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Kathryn D. Bennett
James R. Biggs
P. R. Fresquez

Los Alamos
NATIONAL LABORATORY
Los Alamos, New Mexico 87545

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RADIONUCLIDE CONTAMINANT ANALYSIS OF SMALL MAMMALS AT AREA G, TECHNICAL AREA 54, 1997

(with cumulative summary 1994–1997)

by

Kathryn D. Bennett, James R. Biggs, and P. R. Fresquez

ABSTRACT

In 1997, small mammals were sampled at four locations at Area G, Technical Area 54, a control site within the proposed Area G expansion area, and a background site on Frijoles Mesa. The purpose of the sampling was to (1) identify radionuclides that are present within rodent tissues at waste burial sites, (2) compare the amount of radionuclide uptake by small mammals at waste burial sites to a control site, and (3) identify the primary mode of contamination to small mammals, either through surface contact or ingestion/inhalation. Three composite samples of approximately 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. Higher levels of total U and ^{137}Cs were detected in pelts as compared to the carcasses of small mammals, and ^{90}Sr was found to be higher in carcasses. Concentrations of other measured radionuclides in carcasses were not found to be statistically different ($p < 0.05$) from that measured in pelts. However, pelts generally had higher concentrations than carcasses, indicating surface contamination may be the primary contamination mode. Low sample sizes in total number of animals captured during 1997 prevented statistical analysis to compare site to site to all but four sites. Mean concentrations of ^{241}Am, ^{238}Pu, ^{239}Pu, and ^{3}H in small mammal carcasses were found to be statistically greater at the transuranic (TRU) waste pad #2. In addition, mean concentrations of total U, ^{241}Am, and ^{3}H in pelts of small mammals were also statistically greater. The Control Site and Background Site consistently had the lowest mean concentrations of radionuclides. Year to year comparison of mean radionuclide concentrations was conducted where sufficient sample size existed. We found ^{241}Am, ^{238}Pu, ^{239}Pu, and ^{3}H mean concentrations in carcasses to be statistically greater in 1997 than previous years at TRU waste pad #2. However, mean concentrations of ^{137}Cs in small mammal carcasses were higher at the TRU waste pad #2 and Pits 17 and 18 during 1996.

INTRODUCTION

A solid, low-level radioactive waste disposal facility has been operating at Area G, Technical Area (TA) 54 at Los Alamos National Laboratory since 1957 and has been used to dispose of various wastes including tritium waste and transuranic (TRU) waste. The collection and analysis of small mammals at TA-54, Area G, was initiated in 1994 as part of the Enhanced Environmental Annual Surveillance program at Area G by the Environment, 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.

We selected six sites for small mammal trapping. The sites were correlated with vegetation sampling sites (Fresquez et al. 1997)(Figure 1, Table 1): tritium shafts (Site 1), active waste pits (Site 3), TRU waste pad #2 (Site 5), Pits 17 and 18 (Site 7), control site at the Area G expansion area (Site 8), and a background site northeast of the Bandelier National Monument entrance (Site 9). During the 1997 sampling, we adopted the site naming convention used for the vegetation sampling for the small mammal sites. Not all sites have been trapped throughout the sampling years. Sites 5 and 7 were trapped in 1994, 1995, 1996, and 1997. Site 8 was trapped in 1994, 1996, and 1997. We trapped Site 9 in 1995 and 1997. This is the second year of trapping at Site 1 and Site 3. A detailed description of methods used to trap, collect, and analyze rodents is given in Biggs et al. (1995) and Bennett et al. (1996). This report provides results of 1997 sampling and a cumulative summary from 1994–97.

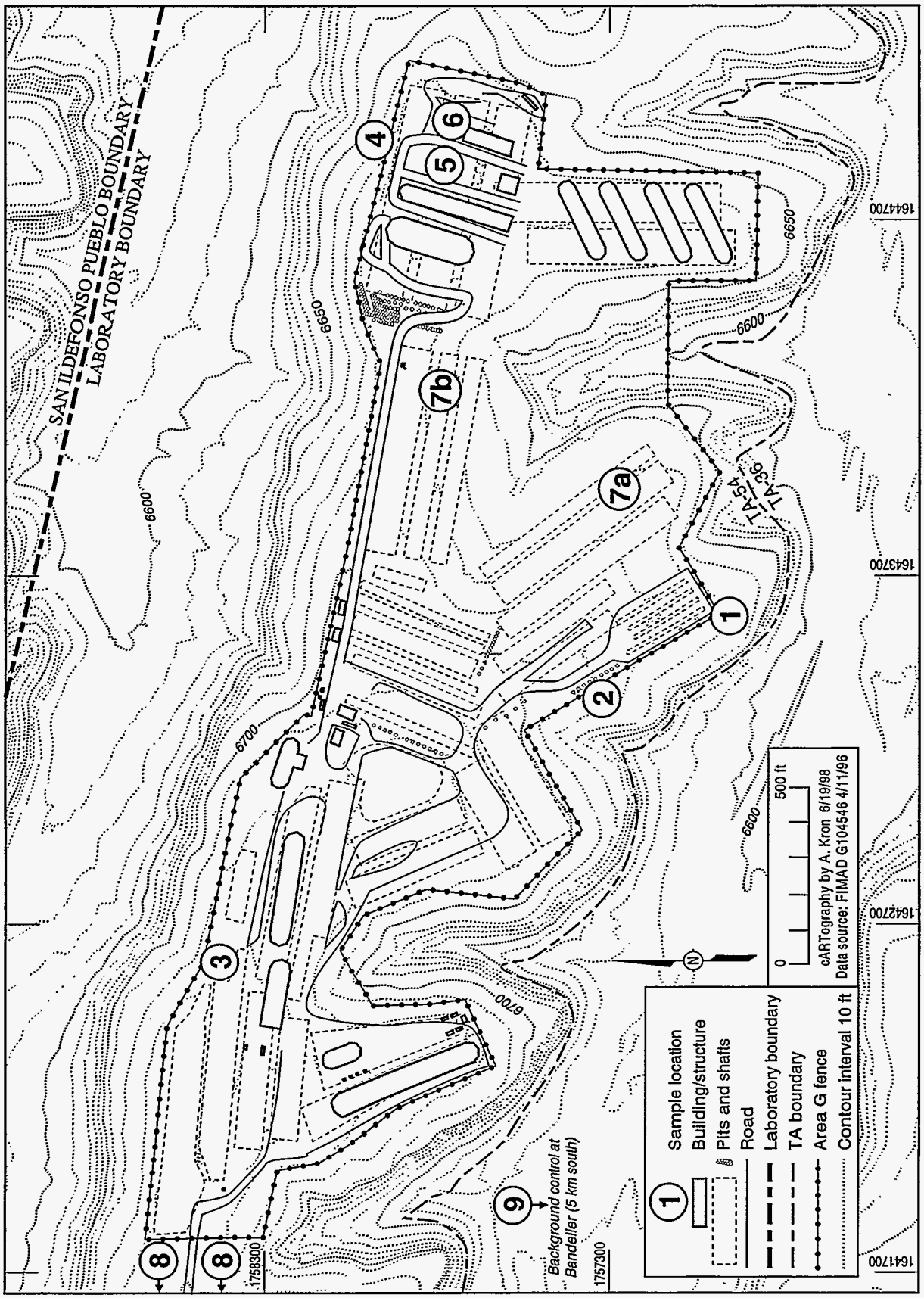


Figure1. Site/sample locations of soil and vegetation at Area G. Site #8 is located farther west and Site #9 is located farther south than what is shown here. Refer to Table 1 to correlate vegetation sampling sites to small mammal sampling sites.

