COMPARISON OF BIRD COMMUNITIES IN SOUTHWESTERN MONTANA AFTER FOURTEEN YEARS OF NATURAL RECOVERY FROM SMELTER IMPACTS [1]

by

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Abstract: Fourteen years after closure of the Anaconda smelters in southwestern Montana, birds were surveyed during the 1994 breeding season along stratified random transects on three areas close to the smelters. Vegetation on these proximal sites had been altered by emissions during the 96 years of smelter operation. Comparable surveys were performed on a more distant reference area. Numbers of species and numbers of birds on the affected sites did not differ significantly from those on the reference area. One of the affected areas had significantly more species than the reference site for the main affects model (ANOVA, $p=0.010$) and for conifer habitat (ANOVA, $p=0.014$). Species richness expressed in rarefaction curves was comparable among areas, but species similarity differed. Smelter effects on the vegetation and subsequent natural recovery, since closure of the smelter in 1980, have created a mosaic of vegetation communities on the affected sites and increased the horizontal diversity of bird habitats (Mann-Whitney Test). These changes appear to have produced the high species richness and abundance of birds found on the affected sites.

Additional Key Words: bird communities, horizontal diversity, natural recovery, smelter, Montana.

Introduction

Since the late 1800s, extensive surface and subsurface mining of large mineral deposits has occurred in southwestern Montana, USA. Much of this mining centered around the communities of Anaconda and Butte. Millions of tons of ore were annually processed which required smelting operations. Several smelter stacks of varying heights were constructed near Anaconda and operated over 96 years from 1883 until 1980.

The tallest of the stacks (Washoe smelter, Figure 1) operated for 78 years, and early in its history produced daily emissions of over one million pounds (Haywood 1907, Keammerer 1995). Emissions included copper, lead, zinc, cadmium, arsenic and sulfur dioxide. Deleterious effects of such emissions have been documented by authors in several countries (Archibold 1978, Conroy and Kramer 1995, Franzin 1984, Gordon and Gorham 1963, Jordon 1975, Kramer 1995, Winterhalder 1995a, Yan and Miller 1984).

The United States Environmental Protection Agency has included much of the area in the vicinity of Butte, Anaconda, and the upper Clark Fork River Valley within three Superfund sites (USEPA 1996), and the State of Montana is seeking natural resource damages under authority provided by the Federal Superfund Program for three upland areas totaling 40.7 km^2 alleged to be injured (Figure 1). Vegetation recovery since 1980 has been aided on small portions of Stucky Ridge and Smelter Hill through reclamation efforts. However, most of the recovery on these two sites, and all recovery on Mount Haggin to date, has been via natural processes. To evaluate recovery of bird communities on these three sites compared to a reference area, surveys were conducted during the breeding season in 1994, fourteen years after smelter operations had ceased.

Study Area

Smelter emissions at Anaconda significantly affected vegetation within several kilometers of the stacks. Although seasonal prevailing winds are almost always southwesterly and westerly (Gechaus 1974), the mountainous topography causes complex patterns of wind drift which created variability in the severity and areal extent of vegetation damage. Another variable affecting damage was distance from the point source (smelter stacks) (Pagenkopf and Maughan 1984). Stucky Ridge and Smelter Hill historically had smelter stacks operating within their boundaries and probably were the most impacted, whereas Mount Haggin, about 8

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kilometers from the Washoe stack, was less affected. Upper slopes of hills were most affected, resulting in loss of vegetation, erosion of topsoil, and loss of the seedbank, thereby impeding reestablishment of vegetation (Haywood 1907, Keammerer 1995).

