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Efficacy of Rock Doves at the Hanford Site, Washington, as Radiological Indicators

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February 1996

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ABSTRACT

I estimated site faithfulness and general movement patterns of five rock dove (Columba livia) flocks to evaluate their efficacy as radiological indicators on the Hanford Site, located in southcentral Washington state, from July 1993 to January 1995. Of 367 individually marked birds, 311 were resighted or recaptured at least once during onsite and offsite monitoring.

Average site faithfulness for all flocks from resightings was 87.1% (sd =16.4%) and was not significantly different than a hypothesized 90% site faithful distribution ($\chi^2 = 3.868$, 4 df, $P > 0.05$). Average site faithfulness from pooled resightings and recaptures was 91.3% (sd = 8.9%), which was also not significantly different than a 90% distribution ($\chi^2 = 2.006$, 4 df, $P > 0.05$). Since Hanford rock doves exhibit site faithfulness and can be easily monitored, I conclude that they can be used as radiological indicators.

I found 107 birds at 21 different locations during offsite surveys in agricultural areas adjacent to the Hanford Site. Mean movement distances from capture areas to offsite locations for each of the five flocks were significantly different ($H = 83.199$, 4 df, $P = 0.000$). Mean movement distances from capture areas to offsite locations for each flock were highly correlated with closest possible distances for each flock ($r^2 = 0.93$, $P = 0.003$). Mean movement directions from capture areas to offsite locations for each flock were significantly different than random movement patterns for each flock.

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INTRODUCTION

Wildlife have been used to detect uptake and biological transport of radionuclides at the United States Department of Energy's Hanford Site in southcentral Washington since the 1940's (Gray 1989). Terrestrial game birds such as California quail (Callipepla californica) and ring-necked pheasant (Phasianus colchicus) are sampled annually to estimate radionuclide concentrations in muscle tissues since they are potential pathways for human uptake of contaminants (Woodruff and Hanf 1992). As resident species, they feed, drink, and breed on or near the Hanford Site. Consequently, any contamination detected above naturally occurring levels can be attributed to Hanford Site sources. Intensive environmental sampling/analysis can then be initiated to identify more precisely the contaminating sources for subsequent clean-up activities. Unfortunately, pheasants and quail are not numerous and are restricted to scarce riparian habitats on the Hanford Site. Non-resident game birds such as waterfowl and mourning doves (Zenaida macroura) are also routinely sampled for contamination, but the amount of time these birds forage on the Hanford Site is limited. All wildlife species that are monitored have been useful as radiological indicators, but are not entirely efficacious.

Rock doves (Columba livia) have not been routinely sampled at the Hanford Site because they have not been thought to be a potential food pathway to humans. However, they are occasionally hunted in agricultural

areas near the Hanford Site. As abundant year-round residents, rock doves are susceptible to uptake and potential transport of Hanford Site radionuclides and are an important species to consider in monitoring schedules because they travel between Hanford Site buildings and offsite agricultural areas (Fitzner and Gray 1991).

Rock doves use buildings on the Hanford Site for roosting and nesting, many of which are potential sources of radionuclides. Due to their close relationship with buildings, rock doves have a greater probability of exposure to radionuclide contamination than do pheasants, quail, and most other wildlife.

Nothing is known about the spatial distribution and movements of rock doves in and around the Hanford Site. Estimating site faithfulness, and, secondarily, movements of free-roaming rock doves is of great value to Hanford Site environmental surveillance. Site fidelity is defined as the propensity for birds to nest or give birth at the same location in successive years, and can occur in migratory (Greenwood 1980) or non-migratory species (Harvey et al. 1979). Site faithfulness in this study is defined as the propensity of birds to stay at the same location throughout the year. In order to be considered reliable indicators of local contaminants, Hanford Site rock doves must exhibit site faithfulness to the areas where they occur. If birds tend to show faithfulness to a particular onsite area, any contamination detected would be

expected to come from either that onsite area or their offsite feeding areas. However, if birds trapped at a certain area do not show faithfulness to that area, but instead move nomadically around the Hanford Site, their value for monitoring would be less definitive because detected contamination could have been picked up at a variety of locations. In addition, estimating general offsite movement patterns of different rock dove flocks would be useful to achieve a more complete understanding of overall spatial distribution.

Therefore, I studied five rock dove flocks nesting and roosting on and near the Hanford Site to estimate site faithfulness and general movement patterns in order to evaluate their efficacy as radiological indicators. Null hypotheses were:

- 1) Hanford Site rock dove flocks exhibit 90 percent site faithfulness to areas of initial capture.
- 2) There is no difference in mean movement distances from capture areas to offsite locations between the Hanford Site rock dove flocks.
- 3) There is no difference in mean movement directions from capture areas to offsite locations between each flock and random directions.

