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MOVEMENTS AND RADIONUCLIDE CONCENTRATIONS OF SAGE GROUSE IN SOUTHEASTERN IDAHO

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Abstract: Movements and radionuclide concentrations of sage grouse (*Centrocercus urophasianus*) summering near nuclear facilities on the Idaho National Engineering Laboratory in southeastern Idaho were studied from 1977 through 1980. From 10 July through 7 September, 95% of all locations ($N = 131$) of radio-marked grouse were within 2 km of their feeding areas on lawns surrounding the facilities. During October and November, 82% of all radiolocations ($N = 22$) were greater than 2 km from these areas. The maximum 1-way movement to winter range was 81 km. Radionuclide concentrations (primarily radiocesium) were higher ($P = 0.05$) in sage grouse summering near a facility with liquid radioactive waste storage than in grouse summering near a solid radioactive waste disposal area or in control areas. The short biological half-life of the ingested radionuclides and the timing of sage grouse movements from summering areas reduced any potential radiation dose to a person consuming 1 of these birds.

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Radionuclides are similar to other environmental pollutants because they can enter biological cycles and may pose a danger to components of these cycles, including wildlife and man (Woodwell 1967). The transport of radionuclides from disposal sites by wildlife has been investigated (Brisbin et al. 1974, Straney et al. 1975, Cadwell et al. 1979, Springer 1979, Halford et al. 1981); however, much of this research has dealt with waterfowl or mammals.

Sage grouse are attracted to nuclear facilities on the Idaho National Engineering Laboratory (INEL) in southeastern Idaho (Connelly 1982) by an abundance of forbs and free water during the summer. Some birds move off-site just prior to or during the hunting season. The objectives of our study were to: (1) document the number of sage grouse and their residence time at INEL facilities, (2) define sage grouse movement patterns

away from INEL facilities, (3) document the kinds and amounts of radionuclides accumulated by grouse summering near INEL facilities, and (4) calculate the potential dose commitment to a person consuming a sage grouse shortly after it left the vicinity of an INEL nuclear facility.

This study was supported by the Office of Health and Environmental Research, U.S. Department of Energy. Technical assistance was supplied by the Idaho Department of Fish and Game. We thank all of the individuals from the above agencies who contributed to this study. We are especially grateful to W. J. Arthur and I. J. Ball for administrative guidance, advice, and field assistance. I. J. Ball, R. J. Jonas, J. M. Peek, and V. Schultz reviewed earlier drafts of this paper. C. Braun and 2 anonymous referees also provided helpful comments on this manuscript.

STUDY AREA

The INEL is a 231,600-ha area administered by the U.S. Department of Energy. The site is in a semiarid, cold desert on the upper Snake River Plain at the foot-

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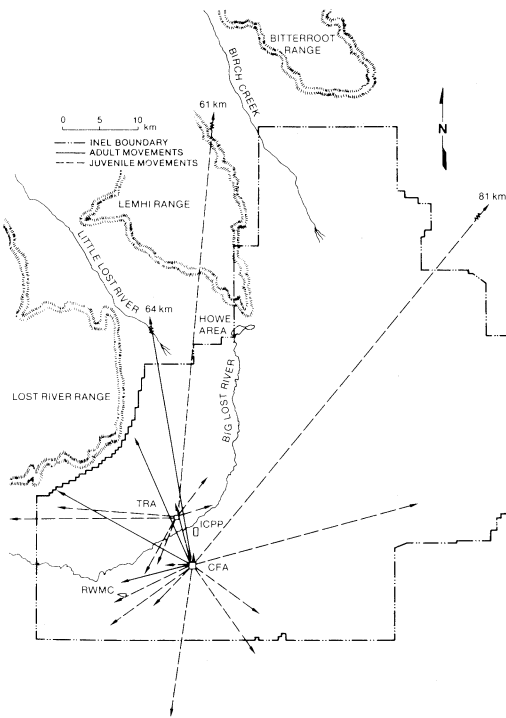


Fig. 1. Study areas and movements of marked sage grouse from the Central Facilities Area (CFA) and the Test Reactor Area (TRA) on the INEL, 1977–80. Distances are indicated for movements greater than 30 km; other movements are drawn to scale.

hills of the Lost River, Lemhi, and Bitterroot mountain ranges. The climate is characterized by hot summers and cold winters with annual precipitation averaging 20.6 cm. Big sagebrush (*Artemisia tridentata*) and bunchgrasses are common in most habitats (Harniss and West 1973).

