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Edited by Hector Hinojosa, Group IRM-CAS

Front cover: Left to right: MacGilivray's warbler (*Oporornis tolmiei*), Wilson's warbler (*Wilsonia pusilla*), and mountain chickadee (*Poecile gambeli*) captured at the DARHT facility.

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BIRD SURVEYS AT DARHT BEFORE AND DURING OPERATIONS: COMPARISON OF SPECIES ABUNDANCE AND COMPOSITION AND TRACE ELEMENT UPTAKE

by

P. R. Fresquez, D. C. Keller, and C. D. Hathcock

ABSTRACT

The Dual-Axis Radiographic Hydrodynamic Test (DARHT) Facility Mitigation Action Plan specifies the comparison of baseline conditions in biotic and abiotic media with those collected after operations have started. Operations at DARHT at Los Alamos National Laboratory started in 2000. In this study, the abundance and composition of birds collected near the DARHT facility from 2003 through 2006 were determined and compared to a preoperational period (1999). In addition, the levels of radionuclides and other inorganic chemicals in birds were compared to regional statistical reference levels (RSRLs). The number and diversity of bird species generally increased over preoperational levels with the greatest number of birds (412) and species (46) occurring in 2005. The most common bird species collected regardless of time periods were the chipping sparrow (*Spizella passerina*), the Virginia's warbler (*Vermivora virginiae*), the western bluebird (*Sialia mexicana*), the broad-tailed hummingbird (*Selasphorus platycercus*), the sage sparrow (*Amphispiza belli*), and the western tanager (*Piranga ludoviciana*). Most radionuclides, with the exception of uranium-234 and uranium-238, in (whole body) birds collected after operations began were either not detected or below RSRLs. Uranium-234 and uranium-238 concentrations in a few samples were far below screening levels and do not pose a potential unacceptable dose to the birds. In contrast, many inorganic chemicals, particularly arsenic and silver, in birds collected before and after operations began were in higher concentrations than RSRLs. Because birds (skin plus feathers) collected in the years before operations began contained higher levels of arsenic and silver than RSRLs and because there was no evidence of these metals in soil and sediment directly around the DARHT facility, the elevated levels of these metals in birds during early operations are probably not related to DARHT operations. Arsenic and silver in birds, however, have decreased over time to near background levels in 2007.

1. INTRODUCTION

The U.S. Department of Energy (DOE) prepared and issued a Mitigation Action Plan (MAP) for the Dual-Axis Radiographic Hydrodynamic Test (DARHT) facility at Los Alamos National Laboratory (LANL) in response to a Record of Decision (USDOE 1995a) for the DARHT Environmental Impact Statement (USDOE 1995b). The DARHT MAP documents, in part, the DOE's commitment to protect natural and cultural resources during the construction, operation, and decommissioning phases of the DARHT facility (USDOE 1996). One of the initial tasks identified in section VIII.A.1(a) of the MAP mandates the measurement of radioactive and other chemicals in soil, sediment, plants, small mammals, bees, and birds during the construction phase of DARHT (1996 through 1999). These data established baseline levels (Nyhan et al. 2001a) so that comparisons could be made to samples collected after operations started to evaluate potential impacts. Operations at DARHT started in 2000.

Although the abundance and composition of bird species were well documented during the preoperational period, the establishment of baseline levels for radionuclides and nonradionuclides in birds was incomplete (Keller and Nyhan 2001). Thus, the purpose of this study was threefold: (1) compare the populations, composition, and diversity of bird species collected from 2003 through 2006 to preoperation levels (1999); (2) establish a baseline for potential contaminants from birds collected from regional sites; and (3) compare these regional samples to samples collected near the DARHT facility from 2003 through 2006 (2003 through 2007 for metals) (operation phase).

2. METHODOLOGY

a. Bird Sampling

Birds were collected according to the Monitoring Avian Population and Survivorship protocol of one netting every 10^{th} day starting in May and extending to August. To this end, 12 mist nets measuring 12 m (39 ft) long by 3 m (10 ft) high and spaced approximately 46 m (150 ft) from one another were located on a 1.6-km-long (1 mile) transect along the edge of Cañon de Valle on the west side of the DARHT facility (Figures 1 and 2). Starting at first light, the mist nets were stretched across two poles and checked for birds at 30- to 45-minute intervals. When a bird was captured in the net, it