Table 1. A Correlation of Small Mammal Sampling Sites to Vegetation Sampling Sites

1994 - 1996 Small Mammal Sampling Site Number	1997 Small Mammal Sampling Site Number	1994 and 1995 Veg. Sampling Site Number (Fresquez et al. 1996 and 1997)	1996 and 1997 Veg. Sampling Site Number (Fresquez et al. 1997 and 1998)
1	5	5, 6	5, 6
2	7		7
Control Site (Site 3)	8		8
Background (Site 4)	9	9	9
Tritium Shafts	1	1	1
Open Active Pits	3	3	3

RESULTS OF 1997 SAMPLING

Species Composition

Deer mouse (*Peromyscus maniculatus*) was the predominant small mammal species captured at Site 5 and Site 7. Harvest mice (*Reithrodontomys megalotis*) were also captured at Site 5 and Site 7 but in lesser numbers than deer mice. One pocket gopher (*Thomomys* spp.) was captured at Site 5 and one brush mouse (*Peromyscus boylii*) was captured at Site 7. Collection of small mammal samples was attempted at the Open Active Pits in the west portion of Area G and at the Tritium Shafts located along the south edge of Area G. Trapping success was very low at both locations. One deer mouse, brush mouse, and pinyon mouse (*Peromyscus trueii*) were the only small mammals captured around the Open Active Pits (Site 3) and the Tritium Shafts (Site 1). Pinyon mouse was the predominant small mammal captured at Site 8 (Control Site) and Site 9 (Background Site). Deer mouse and harvest mouse were also captured at Site 8 and Site 9. In addition, brush mouse was captured at Site 9, but not at Site 8.

Density Estimates

Site 7 had the highest density of animals followed by Site 5 (Table 2). Site 3 had the lowest density. The density of the trapping area for Sites 5 and 7 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 by the bait. Therefore the total effective trapping area is approximately 1.21 ha. Because of the low capture rates at Site 8 and Site 9, capture data from all three grids were pooled to estimate density. Since three grids were pooled for each

Table 2. Rodent Density Estimate of Area G (Sites 1, 3, 5, and 7), Control Site (Site 8), Background Site (Site 9)

SITE 1	**DAY**	**NO. OF CAPTURES**	**NO. OF TRAPS**
	1	4	100
	2	1	100
	3	0	100
	4	0	100
DENSITY (# animals/ha)	5.2 se = 0.1		
95% CONFIDENCE INTERVAL	Lower 95% Limit = 5.0	Upper 95% Limit = 5.4	
SITE 3	**DAY**	**NO. OF CAPTURES**	**NO. OF TRAPS**
	1	2	100
	2	0	100
	3	0	100
	4	0	100
DENSITY (# animals/ha)	2.2 se = 0.1		
95% CONFIDENCE INTERVAL	Lower 95% Limit = 2.1	Upper 95% Limit = 2.3	
SITE 5	**DAY**	**NO. OF CAPTURES**	**NO. OF TRAPS**
	1	7	300
	2	2	300
	3	1	300
	4	1	300
DENSITY (# animals/ha)	10.2 se = 0.4		
95% CONFIDENCE INTERVAL	Lower 95% Limit = 9.5	Upper 95% Limit = 10.9	
SITE 7	**DAY**	**NO. OF CAPTURES**	**NO. OF TRAPS**
	1	6	100
	2	4	100
	3	2	100
	4	3	100
DENSITY (# animals/ha)	19.6 se = 4.0		
95% CONFIDENCE INTERVAL	Lower 95% Limit = 11.0	Upper 95% Limit = 32.3	
SITE 8	**DAY**	**NO. OF CAPTURES**	**NO. OF TRAPS**
	1	3	300
	2	2	300
	3	1	300
	4	6	300
DENSITY (# animals/ha)	7.7 se = 0.6		
95% CONFIDENCE INTERVAL	Lower 95% Limit = 6.5	Upper 95% Limit = 9.0	
SITE 9	**DAY**	**NO. OF CAPTURES**	**NO. OF TRAPS**
	1	2	300
	2	2	300
	3	2	300
	4	2	300
DENSITY (# animals/ha)	4.9 se = 1.9		
	Lower 95% Limit = 1.1	Upper 95% Limit = 8.6	

site to estimate density, the total effective trapping area is approximately 100m by 100 m multiplied by three grids plus a 5-m boundary strip for each of the three grids. Therefore, the total effective trapping area is 3.63 ha. Table 2 gives the number of animals per hectare of each site sampled after adjustment for the total effective trapping area.

Species Weights (Biomass)

The average weight of all species combined and a biomass estimate (average weight ↔ density) were calculated for each site trapped (Table 3). Site 7 had the greatest biomass with Site 3 having the smallest.

Table 3. Average Weights, Densities, and Biomass Estimates for Area G (Sites 1, 3, 5, and 7), the Control Site (Site 8), and Background Site (Site 9)

Sample Location	Average Weight (grams)	Density Estimate (#/ha)	Biomass Estimate (grams/ha)
Site 1	24.9 (se = 4.26)	5.2	129
Site 3	28.0 (se = 9.00)	2.2	62
Site 5	20.8 (se = 2.77)	10.86	226
Site 7	18.47 (se = 4.07)	19.6	362
Site 8	20.76 (se = 2.77)	7.7	160
Site 9	22.88 (se = 3.13)	4.9	112

Radionuclide Analysis

A summary of radionuclide analysis on pelt and carcass samples is given in Table 4. Only the major isotopes of concern are summarized. Statistically different mean concentrations of total U (t-test, t = -4.5918, p = 0.0005) and ^{137}Cs (t-test, t = -3.2112, p = 0.0074) were detected between pelt and carcass small mammal samples with pelts showing the higher concentrations. A significant difference was also detected in the mean concentration of ^{90}Sr between carcasses and pelts (t-test, t = 5.3483, p = 0.0001). Carcasses had the higher concentration as expected. Mean concentration of other radionuclides in carcasses were not found to be statistically different (alpha = 0.05) from that measured in pelts. To further analyze data, a General Linear Model (GLM) was used to determine if the mean radionuclide concentra-

Table 4. Summary of Radionuclide Analysis of Small Mammal Pelts and Carcasses, 1997