A mixture of grass/shrubland, aspen/willow, and mixed-aged conifers, mainly lodgepole pine (*Pinus contorta*) and Douglas fir (*Pseudotsuga menziesii*) dominates the reference area. Mount Haggin and Smelter Hill historically supported a mixture of grass/shrubland, aspen/willow, and mixed ages of coniferous forests. This pattern still holds, but the proportions of each have changed and succession is less advanced. Much of the historic conifer type is gone due to a combination of logging, fire, erosion, and emissions (Haywood 1907). Stucky Ridge is, and probably always has been, covered with predominately grass/shrubland with small patches of aspen/willow along drainages and scattered limber pine (*Pinus flexicaulus*) (Keammerer 1995). The three study sites still contain patches of barren and ruderal areas. Grazing has occurred on the affected and reference areas since the first settlers arrived (Horstman 1984). Although the reference area is within about 14.4 kilometers of the Anaconda smelter stacks, there are no visible or documented effects from smelter emissions. All of the areas occur on similar foothills and mountains, ranging in elevation from 1,615 to 2,296 meters, that are separated by small valleys and bisected by headwater streams of the Clark Fork River.

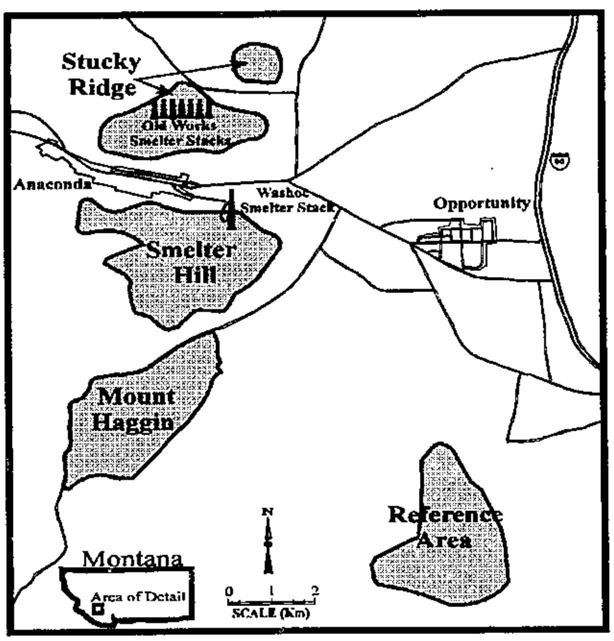

Figure 1. Smelter-affected upland study sites and reference area in relation to paved roads, smelter locations, and the towns of Anaconda and Opportunity, Montana.

Methods

Sampling and analytical procedures were developed to accommodate the diversity of habitats, slopes, elevations, aspects, and large size of areas to be surveyed. Sample areas were stratified and belt transects (transects extending from border to border across the study area) were randomly placed within the stratifications. Transects were oriented at right angles to intersect the primary sources of habitat variation (slope, elevation, and aspect) caused by rapid topographic changes. Exceptions to this method of transect placement were along riparian zones. On each site one transect was placed within the largest riparian zone to sample this important habitat (Bull and Skovlin 1982, Emmerich and Vohs 1982, Finch 1989, Meents et al. 1981, Mills et al. 1991, Stauffer and Best 1980). Transect width was 100 meters and biologists slowly walked the medial line and stopped at listening stations about every 100 meters for 3-5 minutes (Emlen 1971, 1977). All birds observed or heard within the transect boundaries were recorded along with the associated habitat type and transect location. Surveys were conducted from sunrise until 0930-1000 hours during June 1994. Surveys were halted during periods of high winds and/or rain (Bibby et al. 1992). Because estimates of absolute density were not sought, coefficients of detectability were not calculated (Emlen 1977, Kendeigh 1944).

The data for birds were converted into relative densities or birds-per-hectare and species-per-hectare for each transect and habitat type on each site. Densities were then weighted by habitat length and the data transformed with square roots (Zar 1984, Poisson data transformation). Two-way Analyses of Variance (ANOVA) (GLM for weighted data, MINITAB Ver.(10.2)) were performed on the transformed data comparing site and habitat differences for both numbers of birds (abundance) and species (diversity).

Morasita's Index of similarity (Morasita 1959) was used to compare each affected site with the reference area. Percent similarity is an estimate of the percent of species shared or common to both areas and can, with Morasita's procedure, be interpreted as a probability where the index varies from 0 (no similarity) to 1 (complete similarity) (Krebs 1989, Wolda 1981).