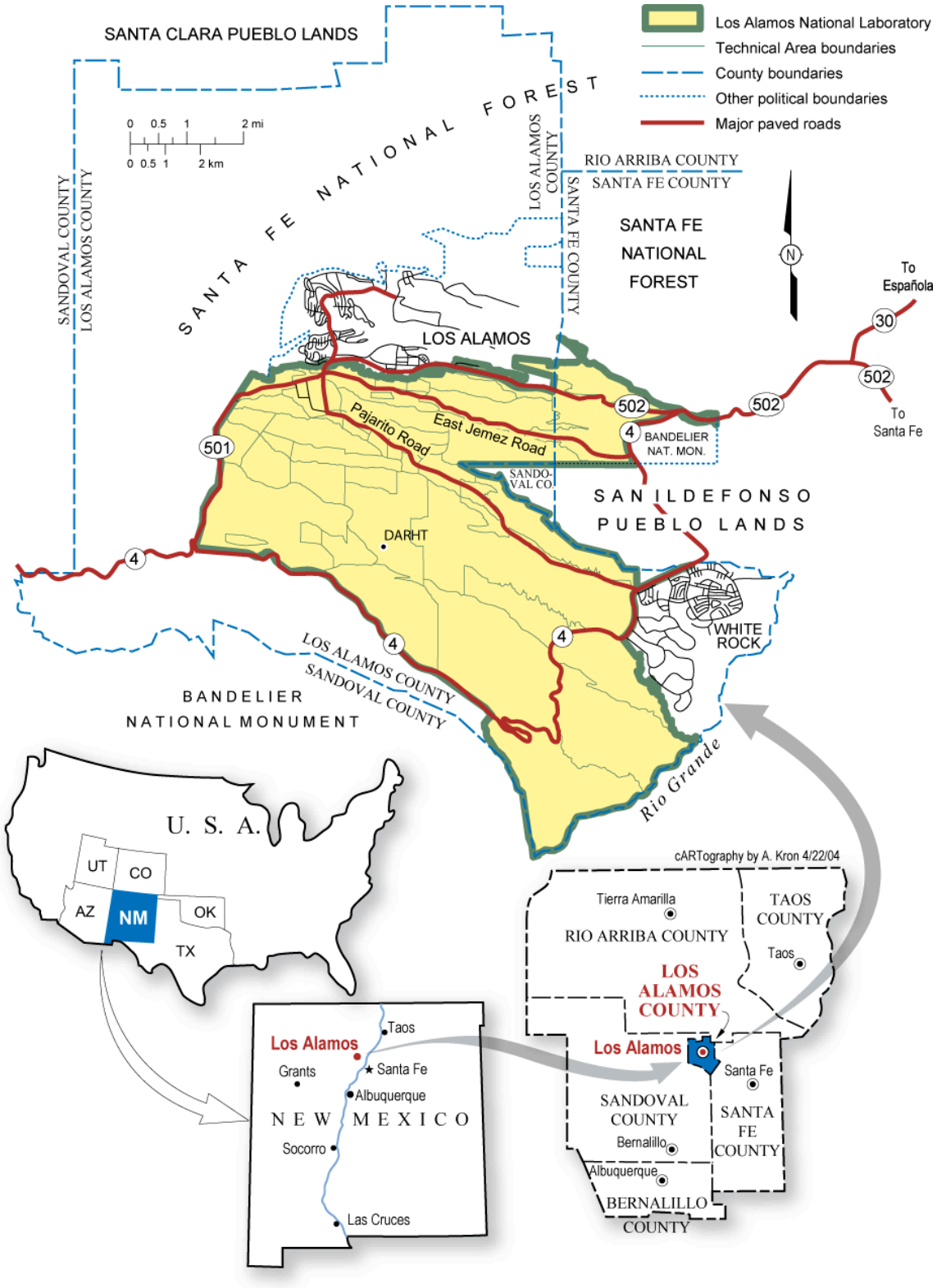

Figure 1. Location of DARHT at LANL.