STUDY AREA

Climate and Topography

The Hanford Site encompasses 1,482 km² of semi-arid, shrub-steppe land north of Richland, Washington (Figure 1). The Columbia River forms part of the Site's eastern boundary. Average annual precipitation is 16 cm and most falls between October and May. Winters are cool (avg. January temp - 1.4°C) and summers are hot and dry (avg. July temp 24.8°C) (Rickard et al. 1988). Site topography ranges from rocky basalt ridges to mobile sand-dunes, and most of the Hanford Site located west of the Columbia River consists of broad plain ranging between 120 and 240 m above mean sea level.

Vegetation

The vegetation of the plain consists primarily of big sagebrush (Artemisia tridentata) with an understory of Sandberg's bluegrass (Agropyron spicatum) and cheatgrass (Bromus tectorum). A narrow corridor of woody riparian vegetation dominated by willow (Salix spp.) and mulberry (Morus alba) exists along the Columbia River.

Land Use

The Hanford Site was established in 1943 as an isolated area for the production of plutonium for the U.S. nuclear weapons program (Fitzner and Gray 1991). Byproducts of this production included gamma, beta, and alpha emitting radionuclides, as well as nonradioactive gaseous, liquid, and solid

Figure 1. Location of Rock Dove Site Faithfulness and Movement Study on the U.S. Department of Energy's Hanford Site near Richland, Washington. Map Courtesy of Battelle PNL, Richland, Washington (S9408023.1).

chemicals (Gray 1989). The site was mostly undeveloped with a few large, widely dispersed clusters of industrial buildings connected by highways and railroads.

The Site itself has had no agriculture or livestock grazing for 50 years. Land adjoining the Hanford Site to the east and north has been under irrigated agriculture since the 1950's. Major crops include soft fruit and apple orchards, grapes, alfalfa, vegetables, and dryland wheat (Gray 1989). Grazing land and a few dairy farms are also scattered throughout the irrigated fields.

The Hanford Townsite (HTS), 100K Area (100K), 200 East Area (200E), and 300 Area (300) were the primary onsite trapping locations (Figure 1). The HTS consisted of an abandoned school house and pump station that were in place before the Hanford Site was established. The HTS supported a flock of rock doves, but did not have contamination readily accessible to birds. Doves also were trapped on the north end of the city of Richland.

METHODS

Field Work

Pilot Study

In order to gain a basic understanding of the movement patterns of the various rock dove flocks, I watched movement patterns and directions at each of the five flocks prior to establishing an experimental design. I watched birds depart nesting and roosting areas in the morning and return in the evening. Movement directions were estimated by obtaining a compass bearing on individual birds or small flocks as they disappeared from view in the distance. Birds from Richland, 300, HTS, and 200E flew eastward, while birds from 100K flew to the northwest. No birds were observed flying south or southwest from the Site boundary. These movement patterns appeared to be logical since agricultural areas were nearest in the directions birds flew, and rangeland predominated in directions not flown. Therefore, I concentrated offsite survey effort in irrigated agricultural areas where birds were observed flying and did not search for offsite locations in rangeland habitat.

Capture and Tagging

Rock doves were periodically captured via walk-in traps baited with corn from July 1993 to September 1994. Some birds were captured with nets as they were flushed out of a building. I marked all captures with colored patagial tags for individual visual identification. Each bird also was given a

uniquely numbered aluminum leg band. Rock dove flock names and patagial tag color were unique to their initial capture location (e.g., HTS, 100K, 200E, 300, and Richland were orange, white, red, green, and blue, respectively). I included city of Richland birds to estimate movements of urban birds to the Hanford Site in order to assess the potential for transport of Hanford Site contamination back into Richland. Patagial tag construction followed Kautz and Seamans (1992). I classified trapped birds as juvenile or adult by cere characteristics. Juveniles were distinguished by the absence of a white cere, which first becomes prominent about the time of sexual maturity and increases in size with age (Wofford and Elder 1967, Kautz and Seamans 1986). Only older juveniles were tagged. Recaptures from all areas also were noted throughout the study.

