A CHARACTERIZATION OF TERRESTRIAL FAUNA AND FLORA IN THE VICINITY OF IRON MOUNTAIN, REDDING, CALIFORNIA

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SUMMARY

Surveys of flora and fauna were conducted in riparian areas of six streams in the general vicinity of the Iron Mountain mine near Redding, California. The surveys were intended to provide part of the information needed for a natural resource damage assessment (NRDA), should such an assessment be desired at some point.

For both birds and plants, the field data clearly show differences between the presumptively contaminated vs. uncontaminated areas. Most of the differences were statistically significant. Although field data also show some statistically significant differences in bird and plant habitat structure between presumptively contaminated vs. uncontaminated areas, it cannot be assumed that those differences are the only cause of the differences in bird and plant communities among streams. Strong circumstantial evidence points to contamination status, in addition to habitat, as a significant factor influencing the bird and plant communities.

Future efforts should focus first on sampling soils and possibly other media at each of the bird and plant survey points, to determine relative degree of contamination, and to then compare that ranking to the presumptive categories assigned those points during this study. Consideration should also be given to confirming results by employing additional protocols specifically mentioned for NRDA studies, such as brain cholinesterase enzyme activity (ChE) determinations and direct measurements of reduced avian reproduction. Finally, the specific pathways by which resources have likely been damaged should be investigated, for example, by monitoring avian feeding habits at nests in relation to invertebrate availability.

1.0 INTRODUCTION

1.1 Study Objective

The main objective of this study was to determine if, in the Iron Mountain study area, the floral and faunal composition differs significantly between points located near areas documented to be experiencing acid mine drainage ("contaminated" points) and analogous points located more distantly ("uncontaminated" points, intended to serve as a control or baseline). This hypothesis was tested to inform a later decision as to the feasibility and desirability of conducting a full-fledged natural resource damage assessment (NRDA) necessary to provide definitive evidence of "injury." Information provided in this report would serve as one component of the NRDA. Data on the chemical and biological condition of streams in the vicinity of our survey points (Alpers et al. 1991, Slotton et al. 1996, CH2M Hill unpublished) were the basis for characterizing contaminated vs. uncontaminated sites.

1.2 The Study Area

The study area northwest of Redding, California includes parts of six perennial streams in the general vicinity of Iron Mountain (Slickrock Creek, Boulder Creek, Spring Creek, South Fork of Spring Creek, Cottonwood Creek, Whiskey Creek). This mostly-uninhabited area of approximately 7 square miles is basically a rugged foothill landscape with Mediterranean-type climate. Elevations of the study points range from 611 to 2869 ft above sea level (median= 1657 ft) and slopes are steep (mostly 50-70%). Most stream channels are moderately steep, with virtually no floodplain or noticeable vegetative transition to adjoining xerophytic vegetation. Near our survey sites, trees are present but mostly are widely spaced, with mixed chaparral occupying much of the watersheds. The survey watersheds are all east- or south-facing. At the study points, the predominant habitat type is Montane Hardwood-Conifer (Mixed Cismontane Woodland), followed by Montane Hardwood (Canyon Live Oak Forest), Mixed Chaparral, and Riparian habitats. Barren areas (tailings, bedrock, landslides, abandoned structures) are present but localized. Soils in most of the study area are shallow and derived from acidic igneous rock.

2.0 METHODS

2.1 Selection of Survey Locations

We selected for study the maximum number of locations that we could find within 5 miles of Iron Mountain, that were of generally similar vegetation type, elevation, aspect, and remoteness, as was done by Hughes (1985). Constraints specific to this study were that each location (survey point) be situated within 300 m of a stream, be spaced no closer than 150 m from the nearest neighboring survey point, and be located within 5 minute's walking distance of the nearest road or neighboring survey point. We also intentionally selected points located near acid mine drainage ("contaminated" points) and a nearly equal number of points located more distantly ("uncontaminated" points). Because these selection criteria were quite specific and the overall study area not large, all candidate points met these criteria and were selected.

2.2 Field Methods

This study used survey protocols that are widely accepted. Concepts for survey design and methods were drafted from the author's experience and after reviewing information on biological monitoring of hazardous waste sites (Warren-Hicks et al. 1989, Linder et al. 1993, BLM 1994) and particularly mines (Moore and Mills 1977, Mason 1978, Pascoe and DalSoglio 1994). Protocols were modified as appropriate for the particular objectives, and for the terrain and resources of the region. The protocols were implemented consistently at both contaminated and uncontaminated points.

2.2.1 Birds

The species composition of the bird community is often an appropriate indicator of ecosystem change because breeding birds tend to remain for several weeks in an area a few acres in size (a territory). Breeding birds consequently tend to integrate the high spatial variability of chemical concentrations, available foods, and microclimatic conditions within those areas. The usefulness of bird species composition, in combination with other indicators, as an indicator of overall watershed condition was convincingly demonstrated by Croonquist and Brooks (1991).

We surveyed birds by direct observation and auditory recognition within the period May 7 - July 2, 1997, following the broadly accepted protocol for point counts of Ralph et al. (1993, 1995). We surveyed birds from 21 streamside locations (termed "points") and 50 roadside locations (also termed "points"). The 21 points were clustered in 7 sites, each containing 3 points. Of the 7 sites, 4 bordered contaminated streams and 3 bordered uncontaminated streams. We used a Trimble Global Positioning System (GPS) to register the exact coordinates of each point for future reference (Figure 1, Table 1).

Figure 1

Figure 1 continued

Table 1. Locations (coordinates) of Iron Mountain points visited by this study.

Based on GPS measurements taken July 1-2, 1997. See map (Figure 1) for general locations.
* = less accurate; latitude and longitude valid only to within 16 meters of true location, and elevation estimated from topographic maps with 80-ft contour intervals.
S = streamside point, R = roadside point, C = presumed contaminated, R= reference (less contaminated)

Point	Latitude	Longitude	Elevation	Type & Assigned Status
BJ1	40°39'35.853N	122°29'50.123W	1371	S-C
BJ2	40°39'39.265N	122°29'54.920W	1432	S-C
BJ3	40°39'43.707N	122°29'58.535W	1542	S-C
BM1	40°40'44.156N	122°30'41.688W	2187	S-C
BM2	40°40'46.337N	122°30'50.261W	2235	S-C
BM3	40°40'46.917N	122°30'54.513W	2267	S-C
BR1	40°39'52.496N	122°30'12.511W	2031	R-C
BR2	40°40'04.908N	122°30'16.026W	1996	R-C
BR3	40°40'19.802N	122°30'21.743W	1947	R-C
BR4	40°40'10.934N	122°30'07.376W	1889	R-C
BR5	40°40'02.284N	122°30'06.518W	1839	R-C
BR6	40°39'53.024N	122°29'56.474W	1801	R-C
BR7	40°40'27.699N	122°30'32.936W	2052	R-C
BR8	40°40'35.186N	122°30'35.866W	2150	R-C
BR9	40°40'41.063N	122°30'38.005W	2131	R-C
BR10	40°40'45.795N	122°30'41.447W	2310	R-C
BR11	40°40'49.304N	122°30'56.844W	2353	R-C
BR12	40°40'49.294N	122°30'56.688W	2330	R-C
BT1	40°40'10.630N	122°30'10.559W	1815	S-C
BT2A	40°40'17.649N	122°30'19.284W	1841	S-C
BT2B	40°40'27.027N	122°30'33.486W	2044	S-C
BT3	40°40'27.035N	122°30'33.757W	2024	S-C
CW1	40°42'13.521N	122°26'57.280W	611	S-R
CW2	40°42'16.023N	122°26'58.673W	649	S-R
CW3	40°42'20.577N	122°26'59.235W	653	S-R
LCR1	40°39'18.421N	122°30'11.548W	1750	R-C
LCR2	40°39'44.649N	122°29'40.352W	1726	R-R
LCR3	40°39'46.259N	122°29'32.084W	1729	R-R
LCR4	40°39'55.349N	122°29'24.447W	1668	R-R
LCR5	40°40'02.966N	122°29'23.932W	1647	R-R
LCR6	40°39'59.740N	122°29'18.235W	1602	R-R
LCR7	40°39'37.434N	122°29'25.468W	1553	R-R
LCR8	40°39'35.268N	122°29'35.756W	1505	R-R
LCR9	40°39'34.466N	122°29'45.369W	1417	R-C
LCR10	40°39'31.306N	122°29'54.385W	1394	R-C
LCR11	40°39'26.191N	122°29'58.024W	1440	R-C
LCR12	40°39'21.730N	122°30'01.731W	1449	R-C

continued

Table 1 (*continued*). Locations (coordinates) of Iron Mountain points visited by this study.
* = less accurate; latitude and longitude valid only to within 16 meters of true location, and elevation estimated from topographic maps with 80-ft contour intervals.
S = streamside point, R = roadside point, C = presumed contaminated, R= reference (less contaminated)