DATE	SAMPLE	SITE	SAMPLE NUMBER[1]	U (μg/g)[4]	^{241}AM (pCi/g)[4]	^{238}PU (pCi/g)[4]	^{239}PU (pCi/g)[4]	^{137}CS (pCi/g)[4]	^{3}H (pCi/l)[5]
06/97	CARCASS	1	603-1C	0.23 (0.02)[2]	0.2508 (0.0131)	0.0086 (0.0023)	0.0723 (0.0062)	0.38 (0.10)	18570000 (500000)
06/97	CARCASS	3	606-3C	0.39 (0.04)	0.2392 (0.0255)	0.0018 (0.0036)	0.0823 (0.0106)	0.91 (0.18)	12800 (1300)
06/97	CARCASS	5	603-5C	0.22 (0.02)	183.60 (6.67)	1.5796 (0.0495)	50.7918 (1.4206)	< 0.10 (0.00)	5870000 (160000)
06/97	CARCASS	5	604-5C	0.18 (0.02)	43.3714 (1.7081)	0.3783 (0.0357)	10.5499 (0.4900)	0.76 (0.19)	3335000 (91000)
06/97	CARCASS	5	605-5C	0.61 (0.06)	76.2940 (4.0381)	0.7281 (0.0246)	21.0810 (0.6016)	< 0.18 (0.00)	5380000 (150000)
06/97	CARCASS	7	603-7C	0.19 (0.02)	0.0901 (0.0080)	0.0100 (0.0016)	0.0680 (0.0044)	0.21 (0.07)	403000 (12000)
06/97	CARCASS	7	604-7C	0.20 (0.02)	0.0956 (0.0127)	0.0013 (0.0019)	0.0608 (0.0062)	0.33 (0.14)	19700 (1600)
06/97	CARCASS	7	605-7C	0.24 (0.02)	0.0643 (0.0097)	0.0120 (0.0027)	0.0417 (0.0048)	0.64 (0.15)	53500 (2700)
06/97	CARCASS	8	604-8C	0.30 (0.03)	0.0780 (0.0181)	0.0164 (0.0026)	0.0193 (0.0026)	< 0.19 (0.00)	820 (690)
06/97	CARCASS	8	606-8C	0.17 (0.02)	0.0142 (0.0029)	0.0010 (0.0010)	0.0077 (0.0021)	< 0.20 (0.00)	550 (680)
06/97	CARCASS	8	610-8C	0.20 (0.02)	0.0314 (0.0061)	-0.0001 (0.0010)	0.0049 (0.0019)	< 0.19 (0.00)	620 (680)
06/97	CARCASS	9	610-9C	0.19 (0.02)	0.0047 (0.0035)	0.0108 (0.0021)	0.0062 (0.0016)	< 0.09 (0.00)	340 (660)
06/97	CARCASS	9	618-9C	0.12 (0.01)	0.0742 (0.0120)	-0.0003 (0.0024)	0.0172 (0.0040)	0.68 (0.16)	690 (690)
06/97	CARCASS	9	619-9C	0.02 (0.01)	0.0096 (0.0072)	-0.0001 (0.0014)	0.0049 (0.0027)	< 0.18 (0.00)	410 (670)
06/97	PELT	1	603-1P	1.24 (0.12)	3.5241 (0.3126)	0.1032 (0.0209)	0.6817 (0.0594)	< 0.92 (0.00)	13600000 (370000)
06/97	PELT	3	603-3P	1.91 (0.19)	0.6357 (0.2485)	-0.0639 (0.0943)	0.1324 (0.0943)	4.80 (1.72)	NA[3]
06/97	PELT	5	603-5P	1.90 (0.19)	899.3779 (46.4050)	5.3534 (0.2637)	162.034 (6.897)	3.11 (0.79)	3075000 (84000)
06/97	PELT	5	604-5P	1.88 (0.19)	975.8168 (50.4967)	7.2433 (0.3760)	206.147 (9.4612)	< 1.51 (0.00)	2520000 (70000)
06/97	PELT	5	605-5P	1.96 (0.20)	31.6746 (2.2138)	0.1576 (0.0361)	3.3243 (0.2400)	15.1 (2.6)	123800 (4800)
06/97	PELT	7	603-7P	1.18 (0.12)	0.3006 (0.0399)	0.0123 (0.0059)	0.1131 (0.0143)	< 1.28 (0.00)	330000 (10000)
06/97	PELT	7	604-7P	1.45 (0.15)	3.8867 (0.3234)	0.0532 (0.0165)	1.1967 (0.0854)	2.74 (0.86)	11100 (1200)
06/97	PELT	7	605-7P	1.01 (0.10)	0.3201 (0.0629)	0.2920 (00333)	0.3511 (0.0369)	< 2.30 (0.00)	43000 (2400)
06/97	PELT	8	604-8P	0.97 (0.10)	0.4550 (0.0853)	0.0010 (0.0124)	0.0735 (0.0230)	< 1.77 (0.00)	1190 (720)
06/97	PELT	8	606-8P	0.43 (0.04)	0.2261 (0.0604)	-0.0084 (0.0133)	0.0808 (0.0312)	< 2.71 (0.00)	240 (660)
06/97	PELT	8	610-8P	0.88 (0.09)	0.2712 (0.0580)	0.0078 (0.0202)	0.1009 (0.0281)	3.05 (0.91)	400 (670)
06/97	PELT	9	610-9P	0.24 (0.02)	0.2196 (0.2020)	0.220 (0.0255)	0.0770 (0.0367)	4.93 (1.75)	100 (650)
06/97	PELT	9	618-9P	0.30 (0.03)	0.6530 (0.1811)	-0.0227 (0.0319)	0.0707 (0.0463)	< 3.32 (0.00)	140 (650)
06/97	PELT	9	619-9P	0.26 (0.03)	0.3513 (0.0938)	0.0132 (0.0233)	0.4726 (0.0816)	< 3.89 (0.00)	450 (610)

[1] Only one composite pelt and carcass sample for Site 1 and Site 3 and only two composites pelt samples for Site 9 were analyzed because of low total ashed weight of combined samples.
[2] Analytical uncertainty (+/- 1SD) is shown in parentheses.
[3] Insufficient sample for H3 analysis
[4] Ashed material.
[5] Tissue moisture.

tions in carcasses and pelts were different between sites, and Duncan's multiple range test (MRT) was used to show where the differences occurred. However, because of low sample sizes, only Sites 5, 7, 8, and 9 were included in the 1997 site analysis. Table 5 provides a summary of the statistical analysis. Mean concentrations of ^{238}Pu, ^{239}Pu, ^{241}Am, and ^{3}H in small mammal carcasses were found to be statistically greater at Site 5 than at Sites 7, 8, and 9. In addition, pelts were also found to have a statistically greater mean concentration of total U, ^{241}Am, and ^{3}H at Site 5.

