RESPONSE OF WINTER BIRDS TO SOIL REMEDIATION ALONG THE COLUMBIA RIVER AT THE HANFORD SITE

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Abstract. The Columbia River at the Hanford Site, located in south-central Washington State, U.S.A., is a regionally important refugium for overwintering birds. Some of the river shoreline has been designated by the U.S. Department of Energy for environmental clean-up following past production of materials for nuclear weapons. We evaluated the effects of soil remediation on winter birds at six inactive nuclear reactor areas. Remediation activities consisted of daily excavation and removal of approximately 1035 t of contaminated soil from previously herbicided and denuded areas located between 30 and 400 m and mostly in line-of-sight of the river shoreline. Remediation activities had no apparent effect on numbers of riverine or terrestrial birds using adjacent undisturbed shoreline and riparian habitat.

Keywords: Columbia River, disturbance, Hanford Site, soil remediation, Washington State, winter birds

1. Introduction and Study Area

Most of the Columbia River in eastern Washington State, U.S.A., has been impounded by a series of hydroelectric dams for 30 yr. The only unimpounded stretch is an 80 km long segment from Priest Rapids Dam downstream to Richland (Figure 1). Most of the western shore of this river segment lies within or borders the U.S. Department of Energy Hanford Site (Figure 1) in Benton County. Public access to the Hanford Site and the river upstream from Richland has been denied since 1943. Consequently, the Hanford Site remains largely undeveloped and has served as a refugium for native steppe wildlife and plants (Gray and Rickard, 1989). However portions of it have been highly disrupted by construction and nuclear waste management activities.

In the years between 1943 and 1965, nine plutonium production reactors were built at six locations along the western shoreline (Figure 1). All of these ceased operation by 1988. During the operational years, streams of reactor coolant water were released into ditches and basins. These contributed radionuclides and toxic chemicals to the ground, contaminating the soil column to various depths. Environmental remediation at the Hanford Site includes excavation and removal of contaminated soils from the reactor areas to a repository more remotely located from the river shore (Washington State Department of Ecology *et al.*, 1998). The

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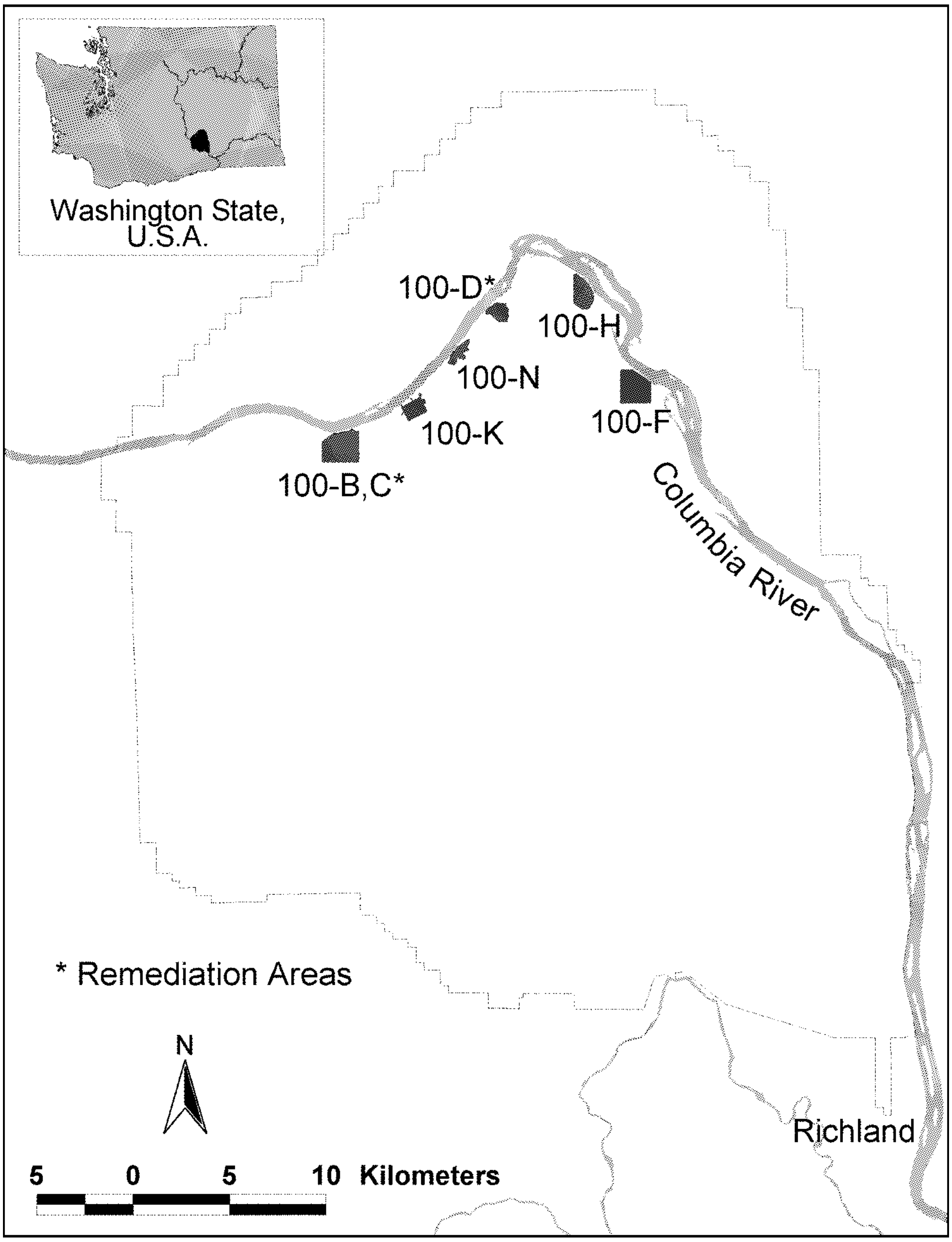