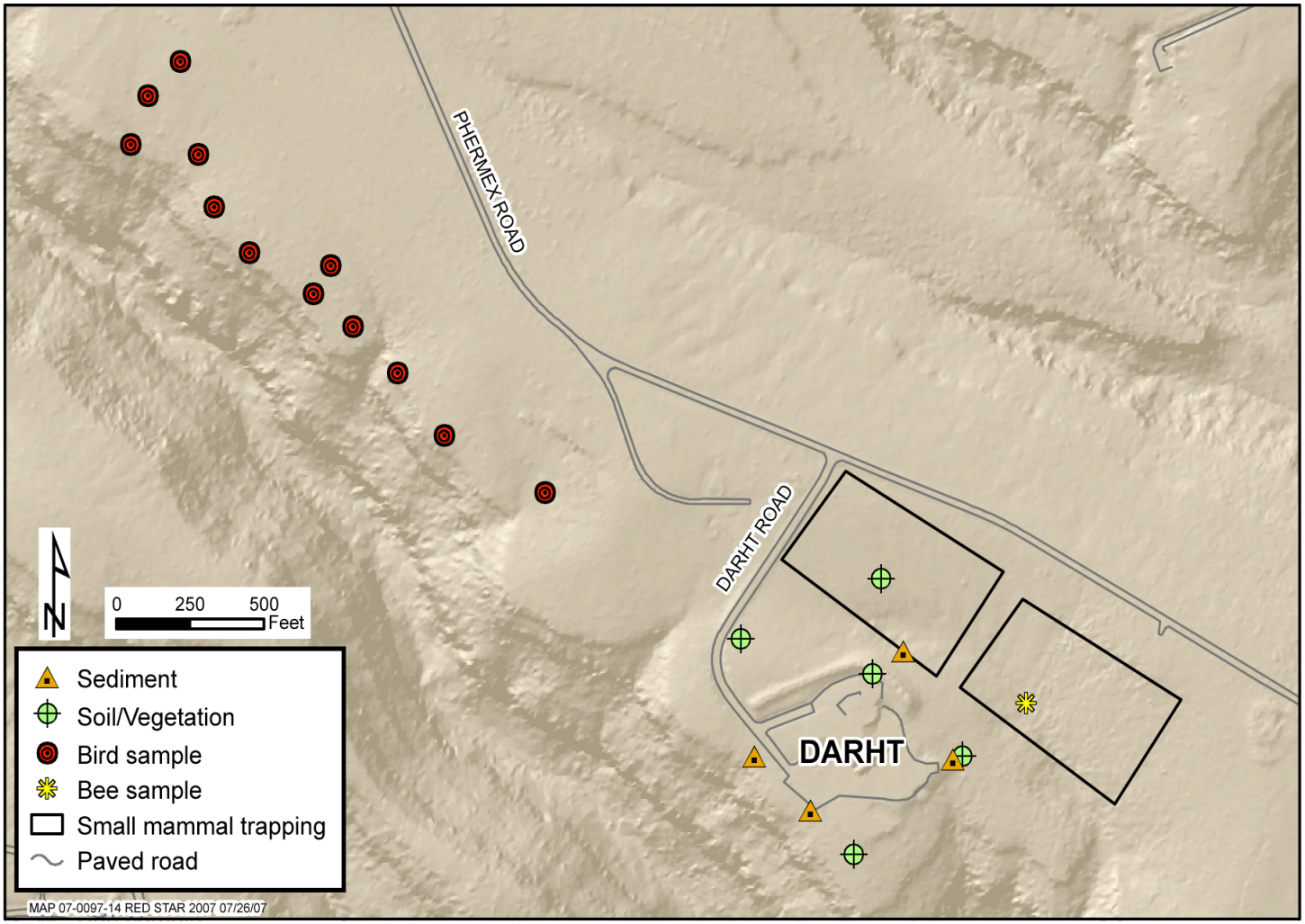

Figure 2. Location of the bird trapping areas on the edge of Cañon de Valle near the DARHT facility.

was removed, identified, and banded.

A certain number of birds representing different species were humanely sacrificed for chemical analysis according to the Institutional Animal Care and Use Committee protocol (IACUC 1996). Samples were placed into individual labeled Ziplock plastic bags and placed into an ice chest cooled to around 4°C. Corresponding reference samples were collected from the Jemez Springs and Nambe, NM, areas approximately 48 km (30 miles) southwest and east, respectively, from LANL. At the laboratory, birds were combined (~two to five birds per sample) and submitted to Paragon Analytics (2003, 2004, and 2005) and Severn Trent Laboratories (2006) for the analysis of tritium (^{3}H), cesium-137 (^{137}Cs), strontium-90 (^{90}Sr), americium-241 (^{241}Am), plutonium-238 (^{238}Pu), plutonium-239,240 (^{239,240}Pu), uranium-234 (^{234}U), uranium-235 (^{235}U), and uranium-238 (^{238}U). In addition, Paragon Analytics analyzed the birds (one bird per sample) from 2003 through 2007 for 23 Target Analyte List (TAL) inorganic chemicals. (Note: Three bird samples in 2007 were inadvertently collected with mouse traps on the north and northeastern side of the DARHT facility.) Results for ^{3}H are reported in pCi per mL, results for the other radionuclides are reported on a pCi per gram ash weight basis (pCi/g ash), and results for the TAL chemicals are reported on a mg/kg or µg/kg wet weight basis.

b. Diversity Comparisons

The following four indices of diversity were used to compare the bird populations between 1999 (preoperational) (Keller and Nyhan 2001) and 2003–2006 (operation phase). First, Shannon's index of species diversity (Zar 1974) was used to estimate community richness as

$$H = - \sum_{i=1}^{S} P_i \log P_i$$

where Pi = proportion of species i in sample, and S = number of species; the corresponding test for evenness is

$$J = H/H_{max}$$

where H_{max} = maximum possible diversity (i.e., log$S$).