Species richness among the affected sites and reference area was compared using total number of species (N_T) and rarefaction curves (James and Rathbun 1981). Also, unique and common bird species were compared with regard to habitat characteristics. Only non-conifer habitats were used for comparison and analysis on Stucky Ridge.

Indices of the horizontal diversity of habitats were estimated for all areas. Vegetation maps were overlaid with a grid of evenly spaced lines perpendicular to the long axis of the area boundary. The number of habitat changes on each grid line were tallied and weighted by line length. A Mann-Whitney test (MINITAB Ver.(10.2)) was used to test for a difference in the median horizontal diversity index between each affected site and the reference area.

Results

An average of 14.6 and 14.2 percent of affected and reference areas was sampled, respectively (Table 1). A total of 83 species of birds were observed, collectively, on the four study sites (Appendix A). Of the four sites, the reference area had the fewest species (46) and Mount Haggin had the most (57) (Table 2).

Table 1. Area size and sampling intensity.

Study Area	Number Transects	Area Sampled (km^2)	Total Transect Length (km)	Percent Area Sampled
Reference	8	13.0	18.5	14.2
Smelter Hill	9	15.7	22.5	14.3
Mount Haggin	9	15.0	19.2	12.8
Stucky Ridge	8	10.1	16.8	16.6

For both numbers of species and numbers of birds there are only two significantly different ANOVA comparisons. Mount Haggin had significantly more species than the reference area for all habitat types combined ($p=0.011$) and for conifer habitat ($p=0.013$) (Table 3).

Table 2. Comparison of uniqueness, species richness, and similarity between affected sites and the reference area.

Study Area	Total No. Species	Total No. Birds	No. species In common With reference	No. species Unique to Areas	Index of Similarity [1]
Reference	46	476	--	--	--
Smelter Hill	53	489	29 (55%)	24 (45%)	0.58
Mount Haggin	57	465	39 (68%)	18 (32%)	0.70
Stucky Ridge	45	252	27 (60%)	18 (40%)	0.34

[1] Morasita's Index of Similarity comparison to reference.

Table 3. Analysis of variance (ANOVA) results testing for a difference in species richness (no. of species) and abundance (no. of birds) between the affected and reference areas.

Habitat type	Area/Reference Comparison	ANOVA p-values # Species	ANOVA p-values # Birds
All types	Smelter Hill	0.450	0.134
	Mount Haggin	0.011 [1]	0.075
	Stucky Ridge	0.445	0.134
Conifer [2]	Smelter Hill	0.443	0.306
	Mount Haggin	0.013 [1]	0.141
Grass/Shrubland	Smelter Hill	0.525	0.435
	Mount Haggin	0.071	0.253
	Stucky Ridge	0.588	0.323

[1] Significantly greater than the reference at alpha= 0.05.

[2] No significant historical conifer habitat on Stucky Ridge.