Figure 1. The Hanford Site and associated nuclear reactor areas in Benton County, south-central Washington state, U.S.A.

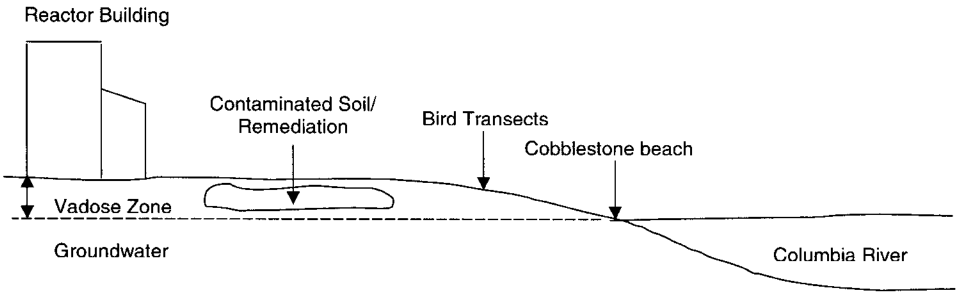

Figure 2. Schematic cross section of the Columbia River shoreline at a typical reactor area.

purpose of this paper is to assess the impact of soil remediation on use of these areas by winter birds.

A schematic drawing of a cross section of the river and adjacent shoreline at a typical reactor area is illustrated in Figure 2. River width varies from 300 to 600 m. The immediate shoreline consists primarily of cobblestone beaches that vary from 3 to 100 m, but are generally less than 10 m wide. Since the river is closed to hunting upstream from Richland (Figure 1), it serves as an important refugium for waterfowl and other riverine birds during winter. Nonetheless, species richness of waterfowl and riverine birds along this segment of the Columbia River is typically low.

Riparian habitat is not well developed along this segment of the Columbia River. Riparian vegetation is generally sparse and woody plants are scarce. The dominant herbaceous plant is reed canarygrass (*Phalaris arundinacea*) and some locations support thickets of shrub willows (*Salix* spp.). Clumps of deciduous trees, mostly black locust (*Robinia pseudo-acacia*), Siberian elm (*Ulmus pumila*), and mulberry (*Morus alba*), are used as night roosts and daytime perches by wintering bald eagles (*Haliaeetus leucocephalus*) (Eisner, 1991; Fitzner and Weiss, 1994). Since trees are otherwise scarce on the semi-arid shrub steppe of the Hanford Site, these are important habitat for nesting and winter resident terrestrial birds. However, species richness of terrestrial birds along this segment of the Columbia River is typically low.

