

RADIONUCLIDES IN MOURNING DOVES NEAR A NUCLEAR FACILITY COMPLEX IN SOUTHEASTERN IDAHO

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The Idaho National Engineering Laboratory (INEL) Site in southeastern Idaho contains the world's largest concentration of nuclear reactors; to date some 52 reactors have been constructed and 17 reactors are still operable. In addition, the INEL contains a nuclear fuel reprocessing plant, terrestrial areas for the disposal of solid radioactive waste and leaching ponds for the disposal of contaminated liquid wastes. With the exception of uranium mining and fuel fabrication, the INEL activities include all of the nuclear fuel cycle.

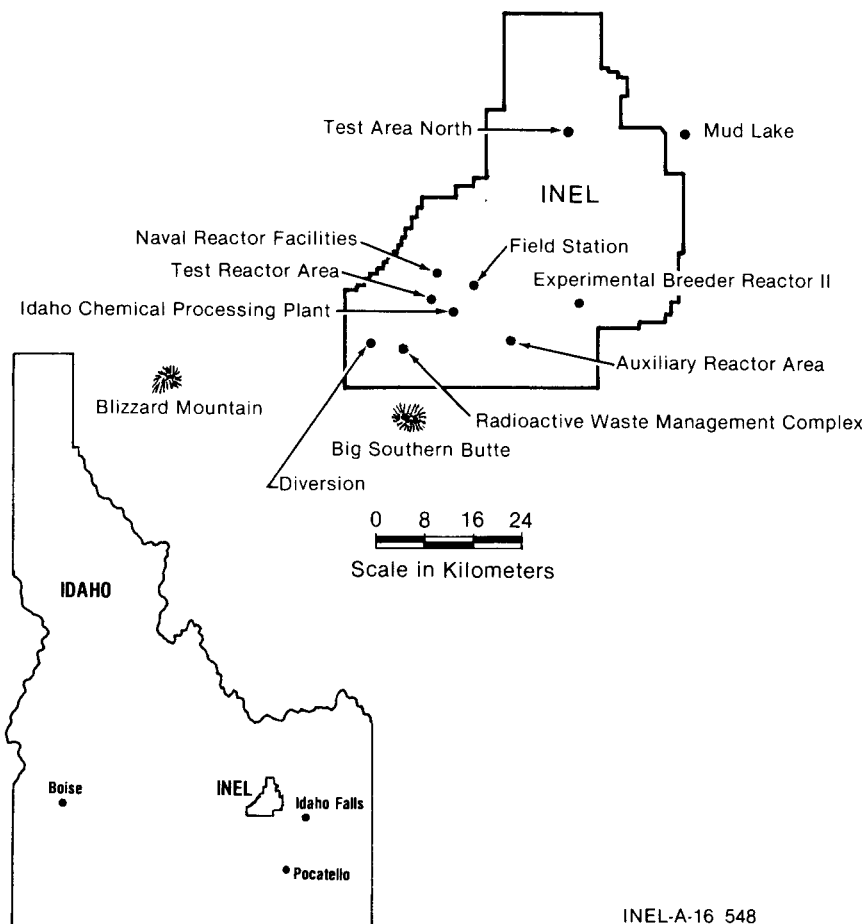
Mourning Doves (*Zenaida macroura*) are ubiquitous game birds in Idaho and are common on the INEL during the summer (Reynolds and Trost 1981). They forage, obtain grit and/or drink water at or near these facilities (Trost et al. 1976, Halford and Millard 1978, Arthur and Markham 1978).

The potential exists for Mourning Doves at these facilities to ingest radionuclides. Since birds are the most mobile of the animals occurring near nuclear facilities and since doves are a popular game species, it is possible that radioactively-contaminated birds could be ingested by, and thus, provide a radiation dose to man. Other predators, such as raptors, could also ingest radionuclides by consuming doves. The purpose of this study was (1) to determine the concentrations of radionuclides in Mourning Dove tissues near various types of nuclear facilities, (2) to determine the consequent radiation dose to doves, (3) to determine the consequence of the transfer of radionuclides through the food chain and (4) to relate these concentrations to potential radiation doses to man.

STUDY AREAS

All but the control study area were located on or adjacent to the INEL Site (Fig. 1) which is a 231,600-ha area, administered by the U.S. Department of Energy, in the upper Snake River Plain in Butte, Jefferson, Bonneville, Clark and Bingham counties, Idaho. Public access to the INEL is controlled, and hunting is not permitted. The primary mission of the INEL is to conduct research and development programs in nuclear energy, geothermal and advanced energy sources, environment, safety and national security applications. The INEL became a National Environmental Research Park in 1975.