Site Faithfulness

Transect routes were driven to estimate site faithfulness of the five flocks from January 1994 to January 1995. Surveys were conducted during the middle of the day to maximize observations as rock doves left the roost at daybreak and late afternoon to feed, and returned periodically throughout the day. The birds tended to congregate on buildings and power lines onsite during the middle of the day and were most detectable at this time. Survey routes were established in eight distinct areas: (1) north end of the city of Richland, (2) 1100 Area (1100), (3) 300 (4) 200E and 200 West (200W), (5) 100K, (6)

100F, and (7) HTS (Figure 1). The city of Richland was included to identify the potential for transport of contamination from birds on the Hanford Site to urban areas. I did not survey some areas on the Hanford Site because rock doves had been removed by animal control agents, birds were not present, or access was restricted for security reasons. The daily sampling order was determined by randomly selecting an initial area then continuing through a standard list until each area had been surveyed (e.g., if 300 was selected, the survey route for the day would be 300, 200E and 200W, 100K, 100F, HTS, Richland, and 1100). The survey consisted of slowly driving through the areas looking for rock doves; all tagged and untagged birds seen from the vehicle with binoculars and/or spotting scope were recorded.

Movements

Technical difficulties precluded the use of radiotelemetry; therefore, I estimated rock dove movements by relocating birds from patagial tag identification from June to December 1994. All agricultural fields, feedlots, barns, silos, circular irrigation rigs, abandoned buildings, and granaries within approximately 15 km of the Hanford Site where rock doves were detected were identified. The number of birds observed varied depending on location and time. A survey list was developed that included all locations where rock doves were consistently observed. Thirty-one locations met this criteria. I grouped these 31 locations into four groups according to geographic location,

and numbered them 1, 2, 3, and 4 (Figure 2). I grouped locations to maximize driving efficiency due to the large size of the survey area. Once or twice a week, a survey was conducted. The first group surveyed each day was randomly chosen and the remainder were surveyed in numerically ascending order (e.g., if group 3 was selected the survey route for the day would be 3, 4, 1, and 2).

At each of the 31 locations, the number of tagged and total number of rock doves observed were tallied. Resightings of tagged birds during surveys were considered "direct" recoveries. New rock dove use areas were noted and added to the survey as discovered. In addition, agricultural areas to the east of the initial survey area were periodically searched for tagged birds to maximize coverage areas. Miscellaneous movement locations and tag information received from October 1993 to January 1995 from farmers, hunters, sportsmen clubs, animal control agents, and our own non-survey resightings were recorded as "indirect" recoveries.

Data Analysis

Site Faithfulness

I estimated site faithfulness for each of the five flocks using resightings, recaptures, and pooled data. I calculated general descriptive statistics for each flock and each set of data.

Figure 2. Locations near the Hanford Site, Washington, that were Surveyed to Estimate Rock Dove Movement Patterns from June to December 1994. Map Developed by Author.

I defined an individual bird as site faithful if every resighting and/or recapture was at the area of initial capture. I estimated an index of flock site faithfulness by dividing the number of tagged birds which had all resightings or recaptures at the site they were initially captured (site faithful individuals) by the total number of tagged individuals from each site observed or recaptured at all sites. I considered a flock site faithful if ≥ 90 percent of the individual birds that were tagged at the area were site faithful. The 90 percent criteria was thought to be stringent enough to be confident in the flock's site faithfulness yet allow for some movement due to factors such as dispersal of young. I tested significance of resighting and pooled data fitting a 90 percent distribution using a χ^2 goodness of fit test at a significance level of $P \leq 0.025$ after a Bonferroni adjustment on the original significance level of $P \leq 0.05$ (Stevens 1986).

Movements

I calculated mean distance between roost site and offsite locations for each flock by averaging distances individual birds traveled from their initial capture area to offsite locations. One random location per bird was used for analysis. Mean flock distances were analyzed using a Kruskal-Wallis nonparametric one-way ANOVA with multiple comparison Z-values (NCSS, Version 5.03, Kayesville, Utah) after appropriate assumptions were tested. To examine the influence proximity to offsite locations had on mean flock

distances, I analyzed mean flock distances and distances from capture area to the closest of all 31 possible locations on the survey route using simple linear regression.

I analyzed movement directions (from initial capture area to offsite locations) for each flock using circular statistics (Batschelet 1981, Zar 1984). A mean angle ($\bar{\theta}$) and mean vector (r) were estimated for each flock based on movement directions of individual birds, where r is an indicator of the degree of concentration. When $r = 1.0$, all birds within a flock would be seen at the same location and when $r = 0.0$, birds would be evenly distributed around a circle (i.e. non-directed movement). I compared the observed mean angle, or direction moved, for each flock to a theoretical mean angle, θ_0 , determined from a random selection of all 31 possible locations. I tested the significance of the difference between the mean angle and random mean angle using confidence intervals (Batschelet 1981:85). I estimated confidence intervals by sample size and the length of the mean vector, r . If the random mean angle did not lie within the confidence interval of the population mean angle, a significant difference existed.

