

**WILDLIFE BIOMONITORING AT THE ANACONDA SMELTER SITE  
DEER LODGE COUNTY, MONTANA**

**FINAL REPORT**

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## **1 INTRODUCTION**

The Anaconda Smelter National Priorities List site (EPA ID No. MTD093291656) in Deer Lodge County, Montana, encompasses over 100 square miles that have been affected by 100 years of milling and smelting operations. Aerial stack emissions and stream discharges, as well as wind dispersal, have transported metal-contaminated wastes over a wide area. These wastes include approximately 230 million cubic yards of concentrated mine tailings, 30 million cubic yards of furnace slag, 500,000 cubic yards of flue dust, and many square miles of contaminated soils (Figure 1-01; CDM 1997). The site was placed on the National Priorities List (NPL) and under the authority of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) on September 8, 1983. The contaminants of concern (COC) at the site are a variety of forms and concentrations of arsenic (As), cadmium (Cd), lead (Pb), copper (Cu) and zinc (Zn).

Ecological effects at the Anaconda site are predominated by extensive phytotoxicity that has left vast areas (approximately 18 square miles) either denuded of vegetation or severely stressed in their vegetative components. Risks to vegetation were documented in the Environmental Protection Agency's (EPA's) Baseline Environmental Risk Assessment (BERA) for the Anaconda Smelter Site (CDM 1997). Significant remedial action has been planned in response to hazards posed to vegetation by metal and As contamination. The BERA for the Site also identified several wildlife receptors having the potential for deleterious exposures to the same contaminants. Excess risk to wildlife has been suggested based on modeling exercises evaluating contaminant uptake from foraging, food chain transfer, drinking water and direct ingestion of contaminated soils. Modeled species, selected as representatives of feeding and habitat guilds (CDM, 1997), were white-tailed deer (*Odocoileus virginianus*), deer mouse (*Peromyscus maniculatus*), American robin (*Turdus migratorius*), red fox (*Vulpes vulpes*) and American kestrel (*Falco sparverius*). Direct assessment of wildlife has been limited. Investigations conducted on the Anaconda Smelter Site have not included studies of actual health effects endpoints in wildlife inhabiting impacted areas.

Currently, risk management decisions have been focused on remediation using soil amendments to reduce the availability of metals and As to vegetation and it is anticipated that these techniques would also indirectly reduce exposure to wildlife receptors. No remedial action, however, has been planned to directly reduce potential metal exposure to wildlife. It is, therefore, important to collect pertinent biological data, both to refine risk models used in the BERA to predict the geographical extent of current wildlife risk, and to determine the most pertinent and cost effective, long term data collections to ensure protection of wildlife species. Investigators at the Institute of Environmental and Human Health at Texas Tech University, Lubbock, Texas, have worked closely with the USEPA Region 8 Superfund Office in Denver, Colorado, and the US Fish and Wildlife Service's Contaminants Division in Helena, Montana, to develop a biomonitoring program that addressed these further data needs. The resulting study, reported herein, investigates metal and As exposure and wildlife health effects at the Anaconda Smelter Site.

This evaluation of the existing health status of wildlife has incorporated rodent and avian species investigations using two approaches. The first evaluated COC exposure and induced health effects in wildlife inhabiting a variety of contaminated areas on, and adjacent to, the Anaconda Smelter Site. Individual-level exposure and health effects assessments and population-level demographic assessments provide data to develop a geographic distribution of potential exposure and effects across contaminated areas of the site. This distribution is designed to be compared to previously predicted COC-related risks to wildlife species in the BERA. A second approach has focused similar techniques on wildlife inhabiting remediated areas of the site for assessment of residual contaminant uptake and effects. Wildlife exposure and effects data, from habitats receiving a variety of remedial actions, are described for comparisons of remediation option efficacy in protecting wildlife health.



## **2 OBJECTIVES**

The objective of this study was to quantify COC (As, Cd, Cu, Pb and Zn) exposure and effects in wildlife inhabiting non-remediated and remediated areas on the Anaconda Smelter NPL Site in Deer Lodge County, Montana.

To attain that objective, two main approaches were pursued:

1. Quantify the level of exposure and effects, and resultant risk, to wildlife inhabiting the Anaconda Smelter site by directly studying representative species inhabiting the site, and
2. Evaluate the nature of changes in metal and As disposition, and the resulting effects, that occur in wildlife following the implementation of remedial options on the site.

### **3 SITE DESCRIPTION**

The Anaconda Regional Water, Waste, and Soils (ARWW&S) Operable Unit (OU) at the Anaconda Smelter NPL Site covers approximately 100 square miles in the southern Deer Lodge Valley and the surrounding foothills area (CDM 1997). The area consists of agricultural, pasture, rangeland, forest, riparian and wetland areas that contain large volumes of wastes, slag, tailings, debris, and contaminated soil, ground water, and surface water from copper and other metal ore milling, smelting, and refining operations conducted on site by the Anaconda Mining Company, and its predecessors and successors, from approximately 1884 to 1980. Waste disposal occurred over approximately 6,000 acres; 13,000 acres of upland terrestrial soils are contaminated by smelter emissions; 4,800 acres of alluvial ground water contain elevated concentrations of arsenic, cadmium, and copper; and 28,600 acres of bedrock ground water exceed the State of Montana standard for arsenic.

Due to the large size of the ARWW&S OU, EPA subdivided the large OU into five subareas, which are listed below.

- Opportunity Ponds
- North Opportunity
- South Opportunity
- Old Works/Stucky Ridge
- Smelter Hill.

A brief description of each subarea, based on the information in the BERA (CDM 1997) is given below.

#### Opportunity Ponds

The Opportunity Ponds Subarea is located within the central portion of the ARWW&S OU and encompasses an area of approximately 11 square miles. The results of the Remedial Investigation (RI) for this subarea indicate large volumes of waste are located within the Opportunity Ponds A, B-1, B-2, C-1, C-2, D-1, and D-2 cells; the Triangle Waste Area; the

South Lime Ditch Area, and the Toe Waste Area. Contaminated soils affected by past smelter emissions have also been identified in some locations throughout the subarea. A portion of the alluvial aquifer underlying the subarea is contaminated with elevated levels of arsenic and cadmium above State of Montana standards for ground water.

The Anaconda-Deer Lodge Planning Board designated the land, which falls within EPA's defined Opportunity Ponds Subarea as open space/recreational use and Waste Management Areas (WMA). EPA has also determined that removal of waste material found in Opportunity Ponds and Cell A is impracticable and/or cost prohibitive due to the large waste volumes involved. The determination to leave waste in place means that ground water will not be remediated underneath these waste materials. Ground water recharge shows no movement of site contaminants of concern to surface water in the Lower Mill Creek or North Drain Ditch.

#### North Opportunity Subarea

The North Opportunity Subarea is located in the northeast portion of the ARWW&S OU and covers an area of approximately 27 square miles in the area north of State Highway 48 and east of the Lost Creek/Galen Highway. Results of RIs for this subarea indicate large volumes of contaminated soils and wastes are located throughout the subarea and along Warm Springs Creek. All surface water is a potential receptor from transport of contaminants of concern via runoff and stream bank erosion.

Land use for the North Opportunity Ponds Subarea is a mixture of rural/residential, agricultural, airport and open space/recreational. Land use deed restrictions were developed for some portions of agricultural lands restricting future residential development of these properties. This subarea covers the lower segment of Warm Springs Creek to its confluence with the Mill-Willow Bypass. Results of ground water monitoring in the shallow alluvial aquifer indicate ground water quality in the subarea is generally good. However, levels of cadmium above the State of Montana standard have been observed from recent ground water monitoring results in the shallow alluvial aquifer in the southwest portion of the subarea.

### South Opportunity Subarea

The South Opportunity Subarea is located in the southern portion of the ARWW&S OU and encompasses an area of approximately 25 square miles. Property in this area is used for a mixture of residential, agricultural, and recreational/open space activities. Sections of property are slated for incorporation into the regional historic trails program, linking the Greenway project along Silver Bow Creek to trails in the Old Works/Anaconda area. The subarea encompasses the lower segments of Mill Creek and Willow Creek to their confluence at the Mill-Willow Bypass.

Approximately 309,000 bank cubic yards (bcy) of wastes have been identified in the South Opportunity Subarea as a result of completion of the RI at the ARWW&S OU. These wastes include:

- Tailings, sediment, and contaminated berm material of the Yellow Ditch;
- Railroad grade material near the Blue Lagoon;
- Contaminated sediment located on the floor of the Blue Lagoon; and
- Streamside tailings located adjacent to Willow Creek.

Portions of all the wastes identified in the subarea are considered a source of ground water contamination to portions of the alluvial aquifer. Wastes identified in the Yellow Ditch and in streamside tailings located near Willow Creek are also considered potential source areas for contamination of surface water in portions of the Yellow Ditch and in the lower reach of Willow Creek, respectively.

### Old Works/Stucky Ridge Subarea

A majority of the Old Works/Stucky Ridge Subarea property was addressed under the OW/EADA Record of Decision (ROD). For remaining properties, located primarily in the upland portions of Stucky Ridge, land use is designated as open space, agricultural and potential residential. Final ground water and surface water decisions were deferred from the OW/EADA ROD to the ARWW&S OU.

As a result of previous actions, EPA and Montana Department of Environmental Quality have approved a remedial decision for some areas of concern in the Old Works/Stucky Ridge Subarea. These areas of concern (Heap Roast Slag, Flood Plain Wastes, and Red Sands) and 323 acres of high arsenic and sparsely vegetated soils have remedial actions currently under construction or completed. The Old Works/Stucky Ridge Subarea overlies both bedrock and alluvial aquifers that are contaminated; however, the bedrock aquifer is fractured and is considered untreatable as a result of a technical impracticability (TI) evaluation (EPA, 1996a).

### Smelter Hill Subarea

The Smelter Hill Subarea is located in the southwest portion of the site and covers an area of approximately 24 square miles. Land uses include WMAs, recreational/open space, agricultural/grazing, wildlife management, and residential land. This subarea covers the major site of smelting and processing activities that occurred between 1907 and 1980 and encompasses the Disturbed Area of Smelter Hill, which includes the Handling/Storage/Process Area, Stack Area, and Smelter Hill Waste Repositories; the Anaconda Ponds; the Main Granulated Slag Pile; East Anaconda Yard Wastes; West Stack Slag; debris located in Nazer Gulch and miscellaneous other small waste piles. The total volume of wastes contained in the subarea is estimated to be 125,079,000 bcy. Based on decisions made in the waste removal evaluation, from this total, approximately 124,900,000 bcy of wastes will remain in place as a designated WMA. This decision to leave wastes in place was made based on a technical impracticability assessment of meeting Applicable or Relevant and Appropriate Requirements (ARARs) for ground water and cost prohibitiveness criteria. The wastes included in the WMA in the Smelter Hill Subarea include the Anaconda Ponds, Smelter Hill Disturbed Area Wastes, the Main Granulated Slag Pile and buried tailings in the East Anaconda Yards. A portion of the Disturbed Area and the exterior berm of the Anaconda Ponds have been reclaimed with a cover of clean soil and vegetation under previous remedial actions. Areas of wastes and mixed waste and soil located in the Disturbed Area, waste and debris located in Nazer Gulch, and slag located in the West Stack Slag area are identified as sources of ground water contamination to the underlying bedrock aquifers. Buried wastes in the East Anaconda Yard and the Main Granulated Slag area, and wastes in

the Anaconda Ponds are potential loading sources to ground water in portions of the underlying alluvial aquifer.

A major portion of contaminated bedrock aquifers covers the backside of Smelter Hill into the Aspen Hills/Clear Creek drainages, in addition to a significant area of the Northern Portion of the State of Montana Mount Haggin Wildlife Management Area (including the Cabbage Gulch drainage). Estimated acreage of contaminated ground water is 23,830 acres. The drainages are a contributor to upper portion of Mill and Willow Creeks, perennial streams with a State of Montana B-1 classification.

## **4 EXPERIMENTAL DESIGN**

### 4.1 General

The experimental design and rationale for the study were established through the data quality objectives (DQO) process. The DQO process establishes a series of steps that ensure that the type, quality and quantity of environmental data used in the decision-making process are appropriate for the intended purpose.

The “Quality Assurance Project Plan for Wildlife Biomonitoring at the Anaconda Smelter Site, Deer Lodge County, Montana” (or QAPP), documents the development of the DQOs and establishes the quality assurance requirements for the project. The Institute of Environmental and Human Health’s Quality Assurance Program, oversaw the quality assurance for the project, under the guidelines established in the QAPP.

### 4.2 Step 1: State the Problem

Because the Anaconda Smelter Site currently has no remedial actions planned to directly reduce potential exposure to As and heavy metals in wildlife, a wildlife biomonitoring study has been performed examining small mammals and avian species.

This 2-year study was conducted to address the following basic problems in the understanding of the current status of wildlife health on the Anaconda Smelter site:

- a. The BERA identified significant areas of risk that included areas where little, if any, remedial action will take place.
- b. The use of literature derived bioaccumulation factors and toxicity reference values in the BERA to model exposures and effects in wildlife contribute significantly to uncertainty in the quantification of wildlife risk.
- c. Because of the uncertainty, and possibility of the inherent conservativeness that was built into the risk models, the true size of the area of wildlife concern may be smaller than originally estimated in the BERA.

- d. Until such time, however, measured estimates of exposure and effects can be made, area estimates of concern in the existing BERA will need to be monitored in the long term which would be very expensive and time consuming.

Furthermore, small subareas within the larger wildlife area of concern identified in the BERA have been, at least to some extent, remediated. This fact allows, to a limited extent, some initial insight into the protectiveness of proposed remedies. Problem definition issues, directed toward measuring decreases in exposure after remedial action, are listed below in the form of questions:

- e. Do the prey items of wildlife receptors have equal, more or less metal residue after soil amendments than before?
- f. Do the tissues of wildlife receptors have equal, more or less metal residue after soil amendments than before or do they vary among amendment options?
- g. Do physiological responses vary by soil amendment treatments?
- h. Do demographic responses differ before and after soil amendments occur?
- i. Do demographic responses vary as a function of soil amendment treatments?

*Conceptual Site Model.* The site conceptual model was described in the site's BERA. It is currently hypothesized that metals and As from contaminated soils are being taken up into food items (vegetation, terrestrial macro-invertebrates, small mammals, etc) and posing potential risk to exposed wildlife species. Further, it is hypothesized that incidental ingestion of soil is a significant contributor to metals exposure.

#### 4.3 Step 2: Identify the Decision

The primary study questions addressed by this project were:

1. What is the true extent of current wildlife risk on the Site?
  - a. The risk models used in the original BERA will be refined by rerunning them using measured data from this study to more accurately define areas of concern.
  - b. By quantifying individual components of wildlife diets, it was hoped a subset of prey items could be identified as a metric for long-term monitoring.
2. What changes in metal and As disposition occur, and what effects result, from the various remedial options?

It was not the intent of this study to recommend remedial options for the Site. Remediation completed for vegetation will take years to establish itself on a large enough scale to ultimately measure influences on population level demographic endpoints. Rather, it is intended to better understand the true extent of wildlife risk on the site, and to collect baseline (pre-remedial) information for a more long-term understanding of the effectiveness of these remedial actions during 5-year review periods. This understanding will allow for focused (both geographically and in terms of sampled matrices) and cost-effective means for the long term monitoring of the effectiveness of the remedial actions.

#### 4.4 Step 3: Identify the Inputs to the Decision

The following informational inputs were required to resolve the decision statement presented in Step 2, above:

1. Metal concentrations in prey items of wildlife species.
2. Metal concentrations in whole body and specific tissues of wildlife species.
3. Measured health effects in the tissues collected from wildlife species.
4. Measured reproductive and demographic endpoints in selected wildlife species.

5. LRES Designation: Proposed or previously performed remedial action.
6. Guidance levels. No nationally recognized standards exist for the measurement of wildlife health. This study will seek to correlate individual health effects and population level demographic impacts with measured exposures of determined concentrations within prey items and subsequent tissue and body burdens. When such relationships are found, the measured dose leading to deleterious effects will be noted as a site-specific guidance level.

#### 4.5 Step 4: Define the Boundaries of the Study

The wildlife biomonitoring project was conducted within the boundaries of, or on sites associated with, the Anaconda Smelter NPL site during the spring, summer and early fall of 1999 and 2000.

#### 4.6 Step 5: Develop a Decision Rule

The purpose of this step is to define the parameters of interest, specify the action levels, and integrate previous DQO outputs into a single statement that describes a logical basis for choosing among alternative actions. The following statements describe the decision rule that applies to this investigation:

- a. *If the concentrations of metals or As in prey items, tissue or whole body of wildlife species in no way correspond to soil concentrations within exposure areas, then it will be determined that no association exists between soil contamination and wildlife exposure.*
- b. *If the concentrations of metals or As in prey items, tissue or whole body of wildlife species in no way correspond to individual health effects and population demographics, then it will be determined that metal or As exposures are of no consequence to wildlife species.*

*c. If the concentrations of metals in prey items, tissue or whole body of wildlife species, and individual health effects and population demographics in no way correspond to remedial actions, it will be determined that remedial options are of no consequence to wildlife species.*

#### 4.7 Step 6: Specify Tolerable Limits on Decision Errors

Metal and As analyses in tissues with small masses tend to increase levels of detection (decrease sensitivity), often to levels within the range of effect concentrations. Analysis performed in 1999 using inductively coupled plasma (ICP) analysis resulted in “below detection level” findings in some tissues, particularly with the As, Cd and Pb determinations. To improve resolution, year 2000 analyses employed graphite furnace atomic absorption (GFAA), effectively dropping detection levels substantially and placing greater confidence in a finding of “below detection level.” Levels of detection are documented for each study component within their respective report sections.

Acceptable levels of metal and As concentration variability, as measured by analysis of spiked duplicate samples and continuing calibrations, were established at 20%. Further, all GFAA analyses were performed in duplicate, and all ICP analyses in triplicate with requirements that CV (coefficient of variation; (standard deviation/mean) \*100) values for the multiple samples were also at or below 20%. A metal concentration variability of greater than 20% between duplicate analyses indicated that the data should be used with caution.

#### 4.8 Step 7: Optimize the Design for Obtaining Data

The numbers of samples for each type of analysis were of reasonable scope, given resource expenditures, to fulfill the needs of the Data Quality Objectives.

#### 4.9 Field Study Approach

Evaluation of exposure and effects in wildlife inhabiting the Anaconda Smelter site was performed by undertaking an intensive biomonitoring program involving field collections

and observations over two spring, summer and early fall field seasons. The studies focused on small mammal and bird populations that lived on the site.

For small mammal populations, a mark-recapture program was established across 6 sites with a range of existing contaminant levels and similar habitat, as well as on a number of previously remediated areas on the site. At the end of each season, animals were collected for analyses using both live trap collections (for fresh tissue collection purposes) and snap-trap collections (for GI tract food item collection and comparison with other tissues). Tissue metal and As levels were determined and health effect endpoints measured. Population demographics were evaluated in detail using the data collected from the mark-recapture activities.

American kestrels (*Falco sparverius*), European starlings (*Sturnus vulgaris*), mountain bluebirds (*Sialia currucoides*), tree swallows (*Tachycineta bicolor*), and black capped chickadees (*Parus atricapillus*) were studied using nest boxes placed across the site to facilitate reproduction attempts in areas with differing levels of contaminant concern. Food items brought to the young were analyzed for metals and As to establish exposure levels and sources. Egg and nestling collections provided samples for analysis of metals and As and biomarkers indicative of health effect endpoints. Reproductive demographics were developed based on regular nest box checks and chick measurements. Though the projects were similar, the kestrel study was conducted and reported separately from the passerine species.

For all project components, exposure and effect endpoints were measured across a variety of sites, ensuring potential for data collection across a range of soil contaminant levels. Risk characterization based on exposure and effect inputs provides bioavailability and dose-response data for the site's wildlife inhabitants as well as inputs for refining site-specific risk models.

## **5 REPORT FORMAT**

### 5.1 General

This printed report contains the findings of studies performed on the Anaconda Smelter site during 1999 and 2000. It is composed of two parts; a main body and an additional appendix section that contains raw data for all summarized tables in the main report.

The data contained in this report supercede all previous data reports generated in this project.

### 5.2 Database Format

With the completion of the 1999 data set, a decision was made to develop a relational database to contain the data generated during the Biomonitoring Program. After consulting with US EPA and US FWS project officers, Microsoft Access was chosen as the database software for the project.

Separate databases were established for each subproject and year. These consist of American kestrels - K1999 and K2000; passerines (European starling and non-starling passerines) - P1999 and P2000; and small mammals - R1999 and R2000. The data were either manually entered into the Access database or imported from Excel spreadsheets according to SOP AQ-1-10-01 (Access database for project T9907/T0014). A unique Sample Identification (ID) Number was assigned to each individual animal, egg, or food item. To assure unique identification of each sub-sample taken from an individual, a two letter code consisting of Sample Type Code and Test Code was used:

Sample Type Codes		Test Codes	
Egg	E	Residues	R
Food Item	F	Porphyrin	P
Blood	B	ALAD	A
Liver	L		
Kidney	K		
Carcass	C		
Mammary Tissue	M		
Fetus	T		
Stomach Content	S		

Example: P2000-001 KR stands for the kidney residue sample of individual 001 from database Passerine 2000.

Forms were developed for data entry and for screening the entered data. The “admission form” gives an overview, on a box-by-box basis, of nest box location, nesting success, and individual animals, eggs, or food items taken from the box for the Kestrel and Passerine Databases. In the case of the Rodent Database, it provides an overview of the animals collected from any one site in the Rodent Database. The “Residue and Biomarker Data” form contains information on all residue and biomarker data available for each of the Sample ID numbers. The form “Measurement Data” contains the information on animal and egg measurements (where applicable), and on organ weights and hematology.

Residue results below detection limit were entered as -1. For statistical analysis, data were queried and exported into a spreadsheet, where values of -1 were changed to the limit value used for particular statistical analyses. Basic statistical analyses were performed in Excel.

### 5.3 Data Table Development and Presentation

An important step in database development was confirming the validity of the database in light of the reported data from the 1999 field season. Database queries were performed to develop tables for the 1999 data, similar to those presented in the March 31, 2000 interim report, yet tied directly to the newly formed 1999 databases. The new tables were QA checked against the previous year's tables for accuracy. In the case of 2000 season data, the same procedure was followed to develop data presentation tables, though the last check against previously presented data was not necessary.

Using a query in Access, box, field, site and animal ID information were added to each Sample ID Number for each table. Endpoint-specific database queries were performed and the results were then downloaded into Excel spreadsheets. Queries were QA/QC reviewed for correct data entry and for assignment of the correct ID Numbers by checking the nest box location and the Field ID numbers against the field notes.

*Summary statistics.* Endpoint-specific database queries were performed and exported to spreadsheet format to provide data input for report tables. The exported query composed the first worksheet in each workbook. In a second workbook worksheet, values of -1, the database numerical code for below detection level (BDL), were replaced with the designation "BDL." Outputs were sorted based on assessment criteria (data type, box and location), and summary statistics (mean, SD) for each assessment criteria were added and saved. The spreadsheets at this level are reported in the appendix tables. For the summary statistic residue data tables, a new worksheet was then established in the same workbook for input of BDL replacement values. Half the detection limit values (see individual tables in each report section that follows) replaced all BDL designations, based on the specific BDL for each species/tissue combination. The file was again saved. For the passerine tables, a new worksheet was inserted to calculate the site means. A final worksheet was created by importing the previous sheet values, removing the individual-based portion of the data and retaining the summary statistics.

Summary statistics tables are presented for most endpoints in this report. As noted above, these tables have incorporated half the detection limit values where an analytical finding was below the detection level. In order to clarify the strength of these statistics in the presence of non-detectable residue levels, there are generally two “N” values presented for the data; the capital “N” which stands for the number of units (i.e., individuals, boxes, sites, etc.) sampled and a small case “n” which is indicative of the number of units with detectable residues. The actual data, from which each table was produced, can be found in the Appendix tables with the same table number as in the report but with the suffix “A” attached to table number.

## **6 SMALL MAMMAL STUDIES**

Small mammals are found in abundance at most hazardous waste sites in North America. Their close association with the soil, small home ranges, relatively short life span and quick reproductive turnover make them good models to study exposure and effects of chemicals on demographic parameters. We monitored small mammal populations and communities in sparse and rich vegetative cover throughout late spring, summer and early autumn periods when rodent abundance and activity are at a maximum. Population (e.g., abundance, recruitment, reproduction, survival) and community (richness, diversity, similarity) parameters were monitored in tandem with biomarkers and soil and tissue residues in order to assess responses of rodent populations to varying levels of in situ metals, as well as potential responses to different remediation strategies. This integrated approach is designed to provide a comprehensive and balanced analysis of the potential effects of metal and As exposure in a population of wildlife.

### 6.1 Small Mammal Methods And Materials

#### 6.1.1 Selection of rodent trapping grid locations

In 1999, ten rodent trapping grids were located on remediated plots (n=4) and naturally vegetated plots (n=6) of varying metal concentrations (Figure 6-01). Minimum distance between any two grids was approximately 200 m, although most grids were separated by at least 1 km. Grids on remediated plots included an ARTS plot on Anaconda Ponds (Anarts) and Opportunity Ponds (Oparts), and the ARTS and ARCO plots on Smelter Hill (Smarts and Smarco, respectively). ARTS plots were remediated under Montana State University's Anaconda Revegetation Treatability Studies program (Montana State Univ., 1997) and the ARCO plot by the Atlantic Richfield Company (ARCO). Naturally vegetated plots included High 1, High 2, Medium 1, Medium 2, Low 1 and Low 2, representing replicated high (> 1000 ppm), medium (100 – 1000 ppm), and low (< 100 ppm) concentrations of arsenic in superficial soil (data from point concentration maps, Natural Resource Information System, Montana State University Library). For the second year of the study (2000), naturally vegetated plots and remediated plots Smarts and Smarco were selected for a second year of

mark-recapture trapping and collections. In addition, an ARTS plot by the Anaconda Raceway Drag Strip (Dstrip) was added in May 2000 for mark-recapture trapping and collections. Remediated plots Anarts and Oparts were removed from mark-recapture analysis for year two due to the remediation decision to cap Anaconda and Opportunity ponds.

Soil samples were collected on October 4 and 5 of 1999 from within 1 m of each artificial burrow location (n=20, described below), and at each corner of the grid (n=4 or 5), to assess soil concentration classifications of High, Medium and Low grids. Also, soil samples were collected from along a uniformly distributed pattern and adjacent to 10 of the 20 artificial burrows (n=10) on all remediated sites. No soil samples were collected in 2000.

Although concentration of arsenic in soil was the primary criterion in selecting and categorizing naturally vegetated plots, care was taken to minimize confounding effects of habitat on rodent populations by selecting habitat of similar vegetative type and cover. To confirm similarity in habitat across grids (especially High, Medium, and Low sites), each site was sampled between July 14 and 22, 1999, and July 17 and 20, 2000, using a 1-m<sup>2</sup> Daubenmire quadrant (Daubenmire, 1959). Ten sampling points per grid were determined by randomly tossing the quadrant into evenly distributed “tenths” of each trapping grid. Daubenmire criteria included estimation of total percent vegetative cover, as well as percent cover by duff, grasses, forbs, live woody, dead woody, moss, fungi bare ground, gravel and rocks.

#### 6.1.2 Mark-Recapture Trapping

All trapping grids on high, medium and low sites consisted of 100 Sherman live traps placed at 10-m intervals within the desired habitat type. Where possible, traps were arranged in a 10 by 10 array. However, several sites consisted of irregularly shaped habitats, therefore, many grids had a unique shape conforming to the general shape of the site. Grids on remediated sites were arranged similarly to naturally vegetated sites, except that due to their smaller size, Oparts and Anarts (5 by 9 grid) consisted of 45 traps and Smarts and Smarco (5 by 10 grids)

50 traps. On Dstrip 50 traps were arranged approximately 10 m apart on a 6 by 9 grid with no traps at the grid corners.

To reduce temperature related trap mortalities, polyester fiberfill was placed near the back of the traps to provide nesting material and care was taken in sheltering traps with surrounding habitat (e.g., grass, rocks). There were no indications during necropsy of consumption of the polyester fiberfill by any of the animals.

In 1999, grids were trapped for 5 sessions, from May 25 through August 21. Each session consisted of four to six consecutive days of trapping, depending on the frequency of new captures on day four. If a relatively large number of new animals were captured on day 4, trapping would continue until the number of new captures decreased to approximately three or less individuals. Grids were left inactive (traps closed) for 14 to 15 days between trapping sessions. Grids were trapped by rotating among three sets of grids consisting of four remediated grids (set 1), High 1, Medium 1 and Low 1 (set 2), and High 2, Medium 2, and Low 2 (set 3). During each session, there were 1-5 days between sets 1 and 2 and one day between sets 2 and 3. Therefore, all high, medium and low sites were trapped within a 9 day period during each session. In 2000, grids were trapped for 5 sessions, beginning May 22<sup>nd</sup> and ending August 25<sup>th</sup>. Trapping methods for the second year of mark-recapture trapping were identical to the previous year except for an increase in the number of trapping days per session and the grid trapping rotation. Each session consisted of five to eight consecutive days of trapping, depending on the frequency of new captures on day five. Grids were trapped by rotating between two sets of grids consisting of the three remediated grids (set 1), and the high, medium and low naturally vegetated grids (set 2).

Traps were opened between 16:00 and 18:00 hr and baited with a mixture of peanut butter and rolled oats. Traps were checked the following morning beginning at first light. Trapping station coordinates were recorded for each closed trap. Traps that were found closed and empty were recorded as “sprung traps”. All captured animals were identified to species and their sex, age, reproductive status, mass and identification (toe-clip number) recorded. Although aged in the field, final age determinations for deer mice and meadow voles were

made in the laboratory using body mass criteria. Deer mice  $\geq 18$  g and meadow voles  $\geq 20$  g were considered adults, with all others classified as nonadults. Reproductive status of females was determined as open, pregnant, lactating, or pregnant and lactating. Lactation was determined by observing mammae condition, and pregnancy by palpating for fetuses. Male reproductive status was determined by the position of the testes as either non-scrotal or scrotal. Mass was determined to the nearest 0.5 grams using a 5, 50, 60, or 100 gram pesola scale that was calibrated during each trap day of use. New captures were given a unique four-digit toe clip identification number. Live animals were released at the station of capture. Dead animals were collected in Ziploc<sup>®</sup> bags and placed in -20°C freezer storage until shipment via Federal Express to TIEHH.

### 6.1.3 Artificial Rodent Burrows

In 1999, twenty artificial rodent burrows were evenly spaced across each trapping grid. Burrows were corkscrewed four inches into the ground, provided with a handful of polyester fiberfill for nesting material, and initially baited with a mixture of peanut butter and rolled oats. Rodent burrows were checked and nesting activity recorded periodically from May until mid August (i.e. checked twice a week in May and June and thereafter, approximately once every two weeks). In July, 1999, rodent burrows were manipulated in an attempt to acquire nesting activity by decreasing and stabilizing their internal temperature. Fifty of the 200 rodent burrows were buried to the bottom of the lid and equipped with a concrete bottom, longer entry tunnel, and a 1.5 to 3 inch thick Styrofoam lid. Twenty-five of the fifty rodent burrows were given a second entry tunnel.

Artificial burrows were checked in May of 2000 but due to inactivity, scheduled checking of artificial burrow usage was abandoned during the remainder of the 2000 field season.

### 6.1.4 Sample Collections

In 1999, 263 deer mice, 64 meadow voles, and 20 northern pocket gophers (*Thomomys talpoides*) were collected for necropsy (by both lethal and non-lethal means) from 12

trapping grids between August 30 and October 6. The additional two grids were high and low arsenic sites used for collecting gophers.

Animals snap-trapped for stomach content samples were stored at  $-20^{\circ}\text{C}$  and shipped via Federal Express overnight to TIEHH. Live-trapped animals were brought to the field laboratory for necropsy. All live-trapped animals were euthanized within 24 hrs. of capture. Animals were anesthetized by carbon dioxide inhalation until abdominal breathing was observed. Whole blood was collected from the retro-orbital sinus plexus into 10.25 x 50mm Vacutainer blood collection tubes containing ethylenediaminetetraacetic acid (EDTA) (Becton Dickenson, Rutherford, NJ) using heparinized microhematocrit tubes as a conduit. Blood samples were shipped via Federal Express overnight to TIEHH where hematological analyses were performed.

Animals were euthanized by inhalation in a saturated carbon dioxide environment and body mass recorded to the nearest 0.01 g. Total length was measured to the nearest 0.5 mm from tip of nose to tip of tail, and body length measured from tip of nose to base of the tail. Necropsies were conducted and the mass ( $\pm 0.001$  g) determined for liver, spleen, thymus, heart, brain, mammary glands, pancreas, uterus, and paired lungs, kidneys, ovaries, adrenals, testes, and epididymides prior to preservation in 10% neutral buffered formalin. Samples of small intestine, cecae, stomach, striated muscle (quadriceps), bone (femur), thyroid gland, and eye were also collected and stored in 10% neutral buffered formalin for histopathologic examination. Blood, liver, kidney, mammary tissue, fetus, stomach contents, and carcass samples from each animal (when available) were stored in 30 ml metals cleaned Wheaton CLEAN-PAK™ sampling containers (Wheaton Science Products, Millville, NJ) and frozen at  $-20^{\circ}\text{C}$  for later residue analysis at TIEHH. Carcass samples consisted of all components of the animal minus the samples collected for residues and biomarkers. Additional samples of liver and kidney were flash-frozen in liquid nitrogen and stored at  $-80^{\circ}\text{C}$  for later analysis of porphyrin profiles.

For the second year of the study, 310 deer mice, 27 meadow voles and 33 gophers were collected for necropsy from 19 trapping grids (9 mark-recapture, 2 gopher and 9 snap trap grids). Necropsy procedures for year 2000 collections were similar to those used in 1999 with a few exceptions. Only liver, kidney, gonads, and bone were collected for histology and mass measurements were limited to liver, spleen, uterus, kidneys, ovaries, testes, and epididymides. In addition to blood residue and hematology analysis, approximately 0.25 ml of blood was collected for an ALAD (delta-aminolevulinic acid dehydratase) biomarker assay.

#### 6.1.5 Exposure Assessment Methodology

Metal and As analyses formed the basis of the exposure assessment methodologies. Food items, in the form of gastro-intestinal tract contents, and tissues of intentionally or opportunistically collected small mammals were acid digested, and metal and As concentrations determined.

*Sample Preparation.* Samples were logged-out of the freezer and digested in 50 ml Teflon beakers. Carcasses were removed from sample containers and placed in larger volume acid-rinsed glass beakers to avoid overflow of froth that developed during digestion of carcasses. All glassware used for this project was soaked in 10% nitric acid for a minimum of two hours, rinsed five times with ultra-pure water, and dried before use.

All digestion procedures were validated with standard reference materials (SRMs) before sample preparation began. Sample preparation procedures were slight modifications of published methods (Adair et al., 1999; Cobb et al., 2000a). Digestion proceeded in 5-50 ml of concentrated Optima grade nitric acid, depending on sample mass. Non-carcass samples were covered with watch glasses and predigested for up to one hour to allow initial hydrolysis to proceed in a controlled fashion. Digestion beakers were then placed on a hot plate that was adjusted to produce a temperature of approximately 120 C in a Teflon beaker containing 25 ml of water. Samples were digested for 2 hours or until the tissue was digested. Digestions were checked periodically to determine if more acid was needed, as

indicated by an absence of NO<sub>2</sub> above the solution and intact tissue in the digestion beaker. Additions of acid aliquots were recorded on data sheets. Carcasses were placed in acid and predigested over night in a covered glass beaker. After pre-digestion, samples were placed on a hot plate with the heating element off. The heat was then slowly increased to continue digestion and to dissolve the 0.5 to 2 inch foam layer above the acid solution. After the foam layer was dissolved, the digestion procedure proceeded as for smaller samples.

Once the tissue was fully digested, the watch glass was removed and the solution volume was reduced to approximately 1 ml for organ tissues and to 10-25 ml for carcass samples. Beakers were removed from hot plate and 30% hydrogen peroxide was added in increments to 1.5 ml. After initial reaction was complete, samples were placed back on hot plate with lids until peroxide reaction was complete. Samples were then removed and allowed to cool. Digests were quantitatively transferred to appropriately sized volumetric flasks (10, 25, 50, 100 ml) with filtering through glass fiber filters in the case of carcasses. Dilution water was added carefully in small aliquots with gentle mixing until the flask was 2/3 full. The solution was then diluted to the mark and inverted to mix. Sample volumes were then readjusted. After repeated inversion, diluted digests were transferred to 15 ml or 50 ml centrifuge tubes for transport to the ICP lab in the Geosciences Department on the Texas Tech University campus. For samples prepared in 2000/2001, a 1 ml aliquot of digest is removed from the centrifuge tube and stored in a 1.5 ml flip cap tube for atomic absorption-graphite furnace analysis. Samples were prepared in batches of no more than 40 analytical samples, one blank, two standard reference materials, and two spiked blanks. Standard reference materials were analyzed in the same manner as field collected samples.

*ICP analyses.* In 1999, all samples were analyzed to determine the concentrations of five COCs: arsenic (As), cadmium (Cd), copper (Cu), lead (Pb), and zinc (Zn). Copper and Zn were the only COCs analyzed on the ICP in 2000. Instrumental analysis was conducted with a Leeman DRE Inductively Coupled Plasma Spectrophotometer with auto-sampler. All data were captured by data management software that is part of the instrument operating system. Spectral emissions for As (197.198 nm), Cd (214.438 nm), Cu (324.754 nm), Pb (220.353 nm), and Zn (213.856 nm) were monitored with background correction. To provide

quantitative instrumental analyses, five point calibration curves were developed for each analyte. NIST traceable standards were used for all standard preparations. Complete calibration was performed daily, and continuing calibration checks were performed following analysis of 10 digested samples or less. There was greater than eighty-five percent agreement between continuing calibration samples and the full calibration curve.

With few exceptions, digested samples were analyzed within 96 hours of preparation. If digests were too concentrated in any element to fall within the calibrated range, one of two procedures was employed. If a sample exceeded the calibration range, another standard was added to the analytical batch. The concentration was compared to that determined by the instrument, and if agreement of >90% was found, sample quantification was used as generated by the instrument. Alternatively, for samples that substantially exceeded the calibration curve or for which an additional calibration point did not fit the existing calibration curve, an appropriate dilution of the sample was made to bring the concentration of the element into the calibrated range. In many of these cases, the other elements were diluted to the point of being non-detectable. Therefore, tabulated data for some samples contain data from more than one ICP run.

*Atomic Absorption-Graphite Furnace Analysis.* Graphite Furnace Atomic Absorption (GFAA) spectroscopy was used to obtain more sensitive results for As, Cd, and Pb in samples collected during the 2000 field season. GFAA analyses were performed with a Varian Analyst 600 spectrophotometer with auto sampler. Instrument operating parameters and modifiers for the second year are listed for each element in Table 6-1. All data were captured by data management software that is part of the instrument operating system. Spectral absorbances for As, Cd and Pb were monitored with Zeeman background correction. Arsenic and Pb were quantified with 20 µl aliquots and Cd was analyzed using 10µl aliquots. This was necessary due to the high sensitivity and short linear range of the Cd response using GFAA. Calibration ranges for each element are listed in Table 6-2. Continuing calibration checks were performed after every 20 analyses and recalibration proceeded if the CCC differed by more than 20% from its calibrated response. Two standard reference materials, two spiked tissue samples, and a method blank were analyzed along with every batch of 40

samples or less. To provide quantitative instrumental analyses, five point calibration curves were developed for each analyte. NIST traceable standards were used for all standard preparations. Complete calibration was performed daily, and continuing calibration checks were performed following analysis of 20 digested samples or less. Continuing calibration results were within 15% deviations of daily calibration curves were .

*Instrument detection limits (IDL).* Reporting limits were evaluated using IDL for As, Cd, Pb, Cu, and Zn. The IDL values on the ICP are as follows: As (0.0679 µg/ml), Cd (0.00502 µg/ml), Cu (0.0103 µg/ml), Pb (0.0308 µg/ml), and Zn (0.0156 µg/ml). The IDL values on the GFAA are the lowest standard concentrations, which are 5.0 µg/l for As and Pb and 0.01µg/l for Cd. The IDL for each element was defined as the mean blank response + 8 times the standard deviation of the blank signal. Adding the standard deviation was done to represent the instrument or analysis noise. This approach provides a detection limit that retains data with <12.5% analytical error. Responses of low concentration standards (0.05 µg/ml for ICP) were compared to the IDL to determine what threshold value could be reported. This approach was taken on the advise of Fish and Wildlife Service and EPA consultants to minimize reporting limit elevation that would accompany use of available SRMs for method detection limit (MDL) calculations. Available tissue SRMs with all COCs generally had very high concentrations and were certified to produce proper analytical results for weights of 0.25 g or higher. This minimum weight and high SRM metal concentration, in essence, preclude a realistic MDL. Metal detection limits of each individual tissue collected for residue analysis from all species are listed in table 6-3.

*Data Transfer/Validation/Storage.* All data from the ICP were maintained in a project subdirectory independent of all other data. Daily back up to a ZIP disk proceeded according to Instrument Center policy. Data were also periodically backed-up to a separate project ZIP disk and stored in a separate facility as a fail-safe for data storage. The AA data were stored, in their raw form, until processed. Periodic backups to the hard drive on the AA computer were performed.

For processing, data were retrieved from the ICP or AA software in Excel format and columns were labeled appropriately. Actual concentration data and appropriate lab and field sample identifiers were extracted from this initial data set. These data were verified and merged with the sample information from field investigations. Data verification ensured that field data and lab data sets were aligned. Dilution information was also added in a dilution column for the appropriate samples. These data were also verified and the file was write-protected and saved. ICP results from diluted samples were shifted into the appropriate rows. The accuracy of the row shifts and dilution factor calculations were then verified. The steps used allowed verification at three critical junctures to insure that appropriate dilution data were incorporated into the data sets without loss of data integrity.

The GFAA required more reruns and dilutions than the ICP. Data processing was, therefore, more cumbersome. A dilution column was added and each sample was assigned a designation: N-not accepted for further processing, B-beyond quality control parameters and therefore qualified, or a (#)-dilution factor. All N values were then deleted out of the spreadsheet. Instrument data from the ICP and GFAA were joined then into a single spreadsheet. Sample IDs from both instruments were checked for alignment, and the calculations to  $\mu\text{g/g}$  were performed and verified. In 2000, data were then imported into Access and verified again.

All analytical data were expressed as  $\mu\text{g}$  analyte / gram tissue ( $\mu\text{g/g}$ ), wet weight. As literature values discussed in this report are occasionally described on a dry weight basis, unless otherwise noted specifically as dry weight (dw), all COC concentrations described in this report are on a wet weight basis.

#### 6.1.6 Effects Assessment Methodology

Biochemical, physiological and demographic assessments were performed to assess the level of adverse health effects that occurred in small mammal populations associated with the Anaconda Smelter site.

#### 6.1.6.1 ALAD analysis

Venous blood was collected for ALAD determinations in heparinized tubes. Packed cell volumes (PCV) were determined prior to freezing the blood samples at  $-80^{\circ}\text{C}$ . Aliquots of whole blood were allowed to thaw at room temperature for 5 minutes prior to assay. Whole blood ALAD activity was measured in triplicate. Three aliquots (0.05 ml each) were each diluted with 1.45 ml of Milli-Q<sup>®</sup> water in clean plastic tubes suitable for centrifugation. The solution was vortexed for 15 seconds to insure complete hemolysis and homogeneity. The tubes, as well as a water blank (1.5 ml), were placed on crushed ice for 10 minutes. After 10 minutes, 1 ml of freshly prepared substrate solution ( $\delta$ -aminolevulinic acid hydrochloride (0.01 M, ALA, Sigma Chemical Co., St. Louis, MO) was added to each tube and mixed. The tubes were placed into a water bath at  $38^{\circ}\text{C}$  to incubate in darkness for exactly one hour (the product, porphobilinogen, is light sensitive). At the termination of the one-hour incubation period, 1 ml of trichloroacetic acid (10% w/v) was added to each sample and blank tube, and mixed to stop the reaction. The tubes were centrifuged at 2000 rpm for 10 minutes to separate the precipitated proteins and supernatant. Under a perchloric acid fume hood, 100  $\mu\text{l}$  of the clear supernatant solution was pipetted into the appropriate wells of a 96-well microtiter plate. Three wells were prepared for each sample tube, each receiving 100  $\mu\text{l}$  of supernatant. 100  $\mu\text{l}$  of Ehrlich's reagent (0.17 M p-dimethylaminobenzaldehyde in perchloric acid/glacial acetic acid, 25%:75%, v/v) were then carefully added to each well. The microtiter plate was covered with a lid and the absorbance read at 6 minutes against a blank at 555 nm in a Molecular Devices SpectroMax<sup>®</sup> spectrophotometric microplate reader (Molecular Devices Corp., Sunnyvale, CA) linked with a computer running Softmax<sup>®</sup> software (Molecular Devices Corp.). A preliminary Standard Test Material activity determination, using domestic porcine blood, was performed daily before samples were run. Absorbance readings were exported into a Microsoft Excel format for analysis. All data files were transferred to a TIEHH network backup subdirectory. Enzyme activity (nmol ALA used\*min<sup>-1</sup>\*ml RBC<sup>-1</sup>, or "units") was calculated from absorbance values using the molar extinction coefficient of  $62,000 \text{ M}^{-1}\text{cm}^{-1}$ .

#### 6.1.6.2 Porphyrin Analysis

*Porphyrin Extraction.* All tissue samples were maintained at  $-80^{\circ}\text{C}$ , wrapped in aluminum foil, until immediately prior to analysis. Tissue porphyrins were extracted using a modification of the extraction procedure of Kennedy and James (1993). Briefly, measured tissue was combined with a 1:1 mixture (6 ml) of 1N HCl:acetonitrile. Samples were homogenized, then centrifuged at 3000-x g (15 minutes on a Beckman Allegra 6R centrifuge, Fullerton, CA), and the resultant supernatant saved. The pellet was re-homogenized with 6 ml of fresh 1:1 HCl:acetonitrile and centrifuged as before. The supernatants were combined and diluted with approximately 70 ml HPLC grade water. The sample was concentrated using a Waters (Milford, MA) C-18 Sep-Pak solid phase extraction cartridge, eluted with acetonitrile (10 ml), placed in a  $35^{\circ}\text{C}$  water bath, and blown down to complete dryness with nitrogen gas. The dried porphyrin samples were re-constituted with 1N HCl (500 ml), filtered ( $0.45\mu\text{m}$ ), and stored at approximately  $4^{\circ}\text{C}$  until and during analysis.

*HPLC and Equipment.* Porphyrin analysis was performed using reverse-phase HPLC (Woods et al., 1995). The 8-, 7-, 6-, 5-, 4-, and 2- carboxylporphyrins were separated using a Waters 6980 separations unit with an Alltech (Deerfield, IL) Econosphere-C18 5um HPLC column, and equipped with a fluorescence detector (Waters model 474) at excitation/emission wavelengths of 390/614 nM. HPLC grade methanol and a sodium phosphate buffer (0.5M, pH 3.5) were used as mobile phases. A mobile phase gradient established by Rummel (2000), characterized for separation of porphyrin peaks, was used during each injection (100  $\mu\text{L}$ ) of sample. Peaks were quantified using a Waters Millennium32 chromatograph control software package returning a calculated amount of each porphyrin in pmol / 100  $\mu\text{L}$  of sample. Dilutions of porphyrin standards (Porphyrin Products, Logan, UT) were used to establish a standard curve prior to each sample batch.

*Data Transfer/Validation/Storage.* All data from the Porphyrin HPLC analysis were maintained in a project subdirectory, where no other data were housed. New files were transferred to a TIEHH network back-up drive. Data were also periodically backed-up to a separate project ZIP disk and stored in a separate facility as a fail-safe for data storage.

For processing, data were retrieved from the Waters Millennium32 software, and entered into MS Excel format according to each samples' unique identifier. Sample weights were retrieved from dissection records, or were entered into Excel, when collected at time of analysis. Actual concentration data and appropriate lab and field sample identifiers were extracted from this initial data set. These data were verified and merged with the sample information from field investigations. Data verification proceeded to ensure that field data and lab data sets were aligned. Porphyrin responses were then calculated within the same table into final concentration format. These data were also verified and the file was write-protected and saved. This process allowed verification that appropriate data were incorporated into the data sets without loss of data integrity.

*Porphyrim Recovery / Detection Limits.* Critical values were established for HPLC analysis of porphyrin profiles. Recovery was established utilizing homogenized chicken liver apportioned into 0.3 g aliquots and frozen at  $-20^{\circ}\text{C}$ . One reference aliquot and one reference aliquot spiked with 100 ml of porphyrin standard were analyzed with each sample run. Eleven aliquots were spiked with the 2-pmol/100 ml standard (resulting in 0.4 pmol / injection), which resulted in a 47.03% recovery rate. However, seven samples were spiked with the 5 pmol/100ml standard (1.0 pmol/ injection), resulting in a mean 97.73% recovery rate, illustrating an adequate recovery at pertinent sample concentrations.

Instrument baseline was established using blank injections (1N HCl) from representative sample runs. Each blank injection was quantified using the calibration curve established for each specific run. Areas of baseline response were assessed at the same retention times of all six porphyrin peaks, and the six responses were averaged to establish a mean 'Baseline' area for the run. A value four times the area of 'Baseline' was chosen as the Instrument Detection Limit (IDL). IDL values were compared with areas quantified for each peak established for the lowest, 0.4 pmol standard. Mean area values for these standards were generally twice the IDL value, ensuring adequate detection of peaks quantified at 0.4 pmol. A Practical Detection Limit (PDL) was established at 0.4 pmol / injection, as this concentration was the lowest standard used in each calibration curve. Any values quantified below this limit were

designated Below Detection Limits (BDL), and assigned a value of 0.2 pmol / injection (half the detection limit) for quantification purposes.

#### 6.1.6.3 Hematology

Complete blood counts were performed using an automated cell counter (System 9010, Serono-Baker Diagnostics, Inc., Allentown, PA). Complete blood counts included white blood cell (WBC), red blood cell (RBC), platelet counts, hemoglobin (HGB), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH) and mean corpuscular hemoglobin concentration (MCHC). Percentage of packed cell volume (PCV) for each blood sample was determined in the field lab using a microhematocrit capillary tube reader after each blood sample was centrifuged in a microhematocrit centrifuge (5 min. at  $8000 \pm 10\%$  RPM). Whole blood smears were prepared in the field lab for differential leukocyte counts at TIEHH. Smears were stained using Hema 3<sup>®</sup> fixative (Biochemical Sciences, Inc., Swedesboro, NJ) or Accustain<sup>™</sup> modified Wright Stain (Sigma Diagnostics, St. Louis, MO). Counting 100 white blood cells from each smear assessed percentage of neutrophils, monocytes, eosinophils, basophils, and lymphocytes.

#### 6.1.6.4 Rodent Demographics

*Abundance.* Program CAPTURE was used to estimate abundance of deer mice and meadow voles. Program CAPTURE uses a model selection algorithm consisting of a series of goodness of fit and likelihood ratio tests, to determine appropriate abundance estimators for each mark-recapture data set (Otis et al., 1978). The model selection algorithm determines whether variation in capture probability is most likely due to behavior (model  $M_b$ ), heterogeneity (model  $M_h$ ), time (model  $M_t$ ), or a combination of these factors (models  $M_{bh}$ ,  $M_{th}$ ,  $M_{tb}$ ,  $M_{hb}$ ,  $M_{bth}$ ). Trap deaths were handled as recommended by Otis et al., (1978). Trap deaths were removed before running the analysis and then added back to the estimated abundance. The jackknife estimator for model  $M_h$  is the most robust estimator (Otis et. al., 1978), and was therefore used for all sites and sessions to standardize error in abundance

estimates due to small sample sizes and subsequent variability among the models selected (Allen and Otis, 1998). When ten or less individuals were captured, the formula:

$$\check{N} = (M_{t+1}) / (1 - (1-p)^t)$$

was used to calculate abundance ( $\check{N}$ ), where  $M_{t+1}$  is the number of unique individuals captured during the trap session,  $t$  is the number of days in the trap session, and  $1 - (1-p)^t$  is the probability that an animal is captured at least once in  $t$  days (Allen and Otis, 1998).

*Survival, Reproduction and Population Structure.* Total, and sex and age-specific finite survival rates for deer mice and meadow voles were estimated using SAS (Krebs, 1989). Age classes include adult (mass  $\geq 18$  g for deer mice and  $\geq 20$  g for meadow voles) and nonadult. Survival estimates, number of reproductively active adult females (RAAF), and number of non-adults (NA), were corrected for a covariate (number recaptured, number of adult females captured, total captured) using a common-slope analysis-of-covariance (ANCOVA) model. The predicted value of the variable and its standard error for each group (grid) was estimated at the grand mean value of the covariate based on the common slope, pooled across groups. The predicted value of each observation (session within grid) was estimated by adding its within-group residual to the predicted value for the group. Computations were performed in Matlab (v5.3), using the Matlab function `ancovpred`, available at

<<http://www.biol.ttu.edu/Faculty/FacPages/Strauss/Matlab/matlab.htm>>.

#### 6.1.6.5 Statistical Methods Integrating Exposure and Effect Assessments

Statistical analyses included use of Matlab<sup>®</sup> (Mathworks, version 5) and SAS<sup>®</sup> (SAS Institute Inc.) to determine relationships among tissue and soil residues.

*Canonical correlation analysis (CCA).* CCA was performed among deer mouse demographic and COC residue profiles for tissue and surface soil. It was assumed that the five sessions/grid for the demographics data set were associated with any one of the samples/grid for the COC profiles in tissue or soil. For each grid, five random samples from each profile were used to perform CCA. This was repeated 1000 times, each time

associating the five sessions with a different set of five COC residue samples. The final results measure the correspondence between the two data sets in terms of correlation between COCs and demographic endpoints among grids, using sessions and samples as replicates within grids.

## 6.2 Small Mammal Results

### 6.2.1 Small Mammal Grid Habitat

Total vegetative cover and grass cover were high on remediated sites, ranging from 60 to 98% and 56 to 98%, respectively in 1999 (Table 6-4). Bare ground was common only at Anarts where it averaged 33.5%. Rocks, moss and forbs were non-existent to uncommon on all remediated sites. Smarts and Smarco had considerably less duff and more gravel than Anarts and Oparts. In 2000, the pond sites were removed from the study. Total vegetative cover and grass cover ranged from 52 to 82% and 24 to 66%, respectively. Gravel was also common, ranging from 37 to 41%. All other microhabitat features were minimal (Table 6-5).

Total vegetative cover was high on naturally vegetated sites with a range of 51 to 99% in 1999 (Table 6-6). Duff and grass cover was also common but variable among sites. Moss was common on Low 1, Low 2 and High 2 sites, whereas lichen was common only on Low 1 and Low 2 sites. Gravel was common on Medium 1 and High 2 sites where it averaged 31 and 30%, respectively. Bare ground was common only on Medium 2 where it averaged 33%. Forbs, woody plants (dead and alive) and rocks were uncommon on naturally vegetated sites. Similar results were observed for sites in 2000 (Table 6-7).

### 6.2.2 Artificial Rodent Burrows

Two hundred artificial burrows were checked for activity on 2,491 occasions and resulted in the capture of six deer mice and four meadow voles. Rodent activity (e.g. presence of feces, nest building, burrowing, and the shelled remains of rolled oats bait) was reported for 48% of the burrow checks (n=1,269) on remediated grids, and 57% on naturally vegetated grids (n=1,222). No litters were found in artificial burrows.

### 6.2.3 Small Mammal Exposure Assessment

*General Comments.* Concentrations of arsenic (As), cadmium (Cd), lead (Pb), copper (Cu), and zinc (Zn) were summarized for soil (LMTS, 2001). COC concentrations in soil were compared to those in deer mouse stomach contents (Figures 6-2 to 6-6), whole blood (Figures 6-7 to 6-11), liver and kidney (Figures 6-12 to 6-20), and carcass (Figures 6-21 to 6-26). COC concentrations in mammary glands and fetuses were determined when the tissues were available. The majority of exposure and effects data were from deer mice and meadow voles, with opportunistic collections of pocket gophers, shrews (*Sorex* sp.), chipmunks (*Eutamias* sp.), and a red fox comprising the balance. In general, all metals were regularly detectable in all matrices with the exception of As, and to some degree Cd. Arsenic was detected with regularity only in carcass, stomach, and to a lesser extent, kidney samples. Cadmium was regularly detected in all matrices except blood and fetal tissue, and to some degree mammary tissue.

Figures 6-17 to 6-20 and Figure 6-26 are reported as examples of how bioavailability of metals could be analyzed using a regression of tissue residues against soil residues on naturally vegetated sites, and then comparing tissue residues from animals collected on remediated sites to the regression line. The data presented in the aforementioned Figures are examples of the procedure, and do not reflect complete statistical analysis of the data.

*Soil Metal and As Analysis.* Soil samples from 10 small mammal sites in 1999 demonstrated the presence of all five COCs (Tables 6-8 and 6-9). As described earlier, six sites were designated as paired low, medium, and high As concentrations (naturally vegetated sites). Post-hoc analysis demonstrated that although the two low sites did have the obviously lowest concentration of As, the sites followed a gradient of As from approximately 100ppm to 1200ppm. Likewise, Cd, Cu, Pb, and Zn varied among the low, medium, and high grids. COC levels on the remediated sites (Anarts, Oparts, Smarts, and Smarco) varied across sites and metals (Table 6-9). For comparison to naturally vegetated sites, As concentrations ranged from about 400 to approximately 880ppm.

Although no soil samples were analyzed for this study from the four areas selected for gopher collections, COC levels were queried from MSU/RRU GIS overlays in an effort to confirm our estimates of low, medium and high As concentrations in the soil. The soil data from this database was used to calculate a mean As concentration of 52.1, 752.5, and 1217.1ppm for the low, medium and high gopher sites used in 1999 and 2000. A separate low gopher site was used in 1999. The mean As concentration for this site was 170.6 ppm.

*Stomach Content Metal and As Analysis.* Metal residues were measured in pocket gophers (n=2), meadow voles (n=12), and deer mice (n=88) collected from remediated and natural vegetation sites in 1999, but not in 2000 (Table 6-10). Overall, all four of the principle metals and As were detected in most of the analyzed samples. Mean concentrations varied dramatically among rodent species and sites, ranging from <1µg/g for As and Cd to over 100 µg/g for Zn.

In general, concentrations of all metals and As in stomach contents of deer mice increased with increasing soil concentrations, with the exception of stomach contents collected from High sites (Figures 6-02 to 6-06). This trend was not observed for meadow voles; however, their low sample sizes confound meaningful interpretation (Table 6-10). Concentrations of most metals were as high or higher on the Anaconda Ponds and Smelter Hill remediated plots than Low, Medium, or High sites. This was especially evident for As in stomach contents of mice collected from the two smelter hill sites which, when compared to stomach content residues from mice collected on H1 and H2, were about an order of magnitude greater (Figure 6-02). Thus, although soil residues were essentially the same between the two High sites and two Smelter Hill remediated sites, As concentration differed in the stomach contents.

*Blood Metal and As Analysis.* Pb, Cu, and Zn were detected regularly in blood samples from all three rodent species, in contrast to As and Cd, which fell below detection limits (Table 6-3) in all but a few cases in 1999 (Tables 6-11 and 6-12; Figures 6-07 to 6-11). Lower detection limits were obtained in 2000 (Table 6-3), resulting in detectable concentrations for Cd, but not As (Figures 6-08, and 6-07 respectively). However, no obvious trends were

observed with regard to differential concentrations among Low, Medium, and High sites (both years) or remediated sites (1999 only).

*Liver Metal and As Analysis.* Most metals were detected in liver samples from all three rodent species in 1999 (analysis not performed in 2000 except for gophers; Tables 6-13 through 6-15). Generally, little notable variation in metal concentrations was observed for As, Cu, and Zn across the Low, Medium, and High sites, or the remediated sites for deer mice (Figures 6-12, 6-15 and 6-16). Cd, and Pb to a degree, were the notable exceptions, with increasing concentrations across the naturally vegetated sites (Figures 6-13 and 6-14). In addition, Cd concentration in deer mice was relatively greater on Smarco, and possibly Smarts remediated sites compared to other sites with similar soil metal concentrations (Figure 6-17). Similar to concentrations of Pb in blood, concentrations of Pb in livers from gophers collected in 2000 showed an increasing trend across Low, Medium, and High sites in both years (Table 6-15).

*Kidney Metal and As Analysis.* All metals were detected regularly in kidney tissue of all three rodent species in both years (Table 6-16 through 6-18). The highest concentrations of As and Cu were found in meadow voles collected from remediated sites (Smarts and Smarco; 1999 only). Also, the frequency of detectable concentrations of Cd appears to increase across the Low, Medium, and High sites. Concentrations of Pb in kidneys from gophers may show the most obvious trend in 1999, with concentrations appearing to be highest in gophers collected from the High site. In 2000, As, Cd, Pb, and Cu appear to increase across Low, Medium, and High sites in gophers, although variation within sites is high (Table 6-17).

Specific to deer mice, Cd and Pb concentrations increased with increasing concentrations of Cd and Pb in the soil across the naturally vegetated sites, but this was not the case for other metals (Figures 6-13 and 6-14). Cd concentrations in kidneys followed a similar pattern as in livers, with concentrations relatively higher in mice from the Smarco remediated site than the others (Figure 6-18 and Tables 6-16 through 6-18). Cd levels tended to be lower in mice from the Anarts remediated site. Similar responses appear to be occurring with other metals, including As (Smarts site; Figure 6-12), Pb (Smarco site; Figure 6-19), and Cu (Smarts and

Oparts sites; Figure 6-20). However, the response for Cu on Oparts was strongly influenced by a single animal, and not very representative of the remaining data (Figure 6-15). These patterns in metal concentration across sites were not observed for Zn (Figure 6-16).

*Mammary Metal and As Analysis.* Arsenic was rarely detected in any rodent species. Cadmium was not detected in any mammary tissues from rodents collected on Low sites, and was rarely detected on others. In deer mice, where sample size was highest, Pb was detected on all sites with the exception of the single individual captured on Oparts (Table 6-19). Residues of Zn and Cu were detected in all rodent species on all sites. Variation in concentration of Zn and Cu among High and Medium sites was not remarkable for any single metal or rodent species.

*Fetus Metal and As Analysis.* Cadmium was not detected in any species, and As was only detected in one sample (meadow vole from Medium 1). All meadow voles analyzed from Smarco, where sample size was greatest (n = 5), contained detectable levels of Pb, whereas deer mice exhibited Pb residues on all sites except Smarco (n=1) (Table 6-20). Concentration of Pb was greatest in deer mice collected from Low 1 and lowest in those from Medium 1. Residues of Zn and Cu were detected in all species on all sites. Variation in concentrations of Zn and Cu among High and Medium sites was not remarkable for any single metal or rodent species.

*Carcass Metal and As Analysis.* All metals and As were detected regularly in carcass tissues of all three rodent species (Table 6-21 and 6-22). In gophers, metal residues increased across Low, Medium and High sites. In meadow voles and deer mice, metal concentrations of As and Pb were similar among Medium and High sites and lower among Low sites. Metal and As concentrations in gophers on High sites were consistently higher than in deer mice and meadow voles.

In some cases, metal concentrations in deer mouse carcasses increased with increasing concentrations of metals in soil (Figures 6-21 to 6-25). This trend was evident primarily for Pb, and As to a lesser extent. Also, results for Pb indicated that carcasses from the Smarco

remediated site had relatively greater concentrations of Pb than for other sites at comparable soil Pb levels (Figure 6-26).

*Additional Opportunistic Species.* Concentrations of metals and As were determined for some combination of kidney, liver, blood, and carcass for 4 gophers, 8 shrews, 4 chipmunks, a red fox, and one deer mouse (Table 6-23). Given the low sample sizes for the three species listed above, comparisons of residue concentrations among sites for these species are nearly impossible. Generally, concentrations of metals in carcasses, kidneys, and livers from shrews and chipmunks were equal to or greater than those observed for deer mice and voles. Metal and As concentrations in the blood, liver, and kidney samples collected from the red fox were similar to many of the levels observed in rodent species. Metal and As concentrations in fox tissues (omitting non-detections) ranged from 0.05 µg/g of Cd in blood to 37.4 µg/g of Zn in liver.

#### 6.2.4 Small Mammal Effects Assessment – Biochemical, Cellular, and Morphological

*ALAD Analyses.* ALAD activity (Table 6-24) in blood was measured for deer mice (Figure 6-27) and gophers (Figure 6-28). Comparisons of ALAD activity in mice to mean soil Pb levels did not reveal any meaningful relationships. Regression analysis between ALAD and blood Pb levels in deer mice was also non-informative ( $R^2=0.05$ ), probably due to the lack of measurable Pb levels in blood and concomitant lack of samples in the analysis (Figure 6-27). Conversely, ALAD activity in gophers demonstrated a negative relationship ( $R^2=0.48$ ) with increasing concentrations of Pb in blood (Figure 6-28).

*Porphyrim Analyses.* Liver and kidney porphyrins (4-, 2-, and total carboxyl porphyrins) exhibited considerable variation among the study sites in 1999 (Tables 6-25 and 6-26). No obvious trends were observed for either carboxyl group or the total porphyrins versus soil or tissue residues (Figures 6-29 to 6-42). The only exception was for gophers, where 4-carboxyl and total porphyrins in kidney samples appeared to increase across Low, Medium, and High sites (Table 6-26). However, little variation ( $R^2<0.10$ , Figures 6-29-6-42 and

regressions not shown) in either 4-carboxyl porphyrin or total porphyrin was explained by variation in Cd, Pb, Cu, or Zn concentrations in liver.

*Hematology.* Red blood cell counts, percentage packed-cell volume, hemoglobin concentration, mean corpuscular volume, mean corpuscular hemoglobin and percentage mean corpuscular hemoglobin concentrations in both deer mice and meadow voles showed very little variability among sites in either year (Tables 6-27 and 6-28). Meadow vole data collected in 1999 from the Low site were slightly more variable, but this is likely a function of low sample numbers from this site. White blood cell counts were not performed on voles in 1999 due to spurious results and inability to validate counts. Hematology was not performed on voles in 2000.

White blood cell counts in deer mice tended to be greater in mice caught on Low, Medium and High sites compared to remediated sites in both years (Tables 6-27 and 6-28). Also, the number of white blood cells in deer mice appeared to increase across Low, Medium and High sites in 1999, but not in 2000. White blood cell counts for gophers (2000 only) were about half as great on High sites compared to others (Table 6-28).

*Morphometrics.* Mean mass for body, liver, kidneys, adrenals, spleen, pancreas, testes, uterus, thymus, heart, lungs, and brain appeared relatively comparable across sites for gophers, meadow voles, and deer mice in 1999 (Table 6-29). Fewer tissues were assessed in 2000 (body, liver, kidneys, spleen, testes, and ovaries), but they also appeared generally comparable across sites for each species (Table 6-30). Data for meadow voles were often scarce, precluding comparisons.

*Toxic Threshold Analysis.* Small mammal tissue data from the Anaconda Smelter were comparable with a limited number of previous studies linking metal concentrations in wildlife blood and tissues to toxic health effects (e.g., low birth weight, decreased testicular weight and sperm motility, altered kidney mass; Figures 6-43 to 6-47). Ma (1996) suggested Pb levels in kidneys and livers exceeding 15 and 5 µg/g dry weight, respectively, were indicative of mammalian toxic exposure to Pb. Conversion of these values to fresh weight

(See section 6.3.1) showed that a small percentage of the small mammals sampled from the Anaconda Smelter exceeded toxic values in the kidney or liver (Figures 6-43 and 6-44). In contrast, a large percentage of the small mammal blood samples exceeded reported toxic levels of Pb in blood (Johansson and Wide, 1986; Figure 6-45). Every vole sampled had blood Pb levels either at or exceeding the toxic level of 0.34 µg/g.

Cooke and Johnson (1990) suggested a level of 100 µg/g wet weight as the critical value of Cd toxicity in mammalian kidneys. With the exception of one pocket gopher collected from a high site, none of the small mammals collected from the Anaconda Smelter had kidney Cd levels that reached or exceeded this level (Figure 6-46). Similar to kidney Cd residues, no small mammals had levels of Cd in the liver that approached a concentration reported to be indicative of Cd toxicity (Hunter et al., 1984; Figure 6-47).

#### 6.2.5 Small Mammal Effects Assessment – Demographics

*Population abundance.* Deer mice were the most common species captured, followed by meadow voles in both years (Tables 6-31 to 6-34). Species rarely captured included northern pocket gopher, chipmunk, shrew, house mouse (*Mus musculus*), shorttailed weasel (*Mustela erminea*), and least weasel (*Mustela rixosa*).

The number of recaptures per session was typically greater for deer mice than meadow voles, and the mean capture probability for all grids generated by program CAPTURE was higher for deer mice than meadow voles (Tables 6-35 and 6-36). Capture probability ranged from 0.24 on Anaconda ARTS in 1999 to 0.69 on Low 1 in 1999. Most capture probabilities were above 0.4.

Estimates of abundance for deer mice varied considerably across sites and sessions in 1999 and 2000 (Tables 6-35 and 6-36). Estimates were routinely higher on Smelter Hill ARTS and ARCO plots, and M1, especially in 1999. Estimates of abundance were low (10 or below) on Medium 2 and Opportunity Ponds ARTS in 1999 and nearly as low on Medium 2 and the Drag Strip ARTS plot in 2000.

*Reproduction and recruitment.* Reproduction, as measured by the number of adult females that were either pregnant and/or lactating, and the number of nonadults in the trappable population, varied across sites and sessions in both years (Table 6-37 through 6-40). Generally, many of the adult females were reproductively active, and young animals were being recruited into the population.

*Survival estimates.* As with reproduction, estimates of survival show no obvious lack of survival of deer mice or meadow voles from one session to the next (Tables 6-41 through 6-44). However, data were severely sparse for meadow voles, especially in 2000.

*Canonical correlation analysis.* Canonical correlation analysis (CCA) is useful for correlating many independent to many dependent variables (e.g., many soil residue values to many demographic endpoints). Thus, it has been used here to help understand how a set of demographic parameters relates to the set of metal residues for soil and tissue. The output includes a correlation coefficient ( $r$ ), P value for test of significance of the correlation, and canonical weights for each original variable in the data set (independent and dependent variables).

CCA of the five COCs in the soil with abundance, nonadult survival, adult survival, reproductive females, and nonadults in the population were conducted for 1999 and 2000 for deer mice on naturally vegetated sites. In 1999, there was a significant ( $P=0.034$ ) relationship between the demographic parameters and soil COCs ( $r=0.68$ ; Table 6-45). In general, as levels of the COCs increased across sites, abundance, nonadult survival and adult survival increased, reproductive females remained relatively constant, and the number of nonadults decreased. In 2000, there was also a significant correlation ( $P=0.035$ ) between the two sets of variables ( $r=0.65$ ; Table 6-45). However, the demographic variables in 2000 responded differently than in 1999, with nonadult survival, reproductive females, and the number of nonadults increasing, and abundance and adult survival remaining relatively constant, or having a slight downward trend. The above analysis was repeated after substituting survival of males and females for survival of adults and nonadults as the analysis endpoint. In 1999 ( $r=0.68$ ) and 2000 ( $r=0.599$ ) results of abundance, number of reproducing

females and number of nonadults were similar to results in the adult/nonadult assessment (Table 6-46). In 1999, and to a lesser extent in 2000, survival of both male and female deer mice increased with soil metal concentrations.

CCA of the five COCs in soil and number of individuals, rodent biomass, and species diversity (community measurements) was performed for 1999 and 2000 (Table 6-47). There was a significant relationship between the two sets of variables in 1999 ( $r=0.67$ ,  $P=0.035$ ) and 2000 ( $r=0.54$ ,  $P=0.048$ ). In 1999, the number of individuals in the community, and to a lesser extent the biomass of the community increased, and species diversity decreased, with COC levels in the soil. This response was reversed in 2000 however, with the number of individuals and biomass weighted slightly negative and species diversity increasing with increasing soil contaminants.

In addition to comparing soil residues to demographic parameters, we compared tissue residues to demographics using CCA. In 1999 and 2000, relationships between tissue residues and demographics were similar to those observed between soil residues and demographic measurements. The most notable exception was the comparison between COC concentrations in stomach contents and demographic responses in 1999. In this case, all demographic measurements were relatively constant across increasing stomach residues, with the exception of increasing numbers of nonadults.

### 6.3 Small Mammal Discussion

#### 6.3.1 Small Mammal Exposure Assessment

Small mammals may be exposed to metals and As through ingestion of contaminated soil, food, water or inhalation of contaminated air, especially as dictated by species-specific life history traits such as diet, burrowing activity, and hibernation (Hunter et al., 1987; Shore and Douben, 1994). Therefore, the level of exposure to different environmental contaminants can vary among different animal species. The small mammal communities on the different grids in this study were compositionally simple, with few species in any community. Deer mice,

followed by meadow voles, were the predominant rodent species on all sites. These species represent relatively similar ecological life histories, although differences in foraging strategies do exist (King, 1968; Reich, 1981). Deer mice tend toward omnivory, whereas meadow voles are more strict herbivores. Other species encountered included pocket gophers (herbivores that consume mostly roots and tubers), chipmunks (omnivores), and one species of shrew (insectivore). Given these differences in life history traits, especially foraging strategy and fossorial behavior, differences in residue concentrations among species are expected. In addition, differences in habitat among sites (i.e., possible differences in food resources) could also play a role in promoting differential exposure among individuals from different sites.

We observed some indications of differential exposure among species as well as between individuals of the same species among sites. For example, concentrations of As were greater in carcasses of gophers than other species, and showed an increasing trend in residue level across the Low, Medium, and High sites. Differences between gophers and other species could be related to the strict fossorial habits of gophers that are the most intimately associated with the soil contaminants. Exposure to metals through the diet also demonstrated some variation among species and sites. Concentrations of As in diets of deer mice tended to be greater on Medium sites compared to Low and High sites, although there was considerable variation in the data. This difference could indicate differential selection of diet items by individuals among sites. Also, in many instances, metal concentrations in various matrices were greater in samples collected from the remediated sites. This finding could indicate inherent differences in the bioavailability of metals among sites, or subtle differences in diet selection and/or other life history strategies. Caution must be exercised when comparing these results however, as sample size is limiting in some instances (e.g., meadow voles).

Although variation among sites and species is observed for essentially all contaminants, results do indicate that small mammals inhabiting the study sites are being exposed to all metals. Initially, High, Medium, and Low sites were selected based on As concentrations in the soil, which is of special interest given the almost complete lack of As in many of the

samples. Undoubtedly, exposure to As occurs as indicated by the detected concentrations in many of the diet and carcass samples, but is most likely readily cleared from the system, primarily through excretion in the urine (Goyer, 1997). Arsenic levels in carcass samples could be a reflection of As-laden soil contamination of the pelage, and not As bound in tissue. Nevertheless, this result implies a potential exposure route to the rodent itself through grooming activities, as well as a significant route of exposure to predators of rodents (e.g., raptors, weasels).

Exposure to some heavy metals is known to result in alterations of various hematological endpoints, including the number of circulating white and red blood cells and morphology of red blood cells (McMurry et al., 1995). Overall, little variation among sites was observed for all hematological parameters measured. White blood cell counts from deer mice collected on Low, Medium, and High sites did show an indication of increasing number that was positively associated with increasing metal concentrations on the sites. Exposure to metals could result in elevated levels of circulating white blood cells if animals are recovering from metal-induced death of cells. However, the significance of these differences is unknown at this time.

Heavy metals have been shown to negatively affect target tissues and reproductive endpoints in small mammals through a number of actions. Although levels of Zn and Cu (both homeostatically regulated essential metals required for a variety of metabolic pathways) in tissues from mice collected on contaminated sites were at or below baseline levels from literature reference sites, published field and laboratory studies indicate that elevated As, Cd, and Pb tissue levels in small mammals inhabiting the Anaconda Smelter Site may be adversely affecting their health (Corpas and Antonio, 1998; McMurry et al., 1995; Swiergosz et al., 1998). For example, Cd concentrations of 30 to 60 ppm wet weight in rat kidneys cause renal cell necrosis and deterioration of proximal tubules (Itokawa et al., 1978; Aughey et al., 1984). Reproductively, prenatal lead exposure to female rats during the third week of gestation has been shown to cause long-term physiological and anatomical effects to reproductive endpoints of male offspring. When pregnant Sprague-Dawley rats were administered lead acetate (0.1%) in their drinking water from day 14 of gestation to

parturition, male offspring at 160 days old showed significantly decreased sperm counts, and enlarged prostates, even though their blood-lead levels at birth were below detection limits (McGivern et al., 1991). In a separate study, a Cd (1.14 mg/kg/day) and Pb (34.5 mg/kg/day) mixture administered in drinking water to female Wistar rats during gestation and early lactation also damaged male pup reproductive systems. Seminiferous tubule diameter and testes weight were both decreased in male offspring (Corpas and Antonio, 1998). Though these levels of exposure generally exceed those seen in the present study, additional studies have documented that rats with blood Pb concentrations of greater than 0.39 ppm have impaired sperm motility, reduced testicular weight and resulted in seminiferous tubular damage (Hildebrand et al., 1973).

Ma (1996) provides some reference values for selected contaminants, including several metals. Lead concentrations of 0.35  $\mu\text{g/g}$  in the blood, and 5 $\mu\text{g/g}$  and 15 $\mu\text{g/g}$  dry weight in mammalian liver and kidneys, respectively, were considered good estimates of benchmark toxicity values. Mean concentrations of Pb in blood in our study routinely exceeded 0.35 ppm (35 $\mu\text{g/dl}$ ), the dose where clinical poisoning begins to occur, typically by 2- to 3-fold. The majority of deer mice, voles and pocket gophers collected from the Anaconda Smelter Site had blood Pb levels above 0.39  $\mu\text{g/g}$ , a level that has been shown to adversely affect male rat reproductive endpoints (e.g. impaired sperm motility, reduced testicular weight, and seminiferous tubular damage; Hildebrand et al., 1973).

Concentrations of metals in our study are expressed on a wet weight basis, making direct comparisons of liver and kidney data from Ma (1996) difficult. However, soft tissues are approximately 70% water by weight, thus, multiplying concentrations of metals expressed on a wet weight basis by three would be a close approximation of concentration on a dry weight basis. Using this conversion, the benchmark values of 5 and 15 $\mu\text{g/g}$  dry weight mentioned above for liver and kidneys would equate to about 1.7 and 5  $\mu\text{g/g}$  wet weight in our study. Few animals exceeded either of these levels in 1999. Exceptions included gophers on the High site whose mean ( $\pm\text{SD}$ ) Pb concentration in liver was 2.04 $\pm$ 0.76 $\mu\text{g/g}$ . Also, mean concentration of Pb in liver samples was 1.94  $\pm$  3.84  $\mu\text{g/g}$  in deer mice collected on the Smelter Hill ARCO plot.

For comparison to other studies associated with the Anaconda site, some data were available from a Clark Fork study (PTI, 1994). Residues for As, Cd, Cu, Pb, and Zn were determined for deer mice (whole body). Maximum values were about 11, 0.5, 80, 11, and 450  $\mu\text{g/g}$  dry wt for As, Cd, Cu, Pb, and Zn, respectively. These values (after conversion to wet weight) are within the range we observed in carcass concentration, with the exception of Zn, which appears higher for the Clark Fork animals.

High doses of As (800 – 1,500 mg/kg) have been shown to induce deleterious effects such as fetal skeletal malformations and prenatal mortality (Hood, 1998). A majority of data for humans and other mammals indicate that nearly 100% of ingested As is absorbed in the gastrointestinal tract during the initial stages of exposure (Bettley and O'Shea 1975; Marafante et al., 1987). Direct measurements of As excretion indicate that very little is excreted in the feces, and that 45-85% is excreted in the urine within 1-3 days (Buchet et al., 1981). Rapid whole body clearance and short half-lives are probable explanations for low As concentrations found in target tissues of small mammals analyzed in this study.

### 6.3.2 Small Mammal Effect Assessment

Exposure to heavy metals at sufficient levels to affect physiological homeostasis would be hypothesized to ultimately affect the mechanisms responsible for maintaining the viability of the population. For example, exposure to metals has been shown to negatively influence reproductive parameters in wild and laboratory rodent species, which in turn could result in a decrease in reproductive fitness and population size (McGivern et al., 1991; Danielsson, 1984; Corpas and Antonio, 1998). Conversely, sites with high contamination levels could serve as sink habitats, conceivably resulting in greater abundances than less contaminated habitats in surrounding areas that constantly feed dispersing individuals to these sub-optimal habitats.

Although capture probabilities were generally high for all sites throughout the trapping season, numbers of animals captured did vary considerably across sites. A broad evaluation of the total numbers of individuals of deer mice and meadow voles does not show an obvious

correspondence to the Low, Medium, and High metal concentration designations in a fashion suggesting a dose-dependent response. For example, some of the most abundant populations appear to reside on sites with the greatest levels of metals. In addition, population numbers did not always match between replicate sites, as with the two Medium sites, one of which (Medium 2) had the lowest number of deer mice, while the other harbored the most captures of individuals. Numbers of meadow voles showed similar variability among sites. However, it must be kept in mind that the original site designations were derived from relatively scant soil residue information from across a wide geographic area. Subsequent to selection of the Low, Medium, and High site classifications, site-specific analyses of residues in soil samples have been conducted that provides a more definitive description of the actual concentrations of metals in the surficial soil. Based on those results, it is clear that the original designation of low, medium, and high does not hold true. Instead, those six sites are best ranked as  $(L1 = L2) < M2 < (M1 = H2) < H1$  for all five COCs. Because of this confounding factor in the experimental design, the actual analysis of demographic parameters for the original High, Medium, and Low sites was analyzed based on site-specific levels of As, Pb, Cd, Cu, and Zn, providing a more robust analysis of the data.

In both years of the study, population and community responses were positively associated with metal concentrations in the soils (naturally vegetated sites), although the response profile differed between years. Undoubtedly, this could be due to differences in the years themselves with respect to climatic conditions, or other factors. Drought and widespread fire in 2000 could have influenced small mammal populations and influenced our results. Nonetheless, the result remains that there is a relationship between the two sets of variables, although not indicative of a cause and effect relationship.

Rodent populations on the four remediated sites were generally quite abundant with the exception of the Oparts plot, which consistently harbored low numbers of individuals. Undoubtedly, these populations, especially on the Oparts and Anarts sites, represent unique conditions, as they are essentially island habitats in the middle of vast tailing ponds. Whether they function as source or sink populations is unknown. These habitats undoubtedly began as sinks, or at least refuges for individuals dispersing from surrounding habitats. It is

unclear if the rodent production on these sites ever results in any movement of individuals off the site and back into adjacent habitats, information that would aid in interpreting the demographic results from the remediated sites.

### 6.3.3 Data Quality Objectives

*Step 4: The Decision Rule.* Three statements were developed that provided the guidance for developing the decision rule for the study. They depend on evaluating relationships between COCs on the site with exposure and effects in the test species. Provided below are responses to each statement based on the data obtained in this study.

*a. If the concentrations of metals or As in prey items, tissue or whole body of wildlife species in no way correspond to soil concentrations within exposure areas, then it will be determined that no association exists between soil contamination and wildlife exposure.*

Concentrations of some metals in diets, liver, kidney, and carcasses do correspond to metals in soils. Concentrations of As, Cd, Pb, Cu, and Zn in stomach contents of deer mice all increase from Low to Medium sites, then drop on High sites. Cd alone increases in liver and kidney samples from deer mice across the Low sites to the Medium and High sites, with equal concentrations between Medium and High sites. Similarly, Pb and As increase in carcass samples of deer mice from the Low sites to Medium and High sites. Thus, Cd, Pb, and As appear to be the only metals that accumulate in tissues in a manner consistent with increasing soil concentrations, and specifically with patterns observed in diet samples for those compounds. The presence of As in carcasses may be more a reflection of As in the fur, and not bound in tissue. Nevertheless, its presence is noteworthy due to the potential for exposure from grooming and trophic transfer to predators. No relationships were observed between COCs in blood and soil for deer mice.

Gophers also exhibited some relationships between tissue COCs and soils, and although we did not analyze actual soil samples for the COCs from the three gopher collection sites, we did confirm our designation of low, medium, and high using the MSU/RRU GIS overlays. Residue data are not available for diet samples in gophers (none were collected). However,

several metals did correspond to site designations of low, medium, and high. Specifically, Pb in blood, As, Cd, Pb, and Cu in livers, Cd and Pb in kidneys (1999), As, Cd, Pb, and Cu in kidneys (2000), and all metals in carcasses increased across low, medium, and high sites. Variation was evident in the data, but the trend was toward a correspondence between these tissues and relative soil concentrations. Apply caution when interpreting the gopher data, as complete soil residue data are currently not available for these sites.

*b. If the concentrations of metals or As in prey items, tissue or whole body of wildlife species in no way correspond to individual health effects and population demographics, then it will be determined that metal or As exposures are of no consequence to wildlife species.*

Several individual health effects and demographic endpoints were assessed in this study, some of which do correspond to variation in residue levels in tissues and soils. Population and community demographics of deer mice did show an association with metal concentrations in soil and tissue, and in general, these associations showed similar within year patterns. In 1999, abundance and survival increased with increasing metal concentrations in soil, whereas reproductively active adult females remained constant, and the number of nonadults in the trappable population decreased. In 2000, abundance and adult survival were relatively constant, with increasing nonadult survival, reproductive females, and number of nonadults.

Regarding community responses, the number of individuals in the community increased, rodent biomass remained relatively constant, and species diversity declined with increasing soil metal concentrations in 1999. In 2000 however, the trend was somewhat reversed, with negative loadings for numbers of individuals and biomass, and a positive canonical weighting for species diversity. In general however, the number of individuals and biomass was relatively constant.

Health effects in general showed limited associations with residues in soils or tissues. These included ALAD activity in gophers, which decreases across low, medium, and high sites, and showed a negative association with increasing blood Pb concentrations ( $R^2=0.44$ ). Also, 4-carboxyl and total porphyrins in kidneys from gophers increase across low, medium, and

high sites, although relationships between porphyrin responses and tissue residues were negligible. No other studied health effects endpoints showed obvious relationships with soil or tissue residues.

Concerning toxic threshold data, data linking metal or As concentrations in tissues with environmental perturbations in mammals are rare with the exception of Pb and to a lesser extent Cd. It is more common to see a specific dose reported in the literature or specific levels of a metal fed to animals via food or drinking water and then report the association between these levels and specific toxic effects. Small mammal data from the Anaconda Smelter did, however, parallel a limited number of previous studies linking metal concentrations in wildlife tissues to toxic health effects. It was more common for tissues collected at the Anaconda Smelter to exceed toxic thresholds for Pb as opposed to Cd. Although few tissues exceed reported toxic levels for Cd, a few gophers did have levels of Cd in their kidneys that have been associated with proteinuria in small mammals (Prigge, E. 1978). However, the significance of proteinuria in wild mammals requires further consideration.

*c. If the concentrations of metals in prey items, tissue or whole body of wildlife species, and individual health effects and population demographics in no way correspond to remedial actions, it will be determined that remedial options are of no consequence to wildlife species.*

Differences were observed between the relative accumulation in tissues in rodents collected from naturally vegetated sites and remediated sites. Deer mice collected from the Smelter Hill ARCO remediated plot tended to have greater burdens of Cd and Pb than their counterparts on sites of similar soil burdens. Specifically, this was observed for Cd in liver and kidney samples and Pb in carcass samples. Likewise, Cd was also greater in liver samples from mice collected from the Smelter Hill ARTS remediated site. ARTS plots on the tailings ponds did not show this response, and in one instance (Cd in kidney samples), concentrations were lower than expected on the Anarts remediated site.

These results suggest two potential characteristics of the remediated plots on Smelter Hill. First, the metals in Smelter Hill soils could be of a more highly bioavailable form than on the

other sites in this study, leading to higher levels of accumulation in tissues at relatively equal soil concentrations. Second, the Smelter Hill ARCO site was the only site in this study that was remediated using the methods of ARCO, and it was the only site with reoccurring high levels of bioavailability. Thus, the remediation process and results on that site may need to be examined, in particular, as a function of the geochemical nature of the site COCs and their response to the tillage and revegetation processes. The nature of the metals on Smelter Hill, as a whole, should be closely scrutinized, as they appear to be more inherently bioavailable than metals on the other sites in this study.

Health effects endpoints and demographics showed no obvious differences between naturally vegetated and remediated sites. Responses in ALAD, porphyrins, hematology, and demographics were all similar between these two site groupings. In particular, small mammal populations appear to be viable on remediated sites, with individuals in different age classes, reproducing females, recruitment of new individuals, and survival comparable to natural vegetation sites.

6.4 Small Mammal Table List and Tables

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Table Number	Table Content continued
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**Table 6-1.** Operating parameters for the graphite furnace used during analyses of year 2000 samples from the Anaconda Smelter. Times noted are hold times only. Ramp times are not indicated.

Parameter	Arsenic		Cadmium		Lead	
Wavelength	193.7		228.8		283.3	
Slit Width	0.7		0.7		0.7	
Read Time (s)	3.0		5.0		5.0	
Initial Temp and Time (sec)	20°C	0	20°C	0	20 °C	0
Dehydration Temp and Time (sec)	110 °C	30	110 °C	20	110 °C	30
Acid Evap Temp and Time (sec)	150 °C	30	150 °C	20	150 °C	30
Ashing Temp and Time (sec)	500 °C 1200 °C	15 20	700 °C	20	850 °C	20
Analysis Temp and Time (sec)	2000 °C	3	1500 °C	3	1600 °C	5
Clean out Temp and Time (sec)	2400 °C	2	2000°C	3	2000 °C	3

**Table 6-2.** Concentrations of calibration standards used for GFAA analyses of biological tissues from the Anaconda Smelter.

Standard level	Arsenic (µg/L)	Cadmium (µg/L)	Lead (µg/L)
1	5.0	0.25	5.0
2	10.0	0.50	10.0
3	20.0	1.0	20.0
4	50.0	5.0	50.0
5	100.0	10.0	100.0

**Table 6-3.** Detection and reporting limits for metals data in biological tissues of mammals inhabiting the Anaconda Smelter Site, 1999 and 2000.