Sage grouse were studied near 3 INEL facilities and in 2 off-site areas (Fig. 1). The Central Facilities Area (CFA) and the Test Reactor Area/Idaho Chemical Processing Plant complex (TRA/ICPP) are in the south central portion of the site along the Big Lost River. Both areas contain irrigated lawns, abundant forbs, and sources of free water. Additionally, the Test Reactor (TRA) contains a leaching pond complex that has been used for the disposal of

low level liquid radioactive waste since 1952 (Halford and Markham 1978). The Idaho Chemical Processing Plant (ICPP) lies 4.7 km southeast of TRA and past atmospheric releases of particulate activity have resulted in surface soil contamination in the ICPP vicinity (Bowman et al. 1976). The CFA contains support services for the INEL and is not a nuclear facility. The Radioactive Waste Management Complex (RWMC) is in the southern portion of the INEL and has been used since 1952 to store transuranic contaminated waste and to dispose of waste contaminated with activation and fission radionuclides. This facility has many disturbed sites containing a variety of forbs and free water is often available.

Two areas were used as control sites. The Howe area contained big sagebrush habitat bordering alfalfa and wheat fields at the mouth of the Little Lost River (Fig. 1). The lower Birch Creek area is an inter-spersion of big and low sagebrush (*A. arbuscula*) habitats approximately 26 km northeast of the Howe area.

METHODS

The study was conducted from June through November 1977–80. Sage grouse were counted during early mornings or evenings at CFA, TRA, and Howe 2 or 3 times/month from June through October. A 14.5-km survey route was established in the Howe area and all grouse observed along this route were recorded. The RWMC and lower Birch Creek were not surveyed because of access and time limitations. Sage grouse were captured with drive traps (Gill 1965) and mist nets at CFA and TRA from July to September 1977–80. All captured birds were banded. Females were fitted with a poncho-mounted transmitter (Amstrup 1980) or a backpack transmitter, or were color-marked with numbered ponchos (Pyrah

1970). Males were fitted with a backpack transmitter or color-marked with numbered patagial tags. Locations of radio-marked birds were obtained at least once a week during the summer and once a month during the fall. The minimum area method (Mohr 1947) was used to estimate home range.

Forty-three (9 adults, 34 juveniles) sage grouse were collected near nuclear facilities and 20 (9 adults, 11 juveniles) were collected in control areas. A 70-g pectoralis muscle sample and the gastrointestinal (G.I.) tract from each grouse were analyzed for gamma-emitting radionuclides using a 65-cm³ lithium-drifted germanium crystal coupled to a computer controlled multichannel analyzer. All tissues were gamma-scanned as fresh or frozen material with uniform dimensions and volumes. Results are reported in picocuries/gram (pCi/g). The minimum detection limit for all nuclides identified ranged from 0.14 to 2.20 pCi/g for muscle samples and from 0.04 to 1.78 pCi/g for G.I. tract samples. Some radioactivity decreased between time of collection and analysis because of the short half-lives of some of the radionuclides; therefore, sample results were corrected for radioactive decay. All data were coded and log-transformed prior to statistical analysis (Steel and Torrie 1980). Analysis of variance and Student's *t* tests were used for statistical comparisons. The least significant difference (lsd) test for unequal sample sizes (Steel and Torrie 1980:192) was used to compare means when ANOVA indicated a significant difference between groups.

The average and maximum potential whole-body dose commitments to a person consuming sage grouse muscle were calculated following Hoenes and Soldat (1977) where

$$DC = \sum_{i=1}^n [DCF_i \cdot M \cdot C_i]$$

and *DC* equals the whole-body dose commitment, *DCF_i* is a dose commitment factor for the *i*th radionuclide, *M* is the muscle mass consumed, and *C_i* is the concentration of the *i*th radionuclide. The average concentration of each radionuclide detected in at least 10% of the muscle samples was used in calculating the average dose commitment. The maximum concentration for each radionuclide detected was used in calculating the maximum dose commitment. Calculations were based on the consumption of the entire muscle mass of 1 sage grouse on the same day the bird left the nuclear facility. Radioactive decay, biological elimination, and volatilization of radionuclides during cooking were not considered in dose calculations.