The vegetation on the INEL Site consists primarily of sagebrush (*Artemisia* sp.)-grass types (Harniss and West 1973, McBride et al. 1978); the predominant shrub is big sagebrush (*Artemisia tridentata*). Other prominent shrubs are rabbitbrush (*Chrysothamnus viscidiflorus*), winter fat (*Eurotia lanata*), snakeweed (*Gutierrezia sarothrae*) and shadscale (*Atriplex confertifolia*). The most common grasses are bottle brush squirrel tail (*Sitanion hystrix*),



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FIG. 1. Locations of Mourning Dove samples on and near the Idaho National Engineering Laboratory Site.

bluebunch wheatgrass (*Agropyron spicatum*), western wheatgrass (*A. smithii*), Indian ricegrass (*Oryzopsis hymenoides*), Great Basin wildrye (*Elymus cinereus*) and needle-and-thread grass (*Stipa comata*).

Doves were collected near seven nuclear facilities. One of these, the Test Reactor Area (TRA), is a nuclear materials testing complex which tests the performance of reactor materials and equipment components in high neutron flux. Since 1952 low-level liquid radioactive waste generated by three test reactors and their support facilities have been disposed of in radioactive leaching ponds adjacent to TRA. The ponds have an area of 1.5 ha. Approximately 48,000 curies (Ci) ($1 \text{ Ci} = 3.7 \times 10^{10}$ nuclear transformations per second) of beta-gamma activation and fission radionuclides were released into the ponds by TRA facilities from 1952–1977 (White 1978). Radionuclides with half-lives (the time for the activity

to decrease by one-half) less than 1 year make up about 80% of this activity. Aquatic and littoral vegetation existing in this area have been previously described (Halford and Millard 1978).

The Radioactive Waste Management Complex presently contains two major waste disposal or storage facilities. The Subsurface Disposal Area (SDA) is a 36-ha area where low-level fission and activation waste from INEL facilities are disposed beneath the soil surface. In addition, plutonium and americium wastes were buried in the SDA prior to late 1970. After 1970, plutonium and americium wastes were stored above ground in the Transuranic Storage Area.

The Auxillary Reactor Area (ARA) contains a variety of development and research programs. Post-irradiation examination of materials and reactor components are carried out in this area. In addition, a reactor, the SL-1, was accidentally destroyed at this location in 1961 and contaminated the immediate surroundings.

Test Area North (TAN) contains several nuclear testing and support facilities. During this study the Loss-of-Fluids Test (LOFT) facility, which is currently investigating the capability of emergency core cooling systems when primary cooling systems failures and leaks are stimulated, was under construction.

The Naval Reactors Facility (NRF) contains four major installations. Three of these are nuclear prototype facilities for the testing and operation of nuclear reactors used to power various U.S. Navy vessels. Another facility receives, examines and prepares naval expended nuclear fuel for shipment to the Idaho Chemical Processing Plant. The Navy also conducts nuclear training for Navy personnel at these facilities. The primary water source of doves in the NRF area is probably two sewage leaching ponds.

The Idaho Chemical Processing Plant (ICPP) dissolves and recovers uranium from spent nuclear fuel and solidifies the resultant liquid waste. During these operations, trace amounts of radionuclides are released in the atmospheric effluents. The ICPP accounts for over 99% of the particulate radionuclides released into the atmosphere from INEL facilities (White 1978).

The Experimental Breeder Reactor-II (EBR-II) is a breeder reactor demonstration plant which also irradiates various reactor fuels and materials for the breeder reactor research program. In addition to EBR-II, three other test reactors, as well as various other nuclear facilities, exist at this location. Doves commonly drink water from either sewage leaching ponds or a waste water pond at this facility.

METHODS

From 29 May–26 July 1974, 252 Mourning Doves were collected periodically at seven on-site locations near nuclear facilities and at a control location (Blizzard Mt.) (Table 1, Fig. 1). From 23 June–14 August 1975, Mourning Doves were collected near the Test Reactor Area, the Idaho Chemical Processing Plant and the Radioactive Waste Management Complex, as well as at four locations on or near the INEL Site and a control area. In 1976 and 1977, additional samples were collected at TRA, ICPP and a control area.

Immediately following collection, the doves were taken to the laboratory. The entire gastrointestinal tract was removed and approximately 20–30 g of muscle tissue were dissected from the carcass. Each tissue sample was placed in a counting vial, weighed and frozen for later analyses. Samples were analyzed for gamma-emitting radionuclides with a 65 cm³ germanium-lithium detector coupled to a computer-controlled multichannel analyzer.

