Bones: The amount of strontium-90 in caribou and reindeer bones seems to be of rather similar magnitude throughout the Arctic. At first glance at Table 1, it would appear that reindeer bones from Greenland have higher amounts than those of caribou from Alaska, but it should be noted that the two samples from Greenland were chosen because the meat from these two animals had the highest amounts of cesium-137 of 10 samples from Greenland.

It can be seen that the amounts of strontium-90 in reindeer bones in Scandinavia have more than doubled between 1956 and 1960-61. Thus the average of 4 samples taken by Hvinden was 100 pc/g Ca in 1956 and that of samples taken by Virkkunen et al (1962) in 1960-61 was 232 pc/g Ca.

Data for strontium-90 in sheep bones in Norway in 1956 are given in Table 1 as a comparison with the strontium-90 in reindeer bones from the same area at the same time. It can be seen that the average for the reindeer (100pc/g Ca) is about 8 times that for sheep bones. I was unable to obtain the amounts of strontium-90 in average U.S. cattle but bones from cattle raised on the Nevada test site (but watered and fed from other sources) are given in Table 1 and can be seen to have amounts far less than those of the Alaskan caribou.

As would be expected, the cesium-137 in bones and antlers is low because cesium-137 and potassium are found primarily in soft tissue in the body.

Antlers: Amounts of strontium-90 in antlers are comparable to that found in bones and are 12-35 times that found in antlers of deer from California, a region of higher fallout amounts than the Arctic. Larson's data on caribou antlers from 1955 to 1959 show that the concentration of strontium-90 has approximately tripled in the 4 year period.

Rumen: Amounts of strontium-90 in the rumen samples are about 10-20 times that found in the meat and bones of the same animals (Schulert, 1962). The high amounts of strontium-90 (3444 pc/g Ca) found in the rumen samples compares well with the data for lichens (Table 2) which have been found to have as much as 10,000 pc/g Ca (Virkkunen, 1962).

Amounts of cesium-137 in rumina from caribou taken in the Cape Thompson area are slightly lower than cesium-137 amounts from lichens in the same area.

Lichens: Data on strontium-90 in lichens are also very sparse (see Table 2). Almost nothing has been reported on variation between different species and in most cases species names are not given. Virkkunen (1962) indicated that he has such data and states in an abstract that *Stereocaulon* sp. had the lowest concentrations and that "reindeer mosses" (*Cladonia* spp.?) had the highest amounts. A comparison with strontium-90 amounts in other plants such as wheat, wild oats, sedges, and willows shows that lichens do have a great ability for concentrating the fallout products. The effects of these high radiation levels on the lichens is not known. Some plants have been found to be extremely sensitive to radiation damage (Sparrow and Evans, 1961). I have found no references to any studies designed to determine the effects of radiation on lichens.

Humans

Strontium-90: (Table 3). The most interesting fact of the comparison of strontium-90 in humans is not in the averages, which are very similar for Finland and for Alaska, but in the unusually high values of a few individuals. Thus Salo (1962) states that in two cases from northern Finland the value was two to three times higher than the mean of the same age group. Both of the individuals lived in a reindeer area.

Table 2. Sr^{90} and Cs^{137} in lichens and a few other plants.

Lichen and Comparative Plant Data

Source	Location	Date	pc/gr. dry wt.	Dpm/Kg wet wt.	Dpm/gr. ash	pc/gCa	Cs^{137} pc/g dry wt.
LICHENS							
Virkkunen (1962)	Finland	?	6			10,000	
Miettinen	Finnish Lapland	1960				350-2,800	
Chariot Environmental Committee (1963)	Cape Thompson	1960	2.0				26
WILD HAY							
Miettinen (1962)	Finnish Lapland					50-300	
WHEAT							
Schulert (1962)	Fairbanks	1960		50.5	3.03	60.5	
"	East U.S.	1960		100	5.89	114	
SEDGES							
Chariot Environmental Committee (1963)	Cape Thompson	1960	3.5				6.6
WILLOW LEAVES							
Chariot Environmental Committee (1963)	Cape Thompson	1960	1.2				3.2

Table 3. Sr^{90} and Cs^{137} in humans from northern areas.

