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by

Kathryn Bennett, James Biggs, and Phil Fresquez

ABSTRACT

At Los Alamos National Laboratory, small mammals were sampled at two waste burial sites (Site 1-recently disturbed and Site 2-partially disturbed) at Area G, Technical Area 54 and a control site on Frijoles Mesa (Site 4) in 1995. Our objectives were 1) to identify radionuclides that are present within surface and subsurface soils at waste burial sites, 2) to compare the amount of radionuclide uptake by small mammals at waste burial sites to a control site, and 3) to identify if the primary mode of contamination to small mammals is by surface contact or ingestion/inhalation. Three composite samples of at least five animals per sample were collected at each site. Pelts and carcasses of each animal were separated and analyzed independently. Samples were analyzed for ^{241}Am, ^{90}Sr, ^{238}Pu, ^{239}Pu, total U, ^{137}Cs, and ^{3}H. Significantly higher (parametric t-test at p=0.05) levels of total U, ^{241}Am, ^{238}Pu, and ^{239}Pu were detected in pelts than in carcasses of small mammals at TA-54. Concentrations of other measured radionuclides in carcasses were nearly equal to or exceeded the mean concentrations in the pelts. Our results show higher concentrations in pelts compared to carcasses, which is similar to what has been found at waste burial/contaminated sites outside of Los Alamos National Laboratory. Site 1 had a significantly higher (alpha=0.05, P=0.0125) mean tritium concentration in carcasses than Site 2 or Site 4. In addition Site 1 also had a significantly higher (alpha=0.05, p=0.0024) mean tritium concentration in pelts than Site 2 or Site 4. Site 2 had a significantly higher (alpha=0.05, P=0.0499) mean ^{239}Pu concentration in carcasses than either Site 1 or Site 4.

INTRODUCTION

A solid, low-level radioactive waste disposal facility has been operating at Area G, Technical Area (TA) 54, Los Alamos National Laboratory (LANL) since 1957 and has been used to dispose of various wastes including tritium waste, transuranic waste, volatile organic compounds, and mixed waste. Environmental monitoring of air, soil, water runoff, and vegetation has been in place to examine potential migration of contaminants. Recently, there has not been sampling to determine contaminant concentration in small mammals within the boundaries of Area G. Consequently, the collection and analysis of small mammals at TA-54, Area G, was initiated as

part of the Enhanced Environmental Annual Surveillance program at Area G by the Environmental, Safety, and Health Division in collaboration with the Solid Waste Management Group. The program is intended to provide data to aid in meeting requirements of DOE Order 5400.1, which specifies monitoring of existing operations at radioactive waste burial sites.

Rodents can affect the distribution of radionuclides at radioactive waste burial sites through their burrowing activities (Arthur et al. 1987). Burrowing activity and mound building can expose contaminated soils that can then be dispersed by wind and water erosion (Winsor and Whicker 1980). Predators of small mammals can also disperse radioactive material in their feces, urine, or regurgitated pellets (Eisler 1994). Burrowing animals can also alter the soil profile by changing the physical and chemical processes in the soil resulting in movements of buried contaminants (Hakonson et al. 1982). In addition, small mammals utilizing waste burial sites can be contaminated through direct contact of contaminated soil or by ingestion of soil (i.e., from soil consumption during pelt grooming) or from foraging on plant resources (O'Farrell and Gilbert 1975) and could subsequently become a form of contaminant transport off-site via predation from predator species (Craig et al. 1979).

The process of collection and analysis of burrowing, small mammals at two waste burial sites (Sites 1 and 2, described in Methodology) within Area G at TA-54 was used 1) to identify radionuclides potentially present within surface and subsurface soils at waste burial sites by sampling small mammal tissue, 2) to quantitatively estimate and compare the amount of radionuclide uptake at specific waste burial sites within Area G to a control site (Site 4) by sampling small mammal carcasses, 3) to determine the primary mode of contamination to small mammals, either by surface contact or through ingestion, and 4) to estimate small mammal densities at each waste burial site and the control site for use in estimating potential contaminant loads within the rodent population. Data collected from the waste burial sites were compared to

a control site. A general description of Area G and the various wastes buried within its boundaries is given in Eklund (1995).

METHODOLOGY

Two sites were selected for sampling (trapping) within Area G (Figure 1) with respect to ongoing disposal operations. These sites are defined as follows:

Site 1) Recently disturbed/contaminated site—This site is a shallow earth-covered storage area for transuranic uranium drums built on top of old previously filled disposal pits. Vegetation is not well established and consists of plant species associated with disturbed ground.

Site 2) Partially disturbed/contaminated waste burial site—This site has established vegetation with a mixture of native plants and plant species associated with disturbed ground.

In addition to these two sites, a control site (Site 4) was selected on Frijoles Mesa south of TA-54 on State Route 4 adjacent to Bandelier National Monument. During the 1994 Area G mammal study, a different control site (Site 3A, 3B, 3C) was used (Biggs et al. 1995) and was located west of Area G on Mesita del Buey (Figure 2). Vegetation samples were also collected at various locations within and near Area G waste burial sites (Fresquez et al. 1996), including two locations at Site 1 of the small mammal sampling areas.

A grid design consisting of 100 snap traps placed approximately 10 m apart in a 10×10 design was used to collect animals at each of the three sites. Snap trapping took place over 3 to 4 nights (until at least 15 animals were captured at each site). Procedures for handling and field processing of small mammals with respect to potential infection of hantavirus are given in Mills et al. (1995) and Biggs and Bennett (1995). These same safety procedures were followed for collecting tissue samples from snap-trapped animals. At least 15 rodents were captured at Sites 1