RESULTS

Captures and Resighting Percentages

A total of 367 (30 juveniles) rock doves were captured and individually tagged from July 1993 to September 1994 (Table 1). Eighteen mortalities from unknown causes were documented throughout the course of the study anywhere from a few days to almost a year after tagging. As the length of time after tagging increased, the number of birds resighted from each tagging period on onsite and offsite surveys declined (Table 2).

Site Faithfulness

Surveys to estimate site faithfulness were conducted from 17 January 1994 to 17 January 1995. Fifty-five surveys were conducted from 17 January through May 1994 (2.9/week). To increase efficiency, surveys were reduced to one/week from June to the end of the study. Twenty-six surveys were conducted from June 1994 through 17 January 1995 (0.8/week). One-hundred-seventy-eight of 367 birds were resighted at least once (Table 3). Eighty-eight birds were resighted from January through May during the three survey/week period. To ensure valid comparisons across all surveys, one survey/week was randomly selected from the three survey/week sampling period. This analysis showed that 70 percent (62) of the birds resighted during the three survey/week sampling period were seen with a one survey/week subsample. Of the remaining 30 percent (26) not detected during

Table 1. Total Number of Rock Doves Captured between July 1993 and September 1994 on the Hanford Site, Washington.

Tagging Period	Richland	300	HTS	200E	100K	Total
July/Aug 93	- ^a	-	0	13	53	66
Sept/Oct 93	-	57	14	22	5	98
Nov/Dec 93	-	-	24	2	1	27
Mar/Apr 94	54	-	-	1	-	55
June/July 94	-	32	23	17	30	102
Aug/Sept 94	-	-	6	13	-	19
Total	54	89	67	68	89	367

^a Trapping was not attempted during this period.

Table 2. Percentage of Hanford Rock Doves Resighted During Surveys in Southcentral Washington from January 1994 to January 1995.

Capture Period	Number Tagged ^b	<u>Percentage Resighted Per Survey Period^a</u>					
		Jan/Feb	Mar/Apr	May/June	July/Aug	Sept/Oct	Nov/Dec ^c
July/Aug 93	55	11	24	15	13	0	0
Sept/Oct 93	92	11	28	25	20	11	10
Nov/Dec 93	27	19	19	15	15	7	7
Mar/Apr 94	55		67	60	44	24	13
June/July 94	98			44	60	34	23
Aug/Sept 94	<u>18</u>				33	67	50
Total	345						

^a Percentage resighted only refers to those birds tagged during specific capture periods and observed during specific survey periods.

^b Does not include documented mortalities from each tagging period.

^c Includes one survey from January 1995.

Table 3. Site Faithfulness Estimated by Resighting, Recapture, and Pooled^a Data of Five Rock Dove Flocks Residing on or near the Hanford Site, Washington, from January 1994 to January 1995.

Area		Faithful ^b	Non-faithful	%
Richland				
	Resighting	44	0	100
	Recapture	29	0	100
	Pooled	49	0	100
300				
	Resighting	43	5	90
	Recapture	47	0	100
	Pooled	60	5	92
HTS				
	Resighting	30	4	88
	Recapture	35	1	97
	Pooled	47	5	90
200E				
	Resighting	16	12	57
	Recapture	43	3	93
	Pooled	43	13	77
100K				
	Resighting	22	2	92
	Recapture	60	0	100
	Pooled	62	2	97
TOTAL				
	Resighting	155	23	87
	Recapture	214	4	98
	Pooled	261	25	91

^a Pooled = birds that were resighted, recaptured, or both.

^b Faithful = birds with 100% of resightings and/or recaptures at the area the bird was initially tagged. Unfaithful = birds that had any resightings or recaptures at an area other than the initial area.

the randomly selected subsample, nine were seen at some time in June or beyond. Therefore, a total of 81 percent (71) of the 88 birds detected during the three survey/week period were detected without the more intensive survey schedule. Further, I estimated site faithfulness by both including and excluding the three survey/week data and no differences in site faithfulness existed. Because of this similarity, I used data from all surveys in site faithful analysis. Individually, the Richland, 300, and 100K flocks exhibited ≥ 90 percent site faithfulness based on resightings alone (Table 3).

Two-hundred-eighteen of the 367 birds captured were recaptured at least once (Table 3). Based on recaptures alone, all five flocks exhibited faithfulness to the area of initial capture. When resighting and recapture data were pooled, 286 of 367 birds were resighted and/or recaptured and only the flock from 200E failed to exhibit site faithfulness (Table 3).