Source	Location	Date	Age	Number of Samples	Sr^{90} pc/gCa	nc/kg body wt.	Cs^{137} Whole ct. in nc	pc/gK
Schulert (1962)	Alaskan Eskimos	Nov. 1959 to Dec. 1960	4 mo.	1	2.4			
			7 yr.	1	3.4			
			16 yr.	1	2.4			
			20-61 yr.	(35)	0.50			
Salo, K. (1962)	Finland	1960-1961	0-5 yr.	3	3.13			
			5-20 yr.	6	1.21			
			over 20 yr.	8	0.54			
Kulp and Schulert (1962)	Ave. American Adult	1961	Adult	?	0.30			
Liden (1961)	N. Sweden	1961	35 yr.	1			196	2,020
			46 yr.	1			361	3,360
			34 yr.	1			242	2,690
	Oslo, Norway		?	15			21	180
	Bergen, Norway		?	6			60	480
Dunning (1962)	U. S.	1960	?	?			90*	

*Highest quarterly value ever recorded.

Table 3. (Continued)

Source	Location	Date	Age	Number of Samples	Sr^{90} pc/gCa	nc/kg body wt.	Cs^{137} Whole ct. in nc	pc/gk
Palmer et al (1962)	Diomede	1962	Adults	8			Max. 35	
							Min. 8	
							Ave. 22	
	Barrow	1962	Adults	259			Max. 166	
							Min. 8	
							Ave. 52	
	Point Hope	1962	Adults	107			Max. 119	
							Min. 3	
							Ave. 17	
	Kotzebue	1962	Adults	132			Max. 518	
							Min. 17	
							Ave. 138	
	Anaktuvuk	1962	Adults	52			Max. 790	
							Min. 83	
							Ave. 421	

Table 3. (Continued)

Source	Location	Date	Age	Number of Samples	Sr^{90} pc/gCa	nc/kg body wt.	Cs^{137} Whole Ct. in nc	pc/gk
Miettinen et al (1963)	Finland Lapps	Oct. 1961						
	Reindeer breeders		Max. 75 yr.	50		Max. 10.9	Max. 790	
			Min. 16 yr.			Min. 1.4	Min. 86	
			Ave. 40 yr.			Ave. 3.91	Ave. 245	
	Reindeer breeding fisheries		Max. 57 yr.	6		Max. 2.41	Max. 140	
			Min. 21 yr.			Min. 1.26	Min. 92	
			Ave. 38 yr.			Ave. 1.83	Ave. 110	
	Other occupation		Max. 60 yr.	7		Max. 3.13	Max. 198	
			Min. 24 yr.			Min. 0.58	Min. 32	
			Ave. 39 yr.			Ave. 2.01	Ave. 129	
	Local Non-Lapps		Max. 69 yr.	16		Max. 3.97	Max. 250	
			Min. 18 yr.			Min. 0.38	Min. 30	
			Ave. 39 yr.			Ave. 1.51	Ave. 101	
	Control Group Helsinki		Max. 53 yr.	5		Max. 0.30	Max. 22	
			Min. 14 yr.			Min. 0.02	Min. 1.2	
			Ave. 28 yr.			Ave. 0.11	Ave. 8.4	

Table 3. (Continued)

Source	Location	Date	Age	Number of Samples	Sr^{90} pc/gCa	nc/kg body wt.	Cs^{137} Whole ct. in nc	pc/gK
Palmer et al (1962)	Hanford Lab Personnel	?	Adults	?			5-7	
Onstead et al (1962)	Germany	1960	Adults	6,000		0.200	11*	

* Based on an average weight of 125 pounds.

The same is true of the Alaskan data. The average of the adult samples (0.5 picocuries/g calcium) lies somewhat above that for the rest of North America (0.3 picocuries/g calcium), but individual adults sampled gave values of 1.9, 1.4, and 1.0 picocuries strontium-90 per gram calcium. Since young children have 8 times the concentration of adults, a child on the same diet as that of the adult with a value of 1.9 would reach 15 picocuries strontium-90 per gram calcium. This would mean that the individuals are receiving about 50 picocuries strontium-90 per gram calcium in their diet, which is about 4 times the U. S. average.

Schulert (1962) also reported on urine samples taken from Eskimos at the village at Shungnak. These showed a concentration of about 25 picocuries strontium-90 per gram calcium, indicating a diet of about twice this amount or 50 picocuries strontium-90 per gram calcium. According to Schulert this would indicate that the strontium-90 is being deposited in their bones at a rate of 12 picocuries strontium-90 per gram calcium, which is about four times the U. S. average.

Cesium-137: In Scandinavia Liden (1961) found that a few Lapps from reindeer areas had cesium-137 amounts many times that of the average of people from the cities of Oslo and Bergen and one person had a whole body count for cesium-137 of 361 nanocuries. In Finland Miettinen (1962d and Miettinen et al, 1963) found that Lapp reindeer breeders had whole body counts averaging 245 nanocuries as compared with an average of 8.4 for people living in the city of Helsinki. He found (personal letter) that some Lapps had whole body counts of about 1000 nanocuries. In Germany in January 1960 the average amount of cesium-137 in 6000 individuals was about 11 nanocuries (using 200 picocuries per kilogram (Onstead et al, 1962) and using an average body weight of 125 lbs).