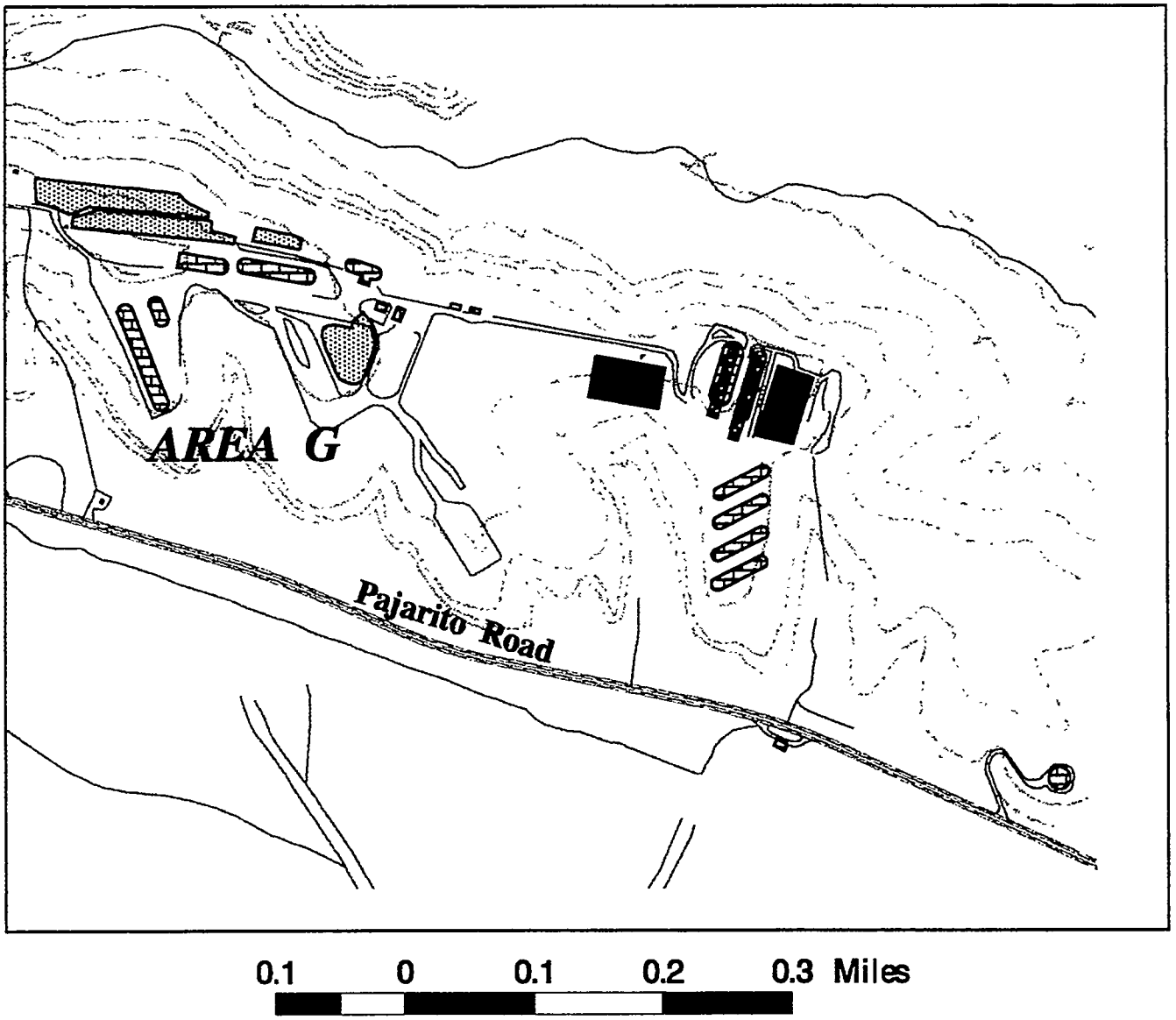


Figure 1. Mammal trapping grids at Area G.

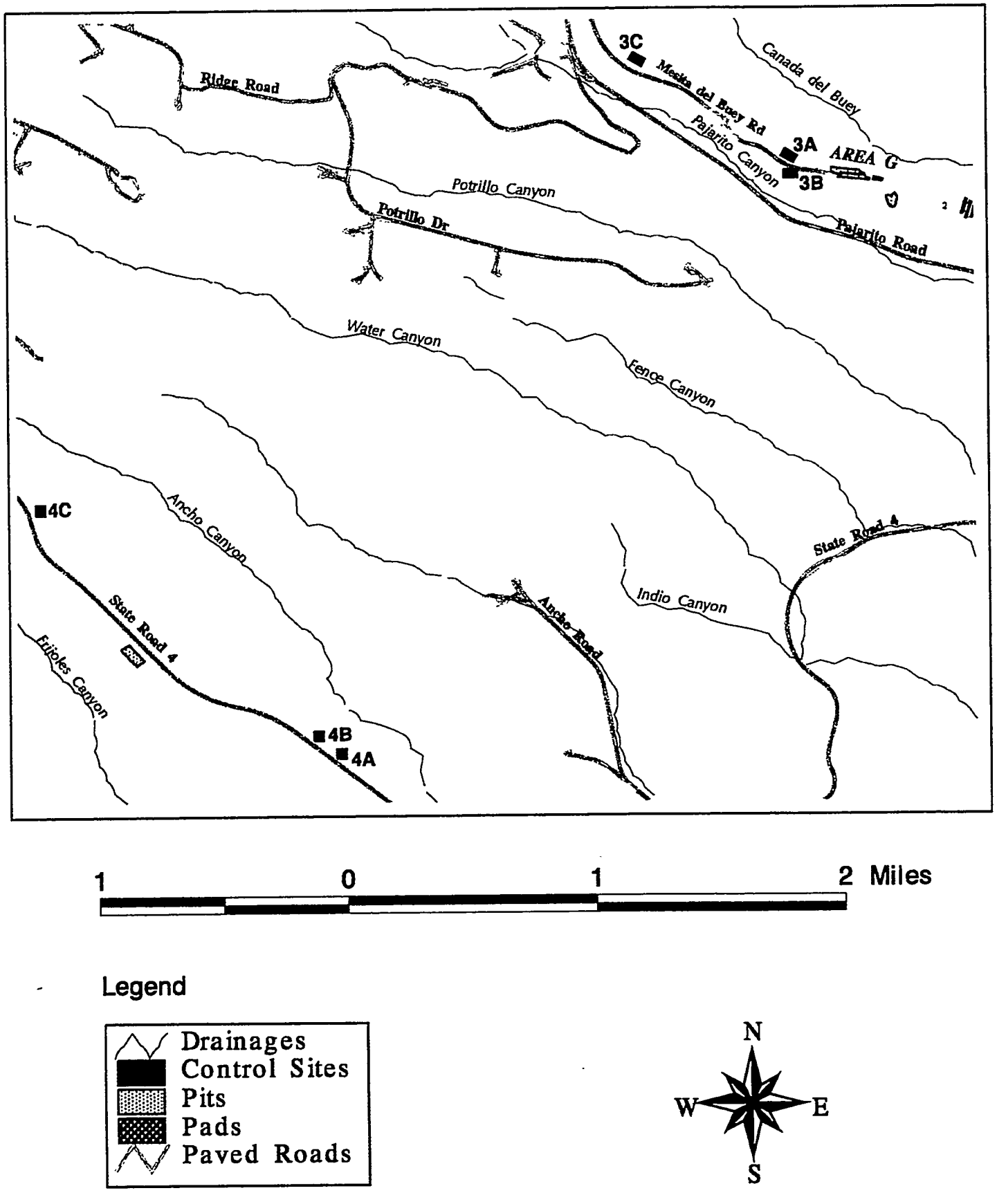


Figure 2. Control Sites for 1994 (3A, 3B, and 3C) and 1995 (4A, 4B, and 4C) for Area G small mammal study.

and 2. However, low capture rates at Site 4 necessitated additional sampling in the vicinity of that location (identified as Sites 4A, 4B, and 4C on Figure 2). Additional snap traps were placed in similar habitat adjacent to State Route 4 on Frijoles Mesa to ensure that a sufficient sample size was obtained for analysis. Snap traps were baited and set in late afternoon and checked in early morning. Traps with animals were taken to a central processing station where pelts were removed. Precautions during handling were taken to minimize cross contamination from carcass to pelt while removing pelts. All external hair was removed from appendages.

