FINAL

BASELINE ECOLOGICAL RISK ASSESSMENT FOR EXPOSURE TO ASBESTOS LIBBY ASBESTOS SUPERFUND SITE

PART 1
OPERABLE UNIT 3

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BERA	Baseline Ecological Risk Assessment
BCS	Biological Condition Score
BMI	Benthic Macroinvertebrate
BTAG	Biological Technical Assistance Group
BTT	Bobtail Creek Tributary
CC	Carney Creek
CSM	Conceptual Site Model
DO	Dissolved Oxygen
DQO	Data Quality Objective
EMAP	Environmental Monitoring and Assessment Program
EPA	U.S. Environmental Protection Agency
EPT	*Ephemeroptera*, *Plecoptera, Trichoptera*
ERT	Environmental Response Team
FEL	Fort Environmental Laboratory, Inc.
GI	Gastrointestinal
HBI	Hilsenhoff Biotic Index
HQ	Hazard Quotient
ISO	International Organization for Standardization
KDC	Kootenai Development Corporation
LA	Libby Amphibole
LRC	Lower Rainy Creek
MDEQ	Montana Department of Environmental Quality
MFL	Million Fibers per Liter
MMI	Multimetric Index
MNHP	Montana National Heritage Program
MFWP	Montana Fish, Wildlife, and Parks
MLE	Maximum Likelihood Estimate
NBF	Neutral Buffered Formalin
NSY	Noisy Creek
OU	Operable Unit
PAH	Polycyclic Aromatic Hydrocarbon
PCB	Polychlorinated Biphenyl
PLM	Polarized Light Microscopy
QAPP	Quality Assurance Project Plan
RBP	Rapid Bioassessment Protocol
RI	Remedial Investigation
SAP	Sampling and Analysis Plan
SVL	Snout-Vent Length
SOP	Standard Operating Procedure
TEM	Transmission Electron Microscopy
TP-TOE	Tailings Pond Toe
TTM	Time to Metamorphosis
URC	Upper Rainy Creek
USGS	U.S. Geological Survey
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service

EXECUTIVE SUMMARY

1.0 INTRODUCTION

This document is a Baseline Ecological Risk Assessment (BERA) for Operable Unit 3 (OU3) of the Libby Asbestos Superfund Site, located near Libby, Montana. The purpose of this BERA is to describe the likelihood, nature, and extent of adverse effects in ecological receptors exposed to asbestos in OU3 as a result of releases of asbestos to the environment from past mining, milling and processing activities at the Site. This information, along with other relevant information, is used by risk managers to decide whether remedial actions are needed to protect ecological receptors in OU3 from the effects of exposure to mining-related environmental asbestos contamination. If actions are warranted, the results of the BERA will be used with other relevant information to assess the appropriate remedial actions needed to protect ecological receptors.

An evaluation of potential ecological risks due to other (non-asbestos) contaminants in OU3 is presented in a separate report (EPA 2013a).

2.0 SITE CHARACTERIZATION

Overview

Libby is a community in northwestern Montana that is located near a large open-pit vermiculite mine, referred to as the Zonolite Mine. The mine began limited operations in the 1920s and was operated on a larger scale from approximately 1963 to 1990. The mine is now closed and all buildings have been removed.

Vermiculite is a naturally-occurring silicate mineral that has found a range of commercial applications such as packing material, attic and wall insulation, various garden and agricultural products, and various cement and building products.

The vermiculite ore deposit at the mine in Libby contains a form of asbestos referred to as Libby Amphibole (LA). Historic mining, milling, and processing of vermiculite at the site are known to have caused releases of vermiculite and LA to the environment. Inhalation of LA is known to have caused a range of adverse health effects in exposed humans, including workers at the mine and processing facilities as well as residents of Libby. Exposure to asbestos released to the environment may also be having adverse effects on aquatic and/or terrestrial wildlife near the mine. Based on these concerns, the U.S. Environmental Protection Agency (EPA) listed the Libby Asbestos Superfund Site on the National Priorities List in October 2002.

Given the size and complexity of the site, EPA divided the site into a series of Operable Units (OUs). This Section presents an evaluation of risks to ecological risks from exposure to LA within OU3, which includes the property in and around the Zonolite Mine and any area impacted by the release and subsequent migration of LA or other contaminants from the mine.

An evaluation of ecological risks for other OUs within the Libby Superfund Site is presented in Part 2 of the Site-wide BERA.

Physical Setting

The terrain in OU3 is mainly mountainous with dense forests and steep slopes. Figure ES-1 shows the main surface features in the vicinity of the mine. There are a number of areas where mine wastes have been disposed, including waste rock dumps (mainly on the south side of the mine), coarse tailings (mainly to the north of the mine), and fine tailings (placed in a tailings impoundment on the west side of the site). The main surface water bodies within OU3 include Rainy Creek, Fleetwood Creek, Carney Creek, the large tailings impoundment on the west side of the mine, and a smaller pond on Rainy Creek below the tailings impoundment.

Nature and Extent of LA Contamination at the Site

A large number of environmental samples from OU3 have been collected and analyzed for LA. These samples have revealed the following general conclusions:

<u>LA in Ore and Mine Wastes:</u> The concentration of LA in veins of amphibole within the vermiculite deposit can be as high as 50-75%. Concentrations of LA in mine waste samples generally are in the range of about 0.2% to 1%, although some samples may be higher.

<u>LA in Ambient Air Near the Mine:</u> LA concentrations in air near the mine are generally low, often below the detection limit. The average concentration is about 0.0002 fibers per cubic centimeter of air (f/cc). LA fibers that occur in air near the mine presumably arise due to wind or other disturbances that release fibers from existing sources (contaminated soil, tailings, waste rock, duff, etc.) into air.

<u>LA in Surface Water:</u> Concentrations of LA in surface waters of OU3 are variable, but are often in the range of 5 to 50 million fibers per liter (MFL), although some samples are higher. Concentrations tend to be highest during the high flows typically associated with the spring runoff.

<u>LA in Tailings and Sediment:</u> LA can be detected in nearly all samples of tailings and sediment from streams and ponds in OU3, with estimated concentrations ranging from less than 0.2% up to as high as 10%.

<u>LA in Forest Soil, Duff, and Tree Bark:</u> Concentrations of LA in soil, duff (forest litter), and tree bark in forest areas around the mine are variable, but show a clear tendency to decrease as a function of distance from the mine.

Ecological Setting

<u>Terrestrial Setting</u>

The mined area was heavily disturbed by past mining activity and some areas remain largely devoid of vegetation. Outside the mined area, the forested area of OU3 is suitable habitat for a wide range of terrestrial species, including a variety of mammals, birds, and reptiles.

<u>Aquatic Setting</u>

The streams and ponds within OU3 provide habitat for a range of aquatic species including fish, benthic macroinvertebrates, and amphibians. Fish surveys performed in OU3 streams indicate that the most common species of fish are western cutthroat trout, rainbow trout, and “cutbow” trout (a rainbow/cutthroat hybrid). Aquatic invertebrate community surveys in OU3 indicate that the most common types of aquatic invertebrates observed include mayflies, stoneflies, caddisflies, true flies, and beetle larvae. The most common amphibian species observed are the tree frog, spotted frog, and western toad.

3.0 PROBLEM FORMULATION

Conceptual Site Model

Based on the information that is available on the nature and extent of LA contamination in the environment in OU3 and the types of species that are known or expected to be present, it is considered likely that many species of ecological receptors, both aquatic and terrestrial, may be exposed to LA. The main focus of this risk assessment includes the following groups:

- Fish
- Benthic macroinvertebrates
- Amphibians
- Mammals
- Birds

Management Goal

The overall management goal identified for ecological receptors at the Libby OU3 site for asbestos contamination is:

> Ensure adequate protection of ecological receptors within OU3 from the adverse effects of exposures to mining-related releases of asbestos to the environment.

For most species, “adequate protection" is defined as the reduction of risks to levels that will result in the recovery and maintenance of healthy local populations and communities of biota. For threatened or endangered species, “adequate protection” is generally interpreted to mean minimizing risks to individual members of the population.

Assessment Endpoints

Assessment endpoints are the characteristics of the ecological systems that are to be protected. Because the risk management goal is formulated in terms of the protection of individuals and populations of ecological receptors, the assessment endpoints selected for use in this problem formulation focus on parameters that are directly related to the management goal. This includes:

- Mortality
- Growth
- Reproduction

If effects on these three assessment endpoints are absent or minimal, it is likely that ecologically significant effects will not occur.

Measures of Effect

There are a number of alternative measures of effect that may be investigated as part of an ecological risk assessment. The primary alternative strategies for characterizing measures of effects are described below.

Hazard Quotients

For most environmental contaminants, the first line of investigation is usually the Hazard Quotient (HQ) Approach. A Hazard Quotient (HQ) is the ratio of the estimated exposure of a receptor to a "benchmark" exposure that is believed to be without significant risk of unacceptable adverse effect. However, there are no established benchmarks for the evaluation of ecological receptors to any form of asbestos, and most of the studies that are available that might potentially serve as a basis for development of a benchmark are based on studies of chrysotile asbestos rather than amphibole asbestos. Consequently, HQ values were not calculated for any exposure scenario, and ecological investigations of the potential effects of LA on ecological receptors in OU3 focused on other measures of effect, as discussed below.

Site-Specific Toxicity Tests

Site-specific toxicity tests measure the response of receptors that are exposed to site media. This may be done either in the field (*in situ*) or in the laboratory using media collected from the site. The chief advantage of either type of study is that site-specific conditions that can influence toxicity are usually accounted for, and that the cumulative effects of all exposure pathways to the medium and all contaminants in the medium are evaluated simultaneously. One potential limitation of this approach is that, if toxic effects are observed when test organisms are exposed to site media, it may not be possible to specify which contaminant or combination of contaminants is responsible for the effect without further testing or evaluation. A second limitation is that it may be difficult to perform tests on site samples that reflect the full range of environmental conditions which may occur in the field across time and space, so it may not be possible to fully identify all conditions that are and are not of concern.

Population and Community Demographic Observations

Another approach for evaluating possible adverse effects of environmental contamination on ecological receptors is to make direct observations on the receptors in the field, seeking to determine whether any receptor population has unusual numbers of individuals (either lower or higher than expected), or whether the diversity (number of different species) of a particular category of receptors is different than expected. The chief advantage of this approach is that observation of community status relate directly to the management goal (protection of populations). However, there are also a number of limitations to this approach. The most important of these is that both the abundance and diversity of a receptor depend on many site-specific factors (habitat suitability, availability of food, predator pressure, natural population cycles, meteorological conditions, etc.), and it is often difficult to know what the expected (non-impacted) abundance and diversity should be in a particular area. This problem is generally approached by seeking an appropriate "reference area" (either the site itself before the impact occurred, or some similar site that has not been impacted), and comparing the observed abundance and diversity in the reference area to that for the site. However, it is sometimes difficult to locate reference areas that are a good match for all important habitat and ecological characteristics.

In-Situ Measures of Exposure and Effects

An additional approach for evaluating the possible adverse effects of environmental contamination on ecological receptors is to make direct observations on receptors in the field, seeking to determine if individuals residing in areas of contamination have an increased frequency and/or severity of lesions and/or deformities compared to organisms residing in uncontaminated reference areas. This method has the advantage of integrating most factors that influence the true level of exposure and toxicity of contaminants in the field. However, if an increased incidence or severity of lesions is observed, it may not be possible to identify with certainty which environmental contaminant(s) is (are) responsible, and it may also be difficult to determine with confidence whether the observed lesions are likely to cause an ecologically significant population-level impact.

Weight of Evidence Evaluation

As noted, each of these alternative strategies for characterizing ecological risks has some advantages and some limitations. Because of this, the risk assessment for OU3 sought to collect information from two or more lines of evidence whenever feasible. If two or more lines of evidence are available, and if the lines of evidence are in general agreement, then confidence in risk conclusions is increased. If two or more lines of evidence do not agree, then careful attention must be given to likely reasons for the disparity, and to decide which line(s) of evidence provide the highest confidence.

Detailed descriptions of the studies performed to investigate potential risks to each group of exposed receptors are presented in Section 4 (fish), Section 5 (benthic macroinvertebrates), Section 6 (amphibians), Section 7 (mammals), and Section 8 (birds) of the main risk assessment. The weight of evidence conclusions are summarized below.

4.0 RISKS TO FISH

Four lines of evidence are available to help evaluate the effects of exposure of fish to LA in site waters, including:

- *In situ* toxicity studies of eyed eggs and alevins
- *In situ* toxicity tests of juvenile trout
- Fish population studies
- Resident fish lesion studies

The population studies indicates that trout population structure in LRC is different from reference streams, with decreased fish density, increased fish size, and decreased biomass. This observation could be consistent with a hypothesis that LA in site waters is toxic to trout and results in a decreased number of fish, but several observations suggest that LA is not the likely cause of the difference:

- There are several habitat quality factors that are lower in LRC than reference streams (especially spawning gravel, woody debris, water temperature, and pool availability). These habitat factors show a relatively strong correlation with trout density, suggesting that habitat likely accounts for much of the apparent difference.
- *In situ* toxicity studies of early life stage trout indicate there might be a small decrease in hatching success of eyed eggs in lower Rainy Creek than in reference streams, but this cannot be attributed to LA. Moreover, the difference is sufficiently small (<10%) that a substantial effect on population density would not be expected (Toll et al. 2013).
- No effects that might contribute to decrease survival of larger fish have been detected, either in caged juvenile fish studies or studies of resident fish. This is consistent with numerous other studies which indicate that early life stages of fish are usually more sensitive to toxicants that larger fish.

Taken together, the weight of evidence suggests that LA in waters of LRC is not causing adverse effects on resident trout. By extension, effects of LA on fish in the Kootenai River (including sensitive species such as the white sturgeon and bull trout) are therefore not of concern, since concentrations of LA in the Kootenai River are substantially lower than in LRC.

Confidence in this conclusion is medium to high. However, observations from the *in situ* exposure studies are limited to the conditions and concentration values that occurred during the studies, and if substantially higher concentrations were to occur in other years, the consequences, if any, cannot be predicted. While observations from fish population surveys are often variable between years, results at this site were relatively consistent across two years, so confidence in these studies is good.

5.0 RISKS TO BENTHIC MACROINVERTEBRATES

Two lines of evidence are available to evaluate effects of site contaminants on benthic macroinvertebrates, including:

- Laboratory-based site-specific sediment toxicity tests in two species of organism (*H. azteca*, and *C. tentans)*
- Site-specific benthic community population studies, augmented with habitat quality studies

The site-specific sediment toxicity tests indicate that effects on growth and reproduction were not apparent in *H. azteca*, and were minor in *C. tentans*. However, an effect of site sediment on survival was noted in both species, with *C. tentans* being more impacted (9-25% decrease) than *H. azteca* (4-6% decrease). It is difficult to judge if LA is the likely cause, because quantitative estimates of LA concentration in the two site sediments are sufficiently uncertain that the presence of a dose-response relationship cannot be ascertained. Even if LA is the cause, the applicability of these results to other species, and hence the potential magnitude of effects on the benthic invertebrate community as a whole, are difficult to judge from this line of evidence alone, and are best determined by evaluating the site specific population studies presented below.

The site-specific population studies suggest that benthic macroinvertebrate communities along lower Rainy Creek may occasionally rank as slightly impaired compared to off-site reference locations, but are not impaired compared to upper Rainy Creek. The differences are not extensive and might be due, at least in part, to differences in habitat quality.

Taken together, these findings support the conclusion that LA contamination in lower Rainy Creek may be causing small to moderate effects on survival of some species, but the overall benthic macroinvertebrate community is not substantially impacted.

Confidence in this conclusion is medium to high. One potential limitation to the site-specific studies is that the test species are not expected to occur in mountain streams, and native species (mainly mayflies, stoneflies, caddisflies, true flies, and beetle larvae) might have differing sensitivities. While benthic community and habitat surveys often display considerable variability between years, in this case the results are relatively consistent between two years, providing good confidence in the survey results.

6.0 RISKS TO AMPHIBIANS

Two lines of evidence are available to evaluate potential effects of LA on amphibians in OU3:

- A site-specific laboratory-based sediment toxicity test
- A field survey of gross and histologic lesion frequency and severity in amphibians collected from OU3 and from reference areas

The site-specific sediment toxicity test did not produce any signs of overt toxicity in any organisms exposed to OU3 sediment. Both survival and growth were higher in organisms exposed to OU3 sediment than for a reference sediment. The only observation of potential concern was an apparent increase in the time to metamorphosis for some organisms that were exposed to OU3 sediment. The ecological significance of this apparent lag in the final stages of development is not certain, but assuming the effect is only a lag (as opposed to an actual cessation of development), it is suspected the effects would likely not be ecologically meaningful. However, it is plausible that the delay might become important if ponds in high exposure areas were to dry up during this critical stage of development.

The survey of external and histological lesions in field-collected organisms indicates that lesions in organisms from OU3 are not more frequent or more severe that in organisms from reference sites, and that all lesions observed are likely the result of parasitism rather than asbestos exposure. This supports the conclusion that LA is not causing any external or internal malformations of concern.

Taken together, these findings support the conclusion that sediments and waters in OU3 are not likely to be causing any ecologically significant adverse effects on amphibian populations.

Confidence in this conclusion is medium to high. The most significant uncertainty is whether the apparent delay in the final stages of metamorphosis might be of concern. Further studies would be need to determine if the apparent lag in final stage development is reproducible, and whether complete metamorphosis is ultimately achieved in exposed organisms.

7.0 RISKS TO MAMMALS

One line of evidence is available to evaluate risks to mammals from LA contamination in forested areas near the mine:

- An evaluation of lesion prevalence and severity in mice captured from OU3 compared to mice from a reference area

This is considered to be a relatively strong line of evidence because a) mice are likely to have high exposure to LA in duff and soil, b) the area selected for study was at the high end of LA contamination observed in duff, and c) the mice collected would have been exposed by all relevant exposure routes (inhalation, ingestion of soil, ingestion of food items).

Although the prevalence or mean severity of some types of lesions was higher in mice from OU3 than the reference area, none of the lesions were judged to be attributable to LA exposure, none were judged to be associated with significant decrements to overall animal health, and no evidence of meaningful differences in body size or age of the mice was detected. Based on this, it is considered likely that LA exposures in OU3 are not causing any ecologically significant effects on populations of small mammals residing in the forest areas of OU3.

Confidence in this conclusion is high. However, there are several uncertainties in extrapolation of the results from this study to other mammals that may be exposed in OU3, including the following:

- Larger mammals generally have longer life spans than mice, and consequently might have higher cumulative exposures than mice. Because effects of inhalation exposure to asbestos are usually found to be related to cumulative exposure in humans and laboratory animals (ATSDR 2001), this raises the possibility that risk of effect might be higher in larger mammals with longer lifespans than mice. However, numerous studies have shown that while effects of asbestos exposure in humans usually take many years to develop, the same effects occur in rats and mice within 1-2 years (ATSDR 2001). Moreover, home range is often much larger for large mammals than small mammals, so longer-lived species such as deer, elk, bear, lynx, etc., would generally be expected to spend only a fraction of their lifespan in the impacted areas near the mine, thereby reducing their tendency for exposure. Although uncertain, there is no compelling evidence to presume that mammals with longer life spans than mice would likely be more at risk than mice.
- The mice that were evaluated were trapped in an area near the mine where concentration levels of LA in duff are at the high end of the range that has been observed in the forest area. However, LA levels on the mine site itself are likely higher due to the presence of LA veins in the ore body as well as in waste rock and tailing deposits onsite. Consequently, mammals residing in the mined area (as opposed to the forest area around the mine) may have higher exposures.

8.0 RISKS TO BIRDS

One line of evidence is available to evaluate the effect of LA exposure on birds exposed in OU3:

- A literature-based evaluation of the relative sensitivity to the effects of inhaled particulates in birds compared to mammals.

Based on the available information, it is concluded that birds are not more sensitive, and are probably less sensitive, to the effects of inhaled particulates than mammals. Because a site-specific study of the effects of LA on small mammals did not detect any evidence for increased incidence or severity of asbestos-related lesions in the respiratory tract (see above), it is concluded that ecologically significant adverse effects are not likely to be of ecological concern in populations of birds exposed to LA in OU3. Although a comparable comparative study was not attempted with regard to relative sensitivity by the oral exposure route, because no effects were noted in the gastrointestinal system of mice exposed in OU3, there is no reason to expect that effects in the gastrointestinal system of birds would be of concern.

Confidence in this conclusion is medium. However, in the absence of direct studies of birds from OU3, several possible uncertainties remain including the following:

- The relative LA exposure levels of birds compared to mice in OU3 is not certain. It is assumed that of the wide variety of bird species that occur in OU3, ground foraging birds with small home ranges would tend to be most exposed, both by inhalation of fibers released to air and by ingestion of prey or food items capture in duff or soil. However, considering that mice are likely exposed nearly continuously in the duff or soil, while birds are likely to be exposed only while foraging, and would likely have low exposure while in trees or bushes, it is considered likely that birds are not more exposed, and might be less exposed, than mice.
- Much of the available information on the relative effects of inhaled particulates in birds is derived from studies of domestic poultry (chickens, ducks). Respiratory demands in wild birds may tend to be higher than in domestic fowl, which might tend to increase exposure. However, wild birds tend to be more robust than domestic fowl, which would tend to decrease sensitivity. Moreover, the basic physiology of the respiratory system is the same in both domestic and wild birds, so the conclusion that birds are not likely to be more sensitive than mammals is considered to be reliable.

9.0 SUMMARY AND CONCLUSION

EPA planned and performed a number of studies to investigate whether ecological receptors in OU3 of the Libby Asbestos Superfund Site were adversely impacted by the presence of LA in the environment.

Studies of fish, benthic invertebrates, and amphibians exposed to LA in surface water and/or sediment revealed no evidence of ecologically significant effects that were attributable to LA. Likewise, in the terrestrial environment, a study of mice exposed to LA in soil and duff in an area of high LA contamination revealed no evidence of effects attributable to LA. These studies indicate that ecological receptors are unlikely to be adversely impacted by LA released to the aquatic or terrestrial environments by previous vermiculite mining and milling activities.

Although there are some uncertainties and limitations associated with this conclusion, these uncertainties do not result in significant uncertainty in the overall finding that ecological receptors in OU3 are unlikely to be adversely impacted by LA released to the environment by previous vermiculite mining and milling activities.

1.0 INTRODUCTION

1.1 Purpose of this Document

This document is a Baseline Ecological Risk Assessment (BERA) for Operable Unit 3 (OU3) of the Libby Asbestos Superfund Site, located near Libby, Montana. The purpose of this BERA is to describe the likelihood, nature, and extent of adverse effects in ecological receptors exposed to asbestos in OU3 as a result of releases of asbestos to the environment from past mining, milling and processing activities at the site. This information, along with other relevant information, is used by risk managers to decide whether remedial actions are needed to protect ecological receptors in OU3 from the effects of exposure to mining-related environmental asbestos contamination. If actions are warranted, the results of the BERA will be used with other relevant information to assess the appropriate remedial actions needed to protect ecological receptors.

An evaluation of potential ecological risks due to other (non-asbestos) contaminants in OU3 is presented in a separate report (EPA 2013a).

1.2 Document Organization

In addition to this introduction, this report is organized into the following main sections.

- Section 2 - This section describes the location, history, and environmental setting of OU3, including information on the nature and extent of asbestos contamination in the environment.
- Section 3 - This section presents the ecological problem formulation, including the site conceptual model for exposure to asbestos, the selection of assessment endpoints, and a description of the measures of effect used to characterize the effects of asbestos exposure.
- Section 4 - This section presents the risk characterization for fish.
- Section 5 - This section presents the risk characterization for benthic macroinvertebrates.
- Section 6 - This section presents the risk characterization for amphibians.
- Section 7 - This section presents the risk characterization for mammals.
- Section 8 - This section presents the risk characterization for birds.
- Section 9 - This section provides citations for all data, methods, studies, and reports utilized in the BERA.

All tables and figures are presented at the end of the document (following the references).

All site-specific study reports that provide data used in the risk assessment are provided electronically in Attachment D.

2.0 SITE CHARACTERIZATION

2.1 Overview

Libby is a community in northwestern Montana (see Figure 2-1 Panel A) that is located near a large open-pit vermiculite mine (Figure 2-1 Panel B). The mine began limited operations in the 1920s and was operated on a larger scale by the W.R. Grace Company (Grace) from approximately 1963 to 1990. Before the mine closed in 1990, Libby produced approximately 70-80% of the world's supply of vermiculite.

Vermiculite is a naturally-occurring silicate mineral that exhibits a sheet-like structure similar to mica. When heated to approximately 870°C, water molecules between the sheets change to vapor and cause the vermiculite to expand like popcorn into a light porous material. This process of expanding vermiculite is termed "exfoliation" or "popping." Both unexpanded and expanded vermiculite have found a range of commercial applications, the most common of which include packing material, attic and wall insulation, various garden and agricultural products, and various cement and building products.

The vermiculite ore deposit at the mine in Libby contains a form of asbestos referred to as Libby Amphibole (LA). Historic mining, milling, and processing of vermiculite at the Site are known to have caused releases of vermiculite and LA to the environment. Inhalation of LA is known to have caused a range of adverse health effects in exposed humans, including workers at the mine and processing facilities (McDonald et al. 1986a, McDonald et al. 1986b, Amandus and Wheeler 1987, McDonald et al. 2004, Whitehouse 2004, Sullivan 2007, Rohs et al. 2007, Larson et al. 2010a, 2010b, 2012a), as well as residents of Libby (Peipins et al. 2003, Whitehouse et al. 2008, Larson et al. 2012b, Antao et al. 2012). Exposure to asbestos released to the environment may also be having adverse effects on aquatic and/or terrestrial wildlife near the mine.

Based mainly on concerns for public health, the U.S. Environmental Protection Agency (EPA) listed the Libby Asbestos Superfund Site on the National Priorities List in October 2002. Given the size and complexity of the site, EPA divided the site into a series of Operable Units (OUs). This document focuses on Operable Unit 3 (OU3), which is defined as follows:

> OU3 includes the property in and around the Zonolite Mine owned by W.R. Grace or Grace-owned subsidiaries (excluding OU2) and any area (including any structure, soil, air, water, sediment or receptor) impacted by the release and subsequent migration of hazardous substances and/or pollutants or contaminants from such property, including, but not limited to, the mine property, the Kootenai River and sediments therein, Rainy Creek, Rainy Creek Road and areas in which tree bark is contaminated with such hazardous substances and/or pollutants and contaminants.

Because the extent of mine-related contamination in tree bark could not be determined until data were collected, EPA established an initial study area for OU3, as shown by the red line in Figure 2-2.

2.2 Physical Setting

2.2.1 Topography

The terrain in OU3 is mainly mountainous with dense forests and steep slopes. Based on the USGS topographic map of the area[1], the mined area is at an elevation of about 3,400 to 4,200 feet, and the Kootenai River is at an elevation of about 2,100 feet.

2.2.2 Land Ownership or Stewardship

OU3 is located within the Kootenai National Forest. Current land ownership in the area is shown in Figure 2-3. Kootenai Development Corporation (KDC), a subsidiary of Grace, owns about 3,500 acres of land that includes the mine and the surrounding area to a distance of about 1 mile. Land surrounding the KDC property is mainly within the Kootenai National Forest and is managed by the U.S. Forest Service. Some land parcels are owned by the State of Montana and some are owned by Plum Creek Timberlands LP for commercial logging. Small areas of private properties near the southern border of the OU3 study area are included in OU4 rather than OU3.

2.2.3 Climate

Northern Montana has a climate characterized by relatively hot summers, cold winters, and low precipitation. Figure 2-4 presents temperature and precipitation data[2] collected at the Libby NE Ranger Station, which is located just west of the town of Libby near the Kootenai River. As indicated, long-term (100-year) average summer high temperatures (degrees Fahrenheit) are in the upper 80s, and long-term average low temperatures are in the 40s. Long-term average winter high temperatures are in the 30s, with average lows less than 20. The western mountain ranges cause Pacific storms to drop much of their moisture before they reach the area, resulting in relatively low precipitation, averaging about 18 inches total per year. The most abundant rainfall occurs in late spring and early summer. In the winter months, snowfall averages 54 inches per year and snow cover typically remains on the ground from November through March.

A meteorological station was installed at the mine site in January 2007, and data are available for seven years of monitoring (through December 2013). Figure 2-5 is a wind rose that summarizes the average speed and direction of winds at the mine over this time interval. As indicated, the

[1] http://www.mytopo.com/products/quad.cfm?code=o48115d5
[2] http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?mtlibb

winds blow predominantly (about 45% of the time) from the southwest toward the northeast, usually at speeds of less than 17 knots (19.5 mph). Winds in the opposite direction (from northeast to southwest) occur about 15% of the time, usually at speeds less than 10 knots (11.5 mph).

2.2.4 Surface Water Features

The mine is located within the Rainy Creek watershed, an area of approximately 17.8 square miles. Figure 2-6 shows the main surface water features of OU3. Primary surface water bodies include:

- Rainy Creek originates between Blue Mountain and the north fork of Jackson Creek at an elevation of about 5,000 feet, and falls to an elevation of 2,080 feet at the confluence with the Kootenai River (Zinner 1982). The average gradient for Rainy Creek is about 12% (Parker and Hudson 1992), and the banks are well vegetated (MWH 2007). The reach of Rainy Creek that occurs up-gradient of the mine site is referred to as Upper Rainy Creek (URC), while the reach adjacent to and down-gradient of the mine site is referred to as Lower Rainy Creek (LRC).

- Fleetwood Creek flows westward along the northern edge of the mined area. The average stream gradient for Fleetwood Creek is about 11% (Parker and Hudson 1992). Under current site conditions, Fleetwood Creek flows through a portion of mine waste before discharging into a large tailings impoundment which was constructed within the former Rainy Creek channel (see below). A small ponded area was identified along Fleetwood Creek during reconnaissance surveys by EPA in 2007.

- Carney Creek flows westward along and through mine waste on the southern side of the mined area before joining Rainy Creek. A small pond is present that was formed when waste piles were deposited in the drainage and blocked the flow of the creek. The pond is vegetated on one side. Several small springs are reported along Carney Creek (Zinner 1982).

- Tailings Impoundment. In 1972, Grace constructed a tailings impoundment (also referred to as the tailings pond) along Rainy Creek to receive tailings produced by a new wet milling process and to recover water for reuse. The height of the dam which forms the impoundment is about 135 feet. The impoundment occupies 70 acres. The impoundment receives water from both upper Rainy Creek and Fleetwood Creek. The impoundment drains through 12 toe drains directly into lower Rainy Creek, and may also discharge to lower Rainy Creek via an overflow channel during high flow events (Parker and Hudson 1992).

- Mill Pond. A pond in the Rainy Creek channel downstream of the tailings impoundment was constructed to provide a water supply for mining operations. This pond, sometimes referred to as the Lower Pond, discharges to Rainy Creek where it mixes with flow from Carney Creek and flows downstream to the Kootenai River.

- Kootenai River. The Kootenai River flows from east to west along the south side of OU3. Flows in the Kootenai River are controlled by the Libby Dam, which was constructed in the late-1960s and early-1970s as part of the Columbia River development for flood control, power generation, and recreation. Daily water flow from the dam[3] generally ranges from 4,000 to 12,000 cubic feet per second (cfs), with maximum discharge flows in late May/early June up to 30,000 cfs.

2.3 Current Condition of the Mine Site

Figure 2-7 shows an aerial view of the current condition of the mine site and the main surface features. As indicated, the mined area was heavily disturbed by the open-pit mining activities, and some areas remain largely devoid of vegetation. There are a number of areas where mine wastes have been disposed, including waste rock dumps (mainly on the south side of the mine), coarse tailings (mainly to the north of the mine), and fine tailings (placed in the tailings impoundment on the west side of the site). All former buildings and mine works at the site have been demolished and removed.

2.4 Nature and Extent of LA Contamination at the Site

2.4.1 Mineral Characteristics of LA

Asbestos is the generic name for a group of naturally-occurring silicate minerals that crystallize in long thin fibers. The basic chemical unit of asbestos is $[SiO4]^{-4}$. This basic unit consists of four oxygen atoms at the apices of a regular tetrahedron surrounding and coordinated with one silicon ion (Si^{+4}) at the center. The silicate tetrahedra can bond to one another through the oxygen atoms, leading to a variety of crystal structures. Different forms of asbestos differ from each other in their crystal structures, and also in the types of cations that bind to the un-bonded oxygen atoms along the silicate chains (EPA 2014).

The U.S. Geological Survey (USGS) performed electron probe micro-analysis and X-ray diffraction analysis of 30 samples obtained from exposed asbestos veins at the mine to identify the type of asbestos present (Meeker et al. 2003). The results indicated that there were several mineral varieties of amphibole asbestos present, including winchite, richterite, tremolite, and magnesioriebeckite. Meeker et al. (2003) noted that, depending on the valence state of iron and

[3] http://waterdata.usgs.gov/mt/nwis/inventory?search_site_no=12301933

data reduction methods utilized, some minerals may also be classified as actinolite. The EPA refers to this mixture of amphibole asbestos minerals as Libby Amphibole asbestos (LA).

2.4.2 Concentrations of LA in Environmental Media

As part of the Remedial Investigation (RI) in OU3, Grace and their contractors, working in cooperation with EPA and with EPA oversight, have collected a large number of environmental samples and analyzed them for LA. All of the sampling and analytical methods have been planned in Sampling and Analysis Plans (SAPs) with associated Quality Assurance Project Plans (QAPPs) and detailed Standard Operating Procedures (SOPs) for sampling and analysis methods. Consequently, all data collected under these governing SAP/QAPPs/SOPs are considered to be appropriate for use in the risk assessment, unless otherwise noted.

Overview of Sampling and Analysis Methods

Air and Water

Samples of air and water are typically collected by drawing a known volume of air or water through a filter, and then examining the filter under a microscope to determine the number of asbestos fibers in the sample. For studies in OU3, analysis was performed using transmission electron microscopy (TEM) in basic accord with the counting and recording rules specified in International Organization for Standardization (ISO) 10312 (ISO 1995). A particle is identified as an LA fiber if it satisfies the following three criteria:

- *Morphology:* The particle is elongated with roughly parallel sides, a length ≥ 0.5 μm, and an aspect ratio (length/width) > 3:1
- *Crystallography:* The particle has an X-ray diffraction pattern consistent with amphibole asbestos
- *Chemistry:* the particle has an energy dispersive X-ray spectrum consistent with known samples of LA from the mine (SRC 2008)

Results are generally expressed as fibers per cubic centimeter (f/cc) in air, or million fibers per liter (MFL) in water[4]. Accuracy and precision of concentration estimates tend to increase as the number of fibers counted increase.

[4] In some samples, fibers occur in complex structures classified as bundles, clusters, or matrix particles. ISO 10312 provides rules for quantifying the contribution of these complex structures to concentration estimates. For simplicity, the term "fiber" is used here to include not only fibers but the more complex structures as well.

Mine Waste, Soil, and Sediment

For studies at OU3, samples of mine waste, soil, and sediment were analyzed by polarized light microscope (PLM) in accordance with Libby-specific SOPs (SRC 2012). Prior to analysis, samples are sieved and ground to reduce maximum particle size to ≤ 250 µm. LA fibers and particles are identified based on their optical characteristics (color, pleochroism, refractive index, birefringence, and extinction angle). The microscopist estimates the area fraction of particles in a field of view that are LA based on a visual comparison of the sample to site-specific standards with known levels of LA, and this is used as an estimate of the mass fraction. Because the visual area estimates are largely subjective, this is a semi-quantitative method, and the amount of LA present is characterized by assigning a semi-quantitative "bin" designation:

Bin	Approximate Range
A	Non-detect
B1	< 0.2%
B2	0.2% to <1%
C	≥ 1%

Samples in Bin C are assigned a quantitative estimate (expressed as mass percent), but these estimates may not be highly accurate or precise.

Duff and Tree Bark

Samples of duff (forest floor litter) and tree bark were analyzed in accord with SOPs developed for use at the Libby site (EPA 2012c, 2012d). In brief, samples are prepared for LA analysis by ashing at high temperature to fully oxidize all organic material. The ashed residue is then suspended in acid (this helps dissolve residual salts in the residue), diluted as needed, filtered, and analyzed by ISO 10312, similar to the method used for water. Results are usually expressed as million fibers per gram dry weight for duff and million fibers per square centimeter of surface area for tree bark.

Summary of LA Concentration Data

A complete database of LA measurements in environmental media in OU3 is provided in CDM Smith (2013a). Results of the sampling and analysis efforts are summarized below, stratified by medium.

LA in Ore and Mine Wastes

LA occurs in cross-cutting veins and dikes that occur throughout the deposit. These veins and dikes generally range from a few millimeters to several meters in thickness, and the LA concentration in these zones is estimated to range between 50-75% (Meeker et al. 2003).

Concentrations of LA measured in several categories of mine waste s collected from in and about the mined area (intentionally excluding samples that were judged to be from amphiboles veins) are summarized in Table 2-1. As indicated, almost all samples contain detectable levels of LA, ranging from PLM Bin B1 (<0.2%) up to Bin C (>1%). Concentration estimates for the Bin C samples ranged from 2% to 8%.

LA in Ambient Air Near the Mine

Data on the concentration of LA in ambient air near the mined area were collected at 12 sampling stations (see Figure 2-8). One round of sampling (four sequential 5-day samples) was collected during the month of October 2007 (EPA 2007), and a second round (8 sequential 5-day samples) was collected in the interval from July to October 2008 (EPA 2008b). The relatively long sampling duration (five days) was used to ensure the samples were representative of long term average concentrations.

Summary statistics are presented in Table 2-2. As shown, LA concentrations were often below the detection limit (typically about 0.0005 f/cc), with an overall average of about 0.0002 f/cc. These concentrations are much lower than were present during the time the mine was active, when concentrations in air often ranged from 1 to more than 100 f/cc (Amandus et al. 1987). The current low levels in air are presumably due to wind or other disturbances that release fibers from existing sources (contaminated soil, tailings, waste rock, duff, etc.) into air.

LA in Surface Water

EPA has collected samples of surface water at a number of on-Site locations (Figure 2-9 Panel A) as well as at two reference streams located several miles west or northwest (cross-wind) of the mine (Figure 2-9 Panel B). Summary statistics are presented in Table 2-3. As shown, in lower Rainy Creek (LRC-1 to LRC-6), mean concentrations commonly range from 3 to 44 MFL, although individual samples may be higher. Generally similar values occur in Fleetwood Creek and Carney Creek at stations adjacent to the mined area (CC-2, FC-2, CC-Pond), although levels in FC-Pond may be somewhat higher (81 MFL). In upper Rainy Creek, concentrations are generally low in the upstream portions (URC-1 and URC-1A), although elevated concentrations have occasionally been observed at URC-2 (this is below a mine roadway constructed in part of mine wastes). LA is generally non-detect or very low in reference creeks and ponds.

Concentrations in the Kootenai River are generally low, with little apparent difference between samples collected upstream and downstream of the confluence with Rainy Creek.

The concentrations of mining-related contaminants in surface waters near the mine site are not constant over time, but tend to vary as a function of flow rates, especially the high flows typically associated with the spring runoff. Figure 2-10 shows the concentrations of LA measured at four stations along lower Rainy Creek in 2008 as a function of time of year. As shown, an increase in concentration was observed during the spring runoff at three of the four stations. Similar increases (of a smaller magnitude) were also noted in Fleetwood Creek and Carney Creek. The reason that no increase was detected at LRC-2 is not known, but might be due to the effect of the Mill Pond which is located a short distance upstream.

<u>LA in Sediment</u>

EPA has collected samples of sediment at a number of locations, typically the same as those where surface water samples were collected (see Figure 2-9). Summary statistics on bin assignments are presented in Table 2-4. As shown, essentially all sediment samples from Lower Rainy Creek, Fleetwood Creek, and Carney Creek, as well as from the tailings impoundment and the Mill Pond, contain detectable levels of LA. The highest frequency of high concentration samples (Bin C) were observed in Carney Creek (which flows adjacent to and downhill of the mined area) and in Rainy Creek just below the tailings impoundment dam (TP-TOE1 and TP-TOE2). Levels in lower Rainy Creek were mainly Bin B1 (<0.2%) or Bin B2 (0.2 to 1%), although several Bin C samples (>1%) were observed. Quantitative estimates for the 62 Bin C samples range from 1% to 10%, with an average of 3%. As noted above, estimates of LA in sediment are semi-quantitative.

Sediment samples from the upper reaches of Upper Rainy Creek (URC-1 and URC-1A) appear to contain little LA, with 5 of 6 being Bin A (non-detect), although one sample was ranked as Bin B1 (<0.2%). Samples from URC-2 do appear to have low levels (mainly < 0.2%). The source of this LA is uncertain, but might either be mining-related or natural levels eroding from the ore body.

Samples of sediment from off-site reference areas and ponds did not contain any detectable levels of LA.

<u>LA in Forest Soil, Duff, and Tree Bark</u>

EPA has collected samples of forest soil, duff, and/or tree bark at a variety of distances and directions from the mine (CDM Smith 2013a, 2013b, 2013c, 2014; EPA 2012b). Several samples have also been collected in the area of Souse Creek by the U.S. Public Health Service

(USPHS 2013). The sampling locations and the resulting LA concentration values are shown in Figure 2-11. In this figure, the results at each station are indicated in a triangular set of symbols:

Top symbol = soil
Bottom left symbol = tree bark
Bottom right symbol = duff

An "x" indicates that no data for that media type are available for that location, while a grey circle indicates the sample was non-detect. Detects are indicated as colored circles, with low values in green, medium values in yellow, and high values in red.

As illustrated, the highest concentrations tended to occur close to the mine, mainly in the primary downwind (northeast) direction, although some high values were also detected in the secondary downwind direction (to the southwest). Although there is moderate variability in the measurements, concentrations in all three media tend to decrease as a function of distance from the mine. This tendency is shown more clearly in Figure 2-12, which plots concentrations in duff and tree bark as a function of distance from the mine. As illustrated, concentrations tend to decrease exponentially as a function of distance from the mine.

2.5 Ecological Setting

2.5.1 Terrestrial Setting

The mined area was heavily disturbed by past mining activity and some areas remain largely devoid of vegetation. Outside the mined area, most of OU3 is forested, with only 4% of the land being classified as non-vegetated (USDAFSR1 2008). Data for the Kootenai National Forest indicate Douglas-fir forest type is the most common, covering nearly 35% of the National Forest land area within OU3. Next in abundance are the lodgepole pine forest and spruce-fir forest types at 17% each, and the western larch forest type at 11%. Other tree species reported in the area are the Black Cottonwood (*Populus trichocarpa*), Quaking Aspen (*Populus tremuloides*), Western Paper Birch (*Betula papyrifera*) and Pacific Yew (*Taxus brevifolia*) (USDAFSR1 2008).

The forested area of OU3 is suitable habitat for a wide range of terrestrial species, including mammals, birds, and reptiles. In order to identify wildlife species likely to occur in OU3, data available from the Montana National Heritage Program (MNHP) was consulted. First, using the MNHP Animal Tracker web page (http://nhp.nris.mt.gov/Tracker/), all species known to occur within Lincoln County, Montana, were identified. Next, the MNHP and Montana Fish, Wildlife and Parks Animal Field Guide (http://fieldguide.mt.gov/) were consulted to determine if a particular species has been observed in the vicinity of OU3. Species not identified within the vicinity of OU3, and those not expected to occur at OU3 based on a consideration of available habitat, were removed. The species that remained are listed in Attachment A, along with information on general habitat requirements, habitat type for foraging and nesting, feeding guild, typical food, migration and hibernation, longevity, home range, and size. The species identified as residing all or part of the year within OU3 include 29 invertebrates (26 terrestrial and three aquatic), seven amphibians, seven reptiles, 175 birds, and 48 mammals.

2.5.2 Aquatic Setting

Rainy Creek Watershed

Within the Rainy Creek watershed there are streams and ponds that provide habitat for a range of aquatic species including fish, invertebrates, and amphibians. Species identified during site-specific ecological population surveys performed as part of the RI at OU3 are summarized in Section 4.3 (fish), Section 5.3 (benthic macroinvertebrates), and Section 6.3 (amphibians). In brief, fish surveys performed in OU3 streams indicate that the most common species of fish are westslope cutthroat trout (*Oncorhynchus clarkii lewisi*), rainbow trout (*Oncorhynchus mykiss*), and “cutbow” trout (a rainbow/cutthroat hybrid). Brook trout (*Salvelinus fontinalis*) were not observed in OU3, but were observed in nearby reference streams. Aquatic invertebrate community surveys in OU3 indicate that the most common types of aquatic invertebrates observed include mayflies, stoneflies, caddisflies, true flies, and beetle larvae. The most common amphibian species observed are the northern tree frog (*Pseudacris regilla*), Columbia spotted frog (*Rana luteiventris*), and western toad (*Bufo boreas*).

Kootenai River

No site-specific studies of aquatic receptors in the Kootenai River have been performed as part of the OU3 RI. However, EPA’s Environmental Monitoring and Assessment Program (EMAP) has collected aquatic community data at a station on the Kootenai River about one mile downstream of the confluence with Rainy Creek. This location was sampled in August 2002. Forty-four species of aquatic invertebrates have been observed, including oligochaetes, insects (diptera, ephemeroptera, trichoptera and hemiptera), coelenterates (hydra), mollusks, and nematodes. Eleven species of fish were observed, including mountain whitefish (*Prosopium williamsoni*), rainbow trout, sockeye salmon (*Oncorhynchus nerka*), cutthroat trout, bull trout (*Salvelinus confluentus*), and several species of forage fish (dace, shiner, sculpin).

2.5.3 Federal and State Species of Special Concern

Table 2-5 lists the animal and plant species currently identified by the U.S. Fish and Wildlife Service (USFWS) as being of Federal concern in the Kootenai Nation Forest (USFWS 2014).