The average faithfulness for all flocks from resightings was 87.1 percent (sd =16.40 percent) and was not significantly different than a hypothesized 90 percent distribution ($\chi^2 = 3.868$, 4 df, $P > 0.05$). The average faithfulness derived from the pooled data was 91.3 percent (sd = 8.93 percent) which was not significantly different than a 90 percent distribution ($\chi^2 = 2.006$, 4 df, $P > 0.05$). Individual birds varied with respect to the number of resightings and/or recaptures (Table 4) and locations where nonfaithful birds were detected varied by flock (Table 5).

Table 4. Descriptive Statistics of Resightings, Recaptures, and Pooled Data of Five Rock Dove Flocks on or near the Hanford Site, Washington, from January 1994 to January 1995.

Location		Sample Size	Mean Number Per Bird	Standard Deviation	Statistic			Maximum
					Median	Mode	Minimum	
Richland	Resighting	44	5.36	5.31	3.00	1	1	23
	Recapture	29	2.34	1.29	2.00	1	1	5
	Pooled	49	6.20	5.60	4.00	2	1	25
300	Resighting	48	3.56	3.11	3.00	1	1	15
	Recapture	47	3.19	2.46	2.00	1	1	10
	Pooled	65	4.94	3.70	4.00	1	1	16
HTS	Resighting	34	9.35	13.20	4.00	1	1	48
	Recapture	36	6.57	8.08	5.00	1	1	45
	Pooled	52	10.54	16.38	5.00	1	1	79
200E	Resighting	28	2.54	2.06	2.00	1	1	10
	Recapture	46	6.15	7.26	4.00	1	1	39
	Pooled	56	6.32	7.19	4.00	1	1	39
100K	Resighting	24	3.67	3.16	2.50	1	1	11
	Recapture	60	4.69	3.94	3.50	1	1	17
	Pooled	64	5.74	5.30	4.00	1	1	26

Table 5. Resighting and Recapture Locations of Nonfaithful Rock Doves from January 1994 to January 1995 on the Hanford Site, Washington.

Initial Capture Area	Bird ID ^a	Number Resights at Initial Area	Number Recaps at Initial Area	New Area	Number Resights at New Area	Number Recaps at New Area
Richland	none					
300	G3	1	0	1100	6	na ^b
	G23	2	1	1100	1	na
	GM	0	2	1100	4	na
	GAJ	0	3	1100	3	na
	G3V	0	0	1100	1	na
HTS	O5	0	0	100F	1	na
	O6	1	0	200W	1	na
	O0	4	0	200E	1	0
	OL4	36	0	200W	1	na
	O4J	3	1	200E	0	1
200E	R06	0	0	HTS	0	16
	R20	0	3	HTS	1	0
	R23	0	0	HTS	3	0
				200W	1	na
	RH	0	1	HTS	2	0
	RJ	0	0	HTS	1	0
	RN	0	0	HTS	2	0
	RT	0	0	HTS	1	1
	FX	0	0	HTS	1	0
	RLO	4	17	HTS	2	0
	RRZ	1	2	HTS	1	0
	ROA	0	0	HTS	1	1
	ROE	6	3	HTS	3	0
				200W	1	na
	RON	2	8	HTS	1	0

Table 5. (Continued). Resighting and Recapture Locations of Nonfaithful Rock Doves from January 1994 to January 1995 on the Hanford Site, Washington.

Initial Capture Area	Bird ID ^a	Number Resights at Initial Area	Number Recaps at Initial Area	New Area	Number Resights at New Area	Number Recaps at New Area
100K						
	W10	0	0	200E	4	0
	W12	0	2	100F	11	na

^a The first letter in each Bird ID signifies the tag color at each area (B=Blue, G=Green, O=Orange, R=Red, W=White).

^b Traps were never set at the 1100 Area, 100F, or 200 West.

Birds tagged from the city of Richland exhibited the highest degree of site faithfulness. Not a single individual tagged in Richland was observed or recaptured anywhere on the Hanford Site (Table 2). Birds tagged from 300 were observed south of their initial capture area at 1100, but never within the city of Richland. The farthest south a 300 (or any Hanford Site) bird was recovered was at the Port of Benton airport, which is located on the border of the 1100 Area and the city of Richland.

Movements

Thirty-six surveys were conducted from 3 June 1994 through 6 December 1994 to estimate offsite movements. Two surveys/week were conducted from June through August and one survey/week was conducted from September through December. Logistical considerations required the reduction in survey frequency. There were 259 direct recoveries of 107 individuals at 21 different locations (Figure 3, Table 6).