Three composite samples were collected at each site with each sample consisting of a minimum of 5 animals. The pelt was separated from the carcass of each animal and analysis was run on the pelt and carcass separately for each radionuclide. Due to total ashed weight, the three composite samples of pelts were combined for each site for only one sample per site, with the exception of ^{3}H. ^{3}H was analyzed on each pelt sample. The samples were placed into 1-L glass beakers and heated to produce condensated water that was collected and analyzed for ^{3}H (Salazar 1984). In addition, the remaining beaker contents were ashed at 500°C for 120 hr. The sample ash was pulverized and homogenized and submitted to a LANL analytical laboratory for the analyses of ^{241}Am, ^{90}Sr, ^{238}Pu, ^{239}Pu, total U, ^{137}Cs. All methods of radiochemical analyses have been described previously (Salazar 1984). Results are reported on a per ash weight basis (g ash). There were insufficient amounts of pelts to analyze the composite samples separately due to a minimum amount of ash required to conduct the analysis. In these cases, the composite samples were combined for each site. Separate analysis of pelts and carcasses allowed for a more accurate determination of the mode of concentration (whether by ingestion/inhalation or surface contact).

The Statistical Analysis System (SAS) was used to analyze all data sets (SAS/STAT User's Guide 1988). A univariate test was used to determine if carcass radionuclide data were normally distributed within each site. Data were normally distributed, therefore a parametric t-test was

used to determine if the means of each radionuclide concentrations were equal between carcasses and pelts. This was not conducted by site since only one pelt sample per site existed. An Analysis of Variance (ANOVA) for equal sample size or a General Linear Model (GLM) for unequal sample size were used to determine if any significant differences in the mean concentration of radionuclides in carcass samples existed between sites (the ANOVA and GLM generates an alpha [probability] at the 0.05 level) and Duncan's multiple range test was used to identify where the significant differences occurred between the sites. In addition, data from 1994 were pooled with data of 1995 and a GLM was used to determine if the mean radionuclide concentrations were statistically different between all sites (Site 1, Site 2, Site 3[a, b, c] and Site 4).

Rodent densities were estimated using Leslie's regression method (Seber 1982) applied to each grid where the daily total number of captures was plotted against the cumulative daily captures. Confidence intervals were calculated at 90% using the general method (Seber 1982).

RESULTS

Species Composition

Deer mice (*Peromyscus maniculatus*) was the only small mammal species captured at Site 1 and was the primary species captured at Site 2. One capture of an additional species, harvest mice (*Riethrodontomys megalotis*) was recorded at Site 2. Deer mice, pinon mice (*P. trueii*), and a silky pocket mouse (*Perognathus flavus*) were captured at the control site, Site 4. Figure 3 illustrates relative species composition of each site trapped.

Density Estimates

The highest densities of animals occurred on Sites 1 and 2 with very low capture rates at the control site, Site 4. Because of the low capture rates at Site 4, only capture data from one of the three grids could be used for density estimation. The density of the trapping area is based on a

100 m by 100 m grid with an additional 5 m boundary strip to help account for animals being drawn into the grid due to the bait. Therefore the total effective trapping area is approximately 1.21 ha. Table 1 gives the estimated density (# animals/ha) of each site sampled after adjustment for the total effective trapping area.

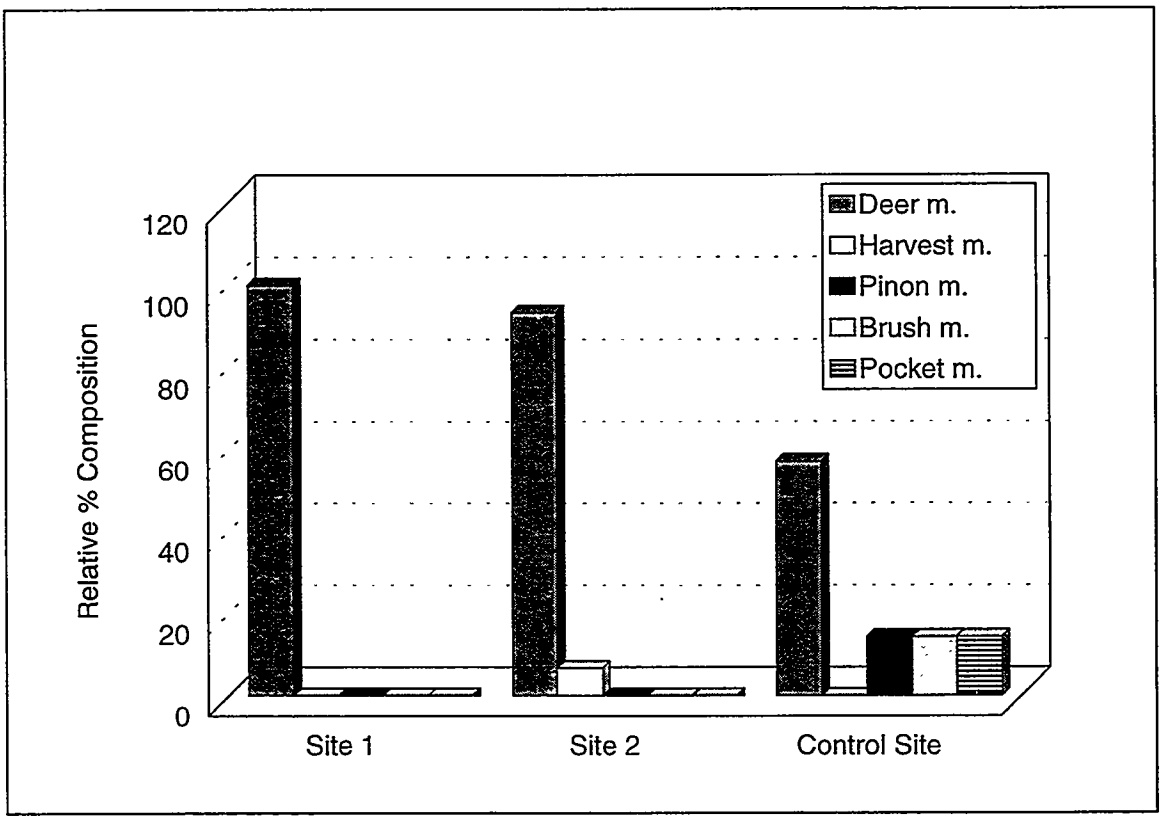


Figure 3. Relative Species Composition by Site.

Table 1. Rodent Density Estimate of Area G (Sites 1 and 2) and Control (Site 4).

SITE 1	DAY	NO. OF CAPTURES	NO. OF TRAPS
	1	12	100
	2	7	100
	3	5	100
DENSITY ESTIMATE (# animals/ ha)	31.74		
VAR(N) ESTIMATE	4.40		
90% CONFIDENCE INTERVAL	Lower 90% Limit 18.49		Upper 90% Limit 45.00

Table 1 (cont.)