During 1974 the estimated minimum detectable concentration (i.e., the minimum concentration in a sample that could be distinguished from instrumentation background determinations) for ¹³⁷Cs in Mourning Dove tissues was 0.4 pCi/g; the detection concentrations for

the other radionuclides were similar. However, during the remainder of the study, the minimum detectable concentration was 0.6 pCi/g. In calculating the mean concentrations, the value of the minimum detectable concentration was used for tissues which did not have detectable ^{137}Cs concentrations.

Since the data were not normally distributed, a nonparametric test, the Kruskal-Wallis test, was used to determine if differences in concentrations among locations or years existed at the <0.05 significance level, and a follow-up test, Dunn's Multiple Comparison Procedure, was used to identify which particular years or locations were significantly different. A significance level of $P < 0.15$ was used in the second test as recommended by Hollander and Wolfe (1973). Since dose determinations were based upon concentrations in tissues, statistical tests were not conducted on the dose data. Statistical relations between the radiation doses for the various years and locations would be similar to those for the radionuclide concentration data.

Potential whole-body dose commitment to man consuming contaminated Mourning Doves:

$$= \left(61 \frac{\text{mrem}}{\mu\text{Ci}} \cdot \frac{X \mu\text{Ci}_{137}\text{Cs in tissue}}{\text{g}} \right) \cdot \left(\text{g of tissue consumed} \right)$$

where:

μCi = microcurie (1 μCi = 10^{-6} Ci)

$X \mu\text{Ci/g}$ = the number of microcuries per gram of tissue, and

mrem = 10^{-3} rem, rem is a unit in radiation protection which relates the absorbed dose to the risk of a resulting biological effect.

For calculations of dose commitment to humans, it was assumed that the Mourning Doves were killed and eaten immediately; biological elimination by the Mourning Doves and any reduction in radioactivity as a result of cooking were not considered in dose calculations; doses were based upon the assumption that a person ate only one Mourning Dove and the weight of the muscle consumed was 25% of the live weight.

Internal dose calculations for doves were made using muscle nuclide concentrations and assuming the radionuclides were in equilibrium with the body and uniformly distributed throughout the body. Using principles established by the I.C.R.P. (1968), the dose to doves from internally deposited radionuclides was calculated as follows:

$$H = 51.2EC \text{ rads}$$

where H = dose commitment (rad), rad is a unit of radiation dose; 51.2 (dis/MeV) (g-rad/d- μCi) is a constant

E = effective absorbed energy per disintegration (MeV/dis.; I.C.R.P. 1959); 0.37 (used value for spleen since this is the lowest E given for ^{137}Cs and doves are small birds so absorption would be minimal), and

C = radionuclide concentration in muscle ($\mu\text{Ci/g}$),

$$\text{therefore } H = 51.2 (0.37) \frac{X \mu\text{Ci}}{\text{g}}$$

RESULTS

Cesium-137 frequently occurred in Mourning Dove tissues from most of the study areas (Tables 1 and 2). Generally ^{137}Cs concentrations in tissues from the control area were near or below the detection limit. During all 4 years of the study, ^{137}Cs concentrations in muscle tissues of doves were

TABLE I
CESIUM-137 CONCENTRATIONS (PCl/G) IN MOURNING DOVE MUSCLE TISSUE

Location	1974			1975			1976			1977		
	\bar{x}	Range	N	\bar{x}	Range	N	\bar{x}	Range	N	\bar{x}	Range	N
Test Reactor Area	1.57ab ¹	<0.4-6.9	17	4.05a	<0.6-24	16	1.48a	1.1-1.5	5	15.85a	<0.6-171	12
Idaho Chemical Processing Plant	3.24b	<0.4-11.6	16	0.84ab	<0.6-1.6	16	1.98a	0.7-5.3	4	—	—	—
Radioactive Waste Management Complex	0.58ac	<0.4-0.9	16	0.63ab	<0.6-0.8	12	—	—	—	—	—	—
Background (control)	0.44c	<0.4-0.8	16	0.75ab	<0.6-2.0	11	<0.6	<0.6	8	<0.6	<0.6	7
Test Area North	0.49ac	<0.4-1.1	16	—	—	—	—	—	—	—	—	—
Experimental Breeder Reactor II	0.40c	<0.4-0.6	16	—	—	—	—	—	—	—	—	—
Auxiliary Reactor Area	<0.40ac	<0.4	4	—	—	—	—	—	—	—	—	—
Naval Reactors Facility	<0.40ac	<0.4	4	—	—	—	—	—	—	—	—	—
Big Southern Butte	—	—	—	0.64b	<0.6-1.1	17	—	—	—	—	—	—
Diversion	—	—	—	<0.6b	<0.6	16	—	—	—	—	—	—
Field Station	—	—	—	0.62b	<0.6-0.8	12	—	—	—	—	—	—
Mud Lake	—	—	—	0.65ab	<0.6-1.0	11	—	—	—	—	—	—

¹ Concentration values in each column not followed by the same letter are significantly different (see text); e.g., during 1974, the TRA samples were significantly different from Background and Experimental Breeder Reactor II samples. The ICPP samples were significantly different from all of the other locations except the TRA.