Point	Latitude	Longitude	Elevation (ft.)	Type & Assigned Status
OSR1*	40°40'40.341N	122°33'55.342W	1400	R-R
OSR2*	40°40'50.524N	122°33'50.099W	1390	R-R
OSR3*	40°40'32.645N	122°34'00.005W	1385	R-R
OSR4*	40°40'20.476N	122°33'54.649W	1370	R-R
OSR5*	40°40'10.001N	122°33'52.743W	1340	R-R
OSR6*	40°40'07.182N	122°33'46.553W	1320	R-R
OSR7*	40°39'57.339N	122°33'36.739W	1300	R-R
OSR8*	40°39'52.212N	122°33'34.275W	1290	R-R
OSR9*	40°39'44.040N	122°33'35.942W	1300	R-R
OSR10*	40°39'33.459N	122°33'33.791W	1290	R-R
OSR11*	40°39'20.420N	122°33'28.797W	1280	R-R
OSR12	40°38'03.781N	122°30'11.056W	1104	R-R
OSR13	40°37'56.734N	122°30'14.000W	1112	R-R
OSR14	40°37'54.462N	122°30'05.251W	1097	R-R
SF1	40°38'03.793N	122°30'09.989W	1097	S-R
SF2	40°38'00.697N	122°30'06.582W	1074	S-R
SF3	40°38'00.332N	122°29'59.882W	978	S-R
SPJ1	40°39'16.658N	122°30'01.326W	1318	S-C
SPJ2	40°39'12.415N	122°30'02.476W	1285	S-C
SPJ3	40°39'06.606N	122°29'59.949W	1208	S-C
SRJ1	40°39'20.543N	122°30'06.313W	1415	S-C
SRJ2	40°39'21.560N	122°30'12.167W	1445	S-C
SRJ3	40°39'25.265N	122°30'15.284W	1510	S-C
SRR1	40°40'35.073N	122°32'18.349W	2869	R-R
SRR2	40°40'25.121N	122°32'13.806W	2831	R-R
SRR3	40°40'16.830N	122°32'05.264W	2768	R-R
SRR4	40°40'11.685N	122°31'55.009W	2716	R-R
SRR5	40°40'04.773N	122°31'45.216W	2668	R-R
SRR6	40°40'00.846N	122°29'28.212W	2480	R-C
SRR7	40°39'58.671N	122°29'23.451W	2330	R-C
SRR8	40°39'37.435N	122°29'28.500W	2300	R-C
SRR9	40°40'00.953N	122°30'55.622W	2263	R-C
SRR10	40°39'58.331N	122°31'40.700W	2224	R-C
SRR11	40°39'57.163N	122°30'28.592W	2176	R-C
SRR12	40°39'51.577N	122°30'22.884W	2131	R-C
SRR13	40°39'43.964N	122°30'12.606W	2023	R-C
UB1	40°40'55.090N	122°31'05.167W	2456	S-R
UB2	no data (satellite inaccessible)			S-R
UB3	no data (satellite inaccessible)			S-R
USP1	40°40'07.795N	122°29'28.397W	1601	S-R
USP2	40°40'11.442N	122°29'27.913W	1676	S-R
USP3	40°40'14.135N	122°29'27.779W	1712	S-R

We used the roadside surveys to augment the streamside surveys because the background noise from rushing water in each stream inhibited our auditory detection of birds to an unquantifiable degree. Nonetheless, all of the roadside locations were within 300 meters of a stream, and most were well within 200 meters -- a sufficient distance to deaden the stream noise, yet still probably reflecting the stream's influence on birds. Most of the roadside survey points were on dirt roads that received virtually no other traffic during this period, and ran along steep canyon slopes. A few (6) roadside survey points were along paved roads with light (1 vehicle/hr) traffic. Of the 50 roadside locations, 24 were near contaminated streams and 26 were near uncontaminated streams.

We visited each survey point 5 times on widely separated dates. Guidance by Verner and Boss (1980) suggests that "it is necessary to inventory an area five or more times to determine whether or not a species actually occurs there." We visited each point 4 times during the early morning hours (mostly 0500 to 1000) and once during the near-dusk hours (mostly 1900 to 2030). We avoided conducting surveys during heavy rain or strong wind. Especially during the first few weeks of this period, some of the detected individuals were likely migrating (i.e., resting briefly on their travel to areas hundreds of miles away). However, during the surveys most birds were likely breeding or attempting to breed within a few hundred meters of the point where they were detected.

Each point of the streamside bird surveys was separated from neighbors by at least 150 meters. The 50 roadside points were strung out at intervals of approximately 300 meters along four transects (i.e., the roads). We counted only birds that were seen during a standard length of time -- 5 minutes per visit for the roadside points and 10 minutes per visit for the streamside points. We visited streamside points longer to partly compensate for the interference from the stream noise. Also, at each site we situated the points at segments of the stream where noise was slightly diminished and in most cases, we established the survey point 5-10 meters uphill from the channel to further reduce noise. During the streamside point visits, we counted only birds detected within 50 meters, whereas for the roadside points, we counted all detected birds and estimated their distance and direction.

2.2.2 Reptiles and Amphibians

We attempted to survey adult amphibians and reptiles (herptiles) as follows:

1. Area Searches:

During the late June visit to each stream we attempted to find herptiles by selectively turning over rocks and debris, both in the water and in immediately adjoining terrestrial areas. We also noted amphibians encountered casually while doing our streamside bird and vegetation surveys at other times. We made no attempt to identify or enumerate tadpoles. We noticed them only in the uncontaminated streams.

In October we used a viewing box similar to that used by Luke and Sterner (1995) in the Cantara investigations to search the water column for Pacific Giant Salamander along the 300 meter study segment of each of our streams. We also again attempted to find herptiles by turning over streamside rocks and debris.

During an early December visit, we conducted nighttime searches along all the roadside survey routes. One observer drove the car very slowly while the other walked just ahead, using a flashlight to check road cuts and roadside drainage ditches for salamanders. Observers alternated duties every half hour during a 3-hour period, during which approximately 3 miles of dirt road were driven and searched. Light rain was falling on 2 of the 5 search nights, and temperatures were mostly in the 40s and 50s.

2. Artificial Covers:

At each streamside site we placed artificial covers at 3 dry locations within the floodplain during the first (early May) visit, and then turned over and examined the covers during the late June visit, the October visit, and the December visit. The artificial covers consisted of a 1-inch layer of wetted straw covered by a 0.5 x 0.5 meter piece of cardboard. In addition, in October we spread 12 black plastic bags (large garbage bags) at each of our streamside sites and checked these during the December visit.

2.2.3 Wildlife Habitat Structure

At each roadside and each streamside point we characterized wildlife habitat structure according to the habitats and habitat elements defined by Mayer and Laudenslayer (1988) -- the standardized classification that is used most widely in California. We implemented this classification using a standardized data form we developed specifically for this project (Figure 2). From the list of all habitat features and elements included in the Mayer and Laudenslayer classification, we included on this form just the items that we expected to not be uniformly present or uniformly absent among our survey points. We inventoried habitats by visual observation during a visit between June 28 and July 2. At roadside points, we mentally divided the 200-m zone surrounding each point into quadrants and assessed habitats and habitat elements within each quadrant. We did likewise for the 50-m zone surrounding each streamside point. We checked the collected information against existing soil-vegetation maps (e.g., Stone et al. 1975) and aerial photographs. We recorded as absent some habitat elements that may have been present at other seasons (e.g., berries) but were not apparent at the time of our bird surveys.

2.2.4 Predicted Wildlife Suitability

We used software from the California Wildlife Habitat Relationships database (CWHR53) to generate lists of species expected to occur in the habitats found at each of our points. The CWHR53 models also provided habitat suitability values (High, Moderate, or Low) for each predicted species. The CWHR first eliminated species that do not occur regularly in Shasta County and species present only during Fall and/or Winter (seasons during which we conducted no bird surveys). The CWHR then predicted species and their associated habitat suitability values in each quadrant at each of our points based on the habitat types, seral stages, and habitat elements that we had recorded as being present. We excluded from the analysis habitats we had found to be no greater than "sparse" at each point. For our data analysis, we composited the lists of species predicted at each site into a single site list, with each species assigned a single habitat suitability value by the CWHR models. That suitability value was the maximum value assigned to the species in any of the habitats in which it was predicted present in any of the quadrants at the site, and the maximum value among breeding, cover, or feeding values during the spring or summer period.