Table 5. Summary of the GLM and MRT for Mean Radionuclide Concentrations in Small Mammal Pelt and Carcass Samples between Sites

Radionuclide	Carcass	Pelt
Total U	NS (f = 1.94, p = 0.2117)	S (f = 44.91, p = 0.0001) Site 5 > 7 > 8 > 9
^{241}Am	S (f = 25.17, p = 0.0004) Site 5 > 7, 8, 9	S (f = 4.40, p = 0.0417) Site 5 > 7, 8, 9
^{238}Pu	S (f = 18.61, p = 0.0010) Site 5 > 7, 8, 9	NS (f = 3.95, p = 0.0533)
^{239}Pu	S (f = 17.17, p = 0.0013) Site 5 > 7, 8, 9	NS (f = 4.02, p = 0.0513)
^{90}Sr	NS (f = 0.68, p = 0.5903)	NS (f = 3.15, p = 0.0864)
^{137}Cs	NS (f = 0.54, p = 0.6721)	NS (f = 0.86, p = 0.4980)
^{3}H	S (f = 32.38, p = 0.0002) Site 5 > 7, 8, 9	S (f = 4.20, p = 0.0464) Site 5 > 7, 8, 9

NS = No statistical difference detected; S = Statistical difference detected.
Sites with a comma separation were not different from each other.

CUMULATIVE SUMMARY

Species Composition

Monitoring species composition over time may provide information about changes in the small mammal community that could be related to operations occurring at Area G. No large differences in species composition were observed from a comparison of year-to-year data from Sites 5 and 7 from 1994 – 1996 (Figure 2). However, in 1997 two additional species were captured at Site 5 (pocket gopher and harvest mouse), and one new species was captured at Site 7 (brush mouse). The control and background sites (Site 8 and Site 9) had similar species composition over the last four years with some minor changes year to year. The captures of two additional species (brush mouse, pocket mouse) occurred in 1995 at the Control Site and brush mouse was again captured at that site in 1997. The very small capture rate at Site

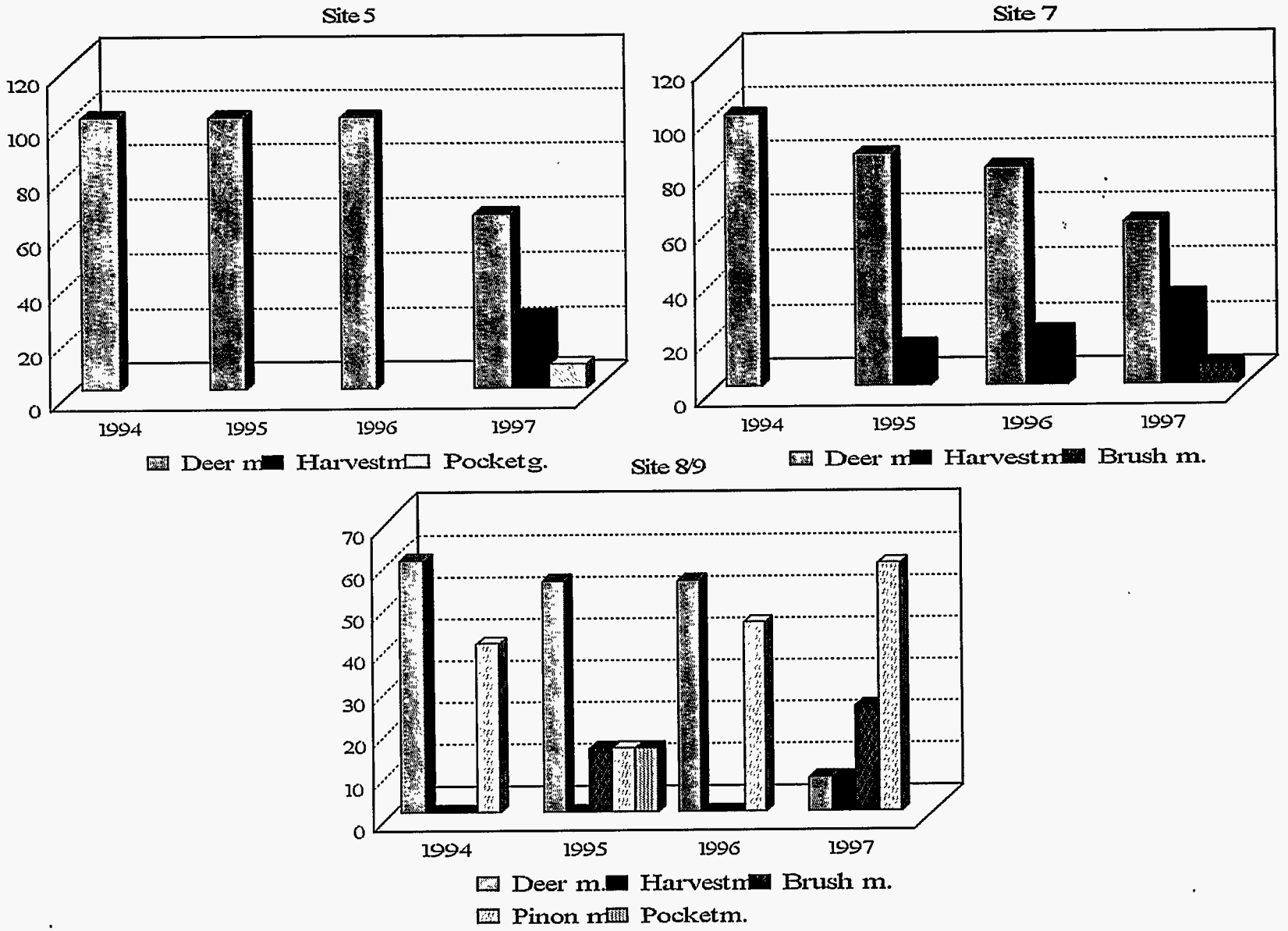


Figure 2. Relative species composition for Area G Sites 5 and 7 and Background (Site 9)/Control Site (Site 8), 1994-1997.

1 and Site 3 prevented a year-to-year comparison.