Table 2-6 lists species currently listed by the Montana Natural Heritage Program (MNHP) as being of concern to the state that occur in the general area of OU3 (Montana Township 31N, Range 30W) (MNHP 2014). Based on an evaluation of habitat requirements, the following listed species are considered to be the most likely to occur in OU3:

Federal

- Bull Trout (*Salvelinus confluentus*)
- White Sturgeon (*Acipenser transmontanus*) (Kootenai River only)
- Grizzly Bear (*Ursus arctos horribilis*)
- Canada Lynx (*Lynx canadensis*)

State

- Coeur d'Alene Salamander (*Plethodon idahoensis*)
- Boreal Toad, Green (also known as Western Toad) (*Bufo boreas*)
- Flammulated Owl (*Otus flammeolus*)
- Northern Goshawk (*Accipiter gentilis*)
- Bull Trout (*Salvelinus confluentus*)
- Torrent Sculpin (*Cottus rhotheus*)
- Westslope Cutthroat Trout (*Oncorhynchus clarkii lewisi*)
- Canada Lynx (*Lynx canadensis*)

The Kootenai River is ranked as critical habitat for the bull trout, and the north-central portion of the OU3 study area includes critical habitat for the Canada lynx.

3.0 PROBLEM FORMULATION

Problem formulation is a systematic planning step that identifies the major concerns and issues to be considered in an ecological risk assessment, and describes the basic approaches that will be used to characterize ecological risks that may exist (EPA 1997). As discussed in EPA (1997), problem formulation is generally an iterative process, undergoing refinement as new information and findings become available.

3.1 Conceptual Site Model

A Conceptual Site Model (CSM) is a schematic summary of what is known about the nature of source materials at a site, the pathways by which contaminants may migrate through the environment, and the scenarios by which ecological receptors may be exposed to site-related contaminants. When information is sufficient, the CSM may also indicate which of the exposure scenarios for each receptor are likely to be of greatest potential concern, and which (if any) are likely to be sufficiently minor that detailed evaluation is not needed. This diagram is generally prepared at the start of the risk assessment process, and is used to help identify the types of studies and data collection efforts that are likely to be useful in evaluating ecological risks at the site.

Figure 3-1 presents the CSM that was developed for exposure of ecological receptors to LA in OU3. The following sections provide a more detailed discussion of the main elements of this CSM.

3.1.1 <u>Potential Sources of Contamination</u>

In the past (when the mine was operating), vermiculite mining and milling activities resulted in releases of LA fibers to air as well as the generation of various types of LA-containing solid waste. Fibers released to air would have been carried downwind in air (mainly to the northeast), followed by deposition of the fibers to soil or duff, or entrapment in tree bark. Various solid wastes that were generated during mining and milling operations (waste rock, waste ore, and tailings) were deposited on-site.

3.1.2 <u>Migration Pathways in the Environment</u>

On-site solid wastes that remain at the site may be a source of on-going release of asbestos to the environment by two main pathways:

Airborne Transport. Asbestos fibers that are present in solid wastes may become suspended in air as the result of various types of disturbances, including wind action and mechanical disturbances caused by human activities (vehicle traffic, operation of heavy machinery, etc.). Once airborne, suspended fibers move with the wind and then settle and become deposited onto surface soils, tree bark, and duff.

Erosion. Asbestos that is present in on-site solid wastes may be carried in surface water runoff (e.g., from rain or snowmelt) into local streams (especially Fleetwood Creek, Carney Creek and Rainy Creek below the tailings impoundment), resulting in contamination of waters and sediments in the streams.

3.1.3 Potentially Exposed Ecological Receptors

As discussed in Section 2.3, there are a large number of ecological species that are likely to occur in OU3 and that could be exposed to mine-related contaminants. However, it is generally not feasible or necessary to evaluate risks to each species individually. Rather, it is usually appropriate to group receptors with similar behaviors and exposure patterns, and to evaluate the risks to each group.

For aquatic and semi-aquatic receptors, organisms are often evaluated in four groups:

- Fish
- Benthic macroinvertebrates
- Amphibians (aquatic life stages)
- Aquatic plants

For terrestrial receptors, organisms are often grouped into the following broad categories:

- Birds
- Mammals
- Terrestrial plants
- Soil invertebrates
- Reptiles

3.1.4 Exposure Pathways of Chief Concern

Most ecological receptors are likely to be exposed to LA in the environment by several pathways (ingestion, inhalation, and/or direct contact), but not all scenarios are equally likely to be of concern and not all require equal levels of investigation. In Figure 3-1, solid circles identify the pathways that were judged to be of greatest potential concern in term of exposure potential.

Open circles identify exposure pathways that are likely to be complete, but are considered likely to be have low exposure or risk potential. Open boxes identify exposure pathways that are judged to be incomplete, negligible, or not applicable. The rationale for these judgments is summarized below.

Fish

The primary exposure pathway of concern for fish is direct contact with asbestos fibers suspended in surface water. Fish may also be exposed to asbestos by incidental ingestion of sediment while feeding, ingestion of contaminated prey items, and direct contact with sediment. Incidental ingestion of sediment is likely to be a minor source of exposure, especially for fish (e.g., trout) that feed mainly in the water column. Likewise, ingestion of prey items is likely to be minor because asbestos is not expected to bioaccumulate in food web items. Direct dermal contact with sediment is also likely to be minor, at least for fish that reside mainly in the water column.

Studies that were performed to evaluate these potential exposure pathways of fish are described in Section 4.0.

Benthic Invertebrates

The exposure pathways of primary concern for benthic invertebrates that reside in stream sediment are direct contact with sediment and with sediment porewater. For organisms that reside in the uppermost layers of the sediment, exposure may also include surface water flowing over and through the sediment. In addition, benthic organisms may be exposed by ingestion of fibers while feeding in the sediment. For this type of organism, distinguishing between direct contact with sediment and ingestion exposure is often not possible, so these pathways are often evaluated together.

Studies that were performed to evaluate these potential exposure pathways of benthic macroinvertebrates are described in Section 5.0.

Amphibians

Amphibians (e.g., frogs, toads) inhabit both aquatic and terrestrial (mainly riparian) environments, with early life stages being primarily aquatic and later life stages being semi-aquatic or terrestrial. In their aquatic life stages, the exposure pathways most likely to be significant are direct contact with surface water and sediment. As for fish, exposure by ingestion of sediments and/or prey items may also occur, and studies of this exposure scenario usually include both pathways. Numerous studies suggest that aquatic early life stages are usually more susceptible to environmental contaminants than older life stages, so exposures of adult amphibians in the terrestrial environment is likely to be of lesser concern than the exposures that occur during development in the aquatic environment.

Studies that were performed to evaluate these potential exposure pathways of amphibians are described in Section 6.0.

Aquatic and Terrestrial Plants

Aquatic plants might be exposed to LA both by direct contact of foliage with fibers in surface water contact of roots with fibers in sediment. Similarly, terrestrial plants may be exposed to asbestos mainly by direct contact of roots with fibers that have been deposited into soil, or by deposition of airborne fibers onto bark or foliar surfaces. Because asbestos exists as solid fibers that are not likely to be taken up into plant tissues, either by foliar contact or through roots, it is not expected that asbestos contamination is of concern for either aquatic or terrestrial plants.

Consequently no studies were planned to evaluate impacts of LA on plants.

Mammals and Birds

Mammals and birds may be exposed to asbestos by ingestion of contaminated soils, surface water, sediment, and food, and by inhalation when feeding or foraging activities result in the disturbance of asbestos-contaminated soils, sediments, or duff. Studies in humans and laboratory animals indicate that inhalation exposures are likely to be the main exposure route of toxicological concern, with oral exposure often tending to cause few significant effects (ATSDR 2001). However, there are some reports of potential effects of asbestos following oral exposure in mammals (see Section 4.1), so oral exposure is indicated by a solid circle in Figure 3-1, both for mammals and for birds.

Direct contact (dermal exposure) of birds and mammals to fibers in soil or other contaminated media may occur, but this exposure route is suspected to be or minor concern, since asbestos is expected to remain mainly on the surface of fur or feathers and is not expected to cross the skin barrier.

Studies that were performed to evaluate exposures of mammals are described in Section 7.0, and an evaluation of potential hazards to birds is discussed in Section 8.

Soil Invertebrates

Soil invertebrates (e.g., worms) may be exposed by direct contact with fibers in soil, and also by ingestion of soil detritus that contains fibers. While the likelihood of LA effects on worms is not known, it was considered likely that benthic macroinvertebrates would have higher exposure than terrestrial invertebrates because concentrations of LA are generally higher in OU3 sediments than in soils. Based on this, no studies of earthworms or other terrestrial invertebrates were planned or performed.

Reptiles

Turtles have been observed in OU3 ponds, and other types of reptiles (snakes) are also present in OU3. These organisms may be exposed to site-related contaminants by direct contact and ingestion of water or sediment, and by ingestion of prey items. While the likelihood of LA effects on reptiles is not known, it was considered likely that amphibians would be more at risk than reptiles, especially considering that reptilian skin is covered in scales that would be expected to decrease exposure from direct contact pathways. Based on this, no studies of reptiles were planned or performed.

3.2 Management Goal and Assessment Techniques

3.2.1 Management Goal

A management goal is a statement of the basic objectives that the risk manager wishes to achieve at a site. The overall management goal identified for ecological health at the Libby OU3 site for asbestos contamination is:

> Ensure adequate protection of ecological receptors within the Libby OU3 Site from the adverse effects of exposures to mining-related releases of asbestos to the environment.

For most species, "adequate protection" is generally defined as the reduction of risks to levels that will result in the recovery and maintenance of healthy local populations and communities of biota (EPA 1999). For the Libby OU3 Site, the assessment populations are defined as the groups of organisms that reside in locations that have been impacted by mining-related releases. For exposure to asbestos, this is believed to include the mined area and the drainages associated with the mined area, as well as surrounding forest lands that were impacted by airborne releases of asbestos.

For threatened or endangered species, "adequate protection" is generally interpreted to mean minimizing risks to individual members of the population.

3.2.2 Assessment Endpoints

Assessment endpoints are explicit statements of the characteristics of the ecological systems that are to be protected. Because the risk management goals are formulated in terms of the protection of populations and communities of ecological receptors, the assessment endpoints selected for use in this problem formulation focus on endpoints that are directly related to the management goals. This includes:

- Mortality
- Growth
- Reproduction

If effects on these three assessment endpoints are absent or minimal, it is likely that ecologically significant effects will not occur.

3.2.3 Measures of Effect

Measures of effect are quantifiable ecological characteristics that can be measured, interpreted, and related to the valued ecological components chosen as the assessment endpoints (EPA 1997, 1998). There are a number of alternative measures of effect that may be investigated as part of an ecological risk assessment. The primary alternative strategies for characterizing measures of effects are described below.

Hazard Quotients

For most environmental contaminants, the first line of investigation is usually the Hazard Quotient (HQ) Approach. A Hazard Quotient (HQ) is the ratio of the estimated exposure of a receptor to a "benchmark" exposure that is believed to be without significant risk of unacceptable adverse effect:

$$HQ = Exposure / Benchmark$$

If the site exposure does not exceed the benchmark ($HQ \leq 1$), it is usually concluded that site-related exposures are of low concern.

However, there are no established benchmarks for the evaluation of ecological receptors to any form of asbestos, and most of the studies that are available that might potentially serve as a basis for development of a benchmark are based on studies of chrysotile asbestos rather than amphibole asbestos. In particular, there are no studies on the toxicity of LA on any class of ecological receptors. Consequently, HQ values were not calculated for any exposure scenario, and ecological investigations of the potential effects of LA on ecological receptors in OU3 focused on other measures of effect, as discussed below.

Site-Specific Toxicity Tests

Site-specific toxicity tests measure the response of receptors that are exposed to site media. This may be done either in the field (*in situ*) or in the laboratory using media collected from the site. The chief advantage of either type of study is that site-specific conditions that can influence toxicity are usually accounted for, and that the cumulative effects of all exposure pathways to the medium and all contaminants in the medium are evaluated simultaneously. One potential limitation of this approach is that, if toxic effects are observed to occur when test organisms are exposed to site media, it may not be possible to specify which contaminant or combination of contaminants is responsible for the effect without further testing or evaluation. A second limitation is that it may be difficult to perform tests on site samples that reflect the full range of environmental conditions which may occur in the field across time and space, so it may not be possible to fully identify all conditions that are and are not of concern.

Population and Community Demographic Observations

Another approach for evaluating possible adverse effects of environmental contamination on ecological receptors is to make direct observations on the receptors in the field, seeking to determine whether any receptor population has unusual numbers of individuals (either lower or higher than expected), or whether the diversity (number of different species) of a particular category of receptors is different than expected. The chief advantage of this approach is that observation of community status relate directly to the management goal (protection of populations). However, there are also a number of important limitations to this approach. The most important of these is that both the abundance and diversity of a receptor depend on many site-specific factors (habitat suitability, availability of food, predator pressure, natural population cycles, meteorological conditions, etc.), and it is often difficult to know what the expected (non-impacted) abundance and diversity should be in a particular area. This problem is generally approached by seeking an appropriate "reference area" (either the site itself before the impact occurred, or some similar site that has not been impacted), and comparing the observed abundance and diversity in the reference area to that for the site. However, it is sometimes difficult to locate reference areas that are a good match for all important habitat characteristics.

In-Situ Measures of Exposure and Effects

An additional approach for evaluating the possible adverse effects of environmental contamination on ecological receptors is to make direct observations on receptors in the field, seeking to determine if individuals residing in areas of contamination have an increased frequency and/or severity of physiological lesions and/or deformities compared to organisms residing in uncontaminated reference areas. This method has the advantage of integrating most (if not all) factors that influence the true level of exposure and toxicity of contaminants in the field. However, if an increased incidence or severity of lesions is observed, it may not be possible to identify with certainty which environmental contaminant(s) is (are) responsible, and it may also be difficult to determine with confidence whether the observed lesions are likely to cause an ecologically significant population-level impact.

Weight of Evidence Evaluation

As noted, each of these alternative strategies for characterizing ecological risks has some advantages and some limitations. Because of this, it is generally desirable to obtain information using two or more alternative strategies, and to seek to reach a weight of evidence conclusion that considers the strengths and limitations of each available line of evidence, including the magnitude and statistical significance of any observed effects. If two or more lines of evidence are available, and if the lines of evidence are in general agreement, then confidence in risk conclusions is increased. If two or more lines of evidence do not agree, then careful attention must be given to likely reasons for the disparity, and to decide which line(s) of evidence provide the highest confidence.

3.2.4 Statistical Methods

When appropriate, statistical tests were used to help evaluate the data obtained from the site-specific studies performed in OU3. In studies where there are replicates for the various treatments [e.g., two or more measurements at a station, two or more stations within a category ("Site" and "Reference")], there are often several options for performing statistical tests. In general, if the differences between replicates within a station and/or between stations within a category are small, it is often useful to combine the data to increase statistical power. However, even in cases where there may be differences between replicates or stations within a category, it may still be useful to group the data by category, assuming that risk management decisions are more likely to be made on a category basis (Site vs Reference) than on a station-by-station basis.

The choice of the most appropriate statistical test(s) depends on the nature of the measurement endpoints. For studies that measure a discrete endpoint (e.g., mortality), there are two basic options that may be illustrated using the following hypothetical data:

Replicate	Site			Reference		
	N	Dead	Rate	N	Dead	Rate
A	10	3	30.0%	15	1	6.7%
B	10	1	10.0%	15	4	26.7%
C	10	4	40.0%	15	2	13.3%

The first approach treats an individual organism as the unit of observation, combining the data across replicates, and comparing the rates between categories using a one-tailed Fisher exact test (FET):

Option 1: By Organism

Category	N	Dead	Rate	FET p value
Site	30	8	26.7%	0.188
Reference	45	7	15.6%	

The second option treats each replicate as the unit of observation and compares the mean of the rates between categories using a one-tailed t-test:

Option 2: By Replicate

Category	N	Mean	Stdev	t-test p value
Site	3	26.7%	15.3%	0.181
Reference	3	15.6%	10.2%	

Each approach has some statistical advantages and potential limitations, and each may provide useful information. Option 1 has the advantage of large sample sizes (which helps increase statistical power) and does not make any assumptions about distributional form. Option 2 avoids pseudoreplication that may occur if unusual conditions occur in one exposure chamber compared to the others within the category, but sample size is small and a normal distribution of the means is assumed.

For continuous measurement endpoints (e.g., fish density, benthic organism growth, lesion severity, etc.), the preferred test is usually a one-tailed Wilcoxon rank sum (WRS) test (also known as the Mann Whitney test). This test evaluates whether measurements from one population consistently tend to be larger (or smaller) than those from the other population. The test is non-parametric, so it is not necessary to make any assumptions about the distributional form of the individual measurements.

3.2.5 Data Evaluation

In general, a three step process was used to evaluate the results of the studies performed, as follows:

1) Was a difference observed? This question was assessed mainly by considering the results of the statistical test(s) used to compare the magnitude and/or severity of the effect in organisms exposed to OU3 media to that for organisms exposed to reference media. The likelihood that an observed difference is due to treatment (i.e., exposure to an OU3 medium) rather than random variation may be judged by the statistical p value. A p value reflects the probability of obtaining the observed difference between site and reference if the null hypothesis (site ≤ reference) is true. The smaller the value of p, the less likely it is that the site and reference are the same and the observed effect occurred by chance. In many cases, a difference is not considered to be "significant" unless the p value is 0.05 or smaller (i.e., there is no more than a 5% chance the observed difference occurred at random). However, as discussed in EPA (2002), while use of a p value of 0.05 as the criterion for "significant" effect ensures that any effect that is identified as significant has a high probability (>95%) of being treatment-related, this criterion also runs the risk that some real effects may be overlooked, which increases the chances of a Type I decision error (deciding the site is not impacted, when it really is). For example, in the case of a p value of 0.07, this would not be considered "significant" even though there is a 93% chance the effect is due to treatment. For this reason, EPA (2002) recommends that when the null hypothesis is "H_0: site ≤ reference", a p value of ≤ 0.20 should be used to define "significant", and this approach has been used in this risk assessment.

   However, use of a p value of ≤ 0.20 to help minimize risk of a Type I decision error does not necessarily mean that an effect with a p value of 0.01 and an effect with a p value 0.19 are equally likely to be treatment-related. Rather, confidence tends to decrease as a continuous (rather than discrete) function of increasing p. For this reason, in this risk assessment, while all effects with p value ≤ 0.20 are considered "significant", a distinction in confidence is indicated by the use of the phrase "statistically significant" to describe differences with p values ≤ 0.05, and the phrase "marginally significant" to characterize effects with p values of 0.06 to 0.20.

2) If a difference was observed, is exposure to LA the cause of the effect? While a low p value indicates that an observed difference is likely to be due to differences between site and reference exposure conditions, it does not necessarily prove that LA in site media is the cause of the effect. This is because there may be several differences (other than the

presence/absence of LA) between site and reference. The question of causality is generally evaluated by considering the following:

a. Is the nature of the observed difference characteristic of the known effects of asbestos on the exposed organisms?
b. Does the magnitude or severity of the effect appear to depend on the level of LA?
c. Are there other recognizable differences (e.g., habitat factors) that might explain some or all of the observed difference?

3) <u>If a difference was observed, and it is or might reasonably be attributed to LA, is the effect ecologically significant</u>? In a well-designed and well-performed study, small differences may sometimes be detected and declared to be "significant". However, statistical significance does not necessarily imply that a difference is of ecological significance. For example, small decreases in the hatch rate of trout eggs might not lead to a meaningful difference in the number of trout surviving to adulthood, since only a small fraction of fish survive to maturity even under normal conditions (Toll et al. 2013). Likewise, increased prevalence of mild external or internal lesions that would not impair the ability of an organism to survive, grow, and reproduce would be unlikely to be of concern. An evaluation of ecological significance is generally based largely on professional judgment, considering the observed magnitude, nature, and severity of the effect to estimate the expected consequences of the effect.

3.3 Role of the BTAG

All studies to investigate the potential effects of LA on ecological receptors in OU3 were planned by EPA working in close cooperation with the Libby OU3 Biological Technical Assistance Group (BTAG). The BTAG included technical and managerial representatives from all of the stakeholders at the site including:

- The U.S. EPA Region 8
- The U.S. EPA headquarters Environmental Response Team (ERT)
- The U.S. Fish and Wildlife Service (USFWS)
- The Montana Department of Environmental Quality (MDEQ)
- W.R. Grace and Co., represented by Remedium Group

Input from the various members of the BTAG was used to strengthen the design of all studies that were performed, thereby maximizing the probability of deriving scientifically reliable data, taking costs and feasibility into account.

4.0 RISKS TO FISH

4.1 Reported Effects

Adverse effects in fish resulting from exposure to asbestos have not been extensively studied, but several relevant reports were located. Brief summaries are presented below.

- Woodhead et al. (1983) exposed Amazon mollies (*Poecilia formosa*) to 0.01-10 mg/L of chrysotile asbestos for six months. Epidermal hypertrophy and necrosis were observed in kidney and gill in many of the fish at exposure concentrations of 0.1 mg/L or higher, and in heart at a concentration of 1 mg/L in three of 20 fish. No adverse effects were observed in liver, muscle or skin.
- Belanger (1985) studied the effects of chrysotile asbestos on adult and juvenile fathead minnows (*Pimephales promelas*). Neither adult nor juvenile minnows suffered acute toxicity at concentrations up to 1E+06 MFL or differential mortality relative to controls up to 100 MFL for 30 days. Length, weight, and swimming performance of adult minnows exposed to asbestos were not significantly affected relative to controls. Juvenile minnows exposed to 1-100 MFL had significantly lower weight.
- Belanger et al. (1990) studied the effects of chrysotile asbestos at concentrations of 0, 0.0001, 0.01, 1, 100 or 10,000 MFL on egg and larval Japanese Medaka (*Oryzias latipes*). Eggs were exposed to chrysotile until hatching (13-21 days) and larval were exposed for thirteen weeks. Exposure of eggs to concentrations of 1 MFL or higher tended to delay hatching, but egg survival (hatching success) was not grossly or significantly impaired. Larval Medaka experienced growth reduction at concentrations of 1 MFL or higher. Fish exposed to 10,000 MFL suffered 100% mortality by 56 days. Fish exposed to 1 MFL or higher developed thickened epidermal tissue. Concentrations of chrysotile as low as 0.01 MFL tended to reduce successful spawns per female and eggs per females, although the differences in eggs per female were not statistically significant.
- Belanger et al. (1986a) exposed coho salmon (*Oncorhynchus kisutch*) and green sunfish (*Lepomis cyanellus*) to chrysotile asbestos at concentrations of 1.5 or 3 MFL. Coho were exposed for 40 or 86 days, while sunfish were exposed for 52 or 67 days. No treatment-related increases in mortality were detected. Coho larvae exposed to 1.5 MFL were significantly more susceptible to an anesthetic stress test, becoming ataxic and losing equilibrium faster than control fish. Two of 106 coho larvae exposed at 3 MFL developed tumorous swellings in the gill region and 3 additional fish developed coelomic distentions leading to death. Larval coho and juvenile green sunfish exposed to 3.0 MFL had epidermal hypertrophy superimposed on hyperplasia, necrotic epidermis, lateral line degradation, and lesions near the branchial region. Lateral line abnormalities were associated with a loss of the ability to maintain normal orientation in the water column.

No studies were located on the toxicity of LA to fish.

4.2 Site-Specific Toxicity Tests

The EPA, working in concert with the Libby OU3 BTAG, determined that site-specific studies of the toxicity of LA-contaminated water would provide one valuable line of evidence to evaluate risks to fish in OU3. Several alternative study designs were pursued. However, all attempts to expose fish to LA under laboratory conditions were judged to be unsuccessful because of a tendency for LA to form clumps and bind to bottles, tubing, and aquaria walls, as described in Attachment B. Based on these difficulties in exposing fish to controlled levels of LA under laboratory conditions, EPA and the BTAG decided the best alternative strategy was to evaluate the toxicity of site waters to fish using an *in situ* exposure design. Because toxicity of water-borne chemicals to fish may depend on the age of the fish exposed (with early life stages often tending to be more sensitive that older life stages), two separate *in situ* studies were planned, with the first focusing on trout that were exposed from the eyed egg stage through hatching and alevin swim-up, and the second focusing on juvenile trout. These studies are described below.

4.2.1 *In Situ* Eyed Egg and Alevin Exposure Studies

An initial study to investigate the effect of *in situ* exposure of eyed eggs and hatched alevins was planned and performed in 2012. Detailed descriptions of the study design and the results are presented in Golder (2013). However, as discussed in Golder (2013), this study was complicated by the fact that a number of organisms went missing during the study, and the conclusions of the study depended strongly on what was assumed about the survival status of these missing organisms. If missing organisms were excluded from the evaluation, or if it were assumed that most missing organisms did not survive, then the data suggested that effects of exposure might be important. In contrast, if it were assumed that most missing organisms did survive but escaped, then the data suggested that any effects of *in situ* exposure would likely not be important.

Because of the uncertainty in the 2012 eyed egg study resulting from the missing organisms, EPA and the BTAG decided that a repeat of the study was necessary, taking care to make changes to minimize the problems encountered in the first study. The design and results of the repeat study are reported in Golder (2014b), and the main findings are summarized below.

Study Design

The data quality objectives (DQOs) for the study are presented in Section 5 of the Phase V, Part B SAP/QAPP (EPA 2012a), and the detailed study protocol is presented in Appendix A.3 of the

SAP/QAPP. Changes that were implemented in 2013 to minimize problems encountered in 2012 are summarized in an addendum to the Phase V Part B SAP (EPA 2013b).

In brief, eyed eggs from native westslope cutthroat trout were obtained from the Montana Fish, Wildlife, and Parks (MFWP) fish hatchery in Anaconda, Montana. The hatchery carefully inspected all eggs and eliminated any that were observed to be cloudy, have no eyes, or have "double eyes".

Eggs were placed in Whitlock-Vibert boxes (30 eggs per box). As illustrated in Figure 4-1, Whitlock-Vibert boxes contain small chambers in the upper portion of the box to house the eggs. After the eggs hatch and after some of the yolk sac has been absorbed, the larval fish fall from the upper egg chamber into a lower protected "nursery" chamber where they rest on the bottom until they develop to the swim-up stage (yolk fully resorbed). Although unaltered boxes allow alevins to escape after swim-up, for this study, each box was modified by attaching rigid plastic mesh (100 openings per in^2) to the inside of each box, using zip-ties to ensure a secure fit. This prevented the escape of the swim-ups and also provided protection from predators.

Exposure Locations

A total of six Whitlock-Vibert boxes were placed in lower Rainy Creek (LRC), with two boxes each at stations LRC-2, LRC-4, and LRC-5. Likewise, a total of six boxes were placed into reference streams, with three boxes each at upper Rainy Creek (URC) station URC-2 and in Noisy Creek (NSY). These locations are shown in Figure 2-9.

In addition, one "dummy" box (i.e., one that did not contain any organisms) was placed in the stream bed at each sampling station between the two boxes with organisms. This "dummy" box was fitted with a sampling port (a PVC tube extending from with the box to above the water surface) to allow sampling of water within the box while located in the stream bed.

At each station, the exact locations for Whitlock-Vibert box deployment were selected to approximate a natural redd that fish could use for spawning. Typically, such areas had gravel or cobble substrates and were outside locations with high stream velocity. Sites were prepared by raking out a depression in the streambed at the selected deployment location. In some cases, structures such as boulders, rocks, or logs were placed upstream to create a breakwater area for placement that ensured flow velocities were not excessive. Each box was placed into a steel cage filled with coarse gravel for burial in the stream bed. The steel cages containing the boxes were placed in the streambed depression, oriented parallel to creek flow, and then covered with gravel (Figure 4-2).

Timing and Duration of Exposure

As discussed in Section 2.4.2, available data indicate that concentrations of LA in OU3 streams tend to increase during the spring runoff. Therefore, the study was implemented as close as was feasible to the peak of the spring hydrograph in order to achieve exposures at the high end of the concentration range. The boxes were left in place until all of the viable eggs had hatched and all living fry had fully resorbed yolks and had reached the swim-up stage.

Field Observations

Each box in LRC, URC, and NSY was observed twice per week until study termination. During each examination, the number of dead eggs and alevins was recorded, along with water temperature and oxygen saturation level. Dead organisms (eggs and alevins) were removed after each observation and submitted for external examination. Remaining organisms were placed into clean Whitlock-Vibert boxes and re-buried (in the gravel-filled cages) in the streambed.

Negative Controls

Three groups of eggs were placed in Whitlock-Vibert boxes and were maintained in aquaria in a temperature-controlled refrigerator in a local laboratory. The temperature was adjusted twice per week to match the temperature observed in LRC.

As was the case in the field, the Whitlock-Vibert boxes in the negative control group were observed and changed twice a week, moving organisms from the old box to a new box in the same manner as for field organisms. At this time, a 70% change in aquarium water was performed. Oxygen levels were also measured twice per week.

All organisms in these negative control groups were monitored for the same biological endpoints evaluated in the field (mortality, hatch rate, etc.).

Laboratory Observations

At the end of exposure, the cages were removed from the streambed and transported in site water to an on-site laboratory where all remaining living alevins were transferred into aquaria. After a brief acclimation period, the swimming behavior of the alevins was observed for 30 minutes. Then, the fish were sacrificed and the weight and length of each fish was measured. Each fish was then placed in preservative for transport to a pathology laboratory for external examination.

Exposure Characterization

Exposure of eggs and alevins was characterized by collecting samples of water from inside the "dummy" Whitlock-Vibert box at each station. To avoid potential bias due to suspended sediment in the water, samples of water from the boxes were withdrawn and discarded until no visible sediment was apparent. In addition, samples of water from the overlying stream were also collected. For the boxes in LRC, water samples were collected twice per week. For the boxes in the reference locations (URC and NSY), water samples were collected once per week. All water samples from site and reference locations were analyzed for LA, treating the water with ozone and ultraviolet light prior to analysis to remove any biological material that might cause fiber clumping and interfere with the analysis.

Data Evaluation

Hatching Success

Egg hatching success was calculated as:

$$Hatching\ success\ (\%) = 100 \cdot \frac{N_{eggs} - Dead_{eggs} - Missing_{ns}}{(N_{eggs} - Missing_{ns})}$$

where:

N_{eggs} = starting number of eggs at the exposure location
$Dead_{eggs}$ = total number of eggs that died before hatching
$Missing_{ns}$ = number of missing organisms whose life stage is not specified (that is, the missing organisms may have been eggs).

Alevin Survival

Alevin survival to the end of the study was calculated as:

$$Alevin\ survival\ (\%) = 100 \cdot \frac{Alive}{Hatched - Missing_{alevin}}$$

where:

Alive = number of alevins alive in the chamber on the last day of the study
Hatched = the number of eggs which are known to have hatched (see above)
$Missing_{alevin}$ = the number of alevins that are missing

Overall Survival

Overall survival (accounting for the combined mortality in both the egg and alevin life stages) was calculated as:

$$Overall\ survival\ (\%) = 100 \cdot \frac{Alive}{N - Missing_{all}}$$

where:

Alive = number of alevins alive in the chamber on the last day of the study
N = the number of eggs at the start of the study
$Missing_{all}$ = the total number of missing organisms (not specified plus alevins)

Results

Detailed results of the 2013 study are presented in Golder (2014b). The main findings are summarized below.

Exposure Conditions

Figure 4-3 Panel A shows flow data for LRC in 2013. As shown, the spring runoff began in early April and continued through late May. The eyed eggs were placed into the stream on May 6, approximately at the peak of the runoff.

Figure 4-3 Panel B shows temperatures monitored in LRC and the reference streams during the eyed egg study. As shown, there is a clear diurnal cycle in water temperature in all streams, with a slow warming trend as the spring progresses. Temperatures in LRC were very similar at all stations, and were several degrees warmer than in the reference reaches. Consequently, fish developed more rapidly in LRC, and exposure in LRC was terminated on May 30 but continued until June 17 at Noisy Creek and June 19 at URC-2.

Figure 4-4 shows measured LA concentrations in water samples collected from inside the Whitlock-Vibert boxes. As indicated, there was variability over time (Panel A). On average across the study duration, exposure levels in LRC ranged from about 40 to 45 MFL, with no apparent spatial pattern (Panel B). Concentrations at the URC-2 and NSY stations were consistently much lower (≤ 0.1 MFL).

Average concentrations of LA (MFL) inside the Whitlock-Vibert boxes tended to be somewhat higher than in the overlying water:

Sampling Station	Inside Box	Overlying Water
LRC-2	41	9
LRC-4	42	31
LRC-5	42	29

Hatching and Survival

Table 4-1 summarizes the hatching and survival data from the 2013 repeat eyed egg study. The data shown in Table 4-1 were used to calculate hatching and survival statistics as described above. The results are shown in Figure 4-5.

Data from replicate Whitlock-Vibert boxes at a station were combined, and results between stations within a category (LRC, Reference, Negative Controls) were compared using a two-tailed Fisher exact test (Golder 2014b). Although some marginally significant differences were noted (e.g., hatching rate was lower in LRC-5 than LRC-4 or LRC-2) (Golder 2014b), none of the differences were statistically significant at the $p \leq 0.05$ level, so the data were combined into three data sets (LRC, Reference, and Negative Controls), and the data were compared using a one-tailed Fisher Exact Test and by one-tailed t-test, as described previously.

The results are shown in Table 4-2. As indicated, there is some variability in the results between statistical test methods, but the pattern of results suggests a small but marginally significant decrease in overall survival in LRC compared to both the Reference Group and the Negative Control Group. This decrease is due mainly to a marginally significant decrease in hatching success in organisms exposed in LRC-5 (see Figure 4-5).

As discussed previously (see Section 3.2.4), when an effect is observed in an *in situ* study, it is sometimes difficult to identify the causal factor(s), which might include both site-related contaminants as well as localized variation of environmental stressors or conditions. In this case, because the average exposure concentrations of LA in water were similar between LRC stations (see Figure 4-4), the lower hatching success in LRC-5 cannot be attributed to LA exposure. Furthermore, the decrease in overall survival is relatively small in magnitude (less than 10%), and effects of this magnitude are unlikely to lead to an ecologically significant decrease in trout population density (Toll et al. 2013).

Size and Growth

Data on the length and weigh of alevins surviving to the end of the study are shown below and are plotted graphically in Figure 4-6.

Station	Size	
	Wt (g)	Length (mm)
LRC-2	0.10	23.9
LRC-4	0.11	23.4
LRC-5	0.10	24.4
URC-2	0.11	24.2
NSY	0.11	24.8
NC	0.11	24.7

As shown, values were very similar between stations, although the mean values for LRC are slightly lower than for reference stations. In some cases the differences are statistically different (Golder 2014b), but these differences are not considered to be large enough to be of significant ecological concern and are most likely explained by the differences in water temperatures and study durations for the LRC and reference stations.

Swimming Behavior

All surviving alevins from each Whitlock-Vibert box were transported to a laboratory where each fish was placed into an individual 1-gallon aquarium filled with water from the stream of origin. After 5 minutes of acclimation, swimming behavior was observed for 30 minutes. Abnormal swimming behaviors included:

- Erratic swimming (e.g., swimming into walls)
- Inability to swim in a straight line
- Floating on side, not moving
- Loss of equilibrium, difficulty maintaining orientation
- Other abnormal swimming patterns

Each abnormal behavior was classified as occasional ("O"), frequent ("F"), or continuous ("C") during the 30 minute period. The data are shown in Table 4-3. Statistical comparisons did not reveal meaningful differences in the frequency of abnormal behaviors between boxes or stations within LRC or within the reference reaches (Golder 2014b), so the data were grouped into LRC, Reference, and Negative Controls. The highest abnormal rate (27%) was observed in the negative control group, with lower rates in LRC (8%) and Reference (4%). Based on the one-tailed Fisher Exact Test, the frequency of abnormal swimming in LRC was marginally significantly higher compared to Reference ($p = 0.139$), but is not higher than the Negative Control group. In a number of fish (12 out of 31 total), the cause of the abnormal swimming was attributed to physical deformities (e.g., body or tail crimps) that prohibited normal swimming (Golder 2014b).

External Lesion Frequency

All alevins were examined by a pathologist for the occurrence of external lesions or abnormalities. A wide variety of lesions were observed, both in fish from LRC stations and from reference stations and negative controls.

Statistical comparisons performed by Golder (2014b) indicated that there were no statistical differences between stations within LRC or within reference locations, except for the skin, caudal fin, yolk sac, and body form, with LRC-5 tending to be different than LRC-2 or LRC-4, and NSY being different than URC. However, based on a p value of 0.20, it would be expected that about 20% of the values would be different on a purely random basis, and the observed frequency (7 out of 44 tests = 16%) is within this range. To further evaluate these differences, EPA chose to perform a statistical evaluation in which the data were stratified by reach rather than by station. Statistical comparisons by station are presented in Golder (2014b, Table 3-15 and Appendix C).

Table 4-4 (Panel A) summarizes the data. As shown, 34 of 122 fish (28%) from LRC stations had one or more lesion, compared to 25 of 132 (19%) for Reference stations and 16 of 67 (24%) for Negative Controls. Based on the one-tailed Fisher exact test, the difference between LRC and Reference was marginally significant ($p = 0.062$), while the difference compared to Negative Controls was not statistically significant.

Table 4-4 (Panel B) summarizes the data stratified by reach and by lesion type. As shown, the frequency of lesions was low for most tissues, with abnormalities being noted most often in yolk sack, caudal fin, or body form. Based on the one-tailed Fisher Exact Test, the difference between LRC and Reference was statistically significant for lesions of the caudal fin and marginally significant for lesions of the yolk sack and the skin. Compared to the Negative Control group, none of the differences were statistically significant.

Nature and Etiology of Lesions

Table 4-5 provides the descriptions of the lesions in yolk sack, tail fin, body form, and skin that were assigned severity scores by the pathologist. As shown, the nature of the lesions ranged from minor (e.g., notched tail fin, skin discoloration) to severe (missing tail, severe body deformity). However, there is no clear pattern of differences in the nature of the abnormalities observed in fish exposed in LRC compared to fish from the Reference or Negative Control groups.

Most of the minor lesions of fins and skin were judged to be attributable to trauma and/or conspecific aggression. Abnormal body forms were attributed to genotypic mutations, but the cause for the mutagenic event could not be determined from a gross pathology perspective. The proliferative epidermal and gill lesions that have been observed during experimental asbestos exposure in fish (Belanger et al. 1986a) were not observed in any study fish.

4.2.2 *In Situ* Juvenile Fish Study

As noted above, effects of exposure of fish to toxicants often depends on life stage, so an *in situ* study of exposures of juvenile trout was planned and performed in 2012.

Study Design

The DQOs for the juvenile trout study are presented in Section 5 of the Phase V, Part B SAP/QAPP (EPA 2012a), and the detailed study protocol is presented in Appendix A.3 of the SAP/QAPP. The major aspects of the study design are summarized below.

Exposed Organisms

The exposed organisms were juvenile cutthroat trout obtained from the MFWP Murray Springs Hatchery, near Eureka, Montana. The trout ranged in length from about 7.5 to 12.5 cm (mean = 10.5 cm) at test initiation.

Cages

Juvenile trout were exposed to surface water in floating cages. The cages were wooden boxes with metal mesh on the bottom and sides, and a solid top that sealed the box. The dimensions of the cage were roughly 13-inches tall, 10-inches wide, and 12-inches long. Floats were attached along the top of the sides to keep the box suspended in the water column (see Figure 4-7). There were 15 fish per cage.

Exposure Stations

Juvenile trout cages were deployed at exposure locations close to the locations used in the eyed egg study. This included two cages each at LRC-2, LRC-4 and LRC-5, and three cages each at URC-2 and NSY. Deployment locations were selected to occur in natural pools (some with modifications by study personnel to decrease flow through the cage if flow velocity was too high).

Field Observations

The cages were checked every day during the study period and cleaned. Cleaning involved gently removing anything trapped against the outside netting and brushing the mesh sides if needed using a bristle brush. Daily field activities included measuring stream flow, dissolved oxygen, and temperature, feeding the juveniles with food provided by MFWP, and recording fish observations. Any dead fish were noted in the field notes, removed from the cage, and transported to a processing facility that was established in Libby. Each dead juvenile from the field was weighed and measured and then preserved for subsequent pathological examination.

Surface water samples were collected twice a week in each LRC location and once weekly for each reference site location. Water samples were collected from a randomly selected cage at each location. All water samples from site and reference locations were analyzed for LA by TEM in basic accordance with ISO 10312 counting and recording rules, treating the water with ozone and ultraviolet light prior to analysis (per Libby laboratory modification LB-000020) to remove any biological material that might cause fiber clumping and interfere with the analysis.

Observations of Swimming Behavior

At the end of the field study period, all surviving juvenile fish were transported to the laboratory in Libby to allow for an observation of swimming behavior. Swimming observations were conducted by placing the surviving trout into a 20-gallon aquarium filled with water from the fish's corresponding creek. The fish were allowed to acclimate for a 15-minute period prior to the start of the swimming observations. Swimming observations were then performed at 2, 10, 20, and 30 minutes from the end of the acclimation period. Swimming behaviors were classified as follows:

Normal	Abnormal
• holding on the bottom of the tank with a vertical orientation • holding static or moving very slowly in the water column	• swimming very fast around the tank • lying on the tank bottom • floating on their side (with no movement) • having difficulty maintaining vertical/horizontal orientation • other unusual activity

Pathology Laboratory Examination

Following completion of observations, the fish were humanely euthanized and preserved for subsequent pathological examination. Preserved fish were sent to an off-site pathology laboratory for evaluation of the frequency and severity of external abnormalities, focusing on the skin, mouth, lateral line, and fins.

Results

Results of the *in situ* juvenile trout study are presented in Golder (2013). The main findings are summarized below.

<u>Exposure Conditions</u>

Juvenile trout were deployed into the floating cages on May 11, 2012, and were exposed *in situ* for 33-34 days.

Figure 4-8 (Panel A) shows the mean temperature measured during the study. As indicated, temperatures were about 1.5 to 2 ºC warmer in the LRC stations than in the reference stations.

Figure 4-8 (Panel B) plots concentration of LA from surface water (sampled from within the floating cages) at each station as a function of time. As shown, there was substantial between-day variability, with an apparent trend for decreasing concentrations over time. Panel C shows the mean concentration of LA at each station. As indicated, average LA concentrations in LRC ranged from about 10 MFL to 30 MFL, with an apparent tendency to increase in the downstream direction. LA was occasionally detected in URC-2 (mean = 2.9 MFL) but was only rarely detected at NSY (mean < 0.02 MFL).

<u>Survival</u>

Table 4-6 summarizes the juvenile trout survival data. As shown, no deaths occurred in any of the LRC stations, while 6 out of 90 juvenile trout died in the reference locations.

<u>Length, Weight, and Growth</u>

Figure 4-9 summarizes data on the size (length and weight) and growth of fish surviving to the end of the study. As indicated, fish exposed in LRC (especially LRC-2 and LRC-4) grew faster and were larger at study termination than fish in the reference streams. When combined across stations, both body weight and length were statistically higher ($p < 0.01$) in fish from LRC compared to reference (Golder 2013). This difference is attributed to the warmer water temperature in LRC than in the reference streams.

Swimming Behavior

Detailed descriptions of the swimming behavior at each station and at each time point of observation are provided in Golder (2013). The results are summarized below.

Station	Total Fish Observed	Abnormal Swimming			
		Number		% Abnormal	
		At any time	After 30 min.	At any time	After 30 min.
LRC-2	30	0	0	0%	0%
LRC-4	30	10	1	33%	3%
LRC-5	29	1	0	3%	0%
URC-2	38	1	0	3%	0%
NSY	37	1	0	3%	0%
Site	89	11	1	12%	1%
Ref	75	2	0	3%	0%

As shown, observations were collected for 89 fish from LRC and 75 fish from reference locations. Of the 89 fish alive from the LRC floating cages, 78 (88%) showed consistently normal behaviors and 11 (12%) showed occasional abnormal behavior. Of the 75 fish alive from the reference areas, 73 (97%) showed consistently normal behaviors and 2 (3%) showed occasional abnormal behaviors at one or more times during the observation period. Based on the Fisher Exact test, the frequency of fish displaying abnormal swimming behaviors at any time during the observation period is statistically higher in LRC than reference streams ($p = 0.02$). However, if the data are grouped by station and analyzed by t-test or Wilcoxon rank Sum test, the difference is not statistically significant ($p = 0.23$ or 0.38, respectively). This is because the difference between LRC and reference was due mainly to abnormal behavior in fish from one station (LRC-4).

Importantly, the abnormal behaviors were mainly transitory, with all but one having disappeared by the end of the 30-minute observation period. Based on observations at the 30-minute time period, differences were not statistically different ($p > 0.20$) by any test.

These results are somewhat difficult to interpret with confidence because of the dependence of outcome on the statistical test employed and the apparent transient nature of the presumptive effect. However, because LA concentrations at LRC-4 were lower than at LRC-5, while prevalence of abnormal swimming was lower at LRC-5 than LRC-4, these differences cannot be attributed to LA. In addition, because effects were relatively infrequent (12% vs 3%) and were nearly entirely transitory in nature, it is considered unlikely that the effects on swimming will result in an ecologically significant impact on survival in the wild.

<u>External Lesions</u>

Frequency and Severity

Juvenile trout from all locations had a spectrum of traumatic and idiopathic gross lesions. Each fish was assigned a severity score for mouth, lateral line, fins, skin, and gills, using the scoring system summarized in Table 4-7.

The data are summarized in Table 4-8. As indicated in Panel A, based on a one-tailed Fisher Exact test, the frequency of lesions was not significantly higher in fish exposed in LRC compared to the reference streams for lesions of the mouth, gills, lateral line, or pelvic, anal, or caudal fins, but was significantly higher ($p \leq 0.05$) for lesions (notching/fraying) of the dorsal and pectoral fins.

The mean severity scores for fish with lesions are shown in Panel B. In most cases, the average severity of the lesions was similar in fish from site and reference streams, and based on a one-tailed Wilcoxon rank Sum test, none of the differences are statistically significant except for dorsal fin.

Etiology

The fin lesions were judged by the pathologist to be associated with the confined cage conditions and/or conspecific aggression. The cause of an increased tendency for aggression in fish in LRC is not known, but might be related their increased size compared to fish in reference station cages. However, other factors (e.g., differences in flow rate through the cage) might also be contributing.

Regardless of the cause(s), the fin lesions are not sufficiently severe to cause a serious impairment of swimming ability in juvenile fish and hence are unlikely to be of significant ecological concern.