SITE 2	DAY	NO. OF CAPTURES	NO. OF TRAPS
	1	5	100
	2	4	100
	3	1	100
	4	2	100
DENSITY ESTIMATE (# animals/ ha	14.08		
VAR(N) ESTIMATE	14.81		
90% CONFIDENCE INTERVAL	Lower 90% Limit 2.85		Upper 90% Limit 25.32

SITE 4	DAY	NO. OF CAPTURES	NO. OF TRAPS
	1	2	100
	2	2	100
	3	1	100
DENSITY ESTIMATE (# animals/ ha)	8.67		
VAR(N) ESTIMATE	15.70		
90% CONFIDENCE INTERVAL	Lower 90% Limit 0.00		Upper 90% Limit 33.69

Species Weights (biomass)

The average weight of all species combined was calculated for each site trapped (Figure 4). Average weights were similar for Sites 1 (18.5 g) and 2 (18.6 g) at Area G. The average weight at the control site, however, was approximately 3 grams lighter (15.5 g). The lighter weight at the control site was due to the greater variation in species composition.

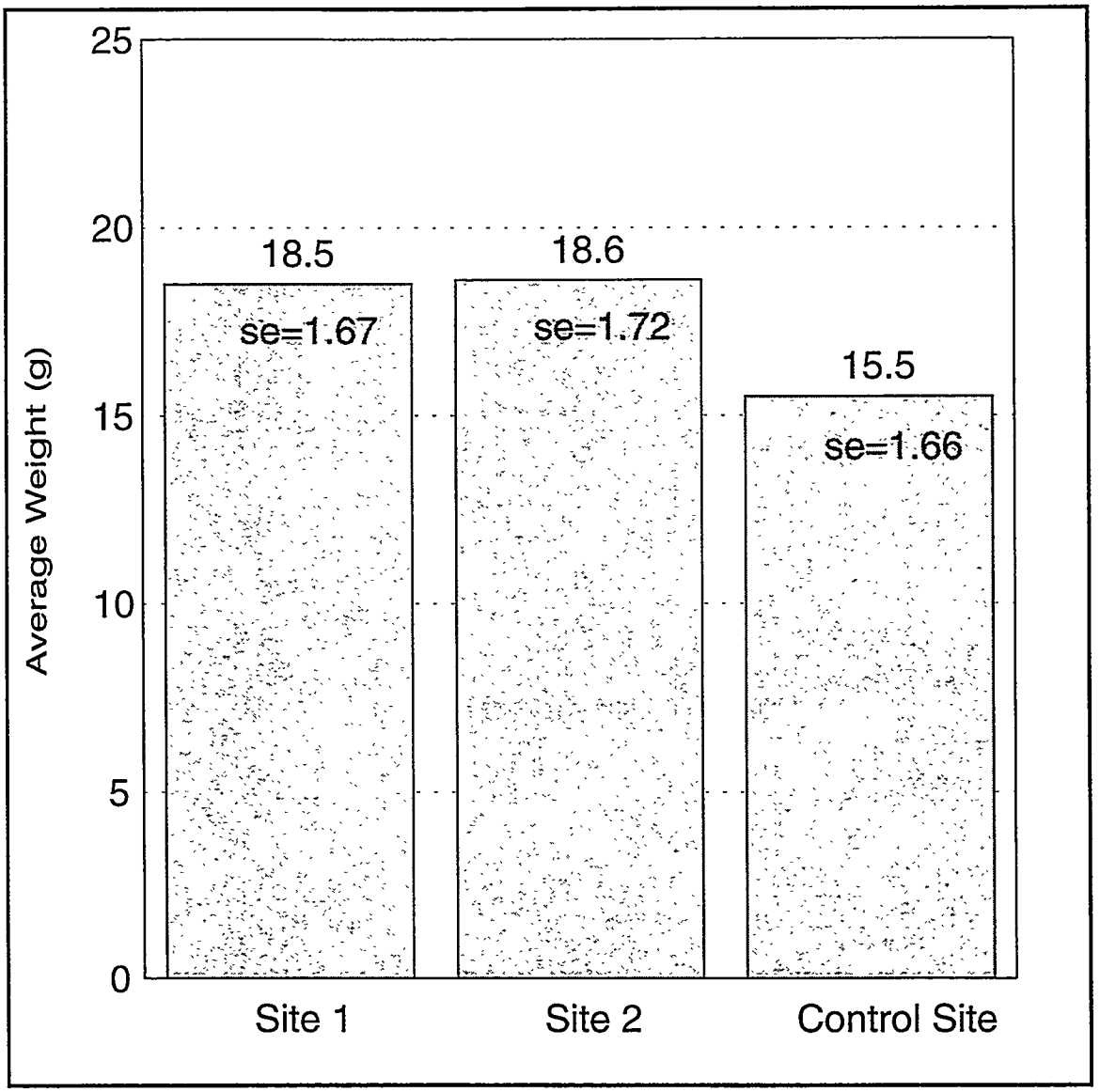


Figure 4. Average Weights For All Species Captured, 1995.

Radionuclide Analysis

Results of data analysis presented in this paper are for the radionuclides total U, ^{241}Am, ^{238}Pu, ^{239}Pu, ^{90}Sr, ^{137}Cs, and ^{3}H (Table 2).

Table 2. Summary of Analytical Results.

Month	*Yr*	*Sample Type*	*Site*	*Sample #*	*U µg/g ash*	*^{241}Am pCi/g ash*	*^{238}Pu pCi/g ash*	*^{239}Pu pCi/g ash*	*^{90}Sr pCi/g ash*	*^{137}Cs pCi/g ash*	*^{3}H pCi/L ash*
06	95	CARCASS	1	1	0.32 (0.03)[1]	0.031 (0.008)	0.011 (0.002)	0.013 (0.002)	1.5 (0.2)	0.07 (0.1)	68500 (3400)
06	95	CARCASS	1	2	0.27 (0.03)	0.02 (0.005)	0.012 (0.003)	0.03 (0.004)	0.5 (0.1)	0.25 (0.14)	185000 (9000)
06	95	CARCASS	1	3	0.59 (0.06)	0.028 (0.008)	0.017 (0.003)	0.029 (0.004)	1.7 (0.2)	0.59 (0.22)	122000 (6000)
06	95	CARCASS	2	1	0.33 (0.03)	0.019 (0.005)	0.045 (0.009)	0.023 (0.007)	0.8 (0.5)	0.4 (0.24)	50300 (2500)
06	95	CARCASS	2	2	0.4 (0.04)	0.107 (0.011)	0.014 (0.003)	0.095 (0.008)	1.4 (0.6)	0.09 (0.14)	3600 (600)
06	95	CARCASS	2	3	0.29 (0.03)	0.071 (0.01)	0.003 (0.003)	0.064 (0.007)	1.0 (0.3)	0.93 (0.33)	8200 (900)
06	95	CARCASS	4	1	1.27 (0.22)	0.009 (0.004)	0.001 (0.003)	0.005 (0.003)	1.5 (0.3)	0.38 (0.58)	300 (300)
06	95	CARCASS	4	2	0.39 (0.04)	0.006 (0.003)	0.004 (0.002)	0.007 (0.003)	1.5 (0.3)	0.92 (0.34)	500 (300)
06	95	CARCASS	4	3	0.46 (0.05)	0.032 (0.016)	0.015 (0.01)	0.003 (0.007)	1.9 (1.0)	5.5 (2.17)	200 (300)
06	95	[2]PELT	1	1	2.12 (0.21)	0.093 (0.021)	0.07 (0.01)	0.115 (0.012)	0.4 (0.4)	0.90 (0.48)	67900 (3400)
06	95	[2]PELT	1	2	.	.	.	.	.	.	67900 (3400)
06	95	[2]PELT	1	3	.	.	.	.	.	.	125000 (6000)
06	95	[2]PELT	2	1	0.9 (0.09)	0.148 (0.029)	0.049 (0.013)	0.226 (0.028)	0.4 (1.1)	0.92 (1.39)	5300 (700)
06	95	[2]PELT	2	2	.	.	.	.	.	.	2400 (500)
06	95	[2]PELT	2	3	.	.	.	.	.	.	8000 (900)
06	95	[2]PELT	4	1	1.77 (0.18)	0.152 (0.029)	0.008 (0.009)	0.16 (0.029)	2.2 (2.0)	3.91 (5.87)	200 (300)
06	95	[2]PELT	4	2	.	.	.	.	.	.	400 (300)
06	95	[2]PELT	4	3	.	.	.	.	.	.	0.0 (300)