Species / Sample	Average Sample Mass	As µg/g	Cd µg/g	Zn µg/g	Pb µg/g	Cu µg/g
<b><u>Detection Limits 1999</u></b>						
<b>Deer Mouse</b>						
Blood	0.485	1.399	0.103	0.321	0.635	0.211
Liver	0.678	1.001	0.074	0.230	0.454	0.151
Kidney	0.149	4.542	0.336	1.044	2.062	0.686
Food	0.565	1.201	0.089	0.276	0.545	0.181
Whole Body	13.395	0.051	0.004	0.012	0.023	0.008
Fetus	1.185	0.573	0.042	0.132	0.260	0.087
Mammary	0.738	0.920	0.068	0.211	0.418	0.139
<b>Microtis</b>						
Blood	0.469	1.447	0.107	0.332	0.657	0.219
Liver	0.884	0.768	0.057	0.176	0.349	0.116
Kidney	0.184	3.691	0.273	0.848	1.676	0.558
Food	0.919	0.738	0.055	0.170	0.335	0.112
Whole Body	21.440	0.032	0.002	0.007	0.014	0.005
Fetus	1.554	0.437	0.032	0.100	0.198	0.066
Mammary	1.185	0.573	0.042	0.132	0.260	0.087
<b>Gopher</b>						
Blood	1.117	0.608	0.045	0.140	0.276	0.092
Liver	1.482	0.458	0.034	0.105	0.208	0.069
Kidney	0.202	3.356	0.248	0.771	1.524	0.507
Whole Body	48.364	0.014	0.001	0.003	0.006	0.002
Mammary	0.605	1.123	0.083	0.258	0.510	0.170
<b>Deer Mouse Opportunistic</b>						
Liver	1.036	0.328	0.024	0.075	0.149	0.049
Kidney	0.130	2.613	0.193	0.600	1.186	0.395
<b>Gopher Opportunistic</b>						
Liver	0.980	0.346	0.026	0.080	0.157	0.052
Kidney	0.297	1.143	0.085	0.263	0.519	0.173
<b>Shrew Opportunistic</b>						
Liver	0.133	0.142	0.011	0.033	0.065	0.021
Kidney	0.058	5.852	0.433	1.345	2.657	0.884
Whole Body	2.386	0.711	0.053	0.163	0.323	0.107
<b>Chipmunk Opportunistic</b>						
Liver	1.654	0.205	0.015	0.047	0.093	0.031
Kidney	0.208	1.632	0.121	0.375	0.741	0.247
<b>Fox Opportunistic</b>						
Blood	7.777	0.044	0.003	0.010	0.020	0.007
Liver	0.996	0.341	0.025	0.078	0.155	0.052
Kidney	0.397	0.854	0.063	0.196	0.388	0.129

Continued

**Table 6-3. Continued**

Species / Sample	Average Sample Mass	As µg/g	Cd µg/g	Zn µg/g	Pb µg/g	Cu µg/g
<b>Reporting Limits 1999</b>						
<b>Deer Mouse</b>						
Blood	0.485	1.399	0.103	0.321	0.635	0.211
Liver	0.678	1.001	0.074	0.230	0.454	0.151
Kidney	0.149	4.542	0.336	1.044	2.062	0.686
Food	0.565	1.201	0.089	0.276	0.545	0.181
Whole Body	13.395	0.051	0.004	0.012	0.023	0.008
Fetus	1.185	0.573	0.042	0.132	0.260	0.087
Mammary	0.738	0.920	0.068	0.211	0.418	0.139
<b>Microtis</b>						
Blood	0.469	1.447	0.107	0.332	0.657	0.219
Liver	0.884	0.768	0.057	0.176	0.349	0.116
Kidney	0.184	3.691	0.273	0.848	1.676	0.558
Food	0.919	0.738	0.055	0.170	0.335	0.112
Whole Body	21.440	0.032	0.002	0.007	0.014	0.005
Fetus	1.554	0.437	0.032	0.100	0.198	0.066
Mammary	1.185	0.573	0.042	0.132	0.260	0.087
<b>Gopher</b>						
Blood	1.117	0.608	0.045	0.140	0.276	0.092
Liver	1.482	0.458	0.034	0.105	0.208	0.069
Kidney	0.202	3.356	0.248	0.771	1.524	0.507
Whole Body	48.364	0.014	0.001	0.003	0.006	0.002
Mammary	0.605	1.123	0.083	0.258	0.510	0.170
<b>Deer Mouse Opportunistic</b>						
Liver	1.036	0.655	0.048	0.151	0.297	0.099
Kidney	0.130	5.226	0.386	1.201	2.372	0.790
<b>Shrew Opportunistic</b>						
Liver	0.133	0.284	0.021	0.065	0.129	0.043
Kidney	0.058	11.704	0.866	2.689	5.313	1.768
Whole Body	2.386	1.422	0.105	0.327	0.646	0.215
<b>Gopher Opportunistic</b>						
Liver	0.980	0.693	0.051	0.159	0.314	0.105
Kidney	0.297	2.286	0.169	0.525	1.038	0.345
<b>Chipmunk Opportunistic</b>						
Liver	1.654	0.410	0.030	0.094	0.186	0.062
Kidney	0.208	3.264	0.241	0.750	1.482	0.493
<b>Fox Opportunistic</b>						
Blood	7.777	0.087	0.006	0.020	0.040	0.013
Liver	0.996	0.682	0.050	0.157	0.310	0.103
Kidney	0.397	1.708	0.126	0.392	0.775	0.258

Continued

**Table 6-3. Continued.**

Species / Sample	Average Sample Mass	As μg/g	Cd μg/g	Zn μg/g	Pb μg/g	Cu μg/g
<b><u>Detection Limits 2000</u></b>						
<b>Deer Mouse</b>						
Blood	0.4475	0.112	0.006	0.349	0.112	0.229
Kidney	0.1522	0.329	0.016	1.025	0.329	0.674
<b>Gopher</b>						
Blood	1.536	0.033	0.002	0.102	0.033	0.067
Liver	2.0509	0.024	0.001	0.076	0.024	0.050
Kidney	0.1845	0.271	0.014	0.845	0.271	0.556
<b><u>Reporting Limits 2000</u></b>						
<b>Deer Mouse</b>						
Blood	0.4475	0.056	0.003	0.174	0.056	0.115
Kidney	0.1522	0.164	0.008	0.512	0.164	0.337
<b>Gopher</b>						
Blood	1.536	0.016	0.001	0.051	0.016	0.033
Liver	2.0509	0.012	0.001	0.038	0.012	0.025
Kidney	0.1845	0.136	0.007	0.423	0.136	0.278

**Table 6-4.** Habitat comparison between remediated grids, Anaconda Smelter Site, 1999.

Grid	Cover* SE	Duff SE	Grass SE	Forbs SE	Bare Gground SE	Rocks SE	Moss SE	Gravel SE	Dead Woody SE	Fungi SE
Smelter Hill ARCO	86.5 5.8	11.2 17	85.5 6	1.1 1	3.3 1.6	7.7 2.3	13.7 5.1	45.6 8.2	0.5 0.2	0 0
Smelter Hill ARTS	66.7 11	3.8 1.2	66.2 11	2 0.7	4.7 2.9	4.1 1.3	3 3	28.7 7.5	0.2 0.1	0 0
Opportunity ARTS	97.5 1.3	78 6.7	97.5 1.3	0 0	2.7 1.3	0 0	3.7 1.9	0 0	0 0	0.1 0.1
Anaconda ARTS	59.6 11	40.5 10	55.6 10	4.5 2.1	33.5 11	0 0	0 0	0.6 0.2	0.8 0.5	0 0

Note: All parameters expressed as a mean percentage determined from Daubenmire plots (n = 10)

\*total vegetative cover

**Table 6-5.** Habitat comparison between remediated grids, Anaconda Smelter Site, 2000.

Grid	Cover* SE	Duff SE	Grass SE	Forbs SE	Bare ground SE	Rocks SE	Moss SE	Gravel SE	Dead Woody SE	Fungi SE
Smelter Hill ARCO	81.8 7.3	37.6 7.6	66 8.8	0.7 0.5	3.1 1.2	8.6 3.8	12.8 4.9	40 9.1	0.9 0.1	0 0
Smelter Hill ARTS	75.5 5.2	27 6.7	64 5.4	0.6 0.2	3.4 1.9	5.3 2.8	0.3 0.2	41 7.5	0.2 0.1	0 0
Drag Strip ARTS	52 5.8	26.1 7.4	23.5 3.7	4 1.5	5.3 1.6	5.6 1.3	0 0.0	37 8.5	9.4 3.2	0 0

Note: All parameters expressed as a mean percentage determined from Daubenmire plots (n = 10)

\*total vegetative cover

**Table 6-6:** Habitat comparison between naturally vegetated grids. Anaconda Smelter Site, 1999.

Grid	Cover* SE	Duff SE	Grass SE	Forbs SE	Dead Woody SE	Bare ground SE	Rocks SE	Moss SE	Gravel SE	Clumps SE	Lichen SE
Low 1	92.5 2	2.8 2	90 3	7 2	6.1 2	5.7 2	0 0	24.6 7	0 0	0 0	20.8 7
Low 2	85.5 5	27 10	72 6	0.5 1	8.6 5	2.4 1	0.5 1	27.5 5	4 4	0 0	15.3 6
Medium 1	50.5 7	20 5	37.2 4	7.7 3	0.1 0	10.6 4	6.2 2	0.7 0	30.6 7	7.2 2	0 0
Medium 2	65.5 10	36 10	55.4 11	9.5 3	0.2 0	33.1 11	0 0	0 0	1.2 0	12.2 9	0 0
High 1	98.5 1	62 10	74.5 7	15.6 8	1 0	0.3 0	0.6 0	6.9 3	0.4 0	17.5 4	0 0
High 2	81 6	17 3	75 7	0.1 0	0.1 0	1.6 1	1 1	25.2 8	30.1 9	7.5 3	0 0

Note: all parameters expressed as a mean percentage determined from Daubenmire plots (n = 10)  
 \*total vegetative cover

**Table 6-7.** Habitat comparison between naturally vegetated grids. Anaconda Smelter Site, 2000.

Grid	Cover* SE	Duff SE	Grass SE	Forbs SE	Dead Woody SE	Bare ground SE	Rocks SE	Moss SE	Gravel SE	Clumps SE	Lichen SE
Low 1	80.5 4.0	29 8.1	48.5 6.0	4.6 1.9	7.4 3.9	13.5 2.6	0.5 0.5	1.6 0.6	0.7 0.5	0 0	10.7 9.4
Low 2	63 9.3	35.7 10.4	38.5 6.5	0.8 0.5	3.5 1.9	20.8 8.0	0 0	9.9 4.0	7.1 4.1	0 0	4.1 4.2
Medium 1	56 7.5	25.5 7.0	38 5.9	6.7 2.9	0.2 0.1	7 1.9	10.6 4.8	3.8 3.5	34.5 9.1	3 2.1	0 0
Medium 2	63.5 5.5	16.5 2.9	44.5 4.0	9.4 2.6	0.4 0.2	33.5 4.9	0 0	0.4 0.2	3 1.0	2.2 1.3	0 0
High 1	87.5 6.0	71.5 8.6	37 8.6	2.7 1.7	1.1 0.5	1.9 1.0	3.5 2.6	3.7 1.6	7.2 5.0	18.6 5.2	0 0
High 2	84 6.8	29.2 8.7	64 8.3	2.6 1.3	0.2 0.1	0.9 0.1	0.1 0.5	13.7 4.2	17.3 8.1	11.6 7.3	0 0

Note: all parameters expressed as a mean percentage determined from Daubenmire plots (n = 10)  
 \*total vegetative cover

**Table 6-8.** Soil residues of naturally vegetated small mammal sites, Anaconda Smelter Site.

Site		As	Cd	Cu	Pb	Zn
		µg/g	µg/g	µg/g	µg/g	µg/g
Low 1	N	24.0	24.0	24.0	24.0	24.0
	Mean	105.1	1.3	152.2	53.3	99.8
	Max	185.0	2.0	239.0	103.0	150.0
	Min	44.0	0.5	88.4	28.3	55.5
	SD	27.4	0.3	30.4	16.7	20.2
Low 2	N	24.0	24.0	24.0	24.0	24.0
	Mean	91.3	1.7	167.3	63.4	119.4
	Max	220.0	9.9	274.0	136.0	183.0
	Min	14.6	0.1	34.1	7.2	27.0
	SD	42.7	1.9	56.7	29.7	33.5
Medium 1	N	25.0	25.0	25.0	25.0	25.0
	Mean	782.1	35.2	1624.0	729.1	812.1
	Max	1810.0	112.0	4370.0	2030.0	2460.0
	Min	190.0	14.1	604.0	236.0	253.0
	SD	363.0	18.0	765.0	408.6	415.7
Medium 2	N	25.0	25.0	25.0	25.0	25.0
	Mean	412.2	11.9	829.2	311.4	290.7
	Max	900.0	23.1	1720.0	837.0	480.0
	Min	149.0	3.8	305.0	56.0	131.0
	SD	197.1	5.2	392.1	163.5	93.1
High 1	N	24.0	24.0	24.0	24.0	24.0
	Mean	1201.6	67.4	3065.1	1387.4	2377.8
	Max	2900.0	165.0	6780.0	3650.0	5660.0
	Min	275.0	4.0	171.0	85.5	328.0
	SD	647.9	38.7	1884.5	1050.1	1256.7
High 2	N	25.0	25.0	25.0	25.0	25.0
	Mean	764.6	34.6	2291.5	623.7	939.3
	Max	1670.0	81.9	6600.0	1740.0	1870.0
	Min	194.0	10.7	698.0	131.0	389.0
	SD	380.2	16.8	1298.9	357.6	359.9

**Table 6-9.** Soil residues of remediated small mammal sites, Anaconda Smelter Site.

Site		As	Cd	Cu	Pb	Zn
		µg/g	µg/g	µg/g	µg/g	µg/g
Anaconda ARTS	N	10.0	10.0	10.0	10.0	10.0
	Mean	608.0	13.2	3246.0	406.7	3892.7
	Max	954.0	17.2	4120.0	607.0	5950.0
	Min	148.0	8.2	2490.0	139.0	977.0
	SD	296.1	2.8	494.8	172.6	1861.2
Opportunity ARTS	N	9.0	9.0	9.0	9.0	9.0
	Mean	398.6	1.7	1059.7	447.2	2303.3
	Max	954.0	5.3	2280.0	711.0	5810.0
	Min	90.8	0.2	263.0	220.0	199.0
	SD	299.7	1.9	657.6	146.9	2150.3
Smelter Hill ARTS	N	10.0	10.0	10.0	10.0	10.0
	Mean	900.0	27.2	671.5	275.3	717.7
	Max	1800.0	58.7	908.0	441.0	1110.0
	Min	311.0	8.6	332.0	110.0	394.0
	SD	490.6	18.4	178.9	104.8	223.3
Smelter Hill ARCO	N	10.0	10.0	10.0	10.0	10.0
	Mean	882.3	9.3	900.0	311.4	1829.4
	Max	2060.0	15.2	1320.0	479.0	2140.0
	Min	379.0	4.0	702.0	233.0	924.0
	SD	502.0	3.5	186.8	81.7	375.7

**Table 6-10.** Stomach content metal and As concentrations. Anaconda Smelter Site, 1999.  
 Values below detection limit were replaced with half detection limits (see Table 6-3).

Species / Site	N	As Cd Pb Cu Zn					
		µg/g	µg/g	µg/g	µg/g	µg/g	
<u>Gopher</u>							
Medium	1	4.122	0.475	1.556	7.895	35.881	
Anaconda ARTS	1	4.113	0.223	5.819	51.149	45.637	
<u>Meadow Vole</u>							
Low 2	1	3.206	0.232	7.594	25.652	47.752	
Medium 2	2	Mean	4.797	1.019	3.743	13.437	54.298
		SD	5.108	0.945	3.402	11.242	45.134
		n	2	2	2	2	2
High 1	1	4.905	0.696	5.596	11.359	72.681	
High 2	1	3.844	1.199	6.203	43.256	96.759	
Anaconda ARTS	1	1.904	0.109	2.050	26.288	41.906	
Smelter Hill ARCO	1	37.016	0.027	13.645	40.866	78.542	
Smelter Hill ARTS	5	Mean	13.614	0.274	1.784	7.685	20.121
		SD	18.628	0.295	1.622	5.304	6.664
		n	4	4	3	5	5
<u>Deer Mouse</u>							
Low 1	16	Mean	1.725	0.080	1.454	14.256	32.918
		SD	2.132	0.079	1.590	19.843	23.157
		n	5	5	12	15	16
Low 2	13	Mean	1.446	0.144	3.097	7.638	28.569
		SD	2.793	0.317	4.793	3.692	17.974
		n	2	2	9	13	13

Continued

**Table 6-10.** Continued.

Species / Site	N						
		As μg/g	Cd μg/g	Pb μg/g	Cu μg/g	Zn μg/g	
<u>Deer Mouse</u> , continued							
Medium 1	10	Mean	6.573	0.274	7.438	24.004	52.441
		SD	6.179	0.299	7.474	20.219	26.470
		n	7	5	10	10	10
Medium 2	6	Mean	10.290	0.391	6.308	27.982	50.589
		SD	13.486	0.316	4.775	21.673	29.702
		n	6	6	6	6	6
High 1	4	Mean	0.633	0.050	1.337	5.813	17.424
		SD	0.067	0.011	0.520	1.639	1.543
		n	1	1	4	4	4
High 2	6	Mean	1.880	0.123	4.634	11.949	24.751
		SD	0.872	0.082	7.032	7.291	6.581
		n	5	4	6	6	6
Anaconda ARTS	5	Mean	6.057	0.190	4.391	94.089	145.636
		SD	10.078	0.134	6.704	144.688	100.337
		n	2	3	3	5	5
Opportunity ARTS	6	Mean	1.038	0.090	3.129	17.877	40.789
		SD	0.692	0.078	2.004	11.907	37.494
		n	3	2	5	5	5
Smelter Hill ARCO	10	Mean	13.024	0.112	4.587	20.026	40.904
		SD	10.961	0.119	3.604	14.447	25.120
		n	9	4	9	9	9
Smelter Hill ARTS	12	Mean	14.445	0.345	3.941	17.076	122.529
		SD	14.251	0.454	6.489	22.148	287.978
		n	10	8	11	12	12

**Table 6-11.** Blood metal and As concentrations from small mammals. Anaconda Smelter Site, 1999. Values below detection limit were replaced with half detection limits (see Table 6-3).

Species / Site	N		As	Cd	Pb	Cu	Zn
			µg/g	µg/g	µg/g	µg/g	µg/g
<u>Gopher</u>							
Low	6	Mean	0.304	0.022	0.650	0.860	4.833
		SD	0.000	0.000	0.347	0.441	1.148
		n	0	0	6	6	6
Medium	6	Mean	0.304	0.045	0.748	1.058	7.092
		SD	0.000	0.044	0.362	0.612	4.124
		n	0	2	5	6	6
High	6	Mean	0.304	0.022	0.926	0.711	4.829
		SD	0.000	0.000	0.280	0.269	1.665
		n	0	0	6	6	6
<u>Meadow Vole</u>							
Low 2	3	Mean	0.723	0.053	1.216	1.062	9.735
		SD	0.000	0.000	0.339	0.518	3.563
		n	0	0	3	3	3
Medium 1	2	Mean	0.723	0.073	0.648	1.640	6.979
		SD	0.000	0.029	0.453	1.160	2.741
		n	0	1	1	2	2
Medium 2	4	Mean	0.723	0.053	4.142	1.267	4.714
		SD	0.000	0.000	3.966	0.782	3.394
		n	0	0	3	4	3
High 1	2	Mean	0.723	0.053	0.805	0.801	11.748
		SD	0.000	0.000	0.674	0.231	10.310
		n	0	0	1	2	2
High 2	10	Mean	0.723	0.053	0.596	1.367	6.507
		SD	0.000	0.000	0.407	0.550	1.947
		n	0	0	4	10	10
Anaconda ARTS	8	Mean	0.723	0.053	0.328	1.130	8.896
		SD	0.000	0.000	0.000	1.170	4.372
		n	0	0	0	7	8

Continued

**Table 6-11.** Continued

Species / Site	N		As	Cd	Pb	Cu	Zn
			µg/g	µg/g	µg/g	µg/g	µg/g
<u>Meadow Vole</u> continued							
Opportunity ARTS	4	Mean	0.723	0.099	1.274	0.706	11.046
		SD	0.000	0.093	1.198	0.463	3.012
		n	0	1	2	3	4
Smelter Hill ARCO	9	Mean	0.723	0.075	0.572	1.024	7.785
		SD	0.000	0.065	0.355	0.463	2.407
		n	0	1	4	9	9
Smelter Hill ARTS	10	Mean	0.723	0.053	0.622	1.134	6.635
		SD	0.000	0.000	0.333	0.325	1.511
		n	0	0	5	10	10
<u>Deer Mouse</u>							
Low 1	19	Mean	0.699	0.062	0.449	1.339	7.353
		SD	0.000	0.044	0.262	0.610	1.779
		n	0	1	4	19	19
Low 2	20	Mean	0.699	0.052	0.501	1.507	7.536
		SD	0.000	0.000	0.314	1.012	2.103
		n	0	0	7	20	20
Medium 1	20	Mean	0.699	0.052	0.590	1.508	7.174
		SD	0.000	0.000	0.335	1.491	1.577
		n	0	0	9	20	20
Medium 2	18	Mean	0.699	0.062	0.475	1.325	7.105
		SD	0.000	0.043	0.290	0.633	0.766
		n	0	1	5	18	18
High 1	18	Mean	0.699	0.052	0.572	1.318	7.355
		SD	0.000	0.000	0.348	0.780	2.268
		n	0	0	7	18	18
High 2	20	Mean	0.699	0.055	0.677	1.338	7.290
		SD	0.000	0.016	0.417	0.566	1.494
		n	0	1	11	20	20

Continued

**Table 6-11.** Continued

Species / Site	N						
		As μg/g	Cd μg/g	Pb μg/g	Cu μg/g	Zn μg/g	
<u>Deer Mouse</u> continued							
Anaconda ARTS	14	Mean	0.699	0.060	0.575	1.354	8.692
		SD	0.000	0.030	0.398	0.367	2.933
		n	0	1	5	14	14
Opportunity ARTS	1		0.699	0.052	1.822	0.106	1.784
Smelter Hill ARCO	10	Mean	0.699	0.052	1.012	1.471	7.018
		SD	0.000	0.000	1.243	0.779	2.291
		n	0	0	5	10	10
Smelter Hill ARTS	11	Mean	0.699	0.052	0.657	1.357	7.425
		SD	0.000	0.000	0.435	0.346	1.732
		n	0	0	5	11	11

**Table 6-12.** Blood metal and As concentrations from small mammals. Anaconda Smelter Site, 2000. Values below detection limit were replaced with half detection limits (see Table 6-3).

Species / Site	N			As	Cd	Pb	Cu	Zn
				µg/g	µg/g	µg/g	µg/g	µg/g
<u>Gopher</u>								
Low	9	Mean		0.156	0.003	0.045	0.610	3.544
		SD		0.318	0.002	0.026	0.266	0.792
		n		3	5	6	9	9
Medium	10	Mean		0.087	0.011	0.040	0.711	4.173
		SD		0.107	0.013	0.039	0.338	2.048
		n		4	9	4	10	10
High	10	Mean		0.069	0.005	0.078	0.513	3.248
		SD		0.095	0.005	0.068	0.162	0.906
		n		6	9	6	10	10
<u>Deer Mouse</u>								
Low 1	12	Mean		0.056	0.012	0.100	1.444	7.662
		SD		0.000	0.025	0.131	0.785	4.843
		n		0	4	2	12	12
Low 2	11	Mean		0.056	0.006	0.056	1.133	6.371
		SD		0.000	0.004	0.000	0.504	1.474
		n		0	4	0	11	11
Medium 1	11	Mean		0.056	0.020	0.204	1.244	7.756
		SD		0.000	0.038	0.406	0.556	3.292
		n		0	9	2	11	11
Medium 2	10	Mean		0.056	0.012	0.105	1.491	9.973
		SD		0.000	0.009	0.125	0.752	6.430
		n		0	8	2	10	10
High 1	10	Mean		0.056	0.013	0.056	1.420	7.412
		SD		0.000	0.010	0.000	0.467	1.516
		n		0	8	0	10	10
High 2	10	Mean		0.056	0.008	0.056	1.188	6.625
		SD		0.000	0.003	0.000	0.294	1.301
		n		0	8	0	10	10

**Table 6-13.** Liver metal and As concentrations of small mammals. Anaconda Smelter Site, 1999. Values below detection limit were replaced with half detection limits (see Table 6-3).

Species / Site	N		As	Cd	Pb	Cu	Zn
			µg/g	µg/g	µg/g	µg/g	µg/g
<u>Gopher</u>							
Low	6	Mean	0.303	0.108	0.490	6.943	27.505
		SD	0.115	0.080	0.113	5.504	5.675
		n	2	6	6	6	6
Medium	7	Mean	1.221	6.860	0.838	8.560	33.358
		SD	0.747	4.983	0.383	3.581	6.427
		n	5	7	7	7	7
High	6	Mean	1.276	2.858	2.044	7.997	33.818
		SD	0.731	4.100	0.760	2.179	8.940
		n	5	6	6	6	6
<u>Meadow Vole</u>							
Low 2	3	Mean	0.384	0.267	0.283	5.861	37.406
		SD	0.000	0.096	0.113	1.628	6.705
		n	0	3	2	3	3
Medium 1	2	Mean	0.967	4.140	0.517	4.521	33.374
		SD	0.824	0.978	0.296	1.714	8.532
		n	1	2	2	2	2
Medium 2	4	Mean	0.384	3.162	0.401	7.716	34.290
		SD	0.000	3.926	0.273	2.484	11.396
		n	0	4	2	4	4
High 1	2	Mean	0.384	3.838	0.249	4.099	31.250
		SD	0.000	0.325	0.106	0.276	0.784
		n	0	2	1	2	2
High 2	11	Mean	0.384	2.658	0.390	6.622	31.410
		SD	0.000	2.208	0.168	6.508	6.540
		n	0	11	8	11	11
Anaconda ARTS	8	Mean	0.384	0.433	0.618	5.040	30.460
		SD	0.000	0.163	0.387	2.242	5.300
		n	0	8	6	8	8

Continued

**Table 6-13.** Continued.

Species / Site	N		As	Cd	Pb	Cu	Zn
			µg/g	µg/g	Mg/g	µg/g	µg/g
<u>Meadow Vole</u> continued							
Opportunity ARTS	4	Mean	0.384	0.122	0.174	4.855	31.487
		SD	0.000	0.113	0.000	1.682	2.502
		n	0	2	0	4	4
Smelter Hill ARCO	9	Mean	0.384	0.246	0.483	6.900	32.901
		SD	0.000	0.132	0.227	5.419	11.387
		n	0	9	7	9	9
Smelter Hill ARTS	14	Mean	0.734	1.304	0.519	5.338	32.313
		SD	0.931	1.324	0.507	1.351	4.791
		n	2	14	8	14	14
<u>Deer Mouse</u>							
Low 1	22	Mean	0.501	0.134	0.344	5.424	32.518
		SD	0.000	0.106	0.375	1.544	10.539
		n	0	16	4	22	22
Low 2	25	Mean	0.501	0.245	0.377	5.223	29.975
		SD	0.000	0.198	0.219	1.173	9.251
		n	0	20	10	24	24
Medium 1	24	Mean	0.501	0.696	0.426	4.803	24.944
		SD	0.000	0.637	0.252	1.103	6.005
		n	0	24	12	24	24
Medium 2	19	Mean	0.501	0.808	0.369	5.748	28.540
		SD	0.000	0.883	0.215	1.824	7.315
		n	0	19	8	19	19
High 1	24	Mean	0.501	0.770	0.388	5.473	25.152
		SD	0.000	0.343	0.281	1.702	6.749
		n	0	24	7	24	24
High 2	27	Mean	0.501	0.750	0.638	5.093	27.446
		SD	0.000	0.430	0.413	0.877	4.744
		n	0	26	17	27	27

Continued

**Table 6-13.** Continued

Species /Site	N						
		As μg/g	Cd μg/g	Pb μg/g	Cu μg/g	Zn μg/g	
<u>Deer Mouse</u> continued							
Anaconda	13	Mean	0.501	0.282	0.326	5.801	29.749
ARTS		SD	0.000	0.228	0.243	3.971	8.238
		n	0	9	2	13	13
Opportunity ARTS	1		0.501	0.037	0.787	6.334	32.002
Smelter Hill	14	Mean	0.501	3.389	1.940	8.010	31.912
ARCO		SD	0.000	2.682	3.836	3.445	5.434
		n	0	14	13	14	14
Smelter Hill	15	Mean	0.501	1.802	0.674	6.273	31.707
ARTS		SD	0.000	1.473	0.275	2.653	9.224
		n	0	15	15	15	15

**Table 6-14.** Liver metal and As concentrations from snap trapped small mammals. Anaconda Smelter Site, 1999. Values below detection limit were replaced with half detection limits (see Table 6-3).

Species / Site	N						
		As ug/g	Cd ug/g	Pb ug/g	Cu ug/g	Zn ug/g	
<u>Meadow Vole</u>							
Smelter Hill ARTS	5	Mean	0.552	1.317	0.128	4.753	29.481
		SD	0.188	1.094	0.068	0.409	3.224
		n	5	5	4	5	5
<u>Deer Mouse</u>							
Anaconda ARTS	3	Mean	0.380	0.382	0.206	7.542	30.127
		SD	0.171	0.559	0.195	1.038	5.592
		n	3	2	2	3	3
High 1	4	Mean	0.164	0.387	0.307	6.287	29.092
		SD	0.069	0.242	0.054	1.149	5.000
		n	4	4	4	4	4
High 2	6	Mean	0.180	0.362	0.252	7.054	24.095
		SD	0.165	0.262	0.110	2.171	3.964
		n	3	6	6	6	6
Low 1	16	Mean	0.043	0.072	0.122	5.453	27.849
		SD	0.000	0.081	0.128	0.824	4.196
		n	0	13	7	16	16
Low 2	11	Mean	0.067	0.007	0.110	5.605	30.502
		SD	0.080	0.008	0.108	0.851	3.664
		n	1	3	5	11	11
Medium 1	9	Mean	0.313	0.373	0.337	6.526	27.564
		SD	0.277	0.438	0.220	1.970	4.016
		n	7	8	7	9	9

Continued

**Table 6-14.** Continued

Species / Site	N		As	Cd	Pb	Cu	Zn
			ug/g	ug/g	Ug/g	ug/g	ug/g
Medium 2	6	Mean	0.361	0.736	0.788	7.699	26.326
		SD	0.520	0.616	0.875	1.683	5.412
		n	3	6	6	6	6
Opportunity ARTS	5	Mean	0.043	0.124	0.137	4.976	23.426
		SD	0.000	0.062	0.070	1.136	6.473
		n	0	5	4	5	5
Smelter Hill ARCO	5	Mean	0.672	0.547	0.573	5.330	25.863
		SD	0.323	0.828	0.308	0.565	4.009
		n	5	5	5	5	5
Smelter Hill ARTS	10	Mean	15.11	0.433	0.199	7.164	27.510
		SD	31.44	0.296	0.310	2.313	4.340
		n	10	10	7	10	10

**Table 6-15.** Liver metal and As concentrations in small mammals. Anaconda Smelter Site, 2000. Values below detection limit were replaced with half detection limits (see Table 6-3).

Species / Site	N			As	Cd	Pb	Cu	Zn
				µg/g	µg/g	µg/g	µg/g	µg/g
<u>Gopher</u>								
Low	9	Mean		0.055	2.420	0.562	8.090	29.086
		SD		0.070	1.733	1.203	1.688	2.475
		n		4	9	7	9	9
Medium	10	Mean		10.161	6.965	0.141	9.544	28.217
		SD		12.729	8.356	0.076	3.623	4.616
		n		8	10	10	10	10
High	10	Mean		1.745	4.610	1.374	14.399	32.126
		SD		2.226	3.411	1.214	16.282	3.048
		n		10	10	10	10	10

**Table 6-16.** Kidney metal and As concentrations in small mammals. Anaconda Smelter Site, 1999. Values below detection limit were replaced with half detection limits (see Table 6-3).

Species / Site	N			As	Cd	Pb	Cu	Zn
				µg/g	µg/g	µg/g	µg/g	µg/g
<u>Gopher</u>								
Low	6	Mean		1.441	0.124	1.764	4.511	22.685
		SD		0.580	0.000	1.659	0.789	2.880
		n		1	0	2	6	6
Medium	7	Mean		1.119	17.018	1.501	4.973	27.922
		SD		0.723	13.105	1.506	1.701	5.081
		N		3	7	2	7	7
High	6	Mean		1.294	6.575	3.449	5.066	24.054
		SD		0.453	8.494	2.561	1.430	3.482
		n		3	6	5	6	6
<u>Meadow Vole</u>								
Low 2	3	Mean		1.846	0.487	1.610	5.770	17.355
		SD		0.000	0.608	0.727	4.070	11.123
		n		0	1	2	3	3
Medium 1	2	Mean		2.429	6.612	1.883	7.491	22.605
		SD		0.824	3.806	1.478	4.248	2.434
		n		1	2	1	2	2
Medium 2	4	Mean		2.707	5.911	1.724	9.255	25.233
		SD		1.722	4.882	1.037	4.833	3.833
		n		1	4	2	4	4
High 1	2	Mean		1.846	16.318	1.869	7.885	32.165
		SD		0.000	6.780	1.458	1.220	4.423
		n		0	2	1	2	2
High 2	10	Mean		1.695	6.973	1.153	6.384	25.447
		SD		0.477	7.564	0.565	0.799	2.272
		n		1	10	3	10	10
Anaconda ARTS	8	Mean		1.641	1.178	1.029	6.419	24.845
		SD		0.406	1.118	0.541	2.624	2.413
		n		2	5	1	8	8

Continued

**Table 6-16.** Continued.

Species / Site	N		As	Cd	Pb	Cu	Zn
			µg/g	µg/g	Mg/g	µg/g	µg/g
<u>Meadow Vole</u> continued							
Opportunity ARTS	4	Mean	1.846	0.371	1.420	7.172	28.892
		SD	0.000	0.469	1.164	1.679	3.066
		n	0	1	1	4	4
Smelter Hill ARCO	9	Mean	5.671	0.351	0.838	16.547	23.996
		SD	9.270	0.428	0.000	18.180	4.642
		n	7	2	0	9	9
Smelter Hill ARTS	10	Mean	11.065	4.077	1.069	24.213	23.747
		SD	12.143	6.122	0.496	20.521	4.478
		n	8	8	2	10	10
<u>Deer Mouse</u>							
Low 1	20	Mean	2.186	2.650	1.981	6.527	28.010
		SD	0.379	10.871	1.480	1.778	11.925
		n	1	2	7	20	20
Low 2	20	Mean	2.271	0.795	1.420	6.214	22.991
		SD	0.000	0.884	0.897	2.396	7.729
		n	0	9	5	20	20
Medium 1	20	Mean	2.121	4.069	1.907	6.717	26.553
		SD	0.470	3.041	1.028	1.948	5.014
		n	2	18	9	20	20
Medium 2	19	Mean	2.040	3.386	1.505	6.694	24.938
		SD	0.478	4.005	0.897	1.960	3.773
		n	4	12	5	19	19
High 1	21	Mean	2.037	3.737	1.660	6.783	28.957
		SD	0.598	1.921	0.949	2.315	7.903
		n	3	20	7	21	21
High 2	20	Mean	2.094	3.821	1.672	6.991	26.057
		SD	0.465	3.296	0.966	1.746	5.820
		n	3	15	7	20	20

Continued

**Table 6-16.** Continued

Species / Site	N						
		As μg/g	Cd μg/g	Pb Mg/g	Cu μg/g	Zn μg/g	
<u>Deer Mouse</u> continued							
Anaconda	14	Mean	2.271	0.260	1.587	6.688	24.779
ARTS		SD	0.000	0.343	1.123	2.127	3.417
		n	0	1	3	14	14
Opportunity ARTS	1		2.271	0.168	1.031	6.615	26.348
Smelter Hill	10	Mean	2.271	14.256	2.529	6.324	28.668
ARCO		SD	0.000	8.391	1.495	1.690	2.915
		n	0	10	6	10	10
Smelter Hill	11	Mean	2.529	7.467	1.489	18.038	61.609
ARTS		SD	2.111	7.275	0.676	28.105	109.934
		n	4	10	4	11	11

**Table 6-17.** Kidney metal and As concentrations in small mammals. Anaconda Smelter Site, 2000. Values below detection limit were replaced with half detection limits (see Table 6-3).

Species / Site	N		As	Cd	Pb	Cu	Zn
			µg/g	µg/g	µg/g	µg/g	µg/g
<u>Gopher</u>							
Low	10	Mean	0.249	10.141	0.309	10.534	31.410
		SD	0.160	7.051	0.207	6.526	12.228
		n	4	8	7	10	10
Medium	10	Mean	1.324	17.730	0.607	18.799	32.348
		SD	0.859	19.389	0.811	19.697	5.224
		n	10	10	8	10	10
High	10	Mean	1.354	28.626	1.811	24.501	39.866
		SD	0.840	26.393	1.011	16.068	11.322
		n	10	10	10	10	10
<u>Deer Mouse</u>							
Low 1	12	Mean	0.164	1.424	0.217	9.100	33.747
		SD	0.000	0.997	0.161	8.390	12.035
		n	0	12	2	12	12
Low 2	11	Mean	0.164	1.237	0.273	18.231	31.170
		SD	0.000	0.900	0.267	18.907	5.860
		n	0	10	2	11	11
Medium 1	11	Mean	0.268	4.023	0.879	7.332	31.318
		SD	0.344	1.702	0.347	5.053	6.499
		n	1	11	10	11	11
Medium 2	10	Mean	0.316	4.516	0.548	6.095	28.901
		SD	0.366	2.823	0.529	3.408	9.535
		n	2	10	5	10	10
High 1	10	Mean	0.380	6.885	1.036	14.750	34.917
		SD	0.317	2.832	1.166	12.424	11.069
		n	4	10	7	10	10
High 2	9	Mean	0.450	5.736	0.565	8.853	36.778
		SD	0.721	3.153	0.361	6.505	11.246
		n	2	9	6	9	9

**Table 6-18.** Kidney metal and As concentrations from snap trapped small mammals. Anaconda Smelter Site, 1999. Values below detection limit were replaced with half detection limits (see Table 6-3).

Species / Site	Site N						
		As ug/g	Cd ug/g	Pb ug/g	Cu ug/g	Zn ug/g	
<u>Gopher</u>							
Anarts		0.247	0.545	1.346	4.887	22.646	
<u>Meadow Vole</u>							
Smelter Hill ARTS	5	Mean	18.681	2.234	1.232	30.317	29.273
		SD	10.354	2.181	0.423	13.028	5.859
		n	5	5	4	5	5
High 1		1.542	4.939	1.706	5.488	33.499	
<u>Deer Mouse</u>							
Anarts	3	Mean	0.378	0.338	3.646	18.275	34.496
		SD	0.370	0.181	3.511	4.316	6.914
		n	1	3	3	3	3
High 1	4	Mean	0.419	1.161	1.119	6.501	24.994
		SD	0.389	0.828	0.414	0.833	1.945
		n	2	3	4	4	4
High 2	6	Mean	0.633	1.031	0.894	8.283	26.780
		SD	0.499	1.203	0.681	0.930	1.742
		n	4	3	5	6	6
Low 1	15	Mean	0.164	0.201	0.492	7.116	27.128
		SD	0.000	0.337	0.530	2.058	3.072
		n	0	10	6	15	15

Continued

**Table 6-18.** Continued

Species / Site	Site N			As	Cd	Pb	Cu	Zn
				ug/g	ug/g	ug/g	ug/g	ug/g
Low 2	11	Mean		0.164	0.030	0.524	7.107	53.139
		SD		0.000	0.042	0.703	1.484	65.909
		n		0	4	3	11	11
Medium 1	9	Mean		1.118	1.386	1.775	8.338	60.438
		SD		0.870	1.774	1.297	2.083	83.643
		n		6	9	9	9	9
Medium 2	6	Mean		0.562	0.946	1.460	9.341	24.290
		SD		0.674	0.781	1.114	4.550	4.510
		n		2	6	6	6	6
Oparts	5	Mean		0.164	0.310	1.059	21.625	60.917
		SD		0.000	0.212	0.869	33.773	80.712
		n		0	5	4	5	5
Smelter Hill ARCO	5	Mean		1.640	1.329	11.046	8.615	30.164
		SD		1.512	1.973	5.768	2.659	10.204
		n		4	5	5	5	5
Smelter Hill ARTS	10	Mean		25.460	1.622	2.371	25.172	27.805
		SD		66.996	1.441	1.597	34.708	4.309
		n		10	10	10	10	10

**Table 6-19.** Mammary gland metal and As concentrations from small mammals. Anaconda Smelter Site, 1999. Values below detection limit were replaced with half detection limits (see Table 6-3).

Species / Site	N	Concentration (µg/g)					
		As	Cd	Pb	Cu	Zn	
<u>Gopher</u>							
Low	1		0.561	0.042	0.255	1.069	11.449
Medium	4	Mean	0.561	0.169	0.255	3.168	9.804
		SD	0.000	0.151	0.000	2.900	4.687
		n	0	2	0	4	4
High	3	Mean	0.561	0.170	0.324	1.512	6.970
		SD	0.000	0.084	0.120	1.498	3.277
		n	0	3	1	3	3
<u>Meadow Vole</u>							
Low 2	1		0.286	0.021	0.130	1.327	7.687
Medium 1	2	Mean	0.286	0.052	0.217	11.055	19.630
		SD	0.000	0.044	0.123	13.767	0.399
		n	0	1	1	2	2
Medium 2	2	Mean	0.286	0.062	0.474	3.743	15.689
		SD	0.000	0.058	0.258	2.001	0.713
		n	0	1	2	2	2
High 1	2	Mean	0.286	0.031	0.232	2.493	20.091
		SD	0.000	0.015	0.144	0.978	15.255
		n	0	1	1	2	2
High 2	4	Mean	0.286	0.068	0.256	5.211	24.386
		SD	0.000	0.069	0.088	2.724	21.157
		n	0	2	3	4	4
Anaconda ARTS	6	Mean	0.286	0.048	0.897	2.085	9.952
		SD	0.000	0.066	1.739	1.981	4.322
		n	0	1	2	6	6

Continued

**Table 6-19.** Continued

Species / Site	N	Concentration (µg/g)					
		As	Cd	Pb	Cu	Zn	
<u>Meadow Vole</u> continued							
Opportunity ARTS	1		0.286	0.021	0.130	0.486	4.176
Smelter Hill ARCO	5	Mean	0.286	0.021	0.581	10.109	22.512
		SD	0.000	0.000	0.329	1.776	3.518
		n	0	0	4	5	5
Smelter Hill ARTS	5	Mean	0.337	0.034	0.360	5.775	13.821
		SD	0.114	0.015	0.268	3.719	4.995
		n	1	3	3	5	5
<u>Deer Mouse</u>							
Low 1	8	Mean	0.460	0.034	0.410	3.264	15.725
		SD	0.000	0.000	0.562	2.652	4.156
		n	0	0	2	8	8
Low 2	6	Mean	0.460	0.034	0.211	2.323	15.362
		SD	0.000	0.000	0.029	1.433	3.867
		n	0	0	2	6	6
Medium 1	11	Mean	0.460	0.038	0.258	6.595	21.664
		SD	0.000	0.011	0.069	11.270	12.973
		n	0	2	5	11	11
Medium 2	8	Mean	0.460	0.105	0.256	3.271	20.403
		SD	0.000	0.184	0.117	2.781	11.640
		n	0	2	2	8	8
High 1	11	Mean	0.460	0.034	0.360	3.384	17.662
		SD	0.000	0.000	0.269	1.572	7.467
		n	0	0	4	11	11
High 2	9	Mean	0.460	0.038	0.230	2.425	14.203
		SD	0.000	0.007	0.036	1.599	4.932
		n	0	3	4	9	9

Continued

**Table 6-19.** Continued

Species / Site	N	Concentration (µg/g)					
		As	Cd	Pb	Cu	Zn	
<u>Deer Mouse</u> continued							
Anaconda ARTS	3	Mean	0.460	0.034	2.077	4.499	14.488
		SD	0.000	0.000	3.235	4.660	8.121
		n	0	0	1	3	3
Opportunity ARTS	1		0.460	0.034	0.209	7.037	8.526
Smelter Hill ARCO	5	Mean	0.460	0.077	0.546	5.198	19.458
		SD	0.000	0.073	0.265	4.070	2.548
		n	0	2	4	5	5
Smelter Hill ARTS	6	Mean	0.460	0.034	0.397	8.502	23.418
		SD	0.000	0.000	0.334	7.393	4.487
		n	0	0	2	6	6

**Table 6-20.** Fetus metal and As concentrations in small mammals. Anaconda Smelter Site, 1999. Values below detection limit were replaced with half detection limits (see Table 6-3).

Species / Site	Fetus N	Site N					
			As μg/g	Cd μg/g	Pb μg/g	Cu μg/g	Zn μg/g
<u>Meadow Vole</u>							
Low 2	1		0.218	0.016	0.099	1.429	13.923
Medium 1	2	Mean	0.267	0.016	0.279	4.498	25.187
		SD	0.070	0.000	0.255	0.170	8.654
		n	1	0	1	2	2
Medium 2		1	0.218	0.016	0.650	1.004	9.477
High 2	2	Mean	0.218	0.016	0.099	1.455	15.474
		SD	0.000	0.000	0.000	0.299	8.513
		n	0	0	0	2	2
Smelter Hill ARCO	5	Mean	0.218	0.016	0.364	1.667	16.399
		SD	0.000	0.000	0.220	0.531	3.065
		n	0	0	5	5	5
Smelter Hill ARTS	3	Mean	0.218	0.016	0.157	1.638	18.792
		SD	0.000	0.000	0.101	1.224	12.714
		n	0	0	1	3	3
<u>Deer Mouse</u>							
Low 1	3	Mean	0.286	0.021	1.014	1.056	14.773
		SD	0.000	0.000	1.114	0.549	6.094
		n	0	0	2	3	3
Medium 1	3	Mean	0.286	0.021	0.125	1.060	11.355
		SD	0.000	0.000	0.009	0.403	1.404
		n	0	0	1	3	3
High 1	2	Mean	0.286	0.021	0.328	1.238	14.454
		SD	0.000	0.000	0.280	0.887	4.109
		n	0	0	1	2	2
Smelter Hill ARCO	1		0.286	0.021	0.130	1.126	10.273
Smelter Hill ARTS	4	Mean	0.286	0.021	0.189	0.957	14.469
		SD	0.000	0.000	0.077	0.181	4.112
		n	0	0	2	4	4

**Table 6-21.** Carcass metal and As concentrations in small mammals. Anaconda Smelter Site, 1999. Values below detection limit were replaced with half detection limits (see Table 6-3).

Species / Site	N	As					Cd	Pb	Cu	Zn
		Mean	SD	n	Mean	SD				
<u>Gopher</u>										
Low	6	Mean	1.177	0.018	0.447	3.331	36.490			
		SD	0.510	0.008	0.118	1.233	6.991			
		n	6	6	6	6	6			
Medium	6	Mean	3.283	0.240	0.940	5.861	43.819			
		SD	1.572	0.185	0.350	1.966	4.490			
		n	6	6	6	6	6			
High	6	Mean	13.762	0.357	3.846	19.095	70.515			
		SD	12.630	0.230	1.809	15.880	45.646			
		n	6	6	6	6	6			
<u>Meadow Vole</u>										
Low 2	3	Mean	0.392	0.034	0.598	2.763	28.376			
		SD	0.239	0.023	0.176	1.309	3.799			
		n	3	3	3	3	3			
Medium 1	2	Mean	9.025	0.300	1.015	9.553	42.516			
		SD	7.378	0.102	0.868	0.282	9.184			
		n	2	2	2	2	2			
Medium 2	4	Mean	2.804	0.197	2.486	7.614	34.977			
		SD	2.319	0.066	1.098	4.243	8.365			
		n	4	4	4	4	4			
High 1	2	Mean	1.502	0.134	2.131	3.881	65.306			
		SD	0.272	0.019	0.428	0.240	92.351			
		n	2	2	2	2	1			
High 2	10	Mean	1.214	0.118	1.667	5.342	39.089			
		SD	0.444	0.029	0.698	1.998	28.813			
		n	10	10	10	10	10			
Anaconda ARTS	8	Mean	0.985	0.079	1.084	14.828	33.056			
		SD	0.365	0.021	0.329	7.205	10.717			
		n	8	8	8	8	8			

Continued

**Table 6-21.** Continued

Species / Site	N		As	Cd	Pb	Cu	Zn
			µg/g	µg/g	µg/g	µg/g	µg/g
<u>Meadow Vole</u> continued							
Opportunity ARTS	4	Mean	0.668	0.053	1.164	4.585	49.181
		SD	0.337	0.044	0.211	0.666	32.580
		n	4	4	4	4	4
Smelter Hill ARCO	9	Mean	2.274	0.035	0.905	3.239	32.088
		SD	1.413	0.021	0.298	0.921	20.408
		n	9	8	9	9	8
Smelter Hill ARTS	10	Mean	3.132	0.103	0.944	3.446	55.915
		SD	3.507	0.086	0.488	1.356	44.075
		n	10	10	10	10	10
<u>Deer Mouse</u>							
Low 1	20	Mean	0.149	0.054	0.558	2.609	30.004
		SD	0.183	0.144	0.175	0.781	9.768
		n	7	6	20	20	20
Low 2	20	Mean	0.072	0.081	0.645	2.432	28.224
		SD	0.120	0.196	0.230	0.644	5.283
		n	3	13	20	20	20
Medium 1	20	Mean	0.827	0.073	1.660	3.510	30.331
		SD	0.469	0.045	0.574	1.337	23.380
		n	19	20	20	20	20
Medium 2	19	Mean	0.585	0.091	1.485	3.420	35.678
		SD	0.433	0.102	0.649	1.195	17.755
		n	15	16	19	19	19
High 1	21	Mean	0.743	0.076	1.992	2.729	38.175
		SD	0.200	0.160	0.557	0.397	13.241
		n	21	20	21	21	21
High 2	20	Mean	0.645	0.078	1.498	3.282	27.067
		SD	0.537	0.120	0.490	0.904	2.821
		n	17	19	20	20	20

Continued

**Table 6-21.** Continued

Species / Site	N						
		As μg/g	Cd μg/g	Pb μg/g	Cu μg/g	Zn μg/g	
<u>Deer Mouse</u> continued							
Anaconda	14	Mean	0.382	0.245	1.116	7.636	30.456
ARTS		SD	0.303	0.575	0.791	2.344	5.890
		n	10	13	14	14	14
Opportunity	1		0.025	1.182	0.780	2.797	27.063
ARTS							
Smelter Hill	10	Mean	1.810	0.109	17.458	3.239	31.596
ARCO		SD	1.043	0.062	9.133	0.751	13.076
		n	10	10	10	10	10
Smelter Hill	12	Mean	3.253	0.093	4.049	3.784	51.381
ARTS		SD	6.106	0.061	2.162	1.365	26.156
		n	11	11	11	11	11

**Table 6-22.** Carcass metal and As concentrations from snap trap samples. Anaconda Smelter Site, 1999. Values below detection limit were replaced with half detection limits (see Table 6-3).

Species / Site	Site N						
		As ug/g	Cd ug/g	Pb ug/g	Cu ug/g	Zn ug/g	
<u>Meadow Vole</u>							
Smelter Hill ARTS	3	Mean	1.742	0.248	2.730	4.253	32.993
		SD	0.660	0.078	0.899	0.240	2.460
		n	3	3	3	3	3
High 1	1		0.024	0.178	0.274	3.855	36.959
<u>Deer Mouse</u>							
Anarts	1		0.477	0.189	4.431	62.153	50.730
High 1	4	Mean	0.002	0.108	0.224	4.468	32.659
		SD	0.000	0.030	0.174	0.848	2.294
		n	0	4	3	4	4
High 2	6	Mean	0.002	0.093	0.195	6.159	32.986
		SD	0.000	0.031	0.040	1.352	2.388
		n	0	6	6	6	6
Low 1	11	Mean	0.002	0.026	0.064	3.237	31.114
		SD	0.000	0.024	0.050	0.607	3.583
		n	0	8	10	11	11
Low 2	10	Mean	0.002	0.046	0.128	3.346	27.938
		SD	0.000	0.078	0.078	0.454	2.780
		n	0	8	10	10	10
Medium 1	9	Mean	0.008	0.145	0.252	7.060	28.002
		SD	0.011	0.092	0.107	3.102	2.670
		n	2	9	9	9	9

Continued

**Table 6-22.** Continued

Species / Site	Site N		As	Cd	Pb	Cu	Zn
			ug/g	ug/g	ug/g	ug/g	ug/g
Medium 2	4	Mean	0.002	0.150	0.243	6.164	28.216
		SD	0.000	0.099	0.089	1.052	1.953
		n	0	4	4	4	4
Opportunity ARTS	3	Mean	0.013	0.034	1.234	4.439	30.577
		SD	0.019	0.036	1.444	0.328	4.532
		n	1	2	3	3	3
Smelter Hill ARCO	2	Mean	1.777	0.223	22.607	5.381	34.398
		SD	2.410	0.214	21.877	1.262	0.096
		n	2	2	2	2	2
Smelter Hill ARTS	2	Mean	0.300	0.065	5.363	9.004	35.413
		SD	0.013	0.016	0.244	7.069	0.625
		n	2	2	2	2	2

**Table 6-23.** Metal and As concentrations of opportunistic small mammal collections. Anaconda Smelter Site, 1999. Values below detection limit were replaced with half detection limits (see Table 6-3).

Field ID	Site	Tissue	As	Cd	Pb	Cu	Zn
			µg/g	µg/g	µg/g	µg/g	µg/g
<u>Gopher</u>							
02	M2	kidney	1.140	2.329	2.514	5.163	28.048
01	M2	kidney	1.140	1.229	4.166	4.598	24.246
03	M2	kidney	2.465	16.501	2.318	6.228	30.435
01	oparts	kidney	1.140	0.080	2.260	4.275	22.801
02	M2	liver	0.350	0.714	1.576	5.140	28.283
01	M2	liver	1.066	0.349	2.645	5.340	25.964
03	M2	liver	6.053	3.882	1.500	10.095	47.041
01	oparts	liver	0.350	0.046	1.079	7.245	25.300
<u>Shrew sp.</u>							
02	H2	carcass	0.710	0.345	5.521	5.795	30.868
01	H2	carcass	1.108	0.288	0.596	4.584	33.458
03	H2	carcass	1.424	0.480	7.629	8.706	39.522
04	H2	carcass	7.256	0.470	1.539	20.991	42.133
01	L2	carcass	0.710	0.055	0.617	2.744	25.492
02	MC-H	carcass	0.545	0.236	1.009	4.039	29.436
01	smarco	carcass	2.381	0.100	1.161	4.892	73.536
04	H2	kidney	5.850	3.412	11.014	24.595	66.655
01	H2	kidney	5.850	10.931	8.322	11.494	39.030
02	H2	kidney	5.850	2.925	2.660	13.522	59.560
03	H2	kidney	5.850	2.208	2.660	8.685	41.911
01	L2	kidney	5.850	0.430	2.660	6.810	62.668
01	MC-H	kidney	5.850	0.430	2.797	9.469	37.410
02	MC-H	kidney	5.850	1.925	2.660	11.194	36.310
01	smarco	kidney	5.850	0.937	5.868	7.081	45.484
04	H2	liver	0.140	3.475	0.060	18.475	60.717
01	H2	liver	0.140	10.183	0.060	26.560	76.147
02	H2	liver	0.140	2.888	3.458	10.275	35.010
03	H2	liver	0.140	2.454	0.060	7.018	27.271
01	L2	liver	0.140	0.682	2.975	7.889	34.013
01	MC-H	liver	0.140	0.218	0.060	7.176	32.563
02	MC-H	liver	0.140	2.423	0.060	10.459	26.041
01	smarco	liver	0.140	0.632	0.060	7.529	32.651

Continued

**Table 6-23.** Continued

Field ID	Site	Tissue	As	Cd	Pb	Cu	Zn
			µg/g	µg/g	µg/g	µg/g	µg/g
<u>Chipmunk</u>							
0011	H1	kidney	1.630	5.902	3.901	6.167	43.635
01	H1	kidney	1.630	1.007	2.214	4.345	25.212
01	H2	kidney	1.630	2.140	2.331	5.379	29.466
0014	M1	kidney	1.630	4.923	2.154	4.560	40.495
0011	H1	liver	1.694	1.306	1.583	3.823	20.938
01	H1	liver	4.699	0.639	1.991	8.322	31.250
01	H2	liver	1.886	1.448	1.316	12.010	28.627
0014	M1	liver	2.964	2.526	1.969	9.966	32.206
<u>Red Fox</u>							
01	road	blood	0.040	0.050	0.261	6.888	11.319
01	road	kidney	0.850	1.195	1.575	4.746	19.512
01	road	liver	0.340	0.199	1.277	37.197	37.398
<u>Deer Mouse</u>							
NB01	M1	kidney	2.610	1.986	1.190	6.251	32.232
NB01	M1	liver	0.330	0.280	0.522	4.552	20.596
NB01	M1	carcass	1.002	0.183	0.891	5.543	27.383

**Table 6-24.** ALAD activity in small mammal blood. Anaconda Smelter Site, 2000.

Species / Site	Site	ALAD Activity	
	N	(nmol ALA/ min*ml RBC)	
<u>Gopher</u>			
Low	10	Mean	53.83
		SD	18.20
		n	10
Medium	9	Mean	56.38
		SD	22.60
		n	9
High	10	Mean	35.03
		SD	9.94
		n	10
<u>Meadow Vole</u>			
High 1	1		5.9
High 2	2	Mean	10.94
		SD	5.70
		n	2
Drag Strip ARTS	2	Mean	28.40
		SD	24.62
		n	2
Smelter Hill ARCO	6	Mean	5.23
		SD	4.04
		n	6
Smelter Hill ARTS	5	Mean	7.39
		SD	4.57
		n	5

Continued

**Table 6-24.** Continued

Species / Site	Site N	ALAD Activity	
		(nmol ALA/ min*ml RBC)	
<u>Deer Mouse</u>			
Low 1	12	Mean	17.63
		SD	9.99
		n	12
Low 2	11	Mean	28.48
		SD	16.52
		n	11
Medium 1	11	Mean	24.18
		SD	11.29
		n	11
Medium 2	10	Mean	15.94
		SD	5.36
		n	10
High 1	10	Mean	17.38
		SD	5.09
		n	10
High 2	10	Mean	22.39
		SD	11.30
		n	10
D-Strip	6	Mean	24.81
		SD	15.28
		n	6
Smelter Hill ARCO	8	Mean	13.13
		SD	7.24
		n	8
Smelter Hill ARTS	10	Mean	21.21
		SD	12.38
		n	10

**Table 6-25.** Small mammal liver porphyrins. Anaconda Smelter Site, 1999. N is the total number of animals measured while n is the number positive for the endpoint.

Species / Site	N	Carboxyl Porphyrins			
		4- pmol/g	2- pmol/g	Total pmol/g	
<u>Gopher</u>					
Low	6	Mean	56.795	83.605	199.720
		SD	23.754	21.908	51.318
		n	6	6	6
Medium	7	Mean	64.686	94.381	188.004
		SD	27.476	84.709	109.752
		n	7	7	7
High	5	Mean	53.326	62.301	154.085
		SD	21.630	18.508	59.930
		n	5	5	5
<u>Meadow Vole</u>					
Low 2	3	Mean	41.374	70.309	156.311
		SD	11.798	55.803	15.165
		n	3	3	3
Medium 1	2	Mean	71.100	54.960	300.349
		SD	2.719	23.418	48.324
		n	2	2	2
Medium 2	4	Mean	61.247	68.907	279.254
		SD	23.170	15.601	147.176
		n	4	4	4
High 1	2	Mean	52.073	63.726	250.215
		SD	19.726	14.803	82.496
		n	2	2	2
High 2	11	Mean	63.592	75.243	242.044
		SD	35.968	67.006	133.773
		n	11	11	11

Continued

**Table 6-25.** Continued

Species / Site	N	Carboxyl Porphyrins			
		4- pmol/g	2- pmol/g	Total pmol/g	
<u>Meadow Vole continued</u>					
Anaconda	8	Mean	62.841	37.370	308.426
ARTS		SD	20.492	16.883	105.506
		n	8	8	8
Opportunity	4	Mean	64.458	81.089	262.789
ARTS		SD	13.592	33.570	92.082
		n	4	4	4
Smelter Hill	9	Mean	72.961	45.535	315.002
ARCO		SD	35.820	38.536	92.840
		n	9	9	9
Smelter Hill	13	Mean	62.949	45.930	207.588
ARTS		SD	37.122	43.597	103.097
		n	13	13	13
<u>Deer Mouse</u>					
Low 1	22	Mean	125.141	105.030	331.866
		SD	176.145	66.559	249.519
		n	22	22	22
Low 2	25	Mean	87.601	83.554	236.801
		SD	45.508	56.690	79.245
		n	25	24	25
Medium 1	23	Mean	61.855	73.446	191.360
		SD	20.505	43.950	94.324
		n	23	23	23
Medium 2	19	Mean	89.709	117.592	260.814
		SD	65.319	107.426	128.252
		n	19	19	19
High 1	25	Mean	71.809	73.550	205.003
		SD	29.679	56.791	88.687
		n	25	25	25

Continued

**Table 6-25.** Continued

Species / Site	N	Carboxyl Porphyrins			
		4- pmol/g	2- pmol/g	Total pmol/g	
<u>Deer Mouse continued</u>					
High 2	27	Mean	77.627	96.871	249.167
		SD	26.719	83.822	93.245
		n	27	27	27
Anaconda ARTS	14	Mean	94.079	82.221	260.828
		SD	49.141	99.569	147.520
		n	14	13	14
Opportunity ARTS	1		100.968	126.865	260.976
Smelter Hill ARCO	14	Mean	89.962	87.956	274.338
		SD	48.248	75.564	181.390
		n	14	14	14
Smelter Hill ARTS	15	Mean	63.644	81.303	268.017
		SD	24.118	80.676	281.729
		n	15	15	15

**Table 6-26.** Small mammal kidney porphyrins. Anaconda Smelter Site, 1999. N is the total number of animals measured while n is the number positive for the endpoint.

Species / Site	N		Carboxyl Porphyrins		
			4- pmol/g	2- pmol/g	Total pmol/g
<u>Gopher</u>					
Low	6	Mean	42.671	60.071	102.742
		SD	14.741	14.917	27.002
		n	6	6	6
Medium	4	Mean	46.639	60.946	107.585
		SD	12.259	17.777	29.488
		n	4	4	4
High	6	Mean	66.706	69.449	136.155
		SD	25.340	22.190	43.633
		n	6	6	6
<u>Meadow Vole</u>					
High 2	1		66.655	93.102	175.135
Smelter Hill ARTS	4	Mean	67.713	41.051	113.952
		SD	25.627	5.998	28.295
		n	4	4	4
<u>Deer Mouse</u>					
Low 1	2	Mean	71.150	50.774	121.924
		SD	45.583	34.460	80.043
		n	2	2	2
Low 2	5	Mean	58.992	45.350	104.341
		SD	19.484	19.343	34.928
		n	5	5	5
Medium 1	4	Mean	40.924	38.042	69.455
		SD	16.628	17.343	14.087
		n	4	3	4

Continued

**Table 6-26.** Continued

Species / Site	N		Carboxyl Porphyrins		
			4	2	Total
			pmol/g	pmol/g	pmol/g
<u>Deer Mouse continued</u>					
High 1	4	Mean	53.374	34.912	88.285
		SD	19.970	6.648	25.803
		n	4	4	4
High 2	7	Mean	71.965	37.176	110.486
		SD	54.150	12.435	66.726
		n	7	6	7
Smelter Hill ARCO	4	Mean	49.509	38.246	92.381
		SD	13.652	23.985	40.942
		n	4	4	4
Smelter Hill ARTS	4	Mean	45.608	42.384	87.992
		SD	20.732	16.477	34.707
		n	4	4	4

**Table 6-27.** Small mammal hematology. Anaconda Smelter Site, 1999. N is the total number of animals measured while n is the number positive for the endpoint. NC is data not collected.

Species / Site	N			WBC	RBC	HGB	PCV	MCV	MCH	MCHC
				x 10 <sup>3</sup> /ul	x 10 <sup>6</sup> /ul	g/dl	%	u <sup>3</sup>	pg	%
<u>Meadow Vole</u>										
Low 2	1		NC		5.770	8.300	49.000	42.800	14.400	33.600
Medium 2	2	Mean	NC		9.990	13.050	45.000	39.700	13.150	33.050
		SD			2.348	2.475	-	1.838	0.636	0.071
		n			2	2	1	2	2	2
High 1	2	Mean	NC		11.300	14.200	47.000	38.000	12.600	33.200
		SD			0.962	0.566	5.657	2.970	0.566	1.131
		n			2	2	2	2	2	2
High 2	6	Mean	NC		9.705	12.933	48.250	41.583	13.683	32.833
		SD			2.091	1.461	7.936	4.605	2.163	2.957
		n			6	6	6	6	6	6
Anaconda ARTS	8	Mean	NC		11.183	14.157	51.333	38.286	12.700	33.171
		SD			1.485	1.706	3.830	2.140	0.563	1.302
		n			7	7	6	7	7	7
Opportunity ARTS	4	Mean	NC		10.265	12.300	47.000	36.425	12.025	33.125
		SD			2.344	2.387	7.071	1.284	0.519	0.991
		n			4	4	2	4	4	4
Smelter Hill ARCO	9	Mean	NC		9.586	13.633	50.429	40.778	14.356	35.256
		SD			1.432	1.909	8.696	1.660	1.911	4.612
		n			9	9	7	9	9	9
Smelter Hill ARTS	11	Mean	NC		9.223	12.873	46.900	42.536	14.036	33.064
		SD			1.374	1.540	9.024	3.116	0.986	1.900
		n			11	11	10	11	11	11

Continued

**Table 6-27.** Continued

Species / Site	N		WBC x 10 <sup>3</sup> /ul	RBC x 10 <sup>6</sup> /ul	HGB g/dl	PCV %	MCV u <sup>3</sup>	MCH pg	MCHC %
<u>Deer Mouse</u>									
Low 1	21	Mean	4.938	9.201	12.933	45.800	42.248	14.124	33.429
		SD	2.978	1.310	1.534	5.415	2.309	0.909	0.629
		n	21	21	21	20	21	21	21
Low 2	20	Mean	5.430	8.739	12.645	45.300	42.565	14.775	34.555
		SD	3.888	1.571	1.481	7.399	3.050	2.354	3.342
		n	20	20	20	20	20	20	20
Medium 1	16	Mean	5.481	9.133	13.256	51.667	43.450	14.625	33.644
		SD	2.323	1.022	1.170	4.053	4.063	1.507	1.177
		n	16	16	16	12	16	16	16
Medium 2	15	Mean	5.773	9.293	13.387	48.800	43.707	14.480	33.200
		SD	3.627	1.444	1.788	8.011	3.477	1.111	1.486
		n	15	15	15	15	15	15	15
High 1	22	Mean	6.109	9.042	13.177	49.167	43.327	14.714	33.932
		SD	3.457	1.127	0.963	4.656	3.349	1.483	1.346
		n	22	22	22	18	22	22	22
High 2	24	Mean	7.113	8.799	12.606	44.467	43.869	14.775	33.625
		SD	4.550	1.463	1.256	6.728	5.914	2.525	2.189
		n	16	16	16	15	16	16	16
Anaconda ARTS	14	Mean	4.614	8.675	13.286	46.929	44.771	15.436	34.443
		SD	1.950	1.440	1.839	8.471	2.131	1.193	1.186
		n	14	14	14	14	14	14	14
Opportunity ARTS	1		2.000	9.490	14.600	50.000	45.200	15.400	34.000
Smelter Hill ARCO	11	Mean	4.582	9.550	14.064	49.000	44.209	14.827	33.509
		SD	2.546	1.530	1.747	5.831	1.701	1.171	1.769
		n	11	11	11	11	11	11	11
Smelter Hill ARTS	10	Mean	4.610	8.958	13.030	43.250	44.480	14.610	32.890
		SD	1.471	1.006	1.142	5.148	2.915	0.844	1.436
		n	10	10	10	8	10	10	10

**Table 6-28.** Small mammal hematology. Anaconda Smelter Site, 2000. N is the total number of animals measured while n is the number positive for the endpoint.

Species / Site	N		WBC x 10 <sup>3</sup> /ul	RBC x 10 <sup>6</sup> /ul	HBG g/dl	PCV %	MCV u <sup>3</sup>	MCH PG	MCHC %
<u>Gopher</u>									
High	10	Mean	2.7	9.8	12.9	42.6	45.1	13.2	29.5
		SD	1.4	1.3	1.3	5.1	4.8	1.0	2.1
		n	10	10	10	10	10	10	10
Medium	9	Mean	5.3	8.6	11.6	41.4	43.9	13.6	31.1
		SD	3.5	1.6	2.0	7.0	3.2	0.7	1.6
		n	9	9	9	9	9	9	9
Low	10	Mean	4.8	9.0	12.9	42.0	46.5	14.4	31.0
		SD	2.5	1.0	0.9	4.4	3.0	0.9	1.2
		n	10	10	10	10	10	10	10
<u>Deer Mouse</u>									
Low 1	12	Mean	4.7	9.7	12.7	46.1	40.6	13.2	32.4
		SD	3.6	0.9	0.9	4.3	2.4	1.1	0.9
		n	12	12	12	12	12	12	12
Low 2	11	Mean	6.8	8.9	13.0	45.7	44.3	14.7	33.1
		SD	9.7	0.9	1.7	4.0	4.4	1.8	0.8
		n	11	11	11	11	11	11	11
Medium 1	11	Mean	3.4	8.5	12.1	46.4	47.5	14.5	30.6
		SD	2.4	1.1	0.6	4.6	4.4	1.6	1.3
		n	11	11	11	11	11	11	11
Medium 2	10	Mean	3.9	8.9	12.2	46.2	45.4	14.0	30.8
		SD	2.1	1.4	1.6	6.0	3.0	1.2	2.7
		n	10	10	10	10	9	9	10
High 1	10	Mean	3.8	9.5	12.7	49.9	41.0	13.5	32.8
		SD	1.9	1.4	0.8	2.3	3.7	1.6	1.2
		n	10	10	10	10	10	10	10
High 2	10	Mean	5.3	8.5	11.1	44.0	40.9	13.3	32.6
		SD	3.3	1.6	1.7	6.9	2.9	1.1	1.2
		n	10	10	9	10	10	10	10

Continued

**Table 6-28.** Continued

Species / Site	N			WBC	RBC	HBG	PCV	MCV	MCH	MCHC
				x 10 <sup>3</sup> /ul	x 10 <sup>6</sup> /ul	g/dl	%	u <sup>3</sup>	PG	%
<u>Deer Mouse</u> continued										
Drag Strip ARTS	6	Mean		5.1	9.3	13.6	48.2	44.8	14.7	32.8
		SD		1.8	1.3	1.4	3.0	2.6	1.0	0.4
		n		6	6	6	6	6	6	6
Smelter Hill ARCO	9	Mean		3.9	8.6	12.8	43.4	44.5	14.8	33.4
		SD		1.9	1.3	1.7	5.1	2.1	0.8	0.8
		n		9	9	9	9	9	9	9
Smelter Hill ARTS	10	Mean		4.9	9.1	12.4	45.4	41.6	13.7	32.8
		SD		3.2	1.0	1.1	4.1	2.1	0.7	0.7
		n		10	10	10	10	10	10	10

**Table 6-29.** Tissue weights of small mammals. Anaconda Smelter Site, 1999. N is the total number of animals measured while n is the number positive for the endpoint.

Species / Site	N		Body	Liver	Kidneys	Adrenals	Spleen	Pancreas	Right	Left	Testes	Uterus	Thymus	Heart	Lungs	Brain	
			Mass	Weight	Weight	Weight	Weight	Weight	Weight	Testis	Testis	Total Weight	Weight	Weight	Weight	Weight	Weight
			(grams)	(grams)	(grams)	(grams)	(grams)	(grams)	(grams)	(grams)	(grams)	(grams)	(grams)	(grams)	(grams)	(grams)	(grams)
<u>Gopher</u>																	
Low	6	Mean	60.1	2.769	0.765	-	0.213	0.101	0.040	0.040	0.080	0.091	0.054	0.356	0.391	1.104	
		SD	9.7	0.447	0.073	-	0.230	0.048	0.005	0.006	0.011	0.093	0.021	0.080	0.048	0.097	
		n	6	6	6	0	6	6	4	4	4	2	5	6	6	6	
Medium	7	Mean	62.1	2.812	0.651	0.020	0.114	0.203	0.071	0.071	0.142	0.059	0.057	0.331	0.423	1.100	
		SD	8.9	0.514	0.062	0.012	0.061	0.122	0.062	0.063	0.125	0.043	0.021	0.056	0.063	0.042	
		n	7	7	7	3	7	7	3	3	3	4	6	7	7	7	
High	6	Mean	64.9	3.008	0.861	-	0.230	0.155	0.033	0.031	0.064	0.080	0.044	0.365	0.496	1.098	
		SD	14.3	0.787	0.184	-	0.280	0.110	0.013	0.011	0.024	0.058	0.011	0.076	0.134	0.047	
		n	6	6	6	0	6	5	2	2	2	4	6	6	6	6	
<u>Meadow Vole</u>																	
Low 2	3	Mean	30.6	1.502	0.377	0.015	0.080	0.135	0.271	0.236	0.507	0.765	0.023	0.178	0.244	0.671	
		SD	2.9	0.250	0.075	0.020	0.028	0.052	0.126	0.052	0.178	-	0.007	0.075	0.073	0.102	
		n	3	3	3	3	3	3	2	2	2	1	2	3	3	3	
Medium 1	2	Mean	29.2	1.987	0.338	0.025	0.103	0.115	-	-	-	0.287	0.045	0.188	0.343	0.641	
		SD	6.6	0.780	0.007	0.002	0.004	0.008	-	-	-	0.160	-	0.013	-	0.025	
		n	2	2	2	2	2	2	0	0	0	2	1	2	1	2	
Medium 2	3	Mean	24.3	1.520	0.300	0.015	0.143	0.151	0.087	0.090	0.177	0.533	0.018	0.168	0.217	0.563	
		SD	5.6	0.323	0.044	0.013	0.072	0.103	0.115	0.123	0.238	0.654	0.013	0.026	0.034	0.090	
		n	4	4	4	4	4	4	2	2	2	2	3	4	4	4	

Continued

**Table 6-29.** Continued.

Species / Site	N		Body Mass (grams)	Liver Weight (grams)	Kidneys Weight (grams)	Adrenals Weight (grams)	Spleen Weight (grams)	Pancreas Weight (grams)	Right Testis (grams)	Left Testis (grams)	Testes Total Weight (grams)	Uterus Weight (grams)	Thymus Weight (grams)	Heart Weight (grams)	Lungs Weight (grams)	Brain Weight (grams)
<u>Meadow Vole</u> continued																
High 1	2	Mean	22.6	1.464	0.320	0.014	0.067	0.134	-	-	-	0.102	0.034	0.141	0.209	0.594
		SD	2.3	0.079	0.051	0.011	0.010	0.043	-	-	-	0.030	0.008	0.003	0.005	0.028
		n	2	2	2	2	2	2	0	0	0	2	2	2	2	2
High 2	11	Mean	28.3	1.673	0.364	0.020	0.162	0.121	0.139	0.138	0.277	0.540	0.021	0.206	0.266	0.616
		SD	5.8	0.454	0.094	0.018	0.158	0.056	0.068	0.067	0.135	0.608	0.015	0.046	0.067	0.059
		n	11	11	11	10	10	10	6	6	6	3	7	10	10	10
Anaconda ARTS	8	Mean	24.7	1.491	0.325	0.013	0.097	0.110	0.037	0.036	0.073	0.086	0.031	0.165	0.276	0.576
		SD	3.6	0.349	0.054	0.008	0.068	0.037	0.005	0.005	0.011	0.062	0.016	0.029	0.084	0.046
		n	8	8	8	8	8	8	2	2	2	5	8	8	8	8
Opportunity ARTS	4	Mean	18.6	0.654	0.242	0.005	0.035	0.080	0.030	0.027	0.056	0.001	0.031	0.120	0.185	0.576
		SD	4.2	0.348	0.066	0.003	0.009	0.038	0.037	0.040	0.076	-	0.016	0.021	0.015	0.033
		n	4	4	4	4	4	4	3	3	3	1	3	4	4	4
Smelter Hill ARCO	9	Mean	32.9	1.598	0.360	0.032	0.127	0.153	0.197	0.146	0.343	1.396	0.019	0.176	0.236	0.610
		SD	9.4	0.379	0.063	0.019	0.074	0.050	0.049	0.094	0.099	0.665	0.016	0.018	0.026	0.054
		n	9	9	9	8	9	9	4	4	4	4	3	9	9	9
Smelter Hill ARTS	14	Mean	33.2	1.688	0.404	0.033	0.196	0.200	0.206	0.231	0.437	0.857	0.034	0.215	0.288	0.652
		SD	9.8	0.522	0.107	0.022	0.152	0.088	0.233	0.223	0.452	0.869	0.008	0.060	0.077	0.043
		n	14	14	14	10	10	10	5	5	5	4	4	10	10	10

Continued

**Table 6-29.** Continued.

Species / Site	N		Body Mass (grams)	Liver Weight (grams)	Kidneys Weight (grams)	Adrenals Weight (grams)	Spleen Weight (grams)	Pancreas Weight (grams)	Right Testis (grams)	Left Testis (grams)	Testes Total Weight (grams)	Uterus Weight (grams)	Thymus Weight (grams)	Heart Weight (grams)	Lungs Weight (grams)	Brain Weight (grams)
<u>Deer Mouse</u>																
Low 1	22	Mean	17.0	1.086	0.289	0.018	0.088	0.138	0.094	0.097	0.191	0.206	0.024	0.164	0.173	0.618
		SD	3.0	0.352	0.057	0.014	0.036	0.118	0.096	0.097	0.193	0.345	0.013	0.033	0.036	0.052
		n	22	22	22	20	20	20	9	9	9	10	16	20	19	20
Low 2	25	Mean	17.0	1.035	0.289	0.016	0.128	0.120	0.051	0.052	0.103	0.044	0.017	0.155	0.181	0.637
		SD	3.7	0.376	0.098	0.006	0.200	0.061	0.076	0.074	0.149	0.053	0.008	0.027	0.039	0.040
		n	25	24	24	20	20	20	10	10	10	9	16	20	20	20
Medium 1	24	Mean	19.9	1.350	0.318	0.019	0.093	0.124	0.120	0.125	0.245	0.301	0.032	0.175	0.204	0.647
		SD	3.4	0.400	0.051	0.008	0.035	0.057	0.100	0.094	0.193	0.428	0.055	0.035	0.050	0.048
		n	24	24	23	20	20	20	8	8	8	12	15	20	20	20
Medium 2	19	Mean	16.8	1.196	0.307	0.024	0.067	0.095	0.016	0.016	0.031	0.111	0.021	0.165	0.180	0.612
		SD	3.8	0.382	0.057	0.028	0.038	0.040	0.016	0.019	0.035	0.096	0.010	0.028	0.038	0.028
		n	19	18	19	19	19	17	10	10	10	9	16	19	19	19
High 1	25	Mean	19.0	1.200	0.304	0.019	0.083	0.119	0.099	0.097	0.184	0.248	0.020	0.169	0.197	0.623
		SD	2.6	0.264	0.053	0.021	0.031	0.047	0.092	0.085	0.174	0.464	0.012	0.023	0.043	0.042
		n	24	25	25	21	21	21	7	8	8	12	19	21	21	21
High 2	27	Mean	18.4	1.134	0.270	0.017	0.082	0.128	0.075	0.075	0.150	0.071	0.020	0.170	0.197	0.635
		SD	3.8	0.503	0.048	0.007	0.030	0.074	0.080	0.080	0.160	0.078	0.012	0.027	0.061	0.041
		n	27	27	27	20	20	20	11	11	11	8	13	20	20	19

Continued

**Table 6-29.** Continued.

Species / Site	N		Body Mass (grams)	Liver Weight (grams)	Kidneys Weight (grams)	Adrenals Weight (grams)	Spleen Weight (grams)	Pancreas Weight (grams)	Right Testis (grams)	Left Testis (grams)	Testes Total Weight (grams)	Uterus Weight (grams)	Thymus Weight (grams)	Heart Weight (grams)	Lungs Weight (grams)	Brain Weight (grams)
<u>Deer Mouse continued</u>																
Anaconda	14	Mean	15.2	0.911	0.226	0.015	0.065	0.090	0.012	0.010	0.022	0.038	0.023	0.140	0.165	0.578
ARTS		SD	2.4	0.269	0.045	0.002	0.051	0.040	0.006	0.005	0.010	0.016	0.011	0.018	0.034	0.066
		n	13	14	13	14	14	14	8	8	8	5	11	14	14	14
Opportunity	1	Mean	14.58	0.8113	0.2532	0.0192	0.033	0.1139	-	-	-	0.0133	0.0256	0.1273	0.1701	0.6909
ARTS		SD	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		n	1	1	1	1	1	1	0	0	0	1	1	1	1	1
Smelter Hill	14	Mean	19.8	1.182	0.319	0.027	0.099	0.126	0.066	0.068	0.133	0.330	0.020	0.156	0.181	0.622
ARCO		SD	2.3	0.363	0.053	0.028	0.049	0.041	0.060	0.064	0.124	0.587	0.008	0.032	0.037	0.049
		n	14	14	14	10	10	10	5	5	5	5	6	10	10	10
Smelter Hill	15	Mean	22.0	1.272	0.318	0.022	0.084	0.146	0.129	0.130	0.259	1.071	0.017	0.176	0.211	0.655
ARTS		SD	4.2	0.325	0.044	0.005	0.022	0.059	0.106	0.106	0.211	0.784	0.008	0.023	0.029	0.051
		n	15	15	14	10	11	11	5	5	5	6	8	11	11	11

**Table 6-30.** Tissue weights of small mammals. Anaconda Smelter Site, 2000. N is the total number of animals measured while n is the number positive for the endpoint.

Species / Site	N		Body Mass (grams)	Liver (grams)	Kidneys (grams)	Spleen (grams)	R. Testis (grams)	L. Testis (grams)	Testes (T) (grams)	Ovaries (grams)
<u>Gopher</u>										
Low	10	Mean	72.8	3.065	0.993	0.156	0.118	0.118	0.236	0.021
		SD	16.7	0.574	0.159	0.104	0.084	0.079	0.163	0.010
		n	9	9	10	10	3	3	3	7
Medium	10	Mean	68.8	3.041	0.723	0.167	0.081	0.074	0.155	0.014
		SD	14.4	0.744	0.190	0.114	0.061	0.058	0.117	0.009
		n	10	10	10	9	7	7	7	3
High	10	Mean	79.3	3.668	0.833	0.137	0.144	0.168	0.312	0.022
		SD	13.1	0.671	0.102	0.045	0.016	0.010	0.025	0.017
		n	10	10	10	10	2	2	2	6
<u>Meadow Vole</u>										
High 1	3	Mean	22.1	1.242	0.383	0.058	0.097	0.084	0.181	0.036
		SD	9.5	0.415	0.047	0.027	0.131	0.111	0.243	-
		n	2	3	3	3	2	2	2	1
High 2	2	Mean	27.2	1.397	0.324	0.075	0.121	0.109	0.230	0.028
		SD	1.7	0.104	0.038	0.009	-	-	-	-
		n	2	2	2	2	1	1	1	1
D-Strip	2	Mean	29.9	1.768	0.449	0.166	0.154	0.145	0.299	0.036
		SD	2.3	0.174	0.038	0.183	-	-	-	-
		n	2	2	2	2	1	1	1	1

Continued

**Table 6-30.** Continued.

Species / Site	N		Body Mass (grams)	Liver (grams)	Kidneys (grams)	Spleen (grams)	R. Testis (grams)	L. Testis (grams)	Testes (T) (grams)	Ovaries (grams)
<u>Meadow Vole</u> continued										
Smelter Hill	6	Mean	23.6	1.003	0.317	0.066	0.107	0.108	0.214	0.032
ARCO		SD	6.7	0.343	0.076	0.038	0.089	0.085	0.173	0.003
		n	6	6	6	6	4	4	4	2
Smelter Hill	5	Mean	27.1	1.277	0.378	0.077	0.116	0.116	0.231	0.027
ARTS		SD	6.5	0.201	0.026	0.046	0.046	0.045	0.091	0.008
		n	5	5	5	5	2	2	2	3
<u>Deer Mouse</u>										
Low 1	12	Mean	21.4	1.637	0.335	0.114	0.152	0.159	0.311	0.036
		SD	3.0	0.340	0.061	0.038	0.075	0.085	0.160	0.006
		n	12	12	12	12	7	7	7	5
Low 2	11	Mean	20.8	1.666	0.339	0.137	0.045	0.048	0.093	0.023
		SD	3.3	0.932	0.084	0.074	0.033	0.037	0.069	0.009
		n	11	11	11	11	7	7	7	4
Medium 1	11	Mean	20.1	1.074	0.286	0.105	0.031	0.036	0.067	0.029
		SD	1.8	0.210	0.039	0.044	0.026	0.026	0.051	0.004
		n	11	11	11	11	6	6	6	5
Medium 2	10	Mean	18.1	1.228	0.279	0.082	0.121	0.124	0.246	0.021
		SD	2.9	0.346	0.044	0.066	0.084	0.089	0.173	0.002
		n	10	10	10	10	5	5	5	4

Continued

**Table 6-30.** Continued.

Species / Site	N		Body Mass (grams)	Liver (grams)	Kidneys (grams)	Spleen (grams)	R. Testis (grams)	L. Testis (grams)	Testes (T) (grams)	Ovaries (grams)
High 1	10	Mean	19.3	1.101	0.289	0.083	0.125	0.128	0.253	0.027
		SD	2.3	0.220	0.020	0.030	0.103	0.108	0.210	0.012
		n	10	10	10	10	5	5	5	5
High 2	10	Mean	19.9	1.259	0.314	0.145	0.048	0.049	0.097	0.028
		SD	3.5	0.354	0.070	0.111	0.050	0.053	0.103	0.013
		n	10	10	10	10	5	5	5	5
D-Strip	6	Mean	19.9	1.220	0.311	0.085	0.217	0.226	0.443	0.042
		SD	3.3	0.344	0.047	0.031	0.007	0.012	0.019	0.005
		n	6	6	6	6	3	3	3	3
Smelter Hill ARCO	9	Mean	22.0	1.137	0.268	0.108	0.110	0.110	0.220	0.030
		SD	8.0	0.276	0.022	0.055	0.105	0.105	0.209	0.011
		n	9	9	9	9	5	5	5	4
Smelter Hill ARTS	10	Mean	21.5	1.157	0.305	0.104	0.172	0.175	0.347	0.038
		SD	2.6	0.202	0.035	0.025	0.088	0.092	0.181	0.023
		n	10	10	10	10	5	5	5	5

**Table 6-31.** Capture statistics for meadow voles on high, medium, and low sites. Anaconda Smelter Site, 1999

Site	Captures			Sex and Age			
	Session	Total	Individuals	Adult Females	Nonadult Females	Adult Males	Nonadult Males
High 1	1	23	16	5	2	9	0
	2	0	0	0	0	0	0
	3	0	0	0	0	0	0
	4	3	2	1	0	1	0
	5	2	2	0	0	1	1
High 2	1	16	9	1	2	3	3
	2	20	9	3	0	1	5
	3	19	11	1	3	6	1
	4	26	17	5	3	9	0
	5	23	13	3	1	6	3
Medium 1	1	4	2	1	0	0	1
	2	4	4	1	0	0	3
	3	6	4	0	0	0	0
	4	5	4	0	0	0	0
	5	3	3	1	0	2	0

Continued

**Table 6-31.** Continued

Site	Session	Captures		Sex and Age			
		Total	Individuals	Adult Females	Nonadult Females	Adult Males	Nonadult Males
Medium 2	1	3	3	2	1	0	0
	2	11	6	2	2	2	0
	3	12	10	3	2	1	4
	4	13	8	1	0	3	4
	5	6	5	1	0	3	1
Low 1	1	8	5	1	0	3	1
	2	33	16	6	1	9	0
	3	5	4	3	0	1	0
	4	1	1	0	0	1	0
	5	0	0	0	0	0	0
Low 2	1	61	36	14	3	10	9
	2	30	19	10	1	8	0
	3	49	22	9	0	12	1
	4	18	11	3	0	8	0
	5	11	6	3	0	3	0

Total capture includes recapture

Total trap nights per session = 400

**Table 6-32.** Capture statistics for deer mice on high, medium, and low sites. Anaconda Smelter Site, 1999.

Site	Session	Captures		Sex and Age			
		Total	Individuals	Adult Females	Nonadult Females	Adult Males	Nonadult Males
High 1	1	54	19	5	7	6	1
	2	55	20	6	4	7	3
	3	85	33	8	9	7	9
	4	67	25	6	6	6	7
	5	57	23	8	5	5	5
High 2	1	30	11	3	1	5	2
	2	37	16	2	2	7	5
	3	33	15	3	3	4	5
	4	41	23	4	5	7	7
	5	30	19	3	5	5	6
Medium 1	1	65	30	8	4	10	8
	2	82	36	8	5	8	15
	3	125	53	9	12	6	26
	4	95	46	6	9	7	24
	5	88	45	5	11	12	17

Continued

**Table 6-32.** Continued

Site	Session	Captures		Sex and Age			
		Total	Individuals	Adult Females	Nonadult Females	Adult Males	Nonadult Males
Medium 2	1	19	8	0	3	3	2
	2	32	9	2	2	3	2
	3	16	6	0	3	3	0
	4	19	9	3	1	5	0
	5	7	6	2	1	3	0
Low 1	1	29	14	1	6	5	2
	2	29	17	4	3	5	5
	3	36	12	2	4	5	1
	4	33	13	6	3	1	3
	5	44	15	8	1	3	3
Low 2	1	31	10	2	1	6	1
	2	35	13	5	1	7	0
	3	39	15	5	2	7	1
	4	43	22	5	6	5	6
	5	37	16	4	6	4	2

Total capture includes recapture  
 Total trap nights per session = 400

**Table 6-33.** Capture statistics for meadow voles on high, medium, and low sites. Anaconda Smelter Site, 2000.

Site	Captures			Sex and Age			
	Session	Total	Individuals	Adult Females	Nonadult Females	Adult Males	Nonadult Males
High 1	1	0	0	0	0	0	0
	2	2	2	0	0	2	0
	3	0	0	0	0	0	0
	4	0	0	0	0	0	0
	5	0	0	0	0	0	0
High 2	1	0	0	0	0	0	0
	2	1	1	1	0	0	0
	3	14	8	2	2	1	3
	4	7	5	3	0	2	0
	5	4	4	2	1	1	0
Medium 1	1	0	0	0	0	0	0
	2	0	0	0	0	0	0
	3	5	3	2	0	1	0
	4	5	3	0	2	1	0
	5	1	1	0	1	0	0

Continued

**Table 6-33.** Continued

Site	Session	Captures		Sex and Age			
		Total	Individuals	Adult Females	Nonadult Females	Adult Males	Nonadult Males
Medium 2	1	0	0	0	0	0	0
	2	0	0	0	0	0	0
	3	0	0	0	0	0	0
	4	1	1	0	0	1	0
	5	1	1	0	0	1	0
Low 1	1	0	0	0	0	0	0
	2	5	2	1	0	1	0
	3	4	2	1	0	1	0
	4	0	0	0	0	0	0
	5	1	1	0	1	0	0
Low 2	1	3	1	0	0	1	0
	2	12	5	2	0	2	1
	3	5	2	1	0	1	0
	4	0	0	0	0	0	0
	5	0	0	0	0	0	0

Total captures include recaptures

Total trap nights ranged from 500 to 800 per session and totaled 15,700 across sessions

**Table 6-34.** Capture statistics for deer mice on high, medium, and low sites.  
 Anaconda Smelter Site, 2000.

Site	Captures			Sex and Age			
	Session	Total	Individuals	Adult Females	Nonadult Females	Adult Males	Nonadult Males
High 1	1	78	26	4	9	9	4
	2	92	28	9	6	10	3
	3	72	28	5	10	6	7
	4	53	19	5	5	5	4
	5	68	22	3	9	4	6
High 2	1	45	18	2	6	6	4
	2	53	20	4	2	6	8
	3	58	17	5	3	5	4
	4	53	20	5	3	4	8
	5	52	19	4	3	4	8
Medium 1	1	89	29	5	9	7	8
	2	126	38	12	7	9	10
	3	59	28	10	4	9	5
	4	70	33	9	5	10	9
	5	57	22	5	5	6	6

Continued

**Table 6-34.** Continued

Site	Session	Captures		Sex and Age			
		Total	Individuals	Adult Females	Nonadult Females	Adult Males	Nonadult Males
Medium 2	1	26	7	3	0	4	0
	2	24	6	1	0	4	1
	3	45	16	4	1	4	7
	4	32	10	1	2	3	4
	5	35	13	3	2	3	5
Low 1	1	137	43	11	13	5	14
	2	81	26	5	5	9	7
	3	66	24	6	3	11	4
	4	54	23	5	7	8	3
	5	65	19	6	4	6	3
Low 2	1	169	41	13	11	9	8
	2	101	34	14	3	13	4
	3	59	22	9	1	8	4
	4	52	20	5	5	8	2
	5	56	23	4	6	11	2

Total captures include recaptures

Total trap nights ranged from 500 to 800 per session and totaled 15,700 across sessions

**Table 6-35.** Deer mouse abundance estimates, capture probability and trap mortalities by session for Anaconda Smelter Site, 1999 grids.

Grid	Session																			
	1				2				3				4				5			
	N	SE	C <sub>P</sub>	T <sub>M</sub>	N	SE	C <sub>P</sub>	T <sub>M</sub>	N	SE	C <sub>P</sub>	T <sub>M</sub>	N	SE	C <sub>P</sub>	T <sub>M</sub>	N	SE	C <sub>P</sub>	T <sub>M</sub>
High 1	19	1.18	0.68	1	21	2.74	0.63	0	34	3.14	0.63	0	27	3.00	0.60	0	26	3.25	0.53	0
High 2	11	1.18	0.63	0	18	2.03	0.51	0	16	1.95	0.48	1	29	3.94	0.35	0	27	4.99	0.27	0
Low 1	16	2.03	0.45	2	27	5.25	0.27	0	12	1.18	0.69	0	15	2.03	0.55	0	15	1.28	0.69	0
Low 2	10	1	0.56	1	14	2.81	0.58	0	15	2.36	0.61	0	37	6.65	0.29	0	16	2.35	0.54	0
Medium 1	34	3.53	0.47	1	41	3.78	0.49	1	61	4.45	0.51	1	57	5.33	0.41	0	64	7.60	0.34	0
Medium 2	8	1	0.56	0	10	1	0.50	0	6	1	0.58	0	10	1	0.44	0	6	1	0.47	0
Anaconda ARTS	19	2.62	0.50	0	17	2.87	0.34	0	26	5.27	0.24	0	17	3.71	0.36	0	15	1.76	0.55	0
Opportunity ARTS	2	1.00	0.58	0	3	1.00	0.55	0	5	1.00	0.49	0	2	1.00	0.43	0	0	0.00	0.00	0
Smelter Hill ARCO	35	6.29	0.31	0	34	5.16	0.35	0	48	7.60	0.26	0	45	6.35	0.32	1	31	4.15	0.41	0
Smelter Hill ARTS	35	3.71	0.51	0	57	4.95	0.47	0	57	5.80	0.41	1	55	5.79	0.45	0	31	3.57	0.45	0

N = abundance estimate, SE = standard error for abundance estimate, C<sub>P</sub> = capture probability, T<sub>M</sub> = trap mortalities

**Table 6-36.** Deer mouse abundance estimates, capture probability and trap mortalities by session for Anaconda Smelter Site, 2000 grids.