4.3 Population Studies

As discussed in Section 3.2.4, population studies are one way to determine if an environmental contaminant appears to be adversely impacting on-site populations of exposed ecological receptors. The EPA, working in concert with the BTAG, determined that site-specific studies of fish populations and habitat in OU3 streams compared to reference streams would provide a valuable line of evidence to evaluate risks to fish in OU3. Consequently, fish population studies were performed in two consecutive years, as described below. The basic requirements of the site-specific fish population studies were specified in the Phase II Part C SAP for the OU3 RI (EPA 2008c). Key elements of these studies are summarized below.

4.3.1 Demographic Studies

Detailed information on the fish community studies is provided in Parametrix (2009d, 2010). Key finding are summarized below.

Study Dates and Locations

Surveys of fish density and diversity were performed in October of 2008 and September 2009 at the following reaches (see Figure 2-9):

- TP-TOE-2
- LRC-1
- LRC-2
- LRC-3
- LRC-5
- URC-1A
- URC-2
- BTT-R1
- NSY-R1

Capture Methods

Fish were collected using electroshocking equipment. Multiple passes of electroshocking were performed at each sampling location. In 2009, minnow traps were also used in addition to the electroshocking passes in an effort to increase the effectiveness of capturing smaller fish. Length, weight, and species type were recorded for each fish collected. Table 4-9 summarizes the number of fish captured during these sampling efforts.

Of potential significance is the observation that fish ≤ 65 mm in length were not detected in lower Rainy Creek stations (LRC-1 to LRC-5) during either of these studies. Because young-of-the-year fish usually fall into this size category, this observation suggests that young-of-the-year are not present, which in turn implies the population in this reach is not reproducing. However, lower Rainy Creek is isolated from upward migration of fish from the Kootenai River by a hanging culvert and is usually (except in times of high water overflow) isolated from downward migration of fish from Upper Rainy Creek by the tailings impoundment (Parametrix 2010). Consequently, it is most likely that the population in Lower Rainy Creek is largely self-sustaining and that young-of-the-year are present. EPA and the BTAG discussed several alternative hypotheses that might explain the apparent absence of small fish, and decided the most likely explanation was that, because the water in lower Rainy Creek is several degrees warmer than in reference creeks, fish in lower Rainy Creek grow faster than in reference locations and exceed the 65 mm length criterion by the time of year the sampling occurred (September, October). This hypothesis is supported by the finding of numerous trout < 65 mm in lower Rainy Creek when sampling occurred in August, as well as a clear difference in growth rates between site and reference streams (see Section 4.4, below). Consequently, no special importance is attributed to this observation.

Predominant Species

Raw data on the species of trout that could be reliably identified by species are shown in Table 4-10. As indicated, lower Rainy Creek stations are populated mainly by rainbow trout, with cutthroat and cutbow trout (a hybrid of rainbow and cutthroat trout) in lower numbers. Cutthroat trout and cutbow trout tend to be predominant in upper Rainy Creek and Noisy Creek, while Bobtail Creek is populated mainly by a mixture of brook trout and rainbow trout.

Population Estimates

Fish caught by electroshocking represent only a subset of the total population present in a sampling reach, even after 2 or 3 passes. For this reason, the total fish population was estimated using a mathematical model available in an application referred to as "Microfish" (v3.0) using a maximum likelihood estimate (MLE) method (Van Deventer and Platts 1989). The calculations were based on all fish captured by electroshocking, but did not include data from the minnow traps[5]. This is because minnow traps were not used in both years, and because the openings on these minnow traps may have been too large (~25 mm in diameter) to effectively capture smaller fish (Parametrix 2010). These MLE population estimates were used to derive an estimated fish population density (total fish per acre) for each sampling station by dividing by the area of the reach evaluated.

Population Attributes

Figure 4-10 provides a graphical summary of the fish density (fish per acre), size (grams) and biomass (kg/acre), stratified by reach. Although there was variability between years, density values for LRC stations were consistently lower than for reference stations (Panel A). However, fish in LRC stations tended to be larger than fish from reference stations (Panel B), so biomass was only slightly decreased, especially compared to BTT and URC-2 (Panel C).

[5] Other methods for estimating fish population density were also evaluated, including the MLE method with the minnow trap data included (as presented in Parametrix 2010) and the CapPost (v1.0) estimation method developed by Peterson and Zhu (2004). All methods yielded generally similar results.

Data for TP-TOE-2 and LRC-1 to LRC-4 were combined into one group (LRC) and data for URC-1A, URC-2, BTT-R1 and NSY-R1 were combined into a second group (Ref). In order to determine if there was a statistically significant difference, the data sets were compared using a two-tailed t-test and a two-tailed WRS test. The results are shown below.

Parameter	Mean Value		Statistical Significance	
	Ref	LRC	t-test	WRS
Density (fish/acre)	3955	654	<0.01	<0.01
Weight (grams)	6.3	21.2	<0.01	<0.01
Biomass (kg/acre)	21.7	13.4	0.047	0.034

As indicated, differences are statistically significant ($p \leq 0.05$) by both tests for all of the endpoints. These data support the conclusion that the fish population structure in LRC is different from that in reference streams, with decreased density, increased size, and decreased biomass.

4.3.2 Habitat Studies

As noted in Section 3.2.4, one of the potential limitations to a site-specific population study is that habitat conditions may not be truly equal in the site and reference reaches, and observed differences in fish density might be related, at least in part, to habitat factors rather than exposure to LA. Two types of habitat factors are of potential importance:

- Barriers to fish movement
- Habitat quality in the reaches being evaluated

Barriers to Movement

A fish barrier assessment along upper and lower Rainy Creek was conducted in the summer and fall of 2009 (Parametrix 2010). The barrier assessment consisted of walking the stream to look for waterfalls, culverts and other structures that may affect fish passage. The most important determinants of a barrier are the height of the barrier and the depth of the plunge pool. When the ratio of the two is less than 0.5, it is unlikely that fish can migrate from downstream to upstream past the barrier, especially when the plunge pool itself is shallow.

As shown in Table 4-11, a total of 17 absolute or potential barriers were identified along LRC. Of these, five were judged to pose little impediment to fish movement, but the others were judged to be potentially significant, with the most important being:

- A hanging culvert just downstream of LRC-5. This creates an absolute barrier to upward migration of fish from the Kootenai River.
- A weir at LRC-6. This also likely prevents upward migration from the Kootenai River because there is no plunge pool at all.
- The dam that forms the tailings impoundment. This 135-foot tall structure represents a complete barrier to upstream movement, and is also a barrier to downstream movement except during times of overflow from the impoundment into lower Rainy Creek.

These potential and absolute barriers limit the migration of fish between different reaches of Rainy Creek, and may be a factor that influences population density within certain reaches.

Habitat Quality

In order to evaluate the potential effect of habitat quality on fish population parameters, EPA collected data on a number of key habitat variables that are considered to be important determinants of fish population density (Raleigh *et al.* 1984). Potential influences of habitat parameters on fish populations were evaluated based on a comparison of measured habitat parameters to ranges that are considered to be optimum for sustaining healthy trout populations (Harig and Fausch 2002, Adams et al. 2008, Hickman and Raleigh 1982, Raleigh 1984, Varley and Gresswell 1988). Figure 4-11 summarizes the findings. In these figures, the optimum ranges are shown by solid red and green lines. As indicated, there are several habitat parameters where conditions in LRC are different from and more frequently outside the optimal range than for the reference streams. This includes:

- Summer temperatures in LRC are warmer than is optimum for cutthroat trout, are near the upper end of the range for rainbow trout, and are higher than in reference streams.
- The amount of large woody debris is lower in LRC than is optimal, and is lower than in reference streams.
- Both the number of pools and the percent of pools in LRC are usually lower than is optimal, and both tend to be lower than in reference streams.

The statistical correlations between population density and biomass and each of the habitat metrics are summarized below:

Habitat Metric	Correlation Coefficient (R)	
	Density	Biomass
Max July/August Temp	-0.66	-0.45
Spawning Gravel	0.89	0.60
% Fines	-0.63	-0.45
Area Woody Debris	0.70	0.20
Pools > 30cm	0.40	0.09
% Pools	0.51	0.76

As indicated, fish density shows a moderately strong direct correlation with the availability of spawning gravel, woody debris, and an inverse correlation with maximum summer temperatures, while biomass is most strongly correlated with spawning gravel and availability of pools. These findings suggest that the changes in population structure (both density and biomass) in LRC are likely largely attributable to differences in habitat variables, especially spawning gravel, woody debris, water temperature, and pool availability. Potential contributions of LA to the observed differences in population structure cannot be determined with certainty, however, if present, they are likely minor relative to the effects of habitat.

4.4 In Situ Lesion Studies

EPA and the BTAG determined that a comparison of the frequency and severity of external and internal lesions in resident fish captured from OU3 to that for fish from reference streams would provide an additional useful line of evidence for evaluating risks to fish. The study requirements were specified in the Phase V Part B SAP/QAPP (EPA 2012a), and the results are presented in Golder (2014a). The main elements and findings of the study are summarized below.

Study Design

Resident trout were collected by electrofishing at five reaches of lower Rainy Creek (TP-TOE-2, LRC-1, LRC-2, LRC-3 and LRC-5), one reach on Noisy Creek (NSY-R1), and two reaches in upper Rainy Creek (URC-1A and URC-2). Minnow traps were also set, but were not effective in capturing fish and no fish from minnow traps were evaluated. Collection occurred from August 1 to August 6, 2012.

The goal of the study was to collect fish in each of two size (length) classes: < 65 mm, and 65-100 mm. A total of 10 fish in each size class were sought from both lower Rainy Creek (5 reaches combined) and from NSY and upper Rainy Creek (combined). Lengths of collected fish were measured in the field to ensure they met the size class requirements. Only cutthroat, rainbow, and cutbow trout in the intended size classes were kept, and all other fish were released. Collected fish were kept in cold water from their respective creek in plastic containers until transported to a laboratory in Libby where they were humanely euthanized, weighed, and re-measured to ensure lengths were accurate. Fish were preserved in 10% neutral buffered formalin solution and sent for pathological examination.

All fish were examined by a board-certified pathologist for external lesions or abnormalities, paying particular attention to the gills and lateral line. The pathologist also selected a subset of the fish for additional histological examination. These fish were sectioned transversely at four locations to include the head and rostral aspect of the coelom and body, such that the gills, cranial line, lateral line, fins, and skin could be examined symmetrically for microscopic lesions, and to evaluate the pathogenesis of any observed macroscopic lesions. Observed external and histologic abnormalities were scored based on severity and extent as follows:

Severity	Score	Extent	Multiplier
None	0	Unilateral	1
Mild	1	Bilateral	2
Moderate	2		
Marked	3		
Severe	4		

Statistical Comparisons

Data from all LRC locations were pooled into a combined Site dataset and data from URC and NSY locations were pooled into a combined Reference dataset for analysis. The frequency of lesions was compared using a one-tailed Fisher Exact test, while severity scores were compared using a one-tailed Wilcoxon Rank Sum test.

Results

<u>Number of Fish Submitted</u>

Table 4-12 summarizes the fish that were captured and submitted for examination. As indicated, there were 10 in each size class (20 total) submitted from LRC (note that all fish were from the upper reaches (TP-TOE-2, LRC-1 and LRC-2), and none were collected from LRC-3 or LRC-5), and there were 15 fish < 65 mm and 25 fish 65-100 mm (40 total) submitted from the three reference locations.

<u>External Lesions</u>

The pathologist performed external examinations of all 60 fish. A summary of the frequency and severity of the abnormalities observed is presented in Table 4-13, and the findings are discussed below.

Lesion Frequency

Panel A summarizes the frequency of external lesions observed in site and reference fish. External lesions were most evident as fraying of the fins, particularly the dorsal, pectoral, pelvic, and tail fins. Statistical evaluation using a one-tailed Fisher Exact test indicated that there were no external abnormalities that occurred more frequently in Site fish than in fish from the reference creeks.

Lesion Severity

Panel B summarizes the mean severity scores for site and reference fish. As seen, mean values were generally the same or higher in fish from reference streams than from site streams, except for tail fin. However, based on a one-tailed Wilcoxon Rank Sum test, this difference was not statistically significant.

Nature and Etiology of External Lesions

A detailed description of the nature and likely etiology of the external lesions is provided in Appendix B of Golder (2014a). Fin lesions were mainly erosions and ulcers of the fin epidermis which were attributed to a combination of traumas (conspecific or other aggression, collisions with substrates or rocks, etc.). Skin lesions presented mainly as small flat patches of white discoloration on the flanks, dorsum and head. In a few fish, the patches or plaques were present dorsally and ventrally around the lateral line. These white patches were attributed to erosions and ulcers in the skin likely due to the same factors causing fin erosions and ulcers. Changes due to tissue processing and formalin fixation may also have contributed to some of the discoloration noted. Raised plaques that could represent epidermal hyperplasia were not seen in these fish. Gill lesions were characterized by white discoloration of the filaments in a few fish. The white coloration in the gills was attributed to the same factors affecting the skin. No lesions were attributed to LA.

Histological Lesions

After completing the external examinations, the pathologist identified a subset of fish with certain external abnormalities for further histological examination. This included 5 fish from each reference stream and 4 fish each from LRC and TP-TOE stations. The fish were selected to include fish with gill spots and other gill issues (including flaring and reddening) as well as some white skin discolorations and plaques. However, the histological examination included all tissues (not just gill and skin).

Frequency and Severity

Histological lesion scores were assigned for each tissue based on the severity and extent as follows:

- Lesion severity (inflammation, hemorrhage, edema, necrosis, etc.)
  0 = no lesions, 1= mild, 2 = moderate, 3 = marked, 4 = severe
- Lesion distribution on skin and fins:
  1 = dorsal, 1 = lateral, 1= ventral, 1 = operculum
- Lesion distribution on all tissues:
  Multiplication factor of 1= unilateral, 2 = bilateral,

The frequency and severity data are summarized in Table 4-14. Because fish were selected to include certain lesions rather than being a random subset of the whole, the frequency data (Panel A) have only limited relevance.

Data on histological lesion severity (Panel B) are more meaningful because the data are based only on the severity scores of observed lesions, not the frequency. As indicated, scores were generally similar or higher in fish from reference stations than LRC, and statistical comparisons based on the one-tailed Wilcoxon Rank Sum test indicated that there were no tissues with statistically significant ($p \leq 0.05$) higher severity in site than reference fish, although a marginally significant ($0.05 < p \leq 0.20$) difference was noted for brain tissue..

Nature and Etiology of Histological Lesions

A detailed description of the nature and likely etiology of the histological lesions is provided in Appendix B of Golder (2014a). The main conclusions reached by the pathologist are summarized below.

> *Skin*: Skin lesions were predominantly acute erosions and ulcers. The etiology of the skin lesions is unknown but resembled those seen in fish as a response to acute stress, suboptimal water quality, exposure to various toxicants, trauma, or combinations thereof.
>
> *Cranial and lateral lines*: Lesions of the cranial and lateral line included inflammation, edema, necrosis, luminal and peripheral hemorrhage, and accumulation of luminal debris. It appeared that the lesions and inflammation were mainly extensions of the skin lesions, and that the epithelial necrosis was not due to asbestos exposure but rather was most likely due to stress or capture technique.

Gills: The principal lesions in gills included atrophy or necrosis of the secondary lamellae and interstitial lymphocytic inflammation. These effects were judged to be due to irritation and/or antigenic stimulation, and possibly from post mortem autolysis. Gill lesions associated with asbestos exposure were not seen in these fish.

Fins: Lesions of the fin were seen in fish from all locations. Lesions were mainly erosions or ulceration of the skin, similar to that seen in the trunk and head. Other lesions atrophic changes likely corresponding to the frayed appearance noted in the gross exams. It was unclear if these atrophic changes were due to external irritation, toxicant exposure, trauma or stress related damage to the epidermis, or intrinsic factors such as genetics, nutrition, or metabolic derangements. Fin lesions associated with asbestos exposure have not been documented.

Oral mucous membranes: Lesions were primarily lymphocytic inflammation in the submucosa and epithelial layers, and more or less diffuse. The lesions were attributed to antigenic stimulation, the mouth being one of the first sites of environmental antigen exposure.

Nasal mucous membranes: Lesions in the nasal mucosa included mild inflammation, erosions and necrosis. These lesions likely had the same pathogenesis as for skin and cranial/lateral lines. Nasal mucosal lesions have not been described in fish experimentally or naturally exposed to asbestos.

Corneas: Lesions were acute erosions or ulcers of the external corneal epithelial layer and edema in the underlying corneal stroma. These lesions likely had the same pathogenesis as those for skin, although euthanasia procedures or post mortem abrasions may also have contributed.

Brain and skeletal muscle lesions: Acute hemorrhage was frequently detected in fish from all groups, primarily in the facial muscles and in the meninges of the brain. Hemorrhage was accompanied by acute rhabdomyolysis in the skeletal muscle, and hydrocephalus in the brain. These lesions were attributed to the manner of capture (electroshock).

.*Skeleton:* Some mild curvature of the spine was seen in few fish. A representative fish examined histologically revealed no abnormalities in histogenesis of bone, bone symmetry or degeneration of spinal cord, and the curvature was attributed to hyperflexion associated with tissue fixation.

Additional tissues: Several different tissues were examined opportunistically in the histologic analysis. No lesions were seen in these additional tissues.

Lesion Summary

Gross and histologic lesions were seen in all groups, primarily involving the fins, skin and gills. Neither the frequency of occurrence nor the severities of external abnormalities were statistically higher in Site fish compared to reference fish in any case. Histologic lesions were more extensive in the gills and skin than were apparent from gross (external) examination, suggesting that gross lesion assessment is not a sensitive means of identifying lesions in these fish. No primary infectious agents or deposition materials were identified histologically that would account for the lesions, although the light microscopy techniques used in this study would not have been able to detect structures lower than 1 μm in diameter. No unique lesion morphology was identified to suggest that asbestos was a contributing factor to lesion development in the study creeks, and all of the lesions observed are commonly encountered in captive and wild fish and attributed to a combination of trauma, stress, or suboptimal water quality.

4.5 Weight of Evidence Evaluation for Fish

Four lines of evidence are available to help evaluate the effects of exposure of fish to LA in site waters, including:

- *In situ* toxicity studies of eyed eggs and alevins
- *In situ* toxicity tests of juvenile trout
- Fish population studies
- Resident fish lesion studies

The data and conclusions from these lines of evidence are summarized in Table 4-15.

The population studies indicates that trout population structure in LRC is different from reference streams, with decreased fish density, increased fish size, and decreased biomass. This observation could be consistent with a hypothesis that LA in site waters is toxic to trout and results in a decreased number of fish, but several observations suggest that LA is not the likely cause of the difference:

.

- There are several habitat quality factors that are lower in LRC than reference streams (especially spawning gravel, woody debris, water temperature, and pool availability). These habitat factors show a relatively strong correlation with trout density, suggesting that habitat likely accounts for much of the apparent difference.

- *In situ* toxicity studies of early life stage trout indicate there might be a small decrease in hatching success of eyed eggs in lower Rainy Creek than in reference streams, but this cannot be attributed to LA. Moreover, the difference is sufficiently small (<10%) that a substantial effect on population density would not be expected (Toll et al. 2013).
- No effects that might contribute to decrease survival of larger fish have been detected, either in caged juvenile fish studies or studies of resident fish. This is consistent with numerous other studies which indicate that early life stages of fish are usually more sensitive to toxicants that larger fish.

Taken together, the weight of evidence suggests that LA in waters of LRC is not causing adverse effects on resident trout. By extension, effects of LA on fish in the Kootenai River (including sensitive species such as the white sturgeon and bull trout) are therefore not of concern, since concentrations of LA in the Kootenai River are substantially lower than in LRC.

Confidence in this conclusion is medium to high. The chief limitation to the *in situ* exposure studies is that there is no control over environmental variables and the findings are limited to the conditions and concentration values that occurred during the studies (about 40-45 MFL for eyed eggs and about 10-30 MFL for juvenile trout). Consequently, if substantially higher concentrations were to occur in other years, the consequences, if any, cannot be predicted. In general, the chief limitation to fish population surveys is that population parameters and habitat variable often tend to be variable between years, making it difficult to distinguish between random and site-related differences. However, in this case, results were relatively consistent across two years, so confidence in these studies is good.

5.0 RISKS TO BENTHIC MACROINVERTEBRATES

5.1 Reported Effects

The toxic effects of asbestos on benthic macroinvertebrates have not been extensively-studied. Relevant studies that were located are summarized below.

- Stewart and Shurr (1980) exposed larval *Artemia salina*, a filter-feeding saltwater crustacean, to suspensions of chrysotile or crocidolite asbestos. The authors reported that both forms of asbestos caused a decrease (usually about 20%) in larval survival at concentrations up to 400 mg/L, with no additional increases at higher concentrations. A suspension of "short chrysotile" was judged to be more potent than "medium" or "long" chrysotile, although all forms caused the same level of mortality at high concentrations (400 mg/L or more). Crocidolite was found to be of similar toxicity as chrysotile when concentrations and fiber length were similar. A concentration of 400 mg/L was estimated to correspond to concentrations of about 40-200 MFL, depending on fiber length.

- Belanger et al. (1986b, 1986c) investigated the effects of chrysotile exposure on larval, juvenile, and adult Asiatic clams (*Corbicula sp*.). Siphoning activity and shell growth of adult clams and siphoning activity, shell growth, and weight gain of juveniles were significantly reduced following 30 days of exposure to 0.1 MFL chrysotile. Exposure to 0.001 to 100 MFL caused a significant reduction in release of larva by brooding adults as well as increased mortality in larva.

No studies were located on the effects of LA on any species of benthic invertebrate.

5.2 Laboratory Toxicity Tests

The EPA, working in concert with the Libby OU3 BTAG, determined that site-specific studies of the toxicity of LA-contaminated sediment from OU3 would provide one valuable line of evidence to evaluate risks to benthic macroinvertebrates.

5.2.1 Study Design

The overall study requirements developed by EPA and the BTAG were specified in Section 5 of the Phase 2 Part C SAP of the RI for OU3 (EPA 2008c). In brief, the SAP specified that static renewal lifecycle tests be performed for two species of organisms (the amphipod *Hyalella azteca* and the midge *Chironomus tentans)*, comparing the effects of exposure to site sediments to appropriate reference and control sediments. Based on these requirements, the performing laboratory (Parametrix, Inc.) submitted study protocols that were designed to comply with EPA standard methods (EPA 2000) and the Phase 2 SAP. The protocols were reviewed and approved by EPA and the BTAG, and the studies were implemented in 2009. Detailed results are presented in Parametrix (2009b,c), and key features are summarized below.

Treatments

For each species, seven treatments were evaluated:

Category	Treatment	Description
Artificial sediment	1	75% Sand, 20% Clay, 5% Peat
	2	75% Sand, 20% Clay, 5% Peat
Reference Sediment	3	Sediment from Beaver Creek, Oregon
Site-specific reference sediment	4	Sediment from Bobtail Creek Tributary (BTT-R1)
	5	Sediment from Noisy Creek (NSY-R1)
Site-specific contaminated sediment	6	Sediment from Carney Creek (CC-1)
	7	Sediment from Tailings Pond Toe (TP-TOE2)

Treatments 1, 2 and 3 are used mainly to determine if the test conditions were acceptable. Effects of site-related contamination were determined by comparison of Treatments 6 and 7 (individually) to Treatments 4 and 5 (combined).

Sediment Properties

Table 5-1 summarizes data on the physical characteristics of the site-specific sediments evaluated. As indicated, the sediments from contaminated areas in OU3 (CC-1 and TP-TOE2) were generally similar to those from Reference area NSY-R1, while sediment from Reference area BTT-R1 tended to be higher in gravel, silt, and TOC and lower in sand than the other sites.

Table 5-2 (top line) summarizes PLM-based estimates of the concentration of LA in site-specific sediments. As indicated, the concentration of LA was estimated to be 5% and 3% in the CC-1 and TP-TOE2 samples, respectively. These concentrations are at the high end of LA concentrations that have been observed in OU3 sediments. LA was not detected in site-specific reference sediments.

Table 5-2 (lower rows and footnote) summarizes data on the concentrations of other constituents in the sediments. Concentrations of metals were generally similar in site and reference sediments. Several groups of organic chemicals were analyzed in the two reference sediments (BTT-R1 and NSY-R1), including chlorinated herbicides, organochlorine pesticides, organophosphate pesticides, and semi-volatile organics. None of the organic chemicals were detected at either of the reference sediments (Parametrix 2009b,c).

Overlying Water

The overlying water used for these studies was well water blended with reverse osmosis-treated water for a targeted hardness of 80 to 120 mg/L. Twice each day, fresh water was provided to each exposure chamber to achieve a 95% static renewal of the water. The hardness, alkalinity, total residual chlorine and ammonia of the overlying water were measured weekly during the test. Temperature of the water was maintained at 23 ± 2 °C.

5.2.2 Results for *Hyalella*

The test was initiated with juvenile organisms (7 to 9 days old). Based upon visual observation, the organisms appeared healthy at test initiation (Parametrix 2009b).

Organisms were tested in 16-ounce tall-form glass jars containing 100 mL of sediment and approximately 175 mL of overlying water. There were twelve replicate chambers per treatment, with 10 organisms per replicate, although one replicate from Treatment 5 was inadvertently not seeded with organisms. Feeding occurred daily.

Survival (Figure 5-1 Panel A)

Survival was measured on day 28, day 35, and at study termination (day 42) by pouring out each exposure chamber and counting the number of living adult organisms present. In the artificial controls (Treatments 1 and 2), mean survival at day 28 (70% and 61%) was lower than the usual acceptance criterion of 80%, suggesting that the data from these treatments might not be reliable. However, mean survival in the field-collected reference sediments (Treatments 3, 4, and 5) were all higher than 80%. Consequently, comparisons between LA-containing sediments (Treatments 6 and 7) and the field collected reference sediments are judged to be reliable.

Mean survival rates for Treatments 6 and 7 were compared to the mean survival rate for the site-specific reference sediments (Treatments 4 and 5, combined) using a one-tailed t-test. As summarized below, no statistically significant ($p \leq 0.05$) decrease in survival was observed in either of the LA-containing sediments on any of the exposure days, although marginally significant ($0.05 < p \leq 0.20$) decreases were noted for Treatment 6 on days 35 and 42.

t-Test Comparison	p Value		
	Day 28	Day 35	Day 42
6 vs 4&5	0.23	0.20	0.10
7 vs 4&5	0.36	0.80	0.24

Growth (Figure 5-1 Panel B)

Mean body weight (dry weight) of surviving adult organisms was measured in four of the replicates from each treatment group on day 28 and in the remaining eight replicates on day 42. As shown in Panel B, mean weights for organisms in Treatments 6 and 7 were higher than for Treatments 4 and 5, either alone or combined, on both day 28 and 42.

Reproduction (Figure 5-1 Panel C)

Reproduction was measured on days 35 and 42 by pouring out each exposure chamber and counting the number of juvenile organisms present. As shown in Panel C, mean reproduction rates were higher in Treatments 6 and 7 than in Treatments 4 and 5, alone or combined, on both day 35 and 42.

Exposure Concentrations in Porewater

In the *Hyalella* study, an effort was made to measure the concentration of LA in sediment porewater at the start and finish of the study, since porewater is often thought to be the primary exposure medium in sediment toxicity studies. In brief, five replicates per treatment were fitted with a suction lysimeter which consisted of borosilicate glass tubing with a 2.5 mm hole mounted into the bottom of the test chamber. The tubing entered the chamber horizontally at the bottom of the sediment layer. The end of the tubing within the chamber was fitted with 250 µm stainless steel mesh which was intended to minimize entry of sediment particles. The outside end of the tubing was then connected to a syringe that was used to slowly withdraw porewater from the test chamber. Up to 20 mL of porewater from each replicate were extracted into amber glass vials and sent for LA analysis by TEM. However, in several cases, the screen became clogged with sediment, and porewater was successfully collected only from Treatment 1 (control sediment), Treatment 5 (NSY-R1) and both asbestos sediments (Treatments 6 and 7).

The results are shown in Table 5-3. As expected, LA was not detected in porewater from the control or reference sediments. For the LA-contaminated sediments, porewater concentrations were quite variable between replicates, but there was a clear tendency for the concentration at the end of the study to be lower than measured at the start of the study. Although these data suggest that LA exposure levels may have tended to decrease during the study, this is not considered to be the most likely explanation for the data. Rather, it is considered implausible that the gentle water exchange protocol used in the studies could actually result in a significant depletion of LA from the bulk sediment, and the apparent difference between the starting and ending concentrations is probably due to either a) a higher level of bulk sediment in the porewater samples collected at the start than at the end, and/or b) the effect of biofouling of the lysimeter tube between the start and end of the study. Consequently, these porewater results are not interpreted to indicate a significant uncertainty or limitation to the site-specific sediment toxicity studies.

5.2.3 Results for *Chironomus*

The test was initiated with newly-hatched (< 24 hours old) larval Chironomids. Based upon visual observation, the newly-hatched larvae appeared to be healthy, exhibiting vigorous movement within the water column (Parametrix 2009c). Organisms were exposed in 16-ounce tall-form glass jars containing 100 mL of sediment and approximately 175 mL of overlying water. There were twelve replicate chambers per concentration, with 15 organisms per replicate. However, two replicates were inadvertently double-seeded and three replicates were inadvertently unseeded, thereby diminishing the number of observations for some endpoints. Feeding occurred daily.

Survival (Figure 5-2 Panel A)

The usual criterion for acceptability of a sediment toxicity test using Chironomids is 70% survival in control treatments on day 20. Although survival on day 20 was not measured, on day 24, survival was lower than 70% for Treatments 1, 3 and 5. The reason for this low survival in control groups is not clear. Some deaths may have occurred between day 20 and day 24, but the number (if any) is unknown. In addition, a number of indigenous organisms were noted in the site and field-collected sediments, which might influence the survival of the test organisms.

Mean survival rates for Treatments 6 and 7 were compared to the average survival rate for the site-specific reference sediments (Treatments 4 and 5, combined) using a one-tailed t-test. As summarized below, no statistically significant ($p \leq 0.05$) decrease in survival for the LA-containing sediments was noted at Day 24, but a marginally significant ($0.05 < p \leq 0.20$) decrease was noted for Treatment 6 and a statistically significant ($p \leq 0.05$) decrease for Treatment 7 was noted on Day 52.

t-test	p value	
Comparison	Day 24	Day 52
6 vs 4&5	0.333	0.151
7 vs 4&5	0.958	0.006

Emergence (Figure 5-2 Panel B)

Emergence traps were put into place on day 20 or 21. Following emergence, males and females were paired from within the same treatment, but not necessarily from within the same replicate. Males from auxiliary chambers were used as needed to provide a sufficient number of males for mating with the females. The pairs were housed in emergence chambers and monitored daily for release of egg masses and adult mortality. If all males died within an emergence chamber prior to a female releasing an egg mass, secondary males were placed in the chamber. Once egg masses were deposited, they were removed and counted by ring method or direct counts. Egg masses for direct counts were placed in a test tube with sulfuric acid solution and counted the next day. These eggs were not used in the hatchability analysis. Egg masses that were counted by ring method on the day of deposition were placed in a small beaker of clean overlying water and allowed 6 days to complete hatching. On the 6th day, the number of unhatched eggs was counted for use in the hatchability calculation. Test termination occurred when there was no emergence for at least 7 days in each treatment.

Nearly all organisms that successfully emerged survived to day 52. Consequently, emergence values are nearly identical to survival values at day 52. As above, when compared to the site-specific reference sediments (Treatments 4 and 5 combined), a marginally significant ($0.05 < p \leq 0.20$) decrease was noted for Treatment 6 and a statistically significant ($p \leq 0.05$) decrease for Treatment 7 was noted on Day 52.

Growth (Figure 5-2 Panel C

Growth was evaluated on day 24. Four replicates in each treatment were poured into a glass pan and then sieved through a 425 µm mesh screen to recover organisms. Sieved organisms from within a replicate were composited and weighed, both on a dry weight and ash-free dry weight basis. Of these measures, EPA recommends the ash-free measurement as most reliable (EPA 2000). The ash-free for Treatments 6 and 7 were compared to Treatments 4 and 5 (combined) using a one-tailed t-test. As indicated below, Treatment 6 was statistically marginally lower ($0.05 < p \leq 0.20$) than reference, but Treatment 7 was not significantly different ($p > 0.20$).

t-test Comparison	p value
6 vs 4&5	0.170
7 vs 4&5	0.430

Reproduction (Figure 5-2 Panel D)

Reproduction was analyzed as the number of eggs within an egg case and also the hatchability of those eggs. Control performance criteria (EPA 2000) state that the mean number of eggs/egg case should be greater than or equal to 800 and the percent hatchability should be greater than or equal to 80%. All treatment groups averaged over 1,500 eggs/case and averaged over 94% hatchability.

When compared to the site-specific reference sediments (Treatments 4 and 5 combined) using a one-tailed t-test, no statistically significant decreases in eggs per female were observed for either Treatment 6 or Treatment 7 ($p > 0.20$). Hatching success was statistically lower ($p = 0.04$) for Treatment 6 (96.8%) than the reference sediments (98.1%), but the difference is so small (1.3%) that this is not considered to be ecologically significant.

5.2.4 Discussion

In *Hyalella*, a marginally significant ($0.05 < p \leq 0.20$) decrease in survival was noted for organisms exposed to sediments from CC-1, but no other significant effects on survival, growth or reproduction were observed ($p > 0.20$). For *Chironomus*, a statistically significant ($p \leq 0.05$) decrease in survival and a marginally significant ($0.05 < p \leq 0.20$) decrease in growth was noted for organisms exposed to sediment from CC-1, and a marginally significant ($0.05 < p \leq 0.20$) decrease in survival was noted for organisms exposed to sediment from TP-TOE2. The difference in survival was relatively small in *Hyalella* (4-6%), but was larger in *Chironomus* (9-25%). These data are interpreted to indicate that LA-contaminated sediment might cause moderate decreases in survival of some species of invertebrates, but the applicability of these results to other species is best determined using other lines of evidence.

5.3 Population Studies

The EPA, working in concert with the Libby OU3 BTAG, determined that site-specific studies of the density and diversity of benthic macroinvertebrates in Rainy Creek and appropriate reference streams would provide a valuable second line of evidence to evaluate risks to benthic macroinvertebrates in OU3. The overall study requirements developed by EPA and the BTAG were specified in Section 5 of the Phase II Part C SAP of the RI for OU3 (EPA 2008c) and in Section 4.2 of the Phase III SAP of the RI for OU3 (EPA 2009). The studies were performed in 2008 and 2009, and the detailed methods and findings are reported in Parametrix (2009d, 2010).

5.3.1 Demographic Measurements

Sampling Locations

Benthic macroinvertebrate population/community surveys were performed at two stations on upper Rainy Creek (URC-1A and URC-2) and five stations on lower Rainy Creek (TP-TOE-2, LRC-1, LRC-2, LRC-3, LRC-5). Population/community studies were also performed at the Noisy Creek (NSY-R1) and Bobtail Creek tributary (BTT-R1) reference stations. Based on a consideration of stream gradient and other features, the Noisy Creek station (NSY-R1) is considered to be the most appropriate reference for comparison to upper Rainy Creek stations

(URC-1A and URC-2), and Bobtail Creek tributary (BTT-R1) is the most appropriate reference for comparison to lower Rainy Creek stations.

Sampling Methods

Macroinvertebrates were collected using two different methods: a kick net and a Surber sampler. Details of these collection techniques are described in SOP# BMI-LIBBY-OU3 (Rev. 0).

- The kick net method follows EPA's current Rapid Bioassessment Protocol (RBP) (Barbour et al. 1999). This method is a semi-quantitative sampling technique designed to collect a representative macroinvertebrate sample along a single meander length of a stream. Benthic macroinvertebrates are collected from all available in-stream habitats by kicking the substrate or jabbing with a D-frame dip net. A total of 20 jabs (or kicks) are taken from all major habitat types in the reach, resulting in sampling approximately 3.1 m^2 of habitat. Because of the relatively large area sampled, the kick net approach tends to minimize small-scale variability in benthic density and diversity at a station.

- The Surber method collects benthic macroinvertebrate community data using a 0.279 m^2 sampler frame with a 250 μm mesh net. Samples are collected by disturbing the area within the square sampling frame by hand and scrubbing individual woody debris and cobbles within the square sampling area for a total of 90 seconds, then allowing the invertebrates and detritus to wash downstream into the net. Three sampling areas for each station were composited to form a single sample with a total area of 0.837 m^2. While the Surber method is more quantitative than the RBP kick net method, because of the relatively small area sampled, the Surber method may be influenced by small-scale variability in benthic organism density.

RBP Data Evaluation

For both sampling methods, benthic organisms collected from a location are sorted in a laboratory and identified to the lowest practical taxon (generally genus or species). Based on the count of organisms by taxon, up to 38 alternative macroinvertebrate metrics may be calculated and used to evaluate the status of the benthic community. The choice of the most relevant and useful indices depends on the nature of the stream being sampled and the types of organisms that are expected to be present (Barbour et al. 1999).

For the kick net samples collected in accordance with the RBP method, 9 metrics were selected by EPA and the BTAG as being most useful for evaluation of benthic communities in OU3 streams:

1) Taxa Richness (total number of taxa)
2) Total Density (organisms per unit area)
3) EPT Index (number of EPT taxa)[6]
4) Shannon-Weaver Diversity
5) % Ephemeroptera
6) % Tolerant organisms
7) % Contribution Dominant Taxon
8) % Scrapers
9) % Clingers

Table 5-4 presents the data for the RBP kick net samples collected in 2008 and 2009. For each metric, the value measured at a potentially impacted station is divided by the value for an appropriate reference station, and assigned a score based on the ratio:

Metric	Assigned Score			
	6	4	2	0
1) Taxa Richness (Number of Taxa)	>80%	60-80%	40-60%	<40%
2) Total Density	>80%	60-80%	40-60%	<40%
3) EPT Index (number of taxa at station)	>90%	80-90%	70-80%	<70%
4) Shannon -Weaver Diversity	>85%	70-85%	50-70%	<50%
5) % Ephemeroptera	>50%	35-50%	20-35%	<20%
6) % Tolerant organisms	>80%	60-80%	40-60%	<40%
7) % Contribution Dominant Taxon	<20%	20-30%	30-40%	>40%
8) % Scrapers	>50%	35-50%	20-35%	<20%
9) % Clingers	>50%	35-50%	20-35%	<20%

The metric-specific scores are then summed across all of the metrics to obtain the overall Biological Condition Score (BCS). The BCS at a potentially impacted station is evaluated by comparison to the BCS value at an appropriate reference station:

Ratio of BCS Values (Site/Reference)	Interpretation
≥ 0.8	Unimpaired
0.5 to 0.8	Slightly impaired
0.2 to 0.5	Moderately impaired
< 0.2	Severely impaired

As shown in Table 2-4, LA was never detected in sediments from either BTT or NSY, indicating that these stations are, from a contaminant standpoint, suitable reference locations. However,

[6] EPT = Ephemeroptera, plecoptera, trichoptera,

LA was detected in one of 3 sediment samples from URC-1A and in 3 of 3 samples from URC-2, suggesting that these stations may not be reliable for use as reference.

Table 5-5 shows the BCS calculations using BTT and NSY as reference. These results are also presented graphically in Figure 5-3. Using the mean of both reference stations for both years (53.5 in this case), stations along LRC tend to fluctuate over time between unimpaired (6 of 10) and slightly impaired (4 of 10). If URC-1A and URC-2 are accepted as reference along with BTT and NSY, then stations along LRC tend to fluctuate over time between unimpaired (8 of 10) and slightly impaired (2 of 10).

Surber Data Evaluation

The U.S. Forest Service (USFS) has utilized the Surber sampling method to collect benthic invertebrates from several locations in the Kootenai National Forest over multiple years (1998-2006) (Vinson 2007). These data have been evaluated by the State using a scoring system developed by MDEQ (Jessup et al. 2006, MDEQ 2006). MDEQ screened all of the RBP metrics for their capacity to correctly detect stressed conditions in Montana streams. For mountain streams, a 7-metric index (referred to as the Mountain MMI) was identified as being preferred, using the scoring protocol shown below:

Metric	**MDEQ Mountain MMI Scores**			
	3	2	1	0
1. Taxa Richness (Number of Taxa)	>28	28-24	23-19	<19
2. EPT Index (Number of Taxa/Station)	>19	19-17	16-15	<15
3. Hilsenhoff Biotic Index (HBI) Score	<3	3-4	4.01-5	>5
4. % Contribution Dominant Taxa	<25	25-35	35.01-45	>45
5. Collector/Gatherer (% Abundance)	<60	60-70	70.01-80	>80
6. EPT Abundance	>70	70-55.01	55-40	<40
7. Scraper/Shredder (% Abundance)	>55	55-40.01	40-25	<25

In order to be able to utilize these USFS data as well as the data from the OU3 reference streams (Bobtail Creek Tributary and Noisy Creek) as a frame of reference for evaluation of benthic macroinvertebrate (BMI) community status at streams along Rainy Creek, the OU3 Surber data were also evaluated using the MDEQ Mountain MMI approach. The resultant Mountain MMI scores are shown in Table 5-6, and the values are presented graphically in Figure 5-4. As seen, the USFS Kootenai National Forest reference stations range from about 8 to about 20. The two OU3 reference streams are quite different from each other, with scores of about 6 (BTT-R1) and

20 (NSY-R1). This difference is due mainly to a decrease abundance and diversity of EPT species as well as a decrease in the abundance of shredders and scrapers in BTT.

Scores in upper Rainy Creek (URC-1A and URC-2) were generally high, although URC-1A was low in 2008. Scores for lower Rainy Creek (LRC-1, LRC-2, LRC-3 and LRC-5) are generally at the low end of the reference range (about 6-9), although several higher scores were noted in LRC-3 and LRC-5 in 2009.

Based on the MDEQ scoring system, the data are consistent with the hypothesis that the benthic communities in lower Rainy Creek are within the range observed at reference stations, although it is likely they are mainly at the lower end of the range.

5.3.2 Habitat Studies

Although site-specific reference stations were selected in order to obtain a good match in key habitat factors, a perfect habitat match between site and reference locations is never possible. Therefore, because benthic community scores for on-site locations tend to be may be at the low end of what is expected based on reference stations, a quantitative habitat assessment was performed in order to judge whether any apparent differences in population metrics might be explained in terms of habitat differences.

To this end, benthic habitat quality data were collected in 2008 and 2009 according to methods described in EPA's RBP protocol (Barbour et al. 1999). The habitat quality variables considered include availability of cover, embeddedness, water velocity and depth, sediment deposition, channel flow and stability, frequency of riffles, bank stability, and the amount of bank vegetation. The habitat quality data are shown in Table 5-8.

The data for each metric were summed to generate the Habitat Quality Score which are evaluated in accordance with the following:

Habitat Quality Score	Interpretation
160-200	Optimal
110-159	Sub-Optimal
60-109	Marginal
< 60	Poor

Figure 5-5 shows the results graphically. As shown, habitat scores at a station tend to vary somewhat between years. This may be due to authentic variation in habitat quality over time and/or to variation in assignment of scores by the field team. The scores for off-site reference stations (BTT-R1 and NSY-R1) were generally similar to scores for the upper Rainy Creek stations (URC-1A and URC-2), mainly falling in or very close to the optimal range. For stations below the tailings impoundment and in lower Rainy Creek (TP-TOE-2, LRC-1, LRC-2, LRC-3, and LRC-5), habitat scores tended to be somewhat lower, mainly (but not always) falling in the sub-optimal range. Although the differences are not extreme, this tendency for somewhat lower habitat quality scores may be a contributing factor to the tendency for somewhat lower BCS scores in lower Rainy Creek.

Figure 5-6 shows the correlation between BMI community status and habitat quality, both for the Montana MMI metric (Panel A) and the RBP metric (Panel B). As may be seen, the correlations are weak, with R^2 values of less than 0.05. This low correlation is likely due in part to the inherently variable nature of both habitat and community scores, but also suggests that habitat factors alone may not be the only explanation for observed differences.

5.4 *In Situ* Lesion Studies

No studies of *in situ* lesions in benthic macroinvertebrates were performed as part of the RI in OU3.

5.5 Weight of Evidence Evaluation

Two lines of evidence are available to evaluate effects of site contaminants on benthic macroinvertebrates, including:

- Laboratory-based site-specific sediment toxicity tests in two species of organism
- Site-specific benthic community population studies, augmented with habitat quality studies

The data and conclusions from these lines of evidence are summarized in Table 5-9.

The site-specific sediment toxicity tests indicate that effects on growth and reproduction were not apparent in *H. azteca*, and were minor in *C. tentans*. However, an effect of site sediment on survival was noted in both species, with *C. tentans* being more impacted (9-25% decrease) than *H. azteca* (4-6% decrease). It is difficult to judge if LA is the likely cause, because quantitative estimates of LA concentration in the two site sediments are sufficiently uncertain that the presence of a dose-response relationship cannot be ascertained. Even if LA is the cause, the applicability of these results to other species, and hence the potential magnitude of effects on the benthic invertebrate community as a whole, are difficult to judge from this line of evidence alone, and are best determined by evaluating the site specific population studies presented below.

The site-specific population studies suggest that benthic macroinvertebrate communities along lower Rainy Creek may occasionally rank as slightly impaired compared to off-site reference locations, but are not impaired compared to upper Rainy Creek. The differences are not extensive and might be due, at least in part, to differences in habitat quality.

Taken together, these findings support the conclusion that LA contamination in lower Rainy Creek may be causing small to moderate effects on survival of some species, but the overall benthic macroinvertebrate community is not substantially impacted.

Confidence in this conclusion is medium to high. One potential limitation to the site-specific studies is that the test species (*H. azteca* and *C. tentans*) are not expected to occur in mountain streams, and native species (mainly mayflies, stoneflies, caddisflies, true flies, and beetle larvae) might have differing sensitivities. While benthic community and habitat surveys often display considerable variability between years, in this case the results are relatively consistent between two years, providing good confidence in the survey results.

6.0 RISKS TO AMPHIBIANS

6.1 Reported Effects

No studies were located on effects of asbestos exposure on amphibian species.