TABLE 2
CESIUM-137 CONCENTRATIONS (pCi/g) IN MOURNING DOVE GASTROINTESTINAL TRACTS

Location	1974			1975			1976			1977		
	\bar{x}	Range	N	\bar{x}	Range	N	\bar{x}	Range	N	\bar{x}	Range	N
Test Reactor Area	2.12ab ¹	<0.4-7.8	17	41.1a	<0.6-430	16	1.12a	<0.6-1.6	5	75.8a	<0.6-419	12
Idaho Chemical Processing Plant	14.75b	<0.6-139	16	2.3ab	<0.6-7.8	16	1.3a	<0.6-2.8	3	—	—	—
Radioactive Waste Management Complex	0.83a	<0.6-1.7	12	1.2abc	<0.6-4	12	—	—	—	—	—	—
Background (control)	1.08a	<0.6-7	16	1.6abc	<0.6-7	11	0.8a	<0.6-1.2	8	<0.6a	<0.6	7
Test Area North	0.83a	<0.6-1.6	16	—	—	—	—	—	—	—	—	—
Experimental Breeder Reactor II	0.83a	<0.6-3.3	16	—	—	—	—	—	—	—	—	—
Auxiliary Reactor Area	<0.6a	<0.6	4	—	—	—	—	—	—	—	—	—
Naval Reactors Facility	<0.6a	—	4	—	—	—	—	—	—	—	—	—
Big South Butte	—	—	—	0.86ab	<0.6-2.2	17	—	—	—	—	—	—
Diversion	—	—	—	0.64c	<0.6-1.2	16	—	—	—	—	—	—
Field Station	—	—	—	1.11abc	<0.6-4.8	12	—	—	—	—	—	—
Mud Lake	—	—	—	0.81abc	<0.6-1.6	11	—	—	—	—	—	—

¹ Concentration values in each column not followed by the same letter are different.

TABLE 3
RADIONUCLIDES OTHER THAN CESIUM-137 IN MOURNING DOVE TISSUES 1974-1977

Radionuclide	Test Reactor Area				Idaho Chemical Processing Plant			
	Muscle % occur- rence	(N = 50) Max. concentration pCi/g	GI % occur- rence	(N = 50) Max. concentration pCi/g	Muscle % occur- rence	(N = 50) Max. concentration pCi/g	GI % occur- rence	(N = 50) Max. concentration pCi/g
Cesium-134	24	19	20	39.5	11	0.7	9	9.5
Iodine-131	4	1.8	22	87	—	—	3	15
Cobalt-60	26	2.2	34	227	11	8.3	9	1.2
Chromium-51	2	139	34	2620	6	0.5	3	27
Lanthanum-140	—	—	8	3.1	—	—	—	—
Cerium-141	—	—	4	37	—	—	—	—
Cerium-144	—	—	6	68.7	—	—	—	—
Ruthenium-103	—	—	2	0.9	—	—	—	—
Ruthenium-106	—	—	—	—	—	—	3	54
Manganese-54	—	—	2	8.6	—	—	—	—
Cobalt-57	—	—	2	0.3	—	—	—	—
Cobalt-58	—	—	2	0.5	—	—	—	—
Niobium-95	2	0.2	6	47	—	—	3	0.6
Zirconium-95	—	—	8	38.1	—	—	—	—
Selenium-75	4	6.5	8	10.5	—	—	—	—
Cesium-132	2	89.5	—	—	—	—	—	—
Hafnium-181	—	—	2	17.4	—	—	—	—
Zinc-65	—	—	2	21.5	—	—	—	—
Antimony-125	—	—	2	1.1	—	—	3	4.8
Barium-140	—	—	4	5.0	—	—	—	—