Grid	Session																			
	1				2				3				4				5			
	N	SE	C <sub>P</sub>	T <sub>M</sub>	N	SE	C <sub>P</sub>	T <sub>M</sub>	N	SE	C <sub>P</sub>	T <sub>M</sub>	N	SE	C <sub>P</sub>	T <sub>M</sub>	N	SE	C <sub>P</sub>	T <sub>M</sub>
High 1	26	2.46	0.58	0	29	2.78	0.63	0	32	3.79	0.43	1	21	2.14	0.50	0	21	2.14	0.57	3
High 2	20	3.04	0.43	0	23	3.35	0.46	0	18	1.75	0.61	0	22	3.08	0.46	0	22	3.35	0.47	0
Low 1	52	6.16	0.38	1	27	2.83	0.59	1	25	2.77	0.53	1	29	4.98	0.36	0	21	2.14	0.62	0
Low 2	44	3.53	0.48	0	36	3.03	0.56	0	24	3.03	0.49	0	24	4.07	0.42	0	26	3.28	0.43	0
Medium 1	29	2.60	0.61	2	41	3.46	0.45	1	34	4.19	0.34	0	40	4.39	0.34	0	23	3.09	0.45	1
Medium 2	7	1.00	0.50	0	6	1.00	0.54	0	16	2.49	0.53	0	10	0.72	0.64	0	15	2.14	0.47	0
Drag Strip ARTS	9	1.00	0.50	0	4	1.00	0.52	0	11	1.00	0.48	0	11	1.00	0.48	1	2	1.00	0.48	0
Smelter Hill ARCO	26	3.67	0.38	0	32	3.26	0.38	0	42	4.41	0.41	0	42	3.52	0.53	0	39	7.92	0.27	0
Smelter Hill ARTS	27	2.14	0.64	0	34	3.03	0.55	0	47	3.14	0.56	0	41	3.28	0.55	0	31	2.90	0.54	0

N = abundance estimate, SE = standard error for abundance estimate, C<sub>P</sub> = capture probability, T<sub>M</sub> = trap mortalities

**Table 6-37.** Fractions of meadow vole reproduction parameters by session for Anaconda Smelter Site, 1999 grids.

Grid	Reproductively Active Adult Females by Session					Non-adults by Session				
	1	2	3	4	5	1	2	3	4	5
High 1	$\frac{1}{5}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{1}{1}$	$\frac{0}{0}$	$\frac{2}{16}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{2}$	$\frac{1}{2}$
High 2	$\frac{0}{1}$	$\frac{0}{3}$	$\frac{1}{1}$	$\frac{2}{5}$	$\frac{1}{3}$	$\frac{5}{9}$	$\frac{5}{9}$	$\frac{4}{11}$	$\frac{3}{17}$	$\frac{4}{13}$
Low 1	$\frac{1}{1}$	$\frac{2}{6}$	$\frac{1}{3}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{1}{5}$	$\frac{1}{16}$	$\frac{0}{4}$	$\frac{0}{1}$	$\frac{0}{0}$
Low 2	$\frac{1}{14}$	$\frac{3}{10}$	$\frac{5}{10}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{11}{35}$	$\frac{1}{19}$	$\frac{1}{22}$	$\frac{0}{11}$	$\frac{0}{6}$
Medium 1	$\frac{1}{1}$	$\frac{0}{1}$	$\frac{0}{0}$	$\frac{0}{1}$	$\frac{0}{1}$	$\frac{1}{2}$	$\frac{3}{4}$	$\frac{4}{4}$	$\frac{1}{4}$	$\frac{0}{3}$
Medium 2	$\frac{0}{2}$	$\frac{1}{2}$	$\frac{2}{3}$	$\frac{0}{1}$	$\frac{1}{1}$	$\frac{1}{3}$	$\frac{2}{6}$	$\frac{6}{10}$	$\frac{4}{8}$	$\frac{1}{5}$
Anaconda ARTS	$\frac{0}{1}$	$\frac{2}{8}$	$\frac{3}{8}$	$\frac{3}{12}$	$\frac{3}{5}$	$\frac{0}{1}$	$\frac{10}{20}$	$\frac{3}{12}$	$\frac{3}{19}$	$\frac{4}{10}$
Opportunity ARTS	$\frac{0}{0}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{0}{1}$	$\frac{0}{1}$	$\frac{2}{4}$	$\frac{0}{4}$	$\frac{0}{4}$	$\frac{2}{4}$	$\frac{3}{4}$
Smelter Hill ARCO	$\frac{0}{0}$	$\frac{1}{3}$	$\frac{2}{7}$	$\frac{1}{7}$	$\frac{2}{9}$	$\frac{0}{0}$	$\frac{1}{12}$	$\frac{0}{17}$	$\frac{2}{16}$	$\frac{0}{17}$
Smelter Hill ARTS	$\frac{1}{2}$	$\frac{3}{5}$	$\frac{3}{11}$	$\frac{1}{10}$	$\frac{2}{7}$	$\frac{1}{4}$	$\frac{4}{14}$	$\frac{1}{21}$	$\frac{0}{15}$	$\frac{1}{10}$

Sessions 1 to 5 consisted of 4-6 consecutive days of trapping separated by 14–15 days from May 25 to August 21, 1999.

For reproductively active adult females; numerator = number of reproductively active adult females, denominator = total number of adult females captured

For Non-adults; numerator = number of non-adults, denominator = total number of deer mice captured

**Table 6-38.** Fractions of deer mouse reproduction parameters by session for Anaconda Smelter Site, 1999 grids.

Grid	Reproductively Active Adult Females by Session					Non-adults by Session				
	1	2	3	4	5	1	2	3	4	5
High 1	$\frac{4}{5}$	$\frac{5}{6}$	$\frac{7}{8}$	$\frac{3}{6}$	$\frac{8}{8}$	$\frac{8}{19}$	$\frac{7}{20}$	$\frac{18}{33}$	$\frac{13}{25}$	$\frac{10}{23}$
High 2	$\frac{2}{3}$	$\frac{2}{2}$	$\frac{3}{3}$	$\frac{4}{4}$	$\frac{2}{3}$	$\frac{3}{11}$	$\frac{7}{16}$	$\frac{8}{15}$	$\frac{11}{22}$	$\frac{11}{19}$
Low 1	$\frac{1}{1}$	$\frac{2}{4}$	$\frac{2}{2}$	$\frac{4}{6}$	$\frac{8}{8}$	$\frac{8}{14}$	$\frac{8}{17}$	$\frac{5}{12}$	$\frac{6}{13}$	$\frac{4}{15}$
Low 2	$\frac{0}{2}$	$\frac{4}{5}$	$\frac{3}{5}$	$\frac{4}{5}$	$\frac{4}{4}$	$\frac{2}{10}$	$\frac{1}{13}$	$\frac{3}{15}$	$\frac{12}{22}$	$\frac{8}{16}$
Medium 1	$\frac{6}{8}$	$\frac{7}{8}$	$\frac{3}{9}$	$\frac{5}{6}$	$\frac{4}{5}$	$\frac{12}{30}$	$\frac{20}{36}$	$\frac{38}{53}$	$\frac{33}{46}$	$\frac{28}{45}$
Medium 2	$\frac{0}{0}$	$\frac{0}{2}$	$\frac{0}{0}$	$\frac{3}{3}$	$\frac{2}{2}$	$\frac{5}{8}$	$\frac{4}{9}$	$\frac{3}{6}$	$\frac{1}{9}$	$\frac{1}{6}$
Anaconda ARTS	$\frac{0}{3}$	$\frac{4}{6}$	$\frac{2}{3}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{12}{18}$	$\frac{7}{16}$	$\frac{12}{16}$	$\frac{11}{13}$	$\frac{13}{14}$
Opportunity ARTS	$\frac{0}{0}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{0}{0}$	$\frac{0}{2}$	$\frac{1}{2}$	$\frac{0}{3}$	$\frac{2}{5}$	$\frac{1}{2}$	$\frac{0}{0}$
Smelter Hill ARCO	$\frac{0}{2}$	$\frac{5}{7}$	$\frac{10}{15}$	$\frac{10}{17}$	$\frac{7}{9}$	$\frac{8}{22}$	$\frac{3}{25}$	$\frac{4}{29}$	$\frac{6}{31}$	$\frac{8}{25}$
Smelter Hill ARTS	$\frac{2}{10}$	$\frac{11}{20}$	$\frac{8}{21}$	$\frac{16}{25}$	$\frac{12}{13}$	$\frac{10}{30}$	$\frac{10}{48}$	$\frac{11}{45}$	$\frac{6}{44}$	$\frac{9}{27}$

Sessions 1 to 5 consisted of 4-6 consecutive days of trapping separated by 14–15 days from May 25 to August 21, 1999.

For reproductively active adult females; numerator = number of reproductively active adult females, denominator = total number of adult females captured

For Non-adults; numerator = number of non-adults, denominator = total number of deer mice captured

**Table 6-39.** Fractions of meadow vole reproduction parameters by session for Anaconda Smelter Site, 2000 grids.

Grid	Reproductively Active Adult Females by Session					Non-adults by Session				
	1	2	3	4	5	1	2	3	4	5
High 1	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{2}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$
High 2	$\frac{0}{0}$	$\frac{0}{1}$	$\frac{1}{2}$	$\frac{0}{3}$	$\frac{0}{2}$	$\frac{0}{0}$	$\frac{0}{1}$	$\frac{5}{8}$	$\frac{0}{5}$	$\frac{1}{4}$
Low 1	$\frac{0}{0}$	$\frac{0}{1}$	$\frac{0}{1}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{2}$	$\frac{0}{2}$	$\frac{0}{0}$	$\frac{1}{1}$
Low 2	$\frac{0}{0}$	$\frac{0}{2}$	$\frac{0}{1}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{1}$	$\frac{1}{5}$	$\frac{0}{2}$	$\frac{0}{0}$	$\frac{0}{0}$
Medium 1	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{2}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{3}$	$\frac{2}{3}$	$\frac{1}{1}$
Medium 2	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{1}$	$\frac{0}{1}$
Drag Strip ARTS	$\frac{0}{1}$	$\frac{0}{1}$	$\frac{0}{0}$	$\frac{0}{2}$	$\frac{0}{2}$	$\frac{4}{5}$	$\frac{10}{13}$	$\frac{2}{3}$	$\frac{0}{3}$	$\frac{0}{3}$
Smelter Hill ARCO	$\frac{0}{2}$	$\frac{3}{6}$	$\frac{3}{4}$	$\frac{2}{3}$	$\frac{1}{4}$	$\frac{0}{2}$	$\frac{9}{22}$	$\frac{8}{20}$	$\frac{2}{7}$	$\frac{1}{7}$
Smelter Hill ARTS	$\frac{0}{0}$	$\frac{0}{2}$	$\frac{0}{1}$	$\frac{0}{2}$	$\frac{0}{1}$	$\frac{1}{2}$	$\frac{0}{4}$	$\frac{0}{2}$	$\frac{0}{4}$	$\frac{0}{2}$

Sessions 1 to 5 consisted of 5-8 consecutive days of trapping separated by 11–14 days from May 22 to August 25, 2000.

For reproductively active adult females; numerator = number of reproductively active adult females, denominator = total number of adult females captured

For Non-adults; numerator = number of non-adults, denominator = total number of deer mice captured

**Table 6-40.** Fractions of deer mouse reproduction parameters by session for Anaconda Smelter Site, 2000 grids.

Grid	Reproductively Active Adult Females by Session					Non-adults by Session				
	1	2	3	4	5	1	2	3	4	5
High 1	$\frac{4}{4}$	$\frac{6}{9}$	$\frac{3}{5}$	$\frac{4}{5}$	$\frac{2}{3}$	$\frac{13}{26}$	$\frac{9}{28}$	$\frac{16}{27}$	$\frac{9}{19}$	$\frac{15}{22}$
High 2	$\frac{1}{2}$	$\frac{3}{4}$	$\frac{3}{5}$	$\frac{4}{5}$	$\frac{3}{4}$	$\frac{10}{18}$	$\frac{10}{20}$	$\frac{7}{17}$	$\frac{11}{20}$	$\frac{11}{19}$
Low 1	$\frac{10}{11}$	$\frac{3}{5}$	$\frac{4}{6}$	$\frac{2}{5}$	$\frac{5}{6}$	$\frac{27}{43}$	$\frac{12}{26}$	$\frac{7}{24}$	$\frac{10}{23}$	$\frac{7}{19}$
Low 2	$\frac{9}{13}$	$\frac{8}{14}$	$\frac{6}{9}$	$\frac{2}{5}$	$\frac{1}{4}$	$\frac{19}{41}$	$\frac{7}{34}$	$\frac{5}{22}$	$\frac{7}{20}$	$\frac{8}{23}$
Medium 1	$\frac{4}{5}$	$\frac{9}{12}$	$\frac{4}{10}$	$\frac{6}{9}$	$\frac{3}{5}$	$\frac{17}{29}$	$\frac{17}{38}$	$\frac{9}{28}$	$\frac{13}{32}$	$\frac{11}{22}$
Medium 2	$\frac{1}{3}$	$\frac{0}{1}$	$\frac{2}{4}$	$\frac{1}{1}$	$\frac{2}{3}$	$\frac{0}{7}$	$\frac{1}{6}$	$\frac{8}{16}$	$\frac{6}{10}$	$\frac{7}{13}$
Drag Strip ARTS	$\frac{1}{1}$	$\frac{1}{2}$	$\frac{2}{4}$	$\frac{2}{3}$	$\frac{0}{1}$	$\frac{6}{8}$	$\frac{1}{4}$	$\frac{3}{10}$	$\frac{5}{10}$	$\frac{1}{2}$
Smelter Hill ARCO	$\frac{7}{7}$	$\frac{7}{11}$	$\frac{11}{16}$	$\frac{8}{12}$	$\frac{5}{5}$	$\frac{12}{23}$	$\frac{8}{30}$	$\frac{10}{36}$	$\frac{18}{38}$	$\frac{12}{22}$
Smelter Hill ARTS	$\frac{6}{8}$	$\frac{8}{13}$	$\frac{10}{15}$	$\frac{8}{12}$	$\frac{5}{9}$	$\frac{10}{25}$	$\frac{10}{32}$	$\frac{17}{45}$	$\frac{16}{38}$	$\frac{15}{30}$

Sessions 1 to 5 consisted of 5-8 consecutive days of trapping separated by 11–14 days from May 22 to August 25, 2000.

For reproductively active adult females; numerator = number of reproductively active adult females, denominator = total number of adult females captured

For Non-adults; numerator = number of non-adults, denominator = total number of deer mice captured

**Table 6-41.** Fractions of meadow vole survival by session for Anaconda Smelter Site, 1999 grids.

Grid	Session <sup>1</sup> and Survival Parameter <sup>2</sup>																			
	1					2					3					4				
	T	A	NA	M	F	T	A	NA	M	F	T	A	NA	M	F	T	A	NA	M	F
High 1	$\frac{0}{6}$	$\frac{0}{5}$	$\frac{0}{1}$	$\frac{0}{3}$	$\frac{0}{3}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{2}$	$\frac{0}{2}$	$\frac{0}{0}$	$\frac{0}{1}$	$\frac{0}{1}$
High 2	$\frac{7}{7}$	$\frac{3}{3}$	$\frac{4}{4}$	$\frac{5}{5}$	$\frac{2}{2}$	$\frac{5}{9}$	$\frac{3}{4}$	$\frac{2}{5}$	$\frac{3}{6}$	$\frac{2}{3}$	$\frac{6}{8}$	$\frac{4}{4}$	$\frac{2}{4}$	$\frac{4}{5}$	$\frac{2}{3}$	$\frac{10}{16}$	$\frac{7}{13}$	$\frac{3}{3}$	$\frac{6}{9}$	$\frac{4}{7}$
Medium 1	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{2}{4}$	$\frac{0}{1}$	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{0}{1}$	$\frac{0}{4}$	$\frac{0}{0}$	$\frac{0}{4}$	$\frac{0}{4}$	$\frac{0}{0}$	$\frac{3}{4}$	$\frac{3}{3}$	$\frac{0}{1}$	$\frac{2}{2}$	$\frac{1}{2}$
Medium 2	$\frac{1}{3}$	$\frac{1}{2}$	$\frac{0}{1}$	$\frac{0}{0}$	$\frac{1}{3}$	$\frac{3}{5}$	$\frac{2}{4}$	$\frac{1}{1}$	$\frac{0}{2}$	$\frac{3}{3}$	$\frac{3}{5}$	$\frac{1}{1}$	$\frac{2}{4}$	$\frac{1}{2}$	$\frac{2}{3}$	$\frac{3}{8}$	$\frac{2}{4}$	$\frac{1}{4}$	$\frac{3}{7}$	$\frac{0}{1}$
Low 1	$\frac{2}{5}$	$\frac{2}{4}$	$\frac{0}{1}$	$\frac{1}{4}$	$\frac{1}{1}$	$\frac{4}{13}$	$\frac{4}{13}$	$\frac{0}{0}$	$\frac{1}{8}$	$\frac{3}{5}$	$\frac{0}{3}$	$\frac{0}{3}$	$\frac{0}{0}$	$\frac{0}{1}$	$\frac{0}{2}$	$\frac{0}{1}$	$\frac{0}{1}$	$\frac{0}{0}$	$\frac{0}{1}$	$\frac{0}{0}$
Low 2	$\frac{14}{30}$	$\frac{11}{18}$	$\frac{2}{11}$	$\frac{7}{17}$	$\frac{7}{13}$	$\frac{15}{19}$	$\frac{14}{18}$	$\frac{1}{1}$	$\frac{7}{8}$	$\frac{8}{11}$	$\frac{10}{21}$	$\frac{10}{20}$	$\frac{0}{1}$	$\frac{7}{12}$	$\frac{3}{9}$	$\frac{5}{11}$	$\frac{5}{11}$	$\frac{0}{0}$	$\frac{3}{8}$	$\frac{2}{3}$
Anaconda ARTS	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{12}{19}$	$\frac{7}{9}$	$\frac{5}{10}$	$\frac{3}{7}$	$\frac{9}{12}$	$\frac{10}{12}$	$\frac{9}{9}$	$\frac{1}{3}$	$\frac{2}{4}$	$\frac{8}{8}$	$\frac{9}{16}$	$\frac{8}{14}$	$\frac{1}{2}$	$\frac{2}{4}$	$\frac{7}{12}$
Opportunity ARTS	$\frac{0}{3}$	$\frac{0}{2}$	$\frac{0}{1}$	$\frac{0}{3}$	$\frac{0}{0}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{0}{0}$	$\frac{2}{2}$	$\frac{1}{2}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{0}{0}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{2}{4}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{0}{2}$	$\frac{2}{2}$
Smelter Hill ARCO	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{11}{13}$	$\frac{10}{11}$	$\frac{1}{1}$	$\frac{8}{9}$	$\frac{3}{4}$	$\frac{11}{14}$	$\frac{11}{14}$	$\frac{0}{0}$	$\frac{5}{7}$	$\frac{6}{7}$	$\frac{11}{14}$	$\frac{10}{13}$	$\frac{1}{1}$	$\frac{4}{6}$	$\frac{7}{8}$
Smelter Hill ARTS	$\frac{1}{3}$	$\frac{1}{2}$	$\frac{0}{1}$	$\frac{1}{1}$	$\frac{0}{2}$	$\frac{9}{13}$	$\frac{6}{9}$	$\frac{3}{4}$	$\frac{2}{6}$	$\frac{7}{7}$	$\frac{12}{19}$	$\frac{11}{18}$	$\frac{1}{1}$	$\frac{3}{8}$	$\frac{9}{11}$	$\frac{7}{13}$	$\frac{7}{13}$	$\frac{0}{0}$	$\frac{2}{2}$	$\frac{5}{10}$

<sup>1</sup> Sessions 1 to 4 consisted of 4-6 consecutive days of trapping separated by 14–15 days from May 25 to July 291, 1999

<sup>2</sup> Survival Parameters include: T = total, A = adult, NA = non-adult, M = male, and F = female.

Numerator = total known to survive to next session, and denominator = total number of deer mice captured that session.

**Table 6-42.** Fractions of deer mouse survival by session for Anaconda Smelter Site, 1999 grids.

Grid	Session <sup>1</sup> and Survival Parameter <sup>2</sup>																			
	1					2					3					4				
	T	A	NA	M	F	T	A	NA	M	F	T	A	NA	M	F	T	A	NA	M	F
High 1	$\frac{12}{18}$	$\frac{8}{10}$	$\frac{4}{8}$	$\frac{4}{6}$	$\frac{8}{12}$	$\frac{19}{20}$	$\frac{13}{13}$	$\frac{6}{7}$	$\frac{10}{10}$	$\frac{9}{10}$	$\frac{25}{33}$	$\frac{12}{15}$	$\frac{13}{18}$	$\frac{11}{16}$	$\frac{14}{17}$	$\frac{18}{25}$	$\frac{9}{12}$	$\frac{9}{13}$	$\frac{9}{13}$	$\frac{9}{12}$
High 2	$\frac{7}{11}$	$\frac{6}{8}$	$\frac{1}{3}$	$\frac{4}{7}$	$\frac{3}{4}$	$\frac{15}{16}$	$\frac{8}{9}$	$\frac{7}{7}$	$\frac{11}{12}$	$\frac{4}{4}$	$\frac{14}{14}$	$\frac{6}{6}$	$\frac{8}{8}$	$\frac{8}{8}$	$\frac{6}{6}$	$\frac{17}{22}$	$\frac{5}{11}$	$\frac{11}{11}$	$\frac{10}{14}$	$\frac{7}{9}$
Medium 1	$\frac{22}{29}$	$\frac{13}{17}$	$\frac{9}{12}$	$\frac{13}{18}$	$\frac{9}{11}$	$\frac{33}{35}$	$\frac{14}{16}$	$\frac{19}{19}$	$\frac{20}{22}$	$\frac{13}{13}$	$\frac{41}{52}$	$\frac{12}{14}$	$\frac{29}{38}$	$\frac{25}{31}$	$\frac{16}{21}$	$\frac{32}{46}$	$\frac{8}{13}$	$\frac{24}{33}$	$\frac{21}{31}$	$\frac{11}{15}$
Medium 2	$\frac{5}{8}$	$\frac{2}{3}$	$\frac{3}{5}$	$\frac{3}{5}$	$\frac{2}{3}$	$\frac{6}{9}$	$\frac{3}{5}$	$\frac{3}{4}$	$\frac{3}{5}$	$\frac{3}{4}$	$\frac{4}{6}$	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{5}{9}$	$\frac{4}{8}$	$\frac{1}{1}$	$\frac{2}{5}$	$\frac{3}{4}$
Low 1	$\frac{5}{12}$	$\frac{2}{5}$	$\frac{3}{7}$	$\frac{2}{6}$	$\frac{3}{6}$	$\frac{10}{17}$	$\frac{5}{9}$	$\frac{5}{8}$	$\frac{6}{10}$	$\frac{4}{7}$	$\frac{9}{12}$	$\frac{5}{7}$	$\frac{4}{5}$	$\frac{4}{6}$	$\frac{5}{6}$	$\frac{7}{13}$	$\frac{5}{7}$	$\frac{2}{6}$	$\frac{2}{4}$	$\frac{5}{9}$
Low 2	$\frac{8}{9}$	$\frac{6}{7}$	$\frac{2}{2}$	$\frac{5}{6}$	$\frac{3}{3}$	$\frac{9}{13}$	$\frac{9}{12}$	$\frac{0}{1}$	$\frac{4}{7}$	$\frac{5}{6}$	$\frac{11}{15}$	$\frac{8}{12}$	$\frac{3}{3}$	$\frac{6}{8}$	$\frac{5}{7}$	$\frac{12}{21}$	$\frac{7}{10}$	$\frac{5}{12}$	$\frac{5}{11}$	$\frac{7}{11}$
Anaconda ARTS	$\frac{10}{18}$	$\frac{4}{6}$	$\frac{6}{12}$	$\frac{4}{8}$	$\frac{6}{10}$	$\frac{10}{16}$	$\frac{5}{9}$	$\frac{5}{7}$	$\frac{3}{6}$	$\frac{7}{10}$	$\frac{10}{16}$	$\frac{2}{4}$	$\frac{8}{12}$	$\frac{7}{8}$	$\frac{3}{8}$	$\frac{11}{13}$	$\frac{1}{2}$	$\frac{10}{11}$	$\frac{6}{7}$	$\frac{5}{6}$
Opportunity ARTS	$\frac{2}{2}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{2}{2}$	$\frac{0}{0}$	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{0}{0}$	$\frac{1}{2}$	$\frac{1}{1}$	$\frac{2}{5}$	$\frac{1}{3}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{3}$	$\frac{0}{2}$	$\frac{0}{1}$	$\frac{0}{1}$	$\frac{0}{1}$	$\frac{0}{1}$
Smelter Hill ARCO	$\frac{18}{22}$	$\frac{10}{14}$	$\frac{8}{8}$	$\frac{11}{15}$	$\frac{7}{7}$	$\frac{22}{25}$	$\frac{19}{22}$	$\frac{3}{3}$	$\frac{11}{14}$	$\frac{10}{10}$	$\frac{22}{29}$	$\frac{20}{25}$	$\frac{2}{4}$	$\frac{8}{10}$	$\frac{14}{19}$	$\frac{14}{30}$	$\frac{12}{24}$	$\frac{2}{6}$	$\frac{5}{11}$	$\frac{9}{19}$
Smelter Hill ARTS	$\frac{29}{30}$	$\frac{19}{20}$	$\frac{10}{10}$	$\frac{13}{14}$	$\frac{16}{16}$	$\frac{40}{48}$	$\frac{31}{38}$	$\frac{9}{10}$	$\frac{19}{24}$	$\frac{21}{24}$	$\frac{31}{44}$	$\frac{23}{33}$	$\frac{8}{11}$	$\frac{15}{20}$	$\frac{16}{24}$	$\frac{20}{44}$	$\frac{16}{38}$	$\frac{4}{6}$	$\frac{8}{17}$	$\frac{12}{27}$

<sup>1</sup> Sessions 1 to 4 consisted of 4-6 consecutive days of trapping separated by 14-15 days from May 25 to July 291, 1999

<sup>2</sup> Survival Parameters include: T = total, A = adult, NA = non-adult, M = male, and F = female.

Numerator = total known to survive to next session, and denominator = total number of deer mice captured that session.

**Table 6-43.** Fractions of meadow vole survival by session for Anaconda Smelter Site, 2000 grids.

Grid	Session <sup>1</sup> and Survival Parameter <sup>2</sup>																			
	1					2					3					4				
	T	A	NA	M	F	T	A	NA	M	F	T	A	NA	M	F	T	A	NA	M	F
High 1	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{2}$	$\frac{0}{2}$	$\frac{0}{0}$	$\frac{0}{2}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$
High 2	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{1}{1}$	$\frac{3}{8}$	$\frac{2}{3}$	$\frac{1}{5}$	$\frac{0}{4}$	$\frac{3}{4}$	$\frac{3}{5}$	$\frac{3}{5}$	$\frac{0}{0}$	$\frac{1}{2}$	$\frac{2}{3}$
Medium 1	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{0}{0}$	$\frac{1}{1}$	$\frac{0}{2}$	$\frac{1}{3}$	$\frac{0}{1}$	$\frac{1}{2}$	$\frac{0}{1}$	$\frac{1}{2}$
Medium 2	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{1}$	$\frac{0}{1}$	$\frac{0}{0}$	$\frac{0}{1}$	$\frac{0}{0}$
Low 1	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{2}{2}$	$\frac{2}{2}$	$\frac{0}{0}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{0}{2}$	$\frac{0}{2}$	$\frac{0}{0}$	$\frac{0}{1}$	$\frac{0}{1}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$
Low 2	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{0}{0}$	$\frac{1}{1}$	$\frac{0}{0}$	$\frac{1}{5}$	$\frac{1}{4}$	$\frac{0}{1}$	$\frac{1}{3}$	$\frac{0}{2}$	$\frac{0}{1}$	$\frac{0}{1}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{1}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{0}{0}$
Drag Strip ARTS	$\frac{2}{5}$	$\frac{0}{1}$	$\frac{2}{4}$	$\frac{2}{3}$	$\frac{0}{2}$	$\frac{4}{13}$	$\frac{1}{3}$	$\frac{3}{10}$	$\frac{2}{10}$	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{1}{1}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{1}$	$\frac{3}{3}$	$\frac{3}{3}$	$\frac{0}{0}$	$\frac{1}{1}$	$\frac{2}{2}$
Smelter Hill ARCO	$\frac{2}{2}$	$\frac{2}{2}$	$\frac{0}{0}$	$\frac{0}{0}$	$\frac{2}{2}$	$\frac{13}{21}$	$\frac{8}{12}$	$\frac{5}{9}$	$\frac{9}{13}$	$\frac{4}{8}$	$\frac{7}{20}$	$\frac{5}{12}$	$\frac{2}{8}$	$\frac{3}{15}$	$\frac{4}{5}$	$\frac{6}{7}$	$\frac{5}{5}$	$\frac{1}{2}$	$\frac{3}{3}$	$\frac{3}{4}$
Smelter Hill ARTS	$\frac{1}{2}$	$\frac{1}{1}$	$\frac{0}{1}$	$\frac{0}{0}$	$\frac{1}{2}$	$\frac{3}{3}$	$\frac{3}{3}$	$\frac{0}{0}$	$\frac{1}{1}$	$\frac{2}{2}$	$\frac{2}{2}$	$\frac{2}{2}$	$\frac{0}{0}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{0}{0}$	$\frac{1}{2}$	$\frac{1}{2}$

<sup>1</sup> Sessions 1 to 4 consisted of 5-8 consecutive days of trapping separated by 11-14 days from May 22 to July 31, 2000.

<sup>2</sup> Survival Parameters include: T = total, A = adult, NA = non-adult, M = male, and F = female.

Numerator = total known to survive to next session, and denominator = total number of deer mice captured that session.

**Table 6-44.** Fractions of deer mouse survival by session for Anaconda Smelter Site, 2000 grids.

Grid	Session <sup>1</sup> and Survival Parameter <sup>2</sup>																			
	1					2					3					4				
	T	A	NA	M	F	T	A	NA	M	F	T	A	NA	M	F	T	A	NA	M	F
High 1	$\frac{21}{26}$	$\frac{10}{13}$	$\frac{11}{13}$	$\frac{10}{13}$	$\frac{11}{13}$	$\frac{19}{28}$	$\frac{12}{19}$	$\frac{7}{9}$	$\frac{8}{13}$	$\frac{11}{15}$	$\frac{15}{27}$	$\frac{5}{11}$	$\frac{10}{15}$	$\frac{8}{13}$	$\frac{7}{14}$	$\frac{13}{19}$	$\frac{5}{10}$	$\frac{8}{9}$	$\frac{6}{9}$	$\frac{7}{10}$
High 2	$\frac{13}{18}$	$\frac{6}{8}$	$\frac{7}{10}$	$\frac{9}{10}$	$\frac{4}{8}$	$\frac{14}{20}$	$\frac{6}{10}$	$\frac{8}{10}$	$\frac{10}{14}$	$\frac{4}{6}$	$\frac{13}{17}$	$\frac{8}{10}$	$\frac{5}{7}$	$\frac{9}{9}$	$\frac{4}{8}$	$\frac{16}{20}$	$\frac{7}{9}$	$\frac{9}{11}$	$\frac{9}{12}$	$\frac{7}{8}$
Medium 1	$\frac{18}{27}$	$\frac{6}{10}$	$\frac{12}{17}$	$\frac{10}{13}$	$\frac{8}{14}$	$\frac{24}{37}$	$\frac{12}{20}$	$\frac{12}{17}$	$\frac{14}{19}$	$\frac{10}{18}$	$\frac{22}{28}$	$\frac{15}{19}$	$\frac{7}{9}$	$\frac{12}{14}$	$\frac{10}{14}$	$\frac{15}{33}$	$\frac{9}{19}$	$\frac{6}{13}$	$\frac{10}{19}$	$\frac{5}{14}$
Medium 2	$\frac{2}{7}$	$\frac{2}{7}$	$\frac{0}{0}$	$\frac{0}{4}$	$\frac{2}{3}$	$\frac{4}{6}$	$\frac{3}{5}$	$\frac{1}{1}$	$\frac{3}{5}$	$\frac{1}{1}$	$\frac{8}{16}$	$\frac{5}{8}$	$\frac{3}{8}$	$\frac{5}{11}$	$\frac{3}{5}$	$\frac{7}{10}$	$\frac{3}{4}$	$\frac{4}{6}$	$\frac{4}{7}$	$\frac{3}{3}$
Low 1	$\frac{21}{42}$	$\frac{8}{15}$	$\frac{13}{27}$	$\frac{13}{19}$	$\frac{8}{23}$	$\frac{17}{25}$	$\frac{11}{14}$	$\frac{6}{11}$	$\frac{8}{15}$	$\frac{9}{10}$	$\frac{17}{23}$	$\frac{12}{16}$	$\frac{5}{7}$	$\frac{9}{15}$	$\frac{8}{8}$	$\frac{15}{23}$	$\frac{9}{13}$	$\frac{6}{10}$	$\frac{7}{11}$	$\frac{8}{12}$
Low 2	$\frac{29}{41}$	$\frac{14}{22}$	$\frac{14}{19}$	$\frac{14}{17}$	$\frac{14}{24}$	$\frac{21}{34}$	$\frac{17}{27}$	$\frac{4}{7}$	$\frac{11}{17}$	$\frac{10}{17}$	$\frac{16}{22}$	$\frac{11}{17}$	$\frac{5}{5}$	$\frac{11}{12}$	$\frac{5}{10}$	$\frac{12}{20}$	$\frac{8}{13}$	$\frac{4}{7}$	$\frac{9}{10}$	$\frac{3}{10}$
Drag Strip ARTS	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{2}{6}$	$\frac{1}{4}$	$\frac{2}{4}$	$\frac{3}{4}$	$\frac{3}{3}$	$\frac{0}{1}$	$\frac{1}{1}$	$\frac{2}{3}$	$\frac{5}{10}$	$\frac{4}{7}$	$\frac{1}{3}$	$\frac{2}{4}$	$\frac{3}{6}$	$\frac{2}{9}$	$\frac{1}{5}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{5}$
Smelter Hill ARCO	$\frac{15}{23}$	$\frac{7}{11}$	$\frac{8}{12}$	$\frac{7}{8}$	$\frac{8}{15}$	$\frac{25}{30}$	$\frac{19}{22}$	$\frac{6}{8}$	$\frac{10}{12}$	$\frac{15}{18}$	$\frac{27}{36}$	$\frac{20}{26}$	$\frac{7}{10}$	$\frac{12}{16}$	$\frac{15}{20}$	$\frac{19}{38}$	$\frac{19}{20}$	$\frac{10}{18}$	$\frac{13}{18}$	$\frac{6}{20}$
Smelter Hill ARTS	$\frac{20}{25}$	$\frac{13}{15}$	$\frac{7}{10}$	$\frac{8}{10}$	$\frac{12}{15}$	$\frac{30}{32}$	$\frac{20}{22}$	$\frac{10}{10}$	$\frac{15}{15}$	$\frac{15}{17}$	$\frac{33}{45}$	$\frac{19}{28}$	$\frac{14}{17}$	$\frac{14}{21}$	$\frac{19}{24}$	$\frac{21}{38}$	$\frac{13}{22}$	$\frac{8}{16}$	$\frac{8}{17}$	$\frac{13}{21}$

<sup>1</sup> Sessions 1 to 4 consisted of 5-8 consecutive days of trapping separated by 11–14 days from May 22 to July 31, 2000.

<sup>2</sup> Survival Parameters include: T = total, A = adult, NA = non-adult, M = male, and F = female.

Numerator = total known to survive to next session, and denominator = total number of deer mice captured that session.

**Table 6-45.** Canonical weights for deer mouse population parameters and soil COC variables, emphasizing adult and non-adult survival analysis, Anaconda Smelter Site, 1999 and 2000. Correlation coefficient (r) of the first canonical root was 0.68 in 1999 (p= 0.034) and 0.65 in 2000 (p= 0.035).

Variable	Year	
	1999	2000
Arsenic	0.5588	0.5648
Cadmium	0.5697	0.5752
Copper	0.4794	0.5810
Lead	0.5091	0.5057
Zinc	0.4853	0.5876
Abundance	0.5201	-0.1194
Nonadult Survival	0.3540	0.5703
Adult Survival	0.6353	-0.0218
Reproductive Females	0.1096	0.4301
Nonadults	-0.2686	0.3585

**Table 6-46.** Canonical weights for deer mouse population parameters and soil COC variables, emphasizing male and female survival analysis, Anaconda Smelter Site, 1999 and 2000. Correlation coefficient (r) of the first canonical root was 0.68 in 1999 (p = 0.021) and 0.599 in 2000 (p = 0.043).

Variable	Year	
	1999	2000
Arsenic	0.5694	0.3413
Cadmium	0.5667	0.3367
Copper	0.4896	0.3996
Lead	0.5101	0.2884
Zinc	0.4529	0.3414
Abundance	0.5703	-0.2087
Male Survival	0.6244	0.3507
Female Survival	0.6785	0.2113
Reproductive Females	0.0872	0.4958
Nonadults	-0.2408	0.3745

**Table 6-47.** Canonical weights for rodent community parameters and soil COC variables, Anaconda Smelter Site, 1999 and 2000. Correlation coefficient ( $r$ ) of the first canonical root was 0.67 in 1999 ( $p= 0.035$ ) and 0.54 in 2000 ( $p=0.048$ ).

Variable	Year	
	1999	2000
Arsenic	0.4617	0.2338
Cadmium	0.4645	0.2017
Copper	0.3635	0.2757
Lead	0.4325	0.1997
Zinc	0.3728	0.1547
Number of Individuals	0.3518	-0.0553
Rodent Biomass	0.1174	-0.0796
Species Diversity	-0.5286	0.2005

6.5 Small Mammal Figure List and Figures

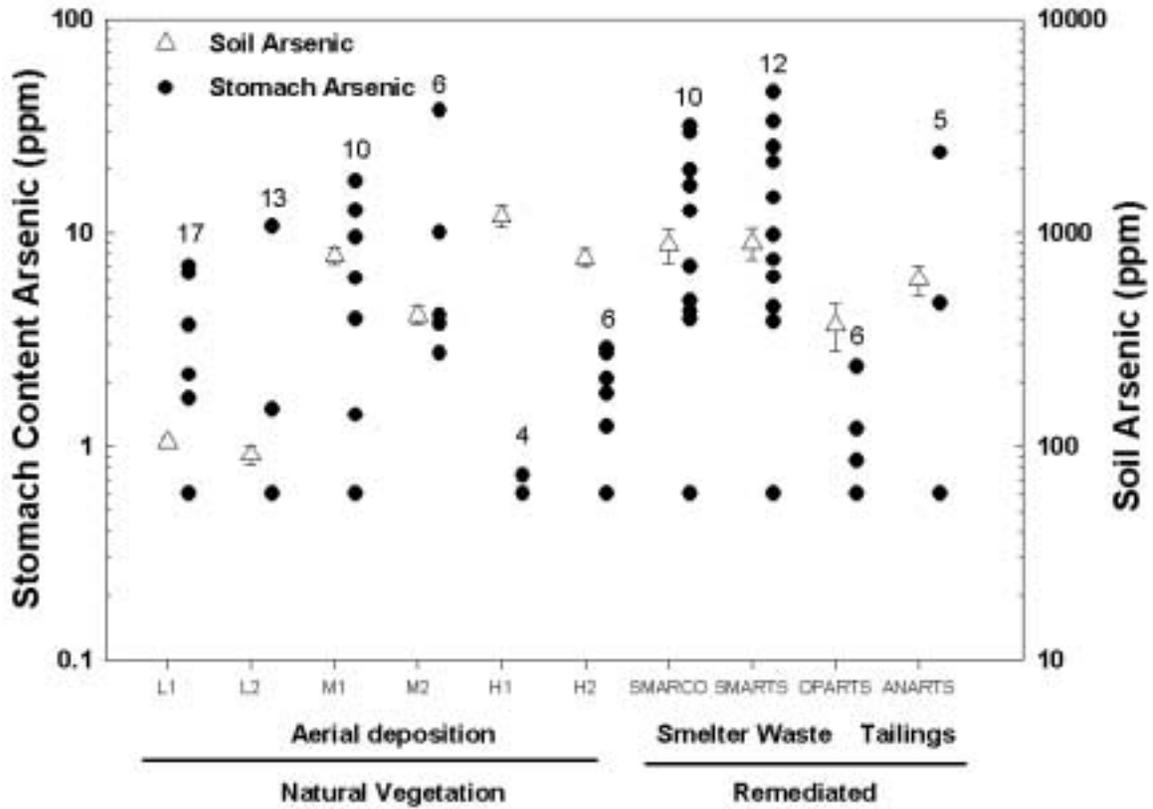
Figure	Small Mammal List of Figures Figure Content
6-1	Map of grid locations for small mammal trapping in 1999 and 2000
6-2	Mean ( $\pm$ SE) As in soil and individual deer mouse stomach content samples in 1999 and 2000.
6-3	Mean ( $\pm$ SE) Cd in soil and individual deer mouse stomach content samples in 1999 and 2000.
6-4	Mean ( $\pm$ SE) Pb in soil and individual deer mouse stomach content samples in 1999 and 2000.
6-5	Mean ( $\pm$ SE) Cu in soil and individual deer mouse stomach content samples in 1999 and 2000.
6-6	Mean ( $\pm$ SE) Zn in soil and individual deer mouse stomach content samples in 1999 and 2000.
6-7	Mean ( $\pm$ SE) As in soil and individual deer mouse blood samples in 1999 and 2000.
6-8	Mean ( $\pm$ SE) Cd in soil and individual deer mouse blood samples in 1999 and 2000.
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6-12	Mean ( $\pm$ SE) As in soil and individual deer mouse liver and kidney samples in 1999 and 2000.
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6-17	Regression of mean deer mice liver Cd from natural vegetation sites as a function of mean soil Cd . Remediated sites plotted but no regression.
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6-19	Regression of mean deer mice kidney Pb from natural vegetation sites as a function of mean soil Pb . Remediated sites plotted but no regression.
6-20	Regression of mean deer mice kidney Cu from natural vegetation sites as a function of mean soil Cu . Remediated sites plotted but no regression.
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6-25	Mean ( $\pm$ SE) Zn in soil and individual deer mouse carcass samples 1999 and 2000.
6-26	Regression of mean deer mice carcass Pb from natural vegetated sites as a function of mean soil Pb . Remediated sites plotted but no regression.

Continued

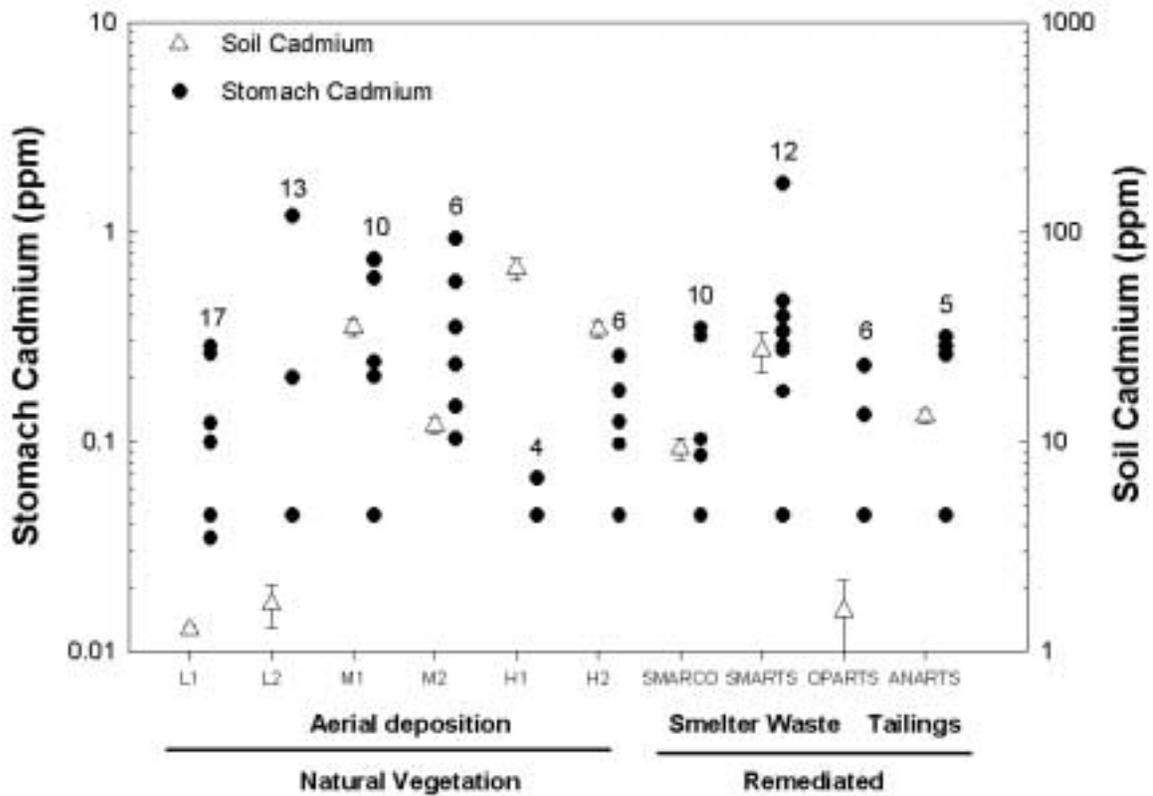
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<b>Figure</b>	<b>Figure Content</b>
6-27	Regression of mean deer mouse ALAD activity as a function of Pb concentration in respective deer mouse blood samples in 2000.
6-28	Regression analysis in pocket gopher blood ALAD activity as a function of Pb concentration in respective pocket gopher blood samples.
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6-30	Mean ( $\pm$ SE) As in soil and total porphyrins in individual deer mouse liver samples in 1999.
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6-34	Mean ( $\pm$ SE) Cu in soil and total porphyrins in individual deer mouse liver samples in 1999.
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6-39	Regression analysis of total porphyrins in deer mouse liver samples as a function of Pb in respective deer mouse liver samples in 1999.
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6-41	Regression analysis of total porphyrins in deer mouse liver samples as a function of Cu in respective deer mouse liver samples 1999.
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6-43	Pb in individual deer mouse, meadow vole, and pocket gopher kidneys in 1999 and 2000. Dashed line indicates toxic effects.
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6-45	Pb in individual deer mouse, meadow vole, and pocket gopher blood samples in 1999 and 2000. Dashed line indicates toxic effects.
6-46	Cd in individual deer mouse, meadow vole, and pocket gopher kidneys in 1999 and 2000. Dashed line indicates toxic effects.
6-47	Cd in individual deer mouse, meadow vole, and pocket gopher livers. Dashed line indicates toxic effects.

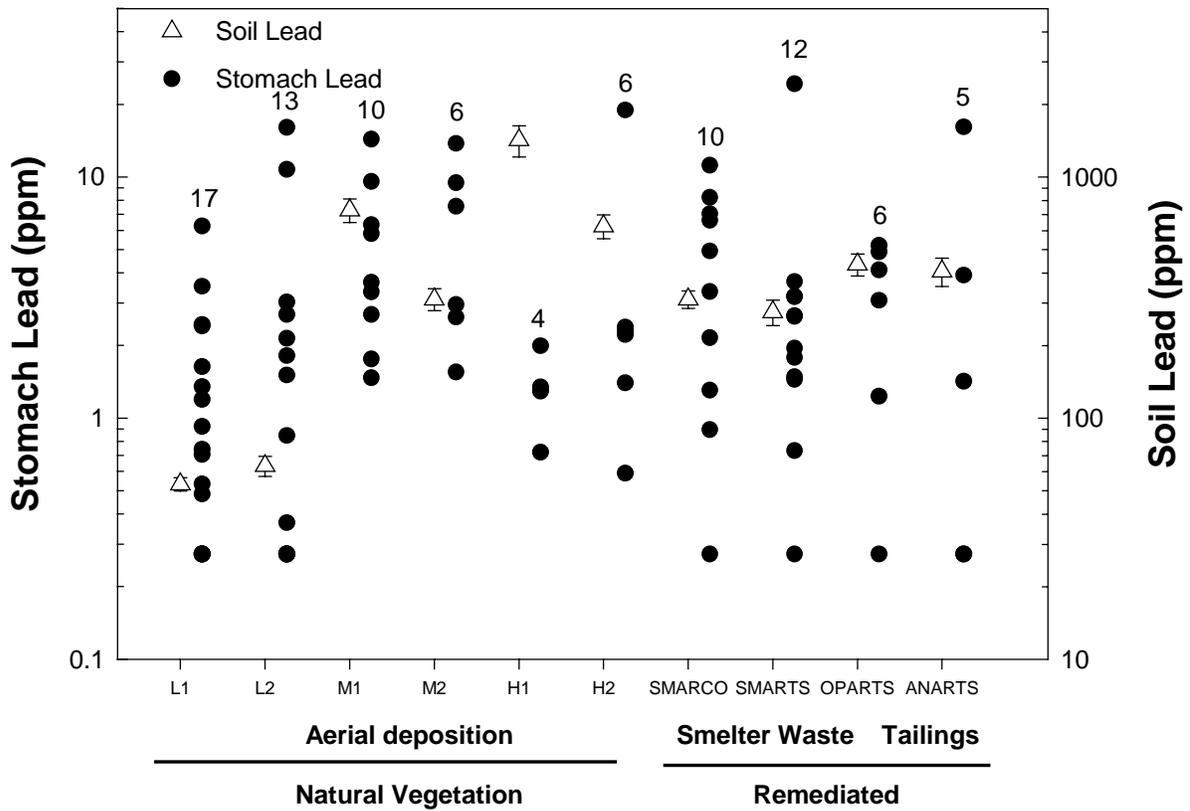




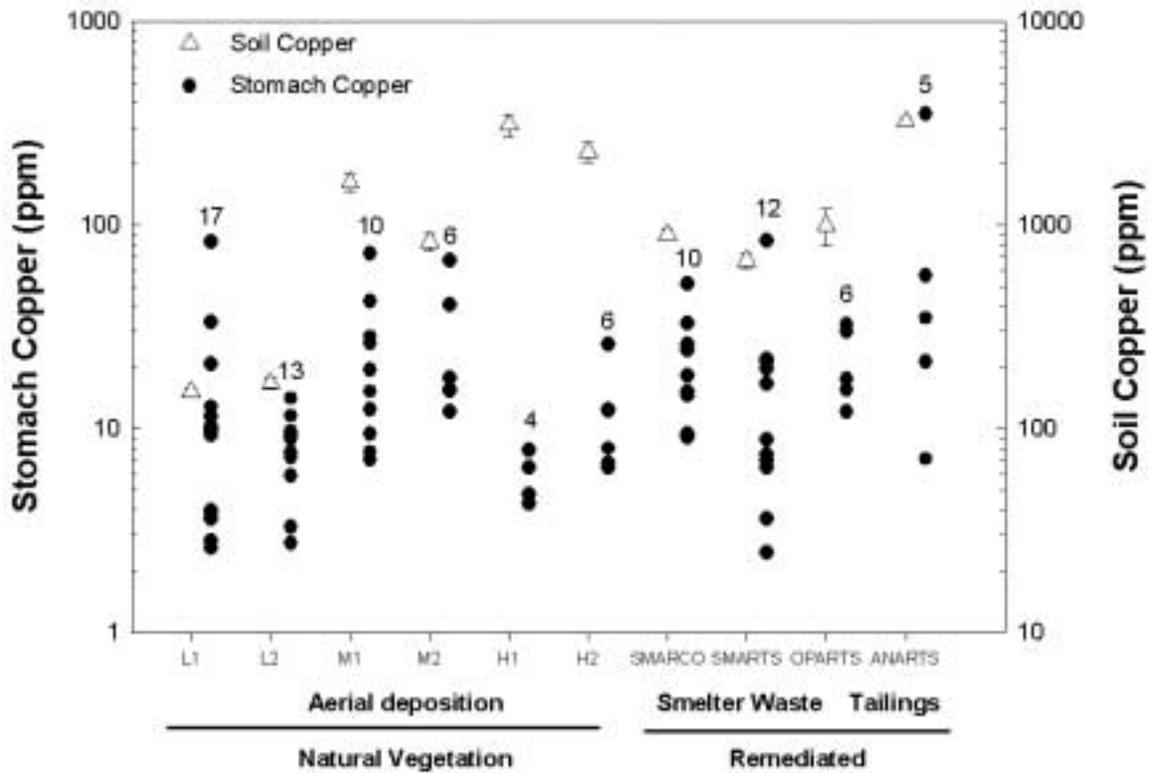
**Figure 6-2.** Mean ( $\pm$ SE) arsenic concentrations in soil ( $\Delta$ ) and individual deer mouse stomach content samples ( $\bullet$ ) collected from ten study sites in 1999 and 2000 at the Anaconda Smelter NPL site in Anaconda, Montana. Numbers above scatter plots indicate total number of stomach content samples collected from each site. Sample size for As soil means was 24 to 25 for natural vegetation sites and 9 to 10 for remediated sites.



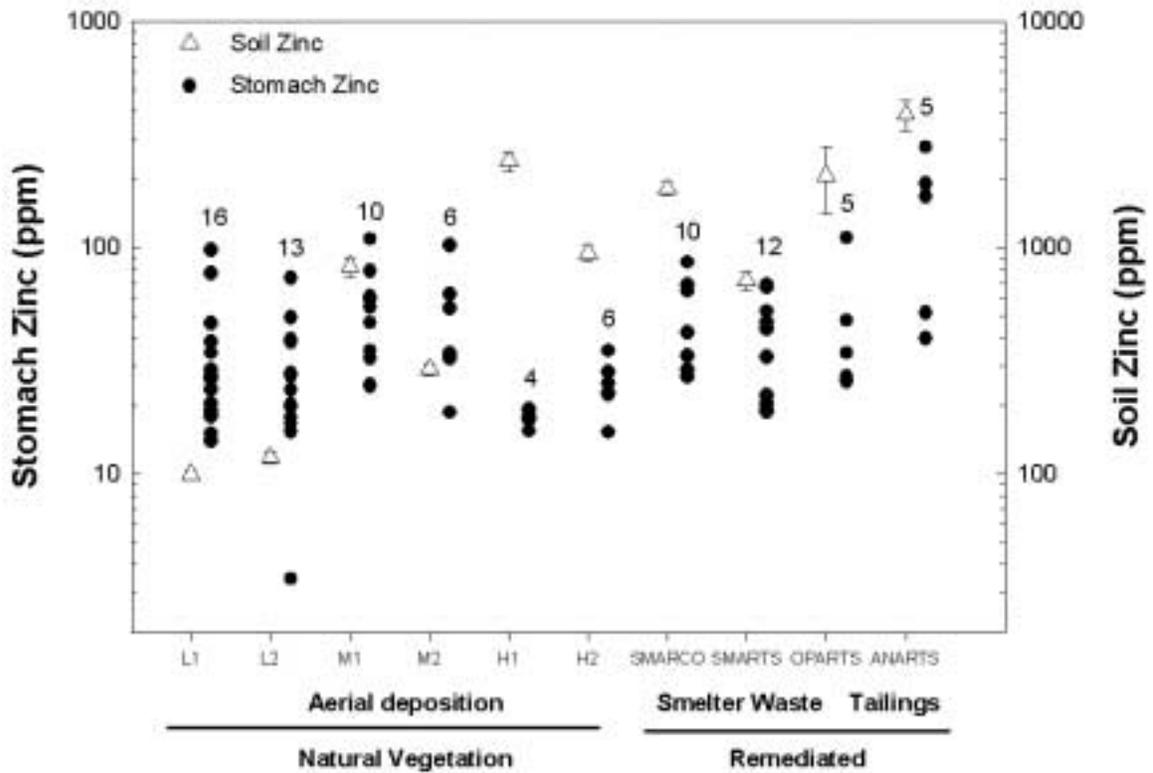
**Figure 6-3.** Mean ( $\pm$ SE) cadmium concentrations in soil ( $\Delta$ ) and individual deer mouse stomach content samples ( $\bullet$ ) collected from ten study sites in 1999 and 2000 at the Anaconda Smelter NPL site in Anaconda, Montana. Numbers above scatter plots indicate total number of stomach content samples collected from each site. Sample size for Cd soil means was 24 to 25 for natural vegetation sites and 9 to 10 for remediated sites.



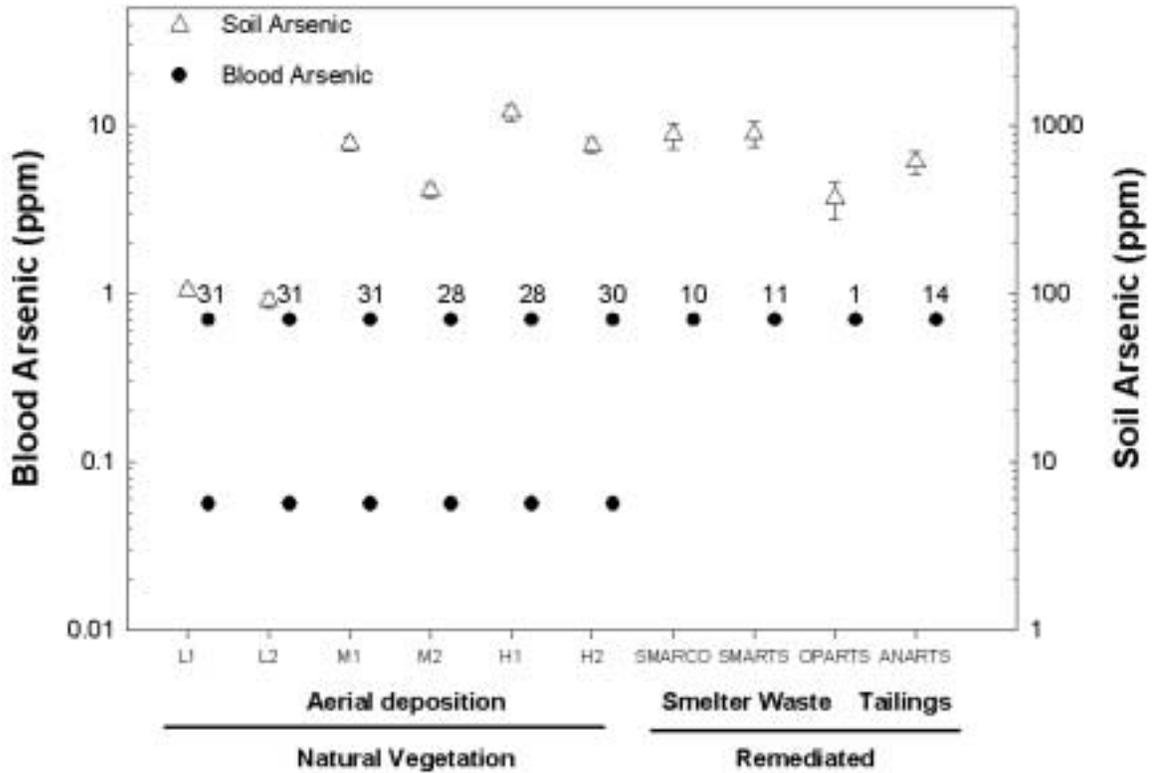
**Figure 6-4.** Mean ( $\pm$ SE) lead concentrations in soil ( $-\Delta-$ ) and individual deer mouse stomach content samples ( $-\bullet-$ ) collected from ten study sites in 1999 and 2000 at the Anaconda Smelter NPL site in Anaconda, Montana. Numbers above scatter plots indicate total number of stomach content samples collected from each site. Sample size for Pb soil means was 24 to 25 for natural vegetation sites and 9 to 10 for remediated sites.



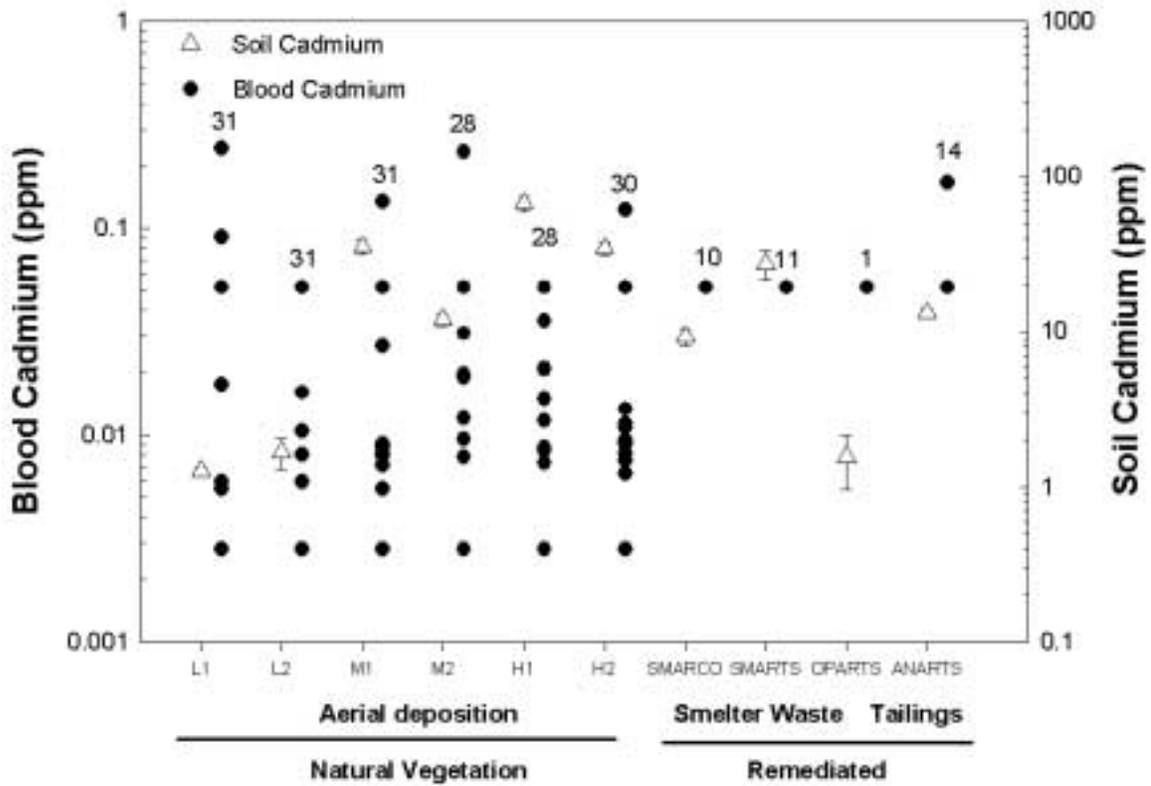
**Figure 6-5.** Mean ( $\pm$ SE) copper concentrations in soil ( $\Delta$ ) and individual deer mouse stomach content samples ( $\bullet$ ) collected from ten study sites in 1999 and 2000 at the Anaconda Smelter NPL site in Anaconda, Montana. Numbers above scatter plots indicate total number of stomach content samples collected from each site. Sample size for Cu soil means was 24 to 25 for natural vegetation sites and 9 to 10 for remediated sites.



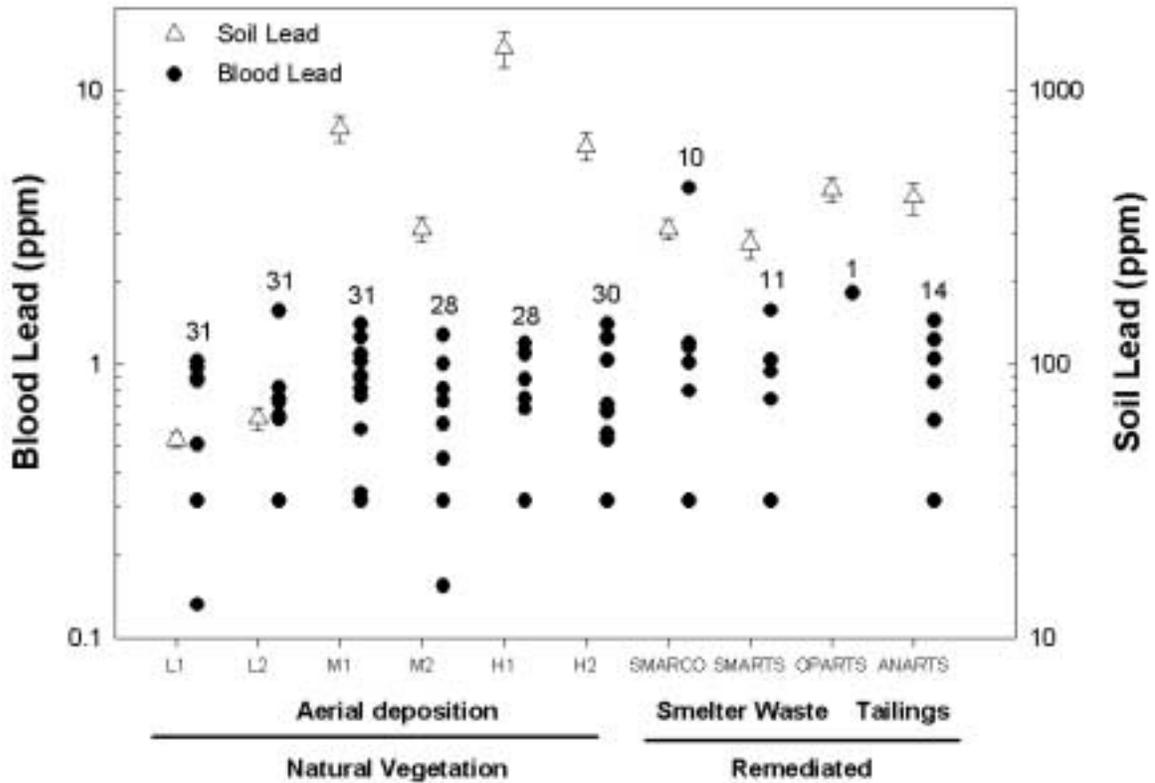
**Figure 6-6.** Mean ( $\pm$ SE) zinc concentrations in soil ( $-\Delta-$ ) and individual deer mouse stomach content samples ( $-\bullet-$ ) collected from ten study sites in 1999 and 2000 at the Anaconda Smelter NPL site in Anaconda, Montana. Numbers above scatter plots indicate total number of stomach content samples collected from each site. Sample size for Zn soil means was 24 to 25 for natural vegetation sites and 9 to 10 for remediated sites.



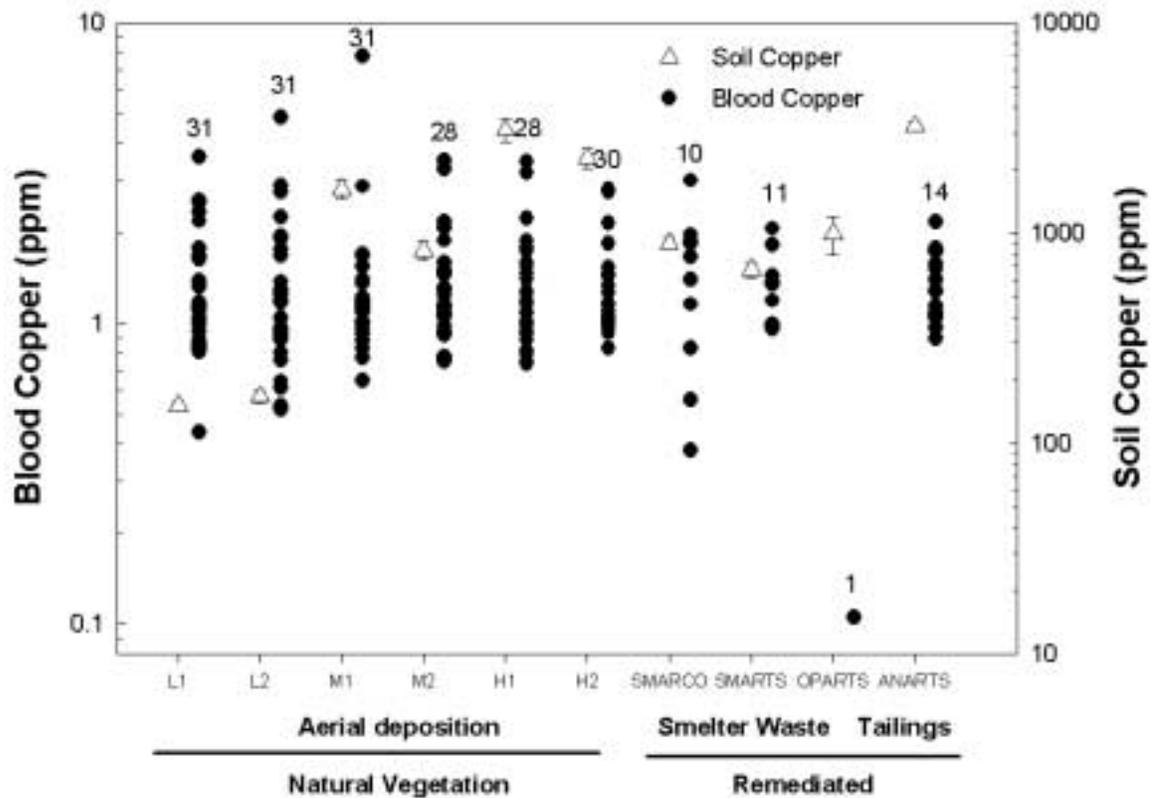
**Figure 6-7.** Mean ( $\pm$ SE) arsenic concentrations in soil ( $\Delta$ ) and individual deer mouse blood samples ( $\bullet$ ) collected from ten study sites in 1999 and 2000 at the Anaconda Smelter NPL site in Anaconda, Montana. Numbers above scatter plots indicate total number of blood samples collected from each site. Sample size for As soil means was 24 to 25 for natural vegetation sites and 9 to 10 for remediated sites.



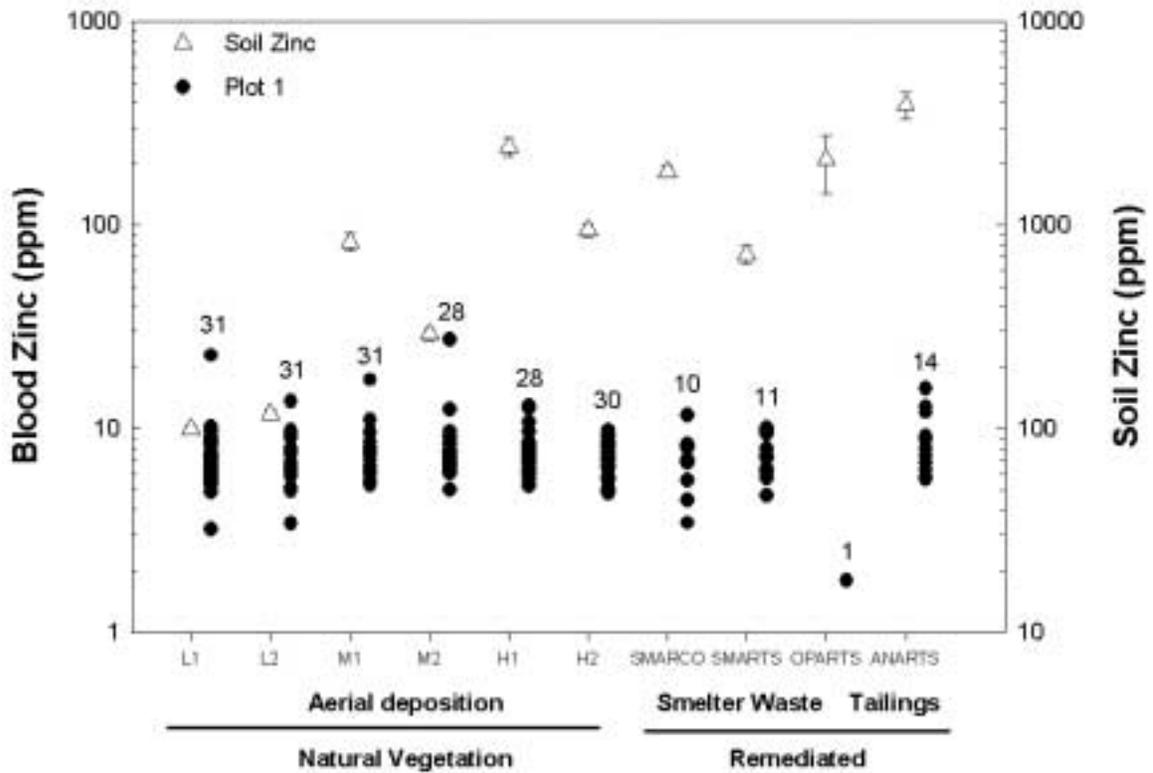
**Figure 6-8.** Mean ( $\pm$ SE) cadmium concentrations in soil ( $\Delta$ ) and individual deer mouse blood samples ( $\bullet$ ) collected from ten study sites in 1999 and 2000 at the Anaconda Smelter NPL site in Anaconda, Montana. Numbers above scatter plots indicate total number of blood samples collected from each site. Sample size for Cd soil means was 24 to 25 for natural vegetation sites and 9 to 10 for remediated sites.



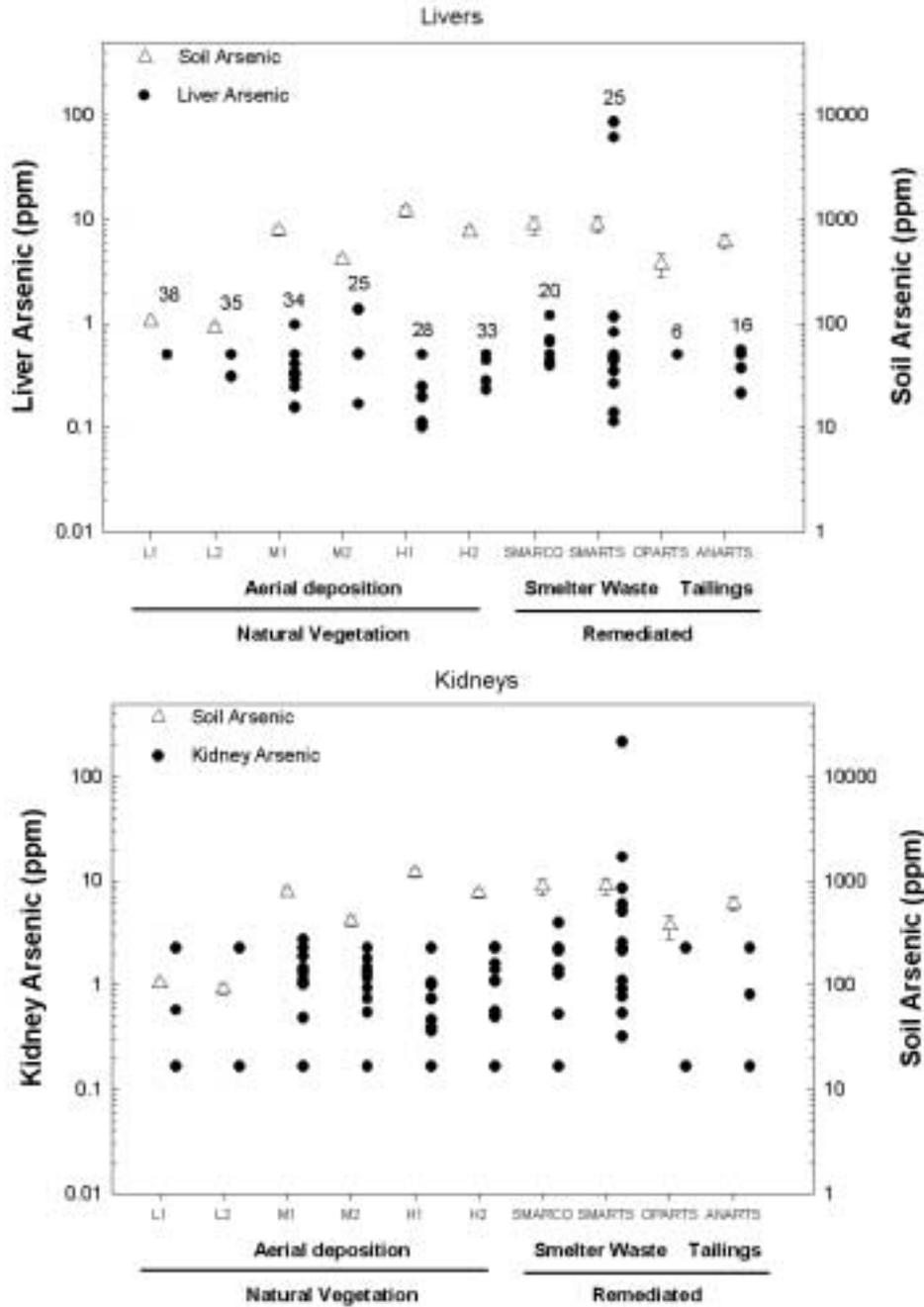
**Figure 6-9.** Mean ( $\pm$ SE) lead concentrations in soil ( $\Delta$ ) and individual deer mouse blood samples ( $\bullet$ ) collected from ten study sites in 1999 and 2000 at the Anaconda Smelter NPL site in Anaconda, Montana. Numbers above scatter plots indicate total number of blood samples collected from each site. Sample size for Pb soil means was 24 to 25 for natural vegetation sites and 9 to 10 for remediated sites.



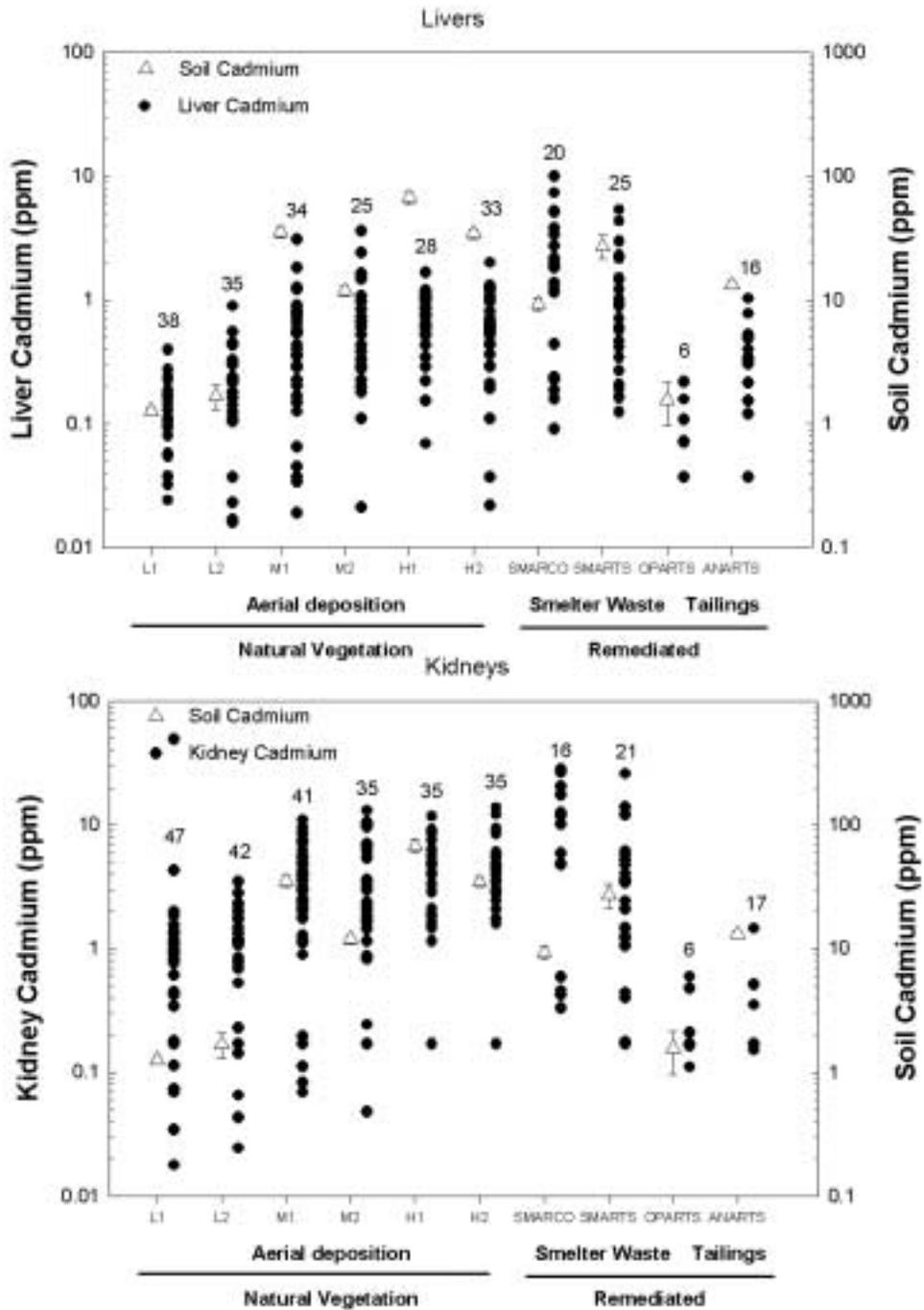
**Figure 6-10.** Mean ( $\pm$ SE) copper concentrations in soil ( $\Delta$ ) and individual deer mouse blood samples ( $\bullet$ ) collected from ten study sites in 1999 and 2000 at the Anaconda Smelter NPL site in Anaconda, Montana. Numbers above scatter plots indicate total number of blood samples collected from each site. Sample size for Cu soil means was 24 to 25 for natural vegetation sites and 9 to 10 for remediated sites.



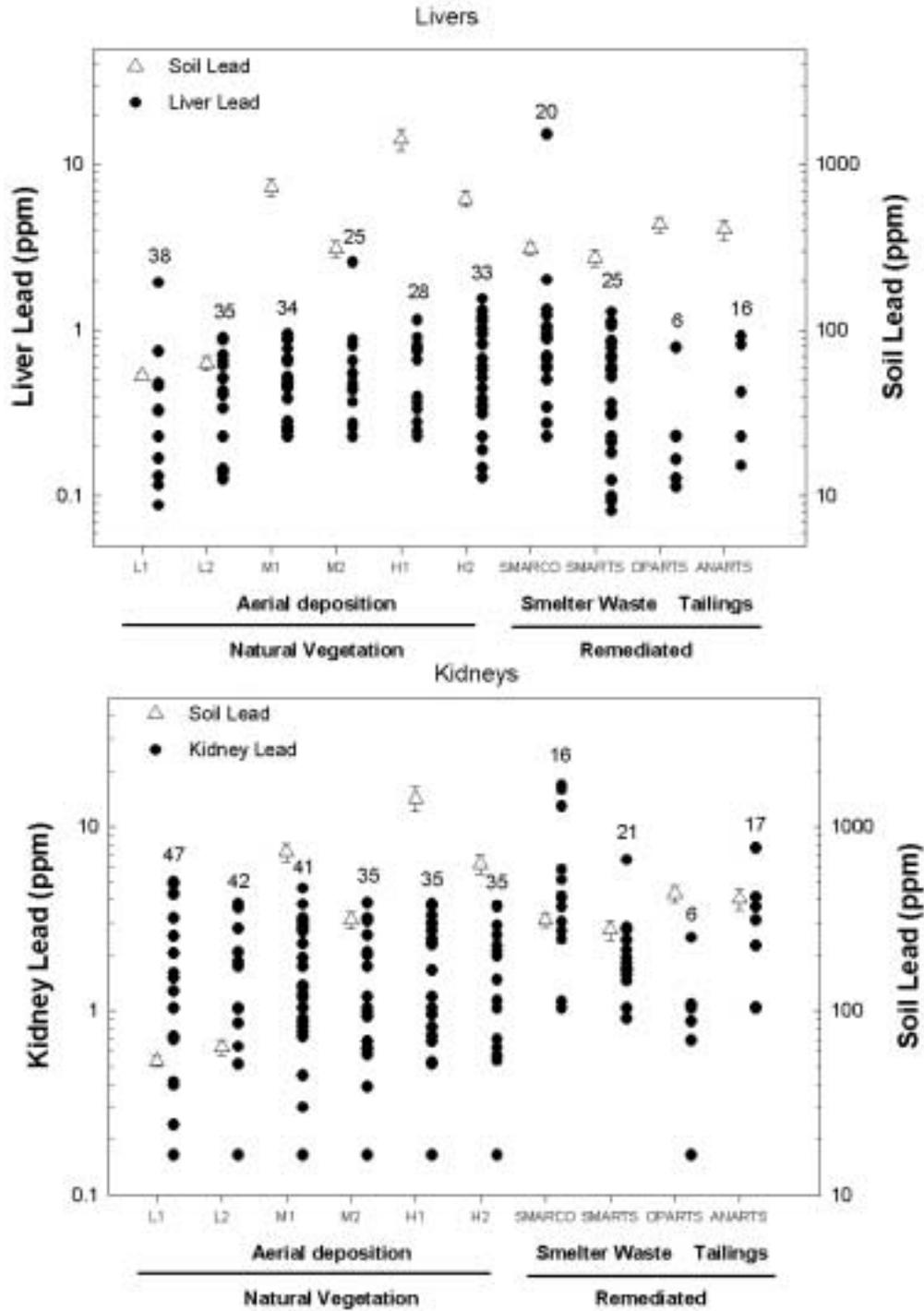
**Figure 6-11.** Mean ( $\pm$ SE) zinc concentrations in soil ( $\Delta$ ) and individual deer mouse blood samples ( $\bullet$ ) collected from ten study sites in 1999 and 2000 at the Anaconda Smelter NPL site in Anaconda, Montana. Numbers above scatter plots indicate total number of blood samples collected from each site. Sample size for Zn soil means was 24 to 25 for natural vegetation sites and 9 to 10 for remediated sites.



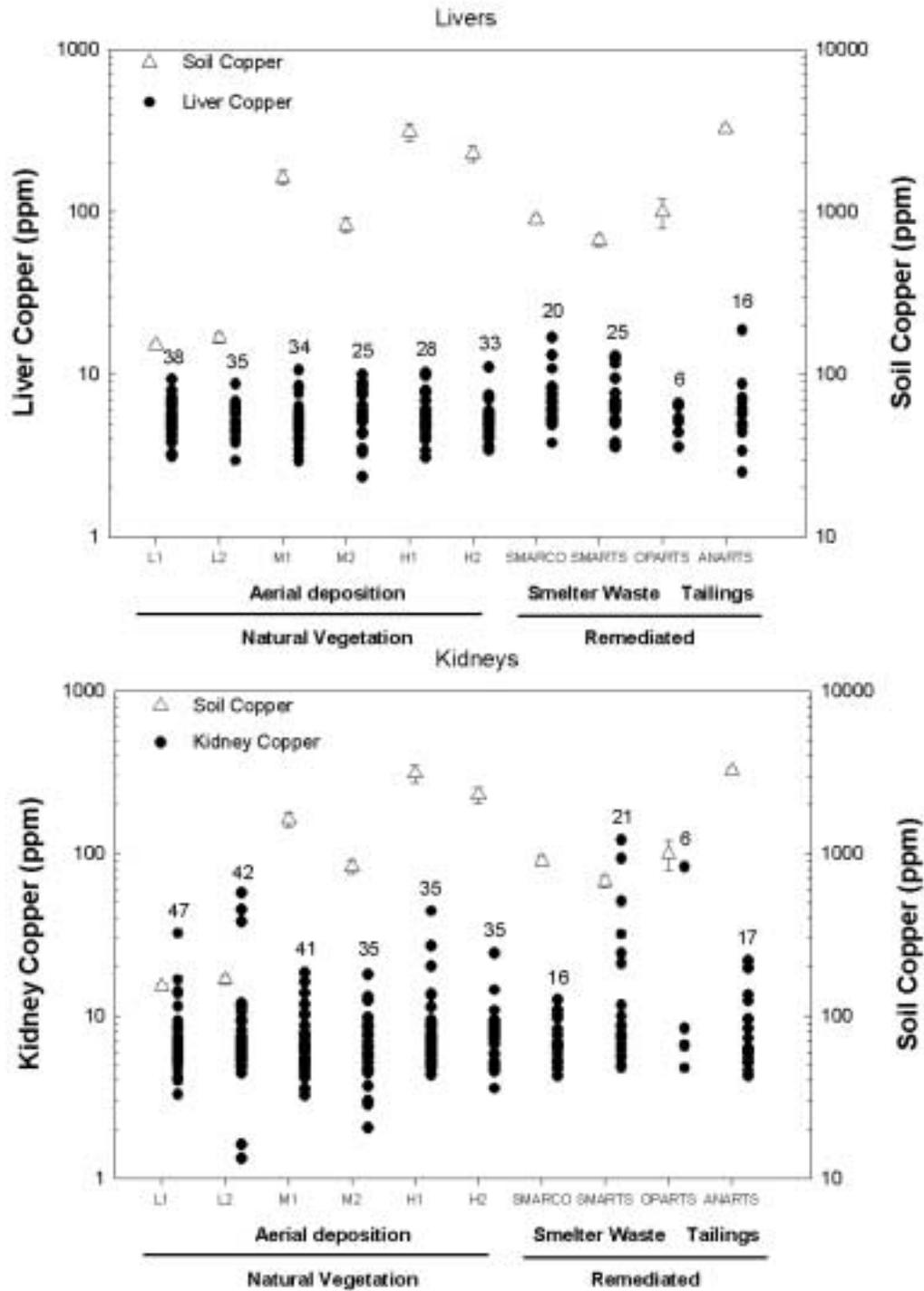
**Figure 6-12.** Mean ( $\pm$ SE) arsenic concentrations in soil ( $-\Delta-$ ) and individual deer mouse liver and kidney samples ( $-\bullet-$ ) collected from ten study sites in 1999 and 2000 at the Anaconda Smelter NPL site in Anaconda, Montana. Numbers above scatter plots indicate total number of tissue samples collected from each site. Sample size for As soil means was 24 to 25 for natural vegetation sites and 9 to 10 for remediated sites.



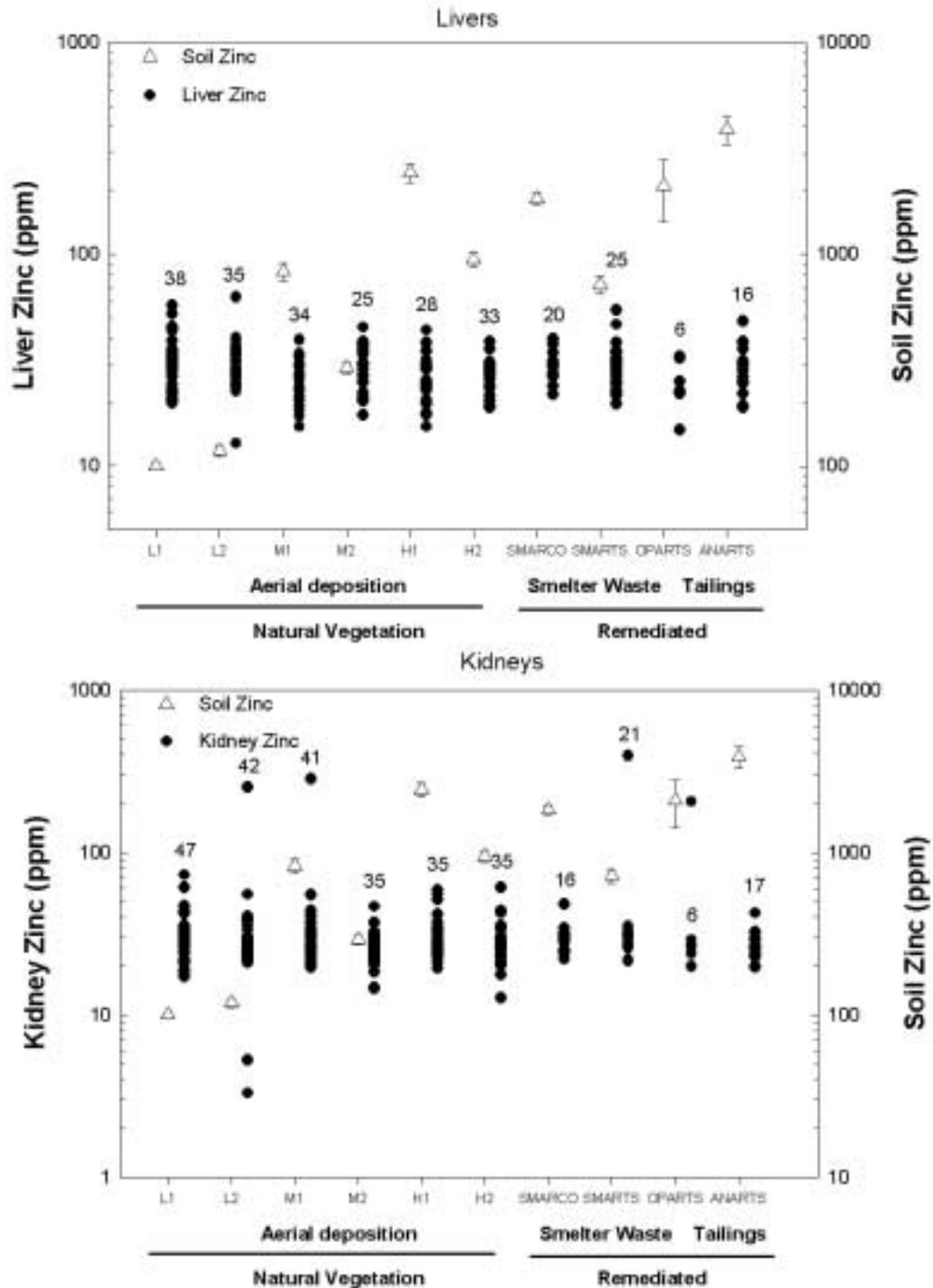
**Figure 6-13.** Mean ( $\pm$ SE) cadmium concentrations in soil ( $\Delta$ ) and individual deer mouse liver and kidney samples ( $\bullet$ ) collected from ten study sites in 1999 and 2000 at the Anaconda Smelter NPL site in Anaconda, Montana. Numbers above scatter plots indicate total number of tissue samples collected from each site. Sample size for Cd soil means was 24 to 25 for natural vegetation sites and 9 to 10 for remediated sites.



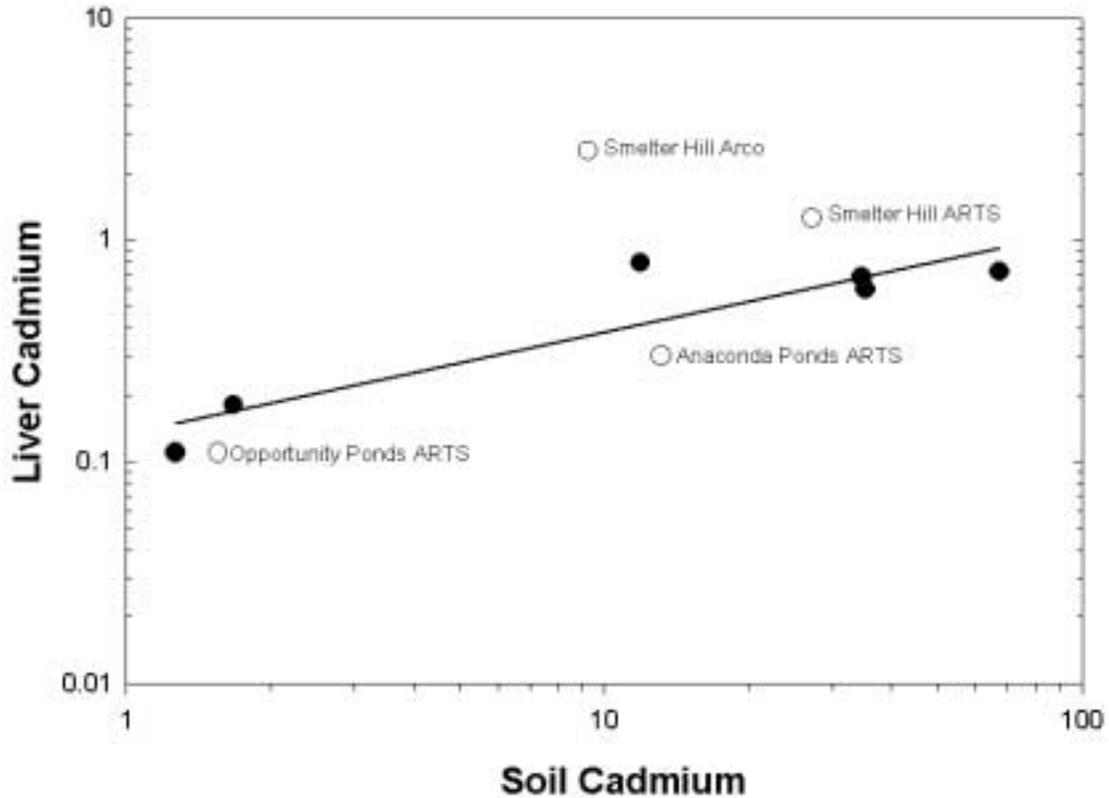
**Figure 6-14.** Mean ( $\pm$ SE) lead concentrations in soil (- $\Delta$ -) and individual deer mouse liver and kidney samples (- $\bullet$ -) collected from ten study sites in 1999 and 2000 at the Anaconda Smelter NPL site in Anaconda, Montana. Numbers above scatter plots indicate total number of tissue samples collected from each site. Sample size for Pb soil means was 24 to 25 for natural vegetation sites and 9 to 10 for remediated sites.