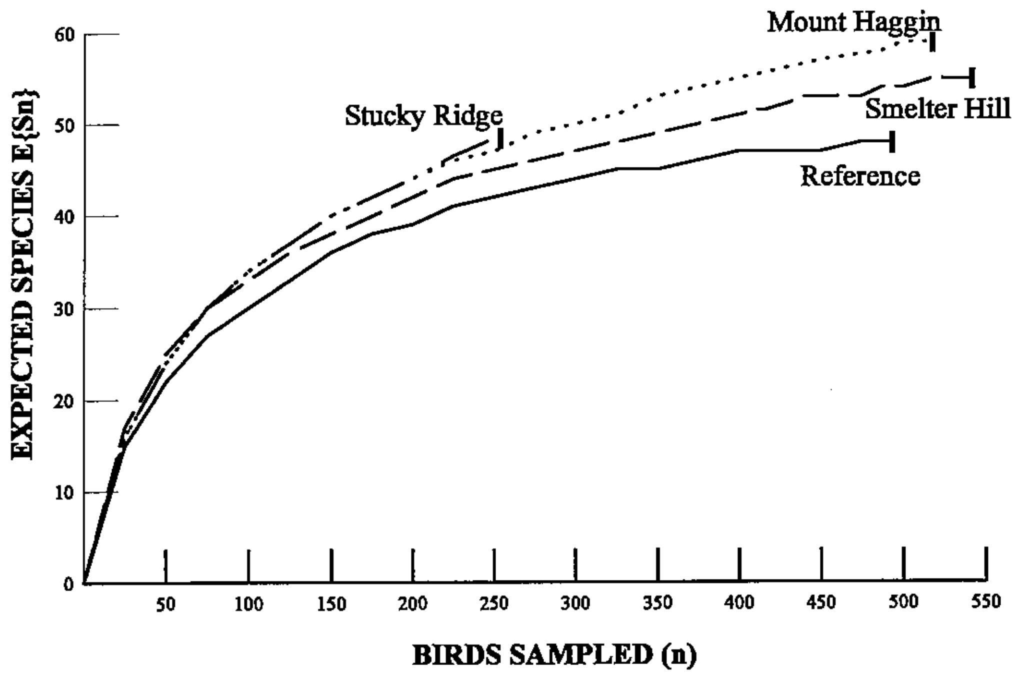

Figure 2. Rarefaction curves for predicting the number of species for a given sampling intensity for the affected areas (Stuckly Ridge, Smelter Hill, and Mount Haggin) and the reference area.

Species richness values for Smelter Hill (N=53), and Mount Haggin (N=57) were higher than for the reference area (N=46) (Table 2). Species richness for Stucky Ridge (N=45) was almost identical to the reference area. Rarefaction curves for all three affected sites were higher than for the reference area (Figure 2). Given equal sampling effort, more species would be expected on all three affected sites.

Mount Haggin had the highest similarity with the reference area, with 39 species in common and a Morasita's Index of 0.7. Stucky Ridge and the reference area had 27 species in common but were the least similar according to Morasita's Index (0.34) (Table 2).

Adjusted for area sampled, there were more individual birds observed for 42 of the 53 species found on Smelter Hill, 33 of the 57 species found on Mount Haggin, and 24 of the 45 species found on Stucky Ridge than were found on the reference area. There was a single observation each of two species (common snipe (*Gallinago gallinago*) and pygmy nuthatch (*Sitta pygmaea*)) that were observed only on the reference area and not on the affected areas. Five bird species (Brewer's blackbird (*Euphagus cyanocephalus*), cedar waxwing (*Bombycilla cedrorum*), common raven (*Corvus corax*), red crossbill (*Loxia curvirostra*), and white-crowned sparrow (*Zonotrichia leucophrys*)) were found on all the affected areas but not on the reference (Appendix A). The most abundant bird species common to all areas were the American robin (*Turdus migratorius*), Clark's nutcracker (*Nucifraga columbiana*), dark-eyed junco (*Junco hyemalis*), pine siskin (*Carduelis pinus*), song sparrow (*Melospiza melodia*), and vesper sparrow (*Pooedetes gramineus*).

Discussion

Smelter Hill and Mount Haggin had higher species richness and numbers of birds than the reference area. These results indicate that natural recovery on these affected areas has been significant. The area least similar to the reference site was Stucky Ridge. Although species richness was high (N=45), the index of similarity was low (0.34) and the number of birds observed was about 53 % of those observed on the reference area. The lower similarity of Stucky Ridge to the reference area can be attributed in part to dominance of short-grass habitat, year-round cattle grazing (most of Stucky Ridge is deeded land), and existence of relatively high proportions of ruderal and barren areas created by smelter emissions.