[1]Analytical uncertainty (+/- 1SD) is shown in parentheses.
[2]Only one composite pelt sample was analyzed per site due to low total ashed weight of combined samples.

The mean concentration of each radionuclide found in carcasses and pelts by site is given in Tables 3 and 4, respectively, and shown in Figure 5. For most sites, the mean concentrations of radionuclides in carcasses were lower than the concentrations found in pelts for total U, ^{241}Am, ^{238}Pu, and ^{239}Pu. For the remaining radionuclides, concentrations in carcasses were usually nearly equal to or exceeded the mean concentrations in the pelts. An ANOVA test was used to

determine if the mean radionuclide concentrations in carcasses were different between sites, and Duncan's multiple range test was used to show where the differences occurred. The results are discussed below.

Table 3. Mean Radionuclide Concentrations for Small Mammal Carcass Samples.[a]

	SITE 1			SITE 2			SITE 4		
RADIONUCLIDE	N	Mean		N	Mean		N	Mean	
Total U	3	0.393		3	0.347		3	0.707	
^{241}Am	3	0.026		3	0.066		3	0.016	
^{238}Pu	3	0.013		3	0.021		3	0.007	
^{239}Pu	3	0.024		3	0.061		3	0.005	
^{90}Sr	3	1.233		3	1.067		3	1.633	
^{137}Cs	3	0.303		3	0.473		3	2.267	
^{3}H	3	125167		3	20700		3	333	

[a] Radionuclide concentrations for U are measured µg/g ash; ^{3}H are in pCi/L, all other contaminants are measured in pCi/g ash.

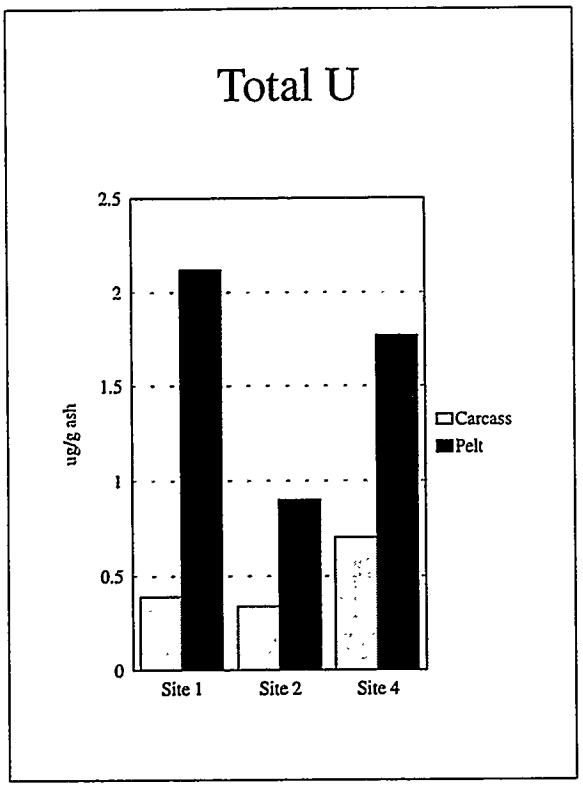
Table 4. Radionuclide Concentrations for Small Mammal Pelt Samples.[a]

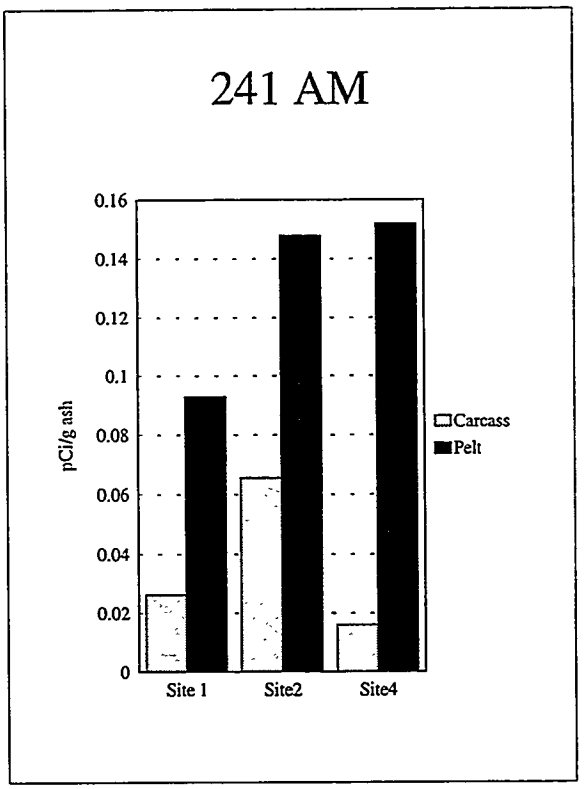
	SITE 1		SITE 2		SITE 4	
RADIONUCLIDE	N	CONCENTRATION	N	CONCENTRATION	N	CONCENTRATION
Total U	1	2.12	1	0.9	1	1.77
^{241}Am	1	0.093	1	0.148	1	0.152
^{238}Pu	1	0.07	1	0.049	1	0.008
^{239}Pu	1	0.115	1	0.226	1	0.16
^{90}Sr	1	0.4	1	0.4	1	2.2
^{137}Cs	1	0.9	1	0.92	1	3.91
^{3}H	3	86933	3	5233	3	200