2.2.5 Plants and Plant Habitat

We surveyed plant community composition according to the published standards of the California Native Plant Society (1996). We established 3 riparian transects at each of the 7 streamside bird sites (4 contaminated, 3 uncontaminated) and at an additional 2 streamside locations (one contaminated, one uncontaminated). Each transect was centered near a streamside bird survey point, was 50 meters long, and contained 100 points. Thus, the plant survey points were spaced 0.5 meters apart, for a total of 300 points per site. At each point along the transect, we placed a rod and made a visual vertical projection to determine all species "hit" in the herb, shrub, and tree canopy. While doing so we also searched a 2.5-m band on both sides of the transect centerline for any species that were missed using the "hit" protocol. We implemented this at all sites between May 28 and June 6. We revisited all sites between June 28 and July 2 to systematically search for any species that had been missed during the first period. We identified all vascular plants to species, except for some grasslike plants which could be identified only to genus.

Laying out the transects posed a challenge because sharply winding channels and cliffs at many sites made it impossible to establish a straight line over a distance of 50 meters without much of the line being over water or situated on the tops of unscalable cliffs. We responded to this situation by dividing each transect into five 10-meter segments. The beginning point of the first segment consisted of whatever plant was closest to water 25 meters from the first bird survey point, and the ending point was whatever plant was closest to water at the end of the 10-meter distance, moving toward the bird survey point. Each subsequent 10-meter segment was oriented such that its beginning point was the ending point of the prior segment, and its ending point was whatever plant stem was closest to water at exactly 10 meters farther along the channel. For streams oriented mostly north-south, we always located the transects along the east side of the stream, whereas for east-west streams, we located the transects along the north side.

2.3 Data Analysis

2.3.1 Database Organization and Checking

Data were entered onto a Microsoft Excel spreadsheet and converted to Paradox database files. Printouts were compared line-by-line with field sheets to confirm the data had been correctly recorded and entered.

We used site (or route) name and point number to link the bird data with habitat structure and vegetation data. Bird positional data from roadside points were also further assigned to the quadrants in which the habitat data were collected.

2.3.2 Statistical Analysis

Statistical analyses involved the graphical examination of means and confidence intervals, use of nonparametric statistics (Mann-Whitney U test), contingency tables (Chi-square and Fisher's exact test), Agglomerative Clustering, and Multi-response Permutation Procedures (MRPP, Mielke et al. 1981). Statistical analyses were performed on a PC with a Pentium processor, using commercial software (PC-ORD and StatGraphics Plus) as well as a statistics program written in VisualBasic specifically for this project to calculate the Q-statistic, Jaccard measure, and Morista-Horn similarity measure.

Figure 2. Field form used for estimation of wildlife habitat structure variables

Figure 2 (*continued*). Field form used for estimation of wildlife habitat structure variables

Bird Data. We summarized bird data according to streamside or roadside survey point (not by route or site), creating the following variables:

Number of species (richness):

1. maximum from among 5 visits to each point
2. average of 5 visits to each point
3. cumulative total from 5 visits to each point

Frequency of occurrence of each species (# of visits)

1. maximum from among all species found at the point
2. average of all species found at the point

Herptiles. Because our herptile surveys were qualitative, we prepared no quantitative synopsis.

Wildlife Habitat Structure. We summarized wildlife habitat data by point and quadrant, creating the following variables that describe structure within a radius of 200 meters of each point:

Habitat classes (percent coverage of each)

Number of size classes (seedling/sapling/pole/small tree/large tree)

Frequency of each size class of each habitat, summed across all 4 quadrants

Weighted frequency of size classes (sparse=1, open=2, moderate=3, dense=4), by habitat class and total across all classes:

1. summed across all 4 quadrants
2. maximum in any quadrant

Frequency of each "habitat element," summed across 4 quadrants

Predicted Wildlife Suitability. We tested the hypothesis that there is no significant difference in the structure of the bird community predicted (by the CWHR models) in contaminated vs. uncontaminated sites. We used the CWHR as an integrating too for our habitat data, and reasoned that if habitat structural differences between the two types of sites were ecologically significant, the CWHR models would predict significantly different bird communities, since the CWHR models do not account for contamination effects on bird habitat use. Conversely, if the CWHR models predicted no significant differences in bird communities in contaminated vs. uncontaminated sites, but if such differences were found by our surveys, then contamination might be a factor responsible for the differences. Prior to this analysis we discussed our intended application with Dr. Barrett Garrison who has directed the development and testing of the CWHR.

Plants and Plant Habitat. We summarized data from the plant transects, creating the following variables:

Number of species (richness) per transect:

1. including just the species at the 0.5-m "hits"
2. also including additional species found between the "hit" points and/or within 2.5 meters on either side of the transect

Frequency of occurrence of each species (hits per transect)

Frequency of occurrence of trees, shrubs, herbs (hits per transect)

Frequency of occurrence of any plant (total hits per transect, all species)

Frequency of occurrence of each substrate type (hits per transect)

3.0 RESULTS

3.1 Birds

Streamside Points

The mean number of bird species detected within 50 m of the streamside points during a 10-minute count was 2.25 (range= .6 to 5). The cumulative species total from all five visits averaged 7 species per point (range= 3 to 13).

Bird species richness was significantly lower at points that were close to contaminated streams. More precisely, the number of species found during the most productive of five visits was 4.33 for the uncontaminated points but only 2.78 for contaminated points. These results are statistically significant (p= .0310, Mann-Whitney U test, n=21 points).

Not only the number of species, but the number of individual birds totalled over the five visits was also significantly less at the contaminated points (p=.0043, Mann-Whitney U, n=21, fly-over species and probable migrants excluded). Visits to streamside contaminated points were at least twice as likely to produce no birds as similar visits to uncontaminated sites. Bird species found at the uncontaminated points also were more dependably present than those found at contaminated points, and this phenomenon was statistically significant (p=0.0087, Mann-Whitney U test, n= 41 species). For example, an average species at an uncontaminated streamside point was found during 1.78 of the 5 visits, whereas a species at a contaminated streamside point was found during only 1.3 of the 5 visits.

Species whose affinities for uncontaminated sites were statistically significant were Wrentit, Western Tanager, and Spotted Towhee, whereas only Violet-green Swallow showed significant affinity with contaminated sites ($p<0.05$, Fisher's exact test). More than half the 41 species found along streams were found only at the uncontaminated points, whereas 12% (5) were found only at contaminated points (Table 2). Of the 24 species found only at uncontaminated sites or showing statistical affinity for such, 14 are nationally recognized as a sensitive resource because they migrate long distances in winter to the tropics ("Neotropical migrants"). The percent similarity in bird community composition among all streamside points was 77% (Jaccard index). By comparison, among the uncontaminated points the mean similarity was 87% and among contaminated points it was 74%.

Another way of examining the bird data is to look at the avian community structure and ask: Are the species of birds that occur at uncontaminated sites different, overall, than those that occur at contaminated sites? That is, are the similarities between any two randomly-chosen uncontaminated sites (or any two randomly-chosen contaminated sites) usually greater than the similarities between two sites, one chosen randomly from the uncontaminated group and the other from the contaminated group? Using MRPP -- a technique that is perhaps the only analytical technique applicable to answering such questions -- we found a statistically significant difference in community structure between uncontaminated and contaminated streamside sites (p=.0015, n= 41 species and 21 points). This relationship held true regardless of whether species abundance and frequency (in addition to identity) was taken into account, and regardless of whether we used Jaccard similarity or the generally more robust Morista-Horn calculation (Jackson et al. 1989).