significantly ($P < 0.005$) different among areas (Table 1). The doves which contained significantly more ^{137}Cs in muscle tissues than control birds were from the TRA and the ICPP. The highest muscle concentration, 171 pCi/g, occurred in a bird collected in the TRA. The highest concentration of ^{137}Cs in a dove collected near the ICPP was 11.6 pCi/g. Birds collected near the RWMC, TAN, EBR-II, ARA and NRF contained ^{137}Cs concentrations similar to that in control birds. The ^{137}Cs concentrations in birds collected near the TRA and the ICPP were variable (Table 1). Birds with non-detectable ^{137}Cs concentrations were collected from both areas during each year of the study. The highest ^{137}Cs concentration in muscle from areas other than these two areas was 2.0 pCi/g and occurred in a dove collected from the background or control locations. The annual average ^{137}Cs in tissues of doves collected near the ICPP and the TRA also varied between years. However, only the data at the ICPP were significantly different between years.

Cesium-137 concentrations in dove gastrointestinal tracts were signifi-

TABLE 4
INTERNAL RADIATION DOSE RATES TO MOURNING DOVES FROM CESIUM-137 IN MUSCLE
FROM 1974-1977 RADIATION DOSE (MRAD¹/DAY)

Collection site	1974		1975		1976		1977	
	\bar{x}	Range	\bar{x}	Range	\bar{x}	Range	\bar{x}	Range
Test Reactor Area	0.03	<0.01-0.13	0.08	<0.01-0.45	0.03	0.02-0.04	0.30	<0.01-3.24
Idaho Chemical								
Processing Plant	0.06	<0.01-0.22	0.02	<0.01-0.03	0.04	0.01-0.1	—	—
Radioactive Waste								
Management								
Complex	0.01	<0.01-0.02	0.01	<0.01-0.02	—	—	—	—
Control	0.01	<0.01-0.02	0.02	<0.01-0.04	0.01	—	—	—

¹ mrad = 10³ rad, a rad is a measurement of absorbed radiation dose.

cantly different ($P < 0.05$) among areas during 1974 and 1975 (Table 2). Gastrointestinal tracts of the doves collected near the ICPP and the TRA were significantly higher than those of the control birds or of the birds from other on-site areas. The highest ¹³⁷Cs concentration in the GI tracts was from the TRA (430 pCi/g). The highest concentration in ICPP gastrointestinal tissues was 139 pCi/g. The highest ¹³⁷Cs concentration in gastrointestinal tracts from areas other than ICPP and TRA was 7 pCi/g and occurred in a control bird.

Twenty radionuclides other than ¹³⁷Cs were detected in muscle and GI tracts of doves from the TRA and the ICPP during the 4-year study (Table 3). In comparison, only three radionuclides other than ¹³⁷Cs were detected in tissues of control doves. Chromium-51 occurred in one control GI tract at a concentration of 11 pCi/g. Cobalt-60 and ¹⁸¹Hf each occurred in one control GI tract at concentrations less than twice the minimum detectable concentration.

Five radionuclides, ⁶⁰Co, ¹⁰³Ru, ¹⁰⁶Ru, ⁵⁴Mn and ¹²⁵Sb, occurred in seven dove tissues at locations on the INEL Site other than the TRA and the ICPP. Of these five radionuclides, only ¹⁰³Ru was detected in 1800 ml samples of rumen contents from off-site pronghorn antelope (*Antilocapra americana*) during the same period as this study (Markham et al. 1982). Therefore, at least four of these radionuclides in doves from other INEL locations likely resulted from INEL atmospheric or liquid discharges. The concentrations in the seven GI tract and muscle samples were less than twice the minimum detectable concentration for each radionuclide.

Dose rates to Mourning Doves from radionuclides deposited in the muscle ranged from <0.1-3.2 mrad/day (Table 4). Birds from TRA received

the highest doses in 1975 and 1977. ICPP birds had the highest doses in 1974 and 1976. The maximum dose received was by a TRA bird in 1977.

The maximum radiation dose commitment from ^{137}Cs to a person who might consume muscle tissue of a dove was 0.3 mrem. The average calculated dose for consuming doves from the TRA and the ICPP was 0.01 mrem. The other radionuclides present in dove tissues would provide an insignificant dose to people consuming dove tissues because of their low occurrence in tissues and/or their relatively low energy gamma rays and low concentration as compared to ^{137}Cs .