RESULTS

Residence Time and Movements

Sage grouse arrived on the study areas between mid-June and mid-July and remained until early September to mid-November. Grouse left the CFA and TRA later in relatively dry summers (<4 cm precipitation, Jul-Sep); however, spring precipitation did not affect arrival dates. Sage grouse using the Howe area arrived later in a dry spring (May-Jun precipitation = 2.5 cm) and remained longer during wet summers (>5.5 cm precipitation). Grouse were present at INEL facilities from 43 to 139 days and averaged 95 days/year from 1977 through 1980. Sage grouse used the Howe area an average of 102 days/year from 1978 through 1980. Survey counts from CFA, TRA, and Howe reflected a generally stable to increasing population from 1977 to 1979 with a slight decrease in 1980; however, these data may be biased during drier years if more grouse concentrated near these relatively moist sites.

Highest counts of sage grouse occurred

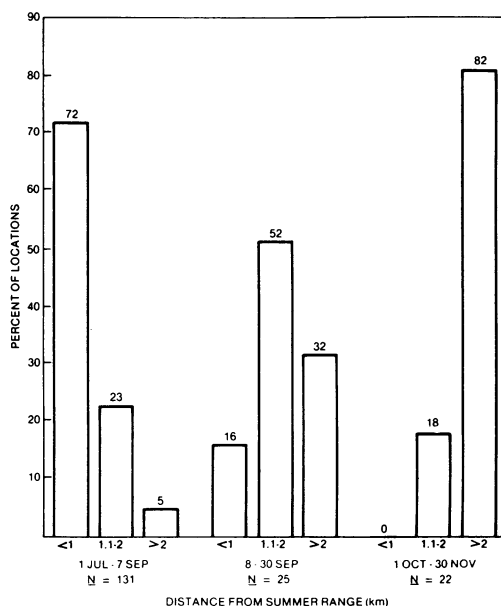


Fig. 2. Frequency of locations of radio-marked sage grouse with respect to their capture sites on summer range at INEL facilities. The number of locations (N) is indicated for each period.

in August or September in all areas for 1977–80. Sage grouse used the CFA during October 1977–79, but not in 1980. Sage grouse use of the TRA and Howe area was minimal during October 1977–80.

From 1977 to 1980, 245 sage grouse were marked at CFA and TRA; 84% of these were captured before 7 August. Data were obtained on the movements of 29 grouse, 14 of which were radio-marked. Of this sample, dispersal of 22 grouse from their summering areas was documented. We recorded 178 radiolocations while monitoring these birds over a total of 550 grouse days.

From 10 July to 7 September, 72% of all radiolocations ($N = 131$) were ≤ 1 km from the facilities and 95% were within 2 km (Fig. 2). Some individuals did not remain near their capture sites for the entire summer. Three of 14 radio-marked sage grouse left summer areas prior to 7

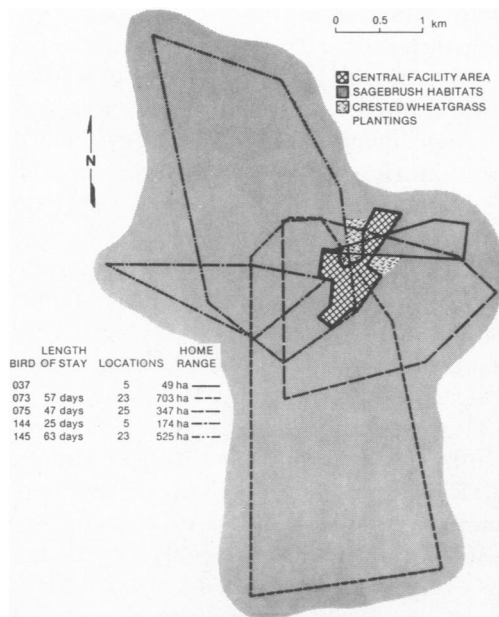


Fig. 3. Summer home ranges of 5 adult female sage grouse marked at the Central Facilities Area on the INEL during 1979–80. Length of stay, number of radiolocations, and size of summer range are indicated for each bird. The transmitter on female 037 stopped functioning after 21 days.

September; 2 moved to sagebrush habitats and 1 moved to another INEL facility. One of the grouse that moved to sagebrush habitat returned to the CFA after 14 days; the other grouse was killed by a predator approximately 2 weeks after leaving its summer range. At least 3 color-marked grouse also left their banding areas before 7 September. Two moved from the CFA to the TRA and the 3rd was killed on a highway near the RWMC. Relatively few locations were within 1 km of summer trapping sites during the last 3 weeks of September. By the first week of October, most birds had abandoned summering areas and were in sagebrush habitats. Most October–November radiolocations were > 2 km from the facilities and ranged from 2 to 32 km (Fig. 2). Movements were generally north or south from the INEL

facilities (Fig. 1). The average 1-way movements to winter range from the CFA and TRA were 19.9 and 15.5 km, respectively (range = 0.2–81.0 km).