Table 2. Bird species associations with contaminated or uncontaminated points, based on early summer *streamside* surveys in the Iron Mountain area

* = association was significant ($p<0.05$, Chi-square or Fisher's exact test)
(h) = greater occurrence corresponds to structurally more-suitable habitat for the species at sites of this type, as determined by CWHR models

Occurred Predominantly at Contaminated Points:

	# of records: uncontam.	contam.
Barn Swallow	0	1
Cedar Waxwing	0	1
Common Raven	0	1
Lazuli Bunting	0	1
Turkey Vulture	0	1
Band-tailed Pigeon	1	2
Mourning Dove	1	2
*Violet-green Swallow	1	6
*Steller's Jay	8	13

Occurred Predominantly at Uncontaminated Points:

	uncontam.	contam.
Black-chinned Hummingb	1	0
Ash-throated Flycatcher	1	0
California Quail	1 (h)	0
Dusky Flycatcher	1	0
Hairy Woodpecker	1	0
Townsend's Warbler	1	0
Wilson's Warbler	1	0
Am. Dipper	2	0
Bewick's Wren	2	0
Cliff Swallow	2	0
Red-tailed Hawk	2	0
Blue-gray Gnatcatcher	3	0
California Towhee	3	0
Hutton's Vireo	3	1
Lesser Goldfinch	3	0
Pacific-slope Flycatcher	3 (h)	0
Oak Titmouse	3	1
Solitary Vireo	3	0
W. Wood-Pewee	3	0
Black Phoebe	4	0
Brown-headed Cowbird	4	1
Downy Woodpecker	4 (h)	0
*Yellow-breasted Chat	5	0
Orange-crowned Warbler	7	2
Am. Robin	8	3
W. Scrub-Jay	8	3
*W. Tanager	13	0
*Wrentit	15	1
Black-headed Grosbeak	17	8
*Spotted Towhee	34	11

Table 3. Bird species associations with contaminated or uncontaminated points, based on early summer *roadside* surveys in the Iron Mountain area

* association was significant ($p<0.05$, Fisher's exact test)
(h) = greater occurrence corresponds to structurally more-suitable habitat for the species at sites of this type, as determined by CWHR models

	# of records:	
Occurred Predominantly at Contaminated Points:	uncontam.	contam.
Barn Swallow	0	2
Cooper's Hawk	0	1
N. Rough-winged Swallow	0	2
Red-tailed Hawk	0	1
Wilson's Warbler	0	2
*Band-tailed Pigeon	1	7
Cedar Waxwing	1	2
Hutton's Vireo	1	4
Turkey Vulture	1	3
*Violet-green Swallow	3	12
Canyon Wren	6	13
Mountain Quail	19	26
Occurred Predominantly at Uncontaminated Points:		
Belted Kingfisher	1	0
Bushtit	1	0
European Starling	1	0
MacGillivray's Warbler (h)	1	0
Purple Finch	1	0
Red-breasted Sapsucker (h)	1	0
W. Screech-Owl	1	0
Warbling Vireo	1	0
Yellow Warbler (h)	1	0
Yellow-breasted Chat	1	0
Ash-throated Flycatcher	2	0
Common Raven	2	0
Lazuli Bunting (h)	2	0
N. Pygmy-Owl	2	0
Rock Wren	2	0
Yellow-rumped Warbler	2	0
Blue-gray Gnatcatcher	3	0
California Towhee	3	0
Downy Woodpecker (h)	3	0
Dusky Flycatcher	4	0

continued

Table 3 (*continued*). Bird species associations with contaminated or uncontaminated points, based on early summer *roadside* surveys in the Iron Mountain area

* = association was significant ($p<0.05$, Chi-square or Fisher's exact test)
(h) = greater occurrence corresponds to structurally more-suitable habitat for the species at sites of this type, as determined by CWHR models

Occurred Predominantly at Uncontaminated Points:

	# of records:	
	uncontam.	contam.
Lesser Goldfinch	4	0
Black-chinned Hummingbird	5	1
*W. Wood-Pewee	5	0
Solitary Vireo	6	4
Brown-headed Cowbird	7 (h)	4
*Oak Titmouse	9	1
N. Flicker	11	5
*Nashville Warbler	11	3
*Red-breasted Nuthatch	11	2
Bewick's Wren	13 (h)	4
*Pacific-slope Flycatcher	13	0
W. Scrub-Jay	13	6
Mourning Dove	17	13
Am. Robin	33	26
W. Tanager	44	29
*Orange-crowned Warbler	47	26
*Wrentit	62	19
*Spotted Towhee	91	43

Roadside Points

The mean number of bird species detected within 200 m of the observation point during a single 5-minute roadside point count was 4.01 (range= 0 to 11). The cumulative species total per point from all five visits averaged 11.02 (range= 3 to 18).

Bird species richness was significantly lower at roadside points that were close to contaminated streams. More precisely, the number of species found during the most productive of five visits averaged 7.23 for the uncontaminated points, but only 5.00 for contaminated points. These results are statistically significant (p=.0008, Mann-Whitney U test, n=50 points). Not only the number of species, but the number of individual birds totalled over the five visits was also significantly less at the contaminated roadside points (p=.0012, Mann-Whitney U, n=50). Bird species found at the uncontaminated points also were more dependably present than those found at contaminated points, although not significantly.

Along roadsides, the species that were significantly less likely to occur near contaminated streams were Wrentit, Oak Titmouse, Red-breasted Nuthatch, Western Flycatcher, Orange-crowned Warbler, and Spotted Towhee. Only Band-tailed Pigeon and Violet-green Swallow were statistically more likely to occur near contaminated streams. Of the 58 species found at the roadside points, 23 (40%) were found only at the uncontaminated points, whereas 5 (9%) were found only at contaminated points (Table 3). Of the 29 species found only at uncontaminated sites or showing statistical affinity for such, 15 are Neotropical migrants. Raptors (birds of prey) were in most cases found only once at any given roadside or streamside point, due to their tendency to cover large areas while foraging. Raptors we noted were Cooper's Hawk, Red-tailed Hawk, Northern Pygmy-Owl, and Western Screech-Owl.

Again using MRPP to examine overall community structure, we found a statistically significant difference in avian community structure between uncontaminated and contaminated roadside sites (p<.0001, n= 48 species and 50 points). This relationship held true regardless of whether species abundance (in addition to identity) was taken into account. The percent similarity in bird community composition among all roadside points was 23% (Jaccard index). By comparison, among the uncontaminated points the mean similarity was 25% and among contaminated points it was 32%. Among the 26 roadside points we classified as uncontaminated, ten showed some similarity in their species composition to contaminated points (Figure 3). Likewise, among the 24 roadside points we classified as contaminated, three (LCR1, SRR11, and SRR12) were anomalous in that their species composition showed more similarity to uncontaminated than to the other contaminated points.

Robustness, Bias, and Representativeness of Results

We used three strategies, separately and together, to investigate the robustness of the conclusions resulting from the initial statistical analysis of streamside and roadside bird data. First, we substituted "average" and "cumulative total" (rather than "maximum") as indicators of species richness. Second, we dropped from the initial analysis any species that (a) were only seen flying over the survey point, not within it, or (b) characteristically breed outside the region and were seen only during May, thus suggesting they were migrants rather than local breeders. Third, we reclassified two of the roadside points that were geographically transitional between contaminated and uncontaminated areas, labeling them "uncontaminated" rather than "contaminated." Still, the results were similar. In nearly all analysis scenarios, avian species richness was still found to be significantly less at contaminated points ($p<0.05$, Mann-Whitney U test), and in no case was found to be greater.

Figure 3. Cluster analysis dendrogram of roadside bird survey points

Points linked most closely are most similar with regard to bird species. Contaminated points are preceded by an asterisk (*). Cluster analysis was executed using PC-ORD software, based on Euclidean distance using Ward's method and the Sorensen similarity index.

To check for methodological bias, we examined the conditions under which points were surveyed for birds. For the streamside points, there was no significant difference between uncontaminated vs. contaminated with regard to the average calendar date during which points were visited (p=.5414, Mann Whitney U test), or the frequency of evening counts (p=.5460, Fisher's exact test). Likewise, for the roadside points, there was no significant difference between uncontaminated vs. contaminated with regard to either the average calendar date (p=.2584, Mann Whitney U test) or frequency of evening counts (p=.8757, Fisher's exact test). This lack of bias is unsurprising because field surveys were designed to minimize exactly these kinds of bias.

Our streamside data seem generally representative of northern California riparian-chaparral habitat. During 38.4 hours of survey time we detected 65% of the appoximately 95 species expected in these habitats in Shasta County (California Wildlife Habitat Relationships Database, Version 5.3). To compare our results to those of a study in somewhat similar habitat 60 miles to the north (Nur et al. 1996), we randomly sampled our data to determine the number of species that would be detected at any 13 points (the number sampled by the Nur et study). The resulting mean value for species richness (33.06) is very close to the mean from the Nur et al. study (30.5, range 23 to 41). Our slightly higher value can be partly attributed to the fact that we visited each of our points 5 rather than 3 times. We found an average of 8.1 individuals per streamside point (adjusted for a total of 3 visits) whereas the Nur et al. study, which focused on riparian habitats impacted acutely by a contaminant spill, reported a much lower average of 1.5 individuals per streamside point from a total of 3 visits to each of their points.