The data reported by Palmer et al (1962) for Alaska are even more startling. These men made whole body counts for cesium-137 for most of the natives and white residents of the villages of Diomede, Barrow, Point Hope, Kotzebue, and Anaktuvuk. The results show that cesium-137 concentrations are closely related to diet. The coastal villagers (except Kotzebue) have low concentrations as compared with the inland villagers of Anaktuvuk.

The average whole body count for the residents of Anaktuvuk was 421 nanocuries and several individuals had whole body counts of nearly 800 nanocuries. According to Miettinen (personal letter) the cesium-137 in Lapps during the summer of 1962 was only about half of what it was during early spring of the same year. If the cesium-137 in the Alaskan natives followed the same pattern, they may have actually had nearly double the amounts measured by Palmer et al (1962). The variation in cesium-137 amounts in the Lapps with different seasons points out the need for more information on variations in Alaskan Eskimos.

Discussion

It is obvious that diet is extremely important in relation to the amount of strontium-90 and other radioelements that are taken into the system. This is shown in Table 3 comparing cesium-137 amounts in reindeer breeding Lapps and in Lapps obtaining food from fish and other sources. The average U. S. citizen received only 1.2 per cent of his strontium-90 from meat but about 46 per cent of it from milk (Kulp and Schulert 1962). An Alaskan Eskimo or trapper, living largely on meat and using little or no milk, would be expected to obtain nearly all of his strontium-90 from meat. Miettinen (1962a) and Miettinen et al (1963) found that reindeer-eating Lapps received 60-90 per cent of their cesium-137 from reindeer meat. No data are available comparing strontium-90 in various items of the diet of Eskimos with the amounts of strontium-90 in their bodies. Kulp and Schulert (1962) however have estimated the amounts of strontium-90 in various diets throughout the world based, in some cases, on very limited sampling of their foods. These results are given in Table 4.

Table 4. (From Kulp and Schulert, 1962) Maximum concentrations of Sr^{90} in theoretical diets in 1959.

Situation	Diet pc Sr^{90}/g Ca
1. Av. Eastern U.S. 40-60", 30-50^{o}N average diet	16
2. Maximum milk in U. S. farm	30-40
3. Maximum milk in U. K. (Cardiganshire)	30-40
4. Continental elementary rice diet 30-50^{o}N	20-60
5. U. S. Non-milk, vegetarian diet	10-60
6. Upper Amazon, primitive tribes basing diet on yuca and platano	50-70
7. Caribou based diet inland Alaskan Eskimo	100-200

The "Radiation Protection Guide" sets maximum permissible amounts for strontium-90 on the diet. These amounts in strontium units (equivalent to picocuries per gram of calcium) are in three ranges:

0 - 20 SU	no action required
20 - 200 SU	"active surveillance and routine control"
200 - 2000 SU	required "appropriate positive control measures"

It can be seen from Schulert's (1962) data that in 1961 the Anaktuvuk and Shungnak caribou were approaching the upper limits of the 20-200 range. Natives feeding entirely or largely on caribou meat would therefore require either "routine control" or "positive control measures" on their diet by the Public Health Service. However, as pointed out by the Consumer Report (March 1962) the U. S. Department of Health, Education, and Welfare has not as yet decided what these routine or positive controls should be for radioactive materials resulting from fallout. It should also be noted that the U. S. Department of Health, Education, and Welfare has refused to take action in cases where fallout amounts have exceeded the Radiation Protection Guide levels and consequently individual states have taken their own control action or have set up procedures for doing so in the future (Wurtz, 1962).

In regard to cesium-137, the figures from Anaktuvuk Pass show that there is a serious problem in Alaska for areas where natives feed primarily on caribou. The maximum permissible whole body dose of cesium-137 as established by the Federal Radiation Council is 3000 nanocuries for individuals and 1000 for populations. The average for Anaktuvuk is 425 nanocuries, nearly one half of the maximum permissible amount, and higher levels can be expected in the future if testing continues.

As far as the majority of Alaskans go - that is those living in cities or on homesteads, the coastal Eskimos utilizing fish and sea mammals as well as caribou and reindeer, and the interior Indian and trapper, utilizing moose and fish and other foods - there is no real danger from eating considerable quantities of caribou meat at the 1960-1961 levels of concentration of cesium-137 and strontium-90. However, there is a considerable possibility that the inland Eskimo, eating large quantities of caribou meat, may receive maximum permissible doses.