Upland vegetation consists mostly of cheatgrass (*Bromus tectorum*), gray rabbitbrush (*Chrysothamnus nauseosus*), and big sagebrush (*Artemisia tridentata*). The reactor buildings are located in upland areas approximately 400 m inland from the river shore and the contaminated soil is located between the reactor buildings and the river (Figure 2).

Soil remediation at 100-BC and 100-D (Figure 1) began in July and November 1996, respectively, and continued through the winter of 1996–1997. Remediation was performed between 08:00 and 16:00 hr Monday through Friday. Twenty workers and one large trackhoe excavated soil that was removed by dump trucks ($\sim$17 t capacity) that made 60 trips per day, removing about 1035 t of contaminated soil daily. Soil remediation occurred between 30 and 400 m from the river shoreline in areas previously herbicided and devoid of vegetation. Consequently, extant riparian and upland vegetation between the remediation site and the river was not disturbed. Soil remediation activities generally occurred in line-of-sight of the river shoreline, except during excavation of low-lying areas.

Surveys were initiated in 1994 to document winter bird use of the river shoreline and riparian habitat at the six reactor areas. These surveys were continued through 1997 in order to be concurrent with soil excavation and removal activities at 100-BC and 100-D. Riverine and terrestrial avian species at all the reactor areas are occasionally exposed to routine Hanford Site operation and maintenance activities that consist of well drilling and sampling; surface radiation surveys and sampling; river monitoring; security patrols; river tours, and archaeological and ecological studies. These activities have been ongoing for several decades and occur irregularly in time and space. Although birds may be habituated to some of these activities, we had no hypothesis regarding the potential effects of soil remediation, a much more acute and continual type of disturbance, on avian use of the river shoreline and riparian habitat.

2. Methods

Avian surveys consisted of walking 1 km transects at 100-BC and 100-D (remediation areas) and at 100-K, 100-N, 100-H, and 100-F (non-remediation areas). Survey time varied depending on the abundance and variety of avifauna encountered, but was generally about one hour per transect. Transects were surveyed during December, January, and February of 1994–1995 and 1995–1996 (prior to remediation at 100-BC and 100-D), and 1996–1997 (during remediation at 100-BC and 100-D).

At each reactor area, a single 1 km transect was located on a small bluff overlooking the river shore (Figure 2), that permitted observation of both riverine and terrestrial birds simultaneously. Transects were located at least 100 m from and roughly parallel to remediation areas. Transects were surveyed by pairs of observers during morning hours Monday through Friday. The same observers conducted the majority of the surveys.

Birds within 100 m on both sides of each transect were identified visually and counted. Birds that flew through and did not stop in the survey area were not counted. Each transect at each reactor area was surveyed repeatedly, for a total of eighty-five surveys (Table I).

Counts of each species were totaled for each transect. These counts were summed over all species within each of six foraging guilds (Tables I and II). Summing counts within guilds largely eliminated zero values associated with individual species.

TABLE I

Number of surveys completed and total counts for each foraging guild, by winter and reactor area. Reactor areas 100-BC and 100-D were remediated in 1996–1997

Reactor area	Foraging guild[a]							Surveys completed
	Branch foragers	Fish eaters	Field foragers	Ground foragers	Predators/ scavengers	River foragers	Total	
Winter 1994–1995								
100-BC	0	100	1343	97	18	73	1631	4
100-D	3	1	802	34	15	109	964	2
100-F	0	50	150	68	22	202	492	3
100-H	6	39	1380	23	16	99	1563	5
100-K	0	14	409	93	6	25	547	2
100-N	12	10	1278	33	2	62	1397	5
Total	21	214	5362	348	79	570	6594	21
Winter1995–1996								
100-BC	18	14	925	54	5	52	1068	7
100-D	0	45	322	134	3	58	562	6
100-F	0	2	1951	137	16	18	2124	5
100-H	15	134	702	64	3	1	919	6
100-K	0	6	815	31	1	18	871	4
100-N	17	13	307	39	0	14	390	4
Total	50	214	5022	459	28	161	5934	32
Winter1996–1997								
100-BC	0	71	427	282	4	21	805	6
100-D	6	16	62	140	3	86	313	5
100-F	0	9	1222	60	1	18	1310	6
100-H	0	64	854	336	3	17	1274	6
100-K	0	38	197	83	8	26	352	6
100-N	0	31	66	37	13	13	160	3
Total	6	229	2828	938	32	181	4214	32
Grand total	77	657	13212	1745	139	912	16742	85

[a] Species within each foraging guild are identified in Table II.