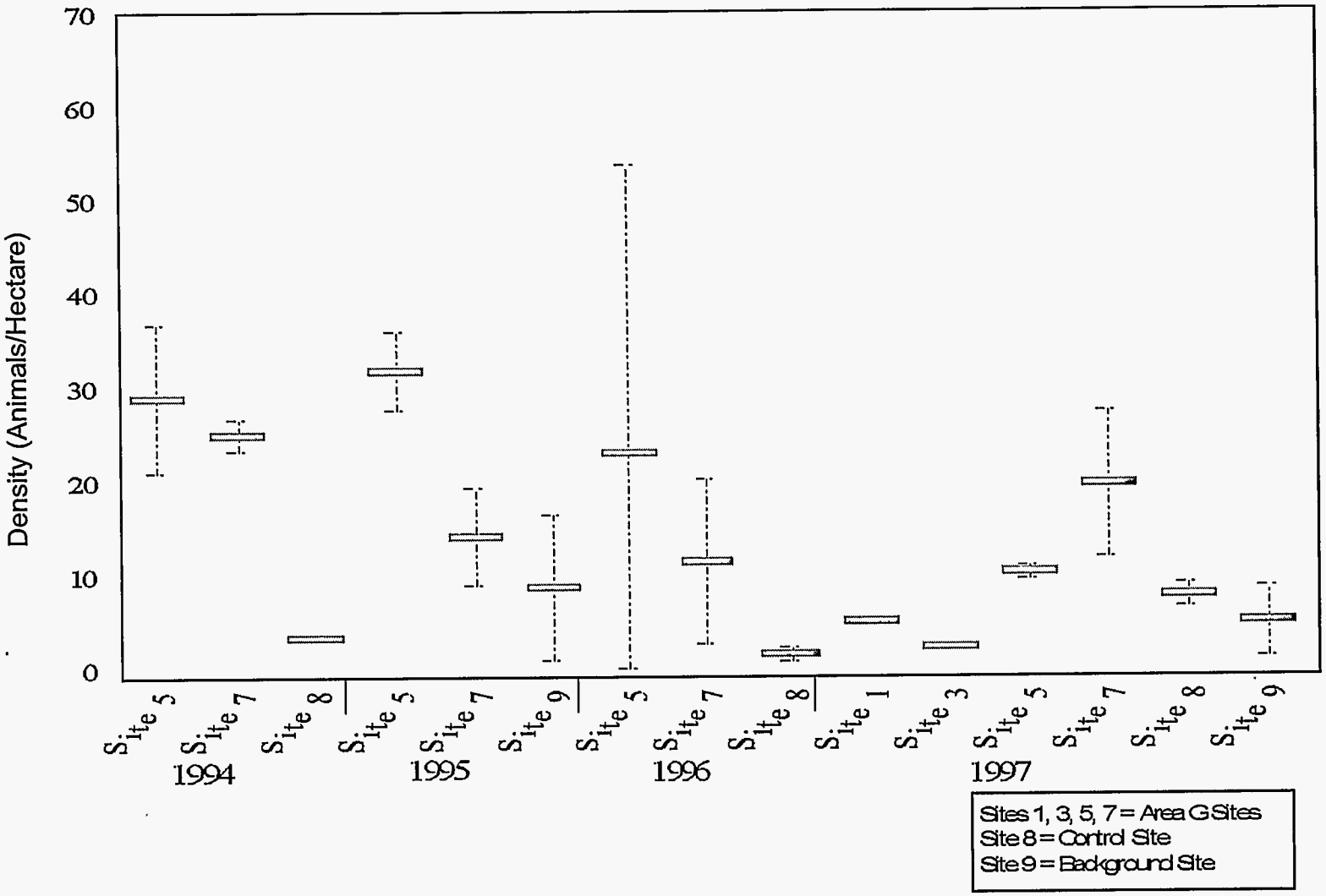
Density and Biomass Estimates

Monitoring density and biomass over time can also provide information as to changes in the small mammal community that could be related to operations occurring at Area G. In addition, this information is needed for ecological risk models. Density estimations were made for each year of sampling using Leslie's regression method (Seber 1982). Confidence intervals were calculated at 95% using the general method (Seber 1982). Biomass estimates were estimated for each year of sampling by multiplying the density estimate by the mean weight. The biomass is a product of two random variables; therefore we selected Goodman's estimator for variance (Goodman 1960). We calculated confidence intervals of 95%.

There are only slight changes in the density (Figure 3) and biomass (Figure 4) of small mammals at each of the sampled sites from year to year. However, the density and biomass of small mammals remains greater from year to year at the Area G sampling locations compared to the Control Site or Background Site.

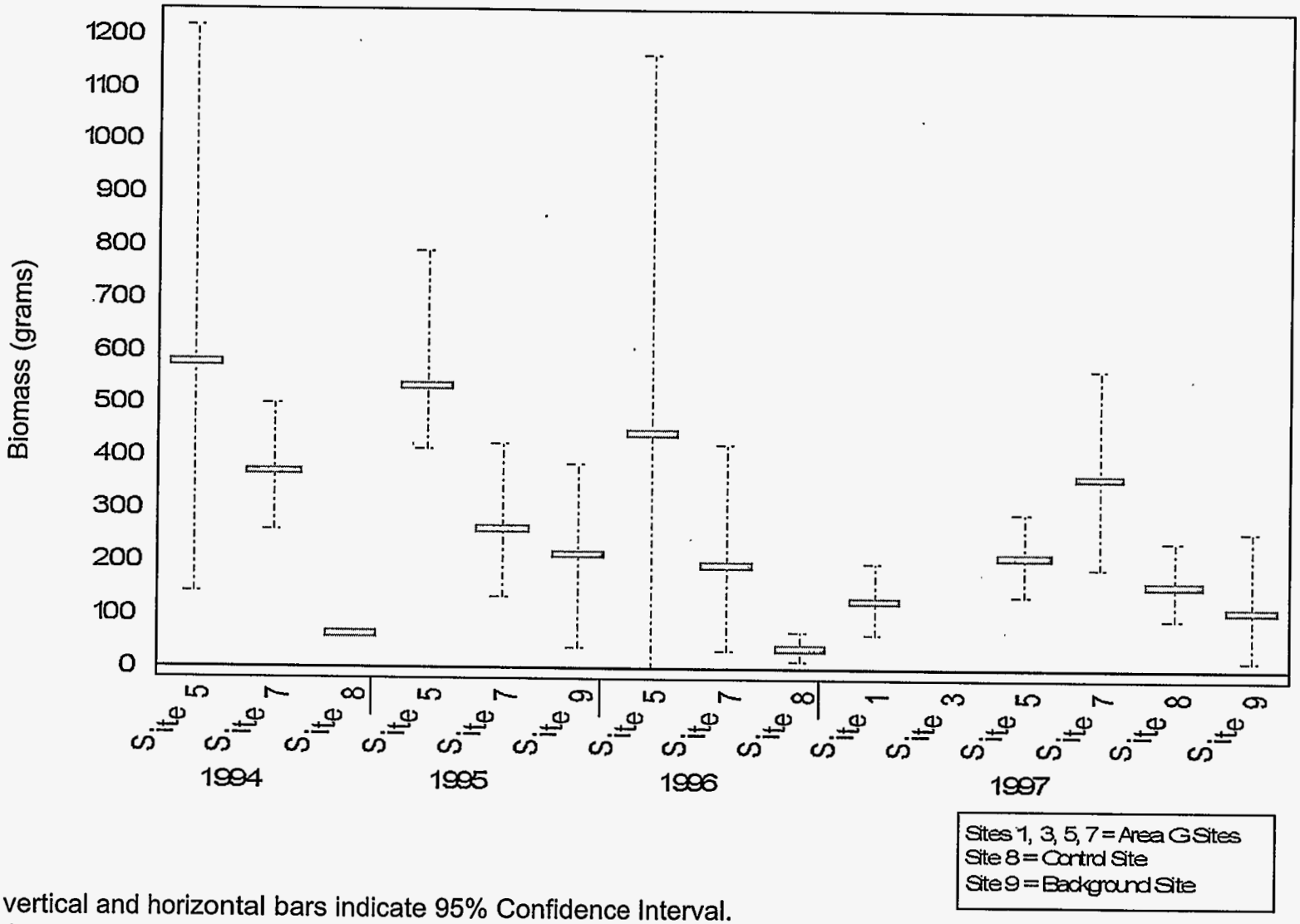
Mean Radionuclide Concentrations for Carcasses