An estimate of the similarity in the species composition among the sample populations was calculated with Sorensen's Presence Community Coefficient (SPCC), which was described by Mueller-Dombois and Ellenberg (1974) as

$$SPCC = 200C/A+B$$

where C is the total number of species common to two samples, A is the total number of species in Sample A, and B is the total number of species in Sample B. If the same species were found in both samples, the community coefficient would be 100, whereas if they had no species in common, the community coefficient would be 0.

Sorensen's Quantitative Community Coefficient (SQCC), which estimates the similarity in the relative abundance of species between samples, was also calculated. The SQCC is described by Mueller-Dombois and Ellenberg (1974) as

$$SQCC = 200Mw/M_A + M_B$$

where Mw refers to the total of the smaller quantitative values of the species common to two samples, M_A is the total number of individual counts in Sample A, and M_B is the total number of individual counts in Sample B.

c. Comparison Levels of Elements in Biota

To evaluate potential impacts from radionuclides and inorganic chemicals, the analytical results of bird samples collected near the DARHT facility were compared to regional statistical reference levels (RSRLs). RSRLs are the upper-level background concentration (mean plus three standard deviations = 99% confidence level) derived from birds collected from regional areas and represent fallout and natural sources. Where the levels of radionuclides exceed RSRLs, we compared the concentrations to biota dose screening levels (SLs). SLs were developed to identify the contaminants of potential concern at 10% of the 0.1 rad/d standard for terrestrial animals (USDOE 2002). If a constituent exceeds a SL, the reason for that increase is more thoroughly investigated.

Also, if any radionuclides exceed a SL, a dose using all of the measured radionuclides is calculated and compared to the standard. There are no SLs for inorganic chemicals in tissues of birds; however, when available they are compared to toxicity values in the literature.

d. Determining the Composition of Uranium

To determine the source of uranium in birds at the 99% confidence level, the uranium isotopic distribution of ^{234}U and ^{238}U, which for naturally occurring uranium is one, was assessed using the following steps: (1) the difference between ^{234}U and ^{238}U was calculated, (2) the squares of their uncertainties were summed and the square root of this number was taken, (3) the ^{234}U and ^{238}U difference was divided by the pooled square root, (4) if the result was greater than 3, it was observed whether the ^{234}U value or the ^{238}U value was larger, (5) if the ^{234}U value was larger, excess enriched uranium was indicated. Conversely, if the ^{238}U value was larger, excess depleted uranium was indicated.

3. RESULTS

a. Abundance and Composition of Birds

The number and composition of birds collected near the DARHT facility from 2003–2006 (operation phase) as compared to 1999 (preoperations) (Keller and Nyhan 2001) are presented in Table 1. Shannon's diversity and evenness of bird species within all the time periods was high and generally increased over time. The time with the greatest number of birds (412) and species (46) was in 2005. Birds occurring most often in the vicinity of DARHT, regardless of time, included the chipping sparrow (*Spizella passerina*), the Virginia's warbler (*Vermivora virginiae*), the western bluebird (*Sialia mexicana*), the broad-tailed hummingbird (*Selasphorus platycercus*), the sage sparrow (*Amphispiza belli*), and the western tanager (*Piranga ludoviciana*).

Table 1. Distribution and Relative Density of Birds Collected Near the DARHT Facility Before (1999) and During Operations (2003 to 2006)

	Pre-operational	Operation Phase			
Birds	**1999[a]**	**2003**	**2004**	**2005**	**2006**
American Robin				1	
American Kestrel	1				
Ash-Throated Flycatcher	5	5	3	3	1
Audubon's Warbler	5	2	1	28	3
Bewick's Wren		5			
Black-chinned Hummingbird					1
Black-headed Grosbeak	2	1		9	
Black-throated Gray Warbler					1
Blue-gray Gnatcatcher		2		2	6
Broad-tailed Hummingbird	11	11	16	13	4
Brown Creeper			1	2	
Bullock's Oriole					1
Bushtit					13
Calliope Hummingbird					1
Canyon Towhee				1	
Canyon Wren			1	4	1
Cassin's Kingbird			1		
Chipping Sparrow	7	19	18	31	20
Common Bushtit	2	7			
Common Nighthawk					1
Common Poorwill				1	
Cordilleran Flycatcher				4	
Dusky Flycatcher	2		1	3	4
Gray Flycatcher	6	8		3	4
Green-tailed Towhee	1			3	3
Grey-headed Junco				14	
Hairy Woodpecker	5	6	2	7	1
Hermit Thrush	1	3		3	1
House Finch		7	4	12	8
House Wren		1			1
Juniper Titmouse		14	1	4	1
Lark Sparrow					1
Lesser Goldfinch		3	4	3	
MacGillivray's Warbler		1		1	
Mountain Bluebird	2	6	3	2	3
Mountain Chickadee	5	2	1	5	1
Northern Mockingbird					3
Olive-sided Flycatcher					1
Orange-crowned Warbler				2	

Table 1 (cont.)