DISCUSSION

Mourning Doves collected at the Test Reactor Area and the Idaho Chemical Processing Plant generally contained higher ^{137}Cs concentrations and had a higher occurrence of other radionuclides than did birds from the control area and other INEL facilities. The ICPP releases over 99% of the particulate radionuclide emissions of INEL facilities. Similarly, the TRA radioactive leaching ponds have received approximately 85% of the total radioactive waste water discharged to the lithosphere from all INEL facilities (Millard et al. 1976). Therefore, the two primary sources of contamination for doves on the INEL Site were atmospheric effluents associated with nuclear fuel reprocessing and liquid effluents associated with test reactors. The storage of solid radioactive waste beneath the soil surface at the RWMC apparently did not contribute to the body burden of radionuclides in doves. Other on-site nuclear facilities such as reactors and nuclear fuel handling and examination facilities were not sources of contamination for these birds either. The ^{137}Cs concentrations in control birds were likely due to worldwide fallout from previous atmospheric testing of nuclear weapons.

A variety of wildlife, including 94 bird species, have been observed at the TRA radioactive leaching ponds (Halford and Millard 1978). Many of these birds either feed or drink at these ponds. Waterfowl collected from the TRA ponds during the same years as this study contained average ^{137}Cs muscle concentrations that were over 150 times larger than the average concentrations in Mourning Doves (Halford et al. 1981). Raptors within 3.5 km of the TRA apparently obtained a portion of their prey near the leaching ponds. Raptor nestlings located within 0.2 km of the ponds contained wholebody radionuclide concentrations which ranged from 1.3–87 pCi/g (Craig et al. 1979). Adult Barn Swallows (*Hirundo rustica*) nesting near the TRA radioactive leaching ponds contained average wholebody ^{137}Cs concentrations of 90 pCi/g and also contained higher concentrations of several other radionuclides than did doves (Millard et al. 1978). Sage Grouse (*Centrocercus urophasianus*) also have been studied at the TRA

pond and contained concentrations of ^{137}Cs which were similar to those occurring in doves (Connelly and Markham, in press).

Based on our observations, Mourning Doves at the TRA ponds primarily drink water in this area, but do not feed extensively. Therefore, their concentrations of ^{137}Cs were lower than Barn Swallows, waterfowl and raptors which also feed in the area. Raptors apparently obtained their radionuclide body burden from prey captured near the TRA ponds (Craig et al. 1979). Barn Swallows feed on emerging insects from the pond (Millard et al. 1978) and waterfowl feed on pond flora and fauna (Halford et al. 1981). Sage Grouse occasionally feed on littoral vegetation and some likely drink at these ponds. The ^{137}Cs concentrations in the water at the TRA ponds are factors of 80–30,000 times less than concentrations in flora and fauna in the ponds (Millard et al. 1978).

We have observed doves feeding and obtaining grit in and around the ICPP area. Raptors, which also likely obtained a portion of their diet from the ICPP area, generally contained lower radionuclide concentrations than doves collected near the ICPP (Craig et al. 1979). Muscle from pronghorn antelope collected 1974–1976 within 10 km of the ICPP averaged 0.3 pCi $^{137}\text{Cs}/\text{g}$ (Markham et al. 1982), which was lower than the concentrations in ICPP doves. However, the pronghorn and raptor samples were obtained over a much larger area than were the doves.

Studies by our laboratory indicate that ^{137}Cs concentrations in soil surrounding the ICPP rapidly decrease with distance. Therefore, the relative locations of feeding activities in the ICPP area would affect ^{137}Cs concentrations. Also, part of the variability of ^{137}Cs in dove tissues was probably due to the variable amount of time doves spent drinking at TRA or feeding near the ICPP. Water was available at other locations at the ICPP and TRA, so doves could spend considerable periods of time at either facility without having to drink water from the radioactive leaching ponds. The differences in regularity of individuals drinking at the radioactive leaching pond also likely affected the variability of ^{137}Cs concentrations.

The average ^{137}Cs muscle concentrations in doves at the ICPP during 1974, 1975 and 1976 were 3.24, 0.84 and 1.98 pCi/g, respectively. The ICPP released 6.7, 0.6 and 0.1 Ci of $^{137}\text{Cs}/\text{year}$ in its atmospheric effluents for 1974, 1975 and 1976, respectively. During 1975, additional filters were added to the filter system at the ICPP. Thus, the total atmospheric releases of ^{137}Cs in 1975 and 1976 were reduced over those of 1974. Subsequently, the ^{137}Cs concentrations in dove tissues from the ICPP area were reduced.

Radiation dose rates received by doves ingesting radionuclides were similar to those received by raptors nesting near TRA and ICPP (Craig et al. 1979). Deer mice (*Peromyscus maniculatus*) from the TRA received

average internal dose rates of 5 mrem/day (Halford and Markham 1978), about 15 times higher than the highest mean internal dose rate to doves. Young Barn Swallows at TRA received average daily doses of 220 mrad (Millard et al. 1978), over 700 times the doses received by Mourning Doves. All of the previously mentioned studies have found no radiation-induced effects from the ingestion of radionuclides. The doses received by doves in this study (Table 4) are low compared to doses cited in these previous studies and therefore would not be expected to produce any radiation hazard to the birds.