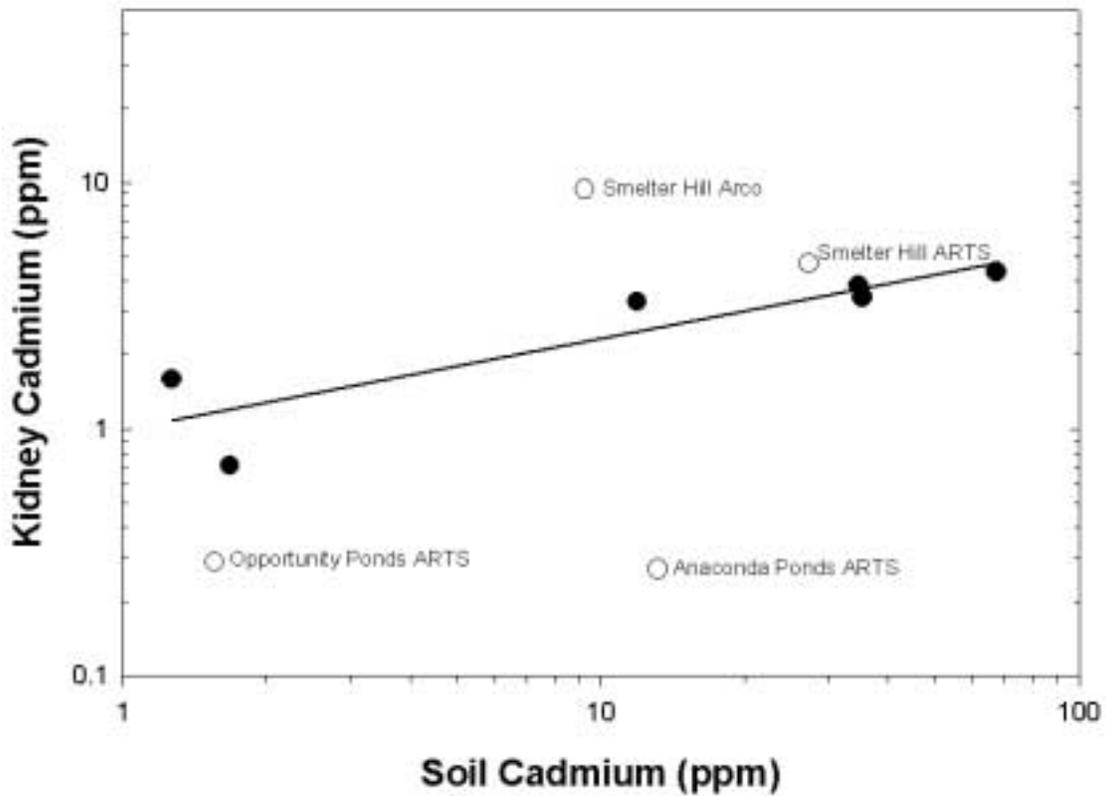
**Figure 6-15.** Mean ( $\pm$ SE) copper concentrations in soil ( $\Delta$ ) and individual deer mouse liver and kidney samples ( $\bullet$ ) collected from ten study sites in 1999 and 2000 at the Anaconda Smelter NPL site in Anaconda, Montana. Numbers above scatter plots indicate total number of tissue samples collected from each site. Sample size for Cu soil means was 24 to 25 for natural vegetation sites and 9 to 10 for remediated sites.



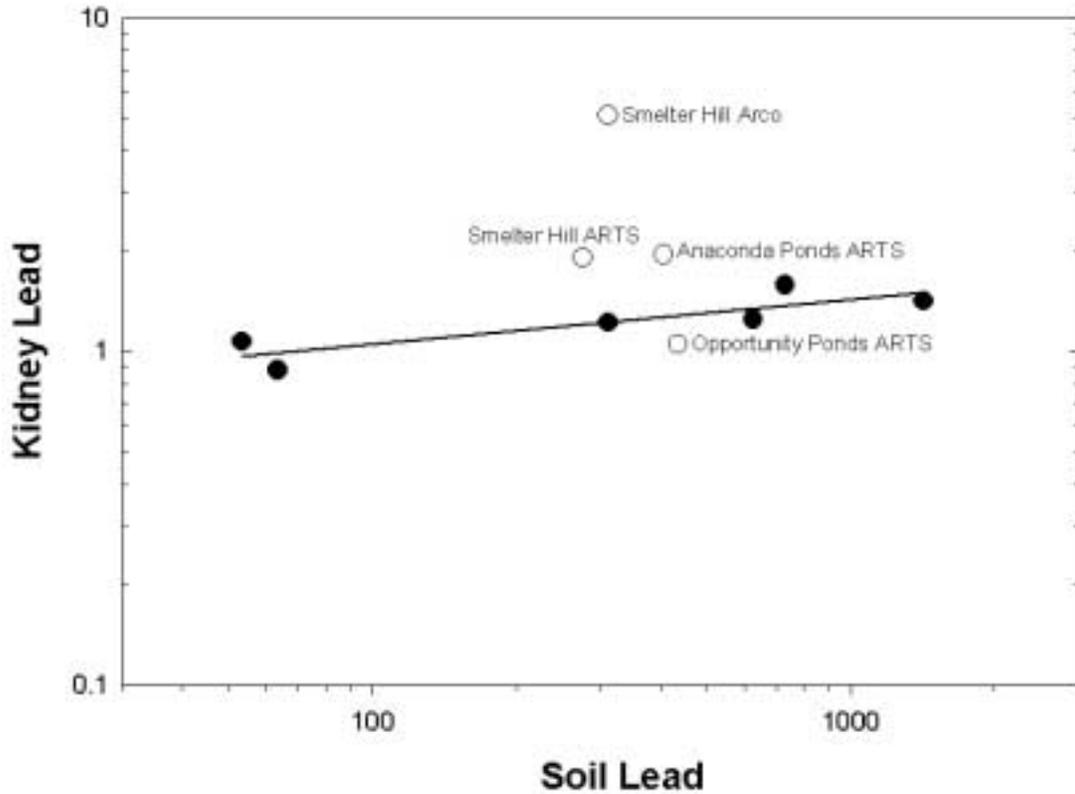
**Figure 6-16.** Mean ( $\pm$ SE) zinc concentrations in soil ( $-\Delta-$ ) and individual deer mouse liver and kidney samples ( $-\bullet-$ ) collected from ten study sites in 1999 and 2000 at the Anaconda Smelter NPL site in Anaconda, Montana. Numbers above scatter plots indicate total number of tissue samples collected from each site. Sample size for Zn soil means was 24 to 25 for natural vegetation sites and 9 to 10 for remediated sites.



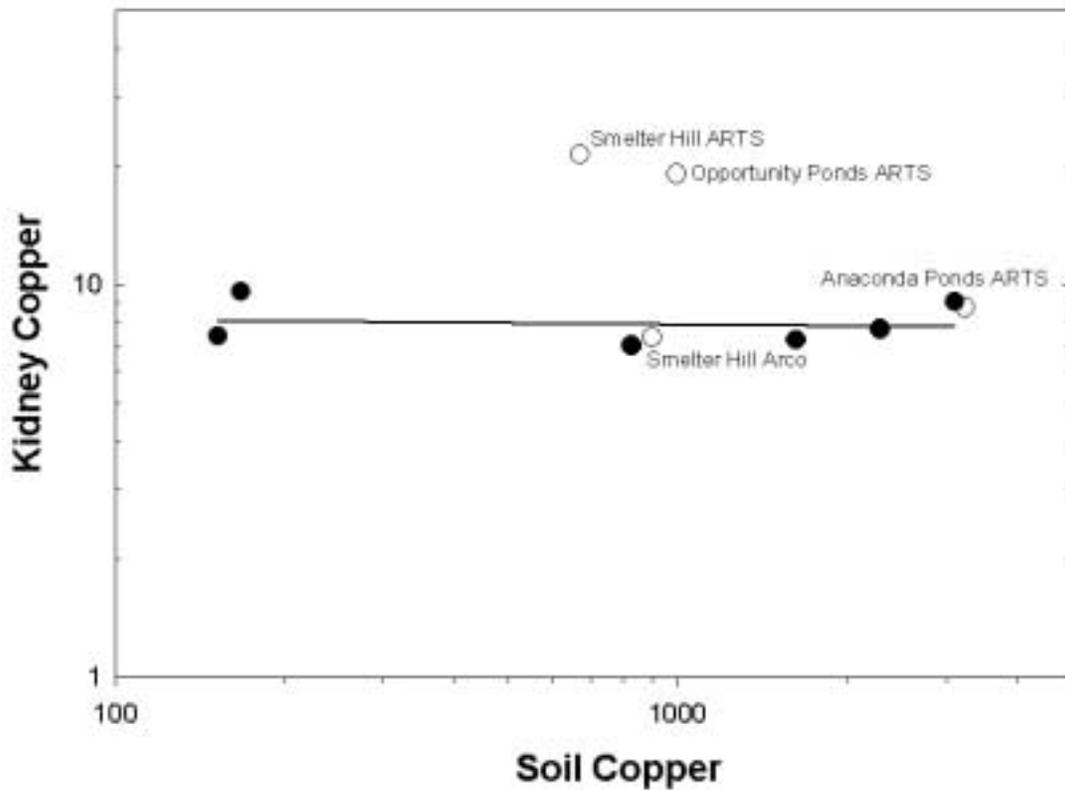
**Figure 6-17.** Regression analysis expressing changes in mean deer mice liver Cd concentrations collected on natural vegetation sites (-●-) as a function of mean soil Cd concentrations. Regression line shown is calculated to fit only the natural vegetation sites. Remediated sites (-○-) are not used in the regression calculation but are plotted as an attempt to show differences in Cd bioavailability between remediated and natural vegetation sites.



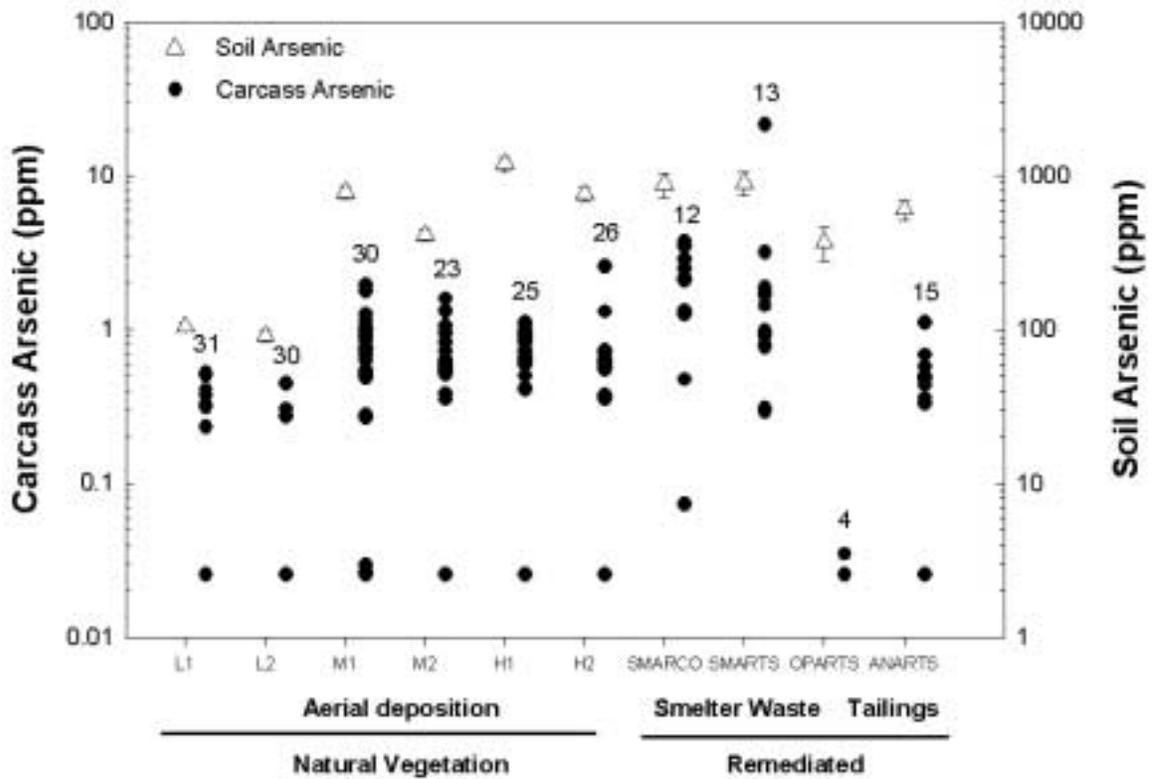
**Figure 6-18.** Regression analysis expressing changes in mean deer mice kidney Cd concentrations collected on natural vegetation sites (-●-) as a function of mean soil Cd concentrations. Regression line shown is calculated to fit only the natural vegetation sites. Remediated sites (-○-) are not used in the regression calculation but are plotted as an attempt to show differences in Cd bioavailability between remediated and natural vegetation sites.



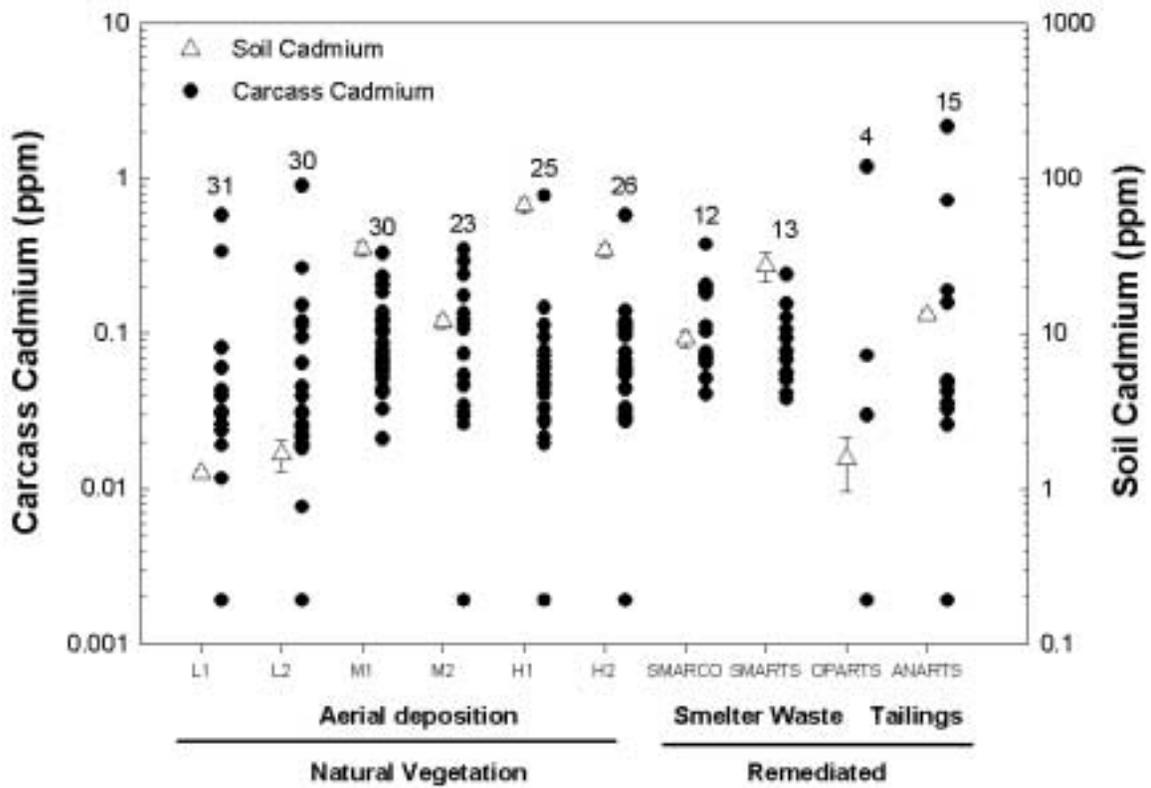
**Figure 6-19.** Regression analysis expressing changes in mean deer mice kidney Pb concentrations collected on natural vegetation sites (-●-) as a function of mean soil Pb concentrations. Regression line shown is calculated to fit only the natural vegetation sites. Remediated sites (-○-) are not used in the regression calculation but are plotted as an attempt to show differences in Pb bioavailability between remediated and natural vegetation sites.



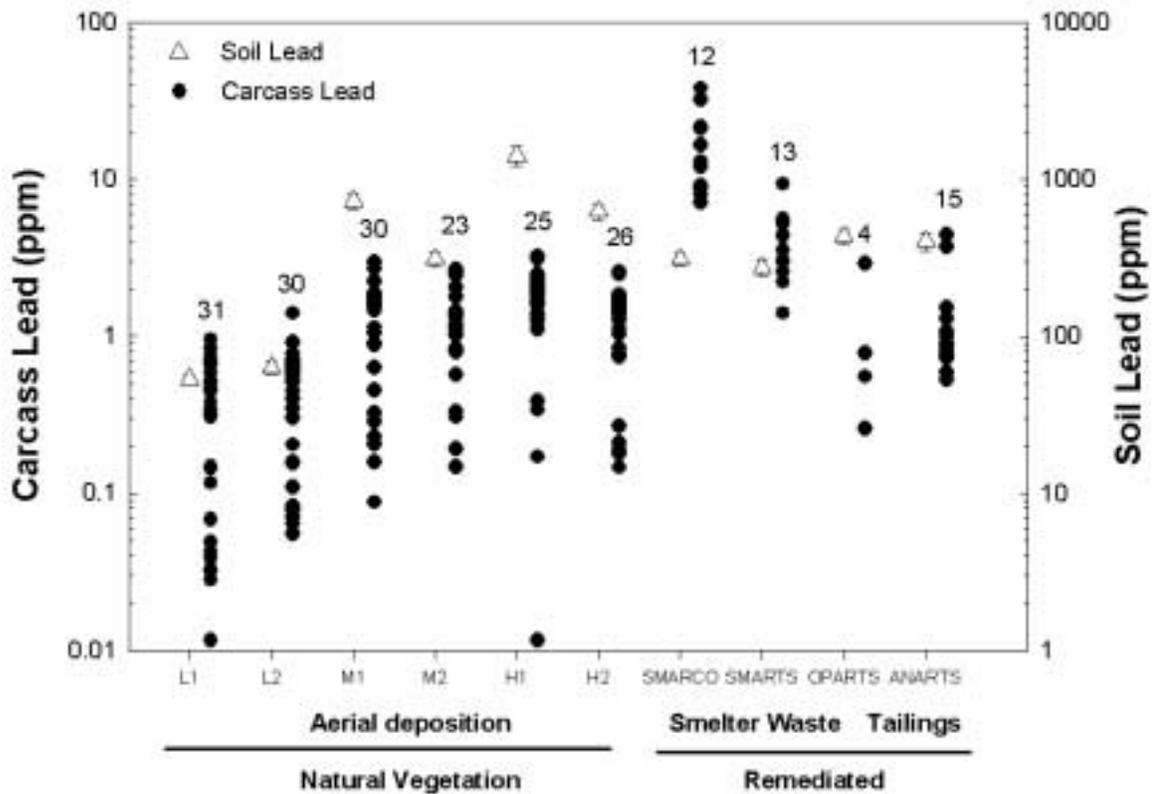
**Figure 6-20.** Regression analysis expressing changes in mean deer mice kidney Cu concentrations collected on natural vegetation sites (-●-) as a function of mean soil Cu concentrations. Regression line shown is calculated to fit only the natural vegetation sites. Remediated sites (-○-) are not used in the regression calculation but are plotted as an attempt to show differences in Cu bioavailability between remediated and natural vegetation sites.



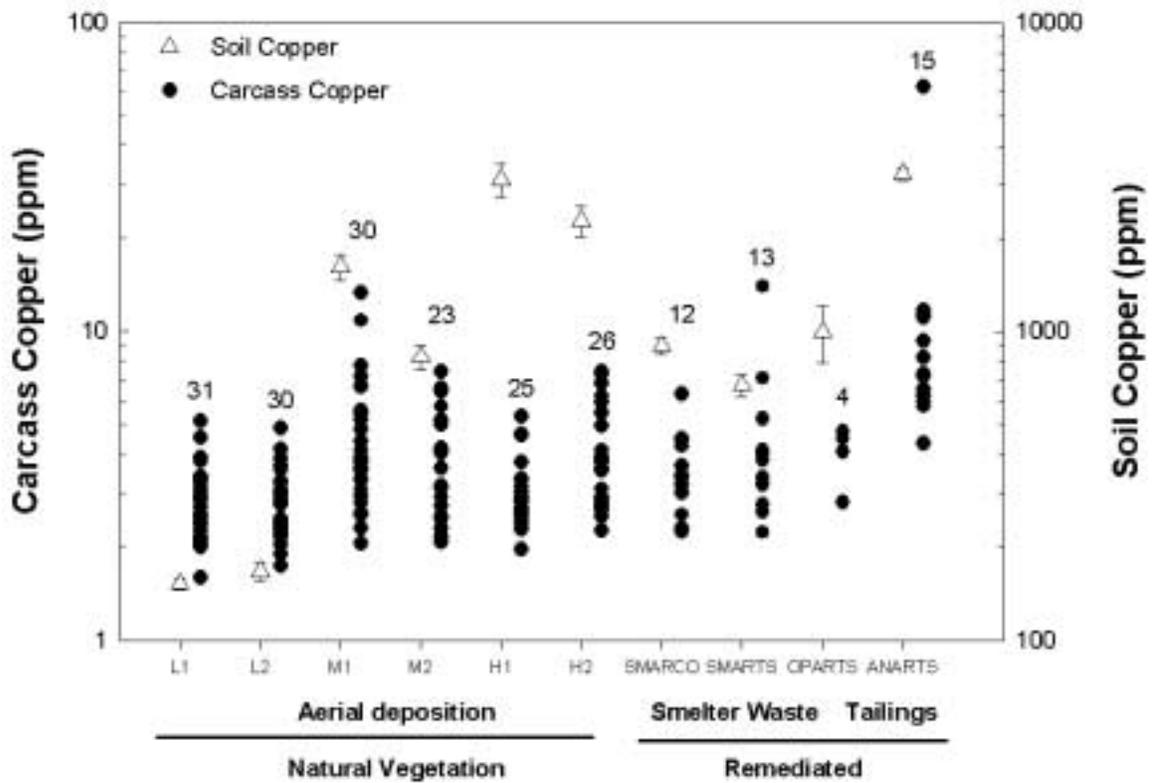
**Figure 6-21.** Mean ( $\pm$ SE) arsenic concentrations in soil ( $\Delta$ ) and individual deer mouse carcass samples ( $\bullet$ ) collected from ten study sites in 1999 and 2000 at the Anaconda Smelter NPL site in Anaconda, Montana. Numbers above scatter plots indicate total number of carcasses collected from each site. Sample size for As soil means was 24 to 25 for natural vegetation sites and 9 to 10 for remediated sites.



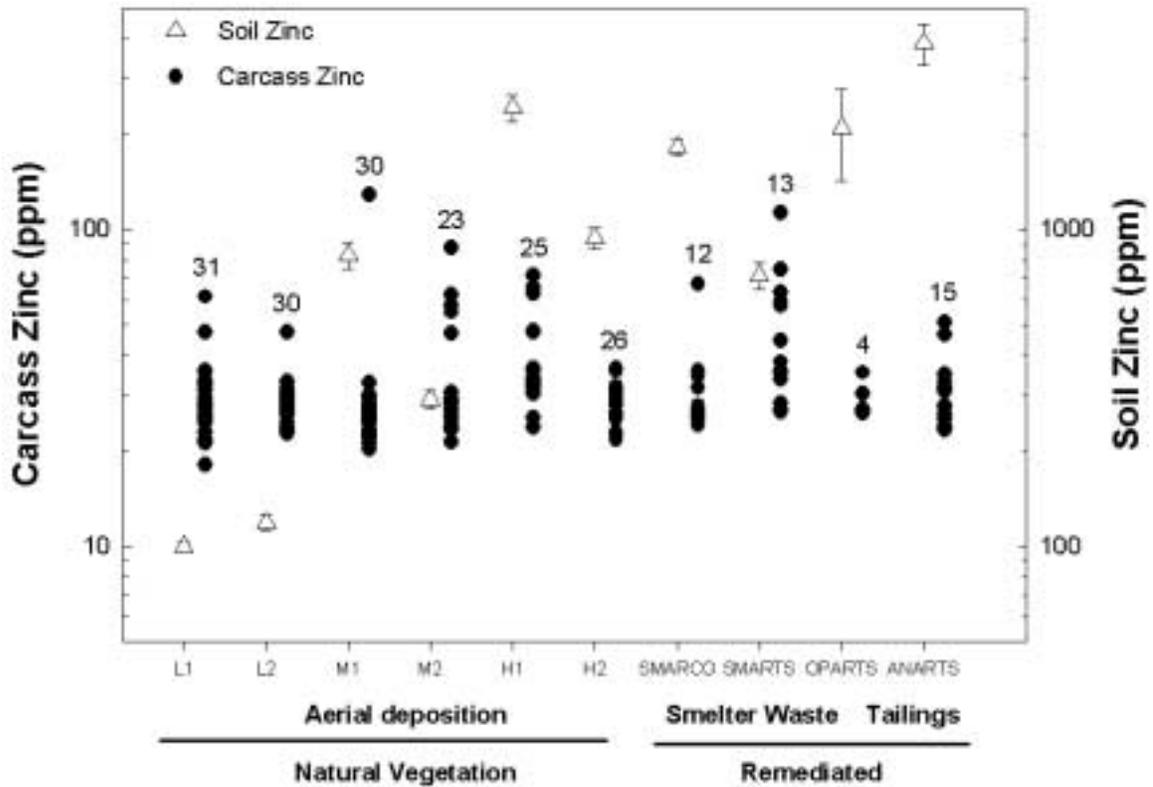
**Figure 6-22.** Mean ( $\pm$ SE) cadmium concentrations in soil ( $\Delta$ ) and individual deer mouse carcass samples ( $\bullet$ ) collected from ten study sites in 1999 and 2000 at the Anaconda Smelter NPL site in Anaconda, Montana. Numbers above scatter plots indicate total number of carcasses collected from each site. Sample size for Cd soil means was 24 to 25 for natural vegetation sites and 9 to 10 for remediated sites.



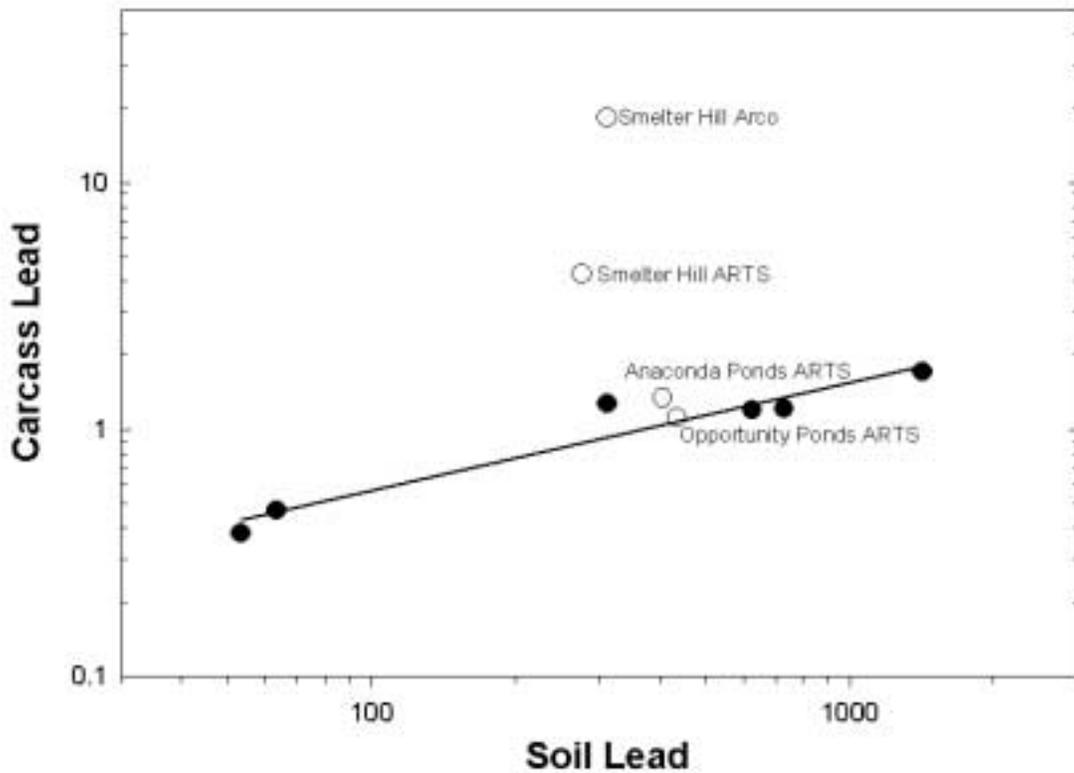
**Figure 6-23.** Mean ( $\pm$ SE) lead concentrations in soil ( $\Delta$ ) and individual deer mouse carcass samples ( $\bullet$ ) collected from ten study sites in 1999 and 2000 at the Anaconda Smelter NPL site in Anaconda, Montana. Numbers above scatter plots indicate total number of carcasses collected from each site. Sample size for Pb soil means was 24 to 25 for natural vegetation sites and 9 to 10 for remediated sites.



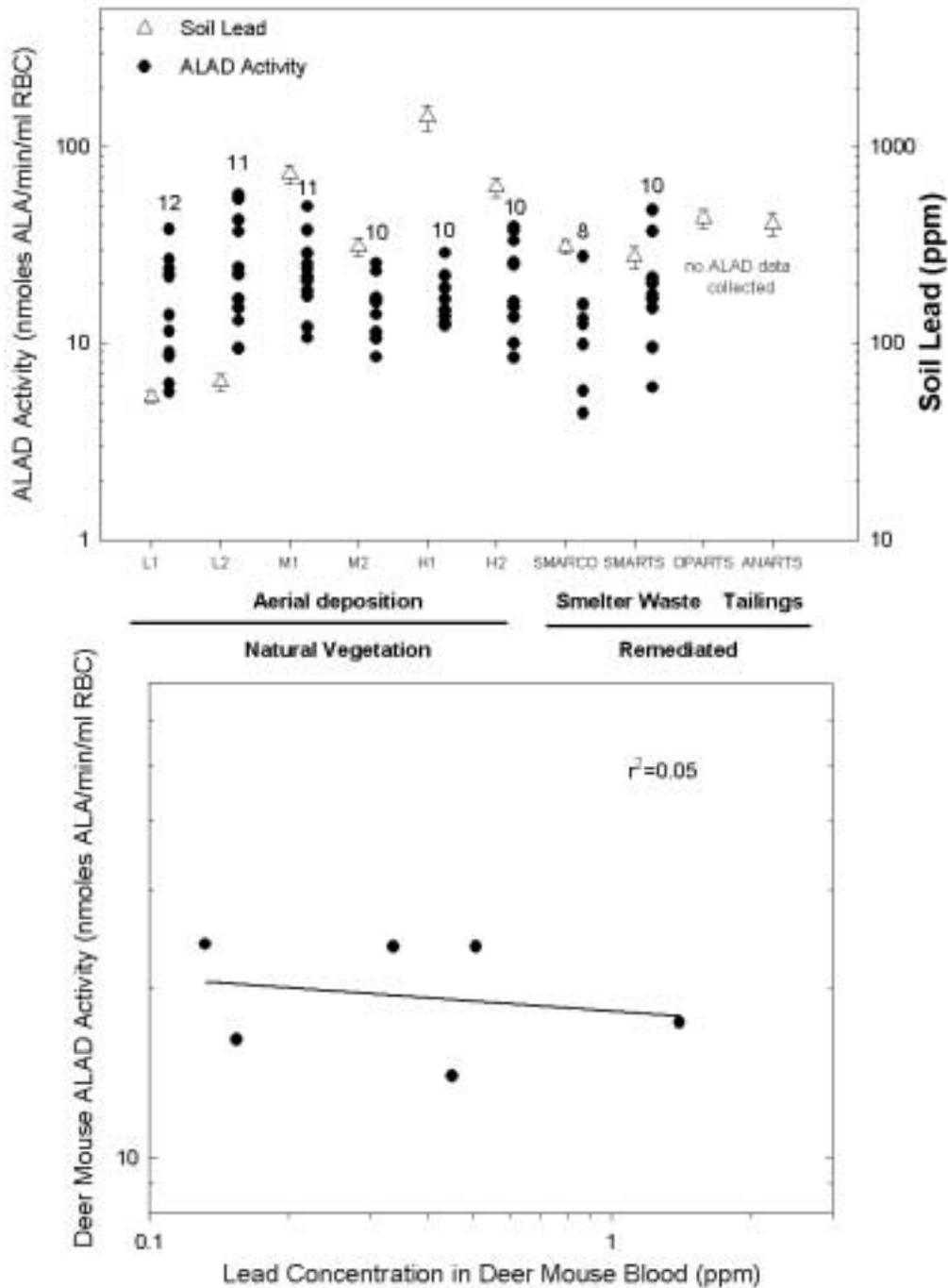
**Figure 6-24.** Mean ( $\pm$ SE) copper concentrations in soil ( $\Delta$ ) and individual deer mouse carcass samples ( $\bullet$ ) collected from ten study sites in 1999 and 2000 at the Anaconda Smelter NPL site in Anaconda, Montana. Numbers above scatter plots indicate total number of carcasses collected from each site. Sample size for Cu soil means was 24 to 25 for natural vegetation sites and 9 to 10 for remediated sites.



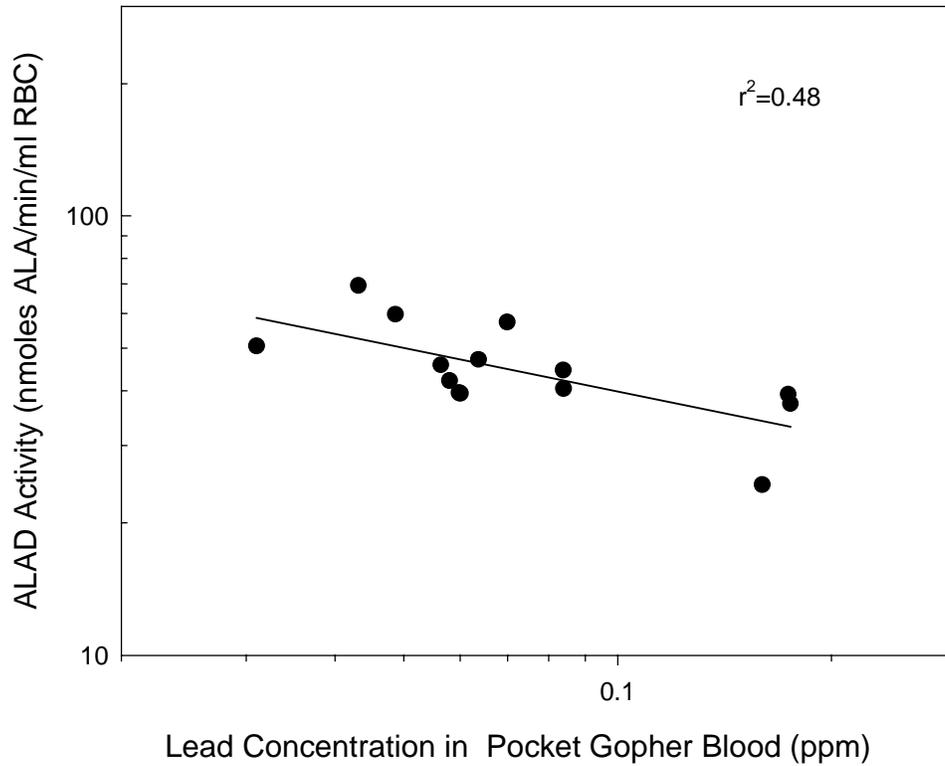
**Figure 6-25.** Mean ( $\pm$ SE) zinc concentrations in soil ( $\Delta$ ) and individual deer mouse carcass samples ( $\bullet$ ) collected from ten study sites in 1999 and 2000 at the Anaconda Smelter NPL site in Anaconda, Montana. Numbers above scatter plots indicate total number of carcasses collected from each site. Sample size for Zn soil means was 24 to 25 for natural vegetation sites and 9 to 10 for remediated sites.



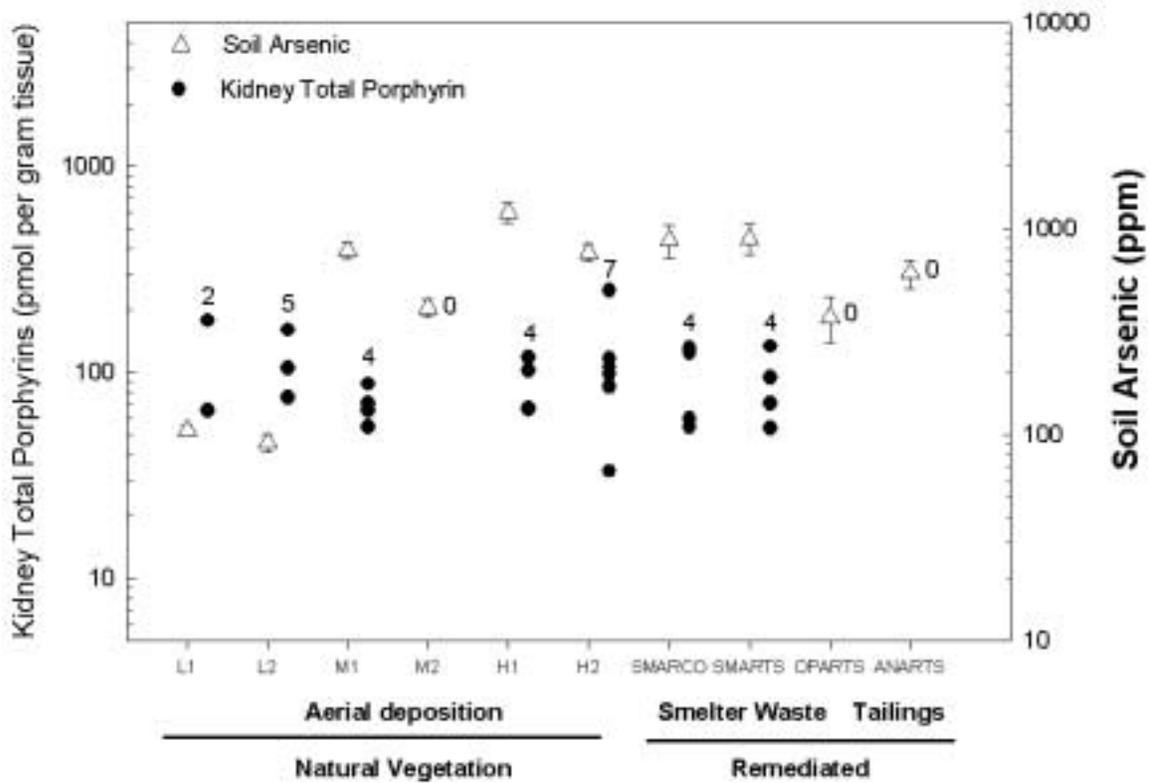
**Figure 6-26.** Regression analysis expressing changes in mean deer mice carcass Pb concentrations collected on natural vegetation sites (-●-) as a function of mean soil Pb concentrations. Regression line shown is calculated to fit only the natural vegetation sites. Remediated sites (-○-) are not used in the regression calculation but are plotted as an attempt to show differences in Pb bioavailability between remediated and natural vegetation sites.



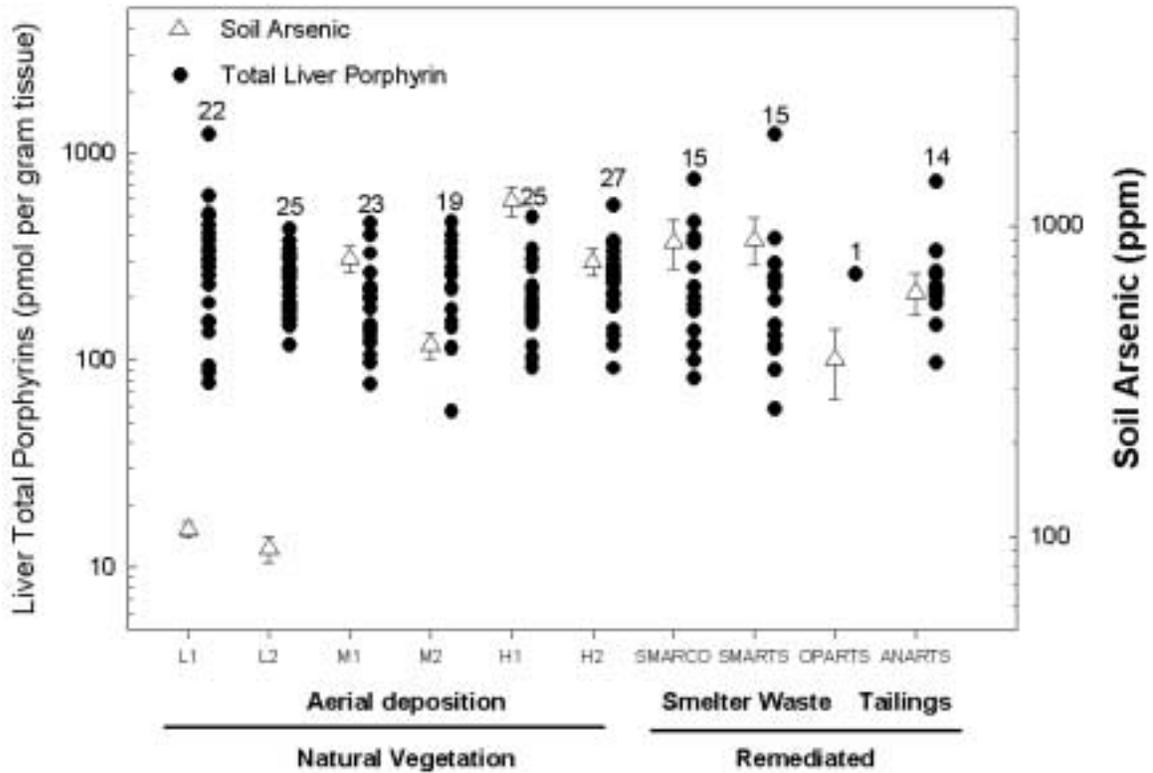
**Figure 6-27.** Mean ( $\pm$ SE) lead concentrations in soil (- $\Delta$ -) and ALAD activity in individual deer mouse blood samples (- $\bullet$ -) collected from eight study sites in 2000 at the Anaconda Smelter NPL site in Anaconda, Montana. Numbers above scatter plots indicate total number of blood samples collected for ALAD analysis from each site. Sample size for Pb soil means was 24 to 25 for natural vegetation sites and 9 to 10 for remediated sites. Regression analysis expresses changes in deer mouse ALAD activity as a function of Pb concentration in respective deer mouse blood samples.



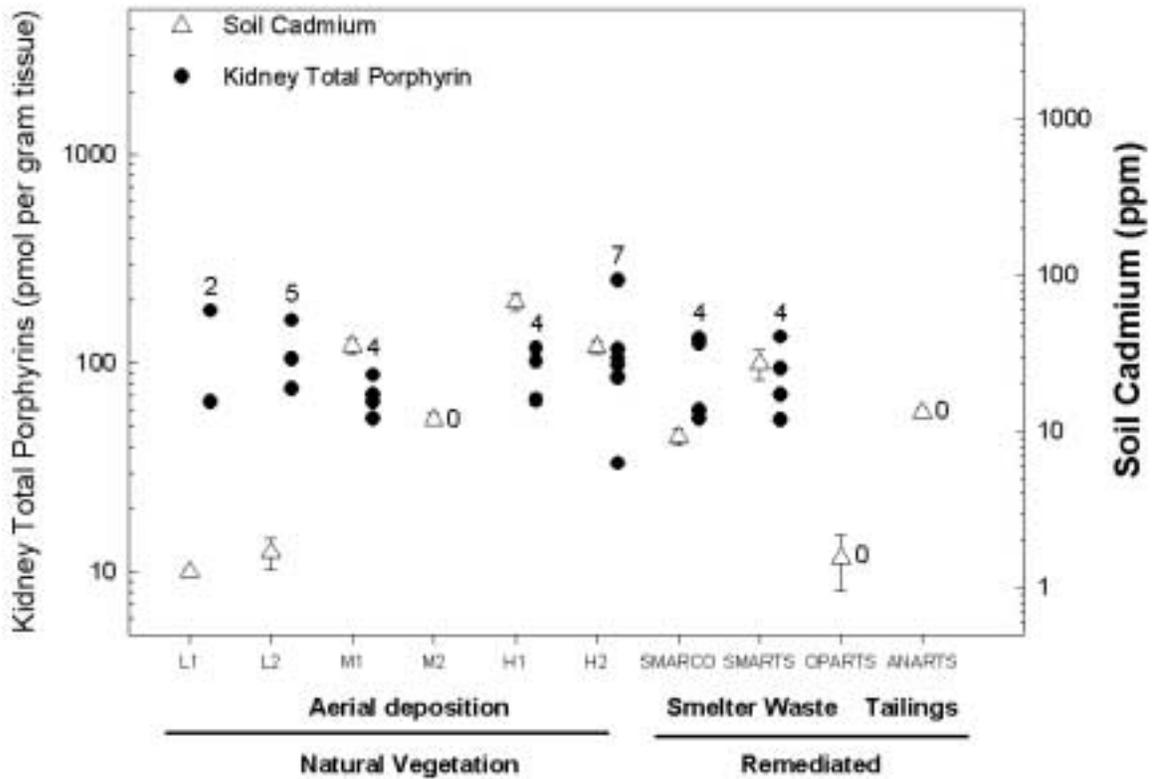
**Figure 6-28.** Regression analysis expressing changes in pocket gopher blood ALAD activity as a function of Pb concentration in respective pocket gopher blood samples. Gophers were collected from three natural vegetation study sites in 2000 at the Anaconda Smelter NPL site in Anaconda, Montana.



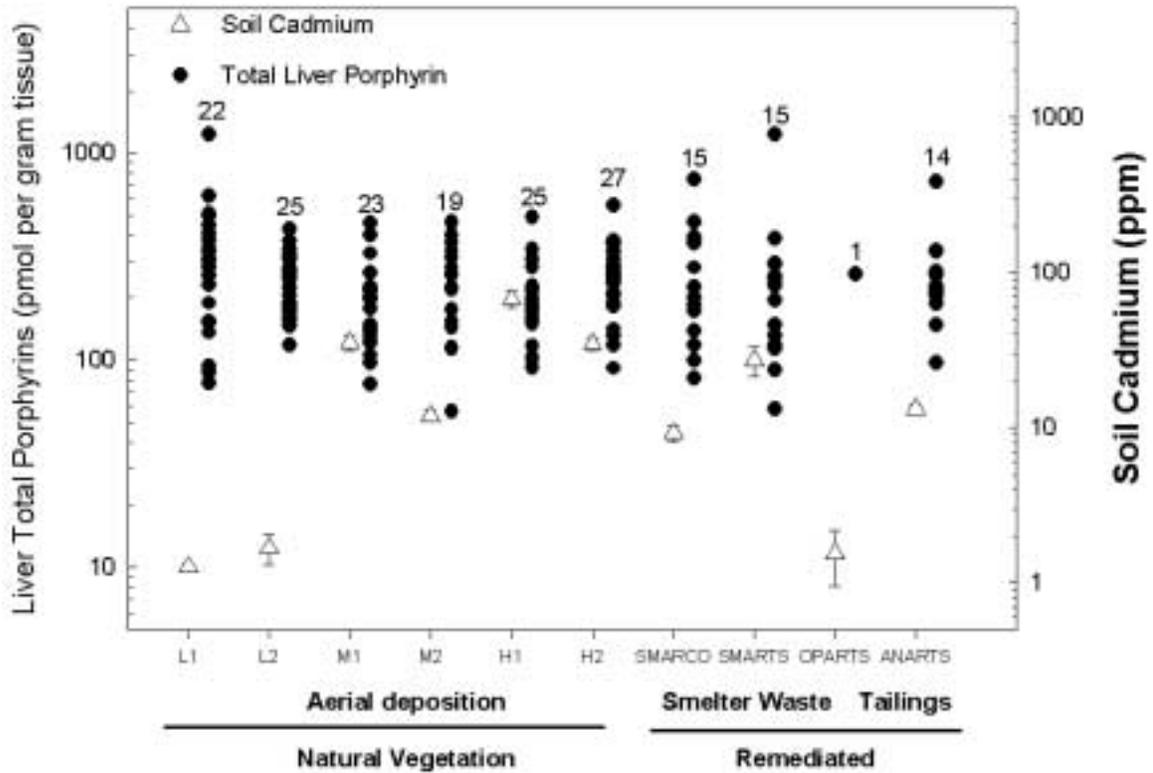
**Figure 6-29.** Mean ( $\pm$ SE) arsenic concentrations in soil ( $-\Delta-$ ) and total porphyrins in individual deer mouse kidney samples ( $-\bullet-$ ) collected from ten study sites in 1999 at the Anaconda Smelter NPL site in Anaconda, Montana. Numbers above scatter plots indicate total number of kidneys collected from each site for total porphyrin analysis. Sample size for As soil means was 24 to 25 for natural vegetation sites and 9 to 10 for remediated sites.



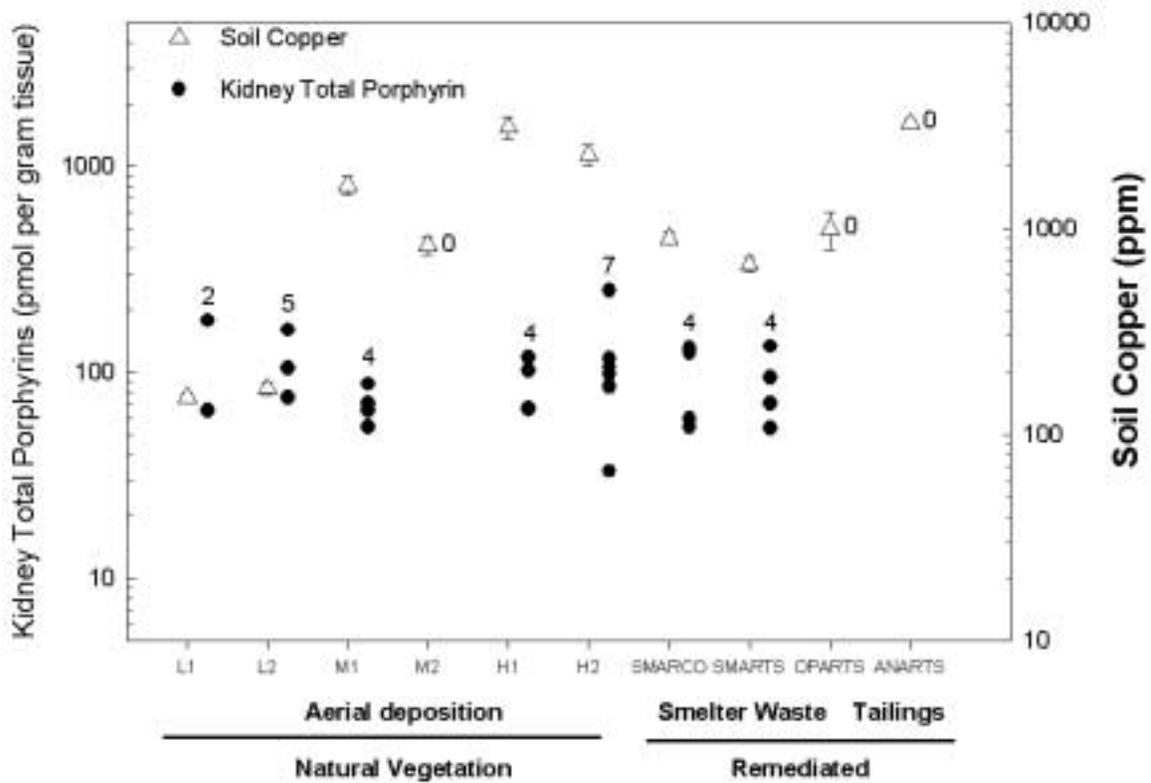
**Figure 6-30.** Mean ( $\pm$ SE) arsenic concentrations in soil ( $-\Delta-$ ) and total porphyrins in individual deer mouse liver samples ( $-\bullet-$ ) collected from ten study sites in 1999 at the Anaconda Smelter NPL site in Anaconda, Montana. Numbers above scatter plots indicate total number of livers collected from each site for total porphyrin analysis. Sample size for As soil means was 24 to 25 for natural vegetation sites and 9 to 10 for remediated sites.



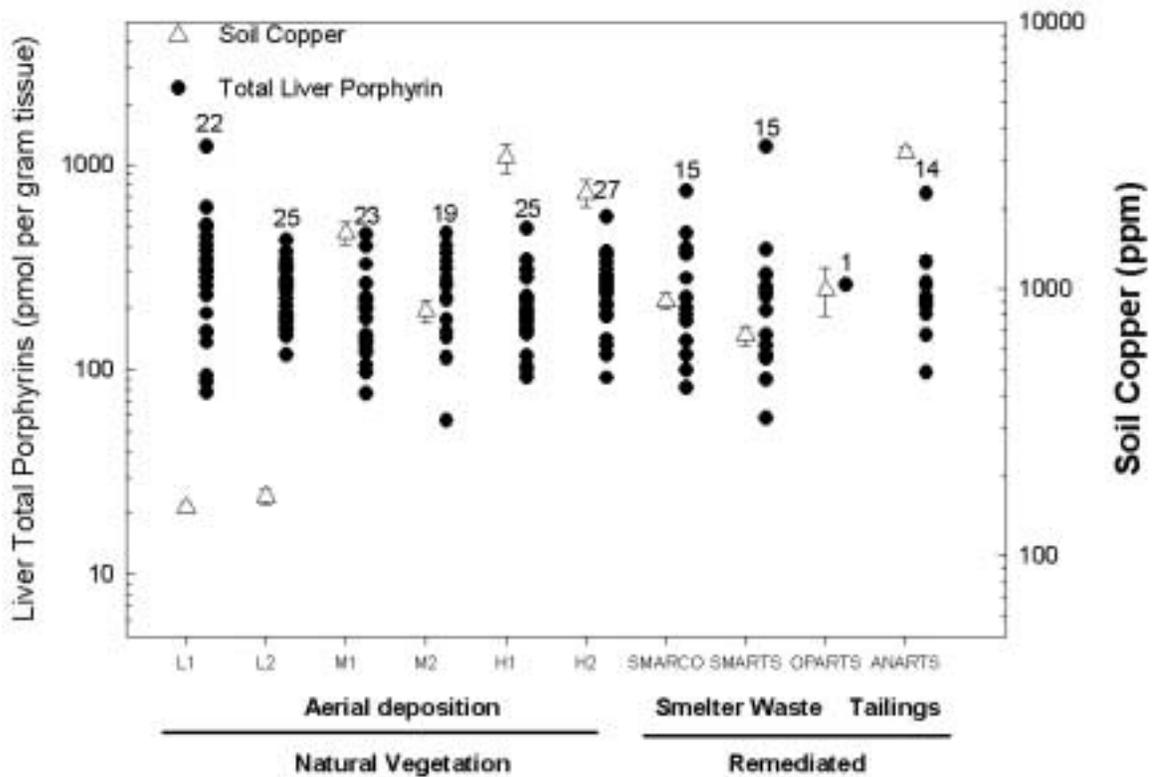
**Figure 6-31.** Mean ( $\pm$ SE) cadmium concentrations in soil ( $-\Delta-$ ) and total porphyrins in individual deer mouse kidney samples ( $-\bullet-$ ) collected from ten study sites in 1999 at the Anaconda Smelter NPL site in Anaconda, Montana. Numbers above scatter plots indicate total number of kidneys collected from each site for total porphyrin analysis. Sample size for Cd soil means was 24 to 25 for natural vegetation sites and 9 to 10 for remediated sites.



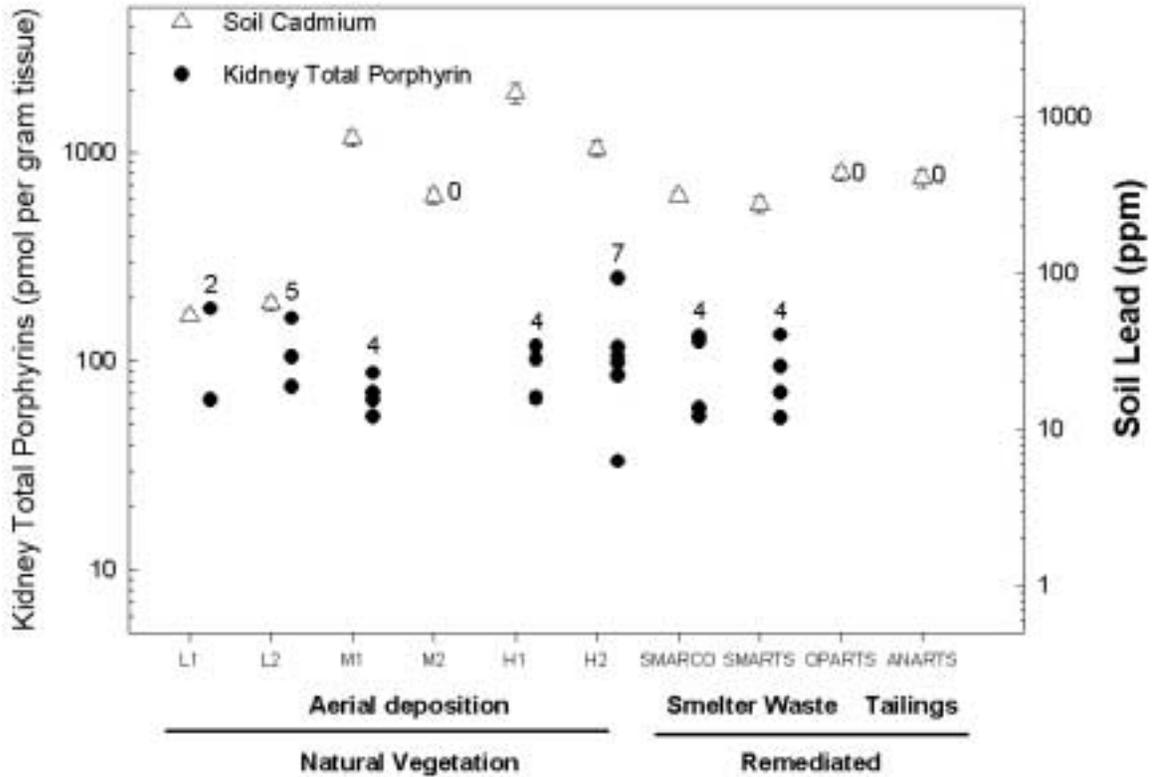
**Figure 6-32.** Mean ( $\pm$ SE) cadmium concentrations in soil (- $\Delta$ -) and total porphyrins in individual deer mouse liver samples (- $\bullet$ -) collected from ten study sites in 1999 at the Anaconda Smelter NPL site in Anaconda, Montana. Numbers above scatter plots indicate total number of livers collected from each site for total porphyrin analysis. Sample size for Cd soil means was 24 to 25 for natural vegetation sites and 9 to 10 for remediated sites.



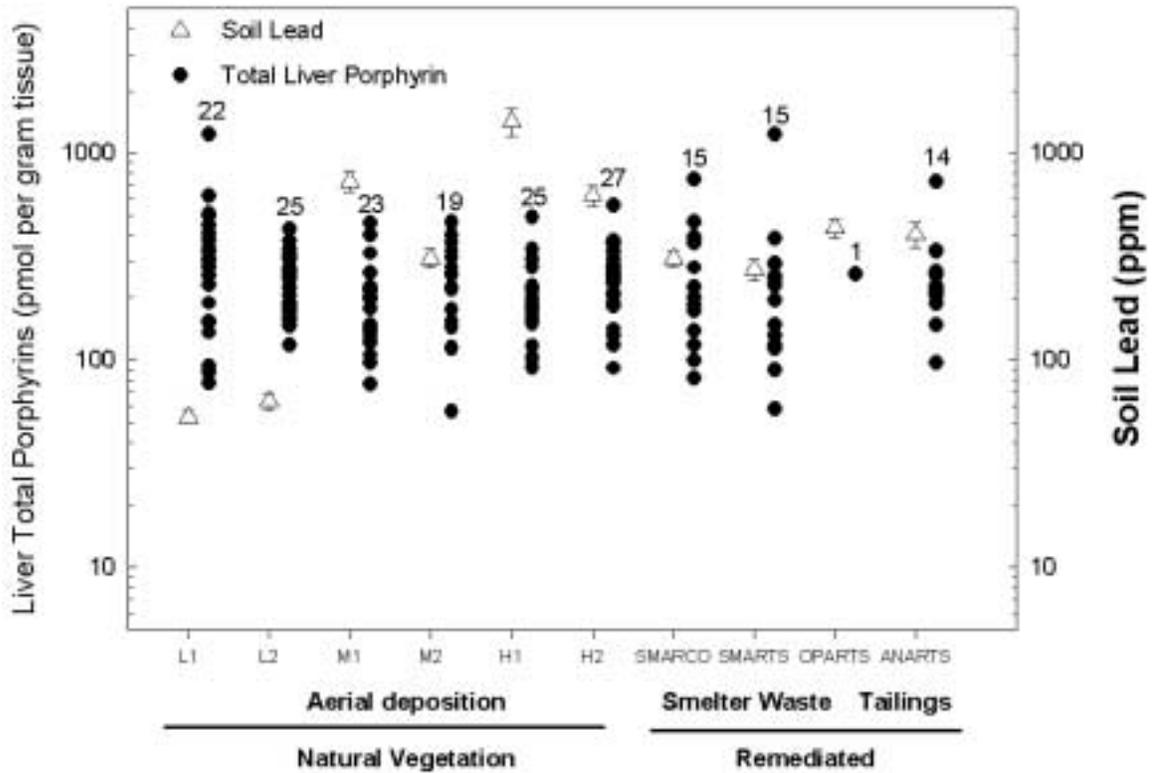
**Figure 6-33.** Mean ( $\pm$ SE) copper concentrations in soil ( $\Delta$ ) and total porphyrins in individual deer mouse kidney samples ( $\bullet$ ) collected from ten study sites in 1999 at the Anaconda Smelter NPL site in Anaconda, Montana. Numbers above scatter plots indicate total number of kidneys collected from each site for total porphyrin analysis. Sample size for Cu soil means was 24 to 25 for natural vegetation sites and 9 to 10 for remediated sites.



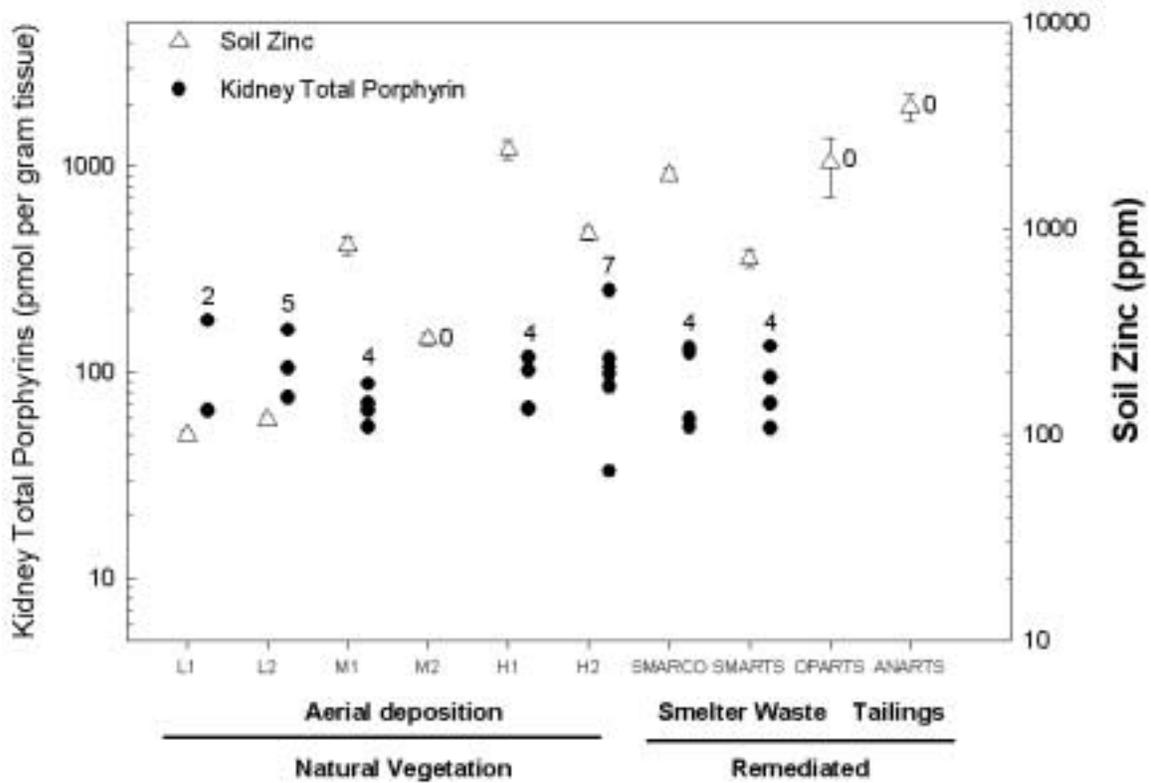
**Figure 6-34.** Mean ( $\pm$ SE) copper concentrations in soil ( $-\Delta-$ ) and total porphyrins in individual deer mouse liver samples ( $-\bullet-$ ) collected from ten study sites in 1999 at the Anaconda Smelter NPL site in Anaconda, Montana. Numbers above scatter plots indicate total number of livers collected from each site for total porphyrin analysis. Sample size for Cu soil means was 24 to 25 for natural vegetation sites and 9 to 10 for remediated sites.



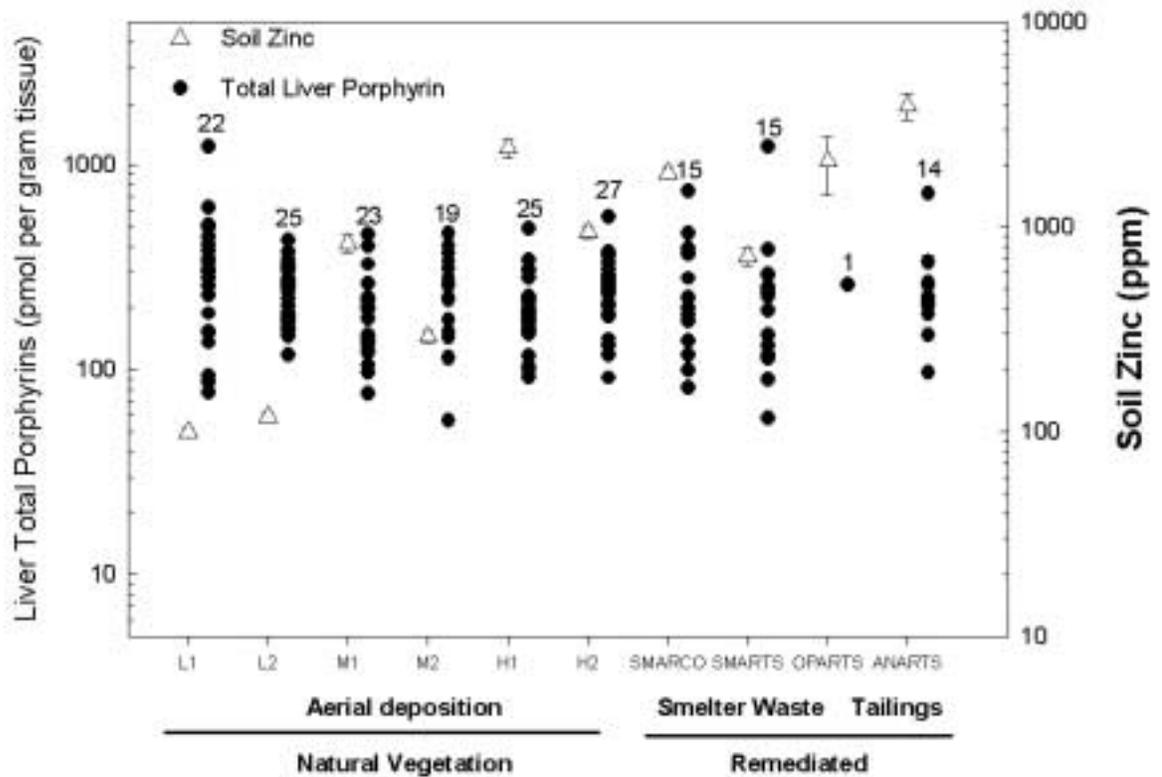
**Figure 6-35.** Mean ( $\pm$ SE) lead concentrations in soil ( $\Delta$ ) and total porphyrins in individual deer mouse kidney samples ( $\bullet$ ) collected from ten study sites in 1999 at the Anaconda Smelter NPL site in Anaconda, Montana. Numbers above scatter plots indicate total number of kidneys collected from each site for total porphyrin analysis. Sample size for Pb soil means was 24 to 25 for natural vegetation sites and 9 to 10 for remediated sites.



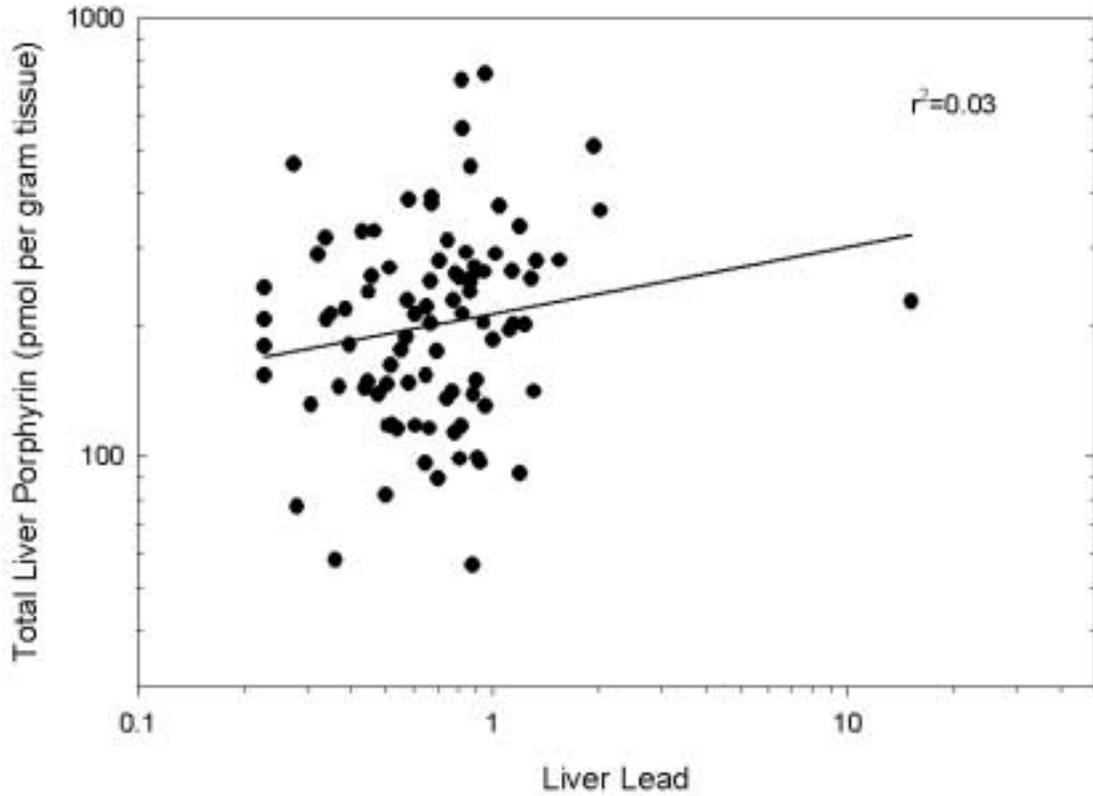
**Figure 6-36.** Mean ( $\pm$ SE) lead concentrations in soil ( $\Delta$ ) and total porphyrins in individual deer mouse liver samples ( $\bullet$ ) collected from ten study sites in 1999 at the Anaconda Smelter NPL site in Anaconda, Montana. Numbers above scatter plots indicate total number of livers collected from each site for total porphyrin analysis. Sample size for Pb soil means was 24 to 25 for natural vegetation sites and 9 to 10 for remediated sites.



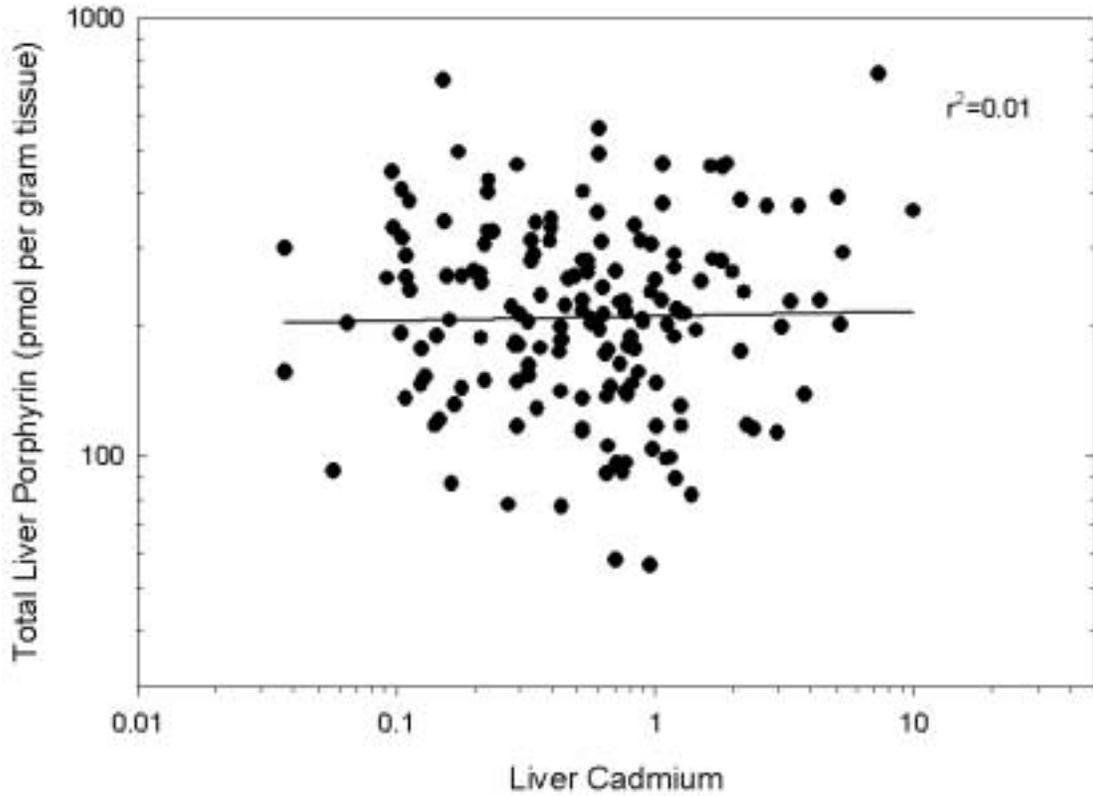
**Figure 6-37.** Mean ( $\pm$ SE) zinc concentrations in soil ( $-\Delta-$ ) and total porphyrins in individual deer mouse kidney samples ( $-\bullet-$ ) collected from ten study sites in 1999 at the Anaconda Smelter NPL site in Anaconda, Montana. Numbers above scatter plots indicate total number of kidneys collected from each site for total porphyrin analysis. Sample size for Zn soil means was 24 to 25 for natural vegetation sites and 9 to 10 for remediated sites.



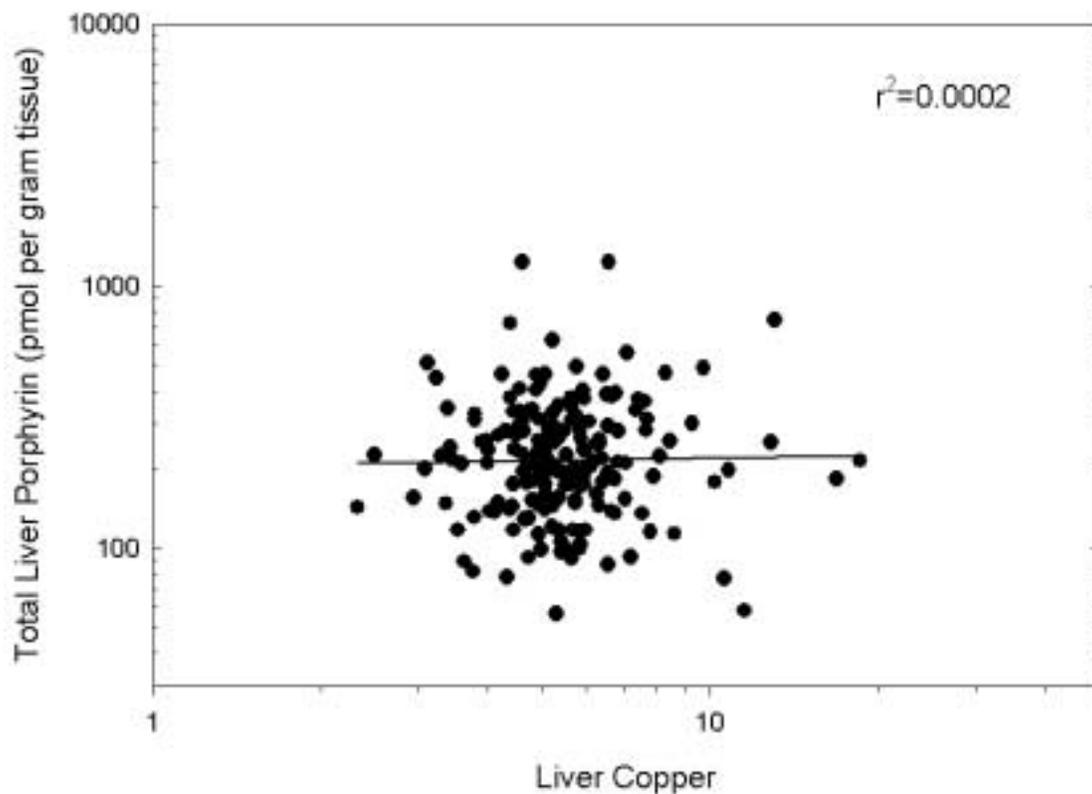
**Figure 6-38.** Mean ( $\pm$ SE) zinc concentrations in soil (- $\Delta$ -) and total porphyrins in individual deer mouse liver samples (- $\bullet$ -) collected from ten study sites in 1999 at the Anaconda Smelter NPL site in Anaconda, Montana. Numbers above scatter plots indicate total number of livers collected from each site for total porphyrin analysis. Sample size for Zn soil means was 24 to 25 for natural vegetation sites and 9 to 10 for remediated sites.



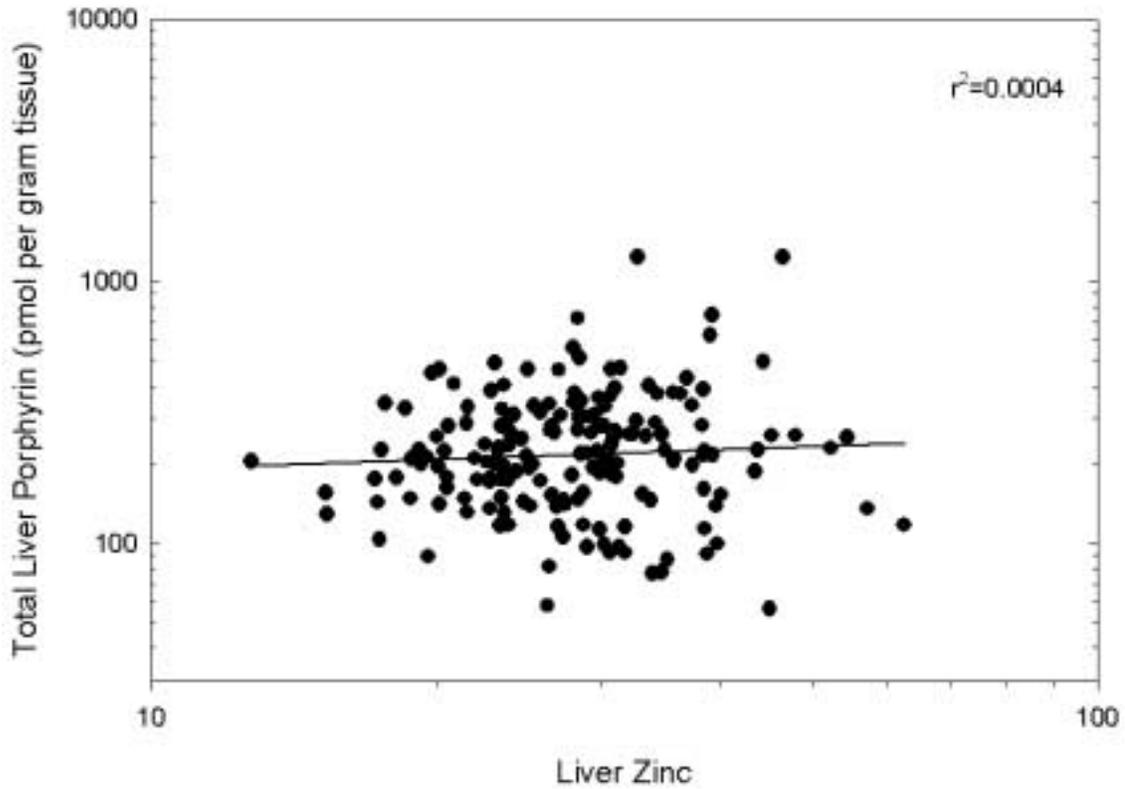
**Figure 6-39.** Regression analysis expressing changes in total porphyrins in individual deer mouse liver samples as a function of Pb concentrations in respective deer mouse liver samples. Deer mice were collected from ten study sites in 1999 at the Anaconda Smelter NPL site in Anaconda, Montana.



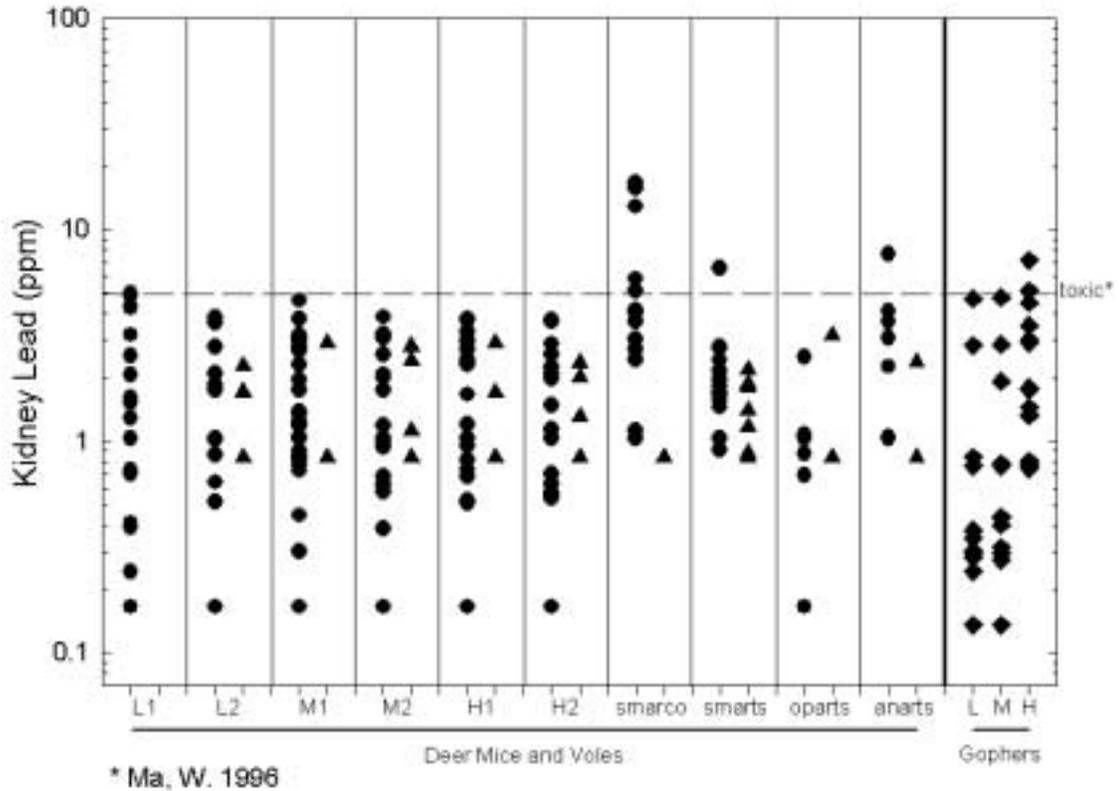
**Figure 6-40.** Regression analysis expressing changes in total porphyrins in individual deer mouse liver samples as a function of Cd concentrations in respective deer mouse liver samples. Deer mice were collected from ten study sites in 1999 at the Anaconda Smelter NPL site in Anaconda, Montana.



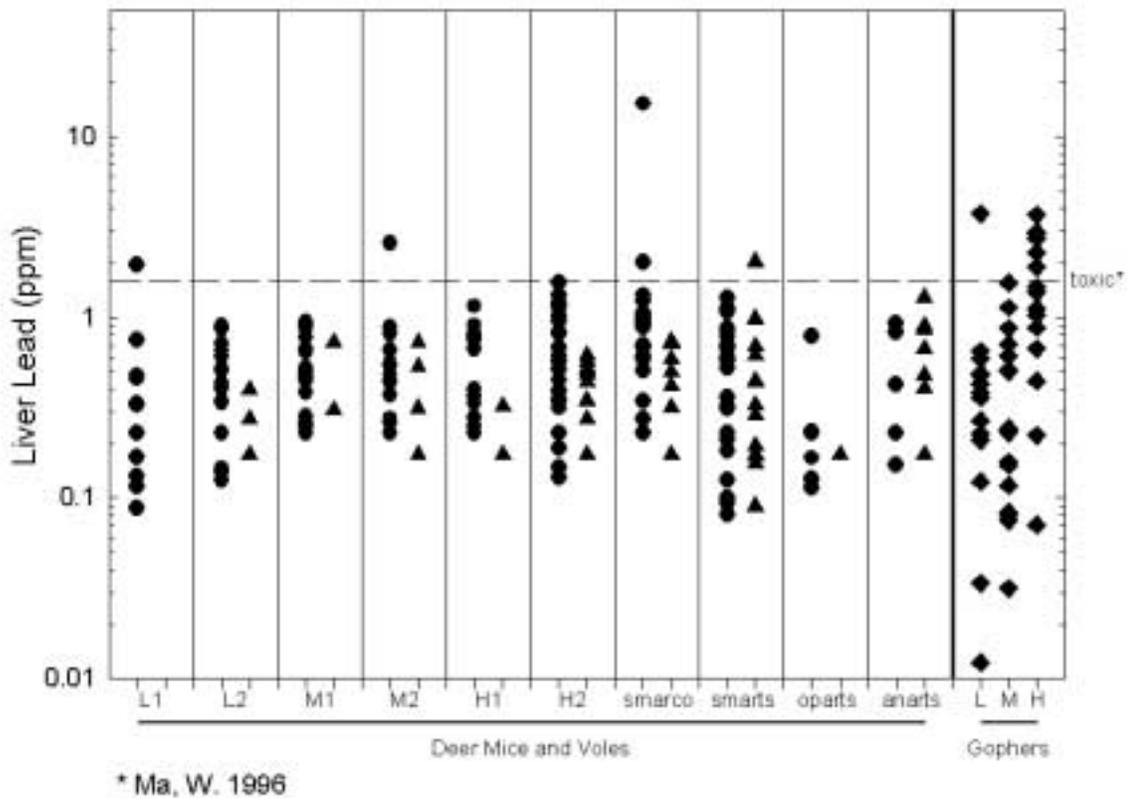
**6-41.** Regression analysis expressing changes in total porphyrins in individual deer mouse liver samples as a function of Cu concentrations in respective deer mouse liver samples. Deer mice were collected from ten study sites in 1999 at the Anaconda Smelter NPL site in Anaconda, Montana.



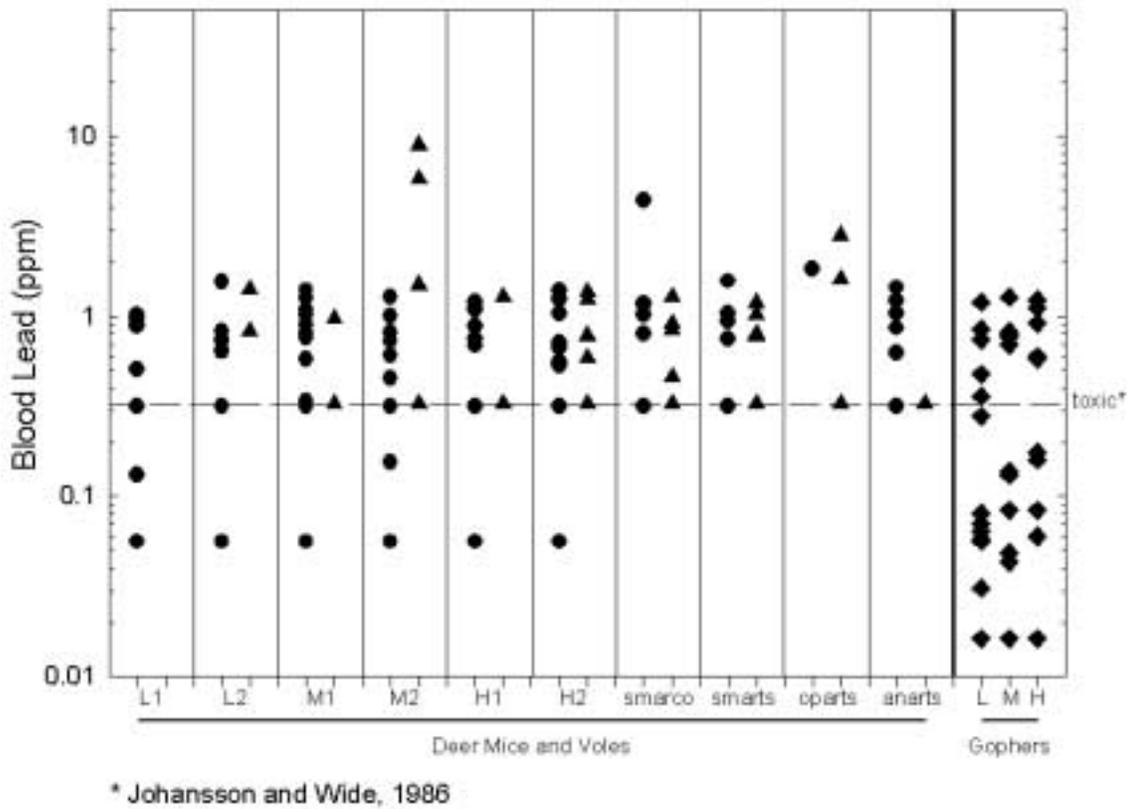
**Figure 6-42.** Regression analysis expressing changes in total porphyrins in individual deer mouse liver samples as a function of Zn concentrations in respective deer mouse liver samples. Deer mice were collected from ten study sites in 1999 at the Anaconda Smelter NPL site in Anaconda, Montana.



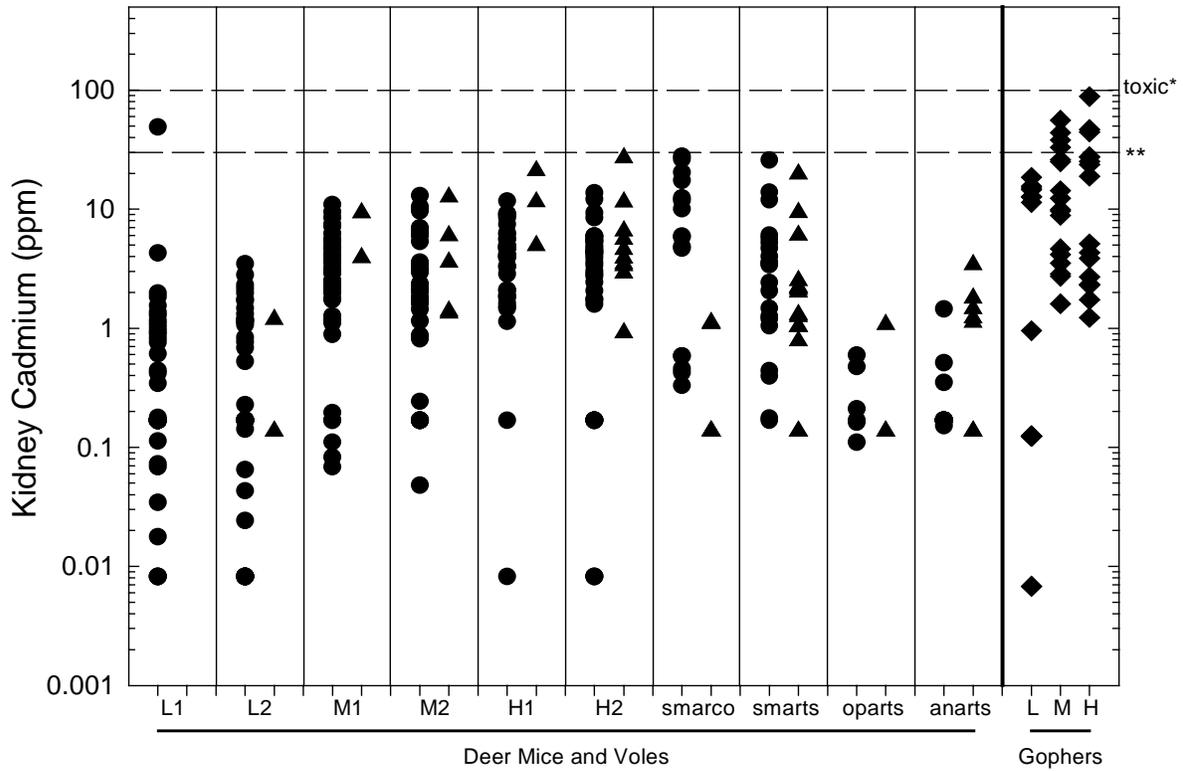
**Figure 6-43.** Lead concentrations in individual deer mouse (-●-), meadow vole (-▲-), and pocket gopher (-◆-) kidneys collected from thirteen study sites in 1999 and 2000 at the Anaconda Smelter NPL site in Anaconda, Montana. Dashed line indicates concentration of Pb in small mammal kidneys documented to produce toxic effects.