Decades of smelter emissions along with other anthropogenic perturbations adversely impacted the vegetation in areas near the Anaconda smelters, particularly mature forest. Portions of some areas were reduced to a barren or primary successional stage. However, much of the affected areas is now early successional grass/shrubland, aspen, and young conifers (Smelter Hill has no conifer cover except for a few scattered limber pine trees). The years of perturbations and subsequent ongoing reestablishment and regeneration have created a greater horizontal complexity of habitats than currently exists on similar unaffected areas. The change has produced a patchy mosaic of early and mixed successional stages offering more habitat types with more edge. Such conditions usually produce higher bird species diversity (James and Rathbun 1981) than is found in mature lodgepole pine/Douglas fir forests that exist on the reference area. Such habitats are preferred by some bird species such as white-crowned sparrow and mourning dove (*Zenaida macroura*) (Brown 1991, Cody 1968, James and Rathbun 1981, Patton 1992). Other species such as Swainson's thrush (*Catharus ustalatus*) and yellow warbler (*Dendroica petechia*) prefer early successional habitats with regenerative vegetation that is dense and of high volume (James and Warner 1982, MacArthur and MacArthur 1961, Mills et al. 1991, Shugart and James 1973). Additional change in species composition on the affected areas has probably resulted from replacement of some species of birds with others that more readily occupy ruderal areas invaded by plants like woods rose (*Rosa woodsii*) and thistle (*Cirsium arvense*). Such species include American goldfinch (*Carduelis tristis*) and cedar waxwing. Other species such as the rock wren (*Salpinctes obsoletus*) and mountain bluebird (*Sialia currucoides*) may prefer the open habitats with exposed boulders that exist on the affected areas (see Appendix A).

Natural recovery of the area has been significant in a relatively short period of time (14 years). Although highly variable, similar rates of recovery of vegetation have been found at portions of smelter impacted areas near Sudbury, Canada (Winterhalder 1995b), along riparian areas in northeast Oregon, USA (Kauffman et al. 1995), and in some areas after the Mount Saint Helen's eruption in Washington State, USA (Franklin et al. 1988).

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Appendix A. List of bird species and numbers of each observed on study areas in southwestern Montana during bird surveys (June 1994).

Species	Scientific name	Numbers observed on each area			
		Reference Area	Stucky Ridge	Smelter Hill	Mount Haggin
American crow	*Corvus brachyrhynchos*	1	3	2	.
American goldfinch	*Carduelis tristis*	.	7	1	.
American kestrel	*Falco sparverius*	.	.	1	2
American redstart	*Setophaga ruticilla*	.	1	.	.
American robin	*Turdus migratorius*	19	14	37	22
Bank swallow	*Riparia riparia*	.	.	3	.
Belted kingfisher	*Ceryle alcyon*	.	.	1	.
Black-billed magpie	*Pica pica*	.	19	2	.
Black-capped chickadee	*Parus atricapillus*	4	3	13	12
Black-headed grosbeak	*Pheucticus melanocephalus*	3	3	6	1
Blue grouse	*Dendragopus obscurus*	.	.	2	1
Brewer's blackbird	*Euphagus cyanocephalus*	.	4	2	1
Brewer's sparrow	*Spizella breweri*	.	3	.	1
Brown-headed cowbird	*Molothrus ater*	14	3	47	8
Cassin's finch	*Carpodacus cassinii*	5	6	.	.
Cedar waxwing	*Bombycilla cedrorum*	.	9	25	30
Chipping sparrow	*Spizella passerina*	28	1	.	5
Clark's nutcracker	*Nucifraga columbiana*	37	27	19	23
Clay-colored sparrow	*Spizella pallida*	.	.	1	1
Cliff swallow	*Hirundo pyrrhonota*	.	.	2	.
Common merganser	*Mergus merganser*	.	.	.	1
Common nighthawk	*Chordeiles minor*	4	1	.	1
Common raven	*Corvus corax*	.	3	1	4
Common snipe	*Gallinago gallinago*	2	.	.	.
Dark-eyed junco	*Junco hyemalis*	53	9	43	73
Dusky flycatcher	*Empidonax oberholseri*	.	.	27	14
Empidonax flycatcher	*Empidonax sp.*	3	.	18	7
European starling	*Sturnus vulagaris*	.	7	2	.
Flamulated owl	*Otus flammeolus*	.	1	.	1
Fox sparrow	*Passerella iliaca*	.	.	13	.
Gadwall	*Anas strepera*	.	.	2	.
Grasshopper sparrow	*Ammodramus savannarum*	4	2	9	5
Gray jay	*Perisorius canadensis*	1	1	1	.
Great blue heron	*Ardea herodias*	.	3	4	.
Great horned owl	*Bubo virginianus*	.	.	2	.
Green-tailed towhee	*Pipilo chlorurus*	.	1	.	3
Green-winged teal	*Anas crecca*	.	.	.	9
Hairy woodpecker	*Picoides villosus*	5	.	.	1
Hermit thrush	*Catharus guttatus*	3	.	11	2
Horned lark	*Eremophila alpestris*	.	.	1	.
House wren	*Trohlodytes aedon*	.	.	2	.
Killdeer	*Charadrius vociferus*	.	.	3	.