Cobalt-58, ^{51}Cr and ^{131}I were present in three doves collected at ICPP. These radionuclides do not normally occur in ICPP atmospheric effluents (White 1978) since nuclear fuels reprocessed at the ICPP have been aged sufficiently so that these short-lived isotopes have decayed. Therefore, the presence of these radionuclides in these three ICPP birds indicate that these birds were present at the TRA radioactive leaching ponds at some earlier date. Although the ICPP and TRA sites are only 3 km apart, little mixing of these birds apparently occurred.

Similarly, there was no evidence that large numbers of doves became contaminated and moved to other portions of the INEL Site. Since ^{137}Cs is a ubiquitous fallout product from previous above-ground nuclear bomb tests, its presence or absence could not be used to determine whether doves had visited TRA prior to collection. However, 20 radionuclides other than ^{137}Cs that do not normally occur in worldwide fallout were detected in muscle and GI tract samples from TRA birds and these could be used to determine their past presence at TRA. Only 4 of 124 doves collected on or near the site at locations other than ICPP and TRA contained radionuclides that could be traced to the TRA radioactive leaching ponds.

The INEL Site is closed to hunting so no Mourning Doves are legally harvested there. However, doves at TRA and ICPP are available for harvest by sportsmen during the September hunting seasons when the doves frequently fly offsite to feed on wheat (Trost et al. 1976) or migrate from the INEL Site. The potential radiation dose equivalent to a human eating a dove, containing the maximum ^{137}Cs concentration observed in muscle tissue in this study, was only 0.3 mrem. In perspective, this dose is approximately 0.3% of the average 117 mrem/year radiation dose equivalent received by humans in the INEL area from naturally occurring external radiation (U.S. Dept. Energy 1979) and 2% of the 17 mrem people received from ^{40}K , a naturally occurring radionuclide in the body (Klement et al. 1972). The maximum permissible wholebody dose commitment to an individual in the general population, as established by the I.C.R.P. (1959) and the U.S. Dept. Energy (1977), is 500 mrem/year. The radiation dose to humans from consuming doves would be negligible. Waterfowl from the

TRA which contained higher concentrations than doves and had greater mass have also been shown not to be a hazard to people consuming them (Halford et al. 1981). Although not determined, the biological half-life (the time necessary for one-half of the cesium to be eliminated from the body) for doves is probably similar to the 11-day average for Mallards (*Anas platyrhynchos*) (Halford et al., unpubl.), the 6-day average for Wood Ducks (*Aix sponsa*) (Fendley et al. 1977) and the 6.7-day half-life reported for Blue Jays (*Cyanocitta cristata*) (Levy 1975). Therefore, it is likely that the doves would quickly eliminate the ^{137}Cs once they migrated from the source of contamination.

SUMMARY

Tissues from 252 Mourning Doves (*Zenaida macroura*) were collected near seven different types of nuclear facilities and four other locations on and near the Idaho National Engineering Laboratory Site in southeastern Idaho and analyzed for gamma emitting radionuclides. Cesium-137 was the only radionuclide commonly present in tissues from all locations. Only Mourning Doves collected at the Test Reactor Area (TRA) and the Idaho Chemical Processing Plant (ICPP) contained higher concentrations of ^{137}Cs than control birds. Twenty radionuclides other than ^{137}Cs were detected in samples from TRA and ICPP but their frequency of occurrence and concentrations were much lower than for ^{137}Cs . Cesium-137 and other radionuclides in doves from the ICPP had their origin as atmospheric effluents from the ICPP while radionuclides in the TRA birds originated from radioactive leaching ponds. There was no evidence the doves became contaminated at TRA and moved to other locations as only four of the 124 doves collected at other locations on and near the INEL Site contained radionuclides that originated from TRA. Cesium-137 in muscle tissues would contribute a negligible potential radiation dose to the birds or to humans consuming the doves.