6.2 Laboratory Toxicity Tests

The EPA, working in concert with the Libby OU3 BTAG, considered several options for laboratory-based toxicity tests to evaluate potential effects of exposure to LA in site media on amphibians. Although exposure from direct contact with contaminated surface water is likely to be an important exposure route for amphibians in OU3, a laboratory-based study of surface water exposure was not considered feasible due to the technical problems of LA clumping and binding to aquaria walls, as described in Section 4. Consequently, EPA and the BTAG decided to perform a study in which amphibians were exposed to LA-contaminated site sediment. It was considered likely that the sediment would contribute LA fibers to the overlying water used in the study, and that exposure would be similar to that which occurs in the field.

The overall study requirements developed by EPA and the BTAG were specified in Section 3 of the Phase 5 Part B SAP/QAPP of the RI for OU3 (EPA 2012a). Based on these requirements, the performing laboratory (Fort Environmental Laboratory, Inc. [FEL]) developed a detailed study protocol (FEL 2012), which was reviewed and approved by EPA and the BTAG. The study was implemented in 2013, and the results are presented in FEL (2013).

6.2.1 <u>Study Design</u>

The goal of the study was to determine if exposure of amphibians to LA in sediment from OU3 would result in an increase in adverse effects compared to organisms exposed to reference sediment. Endpoints selected for evaluation included survival, growth, and development (completion of metamorphosis). Reproduction was also considered as a potential endpoint, but the length of time required to assess this endpoint (5-6 additional months of exposure) was determined to be impractical.

The test species selected for use in the test was the southern leopard frog (*R. sphenocephala*). Three treatment conditions were evaluated:

1) Laboratory dilution water and inert sterilized sand
2) Laboratory dilution water and an off-site reference sediment
3) Laboratory dilution water and field-collected sediment from the Libby site

The site sediment used in Treatment #3 was collected from Carney Creek, and was estimated to contain about 4-7% LA by mass, which is within the upper range of concentrations that have been observed in site sediments. The off-site reference sediment was collected from a pond in Oklahoma.

Each exposure treatment was evaluated in quadruplicate (i.e., 4 replicates), with 20 organisms per replicate. Exposure occurred in glass aquaria. Sediment or sand (1.5 kg) was added directly to the bottom of each aquarium and 6 L of laboratory water was added (1:4 ratio). The water was then changed using a flow-through system in which laboratory water flowed through the tanks at a rate of 12 mL/min (2.9 volume exchanges per day). The sediment/sand and water were allowed to equilibrate for 24 hours prior the introduction of test organisms. Fluorescent lighting was used to provide a photoperiod of 12 hours of light and 12 hours of dark at an intensity that ranged from 600 to 2,000 lux (lumens/m^2) at the water surface. Water temperature was maintained at 22.1-23.0 ºC, pH maintained between 6.4 to 7.9, and the dissolved oxygen (DO) concentration > 3.5 mg/L (> 40% of the air saturation) in each test tank. Food (boiled lettuce) was provided daily *ad libitum*. Each tank was siphoned on a daily basis to remove uneaten food and waste products, taking care to minimize stress and trauma to the animals.

Exposure began with larva at Gosner stage 20 (free swimming tadpoles). Mortality observations and developmental stage determination were made daily, and any dead larvae were immediately removed, preserved in 10% neutral buffered formalin (NBF), and necropsied. During the exposure phase, the Gosner stage of organisms was recorded, as was the time to metamorphosis (TTM) for each larvae and the weight of each newly metamorphosed larvae. The exposure phase was terminated when all of the surviving organisms in Treatment #1 completed metamorphosis (Gosner stage 46).

After exposure termination, all surviving test organisms were anesthetized, digital photos were taken to allow measurement of snout-vent length (SVL), whole body weight was measured, external malformation was assessed, and blood (plasma) was collected. The test organisms were then euthanized and examined for visceral (internal) abnormalities. The head and carcass (with gonads) were fixed in Davidson’s Solution and preserved in 10% NBF for possible future histopathology.

6.2.2 Results

No signs of overt toxicity, abnormal behavior, or visible malformations or lesions were observed in any of the organisms in the study (FEL 2013).

Table 6-1 presents summary statistics for survival and growth endpoints. Treatment 1 (sterile sand) was used mainly to assess test acceptability, while effects of LA were assessed mainly by comparison of Treatment 2 (off-site reference sediment) to Treatment 3 (OU3 sediment).

As shown, based on a one-tailed Fisher Exact test, survival at study termination for Treatment 3 was higher than for Treatment 2 (off-site reference sediment). Similar results are obtained based on a one-tailed t-test.

Surviving organisms in Treatment 3 were larger, as indicated by both weight and SVL measures, than surviving organisms in Treatment 2. This is probably not the result of differences in ingestion of added food (boiled lettuce), which was generally similar between all groups (FEL 2013). Rather, the authors of the report stated that the increased size of the organisms in Treatment 3 was likely the result of consumption of food material in the Carney Creek sediment that was not present in either the control or reference sediments. Similar results were obtained when the comparison was based only on organisms that had reached Gosner Stage 46 by days 81-83 (FEL 2013).

Figure 6-1 shows the number of organisms surviving and the number of organisms that had completed metamorphosis (Gosner stage 46) as a function of exposure day. As is often observed, mortality was essentially zero until development had preceded well into the prometamorphic and metamorphic climax windows. This is generally the most stressful period in the development of larval amphibians due to the high energy demands and cascade of morphological and biochemical re-programming that occurs in preparation for terrestrial life.

The authors of the report stated that the median time to metamorphosis (MMT) (defined as the day on which the number of organisms that had completed metamorphosis was equal to or greater than ½ the final number of organisms that completed metamorphosis at study termination) was similar for Treatment 1 (81.0 days), Treatment 2 (80.5 days) and Treatment 3 (82.0 days), and these values were not statistically different from each other. However, as indicated in Figure 6-1 (Panels A and B), all but one surviving organism in Treatments 1 and 2 had completed metamorphosis by day 82 (vertical dashed line), while in Treatment 3, only about 28% of the surviving organisms had completed metamorphosis by day 82, and only 41% had completed metamorphosis by study termination on day 94 (see Panel D). This result suggests that exposure to site sediment might be causing a delay in development of a substantial fraction of the organisms. On day 94, the distribution of Gosner stages in Treatment 3 was as follows:

Gosner Stage	Day 94 Survivors	
	Number	Percentage
42	5	9%
43	8	14%
44	9	16%
45	11	20%
46	23	41%

Whether this apparent lag in the development of some (more than half) of the organisms in Treatment 3 (exposure to LA-contaminated sediment) would result in an ecologically significant population-level impact on survival or reproduction is uncertain, However, assuming that the final stages of development are only delayed (and not entirely curtailed), is suspected that ecological consequences would likely be minimal, because organisms that have reached Gosner stages 43-45 have nearly fully developed limbs and mouth, and the tail is largely resorbed.

6.3 Population Studies

No quantitative studies of amphibian density or diversity were implemented as part of the RI for OU3.

6.4 In Situ Lesion Studies

In order to provide a second line of evidence to support an evaluation of risks to amphibians, EPA and the BTAG designed a field survey to determine if the prevalence and/or severity of gross or microscopic lesions was higher in organisms residing in OU3 than in organisms inhabiting reference areas.

The overall study requirements developed by EPA and the BTAG were specified in Section 4 of the Phase 5 Part B SAP/QAPP of the RI for OU3 (EPA 2012a). Based on these requirements, the performing laboratory (FEL) developed a detailed field study protocol (see Appendix A.2 of the Phase V-B SAP/QAPP) which was reviewed and approved by EPA and the BTAG. The study was implemented in 2012, and the results are presented in Golder (2014c).

6.4.1 Study Design

Study Areas

Study areas included four ponds within OU3 where water and sediment are both impacted by LA, as well as from three reference ponds/lakes in areas sufficiently remote from the mine that contamination with vermiculite or LA from the mine is not expected.

Location	Study Areas	Location Code
OU3	Carney Creek Pond	CAP
	Fleetwood Creek Pond	FP
	Mill Pond	MP
	Tailings Pond	TOP
Reference	Teepee Pond	TPE
	Banana Lake	BL
	Bobtail Pond	BP

Exposure Characterization

Sediment samples were collected for from each study location at the beginning and end of the study. The initial sediment samples were analyzed both for LA and also for other priority pollutants. Sediment samples collected at the conclusion of the study were only analyzed for LA.

Surface water samples were collected once a week from each OU3 pond throughout the course of the study. At the reference ponds, surface water samples were collected at the start and conclusion of the study.

Quality control field blanks and field duplicates were collected throughout the study according to the SAP/QAPP (EPA 2012a).

Life Stages and Measurement Endpoints

The field study investigated the potential for adverse effects in each of four stages of amphibian development, as follows:

Developmental Stage	Field Stage	Gosner Stage
Egg mass	--	--
Larval pre-metamorphosis	1-2	21-25
Larval Proto-metamorphosis	3-6	37-40
Metamorphosed	8	46

Measurement endpoints for each developmental window are summarized in Table 6-2.

Target Species

Based on the frequency of occurrence during preliminary site reconnaissance, three species were targeted for specimen collection during the study:

- Western toad (*Bufo boreas*)
- Northern tree frog (*Pseudacris regilla*)
- Columbia spotted frog (*Rana luteiventris*)

6.4.2 Results

Exposure Characterization

Sediment

Concentrations of LA in sediment samples from each location estimated by PLM are summarized in Table 6-3. As noted in Section 2.4.2, these estimates are semi-quantitative and may not be highly precise. As indicated, estimated LA concentrations were highest in the Carney Creek and Fleetwood Creek ponds, with lower but consistently detectable concentrations in the Mill Pond and the Tailings Pond. LA was not detected in any sediment samples from any of the reference locations.

Analysis of the sediments for a wide range of other (non-LA) contaminants, including metals, pesticides, semi-volatiles, polycyclic aromatic hydrocarbons (PAHs), and polychlorinated biphenyls (PCBs), did not reveal the presence of any unusual or meaningfully different concentrations of any other analyte.

Water

Concentrations of LA measured in water samples from the OU3 study areas tended to vary substantially between samples. Summary statistics are shown in Table 6-4 (Panel A). The cause of the high variability is not certain, but might be due in part to variable levels of sediment inadvertently included in water during sample collection. At reference areas, LA was not detected in water samples from either Bobtail Pond or Teepee Pond, with one low detection in Banana Lake.

Water temperature in the ponds increased as the study progressed. Initial temperatures were generally in the 5-10 ºC range, and these increased to 20-25 ºC by the end of the study. Summary statistics are shown in Table 6-4 (Panel B).

Organisms Collected

At each location, the goal was to collect and evaluate 4 egg masses, 40 pre-metamorphs (Gosner stages 21-25), 40 proto-metamorphs (Gosner stages 37-40), and 20 metamorphs (Gosner stage

46) of each of the three target species. The numbers of organisms actually collected, stratified by species and by life stage, are shown in Table 6-5.

As indicated, target numbers were not achieved for all species in all areas. In particular, no samples of any species were collected at the Mill Pond. In addition, the only western toads collected were in field stages 1-2. Because of the very limited number of toads collected, subsequent data evaluations focused on the northern tree frog and the Columbia spotted frog.

Size and Weight Measurements

Figures 6-2, 6-3, and 6-4 summarize the size and weight data for field-collected amphibians, stratified according to developmental stage. In each figure, the bar heights represent the mean values, and the error bars represent the standard deviations.

As shown in Figure 6-2, there is high variability within and between groups for early developmental stages (field stages 1-2), but this variability tends to decrease for field stages 3-6 (Figure 6-3) and becomes relatively small for metamorphs (Figure 6-4). Although some of the differences are statistically significant (Golder 2014c), there is no consistent pattern of decreases in either size or weight for organisms collected from OU3 compared to organisms from reference locations. Based on these data, it does not appear that exposure to LA in OU3 has any ecologically meaningful effect on size or weight of exposed amphibians.

Prevalence of Gross External and Internal Abnormalities

External examinations of all collected organisms focused on eyes, mouth, torso, and hind limbs. Internal (visceral) examinations were conducted on all the metamorphosed frogs and focused on the general appearance of the major organs (i.e., liver, kidneys, heart, and lungs). Results of the external examinations are presented in full in Appendix B of Golder (2014c).

In brief, a total of 792 amphibian specimens were examined. Of these, no external malformations were observed in any of the egg or larval (premetamorph and prometamorph) amphibians examined. In metamorphs (n = 118), only one malformation was observed. This malformation was characterized as a missing hind leg, and was observed in a single tree frog metamorph collected from Fleetwood Pond. Based on the external examination, the missing leg was judged to be the result of predation.

Overall, the laboratory concluded that the specimens from LA-containing ponds and reference ponds in OU3 were all normal and healthy appearing with development patterns consistent with normal wild field amphibian populations

Frequency and Severity of Histological Abnormalities

A total of 145 fully metamorphosed amphibians were examined histologically to evaluate the frequency and severity of microscopic lesions observed. Table 6-6 summarizes the organisms that were evaluated. The histologic examination included an inspection of 47 different tissues (Table 6-7), although not all tissues were visible in the slides prepared from each organism.

<u>Frequency</u>

Table 6-8 summarizes data on the frequency of lesions. Tissues where lesions were not observed in any organisms from either OU3 or Reference locations are not included in the table.

As shown, lesion frequency was statistically higher ($p \leq 0.05$) at OU3 than for Reference for only 1 tissue: coelomic cavity in Columbia spotted frogs. This rate (approximately 1 out of 94) is within the range that would be expected to occur at random (≈ 5%). Indeed, based on a p value of 0.20, there are more cases where the rate is higher in organisms from Reference areas (N = 22) than in organisms from OU3 (N = 3). These statistics indicate that lesions are not meaningfully more frequent in amphibians from OU3 than from Reference areas.

<u>Severity</u>

Lesions in each tissue type were assigned a severity score using the following system:

Lesion Severity	Score	Distribution	Multiplier
None	0	Focal	1
Mild	1	Multifocal	2
Moderate	2	Diffuse	3
Marked	3		
Severe	4		

Parasites were assigned a score of 1 if focal or 2 if multifocal, except for trematode microgranulomas in kidney which were scored as follows:

1-3 trematode microgranulomas = 1
4-6 trematode microgranulomas = 2
>6 trematode microgranulomas = 3

For each animal, the scores across all tissues were added and divided by the number of tissues evaluated to yield a "body score".

Table 6-9 summarizes the mean severity scores in organisms from OU3 was compared to that for Reference organisms. As above, tissues where lesions were not observed in any organisms from either OU3 or Reference locations are not included in the table. In cases where lesions were observed in at least one animal from both OU3 and reference areas, the severity data were compared using the Wilcoxon Rank Sum test. Statistical comparisons of severity are not possible when lesions are present in one group but not the other. The results of the one-tailed statistical comparison are shown in the right-hand column of Table 6-9.

As shown, lesion severity was statistically higher ($p \leq 0.05$) at OU3 than for Reference for only 2 tissues: coelomic cavity in Columbia spotted frogs and skeletal muscle in northern tree frogs. This rate (approximately 2 out of 94) is within the range that would be expected at random (≈ 5%), suggesting that there is no apparent tendency for tissue lesions to be more severe in OU3 that in Reference areas.

Summary statistics for total body score are presented below.

	Spotted Frog		Tree frog	
Parameter	OU3	Ref	OU3	Ref
N	41	60	23	21
Mean	0.256	0.361	0.167	0.238
Stdev	0.105	0.170	0.105	0.133
WRS 2-T	0.002		0.113	
WRS 1-T	0.999		0.944	

As indicated, body scores reflecting the total frequency and severity of lesions was higher for organisms from Reference areas than from OU3, both for Columbia spotted frogs and northern tree frogs.

Nature and Etiology of Histologic Lesions

Nearly all of the tissue lesions observed in organisms from both OU3 and Reference areas were inflammatory in nature and were attributed to parasitism. For example, lesions of the coelomic cavity [which were both more frequent (46% vs 22%) and more severe (2.53 vs 1.62) in Columbia spotted frogs from OU3 than Reference areas] were due almost entirely to lymphoplasmacytic granulocytic inflammation and trematode microgranuloma, with occasional cases of protozoan or myxozoan infection. Such parasitic conditions are considered to be normal in wild populations, and were not judged by the pathologist to be related to asbestos exposure.

6.5 Weight of Evidence Evaluation

Two lines of evidence are available to evaluate potential effects of LA on amphibians in OU3:

- A site-specific laboratory-based sediment toxicity test
- A field survey of gross and histologic lesion frequency and severity in amphibians ..collected from OU3 and from reference areas

The data and conclusions from these lines of evidence are summarized in Table 6-10.

The site-specific sediment toxicity test did not produce any signs of overt toxicity in any organisms exposed to OU3 sediment. Both survival and growth were higher in organisms exposed to OU3 sediment than for reference sediment. The only observation of potential concern was an apparent increase in the time to metamorphosis for some organisms that were exposed to OU3 sediment. The ecological significance of this apparent lag in the final stages of development is not certain, but assuming the effect is only a lag (as opposed to an actual cessation of development), it is suspected the effects would likely not be ecologically meaningful. However, it is plausible that the delay might become important if ponds in high exposure areas were to dry up during this critical stage of development.

The survey of external and histological lesions in field-collected organisms indicates that lesions in organisms from OU3 are not more frequent or more severe that in organisms from reference sites, and that all lesions observed are likely the result of parasitism rather than asbestos exposure. This supports the conclusion that LA is not causing any external or internal malformations of concern.

Taken together, these findings support the conclusion that sediments and waters in OU3 are not likely to be causing any ecologically significant adverse effects on amphibian populations.

Confidence in this conclusion is medium to high. The most significant uncertainty is whether the apparent delay in the final stages of metamorphosis might be of concern. Further studies would be need to determine if the apparent lag in final stage development is reproducible, and whether complete metamorphosis is ultimately achieved in exposed organisms.

7.0 RISKS TO MAMMALS

7.1 Reported Effects

Although no studies were located on the effects of LA in mammals, the effects of other forms of asbestos have been relatively well characterized. ATSDR (2001) provides a summary of 22 inhalation studies and 15 oral exposure studies in animals (mainly rats), and Appendix D of EPA (2009) also summarizes available studies in mammals. In brief, these studies support the following main conclusions:

- Following inhalation exposure, the most characteristic effects include increased occurrence of a) pleural and interstitial lung fibrosis, b) lung cancer (adenomas, adenocarcinomas, or squamous cell carcinomas), and c) pleural and peritoneal mesothelioma. These effects in the lung and pleura are generally thought to occur because asbestos fibers which deposit in the lung are very durable, and their presence in the lung triggers a persistent inflammatory response that can harm the adjacent lung tissue.

- For oral exposures to asbestos (amosite, chrysotile, tremolite, or crocidolite), there is generally little or no evidence of histological or clinical injury to any systemic tissues, with the possible exception of effects on the gastrointestinal tract. For example, a series of lifetime feeding studies in rats and hamsters did not observe any systemic lesions except for benign adenomatous intestinal polyps in the large intestines of male rats. Studies by other researchers have reported possible signs of injury to the colon including inflammation, benign productive peritonitis, increases in aberrant crypt foci (putative precursors of colon cancer), and colon cancer (carcinomas, adenomas and adenocarcinomas).

- Other possible target tissues where pathologic changes have been noted but not definitively liked to asbestos exposure include the thyroid and adrenals.

Based on these findings in laboratory animals, it is expected that the primary target tissues of inhalation and oral exposure of rodents to asbestos are the pulmonary tract and the gastrointestinal tract, with a possibility that the thyroid and/or adrenal might also be impacted.

7.2 Laboratory Toxicity Tests

No site-specific toxicity tests in mammals were performed as part of the RI at OU3.

7.3 Population Studies

No site-specific population studies of mammalian density or diversity were implemented as part of the RI for OU3.

7.4 *In Situ* Lesion Studies

The EPA, working in concert with the Libby OU3 BTAG, determined that the approach most likely to provide reliable information on the potential adverse effects of LA on mammals in OU3 was a field study that compared the prevalence and severity of gross and microscopic lesions in mammals residing in OU3 to that observed in animals residing in a reference location. This type of study has the advantage that it allows an assessment of potential effects from all media and all exposure routes. A disadvantage is that, if a difference in lesion prevalence or severity is observed, it may be difficult to identify the causal factor(s) and to establish an exposure-response relationship.

7.4.1 Study Design

The overall goals and data quality objectives for the study were specified in Revision 1 of the Phase III SAP/QAPP of the RI for OU3 (EPA 2009). The study was implemented in the summer of 2009, and the results are presented in Golder (2010).

Target Species

There are many different species of mammalian receptors that may be exposed to LA in OU3, but it is neither feasible nor necessary to attempt to collect organisms from each species. Rather, attention was focused on species that were judged to be most likely to have high exposure (especially inhalation exposure) to LA in soil and forest duff. As part of the Problem Formulation (EPA 2008c), EPA concluded that species most likely to have high exposures were small home range mammals that foraged on the ground directly in the forest duff. Based on this, and considering the species of small mammals most likely to be present in OU3, EPA identified the deer mouse (*Peromyscus maniculatus*) and the southern red-backed vole (*Clethrionomys gapperi*) as target species for the study. Daily average exposures of larger species of mammal (deer, elk, bear, moose, lynx, etc.) are expected to be lower than for mice and voles, both because of the larger home range size for these species, and also because larger mammals are likely to have less extensive and less intimate contact with contaminated duff and soil. However, cumulative exposures might tend to be higher due to longer lifespans.

Trap Types

Small mammal collection was performed using live traps baited with peanut butter and oats. Live trapping was selected to ensure that captured animals of the target species would be suitable for gross and histological examination, since animals collected from kill traps begin to decompose quickly, making tissue examination impossible. Traps were set in the evening just before dusk and were collected shortly after dawn the next morning.

Study Locations

In order to maximize the probability of detecting *in situ* effects if they are present, the small mammal survey was performed at a location just north (downwind) of the mined area where exposures to LA were expected to be highest. The general location of the trapping area was established by identifying locations where concentrations in duff were consistently at the high end of what has been measured at the site. The red polygon in Figure 7-1 shows the area selected. This polygon covers an area of about 716,000 m^2 (72 hectares), and is flanked by four stations (indicated by yellow dots) where measured LA concentrations in duff ranged from 2,200 to 3,100 million fibers per gram, all of which are at the high end of the range of LA levels that have been measured in duff.

A site reconnaissance was performed in June 2009 to identify specific locations for trap lines, taking both habitat and accessibility into account. The exact locations of five trap lines in the exposure area are shown by the blue dots in Figure 7-1.

The reference area selected for study was located in the Kootenai National Forest near Sheldon Mountain, about 7-8 miles west north-west (cross-wind) of the mined area. The locations of three trap lines established in the reference area are shown by the blue dots in Figure 7-2.

Sample Size

Based on power calculations performed by EPA, it was expected that a sample size of about 30 animals per species per area would be sufficient to have a high probability of detecting a difference in lesion prevalence, even if variability between animals was high.

Measurement Endpoints

All traps that were found to contain an individual of either target species were promptly transported in the trap to a pre-established necropsy and tissue preparation station. Non-target species were promptly released.

Each of the target species animals was sacrificed by carbon dioxide asphyxiation and subjected to prompt necropsy and collection of target tissues for histopathology. The details of the necroscopic examination and collection of tissues is described in SOP MAMMAL-LIBBY-OU3.

Necropsy included examination of internal organs for color, size (swelling), and other gross abnormalities including the presence of macroscopic lesions, nodules, or plaques.

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For the histological examination, target tissues included the larynx, thyroid, complete gastrointestinal (GI) tract (esophagus, stomach, small intestine, large intestine, rectum and anus), complete pulmonary tract (trachea, bronchi, lungs), and adrenal glands (EPA 2009). Samples of each target tissue were removed and preserved by placement into formalin fixative. The eye ball from both eyes of each mammal was also removed and preserved for analyses of eye lens weight for use in determination of animal age. Carcasses were retained and preserved in case future analyses of the remaining tissues were needed.

Tissue samples for possible future LA analysis were harvested prior to contact with the formalin preservative.

7.4.2 Results

Population Demographics

Table 7-1 shows number of the species of small mammals that were captured in OU3 and the reference area. As indicated, the most common species trapped was the deer mouse, which had been previously been selected as a target species. However, no voles were captured in either OU3 or the reference area. Consequently, the focus of the study was restricted to deer mice.

Table 7-2 presents summary statistics on size (body weight and length) for the deer mice captured. As shown, body weights of both males and females were similar in the OU3 study area and the reference area, and the differences were not statistically significant (t-test $p = 0.265$ for females, 0.429 for males). Lengths (nose to tip of tail) were also generally similar, although there was a statistically significant difference ($p = 0.042$) for females.

Table 7-3 presents summary statistics on the gender distribution of mice collected. As shown, the fraction of females was somewhat higher in reference areas (65%) than in OU3 (45%), but this difference is only marginally statistically significant ($p = 0.103$).

Table 7-4 presents summary statistics on the age of the captured mice, based on measurements of the weight of the lens of the eye. As shown, average ages tended to fall into the 100-200 day range, although males from Trap Line C in the reference area tended to be somewhat older. Based on these data as well as necroscopic examination (see below), it was concluded that all of the mice were adults. Differences in age between reference and OU3 animals were not statistically significant (t-test p = 0.560 for females, 0.438 for males).

Necropsy Findings

Each animal was examined externally for abnormalities, measured (length from snout to tip of tail), and photographed to document dorsal and ventral views. Animals were opened and the body cavity and viscera photographed to provide a view of internal organ placement and appearance. Internal organs were examined for abnormalities and lesions and additional photographs taken as necessary. Where necessary, the sex of an animal was confirmed through internal examination and pregnancy (if visually apparent) was noted. Additional photographs of internal lesions (if any) were taken and frame numbers recorded in the logbooks.

None of the female mice were pregnant at the time of necropsy though at least one animal was thought to be lactating.

No deformities or other gross abnormalities were observed in any of the animals, and all animals appeared to be in good health. Clear evidence of consumption of trap bait was observed in many animals (stomachs full of oats). A number of animals exhibited evidence of either active or previous infection by bot flies (*Cuterebra sp*.), largely in the perirectal area, though these infections did not appear to have any apparent impact on the health of the animals.

Histopathology Findings

Target tissues for histology were harvested from all animals without incident, with the exception of the trachea and thyroid of a single reference animal, which were lost during necropsy.

All preserved samples were submitted for histological examination by a board-certified pathologist. All tissue lesions were scored based on severity and extent, as well as an assessment as to whether the lesion was similar to those caused by asbestos:

Severity	Score	Extent	Score	Pathos Factor	Value
None	0	Focal	0	Non-asbestos-like effect	1
Minimal	1	Multifocal	1	Asbestos-like effect	2
Mild	2	Diffuse	2		
Moderate	3				
Marked	4				
Severe	5				

Each lesion was scored as the sum of the severity score and the extent score, multiplied by the pathos factor (2 for lesion types that were similar to or overlapped those of asbestos, or 1 for lesion types that were not related to asbestos). For example, a mild focal lesion that did not resemble an asbestos-related effect received a score of $(2+0) \cdot 1 = 2$, and a moderate multifocal lesion that resembled an asbestos-related effect received a score of $(3+1) \cdot 2 = 8$.

Parasites were scored and other lesions such as granulomas, hemosiderin, foreign bodies, etc., were scored as 1.

Frequency and Severity of Histological Lesions

Table 7-5 summarizes the frequency and severity data reported by the pathologist. As shown, mild lesions of the respiratory system and gastrointestinal were common in animals from both the site and reference trapping areas. Based on a one-tailed Fisher Exact test, the frequency of lesions was marginally significantly higher ($0.05 < p \leq 0.20$) in animals from the site than from the reference area for larynx, left mainstem bronchus, duodenum, and jejunum. Based on the Wilcoxon Rank Sum test, the median severity of lesions was significantly higher ($p \leq 0.05$) for larynx, and marginally significantly higher for right mainstem bronchus and cardiac stomach.

Nature and Etiology of Histological Lesions

A detailed discussion of the nature and likely etiology of each type of lesion observed is presented in the histopathology report prepared by the pathologist (Appendix I to Golder 2010). The main conclusions reached by the pathologist are summarized below:

> <u>Respiratory tract lesions</u>. Although histological changes were observed in the respiratory tract of all the study mice evaluated, the histologic patterns were not typical of asbestos exposure. Rather, the lesions were largely attributed to infectious disease, and it is likely that the bulk of the respiratory and pleural inflammatory changes in these mice are due to parasitism. It was considered unlikely that fibrotic lesions observed were due to asbestosis, since the inflammatory changes were similar to those seen in other tissues and no interstitial fibrosis was noted. A few mice had small foci of hemosiderosis in the lungs, but these foci were judged to be due to vascular damage associated with parasitism and inflammation rather than asbestos exposure.
>
> <u>Alimentary tract lesions</u>. Alimentary tract lesions were primarily inflammatory, mild and mostly confined to the small intestine. With the exception of a few foreign body granulomas, all inflammatory changes were attributed to parasitism. A single squamous papilloma was noted in the anus of one mouse. This lesion may have been induced by

trauma, papillomavirus or herpesvirus infection. The adenomatous polyps described in rodents experimentally exposed to oral asbestos were not seen in this study.

Thyroid lesions. Thyroid lesions in these mice included mild cystic ectasia and mild colloid depletion in one mouse, and mild diffuse follicular epithelial cell hypertrophy noted in one mouse. These findings were considered incidental and may have been age related, or due to illness associated with other disease processes. The C cell hyperplasia and adenomas associated with experimental exposure to asbestos in rats were not seen in the study mice.

Adrenal lesions. Adrenal lesions in these mice were uncommon and included inflammation, hemosiderosis and vacuolar change in cortical epithelium. The inflammation and hemosiderosis were likely due to parasite migration. Vacuolar change is common in the adrenal cortex of mammals, and can be due to lipidosis or stress. No neoplastic processes were seen in the adrenal, including the adenomas reported in hamsters exposed orally to asbestos.

Hepatic lesions. Two primary hepatic lesions were noted in the livers that were examined histologically. Capillariasis due to *C. hepatica* was fulminate in 8 of the 9 livers. In spite of the severity and chronicity of the lesions, it is possible that the condition was well tolerated in the affected mice, since they appeared to be in good nutritional status. The portal tract in all examined livers had mild infiltrates of lymphocytes and plasma cells. This is a common lesion associated with ascending inflammatory processes of the biliary tree, and likely also was due to parasitism. No toxic or neoplastic lesions were seen in the examined livers.

Other (opportunistic) tissues. In small animals such as mice, it can be difficult to isolate a single tissue macroscopically and it is common to harvest adjacent tissue as well; these adjacent tissues are referred to as opportunistic. For instance, it was common to have pancreas on the same slide as small intestine, or salivary gland on the same slide as thyroid. Appendix 2 of the pathologist’s report provided data for a range of opportunistic tissues that were examined, including parathyroid gland, adipose tissue, pancreas, salivary gland, bone and bone marrow, cartilage, skeletal muscle, lymph nodes, ovary, uterus, placenta, testicles, and kidney. Lesions in these opportunistic tissues mirrored those seen in the target tissues, and provided no further information that would indicate exposure to asbestos in the study mice.

Summary of Lesions

A broad spectrum of lesions was seen in various tissues of the mice. However, none of the lesions were judged to be consistent with asbestos exposure, but rather were most likely due to parasitism or infectious disease.

7.5 Weight of Evidence Evaluation

One line of evidence is available to evaluate risks to mammals from LA contamination in forested areas near the mine:

- An evaluation of lesion prevalence and severity in mice captured from OU3 compared to mice from a reference area

The data and conclusions from this line of evidence are summarized in Table 7-6.

This is considered to be a relatively strong line of evidence because a) mice are likely to have high exposure to LA in duff and soil, b) the area selected for study was at the high end of LA contamination observed in duff, and c) the mice collected would have been exposed by all relevant exposure routes (inhalation, ingestion of soil, ingestion of food items).

Although the prevalence or mean severity of some types of lesions was higher in mice from OU3 than the reference area, none of the lesions were judged to be attributable to LA exposure, none were judged to be associated with significant decrements to overall animal health, and no evidence of meaningful differences in body size or age of the mice was detected. Based on this, it is considered likely that LA exposures in OU3 are not causing any ecologically significant effects on populations of small mammals residing in the forest areas of OU3.

Confidence in this conclusion is high. However, there are several uncertainties in extrapolation of the results from this study to other mammals that may be exposed in OU3, including the following:

- Larger mammals generally have longer life spans than mice, and consequently might have higher cumulative exposures than mice. Because effects of inhalation exposure to asbestos are usually found to be related to cumulative exposure in humans and laboratory animals (ATSDR 2001), this raises the possibility that risk of effect might be higher in larger mammals with longer lifespans than mice. However, numerous studies have shown that while effects of asbestos exposure in humans usually take many years to develop, the same effects occur in rats and mice within 1-2 years (ATSDR 2001). Moreover, home range is often much larger for large mammals than small mammals, so longer-lived species such as deer, elk, bear, lynx, etc., would generally be expected to spend only a fraction of their lifespan in the impacted areas near the mine, thereby reducing their tendency for exposure. Although uncertain, there is no compelling evidence to presume that mammals with longer life spans than mice would likely be more at risk than mice.

- The mice that were evaluated were trapped in an area near the mine where concentration levels of LA in duff are at the high end of the range that has been observed in the forest area. However, LA levels on the mine site itself are likely higher due to the presence of LA veins in the ore body as well as in waste rock and tailing deposits onsite. Consequently, mammals residing in the mined area (as opposed to the forest area around the mine) may have higher exposures.

8.0 RISKS TO BIRDS

8.1 Reported Effects

Only one study was located on the effects of exposure of birds to asbestos.

- Peacock and Peacock (1965) reported that when finely ground asbestos suspended in tributyl glycerin was injected into the axillary air sacs of White Leghorn chickens, the material spread deeply into the respiratory system, ultimately reaching the pulmonary alveoli. The immediate reaction to asbestos injection was inflammation, with rapid engulfment of fibers by macrophages followed by transport to neighboring sub-epithelial lymphoid follicles. When six adult chickens (aged 2-6 years) were injected in the right axillary air sac with an unknown type of asbestos (amount not specified), one bird died after one year with a massive tumor involving the right lung. In a second experiment, one group of 12 pullets (3 months old) were injected in the left axillary air sac with amosite (amount not reported), and a second group of 12 pullets was injected with crocidolite (amount not reported). In the amosite group, of 10 birds that died or were killed, one had a neoplastic tumor involving the left axilla. In the crocidolite group, of six birds that died or were killed, one had a neoplastic tumor of the left axilla. A second bird had a granuloma that was thought to be due to inadvertent injection of the crocidolite into connective tissue rather than the lumen of the air sac. The authors stated that no tumors occurred in hundreds of control birds, and concluded that injection of asbestos was tumorigenic in birds. .

Because injection of asbestos into the respiratory system is not an exposure pathway that occurs in the field, the effects reported in this study may or may not provide a reliable indication of the nature of effects that could occur following high level inhalation exposure in wild birds. No studies were located on the effects of LA on birds.

8.2 Laboratory Toxicity Tests

No site-specific toxicity tests in birds were performed as part of the RI at OU3.

8.3 Population Studies

No site-specific population studies of avian density or diversity were implemented as part of the RI for OU3.

8.4 *In Situ* Lesion Studies

The EPA, working in concert with the BTAG, considered performing a study of the prevalence of lesions in ground-foraging birds in OU3, similar to the study that was performed for small mammals (see Section 7). However, before implementing such a complex study, the EPA decided to seek an expert opinion on the relative sensitivity of birds and small mammals to inhalation exposure to asbestos. If birds were found to be no more sensitive to the potential effects of asbestos inhalation than small mammals, and given the expectation that exposures of ground-dwelling birds would likely be no higher, and might be lower, than exposures of small mammals, it could then be concluded with reasonable confidence that inhalation risks to birds would be no higher, and might be lower, than for small mammals. Given the lack of evidence for an effect of LA in mice (see Section 7), if birds were no more susceptible than mice, it could then be concluded without the need for an avian lesion study that risk to birds was of low concern. A comparable comparative analysis of relative sensitivity by the oral route was not deemed necessary because no effects of oral exposure were detected in the mammalian study.

The effort was begun by searching the current literature to identify independent scientists who were publishing research on the adverse effects of particulates on the respiratory tract of birds. A number of such individuals were identified and evaluated. After consultation with EPA and the BTAG, Robert F. Wideman, Jr., Ph.D., Professor and Associate Director, Center of Excellence for Poultry Science, University of Arkansas, was identified as the preferred candidate. Dr. Wideman was contacted, and he agreed to provide his assessment of the relative sensitivity of birds and mammals to inhalation exposures to asbestos.

The report prepared by Dr. Wideman (Wideman 2011) is provided in Attachment C to this risk assessment. This report includes a review of the anatomy and physiology of the avian respiratory system, a summary of reports that were located on the depositional patterns and physiological responses to inhaled particulates in birds, and a synthesis of available information to draw conclusions about the likelihood of effects of LA on birds in OU3. Key findings from this report are summarized briefly below:

1. The respiratory tract of birds is quite different from that of mammals. Avian lungs remain essentially fixed in volume throughout the respiratory cycle, neither inflating during inspiration nor deflating during expiration. Rather, thoracic and abdominal musculature propels air through the respiratory ducts in a bellows-like fashion, using air sacs as elastic, inflatable internal reservoirs for "fresh" and "stale" air.
2. Similar to mammals, when birds inhale particulates in air, larger particles tend to be deposited in the higher portion of the airways, with smaller particles penetrating deeper into respiratory tract, depositing mainly where airflow slows or reverses direction during respiration.

3. Birds have several defenses against harmful effects of inhaled particulates, including a mucociliary escalator that is likely to be several times more effective than in mammals, as well as phagocytic macrophages (located mainly within the epithelial cells lining the atria and infundibula) and blood-borne immune responses.
4. Particles deposited in air sacs are likely to be engulfed by macrophages and cleared from the air sacs.
5. Similarly, particles trapped in the protective mucus of the nasal passageways, pharynx and ciliated conducting airways will have little biological impact on those structures, and will be cleared rapidly by the mucociliary escalator. Mucus-containing particles cleared from the upper airways will be swallowed, enter the gastrointestinal tract, and excreted in the feces.
6. Particles deposited in the parabronchi will be phagocytized predominately by epithelial cells that line the atria and infundibula, but also by resident macrophages in the lumen and interstitial macrophages. Engulfed particulates such as asbestos fibers that cannot be degraded or digested intracellularly by the epithelial cells and interstitial macrophages remain *in situ*, presumably causing a release of chemical modulators that provoke ongoing focal inflammatory reactions. However, these intrapulmonary inflammatory responses appear to have minimal impact on the function or viability of affected birds.

Based on these observations, Dr. Wideman concluded:

- There is no evidence that the lungs of wild avian species are anatomically, physiologically, or immunologically more susceptible to inhaled particulates than mammalian lungs.
- Some birds in OU3 may be expected to exhibit histological evidence of intrapulmonary LA particulate exposure, but little or no impact on the physiological function or viability of resident avian populations would likely be discernible.
- Assuming equal levels of inhalation exposure, mammals are likely to be more sensitive to particle inhalation than birds.

8.5 Weight of Evidence Evaluation

One line of evidence is available to evaluate the effect of LA exposure on birds exposed in OU3:

- A literature-based evaluation of the relative sensitivity to the effects of inhaled particulates in birds compared to mammals.

Based on the available information, it is concluded that birds are not more sensitive, and are probably less sensitive, to the effects of inhaled particulates than mammals. Because a site-specific study of the effects of LA on small mammals did not detect any evidence for increased incidence or severity of asbestos-related lesions in the respiratory tract (see Section 7), it is concluded that ecologically significant adverse effects are not likely to be of ecological concern in populations of birds exposed to LA in OU3. Although a comparable comparative study was not attempted with regard to relative sensitivity by the oral exposure route, because no effects were noted in the gastrointestinal system of mice exposed in OU3, there is no reason to expect that effects in the gastrointestinal system of birds would be of concern.

Confidence in this conclusion is medium. However, in the absence of direct studies of birds from OU3, several possible uncertainties remain including the following:

a) The relative LA exposure levels of birds compared to mice in OU3 is not certain. It is assumed that of the wide variety of bird species that occur in OU3, ground foraging birds with small home ranges would tend to be most exposed, both by inhalation of fibers released to air and by ingestion of prey or food items capture in duff or soil. However, considering that mice are likely exposed nearly continuously in the duff or soil, while birds are likely to be exposed only while foraging, and would likely have low exposure while in trees or bushes, it is considered likely that birds are not more exposed, and might be less exposed, than mice.
b) Much of the available information on the relative effects of inhaled particulates in birds is derived from studies of domestic poultry (chickens, ducks). In general, wild birds tend to be more robust than domestic fowl, which would tend to decrease sensitivity (Wideman 2011). However, if effects on respiratory function do occur in wild birds, they might have larger consequences than observed in domestic fowl due to the higher demands on respiratory function during migration. Noting that these two uncertainties could influence risk estimates in opposite directions, and that migratory birds are likely to have lower exposures than resident birds, the conclusion that birds are not likely to be more sensitive than mammals is considered to be reliable.

9.0 SUMMARY AND CONCLUSIONS

EPA planned and performed a number of studies to investigate whether ecological receptors in OU3 of the Libby Asbestos Superfund Site were adversely impacted by the presence of LA in the environment.

Studies of fish, benthic invertebrates, and amphibians exposed to LA in surface water and/or sediment revealed no evidence of ecologically significant effects that were attributable to LA. Likewise, in the terrestrial environment, a study of mice exposed to LA in soil and duff in an area of high LA contamination revealed no evidence of effects attributable to LA. These studies indicate that ecological receptors are unlikely to be adversely impacted by LA released to the aquatic or terrestrial environments by previous vermiculite mining and milling activities.

Nevertheless, there are some uncertainties and limitations associated with this conclusion, including the following:

Aquatic Setting

- Studies of fish exposed to LA in surface water were limited to the concentration levels that occurred during the study. If substantially higher concentrations occurred at other times, it is unknown whether effects might occur.
- Studies of two benthic invertebrate species (*H. azteca* and *C. tentans*) indicated that exposure to site sediments may cause increased mortality, but the species tested are not native to mountain streams and it is uncertain whether native species would display similar effects.
- Studies of amphibians exposed to LA in site sediments appeared to experience a lag in the final stages of metamorphosis. The cause of this apparent lag is not known, and the ecological consequences are uncertain. However, because the lag appears to be minor, it is considered likely the effects would not be ecologically significant.

Terrestrial Setting

- No site-specific studies were performed to evaluate risks to birds. However, a review of available information on the respiratory physiology and relative sensitivity of birds compared to mammals indicates that birds are not likely to be more sensitive, and may be less sensitive, than mammals. Because no effects were observed in mice, this indicates that effects in birds are unlikely to be significant.
- No studies were performed to investigate risks to reptiles. However, there is no reason to suspect that reptiles are more sensitive or more exposed than amphibians. Because

amphibians do not appear to be significantly affected, effects in reptiles are unlikely to be significant.

- No studies were performed to investigate risks to aquatic or terrestrial plants. Because LA fibers are solid fibers and are insoluble in water, it is not expected that LA will cross root or foliage layers, and hence it is not expected that LA would have any adverse effects on either aquatic or terrestrial plants.
- No studies of risks to terrestrial receptors were performed at the mine site itself. Because LA levels in veins and waste material on the mine site may be higher than in the surrounding forest area, it is uncertain whether terrestrial receptors exposed on the mine site might be affected.
- No studies were performed to investigate risks to terrestrial invertebrates (e.g., earthworms). However, there is no reason to suspect that terrestrial invertebrates would be more sensitive or more exposed than aquatic (benthic) invertebrates. Because benthic invertebrates do not appear to be significantly affected, effects on terrestrial invertebrates are unlikely to be significant.

Based on these considerations, it is concluded that the limitations to the available studies do not result in significant uncertainty in the finding that ecological receptors in OU3 are unlikely to be adversely impacted by LA released to the environment by previous vermiculite mining and milling activities.