TABLE II

Twenty-five avian species surveyed, grouped by foraging guild

Foraging guild/Common name	Scientific name
Riverine species	
Field foragers	
Canada goose	*Branta canadensis*
Mallard duck	*Anas platyrhynchos*
Fish eaters	
American white pelican	*Pelecanus erythrorhynchos*
Common merganser	*Mergus merganser*
Double-crested cormorant	*Phalacrocorax auritus*
Great blue heron	*Ardea herodias*
River foragers	
American coot	*Fulica americana*
Barrow’s goldeneye	*Bucephala islandica*
Bufflehead	*Bucephala albeola*
Common goldeneye	*Bucephala clangula*
Terrestrial species	
Branch foragers	
Yellow-rumped warbler	*Dendroica coronata*
Ground foragers	
American goldfinch	*Carduelis tristis*
American tree sparrow	*Spizella arborea*
California quail	*Callipepla californica*
Dark-eyed junco	*Junco hyemalis*
European starling	*Sturnus vulgaris*
Horned lark	*Eremophila alpestris*
House finch	*Carpodacus mexicanus*
Red-winged blackbird	*Agelaius phoeniceus*
Ring-necked pheasant	*Phasianus colchicus*
Song sparrow	*Melospiza melodia*
Western meadowlark	*Sturnella neglecta*
White-crowned sparrow	*Zonotrichia leucophrys*
Predators/scavengers	
Bald eagle	*Haliaeetus leucocephalus*
Black-billed magpie	*Pica pica*

Zero values are typical of surveys of winter birds due to their general tendency to congregate in flocks, which may create sparse data sets, particularly for less common species.

Two multi-way contingency tables were created using the factors in Table I, i.e., winter, reactor area, and foraging guild. The first contingency table utilized the full data set, i.e., all winters, areas, and guilds. The second contingency table consisted of a partial data set, i.e., all winters, remediation areas only, and all guilds.

The influence of winter, reactor area, and foraging guild on the counts (Table I) was assessed using two log-linear regression models, each corresponding to one of the contingency tables. Count data are typically modeled using a Poisson error structure and the log-linear regression model is a common choice for such survey count data (McCullagh and Nelder, 1989). Although reasonably consistent, the number of surveys varied between winters and reactor areas (Table I). To account for this imbalance, an 'offset' term was included in the models. Although 'model fit' was adequate, substantial overdispersion in the data was evident. Consequently, the F-test was used in lieu of the more standard Chi-Square test (McCullagh and Nelder, 1989).

Because soil remediation was area and winter specific, the effect of remediation on counts could only be assessed with respect to 100-BC and 100-D during the winter of 1996–1997. The effect of remediation was first evaluated generally in the log-linear models using two, two-way interactions, area-by-winter and winter-by-guild. Significant interactions were further evaluated via contrasts as follows. One of the levels of each factor in the interaction term was designated as a reference level and assigned a value of zero. Parameter estimates were calculated for the non-reference factor levels. The effects of these estimates were evaluated by considering their sign (positive or negative) and magnitude relative to zero, and their probabilities.

3. Results and Conclusion

The main model factors (i.e., winter, area, and guild) and interactions (i.e., area $\times$ winter and winter $\times$ guild) were statistically significant (Tables III and IV). Total counts summed over all guilds at 100-BC, 100-D, 100-F, 100-H, and 100-K were significantly higher prior to remediation than during remediation, particularly during the first winter (Tables I and V). However, counts of individual guilds at 100-BC and 100-D prior to remediation were not significantly different from those during remediation (test statistics and significance levels ranged from $X^2_{0.05,\ 1} = 0.0$, $P = 0.97$ for predators/scavengers to $X^2_{0.05,\ 1} = 3.15$, $P = 0.08$ for ground foragers).