Our roadside data also seem generally representative of northern California riparian-chaparral habitat. The abundance rankings of species we found at our roadside points were significantly correlated with the abundance rankings of non-aquatic species found on a local Breeding Bird Survey route (Shasta Lake, average of 1981-1991)(p<.0001, n= 86 species, Spearman pairwise rank correlation). All but 11 of the 51 most frequent species on the BBS route were among the 51 species we found at our roadside survey points. The local species that we failed to find in the Iron Mountain study area were House Wren, White-breasted Nuthatch, Pacific-slope Flycatcher, Tree Swallow, Chestnut-backed Chickadee, Bullock's Oriole, Downy Woodpecker, Vaux's Swift, Brewer's Blackbird, European Starling, and Yellow Warbler. Most of these are species that prefer residential and agricultural areas. Overall, we found an average of 4.27 individual birds per visit to a roadside point (range among points = 0.8 to 7.8 individuals). In comparison, the Shasta Lake BBS reports an average of about 13 individual birds per point.

3.2 Reptiles and Amphibians

We did not observe a large enough number of individual adult amphibians and reptiles to draw any conclusions. The paucity of observations was due to the ineffectiveness in this terrain of even the most widely-used protocols for herptile surveys. Relatively few species use low- and mid-elevation habitats in Shasta County. Our qualitative observations are reported in Table 6.

3.3 Wildlife Habitat Structure

<u>Streamside Points</u>

The predominant habitat in 8 of the 21 points was Montane Hardwood-Conifer, and Montane Hardwood in another 8 points. Other habitats present but not predominating included Riverine (present at all 20 points), Riparian (9 points), Mixed Chaparral (5 points), and Barren (4 points).

The uncontaminated streamside points had significantly more Riparian ($p<.0001$) and Mixed Chaparral ($p<.05$), and significantly less Barren ($p<.001$) habitat, as compared with contaminated points. The proportions of vegetation size classes within habitats did not differ significantly between contaminated and uncontaminated sites ($p<0.05$, Fisher's exact test). Significantly more uncontaminated than contaminated points had tree, shrub, and herbaceous subcanopy layers and berries at the time of the bird surveys. Significantly more contaminated than uncontaminated streamside points had rocky talus and small snags.

<u>Roadside Points</u>

Montane Hardwood-Conifer habitat predominated at the most points (48%), followed by Montane Hardwood (at 41%), Mixed Chaparral (at 5%), and Riparian habitat (at 1%). Riverine habitat was at least present at 37% of the points, Barren at 26%, Riparian at 19%, and Mixed Chaparral at 5%.

Uncontaminated points had significantly more Riparian ($p<.0001$) and significantly less Barren ($p<.0015$) as compared with contaminated points. In Montane Hardwood-Conifer habitat, the uncontaminated points contained a significantly higher proportion of saplings and relatively large trees, but otherwise the proportions of vegetation size classes within habitats did not differ significantly between contaminated and uncontaminated sites. Significantly more uncontaminated than contaminated points had an herbaceous subcanopy layer, large (>11 inch diameter) hardwood trees, and berries at the time of the bird surveys. Significantly more contaminated than uncontaminated roadside points had rocky talus.

3.4 Influence of Habitat Structure vs. Contamination on Birds

Although statistical differences with regard to habitat structure existed between contaminated and uncontaminated sites (as noted above), these differences were apparently not of sufficient magnitude to influence the occurrence of most bird species. This is suggested by an analysis wherein we used our habitat structure data and the CWHR models to predict species that should occur at our uncontaminated vs. contaminated sites, based only on habitat structure and putting aside any possible influence of contamination. We then compared these predictions with what we actually found, and attributed the difference between predicted and found to the possible effects of contamination. This analysis showed the following:

<u>Streamside Points</u>

1. The mean *number of species* predicted to potentially occur at contaminated points (131, range 104-176) did not differ significantly from the mean number predicted to occur at uncontaminated points (128, range 107-138), according to the Mann-Whitney U test, $p=.6948$, $n= 21$).

2. The mean *habitat suitability score* of species predicted to occur at contaminated points (..7645) did not differ significantly from the mean score predicted for uncontaminated points (.7758), regardless of whether we considered just the species that were both predicted and detected (Mann-Whitney U test, $p=.6937$, $n=145$), or all species that were predicted regardless of whether they were detected (Mann-Whitney U test, $p= .2478$, $n= 2713$).

3. The *percent similarity* in *predicted* species composition (Jaccard index) was 74% among contaminated points, 87% among uncontaminated points, and 77% among all streamside points. Thus, habitat differences between contaminated and uncontaminated points, as integrated by the habitat model species predictions, were not great.

4. A stepwise regression analysis of bird frequency vs. contamination status and 10 habitat variables (variables chosen because they were not correlated among themselves but were individually correlated with bird frequency) produced a final model in which contamination status was among the other 3 remaining variables that were associated most strongly with bird frequency. That final model explained 83% of the variability in bird frequency. A model based on contamination status alone (after accounting for effects of habitat) explained 56% of the variability.

5. Species with the strongest tendency to be absent at contaminated sites, even when predicted to be present there based on the availability of suitable habitat, were Western Tanager, Wrentit, and a host of aquatic species (waterfowl, shorebirds, large wading birds) for which the habitat was only marginally suitable.

Roadside Points

1. The mean *number of species* predicted to potentially occur at contaminated points (131, range 104-176) did not differ significantly from the mean number predicted to occur at uncontaminated points (128, range 107-138), according to the Mann-Whitney U test, p=.6948, n= 21).

2. The mean *habitat suitability score* of species predicted to occur at contaminated points (.7746) did not differ significantly from the mean score predicted for uncontaminated points (.7903), regardless of whether we considered just the species that were both predicted and detected (Mann-Whitney U test, p=.6937, n=145), or all species that were predicted regardless of whether they were detected (Mann-Whitney U test, p= .2478, n= 2713).

3. The *percent similarity* in predicted species composition (Jaccard index) was 81% among contaminated sites, 85% among uncontaminated sites, and 80% among all roadsite sites. Thus, habitat differences between contaminated and uncontaminated sites, as integrated by the habitat model's bird species predictions, were not great.

4. A stepwise regression analysis of number of *individual birds* vs. contamination status and 6 habitat variables (variables chosen because they were not correlated among themselves but were individually correlated with bird frequency) produced a final model in which contamination status was among the 2 remaining variables that were associated most strongly with individual birds (the other variable was "percent riparian cover." The final model explained 35% of the variability in number of individual birds. A model based on contamination status alone (after accounting for effects of riparian habitat) explained 30% of the variability.

A stepwise regression analysis of number of bird *species* (maximum richness per point) vs. contamination status and 7 habitat variables (variables chosen because they were not correlated among themselves but were individually correlated with bird frequency) produced a final model in which contamination status was among the 2 remaining variables that were associated most strongly with bird frequency. That final model explained 30% of the variability in bird richness. A model based on contamination status alone (after accounting for effects of habitat) explained 22% of the variability.

5. Species with the strongest tendency to be absent at contaminated sites, even when predicted to be present there based on the availability of suitable habitat, included a host of aquatic species for which the habitat was only marginally suitable, plus Western Flycatcher, Orange-crowned Warbler, Wrentit, and Spotted Towhee.

3.5 Plants

3.5.1 Richness and Community Composition

The mean number of plant species per transect was 11 (range, 3 to 17). In contrast to birds, uncontaminated transects were not significantly richer in plants than contaminated transects (p=.6612, Mann-Whitney U test, n=30)(Tables 4 & 5). About 55% of the occurrences of a tree layer and 65% of the occurrences of an herbaceous layer were at points on the uncontaminated transects, whereas 52% of the occurrences of a shrub layer were at points on the contaminated transects. Differences in the proportions of trees, shrubs, and herbaceous vegetation in uncontaminated vs. contaminated transects were not statistically significant (p=.3705 for trees, p=.4754 for shrubs, p=.1786 for herbaceous, Mann-Whitney U test, n=30).