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TABLES AND FIGURES

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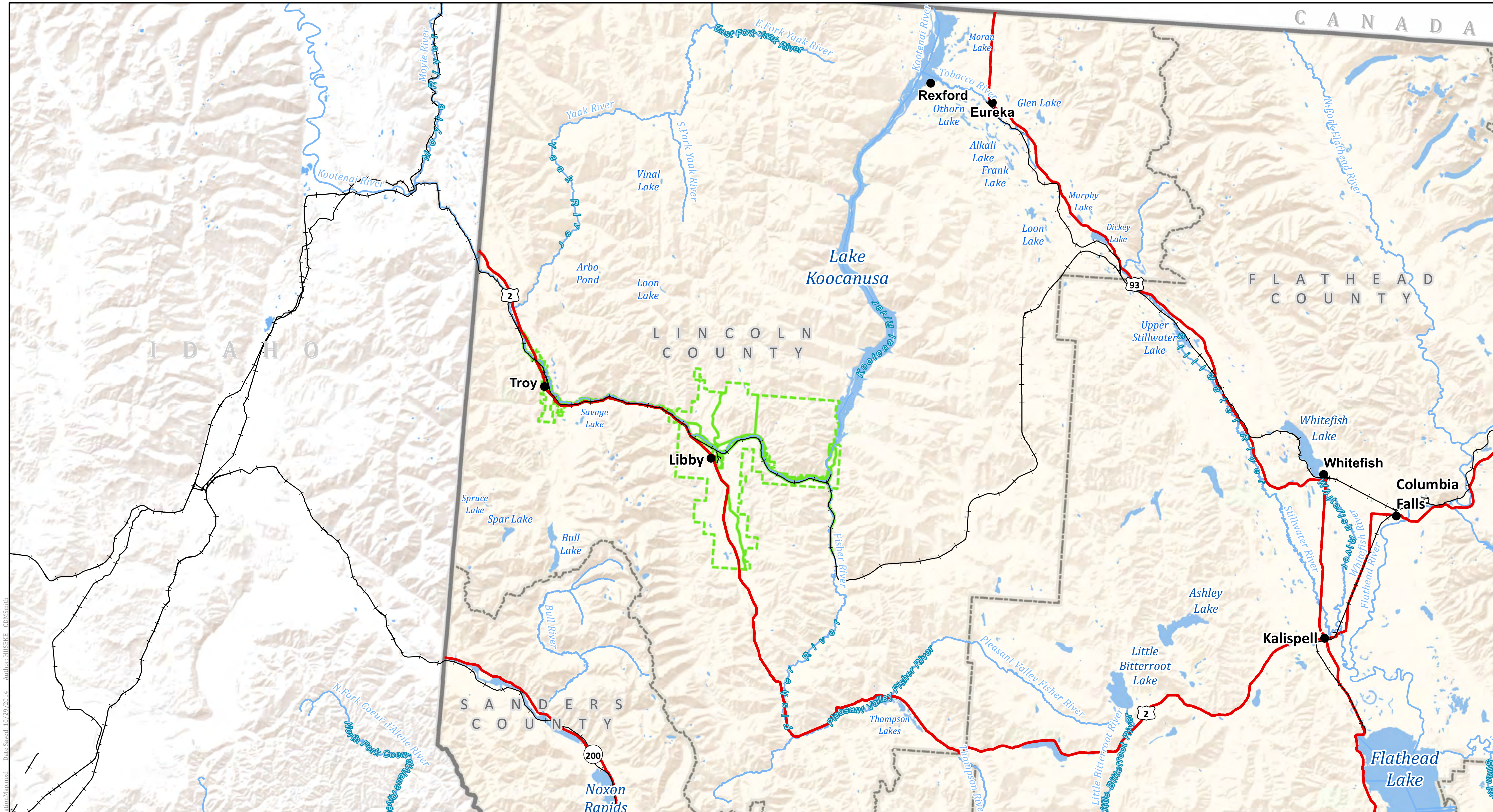

- ● City
- Railroad
- Highway
- River
- Waterbody
- Libby Asbestos Superfund Site

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Road and Railroad Source: US Census Tiger/Line
Waterways and Waterbodies Source: National Hydrography Dataset - USGS

N

0 4 8 16
Miles

CDM Smith

Figure 2-1 Panel A
Location of Libby

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CDM Smith

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Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, i-cubed, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 2-1 Panel B
Proximity of Vermiculite Mine to Libby

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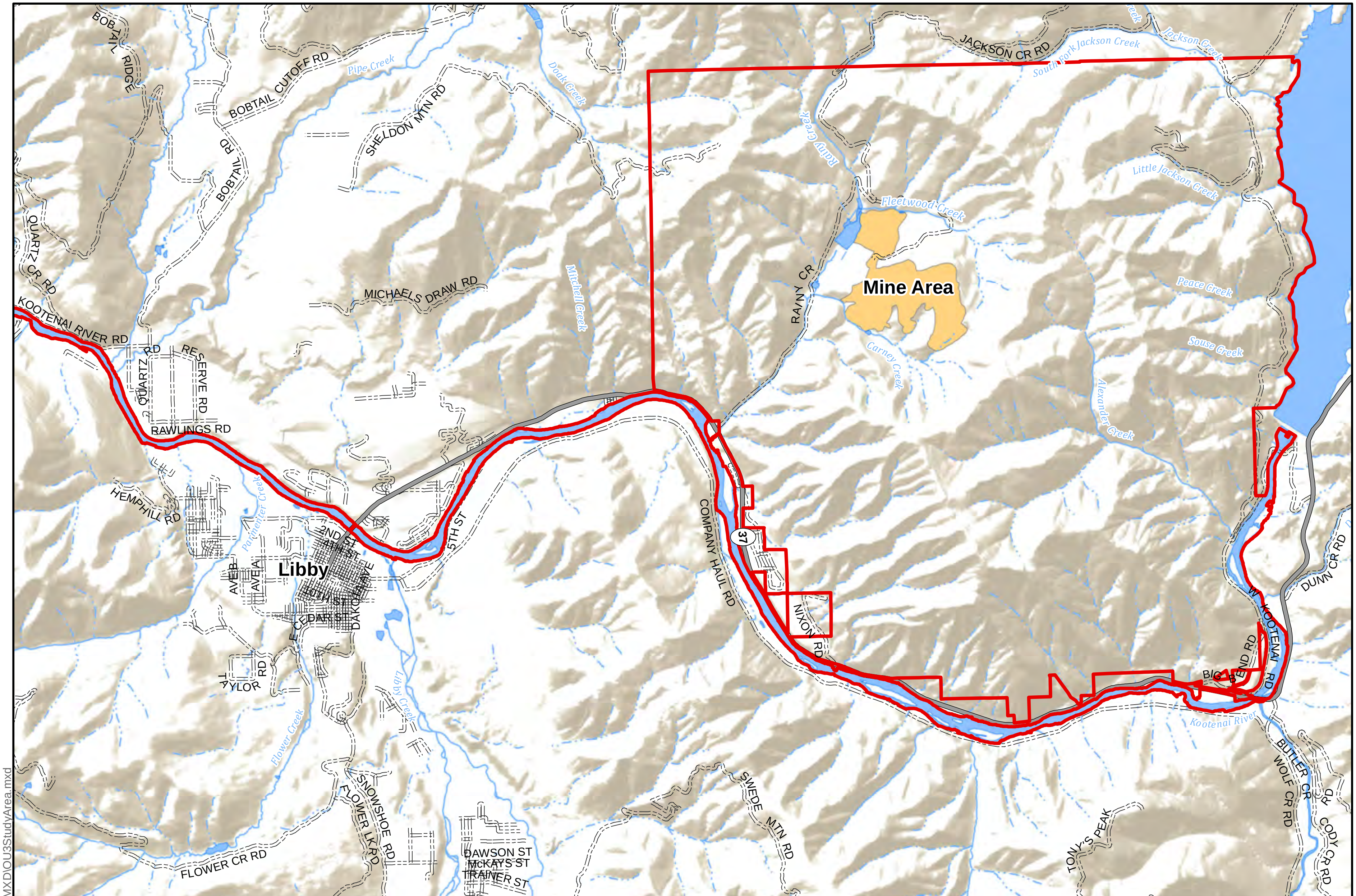
Miles



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Preliminary OU3 Study Area

Primary Road

County Road

Open Water

Perennial Stream

Intermittent Stream

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Service Layer Credits: Sources: Esri, USGS, NOAA

N

0 0.5 1 2

Miles

Figure 2-2

OU3 Study Area

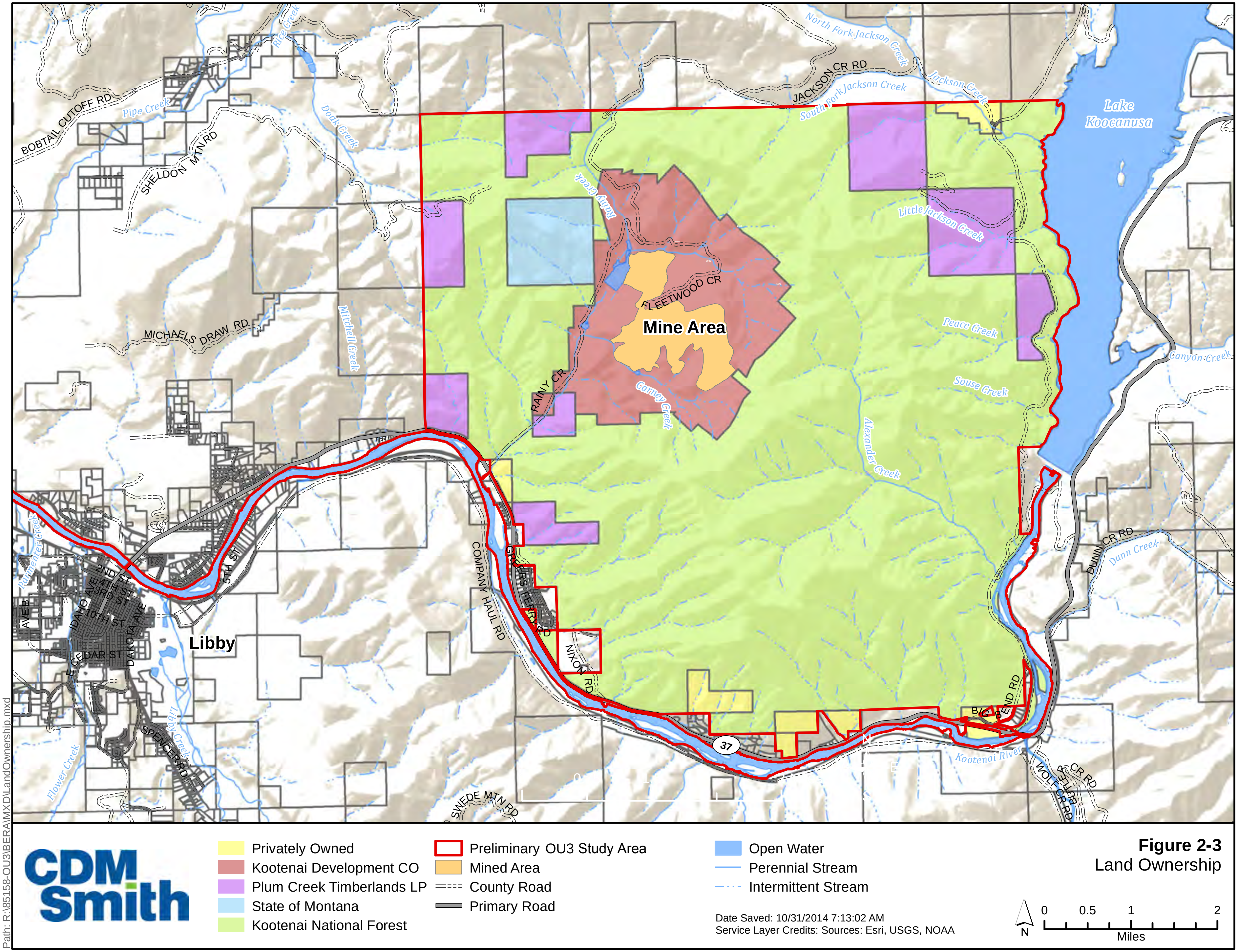

Figure 2-3
Land Ownership

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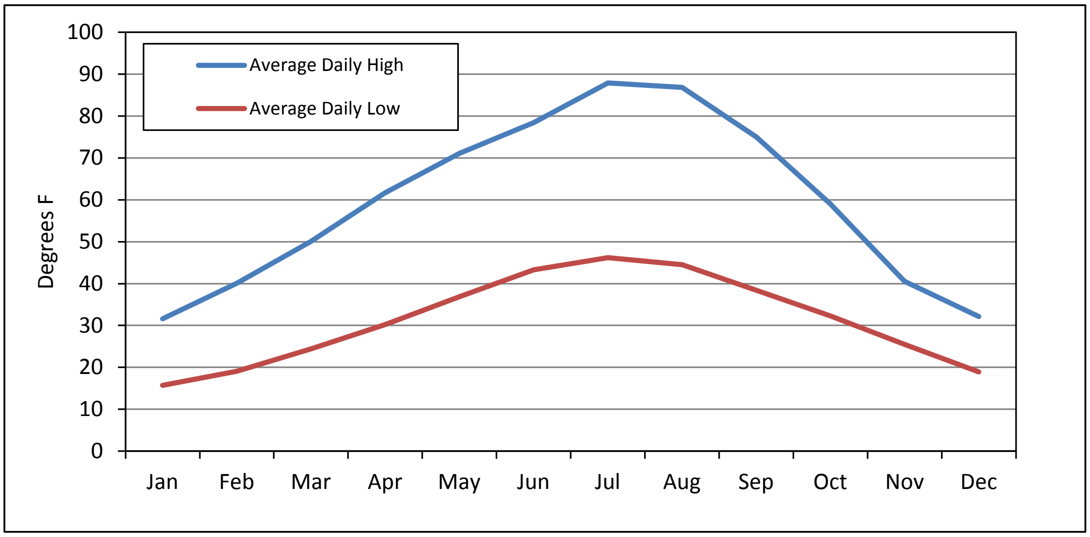
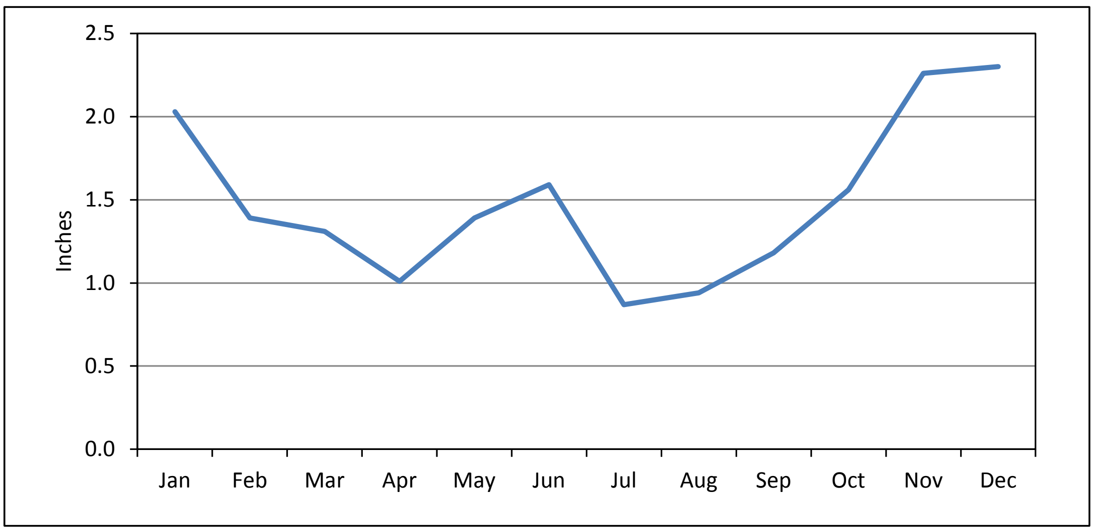
Figure 2-4. Average Temperature and Precipitation in Libby

Panel A: Average Daily High and Low Temperatures



Panel B: Monthly Average Total Preciptation



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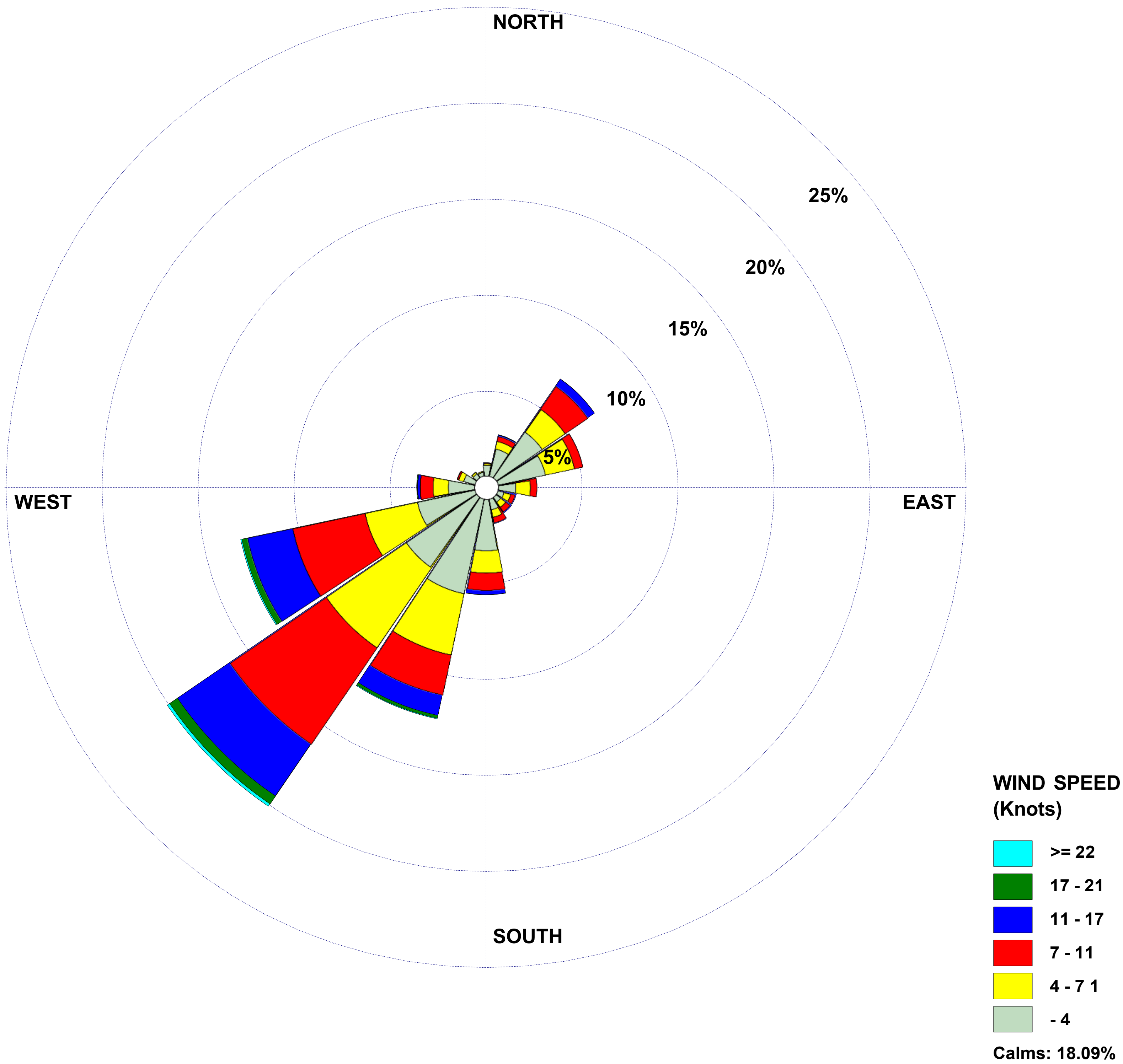
WIND ROSE PLOT:

Station # 8 - Zonolite, MT

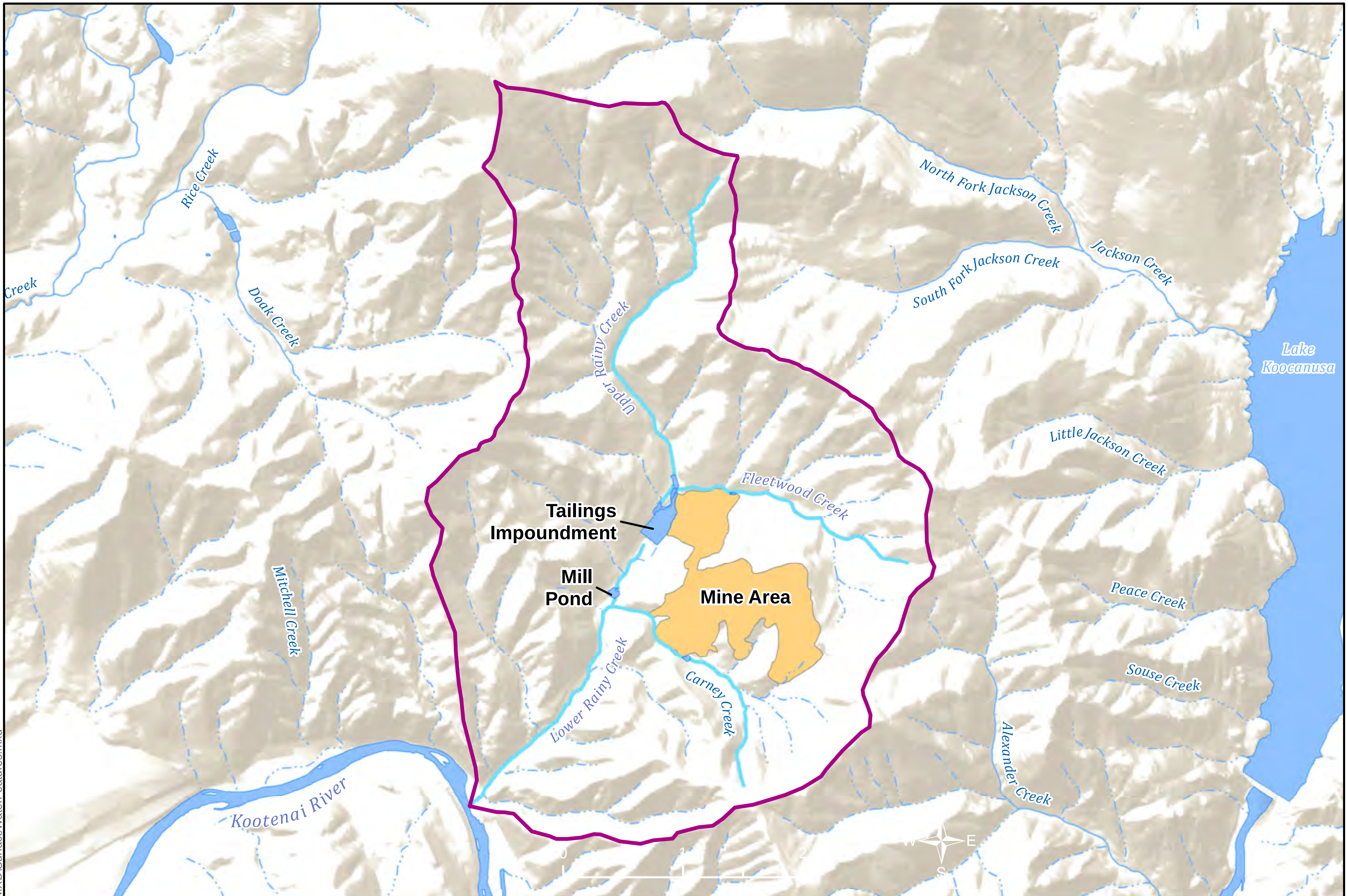
DISPLAY:

Wind Speed Direction
(blowing from)



COMMENTS:	DATA PERIOD:	COMPANY NAME:	
	Start Date: 1/4/2007 - 00:00 End Date: 12/31/2013 - 10:00	CDM Smith	
		MODELER: WRPLOT - Lakes Environmental	Figure 2-5. Wind Rose at the Mine Site
	CALM WINDS: 18.09%	TOTAL COUNT: 56754 hrs.	
	AVG. WIND SPEED: 4.58 Knots	DATE: 1/15/2014	PROJECT NO.: Libby Asbestos Superfund Site

WRPLOT View - Lakes Environmental Software



Mined Area
Open Water
Streams in Rainy Creek Watershed
Perennial Stream
Intermittent Stream
Rainy Creek Watershed

Date Saved: 10/31/2014 7:17:22 AM
Service Layer Credits: Sources: Esri, USGS, NOAA

CDM Smith

Figure 2-6
Surface Water Features

N
0 0.25 0.5 1 1.5
Miles

Path: R:\85158-OU3\BERA\MXD\SurfaceWaterFeatures.mxd

Path: R:\85158-OU3\BERA\MXD\MinedAreaFeatures.mxd

CDM Smith

County Road
Primary Road
Open Water
Perennial Stream
Intermittent Stream

Date Saved: 10/29/2014 4:19:18 PM
Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, i-cubed, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 2-7
Mined Area Features

N
0 0.125 0.25 0.5
Miles

Phase 1 Air Monitoring Location

Phase 2 Air Monitoring Location

Meterological Station

County Road

Primary Road

Perennial Stream

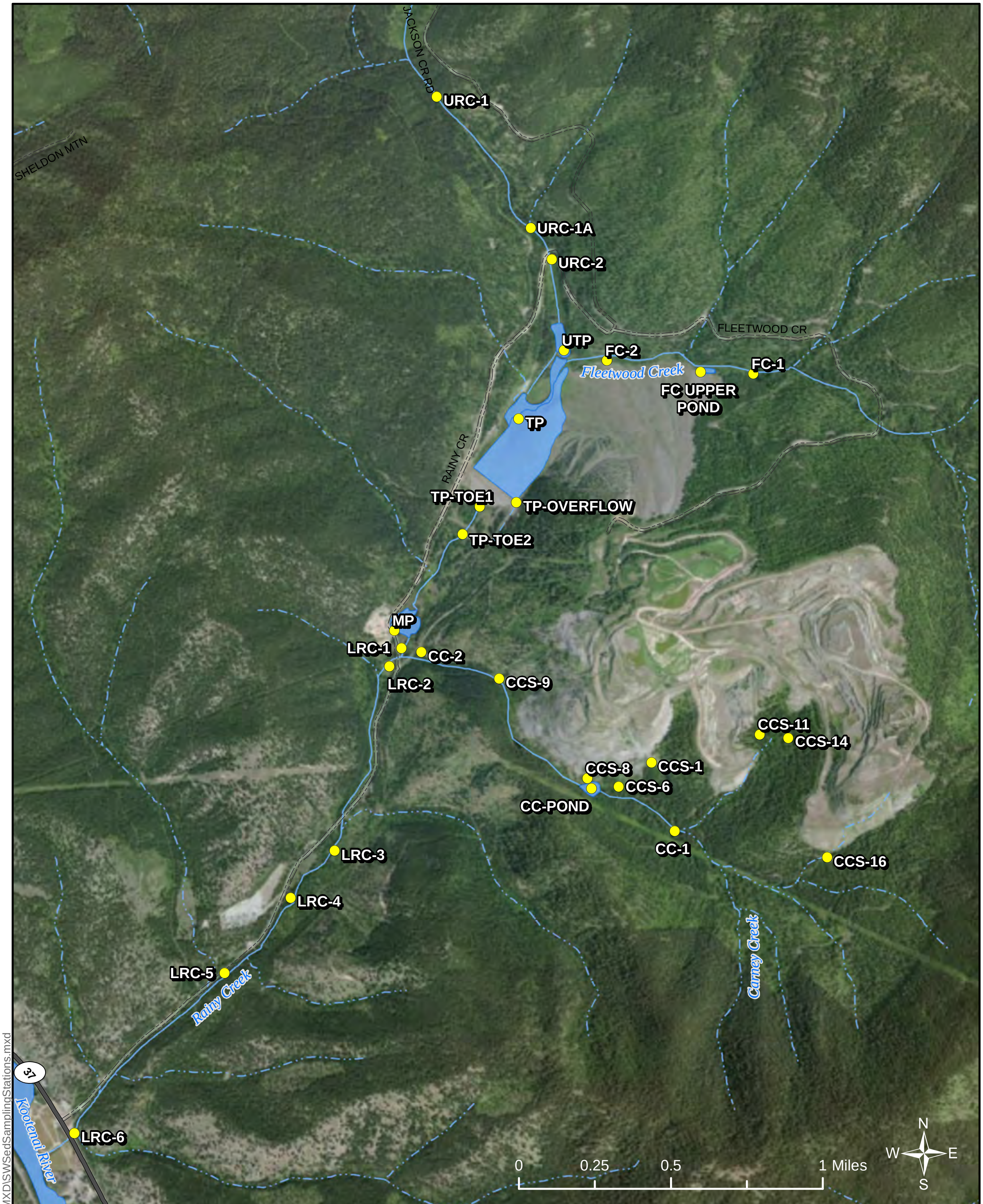
Intermittent Stream

Open Water

Date Saved: 10/29/2014 4:24:37 PM

Figure 2-8
Ambient Air Monitoring Locations, Phases I and II

CDM Smith



Path: R:\85158-OU3\BERA\MXD\SWSedSamplingStations.mxd

CDM Smith

Surface Water/Sediment Sampling Location

County Road

Primary Road

Perennial Stream

Intermittent Stream

Open Water

Date Saved: 10/31/2014 10:22:13 AM

Figure 2-9 Panel A
Surface Water and Sediment Sampling Stations

Aquatic Reference Location
Open Water
Perennial Stream
Intermittent Stream

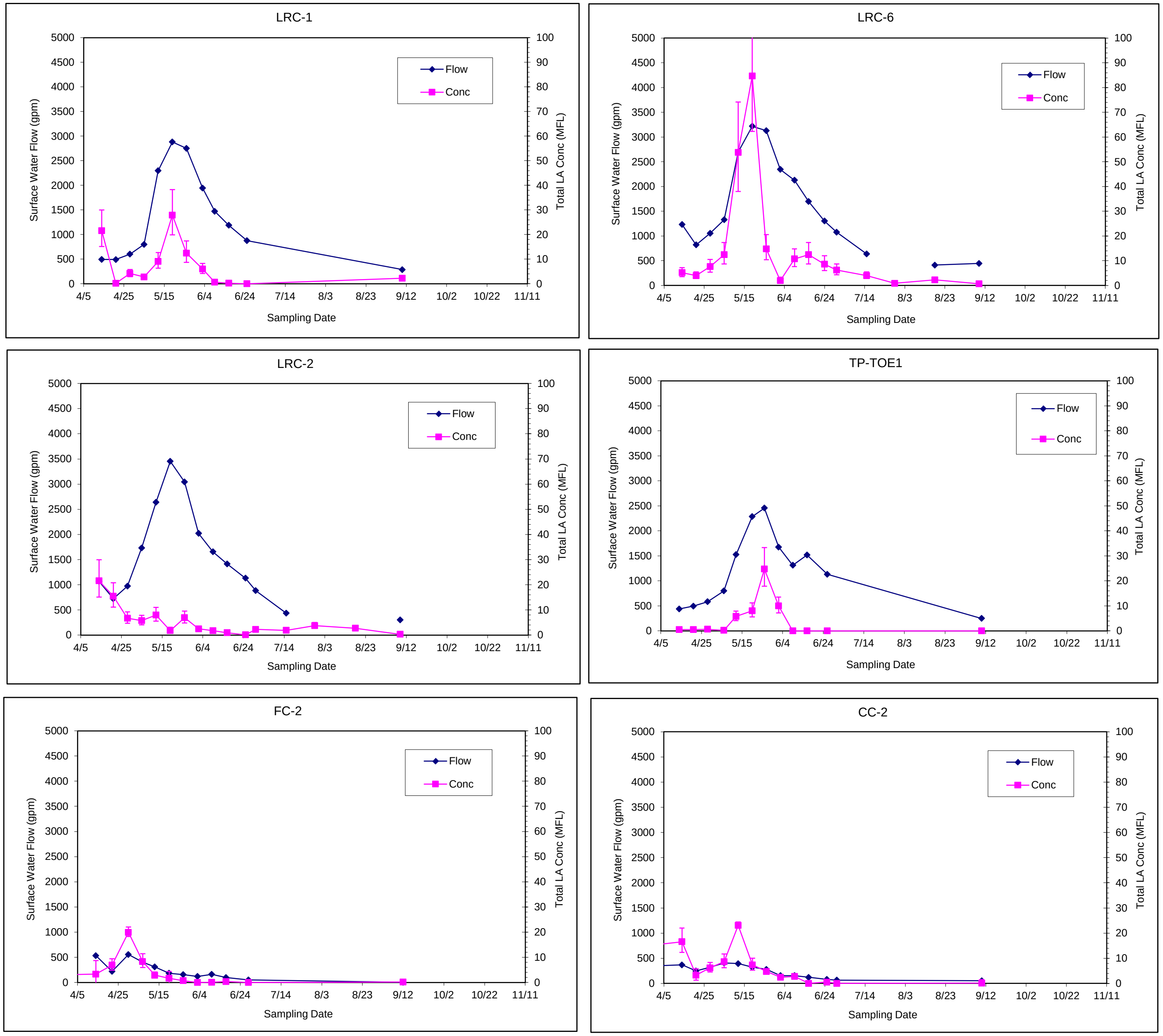
Date Saved: 10/31/2014 7:29:03 AM

Figure 2-9 Panel B
Reference Stream Sampling Locations

CDM Smith

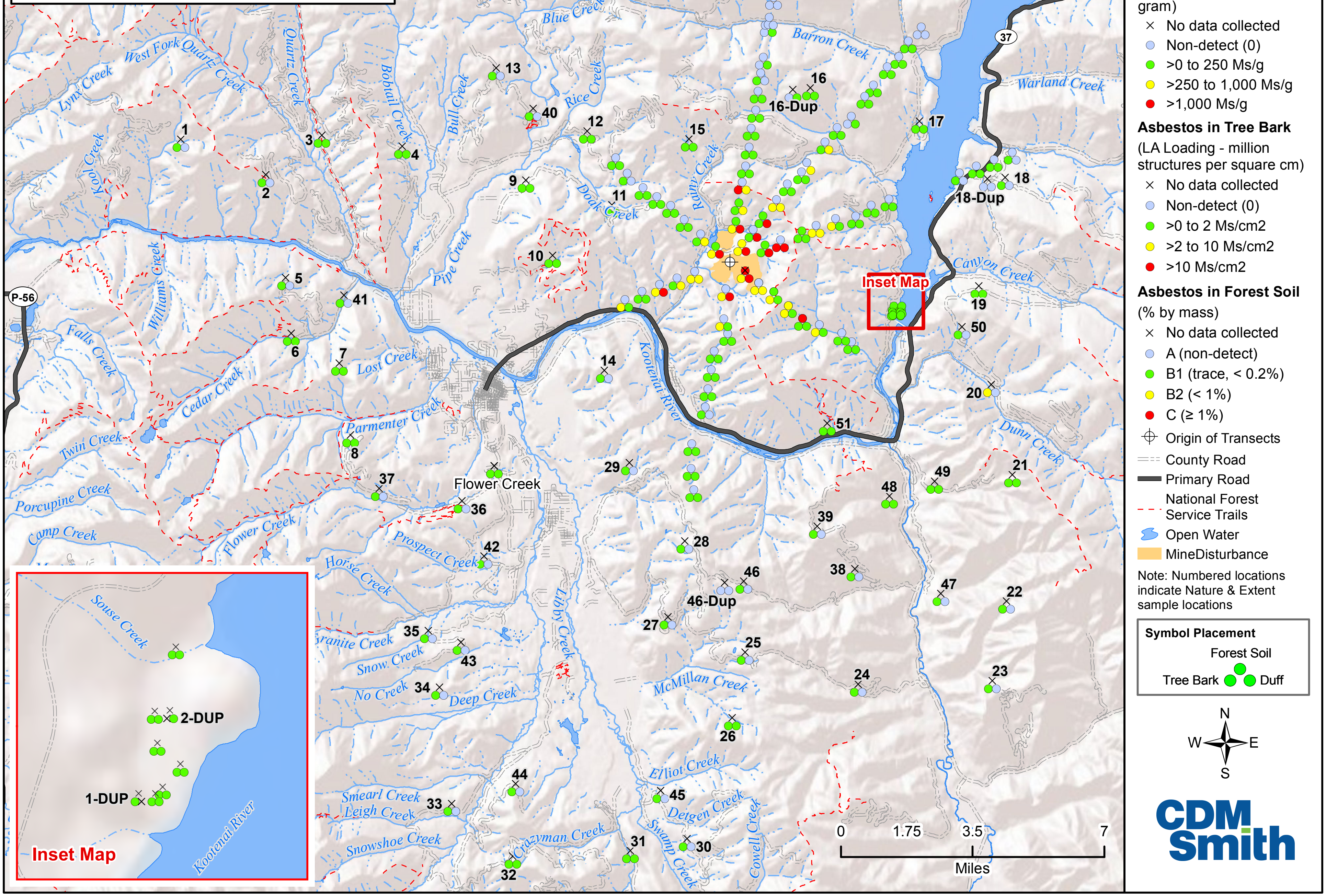
Path: R:\85158-OU3\BERA\MXD\ReferenceStreamSamplingLocations.mxd

Figure 2-10
LA Concentration vs. Flow in Lower Rainy Creek



Data Source: CDM Smith 2013a

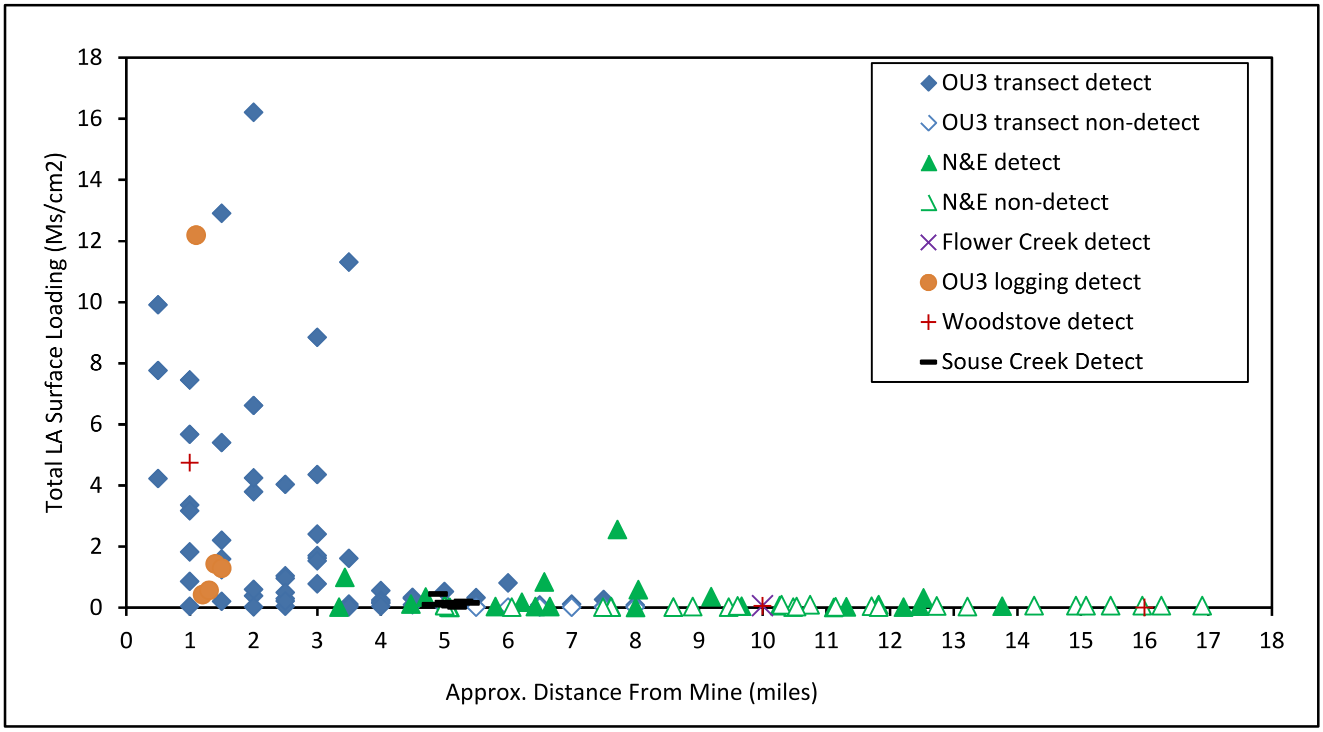
Figure 2-11
LA Concentrations in Soil, Tree Bark, and Duff



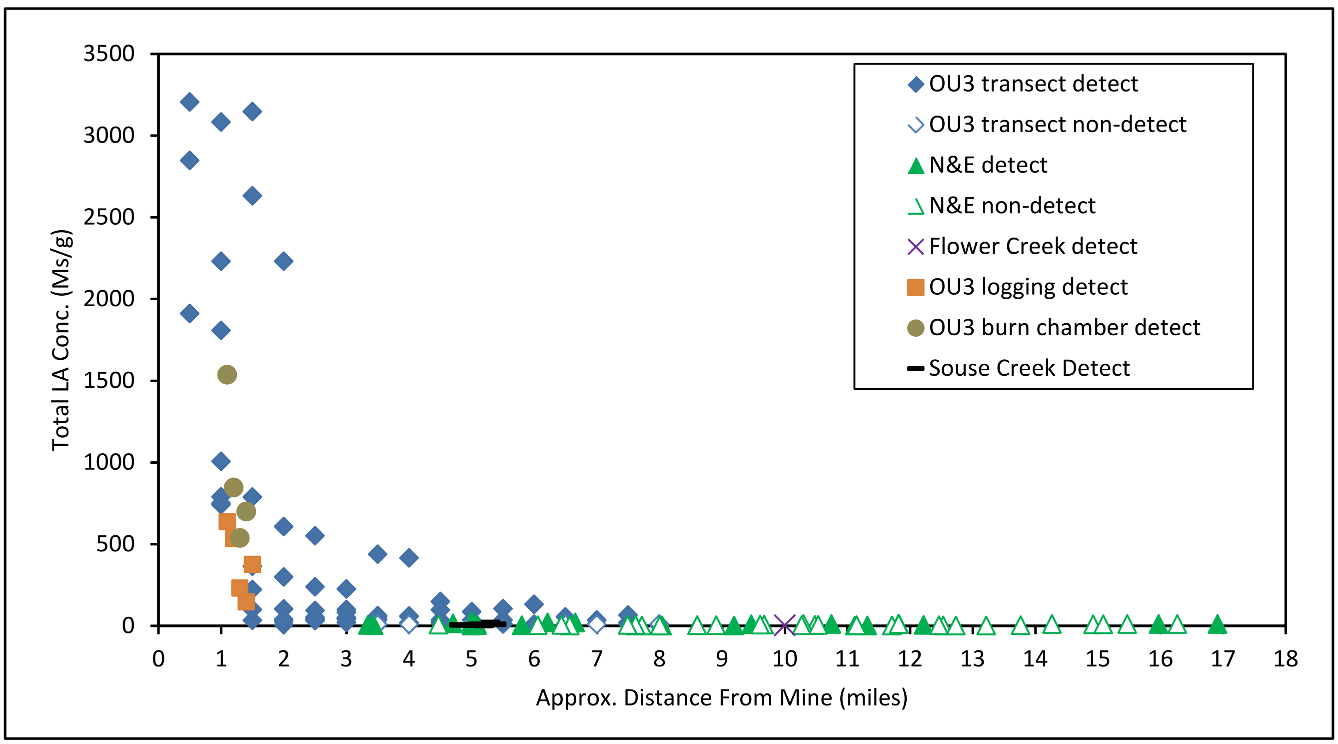
Path: R:\85158-OU3\3120.001-RA\GIS\MXD\TreeBarKDuff_with_SoilDuffBark_12022014.mxd

Figure 2-12
LA Concentrations in Bark and Duff as a Function of Distance from the Mine

Panel A: LA in Tree Bark

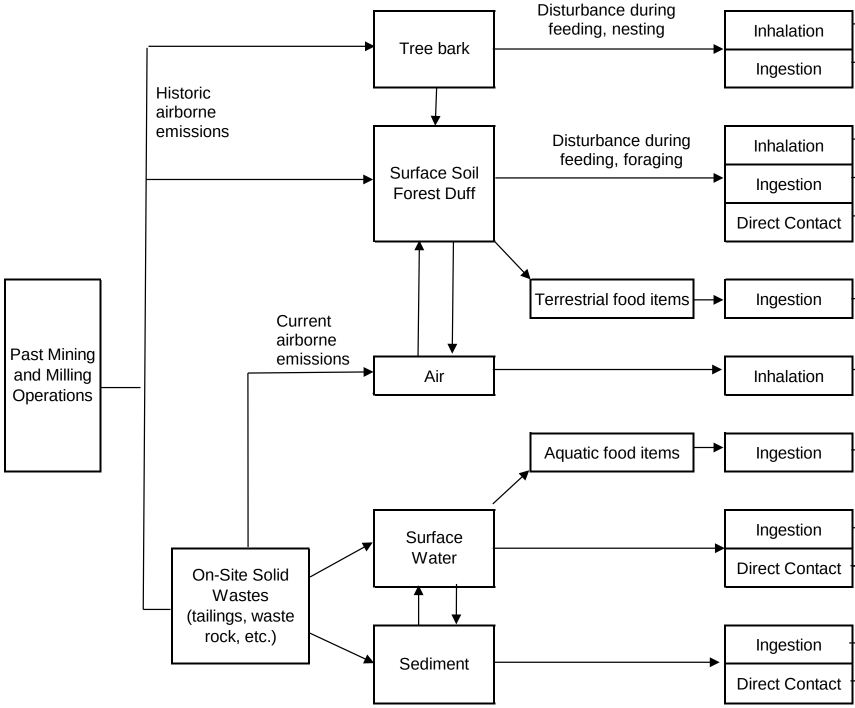


Panel B: LA in Duff



Data Sources: EPA 2012b; USPHS 2013; CDM Smith 2013a, 2013b, 2013c, 2014

Figure 3-1. Conceptual Site Model for Ecological Exposure to Asbestos

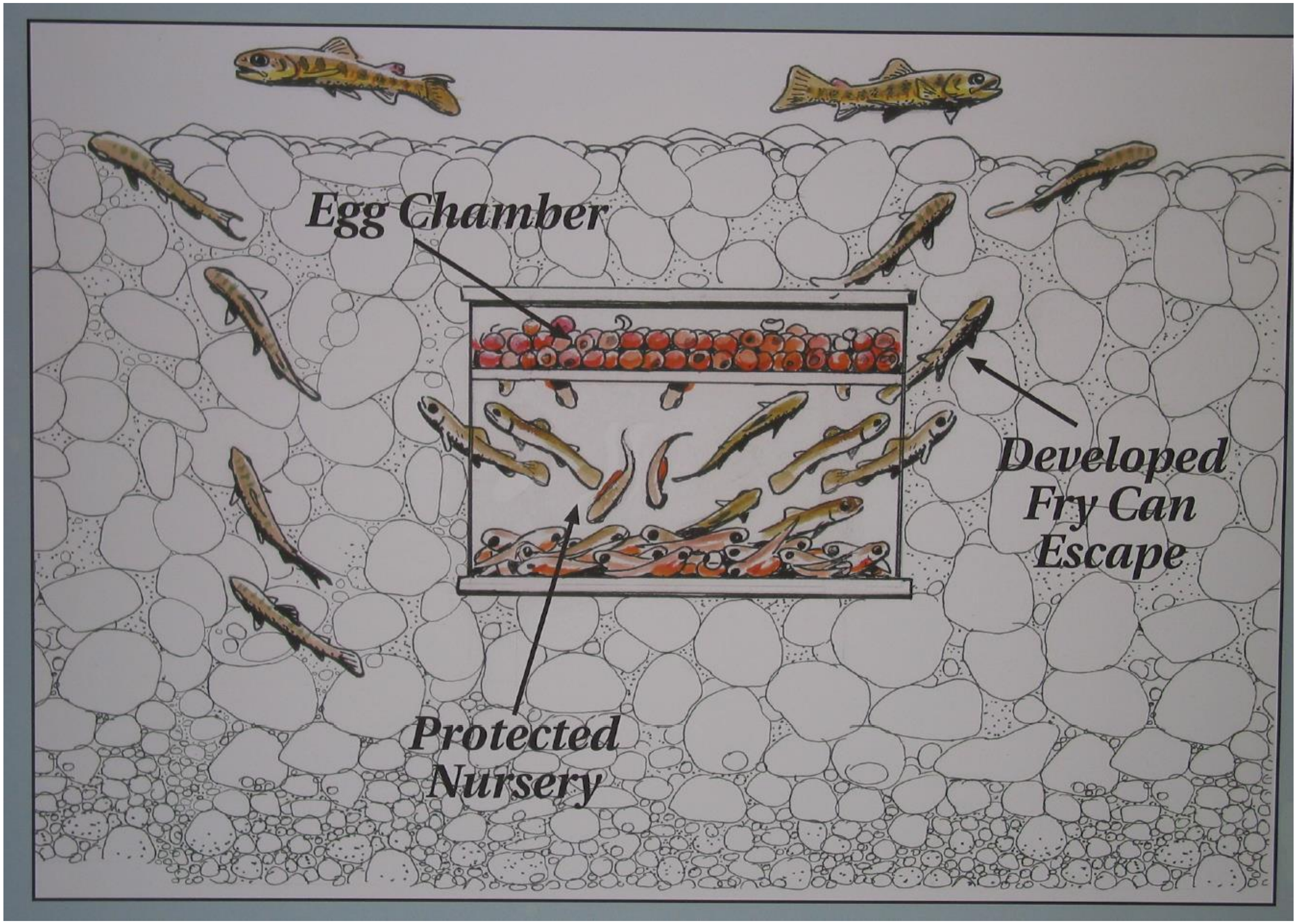


<table>
<tr><th>Medium</th><th>Route</th><th>Fish</th><th>Benthic Inverts.</th><th>Amphibians</th><th>Aquatic Plants</th><th>Terrestrial Plants</th><th>Birds</th><th>Mammals</th><th>Soil Inverts.</th><th>Reptiles</th><th></th></tr>
<tr><td rowspan="2">Tree bark</td><td>Inhalation</td><td></td><td></td><td></td><td></td><td></td><td>O</td><td></td><td></td><td></td><td rowspan="7">Terrestrial environment</td></tr>
<tr><td>Ingestion</td><td></td><td></td><td></td><td></td><td></td><td>O</td><td></td><td></td><td></td></tr>
<tr><td rowspan="3">Surface Soil Forest Duff</td><td>Inhalation</td><td></td><td></td><td>O</td><td></td><td></td><td>●</td><td>●</td><td></td><td>O</td></tr>
<tr><td>Ingestion</td><td></td><td></td><td>O</td><td></td><td></td><td>●</td><td>●</td><td rowspan="2">●</td><td>O</td></tr>
<tr><td>Direct Contact</td><td></td><td></td><td>O</td><td></td><td>O</td><td>O</td><td>O</td><td>O</td></tr>
<tr><td>Terrestrial food items</td><td>Ingestion</td><td></td><td></td><td>O</td><td></td><td></td><td>O</td><td>O</td><td></td><td>O</td></tr>
<tr><td>Air</td><td>Inhalation</td><td></td><td></td><td>O</td><td></td><td></td><td>O</td><td>O</td><td></td><td>O</td></tr>
<tr><td>Aquatic food items</td><td>Ingestion</td><td>O</td><td>O</td><td>O</td><td></td><td></td><td></td><td></td><td></td><td>O</td><td rowspan="5">Aquatic environment</td></tr>
<tr><td rowspan="2">Surface Water</td><td>Ingestion</td><td>O</td><td>O</td><td>O</td><td></td><td></td><td>O</td><td>O</td><td></td><td>O</td></tr>
<tr><td>Direct Contact</td><td>●</td><td>●</td><td>●</td><td>O</td><td></td><td></td><td></td><td></td><td>O</td></tr>
<tr><td rowspan="2">Sediment</td><td>Ingestion</td><td>O</td><td rowspan="2">●</td><td rowspan="2">●</td><td></td><td></td><td></td><td></td><td></td><td>●</td></tr>
<tr><td>Direct Contact</td><td>O</td><td>O</td><td></td><td></td><td></td><td></td><td>●</td></tr>
</table>