Appendix A Continued. List of bird species and numbers of each observed on study areas in southwestern Montana during bird surveys (June 1994).

Species	Scientific name	Numbers observed on each area			
		Reference Area	Stucky Ridge	Smelter Hill	Mount Haggin
Lark sparrow	*Chondestes grammacus*	.	2	.	.
Lazuli bunting	*Passerina amoena*	7	11	.	.
Lincoln's sparrow	*Melospiza lincolnii*	2	1	7	1
MacGillivray's warbler	*Oporornis tolmiei*	6	.	2	1
Mountain bluebird	*Sialia currucoides*	1	1	8	4
Mountain chickadee	*Parus gambeli*	36	1	13	7
Mourning dove	*Zenaida macroura*	1	8	20	4
Northern flicker	*Colaptes auratus*	2	2	5	9
Northern goshawk	*Accipiter gentilis*	.	.	.	1
Northern rough-winged swallow	*Stelgidopteryx serri pennis*	.	6	.	1
Orange-crowned warbler	*Vermivora celata*	.	.	.	7
Pine siskin	*Carduelis pinus*	21	9	3	14
Prairie falcon	*Falco mexicanus*	.	1	.	1
Pygmy nuthatch	*Sitta pygmaea*	1	.	.	.
Red crossbill	*Loxia curvirosta*	.	5	1	34
Red-breasted nuthatch	*Sitta canadensis*	14	1	.	3
Red-naped sapsucker	*Sphyrapicus nuchalis*	6	.	.	2
Red-tailed hawk	*Buteo jamaicensis*	3	.	3	1
Red-winged blackbird	*Agelaius phoeniceus*	.	.	2	.
Rock dove	*Columba livia*	.	6	.	.
Rock wren	*Salpinctes obsoletus*	1	19	6	3
Ruby-crowned kinglet	*Regulus calendula*	31	.	9	3
Ruffed grouse	*Bonasa umbellus*	2	.	.	21
Solitary vireo	*Vireo solitarius*	7	.	.	7
Song sparrow	*Melospiza melodia*	5	2	14	4
Spotted sandpiper	*Actitus macularia*	.	.	1	.
Swainson's thrush	*Catharus ustulatus*	7	.	9	13
Townsend's solitaire	*Myadestes towndendi*	5	.	.	7
Townsend's warbler	*Dendroica townsendi*	3	.	.	1
Veery	*Catharus fuscescens*	2	.	8	4
Vesper sparrow	*Pooecetes gramineus*	7	35	23	9
Warbling vireo	*Vireo gilvus*	48	1	16	35
Western flycatcher	*Empidonax difficilis*	3	.	.	3
Western meadowlark	*Sturnella neglecta*	3	1	.	.
Western screech owl	*Otus kennicottii*	.	1	.	.
Western tanager	*Piranga ludoviciana*	39	.	.	1
White-breasted nuthatch	*Sitta carolinensis*	2	.	1	2
White-crowned sparrow	*Zonotrichia leucophrys*	.	6	9	19
Willow flycatcher	*Empidonax traillii*	4	.	3	1
Yellow warbler	*Dendroica petechia*	4	1	23	7
Yellow-rumped warbler	*Dendroica coronata*	17	1	.	7