**Figure 6-44.** Lead concentrations in individual deer mouse (-●-), meadow vole (-▲-), and pocket gopher (-◆-) livers collected from thirteen study sites in 1999 and 2000 at the Anaconda Smelter NPL site in Anaconda, Montana. Dashed line indicates concentration of Pb in small mammal livers documented to produce toxic effects.



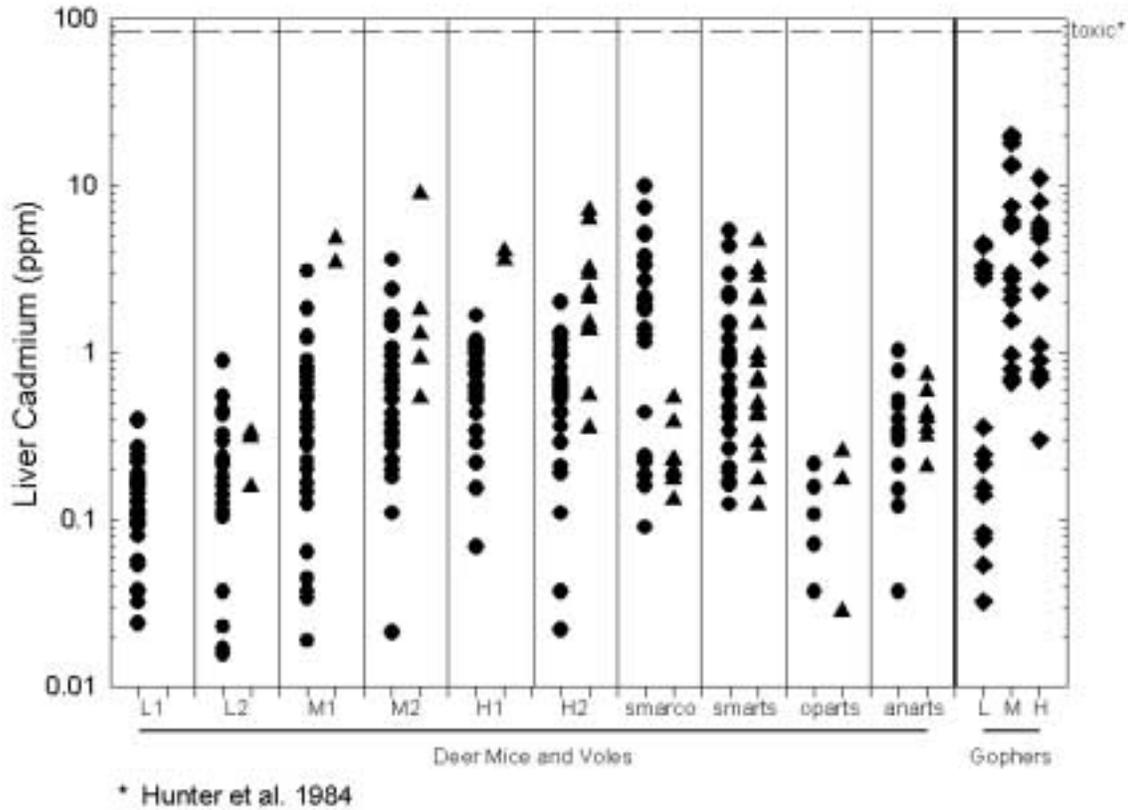
**Figure 6-45.** Lead concentrations in individual deer mouse (-●-), meadow vole (-▲-), and pocket gopher (-◆-) blood samples collected from thirteen study sites in 1999 and 2000 at the Anaconda Smelter NPL site in Anaconda, Montana. Dashed line indicates concentration of Pb in small mammal blood documented to produce toxic effects.



\* Cooke et al., 1990

\*\* Levels in rat kidneys associated with proteinuria. Prigge, 1978

**Figure 6-46.** Cadmium concentrations in individual deer mouse (-●-), meadow vole (-▲-), and pocket gopher (-◆-) kidneys collected from thirteen study sites in 1999 and 2000 at the Anaconda Smelter NPL site in Anaconda, Montana. Dashed line indicates concentration of Cd in small mammal kidneys documented to produce toxic effects.



**Figure 6-47.** Cadmium concentrations in individual deer mouse (-●-), meadow vole (-▲-), and pocket gopher (-◆-) livers collected from thirteen study sites in 1999 and 2000 at the Anaconda Smelter NPL site in Anaconda, Montana. Dashed line indicates concentration of Cd in small mammal livers documented to produce toxic effects.

## **7 PASSERINE STUDIES**

Passerine species assessments have been used successfully in the evaluation of contaminant exposure and effects in ecosystems (Getz et al., 1977; Blus et al., 1995; Burger et al., 1999; Cobb et al., 2000b). European starlings have been used frequently since they will readily utilize artificial nest boxes, and will tolerate significant handling of nestlings. Their status as an introduced pest species in North America adds to their utility. Nest boxes can be placed every 10 m in study site arrays to attract starling populations to desired study areas. The collection of nestling food items may be performed non-lethally and without impact on health outcomes for nestlings (Mellott and Woods, 1993). By measuring contaminants in food items and in tissues, exposure and trophic transport can be assessed. Coupling these data to health effect biomarkers completes the assessment of toxicant-induced effects at the individual or population level. The following text describes a two-year field and laboratory investigation to assess As, Cd, Pb, Cu, and Zn exposure and toxicity in starlings and other passerines inhabiting the Anaconda Smelter Site.

Starling and bluebird nest box arrays were situated throughout the study area to induce passerine nesting on the Anaconda sites. Arrays were placed on sites to allow assessments over a wide range of potential COC exposures (Figure 7-1). Birds were attracted to the area to serve as natural integrators of bioavailable COCs. In such study designs, passerine nestlings provide information regarding contaminant exposure, and biochemical and demographic effects.

Passerine exposure to and accumulation of heavy metals were monitored by determining COC concentrations in tissues collected at life stages that ranged from *in ovo* to fledging. Eggs were collected early in the nesting cycle to evaluate the possible maternal transfer of COCs to offspring. After nestlings hatched, food items were collected during the nestling growth phase to evaluate exposure via ingestion. Once nestlings reached fledging status, target tissues (blood, liver, and kidney) were analyzed for COC accumulation.

Profiles of highly carboxylated porphyrins were evaluated as biomarkers of effect.

Alteration of tissue porphyrin profiles has been shown in starlings following exposure to Hg, Pb, and As (Akins et al., 1993; Akins, 1995) as well as in mixed metal exposures (Trust et al. 2000). Liver and kidney porphyrins were evaluated during years one and two. Blood ALAD was measured during year 2 to better assess the effects of blood Pb occurrence in the sub-clinical to toxic range. Nesting demographics were also used as an indicator of effect.

Finally, exposure data were compared to documented literature concentrations that produce adverse effects in other avian species (Beyer 1996), as well as to existing data describing background metal concentrations and metal exposure in regional mining areas (Blus et al., 1995; Johnson et al., 1999).

### Passerine Methods and Materials

#### 7.1.0 Nest Box Placement

In October 1998, 300 starling and 50 bluebird nest boxes were erected in 18 arrays throughout the study area (Figure 7-1). Array placement spanned a large area surrounding Smelter Hill and the Opportunity Ponds tailing piles. Array locations were designed to provide a gradient of potential contaminant exposure for passerines and to encompass different habitat types. Individual arrays were designated by single letter names ranging from A through R (Table 7-1). Nest boxes within each array were numbered sequentially starting with the number "1". Individual starling nest boxes were thus uniquely identified by the combination of their array letter and box number. SF09, for example, is Starling box 9 on Array F. Passerines nesting in bluebird or kestrel boxes used the designator "B" or "K", respectively, followed by the box number designation 1 through 45 for bluebird boxes (Table 7-1) or 1 through 50 for kestrel boxes (Table 8-1). Between the 1999 and 2000 breeding seasons, some bluebird nest boxes were moved between sites and to new sites, resulting in a renumbering of box ID numbers. A concordance for the two year numbering system can be found in Table 7-1.

### 7.1.1 Daily Box Monitoring

Beginning in May, boxes were checked every three days to observe passerine activity. Activity was measured on a five-point scale with entries that represented nesting stages ranging from no avian activity (0) to complete nest built (4).

After a nest was completed, boxes were monitored daily to determine egg laying order. Upon re-inspection, a marked egg was removed (an entire clutch was removed from one box to examine intra-clutch variability), wrapped in clean Kimwipes<sup>®</sup>, and placed in a certified clean vial for later analysis. The egg was then weighed and length and width were each measured in triplicate. Egg contents were removed through a circular incision at the air cell, placed into a new certified clean vial and immediately frozen at -20°C for storage until metals analysis.

### 7.1.2 Nestling Monitoring and Measurement

Starling clutches were monitored every three days until 13 days after the last egg was laid. Eggs were then monitored daily to determine hatch date, which occurred approximately 15 days after incubation was initiated (all other passerines were monitored at times appropriate for species incubation period). The passerine species studied all delay incubation until egg laying is near completion. Therefore, eggs typically hatch within one day of each other. Clutch age (post-hatch) was recorded as the hatch date of the last nestling. Addled eggs were collected five days post-hatch, weighed and measured as above. Contents were removed for determination of egg viability, or embryo age at death. All contents were collected and stored in certified metal clean vials at -20°C for metals analysis.

Starling morphological measurements were obtained from nestlings immediately prior to esophageal constriction attempts (see Section 7.1.3). In 1999, sampled nestlings were 5 and 10 days old. In 2000, nestlings were measured at approximately 5, 8, 12, and 15 days post-hatch (all other passerines were monitored at times appropriate for species nesting period). Nestlings were weighed in a tared bag that was attached to a Pesola<sup>®</sup> spring scale. Measurements of bill depth and tarsus length were taken from nestlings using a caliper. All

weights and measurements were recorded on a form to the nearest tenth of a gram and one millimeter, respectively. Nestlings were visually inspected for any obvious signs of ectoparasites, general health status, or any other notable concerns.

#### 7.1.3 Esophageal Constriction

Nestling food item preference and contaminant exposure were determined by collecting prey items at times of nestling monitoring. In 1999, attempts were made to secure two food samples from nestlings at days 5 and 10 (all other passerines were monitored at times appropriate for species nesting period). Four attempts were made in 2000 to collect food samples from nestlings at approximately days 5, 8, 12, and 15 post-hatch. Nestlings were fitted with esophageal constriction devices (Mellot and Woods, 1993), which prevented food items from entering the crop and allowed for unimpeded breathing and blood circulation. The avian species sampled dictated the size of plastic cable ties used for constrictors and the attempt dates. The constrictors were left in place for up to one hour, and adult feeding activities were monitored and documented from an appropriate distance. At each sampling, food items from all nestlings within a nest box were pooled and stored at  $-20^{\circ}\text{C}$  in vials certified clean for metals analysis. Food item analysis was performed on these pooled samples from single day sampling events.

#### 7.1.4 Nestling Retrieval and Dissection

At day 15 post-hatch, starling nestlings were collected from nest boxes (a single nestling of all other passerines was retrieved at times appropriate for species fledging period). In 1999, three randomly selected starling nestlings (a residue nestling, a biomarker nestling, and a histopathology nestling) were removed for dissection. In 2000, all starling nestlings were removed from the nest, and one nestling was randomly selected for dissection. Entire starling clutches were sampled from a number of nest boxes to examine intra-clutch variation. All nestlings were euthanized by  $\text{CO}_2$  asphyxiation.

*Blood sampling.* A blood sample was collected from at least two nestlings per nest by cardiac or jugular venipuncture at the time of euthanasia. The sample collected from the residue

nestling in 1999 or the dissected nestling in 2000 was stored in a vial certified clean for metals analysis. Another blood sample contained heparin and was split into aliquots. One aliquot was separated into plasma and red blood cells. The other was used for complete blood cell counts. In 2000, a third aliquot was collected into a 1.5 ml tube and stored at  $-80^{\circ}\text{C}$  for ALAD analysis. Packed cell volumes (PCVs) of the year 2000 samples were determined using 100  $\mu\text{l}$  microhematocrit capillary tubes and a microhematocrit centrifuge. Remaining blood for ALAD analysis was frozen at  $-80^{\circ}\text{C}$ .

*Tissue Collection.* In 1999, the euthanized residue nestling was placed in a cleaned, certified clean glass jar and stored at  $-20^{\circ}\text{C}$  for dissection at TIEHH. In 2000, a single nestling from each nest was dissected at the field lab to collect tissues for biomarker and residue analysis. Total weights were documented for the brain, spleen, bursa, liver, and kidney tissues of each collected nestling. Liver and kidney samples that were collected for residue analysis were stored in certified clean vials at  $-20^{\circ}\text{C}$  until analysis. Liver and kidney tissues that were collected for biomarker analysis were wrapped in aluminum foil and frozen at  $-80^{\circ}\text{C}$ . Representative portions of the following tissues were fixed in 10% buffered formalin for histopathological analysis: liver, kidney, brain, eye, heart, brachial plexus, cecae, stomach, intestine, femoral muscle, femoral bone, spleen, bursa, thyroid, thymus, lung, intestine, pancreas, adrenal, and gonad. Results of these analyses are not reported in this document.

#### 7.1.5 Exposure Assessment Methodology

COC exposure in passerines was assessed by quantifying metal and As levels in eggs, nestling food items, tissues, and blood, and in the soils associated with active starling nest box arrays. Relationships between COC levels in soils and food items, and soils and tissue levels were assessed to determine the concordance between site contamination, the food item exposure pathway and nestling exposure.

Metal and As concentrations, except for soils (see below), were determined as described in Section 6.1.8 of this report. Detection limits and reporting values for metals specific to passerine matrices are listed in Table 7-2. COC concentrations are expressed on a box or site specific basis. Mean COC concentrations described on a site basis are derived, first as the

mean of metal or As concentration from samples collected from individual boxes, which were then averaged to create a site average. COC concentrations in soils collected near arrays were averaged using arithmetic means.

COCs were measured in forty soil samples, each, from starling foraging areas associated with Sites N, O, and Q. Samples were collected after the 1999 field season by investigators from USEPA and USFWS and were processed by an EPA contract laboratory (LMTS 2001). Arithmetic means of metal concentrations in soil from these sampling locations were used to estimate metal content in soils around each nest box array.

Soil data from previous studies were used to assess COC concentrations at or near Sites K, L, P and R where soil sampling did not occur. Soil data were chosen from the Montana State University/Reclamation Research Unit GIS overlays (RRU 2000) for the site. Queried data sets from the program's Access database were exported to EXCEL where data were truncated to include only surface sampling depths that penetrated no deeper than 3 in. (25 cm) and were within 400 m of the nest box arrays. Data sets contained multiple entries for most COCs. Arithmetic means were determined for each soil sampling point. Metal data from each point were then used to estimate arithmetic mean metal concentrations in soils around each nest box array.

#### 7.1.6 Effects Assessment Methodology

The effects of metal and As exposure in passerines inhabiting the Anaconda Smelter site were assessed using two biochemical endpoints, inhibition of blood ALAD activity (2000 only) and liver and kidney porphyrin profile alterations (1999 and 2000), the methods for which are described in section 6.1.9. PCV values were used for final calculation of ALAD activities. When PCV values were not available due to small sample size (2 starlings, 2 bluebirds and 1 swallow), the mean PCV value for the species was used for the determination. Tissue level assessments included tissue weight, and gross pathology. Nestling growth characteristics were taken, and comparisons made among sites provided insight to whole animal level effects.

Reproductive demographics provided population-level assessment data for each species. Data collected included the following: Clutches initiated (number boxes with at least one egg laid), the numbers of eggs laid, collected, missing at hatch or addled, and numbers of nestlings to hatch, die (or go missing), and live (to fledge). The demographic statistics calculated from the data were: percent of eggs hatched (nestlings to hatch/eggs at hatch), percent fledging efficiency (live nestlings/nestlings to hatch), percent nesting efficiency (live nestlings/(eggs laid-eggs collected)), and percent nesting success (sum of boxes with >1 live nestling/clutches initiated).

#### 7.1.7 Statistical Evaluation

Metal accumulation rates in starling food items, blood, liver, and kidney were determined using the mean soil and matrix COC concentrations from each site. Metal accumulation, as a function of soil COC concentration, was evaluated with linear regression. Though a few Pb profiles may have been best described by exponentials, the improvements in regression over linear regressions were marginal (increased  $r^2$  was less than 0.05). For ease of interpretation, linear regressions were used in all cases. All regressions were performed using Microsoft® EXCEL (2000 edition). European starling exposure and effects data were compared within the study based on avian nest box locations. Matlab (version 5, Mathworks) was used to perform nested ANOVA analysis to examine site differences in tissues and food metal and As concentrations ( $\alpha = 0.05$ ). Bonferonni post-hoc tests were used to determine which sites were different. Demographic and growth data were evaluated using literature-based benchmark data from reference and contaminated sites using the same or similar avian species to determine how nesting demographics of passerines compare to what might be considered normal or toxic. Multiple regression analysis (Pro-Stat, version 1.52, Polystat software © 1996) was used to determine the influence of metal and As concentrations in kidney and liver samples on biomarker response. All ANOVA analyses were performed on log transformed data collected from individual nestlings. Box data were used for porphyrin on metal multiple regressions, because we were not always able to use the same animal for residue and biomarker analysis.

## 7.2 Passerine Results

### 7.2.0 Nest Box Utilization

*Starlings.* In 1999, starlings initiated nests at five of the eighteen sites: K, L, N, O, and Q (Figure 7-1 and Table 7-1). Sites K and L were perpendicular to Galen Road, directly across from each other. Arrays were placed along the riparian tree line of Warm Springs Creek. At the time of monitoring, Site L was being remediated by tilling industrial lime into the soil. This remedial action removed any forb or grass cover present. The site was reseeded the following year. Site K was not tilled and had only sparse vegetation. Large numbers of small cottonwoods were present east of the array. Birds from Sites K and L appeared to forage in the cottonwood trees and/or to the south west. Site N was located around a large grove of trees on the northwest corner of Opportunity Pond Cell-C (just south of HWY 48). Site O was located south of Opportunity Pond Cell-D (just west of HWY 90). The array bordered a tree line that was perpendicular to the highway and the pond. The boxes faced a large grassy field, and adults were seen feeding directly by the boxes. Site Q was located just east of the Opportunity Pond Cell-C berm. It contained 20 boxes arranged in two parallel arrays.

In 2000, starling-nesting activity was noted at Sites K, L, N, P and R. Site L was reseeded early in the season, with only limited growth appearing by mid-summer. Sites K and N were unchanged. Site P was located in the ARTS experimental plot in Opportunity Pond Cell-D. Most adults from Site P were observed flying north toward the edge of Cell-D to forage. After the 1999 season, the R array was moved from south of Opportunity Ponds to the north end of Warm Springs Ponds Wildlife Management Area, just north of the northernmost settling pond. The site was well vegetated, with highly diverse feeding areas.

*Non-Starling Passerines.* Tree swallows (*Tachycineta bicolor*); mountain bluebirds (*Sialia currucoides*) and black-capped chickadees (*Poecile atricapilla*) bred in nest boxes throughout the study site. Passerine nesting activity in 1999 was seen in starling, kestrel, and bluebird specified boxes. Bluebirds nested across the study area (Starling Sites B, F, and H along with one in Kestrel Box K 08). Tree swallows nested at starling Sites B, J, N, P, and

Q, bluebird box B 29, and kestrel box K 47. Tree swallows nested on the Anaconda and Opportunity Ponds ARTS plots, the only nesting activity noted at either of these Starling sites. A single chickadee nest was initiated in a bluebird box (B 44) at the original Site R location. No nesting demographics besides site presence were maintained for these three species in 1999.

In 2000, bluebirds nested again at Starling Sites B, F, and H, while new bluebird nesting activity occurred at Starling Sites C, G, I, K, M, and O. Bluebirds initiated nests in four kestrel boxes (but K 21 was the only successful nest) and one bluebird box (B 23). Tree swallow activity was noted at starling Sites B, F, H, I, J, K, N, O, P and R, as well as two bluebird boxes (B 32 and B 36). Three chickadee nests were initiated in 2000, with one each at Starling Sites B and L, as well as one in bluebird box, B 38, used in the previous year (bluebird box B 44 in 1999, see Table 7-1).

## 7.2.1 Exposure Assessment Results

### 7.2.1.1 Soil Metal and As Analysis.

Soil COC concentrations varied within and among analyzed array sites (Table 7-3). Soils from Site K and L contained the highest mean concentrations of all COCs, with levels generally double those of the next highest concentrations. Alternatively, Site P COC levels were only 1-5% of those levels found on Sites K and L. Sites O, N, R and Q had intermediate COC concentrations between those of Sites K/L and P. This variation provided nearly two orders of magnitude in soil concentrations between sites. Within sites, Cu was the most abundant COC, followed by Zn and As, and then Pb. Cadmium levels did not exceed 13 µg/g and were the lowest COC concentrations on all sites.

### 7.2.1.2 Food Item Metal and As Analysis

*Starlings.* Food samples contained primarily small invertebrates, the most common of which were lepidoptera larvae, grasshoppers, beetles, flies, and several kinds of pupa. Cicada, spider and June bug samples were also identified. Lepidoptera larvae contained significantly

higher As concentrations than grasshoppers collected on the same sites, during 1999. All COCs were detected in all food samples with the exception of one sample from Site Q (Table 7-4). Site mean food COC concentration ranges were As, 4.09 µg/g to 32.6 µg/g; Cd, 0.103 µg/g to 2.47 µg/g; Pb, 1.70 µg/g to 25.5 µg/g; Cu, 33.0 µg/g to 106 µg/g; and Zn 66.1 µg/g to 168 µg/g. Mean food item residues were highest at Site K during the 1999 field season. Food items from Site N contained the lowest mean concentrations of As, while those from Site O contained the lowest mean concentrations of Cd. Site Q food samples contained the lowest mean concentrations of Pb, Cu and Zn.

Mean COC occurrences in food items collected during the 2000 field season are presented in Table 7-5. In general, COC concentrations in starling food items from 2000 were similar to those from the same sites in 1999. As in 1999, all COC concentrations in starling food items were highest in those collected from Site K in 2000. The primary food choices for starlings in 2000 were lepidopteron larvae, grasshoppers, beetles, ants, and cicadas, with the composition depending on the site.

Of the samples analyzed for metal content, metal concentrations in food items demonstrated the greatest correlation with mean metal concentrations in soil (Figure 7-2). Lead in food items was the most highly correlated ( $r^2 = 0.8753$ ), and all other COCs were marginally correlated with  $r^2$  values ranging from 0.35 to 0.46. A notable pattern was the generally decreased accumulation of metals in food items from Site L compared to those of Site K. Though both sites had similar soil contaminant levels, Site L food items were generally less contaminated than Site K. Removal of Site L data from COC regressions increased correlations between soils and food (Figure 7-3,  $0.69 < r^2 < 0.94$ ). The reduced food item contamination at Site L could be a result of tilling processes that reduced surface soil COC concentrations, COC stabilization due to liming, or perhaps foraging by adult starlings in less disturbed areas with reduced metal concentrations.

*Non-Starling Passerines.* During 1999, tree swallow food items had no detectable As. All bluebird and chickadee food items contained detectable As, albeit at variable concentrations (Table 7-4). Cadmium concentrations in the non-starling food samples ranged from 0.447

$\mu\text{g/g}$  to  $1.59 \mu\text{g/g}$  among the species. Copper and Zn concentrations in the food were also variable within and between species. Food samples from tree swallows were usually a single bolus, composed of a variety of insects, including small flies, ants, and gnats. Bluebird food samples were generally grasshoppers and lepidoptera larvae.

Food item levels of COCs from each site during the 2000 field season are presented in Table 7-5. More food samples were collected from bluebirds and tree swallows in 2000 allowing for site comparisons within years that were not available in 1999. Bluebirds ate similar food items to starlings inhabiting the same sites. Tree swallows ate invertebrates similar to those in 1999. Arsenic concentrations were  $> 20.0 \mu\text{g/g}$  at three sites for bluebirds and at one site for tree swallows. Cadmium concentrations were greater than  $1 \mu\text{g/g}$  at 5 bluebird sites and 2 tree swallow sites. Arsenic, Pb, Cu, and Zn concentrations in one blue bird food sample (Box K 21) were the highest of any site in 2000. No food samples were collected from chickadees in 2000.

#### 7.2.1.3 Egg Metal and As Analysis

*Starlings.* A representative subset of eggs collected in 1999 was analyzed. Arsenic occurred in eggs from Site L and no other (Table 7-6), while Cd was not detected in any egg samples. Eighty percent of eggs contained detectable Pb concentrations, with a mean of  $0.10 \pm 0.02 \mu\text{g/g}$ . Mean egg concentrations of non-essential COCs were below  $0.126 \mu\text{g/g}$  at all sites. Copper ranged from  $0.267 \mu\text{g/g}$  (Site Q) to  $0.439 \mu\text{g/g}$  (Site K), and Zn occurred at concentrations from  $3.98 \mu\text{g/g}$  (Site Q) to  $8.88 \mu\text{g/g}$  (Site L). Eggs from one starling nest found in a kestrel box (K36; Figure 8-1) contained slightly higher Pb and Zn than the maximum mean concentrations observed on the five primary sites. This nest box was located on the northern end of Opportunity Ponds.

*Non-Starling Passerines.* Five bluebird eggs were analyzed for COCs in 1999. A single egg contained detectable Cd and a different egg contained detectable Pb. Both concentrations were below  $0.15 \mu\text{g/g}$ . Bluebird eggs contained Cu and Zn concentrations similar, though slightly higher, than concentrations in starling eggs. Tree swallow and chickadee eggs were

not sampled in 1999 and no passerine eggs were collected for analysis as part of the year 2000 assessment.

#### 7.2.1.4 Blood Metal and As Analyses

*Starlings.* Few blood samples collected during 1999 contained detectable As or Cd concentrations (Table 7-7). Sites K, N and Q each had one sample with detectable As while Cd was detected in only one blood sample from Site K. In the 23 analyzed samples, Pb, Cu, and Zn were detected in 20, 23, and 23 samples, respectively. Site Q blood samples contained the highest Pb concentrations ( $0.264 \pm 0.062$   $\mu\text{g/g}$ , mean  $\pm$  SD), while starlings from Site K contained the lowest concentrations ( $0.162 \pm 0.046$   $\mu\text{g/g}$ ). Mean Pb, Cu and Zn varied little between the arrays on different sites.

Mean blood COC concentrations from the 2000 field season are presented in Table 7-8. Arsenic and Cd were again infrequently detected in blood. Blood from Site K had the highest mean Pb concentration, while blood from Site P contained the lowest. Copper and Zn were highest on Sites L and K, respectively. There was a consistent pattern of As, Cd and Pb occurrences at each site in each year. The data demonstrate low concentrations of Cd and As in blood from most sites with somewhat elevated concentrations in a few instances. An unusual finding for year 2000 was the concentration of Cu in blood samples, which in general, was an order of magnitude above levels in 1999 samples. As blood collections were made similarly and at the same nestling age as in the 1999 collections, differences due to bird age were not the cause. Further, as this increase was not mirrored in food items as a source, in liver or kidney tissues as a sink, nor in other metals in the same blood samples, these Cu data are considered suspect.

*Non-Starling Passerines.* In 1999, blood samples were taken from tree swallows and bluebirds throughout the study site. Neither As nor Cd was detected, while Pb was found in 4 of 6 tree swallow nestlings but not in bluebirds (Table 7-7). Tree swallows contained a Pb maximum of 1.13  $\mu\text{g/g}$  and a mean of 0.39  $\mu\text{g/g}$ . Zinc was found in both bluebirds and tree swallows at consistent levels throughout the occupied study areas. Copper was detected in all samples and ranged from 0.224  $\mu\text{g/g}$  to 3.32  $\mu\text{g/g}$ . Mean levels of COCs in blood from

each site during the 2000 field season are presented in Table 7-8. Bluebird blood from Site C contained the highest mean As concentration. Chickadees were found to have the highest concentration of Cd, Pb, Cu, and Zn of all three passerine species. As in year 2000 starlings, Cu levels in year 2000 passerine blood samples were elevated an order of magnitude higher than 1999 levels. This elevation does not appear reasonable as noted for starling blood data.

#### 7.2.1.5 Liver Metal and As Analyses

*Starlings.* During 1999, As concentrations above detection limits in livers occurred only on Site N (Table 7-9). Mean concentrations of all other COCs were greatest at Sites K and L. Zinc concentrations from all sites varied between 19.2 µg/g to 29.0 µg/g and Cu from 6.76 µg/g to 14.4 µg/g, with minimum values on Site N and maximum on Site K. Mean Pb concentrations ranged from 0.628 µg/g on Site O to 1.70 µg/g on Site K. Few liver samples collected from Sites O and Q in 1999 had detectable Cd concentrations.

Starling liver COCs from the 2000 field season are presented in Table 7-10. At most, one box per site contained a liver sample with detectable As, producing mean values less than 0.1 µg/g. Cadmium, Pb, and Zn concentrations were highest at Site K, while Cu was most concentrated on Site L. COC residues in passerine livers show a consistent pattern of COC occurrence at all sites common in both years. Cadmium was more prevalent in liver samples for 2000 than in those from 1999, exceeding 1 µg/g at Sites K and L. When comparing all individuals from study sites, Cu and Zn concentrations were significantly higher in livers collected in 2000 than in livers from 1999.

Mean liver COC concentrations for each site were compared with their respective soil concentrations across both years. Liver Pb correlated better with soil Pb ( $r^2 = 0.6838$ , Figure 7-4) than did the other liver COCs when compared to soil COC concentrations ( $0.001 < r^2 < 0.26$ ). Hypothesizing that the poor correlations may have been due to lower COC availability at Site L after liming, we removed data for Site L from the regression analysis (Figure 7-5). Little or no improvement in the regressions occurred. Thus, COC occurrence

in starling livers at Site L after liming does not appear to have been altered relative to the availability at other sites.

*Non-Starling Passerines.* Liver COCs were also examined in non-starling passerines. Measurable arsenic levels occurred at 3.47 µg/g in the liver of a single bluebird occupying kestrel box 8 at the base of Smelter Hill. No Cd was detected in tree swallow or chickadee livers, although three bluebird liver samples had detectable Cd. Cadmium concentrations in two of the bluebird livers in 1999 were >0.2 µg/g Cd. The highest Cd concentration was 0.46 µg/g (Site H), followed by 0.27 µg/g at Site F. The bluebird liver from Site H contained 4.75 µg/g Pb, 3-fold higher than levels found in other bluebird and chickadee livers and approximately 10-fold higher than levels in most swallows. Zinc concentrations ranged from 18.7 µg/g to 31.3 µg/g in tree swallow livers, which was slightly lower than Zn in bluebird and chickadee livers. Intra clutch variability was monitored for non-starling passerines using the tree swallow clutch from SB12 (Table 7-9). The mean Pb concentration for all four chicks in this clutch was  $0.691 \pm 0.582$  µg/g, double the concentration found in the other tree swallows with detectable Pb.

Mean liver COC levels from each site during the 2000 field season are presented in Table 7-10. In 2000, As was found more frequently in bluebird livers than in livers of other species. Livers from all sampled birds contained detectable concentrations of Cd, Cu, and Zn. All chickadees and 16 of 18 bluebirds contained detectable Pb. Lead was found less frequently in tree swallow livers. Bluebird liver Cd ranged from 0.091 µg/g to 0.426 µg/g. Lead in bluebird livers ranged from 0.019 µg/g to 3.145 µg/g. Copper ranged from 8.855 µg/g to 17.469 µg/g, and Zn ranged from 25.757 µg/g to 37.133 µg/g. Bluebird liver COCs did not appear to be different based on nest box location. In 2000, 1 of 3 chickadee livers and 1 of 13 tree swallow livers contained > 0.2 µg/g Cd.

#### 7.2.1.6 Kidney Metal and As Analyses

*Starlings.* Nestling kidney As was found in three, and Cd was found in one of the 21 boxes sampled in 1999 (Table 7-11). Site means of As levels ranged from 3.02 µg/g to 4.51 µg/g.

Cadmium levels from Site N kidneys were barely above the reporting limit at 0.090 µg/g. Arithmetic means for the other COCs were generally highest at Site K though there was little variation in Cu and Zn levels. A kidney sample from Site K, box 1, contained As and Pb concentrations >20 µg/g. The high concentrations in that sample produced the large deviation in the site As and Pb means. Otherwise, Pb levels ranged from 1.02 µg/g to 2.58 µg/g, increasing between sites consistent with increasing soil Pb.

COC levels in starling kidneys during the 2000 field season are presented in Table 7-12. Kidney samples collected from Sites K and L in 2000 contained higher concentrations of COCs than from other sites, which is in keeping with most tissue residue data from 2000. Mean Pb in starling kidneys from two boxes each on Sites K and L exceeded 4 and 5 µg/g, respectively. During 1999, too few detectable Cd residues were observed in passerine kidneys to allow statistical comparisons. In 2000, starling kidneys from Site K contained more than 1 µg/g Cd. Residues in passerine kidney from Sites K, L and N showed a consistent pattern of COC occurrence across years.

Lead, Cd, and Cu concentrations in kidneys correlated better with their respective COC concentrations in soil than did liver values (Figure 7-6). The Pb correlation between kidney and soil had an  $r^2 > 0.75$ , while As, Cd and Zn correlated poorly, with  $0.08 < r^2 < 0.27$ . Removing Site L data from the analysis improved all regressions describing COC movement from soil to kidney ( $0.16 < r^2 < 0.85$ ; Figure 7-7) and made Cd and Zn regressions significant. Arsenic regressions were insignificant with and without Site L data present, primarily because of the few samples with detectable concentrations of As.

*Non-Starling Passerines.* Kidney tissues were collected from bluebirds, tree swallows and a chickadee. No As, Cd, or Pb were detected in any species in 1999 (Table 7-11), while Zn and Cu concentrations were fairly consistent between and within species. Mean occurrence of each COC in kidney tissue from each site during the 2000 field season is presented in Table 7-12. Residue profiles in kidney were similar among years. Cadmium and Pb concentrations in kidney were highest in bluebirds from Site C, with one Pb occurrence exceeding 5 µg/g. Mean kidney Cu in bluebirds exceeded 33 µg/g at Site B, and 26 µg/g at

Site H. Six of 12 site means for Cd in bluebird kidney exceeded 0.2 µg/g. Two of three chickadee kidneys contained >0.2 µg/g Cd. Three of 13 tree swallow kidneys also exceeded 0.2 µg/g.

#### 7.2.1.7 Opportunistic Passerine Tissue Analyses

*Adult Tree Swallows.* During 1999 and 2000, over 30 adult tree swallows were found dead inside nest boxes. Tissues from 18 of the opportunistic samples collected in 1999 were analyzed for COC concentrations (Table 7-13 and Table 7-14; all opportunistic tree swallows reported in 1999 were adults). All adult swallows contained detectable Cd in liver and kidney tissues. Liver Cd concentrations ranged from 0.604 µg/g (bluebird box 34) to 2.350 µg/g (bluebird box 8). Cadmium concentrations in kidney were from 0.882 µg/g (bluebird box 27) to 5.85 µg/g (bluebird box 8). These elevated Cd concentrations in adult swallows were the primary difference between nestling and adult COC profiles. One of 18 adult swallow kidney samples contained 0.31 µg/g Pb. Otherwise Pb and As were not detected in tree swallow tissues. Copper content was consistent between livers and more variable in kidneys. Zinc was the most concentrated COC in swallow liver and kidney, with an average of box means from Table 7-13 equal to  $41.3 \pm 1.20$  µg/g (liver) and from Table 7-14 equal to  $32.0 \pm 18.9$  µg/g (kidney).

*Passerine Nestlings.* During the 1999 and 2000 field season, nestlings that were found dead in the box were opportunistically collected for residue analysis. In 1999, opportunistic starling nestlings and a bluebird nestling were collected from Starling Sites K, L, N, and O. Liver As, Cd, Pb and Cu levels from opportunistic starlings in 1999 were similar to levels found in collected nestlings from those sites (compare Table 7-13 to Table 7-9). The only notable difference in opportunistic birds was Zn levels elevated to the 30 µg/g to 35 µg/g range compared to the 19 µg/g to 29 µg/g range of collected nestlings. In spite of a slightly elevated As level, the single opportunistic bluebird had a similar residue profile to collected bluebirds. Kidney residue concentrations were also similar between mortalities and live collected birds (Table 7-14, compared to Table 7-11). A single nestling from Site N was found with detectable As and Cd concentrations, while one starling nestling from Site O with

a detectable Cd concentration high enough to make the site average  $0.242 \pm 0.281$   $\mu\text{g/g}$ . The bluebird did not contain detectable As, Cd, or Pb levels.

In 2000, opportunistic starling (Sites N and R), bluebird (Site H), and tree swallow (Sites H, I, N, O and R) nestlings were collected. Liver tissue metal levels were generally lower in mortalities compared to live-captured birds (Table 7-15, compared to Table 7-10). Nestlings of all species seldom contained detectable As, though the highest value was found in a starling from Site N. Cadmium concentrations in liver were also highest for starlings from Site N, while Pb was highest at Site R. Tree swallows from Site H contained the highest Cu concentration in liver, while those from Site R contained the highest Zn. Kidney COC levels were generally similar between survivors and mortalities (Table 7-16, compared to Table 7-12), with slight elevation in kidney copper in the mortalities. Nestling kidneys seldom contained As or Cd, though again, the highest concentrations of these elements were found in starlings from Site N. Lead was highest in starlings from Site R, while Cu and Zn were highest in tree swallows from Site R as well.

## 7.2.2 Passerines Effects Assessment – Biochemical, Cellular and Morphological

### 7.2.2.1 Porphyrim Analyses

*Starlings.* Porphyrim profiles were determined for liver and kidney tissues from starlings in both 1999 and 2000 (Table 7-17 to Table 7-21). Total carboxyl porphyrin (CP) concentrations in 1999 were primarily composed of 4-CP and 2-CP. The 8-, 7-, 6-, and 5-CPs were seldom detected, and they were at much lower concentrations than the 2- and 4-CPs in both liver and kidney tissues. The 4-CP and 2-CP peaks were, therefore, specifically quantified, while total CP values were calculated using concentrations from all detectable CPs. The Site means discussed below are means of concentrations (pmol/g tissue) obtained from tissues collected from individual boxes.

In 1999, the mean site concentrations for liver 4-CP were between 24 and 63 pmol/g and for 2-CP, between 7 and 12 pmol/g (Table 7-17). Total CP concentrations in livers from starlings were between 33 and 80 pmol/g. Total, 2-, and 4-CP concentrations for Sites K, L, and N were higher than those of Sites O and Q. Kidney CP profiles contained little or no 7-,

6-, or 5-CP, but they contained higher concentrations of 2-CP and 4-CP than liver tissues (Table 7-19). The site average 4-CP concentrations were between 25 pmol/g and 72 pmol/g and 2-CP was between 11 pmol/g and 22 pmol/g in kidneys. Total CP concentrations were between 46-108 pmol/g. The site mean porphyrin concentrations in kidneys for Sites K, L, and N were higher, as they were in livers, than porphyrin concentrations for Sites O and Q.

Porphyrin levels in 2000 were, in general, elevated above 1999 levels. In 2000, as with 1999, there were few if any detectable 7-, 6-, 5-CPs. Liver total porphyrin concentrations (Table 7-18) ranged from 77.6 pmol/g to 119 pmol/g. The 4-CP concentrations in liver were between 64 pmol/g and 87 pmol/g, while 2-CP concentrations were between 11 pmol/g and 16 pmol/g. Kidney samples collected from starlings contained mean total CP concentrations of 101 pmol/g to 160 pmol/g (Table 7-20). The 4-CP concentrations in kidneys ranged from 45.1 pmol/g to 108 pmol/g and were more variable within and between sites than were the 2-CP values at 23.7 to 33.0 pmol/g. The patterns of elevated porphyrin levels from Site K, L and N nestlings noted in 1999 were repeated in kidney tissues and in the 2- and total CP levels of liver tissues in 2000.

*Non-Starling Passerines.* Porphyrin analyses were not performed on tissues collected from non-starling passerines.

#### 7.2.2.2 ALAD Analyses and Packed Cell Volumes

*Starlings.* Packed cell volumes and erythrocyte ALAD activity were determined for all dissected starlings during 2000 (Table 7-22). Site means showed a wide range of ALAD activities with Sites K, L and P ( $66.97 \pm 17.1$ ,  $86.52 \pm 7.02$ , and  $88.33 \pm 25.5$ , respectively) showing lower levels than Sites N and R ( $105.04 \pm 23.5$  and  $115.61 \pm 16.0$ , respectively). PCVs ranged from a mean of 31.2% to 43.6%

*Non-Starling Passerines.* Blood samples were collected from nestlings in 17 bluebird, 3 chickadee and 11 tree swallow clutches. Bluebird and tree swallow nests were dispersed across the study area. Bluebird ALAD activity varied from 47.36 to 126.56 units in birds from Starling Site C and bluebird box 23, respectively (Table 7-22). Tree swallows followed

a similar trend, as ALAD activity ranged from 55.64 (Bluebird 36) to 133.19 units (SR10), with a mean of  $81.47 \pm 24.3$  units. Chickadee nestlings contrasted considerably, with ALAD values of 108.4, 100.1 and 26.0 units identified from the three nest box sites (bluebird box B38, SL02 and SB12 respectively).

### 7.2.2.3 Tissue Weights

*Starlings.* Total weights of passerine kidney, liver, bursa, spleen, and brain were collected at necropsy in both 1999 (Table 7-23) and 2000 (Table 7-24). In 1999, site averages for kidney weights ranged from  $0.861 \pm 0.192$  g to  $1.11 \pm 0.119$  g. Liver sample weights varied  $3.08 \pm 1.19$  g to  $4.38 \pm 0.623$  g. Bursa and spleen weights had less within site variability than did liver and kidney weights. In 2000, site averages for kidney weights ranged from  $0.782 \pm 0.125$  g to  $0.97 \pm 0.044$  g. Liver weights ranged from  $2.55 \pm 0.714$  g to  $3.40 \pm 0.436$  g.

Spleen weights were significantly different in 2000 with Site R weights being significantly higher than those from other sites (Figure 7-8). Kidney and liver weights from Sites K, N, and R were lowest, with Site O intermediate, and Site L highest in 1999. There were no significant site differences in any other tissue weights collected from starling nestlings at age 15 days.

*Non-Starling Passerines.* Five bluebirds were collected in 1999, with each bird occupying a different site. The average total kidney and liver weights were approximately 0.38g and 1.1g, respectively, for birds collected. Two tree swallows were collected from most nests in 1999 and box averages were obtained. The tree swallow total kidney weights were between 0.262 g and 0.360 g (Table 7-23). Tree swallow liver weights were between 0.806 g and 1.65 g. In 2000, bluebirds were collected from 11 sites with average kidney weights ranging from 0.311 g to 0.414 g. Liver weights ranged from 0.849 g to 1.29 g (Table 7-24).

### 7.2.3 Passerine Effects Assessment - Reproductive Demographics

#### 7.2.3.1 Nesting and Hatching Success

*Starlings.* In 1999, starlings initiated clutches in 38.1% (Table 7-25) of the available boxes in arrays K, L, N, O and Q. The proportion of boxes with initiated clutches ranged from 30% at Site Q to 47.4% at Site O. Representative eggs were collected from most clutches for COC analysis. Mean clutch size ranged from  $3.00 \pm 1.73$  (L) to  $4.75 \pm 0.89$  eggs (N), however, many eggs were lost during nesting, thus reducing mean clutch size at hatch to  $2.29 \pm 1.80$  and  $4.14 \pm 0.69$  for Sites L and N, respectively. Subsequently, hatching success (nestlings / eggs at hatch) varied from 68.3% (Q) to 93.8% (K) with mean numbers of hatchlings ranging from  $1.86 \pm 1.57$  (L) to  $3.43 \pm 0.79$  (N). Nesting success (successful nests of at least one nestling / occupied nests) for each site was generally low, ranging from 55.6% at Site O to 66.7% for Site Q. Starlings were generally not seen near non-active (no nest initiation) arrays.

In 2000, starlings initiated clutches in 31.2% (range from 10% - Site L to 65% - Site R) of the available nest boxes (Table 7-26). Eggs were collected from several active nests for chemical analysis. Mean clutch size ranged from  $3.33 \pm 2.08$  (P) to  $4.90 \pm 1.10$  eggs (N). Mean clutch size at hatch varied from  $3.00 \pm 2.65$  to  $4.50 \pm 1.08$  for the P and N sites respectively. Hatching success (nestlings / eggs at hatch) was 66.7% (L) to 100% (K and P) with mean numbers of hatchlings ranging from  $2.50 \pm 2.12$  (L) to  $4.20 \pm 1.03$  (N). Nesting success (successful nests of at least one nestling / occupied nests) was 61.5% and 66.7% for Sites R and P respectively. Sites K and L both had 100% nesting success. No significant relationships were found in regressions of metal concentrations in soil against starling Nesting Efficiency (Figure 7-9) or Nesting Success (Figure 7-10).

*Non-Starling Passerines.* Bluebirds, tree swallows and chickadees were more active in 2000 than 1999, initiating 21, 15 and 3, clutches respectively (Table 7-27). Bluebirds laid 114 eggs with a mean of 5.43 eggs laid per clutch, while swallows (83 eggs) and chickadees (22 eggs) had mean eggs per clutch of 5.53 and 7.33 respectively. Ninety bluebird eggs hatched, in addition to the 70 tree swallows and 11 chickadee nestlings that hatched. Hatching

success of the three species was 86.1% for bluebird (mean of 4.29 nestlings at hatch), 92.1% for swallow (mean 4.67 nestlings) and 46.3% for chickadees (mean 3.67 nestlings).

### 7.2.3.2 Hatchling and Fledgling Success

*Starlings.* In 1999, mean starling nestlings per box (at day 15 post-hatch) varied from  $1.29 \pm 1.25$  (L) to  $1.88 \pm 1.55$  (O). Site N had the greatest number of missing or dead nestlings ( $1.50 \pm 1.41$  per box). Fledging efficiency (number of nestlings at fledge / number hatched) was  $50.0 \pm 38.2\%$  at Site N, to  $75.0 \pm 38.7\%$  for Site O. Nest abandonment, harsh weather events, and predation appeared to have caused most of the noted nestling deaths. Subsequently, nesting efficiency (number of nestlings at fledge / number of eggs laid) was low, with values from 40.5% (N) to 60.0 (K and O).

In 2000, the number of live nestlings per box (at day 15 post-hatch) ranged from  $1.62 \pm 1.76$  (R) to  $3.10 \pm 1.37$  (N). Site R had the greatest number of missing or dead nestlings ( $1.15 \pm 1.91$  per box). Fledging efficiency (number of nestlings at fledge / number of nestlings hatched) was similar to the previous year, with observed efficiencies of  $48.8 \pm 42.7\%$  at Site R, to  $87.5 \pm 17.7\%$  for Site L. Nesting efficiency varied dramatically, with Site R averaging 39.7% and Site K averaging 83.3%.

*Non-Starling Passerines.* Demographic data were collected for bluebirds, chickadees and tree swallows in 2000 only, because there were too few nests for each of the non-passerine species in 1999 (Table 7-27). Numerous passerine nestlings either died or were missing from the box. Bluebirds had a mean of 2.62 nestlings at fledge age per box, while chickadees and swallows averaged 2.67 and 3.00, respectively. Fledging efficiency was 80.5% for bluebirds, 100.0% for chickadees, and 85.0% for swallows. The nesting efficiency (number of nestlings at fledge / eggs laid) was 63.4%, 44.7%, and 70.5% for bluebirds, chickadees, and tree swallows, respectively.

### 7.2.3.3 Morphological Measurements

*Starlings.* In 1999, birds were weighed and measured at ages 5, 10, and 15 post hatch. Different factors influence the variability of mean nestling weights on the sites. Table 7-28 shows the day 15 site average weight and measurements. Box 15 on Site K contained a moribund nestling at collection. It weighed half that of the other nestling in the box and had labored breathing. This chick had the highest liver Pb (2.13  $\mu\text{g/g}$ ) and Zn (46  $\mu\text{g/g}$ ) levels of all collected starlings in 1999 (Table 7-9A) while its kidney levels of these metals were among the highest in 1999 starlings at 3.99  $\mu\text{g/g}$  and 33.1  $\mu\text{g/g}$ , respectively (Table 7-11A). Box 3 on Site L had an underdeveloped and ill nestling that weighed about 2/3 of the weight of the other nestlings in the box. Mites and insect larvae (concluded to be blow fly larvae) were found in the transport box of this nestling. Several nestlings from Site N, box 1 died, and both collected nestlings weighed less than others from Site N. The nestlings in box 12 on Site O weighed 15 grams less than other nestlings on that site, which accounts for most of the variability of the Site O mean nestling weights ( $67.6 \pm 12.7$  g). Adults from that box were not as attentive as other adults on that site. Except for the nestling from SK15, the remaining nestlings did not have notable metal levels.

In 2000, weights and measures from starlings were collected at 4 time points, with time points 1 to 4 representing nestling growth stages (Table 7-29). Growth data generally followed logarithmic progressions as might be expected during the time interval of study. Site mean body weights for day 15 starlings were comparable and did not display variation that might suggest COC-dependent depressions.

### 7.3 Passerine Discussion

#### 7.3.0.1 Nest Box Usage

In general, starling-nesting activity was lower at the study site than expected. Over two years, only seven of 18 nesting arrays had starling nest initiation, with five sites showing activity for each year. Starlings were absent from arrays on and around Smelter Hill or Anaconda Ponds, with the majority of activity in arrays in close proximity to Warm Springs creek or the Clark Fork River. Three sites (K, L and N) were utilized both years allowing for site comparisons over two breeding seasons. Nest box utilization varied dramatically (10%–65%), between years and between sites. An increase in nest box usage is generally seen in consecutive year studies (Custer and Custer, 2000), but site-specific activity can vary dramatically (Hooper and Skipper, 1994) due to the flocking behavior of starlings. Sites K and L offer a unique comparison opportunity as they were located across Galen Road from each other, and differ in remedial treatment. In 1999, tilling and liming occurred in the field directly in front of the Site L array, with much of the activities synchronous with clutch initiation and hatching. Despite these actions, nest demographics did not appear to differ greatly between this site and Site K, which had no remedial activity. In 2000, Site L was reseeded and began showing sparse vegetative growth early in the season. Both Sites K and L experienced low nest initiation (2 clutches at each site), which was lower than in the previous year. Alternatively, Site N was utilized over both years with 40% and 50% box utilization in 1999 and 2000. This site appears to offer the most heterogeneous habitat with large groves of trees, well-covered fields, and a nearby riparian corridor. In addition to all the study species noted, a variety of passerines, flycatchers, raptors and waterfowl were seen throughout the immediate area during both years. This site had the highest number of eggs laid per clutch of any site (4.75 and 4.90 for the two years), as well as the highest number of nestlings at hatch (3.43 and 4.20). The four remaining starling-occupied sites varied only slightly, though no single site differed notably. Site P was unique in that it is found in the middle of Opportunity Ponds, surrounding the ARTS research plot. Very little avian activity was ever observed in this area, yet there were two successful starling nests in 2000 and a tree swallow nest each year of the study.

Bluebird, tree swallow and black-capped chickadee activity showed an expected increase in nesting activity from 1999 to 2000. Studies have shown that some birds, bluebirds in particular, are wary of nest boxes and will not nest in them until they are acclimated to them for some time (Custer and Custer, 2000). These three species were noted in small numbers across the study area. Bluebirds initiated 21 clutches in 2000, 7 of which may have been a second clutch from a local pair, laid after fledging of their first clutch. Four late clutches were initiated in the same box as an earlier clutch (Starling Sites B, F, M and bluebird box 23), while three clutches were initiated in boxes near an early clutch box at the same site (Starling Site C, H and K). Tree swallows were often seen in flocks of interacting adults. During nest initiation of both seasons, numerous adults were found dead inside assorted starling and bluebird boxes. Several times an additional adult was found alive in the same box, and blood was noted on the nest box walls suggesting defense of males over potential nesting sites (Robertson et al., 1992). Dead swallows were collected, and in subsequent dissection of a representative sample were largely found to be sexually active (enlarged testes) males. However, actual nest initiations of tree swallows were much lower than would be expected if the tree swallows were competing for the boxes. Black-capped chickadees appeared to be relatively scarce throughout the study area, though their secretive nature allows them to be easily overlooked.

### 7.3.1 Exposure Assessment Discussion

*Food Item Exposure.* When all sites were considered, evaluations of COC uptake from soil into food items demonstrated positive correlations for Cd, Pb, and Cu ( $r^2 = 0.409$  and  $p = 0.046$ ,  $r^2 = 0.875$  and  $p = <0.001$ ,  $r^2 = 0.452$   $p = 0.033$ , respectively; Figure 7-02). Removing the recently remediated Site L from the analysis improved regression slopes for all COCs (Figure 7-03). All regressions post Site L removal were also significant. The most substantial improvements were for As and Zn, where the correlations improved from  $r^2 = 0.36$  to  $r^2 = 0.70$  ( $p = 0.01$ ) and  $r^2 = 0.38$  to  $r^2 = 0.76$  ( $p = 0.005$ ). The increased significance of soil COC-to-food COC regressions suggest that uptake into invertebrates was affected by soil remediation at Site L. Food item evaluations once the area of Site L recovers from the

remediation process would provide a better understanding of the results. Decreased avian exposure due to the remediation process would likely benefit avian species.

Differences in prey item choice and collection time appear to influence exposure via food item consumption in the Anaconda area. For example, starlings inhabiting Sites K and L in 1999 consumed primarily lepidopteron larvae while starlings from other sites consumed grasshoppers with few lepidopteran larvae. Grasshopper samples had generally lower COC concentrations than did samples composed of lepidopteron larvae. Another difference in prey item choice was demonstrated in 2000 at Sites K and L where food samples collected from nestlings were composed almost exclusively of cicada. In both years, samples of food and nestling tissues from the K and L sites contained significantly higher Pb concentrations than samples from other sites.

*Passerine Egg Metal and As Analysis (1999):* COC levels in eggs were low compared to most tissues. There was a lack of detectable As and Cd levels for all but one sample for each metal and in each case, the measured value was low. Lead levels were generally below 0.2 µg/g in starlings and not detectable in 4 of 5 bluebird eggs sampled. Copper levels were less than 0.5 µg/g while Zn levels ranged from 4 to 8.9 µg/g in starlings and from 8.1 to 13.2 in mountain bluebirds. These levels are within or below normal ranges for the metals of concern, and provide evidence that maternal transfer of metals through egg deposition is not a substantial transfer route to the nestling.

*Blood exposure:* Though most non-essential metals were at or below detectable concentrations in blood, improved detection levels in 2000 provided more reliable data for As, Cd and Pb, replacing reporting limits with actual concentrations. During 1999, As and Cd occurred infrequently above detection limits in blood samples while Pb, Cu, and Zn concentrations were consistent across study sites. However, blood collected during the 2000 field season contained substantially more Cu than in 1999. This altered the relative amounts of Cu in blood, making inter-year and overall comparisons difficult.

Blood metal levels are more dynamic than tissue levels (Smith et al., 1994; Rozman and Klaassen, 1996), due to their primary dependence on food item levels, whose heterogeneity was demonstrated in food item analysis, above. For this reason, metal concentrations from single time point blood samples are unlikely to correlate well with metal concentrations in other, less dynamic, tissues. Correlations between metals in passerine blood and less dynamic tissues in this study were poor (data not shown), however, examinations with biomarker endpoints provided more reliable information (see ALAD discussion).

*Kidney exposure:* COC comparisons between soil and kidneys were significantly correlated for Pb ( $r^2 = 0.75$ ,  $p = 0.001$ ) and Cu ( $r^2 = 0.43$ ,  $p=0.038$ ), when all sites were evaluated (Figure 7-06). Site L tissues tended to have lower concentrations of most metals than tissues from other sites. Removing Site L from the analysis improved each regression and increased the regression slopes for all COCs (Figure 7-07). Increased slopes in this case suggest that remediation lowered uptake of COCs into kidney tissue. Zinc correlations became significant with the removal of Site L data ( $r^2= 0.52$ ,  $p= 0.044$ ).

*Liver Exposure.* Soil Pb concentrations described a significant amount of the Pb in livers of starlings ( $p=0.03$ , Figure 7-4), if all sites were used in the regression. Copper correlations were poor, likely because homeostatic Cu regulation was sufficient to keep liver Cu relatively constant. When Site L data were removed from the regression, Pb was still the only COC in soil that describes a significant amount of the lead in livers (Figure 7-5). Regression analyses of As or Cd soil levels against their respective liver concentrations were not significant due to the prevalence of non-detectable levels in 1999 liver samples. Regardless of detection limits, however, Cd concentrations in 2000 were higher than Cd concentrations in 1999. Food source differences between 1999 and 2000, discussed earlier, could explain the COC uptake differences, especially at Sites K and L.

*Adult Tree Swallow Mortalities.* The most notable finding in the adult tree swallow mortalities was elevated Cd in liver and kidney tissues. These elevations are not surprising due to the tendency of Cd to accumulate in these tissues, particularly the kidney, with age. Eight of eighteen (44%) of the adult swallows contained liver: kidney ratios of Cd that

exceeded 0.5, which suggests that swallow exposure to Cd was at least 0.5 mg/kg/day, based on Scheuhammer (1987). A minimum dose of 0.5 mg/kg/day is supported by the three food item samples collected from nestling swallows, with a mean Cd concentration of  $1.18 \pm 0.60$  µg/g. These results indicate that local Cd exposure occurred in adult tree swallows found dead on the Anaconda site, and that the levels are reflective of those found in food item samples collected from nestling swallows on the site.

The threshold of kidney Cd levels indicative of nephrotoxicity is approximately 100 µg/g dw (Scheuhammer, 1987; Beyer et al., 1988), which translates to roughly 25µg/g to 33 µg/g (ww). In 1999, the maximum Cd concentration in adult tree swallow kidneys exceeded 5 µg/g in one instance (Table 7-14) much less than the suggested nephrotoxic concentration. The Cd concentrations in adult swallow livers from Anaconda were greater than the maximum liver Cd levels in tree swallows from mining districts in Idaho (Table 7-13, Blus et al., 1995). In that work and in this study, however, the levels appear to be below those known to affect kidney health.

### 7.3.2 Passerine Effects Assessment

#### 7.3.2.1 Tissue Metal and As Assessment Based on Literature Values

Literature sources can provide perspective and assist interpretation of tissue COC concentrations. Though not always complete for every metal in all tissues studied, the literature was reviewed to better understand the repercussions of COC exposure.

*Blood Metal and As Interpretation.* Toxicity interpretations based on blood or tissue Pb levels have been developed for waterfowl, falconiformes (hawks, eagles and falcons), columbiformes (doves and pigeons) and galliformes (quail, chukar and pheasants), though no specific guidelines exist for passerine species (Franson, 1996). Thresholds have been developed describing effects at the sub-clinical, toxic and lethal levels. Blood Pb levels that fall in the subclinical range, from 0.2 to 1.5-3 ug/g are those that can lead to potential physiological injuries (e.g. ALAD inhibition or porphyrin profile changes) that are likely reversible with removal of Pb exposure. Toxic blood residue levels, from 1.5-3 to 5-10ug/g,

(depending on species) would result in severe physiological effects such as muscle wasting, anemia and generalized weakness. Levels higher than 5 to 10 ug/g are considered compatible with Pb poisoning-induced mortality or severe toxicity. Based on the limited passerine findings noted by Franson (1996), the higher end values of the noted distributions were used due to an apparent higher threshold of toxicity in this group of birds.

In 1999, one tree swallow from Site B contained a blood Pb concentration in the toxic range. Mean blood Pb concentrations in starling nestlings from Starling Sites L and Q exceeded the sub-clinical threshold, as did those of tree swallows from Starling Sites P, Q and those from box B 29. Average blood Pb was elevated above 0.2 µg/g in starling blood from one nest box on Site K, and three of seven nestlings from this Site contained blood Pb above the sub-clinical level. All three chickadee blood samples exceeded the sub-clinical threshold of 0.2 µg/g.

In an Idaho study, American robin nestlings had blood Pb concentrations of  $0.54 \pm 0.24$  µg/g ( $n = 8$ ; Blus et al., 1995). The 1999 Anaconda data set contains no blood samples with Pb concentrations above the mean concentration found in passerines from mining districts in Idaho (Blus and/or Johnson). However, during the 2000 field season, nine of 17 bluebirds and all chickadees accumulated blood Pb concentrations exceeding the 0.54 µg/g found in robins in Idaho. Two of 13 tree swallows from Anaconda had blood Pb concentrations that exceeded mean concentrations (0.18 µg/g) found in Idaho tree swallows.

*Egg Metal and As Interpretation:* Several reviews have examined the use of eggs as indicators of metal exposure (Beyer et al., 1996; Burger, 1994; Burger et al., 1999; Furness, 1996). Arsenic and Cd were detected in only one passerine egg, each, from the Anaconda study, which agrees with the negligible concentrations of As (Custer et al. 2002) and Cd (Beyer et al., 1996; Burger 1994) generally found in avian eggs. Avian egg Pb levels across 25 literature sources ranged from 0.020 µg/g to 6.7 µg/g, with a median of 0.142 µg/g (Burger, 1994; Gochfeld and Burger, 1998). The highest egg Pb level detected on Anaconda sites was 0.142 µg/g, and all values from the present study fall at or below the median of previous studies. Cu and Zn levels were detected at concentrations that are characteristic for

avian eggs (Cu: 0.9 µg/g, Zn: 11 µg/g; Richards and Packard, 1996, cited in Klasing 1998). Overall, levels of COCs in Anaconda site eggs approximate those considered normal for essential elements, are at or below detection levels for As and Cd and are at or below median levels for Pb in avian species. It is not likely that metal and As levels in eggs contribute significantly to the metal or As burden carried by nestlings, suggesting that metal levels in nestling tissues reflect COCs that were accumulated on site.

*Liver Metal and As Interpretation:* Liver tissue from Site K, in 1999, contained more Pb, Cu, and Zn than did livers from other sites. Birds from this site also had the highest concentration and occurrence (75%) of Cd. As levels reached peak levels primarily at Site N.

Previous work with As in birds has focused on both field and laboratory assessments. Field studies with wading birds suggest that liver As levels of <0.5 µg/g (Goede 1985) are considered background, however As levels of 0.4 µg/g (1.3 µg/g d.w.; Camardese et al., 1990) in mallards, though not lethal, were accompanied with perturbations in growth, brain and liver biochemistry, and normal activity patterns. Goede (1985) suggests that levels of 2 to 10 µg/g were consistent with As toxicity while those >10 µg/g were diagnostic of death by As poisoning. Though generally below detection levels in 1999, As occurred at 2.5 and 3.5 µg/g in a live starling and bluebird, respectively, and 2 of 34 nestlings found dead in the nest (1 starling and 1 bluebird) had between 1.2 and 2 µg/g liver As. In 2000, better detection limits demonstrated that As exposures occurred between 0.01 µg/g and 0.5 µg/g in live nestlings. Two starling nestling mortalities reached 0.91 and 2.5 µg/g in 2000, however, most of the opportunistic birds had liver As levels similar to those sampled live. In both 1999 and 2000, the majority of these exposures took place on site N. Hepatic As levels in nestlings at the Anaconda Smelter Site were generally below those that lead to direct mortality, though individuals at the highest levels of exposure were likely affected by clinical effects that occurred at elevated exposure levels of 0.4 µg/g and above

A data compilation of a variety of literature sources indicates Pb in the liver reaches sub-clinical levels at approximately 2 µg/g while concentrations of >5 µg/g are considered toxic (Franson, 1996). Data obtained at the Anaconda Smelter Site showed that Pb concentrations

in individual starling livers exceeded sub-clinical concentrations ( $2\mu\text{g/g}$ ) at Sites K and L in both years (Figure 7-11). One live nestling each year from Site L accumulated Pb in liver at toxic levels. In 2000, two of 17 bluebird nestlings contained liver with Pb above  $2\mu\text{g/g}$  (Figure 7-12). One of the bluebirds at Site C had a liver Pb concentration of  $5.24\mu\text{g/g}$ , a toxic concentration in liver. In 1999, livers of 75% of bluebird nestlings ( $n=4$ ) exceeded  $1\mu\text{g/g}$ . For comparison with Anaconda nestlings, the passerine work in the Coeur d'Alene mining regions of Idaho (Blus et al., 1995; Johnson et al., 1999) documented hepatic Pb levels that range from  $0.72\mu\text{g/g}$  to  $3.67\mu\text{g/g}$ , with a mean of  $1.93 \pm 1.12\mu\text{g/g}$  ( $n=5$ ). Of the COCs studied, Pb appears to reach levels of greatest concern.

*Kidney Metal and As Interpretation:* Kidneys, in 1999, generally contained less than  $4\mu\text{g/g}$  Pb. The highest Pb and As concentrations in kidney were from a live starling nestling collected in 1999 at Site K (box 01, nestling B, Table 7-11A) and were  $27.5\mu\text{g/g}$  and  $28.1\mu\text{g/g}$ , respectively, consistent with elevated food item levels in this box. Several nestlings from nest SK01 died prior to reaching fledging age. There were, however, no other signs of toxicity from nestlings in that nest. The nestling collected from box SK15 had high liver and kidney Pb levels ( $2.13\mu\text{g/g}$  and  $4.0\mu\text{g/g}$  respectively), and high liver Cu and Zn levels. The analytical and morphological data (neck curvature and wasting) for this nestling suggested Pb toxicity. Cadmium concentrations in kidneys from Sites K and L were significantly higher in 2000 compared to those in 1999. Arsenic and Pb accumulations in kidneys were also higher in 2000 than in 1999 at the same sites, although the overall metal concentrations were not significantly different. Lead concentrations in kidney are diagnostic of sub-clinical effects at  $2\mu\text{g/g}$  to  $20\mu\text{g/g}$ , while  $>15\mu\text{g/g}$  indicates toxic exposure and  $>40\mu\text{g/g}$  indicates a possible cause of death (Franson, 1996). Seventeen nestlings had kidney Pb concentrations in the sub-clinical concentration range (Figure 7-13). Lead was not detected in kidneys of other species collected in 1999 (Figure 7-14). During 2000, there was one bluebird nestling with kidney Pb exceeding  $10\mu\text{g/g}$  at Site C.

*Intra-nest Metal and As Comparisons:* Comparisons of tissue metal levels in live and dead starling nestlings demonstrated that there was little difference in concentrations between survivors and mortalities on each site (Tables 7-9 through 7-16), suggesting that mortality

occurred in individuals with metal levels characteristic of all birds on any particular site. Although there were insufficient numbers of dead and live nestlings collected from the same clutch to make statistical comparisons, observations about COC accumulation in both live and dead nestlings can be made from the available data (Tables 7-09A to 7-15A). Opportunistically collected chicks often contained higher COC concentrations than did their live collected siblings. This pattern was more apparent in 2000 than in 1999.

During the 1999 field season, intra-nest comparisons for both liver and kidney could be made for 9 starling nests, 1 bluebird nest, and 1 tree swallow nest. For liver, opportunistic chick mortalities from SK01 contained lower Cd, Pb, Cu and Zn than did live chicks from the same box. However, in SK12, Cd, and Zn were elevated in dead chicks while Cu was lower. Copper decreased and Zn increased in dead chicks from SL20. At SN01, dead chicks contained elevated Pb along with decreased Cu and Zn, while all COCs were elevated in dead chicks relative to live chicks in SN06. Arsenic and Zn were lower in dead than live chicks from SN07. Dead nestlings from SN14 and SO12 contained elevated Pb, Cu, and Zn relative to live chicks. Opportunistically collected chicks from SO14 contained elevated Cd, Pb, and Zn in liver compared to concentrations found in livers of their live collected siblings. The dead mountain bluebird nestling from nest SH12 contained As that was elevated while all other COCs were decreased. Tree swallow nestlings that died in box B#29 contained elevated Cd, Cu, and Zn in their livers as compared to contaminant concentrations in the liver from their sibling.

Kidney samples (in 1999) from SK01 opportunistic chicks contained lower Pb and Zn than did their live siblings. Zinc was the sole COC to increase in dead chicks from SK12. At SL20, Cu was decreased compared to live chicks. At nests SN01, SN06 and SN14 dead chicks contained less Pb than did live chicks. Dead chicks from nests SN06 and SN04 also contained less Cu. At Site O, dead chicks from nest SO12 contained higher Pb, Cu, and Zn, while dead chicks from SO14 contained higher Cd, Pb, and Zn.

During the 2000 field season, live and dead starling nestlings were collected from 3 nests (SN04, SN06, and SN09). Liver from opportunistically collected chicks contained higher

concentrations of all COCs in nest SN04. In nest SN06 opportunistically collected nestlings contained lower Cd and higher Pb in liver than did their live siblings. Arsenic was elevated in opportunistically collected chicks from SN09, while Pb and Cd were found at lower concentrations compared to live siblings. Kidneys from dead nestlings at starling Site N (SN04, SN06, SN09) contained elevated As compared to live chicks. This was generally accompanied by decreases in other COC concentrations. Dead bluebird chicks (SH08) and Tree swallow chicks (SH02) also demonstrated an increase in As with concomitant decreases in all other COCs.

There was substantial variability in the comparisons of metal and As levels in live and dead nestlings. Some nestlings clearly contained levels known to be toxic and, on rare occasions, lethal to avian species. Sufficient data do not exist, however, to broadly conclude that the levels of COCs were high enough in nestling mortalities to generally be considered their cause of death.

#### 7.3.2.2 Porphyrin Profiles

European starlings inhabiting nest box arrays in areas with higher COC concentrations had elevated tissue levels of carboxylated porphyrins. In 1999, liver and kidney 4-, 2-, and total CP levels were elevated in nestlings inhabiting Sites N, K and L, resulting in levels up to twice those seen in nestlings from Sites O and Q. Though elevated overall and somewhat more variable, results in 2000 also demonstrated elevated levels of 2-, 4- and total CP in kidneys, and 4- and total CP in liver, of nestlings on Sites N, K, and L.

Liver and kidney porphyrin profiles of avian species are known to respond to environmental metal exposures (Akins et al., 1993; Akins, 1995, Trust et al., 2000). In nestling European starlings, Pb causes increased 4-, 2- and total CP in both liver and kidney while As causes similar elevations in the liver (Akins 1995). The elevations noted in that work, as in the findings with Anaconda starlings, did not generally exceed a doubling in levels, even at Akins' highest Pb dose of 400 mg/kg or As dose of 12 mg/kg (both were cumulative doses delivered over 4 days spread across nestling development). These similar results are

consistent between the controlled dosing study (Akins 1995) and the current biomonitoring assessment.

Fowler and Mahaffey (1978) have previously showed interactive effects from Pb, Cd, and As exposures in porphyrin excretion patterns, suggesting that direct correlations of individual metal concentrations with porphyrin levels may not fully represent the scope of cause and effect relationships. Combinations of metals can influence uptake and distribution of each metal and can also influence the effect of each metal on target sites (Krishnan and Brodeur, 1991; Goyer, 1997).

Multiple regressions of nestling porphyrins with COCs in kidneys (Table 7-21) showed that Cd, Pb and Cu all positively influenced, while Zn and As had negative effects on, porphyrin levels. Similar relationships were noted in the liver, though Pb was less responsible for increases in 2-CP levels. Correlation coefficients, all greater than 0.62, suggest that the metals describe a large proportion of the porphyrin changes. This model provides an interesting view of the role combinations of metals might play in the overall effect on porphyrin levels. Given previous findings of As causing porphyrin increases in starling liver (Akins 1995), the model's suggestion that As has a negative influence on porphyrins seems counterintuitive. Alternatively, it may indicate that in combinations, metals may behave as competitors for porphyrinogenic mechanisms, leading to effects that differ from those seen under single chemical exposure scenarios. Changes in porphyrin profiles due to metal mixture exposures thus represent an integration of responses rather than the effects of any single component.

#### 7.3.2.3 ALAD Activity

Lead has been well characterized as an inhibitor of ALAD enzyme activity (Eisler, 1988, Hoffman et al., 1985; Franson et al., 1983). As an essential enzyme in the biosynthesis of heme, ALAD provides a sensitive indicator of health effects due to Pb contamination in birds. Activity levels of ALAD in nestling starlings were depressed on sites where Pb exposure was highest. There was a significant negative correlation between mean box

ALAD activity and blood Pb concentration ( $r = -0.696$ ;  $p < 0.01$ ), with approximately 53% of this variation explained by the relationship ( $r^2 = 0.5296$ ; Figure 7-15). Though the current study did not incorporate a reference site, *per se*, there were 4 nest boxes with nestlings having no detectable blood Pb (boxes SN05, SR02, SR05 and SR14; Table 7-22A). The mean ( $\pm$  s.d.) ALAD activity for these 4 starling boxes was  $124.5 \pm 21.3$  units. A comparison of ALAD site means, across Anaconda starling Sites K, L, N, P and R (Table 7-22), to this internal reference value indicates that ALAD activities were inhibited 46%, 30%, 15%, 29% and 7%, respectively. A more detailed assessment shows that 17% (4/23; nests from boxes SN13, SN01, SP01 and SK01; Table 7-22A) of individual nest box ALAD activities were inhibited 40% or more (Figure 7-17). One of the values, from the nest in SK01, was inhibited greater than 50%. The average level of starling ALAD inhibition was  $13.5\% \pm 24.0\%$ .

Percent packed cell volumes for starlings were assessed similarly to those of ALAD activities, with comparisons between sites as well as the establishment of a reference value determined from the individuals with non-detectable lead levels in their blood. ANOVA Comparison of mean PCV values across starling sites found a marginally significant difference between sites ( $p = 0.057$ ), specifically between Sites K and L (43.6% versus 31.2%, respectively, Tukey's post hoc test). The PCV value for the internal PCV reference was  $38.3 \pm 6.3$  (mean  $\pm$  s.d.,  $N = 4$ ) in starling nestlings (Table 7-22A). The small sample sizes for sites K, L and P preclude meaningful comparison for them using this approach, while Sites N and R were each within 3% of the mean PCV value. Based on both of these approaches, the difference in PCV values between sites does not appear biologically significant.

Bluebirds also showed a significant negative correlation ( $r = -0.723$ ;  $P = 0.001$ ), with 44% of ALAD activity explained by blood Pb concentration ( $r^2 = 0.4356$ , Figure 7-16). A similar treatment of bluebird ALAD data provided 5 nest boxes with non-detectable blood Pb levels (boxes B#23, K#21, SM09-1, SM09-2 (a separate clutch from SM09-1) and SO17; Table 7-22A). The mean ( $\pm$  s.d.) ALAD activity for these 5 bluebird nests boxes was  $104.4 \pm 16.3$  units. A comparison of the ALAD activities of the 18 bluebird nests studied shows that 17%

(3/18; nests from box numbers SK07, SC02 and SC10) were inhibited greater than 40% (Figure 17). Two of the values, nests from the starling C array, were inhibited greater than 50%. The finding that the most significant effects of Pb exposure occurred on Site C is important due to the generally low coverage given to the sites on or behind Smelter Hill. The average level of mountain bluebird ALAD inhibition was  $17.8 \pm 18.8\%$ .

No significant correlations were detected in tree swallows, as nine of eleven blood Pb samples were below detection levels. Chickadee nestlings, with only three data points, showed a 76% difference between highest (108.4 units; B#38) and lowest values (26.04 units; B#12), however, there was not a dose-dependent relationship amongst the three box values.

In studies of passerine species associated with Idaho's Coeur d'Alene River Basin site, a nearby lead contaminated Superfund site in Idaho, ALAD was assessed similarly to the approach used in the Anaconda study (Johnson et al. 1999). Song sparrows (*Melospiza melodia*) inhabiting contaminated sites had ALAD activities inhibited 51% compared to reference sparrows. Though blood Pb levels were not measured, liver lead levels of 1.93 and 0.1  $\mu\text{g/g}$  were found in their contaminated and reference birds, respectively. These exposure levels compare favorably with Anaconda data from Site K and L where liver Pb averaged 2.41 and 1.57  $\mu\text{g/g}$ , respectively. As the single Anaconda starling nest with ALAD inhibition greater than 50% was on Site K (Box SK01, 56% inhibited), the Coeur d'Alene River Basin study seems consistent with the findings of the present study.

In our study, one starling and two bluebird ALAD values exceeded a 50% level of inhibition with 17% of values for each species at or approaching this value. The limited scope of this study provides ALAD data on developing nestlings only. As these data provide evidence that Pb exposure is reaching levels that can disrupt heme synthesis pathways in avian species inhabiting the site, consideration in future studies should be given to other species with similar or greater potential for Pb exposure.

#### 7.3.2.4 Nest box Demographics and Nestling Morphology

In 1999, several late season cold weather events appeared have influenced clutch initiation and hatching success. Two such events, of approximately 1-week duration each, occurred during nest initiation and hatch of many clutches. Events such as these are likely to have had an effect on nesting success and fledging efficiency (Cabe, 1993). Conversely, extremely high ambient temperatures, as seen during the 2000 season, have been noted to increase nestling mortality as well (Cabe, 1993). In general, reproductive demographics across the site for both years were within literature values (Cabe, 1993; Hooper and Skipper, 1994; Collins and DeVos, 1966). Decreases due to predation were notably low, as few mammalian or reptilian predators were identified on the site. A small number of avian predation events were suspected or recognized. A Cooper's hawk was observed atop nest boxes at Site R (2000) with a clutch found subsequently missing or dead, a great-horned owl was noted often near Site N, and an unidentified raptor is believe to have removed a clutch at Site O (1999).

Starling clutch sizes averaged 4.18 eggs per clutch for all sites across both years, slightly lower than that given by Cabe (1993; mean clutch 4.45) or Collins and DeVos (1966; mean clutch 5.5). Nevertheless, average nest and fledging success for all sites over both years were within the values given by Cabe (1993; 48-71% and 52-79% respectively). The three remaining passerine species appear to have experienced very good reproductive success, as nesting success was above 90% for all species. Blowfly larvae (*Protocalliphora* sp.) parasitized starlings, bluebirds and tree swallows during both seasons, though clutch infection was found to be more extensive in tree swallows in 2000. Larvae appeared to be a heavy burden to numerous individuals (nares malformations, open sores in skin). Robertson et al. (1992) reported similar blowfly larvae infestations in passerines. Chickadees had successful clutches for all attempts. Most addled chickadee eggs were from two clutches where eggs were laid days before a cold front that lasted several days, likely leading to embryo deaths. These circumstances lowered the nesting efficiency (nestlings fledged/eggs laid) for chickadees to 44.7%, while resulting fledging efficiency (nestlings fledged/hatched egg) was 100%. Reproductive demographics for starlings and the three species of passerine agree with reproduction results previously reported (Kessel, 1957).

Alone, the morphological data confirmed that ill nestlings grew at a slower rate, but the data do not suggest that adverse morphological outcomes occurred due to COC exposure.

Kidney, liver, bursa, and brain weights were not different between sites. However, spleen tissue weights were more varied within and between sites.

### 7.3.3 Data Quality Objectives

The Data Quality Objectives encompass the experimental design and rationale for the biomonitoring study at the Anaconda Smelter. Central to the process is developing the data necessary to assess the questions posed by the decision rule. The data sets allow an assessment of passerine status on and around the Smelter site.

*Step 4: The Decision Rule.* Three statements were developed that provide the guidance for developing the decision rule for the study. They depend on evaluating relationships between COCs on the site with exposure and effects in the test species. Provided, below, are data summaries from the biomonitoring program that directly address each statement.

*a. If the concentrations of metals or As in prey items, tissue or whole body of wildlife species in no way correspond to soil concentrations within exposure areas, then it will be determined that no association exists between soil contamination and wildlife exposure.*

An association between soil contamination and food items has been established with high confidence. Mean COC concentrations in food items were significantly correlated with all COC concentrations in soil ( $0.37 < r^2 < 0.88$ ). Lead showed the strongest correlation. When the remediated site, Site L, was removed from the analysis, all correlations exceeded 0.69. A further association between soil contamination and passerine species exposure has been demonstrated for passerines, for both liver and kidney residues. Significant correlations were observed between soil and kidney Pb, Cu and Zn levels in the absence of Site L data (Pb and Cu only if Site L is included). Liver levels of Pb correlated significantly with soil levels regardless of the inclusion of Site L in the assessments. COC concentrations in blood did not

correlate with COC concentrations in soil. The best relationships between COCs in avian tissues and COCs in soil were found for Pb at non-remediated sites ( $0.70 < r^2 < 0.85$ ).

*b. If the concentrations of metals or As in prey items, tissue or whole body of wildlife species in no way correspond to individual health effects and population demographics, then it will be determined that metal or As exposures are of no consequence to wildlife species;*

Assessments of porphyrin profiles suggest a dose-response relationship with Cu, Pb and Cd accumulation that is modulated by Zn concentration and to a lesser extent by As. ALAD activity in starlings as well as bluebirds was significantly depressed by increased Pb levels in blood. There were differences between years in food item profiles, levels of metal uptake and porphyrin response at the sites studied during both years, indicating that variation in prey characteristics can lead to variation in exposure and thus effects. Comparison of tissue Pb concentrations and ALAD inhibition levels with literature-based hazard criteria indicates that a small proportion of individuals is exposed to potentially toxic Pb levels. Metal and As exposure and accumulation could not be statistically tied to adverse effects on reproduction of starlings inhabiting the Anaconda site.

*c. If the concentrations of metals in prey items, tissue or whole body of wildlife species, and individual health effects and population demographics in no way correspond to remedial actions, it will be determined that remedial options are of no consequence to wildlife species.*

Individual passerine nests were initiated on the Smelter Hill, Opportunity Ponds, and Anaconda Ponds ARTS remediation plots with limited success. Starlings nested on the Opportunity Ponds ARTS remediation site in 2000, only. Alternatively, Site L underwent liming, tilling and vegetative cover planting in 1999. Site L and the adjacent, and un-remediated, Site K were heavily utilized during that time. Starling food item COC levels obtained from birds on Site L were generally lower than those obtained from Site K for both study years. Improved correlation between site soil and starling food item and kidney tissue metal concentrations occurred when Site L data were removed, suggesting that the generally lower tissue metal levels of Site L birds may have been due to a decrease in availability of soil contaminants on that site. It is unclear if the cause of this finding was diluted COC concentrations in tilled and limed soils, decreased COC availability due to lime effects on

COCs, or simply foraging by adult starlings in undisturbed, perhaps less contaminated areas. Liver COC levels on Site L, however, were less consistent and elevated levels were highest on Sites L and K for a variety of COC/tissue combinations. Given that baseline exposure data were not available before remediation, it is difficult to define the role played by remediation in the findings from Site L.

Passerine Tables and List of Tables

**List of Passerine Tables**

<b>Table Number</b>	<b>Passerine Table Content</b>
7-1	Nest Box Placement and Use
7-2	Detection and Reporting Limits for Metals Data
7-3	Soil Metal and As Concentration from Passerine Sites
7-4	Food Item COCs 1999
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7-7	Blood COCs 1999
7-8	Blood COCs 2000
7-9	Liver COCs Nestlings 1999
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7-12	Kidney COCs Nestlings 2000
7-13	Liver COCs Opportunistic Collections 1999
7-14	Kidney COCs Opportunistic Collections 1999
7-15	Liver COCs Opportunistic Collections 2000
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7-21	Porphyrim regression kidney and liver 1999/2000 combined
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7-25	Demographics European Starlings 1999
7-26	Demographics European Starlings 2000
7-27	Demographics European Bluebird, Tree Swallow, Chickadee 2000
7-28	Body Weight and Morphological Measurement 1999
7-29	Body Weight and Morphological Measurement 2000

**Table 7-1.** Placement and use of starling and bluebird nest boxes in 1999 and 2000 at the Anaconda Smelter Site.

Site or Box ID <sup>2</sup>	Activity <sup>1</sup>		No. of Boxes	Description
	1999	2000		
<u>Starling Arrays</u>				
A	NO	NO	20	Location: East-facing slope south of Smelter Hill, Split array; 10 boxes on either side of Aspen grove Ephemeral pond near the eastern row of boxes
B	BB,TS	BB,BC TS	30	Location: Saddle just south of Smelter Hill. Array follows aspen tree line northward toward Smelter
C	NO	BB	10	Location: Steep north-facing slope just south of Smelter Hill Live and dead aspen and sporadic vegetation.
D	NO	NO	20	Location: Northeast slope at the bottom of Smelter Hill Array follows northeast along aspen tree line. Natural warm spring east across field.
E	NO	NO	5	Location: Upslope from D, across road. Limited aspen and sporadic vegetation(1999). Grassy(2000).
F	BB	BB,TS	10	Location: ARTS plot at base of Smelter stack. Array ran east west following ditch around hill. Limited replanted grasses. Exposed to high winds.
G	NO	BB	10	Location: ARTS plot north, downhill of Smelter stack. Array split by road. Limited replanted grasses.
H	BB	BB,TS	15	Location: Remediated field northeast at base of Smelter Hill. Limited replanted grasses. 5 boxes parallel road, 10 boxes perpendicular.

Continued

**Table 7-1.** Continued

Site or Box ID <sup>2</sup>	Activity		No. of Boxes	Description
	1999	2000		
<u>Starling Arrays</u>		Continued		
I	NO	BB,TS	20	Location: ARTS plot along southern edge of Anaconda Pond Boxes follow the northwest corner of plot.
J	TS	TS	14	Location: ARTS plot in center of Anaconda Pond Boxes follow the northwest corner of plot.
K	ES	ES,TS BB	18	Location: Field bordering Warm Springs Creek. Array along Cottonwoods that follow creek. East of Galen Rd. Limited vegetation and Cottonwoods.
L	ES	ES,BC	20	Location: Field bordering Warm Springs Creek. West of Galen Rd., NE of Site K. (soil tilled and limed, 1999) No vegetation (1999). Limited grass and forbs (2000)
M	NO	BB	15	Location: Hillside east of Old works, west Anaconda Speedway Arrays along tree line and ditch, limited vegetation.
N	ES,TS	ES,TS	20	Location: Northwest corner of Opportunity Ponds Cell-C. Array follows border of tree grove. Well vegetated. Across Highway 48 from Warm Springs creek.
O	ES	BB,TS	20	Location: South of Opportunity Pond Cell-D. Just west of I-90. South facing array following tree line. Standing pools just west of array at base of berm.
P	TS	ES,TS	15	Location: ARTS plot in middle of Opportunity Pond, Cell-D. Array follows northeast corners.

Continued

**Table 7-1.** Continued

Site or Box ID <sup>2</sup>	Activity		No. of Boxes	Description
	1999	2000		
<u>Starling Arrays</u>				
Continued				
Q	ES,TS	NO	20	Location: East of Opportunity Pond Cell-C berm. Split array: 10 boxes along east-west tree lines. 3 bluebird boxes in field just east of main array.
R	NO	ES,TS	22	Location: 1999 – South of Opportunity Ponds, near the border of Cells B and C. Location: 2000 – North of Warm Springs Ponds W.M.A. Surrounding several tree groves, at last settling pond.

Bluebird Boxes

1999	2000				
1-2	1-2	NO	NO	2	Location: Associated with starling array Site A.
3-4	3-4	NO	NO	2	Location: Associated with starling array Site B.
5	5	NO	NO	1	Location: Associated with starling array Site C.
6-8	6-8	NO	NO	3	Location: Associated with starling array Site D.
9	9	NO	NO	1	Location: Associated with starling array Site E.
10-11	10-11	NO	NO	2	Location: Associated with starling array Site G.
12-14	12-14	NO	NO	3	Location: Associated with starling array Site H.
15		NO	NO	1	Location: Associated with starling array Site I.
16-17		NO	NO	2	Location: Associated with starling array Site J.
17-19	15-17	NO	NO	3	Location: On fence along road to the site-laboratory.

Continued

**Table 7-1.** Continued

Site or Box ID <sup>2</sup>	Activity		No. of Boxes	Description
	1999	2000		
<u>Bluebird boxes</u>		Continued		
	<u>1999</u>	<u>2000</u>		
20-21	18-19	NO	NO	2 Location: Associated with starling array Site K.
22-23	20-21	NO	NO	2 Location: Associated with starling array Site L.
24	22	NO	NO	1 Location: Associated with starling array Site M.
25-28		NO	NO	4 Location: Home of Hans Lampert. Warm Springs Road.
29-30	23-24	TS	BB	2 Location: Associated with starling array Site N.
31-34	25-28	NO	NO	4 Location: Associated with starling array Site O. 2 boxes on fence parallel to array; 2 boxes at ends of array.
35	29	NO	NO	1 Location: Associated with starling array Site P.
36-41	30-35	NO	TS	6 Location: Associated with starling array Site Q. 2 boxes at ends of array, 1 center. 3 boxes across berm and aligned with boxes at Q
42-44	36-38	BC	BC,TS	3 Location: Associated with starling array Site R (1999).
39-43		NO	NO	5 Location: Associated with starling array Site R (2000). 4 boxes at ends of arrays. 1 box in adjacent field to east.
44-45		NO	NO	2 Location: At Montana State Hospital. On fence next to Kestrel box 47.

1. Activity is designated by the species nesting on the site: ES – European starling, BB – mountain bluebird, TS – tree swallow, BC – black-capped chickadee, NO – No nesting activity at site.
2. Bluebird box ID numbers were shifted in year 2000. Boxes with single ID numbers were unique in the year indicated. Boxes with two ID numbers reflect change in ID system in 2000.

**Table 7-2.** Detection limits and reporting limits for metals data in passerine samples collected at the Anaconda Smelter site, 1999 and 2000. Reporting limits are one half detection limits.

Sample Type	Average Sample Mass	As	Cd	Pb	Cu	Zn
		µg/g	µg/g	µg/g	µg/g	µg/g
Detection Limits 1999						
Blood	1.538	0.441	0.033	0.200	0.067	0.101
Liver	0.785	0.865	0.064	0.393	0.131	0.199
Kidney	0.312	2.18	0.161	0.988	0.329	0.500
Egg	5.071	0.134	0.010	0.061	0.020	0.031
Food	1.078	0.630	0.047	0.286	0.095	0.145
Reporting Limits 1999						
Blood	1.538	0.221	0.016	0.100	0.033	0.051
Liver	0.785	0.432	0.032	0.196	0.065	0.099
Kidney	0.312	1.088	0.080	0.494	0.164	0.250
Egg	5.071	0.067	0.005	0.030	0.010	0.015
Food	1.078	0.315	0.023	0.143	0.048	0.072
Detection Limits 2000						
Blood	0.836	0.060	0.003	0.060	0.123	0.187
Liver	1.344	0.037	0.002	0.037	0.076	0.116
Kidney	0.353	0.142	0.007	0.142	0.291	0.442
Food	1.1514	0.043	0.002	0.043	0.089	0.135
Reporting Limits 2000						
Blood	0.836	0.030	0.001	0.030	0.061	0.093
Liver	1.344	0.019	0.001	0.019	0.038	0.058
Kidney	0.353	0.071	0.004	0.071	0.145	0.221
Food	1.1514	0.022	0.001	0.022	0.045	0.068

**Table 7-3.** Soil metal and As concentrations from passerine sites, Anaconda Smelter site. N is the number of samples used to calculate the mean value.

Site	As		Cd	Pb	Cu	Zn
		µg/g	µg/g	µg/g	µg/g	µg/g
Starling K <sup>1</sup>	Mean	1373.57	12.48	654.93	3273.93	1170.93
	Max	3620.00	21.00	1200.00	13000.00	1930.00
	Min	352.00	4.00	159.00	1070.00	411.00
	S.D.	811.91	6.80	372.75	3252.60	500.54
	N	14	7	7	14	14
Starling L <sup>1</sup>	Mean	1103.00	12.20	450.57	4591.94	1651.39
	Max	3620	20.8	1200	13000	4675
	Min	211	3	58	1070	383
	S.D.	870.39	5.57	329.33	3160.54	1024.47
	N	21	13	15	18	18
Starling N <sup>2</sup>	Mean	287.8	6.5	207.1	726.4	694.7
	Max	576.0	13.0	527.0	1370.0	1280.0
	Min	58.5	1.8	59.1	212.0	279.0
	S.D.	129.7	2.6	105.6	258.3	237.1
	N	39	39	39	39	39
Starling O <sup>2</sup>	Mean	512.1	2.9	179.9	1479.0	378.9
	Max	2180.0	12.1	451.0	8950.0	1640.0
	Min	84.8	0.2	30.7	237.0	82.5
	S.D.	426.2	2.6	115.0	2045.6	328.2
	N	40	40	40	40	40
Starling P <sup>1</sup>	Mean	11.96	0.66	18.96	133.94	79.64
	Max	18.50	0.88	54.20	301.60	165.00
	Min	5.60	0.58	7.41	21.47	29.13
	S.D.	5.93	0.10	16.25	97.04	47.14
	N	7	7	7	7	7

Continued

**Table 7-3. Continued**

Site		As	Cd	Pb	Cu	Zn
		µg/g	µg/g	µg/g	µg/g	µg/g
Starling Q <sup>2</sup>	Mean	153.1	4.0	128.6	710.5	586.0
	Max	422.0	10.4	442.0	2650.0	2550.0
	Min	21.6	0.7	18.3	54.7	60.0
	S.D.	87.4	2.4	89.4	621.6	494.2
	N	40	40	40	40	40
Starling R <sup>1</sup>	Mean	264.00	3.28	208.88	1019.83	348.00
	Max	630.00	7.00	561.00	2460.00	645.00
	Min	29.00	1.12	32.50	59.50	55.00
	S.D.	261.01	2.57	240.23	1270.15	295.02
	N	4	4	4	3	3

1. Soil metal concentrations from RRU (2002), see Section 7.1.5. 2. Soil metal concentrations from LMTS (2001)

**Table 7-4.** Metal and As concentrations in food items from passerine species inhabiting the Anaconda Smelter site, 1999. Values below detection limit were replaced with reporting limits (see Table 7-2). Site N (Box N) is the total number of boxes (individual samples). n - number of boxes (individuals) with at least one detectable value.