Due to large departures from normality in the distance data (distances from capture areas of individual birds to offsite locations where birds were observed), a Kruskal-Wallis one-way ANOVA was used. Mean distances from capture areas to offsite locations for each flock were significantly different ($H = 84.837$, 4 df, $P < 0.000$). Kruskal-Wallis multiple comparisons (NCSS version 5.03, Kayesville, Utah) indicated that 200E had the longest mean distance, HTS and 100K had intermediate distances, and Richland

Figure 3. Direct Recoveries from Five Rock Dove Flocks in Agricultural Areas around the Hanford Site, Washington, from June to December 1994. Length of Line Indicates Distance from Capture Area to Offsite Location. Map Developed by Author.

Table 6. Direct Recoveries of Rock Doves from June to December 1994 from 21 Locations around the Hanford Site, Washington.

Initial Capture Area	Sample Size	Total Observations ^a	Median	Minimum	Maximum
Richland	23	49	2	1	7
300	28	83	2	1	10
HTS	12	25	2	1	8
200E	19	36	1	1	5
100K	25	66	1	1	11

^a Does not include 12 unknown individuals whose tag color was identified but could not be individually identified. There was 1 unknown from Richland, 2 from 300 Area, 3 from HTS, 3 from 200E, and 3 from 100K.

and the 300 Area had the shortest movement distance (Table 7). The longest distances between capture area and offsite locations for individual birds were a 200E bird seen at a granary almost 30 km away and a bird tagged at 100K seen on an irrigation rig just over 28 km away. Mean flock distances were highly correlated with closest possible locations to each area ($r^2 = 0.93$, $P = 0.003$). Flocks from each area showed distinctly non-random movement patterns. Mean vectors (r) were close to 1.0 for all flocks and random mean angles (θ_0) for all flocks were outside the 99 percent confidence intervals for the mean angles ($\emptyset$) from each area (Table 8).

There were 74 indirect recoveries (excluding 17 known tag colors, but unknown individuals) of 58 individuals at 15 different locations from October 1993 through January 1995 (Figure 4). One unknown individual was the lone indirect recovery of a Richland bird in the city of Pasco.

Ancillary Information

I received additional data concerning tagged bird movements from other sources. Animal control was conducted at several areas on or near the Hanford Site periodically throughout the study. Almost 14,500 birds were recovered on or within approximately 64 km of the Hanford Site. Of these birds, one Richland bird was found in the city of Pasco, one 300 bird was found at the Port of Benton airport just south of the 1100 Area, one HTS bird was

Table 7. Multiple Comparisons of Mean Distances from Capture Areas to Offsite Locations of Rock Dove Flocks on the Hanford Site, Washington, June to December 1994.

Capture Area	Mean Distance (km)	sd ^a	Mean Rank	Similarity ^b	n ^c
300	6.11	1.90	25.32	*	28
Richland	7.10	4.07	31.09	*	23
HTS	11.54	2.03	57.75	*	12
100K	16.19	2.35	71.90	*	25
200E	23.52	1.70	98.00	*	19

^a sd = standard deviation.

^b Locations with asterisks in the same vertical column are not significantly different.

^c n = sample size.

Table 8. Random Mean Angles (θ_0), Mean Angles ($\bar{\theta}$), Mean Vectors (r), and 99% CI for Five Rock Dove Flocks Moving off the Hanford Site, Washington, from June to December 1994.

Location	θ_0	$\bar{\theta}$	r	99% CI	Significance
Richland	21°	54°	0.9340	40 < $\bar{\theta}$ < 68	*a
300	31°	75°	0.8360	57 < $\bar{\theta}$ < 93	•
HTS	89°	136°	0.9999	128 < $\bar{\theta}$ < 144	•
200E	99°	79°	0.9998	70 < $\bar{\theta}$ < 88	*
100K	115°	315°	0.9899	310 < $\bar{\theta}$ < 320	•

a • = $\underline{P} < 0.01$

Figure 4. Indirect Recoveries from Five Rock Dove Flocks in Agricultural Areas around the Hanford Site, Washington, from October 1993 through January 1995. One Indirect Recovery from the City of Pasco is Not Shown. Length of Line Indicates Distance from Capture Area to Offsite Location. Map Developed by Author.

found at WPPSS (Figure 1), one 100K bird was found at 100N, and three 100K birds were found at a feedlot northwest of 100K.

From mid-July through December 1994, 100N and 100D (Figure 1) were periodically trapped and added to the survey route. These areas were initially excluded from the survey because security measures prevented access to locations where birds frequented (100N) and poor visibility made the area inefficient to include (100D). I added them not to tag additional birds from these areas, but to provide additional information on flock movements to these areas after security became less stringent. No tagged birds were ever resighted. Two birds from 100K, however, were recaptured. One bird was recaptured 10 times at 100N and the other bird was recaptured three times at 100D.