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LITERATURE CITED

- ARTHUR, W. J. AND O. D. MARKHAM. 1978. Ecology studies at the Idaho National Engineering Laboratory Radioactive Waste Management Complex. Pp. 74-92 in Ecological studies on the Idaho National Engineering Laboratory Site 1978 progress report, IDO-12087 (O. D. Markham, ed.), Natl. Tech. Info. Serv., Springfield, Virginia.
- CONNELLY, J. W. AND O. D. MARKHAM. 1982. Movements and radionuclide concentrations of Sage Grouse in southeastern Idaho. *J. Wildl. Manage.* In press.
- CRAIG, T. H., D. K. HALFORD AND O. D. MARKHAM. 1979. Radionuclide concentrations in nesting raptors near nuclear facilities. *Wilson Bull.* 91:72-77.
- FENDLEY, T. T., M. N. MANLOVE AND I. L. BRISBIN, JR. 1977. The accumulation and elimination of radiocesium by naturally contaminated Wood Ducks. *Health Phys.* 32:415-422.

- HALFORD, D. K. AND O. D. MARKHAM. 1978. Radiation dosimetry of small mammals inhabiting a liquid radioactive waste disposal area. *Ecology* 59:1047-1054.
- AND J. B. MILLARD. 1978. Vertebrate fauna of a radioactive leaching pond complex in southeastern Idaho. *Great Basin Nat.* 38:64-70.
- , J. B. MILLARD AND O. D. MARKHAM. 1981. Radionuclide concentrations in waterfowl using a liquid radioactive waste disposal area and the potential radiation dose to man. *Health Phys.* 40:173-181.
- HARNISS, R. O. AND N. E. WEST. 1973. Vegetation patterns of the National Reactor Testing Station, southeastern Idaho. *Northwest Sci.* 47:30-43.
- HOLLANDER, M. AND D. A. WOLFE. 1973. *Nonparametric statistical methods*. John Wiley and Sons, New York, New York.
- INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION. 1959. *Permissible doses for internal radiation*, Publ. 2. Pergamon Press, London, England.
- . 1968. *Evaluation of radiation doses to body tissues from internal contamination due to occupation exposure*, Publ. 10. Pergamon Press, London, England.
- KLEMENT, A. W., JR., C. R. MILLER, R. P. MINX AND B. SCHLEIEN. 1972. *Estimates of ionizing radiation doses in the United States*. 1960. ORP/CSD 72-1. U.S. Environ. Protection Agency, Rockville, Maryland.
- LEVY, C. K. 1975. Avian radioecology on a nuclear power station site. *Tech. Progr. Rept. Manomet Bird Observatory, Manomet, Massachusetts*.
- MARKHAM, O. D., D. K. HALFORD, R. E. AUTENRIETH AND R. L. DICKSON. 1982. Radionuclides in pronghorn resulting from nuclear fuel reprocessing and worldwide fallout. *J. Wildl. Manage.* 46:30-42.
- MCBRIDE, R., N. R. FRENCH, A. H. DAHL AND J. E. DETMER. 1978. Vegetation types and surface soils of the Idaho National Engineering Laboratory Site, IDO-12084. *Natl. Tech. Info. Serv.*, Springfield, Virginia.
- MILLARD, J. B., F. W. WHICKER AND O. D. MARKHAM. 1976. An ecological study of the Test Reactor Area radioactive leaching ponds. Pp. 17-18 *in* 1975 progress report Idaho Natl. Engin. Lab. Site radioecology-ecology program, IDO-12080. *Natl. Tech. Info. Serv.*, Springfield, Virginia.
- , ——— AND ———. 1978. Barn Swallows nesting near radioactive leaching ponds in southeastern Idaho. Pp. 1-14 *in* Ecological studies on the Idaho Natl. Engin. Lab. Site 1978 progress report, IDO-12087. *Natl. Tech. Info. Serv.*, Springfield, Virginia.
- REYNOLDS, T. D. AND C. H. TROST. 1981. Grazing, crested wheatgrass, and bird populations in southeastern Idaho. *Northwest Sci.* 55:225-234.
- TROST, C. H., O. D. MARKHAM AND J. DEHERRERA. 1976. Food and habits of doves on the INEL Site. Pp. 7-9 *in* Summaries of the Idaho National Engineering Laboratory Site ecological information meeting, IDO-12079 (O. D. Markham, ed.). *Natl. Tech. Info. Serv.*, Springfield, Virginia.
- U.S. DEPARTMENT OF ENERGY. 1977. *Standards of radiation protection*. U.S. Energy Research and Development Administration Manual Chapter 0524, Washington, D.C.
- U.S. DEPARTMENT OF ENERGY. 1979. *1978 Environmental monitoring program report for Idaho Natl. Engin. Lab. Site*, IDO-12082. *Natl. Tech. Info. Serv.*, Springfield, Virginia.
- WHITE, S. S. 1978. *Idaho National Engineering Laboratory radioactive waste management information 1977 summary and record-to-date*, IDO-10054(77).

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