Uncontaminated transects had significantly more individual plants (p=.0135), and the particular species that made up the plant community differed from species found on contaminated transects. As revealed by MRPP analysis, the overall community structures of uncontaminated vs. contaminated transects were clearly distinct (p<.0001). Contamination status was a statistically significant classifier of transects regardless of whether information on species abundance (in addition to species identity) was included, and regardless of whether we included all species found along transects or just those at the 0.5-meter survey spots. Among the 15 transects we classified as uncontaminated, only two (SF1 and SF2) were more similar in their species composition to contaminated than to the other uncontaminated transects (Figure 4). The SF2 transect's apparent similarity to more contaminated transects is likely due to a methodological error: only 80, rather than the usual 100, points were surveyed on this transect.

3.5 Plant Habitat

In this study area, plants grow commonly on soil, gravel, and sand substrates, whereas very few plants grow in flowing water or on bedrock, due mainly to the physical characteristics of those substrates. Bedrock was significantly more likely to be associated with contaminated than uncontaminated sites that we surveyed, and the relatively low frequency of plants on the contaminated transects may have been related to this fact (p=.0367, Mann-Whitney U test). However, the <u>un</u>contaminated transects were also likely (p=.0208) to contain unsuitable substrate -- in their case, water. Yet, plant *frequency* there was high (r=.5046, p=.0066, Spearman rank correlation of water with plant frequency). Plant *richness* failed to show any significant association with the extent of either water or bedrock (p>.05, Spearman pairwise rank test).

Table 4. Plant species associated more often with contaminated points, based on frequency of occurrence on 30 transects (with 1500 contaminated points, 1480 uncontaminated points).

* = association was significant (p<0.05, Chi-square or Fisher's exact test)

	FREQUENCY (# of hits)	
	uncontam.	contam.
**Quercus chrysolepis*	266	726
**Quercus kelloggii*	30	114
**Heteromeles arbutifolia*	40	112
**Lonicera hispidula*	3	74
**Toxicodendron diversilobum*	5	71
**Arctostaphylos viscida*	6	68
**Cornus glabrata*	4	67
**Cytisus scoparius*	21	57
**Pinus sabiniana*	4	55
**Calocedrus decurrens*	0	43
**Rhamnus californica*	2	32
**Rhododendron occidentale*	11	28
**Festuca arundinacea*	0	23
**Aesculus californica*	0	19
**Polystichum imbricans*	4	19
*Unidentified grass sp.	1	10
Aristolochia californica	0	5
Hieracium bolanderi	0	5
Galium nuttallii	0	4
Unidentified species-WIL	0	4
Unidentified grassB	0	3
Antennaria argentea	0	2
Unidentified fescue	0	2
Unidentified grass A	0	2
Ceanothus lemmonii	0	1
Dudleya cymosa	0	1
Pedicularis densiflora	0	1
Dichelostemma capitatum	0	1

Table 5. Plant species associated more often with <u>un</u>contaminated points, based on frequency of occurrence on 30 transects (with 1500 contaminated points, 1480 uncontaminated points).

* = association was significant ($p<0.05$, Chi-square or Fisher's exact test)

	FREQUENCY (# of hits)	
	uncontam.	contam.
**Alnus rhombifolia*	717	24
**Acer macrophyllum*	302	22
**Carex nudata*	214	48
**Cornus nuttallii*	151	15
**Nerium oleander*	137	0
**Acer circinatum*	131	1
**Rubus discolor*	122	1
**Vitis californica*	92	3
**Pseudotsuga menziesii*	90	59
**Heracleum lanatum*	38	0
**Fraxinus latifolia*	30	0
**Taxus brevifolia*	30	16
**Darmera peltata*	26	1
**Aira caryophyllea*	21	0
**Salix lasiolepis*	21	10
**Woodwardia fimbriata*	19	2
**Populus trichocarpa*	14	0
**Osmorhiza chilensis*	11	0
Ailanthus altissima	9	0
Ceanothus cuneatus	5	0
Pteridium aquilinum	5	2
Artemisia douglasiana	2	0
Ficus edulis	2	0
Pinus attenuata	2	0
Hypericum mutilum	1	0
Hypericum perforatum	1	0
Lilium pardalinum	1	0
Potentilla glandulosa	1	0
Unidentified species	1	0

Table 6. Annotated list of reptiles and amphibians found during field surveys in the Iron Mountain area

California (Pacific) Giant Salamander (*Dicamptodon ensatus*). A few individuals were noted in early May, all in uncontaminated areas (upper Boulder Creek, Cottonwood Creek).

Black Salamander (*Aneides flavipunctatus*). In early June we noted one individual at the base of a rivulet entering the margin of Slickrock Creek (near SRJ2 -- a contaminated point) during a rainstorm. In December we found another individual about 200 meters downstream of this point under an artificial (straw) cover.

Ensatina (*Ensatina eschscholtzi*). Our records were:

Location	Month	Condition
Boulder Creek (UB1)	June	Under artificial cover (straw)
Upper Slickrock (USP3)	December	Under artificial cover (plastic)
LCR6	December	roadside ditch (2 small individuals)
LCR4	December	road cut (2 individuals)
BR10	December	road cut
BR11	December	road cut (1 very large individual)
BR2	December	road cut
LCR4	December	road cut
BR11	December	road cut (2 individuals)

Western Toad (*Bufo boreas*). Noted regularly along upper Slickrock, Cottonwood, and South Fork stream segments (all uncontaminated).

Pacific Treefrog (*Hyla regilla*). Common, widespread, and frequently heard in early May. Occurred along the margins of all streams with about equal frequency (quantification would have been meaningless because detections seemed to be influenced by subtle variations in temperature, humidity, and time of day).

Foothill Yellow-legged Frog (*Rana boylei*). Single adults were found in early May in two streams, both uncontaminated: Cottonwood, and South Fork of Spring Creek.

Western Fence Lizard (*Sceloporus occidentalis*). Seen regularly outside the riparian zone in all areas.

Southern Alligator Lizard (*Elgaria multicarinata*). Found single individuals along the woodland edge of Spring Creek (contaminated) below its junction with Slickrock Creek, and along the edge of upper Boulder Creek (uncontaminated).

Striped Racer (*Masticophis lateralis*). Found single individual in South Fork of Spring Creek (uncontaminated).

Gopher Snake (*Pituophis melanoleucus*). Noted several individuals on a single day in early June, about 100 meters uphill from South Fork of Spring Creek (uncontaminated).

California Mountain Kingsnake (*Lampropeltis zonata*). Discovered a single individual in oak woods bordering lower Boulder Creek (near BT3 -- contaminated)

Common Garter Snake (*Thamnophis sirtalis*). Found individuals on several occasions during May and June along South Fork of Spring Creek (uncontaminated).

Overall, 18 species occurred significantly more on uncontaminated transects, whereas 16 occurred significantly more on contaminated transects (Table 5). The percent similarity in plant species composition among all transects was 23% (Jaccard index). By comparison, among the uncontaminated transects the mean similarity was 32% and among contaminated transects it was 25%. Uncontaminated transects had a significantly higher proportion of plants that prefer or grow successfully in water or wet soil.

3.5.2 Representativeness

From these late-spring visits to 3000 survey points along 30 transects in mid-elevation riparian habitats of western Shasta County, we detected 79 (10%) of the 831 plant species reported previously from searches of all habitats and elevations in western Shasta County (Biek 1988). We found no species new to western Shasta County. The following species had been previously reported to occur on Iron Mountain in recent decades (Stone et al. 1975, Biek 1988) but we did not detect them along our riparian transects:

Asteraceae: *Calycadenia ciliosa, Filago (Logfia) gallica, Helianthella californica, Hieracium album, Lessingia nemoclada*
Caprifoliaceae: *Lonicera interrupta*
Convulvaceae: *Calystegia polymorpha*
Cyperaceae: *Carex multicaulis*
Ericaceae: *Arctostaphylos mallorvi, Ledum glandulosum*
Fabaceae: *Lathyrus sulphureus, Lupinus albifrons. L. latifolius*
Gentianaceae: *Frasera albicaulis*
Hypericaceae: *Hypericum concinnum*
Iridaceae: *Iris tenuissima*
Lamiaceae: *Monardella odortissima*
Oleaceae: *Fraxinus dipetala*
Onagraceae: *Epilobium minutum*
Pinaceae: *Pinus lambertiana, P. ponderosa*
Poaceae: *Agrostis diegoensis, Bromus rubens, Festuca californica, F. myuros, F. occidentalis, F. reflexa, Gastridium ventricosum, Poa scabrella, Setaria geniculata, Sitanion hansenii, Stipa californica*
Polemoniaceae: *Gilia capitata*
Polypodiaceae: *Pellea mucronata*
Rhamnaceae: *Ceanothus integerrimus, Rhamnus rubra*
Rosaceae: *Amelanchier pallida, Cercocarpus betuloides*
Santalaceae: *Commandra umbellata*
Scrophulariaceae: *Antirrhinum cornutum*
Styracaceae: *Styrax officinalis*

3.6 Other Observations

Incidental to our field work we noted enormous aggregations of a non-native insect, the Multicolored Asian Lady Beetle (*Harmonia axyridis*). These aggregations occurred in the same areas regardless of date (May 7 to July 2) and the contamination category of the site. The largest occurrences consisted of swarms that blanketed the ground and vegetation over areas of approximately 0.5 acre. In many years of field work in the western United States, I have never seen such large aggregations. This insect feeds on aphids, probably has few avian predators because of its recently introduced status, and requires semi-enclosed structures (such as mine tunnels) for overwintering. If this species is displacing native insects, even locally, the chronology of food availability for insectivorous birds could be altered.