DISCUSSION

There was considerable variation in the number of times birds were resighted or recaptured after initial capture. Many reasons could have accounted for this variation. Low detectability as a result of location of roosting areas, animal control trapping, construction near and demolition of roosting areas, capture and natural mortality, predation, poisoning and hunting by humans, and tag loss were all reasons I may not have been able to detect birds or were reasons for a decrease in the sample size of tagged birds.

Site Faithfulness

The purpose of this study was to assess the efficacy of Hanford rock doves as radiological indicators based on their spatial movements from capture areas. Site faithfulness of rock doves will be critical to their use as indicators since detected contamination would be expected to come from a certain area only if this condition were true. In 1982, 75 to 100 birds were qualitatively estimated to have been flying between the 100 and 200 Areas (pers. comm., R. Johnson, 1993, Westinghouse Hanford Company, Richland, WA) an observation suggesting nonfaithfulness for some flocks on the Hanford Site. In contrast, the five flocks I studied exhibited site faithfulness.

Rock doves roosted and nested on other areas on Hanford in addition to areas examined in this study. I cannot infer site-faithfulness for them or assume that the flocks I studied never visited these locations.

Anecdotal data suggested that there was minimal movement to some of these areas. Further research will be required to determine spatial movements of those flocks and movements by other flocks on Hanford to those areas.

Concern over potential transport of contamination to Richland from Hanford birds traveling to Richland or Richland birds traveling to Hanford and back does not appear to be warranted at this time. Hanford and Richland flocks appear to be separate.

Individually, only 200E birds were nonfaithful (Table 3). It is important to note, however, that even those individual birds that were not site faithful often had just as many observations at the initial capture area as at other locations (Table 5). Consequently, birds defined as nonfaithful were not necessarily observed consistently or frequently at other locations. In addition, of the 13 nonfaithful 200E birds, 11 were resighted and/or recaptured only at HTS (Table 4). Since HTS did not have contamination readily accessible to rock doves, I suggest that the 200E flock also met the criteria. The characteristics of HTS did not warrant the rejection of the 200E flock as an indicator. For 200E, it appeared that birds merely used the HTS as a stopover or resting location between 200E and offsite feeding locations.

Some tagged birds were observed at other locations apart from the onsite survey. The ancillary information I received from animal control and my own additional information from 100N and 100D suggested that there was

minimal movement between areas not detected from the onsite survey. It was possible that other birds exhibited the same unfaithfulness to both areas surveyed and areas not in the survey, yet went undetected. Site faithfulness would have been overestimated if this was common. However, the fact that only seven of my tagged birds appeared in almost 14,500 birds recovered within approximately 64 km of the Hanford Site by various animal control projects provided additional credibility to the survey results. Therefore, rock doves from 300, 200E, HTS, and 100K could be used as radiological indicators.

Although site faithfulness as defined in this study had not been specifically addressed by other research, my results could be compared to findings regarding general habits of rock doves. Murton et al. (1972) proposed that large flocks of rock doves feeding on grain in Manchester, England, were stable groups, comprised of the same individuals. Murton et al. (1974) suggested that dominant individuals maintained the same roosting and nesting areas throughout the year, usually at their place of birth. In contrast, Wofford and Elder (1967) found no site tenacity to roosting and nesting areas, but suggested that this could have been a response to various disturbances and was not necessarily a normal characteristic of the population. Lefebvre (1985) suggested that urban pigeon flocks that depend on small, unpredictable food sources have more open (nonfaithful) populations since the birds need to constantly search for food. Williams and Fleischer (1989) proposed that both

easily accessible food sources and homing behavior to place of birth were factors involved in high site fidelity of rock doves in Hawaii. From band resightings, they also found little movement between different areas.

Agricultural areas near the Hanford Site seemed to provide rock doves with fairly large and reliable food sources throughout the year, and allowed for the development of closed, or site-faithful, populations.

Other characteristics of Hanford Site rock doves, coupled with their site faithfulness, will qualify them as a useful monitoring species. Hanford Site rock doves have been exposed to radioactive contamination (Conklin et al. 1985, pers. comm., L. Cadwell, 1993, PNL, Richland, WA) and heavy metal contamination has occurred in rock doves in other areas around the world (Hutton and Goodman 1980, Husain and Kaphalia 1990, Janiga et al. 1990). Unlike pheasants and quail, rock doves could potentially become habituated to nest in shelters, or "cotes," and remain free to forage in surrounding areas. Pheasants and quail are presently collected by shooting, but cote nesting rock doves could be captured alive, checked for elevated levels of radioactivity, and returned to the cote. Contaminated individuals could be radiotransmitted and tracked to the source(s) of contamination. Once cotes were occupied, feces, egg shells, egg contents, or blood (or bone and tissues) could be analyzed for concentrations of various contaminants. Hatching success and growth rates of squab also could be measured and compared with rock doves

nesting at offsite control areas to detect abnormal growth patterns (pers. comm., B. Tiller and W. Rickard, 1993, PNL, Richland, WA).