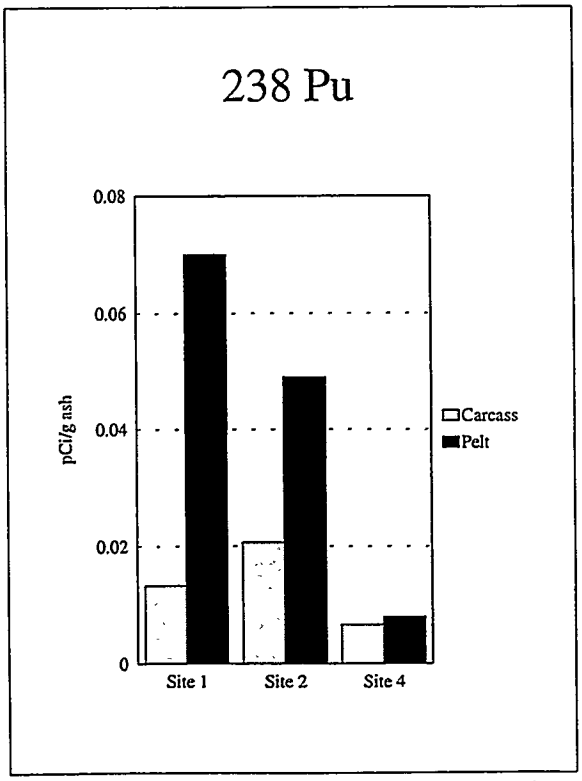
[a] Radionuclide concentrations for U are measured µg/g ash; ^{3}H are in pCi/L, all other contaminants are measured in pCi/g ash.

Total U

There were no significant differences (alpha 0.05) in total U in carcasses between Sites 1, 2, and 4 (F= 1.30, p=0.3399). However, Site 1 had significantly higher (alpha=0.05, P=0.0095) mean total U concentrations in carcasses than Sites 2 and 3 in 1994. Data pooled from 1994 and combined with 1995 did not find significant differences in mean total U concentrations between sites (1, 2, 3,and 4) (F= 3.14, p= 0.0591).







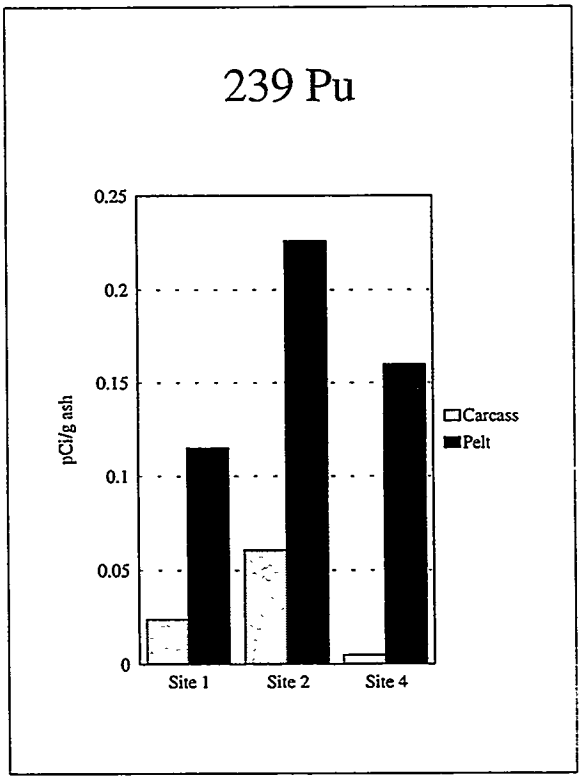
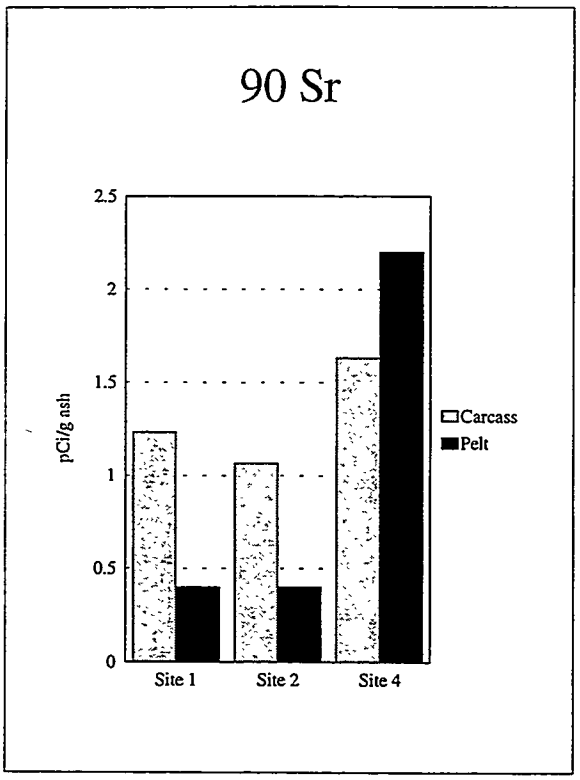
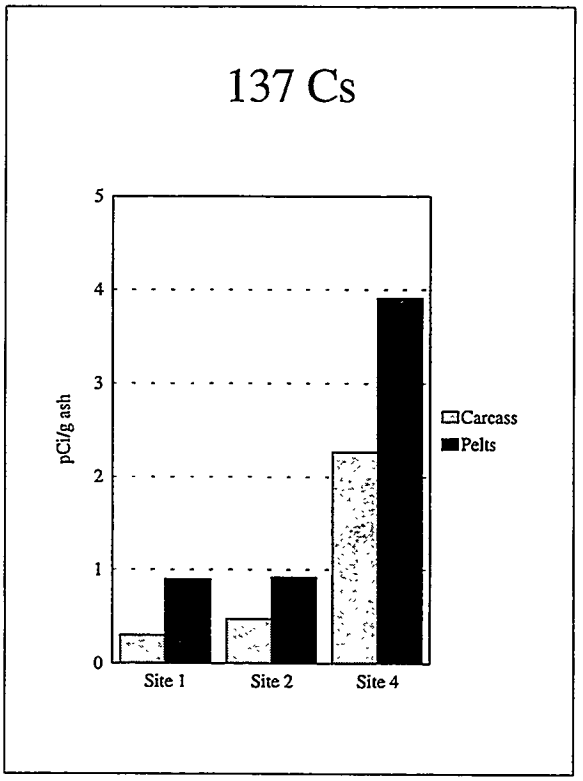


Figure 5. Mean Radionuclide Concentrations in Carcasses and Pelts.