We used a GLM and MRT to test for statistical differences in mean concentration of radionuclides at the sites between years. Because of insufficient sample size, Sites 5, 7, and 8 were the only sites evaluated. Some mean radionuclide concentrations in small mammal carcass were found to be statistically different (alpha = 0.05) between years at the same site. At Site 5, we found carcass mean concentrations of ^{241}Am, ^{238}Pu, ^{239}Pu, and ^{3}H to be statistically greater in 1997 than previous years (Table 6). However, ^{137}Cs was highest at Site 5 in 1996, and Site 7 concentrations were higher in 1996 and 1995 compared to 1997 and 1994. Figure 5 shows graphical plots of mean radionuclide concentrations by year at each site.



Dashed vertical and horizontal bars indicate 95% Confidence Interval.
Solid horizontal bars indicate the density estimate.

Figure 3. Rodent density by site and year.



Dashed vertical and horizontal bars indicate 95% Confidence Interval.
Solid horizontal bars indicate the biomass estimate.

Figure 4. Biomass estimate for Area G, Control, and Background Sites.

Table 6. Summary of GLM and MRT for Mean Radionuclide Concentrations in Carcasses of Small Mammals at Each Site Between Years

Radionuclide	Site 5	Site 7	Site 8
Total U	NS	NS	NS
^{241}Am	S (p = 0.0219) 1997 > 1996, 1995, 1994	NS	NS
^{238}Pu	S (p = 0.0291) 1997 > 1996,1995,1994	NS	NS
^{239}Pu	S (p = 0.0285) 1997 > 1996, 1995, 1994	NS	NS
^{137}Cs	S (p = 0.0028) 1996 > 1997, 1995, 1994	S (p = 0.0334) 1996, 1995 > 1997, 1994	S (p = 0.0177) 1996 > 1997, 1995, 1994
^{90}Sr	*	*	*
^{3}H	S (p = 0.0004) 1997 > 1996, 1995, 1994	NS	*

NS = No Stastistcal difference detected; S = Statistical difference detected.
Years with a comma separation were not different from each other.
* = Insufficient data to perform analysis.

Mean Radionuclide Concentrations for Pelts

At Site 5, 241Am, 238Pu, 239Pu, and 3H mean concentrations showed a sharp rise in 1997 compared to the previous years (Figure 6). However, samples sizes were too small to test for statistical differences. All other mean radionuclide concentrations were similar to previous years, and in some cases, 1997 concentrations were lower than previous years. In addition, pelts tended to have overall higher concentrations than carcasses indicating surface contamination may be a primary contamination mode. More data are required to perform further analysis.

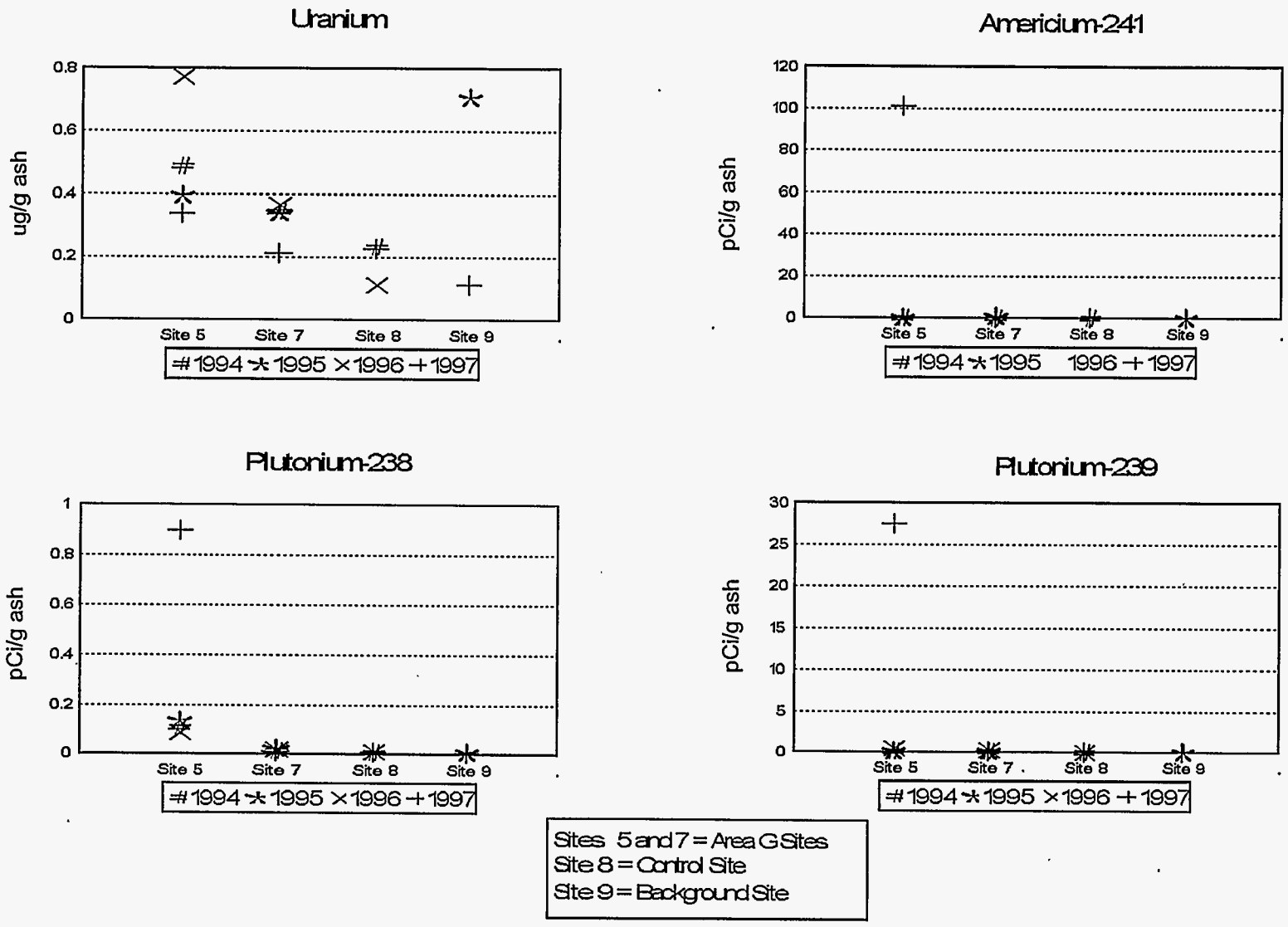


Figure 5. Radionuclide concentrations in rodent carcasses, 1994-1997.