	Pre-operational	Operation Phase			
Birds	**1999[a]**	**2003**	**2004**	**2005**	**2006**
Pine Siskin				2	
Plumbeous Vireo	3	3		2	
Pygmy Nuthatch	15		5	1	
Red-breasted Nuthatch					2
Red-tailed Hawk					1
Red-shafted Flicker	3	1		1	3
Rock Wren			10	24	10
Ruby-crowned Kinglet		1		1	
Rufous Hummingbird	4	2	1	9	13
Sage Sparrow	6	13	3	18	3
Savannah Sparrow	3				
Say's Phoebe			3		
Scrub Jay			1		
Spotted Towhee	2	6	3	9	8
Steller's Jay	2				
Townsend's Solitaire	2		2	3	3
Vesper Sparrow				1	
Violet-green Swallow			1	2	2
Virginia's Warbler	14	3	13	33	23
Warbling Vireo	1				
Western Bluebird	11	21	9	20	8
Western Shrub Jay				1	1
Western Tanager	1	4	5	102	1
Western Wood-Pewee	1	5	7	7	1
White-breasted Nuthatch	2	2	6	8	2
Williamson's Sapsucker	1			1	
Wilson's Warbler	1			5	2
Yellow Warbler				1	
No. of birds	127	164	126	412	168
No. of species	31	29	28	46	41
Diversity	1.26	1.31	1.26	1.30	1.38
Evenness	0.85	0.90	0.87	0.78	0.86

[a]Data from Keller and Nyhan (2001).

Although the diversity and the frequency of the most common bird species did not substantially change between time periods, the overall composition in the type and relative abundance of birds collected during 2003–2006 was different than for 1999 (about 64% in species types and about 47% in abundance) (Table 2). The difference in

the composition of bird species between the two times may have been related to the change in vegetation created as a result of the Cerro Grande fire that burned near the DARHT complex and through the bird netting locations in 2000. Studies have shown that a change in the vegetative physiognomy following a stand-replacement fire in the Rocky Mountain region may change the composition of bird species considerably (Hutto 1995, Kotliar et al. 2002, Smucker et al. 2005).

Table 2. Similarity Coefficients of Bird Populations Occurring Near the DARHT Facility from 2003–2006 (Operation Phase) as Compared to 1999 (Preoperation)

Year	SPCC[a]	SQCC[b]
2003	70	52
2004	61	53
2005	65	36
2006	61	46
Mean	64	47

[a]Sorensen's Presence Community Coefficient
[b]Sorensen's Quantitative Community Coefficient

b. Radionuclide Concentrations

Radionuclide concentrations in whole bird samples collected west of the DARHT facility from 2003–2006 as compared to the RSRLs are presented in Table 3. All radionuclides, with the exception of ^{234}U and ^{238}U, were either not detected or below RSRLs. A detected value is one in which the result is greater than three counting uncertainties and the RSRL is the upper-limit background concentration. The few detected ^{234}U and ^{238}U concentrations occurred mostly in birds collected in 2003, and the distribution of these radionuclides was indicative of depleted uranium. Depleted uranium, a metal used as a substitute for the enriched uranium in weapon components tested at LANL, has also been detected in soil and vegetation (Fresquez 2004), bees (Hathcock and Haarmann 2004), and small mammals (Fresquez 2005) around the DARHT facility. Although some of the bird samples contained uranium isotopes above RSRLs, the levels were far below SLs and do not result in a potential unacceptable dose to the birds.

Table 3. Radionuclide Concentrations (± 3TPU) in Birds Collected West of the DARHT Facility at Technical Area 15 from 2003–2006 as Compared to Background (Bold values are higher than both 3TPU and RSRL.)