We estimated summer (10 Jul–7 Sep) home ranges for 5 adult females, 2 juvenile males, and 1 juvenile female. The 5 adults were marked in mid-July at the CFA and 4 had broods when captured. Females with broods remained at the CFA for an average of 47 days after being marked and had a mean summer range of 406 ha. The female without a brood remained at the CFA for 25 days and occupied a summer range of 174 ha (Fig. 3). The 3 juveniles were marked at TRA in late July and early August and remained at this facility for an average of 35 days. All 3 juveniles were associated with broods when captured. These birds occupied a mean summer range of 94 ha (Fig. 4). The estimated residence times at these facilities are minimum because the exact arrival dates for these birds were not known.

Six radio-marked grouse were monitored throughout the hunting season and none left the site during this period. Only 5 hunter band recoveries were obtained from the 245 sage grouse marked and 1 of these birds was shot on the INEL.

Radionuclide Concentrations

Seventeen radionuclides were detected in sage grouse collected at TRA/ICPP and 2 radionuclides were detected in RWMC birds (Table 1). Seven radionuclides were detected in grouse collected in control areas. ^{137}Cs was the most frequently occurring radionuclide and was detected in samples from all locations. Of the radionuclides detected, only ^{137}Cs , ^{134}Cs , ^{60}Co , and ^{106}Ru had half-lives exceeding 1 year. ^{51}Cr had the highest average concentration in G.I. tract samples, but was not detected in muscle samples. ^{137}Cs had the highest average concentration in muscle

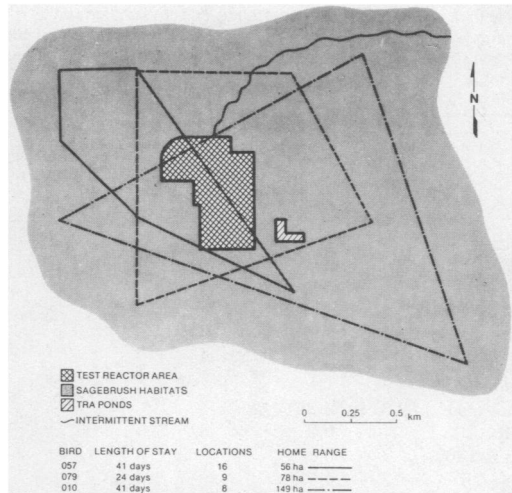


Fig. 4. Summer home ranges of 3 juvenile sage grouse marked at the Test Reactor Area on the INEL during 1978–79. Length of stay, number of radiolocations, and size of summer range are indicated for each bird.

samples and was the only radionuclide detected in at least 25% of the muscle samples from all areas.

Radionuclide concentrations in muscle samples of grouse collected at TRA/ICPP ($\bar{x} = 0.29 \text{ pCi/g}$, $N = 29$) were higher (ANOVA, $P = 0.05$) than those of control birds ($\bar{x} = 0.13 \text{ pCi/g}$, $N = 20$). No difference was found in muscle concentrations between TRA/ICPP and RWMC samples ($\bar{x} = 0.14 \text{ pCi/g}$, $N = 14$) or between RWMC and control samples ($P > 0.05$). G.I. tract radionuclide concentrations in grouse from TRA/ICPP ($\bar{x} = 0.80 \text{ pCi/g}$, $N = 29$) were higher than those of RWMC ($\bar{x} = 0.05 \text{ pCi/g}$, $N = 14$) or control birds ($\bar{x} = 0.11 \text{ pCi/g}$, $N = 19$) ($P < 0.001$). No difference ($P > 0.05$) existed between G.I. tract concentrations in RWMC and control grouse.

G.I. tract radionuclide concentrations in both RWMC and control samples were equal to or less than muscle concentrations; however, in TRA/ICPP grouse, G.I. tract concentrations were higher (t test,

Table 1. Frequency of occurrence (%) and maximum and mean^a radionuclide concentrations (pCi/g fresh weight) in tissue samples from sage grouse collected during summer and fall 1977–79 at the Test Reactor Area/Idaho Chemical Processing Plant (TRA/ICPP) complex, the Radioactive Waste Management Complex (RWMC), and in off-site control areas, southeastern Idaho.