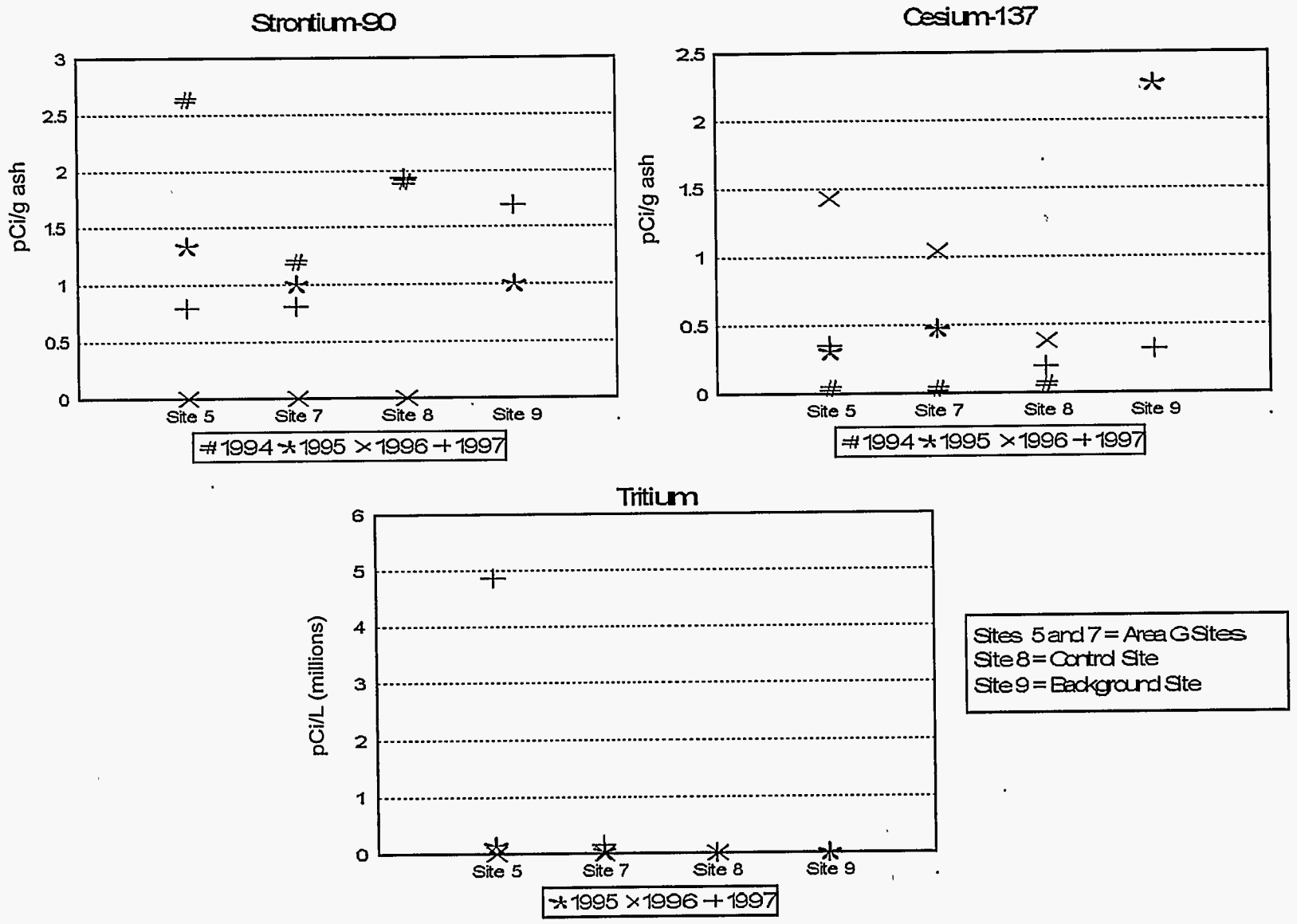


Figure 5 (cont.). Radionuclide concentrations in rodent carcasses, 1994-1997.