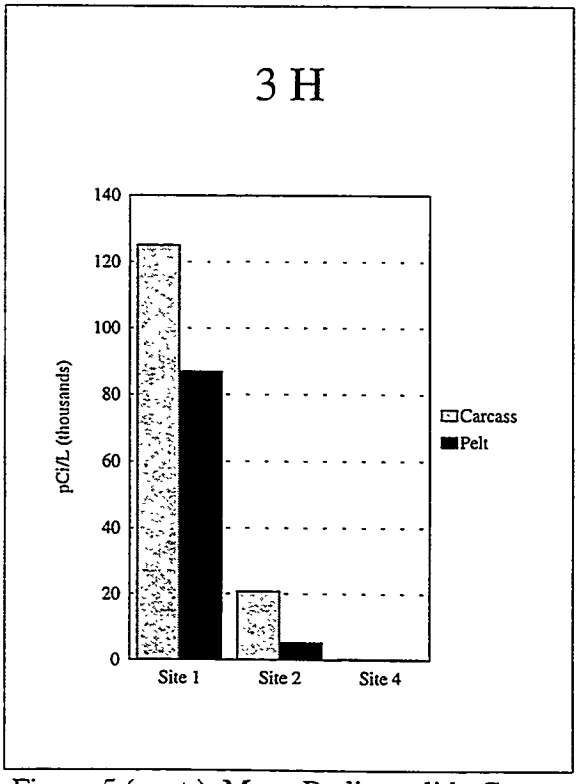


Figure 5 (cont.). Mean Radionuclide Concentrations in Carcasses and Pelts.

^{3}H

The mean concentration of ^{3}H was significantly higher at Site 1 than at Site 2 or Site 4 in both carcass ($F= 9.94$, $p = 0.0125$) and pelt ($F=19.49$, $p = 0.0024$). However, no statistical difference was detected between Site 2 and Site 4. ^{3}H analysis was not performed in 1994 so further comparisons are not possible.

^{239}Pu

There was a significant (alpha = 0.05) difference in the mean ^{239}Pu concentration in carcass between Sites 1, 2, and 4 ($F= 5.15$, $p = 0.0499$). The mean carcass concentration of ^{239}Pu was 2.5 times higher than Site 1 and 12 times higher than the control site, Site 4. Data from 1994 were similar. Pooled data from 1995 and 1994 revealed a significant difference in the mean ^{239} Pu concentration in carcasses between sites ($F= 9.55$, $p = 0.0011$). Site 2 had the highest concentration (0.0695 µg/g ash) and Site 3 had the lowest (0.0030 µg/g ash).

^{241}Am, ^{238}Pu, ^{137}Cs, and ^{90}Sr

There were no significant differences (alpha=0.05) in concentrations of ^{241}Am ($p = 0.135$), ^{238}Pu ($p = 0.4848$), ^{137}Cs ($p = 0.3385$), and ^{90}Sr ($p = 0.3251$) in rodent carcasses between sites. Data pooled from 1995 and 1994 samples showed no changes in statistical differences, with the exception of ^{241} Am. Mean concentrations of ^{241}Am were significantly different between sites ($F = 4.19$, $p = 0.0259$). Site 2 has significantly higher ^{90}Sr concentrations in rodent carcass than Sites 1, 3, or 4. No statistical difference was detected between Sites 1, 3, and 4.

Analysis was conducted on overall mean concentrations of radionuclides to determine if differences existed between pelts and carcasses (Figure 6). The analysis was not conducted by site because only one pelt sample per site was analyzed. For all sites combined, significant differences (alpha = 0.05) between pelt and carcass concentrations occurred for total U, ^{241}Am, ^{238}Pu, and ^{239}Pu, pelts being higher in all cases.

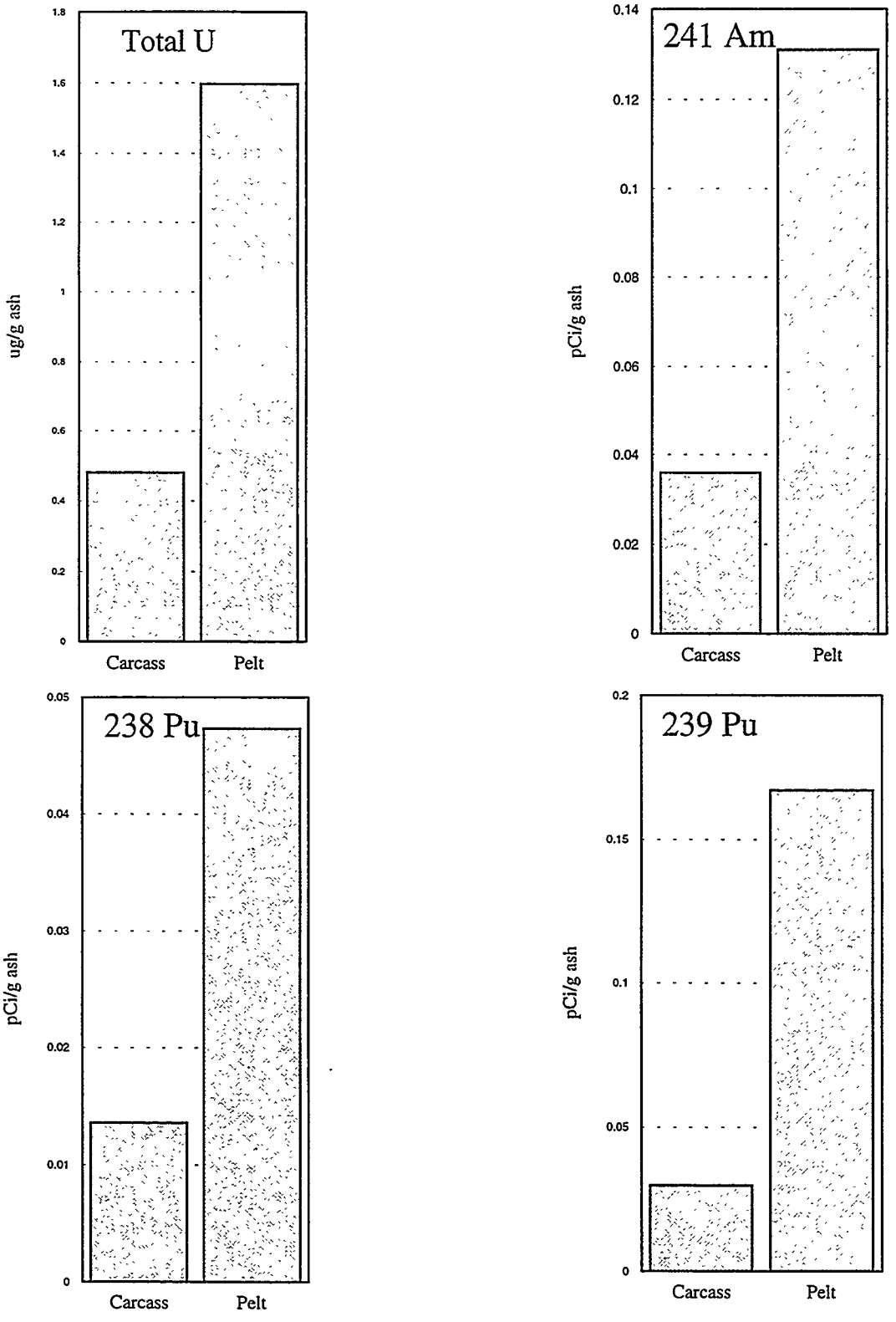


Figure 6. Overall Mean Contaminant Concentrations in Pelts and Carcasses.