Location/ Bird Sample	^{3}H pCi/mL		^{90}Sr pCi/g ash		^{137}Cs pCi/g ash		^{238}Pu pCi/g ash		$^{239,240}Pu$ pCi/g ash	
	Result	3TPU[a]	Result	3TPU	Result	3TPU	Result	3TPU	Result	3TPU
2003										
Spotted Towhee	0.29	0.50	0.88	0.33	0.030	0.42	0.0	0.0031	0.0059	0.0050
Canyon Towhee/Spotted Towhee	0.0	0.48	0.51	0.20	0.10	0.85	-0.00040	0.0031	0.0088	0.0061
Western Bluebird	-0.13	0.48	1.1	0.42	-0.20	2.1	0.0	0.010	0.0040	0.010
Chipping Sparrow/Sage Sparrow	-0.25	0.48	0.60	0.23	-0.20	0.77	0.00040	0.0030	0.0057	0.0051
Chipping Sparrow/Lark Sparrow	0.23	0.50	0.43	0.17	-0.070	0.73	0.0	0.0032	0.0043	0.0042
2004										
Spotted Towhee/Virginia's Warbler	0.28	0.50	0.68	0.30	1.4	2.3	-0.0027	0.0099	0.0040	0.010
2005										
Spotted Towhee	-0.32	0.47	1.3	0.48	0.10	0.80	0.0	0.0040	0.0038	0.0049
2006										
House Finch/Chipping Sparrow	-0.0080	0.72	0.95	1.2	0.21	8.2	0.020	0.053	0.020	0.053
Spotted Towhee	0.17	0.36	0.32	0.63	0.19	4.3	0.0	0.0	0.016	0.052
Background										
House Sparrow	-2.1	1.1	0.84	1.0	0.15	3.9	0.0	0.0	0.011	0.044
House Finch	-0.024	0.29	0.88	0.95	-0.063	5.0	-0.0059	0.042	-0.012	0.049
House Finch	0.37	0.75			0.21	3.8	0.0050	0.038	0.011	0.045
Mourning Dove	0.16	0.36	0.61	1.8	-0.42	3.7	0.0	0.0	0.011	0.047
Mourning Dove	0.12	0.39	0.61	0.76	0.57	4.2	0.011	0.045	0.0053	0.040
American Robin	0.35	0.69	0.21	0.69	0.88	4.0	0.0	0.0	0.0	0.0
Mean	-0.19		0.63		0.22		0.0016		0.0043	
Std Dev	0.96		0.27		0.46		0.0056		0.0090	
RSRL[b]	2.7		1.4		1.6		0.019		0.031	
SL[c]	34500		3614		4874		39		39	

Table 3. Continued.

Location/ Bird Sample	^{241}Am pCi/g ash Result	3TPU	^{234}U pCi/g ash Result	3TPU	^{235}U pCi/g ash Result	3TPU	^{238}U pCi/g ash Result	3TPU
2003								
Spotted Towhee	0.0024	0.0030						
Canyon Towhee/Spotted Towhee	0.0039	0.0042	0.36	0.062	0.017	0.0064	**0.67***	0.11
Western Bluebird	0.0046	0.0084	0.21	0.046	0.0076	0.0073	0.33*	0.064
Chipping Sparrow/Sage Sparrow	0.0011	0.0036	0.40	0.067	0.017	0.0065	0.52*	0.086
Chipping Sparrow/Lark Sparrow	0.0026	0.0047	**0.59**	0.098	0.033	0.0092	**0.91***	0.15
2004								
Spotted Towhee/Virginia's Warbler	0.0046	0.0094	0.086	0.024	0.0014	0.0067	0.097	0.027
2005								
Spotted Towhee	0.00070	0.0045	0.35	0.061	0.014	0.0064	**0.62***	0.10
2006								
House Finch/Chipping Sparrow	0.0053	0.041	0.11	0.13	0.0	0.0	0.18	0.16
Spotted Towhee	-0.012	0.050	0.33	0.21	0.029	0.076	0.37	0.23
Background								
House Sparrow	0.011	0.047	0.20	0.18	0.014	0.062	0.29	0.20
House Finch	0.0053	0.041	0.14	0.16	-0.0071	0.050	0.26	0.18
House Finch	0.0110	0.045	0.38	0.24	0.014	0.059	0.36	0.22
Mourning Dove	0.0	0.0	0.080	0.14	0.019	0.061	0.17	0.14
Mourning Dove	0.0	0.0	0.055	0.088	0.0	0.0	0.074	0.10
American Robin	0.0050	0.038	0.17	0.16	-0.00063	0.056	0.053	0.082
Mean	0.0054		0.17		0.0066		0.20	
Std Dev	0.0049		0.11		0.011		0.12	
RSRL[b]	0.020		0.51		0.040		0.58	
SL[c]	37		42		42		42	

[a]Values are the total propagated uncertainty at the 99% confidence level.
[b]Regional statistical reference level; this is the upper-limit background concentration (mean + 3 std dev) from the present data.
[c]Screening level is based on 10% of the standard. *Indicates depleted uranium.
Note: The dry/wet ratio for birds is 0.34 and the ash/dry weight ratio is 0.14 (Fresquez et al. 2007).
Note: Paragon Analytics analyzed years 2003–2005 and Severn Trent analyzed year 2006 and background.

c. Trace Element Concentrations

There were many inorganic chemicals detected above RSRLs in bird samples collected near the DARHT facility from 2003 through 2007 (Table 4). The inorganic chemicals above the RSRLs in two or more bird samples included aluminum (Al), barium (Ba), iron (Fe), magnesium (Mg), manganese (Mn), arsenic (As), lead (Pb), silver (Ag), thallium (Tl), and mercury (Hg). While most of these metals in birds were just above the RSRLs, the highest amount of As (0.90 mg/kg) and Ag (0.60 mg/kg) were about one and two orders of magnitude higher than background, respectively. Because bird pelts (skin plus feathers) collected before the start up of operations showed higher concentrations of these metals than RSRLs (Keller and Nyhan 2001) and because there is no evidence of these metals being elevated in soil and sediment collected directly around the DARHT facility (Fresquez 2005 and 2006), the source of these metals may be from other sites other than the DARHT facility.