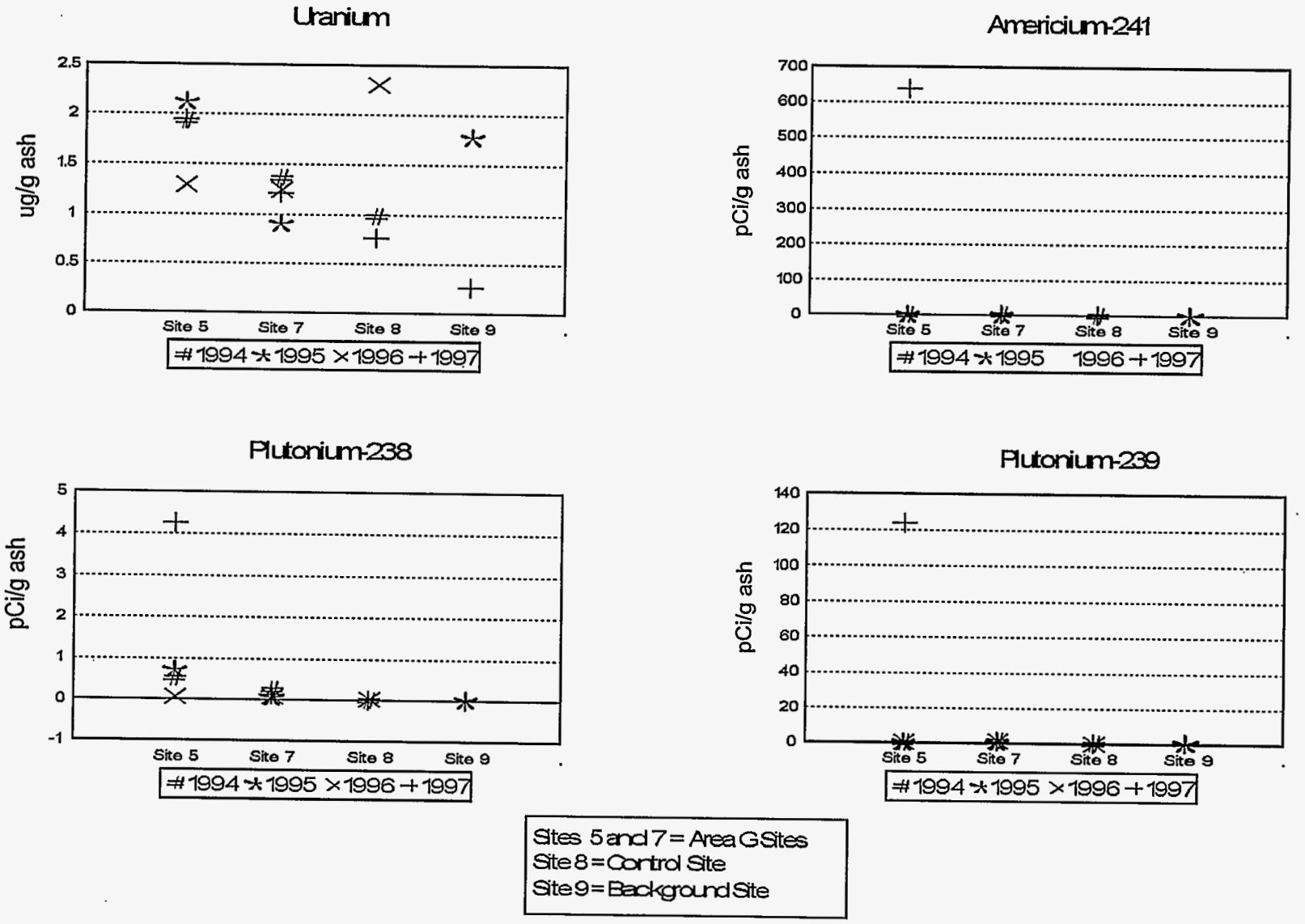


Figure 6. Radionuclide concentrations in rodent pelts, 1994-1997.

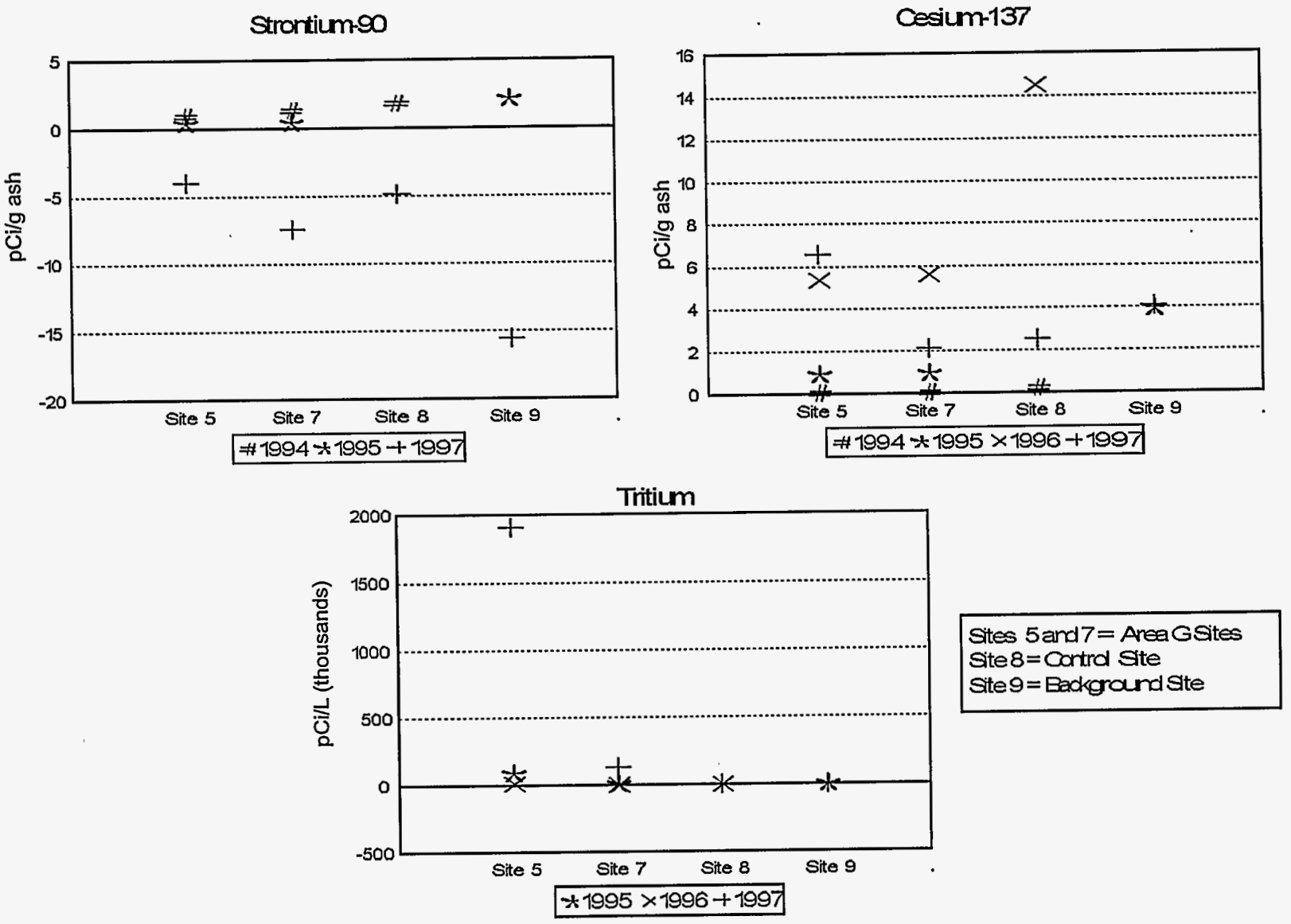


Figure 6 (cont.). Radionuclide concentrations in rodent pelts, 1994-1997.

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REFERENCES

Bennett, K. D., J. R. Biggs, and P. R. Fresquez, "Radionuclide Contaminant Analysis of Small Mammals at Area G, TA-54, 1995," Los Alamos National Laboratory report LA-13242-MS (1996).

Biggs, J. R., K. D. Bennett, and P. R. Fresquez, "Radionuclide Contaminant Analysis of Small Mammals at Area G, TA-54, 1994," Los Alamos National Laboratory report LA-13015-MS (1995).

Goodman, L. A., "On the Exact Variance of Products," J. of Am. Stat. Assoc. **55**:708–713 (1960).

Fresquez, P. R., R. J. Wechsler, and L. Naranjo, "Radionuclide Concentrations in Soils and Vegetation at Low-Level Radioactive Waste Disposal Area G during the 1997 Growing Season," Los Alamos National Laboratory report LA-13495-PR (1998).

Fresquez, P. R., E. L. Vold, and L. Naranjo, "Radionuclide Concentrations in Soils and Vegetation at Low-Level Radioactive Waste Disposal Area G during the 1996 Growing Season," Los Alamos National Laboratory report LA-13332-PR (1997).

Fresquez, P. R., E. L. Vold, and L. Naranjo, "Radionuclide Concentrations in Soils and Vegetation at Low-Level Radioactive Waste Disposal Area G during the 1995 Growing Season," Los Alamos National Laboratory report LA-13124-PR (1996).

Seber, G. A., *The Estimation of Animal Abundance and Related Parameters,* second edition, (Charles Griffin and Co., London 1982).