Figure 4. Cluster analysis dendrogram of plant community transects

Points linked most closely are most similar with regard to plant species. Contaminated points are preceded by an asterisk (*). Cluster analysis was executed using PC-ORD software, based on Euclidean distance using Ward's method and the Sorensen similarity index.

4.0 DISCUSSION

4.1 Conceptual Background

Features of mining operations (such as those at Iron Mountain) that have the potential for persisting for years after mine shut-down include (Richardson and Pratt 1980):

- alteration of watershed surface topography
- alteration of runoff timing, duration, and magnitude
- alteration of fire frequency
- introduction of abnormal loads and/or concentrations of heavy metals
- introduction of roads, bridges, buildings, and debris
- introduction of plants (especially non-native species, as part of revegetation programs)

Some of these features can interact, and in turn can trigger:

- erosion and acidification of soils and streams
- sedimentation of water bodies
- alteration of soil fertility and texture
- alteration of ambient temperature and wind

These factors also can interact, and can in turn cause the species composition of the native plant community to change, as some plant species benefit and others are harmed. Benefit or harm to a plant species from these factors can be expressed acutely, or more often as sublethal, long-term changes, as the rates of germination, growth, productivity, fertility, survival, and dispersal success of individual plants and populations change in response to the chemical and physical changes in the environment as induced by mining activities. These changes are more likely to occur in some species than others because of differences in characteristic life form and life history.

Because the initial factors affect different plant species selectively, the usually predictable pattern of plant succession can change. As succession changes, the plant community potentially takes on a new physical structure (e.g., changes in cover density, mean height, number of strata), and as a result, animal species are differentially affected. Animals also can experience acute or sublethal effects as they ingest heavy metals in food, grit, and drinking water, or as they encounter changes in the availability or nutritional quality of foods. Regardless of the particular pathways by which changes occur, animals in the vicinity of mining operations can consequently suffer changes in fecundity, mortality, and capacity for dispersal.

Changes in animal and plant community composition can be viewed positively or negatively, depending on the species that decrease and the values publicly associated with those species. Nonetheless, because of concerns arising from widely-documented long-term losses of biodiversity in many regions, a significant diminuation of the richness (number) of native species at any geographic scale is often of high public concern.

4.2 Iron Mountain Conditions

The primary contaminants in the study area soils and streams are believed to be excessive concentrations of zinc, copper, iron, and acidity (Prokopovich 1965, Turek 1986). Near survey points we had categorized as "contaminated," the average biweekly aquatic concentrations during the survey period (June 1997) for dissolved zinc ranged from 123 to 4480 ug/L, for dissolved copper ranged from 64 to 4010 ug/L, and for pH ranged from 3.17 to 5.90. For survey points we had categorized as "uncontaminated," the comparable measures had values of 16-231 ug/L for zinc, 15-31 ug/L for copper, and 6.77-7.03 for pH (data provided by CH2M Hill, Inc.). Data were not available from near all our survey points.

Expectations of long-term localized reduction in species richness from mining operations are well-grounded in theory and by results of studies of individual plants and animals. However, there have been only a few published attempts (e.g., Galbraith et al. 1995, LeJeune et al. 1996) to verify the prevalence and persistence of changes in plants and animals at a *community* level as a result of sublethal chemical stresses from abandoned mine tailings. Our findings of reduced species richness and vertical structure of plant communities parallel those reported by the other studies of metal-contaminated soils.

Plants are highly sensitive to concentrations of zinc and copper, with growth of many species being reduced by zinc concentrations that exceed 1000 ug/L and damaging physiological effects occurring at 200 ug/L (Pahlsson 1989, Pascoe et al. 1994, Eisler 1997). Plants and animals that inhabit *riparian* habitats and wetlands seem especially prone to experiencing bioconcentration of heavy metals from mining operations (e.g., Moore et al. 1991, Barrick and Noble 1993). Uptake occurs readily, especially in spring. Copper concentrations of only 15 to 20 ug/L in leaves are associated with inhibited growth of some plants (Pahlsson 1989). Given the concentrations in Iron Mountain streams (123-4480 ug/L for zinc and 64-4010 ug/L for copper) and riparian soils (14 - 591 ppm; unpublished BLM data), the potential for adverse effects to plants -- at least those nearest the streams-- seems very real. Indeed, our data show that plant species that are the most water-tolerant occur significantly more often along our uncontaminated streams, and this could be because such species cannot tolerate the chemical conditions of water at the contaminated sites. Even when plants are not directly in the water, their roots are likely in contact with metal-laden groundwater that seeps out where mountain slopes join streams. Although some plant species over time can evolve a tolerance to mildly elevated concentrations of heavy metals, the potential for widespread damage remains high. Moreover, loss of plants in contaminated areas has the potential to affect streamside soil fertility as well as biodiversity and wildlife habitat. This is because alder (*Alnus* spp.), which normally benefits soil fertility by fixing nitrogen, may lose this ability when soil copper concentrations exceed 40 ug/L (Pahlsson 1989). We found alder existing at only 24 of our contaminated points, compared with 717 of the uncontaminated points.

Although we did not sample amphibians quantitatively, the apparent absence of tadpoles in our contaminated streams is not surprising. A copper concentration as low as 39 mg/L has been shown to affect survival of tadpoles (Khangarot et al. 1985) and sediment concentrations of 300-450 ug/L copper and 650-1060 ug/L zinc have been associated with frog malformations in laboratory studies (Pascoe et al. 1994). A copper concentration of 315 ug/L harms embryos of aquatic salamanders (Horne and Dunson 1994). A zinc concentration of 400 ug/L adversely affects toad embryos

(Linder et al. 1991, cited in Schuytema and Nebeker 1996) and 2000 ug/L is damaging to salamander embryos (Horne and Dunson 1994).

There are no data on metal tolerence thresholds for *birds* typical of our study area, but elevated concentrations of heavy metals have been documented in wildlife at other sites contaminated with mining wastes (e.g., Hunter et al. 1987, Pascoe et al. 1994) and there is no reason to believe this situation has been avoided at Iron Mountain. Even if birds were not to be affected acutely by metal toxicity at the Iron Mountain site, they could suffer from a metal-toxicity-related reduction in food supplies, or changes in the seasonal availability of food as a result of altered plant and insect community composition. This is highlighted by a pattern in our data. There are clear differences in the types of birds that exist at the uncontaminated vs. contaminated points. A majority of the bird species that were present at our uncontaminated sites, but absent or significantly less common at contaminated sites, feed on invertebrates (e.g., aquatic insects, soil crustaceans). An obvious example is the American Dipper, a bird that forages almost entirely on aquatic invertebrates, and was absent from all of our contaminated points in spite of an abundance of physically suitable habitat at those points. Unmistakable reductions in invertebrate species richness and abundance in contaminated vs. uncontaminated streams on Iron Mountain have been documented recently (Slotton et al. 1996). Perhaps not coincidentally, we found very few insectivorous bird species at contaminated points. Those that we did find were swallows (Barn and Violet-green) that cruise large areas in search of flying insects and are attracted to abandoned mine buildings for nesting. Concentrations of zinc and copper similar to those in our streams have been shown to harm invertebrates and fish in nearby Keswick Reservoir (Fujimura et al. 1995).

6.0 LITERATURE

Alpers, C.N., D.K. Nordstrom, and J.M. Burchard. 1991. Compilation and Interpretation of Water Quality and Discharge Data for Acidic Mine Waters at Iron Mountain, Shasta County, California, 1940-91. Water Resour. Investiga. Rep. 91-4160, U.S. Geol. Surv., Denver, Colorado.