The metals in these wild birds may be from either of two sources. One possibility is that they picked up these metals during their annual migrations to Mexico and Central or South America and the second possibility is that these metals were obtained from within Laboratory grounds. There are many potential release sites within Laboratory lands that may contain metals above background near the DARHT facility; but one in particular, a photographic outfall within Technical Area 16 that converges into Cañon de Valle just upgradient of the DARHT area, contained Ag at one time up to 25,000 mg/kg in sediment, 15,000 mg/kg in soil, and 10 mg/kg in plants (Kasunic et al. 1985). Although the site was partly remediated in 2000, the concentrations of As and Ag in soil are still above SLs (LANL 2005) and the concentrations of Ag in storm water runoff within Cañon de Valle from 2001 (Rodgers et al. 2002) to 2005 (Gallaher et al. 2006) were higher than background—the highest level measured was 0.30 mg/L.

Although no data could be found of As and Ag in the tissues of wild birds to evaluate toxicity, there was one study that evaluated the toxicity of high levels of Ag in the drinking water supply of domestic poultry. Silver was harmful to chicks at concentrations as low as 100 mg/L in drinking water (Smith and Carson 1977). Albeit the significance of this level is difficult to evaluate with regard to the natural

Table 4. Total Inorganic Element Concentrations in Birds Collected Near the DARHT Facility at Technical Area 15 from 2003–2007 as Compared to Background (Bold values are higher than the RSRL.)

Location/ Bird Sample	Al [a,b] mg/kg wet	Ba mg/kg wet	Be mg/kg wet	Ca mg/kg wet	Cr mg/kg wet	Co mg/kg wet	Cu mg/kg wet	Fe mg/kg wet	Mg mg/kg wet	Mn mg/kg wet
2003										
Spotted Towhee	77	**4.1**	U	3800	0.19	0.048	4.4	**410**	**320**	**9.0**
Canyon Towhee/Spotted Towhee	42	**3.2**	U	3600	0.15	0.046	3.8	**330**	270	**6.8**
Western Bluebird	20	2.8	U	2500	0.12	0.033	5.4	160	300	5.3
Chipping Sparrow/Sage Sparrow	50	1.7	U	2400	0.16	0.034	**6.1**	120	**340**	5.4
Chipping Sparrow/Lark Sparrow	**140**	**5.1**	U	4400	0.20	0.060	2.6	210	**320**	**7.2**
2004										
Spotted Towhee/Virginia's Warbler	8.1	1.7	U	3900	0.22	0.023	5.3	210	250	2.3
2005										
Spotted Towhee	20	**4.0**	U	2700	0.12	0.021	3.3	**230**	250	3.0
2006										
House Finch/Chipping Sparrow	33	2.3	U	6800	0.22	U	3.6	62	310	1.8
Spotted Towhee	**170**	**7.0**	**0.015**	6700	0.29	0.065	3.0	**420**	270	**7.4**
2007										
Spotted Towhee	46	**7.7**	U	12000	0.24	0.029	2.7	100	240	2.3
Spotted Towhee	24	**10**	U	9200	0.21	0.018	2.4	110	270	1.7
Spotted Towhee	73	**11**	U	7300	0.22	0.031	2.6	150	270	3.4
Background										
House Sparrow	46	2.2	U	9500	0.25	0.030	1.8	92	270	3.8
House Finch	3.7	1.1	U	7300	0.16	U	3.5	70	240	0.59
House Finch	6.9	1.2	U	7400	0.19	U	3.9	52	260	0.77
Mourning Dove	9.9	0.37	U	560	0.083	0.027	3.4	120	210	1.1
Mourning Dove	10	0.78	U	12000	0.25	U	1.7	76	240	0.97
American Robin	71	0.70	U	2700	1.3	0.063	3.2	170	200	4.1
Mean	25	1.1	0.0036	6577	0.37	0.026	2.9	97	237	1.9
Std Dev	28	0.63	0.0028	4252	0.46	0.020	0.93	43	27	1.6
RL[c]			0.0099			0.020				
RSRL[d]	107	3.0	0.012	19332	1.7	0.086	5.7	224	319	6.7

Table 4. Continued.