Nuclide	TRA/ICPP						RWMC						Control areas					
	G.I. tract (N = 29)			Muscle (N = 29)			G.I. tract (N = 14)			Muscle (N = 14)			G.I. tract (N = 19)			Muscle (N = 20)		
	Freq.	Max.	$\bar{x}$	Freq.	Max.	$\bar{x}$	Freq.	Max.	$\bar{x}$	Freq.	Max.	$\bar{x}$	Freq.	Max.	$\bar{x}$	Freq.	Max.	$\bar{x}$
Cr-51	38	539.0	60.3		b			b			b			b			b	
Cs-137	93	107.0	6.2	86	30.1	1.8	100	0.2	0.1	100	0.4	0.3	89	0.2	0.1	90	0.4	0.3
Co-60	31	25.2	2.0	24	1.9													
Ce-144	7	7.1			b			b			b		5	1.5			b	
Cs-134	28	26.8	1.3	14	5.8			b			b			b			b	
Nb-95	24	1.8		3	0.2			b			b		16	0.7			b	
Zr-95	10	1.1						b			b		11	0.7			b	
Ce-141	3	2.2						b			b		11	0.8			b	
Ru-103	7	0.9		3	0.4			b		7	0.6		11	0.6		5	0.3	
La-140	7	0.6			b			b			b			b			b	
Se-75	17	4.5		3	1.4			ND			ND			ND			ND	
Na-24		ND		3	3.8 ^c			ND			ND			ND			ND	
Ru-106		ND			ND			ND			ND			ND		11	1.5	
Co-58	3	0.1			ND													
Hg-203	7	0.6		7	0.5													
Ba-140		ND		3	2.7													
Mn-54	14	0.7		3	0.3													
Zn-65	34	12.7	0.9	7	1.5													

^a Means only given for those radionuclides occurring in at least 25% of the samples. A zero was used in computing means when nuclides were below detection limits.

^b Not detected.

^c Ci/g.

$P < 0.001$) than muscle concentrations. Additionally, there was a greater number of radionuclides in G.I. tract samples and they occurred with greater frequency (Table 1).

Dose Commitments

The average and maximum potential dose commitments to a person consuming the entire muscle mass of a sage grouse were greater for sage grouse from TRA/ICPP than for either RWMC or control grouse (Table 2). The highest estimated potential dose commitment was 2.37 mrem and would have resulted from consuming an adult male sage grouse that summered near TRA/ICPP. The average and maximum potential dose commitments from RWMC and control grouse ranged from 0.01 to 0.04 mrem. Little difference in either the average or maximum

potential dose commitment was noted between the RWMC or control areas. Potential dose commitments varied because of the difference in body size of the different sage grouse sex and age-classes.

DISCUSSION

Lawns surrounding the INEL facilities provide a unique substitute for natural meadows as do alfalfa fields near the Howe study area. Both provide a predictable source of forbs, insects, and free water during the summer and early fall. Because they are irrigated, neither type of summering area is as seriously affected by drought as are natural meadows. Sage grouse used lawns and other moist areas near the facilities for feeding and loafing in the early morning and evening and spent most of the day in adjacent sage-

Table 2. Estimated dose commitments (mrem)^a to a person consuming the entire muscle mass^b of a sage grouse from the Test Reactor Area/Idaho Chemical Processing Plant (TRA/ICPP) complex, the Radioactive Waste Management Complex (RWMC), and from off-site control areas, southeastern Idaho.

Sage grouse	TRA/ICPP (N = 29)		RWMC (N = 14)		Control areas (N = 20)	
	Max.	$\bar{x}^c$	Max.	$\bar{x}^c$	Max.	$\bar{x}^c$
Male						
Juvenile	1.66	0.10	0.02	0.01	0.03	0.01
Adult	2.37	0.14	0.02	0.02	0.04	0.02
Female						
Juvenile	1.25	0.07	0.01	0.01	0.02	0.01
Adult	1.45	0.08	0.01	0.01	0.03	0.01

^a Doses were based on tissue weight before cooking.

^b Muscle was about 42% of live sage grouse weight.

^c Only radionuclides occurring in at least 10% of the muscle samples were used in calculating the mean dose commitment.

brush areas, usually less than 1 km from feeding sites. This pattern of use is similar to that described for sage grouse using alfalfa fields (Patterson 1952) and upland meadows (Oakleaf 1971). INEL sage grouse remained on summering areas well into September and in several years some birds did not return to sagebrush habitats until October or November. In contrast, Wallestad (1971) reported that many sage grouse broods in Montana moved back to sagebrush habitats in late August and September.