LEGEND

●	Pathway is believed to be complete, and might be significant
O	Pathway is believed to be complete, but is probably minor, at least in comparison to other pathways
	Pathway is believed to be incomplete, negligible, or not applicable

Figure 4-1. Design and Function of a Whitlock-Vibert Box



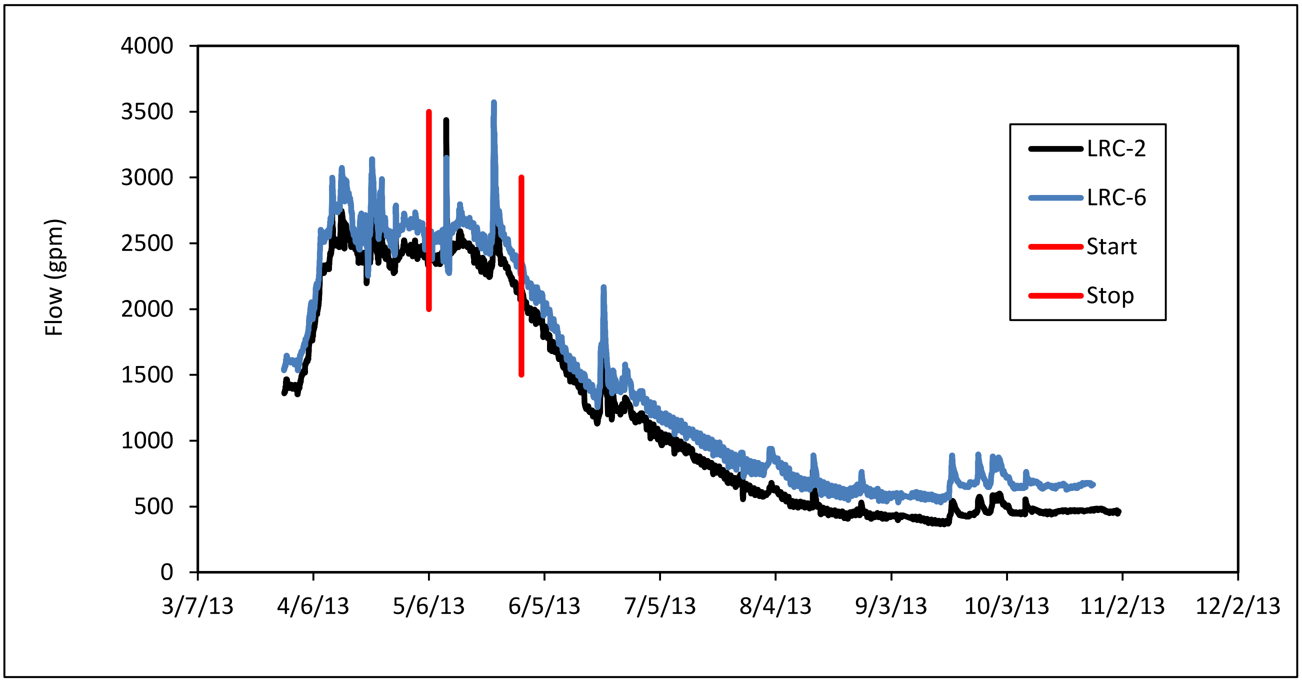
Data Source: http://fedflyfishers.org/Conservation/Whitlock-VibertBox.aspx

Figure 4-2. Example of Whitlock-Vibert Boxes Buried in Sediment in Lower Rainy Creek

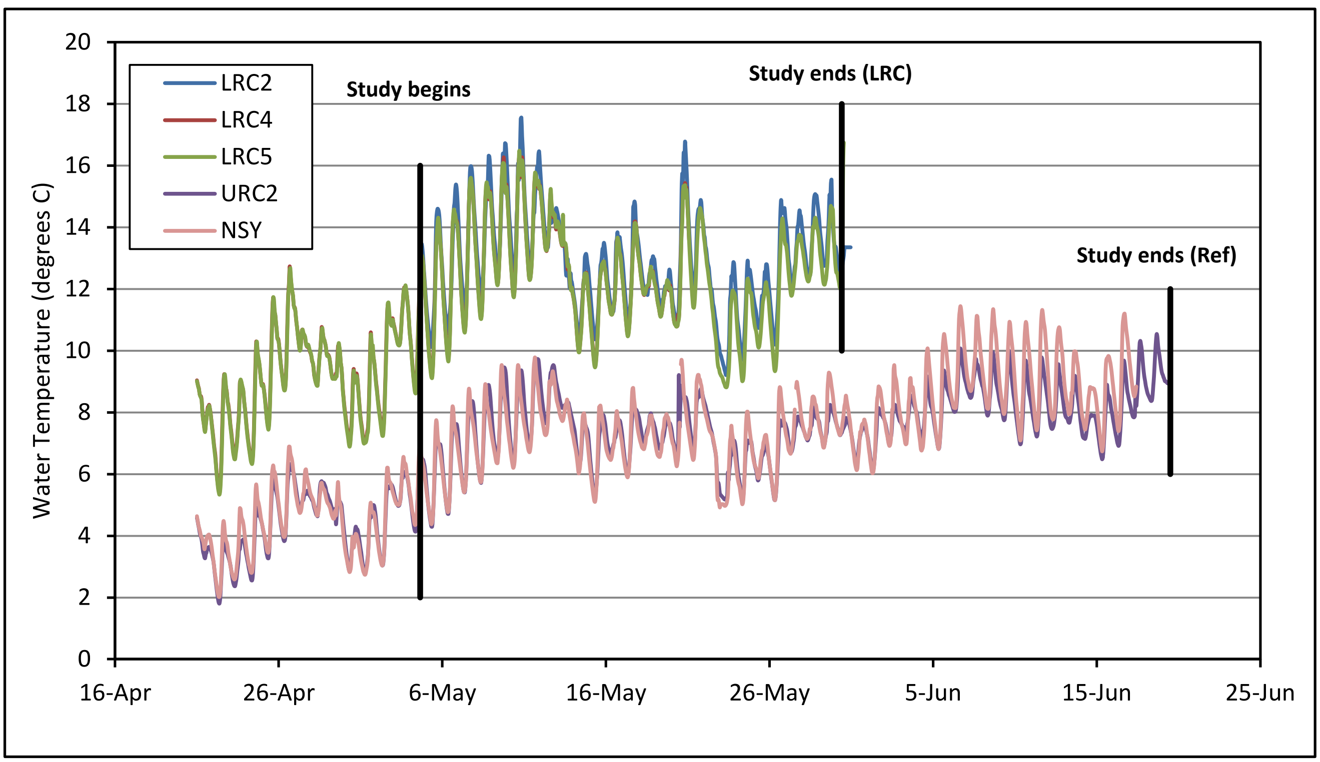
Data Source: Golder 2014b

Figure 4-3. 2013 Eyed Egg Exposure Study Temperature and Flow Data

Panel A: Stream Flow



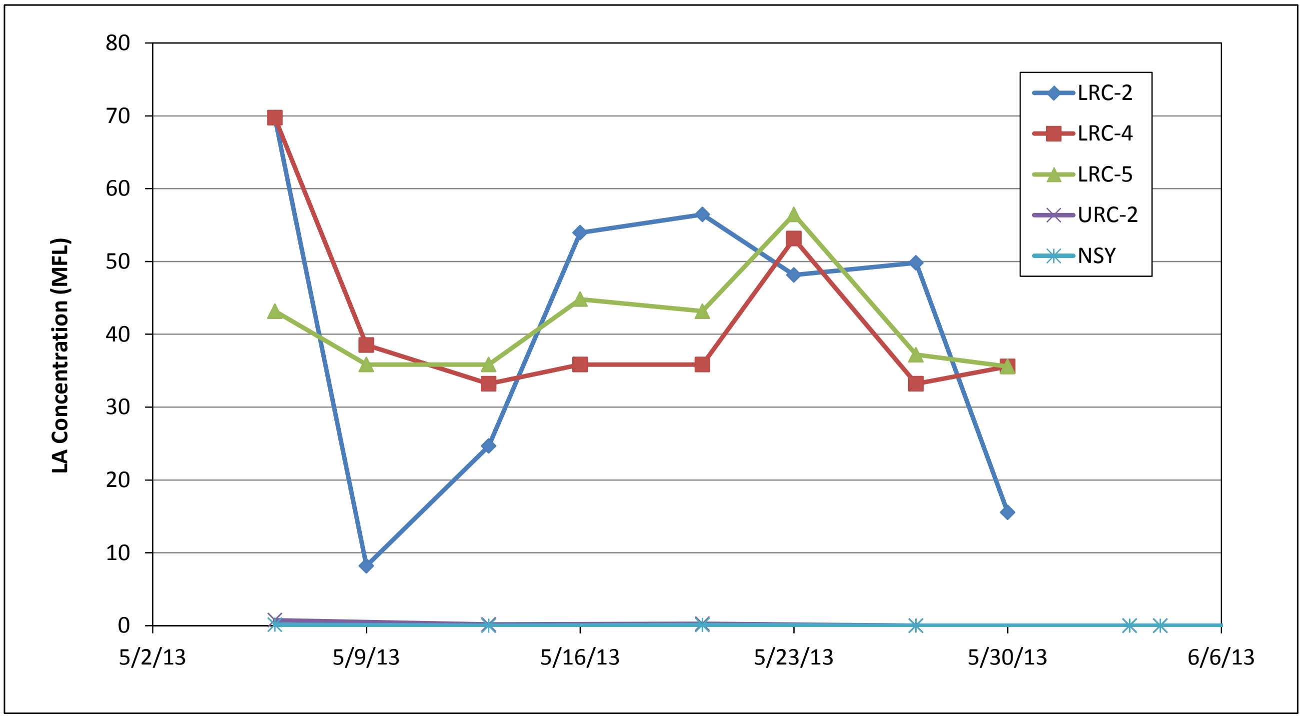
Panel B: Temperature



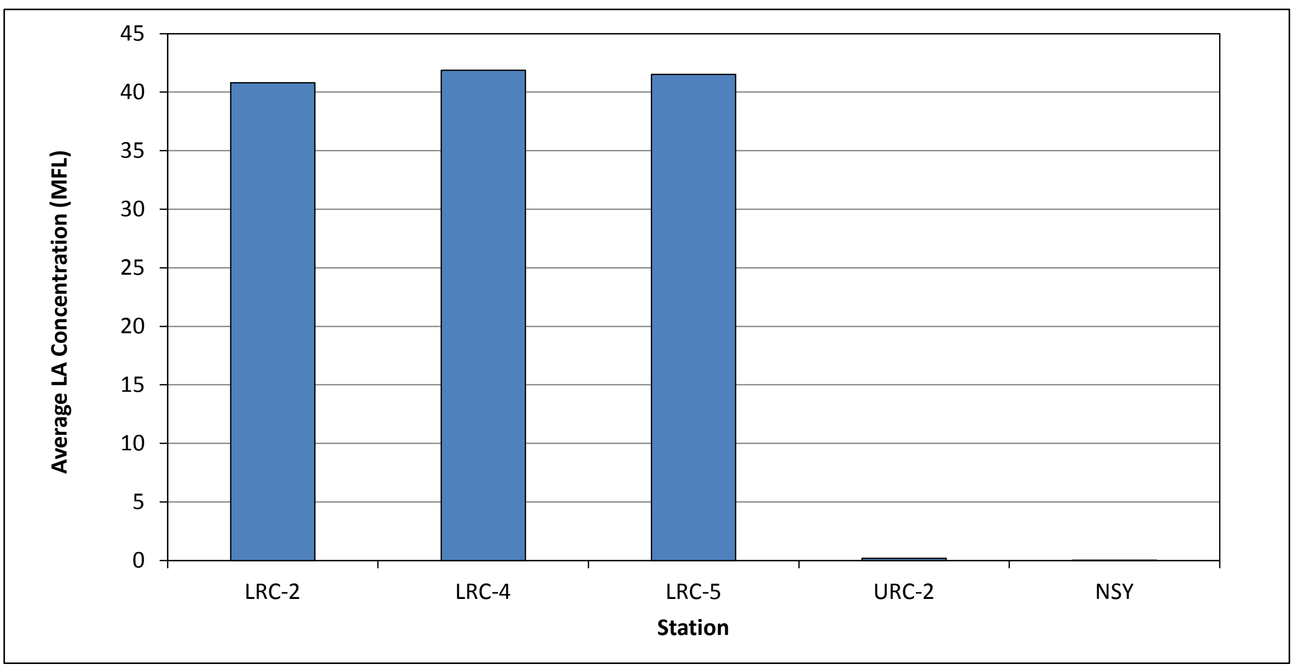
Data Source: Golder 2014b

Figure 4-4. 2013 Eyed Egg Exposure Concentrations

Panel A: Concentration vs. Day



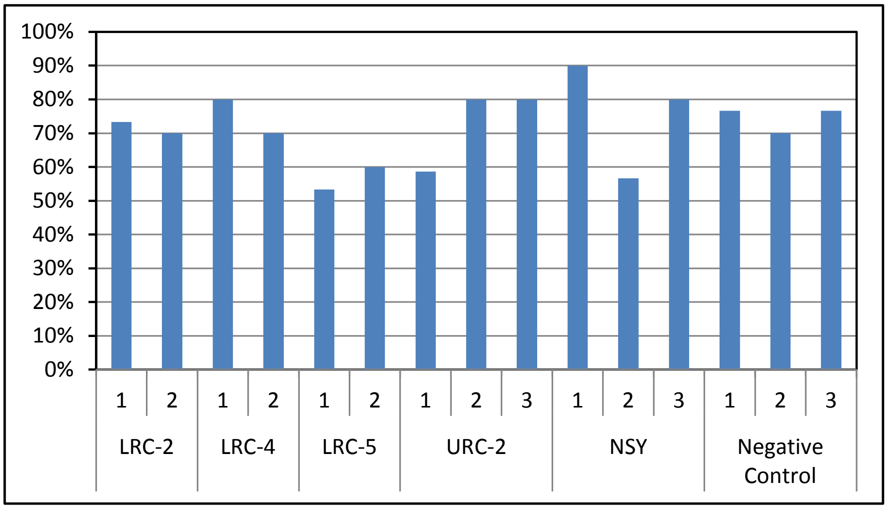
Panel B: Average Exposure Concentration



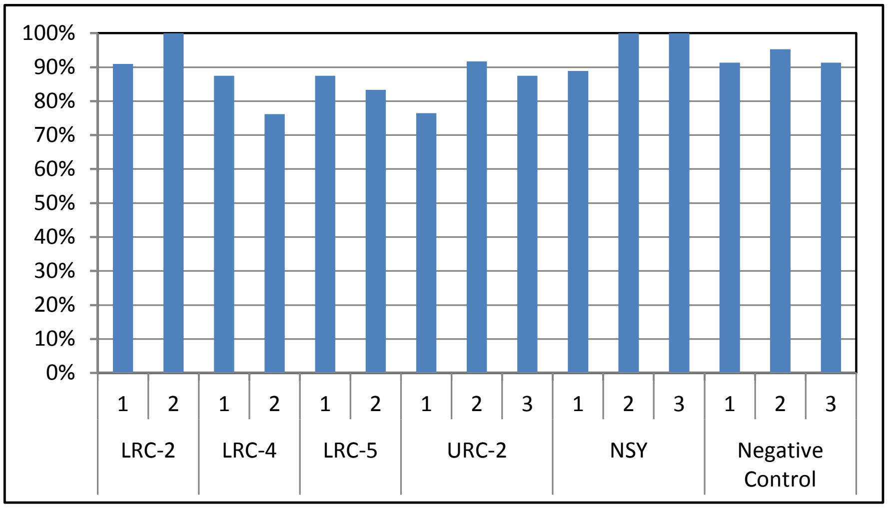
Data Source: Golder 2014b

Figure 4-5. 2013 Eyed Egg Study Results

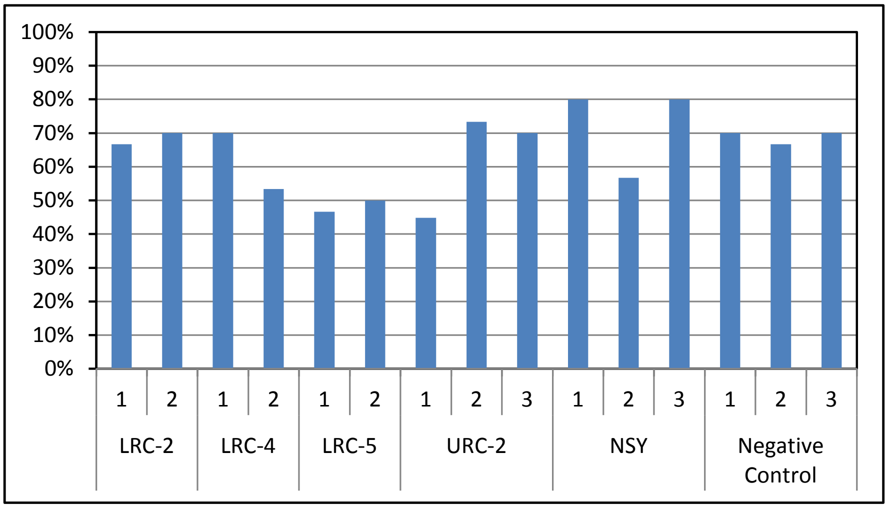
Panel A: Hatching Success



Panel B: Alevin Survival



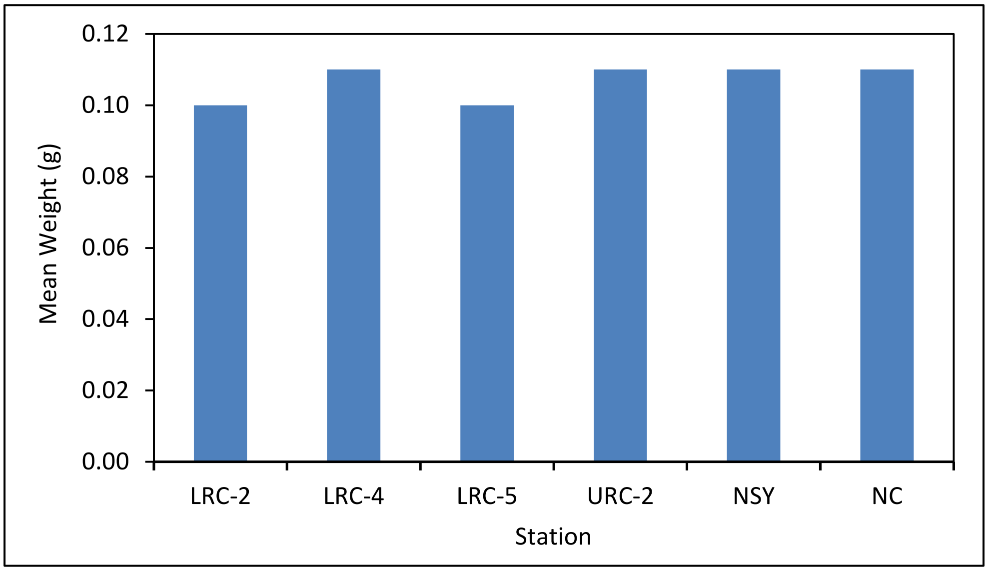
Panel C: Overall Survival



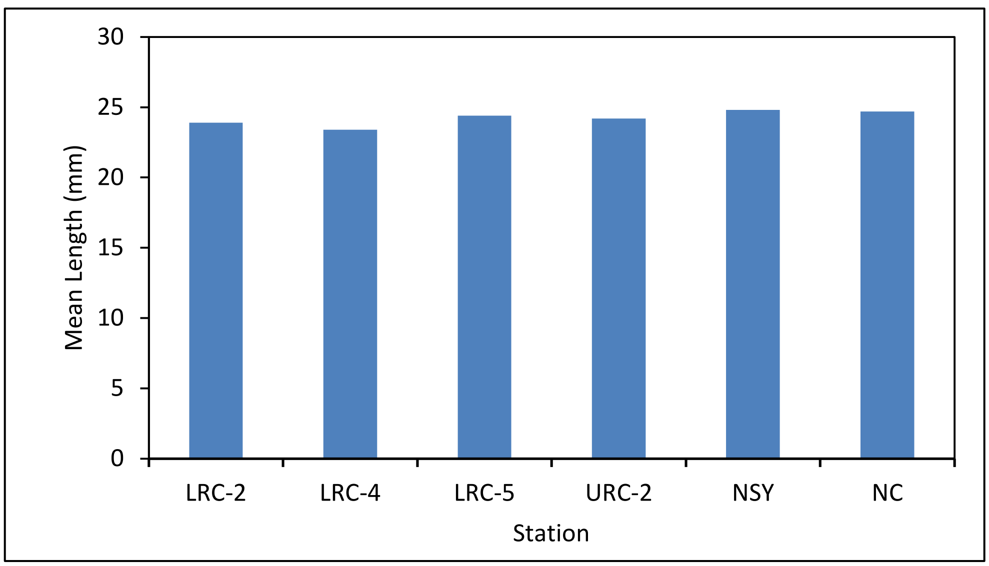
Data Source: Golder 2014b

Figure 4-6 2013 Alevin Size and Weight Data

Panel A: Mean Weight at Termination (g)



Panel B: Mean Length at Termination (mm)



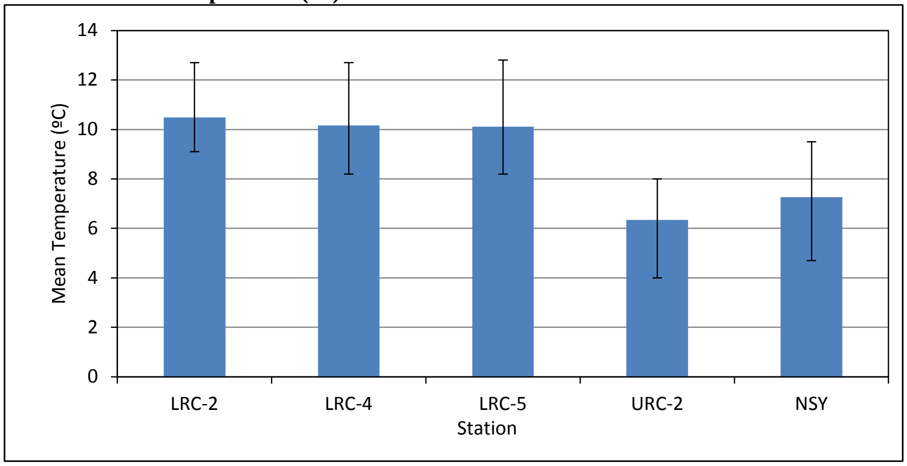
Data Source: Golder 2014b

Figure 4-7. Example Juvenile Trout Cages

Data Source: Golder 2013

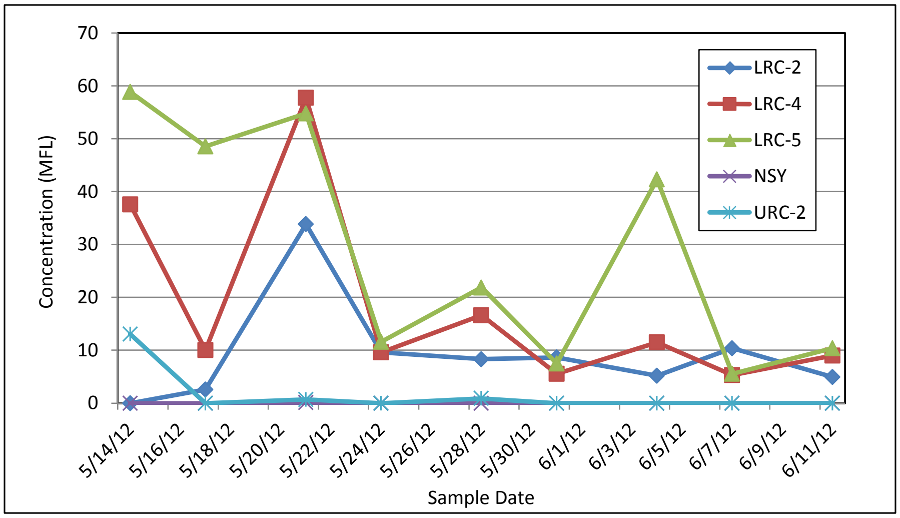
Figure 4-8. Juvenile Trout *In Situ* Exposure Conditions

Panel A: Mean Temperature (ºC)

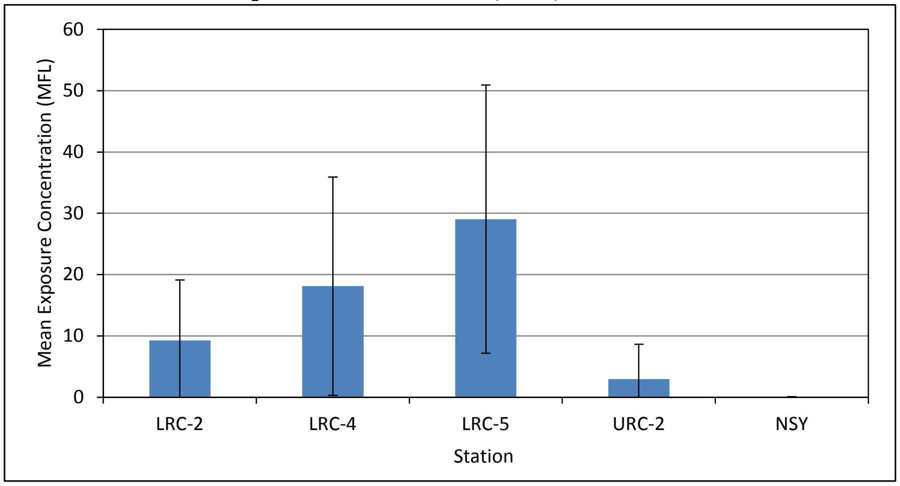


Error bars indicate minimum and maximum values
Data source: Golder 2013

Panel B: LA Concentration (MFL) vs Time



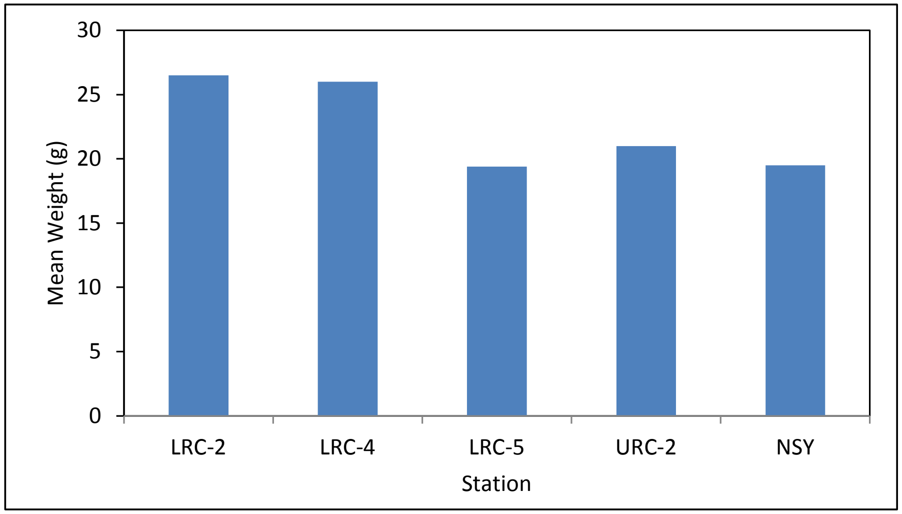
Panel C: Mean LA Exposure Concentration (MFL)



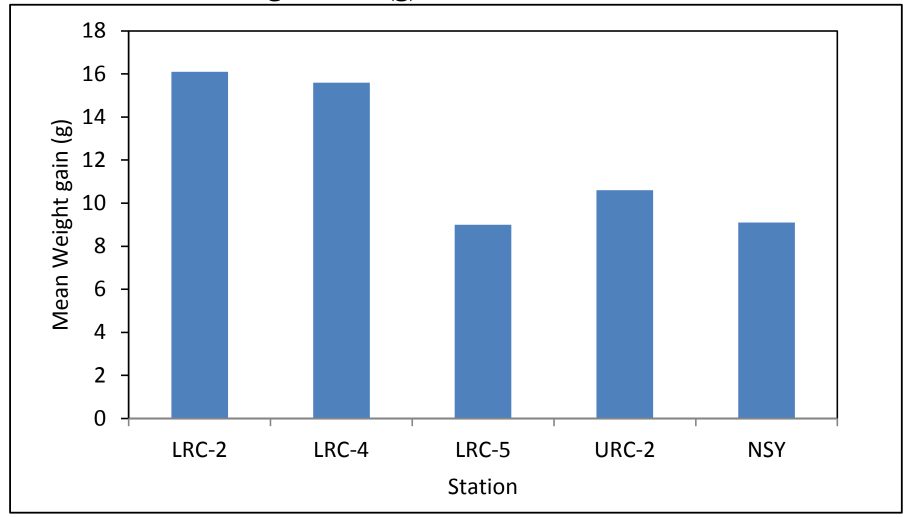
Error bars indicate standard deviation
Data Source: CDM 2013a

Figure 4-9 Juvenile Trout Size and Growth Data

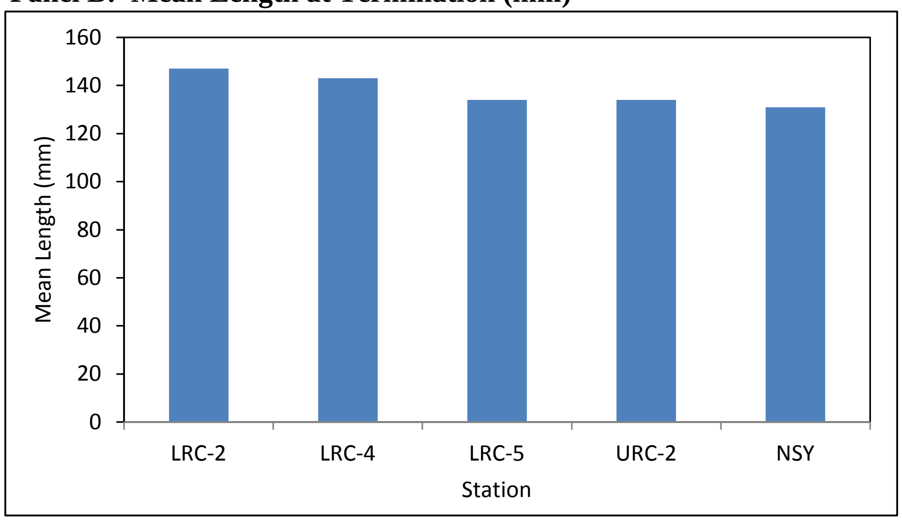
Panel A: Mean Weight at Termination (g)



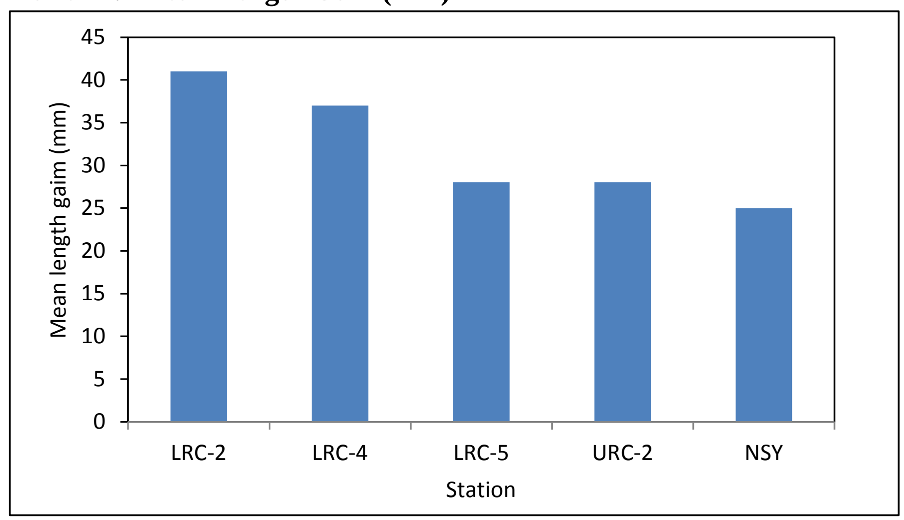
Panel C: Mean Weight Gain (g)



Panel B: Mean Length at Termination (mm)



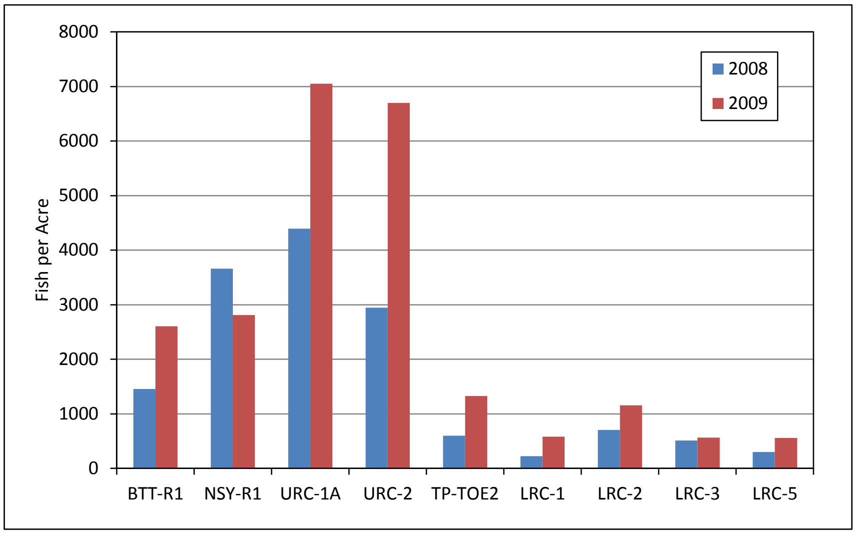
Panel D: Mean Length Gain (mm)



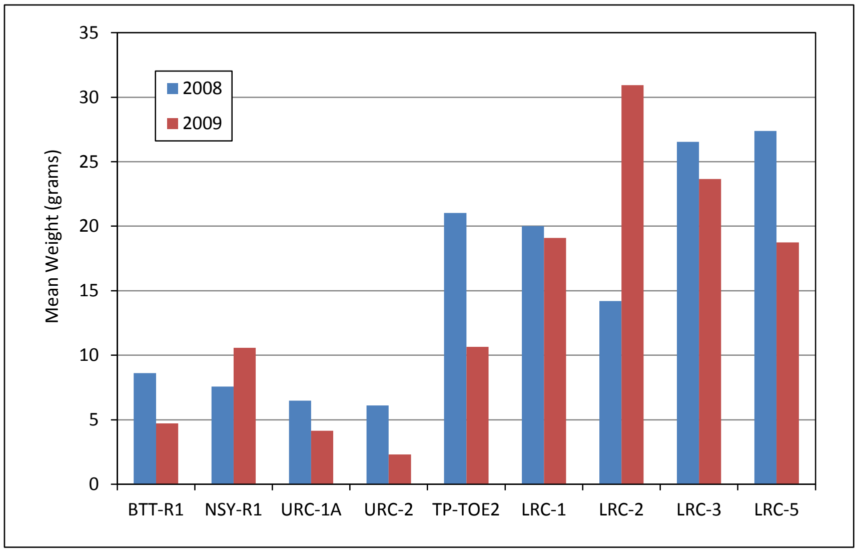
Data Source: Golder 2013

Figure 4-10. Fish Density, Weight, and Biomass

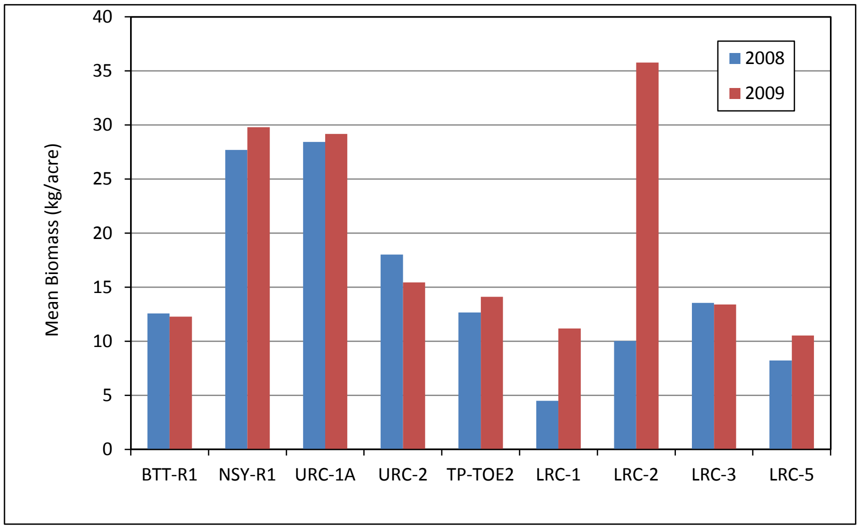
Panel A: Density



Panel B: Mean Weight



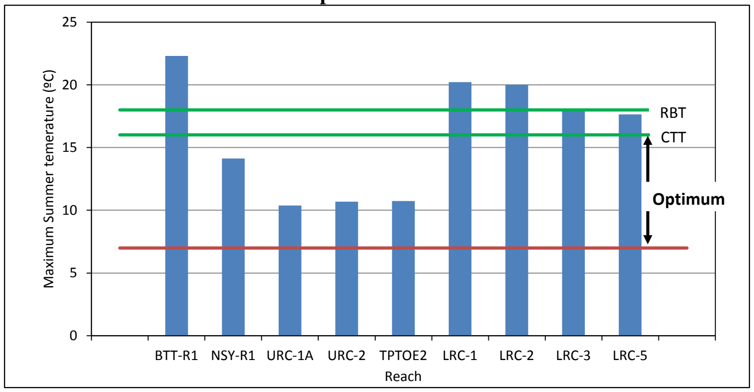
Panel C: Biomass



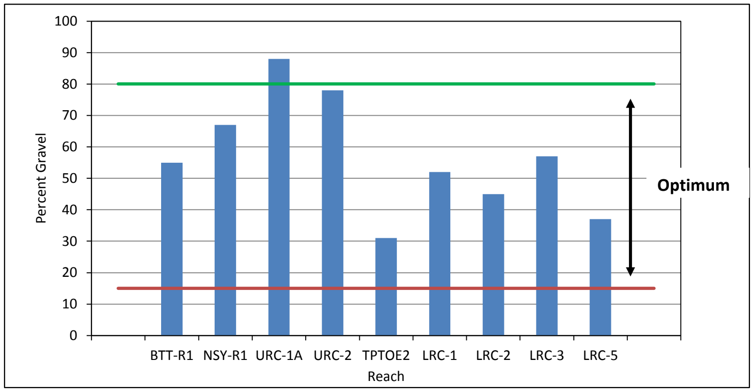
Data Source: Parametrix 2009d, 2010

Figure 4-11. Habitat Quality Metrics

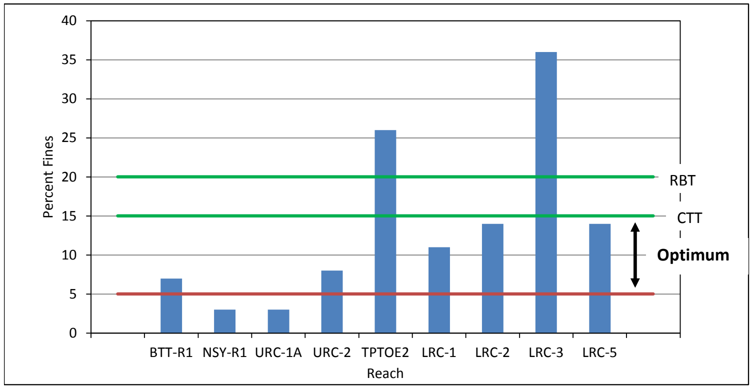
Panel A: Maximum Summer Pemperature



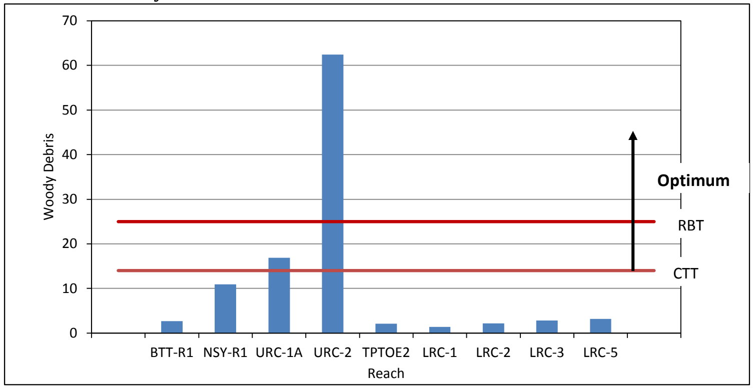
Panel B: Percent Gravel



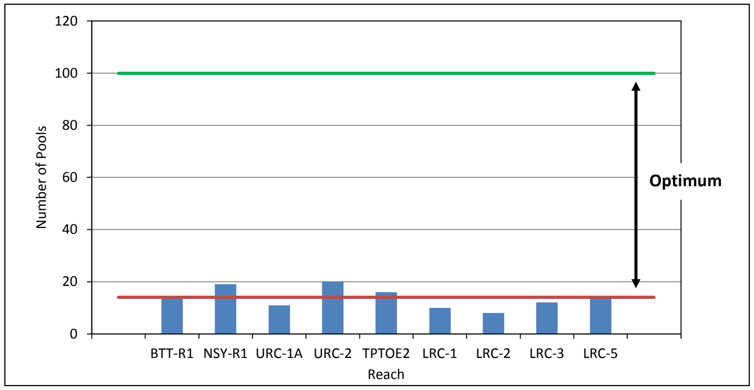
Panel C: Percent Fines



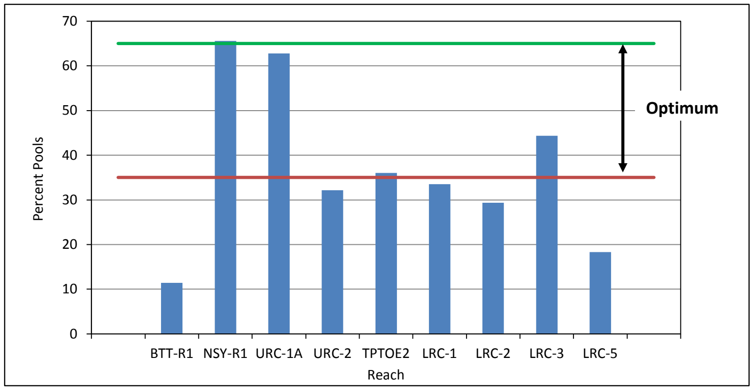
Panel D: Woody Debris



Panel E: Number of Pools



Panel F: Percent Pools

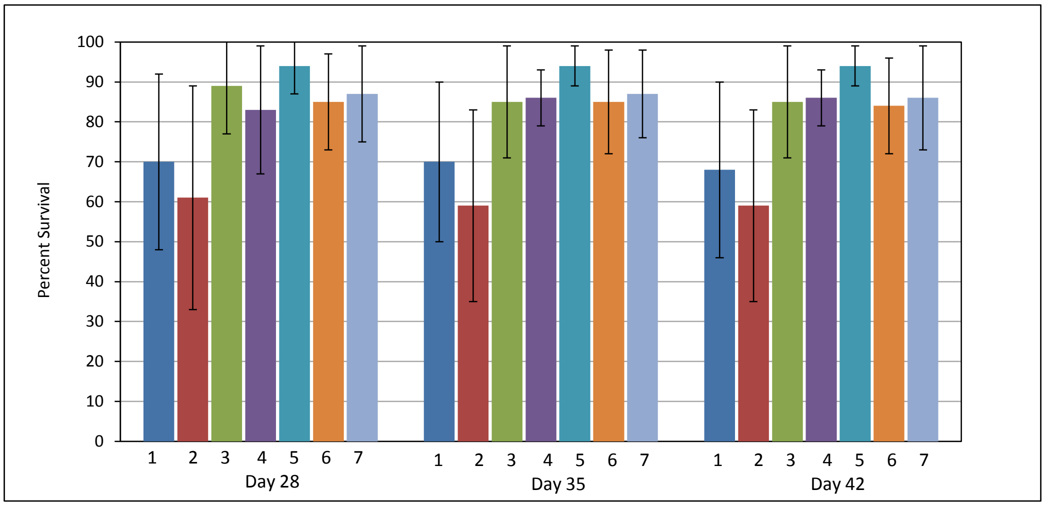


RBT = rainbow trout
CTT = Cutthroat trout

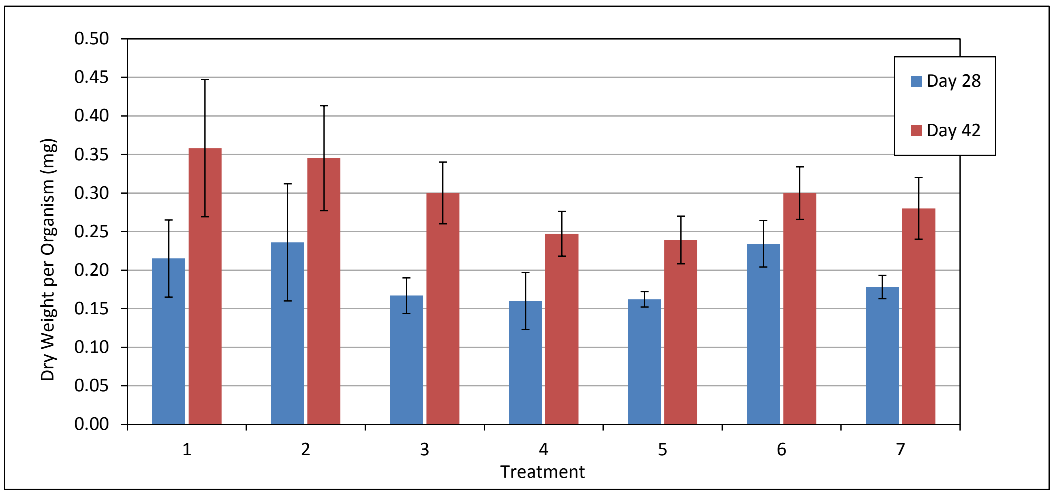
Data Source:

Figure 5-1 Laboratory Toxicity Results for *Hyalella azteca*

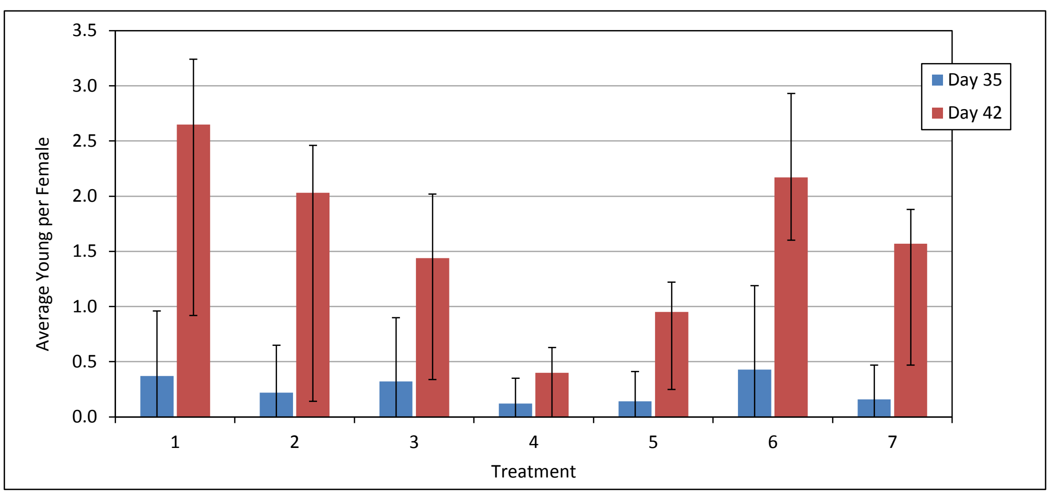
Panel A: Survival



Panel B: Growth Metrices



Panel C: Reproduction

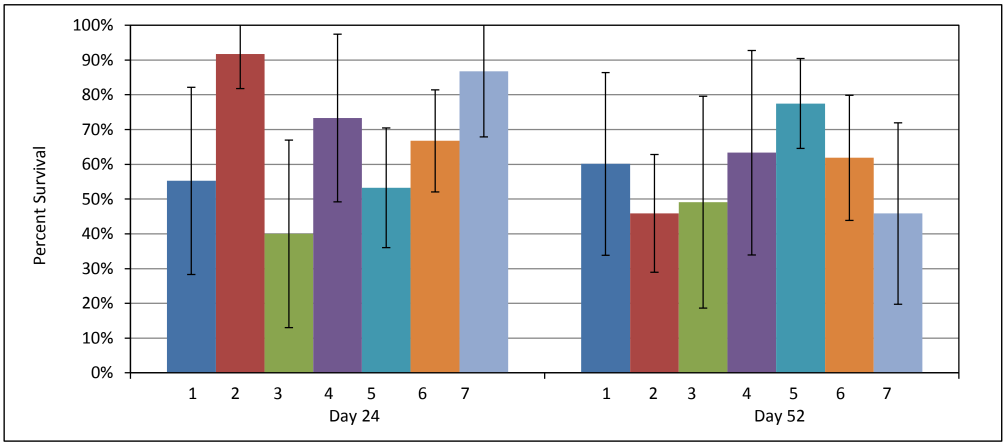


Data source: Parametrix 2009b
Error bars indicate standard deviations

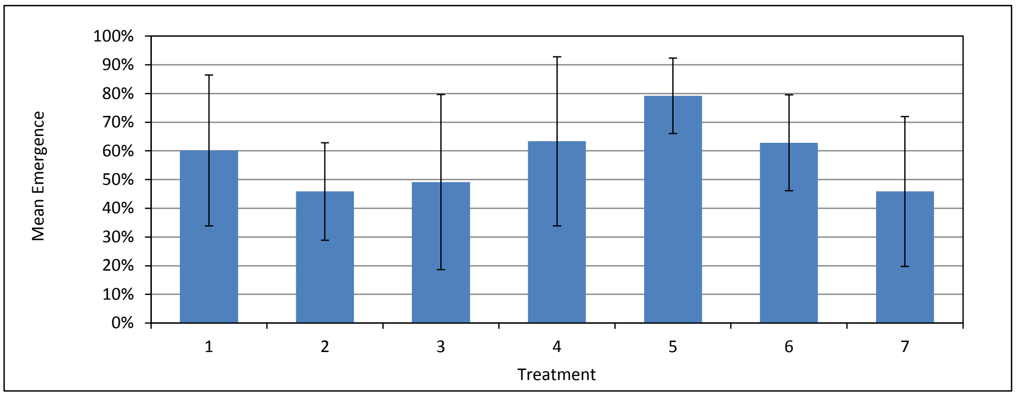
Treatments		
	1	Laboratory Control
	2	Laboratory Control
	3	Field Control
	4	Site Reference (BTT)
	5	Site Reference (NSY)
	6	Site (CC-1)
	7	Site (TP-TOE-2)

Figure 5-2 Laboratory Toxicity Results for *Chironomus tentans*

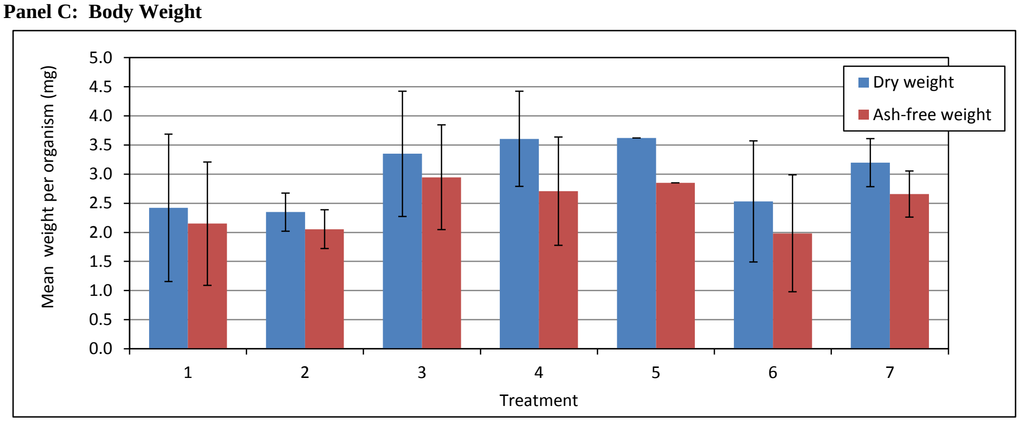
Panel A: Survival



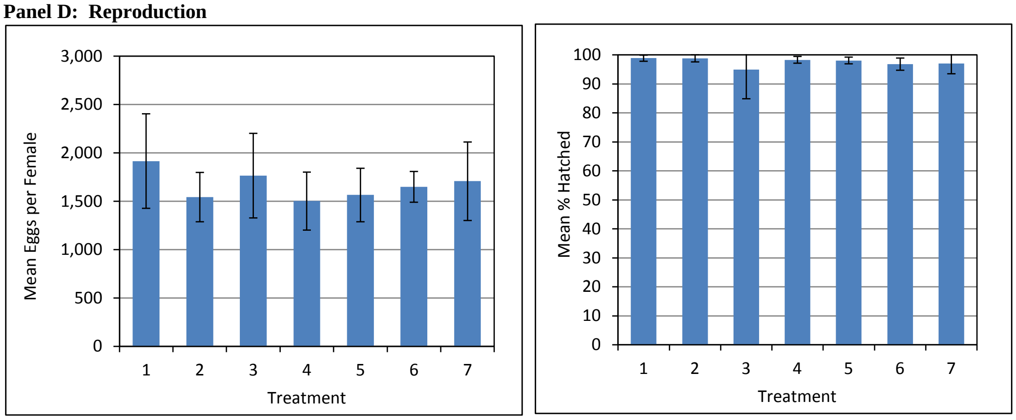
Panel B: Emergence



Panel C: Body Weight

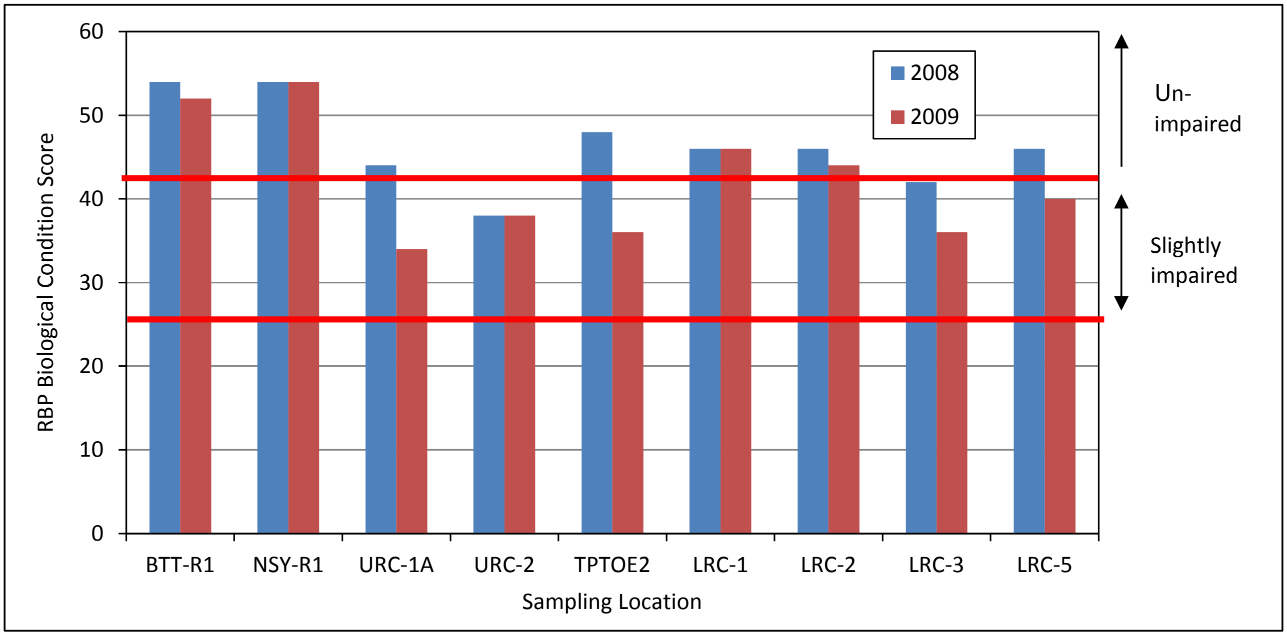


Panel D: Reproduction



Data Source: Parametrix 2009c (Appendix A)
Error bars indicate standard deciations

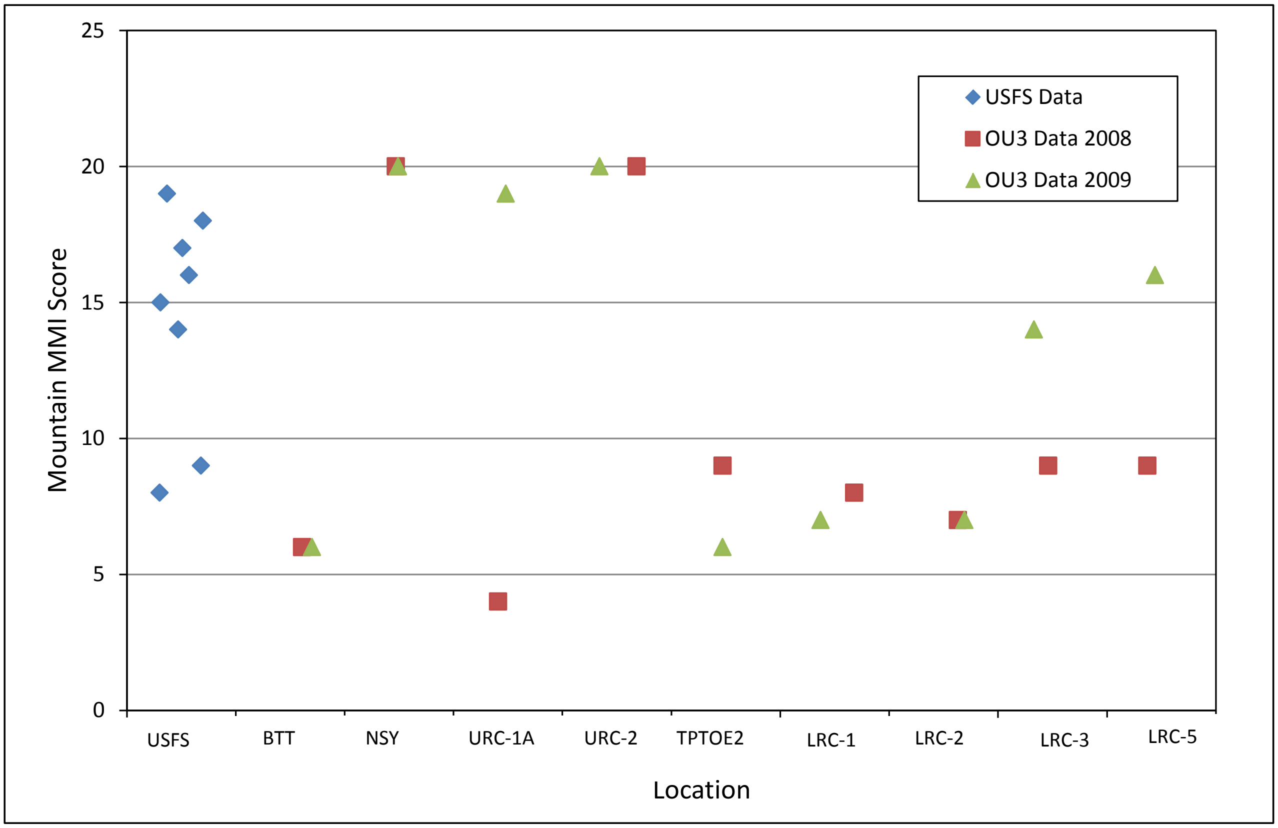
Figure 5-3. RBP Biological Condition Scores



Unimpaired = 53.5 x 0.8 = 42.8
Slightly impaired = 53.5 x 0.5 = 26.8

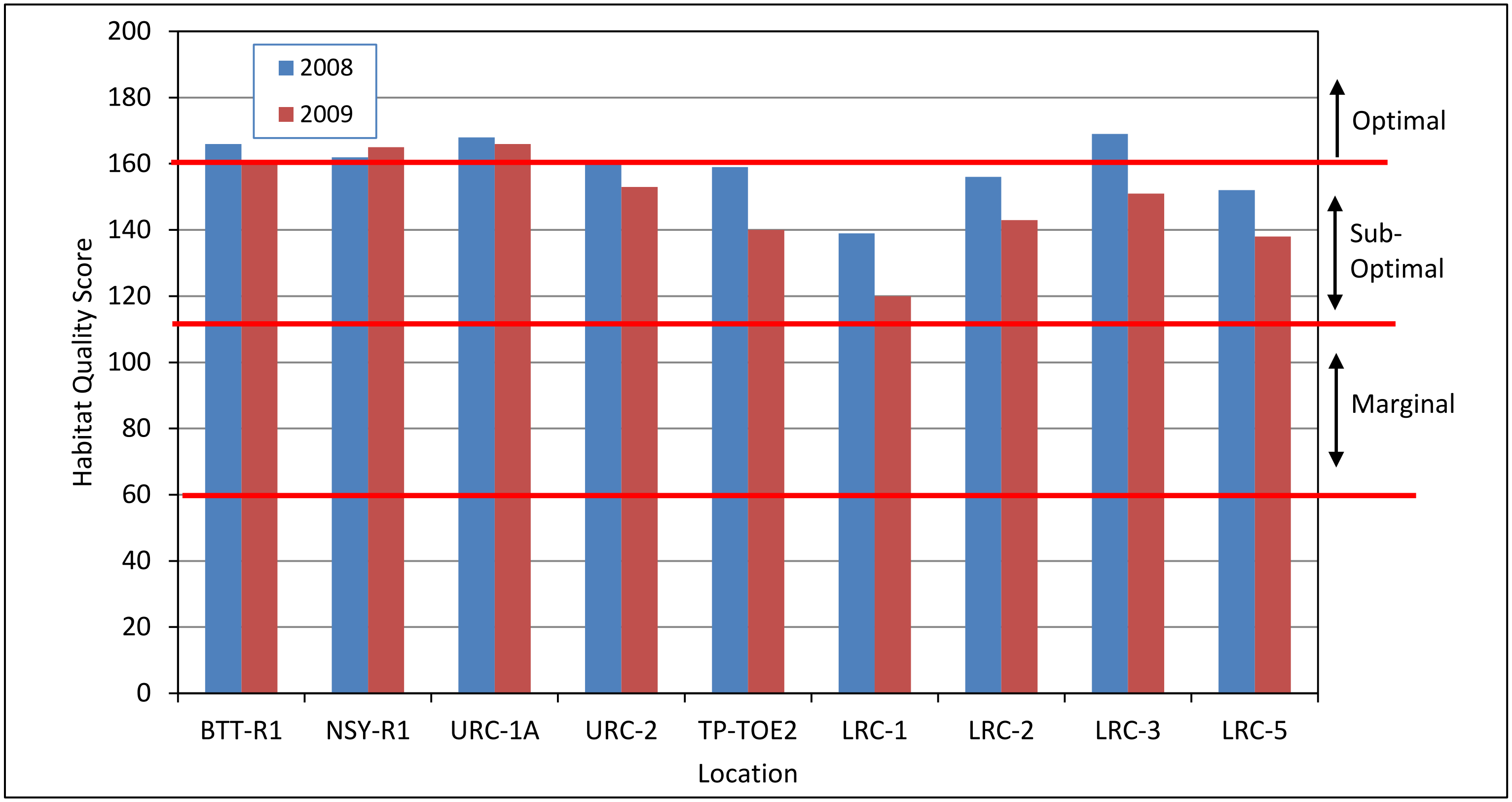
Data Source: Parametrix 2009d, 2010

Figure 5-4. Mountain MMI Scores



Data Source: Vinson 2007; Parametrix 2009d, 2010

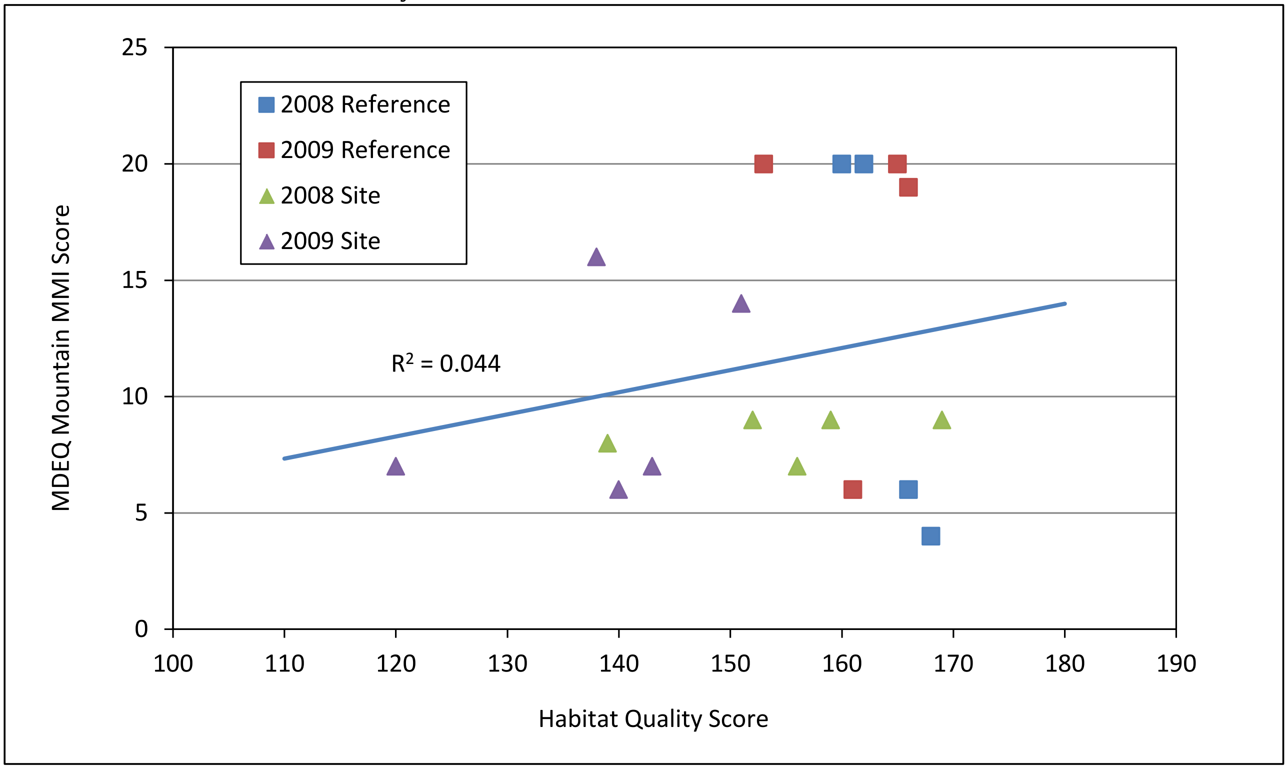
Figure 5-5. Habitat Quality Scores



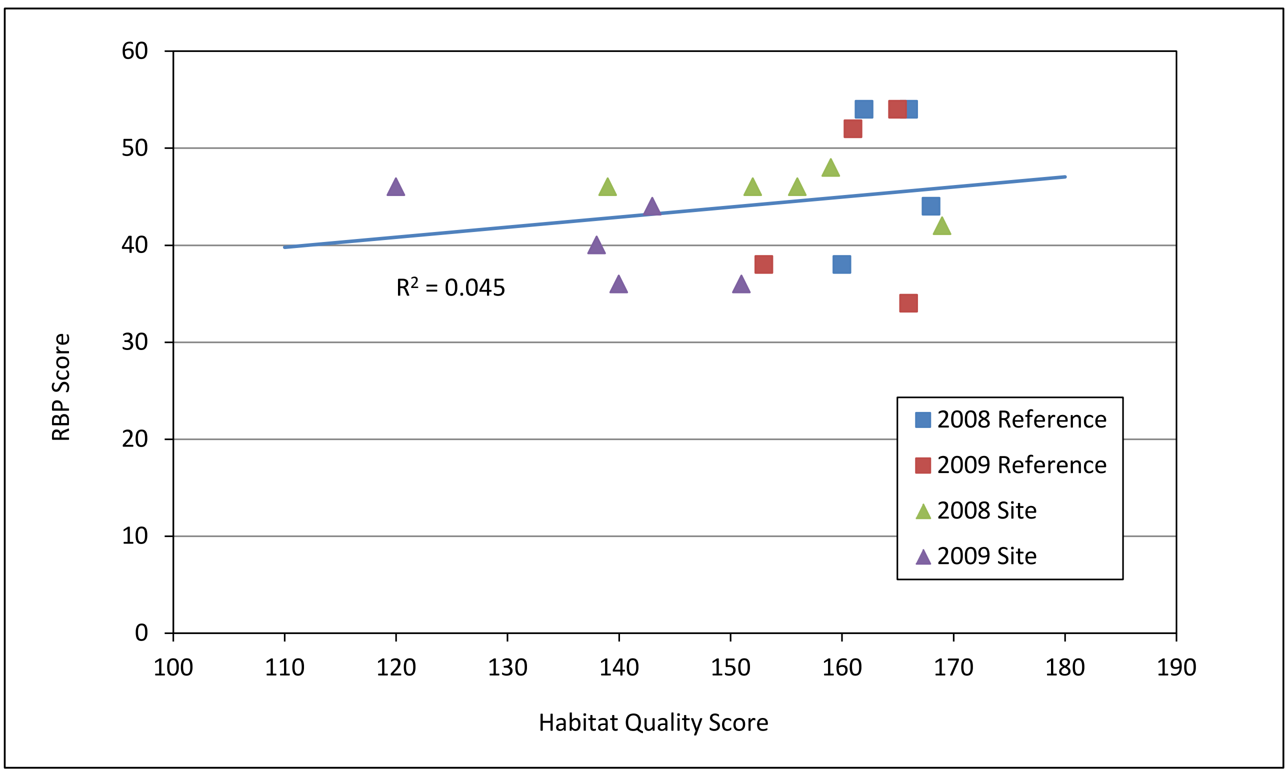
Data Source: Parametrix 2009d, 2010

Figure 5-6. Correlation between Community Status and Habitat Quality

Panel A: Based on MMI Community Score



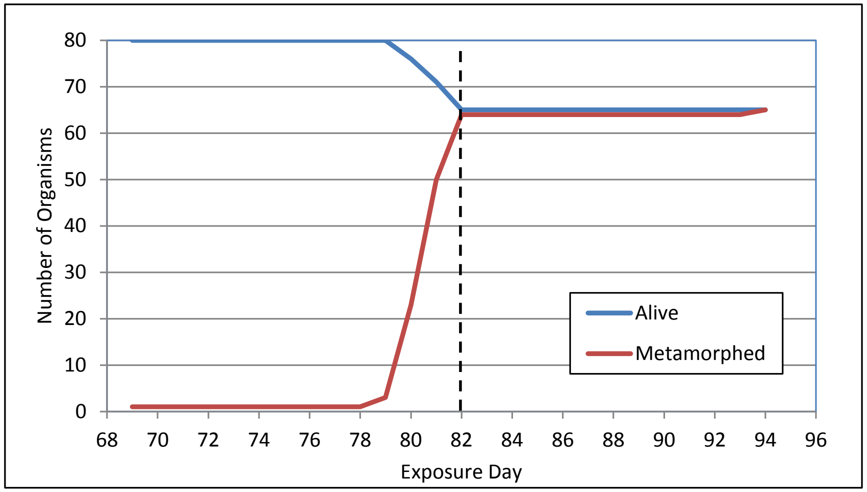
Panel B: Based on RBP Score



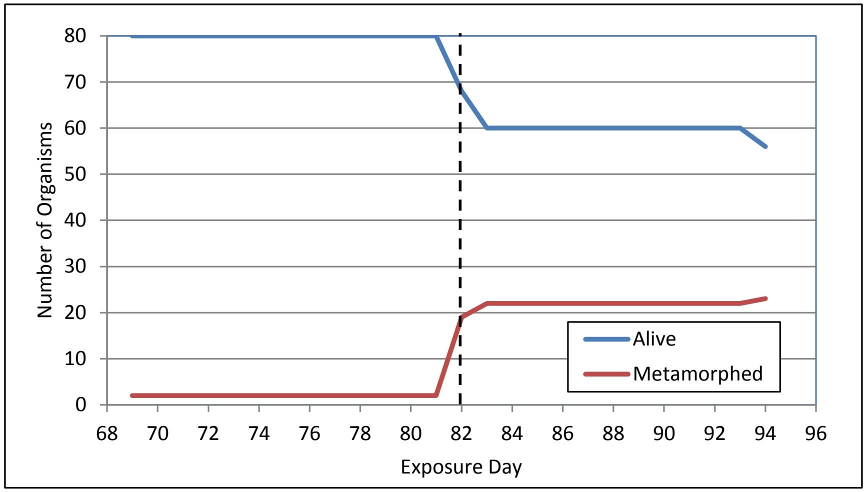
Data source: Parametrix 2009d, 2010

Figure 6-1. Survival and Metamorphosis in Exposed Organisms

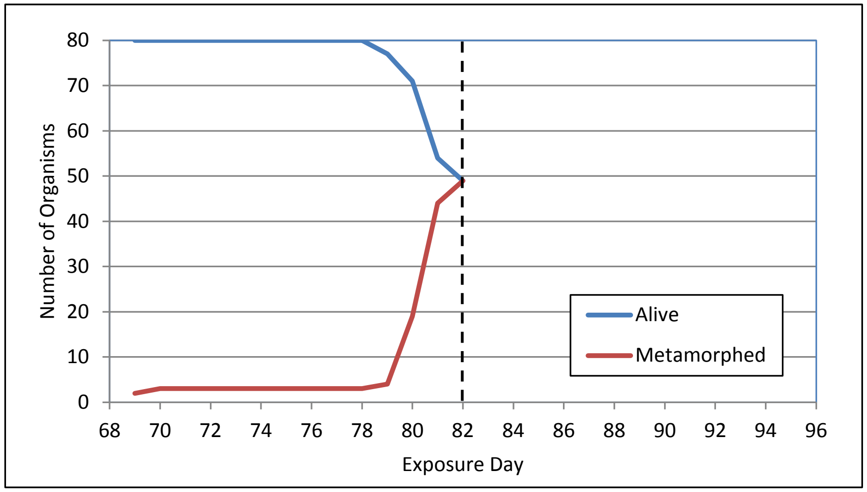
Panel A: Treatment 1 (Control Sediment)



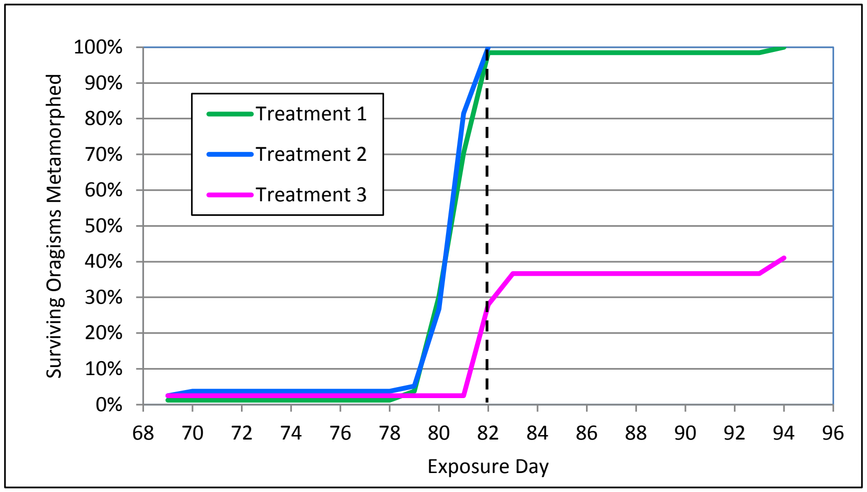
Panel C: Treatment 3 (Carney Creek Sediment)



Panel B: Treatment 2 (Reference Sediment)



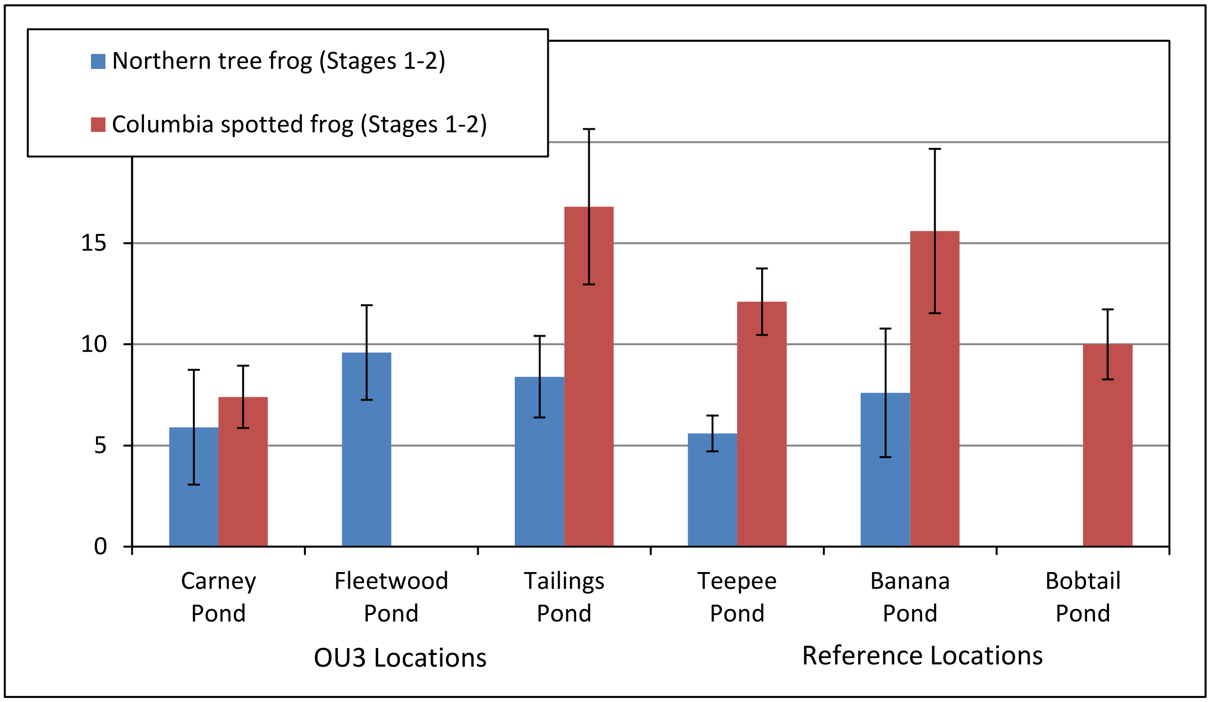
Panel D: Percent of Survivors Metamorphed



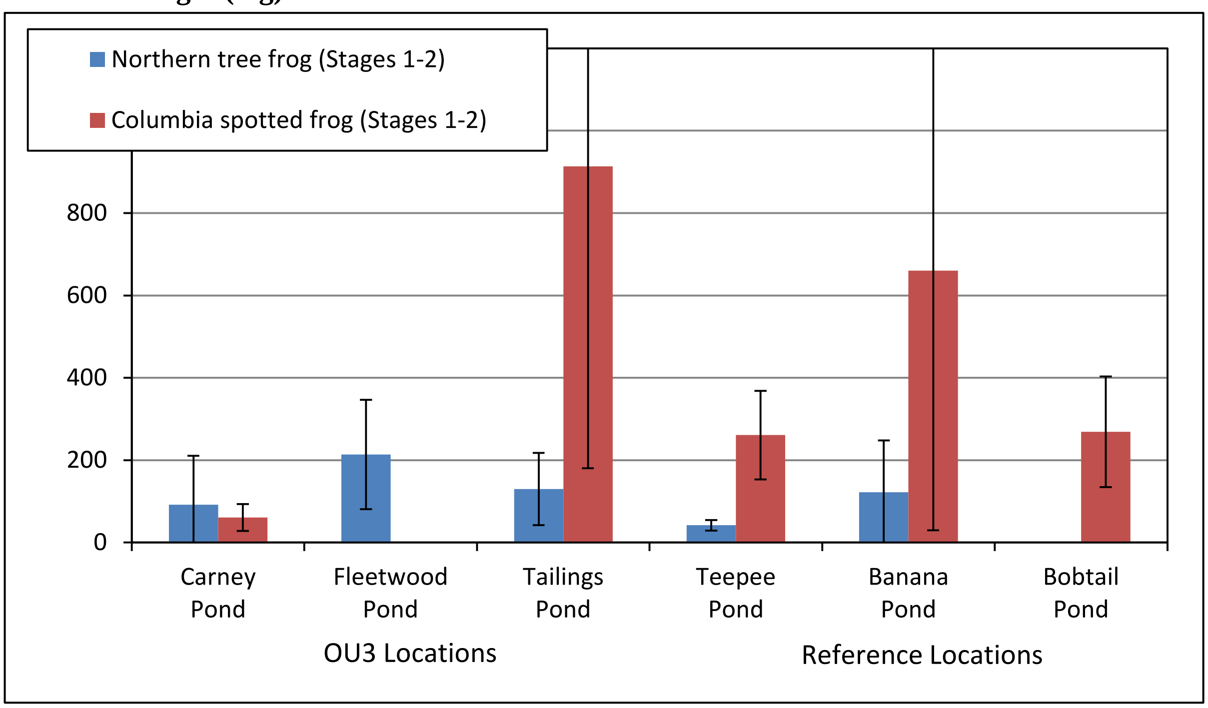
Data source: FEL 2013

Figure 6-2. Size and Weight of Pre-Metamorphic Amphibians
Field Stages 1-2

Panel A: SVL (mm)



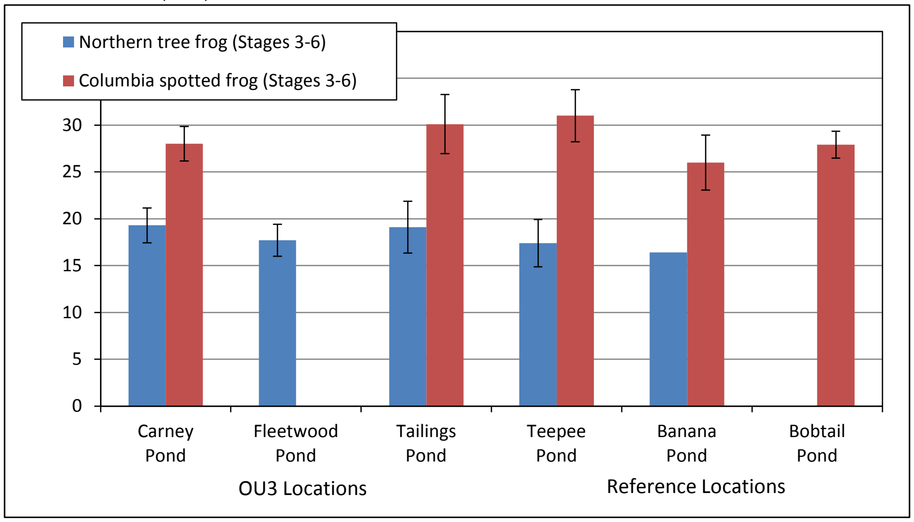
Panel B: Weight (mg)



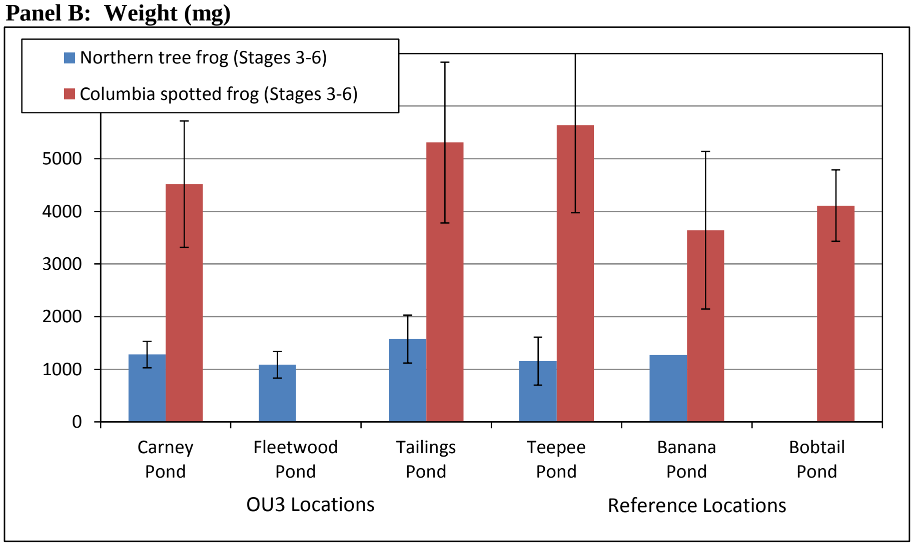
Data Source: FEL 2013
Error bars indicate standard deviations

Figure 6-3. Size and Weight of Proto-Metamorphic Amphibians Field Stages 3-6

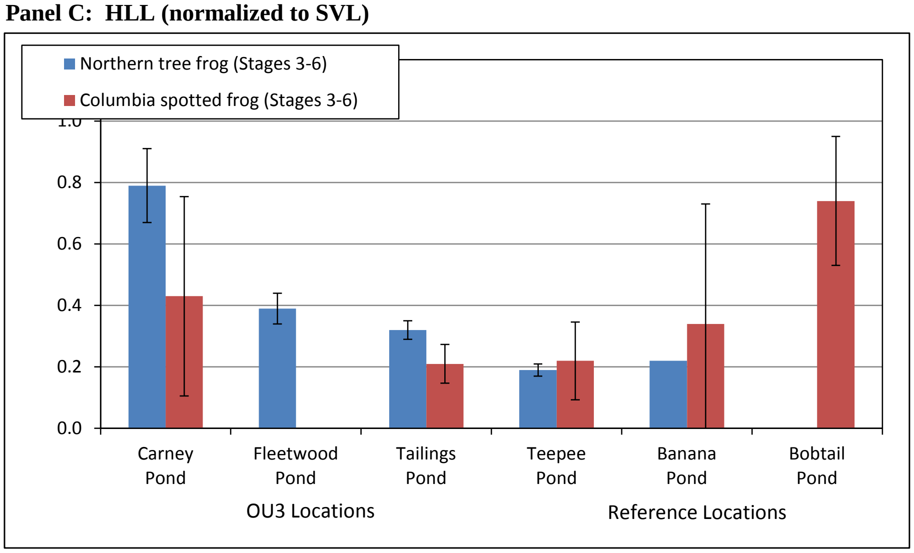
Panel A: SVL (mm)



Panel B: Weight (mg)



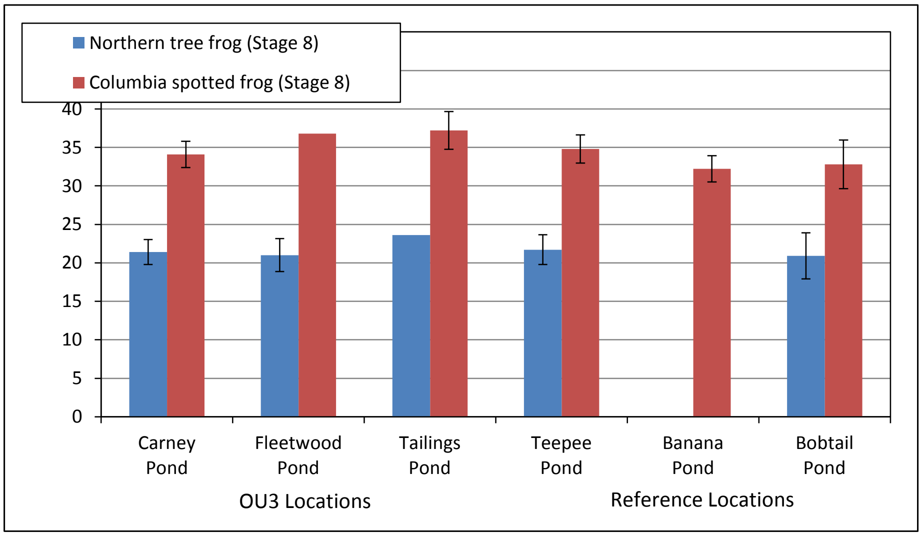
Panel C: HLL (normalized to SVL)