Site or Box ID <sup>1</sup>	Box N	Site N		As μg/g	Cd μg/g	Pb μg/g	Cu μg/g	Zn μg/g
<u>European Starlings</u>								
Site K		4	Mean	32.578	2.474	25.530	106.545	167.520
			SD	34.436	3.657	30.846	53.238	68.923
			n	4	4	4	4	4
Site L		3	Mean	12.330	0.403	6.691	64.892	116.784
			SD	7.969	0.261	6.347	36.821	73.954
			n	3	3	3	3	3
Site N		5	Mean	4.091	1.302	2.205	53.768	90.962
			SD	1.358	0.725	1.530	17.254	29.287
			n	5	5	5	5	5
Site O		6	Mean	4.643	0.103	1.943	60.875	77.661
			SD	2.129	0.036	0.686	25.088	29.903
			n	6	6	6	6	6
Site Q		4	Mean	17.351	0.206	1.696	32.996	66.058
			SD	20.962	0.211	1.561	8.718	31.370
			n	4	3	4	4	4
<u>Mountain Bluebird</u>								
K 08		1		1.762	1.507	1.246	34.280	89.687
SF09	3		Mean	31.956	0.447	4.411	49.604	75.857
			SD	35.861	0.492	3.986	14.816	3.025
			n	3	2	2	3	3
<u>Chickadee</u>								
B 44		1		4.655	0.450	3.989	27.039	69.122
<u>Tree Swallow</u>								
K 47		1		0.315	0.490	0.143	44.617	56.499
SB12		1		0.315	1.592	1.272	12.935	52.621
SQ03		1		0.315	1.573	0.143	13.884	127.127

1. Site is starling array. Box ID is identified by box type (B- bluebird, K- kestrel) and specific box number; or by box type (S-starling), site, and box number.

**Table 7-5.** Metal and As concentrations in food items from passerine species inhabiting the Anaconda Smelter Site, 2000. Values below detection limit were replaced with reporting limits (see Table 7-2). Site N (Box N) is the total number of boxes (individual samples). n - number of boxes (individuals) with at least one detectable value.

Site or Box ID <sup>1</sup>	Box N	Site N		As μg/g	Cd μg/g	Pb μg/g	Cu μg/g	Zn μg/g
<u>European Starling</u>								
Site K	2		Mean	47.490	3.039	22.982	121.145	229.275
			SD	11.464	0.202	0.367	12.421	31.028
			n	2	2	2	2	2
Site L	2		Mean	5.044	0.678	12.447	60.862	109.310
			SD	2.280	0.624	14.164	28.356	69.227
			n	2	2	2	2	2
Site N	9		Mean	14.407	0.643	1.039	16.998	64.990
			SD	31.958	0.211	0.675	8.349	12.696
			n	8	9	7	9	9
Site P	2		Mean	11.791	0.392	0.844	10.990	50.998
			SD	5.312	0.002	0.470	0.726	7.647
			n	2	2	2	2	2
Site R	10		Mean	3.835	0.324	1.525	16.361	48.771
			SD	2.902	0.170	1.373	8.480	12.390
			n	10	10	10	10	10
<u>Mountain Bluebird</u>								
Site B	2		Mean	2.399	4.055	0.795	42.423	97.492
			SD	0.601	2.491	0.008	21.821	24.642
			n	2	2	2	2	2
Site C	2		Mean	26.338	3.896	10.540	75.665	162.907
			SD	3.548	3.397	11.199	43.555	6.838
			n	2	2	2	2	2

Continued

**Table 7-5.** Continued

Site or Box ID <sup>1</sup>	Box N	Site N		As	Cd	Pb	Cu	Zn
				µg/g	µg/g	µg/g	µg/g	µg/g
Site F		2	Mean	22.587	0.465	1.407	25.116	61.613
			SD	10.058	0.312	1.033	18.478	24.436
			n	2	2	2	2	2
Site G		2	Mean	11.616	1.853	2.877	57.571	153.882
			SD	1.730	1.850	1.648	16.821	93.057
			n	2	2	2	2	2
Site H		2	Mean	14.696	1.011	6.792	48.688	147.140
			SD	18.663	1.095	7.264	26.896	73.631
			n	2	2	2	2	2
SI06	4		Mean	1.796	0.623	2.050	67.158	77.491
			SD	2.605	0.810	1.954	32.563	20.454
			n	4	4	4	4	4
Site K		2	Mean	29.275	0.467	8.403	111.225	94.164
			SD	27.688	0.396	7.683	33.909	44.695
			n	2	2	2	2	2
Site M		2	Mean	6.821	0.608	2.076	59.861	73.404
			SD	5.183	0.160	2.546	19.224	16.506
			n	2	2	2	2	2
SO17	3		Mean	8.799	0.228	3.196	114.683	96.663
			SD	13.443	0.206	4.223	76.197	24.917
			n	3	3	3	3	3
K 21	2		Mean	81.074	1.874	23.619	213.306	194.818
			SD	121.848	1.700	38.487	252.743	142.352
			n	2	2	2	2	2
B 23		2	Mean	1.065	0.321	0.273	31.658	57.907
			SD	0.789	0.176	0.085	23.757	14.365
			n	2	2	2	2	2

Continued

**Table 7-5.** Continued

Site or Box ID <sup>1</sup>	Box N	Site N		As µg/g	Cd µg/g	Pb µg/g	Cu µg/g	Zn µg/g
<u>Tree swallow</u>								
SB03	4		Mean	64.658	1.295	0.379	10.313	70.078
			SD	108.788	0.857	0.320	3.223	25.322
			n	4	4	4	4	4
SH02	2		Mean	0.531	0.581	0.251	21.541	42.940
			SD	0.720	0.397	0.324	15.214	8.783
			n	2	2	2	2	2
SI18	4		Mean	2.011	0.844	0.109	10.021	26.966
			SD	3.289	0.730	0.084	4.826	2.303
			n	4	4	4	4	4
SJ06	3		Mean	0.241	0.647	0.022	27.498	56.741
			SD	0.380	0.312	0.000	33.249	14.475
			n	3	3	3	3	3
Site K		2	Mean	0.347	0.844	0.489	23.523	38.674
			SD	0.370	0.091	0.331	17.477	9.360
			n	2	2	2	2	2
SN02	4		Mean	0.431	1.469	0.457	9.414	68.491
			SD	0.295	1.268	0.194	3.936	43.945
			n	4	4	4	4	4
Site O		2	Mean	0.067	0.425	0.218	5.810	34.173
			SD	0.064	0.174	0.121	2.370	15.123
			n	2	2	2	2	2
SP09	4		Mean	2.783	0.307	1.890	17.466	65.946
			SD	3.448	0.216	2.062	12.363	36.747
			n	4	4	4	4	4

Continued

**Table 7-5.** Continued

Site or Box ID <sup>1</sup>	Box N	Site N		As μg/g	Cd μg/g	Pb μg/g	Cu μg/g	Zn μg/g
<u>Tree swallow</u>	Continued							
SR10	3		Mean	0.022	1.063	1.082	105.124	70.783
			SD	0.000	0.972	1.537	133.448	63.559
			n	0	3	3	3	3
B 32	3		Mean	0.022	0.197	0.231	30.980	35.462
			SD	0.000	0.173	0.362	23.608	7.465
			n	3	3	3	3	3
B 36	1			0.022	0.200	0.022	8.694	27.473

1. Site is starling array. Box ID is identified by box type (B- bluebird, K- kestrel) and specific box number; or by box type (S-starling), site, and box number.

**Table 7-6.** Metal and As concentrations in passerine egg from the Anaconda Smelter Site, 1999. Values below detection limit were replaced with reporting limits (see Table 7-2). Site N (Box N) is the total number of boxes (individual samples) n - number of boxes (individuals) with at least one detectable value.

Site or Box ID <sup>1</sup>	Box N	Site N		As μg/g	Cd μg/g	Pb μg/g	Cu μg/g	Zn μg/g
<u>European Starling</u>								
Site K	1			0.067	0.005	0.108	0.439	8.103
Site L		2	Mean	0.093	0.005	0.125	0.394	8.880
			SD	0.037	0.000	0.010	0.036	1.323
			n	1	0	2	2	2
Site N		2	Mean	0.067	0.005	0.074	0.360	7.439
			SD	0.000	0.000	0.063	0.099	0.644
			n	0	0	1	2	2
Site O		2	Mean	0.067	0.005	0.075	0.391	5.747
			SD	0.000	0.000	0.009	0.072	0.291
			n	0	0	2	2	2
Site Q	1			0.067	0.005	0.030	0.267	3.976
K 31 <sup>2</sup>	8		Mean	0.067	0.005	0.072	0.281	5.561
			SD	0.000	0.000	0.038	0.169	3.594
			n	0	0	5	6	6
K 36	1			0.067	0.005	0.132	0.408	8.916
<u>Mountain Bluebird</u>								
K 18	1			0.067	0.005	0.142	0.386	8.137
K 22	1			0.067	0.005	0.030	0.345	11.341
SB05	1			0.067	0.005	0.030	0.317	8.366
SF09	1			0.067	0.115	0.030	0.394	9.153
SH12	1			0.067	0.005	0.030	0.348	13.182

1. Site is starling array. Box ID is identified by box type (B- bluebird, K- kestrel) and specific box number; or by box type (S-starling), site, and box number. 2. Denotes kestrel nest box inhabited by starling. Eggs from K 31 combine 2 clutches.

**Table 7-7.** Metal and As concentrations in passerine blood from the Anaconda Smelter Site, 1999. Values below detection limit were replaced with reporting limits (see Table 7-2). Site N (Box N) is the total number of boxes (individual samples) n - number of boxes (individuals) with at least one detectable value.

Site or Box ID <sup>1</sup>	Site N		As μg/g	Cd μg/g	Pb μg/g	Cu μg/g	Zn μg/g
<u>European Starling</u>							
Site K	4	Mean	0.235	0.017	0.162	0.272	5.408
		SD	0.028	0.003	0.046	0.064	1.466
		n	1	1	3	4	4
Site L	4	Mean	0.221	0.016	0.250	0.376	5.534
		SD	0.000	0.000	0.076	0.141	0.894
		n	0	0	4	4	4
Site N	5	Mean	0.315	0.016	0.177	0.221	5.278
		SD	0.211	0.000	0.058	0.033	1.009
		n	1	0	4	5	5
Site O	5	Mean	0.221	0.016	0.186	0.278	5.015
		SD	0.000	0.000	0.054	0.049	0.945
		n	0	0	4	5	5
Site Q	5	Mean	0.339	0.016	0.264	0.284	5.033
		SD	0.263	0.000	0.062	0.034	0.708
		n	4	0	5	5	5
<u>Mountain Bluebird</u>							
K 18	1		0.221	0.016	0.100	0.224	6.580
SH12	1		0.221	0.016	0.100	6.891	5.433
<u>Tree Swallows</u>							
B 29	1		0.221	0.016	0.369	0.447	5.302
K 47	1		0.221	0.016	0.100	0.249	6.501
SB12	1		0.221	0.016	1.135	3.320	7.972
SJ10	1		0.221	0.016	0.100	0.719	7.054
SP11	1		0.221	0.016	0.315	0.315	5.663
SQ03	1		0.221	0.016	0.312	0.587	6.938

1. Site is starling array. Box ID is identified by box type (B- bluebird, K- kestrel) and specific box number; or by box type (S-starling), site, and box number.

**Table 7-8.** Metal and As concentrations in passerine blood from the Anaconda Smelter Site 2000. Values below detection limit were replaced with reporting limits (see Table 7-2). Site N (Box N) is the total number of boxes (individual samples) n - number of boxes (individuals) with at least one detectable value.

Site or BoxID <sup>1</sup>	Box N	Site N		As μg/g	Cd μg/g	Pb μg/g	Cu μg/g	Zn μg/g
<u>European Starling</u>								
Site K		2	Mean	0.209	0.016	0.185	3.638	8.177
			SD	0.005	0.013	0.046	0.710	1.486
			n	2	2	2	2	2
Site L		2	Mean	1.796	0.005	0.136	8.169	6.998
			SD	2.293	0.005	0.002	2.671	1.023
			n	2	1	2	2	2
Site N		9	Mean	0.044	0.004	0.099	3.732	5.474
			SD	0.022	0.006	0.073	1.658	0.703
			n	4	6	8	9	9
Site P		2	Mean	0.041	0.001	0.063	5.274	5.636
			SD	0.001	0.000	0.010	4.903	0.875
			n	2	0	2	2	2
Site R		8	Mean	0.030	0.001	0.071	4.854	6.406
			SD	0.000	0.000	0.049	4.075	2.776
			n	0	0	5	8	8
<u>Mountain Bluebird</u>								
B 23	1			0.030	0.005	0.030	1.372	4.056
K 21	1			0.030	0.016	0.030	3.305	6.613
Site B		2	Mean	0.051	0.008	0.168	1.646	5.488
			SD	0.030	0.004	0.014	0.975	1.821
			n	1	2	2	2	2
Site C		2	Mean	0.117	0.008	0.219	1.140	5.366
			SD	0.046	0.003	0.081	0.007	1.854
			n	2	2	2	2	2

Continued

**Table 7-8. Continued**

Site or Box ID <sup>1</sup>	Box N	Site N		As	Cd	Pb	Cu	Zn
				μg/g	μg/g	μg/g	μg/g	μg/g
Site F		2	Mean	0.030	0.009	0.123	2.313	7.277
			SD	0.000	0.007	0.081	1.026	3.758
			n	0	2	2	2	2
SG01	1			0.030	0.006	0.105	0.867	4.446
Site H		2	Mean	0.030	0.014	0.178	3.978	6.098
			SD	0.000	0.001	0.035	0.046	1.605
			n	0	2	2	2	2
SI06	1			0.030	0.007	0.079	0.867	4.724
Site K		2	Mean	0.030	0.009	0.133	1.731	5.566
			SD	0.000	0.003	0.075	0.187	0.401
			n	0	2	2	2	2
Site M		2	Mean	0.030	0.003	0.030	1.418	4.981
			SD	0.000	0.003	0.000	0.411	0.308
			n	0	1	0	2	2
SO17	1			0.030	0.008	0.030	1.417	5.382
<u>Chickadee</u>								
B 38	1			0.030	0.046	0.497	5.320	12.576
SB12	1			0.030	0.014	0.212	3.098	5.745
SL02	1			0.030	0.037	0.272	7.322	8.561

Continued

**Table 7-8. Continued**

Site or Box ID <sup>1</sup>	Box N	Site N		As μg/g	Cd μg/g	Pb μg/g	Cu μg/g	Zn μg/g
<u>Tree Swallow</u>								
B 32	1			0.030	0.016	0.030	4.735	7.219
B 36	1			0.030	0.009	0.030	3.256	7.452
SB03	1			0.030	0.018	0.030	2.470	7.029
SH02	1			0.030	0.009	0.101	1.301	5.574
SI18	1			0.030	0.015	0.145	5.595	6.378
SJ06	1			0.030	0.010	0.030	0.613	5.720
Site K		2	Mean	0.030	0.005	0.030	2.007	5.551
			SD	0.000	0.006	0.000	0.426	0.715
			n	0	1	0	2	2
SN02	1			0.030	0.008	0.030	4.993	5.518
Site O		2	Mean	0.030	0.014	0.030	2.400	7.047
			SD	0.000	0.002	0.000	1.125	0.217
			n	0	2	0	2	2
SP09	1			0.030	0.010	0.030	5.084	6.891
SR10	1			0.030	0.004	0.030	3.573	3.340

1. Site is starling array. Box ID is identified by box type (B- bluebird, K- kestrel) and specific box number; or by box type (S-starling), site, and box number.

**Table 7-9.** Metal and As concentrations in passerine liver from the Anaconda Smelter Site 1999. Values below detection limit were replaced with reporting limits (see Table 7-2). Site N (Box N) is the total number of boxes (individual samples) n - number of boxes (individuals) with at least one detectable value.

Site or Box ID <sup>1</sup>	Box N	Site N		As μg/g	Cd μg/g	Pb μg/g	Cu μg/g	Zn μg/g
<u>European Starling</u>								
Site K		4	Mean	0.432	0.117	1.698	14.383	28.948
			SD	0.000	0.134	0.432	5.600	11.507
			n	0	3	4	4	4
Site L		4	Mean	0.432	0.044	1.054	11.753	25.296
			SD	0.000	0.024	0.210	6.314	9.899
			n	0	1	4	4	4
Site N		5	Mean	0.838	0.065	0.875	6.759	19.193
			SD	0.907	0.039	0.182	2.933	2.298
			n	4	3	5	5	5
Site O		5	Mean	0.432	0.032	0.628	7.210	19.753
			SD	0.000	0.000	0.123	2.896	3.766
			n	0	0	5	5	5
Site Q		5	Mean	0.432	0.034	1.032	8.812	24.546
			SD	0.000	0.004	0.443	2.132	5.307
			n	0	1	5	5	5
<u>Mountain Bluebird</u>								
K 08	1			3.467	0.152	1.534	13.658	34.649
K 18	1			0.432	0.032	1.379	20.938	39.922
SF09	1			0.432	0.274	1.562	6.789	31.865
SH12	1			0.432	0.461	4.750	16.508	39.188
<u>Chickadee</u>								
B 44	1			0.432	0.032	1.182	10.587	32.762

Continued

**Table 7-9.** Continued

Site or Box ID <sup>1</sup>	Box N	Site N		As μg/g	Cd μg/g	Pb μg/g	Cu μg/g	Zn μg/g
<u>Tree Swallow</u>								
B 29	1			0.432	0.032	0.196	4.673	27.450
K 47	1			0.432	0.032	0.538	5.055	18.706
SB12	4		Mean	0.432	0.032	0.691	4.792	31.273
			SD	0.000	0.000	0.582	1.815	6.709
			n	0	0	2	4	4
SJ10	1			0.432	0.032	0.196	3.208	19.121
SP11	1			0.432	0.032	0.196	5.652	24.774
SQ03	1			0.432	0.032	0.196	4.835	23.153

1. Site is starling array. Box ID is identified by box type (B- bluebird, K- kestrel) and specific box number; or by box type (S-starling), site, and box number.

**Table 7-10.** Metal and As concentrations in passerine liver from the Anaconda Smelter Site, 2000. Values below detection limit were replaced with reporting limits (see Table 7-2). Site N (Box N) is the total number of boxes (individual samples) n - number of boxes (individuals) with at least one detectable value.

Site or Box ID <sup>1</sup>	Box N	Site N		As μg/g	Cd μg/g	Pb μg/g	Cu μg/g	Zn μg/g
<u>European Starling</u>								
Site K		2	Mean	0.081	1.198	2.412	19.829	55.406
			SD	0.073	0.329	0.857	1.126	4.031
			n	2	2	2	2	2
Site L		2	Mean	0.059	0.190	1.566	29.889	52.261
			SD	0.015	0.163	1.930	20.499	14.041
			n	2	2	2	2	2
Site N		9	Mean	0.020	0.519	0.674	18.245	32.468
			SD	0.003	0.794	0.436	9.424	7.002
			n	1	9	9	9	9
Site P		2	Mean	0.032	0.109	0.737	22.114	30.610
			SD	0.018	0.072	0.034	4.780	9.255
			n	1	2	2	2	2
Site R		8	Mean	0.019	0.106	0.215	14.965	26.045
			SD	0.001	0.132	0.142	11.177	3.747
			n	1	8	7	8	8

Mountain Bluebird

B 23		2	Mean	0.019	0.096	0.411	12.612	30.383
			SD	0.000	0.006	0.400	3.206	3.310
			n	0	2	2	2	2
K 21	1			0.060	0.211	0.019	9.565	27.158
Site B		2	Mean	0.066	0.285	0.749	8.855	29.960
			SD	0.066	0.142	0.805	1.527	5.813
			n	1	2	2	2	2

Continued

**Table 7-10.** Continued

Site or Box ID <sup>1</sup>	Box N	Site N		As	Cd	Pb	Cu	Zn
				µg/g	µg/g	µg/g	µg/g	µg/g
Site C		2	Mean	0.416	0.426	3.145	12.398	37.133
			SD	0.094	0.099	2.959	0.557	17.991
			n	2	2	2	2	2
Site F		2	Mean	0.162	0.137	0.652	13.156	29.780
			SD	0.071	0.064	0.781	1.953	7.649
			n	2	2	2	2	2
SG01	1			0.203	0.138	0.283	14.509	26.932
Site H		2	Mean	0.135	0.163	0.946	11.733	36.808
			SD	0.163	0.125	0.467	2.277	6.708
			n	1	2	2	2	2
SI06	1			0.019	0.091	0.176	13.628	25.757
Site K		2	Mean	0.159	0.187	1.908	17.469	28.667
			SD	0.199	0.077	2.218	3.100	5.932
			n	1	2	2	2	2
Site M		2	Mean	0.019	0.109	0.126	10.446	35.043
			SD	0.000	0.022	0.152	1.991	5.836
			n	0	2	1	2	2
SO17	1			0.019	0.116	0.573	15.992	35.003
<u>Chickadee</u>								
B 38	1			0.019	0.101	0.390	18.204	33.441
SB12	1			0.019	0.259	1.339	15.191	30.274
SL02	1			0.019	0.119	1.119	12.321	20.071

Continued

**Table 7-10.** Continued

Site or Box ID <sup>1</sup>	Box N	Site N		As μg/g	Cd μg/g	Pb μg/g	Cu μg/g	Zn μg/g
<u>Tree Swallow</u>								
B 32	1			0.019	0.026	0.019	8.876	21.671
B 36	1			0.019	0.057	0.154	13.594	27.378
SB03	1			0.068	0.359	0.019	16.744	65.728
SH02	1			0.019	0.118	0.064	19.007	28.884
SI18	1			0.019	0.145	0.019	6.671	22.739
SJ06	1			0.019	0.129	0.019	7.995	22.178
Site K		2	Mean	0.019	0.071	0.019	8.322	23.749
			SD	0.000	0.051	0.000	4.363	0.575
			n	0	2	2	2	2
SN02	1			0.019	0.172	0.019	10.164	26.949
Site O		2	Mean	0.019	0.052	0.056	11.282	20.125
			SD	0.000	0.011	0.052	5.869	4.370
			n	0	2	1	2	2
SP09	1			0.019	0.045	0.019	6.003	21.114
SR10	1			0.019	0.024	0.019	5.150	71.571

1. Site is starling array. Box ID is identified by box type (B- bluebird, K- kestrel) and specific box number; or by box type (S-starling), site, and box number.

**Table 7-11.** Metal and As concentrations in passerine kidney from the Anaconda Smelter Site 1999. Values below detection limit were replaced with reporting limits (see Table 7-2). Site N (Box N) is the total number of boxes (individual samples) n - number of boxes (individuals) with at least one detectable value.

Site or Box ID <sup>1</sup>	Box N	Site N		As μg/g	Cd μg/g	Pb μg/g	Cu μg/g	Zn μg/g
<u>European Starlings</u>								
Site K		4	Mean	4.511	0.080	5.570	7.506	24.362
			SD	6.847	0.000	5.820	1.822	6.103
			n	1	0	3	4	4
Site L		4	Mean	1.088	0.080	2.577	7.405	20.992
			SD	0.000	0.000	0.433	0.570	2.038
			n	0	0	4	4	4
Site N		4	Mean	1.088	0.090	2.071	6.259	24.781
			SD	0.000	0.020	0.300	2.808	5.905
			n	0	3	4	4	4
Site O		5	Mean	1.088	0.080	1.217	5.513	21.643
			SD	0.000	0.000	0.859	0.536	2.243
			n	0	0	5	5	5
Site Q		4	Mean	3.015	0.080	1.015	5.775	23.873
			SD	2.885	0.000	0.812	0.730	2.429
			n	2	0	2	4	4
<u>Mountain Bluebird</u>								
K 08	1			1.088	0.080	0.494	7.692	19.945
K 18	1			1.088	0.080	0.494	8.735	31.090
SF09	1			1.088	0.080	0.494	4.505	23.709
SH12	1			1.088	0.080	0.494	7.241	20.862
<u>Chickadee</u>								
B 44	1			1.088	0.080	0.494	5.156	23.754
<u>Tree Swallow</u>								
B 29	1			1.088	0.080	0.494	6.032	21.285
K 47	1			1.088	0.080	0.494	5.631	19.681
SJ10	1			1.088	0.080	0.494	3.762	20.771
SP11	1			1.088	0.080	0.494	6.573	20.326
SQ03	1			1.088	0.080	0.494	4.791	26.925

1. Site is starling array. Box ID is identified by box type (B- bluebird, K- kestrel) and specific box number; or by box type (S-starling), site, and box number.

**Table 7-12.** Metal and As concentrations in passerine kidney from the Anaconda Smelter Site 2000. Values below detection limit were replaced with reporting limits (see Table 7-2). Site N (Box N) is the total number of boxes (individual samples) n - number of boxes (individuals) with at least one detectable value.

Site or Box ID <sup>1</sup>	Box N	Site N		As μg/g	Cd μg/g	Pb μg/g	Cu μg/g	Zn μg/g
<u>European Starling</u>								
Site K		2	Mean	0.380	1.161	4.048	11.018	38.771
			SD	0.020	0.110	0.851	1.785	0.326
			n	2	2	2	2	2
Site L		2	Mean	0.669	0.478	5.262	7.344	25.838
			SD	0.121	0.093	0.002	1.630	5.642
			n	2	2	2	2	2
Site N		9	Mean	0.325	0.198	1.024	6.353	21.221
			SD	0.358	0.102	0.575	1.607	2.992
			n	5	9	7	9	9
Site P		2	Mean	0.400	0.081	1.030	3.945	19.152
			SD	0.274	0.021	0.412	0.512	1.480
			n	2	2	2	2	2
Site R		8	Mean	0.134	0.080	0.500	5.739	21.978
			SD	0.070	0.026	0.247	2.056	3.388
			n	5	8	7	8	8
<u>Mountain Bluebird</u>								
B 23		2	Mean	0.071	0.151	0.507	15.646	23.099
			SD	0.000	0.041	0.616	11.450	3.224
			n	0	2	1	2	2
K 21	1			0.332	0.200	0.071	12.606	22.388
Site B		2	Mean	0.420	0.409	1.004	33.270	23.994
			SD	0.126	0.273	0.570	33.226	2.746
			n	2	2	2	2	2

Continued

**Table 7-12. Continued**

Site or Box ID <sup>1</sup>	Box N	Site N		As µg/g	Cd µg/g	Pb µg/g	Cu µg/g	Zn µg/g
<u>Mountain Bluebird</u> Continued								
Site C		2	Mean	0.903	0.609	5.977	14.316	22.034
			SD	0.213	0.402	6.911	6.823	0.633
			n	2	2	2	2	2
Site F		2	Mean	0.915	0.258	0.728	6.771	22.787
			SD	0.007	0.239	0.770	1.646	1.495
			n	2	2	2	2	2
SG01	1			0.826	0.168	0.295	11.814	22.118
Site H		2	Mean	0.439	0.163	1.183	26.477	26.774
			SD	0.521	0.009	1.018	17.660	5.404
			n	1	2	2	2	2
SI06	1			0.071	0.110	0.265	7.143	21.032
Site K		2	Mean	0.456	0.536	0.915	18.986	25.717
			SD	0.271	0.437	1.194	0.464	3.213
			n	2	2	1	2	2
Site M		2	Mean	0.071	0.216	0.492	21.082	26.826
			SD	0.000	0.149	0.595	15.394	4.710
			n	0	2	1	2	2
SO17	1			0.495	0.092	0.717	10.409	23.298
<u>Chickadee</u>								
B 38	1			0.071	0.004	0.751	23.193	24.339
SB12	1			0.071	0.206	2.903	28.970	24.993
SL02	1			0.458	0.289	1.078	19.463	21.516

Continued

**Table 7-12. Continued**

Site or Box ID <sup>1</sup>	Box N	Site N		As μg/g	Cd μg/g	Pb μg/g	Cu μg/g	Zn μg/g
<u>Tree Swallow</u>								
B 32	1			0.071	0.025	0.071	10.990	19.775
B 36	1			0.071	0.079	0.766	22.100	26.019
SB03	1			1.810	0.347	0.071	11.605	23.993
SH02	1			0.071	0.141	0.071	13.014	22.845
SI18	1			0.193	0.287	0.071	12.429	23.024
SJ06	1			0.071	0.173	0.151	13.005	20.840
Site K		2	Mean	0.071	0.107	0.071	12.687	21.943
			SD	0.000	0.070	0.000	3.950	1.962
			n	0	2	0	2	2
SN02	1			0.071	0.282	0.071	6.001	22.747
Site O		2	Mean	0.071	0.059	0.601	16.028	23.024
			SD	0.000	0.001	0.749	3.735	1.498
			n	0	2	1	2	2
SP09	1			0.071	0.055	0.071	19.058	21.422
SR10	1			0.071	0.067	0.071	15.515	22.216

1. Site is starling array. Box ID is identified by box type (B- bluebird, K- kestrel) and specific box number; or by box type (S-starling), site, and box number.

**Table 7-13.** Metal and As concentrations in liver from opportunistically collected passerine mortalities. Anaconda Smelter Site, 1999. Values below detection limit were replaced with reporting limits (see Table 7-2). Site N (Box N) is the total number of boxes (individual samples) n - number of boxes (individuals) with at least one detectable value.

Site or Box ID <sup>1</sup>	Box N	Site N		As μg/g	Cd μg/g	Pb μg/g	Cu μg/g	Zn μg/g
<u>European Starling</u>								
Site K		2	Mean	0.432	0.032	0.893	14.316	33.546
			SD	0.000	0.000	0.986	1.988	1.415
			n	0	0	1	2	2
Site L	1			0.432	0.032	0.883	10.484	33.691
Site N		6	Mean	0.742	0.092	0.885	13.799	32.743
			SD	0.484	0.040	0.520	6.888	5.588
			n	2	5	6	6	6
Site O		3	Mean	0.432	0.201	0.832	9.779	35.171
			SD	0.000	0.292	0.559	7.594	11.296
			n	0	1	2	3	3
<u>Mountain Bluebird</u>								
SH12	1			1.953	0.032	1.530	7.923	33.358
<u>Tree Swallow<sup>2</sup></u>								
B 08	1			0.432	2.350	0.196	20.841	42.835
B 27	2		Mean	0.432	0.616	0.196	17.891	53.487
			SD	0.000	0.299	0.000	1.088	16.136
			n	0	2	0	2	2
B 28	4		Mean	0.432	0.955	0.196	19.382	41.332
			SD	0.000	0.221	0.000	1.928	1.895
			n	0	4	0	4	4
B 29	3		Mean	0.432	0.677	0.196	16.475	41.758
			SD	0.000	0.117	0.000	2.874	7.595
			n	0	3	0	3	3

Continued

**Table 7-13.** Continued

Site or Box ID <sup>1</sup>	Box N	Site N		As μg/g	Cd μg/g	Pb μg/g	Cu μg/g	Zn μg/g
<u>Tree swallow</u> Continued								
B 32	2		Mean	0.432	0.820	0.196	21.641	44.815
			SD	0.000	0.159	0.000	8.566	0.331
			n	0	2	0	2	2
B 34	4		Mean	0.432	0.604	0.196	13.588	39.888
			SD	0.000	0.110	0.000	4.829	10.179
			n	0	4	0	4	4
SB01	1			0.432	0.654	0.196	15.773	37.269
SP01	1			0.432	0.833	0.196	18.821	40.905

1. Site is starling array. Box ID is identified by box type (B- bluebird, K- kestrel) and specific box number; or by box type (S-starling), site, and box number. 2 -Tree Swallows were adult opportunistic dead animals

**Table 7-14.** Metal and As concentrations in kidney from opportunistic collections passerine mortalities. Anaconda Smelter Site, 1999. Values below detection limit were replaced with reporting limits (see Table 7-2). Site N (Box N) is the total number of boxes (individual samples) n - number of boxes (individuals) with at least one detectable value.

Site or Box ID <sup>1</sup>	Box N	Site N		As μg/g	Cd μg/g	Pb μg/g	Cu μg/g	Zn μg/g
<u>European Starling</u>								
Site K		2	Mean	1.088	0.080	2.505	7.590	26.283
			SD	0.000	0.000	1.054	3.707	3.704
			n	0	0	2	2	2
Site L	1			1.088	0.08	2.418	4.464	24.288
Site N		6	Mean	1.258	0.085	0.906	4.534	20.165
			SD	0.417	0.011	0.501	1.315	2.063
			n	1	2	4	6	6
Site O		3	Mean	1.088	0.242	0.940	5.431	26.897
			SD	0.000	0.281	0.773	2.856	11.118
			n	0	1	1	3	3
<u>Mountain Bluebird</u>								
SH12	1			1.088	0.080	0.494	8.892	37.343
<u>Tree Swallow<sup>2</sup></u>								
B 08	1			1.088	5.847	0.494	9.916	39.987
B 27	2		Mean	1.088	0.882	0.494	20.145	36.486
			SD	0.000	0.576	0.000	4.997	2.277
			n	0	2	0	2	2
B 28	4		Mean	1.088	1.378	0.446	12.323	32.045
			SD	0.000	0.951	0.097	6.918	18.892
			n	0	4	1	4	4

Continued

**Table 7-14.** Continued

Site or Box ID <sup>1</sup>	Box N	Site N		As μg/g	Cd μg/g	Pb μg/g	Cu μg/g	Zn μg/g
B 29	3		Mean	1.088	1.681	0.494	17.657	41.710
			SD	0.000	0.536	0.000	0.443	6.530
			n	0	3	0	3	3
B 32	2		Mean	1.088	1.059	0.494	8.605	32.240
			SD	0.000	0.159	0.000	1.768	1.635
			n	0	2	0	2	2
B 34	4		Mean	1.088	1.218	0.494	8.330	29.590
			SD	0.000	0.225	0.000	3.850	12.048
			n	0	4	0	4	4
SB01	1			1.088	1.753	0.494	8.641	30.333
SP01	1			1.088	2.522	0.494	14.792	27.912

1. Site is starling array. Box ID is identified by box type (B- bluebird, K- kestrel) and specific box number; or by box type (S-starling), site, and box number. 2 - Tree Swallows were adult opportunistic dead animals.

**Table 7-15.** Metal and As concentrations in liver from opportunistically collected passerine mortalities. Anaconda Smelter Site, 2000. Values below detection limit were replaced with reporting limits (see Table 7-2). Site N (Box N) is the total number of boxes (individual samples). n - number of boxes (individuals) with at least one detectable value.

Site or Box ID <sup>1</sup>	Box N	Site N		As μg/g	Cd μg/g	Pb μg/g	Cu μg/g	Zn μg/g
<u>European Starling</u>								
Site N		4	Mean	0.824	0.134	0.233	14.298	32.685
			SD	1.111	0.066	0.305	7.450	11.207
			n	4	4	2	4	4
Site R		3	Mean	0.039	0.124	0.448	13.381	31.571
			SD	0.024	0.057	0.201	7.040	1.798
			n	3	3	3	3	3
<u>Mountain Bluebird</u>								
SH08	3		Mean	0.068	0.100	0.248	12.256	30.426
			SD	0.085	0.036	0.059	5.696	10.432
			n	3	3	3	3	3
<u>Tree Swallow</u>								
SH02	2		Mean	0.019	0.770	0.253	30.624	50.022
			SD	0.000	0.141	0.332	16.257	7.312
			n	0	2	1	2	2
SI18	4		Mean	0.019	0.253	0.172	15.831	41.080
			SD	0.000	0.100	0.141	6.131	4.179
			n	0	4	4	4	4
SN02	2		Mean	0.019	0.106	0.046	7.228	29.697
			SD	0.000	0.011	0.037	1.389	2.202
			n	0	2	1	2	2
SO16	2		Mean	0.019	0.241	0.019	14.763	45.263
			SD	0.000	0.005	0.000	1.536	2.148
			n	0	2	0	2	2
SR10	2		Mean	0.019	0.155	0.074	26.053	61.265
			SD	0.000	0.135	0.078	19.280	8.108
			n	0	2	1	2	2

1. Site is starling array. Box ID is identified by box type (B- bluebird, K- kestrel) and specific box number; or by box type (S-starling), site, and box number.

**Table 7-16.** Metal and As concentrations in kidney from opportunistically collected passerine mortalities. Anaconda Smelter Site, 2000. Values below detection limit were replaced with reporting limits (see Table 7-2). Site N (Box N) is the total number of boxes (individual samples). n - number of boxes (individuals) with at least one detectable value.

Site or Box ID <sup>1</sup>	Box N	Site N		As μg/g	Cd μg/g	Pb μg/g	Cu μg/g	Zn μg/g
<u>European Starling</u>								
Site N		4	Mean	2.221	0.151	1.188	13.482	20.663
			SD	2.112	0.169	1.046	12.288	8.847
			n	4	4	4	4	4
Site R		3	Mean	0.178	0.122	2.732	6.192	20.425
			SD	0.081	0.079	1.352	1.604	1.741
			n	3	3	3	3	3
<u>Mountain Bluebird</u>								
SH08	3		Mean	0.897	0.093	0.464	33.200	22.759
			SD	1.170	0.063	0.039	24.514	8.977
			n	2	3	3	3	3
<u>Tree Swallow</u>								
SH02	2		Mean	0.466	0.720	0.331	36.212	38.080
			SD	0.558	0.165	0.368	9.388	1.793
			n	1	2	1	2	2
SI18	4		Mean	0.214	0.259	0.071	33.215	28.878
			SD	0.181	0.038	0.000	8.391	5.236
			n	2	4	0	4	4
SN02	2		Mean	0.071	0.158	0.071	18.771	23.182
			SD	0.000	0.029	0.000	3.605	1.619
			n	0	2	0	2	2
SO16	2		Mean	0.071	0.186	0.071	40.488	32.705
			SD	0.000	0.002	0.000	21.400	4.913
			n	0	2	0	2	2
SR10	2		Mean	0.071	0.148	0.071	44.736	38.093
			SD	0.000	0.109	0.000	12.178	12.442
			n	0	2	0	2	2

1. Site is starling array. Box ID is identified by box type (B- bluebird, K- kestrel) and specific box number; or by box type (S-starling), site, and box number.

**Table 7-17.** Liver porphyrins from European starlings. Anaconda Smelter Site, 1999. N - total number of boxes sampled; n - number of boxes with at least one detectable level.

Site or Box ID <sup>1</sup>	Site N	Carboxyl Porphyrins (pmol/g)			
		4	2	Total	
<u>European Starling</u>					
Site K	4	Mean	46.183	8.114	56.553
		SD	4.907	2.880	8.587
		n	4	4	4
Site L	4	Mean	62.814	11.920	79.507
		SD	17.905	1.524	13.763
		n	4	4	4
Site N	5	Mean	39.465	10.387	49.851
		SD	20.627	4.753	25.103
		n	5	5	5
Site O	5	Mean	31.932	7.585	39.518
		SD	13.609	3.731	16.868
		n	5	5	5
Site Q	5	Mean	24.474	7.056	33.269
		SD	14.904	3.767	21.800
		n	5	5	5

**Table 7-18.** Liver porphyrins from European starlings. Anaconda Smelter Site, 2000. N - total number of boxes sampled; n - number of boxes with at least one detectable level.

Site	Site N		Carboxyl Porphyrins (pmol/g)		
			4	2	Total
<u>European Starling</u>					
Site K	2	Mean	72.836	13.096	101.749
		SD	13.387	3.849	9.747
		n	2	2	2
Site L	2	Mean	84.265	16.499	118.943
		SD	0.037	2.080	27.828
		n	2	2	2
Site N	9	Mean	86.753	16.442	113.323
		SD	37.670	4.876	41.734
		n	9	9	9
Site P	2	Mean	68.517	15.196	103.414
		SD	14.428	8.711	9.793
		n	2	2	2
Site R	8	Mean	64.296	11.147	77.652
		SD	41.142	3.409	42.021
		n	8	8	8

**Table 7-19.** Kidney porphyrins from European starlings. Anaconda Smelter Site, 1999. N - total number of boxes sampled; n - number of boxes with at least one detectable level.

Site	Site N		Carboxyl Porphyrins (pmol/g)		
			4	2	Total
<u>European Starling</u>					
Site K	4	Mean	60.183	21.972	96.411
		SD	39.755	7.190	52.720
		n	4	4	4
Site L	4	Mean	71.620	21.060	108.311
		SD	32.041	4.672	38.299
		n	4	4	4
Site N	5	Mean	42.584	15.142	72.475
		SD	5.208	4.568	9.928
		n	5	5	5
Site O	5	Mean	25.167	11.273	46.247
		SD	7.917	3.095	14.641
		n	5	5	5
Site Q	5	Mean	24.894	11.353	47.043
		SD	7.899	4.079	11.614
		n	5	5	5

**Table 7-20.** Kidney porphyrins from European starlings. Anaconda Smelter Site, 2000. N - total number of boxes sampled; n - number of boxes with at least one detectable level.

Site	Site N		Carboxyl Porphyrins (pmol/g)		
			4	2	Total
<u>European Starling</u>					
Site K	2	Mean	84.264	32.971	160.456
		SD	22.478	16.104	42.009
		n	2	2	2
Site L	2	Mean	107.743	32.130	139.873
		SD	7.517	3.057	4.460
		n	2	2	2
Site N	9	Mean	71.270	26.571	118.645
		SD	30.518	7.260	34.781
		n	9	9	9
Site P	2	Mean	45.117	25.367	102.392
		SD	2.316	8.062	0.483
		n	2	2	2
Site R	8	Mean	60.962	23.752	101.023
		SD	16.214	6.316	30.878
		n	8	8	8

**Table 7-21.** Coefficients from multiple regression equations<sup>1</sup> of kidney and liver porphyrins versus metal concentrations in the respective tissues.

Factor	Kidney			Liver		
	4-CP	2-CP	TOT-CP	4-CP	2-CP	TOT-CP
Intercept ( $\beta_0$ )	263.8	92.1	372.1	27.8	2.4	41.9
As ( $\beta_1$ )	-15.8	-6.0	-28.4	-26.4	-1.6	-31.2
Cd ( $\beta_2$ )	42.0	16.0	66.4	8.4	3.2	19.0
Pb ( $\beta_3$ )	8.4	-0.2	13.4	17.4	-0.3	19.9
Cu ( $\beta_4$ )	132.5	14.8	114.5	6.9	-0.5	9.1
Zn ( $\beta_5$ )	-204.0	-51.0	-231.2	6.6	8.0	11.9
Correlation (r)	0.676	0.628	0.718	0.798	0.744	0.683

<sup>1</sup> Coefficients fit into the regression equation as follows, where Y is the specific porphyrin measure:

$$Y = \beta_0 + (\log_{10}[\text{As}] * \beta_1) + (\log_{10}[\text{Cd}] * \beta_2) + (\log_{10}[\text{Pb}] * \beta_3) + (\log_{10}[\text{Cu}] * \beta_4) + (\log_{10}[\text{Zn}] * \beta_5)$$

**Table 7-22.** Delta-aminolevulinic acid dehydratase (ALAD) activity measured in blood samples from starling nestlings inhabiting the Anaconda Smelter Superfund Site, 2000.

Site or Box ID <sup>1</sup>	Box N	Site N		PCV %	ALAD Activity nmol ALA*min <sup>-1</sup> *ml RBC <sup>-1</sup>
<u>European Starling</u>					
Site K		2	Mean	43.6	66.97
			SD	0.5	17.05
			n	2	2
Site L		2	Mean	31.2	86.52
			SD	0.2	7.02
			n	2	2
Site N		9	Mean	35.7	105.04
			SD	3.9	23.47
			n	9	9
Site P		2	Mean	35.8	88.33
			SD	5.4	25.45
			n	2	2
Site R		8	Mean	40.8	115.61
			SD	8.0	16.01
			n	8	8
<u>Mountain Bluebird</u>					
B 23		2	Mean	38	126.56
			SD	4.3	0.18
			n	2	2
Site B		2	Mean	39.5	84.03
			SD	4.9	18.24
			n	2	2
Site C		2	Mean	41.5	47.36
			SD	3.5	2.28
			n	2	2

Continued

**Table 7-22.** Continued

Site or Box ID <sup>1</sup>	Box N	Site N	PCV		ALAD Activity
				%	nmol ALA*min <sup>-1</sup> *ml RBC <sup>-1</sup>
Site F		2	Mean	42	99.56
			SD	1.4	10.51
			n	2	2
SG01	1			34	95.86
Site H		2	Mean	42.5	82.18
			SD	4.9	18.84
			n	2	2
SI06	1			42	78.96
Site K		2	Mean	43	87.64
			SD	2.83	47.40
			n	2	2
K 21	1			49	108.63
Site M		2	Mean	40.5	99.94
			SD	0.7	16.11
			n	2	2
SO17	1			44	87.62
<u>Chickadee</u>					
SB12	1			47	26.04
SL02	1			52	100.13
B 38	1			47	108.40
<u>Tree Swallow</u>					
B 36	1			61	55.64
SB03	1			51	85.74

Continued

**Table 7-22.** Continued

Site or Box ID <sup>1</sup>	Box N	Site N		PCV %	ALAD Activity nmol ALA*min <sup>-1</sup> *ml RBC <sup>-1</sup>
<u>Tree Swallow</u>					
SH02	1			63	55.26
SI18	1			38	99.60
SJ06	1			44	66.04
Site K		2	Mean	45	80.89
			SD	2.8	23.54
			n	2	2
SN02	1			40	62.12
Site O		2	Mean	49.5	88.39
			SD	9.2	16.24
			n	2	2
SR10	1			29	133.19

1. Site is starling array. Box ID is identified by box type (B- bluebird, K- kestrel) and specific box number; or by box type (S-starling), site, and box number.

**Table 7-23.** Tissue weights of passerines collected from the Anaconda Smelter site, 1999. Site N (Box N) is the total number of boxes (individual samples). n - number of boxes (individuals) with at least one detectable value.

Site or Box ID <sup>1</sup>	Box N	Site N		Kidney (grams)	Liver (grams)	Bursa (grams)	Spleen (grams)	Brain (grams)
<u>European Starling</u>								
Site K		4	Mean	0.923	3.601	0.112	0.092	1.466
			SD	0.056	0.417	0.021	0.014	0.034
			n	4	4	3	3	3
Site L		4	Mean	1.107	4.384	0.096	0.143	1.473
			SD	0.119	0.623	0.021	0.068	0.073
			n	4	4	4	4	4
Site N		5	Mean	0.862	3.290	0.115	0.092	1.496
			SD	0.105	0.902	0.016	0.040	0.110
			n	5	5	4	5	5
Site O		5	Mean	0.950	3.556	0.170	0.130	1.553
			SD	0.147	1.050	0.074	0.081	0.096
			n	5	5	4	5	5
Site Q		5	Mean	0.861	3.078	0.140	0.065	1.489
			SD	0.192	1.186	0.082	0.036	0.107
			n	5	5	4	4	4
<u>Mountain Bluebird</u>								
K 08	1			0.382	1.499	0.052	0.061	0.540
K 18	1			0.371	1.135	0.045	0.042	0.879
SF09	1			0.381	1.079	0.081	0.047	0.828
SH12	1				1.087	0.048	0.027	0.949
<u>Chickadee</u>								
B 44	1			0.137	0.509	0.032	0.042	0.682

Continued

**Table 7-23.** Continued

Site or Box ID <sup>1</sup>	Box N	Site N		Kidney (grams)	Liver (grams)	Bursa (grams)	Spleen (grams)	Brain (grams)
<u>Tree Swallow</u>								
B 29	2		Mean	0.262	0.806	0.056	0.028	0.481
			SD	0.028	0.024	-	-	-
			n	2	2	1	1	1
K 47	2		Mean	0.320	1.148	0.039	0.078	0.452
			SD	0.006	0.106	-	-	-
			n	2	2	1	1	1
SB12	4		Mean	0.360	1.651	0.052	0.084	0.452
			SD	0.040	0.495	0.009	0.022	0.038
			n	4	4	4	4	4
SJ10	2		Mean	0.343	1.203	0.038	0.083	0.523
			SD	0.010	0.234	-	-	-
			n	2	2	1	1	1
SP11	2		Mean	0.351	0.933	0.062	0.025	0.600
			SD	0.078	0.172	-	-	-
			n	2	2	1	1	1
SQ03	2		Mean	0.280	1.239	0.081	0.072	0.538
			SD	0.117	0.269	-	-	-
			n	2	2	1	1	1

1. Site is starling array. Box ID is identified by box type (B- bluebird, K- kestrel) and specific box number; or by box type (S-starling), site, and box number.

**Table 7-24.** Tissue weights of passerines collected from the Anaconda Smelter site, 2000. Site N (Box N) is the total number of boxes (individual samples). n - number of boxes (individuals) with at least one detectable value.

Site or Box ID <sup>1</sup>	Box N	Site N		Kidney (grams)	Liver (grams)	Bursa (grams)	Spleen (grams)	Brain (grams)
<u>European Starlings</u>								
Site K		2	Mean	0.967	3.069	0.089	0.062	1.363
			SD	0.044	0.276	0.025	0.008	0.034
			n	2	2	2	2	2
Site L		2	Mean	0.908	3.127	0.081	0.071	1.453
			SD	0.118	0.616	0.007	0.039	0.241
			n	2	2	2	2	2
Site N		9	Mean	0.875	3.014	0.099	0.095	1.423
			SD	0.234	1.137	0.043	0.063	0.209
			n	9	9	7	7	7
Site P		2	Mean	0.782	2.547	0.082	0.041	1.415
			SD	0.125	0.714	0.011	0.012	0.022
			n	2	2	2	2	2
Site R		8	Mean	0.846	3.403	0.121	0.129	1.444
			SD	0.088	0.436	0.046	0.077	0.122
			n	8	8	8	8	8
<u>Mountain Bluebird</u>								
B 23	2		Mean	0.354	0.958	0.033	0.025	0.882
			SD	0.013	0.095	-	-	-
			n	2	2	1	1	1
K 21	1			0.390	1.241	NC	NC	NC
SB07	2		Mean	0.350	1.196	0.051	0.042	0.857
			SD	0.010	0.011	-	-	-
			n	2	2	1	1	1
Site C		2	Mean	0.414	1.162	0.032	0.070	0.855
			SD	0.096	0.134	-	-	-
			n	2	2	1	1	1

Continued

**Table 7-24.** Continued

Site or Box ID	Box N	Site N		Kidney (grams)	Liver (grams)	Bursa (grams)	Spleen (grams)	Brain (grams)
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Mountain Bluebird Continued

SF03	2		Mean	0.397	0.934	0.035	0.046	0.858
			SD	0.022	0.129	-	-	-
			n	2	2	1	1	1
SG01	1			0.392	1.294	NC	NC	NC
Site H		2	Mean	0.311	1.095	0.052	0.051	0.930
			SD	0.057	0.258	-	-	-
			n	2	2	1	1	1
SI06	1			0.377	1.218	NC	NC	NC
Site K		2	Mean	0.337	0.869	0.040	0.034	0.911
			SD	0.009	0.033	0.014	0.007	0.031
			n	2	2	2	2	2
Site M		2	Mean	0.330	0.950	0.037	0.065	0.890
			SD	0.007	0.104	-	-	-
			n	2	2	1	1	1
SO17	1			0.330	0.849	0.032	0.047	0.873

Chickadee

SB12	1			0.149	0.412	0.014	0.009	0.596
SL02	1			0.179	0.560	0.019	0.017	0.638

Continued

**Table 7-24.** Continued

Site or Box ID <sup>1</sup>	Box N	Site N		Kidney (grams)	Liver (grams)	Bursa (grams)	Spleen (grams)	Brain (grams)
<u>Tree Swallow</u>								
B 32	1			0.324	1.015	NC	NC	NC
B 36	1			0.270	1.034	0.052	0.047	0.511
SB03	1			0.279	0.997	NC	NC	NC
SH02	1			0.319	1.177	NC	NC	NC
SI18	1			0.323	1.100	NC	NC	NC
SJ06	1			0.355	1.019	NC	NC	NC
Site K		2	Mean	0.280	1.367	NC	NC	NC
			SD	0.006	0.303	-	-	-
			n	2	2	0	0	0
SN02	1			0.235	0.795			
Site O		2	Mean	0.310	1.427	0.033	0.017	0.444
			SD	0.009	0.352	-	-	-
			n	2	2	1	1	1
SP09	1			0.300	1.171	NC	NC	NC
SR10	3		Mean	0.220	0.845	NC	NC	NC
			SD	0.101	0.701	-	-	-
			n	3.000	3.000	0	0	0

1. Site is starling array. Box ID is identified by box type (B- bluebird, K- kestrel) and specific box number; or by box type (S-starling), site, and box number. NC – Data not collected



**Table 7-26.** European starling demographics at the Anaconda Smelter Site, 2000.

	A	B	C	D	E	F	G	H	I	J	K						
Site	Total Clutches	% Boxes Utilized	Eggs Laid	Eggs Collected	Eggs Missing	Eggs at hatch	Nestlings at Hatch	Eggs Added	Nestlings at Day 15	Nestlings Dead or Missing	% Eggs Hatched	% Fledging Efficiency	% Nesting Efficiency	% Nesting Success			
Site Description	Boxes Initiated	(B/A)*100)	(D-E-F)			(H/G)*100	(J/H)*100	(J/(D-E))*100	(SUM Js>1)/B)								
K East of Galen Road	18	2	11.11	Mean 4.50	1.00	0.00	3.50	3.50	0.00	3.00	0.50	100.00	83.33	83.33			
			SD 0.71	0.00	0.00	0.71	0.71	0.00	1.41	0.71	0.00	0.00	23.57	23.57	100.00		
			n 2	2	2	2	2	2	2	2	2	2	2	2			
L West of Galen Road (Limed)	20	2	10.00	Mean 4.50	1.00	0.00	3.50	2.50	1.00	2.00	0.50	66.67	87.50	54.17			
			SD 0.71	0.00	0.00	0.71	2.12	1.41	1.41	0.71	47.14	17.68	29.46	100.00			
			n 2	2	2	2	2	2	2	2	2	2	2	2			
N Opportunity Ponds NW	20	10	50.00	Mean 4.90	0.30	0.10	4.50	4.20	0.30	3.10	1.10	94.00	75.50	69.50			
			SD 1.10	0.48	0.32	1.08	1.03	0.48	1.37	1.37	9.66	31.22	31.13	90.00			
			n 10	10	10	10	10	10	10	10	10	10	10	10			
P Opportunity Ponds Cell-D	15	3	20.00	Mean 3.33	0.00	0.00	3.00	3.00	0.33	2.00	1.00	100.00	67.50	45.00			
			SD 2.08	0.00	0.00	2.65	2.65	0.58	1.73	1.00	0.00	10.61	39.69	66.67			
			n 3	3	3	3	3	3	3	3	3	2	2	3			
R Warm Springs	20	13	65.00	Mean 4.62	0.38	0.15	4.08	3.54	0.54	1.62	1.15	80.77	48.79	39.74			
			SD 0.77	0.51	0.55	1.38	1.90	1.13	1.76	1.91	37.17	42.71	43.19	61.54			
			n 13	13	13	13	13	13	13	13	13	13	11	13			

**Table 7-27.** Bluebird, chickadee, and tree swallow demographics from the Anaconda Smelter Site, 2000.

Species		A	B	C	D	E	F	G	H	I	J				
		Eggs Laid	Eggs Collected	Eggs Missing	Eggs Addled	Eggs At Hatch	Nestlings At Hatch	Nestlings Collected	Nestlings Dead	Nestlings Dead or Missing	Nestlings Fledged	% Eggs Hatched	% Fledging Efficiency	% Nesting Efficiency	% Nesting Success
												(F/E) *100	(J+G)/F *100	(J+G)/A *100	(Sum F)/(Sum A) *100
Bluebird	Mean	5.43	0.00	0.24	0.90	4.95	4.29	0.86	0.24	0.81	2.62	86.09	80.53	63.39	90.48
	SD	0.75	0.00	0.89	1.34	1.80	1.87	0.36	0.70	1.36	1.80	19.03	28.46	36.53	
	n	21	21	21	21	21	21	21	21	21	21	21	19	19	21
Chickadee	Mean	7.33	0.00	0.33	3.33	7.00	3.67	1.00	0.00	0.00	2.67	46.30	100.00	44.71	100.00
	SD	1.53	0.00	0.58	2.08	1.73	3.79	0.00	0.00	0.00	3.79	37.82	0.00	38.72	
	n	3	3	3	3	3	3	3	3	3	3	3	3	3	
Swallow	Mean	5.53	0.00	0.40	0.47	5.07	4.67	0.93	0.80	0.80	3.00	92.07	85.00	70.54	93.33
	SD	0.64	0.00	0.83	0.64	1.53	1.50	0.26	1.47	1.47	1.60	9.62	25.68	29.73	
	n	15	15	15	15	15	15	15	15	15	15	14	14	15	

**Table 7-28.** Body weight and morphological measurement of passerine nestlings at time of collection from sites on the Anaconda Smelter Site, 1999. Site N (Box N) is the total number of boxes (individual samples) n - number of boxes (individuals) with at least one detectable value.

Site or Box ID <sup>1</sup>	Box N	Site N		Weight (grams)	Bill (mm)	Tarsus (mm)
<u>European Starling</u>						
Site K		4	Mean	59.616	9.342	28.103
			SD	13.278	1.250	1.523
			n	4	4	4
Site L		4	Mean	62.889	8.997	30.095
			SD	3.834	0.389	0.200
			n	4	4	4
Site N		5	Mean	58.053	9.690	28.726
			SD	6.654	0.555	0.919
			n	5	5	5
Site O		5	Mean	67.615	10.301	30.085
			SD	12.700	0.715	1.721
			n	5	5	5
Site Q		4	Mean	63.588	9.613	29.486
			SD	8.325	0.485	0.517
			n	4	4	4

Mountain Bluebird

K 08	1			26.45	5.47	21.12
K 18	1			27.02	7.54	24.51
SF09	1			26.52	5.95	20.5
SH12	1			28.82	7.11	23.93

Chickadee

B 44		1		11.46	5.35	17.75
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Continued

**Table 7-28.** Continued

Site or Box ID <sup>1</sup>	Box N	Site N		Weight (grams)	Bill (mm)	Tarsus (mm)
<u>Tree Swallow</u>						
B 29	2		Mean	21.575	5.325	13.585
			SD	1.110	0.346	0.092
			n	2	2	2
K 47	2		Mean	20.765	4.970	12.555
			SD	0.078	0.057	0.544
			n	2	2	2
SB12	3		Mean	20.345	4.728	13.285
			SD	0.804	0.314	0.644
			n	4	4	4
SJ10	2		Mean	20.925	4.705	12.660
			SD	1.492	0.078	0.523
			n	2	2	2
SP11	2		Mean	21.310	4.745	14.295
			SD	0.948	0.064	0.813
			n	2	2	2
SQ03	2		Mean	21.540	4.810	13.355
			SD	1.895	0.113	0.276
			n	2	2	2

1. Site is starling array. Box ID is identified by box type (B- bluebird, K- kestrel) and specific box number; or by box type (S-starling), site, and box number.

**Table 7-29.** Body weight and morphological measurement from passerines from sites on the Anaconda Smelter Site, 2000. Site N (Box N) is the total number of boxes (individual samples). n - number of boxes (individuals) with at least one detectable value.

Site or Box ID <sup>1</sup>	Measured Days	Site N		Weight (grams)	Bill (mm)	Tarsus (mm)
<u>European Starlings</u>						
Site K	Day 5/6	2	Mean	24.19	5.50	18.59
			SD	2.56	0.262	0.921
			n	2	2	2
	Day 8/9	2	Mean	37.25	6.71	24.87
			SD	5.66	0.435	2.71
			n	2	2	2
	Day 10/11	2	Mean	49.50	7.75	29.04
			SD	4.95	0.445	2.25
			n	2	2	2
	Day 13/14	2	Mean	59.13	8.99	31.56
			SD	10.43	0.566	1.49
			n	2	2	2
Site L	Day 5/6	2	Mean	25.08	5.40	19.75
			SD	4.12	0.167	1.20
			n	2	2	2
	Day 8/9	2	Mean	38.67	6.29	24.29
			SD	7.54	0.530	1.96
			n	2	2	2
	Day 10/11	1	Mean	51.00	7.47	28.06
				-	-	-
			n	1	1	1
	Day 13/14	2	Mean	63.33	8.51	32.17
			SD	12.26	0.471	0.754
			n	2	2	2

Continued

**Table 7-29.** Continued

Site or Box ID <sup>1</sup>	Measured Days	Site N		Weight (grams)	Bill (mm)	Tarsus (mm)
<u>Starling</u>						
Continued						
Site N	Day 5/6	9	Mean	33.13	5.99	21.52
			SD	7.82	0.539	3.27
			n	9	9	9
	Day 8/9	9	Mean	47.38	7.16	26.90
			SD	10.21	0.872	3.78
			n	9	9	9
	Day 10/11	7	Mean	56.90	8.32	29.96
			SD	8.74	0.647	2.55
			n	7	7	7
	Day 13/14	9	Mean	60.78	9.32	30.27
			SD	12.70	1.43	2.84
			n	9	9	9
Site P	Day 5/6	2	Mean	23.17	5.20	15.12
			SD	4.95	0.375	3.92
			n	2	2	2
	Day 8/9	2	Mean	41.25	6.59	24.81
			SD	6.25	1.07	5.08
			n	2	2	2
	Day 10/11	1	Mean	50.00	7.13	29.07
				-	-	-
			n	1	1	1
	Day 13/14	2	Mean	60.83	8.72	31.66
			SD	11.08	1.14	2.64
			n	2	2	2

Continued

**Table 7-29.** Continued

Site or Box ID <sup>1</sup>	Measured Days	Site N		Weight (grams)	Bill (mm)	Tarsus (mm)
<u>Starling</u>						
Continued						
Site R	Day 5/6	8	Mean	27.47	5.44	19.34
			SD	6.95	0.579	2.29
			n	8	8	8
	Day 8/9	7	Mean	43.02	6.86	25.62
			SD	11.80	0.647	4.13
			n	7	7	7
	Day 10/11	6	Mean	57.29	8.04	29.67
			SD	10.05	0.397	2.22
			n	6	6	6
	Day 13/14	8	Mean	65.26	9.05	31.54
			SD	8.07	0.674	1.35
			n	7	8	8
<hr/>						
<u>Mountain Bluebird</u>						
Site B 23	Day 5/6	2	Mean	14.25	3.96	15.05
			SD	0.943	0.104	1.95
			n	2	2	2
	Day 8/9	2	Mean	24.63	5.13	22.16
			SD	0.884	0.484	2.27
			n	2	2	2
	Day 10/11	2	Mean	29.42	5.84	24.68
			SD	2.00	0.032	0.799
			n	2	2	2
	Day 13/14	1	Mean	29.25	6.62	25.18
			SD	-	-	-
			n	1	1	1

Continued

**Table 7-29.** Continued

Site or Box ID <sup>1</sup>	Measured Days	Site N		Weight (grams)	Bill (mm)	Tarsus (mm)
<u>Bluebird</u> Continued						
Site K 21	Day 5/6	1	Mean	14.83	4.15	15.45
			SD	-	-	-
			n	1	1	1
	Day 10/11	1	Mean	27.75	6.01	25.09
			SD	-	-	-
			n	1	1	1
Site B	Day 5/6	2	Mean	15.44	4.06	15.58
			SD	4.33	0.323	2.25
			n	2	2	2
	Day 8/9	1	Mean	22.00	4.87	19.86
			SD	-	-	-
			n	1	1	1
	Day 10/11	2	Mean	26.33	5.88	22.96
			SD	1.89	0.035	1.65
			n	2	2	2
	Day 13/14	2	Mean	28.94	6.45	23.56
			SD	0.795	0.154	1.86
			n	2	2	2
Site C	Day 5/6	1	Mean	12.00	3.70	14.70
			SD	-	-	-
			n	1	1	1
	Day 8/9	2	Mean	18.17	4.10	17.98
			SD	4.24	0.818	4.78
			n	2	2	2
	Day 10/11	2	Mean	22.92	4.72	20.75
			SD	0.589	0.839	2.96
			n	2	2	2

Continued

**Table 7-29.** Continued

Site or Box ID <sup>1</sup>	Measured Days	Site N		Weight (grams)	Bill (mm)	Tarsus (mm)
<u>Bluebird</u> Continued						
Site C	Day 13/14	2	Mean	25.58	5.55	23.04
			SD	0.118	0.943	1.65
			n	2	2	2
Site F	Day 5/6	1	Mean	14.00	3.52	15.20
			SD	-	-	-
			n	1	1	1
	Day 8/9	1	Mean	21.50	4.41	21.47
			SD	-	-	-
			n	1	1	1
	Day 10/11	1	Mean	28.00	5.13	23.51
			SD	-	-	-
			n	1	1	1
	Day 13/14	1	Mean	29.50	5.94	25.55
			SD	-	-	-
			n	1	1	1
Site G	Day 5/6	1	Mean	13.75	3.51	15.79
			SD	-	-	-
			n	1	1	1
	Day 8/9	1	Mean	25.50	4.77	20.46
			SD	-	-	-
			n	1	1	1
	Day 13/14	1	Mean	31.00	5.73	25.64
			SD	-	-	-
			n	1	1	1

Continued

**Table 7-29.** Continued

Site or Box ID <sup>1</sup>	Measured Days	Site N		Weight (grams)	Bill (mm)	Tarsus (mm)
<u>Bluebird</u> Continued						
Site H	Day 5/6	2	Mean	12.83	4.15	13.62
			SD	3.54	0.325	3.27
			n	2	2	2
	Day 8/9	1	Mean	20.50	5.05	19.46
			SD	-	-	-
			n	1	1	1
	Day 10/11	2	Mean	28.46	5.70	23.59
			SD	5.01	0.191	0.52
			n	2	2	2
	Day 13/14	2	Mean	28.75	6.45	24.98
			SD	0.825	0.019	1.40
			n	2	2	2
<hr/>						
Site I	Day 5/6	1	Mean	14.88	4.27	16.41
			SD	-	-	-
			n	1	1	1
	Day 10/11	1	Mean	27.50	6.04	24.24
			SD	-	-	-
			n	1	1	1
	Day 13/14	1	Mean	27.25	6.45	24.52
			SD	-	-	-
			n	1	1	1
<hr/>						
Site K	Day 5/6	2	Mean	14.11	3.80	15.95
			SD	2.85	0.031	1.78
			n	2	2	2

Continued

**Table 7-29.** Continued

Site or Box ID <sup>1</sup>	Measured Days	Site N				
				Weight (grams)	Bill (mm)	Tarsus (mm)
Site K	Day 8/9	2	Mean	20.69	4.69	22.57
			SD	5.21	0.025	2.13
			n	2	2	2
	Day 10/11	1	Mean	31.00	5.81	25.47
			SD	-	-	-
			n	1	1	1
	Day 13/14	2	Mean	27.70	6.14	25.49
			SD	3.25	0.496	1.15
			n	2	2	2
Site M	Day 5/6	2	Mean	17.03	4.64	18.32
			SD	1.60	0.179	1.64
			n	2	2	2
	Day 8/9	2	Mean	25.39	5.51	23.42
			SD	0.978	0.152	0.699
			n	2	2	2
	Day 10/11	2	Mean	29.11	6.23	23.87
			SD	0.978	0.099	1.39
			n	2	2	2
	Day 13/14	2	Mean	29.68	6.82	25.09
			SD	0.813	0.055	0.870
			n	2	2	2
Site O	Day 5/6	1	Mean	12.00	3.72	13.73
			SD	-	-	-
			n	1	1	1

Continued

**Table 7-29.** Continued

Site or Box ID <sup>1</sup>	Measured Days	Site N		Weight (grams)	Bill (mm)	Tarsus (mm)
<u>Bluebird</u> Continued						
Site O	Day 8/9	1	Mean	20.20	4.58	20.34
			SD	-	-	-
			n	1	1	1
	Day 10/11	1	Mean	23.50	5.56	22.94
			SD	-	-	-
			n	1	1	1
	Day 13/14	1	Mean	29.30	6.51	23.89
			SD	-	-	-
			n	1	1	1
<u>Chickadees</u>						
B 38	Day 10/11	1		9.50	3.25	16.48
				10.00	3.80	16.10
				10.00	4.36	18.37
Site B	Day 10/11	1	Mean	9.75	4.40	16.71
			SD	-	-	-
			n	1	1	1
	Day 12/13	1	Mean	10.50	4.55	16.49
			SD	-	-	-
			n	1	1	1
	Day 14	1	Mean	10.25	4.98	17.81
			SD	-	-	-
			n	1	1	1

Continued

**Table 7-29.** Continued

Site or Box ID <sup>1</sup>	Measured Days	Site N		Weight (grams)	Bill (mm)	Tarsus (mm)
<u>Chickadees</u> Continued						
SL02	Day 10/11	1	Mean	9.88	4.60	16.02
			SD	-	-	-
			n	1	1	1
	Day 12/13	1	Mean	12.14	4.73	16.86
			SD	-	-	-
			n	1	1	1
	Day 14	1	Mean	11.88	5.27	18.73
			SD	-	-	-
			n	1	1	1
<u>Tree Swallows</u>						
B 32	Day 5/6	1	Mean	7.88	3.30	11.22
			SD	-	-	-
			n	1	1	1
	Day 8/9	1	Mean	18.50	3.98	13.03
			SD	-	-	-
			n	1	1	1
	Day 12/13	1	Mean	21.75	4.57	13.89
			SD	-	-	-
			n	1	1	1
B 36	Day 5/6	1	Mean	10.17	3.42	10.90
			SD	-	-	-
			n	1	1	1
	Day 8/9	1	Mean	14.92	3.71	12.58
			SD	-	-	-
			n	1	1	1

Continued

**Table 7-29.** Continued

Site or Box ID <sup>1</sup>	Measured Days	Site N		Weight (grams)	Bill (mm)	Tarsus (mm)
<u>Tree swallows</u> Continued						
B 36	Day 12/13	1	Mean	22.67	4.59	13.18
			SD	-	-	-
			n	1	1	1
Site B	Day 8/9	1	Mean	15.20	4.17	13.09
			SD	-	-	-
			n	1	1	1
	Day 10/11	1	Mean	17.70	4.36	13.25
			SD	-	-	-
			n	1	1	1
	Day 12/13	1	Mean	18.00	4.53	13.02
			SD	-	-	-
			n	1	1	1
Site H	Day 5/6	1	Mean	9.00	3.30	9.75
			SD	-	-	-
			n	1	1	1
	Day 8/9	1	Mean	17.33	4.02	12.29
			SD	-	-	-
			n	1	1	1
	Day 10/11	1	Mean	20.17	4.47	14.15
			SD	-	-	-
			n	1	1	1
	Day 12/13	1	Mean	22.67	5.04	13.52
			SD	-	-	-
			n	1	1	1

Continued

**Table 7-29.** Continued

Site or Box ID <sup>1</sup>	Measured Days	Site N		Weight (grams)	Bill (mm)	Tarsus (mm)
<u>Tree swallows</u> Continued						
Site I	Day 5/6	1		9.50	3.58	11.43
	Day 8/9	1		13.00	4.08	13.18
	Day 10/11	1		18.00	4.48	14.08
	Day 12/13	1		17.00	4.60	14.18
Site J	Day 5/6	1	Mean	11.00	3.67	11.26
			SD	-	-	-
			n	1	1	1
	Day 8/9	1	Mean	17.00	4.25	12.92
			SD	-	-	-
			n	1	1	1
	Day 12/13	1	Mean	18.40	4.63	12.67
			SD	-	-	-
			n	1	1	1
	Day 12/13	1	Mean	18.40	4.90	12.63
			SD	-	-	-
			n	1	1	1
Site K	Day 5/6	2	Mean	12.65	3.69	12.55
			SD	0.071	0.148	0.086
			n	2	2	2
	Day 8/9	2	Mean	17.35	4.04	13.92
			SD	0.636	0.059	1.19
			n	2	2	2
	Day 10/11	2	Mean	20.40	4.52	13.81
			SD	0.283	0.025	0.028
			n	2	2	2

Continued

**Table 7-29.** Continued

Site or Box ID <sup>1</sup>	Measured Days	Site N		Weight (grams)	Bill (mm)	Tarsus (mm)
<u>Tree swallows</u> Continued						
Site K	Day 12/13	2	Mean	21.10	5.04	13.48
			SD	2.12	0.215	0.281
			n	2	2	2
Site N	Day 5/6	1	Mean	14.00	3.73	12.13
			SD	-	-	-
			n	1	1	1
	Day 8/9	1	Mean	16.50	4.44	13.37
			SD	-	-	-
			n	1	1	1
	Day 10/11	1	Mean	17.50	4.92	13.71
			SD	-	-	-
			n	1	1	1
	Day 12/13	1	Mean	19.00	5.13	13.58
			SD	-	-	-
			n	1	1	1
Site O	Day 5/6	2	Mean	8.17	3.26	10.62
			SD	0.118	0.006	0.653
			n	2	2	2
	Day 8/9	2	Mean	16.06	4.07	12.73
			SD	5.57	0.642	0.877
			n	2	2	2
	Day 10/11	1	Mean	17.50	3.90	12.64
			SD	-	-	-
			n	1	1	1
	Day 12/13	2	Mean	21.42	4.724	13.580
			SD	2.00	0.282	0.017
			n	2	2	2

Continued

**Table 7-29.** Continued

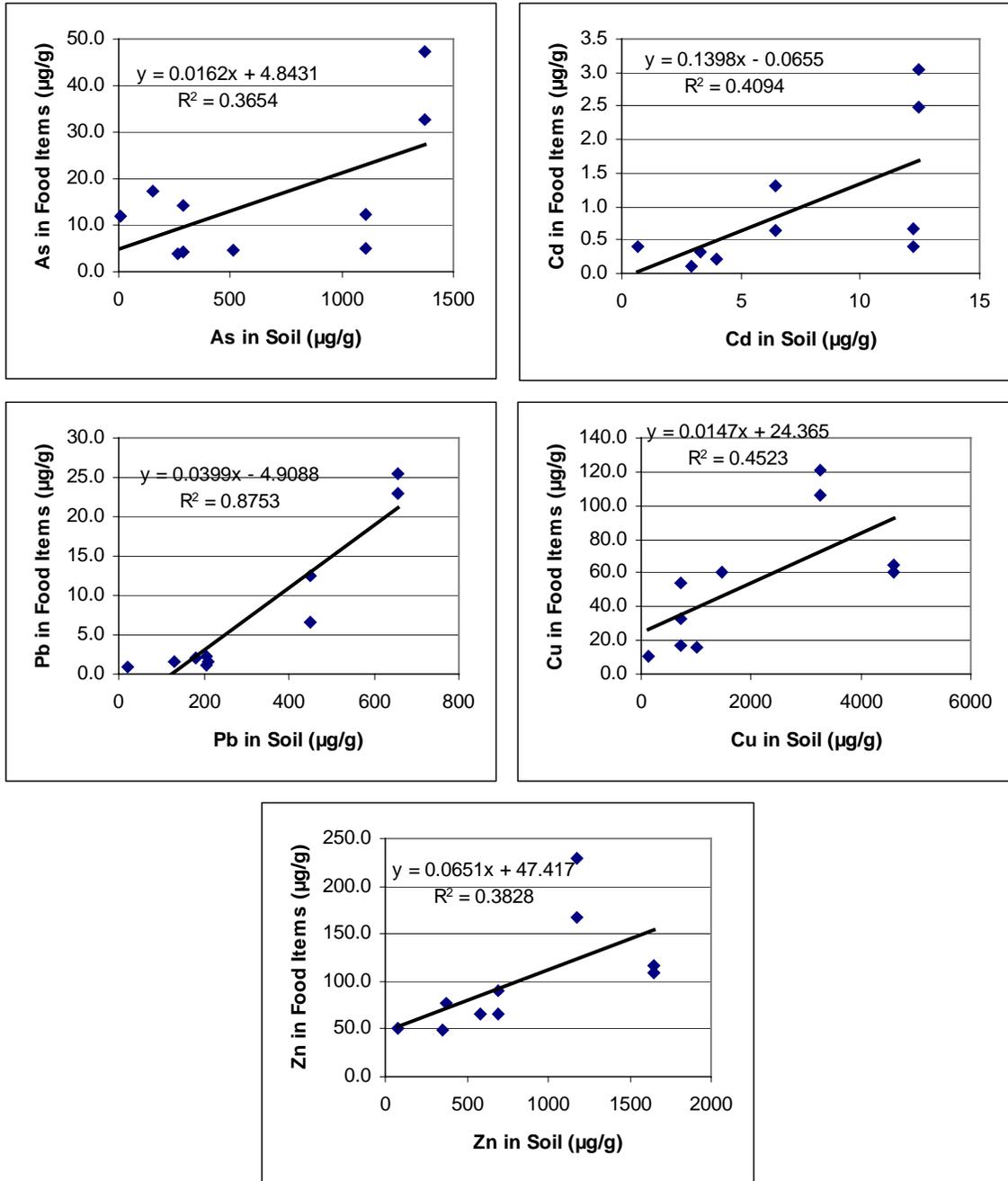
Site or Box ID <sup>1</sup>	Measured Days	Site N				
			Weight (grams)	Bill (mm)	Tarsus (mm)	
<u>Tree swallows</u> Continued						
Site P	Day 5/6	1	Mean	15.13	3.56	13.04
			SD	-	-	-
			n	1	1	1
	Day 8/9	1	Mean	19.75	4.48	13.66
			SD	-	-	-
			n	1	1	1
	Day 10/11	1	Mean	21.75	4.75	14.47
			SD	-	-	-
			n	1	1	1
	Day 12/13	1	Mean	24.25	4.81	14.90
			SD	-	-	-
			n	1	1	1
<hr/>						
Site R	Day 5/6	1	Mean	10.90	3.46	11.23
			SD	-	-	-
			n	1	1	1
	Day 8/9	1	Mean	16.80	4.01	13.41
			SD	-	-	-
			n	1	1	1
	Day 10/11	1	Mean	18.40	4.22	14.80
			SD	-	-	-
			n	1	1	1
	Day 12/13	1	Mean	18.90	4.34	14.36
			SD	-	-	-
			n	1	1	1

1. Site is starling array. Box ID is identified by box type (B- bluebird, K- kestrel) and specific box number; or by box type (S-starling), site, and box number.

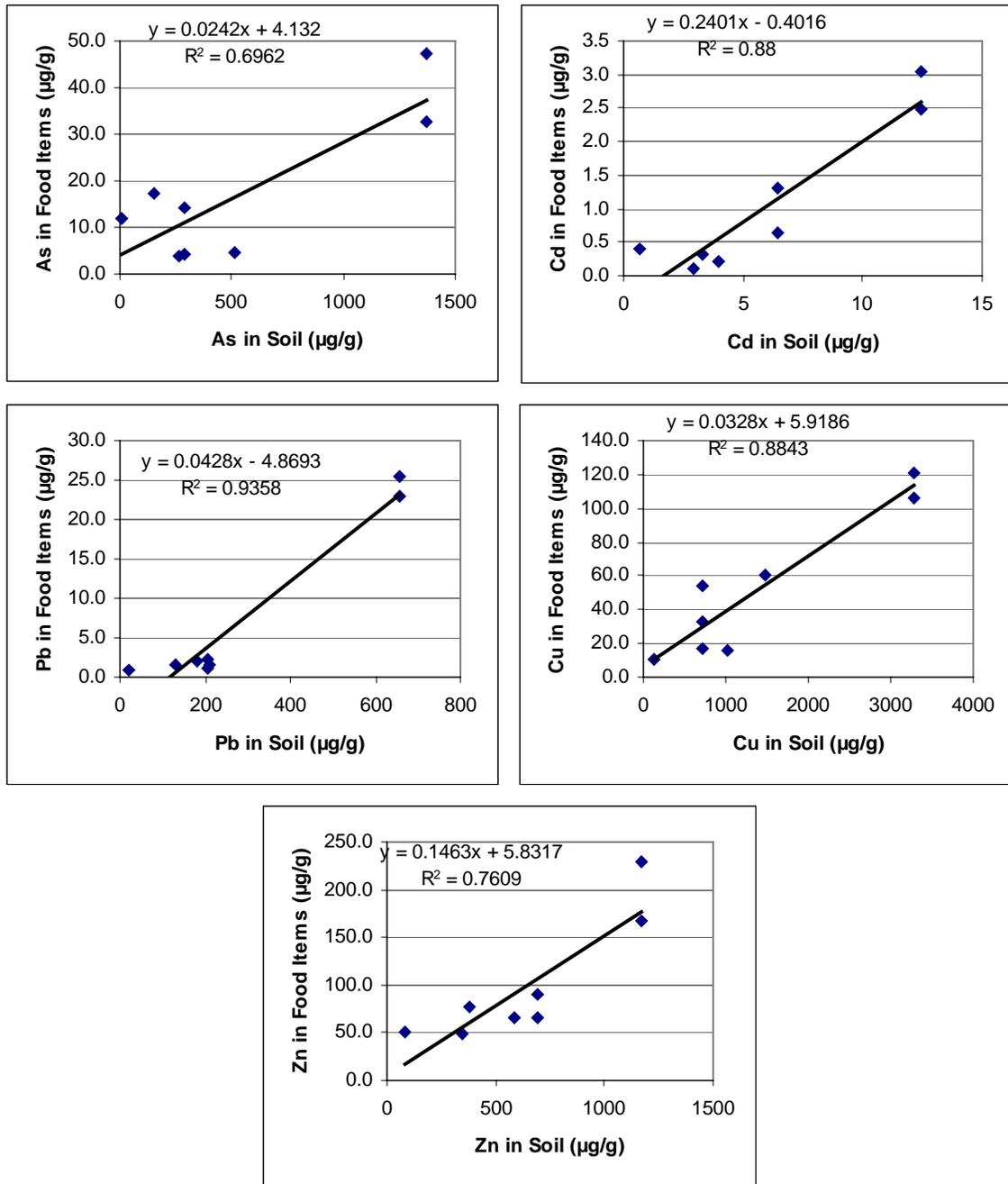
7.4 Passerine Figures and List of Figures

<b>Passerine List of Figures</b>	
<b>Figure Number</b>	<b>Figure Content</b>
7- 1	Map of Anaconda site with Passerine nest box arrays marked
7- 2	Mean site COC accumulation from soil to food.
7- 3	Mean site COC accumulation from soil to food. Site L data removed
7- 4	Mean site COC accumulation from soil to liver
7- 5	Mean site COC accumulation from soil to liver. Site L data removed
7- 6	Mean site COC accumulation from soil to kidney
7- 7	Mean site COC accumulation from soil to kidney. Site L data removed
7- 8	Mean site starling tissue weights from 1999 and 2000
7- 9	Nesting efficiency vs. soil metal concentrations from 1999 and 2000
7- 10	Nesting success vs. soil metal concentrations from 1999 and 2000
7- 11	Liver lead in starlings with sub-clinical and toxic thresholds
7- 12	Liver lead in other passerines with sub-clinical and toxic thresholds
7- 13	Kidney lead in starlings with sub-clinical and toxic thresholds
7- 14	Kidney lead in other passerines with sub-clinical and toxic thresholds
7- 15	Blood ALAD activity vs. blood lead concentration in starlings
7- 16	Blood ALAD activity vs. blood lead concentration in bluebirds
7- 17	Percent ALAD inhibition in nest boxes.

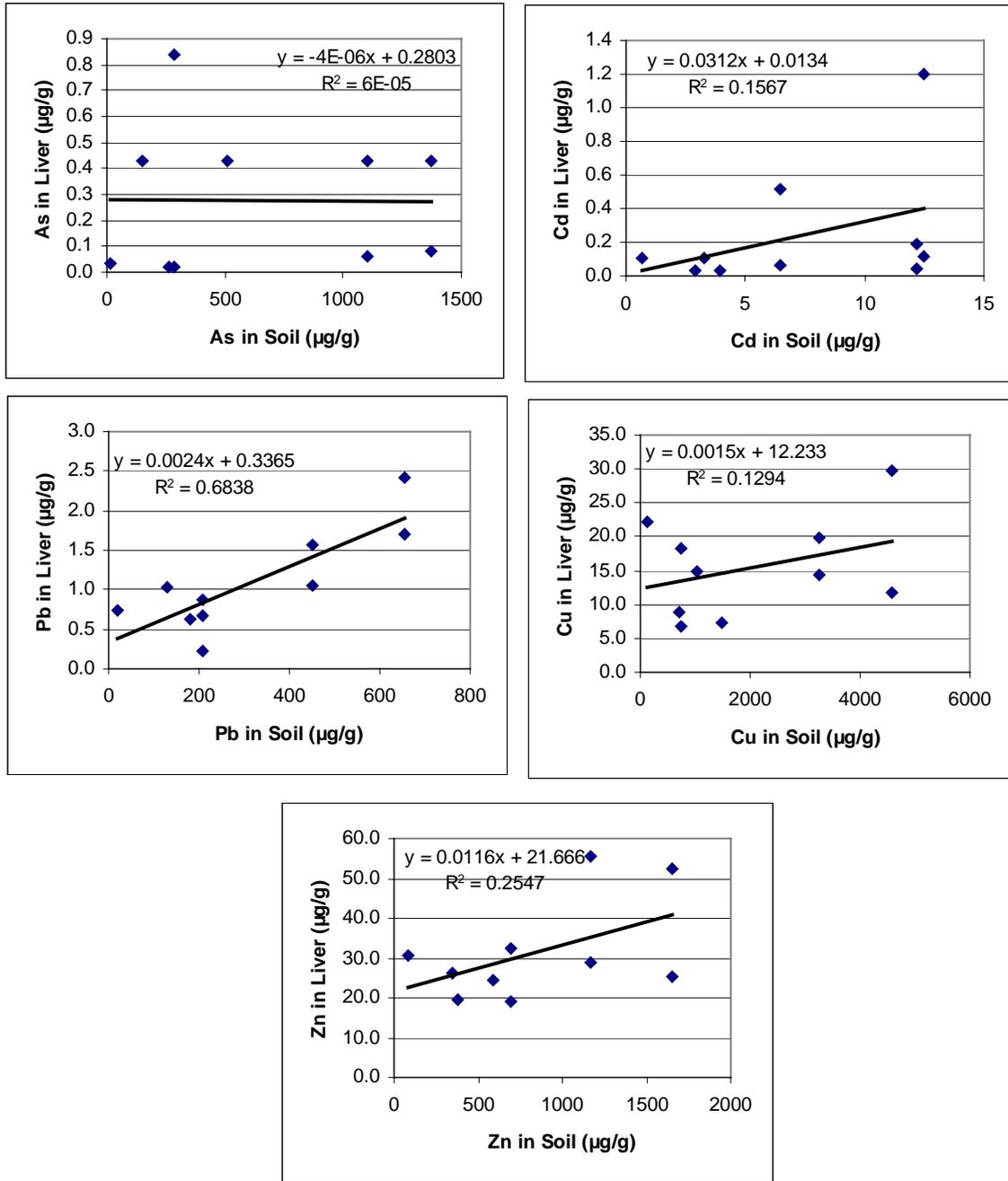




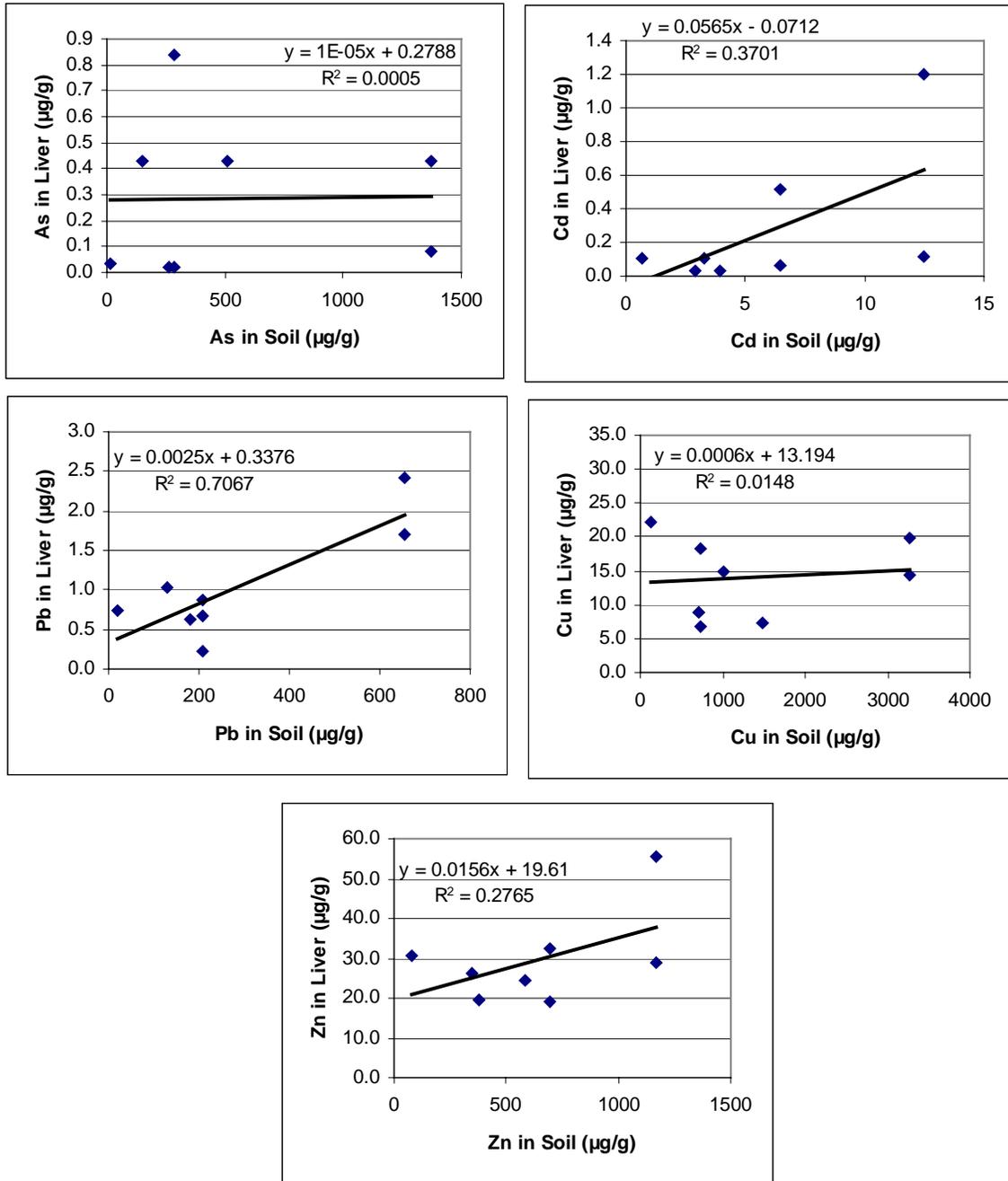
**Figure 7-2.** COC accumulation from soil into food from European starlings inhabiting the Anaconda Smelter Superfund Site. Data represent site means for soil and food items across 1999 and 2000. Regression slopes for Cd, Pb and Cu were significant ( $p=0.046$ ,  $0.000$  and  $0.033$ , respectively).



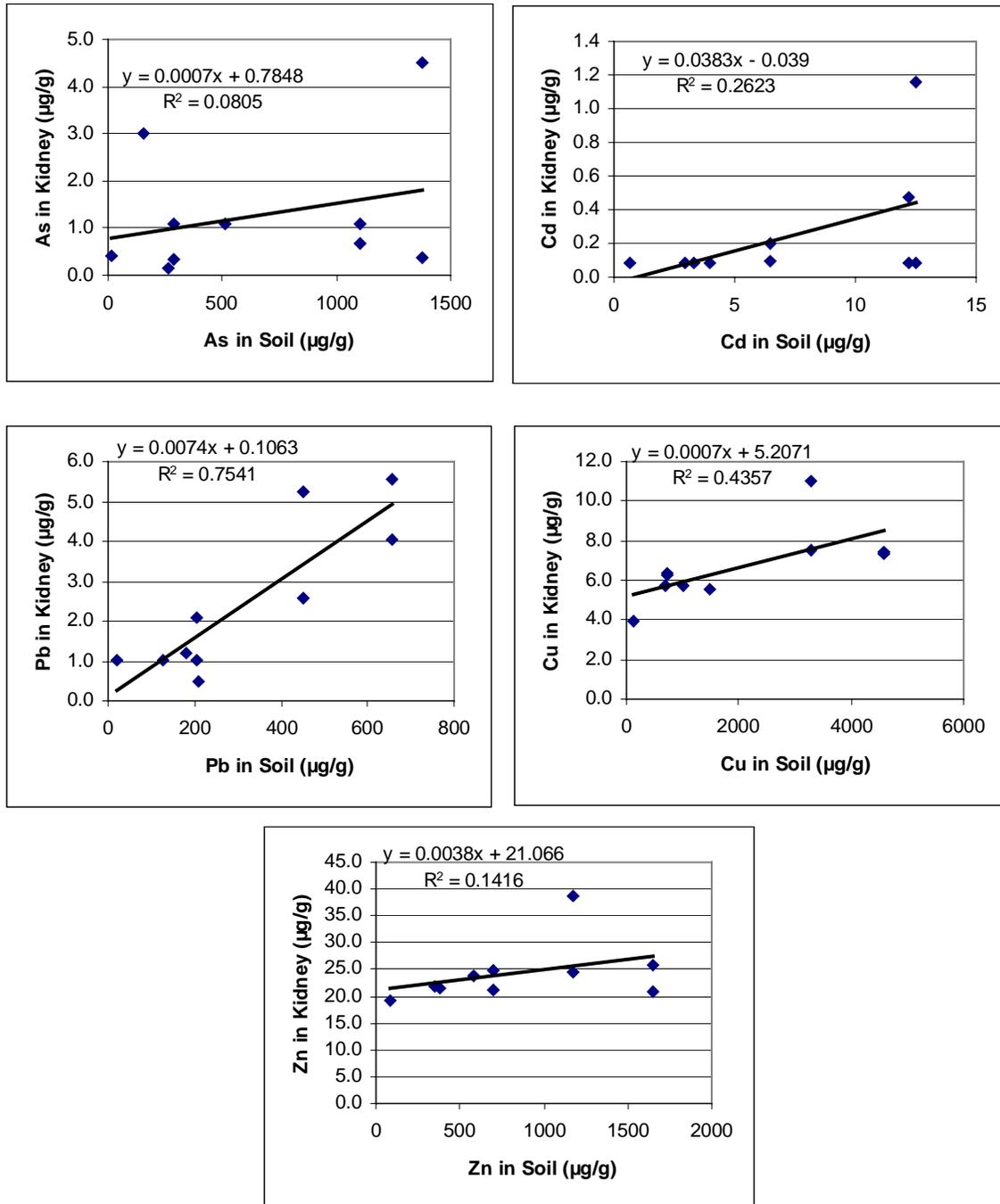
**Figure 7-3.** COC accumulation from soil into food items from European starlings inhabiting the Anaconda Smelter Superfund Site. Data are the same as those in Figure 7-2 except Site L data have been removed. Regression slopes for As, Cd, Pb, Cu and Zn were significant ( $p=0.010, 0.000, 0.000, 0.001$  and  $0.005$ , respectively).