Sage grouse summering near INEL facilities occupied larger summer ranges than grouse using upland meadows (Oakleaf 1971) or sagebrush and bottomland habitats (Wallestad 1971). However, the number of radio-marked birds in all areas was relatively small. The larger summer ranges of INEL sage grouse may be attributable to more human disturbance than occurs near grouse summering in more natural habitats. Also, 4 of the 8 sage grouse for which we have summer range data were monitored during the relatively wet summer of 1980. Sage grouse may occupy larger summer ranges in wet years because of greater availability of succulent forbs and water in sagebrush habitats during these years.

The number and concentration of

radionuclides in sage grouse muscle and G.I. tract samples were generally lower than those reported for waterfowl (Halford et al. 1981) and mourning doves (*Zenaidura macroura*) (Markham and Halford 1982) in the same areas. ¹³⁷Cs concentrations reported for dove muscle were approximately 3 times greater than ¹³⁷Cs concentrations in sage grouse muscle. ¹³⁷Cs concentrations reported for waterfowl muscle were over 400 times greater than those found in sage grouse. The higher concentration in doves and waterfowl were probably due to their greater use of the TRA ponds as compared to use of these ponds by sage grouse. Further, the relatively large summer ranges of INEL sage grouse reduced their exposure to contaminated areas. While some grouse were observed feeding and watering at these ponds, this use was irregular and most birds summering at the TRA used the facility lawns. The difference in radionuclide concentrations between TRA/ICPP and RWMC grouse suggests that the transfer of radioactivity from liquid waste systems is greater than the transfer from solid waste systems.

Although 15 radionuclides were detected in sage grouse G.I. tract samples, many could be considered biologically inactive because they either did not occur

in the muscle or occurred in much smaller concentrations than in the G.I. tract. Because ^{137}Cs and ^{134}Cs follow the same biological pathway as potassium when ingested (Schultz and Whicker 1974), they are readily incorporated into soft tissue and were responsible for the bulk of the radionuclide concentration in grouse muscle tissue. Other radionuclides occurred in muscle tissue but their frequency of occurrence was generally lower. Although a high concentration of ^{24}Na was detected in 1 muscle sample, this value was questionable because the relatively small amount of this nuclide released to the TRA ponds could not account for such a high concentration. We assume that this value was inflated due to external contamination during sample preparation. That radionuclide concentrations in grouse G.I. tract samples were higher than muscle concentrations only at the TRA/ICPP area further reflects the greater number of radionuclides and the higher radionuclide concentrations associated with the immediate TRA/ICPP environment.

The biological half-life of radiocesium for an animal the size of a sage grouse (800–2,500 g) should be between 10 and 15 days (Reichle et al. 1970). If this estimate is correct, any contaminated grouse consumed 10–15 days after leaving the vicinity of a nuclear facility would have lost at least half of its cesium body burden, and, on average, would have less than 1 pCi/g of radiocesium.

The maximum estimated potential whole-body dose commitment to a person eating a sage grouse shortly after it left the vicinity of an INEL facility was 2.37 mrem. The recommended maximum permissible whole-body dose commitment to an individual in the general public is 500 mrem/year (Int. Comm. Radiological Protection 1959) or 208 times the maximum dose commitment from a sage grouse

summering near an INEL facility. To exceed the 500 mrem/year maximum recommended dose commitment, a person would have to eat approximately 422 kg of sage grouse meat or about 211 sage grouse containing maximum concentrations in 1 year.

Sage grouse moved relatively long distances from their summering areas near INEL facilities. Average movements from these facilities were greater than those reported by Wallestad (1971) for Montana sage grouse, but similar to those described by Dalke et al. (1960, 1963) for a sage grouse population in southeastern Idaho. The sage grouse hunting season in Idaho begins the 3rd weekend in September and lasts for 2–3 weeks. The number of grouse from INEL facilities available to hunters was relatively low because most birds did not begin leaving their summering areas until mid-September and had not moved far from these areas until early October. The tendency of these grouse to remain at the facilities throughout the hunting season in drier years further decreased their availability to hunters. The band recovery rate for grouse marked while summering at INEL facilities was 2%, whereas the recovery rate for sage grouse marked on leks located on and near the INEL was 6% (Connelly, unpubl. data), further suggesting that few grouse from INEL facilities moved off-site prior to or during the hunting seasons.

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