SUMMARY

1. Data on strontium-90 and cesium-137 in plants, animals, and man from northern areas are very limited. However, results of analysis of the few samples that have been taken are very similar.

2. Lichens do concentrate fallout products. As much as 10,000 pc/g Ca has been recorded from lichens in Finland. The effects on the lichens of these concentrations are not known.

3. Caribou have high concentrations of strontium-90 in bones and meat, about 25-30 times that found in meat in the average U. S. diet. Cesium-137 amounts in reindeer and caribou are from 3-300 times that for beef. The effects of these concentrations on the caribou are not known, but the amounts present exceed that which is permissible for another mammal, man.

4. A few Alaskan Eskimos have been found to have high concentrations of strontium-90 in their bones but there has as yet been no correlation with diet.

5. Reindeer-eating Lapps were found to have whole body counts of cesium-137 about 20 times higher than that of control groups from southern Norway cities. Inland Alaskan Eskimos at Anaktuvuk have average whole body counts of cesium-137 of 421 nanocuries and a few individuals had nearly 800 nanocuries. This is nearly one half of the maximum permissible concentration as set forth in the Federal Radiation Guide.

6. Diets of caribou-eating Alaskan Eskimos may contain near or over maximum permissible amounts of cesium-137 and strontium-90. Strontium-90 is being deposited in their bones at about 4 times the rate of the average U. S. citizen.

RECOMMENDATIONS

Because of the limited data it is nearly impossible to recommend anything except further study. For further work I would recommend:

1. That data from all samples that have been taken previously be made available.

2. Specific studies be made on the concentration of radioelements in differenct lichen species in different geographic areas and under different ecological conditions.

3. A continuous program of sampling caribou for radioelements in different herds throughout Alaska be initiated. These amounts might be correlated with amounts of concentrations in lichens in different areas. It is especially important to follow changes in cesium-137 and strontium-90 as the result of further atomic testing.

4. Wolf bones, of which the Alaska Department of Fish and Game has many, should be measured for the strontium-90 content because this animal is close to the caribou in the food chain. Amounts of radioactive materials in wolf bones and meat may be correlated with amounts in humans and serve as a useful guide.

5. There should be an extensive program of measuring strontium-90 and cesium-137 in white and native populations and in their diets in all areas in Alaska. Detailed studies should be made so that food intake can be correlated with radioelement amounts. These measurements should also be made on a continuous basis so that they can serve as safeguards should fallout increase greatly in Alaska.

6. One agency in Alaska should have the responsiblity of organizing and conducting these studies with the cooperation of all other state and federal agencies. Data should be made available immediately to any agency concerned with the problem.

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APPENDIX

A few terms and their abbreviations commonly encountered in literature of biological effects of radiation.

Term	Abbreviation	Definition
Curie	c	Unit of rate at which radioactive material gives off nuclear particles. It is equivalent to the number of atomic disintegrations per second in a gram of pure radium and is defined as 37 billion disintegrations per second.
Millicurie	mc	10^3 curies - 37 million disintegrations per second.
Microcurie	uc	10^6 curies - 37 thousand disintegrations per second.
Nanocurie	nc	10^9 curies - 37 disintegrations per second.
Picocurie	pc	10^{12} curies - 2.2 disintegrations perminute.
Micromicrocurie	uuc	= picocurie
	dpm	= disintegrations per minute.
Rad	rad	A unit of absorbed dose - or a measure of radiation exposure which amounts to 100 ergs of energy imparted to one gram of matter by an ionizing radiation of irradiated material at the place of interest.
Milirad	mrad	10^3 rads.
Roentgen	r	A unit of exposure dose that is a measure of the ability of x-rays or gamma rays to produce ionization in air.

Term	Abbreviation	Definition
(Continued)		One roentgen of radiation has the ability to produce an amount of ionization which represents the absorption of approximately 86 ergs of energy from radiation per gram of air.
Relative Biological Effectiveness	RBE	The biological effect per rad of absorbed energy varies according to the type of radiation, i.e. alpha, beta, and gamma rays and neutrons have different biological effects per rad of absorbed energy.
Roentgen Equivalent Man	REM	A unit of absorbed dose of any radiation which has the same biological effect as a rad of "standard" x-rays and gamma rays.
Strontium Unit	SU	One picocurie of strontium-90 per gram of calcium. It is preferable to use pc/gram calcium.
Biological Half Life		The time required for a given species, organ or tissue to eleminate half of a substance which it takes in.