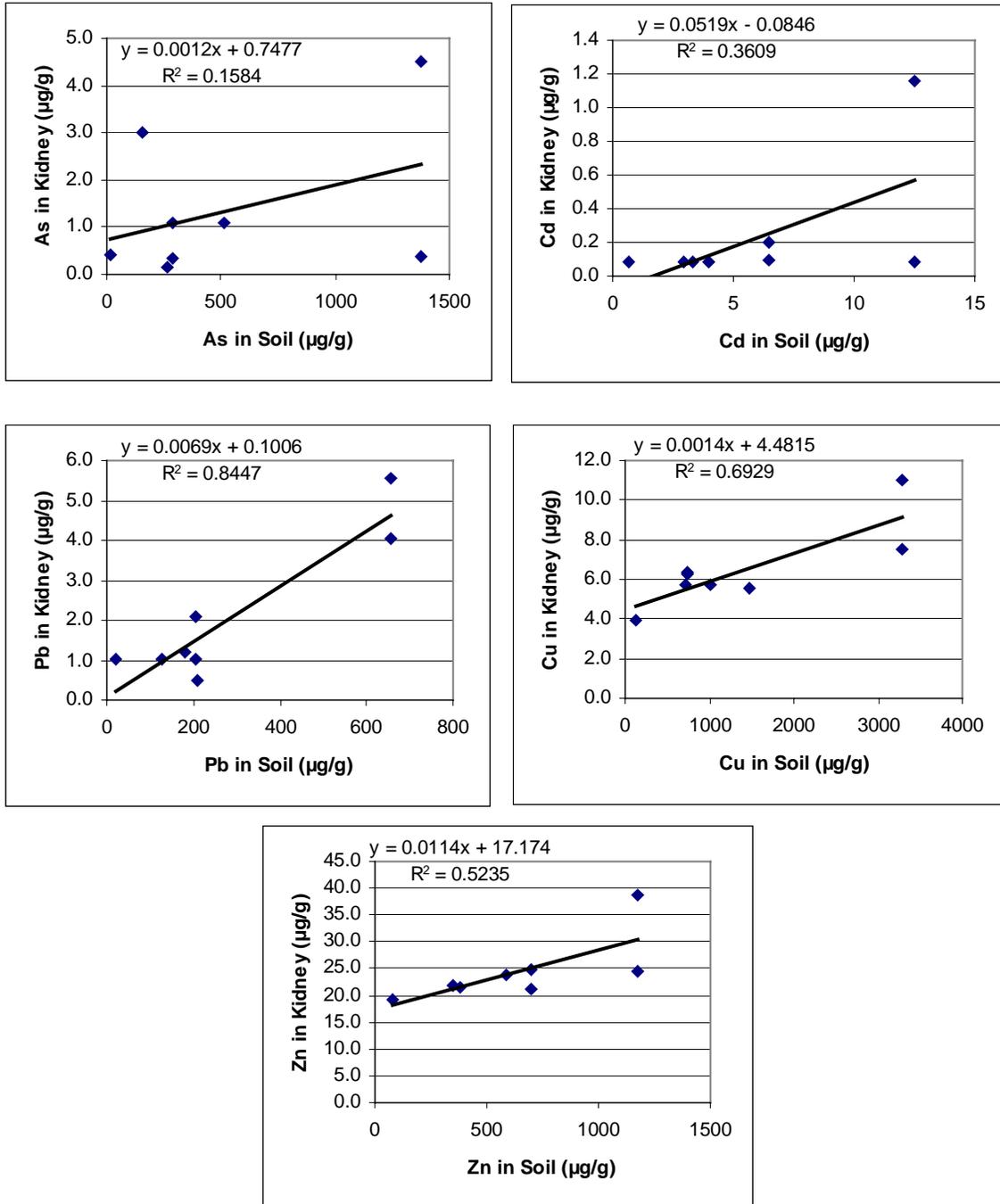
**Figure 7-4.** COC accumulation from soil into liver from European starlings inhabiting the Anaconda Smelter Superfund Site. Data represent site means for soil and food items across 1999 and 2000. Regression slope for Pb was significant ( $p=0.003$ ).



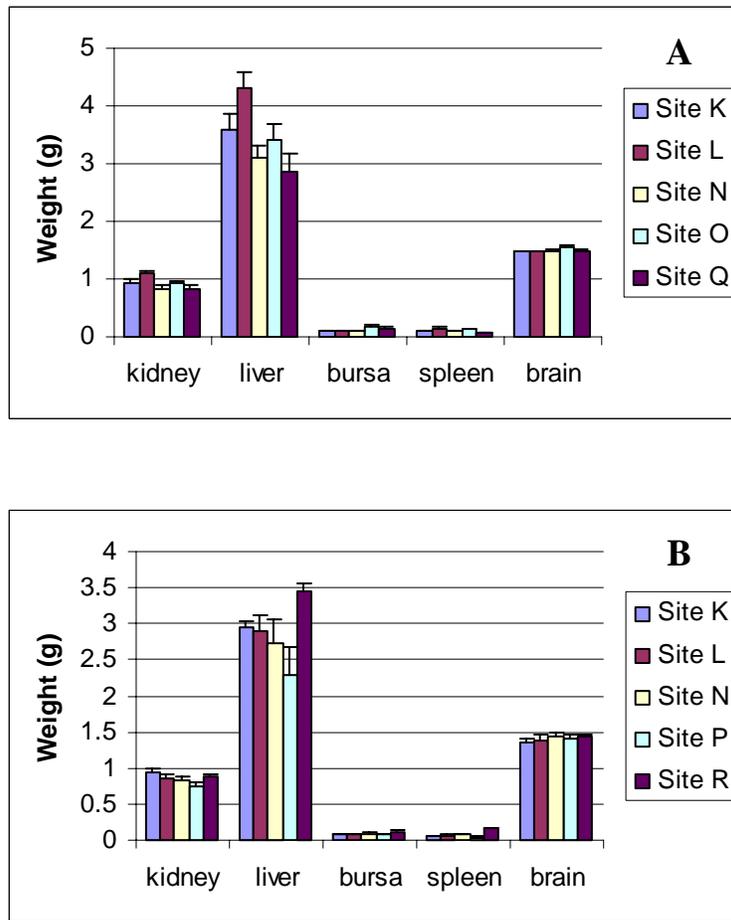
**Figure 7-5.** Site Mean COC accumulation from soil into liver from European starlings inhabiting the Anaconda Smelter Superfund Site. Data are the same as those in Figure 7-4 except Site L data have been removed. Regression slope for Pb was significant ( $p=0.009$ ).



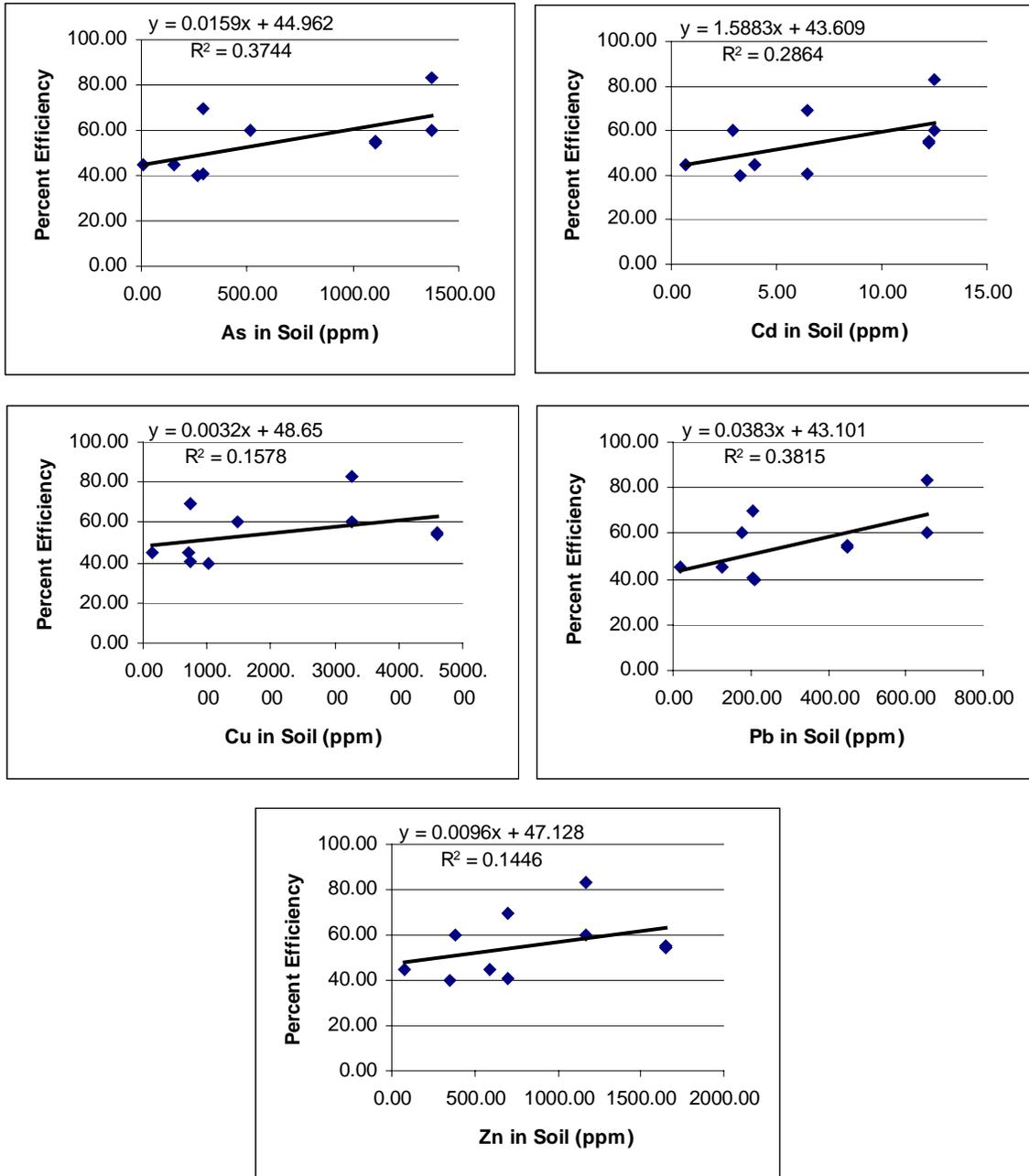
**Figure 7-6.** COC accumulation from soil into kidney in European starlings inhabiting the Anaconda Smelter Superfund Site. Data represent site means for soil and food items across 1999 and 2000. Regression slopes for Pb and Cu were significant ( $p=0.001$  and  $0.037$ , respectively).



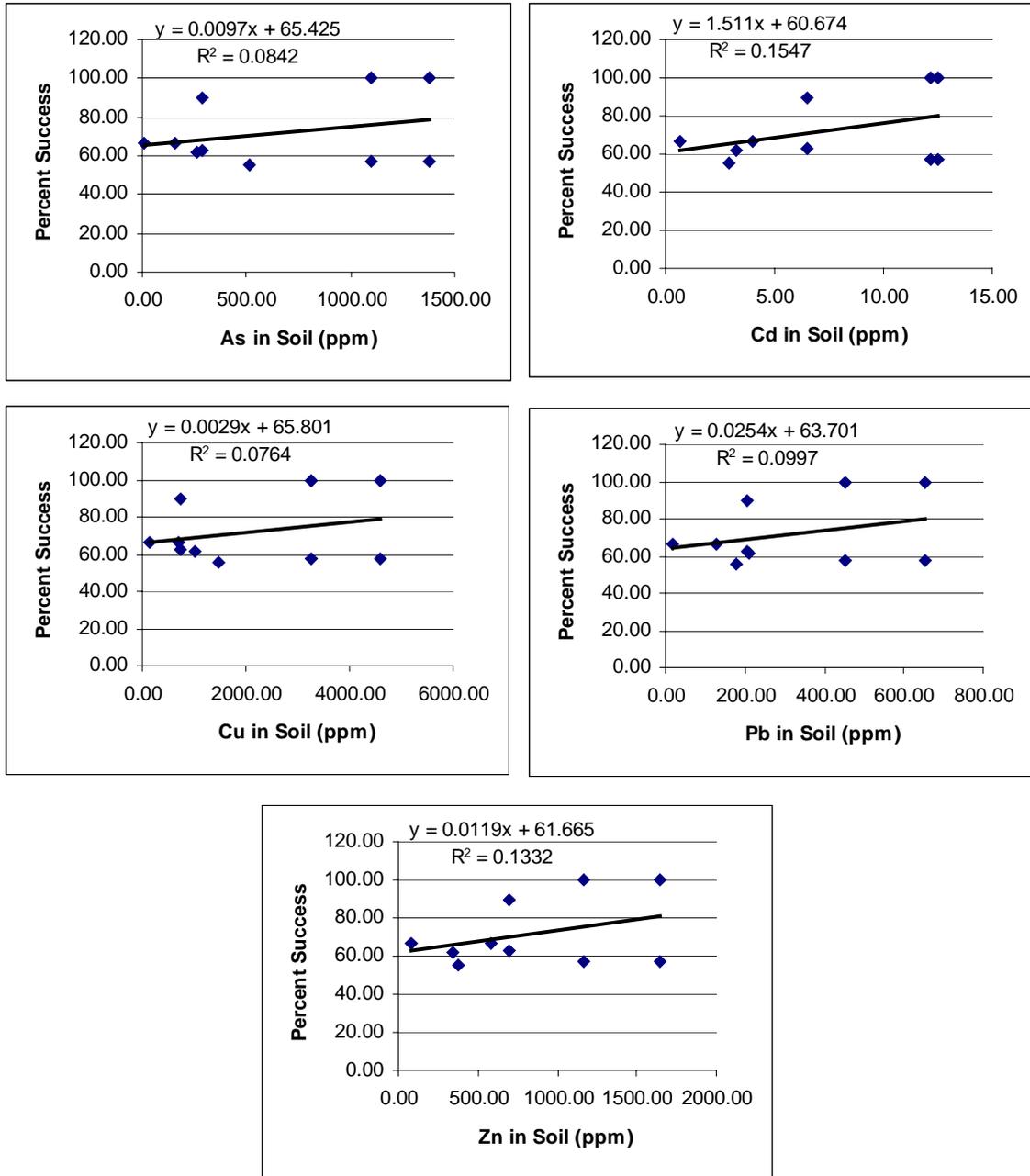
**Figure 7-7.** COC accumulation from soil into kidney in European starlings inhabiting the Anaconda Smelter Superfund Site. Data are the same as those in Figure 7-6 except Site L data have been removed. Regression slopes for Pb, Cu and Zn were significant ( $p=0.001$ ,  $0.010$  and  $0.042$ , respectively).



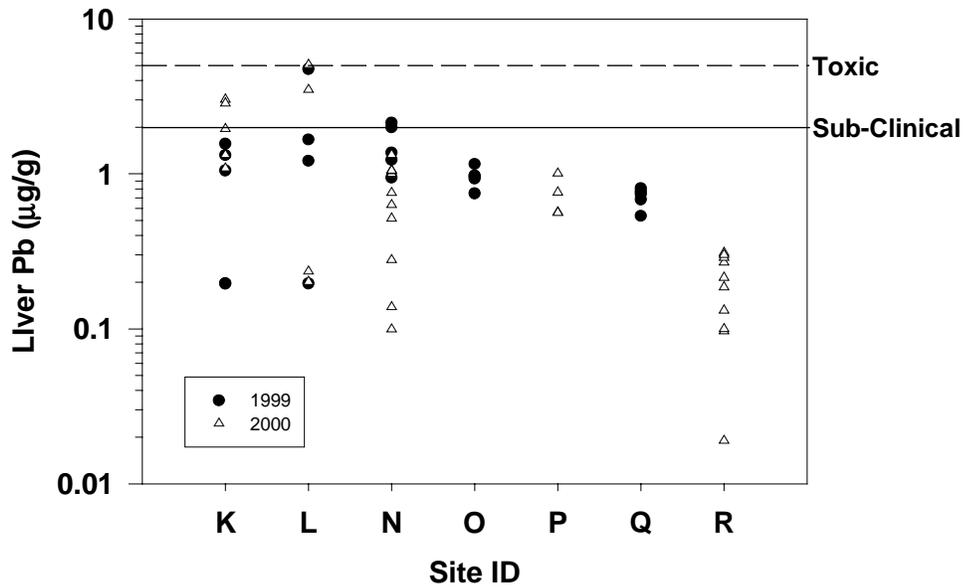
**Figure 7-8.** Site mean + standard deviation of tissue weights (fresh weight) from 15-day-old starling nestlings, Anaconda Smelter Site, 1999 (A) and 2000 (B).



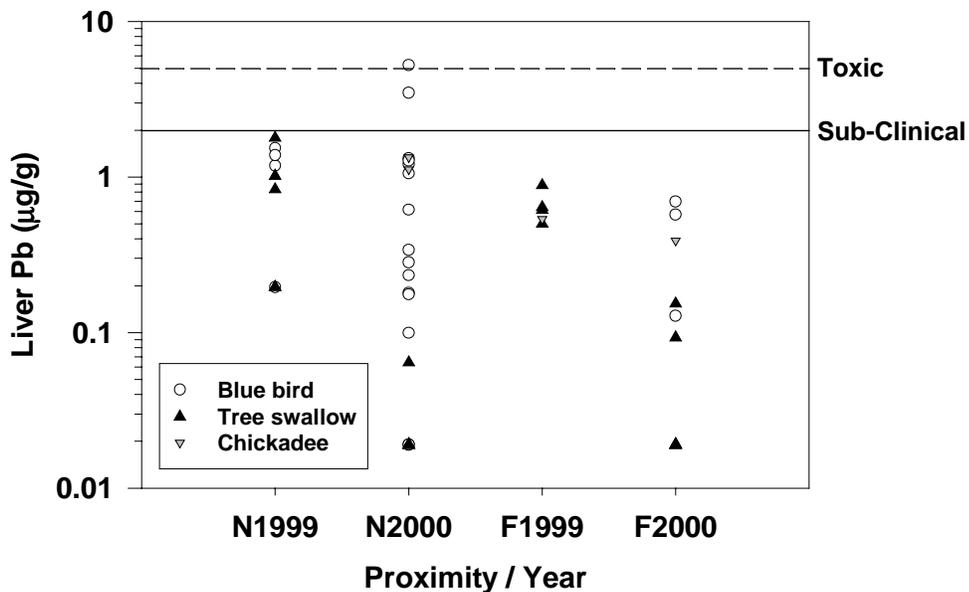
**Figure 7-9.** Regressions of percent nesting efficiency (# nestlings at day 15/ # eggs laid) on soil metal concentrations. Site averages from 1999 and 2000. No significant relationship was detected for any of the metals.



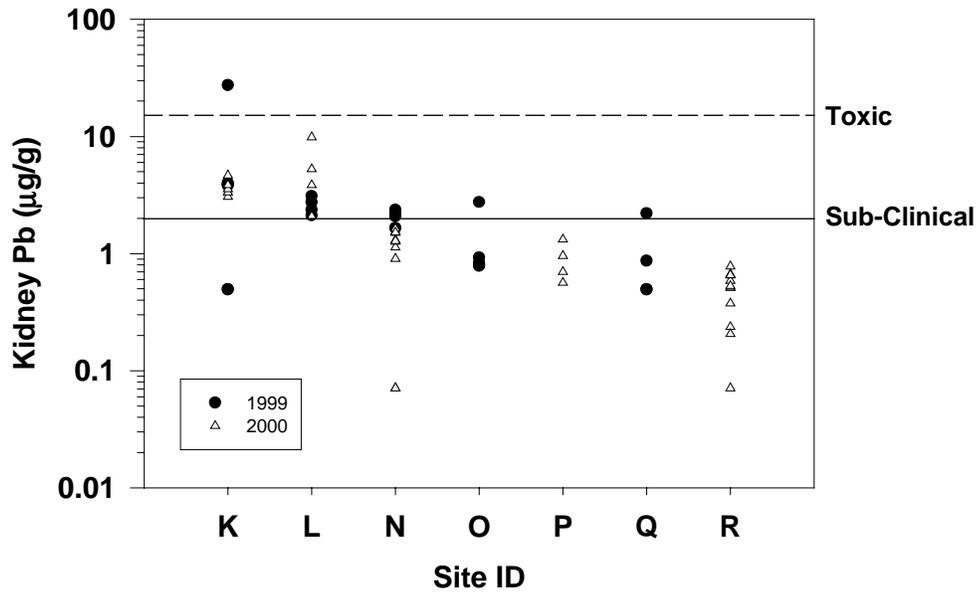
**Figure 7-10.** Regression of percent nesting success (clutches to fledge/clutches initiated) on soil metal concentrations. Success and soil metal concentrations for 1999 and 2000 are plotted. No significant relationship was detected for any of the metals.



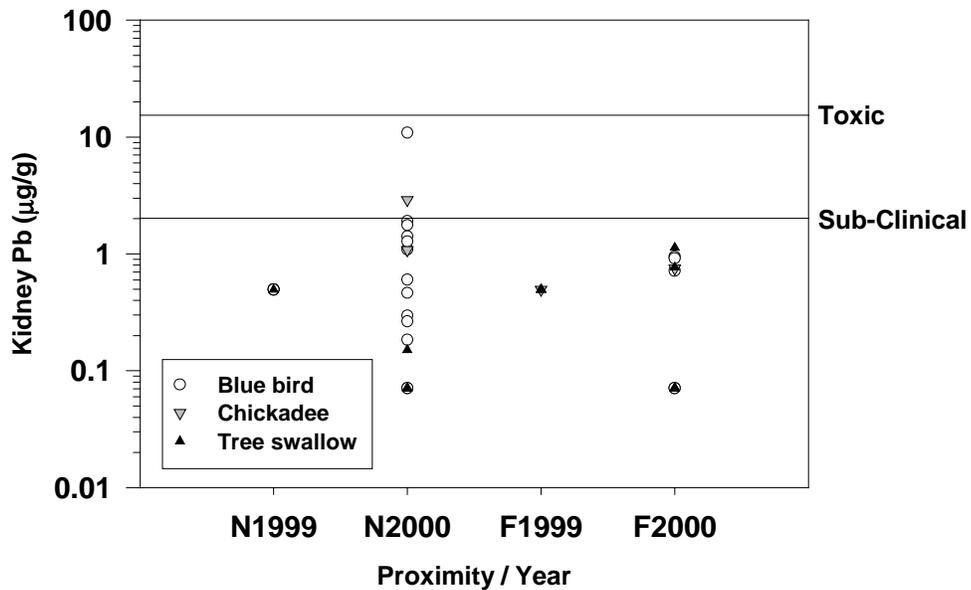
**Figure 7-11.** Lead in livers of individual 15-day-old starlings nestlings, Anaconda Smelter Site, 1999 and 2000. Sub-clinical (solid line) and toxic (dashed line) threshold concentrations of liver lead are displayed.



**Figure 7-12.** Lead in livers of individual fledging age passerines, Anaconda Smelter Site, 1999 and 2000. Proximity represents sites < 2 miles from the smelter stack (near or N) and sites > 2 miles (far or F). Sub-clinical (solid line) and toxic (dashed line) threshold concentrations of liver lead are displayed.



**Figure 7-13.** Lead in kidneys from individual 15-day-old starlings, Anaconda Smelter Site, 1999 and 2000. Sub-clinical (solid line) and toxic (dashed line) threshold concentrations of liver lead are displayed.



**Figure 7-14.** Lead in kidneys from individual fledging-age passerines, Anaconda Smelter Site, 1999 and 2000. Distance is sites < 2 miles from the smelter stack (near or N) and sites > 2 miles (far or F). Sub-clinical (solid line) and toxic (dashed line) threshold concentrations of liver lead are displayed.

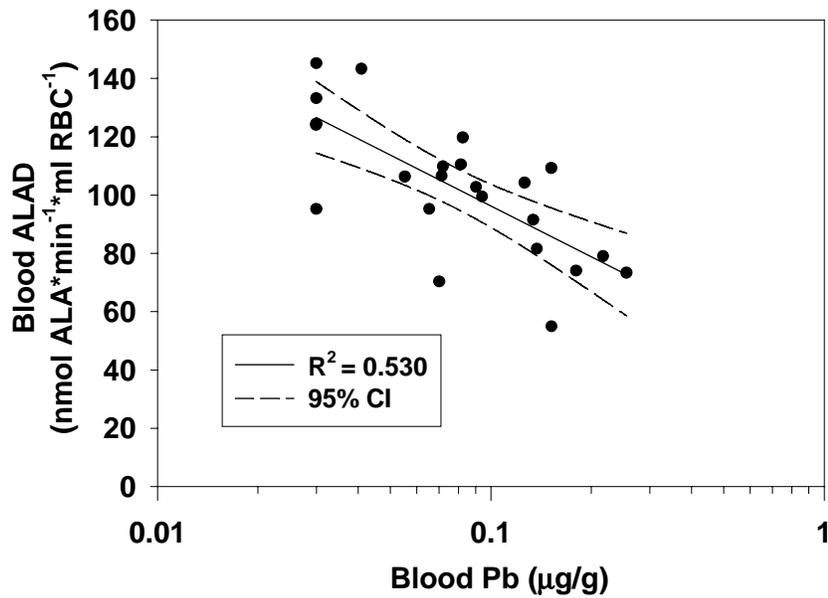


Figure 7-15. Blood ALAD activity response to blood Pb in starlings from the Anaconda Smelter Site, 2000.

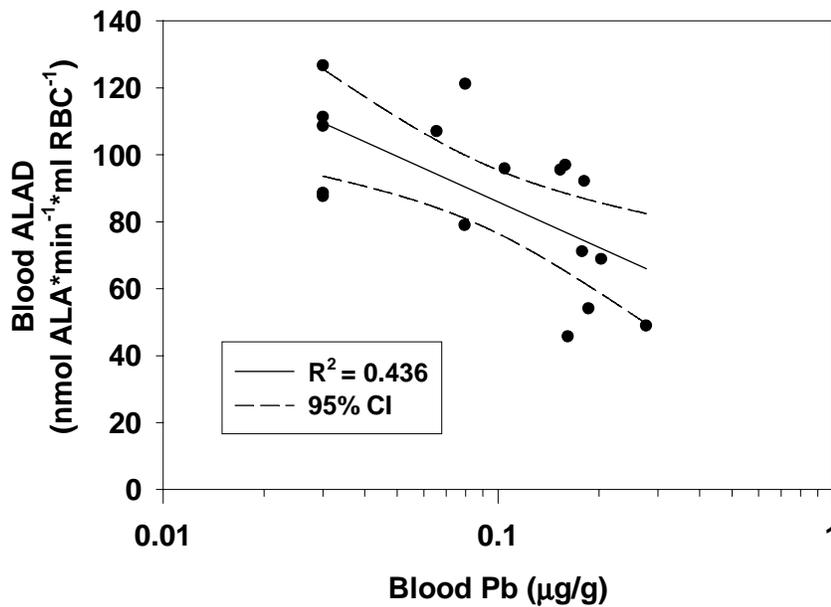
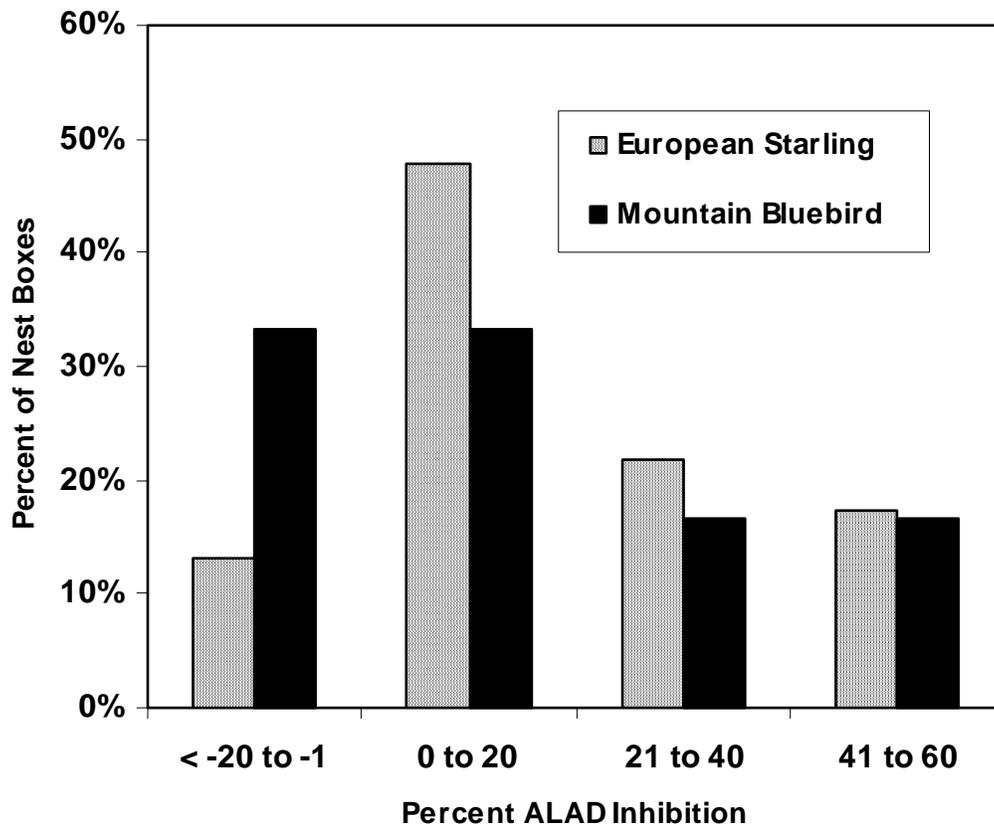


Figure 7-16. Blood ALAD activity response to blood Pb in bluebirds from the Anaconda Smelter Site, 2000.



**Figure 7-17.** Percent of avian nest boxes with increasing levels of ALAD inhibition at the Anaconda Smelter site, 2000. Numbers of nest boxes evaluated were 23 for European starlings and 18 for mountain bluebirds. Percent ALAD inhibition based on comparison with mean ALAD activity of nestlings containing no detectable blood Pb (See 7.3.1.3).

## **8 AMERICAN KESTREL STUDIES**

Avian raptor species have proven useful in investigating the accumulation of environmental contaminants because of their position at the top of trophic food webs. American kestrels are used extensively in this capacity due to their occurrence throughout North America, their willingness to occupy nest boxes, and their tolerance of monitoring and handling procedures. Because focal species of the Anaconda biomonitoring project included local populations of rodents and passerines, the use of kestrels offered an opportunity to examine contaminant effects at a higher trophic level, potentially allowing for correlative analysis between trophic levels. Our study assessed exposure via maternal vertical transmission of contaminants into eggs, food item metal and As in samples collected using esophageal constriction techniques, and metal and As accumulation in the nestling. Effects assessments focused on biochemical, physiological and morphological effects in the nestling, and reproductive demographics at individual nest box and local population levels. American kestrels were employed as a sentinel species for bioaccumulation modeling in the US EPA's Baseline Ecological Risk Assessment for the Anaconda Smelter Site (1997). Field data on the species provides the opportunity to test the accuracy of this model and fine-tune it so it better reflects the findings on the site. All fledglings not collected were permanently banded, allowing an opportunity to identify individuals and investigate their fate in potential future assessments.

### **8.1 American Kestrel Methods And Materials**

Nest box-based studies of American kestrels were performed during the spring and summer breeding seasons of 1999 and 2000. Exposure and effect assessments were made of nestlings, and reproductive success quantified for each nest. In 1999, a representative nestling was collected from each nest to investigate metal and As exposure and effects at the tissue level. Based on the findings of this first year study, the focus of the year 2000 investigation shifted away from nestling collections and focused on blood sample-based exposure and effect assessments. Reproductive demographic information was collected for both study years.

### 8.1.1 Daily Monitoring

In the spring of 1999, 50 kestrel nest boxes, and in the spring of 2000, 49 kestrel nest boxes were monitored throughout the Anaconda Smelter site study area (Figure 8-1). Placement locations represented a gradient of potential contaminant exposure and habitat types. Latitudinal and longitudinal readings were recorded for 35 of the 50 boxes (Table 8-1), with the remainder of nest locations estimated by use of a USGS map. Short descriptions of the placement sites were included. Of the fifty boxes, 70% (35/50) were placed on man-made structures (telephone poles, power poles, metal structures, etc.), with the remainder affixed to selected trees. Beginning in May, boxes were checked every two to six days for nesting activity by kestrels or other species. Activity was measured on a four-point scale indicative of no avian nesting activity (0) to a full nesting attempt (3). For comparative analysis purposes, all nest boxes were combined into two groupings based on their proximity to Smelter Hill: Boxes 01 through 27 were grouped as ‘Smelter Hill’ sites, while boxes 28 through 50 were grouped as ‘Opportunity Ponds’ sites.

In the 1999 field season, the first egg of each active nest was marked with a pencil for identification, and the nest was allowed to remain undisturbed for six days. Upon re-inspection, the marked egg was removed (in 1999, one entire clutch was removed from one box to examine intra-clutch variability), wrapped in clean Kimwipes, and placed in a certified clean vial for analysis. Eggs were then weighed, and length and width measured in triplicate. An incision along the egg’s air cell allowed for removal of contents. Contents were placed into a new certified vial and immediately frozen at  $-20^{\circ}\text{C}$  for metal and As analysis.

In the 2000 field season, nest boxes that showed activity were monitored every three days to check for initiation of clutch. Upon the first egg being laid, the box was left unchecked for four to six days, to allow for undisturbed completion of the clutch.

### 8.1.2 Addled Egg Collection

The lack of either parent in the vicinity and/or the clutch cold to touch, for two consecutive monitoring sessions identified nests as “abandoned”. The clutch was collected, and placed in certified clean vials. Any eggs remaining in the nest five days post-hatching were deemed “unhatched”, and collected in the same manner. Eggs were then weighed, and length and width measured in triplicate. An incision along the egg’s air cell allowed for removal of contents for determination of viability, or aging of embryo at death. Contents were placed into a new certified vial and immediately frozen at  $-20^{\circ}\text{C}$  for metal and As analysis. Egg shells were retained for future assessments as needed.

### 8.1.3 Nestling monitoring and measurement

Clutches were monitored approximately every three days until hatch (roughly 30 days). Kestrels delay incubation until the clutch is near completion; therefore, all eggs typically hatch within one day of each other. Clutch age (post-hatch) was recorded using the hatch date of the last chick. Nestlings were monitored every five days through day 25 post-hatch. Body weight was taken with a Pesola scale, recorded to the nearest gram. Measurements were taken of bill depth and width, as well as tarsus and third toe length. Nestlings were visually inspected for any obvious signs of ectoparasites, general health status, or any other notable observations. Nestlings found dead in the nest were retrieved and, based on tissues available, were analyzed for metals and As.

### 8.1.4 Esophageal Constriction

Contaminant exposure and food item preferences were determined by collection of prey items. Nestlings were fitted temporarily with esophageal constriction devices (Hoff, 1992; Mellot and Woods, 1993), preventing food items from entering the crop and allowing for easy removal. The devices were left in place for up to two hours depending on the time required for the adults to make a feeding foray back to the nest. Adult activity at the nest boxes was monitored from an appropriate distance. All food items obtained from the

collecting session, including items in the nest prior to constrictor fitting, nestling crop contents and those found in the nest when the session ended, were collected and stored frozen in certified clean vials at  $-20^{\circ}\text{C}$ . All samples from nest mates collected on a single date were pooled in the same vial, to ensure adequate mass for analysis.

#### 8.1.5 Nestling sampling

In the 1999 field season, a representative nestling from each nest was retrieved at day 25 post-hatch, euthanized, dissected, and tissues collected. In the 2000 field season, only non-lethal blood samples were collected using venipuncture techniques on all chicks in each box.

At day 25 post-hatch, a randomly selected nestling was removed for tissue collection (an entire clutch was removed from one nest box (Box 19) to examine intra-clutch variation in study endpoints). Each nestling was euthanized by  $\text{CO}_2$  asphyxiation, and a blood sample was collected via cardiac puncture. An aliquot of the sample was stored in a certified clean vial for metal analysis, with the remainder stored appropriately for hematological and biochemical analyses. Red blood cell (RBC) and white blood cell (WBC) counts of each individual were determined with the use of a Hausser Scientific<sup>®</sup> hemacytometer. White blood cells were quantified by counting the number of cells in the four outer squares of the hemacytometer grid. The cell concentration was calculated as follows:

$$\text{Cell count/ml} = \text{Total cell count} * 2500 * \text{dilution factor}$$

Red blood cells were quantified by counting the number of cells in five squares in the large middle square of the grid. Cell concentration was calculated as follows:

$$\text{Cell count/ml} = \text{Total cell count} * 50,000 * \text{dilution factor}$$

A minimum of 27 white cells and 146 red cells, per count, was needed for reliability in cell counts.

The lower half of the large, primary lobe of the liver was removed and placed into a certified vial, weighed, and frozen for metal and As analysis. The remaining upper section, and the entire secondary lobe of the liver was removed, weighed and separated into two aliquots. A small section of the primary lobe was removed and fixed in formalin for histopathological

analysis. The remaining tissues were wrapped in hexane-rinsed aluminum foil and frozen at  $-80^{\circ}\text{C}$  for biochemical analysis.

Avian kidneys are conjoined, thus the right portion of the kidney was removed for metals analysis. The remaining left portion was divided into upper and lower portions and maintained separately at  $-80^{\circ}\text{C}$  for biochemical analysis.

Small representative portions of the following tissues were fixed in formalin for histopathology analysis: kidney, brain, eye, heart, brachial plexus, cecae, stomach, intestine, femoral muscle, femoral bone, spleen, bursa, thyroid, thymus, lung, intestine, pancreas, adrenal and gonad. Histopathology results are not included in this report.

#### 8.1.6 Blood sample collection

Blood sample collections in 2000 were attempted with every nestling at day 10 and day 25 (post-hatch). Unsuccessful collections from day 10 were re-attempted at day 17. Blood samples were collected non-lethally via jugular veni-puncture. The nestlings were weighed and measured just prior to sample collection. Individuals were then held ventrally, allowing the thumb and forefinger to expose the jugular between the feather tracts of the neck. The skin was cleaned with alcohol swabs, and a heparinized 1cc syringe with a 27-gauge needle was used to withdraw the blood sample. Samples collected never exceeded 1% of body weight, so as to reduce any detrimental health effects. The samples were separated into aliquots of approximately 150-200  $\mu\text{l}$  for use in ALAD activity determinations, with the remaining sample collected in certified clean vials for metals analysis. Samples were packed in ice, and immediately returned to lab facilities where they were stored appropriately. Packed cell volumes (PCVs) of the samples were determined using 100  $\mu\text{l}$  microhematocrit capillary tubes and a microhematocrit centrifuge. Remaining blood for ALAD analysis was frozen at  $-80^{\circ}\text{C}$ .

### 8.1.7 Exposure Assessment Methodology

Metal and As concentrations were determined as described in Section 6.1.8 of this report. Food item levels were determined in pooled sample collections of each individual nest for each sampling day. Nestling liver, kidney, and blood samples were analyzed for As, Cd, Cu, Pb and Zn. For data analysis purposes, metal and As chemistry findings that resulted in levels below detection (BDL) were replaced with values of half the detection limit, determined specifically for each analyte in each tissue type (Table 8-2).

### 8.1.8 Effects Assessment Methodology

Potential metal and As effects were measured from the molecular to the population level. At the molecular level, porphyrin profiles from liver and kidney samples collected in 1999, and ALAD from blood samples collected in 2000, were determined. Porphyrin profiles were assayed as described in Section 6.1.9.2. ALAD assessments were assayed as described in Section 6.1.9.1.

At the cellular level, hematology was assessed in 1999 and PCVs in 2000. Histological assessment results are not presented in this report. Tissue level assessment included tissue weight, and gross pathology (see above) in 1999. Nestling growth rates compared between the two sites, provided insight to whole animal level effects while overall reproductive demographics provided a population-level effects assessment.

### 8.1.9 Data Analysis

Data generated from the field and laboratory portions of the study were collected on activity-specific data collection forms, subjected to daily internal QA verification and later transferred to spreadsheets or directly to Microsoft Access<sup>®</sup>, where they were verified and finalized by a formal QA audit.

*Summary statistics.* Demographic and growth data were compared to literature-based benchmark data for uncontaminated, control or reference animals in the same or similar

species to determine how nesting demographics of Anaconda kestrels compare to what might be considered normal. Exposure and effects data were compared within the study based on their location in relation to the Smelter Hill area and the Opportunity Ponds area. Metal concentrations, biochemical endpoints, and morphological measurements were expressed on a per clutch or per site basis as means  $\pm$  standard deviation. All significance tests were performed using Minitab<sup>®</sup> (version 13.31) statistical package or SigmaStat<sup>®</sup> (version 2.0) statistical package, and an alpha value ( $\alpha$ ) of 0.05 was established as our critical probability value for significance. Associations between metal concentrations in food items and tissues and between metal levels and effects endpoints were examined using a Pearson product moment correlation analysis. Further comparisons of tissue metal concentrations, biochemical endpoints, and morphological measurements between sites were examined using a Students t-test. If data normality testing failed, non-parametric data sets were examined using a Mann-Whitney rank-sum test for comparison between sites. A two-way ANOVA was run to evaluate differences in age-wise blood metal accumulation between sites (2000 only), and a Tukey HSD post-hoc test used to examine all pair wise comparisons among means. Linear regression equations were calculated to further examine relationships between multiple tissue metals concentrations, as well as between tissue metals and effects endpoints. Finally, nestling growth curves were estimated in SigmaPlot<sup>®</sup> 2000, using a nonlinear 4-parameter logistic curve estimation:

$$y = y_0 + a / 1 + (x/x_0)^b$$

Difference between sites was calculated by adding the sums of squares and degrees of freedom for both curves (*separate*), and comparing those to the equation sums of squares and degrees of freedom of all nestlings grouped together (*combined*). An F value was calculated using the equation:

$$F = \frac{(SS_{combined} - SS_{separate}) / (DF_{combined} - DF_{separate})}{SS_{combined} / DF_{separate}}$$

## 8.2 American Kestrel Results

During the 1999 and 2000 field seasons, kestrel nest boxes were monitored for nesting activity. During the two seasons, nesting attempts occurred for observed species as follows: 33 American kestrels, 2 Lewis' woodpeckers (*Melanerpes lewis*), 1 northern flicker (*Colaptes auratus*), and 5 bluebirds. Results of the kestrel, woodpecker and flicker nesting attempts are reported here. Bluebird data are included in the European starling / passerine report (Section 7).

### 8.2.1 Nest Box Placement and Use

*1999 Field Season.* Between May 12 and June 21, kestrels initiated nesting attempts in 19 boxes, with 16 (84%) of those attempts located in boxes found on man-made structures. Kestrels occupied 38% (19/50) of available boxes, as indicated by the presence of at least one egg. Pre-incubation removal of an entire clutch of eggs left 18 nests with success potential. Successful nests, with at least one live fledging age chick, occurred in 14 of the 18 initiated nests (78%; Table 8-3). Kestrel activity was well dispersed, resulting in a good distribution of nesting throughout the entire study area. Of the active nests, 47% (boxes 1, 2, 7, 12, 13, 14, 19, 20, and 27) were classified as Smelter Hill associated boxes while 53% (boxes 28, 30, 32, 35, 39, 40, 43, 44, 45, 49) were considered Opportunity Ponds associated boxes. Collections in 1999 included 26 food item, 27 egg, 17 blood and 17 nestling samples. One egg and 1 nestling were collected from each nest box. One entire clutch of eggs (box 40) and an entire nest of 25-day nestlings (box 19) were collected to evaluate intra-clutch variability of measured endpoints. Two nest mortalities were also collected.

*2000 Field Season.* Between May 18 and June 12, 14 clutches were initiated in 49 potential nest boxes (29% occupancy) as one box was removed during the spring due to construction work. Of the 14 clutches, 9 (64.3%) were initiated in man-made structures. Nine clutches successfully hatched at least one nestling (9/14 or 64%; Table 8-4). Of active nests, 43% (boxes 1, 4, 17, 23, 24, and 26) were classified as Smelter Hill associated boxes while 57% (boxes 32, 34, 35, 37, 41, 43, 46 and 50) were considered Opportunity Ponds associated

boxes. In addition, Lewis' woodpeckers initiated clutches in boxes 14 and 15, while a Northern flicker initiated a clutch in box 29. Samples collected in 2000 included 18 food items and 56 blood samples. Unhatched or abandoned eggs (6 and 13, respectively) were collected as in 1999. Six nest mortalities were collected (0 kestrel, 4 Lewis' woodpecker, 2 flicker).

### 8.2.2 Kestrel Exposure Assessment

*Soil Metal and As Analysis.* Due to the extensive area used by foraging kestrels, with estimates ranging from 1-km to 1-mile radius from the nest box (Pers. Comm. – Hoff, 1999), soil samples were not collected specifically for correlation with kestrel exposure data.

*Food Item Metal and Arsenic Analysis.* In 1999, 26 samples of nestling food items were collected through the use of esophageal constriction devices, as well as collected from within the nest box where deposited by an adult (Table 8-5). Seven samples (27%) contained invertebrate items (grasshopper and dragonfly), while two samples (8%) were made up of avian tissue (unidentified passerine). Nineteen samples (73%) were made up of mammalian tissue (vole, deer mouse, etc.). Detectable arsenic concentrations were found in all but two of the samples, with values ranging from below the level of detection ( $<0.120$ ;  $n=2$ ) to  $8.11 \mu\text{g/g}$  (box 13). Significantly higher As levels were detected in samples collected from Smelter Hill sites (mean  $\pm$  SD;  $2.73 \pm 2.56 \mu\text{g/g}$ ) than samples from Opportunity Ponds sites ( $0.739 \pm 0.475 \mu\text{g/g}$ ;  $p=0.011$ ). Cadmium levels had a mean of  $0.168 \pm 0.304 \mu\text{g/g}$  with five samples  $< 0.009$  to a high concentration of  $1.20 \mu\text{g/g}$  (box 01). Lead concentrations ranged from  $< 0.054$  ( $n=1$ ) to  $6.17 \mu\text{g/g}$  (box 13) with a mean of  $1.407 \pm 1.348 \mu\text{g/g}$ . Copper and zinc were found in all food item samples (mean  $12.7 \pm 13.9$  and  $40.7 \pm 12.4 \mu\text{g/g}$ , respectively) with greatest variability in copper levels. There were no significant differences in Cd, Pb, Cu or Zn levels in kestrel food items collected near Smelter Hill compared to those collected near Opportunity Ponds.

In 2000, eighteen food item samples were collected. Three samples (17%) contained avian tissue, eight (44%) contained invertebrates (grasshopper and dragonfly), and eleven (61%)

contained rodent tissue (Table 8-6). Ten samples contained detectable levels of arsenic, with significantly higher levels found in samples collected from Smelter Hill boxes ( $2.24 \pm 2.08$   $\mu\text{g/g}$ ), as compared to Opportunity Ponds boxes ( $0.186 \pm 0.283$   $\mu\text{g/g}$ ;  $p=0.001$ ). Cadmium levels ranged from 0.001 (half LOD value,  $n=4$ ) to 0.960  $\mu\text{g/g}$  with notably higher levels in samples from Smelter Hill boxes ( $0.463 \pm 0.397$   $\mu\text{g/g}$ ) compared to Opportunity Ponds boxes ( $0.147 \pm 0.269$   $\mu\text{g/g}$ ;  $p=0.061$ ). Lead was found in all samples, with significantly higher levels in Smelter Hill samples ( $1.51 \pm 1.21$   $\mu\text{g/g}$ ) compared to Opportunity Ponds samples ( $0.283 \pm 0.337$   $\mu\text{g/g}$ ;  $p=0.010$ ). Copper concentrations ranged from 5.26 to 48.9  $\mu\text{g/g}$  (mean  $16.6 \pm 13.6$   $\mu\text{g/g}$ ), while Zinc levels ranged from 25.4 to a high of 83.2 (mean  $49.2 \pm 17.4$   $\mu\text{g/g}$ ). Food item levels of Cu, Zn and Cd were not significantly different between sites.

Notable differences in metal concentrations were identified between prey types when rodent food items ( $n = 24$ ) were compared to invertebrate (grasshopper and dragonfly) food items ( $n = 10$ ) across both years of the study (Figure 8-2). Arsenic was significantly higher in rodent items ( $1.88 \pm 2.21$   $\mu\text{g/g}$ ) than invertebrate samples ( $0.651 \pm 0.882$   $\mu\text{g/g}$ ;  $p=0.047$ ). Likewise, lead concentrations from rodents ( $1.64 \pm 1.44$   $\mu\text{g/g}$ ) were greater than invertebrate prey items ( $0.471 \pm 0.475$   $\mu\text{g/g}$ ;  $p=0.009$ ). Alternatively, copper levels in invertebrate items ( $21.4 \pm 12.0$   $\mu\text{g/g}$ ) were significantly higher than concentrations found in rodent samples ( $11.6 \pm 14.2$   $\mu\text{g/g}$ ;  $p=0.001$ ). Concentrations of Cd and Zn did not differ significantly between rodent and invertebrate food items.

*Egg Metal and Arsenic Analysis (1999 only)*. Nineteen unincubated eggs, collected from each nest and analyzed for COC, consisted of 13 eggs from individual nests, a clutch of 4 eggs (box 40) for intra-clutch variability assessment, and 2 eggs from nests (boxes 20 and 32) that were abandoned prior to incubation (Table 8-7). Neither arsenic nor cadmium was detected in any of the analyzed eggs (LODs were 0.052 and 0.004  $\mu\text{g/g}$  respectively). Lead was present at detectable levels in all but two eggs (boxes 13 and 44) at levels from 0.029 to 0.103  $\mu\text{g/g}$ , with an average of  $0.039 \pm 0.023$   $\mu\text{g/g}$  and no substantial difference between study areas. Copper and Zinc levels were relatively low, with overall means of 0.171 and 3.20  $\mu\text{g/g}$ , respectively, and no appreciable difference between sites. Intra-clutch variability

was lower than between box variability, with coefficients of variation within clutch of 7 % to 15 % and between clutches ranging from 15% to 59%.

*Blood Metal and As Analyses.* In 1999, blood samples were obtained from the 17 collected nestlings, at day 25 post-hatch. One sample (from box 19) was lost in analysis. These samples contained no detectable arsenic or cadmium concentrations (Table 8-8). Lead was found in all but one nestling samples (LOD 0.194) with a mean concentration of  $0.281 \pm 0.060$   $\mu\text{g/g}$  for all boxes. Blood lead concentrations of Smelter Hill nestlings ( $0.320 \pm 0.065$   $\mu\text{g/g}$ ) were significantly greater than those of Opportunity Ponds nestlings ( $0.251 \pm 0.037$   $\mu\text{g/g}$ ;  $p=0.027$ ). Copper concentrations showed great variation from a low of 0.178  $\mu\text{g/g}$  to a high of 3.03  $\mu\text{g/g}$  with nearly a three fold higher mean in Smelter Hill nestlings ( $1.23 \pm 1.06$   $\mu\text{g/g}$ ) than in Opportunity Ponds nestlings ( $0.453 \pm 0.414$   $\mu\text{g/g}$ ). Also of note was the low Cu concentration found in the box 27 nestling, which alternatively was found to have the highest liver copper concentration. Zinc concentrations, with a mean of  $4.84 \pm 0.596$   $\mu\text{g/g}$ , were relatively consistent between individuals, similar to findings in liver and kidney.

In 2000, blood samples were collected from all individuals at least two times during the nesting period. Collections were attempted at day 10 post-hatch, and individuals from whom samples were not collected at that time were sampled at day 17. A final sample was collected at day 25 post-hatch (Table 8-9; Figure 8-3). Blood As was detected only in 10 and 17 day-post-hatch nestlings ( $n=5$ ) originating from three boxes (1, 43, and 46; mean = 0.096  $\mu\text{g/g}$ ). Cadmium was detected in 51 of 55 samples, ranging from 0.004 to 0.247  $\mu\text{g/g}$ . Substantial increases in Cd, between days 17 and 25, were seen in boxes 01 and 17, with blood concentrations increasing from three to six fold. Blood Cd levels at day 25 were significantly higher in Smelter Hill nestlings ( $0.139 \pm 0.111$ ) than Opportunity Ponds nestlings ( $0.036 \pm 0.024$ ;  $p=0.015$ ). An analysis of Cd across all three age groups and across both sites using a two-way ANOVA showed significant differences between days 10 and day 25 concentrations ( $p=0.02$ ), as well as significant differences between sites-by-age ( $p=0.004$ ). Lead also showed a strong age-dependent increase in six of eight boxes, with three of the four highest concentrations at day 25 from Smelter Hill boxes. Mean Pb values at age 25 post-hatch were significantly higher in samples from Smelter Hill nestlings (0.181

$\pm 0.046$ ) than in samples from Opportunity Ponds nestlings ( $0.103 \pm 0.040$ ;  $p=0.006$ ).

Variance analysis of Pb concentrations showed significant differences between ages (days 10 and 17 vs. 25;  $p=0.05$ ), between the two sites ( $0.001$ ), as well as differences by site-by-age ( $p=0.005$ ). Copper levels were notable, showing a marked age-dependent decrease in seven of eight boxes. Four boxes (01, 17, 34, and 43) showed marked higher concentrations in Cu at the early time points (up to  $4.61 \mu\text{g/g}$ ; box 1), though all samples collected at day 25 were relatively homogeneous, averaging  $0.56 \pm 0.14 \mu\text{g/g}$ . An analysis of variance for Cu values showed significant difference between ages (days 10 and 17 vs. 25;  $p=0.001$ ) and significant site-by-age variation ( $p=0.001$ ). Zinc was relatively homogeneous throughout all samples, with a mean for Smelter Hill boxes of  $6.76 \mu\text{g/g}$  and Opportunity Ponds of  $6.13 \mu\text{g/g}$ . Box 1 levels on day 10 were noteworthy with a mean blood Zn level of  $18.2 + 5.78 \mu\text{g/g}$ . Day 10 values were significantly different from day 25 values ( $p=0.001$ ), and site-by-age variation was significant ( $p=0.002$ ). Thus, with increasing age, blood Cd and Pb increased while Cu and Zn decreased in developing nestlings, and the degree of that change was greater in Smelter Hill nestlings than in those from Opportunity Ponds.

*Liver and Kidney Metal and As Analyses (1999 only).* Liver analyses (Table 8-10) resulted in no detectable levels of arsenic, and only three detections of cadmium, found in nestlings from Smelter Hill boxes (01, 13 and 14), with a detectable average of  $0.120 \mu\text{g/g}$ . Lead was found in all but one liver sample (box 45), varying from  $< 0.350$  (box 45) to a high of  $0.732$  (box 27)  $\mu\text{g/g}$ . Liver lead concentrations were significantly higher in Smelter Hill boxes ( $0.594 \pm 0.097$ ) compared with Opportunity Ponds boxes ( $0.414 \pm 0.121$ ;  $p=0.012$ ). Copper and zinc were found in all tissues, though copper concentrations varied more than those of zinc. Copper concentrations were found to be at their highest in liver tissues, varying from a low of  $7.38$  (box 43) to a high of  $69.8 \mu\text{g/g}$  (box 27), with a mean of  $25.0 \pm 17.3 \mu\text{g/g}$ . Samples from Smelter Hill boxes ( $39.2 \pm 17.4 \mu\text{g/g}$ ) were significantly higher than those of Opportunity Ponds boxes ( $14.4 \pm 6.17 \mu\text{g/g}$ ;  $p=0.001$ ). Liver zinc concentrations were relatively consistent across boxes and sites with an average of  $25.9 \pm 3.41 \mu\text{g/g}$ .

Kidney tissue analyses resulted in no detectable levels of arsenic or lead (LODs =  $0.993 \mu\text{g/g}$  and  $0.451 \mu\text{g/g}$ , respectively; Table 8-11). Measurable kidney cadmium concentrations

occurred in five nestling samples, all from Smelter Hill sites, with concentrations ranging from 0.09 (box 19) to 0.39  $\mu\text{g/g}$  (box 01). As in the liver, copper and zinc were detected in all samples. Copper levels ranged from a low of 3.10 (box 44) to a high 6.15  $\mu\text{g/g}$  (box 14) with a mean of  $3.76 \pm 1.23$ . Zinc levels varied between 14.9 and 21.6  $\mu\text{g/g}$  (mean  $16.7 \pm 1.93$ ).

### 8.2.3 Kestrel Effects Assessment – Biochemical, Cellular and Morphological

*Porphyrin Analyses.* Hepatic and renal porphyrin concentration profiles were relatively consistent for all individuals. In general, 4- and 2- carboxyl porphyrins (CP) constituted the majority of total porphyrin concentration, with 8-, 7-, 6-, and 5- CP observed at lower concentrations or not detected. Metal exposure tends to increase the 4- and 2- CP's (Woods, 1985; Akins et al., 1993). These two porphyrins were specifically tabulated, with a total CP value incorporating any other CP amounts detected. In nestling liver samples, the 4- CP was found at the highest concentrations for all samples with a range of 13.5 to 40.6 and a mean of  $24.7 \pm 7.76$  pmol / gram tissue weight (Table 8-12). The 2- CP ranged from 8.38 to 25.1 with a mean of  $13.8 \pm 4.67$  pmol / gram tissue weight. The hepatic total porphyrin mean was  $47.6 \pm 13.4$  pmol per gram tissue.

Kidney porphyrins showed similar results, with 4- CP in the highest concentrations for all samples with a range from 20.4 to 64.9 (box 43) and a mean of  $27.6 \pm 11.3$  pmol / gram tissue weight (Table 8-13). The 2- CP's had a mean of  $10.3 \pm 3.14$  and the total porphyrin level was  $49.1 \pm 17.7$  pmol / gram tissue.

There were no significant differences in hepatic or renal porphyrin profile components when compared between Smelter Hill- and Opportunity Ponds- associated nest boxes. However, increases in hepatic lead concentrations appear to trigger an increase in 4- CP concentrations (Figure 8-4), though due to wide variability of porphyrin responses, the coefficient of determination ( $r^2=0.327$ ) was not notable. Nevertheless, hepatic lead concentrations above a threshold level of approximately 0.55  $\mu\text{g/g}$  appear to stimulate an increase in hepatic porphyrin concentrations (Figure 8-5).

*ALAD Analyses.* Immediately after collection, packed cell volume (PCV) percentages were determined for each blood sample. Box mean PCV (Table 8-14) values varied between 32.0 and 40.5, with no significant differences between sites, or between age groups. Blood ALAD activity exhibited notable age and site dependent differences, with significant decreases between day 10 and day 25 values ( $p = 0.012$ ), as well as significant differences between Smelter Hill and Opportunity Ponds sites ( $p = 0.033$ ). Mean ALAD activity at day 10 was  $124.8 \pm 14.7$  for Smelter Hill sites, and  $132.9 \pm 12.5$  for Opportunity Ponds sites. Activity at day 17 was  $115 \pm 11.3$  for Smelter Hill, and  $119.2$  for Opportunity Ponds sites. There were no significant differences between Smelter Hill ALAD activities and those from Opportunity ponds on days 10 or 17. Alternatively, ALAD values at day 25 showed a significant difference between sites, as activity on Smelter Hill sites averaged  $90.6 \pm 5.9$ , while the Opportunity Ponds box mean was  $121.7 \pm 10.9$  ( $p = 0.014$ ). The mean ALAD activity from Smelter Hill nestlings was 74.5% of the mean activity level found in Opportunity Ponds nestlings.

*Kestrel Hematology (1999 only).* Counts of both white and red cells were conducted from blood samples collected from all dissected individuals (Table 8-15). Two separate cell counts were conducted for leucocytes, and a mean cell count was used to calculate white cells per ml of whole blood. Intra-clutch variability was remarkably small; with mean WBC count of  $3115 \pm 331.2$  and RBC count of  $5.421 \times 10^6 \pm 0.400 \times 10^6$  cells/ml (CV of 11 and 7%, respectively). Wide variation between boxes was noted however, as the WBC count for all sites averaged  $6989 \pm 5479$  cells/ml. The elevated variability is predominantly due to a single individual (Chick A of Box 43), whose WBC count of 23,594 cells/ml was twice the next highest value. This same individual, conversely, was found to have the lowest RBC count ( $2.04 \times 10^6$  cells/ml), strongly depressed as compared to the site mean of  $6.19 \times 10^6 \pm 1.51 \times 10^6$  cells/ml. Nevertheless, no significant hematological differences were noted between Smelter Hill and Opportunity Ponds sites.

*Kestrel Tissue Weights.* Tissue weights of five organ types were analyzed from nestlings collected in 1999 (Table 8-16). Individual kidney, liver, brain, spleen and bursa weights were assessed, yielding only one significant outlier in the spleen weight category (chick A of

box 43) whose 0.724 g spleen weight was approximately three times greater than the population mean. This was the same individual noted earlier (Chick A of Box 43); with the highest WBC count and lowest RBC count. All other tissue weights for this individual were well within the normal range. There were no significant tissue weight differences between Smelter Hill- and Opportunity Ponds-associated nestlings.

#### 8.2.4 Kestrel Effects Assessment - Reproductive Demographics

*Nesting and Hatching Success.* In 1999, there were 72 eggs laid among the 19 initiated nests (Table 8-17). Removal of 17 unincubated eggs for analysis (4 from box 40 and one each from 13 additional boxes) left 55 eggs available for hatching. Two eggs were noted as missing during incubation monitoring, although no indication of nest parasitism or predation was found at any time at any box. Accounting for sampling and unknown causes of egg removal left 53 eggs, on which hatching and nesting statistics were based.

Four nests, with a total of 5 eggs, were identified as abandoned, three of these occurring soon after a late season cold weather event in early June (boxes 12, 20 and 32), the other being the last clutch initiated in the summer (box 2). Another five eggs from four individual successful boxes remained unhatched and were collected five days after the remainder of their associated clutches hatched. When processed, three of the eggs appeared to be cracked slightly, allowing the contents to dry out completely. No evidence of development was found in these eggs, while one egg (box 45) contained a fetus estimated to have been approximately 20-23 days into the incubation process (Santolo et al., 1997). The remaining egg (box 49) was in normal condition, but appeared to be unfertilized, due to the absence of a blastocyst.

An overall hatching success of 81.1% of available eggs (43/53) was achieved. There were 14 successful nests with live nestlings resulting in a *nesting success* (successful nests / occupied boxes corrected for removal of the box 40 clutch) of 77.8% (14/18; Table 8-17). An average of 4.43 eggs were laid per *successful* nest, while 3.79 eggs were laid per *occupied* nest, the reduction due in equal measure to abandoned clutches of single eggs

during inclement weather and unhatched eggs that were infertile, cracked or contained a dead embryo.

In 2000, a total of 58 eggs were laid in 14 nest boxes (Table 8-17). No eggs were collected based on the previous year's findings. Five eggs from four nests were missing at different times during incubation leaving 53 eggs upon which nesting and hatching statistics are based. Three clutches with a combined total of thirteen eggs were abandoned (4, 4 and 5 eggs in boxes 26, 37 and 41, respectively). A nest predator was indicated in box 41, as small holes were found in all five eggs in the box, suggesting talon or beak punctures. Six eggs from two boxes (a full clutch of two from box 4, and a full clutch of four eggs from box 23) were collected as unhatched while no unhatched eggs from successful nests were discovered. All six eggs were discovered to have slight cracks in the shells, which allowed the contents to dehydrate early in the incubation process. Overall, nine boxes were successful (*nesting success* of 64.3%), with a total of 34 of 53 eggs hatching (64.2%). An average of 4.14 eggs per clutch were laid in *occupied* boxes, with an average of 3.78 eggs laid per clutch in *successful* boxes.

*Hatchling and Fledgling Success.* In 1999, 43 chicks hatched from the 14 successful nests, with an average of 3.07 chicks occurring per successful box (Table 8-17). Two nestlings were later found dead (in boxes 28 and 45), one having been partially eaten by its nest-mates. Both individuals appeared to be runts of the nest, as previous morphological measurements and body weights of both were consistently far below average until death. Thus, 41 chicks reached fledgling age (25 days post hatch), producing a *fledging efficiency* (fledglings / hatchlings) of 95.3% (41/43), and a *nesting efficiency* (fledglings / eggs available) of 77.4% (41/53). Seventeen individuals were removed for tissue analysis, including the entire clutch from nest box 19, to investigate intra-clutch variability for all analytical endpoints. The 24 remaining fledglings were banded with USFWS numbered leg bands prior to fledge and allowed to fledge naturally. Nest checks between 30 and 35 days post-hatch confirmed that all nestling birds greater than 25-days-old left the nest.

In 2000, 34 nestlings hatched from 9 nests for a mean of 3.78 chicks per *successful* nest (Table 8-17). Nest box 32, which had two of four eggs missing during incubation, was found to have the remaining two nestlings missing between 5 and 10 days post hatch. It is likely that both events were due to avian or mammalian predation. All told, 32 of 34 nestlings survived to fledging age for a *fledging efficiency* of 94.1% and a *nesting efficiency* of 60.4% (32/53). No nestlings were collected for tissue analysis, thus the remaining 32 fledglings were banded with USFWS permanent identification leg bands and allowed to fledge undisturbed. As in 1999, nest checks between 30 and 35 days post-hatch confirmed that all nestling birds greater than 25-days-old left the nest.

*Morphological Measurements.* Every five days, beginning at day 5 post-hatch, all chicks in a clutch were monitored for body weight (Figure 8-6) and morphological measurements. In 1999, only chicks collected for analysis were measured at day 25, while all 2000 birds were monitored at that and younger ages. Mean ( $\pm$  S.D.) body weight at day 25 post-hatch in 1999 for all boxes was  $117 \pm 7.86$  g (Table 8-18). Intra-clutch variability, with a mean of  $110 \pm 9.12$ g for the box 19 nestlings, was similar to that between boxes. The four morphological measurements were similarly combined and compared. All results appeared consistent, with no apparent outliers within intra-clutch individuals or between all sampled individuals.

Nestling measurements in 2000 were similarly performed, with weights and the four morphological measurements collected every five days through day 25 (Table 8-19). Mean body weight at day 25 post-hatch for Smelter Hill nestlings ( $127 \pm 7.55$  g; Data source, Table 8-19) was notably greater ( $p=0.051$ ) than Opportunity Ponds nestlings ( $120 \pm 11.4$  g; Data source, Table 8-19). Nestling tarsus length was also significantly higher in day 25 Smelter Hill nestlings ( $42.5 \pm 1.08$  mm;  $p=0.009$ ; Data source, Table 8-19) than in Opportunity Ponds nestlings ( $41.0 \pm 1.60$  mm; Data source, Table 8-19). All remaining measurements were consistent, with no notable differences between sites.

### 8.2.5 Opportunistic Woodpecker Exposure and Effect Assessment

In the 2000 field season, two species of woodpecker initiated clutches in kestrel nest boxes. Two pairs of Lewis' woodpecker adults initiated clutches in Boxes 14 and 15 at the base of Smelter Hill. Both pairs began nesting at approximately the same time (June 12) and as the nests were closely adjacent to one another, the adults were seen interacting with one another on several occasions. A total of nine eggs were laid in two clutches, with one entire clutch (five eggs; box 14) remaining unhatched despite continued parental care. The unhatched eggs were collected a week after their anticipated hatching date, as indicated by the incubation interval of the second pair. A full clutch of four woodpecker nestlings successfully hatched in box 15. In order to reduce abandonment risk, a concern with Lewis' woodpeckers (Tobalske, 1997), the nest box was visited only sporadically. No measurements were taken during this period to ensure the health of the nestlings. Approximately 18 days post-hatch and 4 days after the previous check, the box was visited and was found to have been abandoned by the parents. There was no indication as to the cause of the abandonment. Three nestlings were dead, with the single remaining chick emaciated and unconscious. The three mortalities were collected and the emaciated individual was removed and euthanized at the lab facility. A blood sample was collected just prior to euthanization. All individuals were frozen whole at  $-20^{\circ}\text{C}$  for subsequent metal and As analysis.

A pair of Northern flickers initiated a clutch in kestrel nest box 29 on the north side of Opportunity Ponds. Seven eggs were laid on June 4, with four nestlings successfully hatching. The three remaining eggs were not found at hatch. A disparity existed between nestlings, as two were reduced in size compared to the remaining two. Both stunted individuals were missing from the nest box by 12 days post-hatch. The remaining pair appeared healthy and well fed on day 12, however, both were found dead-in-box on day 14 post-hatch and collected. A rainstorm had occurred the previous night, and the bottom of the nest box was noted to be damp and cold, likely resulting in hypothermia in the still unfeathered nestlings. Both individuals were collected and frozen whole at  $-20^{\circ}\text{C}$  for subsequent metals and As analysis.

Liver and kidney tissues of all collected nestlings were removed and analyzed for contaminants, along with the single blood sample collected. During dissection, the gizzards of both Flicker nestlings were found to be engorged with undigested ants and ant eggs and larvae, which were collected and stored for metal and As analysis. Prior to analysis, the ants were keyed taxonomically (MacKay and Vinson, 1989), and appear to all have been of the genus *Formica*.

Lewis' woodpecker nestlings had increased levels of cadmium in liver ( $0.844 \pm 0.664 \mu\text{g/g}$ ), kidney ( $0.915 \pm 0.688 \mu\text{g/g}$ ) and blood ( $0.278 \mu\text{g/g}$ ; Table 8-20) when compared to the kestrel nestlings. Arsenic was detected in only one liver sample, suggesting a decreased potential for arsenic accumulation in the liver, as compared to the kidney. Lead concentrations were elevated, with mean liver ( $1.25 \pm 0.508 \mu\text{g/g}$ ) and kidney ( $0.485 \pm 0.160 \mu\text{g/g}$ ) levels higher than all American kestrel tissues collected, though the blood Pb level in the surviving chick was below detection. Copper concentrations and variability approximated those found in passerine tissues for liver, kidney and blood matrices. Liver zinc concentrations in Lewis' woodpeckers, however, were higher than those of any other species in this project (mean  $62.1 \pm 20.4 \mu\text{g/g}$ ) with a high concentration of  $88.9 \mu\text{g/g}$ . Kidney and blood zinc levels were unremarkable.

Individual northern flickers also accumulated little arsenic in liver tissue ( $0.027$  and  $0.042 \mu\text{g/g}$ ), though kidney concentrations were increased and variable ( $0.616$  and  $5.19 \mu\text{g/g}$ ; Table 8-20A). Mean cadmium levels were  $0.240 \mu\text{g/g}$  in liver and  $0.319 \mu\text{g/g}$  in kidney (Table 8-20). Lead accumulation was contrary to that found in Lewis' woodpeckers, with lower liver concentrations ( $0.347$  and  $0.267 \mu\text{g/g}$ ) and elevated kidney levels ( $2.95$  and  $1.97 \mu\text{g/g}$ ). Copper and zinc levels were similar to collected passerine tissue concentrations. Flicker stomach contents were found to have high levels of all five COC, with notably high concentrations of arsenic, lead and copper. Mean arsenic was  $2.833 \mu\text{g/g}$ , while mean lead was  $3.610 \mu\text{g/g}$  and copper levels were  $29.71 \mu\text{g/g}$ . Cadmium and zinc were elevated, but within levels of kestrel food items ( $0.2625$  and  $31.33 \mu\text{g/g}$  respectively).

### 8.3 American Kestrel Discussion

American kestrels were found to readily breed throughout the site. Nesting pairs were documented across the area, inhabiting boxes in all habitats. Parental contribution of COC, in-ovo, does not appear to be a concern, as egg contents did not contain noteworthy concentrations (Table 8-7). Clutch numbers appeared normal, and numbers of unsuccessful eggs were not unusual in regard to surrounding soil COC concentrations. An assessment of collected food items, however, demonstrated the potential for exposure to all five COC in nestlings. Investigations of blood, liver and kidney COC concentrations indicated systemic accumulations in all tissues, the most notable being increased blood lead levels occurring at times of critical neurological development (Burger and Gochfeld, 1985). Additionally, metal concentrations were found in higher concentrations for all matrices collected from sites closest to the smelter smoke stack, when compared to samples from more distant nest boxes. Biological markers indicated initiation of the earliest indicators of health effects, in particular, biochemical response of the heme synthesis pathway, in individuals with the highest blood lead levels, demonstrating that lead appears to be the most critical element for exposure in nestlings raised on the site. Nevertheless, no effects were documented in nestling growth, overt health risks, or fledging success in response to the exposure risks. The potential for neurological repercussions from lead exposure are suggested by blood Pb levels.

#### 8.3.1 Kestrel Exposure Assessment

Soil appraisals conducted by the Environmental Protection Agency (CDM 1997) showed a distinct gradient of all five COC concentrations moving away from the Smelter Hill source (the smelter smoke stack). Nevertheless, extensive variation in vegetative cover, historic land-use, and soil contamination may be found within each foraging area, illustrating the difficulty in quantifying actual exposure of the five COC to nestling kestrels, based exclusively on modeled exposures from soil contamination data. Further, due to the wide variations of COC concentrations throughout the site and surrounding area, other methods were essential for assessing actual frequency and magnitude of COC exposure in kestrels. In

response, food items were collected from nestlings at each nest box, allowing us to investigate responses to measured contaminant exposure based on a specific potential dose.

As all five COC were detected in representative food items and kestrel tissues, it appears that risk of exposure is a reasonable concern for American kestrels at the Anaconda Smelter site. Analysis of prey item types indicates that kestrels appeared to rely most heavily upon rodents for nestling food. During both monitoring sessions, rodents represented 74% (1999) and 61% (2000) of the collected prey items, with invertebrate (predominantly grasshopper) and some passerine items comprising the remainder. In nest box observations, many grasshoppers and passerine items appeared to be opportunistically collected by the female as she stayed in close proximity of the nest box, with the majority of food items (primarily rodent) being collected by the male. This finding is consistent with those of Erry et al. (1999) who found significant increases in liver and kidney arsenic in European kestrels, a predominantly rodent predator, when compared to the same tissues of a sparrowhawk (*Accipiter nisus*), a similarly sized avian predator, collected from the same contaminated sites. Separation of prey item COC data into prey class demonstrated significant differences in contaminant levels. Arsenic and lead were detected in significantly higher concentrations in rodent tissue than grasshoppers (Figure 8-2). Subsequently, prey items favored by kestrels, specifically rodents, may result in increased exposure to specific contaminants. However, contaminants found in invertebrate prey may be more available to absorption and accumulation than mammalian items due to sequestration of metals in non-digested bone and hair. Hornfeldt and Nyholm (1996) found pied flycatchers (*Ficedula hypoleuca*) accumulated higher levels of metal contaminants than Tengmalm's owls (*Aegolius funereus*) along the same heavy metal pollution gradient, suggesting a greater transfer potential of heavy metals from invertebrate items. Kestrels are known to be opportunistic hunters, and will select prey based on relative abundance (Bird, 1988). Therefore, the potential exists that an increased reliance of grasshoppers as prey could subsequently increase accumulation levels.

The majority of COCs (arsenic, cadmium and lead) was significantly elevated in food samples collected from nestlings in closer proximity of Smelter Hill when compared to those

from the Opportunity Ponds sites. In as much, the general lack of detectable levels of arsenic and cadmium in kestrel liver, kidney and arsenic in blood on day 25 is notable. Similarly, in owl prey items (Hornfeldt and Nyholm, 1996), increased contaminant levels were noted with decreasing distance to a smelter site, though the nestling owls did not have similar increases in tissue levels. Based on the poor movement of arsenic and cadmium from food items to blood to tissues, it is apparent that relatively efficient removal of arsenic and cadmium from the system occurs prior to tissue accumulation at significant levels. Metallothioneins, in the epithelial lining of the intestine, are responsible for regulating systemic trace mineral absorption. High concentrations of cadmium will increase metallothionein induction (Klasing, 1998), dramatically reducing systemic absorption. Scheuhammer found cadmium absorption from the GI tract to be approximately 0.6% of available, at intake levels similar to those seen in our collected prey items, though a dose-dependent increase in absorption was noted with exposures at levels up to two orders of magnitude above those in this study (Scheuhammer, 1987).

Mean rodent carcass lead levels of 1.639  $\mu\text{g/g}$  in kestrel food items were comparable to carcass data from small mammal investigations occurring as part of this study. In those examinations, vole (*Microtus*) carcasses collected from several locations throughout the superfund site varied from a mean low of 0.6 to a high of 2.5  $\mu\text{g/g}$  lead, while deer mouse (*Peromyscus*) carcasses were more variable with average lead concentrations ranging from 0.6 to a high of 17.5  $\mu\text{g/g}$  (this report, section 6). Carcasses of voles captured from lead acetate contaminated orchards contained 38-ppm lead concentrations (Stendell, 1989). Despite exposure to much higher carcass concentrations than those of this study, captive kestrels maintained on these carcasses for 60 days accumulated only sub-lethal amounts of lead (1-ppm) in their livers by the end of treatment. Interestingly, regurgitated pellets from Stendell's treatment birds were found to contain 130 ppm lead, indicating that much of the rodent body-burden of lead is likely sequestered in low digestibility depots like hair and bone and, are thus, less accessible to the kestrel.

Sequential blood sampling from nestlings in 2000 allowed the investigation of age-specific changes in kestrel contaminant levels (Figure 8-3). Blood cadmium and lead levels

demonstrated noteworthy increases in concentration with age in several nest boxes, primarily from the Smelter Hill area. Dietary metal concentrations from food items did not reflect a temporal increase in exposure level that might explain the increase with age. Further, food consumption rates, on a kg food / kg body wt basis, decrease with nestling age as nestlings approach fledging, which would decrease exposure levels in the face of constant food item COC concentrations (Balgooyen, 1976). As neither metal forms substantial blood depots, the levels likely reflected recent dietary exposure. Increases in blood levels of these metals with age might reflect increased efficiency in absorption from the GI tract. Alternatively, it is known that lead accumulates in bones and feathers (Scheuhammer, 1987; Eisler, 1988), particularly in developing animals (Burger and Gochfeld, 2000). Nestling kestrels reach approximate adult size by day 17-20 (Figure 8-6), with major bone and feather development occurring up until this same period. A likely explanation for lower Cd and Pb levels in younger birds was their sequestration into bone and feather depots during the period of greatest growth. Cessation of rapid bone growth and feather development in the older nestlings likely results in an increase in free circulating blood concentrations of the two contaminants. Spalding et al. (2000) noted similar increases in great egret (*Ardea albus*) blood mercury levels in response to nestling growth and similarly theorized that feather development acted to decrease mercury concentrations in blood, by providing a ready depot during growth.

Kestrel nestlings in the vicinity of Smelter Hill were exposed to elevated cadmium levels via food items. Subsequent elevations were also documented in blood, liver and kidney tissues in the Smelter Hill associated nestlings. Maximum liver levels reached 0.378 µg/g, or approximately 3% of the toxic threshold (13 µg/g) suggested by Eisler (Eisler, 1985). Cadmium, therefore, does not appear to be an *acute* threat to nestling health. Further consideration of cadmium as a cumulative toxicant is not, however, unreasonable. Liver and kidney concentration account for ~90% of the total body burden, bound to metallothionein (Scheuhammer, 1987). With an extremely long biological half-life, cadmium tends to accumulate with age, even in animals exposed to low background levels (Scheuhammer, 1987). Thus, nestlings and adult birds remaining in the vicinity of the smelter for long periods could potentially accumulate levels approaching a toxic threshold. Assessment of

adult cadmium accumulation in the vicinity of the Smelter might be prudent in further assessments, as kestrels have been noted to be philopatric, returning to the same area (even the same nest site) in consecutive years (Hamerstrom, 1973).

Dietary lead exposure appears to be a more significant concern for nestling kestrel health. While liver and kidney concentrations are not at or above published levels of concern, blood lead levels indicate the potential for deleterious health effects, made more significant due to the age of the nestlings. Blood lead levels in falconiformes are considered “sub-clinical” at levels between 0.2 and 1.5  $\mu\text{g/g}$  (Franson, 1996). These levels are elevated above background concentrations (defined as  $<0.2 \mu\text{g/g}$ ) and can cause physiological injury, though effects are likely to recover with removal of the lead source (Franson, 1996). Of the 25-day-old nestlings sampled in 1999, 2 fell into the background, while 14 contained sub-clinical levels (ranging from 0.2 to 0.4  $\mu\text{g/g}$ ). Blood lead levels in year 2000 25-day-old nestlings were lower than in 1999, with three birds having sub-clinical levels and 20 with background levels. In all, box mean blood lead levels were above “sub-clinical” levels in 14 of the 22 boxes occupied over both years (Figure 8-7). The trend toward increasing blood lead levels in Smelter Hill associated nestlings with increasing age suggests that by the time they fledge, nestlings may carry a greater burden than that documented in this study. Similar levels were found in pre-fledge age kestrels raised along the mine waste-contaminated Coeur d’Alene river basin (CDARB) in Idaho, with mean blood lead levels of  $0.24\mu\text{g/g}$ , and similar liver concentrations (Henny et al., 1994). The critical linkage of low-level lead exposure to developmental neurotoxicity in numerous mammalian species has been well established (Ma, 1996; Munoz et al., 1989; Finkelstein et al., 1998). In addition, hatchlings of altricial species (such as kestrels) appear to be more sensitive to moderate lead exposure, with higher sensitivity to lead as determined by growth, biochemical and behavioral development (Hoffman et al., 1985). The potential for developmental impedance in many individuals may be a concern at those levels discovered in our sample tissues.

Franson’s assessment of lead effects in birds does not take into consideration developmental effects of lead, exposure to which, during growth in the nest, can manifest toxicity throughout the rest of the animal’s life. Critical levels for developmental lead toxicity occur

at 20 to 30  $\mu\text{g}/\text{dl}$  (approximately 0.200 to 0.300  $\mu\text{g}/\text{g}$ ) in mammalian species (Ma, 1996), levels similar to those seen in kestrel nestlings. Similar documentation does not exist for avian nestlings, though behavioral and cognitive anomalies have been documented in gull nestlings dosed acutely with lead during early post-hatching development (Burger, 1998). As hatchlings of precocial species appear to be more tolerant of moderate lead exposure than altricial species (Hoffmann et al., 1985), altricial kestrels will likely exhibit a higher sensitivity to lead effects on growth, and biochemical and behavioral development.

In contrast to the lead and cadmium findings, age-dependent decreases in blood copper and zinc levels were identified in several clutches, again most notably from Smelter Hill associated boxes (Figure 8-3). Both copper and zinc are well regulated as, due to their nutritional role, there are mechanisms to maintain homeostatic levels. Plasma copper is generally bound by albumin and ceruloplasmin (Klasing, 1998). Absorption of copper and zinc is regulated primarily by metallothionein in the proventriculus and duodenum, (Klasing, 1998). As noted for lead and cadmium levels, dietary concentrations did not reflect a temporal change that would explain this decrease. Rather, higher levels of blood copper and zinc at younger ages suggest an inability of younger nestlings to maintain homeostatic levels of those metals when exposed to high food concentrations found in food items collected from near Smelter Hill-associated boxes. When confronted with high copper or zinc levels in food, metallothionein induction in avian intestinal epithelium generally assists in impeding absorption, which functions to actively exclude the minerals when presented with unnecessary concentrations (Klasing, 1998). The high levels found in several clutches from day 10 and day 17 suggests decreased capability for induction of sufficient metallothionein synthesis during early nestling development. As copper and zinc levels appeared to resolve at a homeostatic level across all clutches by day 25, a maturation of the induction capacity may have occurred.

### 8.3.2 Kestrel Effects Assessment

Lead intoxication is routinely associated with depressed blood ALAD activity or by elevated protoporphyrin IV (4-CP) levels (Eisler, 1988). Specifically, lead is known to affect the

heme biosynthetic pathway, through inhibition of aminolevulinic acid synthetase (ALAS), ALAD, and ferrochelatase (Fowler and Mahaffey, 1978).

Individual and total hepatic porphyrin concentrations were regressed as a quadratic function of hepatic lead concentration. 33% of the variability of the hepatic 4-CP could be explained by the concentration of total lead in the liver ( $r^2 = 0.327$ , Figure 8-4). In the present study, porphyrin analyses of liver and kidney tissues resulted in no substantial indication of toxicant-induced porphyria in any individuals. Nonetheless, concentration of the four-carboxyl porphyrin (4-CP) in the liver appears to be a potentially useful indicator of lead level concentration of the same tissue (Woods, 1995). In our investigations, one outlier was identified and removed in both the 4-CP and total CP findings. It is unclear as to the reason of the greatly increased porphyrin production in the individual from Box 39 (1999), as tissue and blood lead levels (as well as all COC concentrations) are near the mean for both matrices. A more intensive examination of the linear regression performed on the 4-CP / lead relationship suggests a potential contaminant threshold level, above which porphyric response becomes evident. An examination of individual concentrations showed an increase in liver 4-CP at liver lead above the 0.55- $\mu\text{g/g}$  level that suggests sufficient exposure to initiate disruption of heme synthesis (Figure 8-5). Multiple regression analyses were produced, investigating the relationship between blood and liver metals (lead, copper and zinc) and liver 4-CP concentration. In both, lead tissue concentration proved to be the predominant driver for both equations in increasing porphyrin levels, though blood zinc levels appeared to provide a slight buffer to lead concentration.

$$[4\text{CP}]_L = 12.8 + 0.9 \log_{10}[\text{Pb}]_L + 12.2 \log_{10} [\text{Cu}]_L - 2.7 \log_{10} [\text{Zn}]_L \quad R^2 = 0.21$$

$$[4\text{CP}]_L = 93.2 + 27.1 \log_{10} [\text{Pb}]_{\text{Bl}} - 1.45 \log_{10} [\text{Cu}]_{\text{Bl}} - 79.2 \log_{10} [\text{Zn}]_{\text{Bl}} \quad R^2 = 0.25$$

Inhibition of erythrocyte ALAD activity is a well-established biochemical alteration associated with lead exposure in birds (Hoffman et al., 1985; Franson et al., 1983; Henny et al., 1991, 1994; Beyer et al., 1988). Blood samples collected in 2000 were separated into age classes, which allowed for inspection of both age class differences and lead contaminant affects. Essentially background blood lead levels at the earliest ages resulted in no apparent ALAD effect. With the increased lead concentrations found at day 25, an inhibitory

relationship was detected (Figure 8-8). A comparison of individual ALAD values versus lead concentrations at day 25 (Figure 8-9) illustrates an apparent blood lead threshold level at approximately 0.12  $\mu\text{g/g}$ , above which notable enzyme inhibition starts to become apparent. Comparisons of mean ALAD values of individuals below and above this blood lead threshold demonstrated a 14% decrease (119 units vs. 102 units respectively). Moreover, a comparison of Opportunity Pond versus Smelter Hill mean values showed a 25% inhibition (120 units vs. 90 units respectively) in Smelter Hill nestling blood ALAD. In comparison, nestling kestrels from the Coeur d'Alene river basin (CDARB) exhibited a nearly 55% ALAD activity inhibition, when compared with nestlings from an uncontaminated site (Henny et al., 1994). Mean blood lead levels of the CDARB individuals (0.25 $\mu\text{g/g}$ ) were slightly higher than the mean of those nestlings above the threshold level in this study (0.18 $\mu\text{g/g}$ ), indicating the likelihood of a more dramatic inhibition with slight increases in lead concentration. Again, as with the liver porphyrin results, it appears that blood lead concentration just reached the threshold at which significant ALAD inhibition develops.

Nestlings were examined for other evidence of detrimental health effects due to COC exposure. No evidence of infestation of ecto- or endo-parasites, or any morphological abnormalities were detected. Nestling packed cell volume levels (35.5% to 38.0%) appeared normal as compared to literature values (control – 34.1%; Hoffman et al., 1985), with little variation between individuals. Ten-day old kestrels dosed with 25-mg/kg metallic lead showed slight, but non-significant, decreases in packed cell volume levels (30.9%; Hoffman et al., 1985) despite a 50% reduction in ALAD activity when compared to control values. Kestrel nestling red and white blood cell counts showed wide variability, though predominantly driven by one individual with highly skewed counts for both cell types, indicating anemia (low RBC) and a likely bacterial infection (extremely high WBC). No correlations between blood cell counts could be identified with tissue COC concentrations or nestbox locations. Various representative tissues were collected for histopathology assessment, and will be assessed at a later date, separate from this report.

Previous investigations on kestrels inhabiting contaminated, as well as non-contaminated, sites indicate that reproductive demographic endpoints investigated in Anaconda Smelter site

kestrels were within normal expectations (Wheeler, 1992; Roy, 1997; Negro et al., 1992; Hoff, 1992). In 1999, the decrease in the percentage of eggs hatching was influenced greatly by the abandonment of four of the nests. Three of these nests were initiated within four days of a weeklong cold spell, which appeared to have postponed much nesting activity throughout the study area. Kestrels are much more likely to abandon a nest early in the attempt, and it is likely that the weather change had a direct effect on these abandonments. Of the five unhatched eggs collected, four were found slightly cracked, which allowed for liquid contents to evaporate. Due to the behavior of kestrels to move aside nesting substrate and lay eggs upon the bare wood in nest boxes, accidental cracking during incubation is a potential hazard in nest boxes. Overall, 81.1% (43 of 53) of the eggs not collected for analysis hatched. Similar findings were identified in 2000, as five of six eggs found unhatched appeared to have been cracked early on in incubation. Interestingly, all six composed two entire clutches, whereas no egg from a successful box remained unhatched. The thirteen abandoned eggs were in various stages of incubation, though four from one clutch (box 41) appeared to be infertile.

Nestling body weights and morphological measurements showed little variation, and were within expected values for all ages (Hoff, 1992). Logistical growth curves were established for Smelter Hill and Opportunity Ponds nestlings and compared for differences in body weight growth rate or pattern, with no significant differences detected between the sites (Figure 8-6). Tissue weights showed little variation as well, though one nestling (Box 43 - 1999) was found to have a greatly increased spleen weight. This individual was found to have the highest levels of renal 4- and 2-CP (64.9 and 18.1 pmol/g respectively) discovered in all individuals, as well as the lowest hepatic copper level (7.38 µg/g) detected. This individual also had a white blood cell count over twice as high as the other individuals, along with a depressed red blood cell count. The spleen acts as a bacterial filter and also removes old red blood cells from the circulation. It is unclear what the cause of this individual's anemic condition was, as no unique physical evidence of poor health was noted at the time of dissection.

Demographic analysis between sites and between years varied, though comparisons of demographics are difficult when considering only two breeding seasons which varied greatly in general weather trends. A late season cold snap occurred during the summer of 1999, happening just after several kestrel nest initiations. Conversely, during the summer of 2000, southwestern Montana suffered an extensive drought and record-breaking heat. Also, dozens of forest fires throughout the region resulted in tremendously smoky conditions during the latter part of the summer. The likelihood exists that these conditions may have provoked physical impediments, initiated clutch abandonment, or have affected prey availability. Dawson and Bortolotti (2000) noted that food availability appeared to significantly influence parental provisioning behavior. It is unknown as to what effect these harsh circumstances may have produced in nesting rates, parental care, or reproductive success.

### 8.3.3 Woodpecker Species

Nestling tissue data from Lewis' woodpecker and northern flicker nest mortalities demonstrated elevated metal and As exposure levels in both species. Lewis' woodpecker nestlings, inhabiting nest boxes near the base of Smelter Hill, had elevated exposures to cadmium in liver and kidney, and lead (particularly in the liver) and a suggestion of elevated liver Zn levels. Flicker nestlings, from a box on the northern side of Opportunity ponds, also showed elevated Cd levels while the greater lead elevations occurred in the kidney rather than the liver. The highly elevated kidney As level in one nestling was particularly noteworthy.

Lewis' woodpeckers are opportunistic feeders, eating largely fruits and nuts during the non-breeding season, and a greater proportion of invertebrate food items during the breeding season (Tobalske, 1997). Flickers consume greater proportions of animal material in their diet (60% to 70%) with ants making up over half of the overall diet (Moore, 1995). It is unclear what, if any, difference food items play in tissue specific accumulation seen in these species. Food items (ants) collected from the stomachs of both flicker nestlings contained notable concentrations of all five contaminants. Relatively high concentrations of heavy metals have been reported in ants of the genus *Formica* (Bengtsson and Rundgren, 1984),

particularly those found in proximity to smelter-associated sites (Rabitsch, 1997). Further, the feeding style, supported by the presence of ant eggs and larvae, indicates the proclivity of flickers to forage through the soil in search of ants and their burrows. The likelihood exists that flickers accidentally ingest soil material, further increasing exposure. Due to the sample collection method, any ingested soil passed to the nestlings with their diet of ants was analyzed as part of the sample.

Though cadmium concentrations found in nestling woodpecker tissues are not indicative of clinical levels, the age of the nestling must be taken into consideration. Measured levels suggest a Cd accumulation rate of approximately 0.05  $\mu\text{g/g}$  daily, demonstrating the potential to accumulate hazardous levels (13 to 15 ppm) (Eisler, 1985) well within one year. This is particularly relevant to northern flickers, year-round residents of the region, compared to the migratory Lewis' woodpecker (Tobalske, 1997; Moore, 1995).

Lead concentrations were increased in both woodpecker and flicker tissues, though the greatest accumulation occurred in woodpecker livers ( $1.25 \pm 0.51 \mu\text{g/g}$ ) and flicker kidneys ( $2.46 \pm 0.51 \mu\text{g/g}$ ). Franson (1996) listed sub-clinical levels for three separate avian families starting at 2 ppm for both liver and kidney tissues for adult birds. As the age of both species at collection (Lewis' woodpecker-18 days; Flicker-14 days) was approximately half that at fledge, accumulations by the time the birds left the nest would have likely been higher than those measured in the nestling mortalities, as suggested by the increasing circulating lead levels in kestrels with cessation of bone and feather growth. Potentially toxic lead levels could likely have been exceeded, if the nestlings had survived to fledging age. As noted previously, the sudden failure of the two clutches prior to fledge appeared to be weather-related (flicker) or due to parental neglect (woodpecker).

Finally, the tissue lead levels suggest elevated lead exposure throughout the nestling period, similar to that seen in kestrels, though at higher levels. Concerns over developmental lead neurotoxicity thus apply to woodpeckers as well as to kestrels. The occasion to investigate these two species allowed a unique opportunity. Exposure levels indicate further

investigations are warranted, in particular with the flicker, as they are prevalent throughout the area and likely year-round residents.