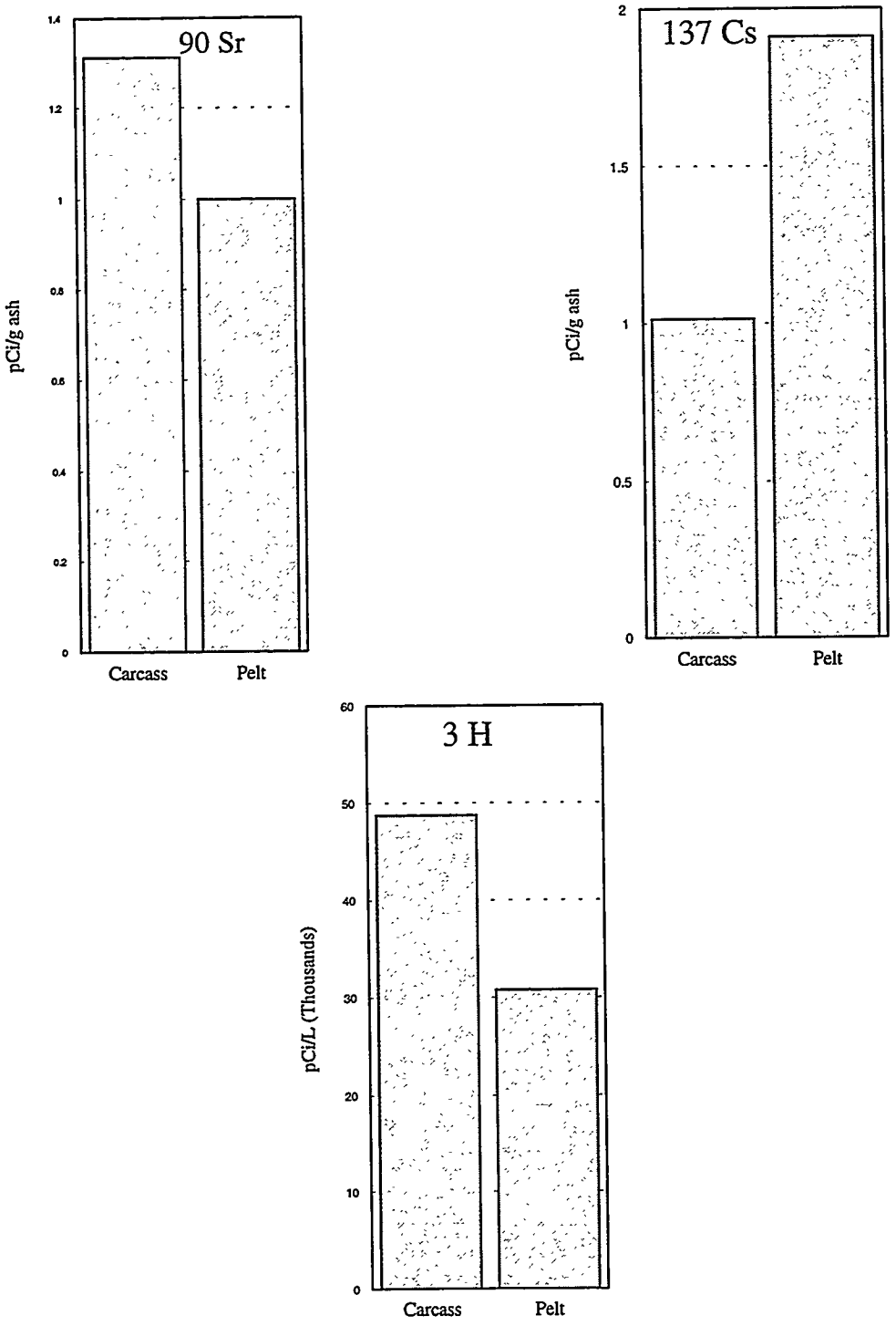


Figure 6 (cont.). Overall Mean Contaminant Concentrations in Pelts and Carcasses.

There were no significant differences in radionuclide measurements in our studies between pelts and carcasses for ^{90}Sr, ^{137}Cs, and ^{3}H.

DISCUSSION

This study was intended to establish baseline measurements of radionuclide concentrations in small mammals at Area G, TA-54, during the summer of 1995. The data can then be used to modify future studies at Area G to better identify radionuclide transport and concentration loads in and around the site.

As shown in Table 1, recorded densities of rodents for the two predisturbed sites within Area G were higher than the recorded densities for the undisturbed control site. Typically, at other predisturbed locations within Laboratory boundaries, small mammal densities have been higher than in undisturbed habitats. The low densities recorded for the control site are also typical of other trapping efforts conducted on mesa top habitats within Laboratory boundaries, especially within pinon pine/juniper woodlands. The primary species collected at Sites 1 and 2 was deer mice. Deer mice are a more "opportunistic" species compared to other mice expected to occur in the vicinity of Area G and are therefore more likely to invade and populate the disturbed sites.

Our studies generally showed greater amounts of radionuclides in the pelts of animals compared to the carcass. In studies conducted at waste burial sites or contaminated sites outside of the Laboratory, similar results were found. Markham et al. (1978) found higher concentrations of ^{238}Pu, ^{239}Pu, and ^{241}Am in the pelts and gastrointestinal tracts compared to the carcass and lungs. Studies conducted at the Idaho National Engineering Laboratory on waste disposal sites also showed that the highest concentrations of ^{238}Pu, $^{239+240}Pu$, ^{241}Am, ^{90}Sr, and ^{137}Cs were in pelt samples (Arthur et al. 1987).

Data pooled with 1994 Area G data showed total U to occur in significantly higher concentrations (in carcasses) at Site 1 compared to Sites 2, 3, and 4. In addition, mean concentrations of ^{3}H in both carcasses and pelts in 1995 were higher at Site 1. Also, Site 2 had higher concentrations of ^{239}Pu compared to Sites 1 or 4, and, when pooled with 1994 data, higher than Sites 1, 3, or 4. Total U concentrations in vegetation collected at Site 1 range from 0.81 to 0.86 μg/g ash (Fresquez et al. 1996) whereas concentrations in small mammal carcasses were less than 0.5 μg/g ash. Additional studies and further monitoring of these sites will more accurately assess if correlations exist between radionuclide concentrations in vegetation and rodents. This information coupled with determining the mode (surface contact, inhalation/ingestion) of contamination to the animal can help to identify potential pathways of contaminants in a particular plant/animal community by examining if radionuclides are ingested, inhaled, or picked up via surface contact. Additional studies that are currently being conducted elsewhere at the Laboratory, coupled with past data collected at the Laboratory, will be used to more closely examine the relationship between food habits of small mammals and radionuclide uptake via vegetation. Knowledge of densities, food habits, and population dynamics will also help to estimate contaminant loads within the biota at the waste site as well as potential transport off the site. The information can also be used to gain a better understanding of the distribution of radionuclides within the biotic community of Area G and its impact, if any, on biotic communities surrounding Area G.

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