Murton et al. (1974) and Krakowski (1982) suggested that dominant pigeons were able to maintain roosting and nesting areas and did not change locations (i.e. site faithful). Krakowski (1982) also noted that sub-adult and non-dominant birds were frequently observed moving to other areas (nonfaithful) to find roosting areas free from harassment by other birds. Only two of the 25 birds that were nonfaithful in this study were juveniles. I do not know what social status the other 23 birds held within their respective flocks. If similar age and dominance relationships existed at the Hanford Site, a natural acclimatization to the cotes would be necessary. These naturally nesting birds would be socially dominant and able to defend their nest site and would not be forced to move to other areas to meet ecological requirements. It must be noted that an inherent assumption would be that cotes would provide a more desirable nesting location than other natural nesting spots and socially dominant birds would compete to secure a nest in them.

Movements

The agricultural areas near the Hanford Site appeared to provide an abundant, if not changing, food supply throughout the year. Livestock manure and feed, and uncontained grain at loading docks, railway stations, and granaries were important foods for feral doves (Potvin et al. 1977, Courtsal

1983, Kramarova 1991) and were also areas used by Hanford Site rock doves. When one food source becomes unavailable, other sources will be quickly found. During winter, and especially in years of above average snowfall, rock doves will flock in large numbers to a few stable, uncovered food sources. During other times of the year, many different locations will provide resources (pers. comm., R. Rada, 1994, USDA ADC, Yakima, WA). Hanford Site rock doves probably used offsite locations that were not detected, especially flocks such as the HTS where I only observed birds at two different areas. This could have been especially true since movement surveys were only conducted for six months from early-summer to mid-winter. However, I felt that areas not discovered during the survey period were likely a result of seasonal changes in food abundance (changing crop harvests) in areas not readily accessible by automobile. Areas east of the survey and more distant from the Hanford Site were periodically searched for additional tagged rock doves and none were found. I also did not believe that areas missed due to the limited duration of the survey would have significantly changed the direction and distance conclusions since late winter and spring were when agricultural food supplies tended to be limited and rock doves flocked in large numbers to stable food sources. I assumed these stable food sources also provided food during times of the year that the survey was conducted, and were therefore included in the

survey. Consequently, few areas were probably missed due to timing of surveys.

Although few researchers have quantified distances, rock doves have used the closest urban or agricultural food source to roosting and nesting locations irrespective of direction (Murton and Westwood 1966, Murton et al. 1972, Havlin 1977, Krakowski 1982, Lefebvre and Giraldeau 1984, Lefebvre 1985). Gompertz (1957) and Goodwin (1960) found that some birds rarely left the city limits of London to feed while other small groups or pairs were observed flying longer distances to find food. In Brno, Czechoslovakia, feral pigeons regularly moved to the surroundings of town in search of food (Havlin 1977, Kramarova 1991). The high correlation between mean movement distance and closest possible distance suggested that Hanford rock dove flocks also moved offsite as efficiently as possible.

Rock dove movements that have been quantified have shown that they have been strong flyers. Murton and Westwood (1966) documented a 16 km flight to a food source. Havlin (1977) found that the usual distance was 6 to 8 km, though 10 km was common and 15 km was rare. He also found one bird at 18 km and suggested that birds at distances up to 30 km were also probably dispersers from town. Hanford rock doves displayed similar movements in that they used food sources close to their roosting and nesting locations (Figures 3 and 4), although I commonly found some birds at greater

mean distances (Table 8). Ferns (1992) suggested short distance flights were especially important for rock doves moving between nesting and roosting areas and cultivated fields in the extreme temperatures of the Negev Desert, Israel. The hot summer climate of southcentral Washington would necessitate similar concerns for Hanford Site rock doves, especially those from areas farther from the Hanford Site border, such as 200E. This also might have explained the high correlation found between mean flock distance and closest possible distance.

I conclude that the high degree of site faithfulness of Hanford Site rock doves allows this species to be used as radiological indicators. However, if cotes are used, I recommend a natural acclimatization process to the cotes due to factors such as age and social dominance. The distinct movement patterns of the Hanford Site flocks I studied will aid in understanding and preventing potential contamination issues in the foreseeable future as the mission of the Hanford Site changes from nuclear materials production to environmental cleanup and eventually release of land for other usage.

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