#### 8.3.4 Data Quality Objective Status

The Data Quality Objectives encompass the experimental design and rationale for the biomonitoring study at the Anaconda Smelter. Central to the process is developing the data necessary to assess the questions posed by the decision rule. The data sets are now established and allow an assessment of American kestrel status on and around the Smelter site.

*Step 4: The Decision Rule.* Three statements were developed that provide the guidance for developing the decision rule for the study. They depend on evaluating relationships between COC on the site with exposure and effects in the test species. Provided below are assessments of the data developed for each question and a response to each statement based on the data.

*a. If the concentrations of metals or As in prey items, tissue or whole body of wildlife species in no way correspond to soil concentrations within exposure areas, then it will be determined that no association exists between soil contamination and wildlife exposure.*

An association between soil contamination and wildlife exposure has been demonstrated for American kestrels. Analyses demonstrate that when kestrel nests are grouped based on their proximity to Smelter Hill and its greater soil contaminant levels, both food items and tissues are contaminated with greater levels of COC. Specifically, food item As, Cd and Pb, blood and liver Cd, Pb and Cu, and kidney Cd levels are all significantly elevated in the vicinity of the Smelter.

*b. If the concentrations of metals or As in prey items, tissue or whole body of wildlife species in no way correspond to individual health effects and population demographics, then it will be determined that metal or As exposures are of no consequence to wildlife species.*

Assessments of porphyrin data suggest responsiveness at upper levels of lead exposure; with similar findings in ALAD inhibition at the highest blood lead levels. Strong correlative evidence exists to show that lead is the primary driver of these health effects in nestling kestrels. Packed cell volume, an integrative endpoint whose depression can indicate serious adverse effects of these two hemoglobin synthesis endpoints, was not affected. Nestling growth and morphological assessments do not show indications of effect based on food or tissue metal contamination. Further, reproductive demographics do not suggest site-specific variation in reproductive success between the Smelter Hill- and Opportunity Ponds-associated nest boxes. No assessment is possible for potential neurological effects in response to increased blood lead concentrations during development. In conclusion, this study demonstrates responses of highly sensitive, sub-clinical health effects endpoints that indicate that metal concentrations occur at levels that perturb physiological processes. Though not sufficiently high to cause direct mortality or reproductive impairment, the effects are above background levels and any increase in COC availability on sites has the potential to increase the degree of their response.

*c. If the concentrations of metals in prey items, tissue or whole body of wildlife species, and individual health effects and population demographics in no way correspond to remedial actions, it will be determined that remedial options are of no consequence to wildlife species.*

The response to this statement must, for now, be left to the results of the passerine and small mammal components of the study. Kestrel foraging areas did include areas that had previously been remediated (i.e., Smelter Hill ARCO plot, Smelter Hill cover areas and the revegetated burms on the pond dikes). These foraging areas, however, also included non-remediated lands, whose inclusion in the foraging range would not allow specific evaluation of remediated area impacts. Until sufficiently large areas have been remediated, exposure and effect data from wide-ranging species such as the kestrel will be most useful for their ability to document COC movement into higher levels of food webs and to integrate larger spatial areas across which this species forages.

8.4 Kestrel Tables and List of Tables

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**Table 8-1.** American kestrel nest boxes deployed on the Anaconda Smelter Site:  
 Lat. and Long. Coordinates with brief descriptions of location and distance from Stack.  
 (\* - Lat. and Long. coordinates map estimated)

Box	Lat.	Long.	Dist. from Stack (m)	Description
1	46-06.00N	112-56.41W	2558 SW	Telephone pole. SW of Smelter hill.
2	46-05.93N	112-55.13W	1737 SW	Telephone pole. S of Smelter hill.
*3	46-06.87N	112-54.84W	44 NE	High voltage tower. Top of smelter hill.
4	46 06.23N	112 -54.51W	1218 SE	Telephone pole. Geysler gulch.
5	46-06.33N	112-54.51W	1046 SE	Cottonwood tree. Geysler gulch.
*6	46-06.33N	112-54.12W	994 SE	Wooden post. Smelter hill aqueduct.
*7	46-07.00N	112-54.76W	295 NE	Telephone pole. Smelter hill water tower.
*8	46-06.86N	112-55.11W	348 NW	Cottonwood tree. Walker gulch, W of stack.
*9	46-06.99N	112-55.50W	890 NW	Small pine tree. Slag Gulch.
10	46-07.15N	112-55.22W	745 NW	Telephone pole. W of lab facility.
*11	46-07.20N	112-55.41W	1378 NW	Power line pole. W of main slagheap.
12	46-06.84N	112-53.91W	1198 SE	Metal trellis. SW of Anaconda pond.
13	46-06.65N	112-53.30W	2017 SE	Power line pole. S of Anaconda pond.
14	46-06.59N	112-52.92W	2519 SE	Power line pole. W of Mill Creek Road.
15	46.06.17N	112-53.10W	2568 SE	Telephone pole. Mill Creek town site.
16	46-06.15N	112-52.42W	3374 SE	Telephone pole. E of Mill Creek town site.
17	46-05.60N	112-52.09W	4229 SE	Cottonwood tree. SE of Mill Creek town site.
18	46-08.08N	112-54.94W	2289 NW	Cottonwood tree. SE of Anaconda landfill.
*19	46-07.47N	112.53.01W	2625 NE	Power line pole. HWY 1, N of Anaconda Pond.
20	46-08.16N	112-53.43W	3036 NE	Telephone pole. E of Galen road.
*21	46-07.84N	112-52.87W	3141 NE	Power line pole, E of HWY 48.
22	46-07.22N	112-51.99W	3736 NE	Cottonwood tree. SE corner of triangle wastes.
23	46-08.64N	112-53.49W	3750 NE	Telephone pole. Mile marker 1 of Galen Road.
24	46.08.64N	112-51.87W	5067 NE	Cottonwood tree. E of airport entrance, Hwy 48.
*25	46-07.88N	112-52.09W	4035 NE	Telephone pole. W of A-cell.
26	46-07.52N	112-51.22W	4827 NE	Wooden post. SW corner of A-cell.
27	46-07.01N	112-51.19W	4712 NE	Power line pole. NW of Country Club road.
*28	46-08.86N	112-51.12W	6067 NE	Telephone pole. HWY 48, NW of Opp. Ponds
*29	46-09.02N	112-50.39W	7004 NE	Cottonwood tree. N berm of C-cell.
30	46-08.10N	112-49.74W	6967 NE	Dead snag. Middle of C Cell.
31	46-07.53N	112-49.76W	6665 NE	A-frame structure. S berm between B & C-cells.

Continued

**Table 8-1.** Continued

Box	Lat.	Long.	Dist. from Stack (m)		Description
32	46-07.48N	112-48.66W	8047	NE	Cottonwood tree. SE corner of C-cell.
33	46-07.92N	112-48.66W	8205	NE	Cottonwood tree. E slope of C-cell.
*34	46-08.73N	112-48.84W	8478	NE	Decant tower. D-cell.
35	46-09.39N	112-49.65W	8177	NE	Cottonwood tree. NW of D-cell.
36	46-09.51N	112-48.99W	9005	NE	Cottonwood tree. N of D-cell.
37	46-09.24N	112-48.38W	9427	NE	Telephone pole. E of D-cell.
*38	46-09.56N	112-47.87W	10286	NE	Telephone pole. E of Box 37.
39	46-08.83N	112-48.19W	9319	NE	Telephone pole. E of D-cell.
40	46-08.53N	112-48.08W	9248	NE	Telephone pole. E of D-cell.
*41	46-08.33N	112-47.95W	9286	NE	Telephone pole. W of Pond entrance from I-90.
*42	46-07.84N	112-48.06W	8925	NE	Telephone pole. E of D-cell.
43	46-07.06N	112-47.94W	8897	NE	Power line pole. S entrance to Warm Springs WMA.
44	46-06.46N	112-47.99W	8854	NE	Power line pole. Road from Opportunity, W of I-90.
45	46-05.25N	112-47.93W	9382	NE	Power line pole. W of I-90, S of HWY 1.
46	46-10.01N	112-48.08W	10493	NE	Cottonwood tree. SW of HWY 48, W of I-90.
47	46-10.31N	112-48.31W	10576	NE	Cottonwood tree. SW corner behind State Hospital.
48	46-10.71N	112-48.15W	11198	NE	Telephone pole. W of State Hospital.
49	46-12.41N	112-45.53W	15805	NE	Telephone pole. S of Lampert Ranch.
50	46-12.69N	112-45.63W	16052	NE	Wooden post. Lampert Ranch.

**Table 8-2.** Detection Limits for Metals data in Biological Tissues of American Kestrels, Lewis Woodpecker and Northern Flicker

Year / Sample Type	Species	Average Sample Mass	As μg/g	Cd μg/g	Pb μg/g	Cu μg/g	Zn μg/g
<b>Detection Limits 1999</b>							
Blood	Kestrel	1.586	0.428	0.032	0.194	0.065	0.098
Liver	Kestrel	0.881	0.771	0.057	0.350	0.116	0.177
Kidney	Kestrel	0.684	0.993	0.073	0.451	0.150	0.228
Egg	Kestrel	12.938	0.052	0.004	0.024	0.008	0.012
Food	Kestrel	5.666	0.120	0.009	0.054	0.018	0.028
<b>Reporting Limits 1999</b>							
Blood	Kestrel	1.586	0.214	0.016	0.097	0.032	0.049
Liver	Kestrel	0.881	0.385	0.028	0.175	0.058	0.089
Kidney	Kestrel	0.684	0.496	0.037	0.225	0.075	0.114
Egg	Kestrel	12.938	0.026	0.002	0.012	0.004	0.006
Food	Kestrel	5.666	0.060	0.004	0.027	0.009	0.014
<b>Detection Limits 2000</b>							
Blood	Kestrel	0.479	0.104	0.005	0.104	0.214	0.326
Food	Kestrel	5.552	0.023	0.001	0.023	0.046	0.070
Liver	Woodpecker	2.313	0.022	0.001	0.022	0.044	0.067
Kidney	Woodpecker	0.968	0.052	0.003	0.052	0.106	0.161
Liver	Flicker	2.596	0.019	0.001	0.019	0.040	0.060
Kidney	Flicker	1.460	0.034	0.002	0.034	0.070	0.107
<b>Reporting Limits 2000</b>							
Blood	Kestrel	0.479	0.052	0.003	0.052	0.107	0.163
Food	Kestrel	5.552	0.011	0.001	0.011	0.023	0.035
Liver	Woodpecker	2.313	0.011	0.001	0.011	0.022	0.034
Kidney	Woodpecker	0.968	0.026	0.001	0.026	0.053	0.081
Liver	Flicker	2.596	0.010	0.000	0.010	0.020	0.030
Kidney	Flicker	1.460	0.017	0.001	0.017	0.035	0.053

\* Reporting limits are half detection limits

**Table 8-3.** Egg and nestling data for occupied American kestrel nest boxes at the Anaconda Smelter Site, 1999

Box No.	Nest Initiation	Eggs					Nestlings			
		No. Laid	Removed For Analysis	Missing	Abandoned	Unhatched	Number Hatched	Survived to Fledging Age	Removed For Analysis	Actually Fledged
K 01	602	4	1	0	0	0	3	3	1	2
K 02***	621	2	0	0	2	0	0	0	0	0
K 07	527	4	1	0	0	0	3	3	1	2
K 12***	531	2	0	1	1	0	0	0	0	0
K 13	518	5	1	0	0	0	4	4	1	3
K 14	602	4	1	0	0	1	2	2	1	1
K 19*	523	5	1	0	0	0	4	4	4	0
K 20***	601	1	0	0	1	0	0	0	0	0
K 27	526	5	1	0	0	0	4	4	1	3
K 28	529	4	1	0	0	0	3	2	1	1
K 30	529	5	1	0	0	0	4	4	1	3
K 32***	603	1	0	0	1	0	0	0	0	0
K 35	529	4	1	0	0	0	3	3	1	2
K 39	529	5	1	0	0	2	2	2	1	1
K 40**	529	4	4	0	0	0	0	0	0	0
K 43	610	4	0	0	0	0	4	4	1	3
K 44	617	4	1	0	0	0	3	3	1	2
K 45	512	5	1	1	0	1	2	1	1	0
K 49	526	4	1	0	0	1	2	2	1	1
Totals		72	17	2	5	5	43	41	17	24

\* All nestlings collected for analysis

\*\* Clutch of eggs collected for analysis

\*\*\* Unsuccessful nesting attempt

**Table 8-4.** Egg and nestling data for occupied American kestrel nest boxes at the Anaconda Smelter Site, 2000.

Box No.	Nest Initiation	Eggs				Nestlings			
		Laid	Missing	Abandoned	Unhatched	Hatched	Survive to Fledge Age	Dead In Box	Actually Fledged
K 01	528	4	0	0	0	4	4	0	4
K 04	609	3	1	0	2	0	0	0	0
K 17	522	4	0	0	0	4	4	0	4
K 23	530	5	1	0	4	0	0	0	0
K 24	520	3	0	0	0	3	3	0	3
K 26	612	4	0	4	0	0	0	0	0
K 32	601	4	2	0	0	2	0*	0	0
K 34	605	4	0	0	0	4	4	0	4
K 35	601	4	0	0	0	4	4	0	4
K 37	601	4	0	4	0	0	0	0	0
K 41	521	5	0	5	0	0	0	0	0
K 43	524	5	0	0	0	5	5	0	5
K 46	610	4	0	0	0	4	4	0	4
K 50	518	5	1	0	0	4	4	0	4
Totals		58	5	13	6	34	32	0	32
Lewis' Woodpecker									
K 15	519	4	0	0	0	4	0	4	0
K 14	611	5	0	0	5	0	0	0	0
Northern Flicker									
K 29	516	7	3	0	0	4	0**	2	0
Totals		16	3	0	5	8	0	6	0

\* All nestlings (n=2) from K 32 missing between Day 5 and 10.

\*\* Two nestlings from K 29 missing between Day 6 and 12.

**Table 8-5.** Food item metal and As concentrations from American kestrel nestlings. Anaconda Smelter Site, 1999. Values below detection limit were replaced with reporting limits (see Table 8-1). N is total sample number; n is number with detectable levels. Samples were collected from nestlings using esophageal constriction (EC) techniques or from nest box substrate were deposited.

Kestrel Box No.	Nest or Date	EC	Food Item	As μg/g	Cd μg/g	Pb μg/g	Cu μg/g	Zn μg/g
<u>Smelter Hill Associated Sites</u>								
K 01	716	EC	Rodent tissue	0.384	0.087	0.488	3.034	30.892
K 01	726	EC	Dragonfly. Grasshopper	0.469	1.200	0.171	12.554	49.084
K 07	709	EC	Rodent tissue	1.128	0.004	0.664	5.152	27.828
K 07	719	Nest	Peromyscus carcass	0.962	0.004	1.018	10.957	30.432
K 13	706	EC	Peromyscus carcass	6.822	0.134	3.312	11.483	42.065
K 13	706	Nest	Peromyscus	8.112	0.339	6.173	35.857	50.660
K 14	714	Nest	Rodent carcass	2.022	0.134	1.133	68.130	55.397
K 14	719	EC	Grasshopper	2.645	0.082	0.861	10.789	74.813
K 19	713	EC	Microtus	2.215	0.034	1.864	11.015	53.844
K 27	705	EC	Rodent carcass	1.469	0.018	0.741	4.601	28.123
K 27	709	EC	Rodent tissue	3.850	0.004	1.640	9.867	32.219
<u>Opportunity Pond Associated Sites</u>								
K 28	711	EC	Grasshopper	0.060	0.004	0.743	16.572	31.500
K 28	721	EC	2 Grasshoppers	1.114	0.184	1.070	32.843	51.641
K 30	720	Nest	Peromyscus	0.389	0.036	0.604	2.035	22.172
K 35	713	EC	Grasshopper	0.060	0.261	0.027	13.367	34.563
K 35	723	Nest	Microtus	1.223	0.058	0.475	3.102	23.100
K 39	710	EC	Avian tissue	0.592	0.094	1.119	13.444	35.288
K 39	720	Nest	Rodent carcass	0.716	0.004	1.904	7.509	51.529
K 43	725	EC	3 Grasshoppers. Rodent tissue	0.521	0.023	0.254	9.481	38.479
K 43	803	EC	2 Grasshoppers. Rodent tissue	0.707	1.116	0.360	8.181	40.462
K 43	803	Nest	Rodent carcass A	0.617	0.037	0.901	2.297	57.497
K 43	803	Nest	Rodent carcass B	0.535	0.036	2.604	5.562	43.925
K 44	725	Nest	Microtus	1.048	0.098	2.209	11.341	33.082
K 44	803	Nest	Avian tissue	0.588	0.203	0.503	6.448	47.747
K 45	705	EC	Rodent tissue	0.973	0.133	2.236	5.809	36.823
K 45	709	Nest	Rodent carcass	1.937	0.049	3.497	8.507	34.801
All Sites	Mean		N=26	1.583	0.168	1.407	12.690	40.691
	SD			1.940	0.304	1.348	13.848	12.358
	n			26	26	26	26	26
Smelter Hill Sites	Mean		N=11	2.734	0.185	1.642	16.676	43.214
	SD			2.562	0.350	1.729	19.157	15.006
	n			11	11	11	11	11
Opportunity Pond Sites	Mean		N=15	0.739	0.156	1.234	9.766	38.841
	SD			0.475	0.277	1.017	7.660	10.159
	n			15	15	15	15	15

**Table 8-6.** Food item metal and As concentrations from American kestrel nestlings. Anaconda Smelter Site, 2000. Values below detection limit were replaced with reporting limits (see Table 8-1). N is total sample number; n is number with detectable levels. Samples were collected from nestlings using esophageal constriction (EC) techniques or from nest box substrate (Nest).

Kestrel Box No.	Date Collected	Collection Method	Food Item	As μg/g	Cd μg/g	Pb μg/g	Cu μg/g	Zn μg/g	
<u>Smelter Hill Associated Sites</u>									
K 01	711	Nest	Lower torso of Passerine	1.031	0.911	1.131	5.288	45.952	
K 01	724	EC	3 Grasshoppers	1.573	0.908	0.220	42.293	67.812	
K 17	711	EC	Rodent parts	1.561	0.606	1.288	13.055	46.724	
K 17	716	EC	4 Grasshoppers. Rodent skull	1.287	0.211	0.438	48.846	82.044	
K 24	710	Nest	1 Whole vole	6.473	0.060	2.837	25.996	45.097	
K 24	713	EC	Rodent leg	1.538	0.084	3.121	6.849	35.738	
<u>Opportunity Pond Associated Sites</u>									
K 34	707	Nest	1 Dragonfly Rodent parts and 1	0.011	0.960	1.296	14.943	83.211	
K 34	717	EC	Grasshopper	0.011	0.108	0.355	16.134	38.535	
K 34	724	EC	2 Grasshoppers	0.555	0.058	0.052	39.512	40.767	
K 35	718	EC	2 Entire Shrews Rodent parts and 1	0.270	0.215	0.134	5.260	35.785	
K 43	711	EC	Grasshopper	0.511	0.052	0.404	9.030	37.421	
K 43	716	EC	2 Grasshoppers	0.011	0.001	0.098	13.199	43.230	
K 46	715	Nest	Rodent torso	0.809	0.001	0.250	7.897	80.166	
K 46	802	EC	Passerine leg and torso	0.011	0.060	0.140	13.528	52.807	
K 50	707	Nest	Rodent backbone Rodent parts and Passerine	0.011	0.001	0.184	6.864	40.603	
K 50	707	Nest	torso	0.011	0.243	0.261	7.039	49.419	
K 50	707	EC	Grasshopper	0.011	0.001	0.172	17.673	35.530	
K 50	713	EC	2 Rodent carcasses	0.011	0.061	0.053	5.877	25.375	
All Sites				Mean	0.872	0.252	0.691	16.627	49.234
				SD	1.524	0.342	0.926	13.584	17.382
N = 18				n	18	18	18	18	18
Smelter Hill Sites				Mean	2.244	0.463	1.506	23.721	53.894
				SD	2.082	0.397	1.213	18.545	17.364
N = 6				n	6	6	6	6	6
Opportunity Pond Sites				Mean	0.186	0.147	0.283	13.080	46.904
				SD	0.283	0.269	0.337	9.362	17.666
N = 12				n	12	12	12	12	12

**Table 8-7.** Egg metal and As concentrations from American kestrel nestlings. Anaconda Smelter Site, 1999. Values below detection limit were replaced with reporting limits (see Table 8-1). N is total sample number; n is number with detectable levels. \* Indicates abandoned and unincubated samples.

Kestrel Box No.	N		As	Cd	Pb	Cu	Zn
			µg/g	µg/g	µg/g	µg/g	µg/g
K 40			0.026	0.002	0.032	0.139	2.724
K 40			0.026	0.002	0.032	0.190	3.427
K 40			0.026	0.002	0.027	0.197	3.366
K 40			0.026	0.002	0.029	0.174	3.480
Box K 40	4	Mean	0.026	0.002	0.030	0.175	3.249
Intra-Clutch		SD	0.000	0.000	0.002	0.026	0.353
N=4		n	4	4	4	4	4
<u>Smelter Hill Associated Sites</u>							
K 01			0.026	0.002	0.033	0.206	2.951
K 07			0.026	0.002	0.073	0.160	2.835
K 13			0.026	0.002	0.012	0.186	2.906
K 14			0.026	0.002	0.029	0.163	3.501
K 19			0.026	0.002	0.062	0.143	3.997
K 20	*		0.026	0.002	0.103	0.158	3.987
K 27			0.026	0.002	0.022	0.155	2.691
<u>Opportunity Pond Associated Sites</u>							
K 28			0.026	0.002	0.034	0.188	3.553
K 30			0.026	0.002	0.047	0.193	2.667
K 32	*		0.026	0.002	0.029	0.179	2.578
K 35			0.026	0.002	0.034	0.129	2.959
K 39			0.026	0.002	0.042	0.182	3.202
K 40		Mean	0.026	0.002	0.030	0.175	3.249
K 44			0.026	0.002	0.012	0.145	2.850
K 45			0.026	0.002	0.036	0.243	3.755
K 49			0.026	0.002	0.029	0.127	3.799
All Sites	16	Mean	0.026	0.002	0.039	0.171	3.217
		SD	0.000	0.000	0.023	0.030	0.485
		n	16	16	16	16	16
Smelter Hill Sites	7	Mean	0.026	0.002	0.048	0.167	3.267
		SD	0.000	0.000	0.033	0.021	0.556
		n	7	7	7	7	7
Opportunity Pond Sites	9	Mean	0.026	0.002	0.032	0.173	3.179
		SD	0.000	0.000	0.010	0.036	0.453
		n	9	9	9	9	9

**Table 8-8.** Blood metal and As concentrations from American kestrel nestlings. Anaconda Smelter Site, 1999. Values below detection limit were replaced with reporting limits (see Table 8-1). N is total sample number; n is number with detectable levels.

Kestrel Box No.	Nestling	N						
			As μg/g	Cd μg/g	Pb μg/g	Cu μg/g	Zn μg/g	
K 19	B		0.214	0.016	0.368	1.906	4.945	
K 19	C		0.214	0.016	0.293	0.270	5.290	
K 19	D		0.214	0.016	0.097	1.570	5.229	
Box K 19 Intra-Clutch N=3		3	Mean SD n	0.214 0.000 3	0.016 0.000 3	0.253 0.140 3	1.249 0.864 3	5.155 0.184 3
<u>Smelter Hill Associated Sites</u>								
K 01	A		0.214	0.016	0.277	0.198	3.867	
K 07	C		0.214	0.016	0.365	1.667	4.986	
K 13	C		0.214	0.016	0.423	3.033	5.622	
K 14	B		0.214	0.016	0.277	1.072	3.864	
K 19	Mean		0.214	0.016	0.253	1.249	5.155	
K 27	B		0.214	0.016	0.325	0.178	5.726	
<u>Opportunity Pond Associated Sites</u>								
K 28	C		0.214	0.016	0.232	1.295	5.450	
K 30	D		0.214	0.016	0.291	0.235	4.815	
K 35	C		0.214	0.016	0.298	0.911	4.738	
K 39	A		0.214	0.016	0.249	0.228	4.740	
K 43	A		0.214	0.016	0.178	0.244	4.124	
K 44	C		0.214	0.016	0.264	0.212	5.311	
K 45	B		0.214	0.016	0.250	0.250	4.564	
K 49	B		0.214	0.016	0.249	0.247	4.868	
All Sites		14	Mean SD n	0.214 0.000 14	0.016 0.000 14	0.281 0.060 14	0.787 0.829 14	4.845 0.596 14
Smelter Hill Sites		6	Mean SD n	0.214 0.000 6	0.016 0.000 6	0.320 0.065 6	1.233 1.062 6	4.870 0.826 6
Opportunity Pond Sites		8	Mean SD n	0.214 0.000 8	0.016 0.000 8	0.251 0.037 8	0.453 0.414 8	4.826 0.415 8

**Table 8-9.** Blood metal and As concentrations from American kestrel nestlings. Anaconda Smelter Site, 2000. Values below detection limit were replaced with reporting limits (see Table 8-1). N is total sample number; n is number with detectable levels.

Box ID	Days post-hatch	N		As	Cd	Pb	Cu	Zn
				µg/g	µg/g	µg/g	µg/g	µg/g
K 01	10	2	Mean	0.083	0.031	0.052	4.611	18.220
			SD	0.044	0.029	0.000	0.690	5.779
			n	1	2	0	2	2
	17	3	Mean	0.052	0.039	0.115	1.260	5.194
			SD	0.000	0.031	0.067	1.361	0.191
			n	0	3	2	3	3
	25	2	Mean	0.052	0.144	0.148	0.476	5.708
			SD	0.000	0.051	0.069	0.096	0.405
			n	0	2	2	2	2
K 17	10	3	Mean	0.052	0.006	0.052	1.867	6.295
			SD	0.000	0.005	0.000	1.219	1.048
			n	0	1	0	3	3
	17	2	Mean	0.052	0.041	0.052	0.815	5.882
			SD	0.000	0.018	0.000	0.525	1.055
			n	0	2	0	2	2
	25	3	Mean	0.052	0.247	0.234	0.663	5.110
			SD	0.000	0.338	0.083	0.174	2.745
			n	0	3	3	3	3
K 24	10	1		0.052	0.004	0.092	1.129	6.353
	17	2	Mean	0.052	0.004	0.053	0.660	4.855
			SD	0.000	0.002	0.001	0.230	0.402
			n	0	1	1	2	2
	25	2	Mean	0.052	0.026	0.162	0.437	4.660
			SD	0.000	0.021	0.048	0.009	0.157
n			0	2	2	2	2	
K 34	10	2	Mean	0.052	0.024	0.052	3.084	10.404
			SD	0.000	0.018	0.000	0.451	2.756
			n	0	2	0	2	2

Continued

**Table 8-9.** Continued

Box ID	Days post-hatch	N		As	Cd	Pb	Cu	Zn
				µg/g	µg/g	µg/g	µg/g	µg/g
K 34 continued	25	4	Mean	0.052	0.027	0.072	0.455	5.031
			SD	0.000	0.022	0.019	0.085	0.397
			n	0	4	3	4	4
K 35	10	3	Mean	0.052	0.007	0.052	1.058	6.536
			SD	0.000	0.001	0.000	0.149	0.231
			n	0	3	0	3	3
	25	4	Mean	0.052	0.076	0.117	0.477	5.117
			SD	0.000	0.140	0.027	0.149	0.570
			n	0	3	4	4	4
K 43	17	5	Mean	0.111	0.148	0.052	2.415	8.941
			SD	0.121	0.098	0.000	2.046	2.449
			n	2	5	0	5	5
	25	3	Mean	0.052	0.019	0.115	0.471	4.302
			SD	0.000	0.013	0.018	0.146	0.480
			n	0	3	3	3	3
K 46	10	4	Mean	0.093	0.017	0.161	0.554	5.816
			SD	0.048	0.003	0.053	0.240	0.471
			n	2	4	4	4	4
	25	3	Mean	0.052	0.037	0.157	0.670	5.041
			SD	0.000	0.011	0.049	0.127	0.143
			n	0	3	3	3	3
K 50	10	4	Mean	0.052	0.005	0.052	0.941	5.935
			SD	0.000	0.001	0.000	0.416	0.415
			n	0	4	0	4	4
	25	3	Mean	0.052	0.019	0.055	0.804	4.641
			SD	0.000	0.008	0.011	0.270	0.481
			n	0	3	3	3	3

**Table 8-10.** Liver metal and As concentrations from American kestrel nestlings. Anaconda Smelter Site, 1999. Values below detection limit were replaced with reporting limits (see Table 8-1). N is total sample number; n is number with detectable levels.

Kestrel Box No.	Nestling	N						
			As µg/g	Cd µg/g	Pb µg/g	Cu µg/g	Zn µg/g	
K 19	A		0.385	0.028	0.541	38.513	26.692	
K 19	B		0.385	0.028	0.637	56.850	27.904	
K 19	C		0.385	0.028	0.553	25.333	24.097	
K 19	D		0.385	0.028	0.568	26.380	21.912	
Box K 19		4	Mean	0.385	0.028	0.575	36.769	25.151
Intra-Clutch			SD	0.000	0.000	0.043	14.663	2.681
N=4			n	4	4	4	4	4
<u>Smelter Hill Associated Sites</u>								
K 01	A		0.385	0.158	0.515	22.011	26.273	
K 07	C		0.385	0.028	0.579	37.976	22.857	
K 13	C		0.385	0.097	0.479	23.720	23.173	
K 14	B		0.385	0.106	0.684	44.923	32.580	
K 19	Mean		0.385	0.028	0.575	36.769	25.151	
K 27	B		0.385	0.028	0.732	69.783	32.250	
<u>Opportunity Pond Associated Sites</u>								
K 28	C		0.385	0.028	0.542	23.133	25.887	
K 30	D		0.385	0.028	0.395	9.873	21.125	
K 35	C		0.385	0.028	0.549	17.260	25.080	
K 39	A		0.385	0.028	0.468	23.071	23.306	
K 43	A		0.385	0.028	0.458	7.376	28.248	
K 44	C		0.385	0.028	0.352	8.788	23.976	
K 45	B		0.385	0.028	0.175	12.922	28.848	
K 49	B		0.385	0.028	0.376	12.484	24.976	
All Sites		14	Mean	0.385	0.048	0.491	25.006	25.981
			SD	0.000	0.041	0.141	17.302	3.411
			n	14	14	14	14	14
Smelter Hill Sites		6	Mean	0.385	0.074	0.594	39.197	27.047
			SD	0.000	0.055	0.097	17.382	4.346
			n	6	6	6	6	6
Opportunity Pond Sites		8	Mean	0.385	0.028	0.414	14.363	25.181
			SD	0.000	0.000	0.121	6.174	2.531
			n	8	8	8	8	8

**Table 8-11.** Kidney metal and As concentrations from American kestrel nestlings. Anaconda Smelter Site, 1999. Values below detection limit were replaced with reporting limits (see Table 8-1). N is total sample number; n is number with detectable levels.

Kestrel Box No.	Nestling	N						
			As μg/g	Cd μg/g	Pb μg/g	Cu μg/g	Zn μg/g	
K 19	A		0.496	0.037	0.225	3.830	15.432	
K 19	C		0.496	0.095	0.225	3.145	15.860	
K 19	D		0.496	0.116	0.225	3.834	17.204	
Box K 19		3	Mean	0.496	0.083	0.225	3.603	16.165
Intra-Clutch			SD	0.000	0.041	0.000	0.397	0.925
N=3			n	3	3	3	3	3
<u>Smelter Hill Associated Sites</u>								
K 01	A		0.496	0.387	0.225	5.196	21.563	
K 13	C		0.496	0.128	0.225	3.191	15.483	
K 14	B		0.496	0.109	0.225	6.154	16.822	
K 19	Mean		0.496	0.083	0.225	3.603	16.165	
K 27	B		0.496	0.037	0.225	3.181	17.776	
<u>Opportunity Pond Associated Sites</u>								
K 28	C		0.496	0.037	0.225	3.041	15.158	
K 30	D		0.496	0.037	0.225	3.359	15.684	
K 35	C		0.496	0.037	0.225	3.627	15.429	
K 39	A		0.496	0.037	0.225	3.186	16.938	
K 43	A		0.496	0.037	0.225	3.652	19.518	
K 44	C		0.496	0.037	0.225	3.101	16.377	
K 45	B		0.496	0.037	0.225	3.446	15.303	
K 49	B		0.496	0.037	0.225	3.038	14.934	
All Sites		13	Mean	0.496	0.080	0.225	3.675	16.704
			SD	0.000	0.098	0.000	0.934	1.932
			n	13	13	13	13	13
Smelter Hill Sites		5	Mean	0.496	0.149	0.225	4.265	17.562
			SD	0.000	0.138	0.000	1.342	2.391
			n	5	5	5	5	5
Opportunity Pond Sites		8	Mean	0.496	0.037	0.225	3.306	16.168
			SD	0.000	0.000	0.000	0.252	1.508
			n	8	8	8	8	8

**Table 8-12.** Liver porphyrins from American Kestrels. Anaconda Smelter Site, 1999. N is total sample number; n is number with detectable levels.

Kestrel Box No.	Nestling	N	Carboxyl Porphyrins			
			4 pmol/g	2 pmol/g	Total pmol/g	
K 19	A		30.756	19.512	64.863	
K 19	B		26.076	10.713	49.519	
K 19	C		31.018	9.406	56.336	
K 19	D		33.060	18.633	50.216	
K 19 Intra-Clutch		4	Mean	30.227	14.566	55.233
			SD	2.953	5.243	7.113
			n	4	4	4
K 01	A		25.232	8.377	39.823	
K 07	C		31.598	13.062	44.661	
K 13	C		16.001	9.270	32.633	
K 14	B		35.596	20.291	67.313	
K 19		4	Mean	30.227	14.566	55.233
K 27	B		25.450	12.872	47.581	
K 28	C		14.746	10.205	30.457	
K 30	D		23.387	12.865	47.387	
K 35	C		21.335	8.906	36.223	
K 39	A		40.647	25.098	80.373	
K 43	A		24.552	18.273	53.714	
K 44	C		13.528	13.979	46.034	
K 45	B		22.450	12.652	43.039	
K 49	B		21.028	12.170	41.295	
All Sites		14	Mean	24.698	13.756	47.555
			SD	7.762	4.669	13.410
			n	14	14	14
Smelter Hill Sites		6	Mean	27.351	13.073	47.874
			SD	6.800	4.263	12.162
			n	6	6	6
Opportunity Pond Sites		8	Mean	22.709	14.269	47.315
			SD	8.264	5.177	15.105
			n	8	8	8

**Table 8-13.** Kidney porphyrins from American Kestrels. Anaconda Smelter Site, 1999. ND is not detected. N is total sample number; n is number with detectable levels.

Kestrel Box No.	Nestling	N		Carboxyl Porphyrins		
				4 pmol/g	2 pmol/g	Total pmol/g
K 19	A			20.384	ND	30.375
K 19	B			23.894	10.377	43.514
K 19	C			23.452	ND	32.652
K 19	D			25.064	14.328	39.392
K 19 Intra-Clutch		4	Mean	23.199	12.353	36.483
			SD	1.996	2.793	6.052
			n	4	2	4
K 01	A			31.434	8.895	67.727
K 07	C			26.464	7.907	43.663
K 13	C			28.353	7.870	44.761
K 14	B			20.560	8.768	38.277
K 19		4	Mean	23.199	12.353	36.483
K 27	B			21.153	8.930	30.082
K 28	C			22.600		28.757
K 30	D			29.630	10.594	40.224
K 35	C			21.317	9.786	61.256
K 39	A			22.091	13.702	63.166
K 43	A			64.916	18.078	92.847
K 44	C			26.962	7.738	42.689
K 45	B			25.316	12.278	60.040
K 49	B			21.885	6.606	37.453
All Sites		14	Mean	27.563	10.269	49.102
			SD	11.289	3.143	17.720
			n	14	13	14
Smelter Hill Sites		6	Mean	25.194	9.120	43.499
			SD	4.297	1.655	13.001
			n	6	6	6
Opportunity Pond Sites		8	Mean	29.340	11.254	53.304
			SD	14.665	3.877	20.379
			n	8	7	8

**Table 8-14.** ALAD and Packed Cell Volume on a Box Mean Basis.  
 Anaconda Smelter Site, - 2000.

Age (Post-hatch)	Kestrel Box No.	PCV (%)	ALAD (units)
<b>Day 10</b>			
Smelter Hill Associated Sites	01	36.5	135.25
	17	34.7	114.40
	24		
	Mean	35.6	124.83
	SD	1.3	14.74
	n	2	2
<b>Opp. Ponds- Associated Sites</b>			
Opp. Ponds- Associated Sites	34	36.0	119.19
	35	40.0	133.36
	46	35.8	149.33
	50	32.0	129.51
	Mean	35.9	132.85
	SD	3.3	12.51
n	4	4	
<b>Day 17</b>			
Smelter Hill Associated Sites	01	35.0	119.63
	17	37.0	123.30
	24	34.5	102.09
	Mean	35.5	115.01
	SD	1.3	11.34
	n	3	3
<b>Opp. Ponds- Associated Sites</b>			
Opp. Ponds- Associated Sites	43	36.2	119.17
	Mean	36.2	119.17
	SD		
n	1	1	
<b>Day 25</b>			
Smelter Hill Associated Sites	01	39.5	96.84
	17	34.0	89.60
	24	40.5	85.23
	Mean	38.0	90.55
	SD	3.5	5.86
	n	3	3
<b>Opp. Ponds- Associated Sites</b>			
Opp. Ponds- Associated Sites	34	34.5	134.30
	35	40.5	113.04
	43	34.8	120.66
	46	36.0	131.12
	50	36.0	109.33
	Mean	36.4	121.69
SD	2.4	10.91	
n	5	5	

**Table 8-15.** Kestrel Nestling Hematology. Anaconda Smelter Site, - 1999. Red and white blood cell counts were performed on samples collected from each retrieved nestling using a hemacytometer.

Box No.	Chick	Hemacytometer count (cells/ ul)	
		WBC	RBC (10 <sup>6</sup> )
K 19	A	2679	5.09
K 19	B	3445	5.33
K 19	C	3278	6.00
K 19	D	3056	5.27
Box K19	Mean	3115	5.42
Intra-clutch	SD	331.2	0.40
	n	4	4
K 01	A	8750	7.91
K 07	C	3657	4.51
K 13	C	4625	7.31
K 14	B	6313	7.78
K 19	Mean	3115	5.42
K 27	B	3722	6.21
K 28	C	8500	6.89
K 30	D	5473	5.57
K 35	C	4938	6.38
K 39	A	5445	5.77
K 43	A	23594	2.04
K 44	C	12688	6.58
K 45	B	2889	5.71
K 49	B	4139	7.18
All Sites	Mean	6989	6.19
	SD	5479	1.51
	n	14	14
Smelter Hill Sites	Mean	5030	6.52
	SD	2041	1.38
	n	6	6
Opportunity Pond Sites	Mean	8458	5.77
	SD	6835	1.61
	n	8	8

**Table 8-16.** Tissue Weights from American kestrel nestlings. Anaconda Smelter Site, 1999. N is the total number of nestlings measured while n is the number positive for the endpoint. NC is not collected.

Kestrel Box No.	N	Nestling	Kidney (gram)	Liver (gram)	Brain (gram)	Spleen (gram)	Bursa (gram)
K 19		A	1.37	3.80	2.11	0.087	0.226
K 19		B	NC	3.93	2.12	0.138	0.402
K 19		C	1.52	3.68	2.23	0.151	0.387
K 19		D	1.25	3.92	2.39	0.128	0.291
Box K 19 Intra-Clutch N=4	4	Mean	1.38	3.83	2.21	0.126	0.327
		SD	0.138	0.119	0.133	0.028	0.083
		n	3	4	4	4	4
K 01		A	1.25	4.42	2.36	0.303	0.453
K 07		C	NC	5.07	2.33	0.362	0.459
K 13		C	1.80	4.47	2.52	0.192	0.387
K 14		B	1.42	3.50	2.20	0.196	0.346
K 19		Mean	1.38	3.83	2.21	0.126	0.327
K 27		B	1.14	3.22	2.26	0.133	0.422
K 28		C	1.69	5.09	2.29	0.272	0.228
K 30		D	1.38	4.40	2.31	0.183	0.349
K 35		C	1.38	3.82	2.28	0.150	0.393
K 39		A	1.20	4.33	2.46	0.160	0.401
K 43		A	1.67	4.76	2.26	0.724	0.286
K 44		C	1.79	4.99	2.32	0.461	0.573
K 45		B	1.55	5.32	1.92	0.265	NC
K 49		B	1.54	3.78	2.43	0.164	0.401
All Sites	N=14	Mean	1.48	4.36	2.30	0.264	0.386
		SD	0.217	0.650	0.141	0.164	0.086
		n	13	14	14	14	13
Smelter Hill Sites	N=6	Mean	1.40	4.08	2.31	0.219	0.399
		SD	0.248	0.691	0.118	0.095	0.055
		n	5	6	6	6	6
Opportunity Pond Sites	N=8	Mean	1.53	4.56	2.29	0.297	0.376
		SD	0.195	0.577	0.164	0.201	0.109
		n	8	8	8	8	7

**Table 8-17.** Demographic parameters for American kestrels nesting at the Anaconda Smelter Site, 1999 and 2000.

Focus of Statistic	Statistic	1999	2000
<b>Nest Box Statistics</b>			
	Nest boxes available	50	49
	Initiated kestrel clutches	19	14
	Percent occupancy	38.0% (19/50)	28.6% (14/49)
<b>Egg Statistics</b>			
	Total eggs laid	72	58
	Number of eggs/ initiated clutch (mean $\pm$ S.D.)	3.79 $\pm$ 1.32 N=19	4.14 $\pm$ 0.66 N=14
	Eggs removed for chemical analysis	17	0
	Eggs missing from nest during incubation	2	5
	Eggs reaching hatch age	53	53
	Eggs abandoned	5	13
	Eggs un-hatched	5	6
	Eggs hatched	43	34
	Hatching success	81.1% (43/53)	64.2% (34/53)
	Successful nests (nests with live nestling)	14	9
	Initiated clutches (corrected for removed clutch)	18	14
	Nesting success (successful nests/clutches initiated)	77.8% (14/18)	64.3% (9/14)
<b>Nestling Statistics</b>			
	Nestlings	43	34
	Missing/dead nestlings	2	2
	Fledglings (survival to 25 days post hatch)	41	32
	Fledging efficiency (fledglings/nestlings)	95.3% (41/43)	94.1% (32/34)
	Nestlings collected for analysis	17	0
	Actual number of fledged nestlings	24	32
<b>General Statistics</b>			
	Number of eggs/successful nest (mean $\pm$ S.D.)	4.43 $\pm$ 0.51 N=14	3.78 $\pm$ 0.83 N=9
	Number of nestlings/successful nest (mean $\pm$ S.D.)	3.07 $\pm$ 0.83 N=14	3.78 $\pm$ 0.83 N=9
	Nesting efficiency (fledglings/eggs at hatch)	77.4% (41/53)	60.4% (32/53)

**Table 8-18.** Body weight and morphological measurements of American kestrel nestlings recorded at time of collection (25 days post hatch). Anaconda Smelter Site, 1999. N is the total number of nestlings measured while n is the number positive for the endpoint.

Kestrel Box ID	N	Individual	Weight (gram)	Tarsus (mm)	Third Toe (mm)	Culmen (mm)	Bill Width (mm)
K 19		A	103.24	37.62	17.11	9.87	5.53
K 19		B	114.13	37.89	17.15	9.92	5.27
K 19		C	121.62	38.89	16.96	10.50	5.32
K 19		D	102.76	38.16	17.45	9.89	5.50
Box K 19 Intra-Clutch N=4		Mean	110.44	38.14	17.17	10.05	5.41
		SD	9.12	0.546	0.205	0.304	0.129
		n	4	4	4	4	4
K 01		A	116.67	42.04	19.86	10.91	5.66
K 07		C	114.20	39.92	18.63	10.21	5.56
K 13		C	132.51	40.67	17.57	11.36	5.72
K 14		B	109.26	38.58	18.46	10.25	5.85
K 19		Mean	110.44	38.14	17.17	10.05	5.41
K 27		B	107.56	42.58	18.29	10.90	5.55
K 28		C	128.76	41.56	18.22	10.21	5.55
K 30		D	125.40	41.27	17.71	9.84	5.50
K 35		C	119.11	43.76	18.87	10.70	5.60
K 39		A	119.30	43.27	18.35	10.11	5.36
K 43		A	114.99	41.96	17.65	9.79	5.39
K 44		C	126.69	38.48	18.01	10.21	6.12
K 45		B	114.85	39.69	17.00	10.10	5.29
K 49		B	109.90	44.76	18.94	10.14	5.91
All Sites	N=14	Mean	117.83	41.19	18.20	10.34	5.60
		SD	7.86	2.05	0.760	0.452	0.232
		n	14	14	14	14	14
Smelter Hill Sites	N=6	Mean	115.11	40.32	18.33	10.61	5.62
		SD	9.16	1.80	0.936	0.519	0.154
		n	6	6	6	6	6
Opportunity Pond Sites	N=8	Mean	119.88	41.84	18.09	10.14	5.59
		SD	6.61	2.09	0.649	0.277	0.287
		n	8	8	8	8	8

**Table 8-19.** Body weight and morphological measurements of American kestrel nestlings recorded on days 5, 10, 15, 20, and 25 post-hatch. Anaconda Smelter Site, 2000.

Box ID	Day Post-Hatch	N		Weight (grams)	Tarsus (mm)	Third Toe (mm)	Culmen (mm)	Bill Width (mm)
K 01	5	4	Mean	26.38	20.01	7.99	7.51	4.89
			SD	7.56	2.45	1.14	0.54	0.17
			n	4	4	4	4	4
	10	4	Mean	73.50	33.28	14.99	8.89	5.87
			SD	16.03	2.88	1.20	0.41	0.19
			n	4	4	4	4	4
	15	4	Mean	116.00	41.81	17.73	9.97	6.49
			SD	9.31	1.79	0.66	0.33	0.25
			n	4	4	4	4	4
	20	4	Mean	127.50	43.37	18.08	10.49	5.82
			SD	7.55	0.90	0.44	0.36	0.15
			n	4	4	4	4	4
	25	4	Mean	126.25	43.33	18.61	10.48	5.90
			SD	8.54	0.74	0.69	0.25	0.21
			n	4	4	4	4	4
K 17	5	4	Mean	50.50	27.59	12.80	8.20	5.47
			SD	1.73	0.62	0.09	0.15	0.12
			n	4	4	4	4	4
	10	4	Mean	99.50	38.62	16.59	9.22	6.02
			SD	1.91	0.54	0.33	0.29	0.06
			n	4	4	4	4	4
	15	4	Mean	120.75	42.34	19.11	9.98	6.04
			SD	5.56	0.69	0.32	0.24	0.10
			n	4	4	4	4	4
	20	4	Mean	132.75	40.24	19.07	10.60	5.88
			SD	5.50	1.61	0.89	0.21	0.09
			n	4	4	4	4	4
	25	4	Mean	126.50	41.92	19.10	10.87	5.97
			SD	9.15	0.93	0.33	0.54	0.07
			n	4	4	4	4	4

Continued

**Table 8-19.** Continued

Box ID	Day Post-Hatch	N		Weight (grams)	Tarsus (mm)	Third Toe (mm)	Culmen (mm)	Bill Width (mm)
K 24	5	3	Mean	42.00	23.55	11.74	7.58	5.32
			SD	5.57	1.79	1.43	0.48	0.25
			n	3	3	3	3	3
	10	3	Mean	86.67	35.42	15.18	8.92	5.96
			SD	3.06	1.93	1.31	0.42	0.24
			n	3	3	3	3	3
	15	3	Mean	122.00	39.70	19.95	9.84	6.08
			SD	3.46	0.11	0.98	0.23	0.38
			n	3	3	3	3	3
	20	3	Mean	125.00	40.81	18.22	10.10	5.94
			SD	4.00	1.29	0.17	0.23	0.34
			n	3	3	3	3	3
	25	3	Mean	129.33	41.63	18.33	10.27	6.02
			SD	6.35	0.82	0.43	0.15	0.30
			n	3	3	3	3	3
K 32	5	2	Mean	44.50	24.59	11.51	7.81	4.90
			SD	7.78	4.14	2.79	0.13	0.21
			n	2	2	2	2	2
K 34	5	4	Mean	41.25	25.52	12.00	8.45	5.57
			SD	6.70	1.11	0.82	0.20	0.50
			n	4	4	4	4	4
	10	4	Mean	91.50	37.41	17.13	9.37	5.73
			SD	8.39	1.62	0.38	0.16	0.42
			n	4	4	4	4	4
	15	4	Mean	100.00	40.14	18.67	9.72	5.65
			SD	7.48	1.52	1.03	0.25	0.30
			n	4	4	4	4	4
	20	4	Mean	105.00	41.30	18.25	10.12	5.76
			SD	6.73	1.87	0.56	0.13	0.30
			n	4	4	4	4	4

Continued

**Table 8-19.** Continued

Box ID	Day Post- Hatch	N		Weight (grams)	Tarsus (mm)	Third Toe (mm)	Culmen (mm)	Bill Width (mm)
K 34 continued	25	4	Mean	105.75	41.60	18.23	10.46	5.72
			SD	5.68	1.48	0.57	0.13	0.29
			n	4	4	4	4	4
K 35	5	4	Mean	43.50	25.19	11.83	8.34	5.52
			SD	4.12	0.72	0.35	0.55	0.38
			n	4	4	4	4	4
	10	4	Mean	89.00	37.18	17.62	9.05	5.70
			SD	5.66	0.85	0.40	0.26	0.36
			n	4	4	4	4	4
	15	4	Mean	105.25	41.04	18.76	9.69	5.70
			SD	2.06	0.79	0.44	0.21	0.33
			n	4	4	4	4	4
	20	4	Mean	126.50	41.40	18.79	10.02	5.51
			SD	4.43	1.31	0.20	0.19	0.43
			n	4	4	4	4	4
	25	4	Mean	115.50	42.54	18.19	10.21	5.51
			SD	3.42	0.20	0.47	0.17	0.26
			n	4	4	4	4	4
K 43	5	5	Mean	32.40	22.06	10.92	7.63	5.07
			SD	6.11	2.31	1.07	0.20	0.35
			n	5	5	5	5	5
	10	5	Mean	75.80	34.26	15.60	8.97	5.77
			SD	7.16	2.35	1.17	0.43	0.09
			n	5	5	5	5	5
	15	5	Mean	103.40	39.53	17.84	9.97	5.76
			SD	8.88	1.30	0.29	0.58	0.25
			n	5	5	5	5	5
	20	5	Mean	115.60	40.05	18.59	10.19	5.70
			SD	6.54	1.39	0.29	0.34	0.16
			n	5	5	5	5	5

Continued

**Table 8-19.** Continued

Box ID	Day Post- Hatch	N		Weight (grams)	Tarsus (mm)	Third Toe (mm)	Culmen (mm)	Bill Width (mm)
K 43 continued	25	5	Mean	126.60	40.84	18.53	10.43	5.99
			SD	9.53	1.14	0.56	0.44	0.22
			n	5	5	5	5	5
K 46	5	4	Mean	44.75	26.21	12.76	8.26	5.37
			SD	5.12	1.33	0.88	0.46	0.40
			n	4	4	4	4	4
	10	4	Mean	84.25	37.59	17.78	9.36	5.89
			SD	7.27	1.77	0.78	0.18	0.31
			n	4	4	4	4	4
	15	4	Mean	105.50	41.05	19.02	9.95	5.74
			SD	5.51	1.19	0.94	0.24	0.35
			n	4	4	4	4	4
	20	4	Mean	107.50	41.85	18.35	10.25	5.71
			SD	8.70	1.28	0.57	0.33	0.32
			n	4	4	4	4	4
	25	4	Mean	120.00	40.93	18.19	10.74	5.81
			SD	9.59	1.97	1.02	0.25	0.34
			n	4	4	4	4	4
K 50	5	4	Mean	36.50	23.30	11.80	7.55	5.19
			SD	2.52	1.11	0.73	0.14	0.20
			n	4	4	4	4	4
	10	4	Mean	85.00	35.70	15.40	8.83	6.12
			SD	4.76	0.41	0.97	0.33	0.21
			n	4	4	4	4	4
	15	4	Mean	98.00	37.32	17.33	9.78	6.23
			SD	4.32	1.36	2.11	0.34	0.54
			n	4	4	4	4	4
	20	4	Mean	112.50	39.40	18.64	9.97	5.67
			SD	10.25	1.31	0.26	0.44	0.22
			n	4	4	4	4	4
	25	4	Mean	132.25	39.11	19.64	10.41	5.83
			SD	5.68	0.91	0.27	0.39	0.17
			n	4	4	4	4	4

**Table 8-20.** Tissue and food item metal and As concentrations from woodpecker species. Anaconda Smelter Site, 2000. Values below detection limit were replaced with half detection limits (see Table 8-1).

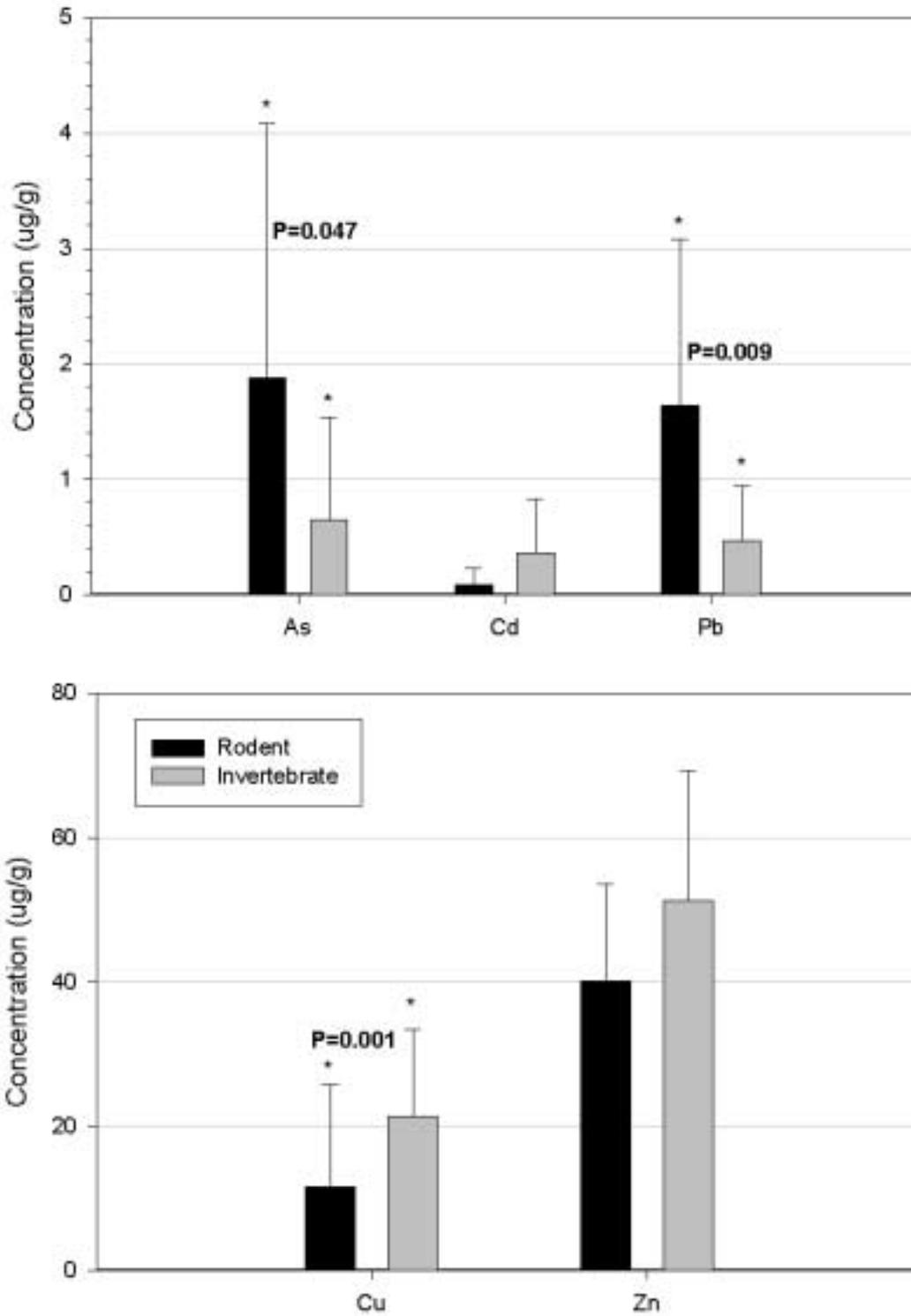
Species / Tissue Type	Box ID	N		As	Cd	Pb	Cu	Zn
				µg/g	µg/g	µg/g	µg/g	µg/g
<u>Lewis'</u> <u>Woodpecker</u>								
Liver	K 15	4	Mean	0.016	0.844	1.254	8.279	62.108
			SD	0.010	0.664	0.508	3.994	20.398
			n	4	4	4	4	4
Kidney	K 15	4	Mean	0.026	0.915	0.485	2.859	17.429
			SD	0.000	0.688	0.160	0.503	2.003
			n	4	4	4	4	4
Blood	K 15	1		0.052	0.278	0.060	0.318	5.093
<u>Flicker</u>								
Liver	K 29	2	Mean	0.034	0.240	0.307	5.295	20.577
			SD	0.011	0.048	0.056	0.789	4.872
			n	2	2	2	2	2
Kidney	K 29	2	Mean	2.901	0.319	2.460	4.665	14.633
			SD	3.232	0.089	0.700	-	-
			n	2	2	2	1	1
Food Items	K 29	2	Mean	2.833	0.262	3.610	29.705	31.331
			SD	3.109	0.092	1.377	19.447	8.603
			n	2	2	2	2	2

8.5 Kestrel Figures and List of Figures

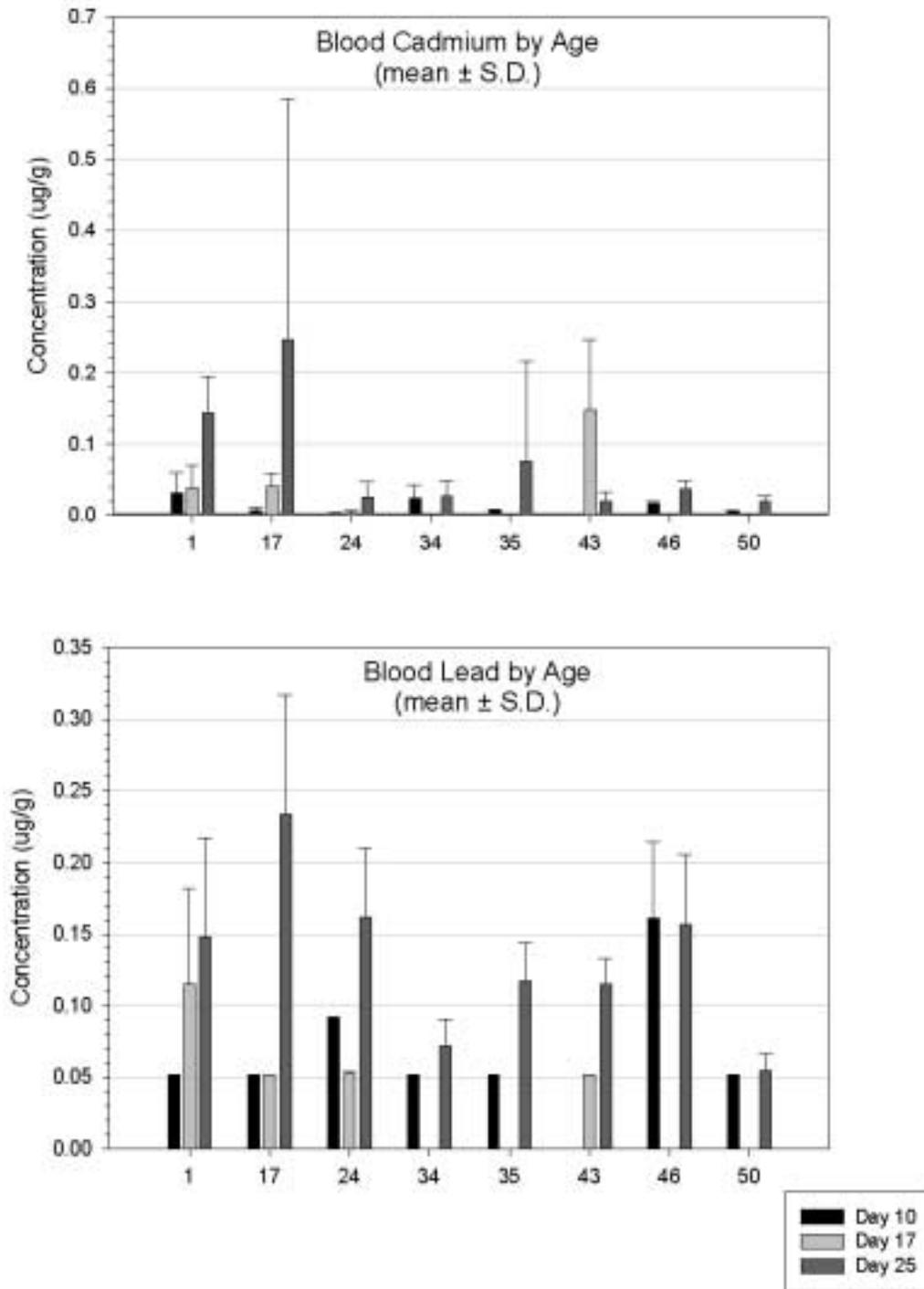
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<b>Kestrel List of Figures</b>	
<b>Figure Number</b>	<b>Figure Content</b>
8-1	Map of Kestrel Nestbox Placement
8-2	Food Type Metal and As Concentrations
8-3	Blood Metal Concentrations by Nestling Age
8-4	Hepatic Porphyrin vs. Lead Regression
8-5	Hepatic Porphyrin vs. Lead with Threshold
8-6	Kestrel Growth Curves
8-7	Blood Lead with Sub-lethal Threshold
8-8	Blood ALAD vs. Lead Regression
8-9	Blood ALAD vs. Lead with Threshold

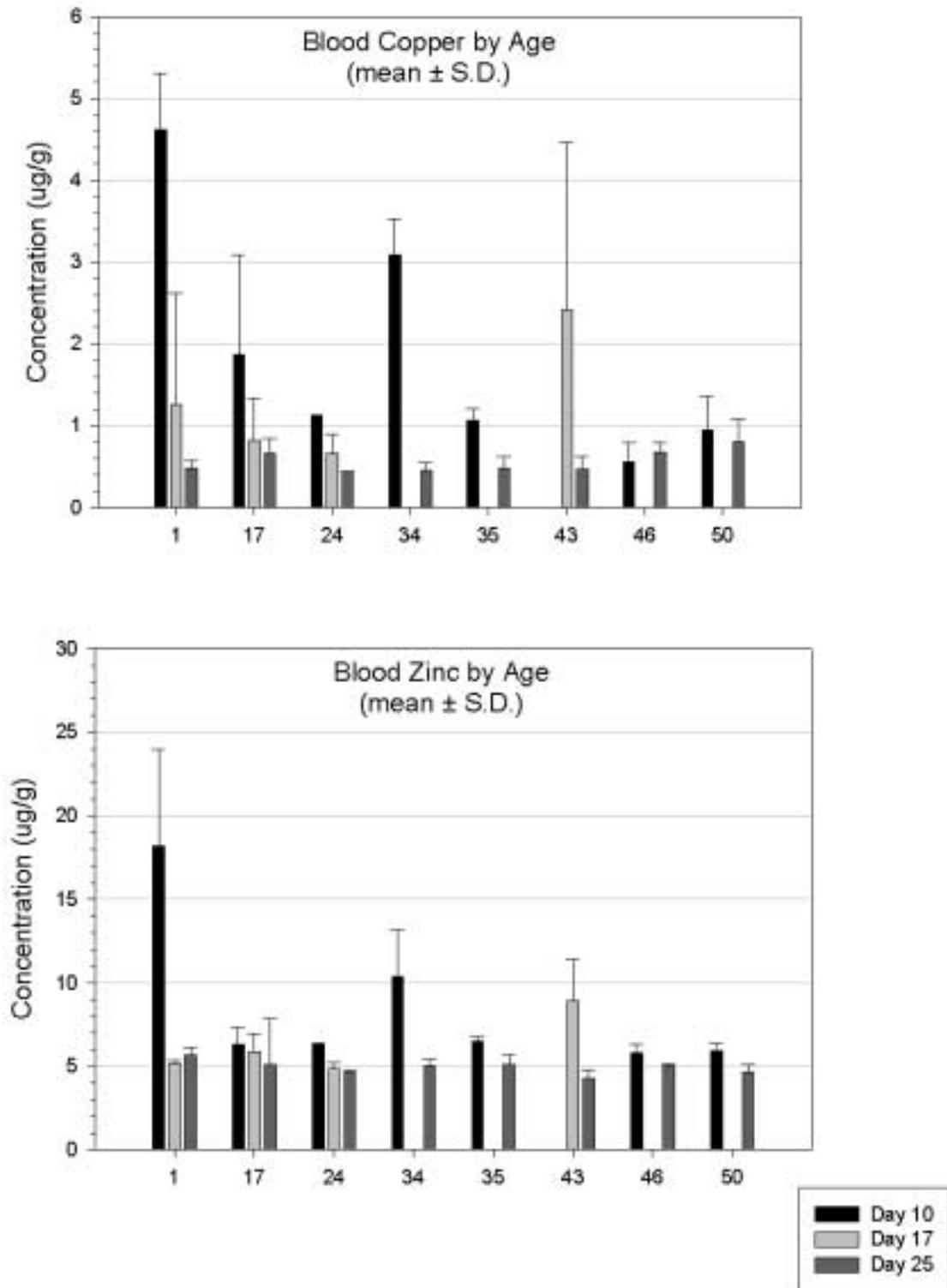




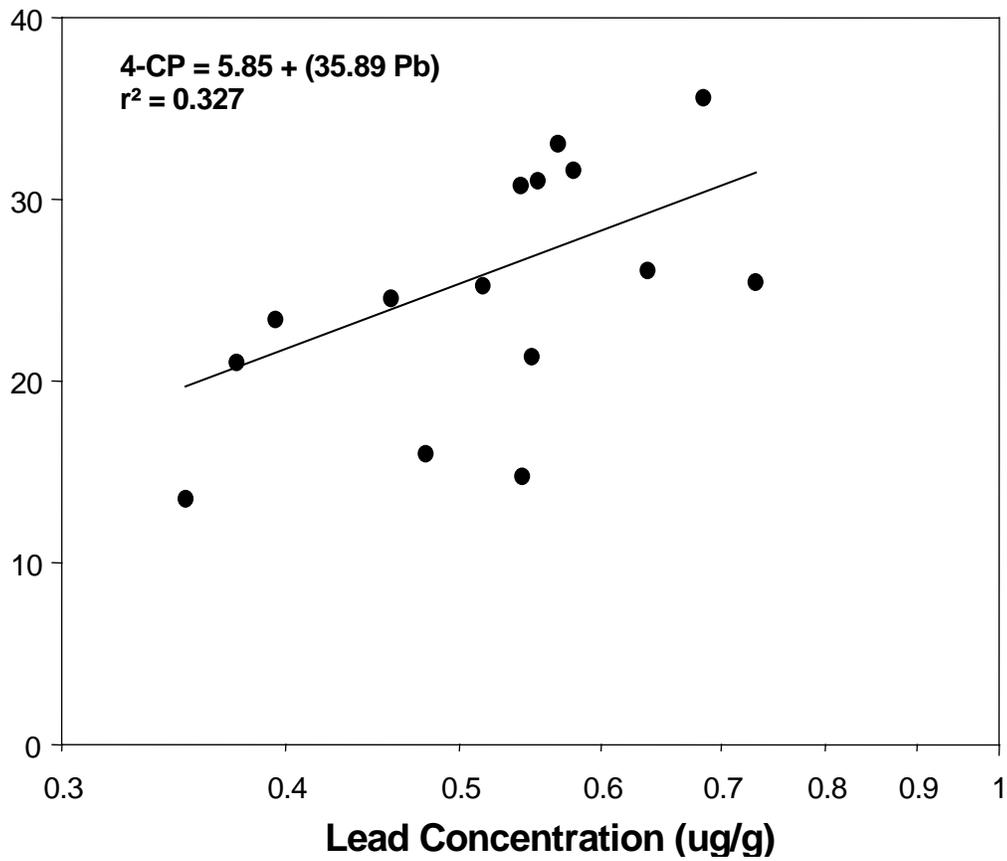
**Figure 8-2.** Carcass metal and As concentration by food item type (rodent vs. invertebrate). Significant differences ( $\alpha=0.05$ ) were detected in arsenic and lead (higher in rodents) and copper (higher in invertebrates).



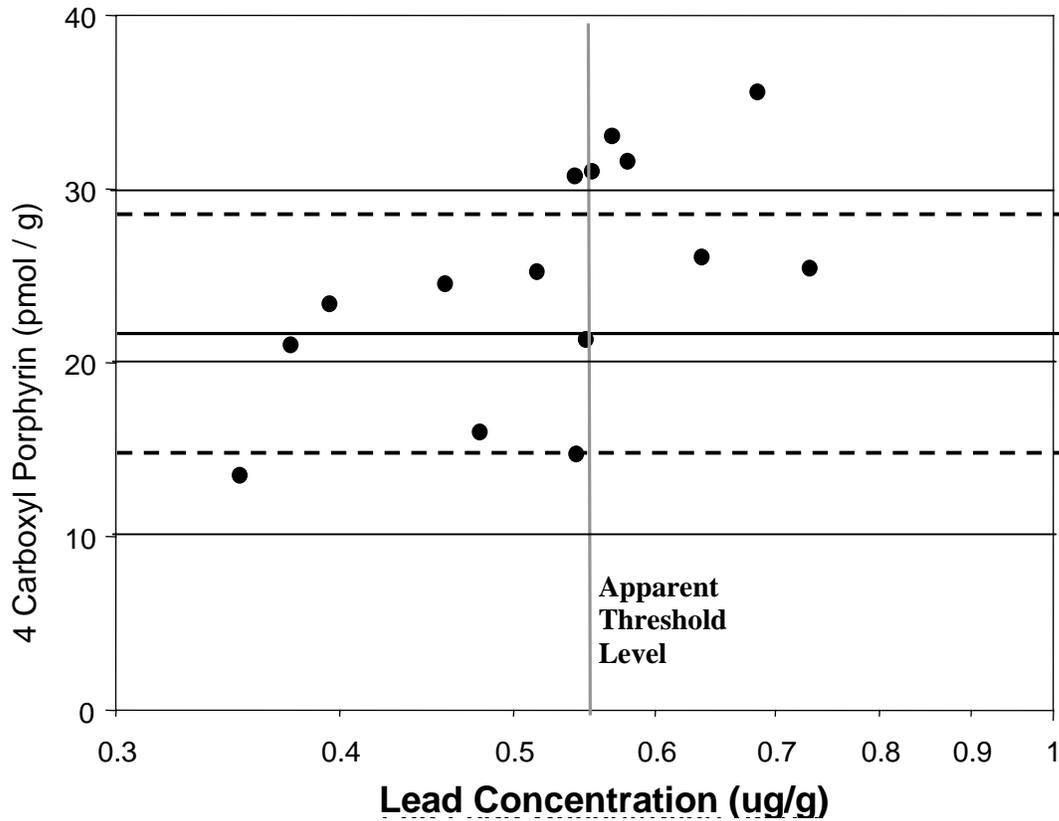
**Figure 8-3.** Mean nest box blood metal and As concentrations by age. Lead and cadmium concentrations showed increasing trends over time, with the highest blood levels occurring at day 25 for the majority of individuals.



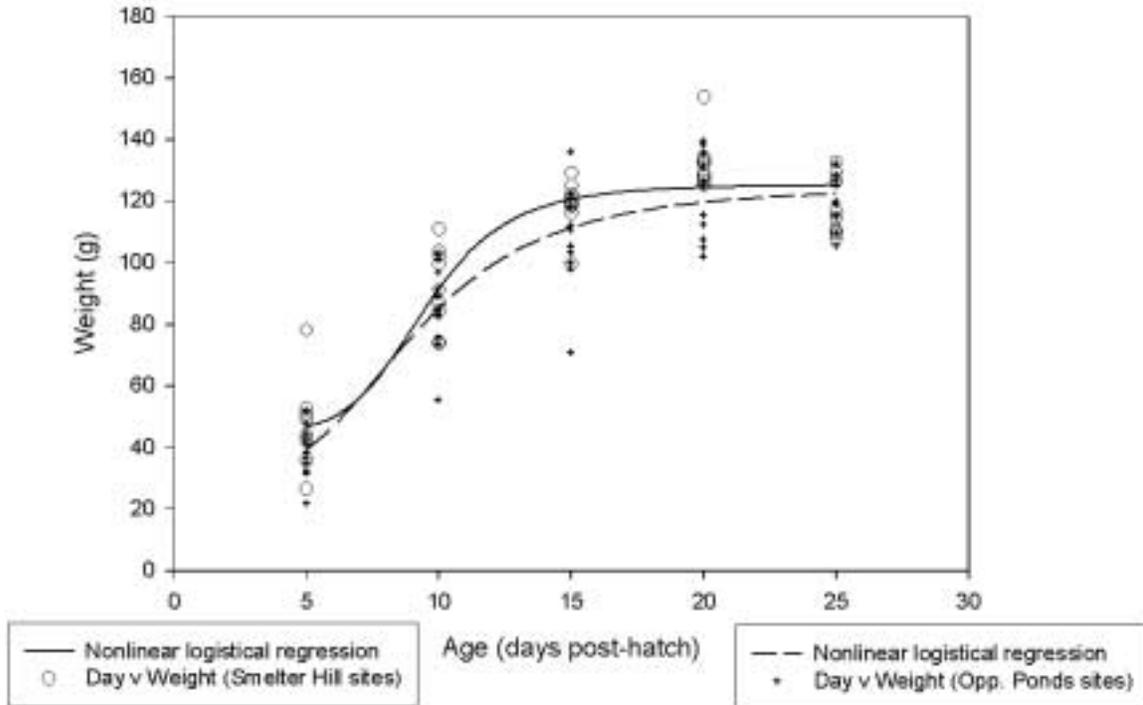
**Figure 8-3 cont.** Mean nest box copper and zinc concentrations appeared to be less regulated at earlier ages, particularly at the Smelter Hill associated sites, where the individuals are likely exposed to higher concentrations in food items.



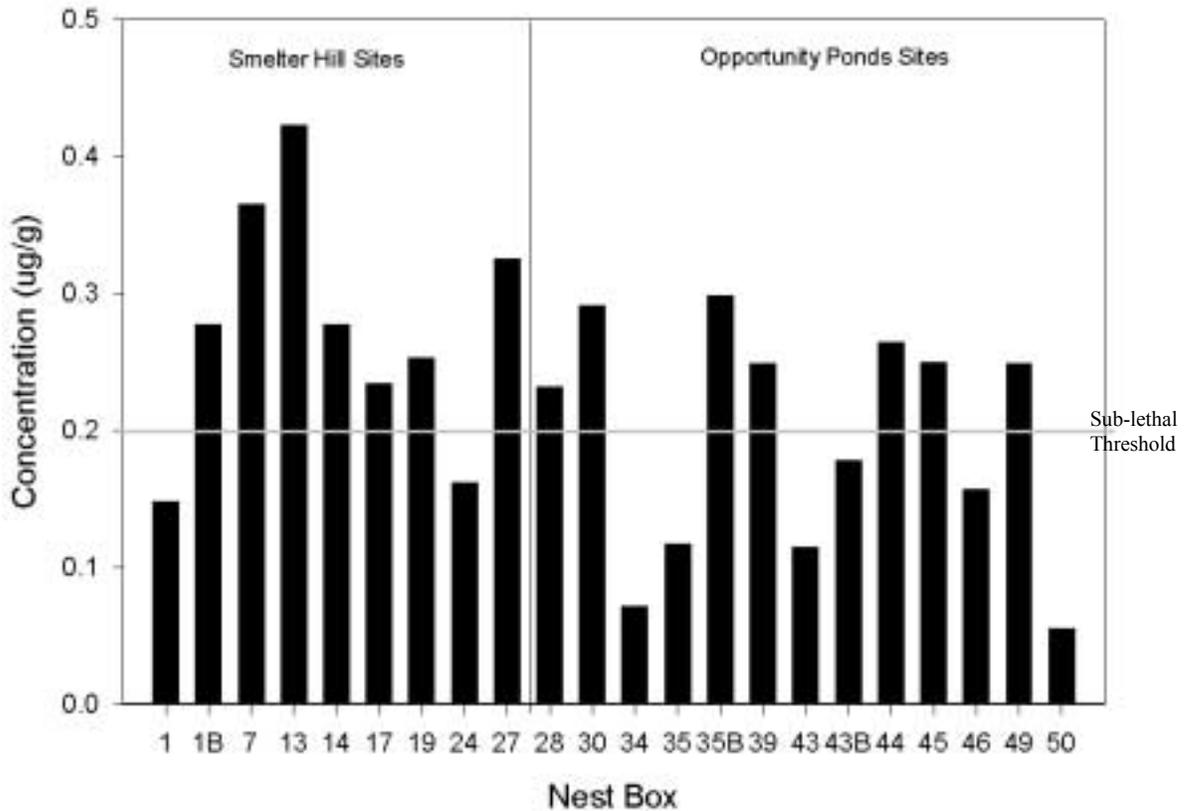
**Figure 8-4.** Hepatic Porphyrin (4-CP) as a Function of Log Lead Concentration. Thirty three percent of the variability of the hepatic 4-CP could be explained by the concentration of total lead in the liver (non-detectable lead and 4-CP outlier removed). Porphyrin responses show a distinct increase in response to increased hepatic lead concentration.



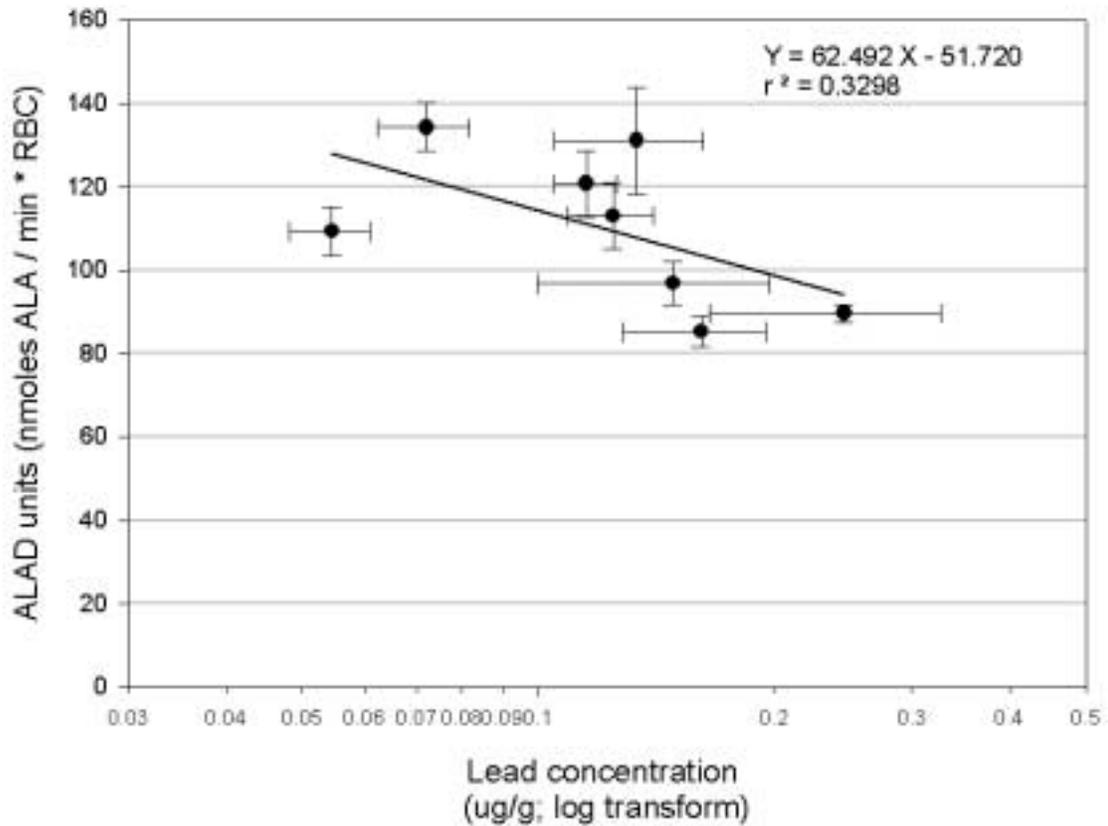
**Figure 8-5.** Hepatic Porphyrin (4-CP) vs. Hepatic Lead Concentration. A potential threshold liver lead level, indicated at approximately 0.55  $\mu\text{g/g}$ , appears to initiate increased concentrations of hepatic 4-CP. Mean ( $\pm 1$  SD) of the 4-CP values below 0.55  $\mu\text{g/g}$  ( $22.2 \pm 6.1$ ) is designated by the solid and dashed horizontal lines. The five 4-CP values with Pb concentrations greater than 0.55  $\mu\text{g/g}$  (greater than the apparent threshold) are all well above the mean, with three values above one standard deviation, indicating the occurrence of an increased porphyrin response.



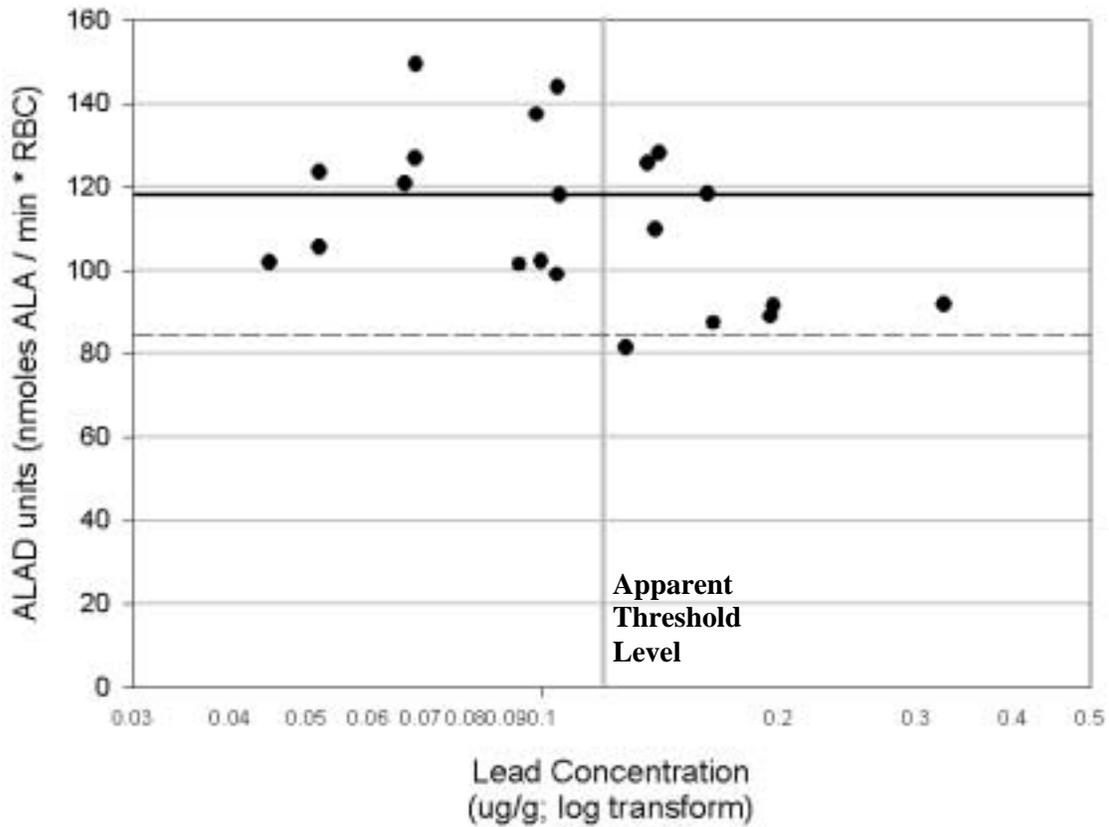
**Figure 8-6.** Growth curve estimates using nonlinear logistic regression. Growth curves compare box means of nestlings raised in Smelter Hill associated boxes to nestlings raised in Opportunity Ponds associated boxes. Nestlings from both years were grouped according to site. No significant difference was detected between curves.



**Figure 8-7.** Blood Lead Concentrations by Box Mean (Both Years). Lead concentrations were significantly greater in Smelter Hill associated sites than Opportunity Ponds associated sites. In addition, 14 of 22 box means showed lead concentrations above sub-clinical threshold levels (0.2 ppm – Franson, 1996; note - clinical effects threshold level = 1 to 1.5 ppm). These concentrations indicate the potential of developmental neurotoxicity in the nestlings.



**Figure 8-8.** Nest Box Mean ( $\pm$  SE) Blood ALAD Activity as a Function of Blood Lead. When expressed as box averages, thirty two percent of the variability of blood ALAD activity could be explained by the concentration of total blood lead. Though ALAD inhibition results were not at sufficient levels indicative for the reduction of heme synthesis, when ALAD is expressed as a function of blood lead, an initiation of enzyme inhibition at highest lead concentrations is detected.



**Figure 8-9.** Nestling erythrocyte ALAD activity vs. blood lead concentration. ALAD activity, when compared as a function of blood lead concentration, showed notable inhibition at the highest lead levels. A potential threshold blood lead level, indicated at  $\sim 0.12 \mu\text{g/g}$ , demonstrates initiation of ALAD activity inhibition. The average of ALAD values below  $0.12 \mu\text{g/g}$  is designated by the solid horizontal line (119 units). The dashed line indicates two times the standard deviation of the mean (83 units). Seven of nine individuals with lead concentrations greater than the threshold have ALAD values below the mean, with five of those below or approaching the 2SD value, indicating a trend of lead induced enzyme inhibition.

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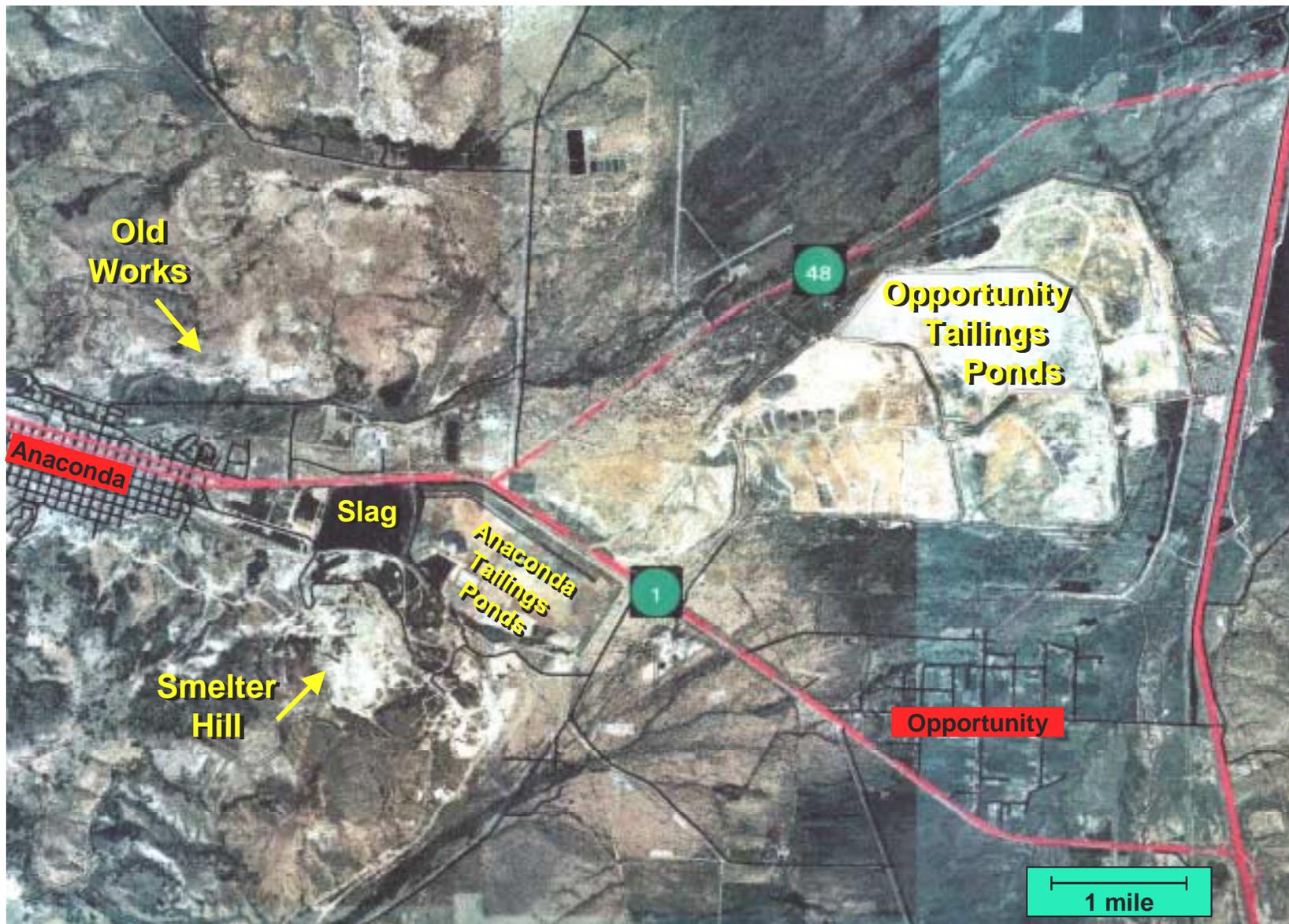
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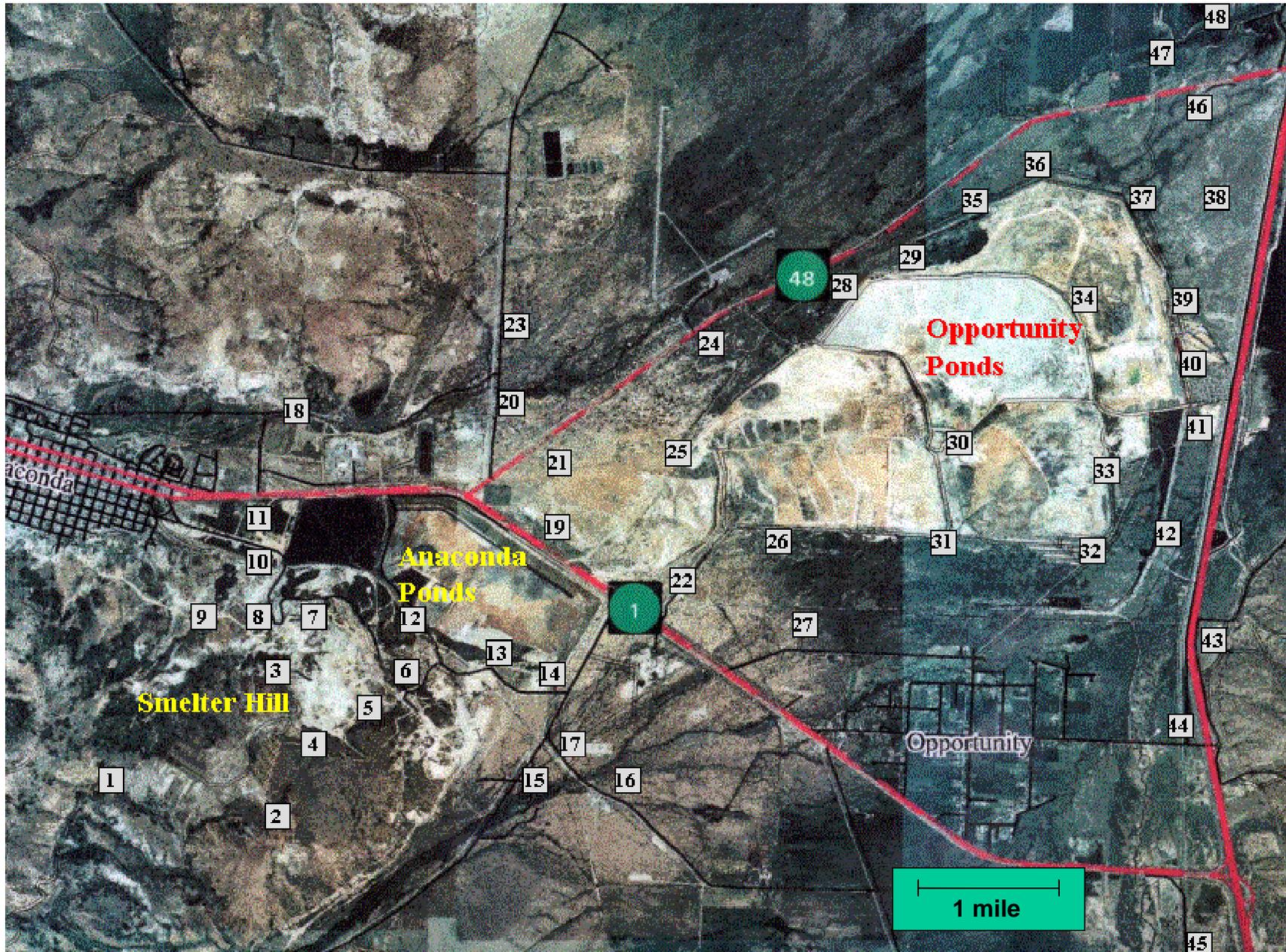
**Figure 1-1.** Aerial view of the Anaconda Smelter Site with approximate locations of major waste deposition sites and local population centers.



**Figure 6-1.** Approximate distribution of primary small mammal monitoring and trapping areas on the Anaconda Smelter Site, 1999 and 2000 field seasons. L1 and L2 were located approximately 13 km (8miles) to the north and east.



**Figure 7-1.** Map of Starling Nest Box Arrays. Yellow dots with text represent nest box arrays of 5 to 20 nest boxes. Box A – Box R are described as Site A – Site R in text.



**Figure 8-1.** Map of Kestrel Nest Box Placement. All nest box locations are indicated by number. Boxes 49 and 50 are located approximately 5km to the northeast of box 48.