Biek, D. 1988. Flora of the Whiskeytown National Recreation Area, Shasta County, California. National Park Service, Whiskeytown, California.

Bureau of Land Management (BLM). 1994. Natural Resource Damage Assessments. Code of Federal Regulations, 43 CFR Part 11 as amended by 59 FR 14262.

California Native Plant Society. 1996. Field Sampling Protocol. California Native Plant Society, Sacramento, CA.

California Wildlife Habitat Relationships Database, Version 5.3. 1997. Courtesy MS-DOS copy provided to Paul Adamus by California Department of Fish and Game.

Croonquist, M.J. and R.P. Brooks. 1991. Use of avian and mammalian guilds as indicators of cumulative impacts in riparian-wetland areas. Environmental Management 15:701-714.

Eisler, R. 1997. Zinc hazards to plants and animals with emphasis on fishery and wildlife resources. pp. 443-537 In: P.N. Cheremisinoff (ed.). Ecological Issues and Environmental Impact Assessment. Gulf Publishing Co., Houston, TX.

Finlayson, B.J. and D.C. Wilson. 1989. Evaluation of lethal levels, release criteria, and water quality objectives for an acid-mine waste. In: G.W. Sutter and M.A. Lewis (eds.), Aquatic Toxicology and Environmental Fate. Am. Soc. for Testing and Materials, Philadelphia, PA.

Fujimura, R.W., C. Huang, and B. Finlayson. 1995. Chemical and Toxicological Characterization of Keswick Reservoir Sediments. California Department of Fish and Game, Elk Grove, California.

Galbraith, H., K. LeJeune, and J. Lipton. 1995. Metal and arsenic impacts to soils, vegetation communities, and wildlife habitat in southwest Montana uplands contaminated by smelter emissions: I. Field evaluation. Envir. Toxicol. Chem.14:1895-1903.

Horne, M.T. and W.A. Dunson. 1994. Exclusion of the Jeffersonian salamander from some potential breeding ponds in Pennsylvania: Effects of pH, temperature, and metals on embryonic development. Arch. Environ. Toxicol. 27:323-330.

Hughes, R.M. 1985. Use of watershed characteristics to select control streams for estimating effects of metal mining wastes on extensively disturbed streams. Envir. Manage. 9:253-262.

Hunter, B.A., M.S. Johnson, and D.J. Thompson. 1987. Ecotoxicology of copper and cadmium in a contaminated grassland ecosystem: I-III. J. Appl. Ecol.24:573-614.

Jackson, D.A., K.M. Somers, and H.H. Harvey. 1989. Similarity coefficients: measures of co-occurrence and association or simply measures of occurrence? Am. Nat. 133:436-453.

Khangarot, B.S., A. Sehgal, and M.K. Bhasin. 1985. Acute toxicity of selected heavy metals on the tadpoles of *Rana hexadactlya*. Acta Hydrochim. Hydrobiol. 13:259-263.

LeJeune, K., H. Galbraith, J. Lipton, and L. Kapustka. 1996. Effects of metals and arsenic on riparian communities in southwest Montana. Ecotoxicology 5:297-312.

Luke, C. and D. Sterner. 1995. Cantara Bridge Chemical Spill, 1994 Aquatic Amphibian Survey. BioSystems Analysis, Inc., Santa Cruz, California.

Mason, W.T. (ed.). 1978. Methods for the Assessment and Prediction of Mineral Mining Impacts on Aquatic Communities: A Review and Analysis. FWS/OBS-78/30, U.S. Fish & Wildl. Serv., Washington, DC.

Mayer, K.E. and W.F. Laudenslayer (eds.). 1988. A Guide to Wildlife Habitats of California. California Department of Fish and Game, Sacramento, CA.

Mielke, P.W., K.J. Berry, and G.W. Brier. 1981. Application of multi-response permutation procedures for examining seasonal changes in monthly sea-level pressure patterns. Monthly Weather Review 109:120-126.

Moore, R. and T. Mills. 1977. An Environmental Guide to Western Surface Mining. II. Impacts, Mitigation, and Monitoring. FWS/OBS-78/04, U.S. Fish & Wildl. Serv., Fort Collins, Colorado.

Nur, N., G.R. Geupel, and G. Ballard. 1996. Assessing the Impact of the Cantara Spill on Terrestrial Bird Populations Along the Sacramento River: Results from the 1995 Field Season and Comparison with Results, 1991-1994. Point Reyes Bird Observatory, Stinson Beach, California.

Pahlsson, A.M.B. 1989. Toxicity of heavy metals (Zn, Cu, Pb) to vascular plants: a literature review. Water Air Soil Pollut. 47:287-319.

Pascoe, G.A., R.J. Blanchet, and G. Linder. 1994a. Bioavailability of metals and arsenic to small mammals at a mining waste-contaminated wetland. Arch. Environ. Contam. Toxicol. 27:44-50.

Pascoe, G.A., R.J. Blanchet, G. Linder, D. Palawski, W.G. Brumbaugh, T.J. Canfield, N.E. Kemble, C.G. Ingersoll, A. Farag, and J.A. DalSoglio. 1994b. Characterization of ecological risks at the Milltown Reservoir-Clark Fork River sediments Superfund site, Montana. Envir. Tox. Chem.13:2043-2058.

Pascoe, G.A., R.J. Blanchet, and G. Linder. 1996. Food chain analysis of exposures and risks to wildlife at a metals-contaminated wetland. Arch. Environ. Contam. Toxicol.30:306-318.

Porter, K.R. and D.E. Hakanson. 1976. Toxicity of mine drainage to embryonic and larval boreal toads. Copeia 1976:327-331.

Prokopovich, N.P. 1965. Siltation and pollution problems in Spring Creek, Shasta County, California. J. Am. Water Works Assoc. 57:986-996.

Ralph, C.J., S. Droege, and J.R. Sauer. 1995. Managing and monitoring birds using point counts: standards and applications. pp. 161-167 In: Monitoring Bird Populations by Point Counts. Gen. Tech. Rep. PSW-GTR-149, USDA Forest Service Pacific Southwest Research Station, Albany, CA.

Ralph, C.J., G.R. Geupel, P. Pyle, T.E. Martin, and D.F. DeSante. 1993. Handbook of Field Methods for Monitoring Landbirds. Gen. Tech. Rep. PSW-GTR-144, USDA Forest Service Pacific Southwest Research Station, Albany, CA.

Richardson, B.Z. and M.M. Pratt. 1980. Environmental Effects of Surface Mining of Minerals Other than Coal: Annotated Bibliography and Summary Report. Gen. Tech. Rep. INT-95, USDA Forest Serv., Ogden, Utah.

Schuytema, G.S. and A.V. Nebeker. 1996. Amphibian Toxicity Data for Water Quality Criteria Chemicals. EPA/600/R-96/124, USEPA Environmental Research Laboratory, Corvallis, OR.

Slotton, D.G., S.M. Ayers, and C.R. Goldman. 1996. Iron Mountain Region, Fall 1996 Stream Biota Preliminary Study. Final Report. Ecological Research Associates, Davis, California.

Staley, C.S. and R.C. Rope. 1993. U.S. Fish and Wildlife Service Lands Biomonitoring Operations Manual. Appendix D. An Introduction to the Use of Flora and Fauna for Contaminant Monitoring. EGG-EST-9222, Center for Environmental Monitoring and Assessment, EG&G Idaho Inc., Idaho Falls, ID.

Stone, C.O., J.I. Mallory, and W.R. Powell. 1975. Tables for the Soil-Vegetation Map, Southwest Quarter of the Trinity Dam Quadrangle (24B-3) and Northwest Quarter of the Weaverville Quadrangle (24C-2), Trinity County, California. Pacific Southwest Forest and Range Experiment Station, USDA Forest Serv., Berkeley, California.

Turek, S.M. 1986. Sacramento River Water Quality and Biology (Keswick Dam to Verona): A Literature Review. California Department of Water Resources, Sacramento, California.

Verner, J. and A.S. Boss. 1980. California Wildlife and Their Habitats: Western Sierra Nevada. Gen. Tech. Rep. PSW-37, USDA Forest Service, Berkeley, CA.

USDA Forest Service. 1996. Checklist of Vascular Plants, Shasta-Trinity National Forests, Northern California. Shasta-Trinity National Forest, Redding, California.