Seventy-nine percent of all observations consisted of field foragers (Canada geese and mallard ducks), by far the most abundant foraging guild in the vicinity of the reactor areas. Sixty-seven percent of the birds were observed at 100-BC,

TABLE III

Analysis of deviance (full data set, i.e., all winters, areas, and guilds) table relating the main factors and area-by-winter interaction to counts

Source	Deviance	Num. DF	Den. DF	*F*	*P*
Intercept	92624.28				
Area	87845.08	5	487	17.92	<0.0001
Winter	72799.8	2	487	141.03	<0.0001
Guild	38676.45	5	487	127.95	<0.0001
Area*Winter	25976.09	10	487	23.81	<0.0001

[a] Significance level $\alpha = 0.05$.

TABLE IV

Analysis of deviance (partial data set, i.e., all winters, remediation areas only, and guilds) table relating the main factors and winter-by-guild interaction to counts

Source	Deviance	Num. DF	Den. DF	*F*	*P*
Intercept	31545.76				
Area	31224.64	1	161	8.69	0.0037
Winter	16122.02	2	161	204.34	<0.0001
Guild	6711.527	5	161	50.93	<0.0001
Winter*Guild	5949.663	10	161	2.06	0.0305

[a] Significance level $\alpha = 0.05$.

100-F, and 100-H. It is unclear why avian abundance is higher in these areas. The decline in total avian numbers over the three years is likely attributable to one or more general phenomena, such as climate, food resources, etc..

The decline in total counts at 100-BC and 100-D over the three winters cannot be attributed to remediation, since a similar decrease was observed in the non-remediation areas. Further, remediation had no observable effects on use of the 100-BC and 100-D areas by individual guilds, as evidenced by similar counts prior to and during remediation. Consequently, riverine and terrestrial winter birds appear to be tolerant of soil remediation, a more acute and continual type of disturbance than the routine Hanford Site operations to which they are occasionally exposed.

Soil remediation occurred in areas that had been previously herbicided to prevent the spread of contamination, and were thus devoid of vegetation. The visual and acoustic effects of remediation activities conducted in these areas did not appear to displace terrestrial winter birds in the surrounding undisturbed riparian and upland habitat.

TABLE V

Analysis of deviance table relating the area-by-winter interaction (Table III), partitioned by levels, to counts

Reactor area	Winter	DF	Estimate	Chi-Square	P^a
100-BC	1994–1995	1	3.4555	25.38	<0.0001
100-BC	1995–1996	1	–0.4747	0.38	0.5353
100-BC	1996–1997	0	0		
100-D	1994–1995	1	5.3851	48.55	<0.0001
100-D	1995–1996	1	–0.2003	0.05	0.8153
100-D	1996–1997	0	0		
100-F	1994–1995	1	3.0578	17.96	<0.0001
100-F	1995–1996	1	2.0623	7.94	0.0048
100-F	1996–1997	0	0		
100-H	1994–1995	1	1.7307	6.69	0.0097
100-H	1995–1996	1	0.0701	0.01	0.926
100-H	1996–1997	0	0		
100-K	1994–1995	1	5.8833	55.78	<0.0001
100-K	1995–1996	1	3.7082	20.14	<0.0001
100-K	1996–1997	0	0		
100-N	1994–1995	0	0		
100-N	1995–1996	0	0		
100-N	1996–1997	0	0		

[a] Significance level $\alpha = 0.05$.

Soil remediation activities were dispersed over a relatively large area (30 and 400 m from the river) and were thus not concentrated in close proximity to the river shoreline. Remediation activities sometimes occurred below grade, back from the edge of the bluff, and were thus occasionally out of line-of-sight of riverine birds. This may, in part at least, account for the apparent lack of effects on riverine bird numbers.

Consequently, soil remediation activities planned for areas deemed important to breeding birds, such as the Columbia River shoreline and riparian zone, may be conducted during winter when the effects of human disturbance are likely to be negligible. However, winter remediation activities that disturb habitat or that are concentrated in close proximity to shoreline areas may require further evaluation.

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