Location/ Bird Sample	Ni mg/kg wet	K mg/kg wet	Na mg/kg wet	V mg/kg wet	Zn mg/kg wet	Sb[e] µg/kg wet	As µg/kg wet	Cd µg/kg wet	Pb µg/kg wet	Se µg/kg wet
2003										
Spotted Towhee	0.19	3000	1100	0.25	27	9.8	**120**	210	370	530
Canyon Towhee/Spotted Towhee	0.13	3200	1100	0.19	27	12	**79**	140	250	550
Western Bluebird	0.092	2500	1100	U	27	12	**81**	210	91	550
Chipping Sparrow/Sage Sparrow	**0.26**	2700	870	0.11	28	18	38	140	170	440
Chipping Sparrow/Lark Sparrow	0.17	2400	1000	0.30	26	18	**110**	130	360	430
2004										
Spotted Towhee/Virginia's Warbler	0.11	2900	930	U	33	13	**900**	110	47	1000
2005										
Spotted Towhee	0.11	2700	1100	0.053	26	7.6	39	120	94	570
2006										
House Finch/Chipping Sparrow	0.072	2700	960	U	26	5.3	U	77	130	570
Spotted Towhee	0.14	2700	880	**0.48**	30	14	**160**	110	**480**	640
2007										
Spotted Towhee	0.038	3000	1000	0.058	28	5.9	20	51	250	400
Spotted Towhee	0.036	2800	1100	0.032	26	5.3	15	8.3	150	330
Spotted Towhee	0.067	2900	990	0.093	24	6.0	24	19	**440**	330
Background										
House Sparrow	0.058	2500	1200	0.13	27	15	50	27	230	880
House Finch	U	3100	900	U	19	3.3	U	11	76	800
House Finch	U	2900	930	U	19	3.3	U	14	170	620
Mourning Dove	U	2800	690	U	14	U	19	110	51	2000
Mourning Dove	U	2900	680	U	21	2.9	U	170	280	490
American Robin	0.16	2100	560	0.24	27	4.9	45	300	110	600
Mean	0.042	2717	827	0.074	21	5.3	25	105	153	898
Std Dev	0.061	360	231	0.094	5.1	4.8	18	114	90	558
RL[c]	0.050			0.050		2.9	19			
RSRL[d]	0.23	3797	1520	0.35	36	20	78	449	423	2572

Table 4. Continued.

Location/ Bird Sample	Ag µg/kg wet	Tl µg/kg wet	Hg[f] mg/kg wet
2003			
Spotted Towhee	**130**	**8.7**	0.054
Canyon Towhee/Spotted Towhee	**160**	1.3	**0.15**
Western Bluebird	**600**	2.2	**0.096**
Chipping Sparrow/Sage Sparrow	**300**	1.9	0.029
Chipping Sparrow/Lark Sparrow	**260**	2.0	0.013
2004			
Spotted Towhee/Virginia's Warbler	**600**	1.5	**0.082**
2005			
Spotted Towhee	**120**	**5.6**	0.052
2006			
House Finch/Chipping Sparrow	**8.4**	U	U
Spotted Towhee	**9.8**	2.7	0.018
2007			
Spotted Towhee	**2.6**	4.6	0.011
Spotted Towhee	1.1	3.6	0.0096
Spotted Towhee	**3.8**	**8.6**	0.024
Background			
House Sparrow	1.4	U	U
House Finch	U	U	U
House Finch	1.1	U	U
Mourning Dove	1.4	3.4	0.052
Mourning Dove	0.99	U	U
American Robin	2.0	U	U
Mean	1.3	1.3	0.010
Std Dev	0.40	1.1	0.021
RL[c]	0.99	1.9	0.0097
RSRL[d]	2.5	4.6	0.072

[a]Concentrations reported in mg/kg dry = ppm and µg/kg dry = ppb.
[b]Al to Zn by method SW6010B and analyzed by inductively coupled plasma.
[c]Reporting limit for undetectable (U) concentrations. For U concentrations, statistics were calculated using estimated numbers. Estimated numbers were given when the result was lower than the reporting limit but greater than the Instrument Detection Level.
[d]Regional statistical reference level; this is the upper-limit background concentration (mean + 3 std dev) from the present data.
[e]Sb to Tl by method SW6020B and analyzed by inductively coupled plasma mass spectroscopy.
[f]Hg by method SW7471 and analyzed by cold vapor atomic adsorption.
Note: Paragon Analytics conducted analysis on all of the metals.

environment, given uncertainties with respect to exposure, feeding habits, and bioavailability, the highest concentration detected in surface waters within Cañon de Valle was considerably below this referenced amount. Also, it should be noted that since 2006 the levels of Ag in birds have decreased sharply.

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