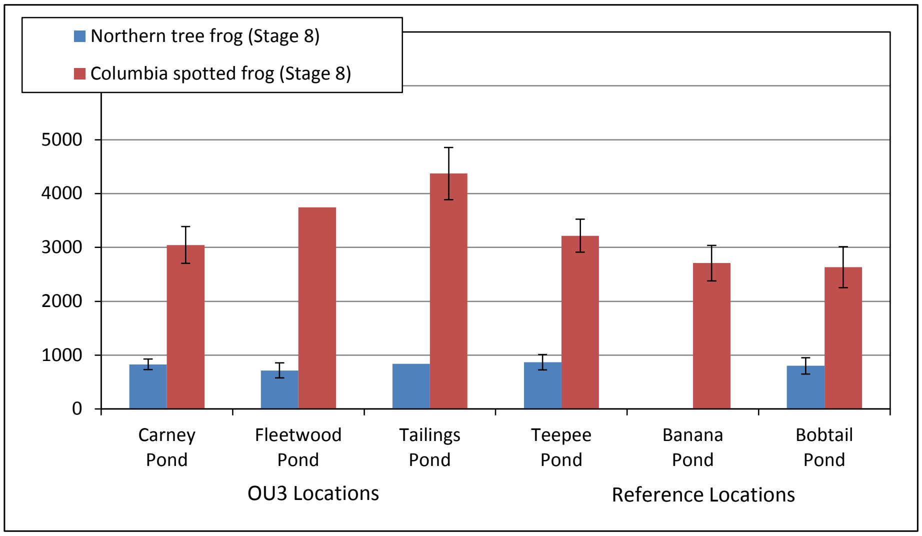
Data Source: FEL 2013
Error bars indicate standard deviations

Figure 6-4. Size and Weight of Metamorphosed Amphibians
Field Stage 8

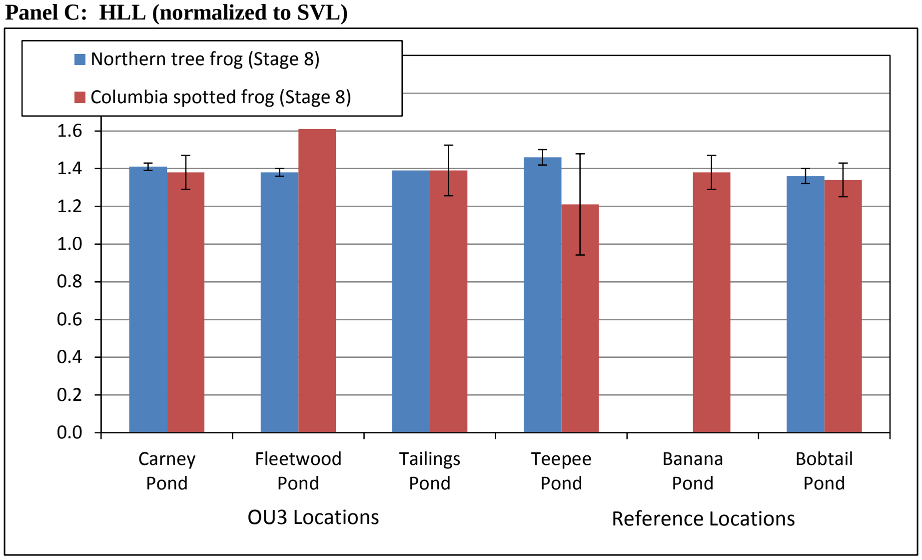
Panel A: SVL (mm)



Panel B: Weight (mg)



Panel C: HLL (normalized to SVL)



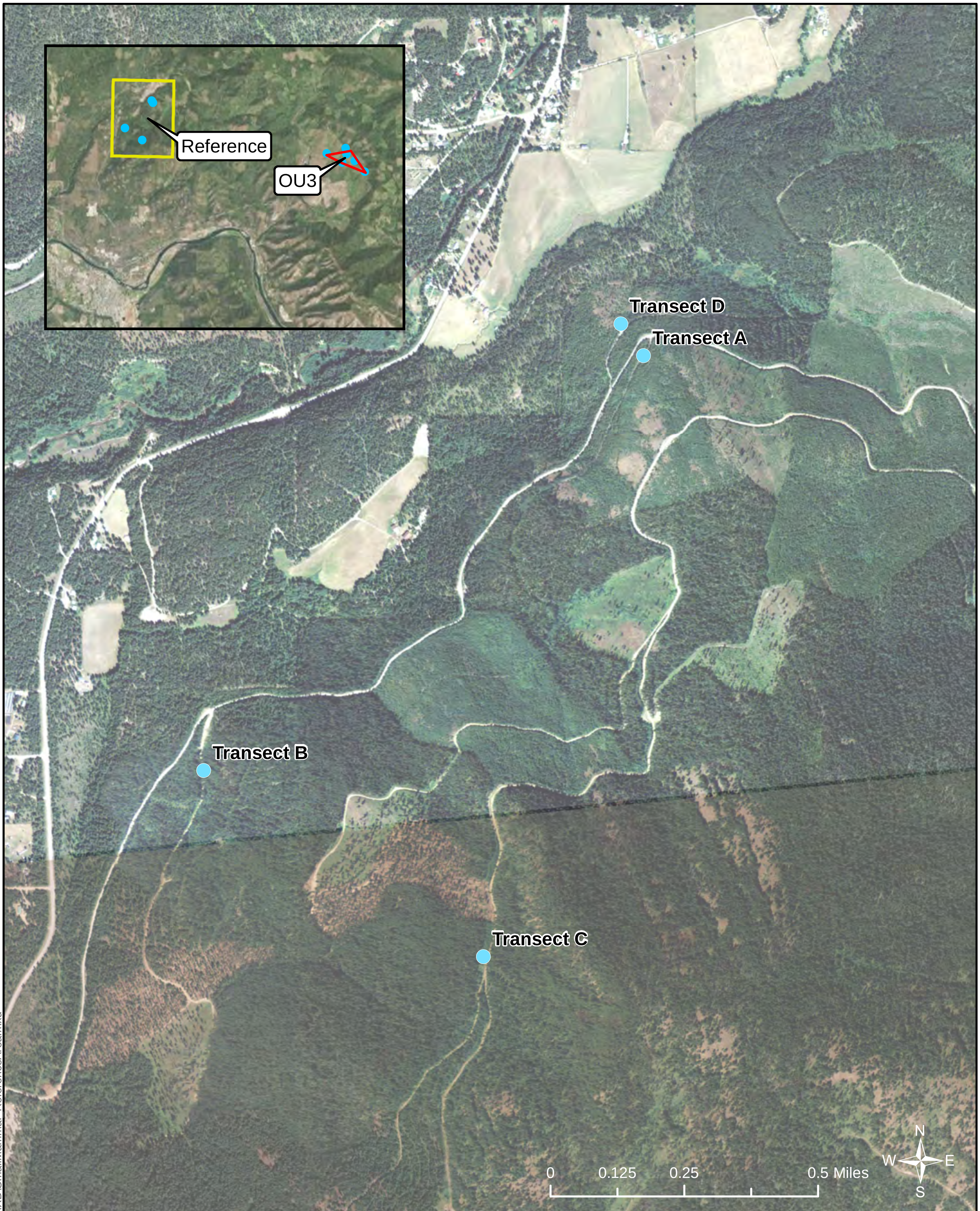
Data Source: FEL 2013
Error bars indicate standard deviations

Transect Location
Target Collection Area
Measured Duff LA Concentration
(million structures per gram)

Date Saved: 10/29/2014 4:27:58 PM

Figure 7-1
Small Mammal Transect
Location for OU3

Path: R:\85158-OU3\BERA\MXD\SmallMammalTransect_OU3.mxd



Transect Location

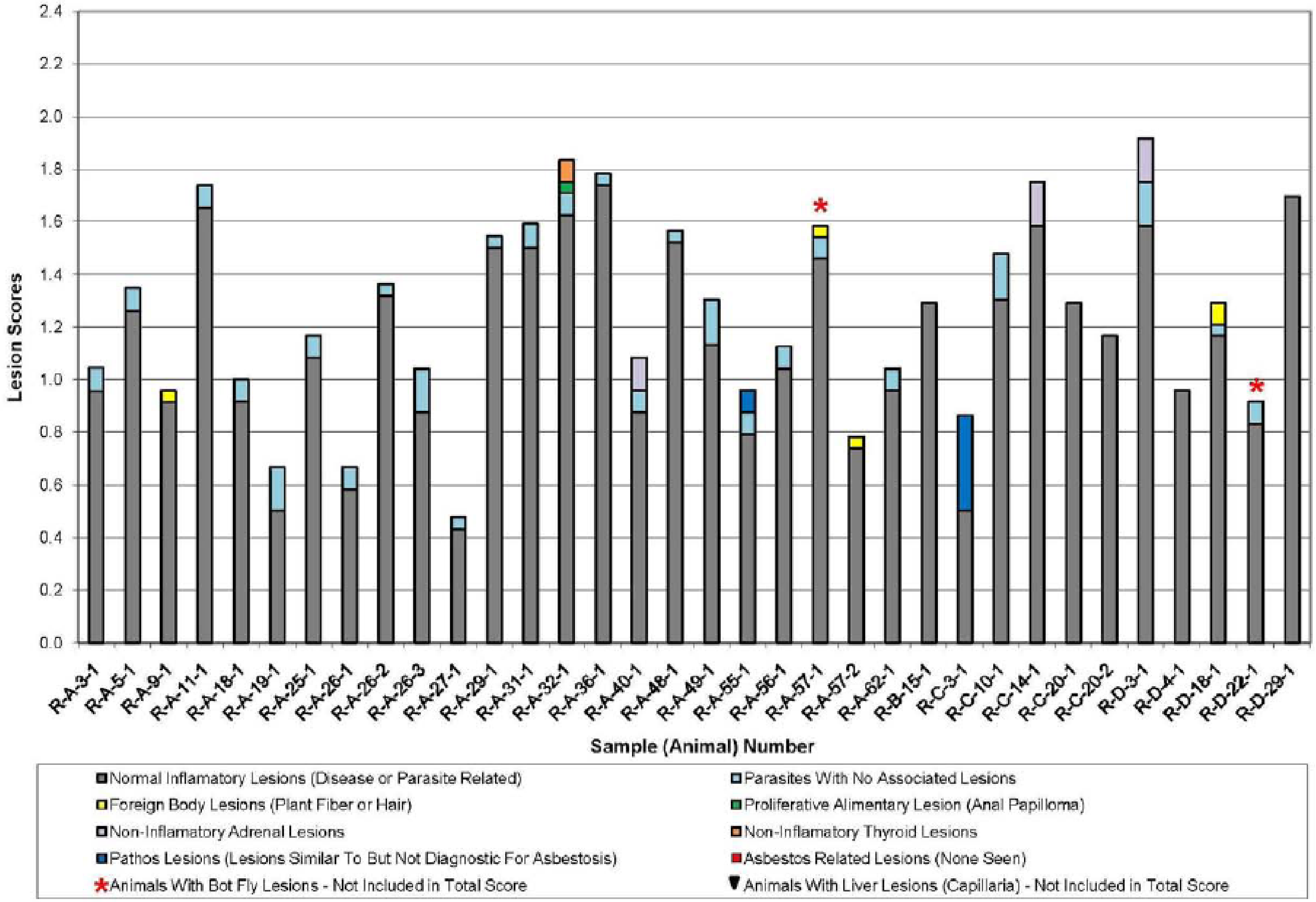
Figure 7-2
Small Mammal Transect Locations
for the Reference Area

Date Saved: 10/31/2014 7:31:20 AM

Path: R:\85158-OU3\BERA\MXD\SmallMammal_ReferenceArea.mxd

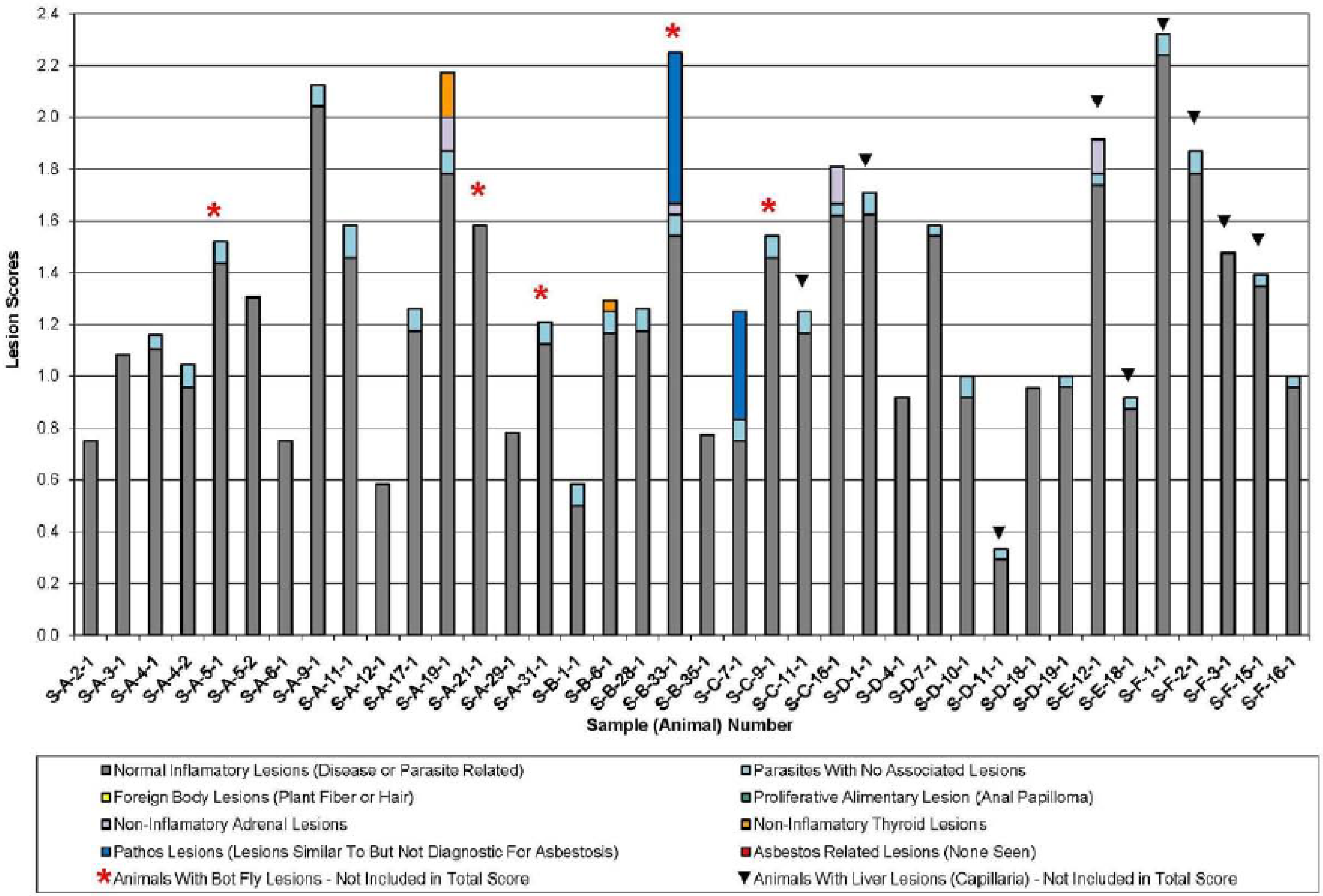
Figure 7-3. Histology Scores for Deer Mice

Panel A: Scores for Animals from Reference Trapping Area



Data Source: Golder 2010

Panel B: Scores for Animals from On-Site Trapping Area



Data Source: Golder 2010

Table 2-1
Summary Statistics for LA in Mine Waste

Sample Type	Count of PLM Bins			
	A	B1	B2	C
Coarse tailings	0	0	3	1
Cover soil	1	1	5	1
Outcrop	0	1	6	1
Road material	0	1	2	0
Waste rock	0	0	9	4
Total	1	3	27	7

Data source: CDM Smith 2013a

Table 2-2
Summary Statistics for LA in Ambient Air

Station ID	No. of Samples	No. of Detects	Mean Conc. (f/cc)
A-1	4	0	0.0000
A-2	4	0	0.0000
A-3	4	0	0.0000
A-4	12	0	0.0000
A-5	13	4	0.0005
A-6	12	1	0.0000
A-7	4	0	0.0000
A-8	12	0	0.0000
A-9	8	4	0.0013
A-10	8	0	0.0000
A-11	8	2	0.0006
A-12	8	0	0.0000
Combined	97	11	0.0002

Data source: CDM Smith 2013a

Table 2-3
Summary Statistics for LA in Surface Water

Location	Stations	N	Detects	LA Conc. (MFL)		
				Mean	Stdev	Max
Upper Rainy Creek	URC-1	3	0	0.0	0.0	--
	URC-1A	13	4	0.0	0.0	0.1
	URC-2	26	15	6.1	25.4	130.0
Lower Rainy Creek	TP-OVERFLOW	7	7	2.7	2.6	6.6
	TP-TOE1	14	9	3.6	7.0	25.0
	TP-TOE2	3	2	0.7	1.1	2.0
	LRC-1	14	13	8.5	10.8	31.0
	LRC-2	55	54	14.0	15.7	66.0
	LRC-3	3	3	3.2	4.2	8.0
	LRC-4	22	22	20.7	15.4	58.0
	LRC-5	22	22	25.4	18.1	59.0
	LRC-6	50	48	43.8	73.1	420.0
Carney Creek	CC-1	3	2	0.9	0.9	1.7
	CC-2	33	31	34.5	62.3	270.0
	CC-POND	24	23	14.8	13.6	45.0
Fleetwood Creek	FC-1	3	2	1.3	2.2	3.9
	FC-2	14	12	3.4	5.5	20.0
	FC-Pond	23	23	81.2	224.9	1100.0
Tailings Pond	TP	50	46	61.7	173.1	1200.0
	UTP	4	4	14.6	11.1	27.0
Mill Pond	MP	32	27	7.7	11.6	52.0
Kootenai River	KR, Upstream	11	3	0.1	0.2	0.7
	KR, Downstream	56	13	0.1	0.2	1.3
Reference Creeks	BTT-R1	1	0	0.0	--	--
	NSY-R1	13	1	0.0	0.0	0.1
Reference Ponds	Banana Lake	2	1	0.0	0.1	0.1
	Tepee Pond 1	2	0	0.0	0.0	--
	Bobtail Pond	2	0	0.0	0.0	--

Data source: CDM Smith 2013a

Table 2-4
Summary Statistics for LA in Sediment

Location	Stations	Count of PLM Bins			
		A	B1	B2	C
Upper Rainy Creek	URC-1	3	0	0	0
	URC-1A	2	1	0	0
	URC-2	0	3	1	0
Lower Rainy Creek	TP-TOE1	0	0	1	2
	TP-TOE2	0	0	0	20
	LRC-1	0	0	3	0
	LRC-2	0	1	2	1
	LRC-3	0	1	1	2
	LRC-4	0	1	2	0
	LRC-5	0	1	2	1
	LRC-6	0	0	3	0
Carney Creek	CC-1	0	0	1	19
	CC-2	0	1	2	0
	CC Pond	0	7	3	4
Fleetwood Creek	FC-1	1	2	0	0
	FC-2	0	4	0	0
	FC Pond	0	2	9	4
Tailings Pond	All	0	14	19	5
Mill Pond	All	0	7	3	4
Kootenai River	KR, Upstream	1	0	0	0
	KR, Downstream	1	4	2	0
Lake Koocanusa	LK-1	1	0	0	0
	LK-2	1	0	0	0
Reference Creeks	BTT-R1	1	0	0	0
	NSY-R1	1	0	0	0
Reference Ponds	Banana Lake	3	0	0	0
	Schrieber Lake	1	0	0	0
	Tepee Pond	4	0	0	0
	Bobtail Pond	4	0	0	0

Data source: CDM Smith 2013a

Table 2-5. Federal Species of Concern in the Kootenai National Forest

Category	Commin Name (*scientific name*)	Status	Range
Mammal	Grizzly Bear (*Ursus arctos horribilis*)	T	Alpine/subalpine coniferous forest of western Montana
	Canada Lynx (*Lynx canadensis*)	T	Montane spruce/fir forest of western Montana
	Wolverine (*Gulo gulo luscus*)	P	High elevation alpine and boreal forests that are cold and with snow lasting into late spring
Fish	White Sturgeon (*Acipenser transmontanus*)	E	Kootenai River
	Bull Trout (*Salvelinus confluentus*)	T, CH	Cold water streams, rivers, lakes; Kootenai River
Plant	Spalding's Campion (*Silene spaldingii*)	T	Open grassland of Flathead and Fisher River drainages
	Whitebark Pine (*Pinus albicaulis*)	C	High elevation upper montaine habitat near treeline in cetral and western Montana

Source: USFWS (2014)

T = Threatened
E = Endangered
P = Proposed
CH = Critical habitat
C = Candidate

Table 2-6. State Species of Concern Occuring In or Near OU3

Group	Common Name	Scientific name	State Rank	Habitat
Mammal	Wolverine	*Gulo gulo*	S3	Boreal Forest and Alpine Habitats
	Hoary Bat	*Lasiurus cinereus*	S3	Riparian and forest
	Canada Lynx	*Lynx canadensis*	S3	Subalpine conifer forest
	Fisher	*Martes pennanti*	S3	Mixed conifer forests
Bird	Northern Goshawk	*Accipiter gentilis*	S3	Mixed conifer forests
	Pileated Woodpecker	*Dryocopus pileatus*	S3	Moist conifer forests
	Cassin's Finch	*Haemorhous cassinii*	S3	Drier conifer forest
	Clark's Nutcracker	*Nucifraga columbiana*	S3	Conifer forest
	Flammulated Owl	*Psiloscops flammeolus*	S3B	Dry conifer forest
	Pacific Wren	*Troglodytes pacificus*	S3	Moist conifer forests
Amphibian	Western Toad	*Anaxyrus boreas*	S2	Wetlands, floodplain pools
	Coeur d'Alene Salamander	*Plethodon idahoensis*	S2	Spring / seep, waterfall, fractured rock
Fish	Torrent Sculpin	*Cottus rhotheus*	S3	Mountain streams, rivers, lakes
	Westslope Cutthroat Trout	*Oncorhynchus clarkii lewisi*	S2	Mountain streams, rivers, lakes
	Bull Trout	*Salvelinus confluentus*	S2	Mountain streams, rivers, lakes

S1 = At high risk because of extremely limited and potentially declining numbers, extent and/or habitat, making it highly vulnerable to global extinction or extirpation in the state.

S2 = At risk because of very limited and potentially declining numbers, extent and/or habitat, making it vulnerable to global extinction or extirpation in the state.

S3 = Potentially at risk because of limited and potentially declining numbers, extent and/or habitat, even though it may be abundant in some areas.

Source MNHP (2014)
Township = 31N, Range = 30W

Table 4-1. 2013 Eyed Egg Survival Data

	LRC-2		LRC-4		LRC-5		URC-2			NSY			Negative Control		
Parameter	1	2	1	2	1	2	1	2	3	1	2	3	1	2	3
Starting eggs	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
Dead eggs	8	9	6	9	14	12	12	6	6	3	13	6	7	9	7
Dead alevins	2	0	3	5	2	3	4	2	3	3	0	0	2	1	2
Alive alevins (last day)	20	21	21	16	14	15	13	22	21	24	17	24	21	20	21
Extra alevins	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Missing/lost egg	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Missing alevins	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Missing (total)	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0

Data Source: Golder 2014b

Table 4-2. 2013 Eyed Egg Study Statistical Comparisons

Endpoint	Group	Mean	Stat Comp	FET	t-test
Hatching Success	LRC	68%	LRC vs Ref	0.106	0.182
	Ref	74%	LRC vs NC	0.162	0.091
	NC	74%	Ref vs NC	0.566	0.485
Alevin Survival	LRC	88%	LRC vs Ref	0.259	0.263
	Ref	91%	LRC vs NC	0.219	0.098
	NC	93%	Ref vs NC	0.472	0.322
Overall Survival	LRC	59%	LRC vs Ref	0.067	0.146
	Ref	68%	LRC vs NC	0.083	0.041
	NC	69%	Ref vs NC	0.472	0.409

FET = One-tailed Fisher Exact Test
t-test = One-tailed t-test
[pink] statistically significant ($p \leq 0.05$)
[yellow] marginally significant ($0.05 < p \leq 0.20$)

Data Source: Golder 2014b

Table 4-3. Abnormal Swimming Behavior in 2013 Study

Station	Box	N Observed	N Abnormal	Freq	Codes
LRC-2	RD	20	3	15%	C2, O4, O4
	YL	21	1	5%	C5
LRC4	RD	21	1	5%	C4/5, F4
	YL	16	1	6%	F4
LRC5	RD	13	1	8%	O5
	YL	15	2	13%	O4, O4
URC2	GN	21	1	5%	F4
	RD	13	0	0%	
	YL	22	0	0%	
NSY	GN	24	2	8%	F4, O3/F4
	RD	24	0	0%	
	YL	17	2	12%	C5, C2/5
NC	1	21	5	24%	C2/C5, O4, O1, F1/F5, C5
	2	20	8	40%	F5, C5, C2/C3/C5, F1, f1, C4, F1, F4
	3	21	4	19%	O5, F4, C5, C1
LRC	All	106	9	8%	
Reference	All	121	5	4%	
NC	All	62	17	27%	

FET Comaprisons	LRC vs Ref	0.139	LRC marginally higher than Ref ($0.05 < p \leq 0.20$)
	LRC vs NC	1.000	LRC lower than NC
	NC vs Ref	0.000	NC significantly higher than Ref ($p \leq 0.05$)

CODES

O = Occasional	1 = Erratic swimming (e.g., swimming into walls)
F - Frequent	2 = Inability to swim in a straight line
C = Continuous	3 = Floating on side, not moving
	4 = Loss of equilibrium, difficulty maintaining orientation
	5 = Other abnormal swimming patterns

Data Source: Golder 2014b

Table 4-4. 2013 Alevin External Lesion Frequency Data

Panel A: Lesion Frequency by Fish

Station	Fish Examined	No lesions	1 or more lesions	% with any lesion	Total lesions	Avg. Lesions/Fish (a)	Avg. Lesions/Fish (b)
LRC-2	43	38	5	12%	9	0.21	1.8
LRC-4	45	29	16	36%	25	0.56	1.6
LRC-5	34	21	13	38%	34	1.00	2.6
URC-2	64	54	10	16%	23	0.36	2.3
NSY	68	52	16	24%	34	0.50	2.1
LRC	122	88	34	28%	68	0.56	2.0
Ref	132	106	26	20%	57	0.43	2.2
NC	67	51	16	24%	29	0.43	1.8
FET p value	LRC vs Ref		0.083				
	LRC vs NC		0.339				

(a) Mean based on all fish
(b) Mean based on fish with one or more lesions

Panel B: Lesion Frequency by Tissue

Station	Total Fish Examined	Number of Fish with One or More Lesions: Yolk sack	Mouth exterior	Mouth interior	Lateral line	Dorsal fin	Adipose fin	Pectoral fin	Pelvic fin	Anal fin	Caudal fin	Skin	Gills	Body form
LRC-2	43	1	0	0	0	0	0	0	0	0	1	1	0	2
LRC-4	45	7	0	1	0	0	0	0	0	0	5	0	0	4
LRC-5	34	3	0	0	0	1	1	1	1	0	6	2	0	7
URC-2	64	7	0	0	0	0	0	0	0	0	0	0	0	4
NSY	68	0	1	0	0	0	0	0	0	0	2	0	0	15
LRC	122	11	0	1	0	1	1	1	1	0	12	3	0	13
Ref	132	7	1	0	0	0	0	0	0	0	2	0	0	19
NC	67	4	0	0	0	0	0	0	0	1	10	0	0	4
FET p value: LRC vs Ref		0.182	1.000	0.480	1.000	0.480	0.480	0.480	0.480	1.000	0.003	0.109	1.000	0.861
FET p value: LRC vs NC		0.330	1.000	0.646	1.000	0.646	0.646	0.646	0.646	1.000	0.898	0.267	1.000	0.211

FET = One-tailed Fisher Exact test

[pink] Significantly higher than comparison ($p \le 0.05$)

[yellow] Marginally higher than comparison ($0.05 < p \le 0.20$)

Data Source: Golder 2014b

Table 4-5 Description of Lesions Observed in Alevins

Tissue	Station	Lesion Description
Yolk Sack	LRC2	oblong, dorsal linear groove, white plaque
	LRC4	resorbed, pitting at side of yolk sack
	LRC4	partial yolk sac depletion
	LRC4	resorbed, pitted
	LRC4	resorbed, pitting
	LRC4	white plaque, adhered foreign material
	LRC4	irregular, slightly oblong, white plaque
	LRC4	irregular, oblong, white plaque, adhered foreign material
	LRC5	minimal
	LRC5	adhered foreign material
	LRC5	irregular, adhered foreign material
	URC2	partial yolk sack, mushy
	URC2	pitted yolk sack
	URC2	pitted yolk sack
	URC2	irregular, elongated
	URC2	elongated, slightly flattened, plaque
	URC2	ovoid, irregular, multiple plaques
	URC2	elongated, partially macerated
	NC1	irregular, elongated, plaque
	NC1	elongated, irregular, plaque, partial maceration
	NC3	ovoid, flat surface, plaque
	NC3	elongated, irregular, plaque, partially macerated
Tail Fin	LRC2	atrophied tail and tail fin
	LRC4	crimped tail
	LRC4	notched tail fin
	LRC4	notched tail fin
	LRC4	crimped tail
	LRC4	notched tail fin
	LRC5	notched tail fin
	LRC5	2 tail fin notches
	LRC5	crimped tail
	LRC5	absent
	LRC5	deformity
	LRC5	notched tail fin
	NC1	frayed
	NC1	kinked tail
	NC1	no tail fin
	NC1	frayed
	NC1	frayed
	NC1	crimped tail
	NC2	crimped tail
	NC3	crimped tail
	NC3	notched tail fin
	NC3	notched tail fin
	NSY	frayed
	NSY	frayed

Tissue	Station	Lesion Description
Body Form	LRC2	scoliosis and lordosis
	LRC2	domed head
	LRC4	domed head, right proptosis
	LRC4	fully emerged
	LRC4	domed head
	LRC4	right microphthalmia
	LRC4	domed head
	LRC5	proximal half of carcass macerated
	LRC5	scoliosis, flattened head, crimped tail
	LRC5	scoliosis, eye asymetry, flattened skull
	LRC5	flattened asymmetrical head, left eye proptosis
	LRC5	scoliosis
	LRC5	cavitation of yolk sack attachment
	LRC5	tail deformity
	URC2	partially macerated (no head)
	URC2	intra coelomic red mass
	URC2	right proptosis
	NSY	autolyzed
	NSY	right micro with possible choristoma, left proptosis, maxillary deformity
	NSY	lordosis, scoliosis, kyphosis
	NSY	mid body crimp, mushy
	NSY	kyphosis, domed head
	NSY	kyphosis, domed head
	NSY	partially flattened head, left proptosis
	NSY	kyphosis, domed head
	NSY	lordosis, carcass "c" shaped
	NSY	broad head
	NSY	carcass "c" shaped
	NSY	left proptosis
	NSY	coiled body
	NSY	domed head
	NC1	kyphosis
	NC2	yolk sack vesicle, tail adhered
	NC2	kyphosis
	NC3	left microphthalmia
Skin	LRC2	focal white plaque, right flank
	LRC5	symetrical palor
	LRC5	difuse right, multifocal left palor

Data Source: Golder 2014b

Table 4-6 Juvenile Trout Survival Data

Station	Cage	N	Dead
LRC-2	1	15	0
	2	15	0
LRC-4	1	15	0
	2	15	0
LRC-5	1	15	0
	2	15	0
URC-2	1	15	2
	2	15	0
	3	15	0
NSY	1	15	1
	2	15	1
	3	15	2
LRC	All	90	0
Reference	All	90	6

Data Source: Golder 2013

Table 4-7. External Lesion Scoring System for Caged Juvenile Trout

Frayed Fins		Notched Fins		Mouth Lesions		Gill Lesions		Lateral Line Plaques	
Score	Description	Score	Description	Score	Description	Score	Description	Score	Description
0	None	0	None	0	None	0	None	0	None
1	Mild	1	1 notch	1	Mild, 1 jaw	1	Focal, one side	1	Focal, one side
2	Moderate	2	2 notches	2	Mild, both jaws	2	Focal both sides or multifocal one side	2	Focal both sides or multifocal one side
3	Marked	3	3 notches	3	Moderate; both jaws, half way to orbit	3	Focal one side, multifocal other side	3	Focal one side, multifocal other side
4	Severe	4	4 notches	4	Marked; both jaws, to orbit	4	Multifocal both sides	4	Multifocal both sides
				5	Severe; both jaws, past orbit				

Data Source: Golder 2013

Table 4-8. Juvenile Trout External Lesion Data

Panel A: Lesion Frequency (Notching, Fraying)

Reach	Mouth (maxillary)	Mouth (mandib.)	Mouth (interior)	Lateral Line	Dorsal Fin	Adipose Fin	Pectoral Fin	Pelvic Fin	Anal Fin	Tail Fin	Skin	Gills
Reference	88/89	87/89	0/89	11/89	30/89	0/89	28/89	0/89	1/89	88/89	0/89	7/89
LRC	90/90	81/90	0/90	1/90	84/90	0/90	80/90	1/90	0/90	84/90	0/90	2/90
FET p	0.497	0.995	1.000	1.000	0.000	1.000	0.000	0.503	1.000	0.993	1.000	0.984

Panel B: Mean Lesion Severity (a)

Reach	Mouth (maxillary)	Mouth (mandib.)	Mouth (interior)	Lateral Line	Dorsal Fin	Adipose Fin	Pectoral Fin	Pelvic Fin	Anal Fin	Tail Fin	Skin	Gills
Reference	1.08	1.08	--	1.36	1.20	--	1.21	--	1.00	2.98	--	1.57
LRC	1.00	1.00	--	1.00	1.63	--	1.24	1.00	--	3.25	--	1.00
WRS p	0.996	0.995	--	0.697	0.001	--	0.461	--	--	0.240	--	0.718

(a) Mean score for fish with lesions

Statistically higher than comparison ($p \leq 0.05$) [highlighted: Panel A Dorsal Fin and Pectoral Fin FET p; Panel B Dorsal Fin WRS p]

Data Source: Golder 2013

Table 4-9
Number of Fish Captured by Electroshocking

Year	Station	Number of Fish	
		≤ 65 mm	> 65 mm
2008	BTT-R1	5	22
	NSY-R1	26	69
	URC-1A	26	17
	URC-2	23	17
	TP-TOE2	0	15
	LRC-1	0	5
	LRC-2	0	11
	LRC-3	0	9
	LRC-5	0	8
2009	BTT-R1	10	48
	NSY-R1	19	54
	URC-1A	29	40
	URC-2	46	45
	TP-TOE2	11	22
	LRC-1	0	13
	LRC-2	0	18
	LRC-3	0	10
	LRC-5	0	15

Data Source: Parametrix 2009d, 2010

Table 4-10. Fish Species Captured by Electroshocking

Station	Brook		Cutbow		Cutthroat		Rainbow	
	2008	2009	2008	2009	2008	2009	2008	2009
BTT-R1	10	30		1			12	13
NSY-R1			59	35		14	1	
URC-1A			17	5		25		
URC-2			17			37		
TP-TOE2			13			1	1	19
LRC-1				1			5	12
LRC-2				1		1	11	14
LRC-3							9	10
LRC-5			1			14	7	1

Data Source: Parametrix 2009d, 2010

Table 4-11. Barriers to Fish Movement in Rainy Creek

Structure	Location (downstream to upstream)	Structure Type	Potential Barrier
1	At Highway 36	Waterfall	Yes
2	At LRC-6	Weir	Yes
3	Between LRC-5 and LRC-6	Waterfall	Yes
4	Between LRC-5 and LRC-6	Waterfall	Yes
5,6	Between LRC-5 and LRC-6	Culvert	Absolute
7	Between LRC-5 and LRC-6	Waterfall	Yes
8	Between LRC-5 and LRC-6	Waterfall	Yes
9	Between LRC-5 and LRC-6	Cascade	Yes
10	Above LRC-3, at Rainy Creek Road	Culvert	No
11	Just below LRC-2	Culvert	No
12	Upstream of LRC-2	Culvert	No
13	Carney Creek confluence with Rainy Creek	Culvert	Yes
14	Upstream of LRC-1	Culvert	No
15	Upstream of TPTOE2	Culvert	No
16	Base of Tailing impoundment	Dam	Absolute
17	Near URC-2	Culvert	Yes

Data Source: Parametrix 2010

Table 4-12. Resident Trout Captured and Evaluated

Group	Location	Size Class					
		< 65 mm		65-100 mm		Total	
		Number Collected	Number Evaluated	Number Collected	Number Evaluated	Number Collected	Number Evaluated
Site	TP-TOE2	6	6	3	2	9	8
	LRC-2	3	2	10	7	13	9
	LRC-3	2	2	1	1	3	3
	LRC-4	0	0	0	0	0	0
	LRC-5	0	0	0	0	0	0
	Total	11	10	14	10	25	20
Reference	URC-2	6	5	11	10	17	15
	URC-1A	4	3	2	2	6	5
	NSY-R1	9	7	14	13	23	20
	Total	19	15	27	25	46	40

Data Source: Golder 2014a

Table 4-13. Resident Trout External Lesion Data

Panel A: Frequency of External Lesions

Reach	Head	Dosal Fin	Adipose Fin	Pectoral Fin	Pelvic Fin	Anal Fin	Tail Fin	Skin	Gills
URC	0/20	4/20	0/20	1/20	6/20	4/20	12/20	2/20	1/20
NSY	0/20	7/20	0/20	3/20	3/20	2/20	12/20	3/20	3/20
LRC	0/12	1/12	0/12	0/12	1/12	0/12	0/12	0/12	3/12
TPTOE	0/8	2/8	0/8	1/8	0/8	0/8	2/8	4/8	0/8
Ref	0/40	11/40	0/40	4/40	9/40	6/40	24/40	5/40	4/40
Site	0/20	3/20	0/20	1/20	1/20	0/20	2/20	4/20	3/20
FET p value	1.00	0.92	1.00	0.88	0.99	1.00	1.00	0.34	0.43

Panel B: Mean Severity of External Lesions (a)

Reach	Head	Dosal Fin	Adipose Fin	Pectoral Fin	Pelvic Fin	Anal Fin	Tail Fin	Skin	Gills
URC	--	2.00	--	1.00	1.00	1.00	1.25	1.00	1.00
NSY	--	1.14	--	1.00	2.00	1.00	1.58	1.00	1.00
LRC	--	1.00	--	--	1.00	--	--	--	1.00
TPTOE	--	1.00	--	1.00	--	--	1.50	1.00	--
Ref	--	1.45	--	1.00	1.33	1.00	1.42	1.00	1.00
Site	--	1.00	--	1.00	1.00	--	1.50	1.00	1.00
WRS p value	--	0.80	--	0.50	0.60	--	0.37	0.50	0.50

(a) Mean score for fish with lesions

Data Source: Golder 2014a

Table 4-14. Resident Trout Histological Lesion Data

Panel A: Frequency of Histological Lesions

Reach	nose	dorsal head skin	lateral head skin	opercula head skin	cranial line	cornea	brain	gills	oral mucosa	nasal mucosa	lateral trunk skin	dorsal trunk skin	ventral trunk skin	lateral line	fins	skeletal muscle
URC	1/5	4/5	5/5	5/5	5/5	2/5	5/5	5/5	5/5	3/3	5/5	2/5	2/5	3/5	5/5	4/5
NSY	0/5	5/5	5/5	5/5	5/5	4/5	5/5	5/5	5/5	4/4	5/5	5/5	5/5	5/5	5/5	3/5
LRC	0/4	2/4	4/4	3/4	4/4	1/4	4/4	4/4	4/4	4/4	4/4	4/4	1/4	4/4	4/4	4/4
TPTOE	0/4	2/4	4/4	4/4	4/4	4/4	4/4	4/4	4/4	4/4	3/4	0/4	0/4	1/4	4/4	4/4
Ref	1/10	9/10	10/10	10/10	10/10	6/10	10/10	10/10	10/10	7/7	10/10	7/10	7/10	8/10	10/10	7/10
Site	0/8	4/8	8/8	7/8	8/8	5/8	8/8	8/8	8/8	8/8	7/8	4/8	1/8	5/8	8/8	8/8
FET p value	1.00	0.99	1.00	1.00	1.00	0.65	1.00	1.00	1.00	1.00	1.00	0.91	1.00	0.91	1.00	0.15

Panel B: Severity of Histological Lesions (a)

Reach	nose	dorsal head skin	lateral head skin	opercula head skin	cranial line	cornea	brain	gills	oral mucosa	nasal mucosa	lateral trunk skin	dorsal trunk skin	ventral trunk skin	lateral line	fins	skeletal muscle
URC	1.00	4.00	3.80	3.60	6.00	1.50	2.60	10.40	1.80	4.00	2.40	1.50	1.50	3.67	1.80	2.00
NSY	--	4.00	4.00	4.20	6.60	2.50	2.80	8.00	1.80	4.00	5.40	5.20	5.20	3.20	2.20	3.00
LRC	--	3.50	2.50	3.00	5.25	4.00	4.25	6.50	1.00	3.75	3.50	3.50	5.00	2.75	2.00	2.75
TPTOE	--	4.00	3.75	3.75	4.00	1.75	2.50	4.00	1.00	2.75	2.00	--	--	2.00	1.50	2.75
Ref	1.00	4.00	3.90	3.90	6.30	2.17	2.70	9.20	1.80	4.00	3.90	4.14	4.14	3.38	2.00	2.43
Site	--	3.75	3.13	3.43	4.63	2.20	3.38	5.25	1.00	3.25	2.86	3.50	5.00	2.60	1.75	2.75
WRS p value	--	0.73	0.91	0.84	0.97	0.50	0.17	0.99	0.99	0.85	0.78	0.61	0.42	0.79	0.56	0.32

(a) Mean severity score in fish with lesions

[yellow] Marginally higher than comparison (0.05 < p ≤ 0.20)

Data Source: Golder 2014a

Table 4-15 Weight of Evidence Summary for Fish

Study Type	Exposure Pathway(s)	Endpoint	Was a Difference Observed?	Is the Difference Attributable to LA ?	Is the Difference Judged to be Ecologically Significant ?	Conclusion	Confidence and Limitations
In situ tests of toxicity on trout eggs and alevins	Direct contact with water	Hatching success, alevin survival, overall survival	Yes. Marginally significant ($0.05<p\leq0.20$) decrease in hatching success and overall survival were observed in LRC compared to reference	No. Most of the difference was due to effects at one station (LRC-5), but LA concentrations were similar at LRC-2 and LRC-4.	No. The magnitude of the decrease was small (<10%). In fish, small decreases in survival of young generally do not result in important differences in number reaching adulthood.	Observed differences cannot be attributed to LA and are deemed too small to elicit population level effects.	Medium. The conclusion only applies to exposure concentrations that do not exceed those that occurred during the study (40-45 MFL). If higher exposures were to occur in other years, effects could occur, although the magnitude and potential significance cannot be estimated.
		Alevin length and weight at study termination	Yes. A few statistically significant ($p\leq0.05$) or marginally significant ($0.05<p\leq0.20$) differences were noted, but the statistical significance is due mainly to very small variance rather than to meaningful differences in size or weight.	No. Differences in water temperature and exposure duration likely account for the small differences.	No. Differences are minor for both weight (<7%) and length (<3%).		
		Prevalence of abnormal swimming in surviving alevins	Yes. Marginally significant ($0.05 < p < 0.20$) increase in prevalence of abnormal swimming occurred in fish from LRC compared to reference , but prevalence was lower than in negative controls.	No. Most abnormal swimming behaviors were attributed to abnormal body forms, which in turn were judged to be due to factors other than LA.	No. Only a small fraction of the fish exhibited abnormal swimming. While these individual fish would likely have decreased chances of survival, the population-level effect was determined to be small.		
		Prevalence and severity of external lesions in alevins	Yes. Marginally significant ($0.05<p\leq0.20$) increase in prevalence of external lesions (mainly of caudal fin) occurred in fish from LRC compared to reference, but prevalence was lower than in negative controls.	No. None of the lesions were characteristic of the effects of asbestos reported in literature studies of asbestos exposure on fish.	No. Most lesions were sufficiently mild that they would not be expected to reduce the chances of survival, growth and reproduction.		
In situ test of toxicity to caged juvenile trout	Direct contact with water, possibly ingestion of native prey species in the water column	Mortality	No. No deaths occurred in any fish exposed in LRC			Observed differences cannot be attributed to LA and are deemed too small to elicit population level effects.	Medium. The conclusion only applies to exposure concentrations that do not exceed those that occurred during the study (8-24 MFL). If higher exposures were to occur in other years, effects could occur, although the magnitude and significance cannot be estimated.
		Length and weight	Yes. Fish exposed in LRC grew faster and were larger than fish in the reference streams.	No. The difference in growth is attributable to warmer water temperature in LRC than reference streams			
		Swimming behavior	Yes. Significant differences were observed when data was organized by reach. When data were evaluated by station however, no significant differences were observed.	No. Exposure concentrations were higher at LRC-5 than LRC-4, while swimming abnormalities were lower at LRC-5 than LRC-4.	No. Effects were relatively infrequent and almost entirely transitory.		
		Lesion prevalence and severity	Yes. Increased frequency of dorsal and caudal fin lesions (notching, fraying) was observed in fish from LRC compared to reference.	No. Lesions were judged to be due to confined conditions in cage and/or aggression between fish	No. Minor fin lesions would not be expected to significantly impact swimming ability		
Population studies	All pathways, including direct contact with water and ingestion exposure (prey, sediment)	Population characteristics (density, size, biomass)	Yes. Population structure in LRC is different than reference streams, with decreased density, increased size, and decreased biomass.	No. Changes in population structure (both density and biomass) are likely largely attributable to differences in habitat.	No. While different than reference, the Site population appears to be stable and self-maintaining.	Observed differences in surveyed populations cannot be attributed to LA and are likely the result of habitat differences.	Medium. Population attributes vary substantially over time, but results were relatively consistent over two years.
Resident trout lesion study		Frequency and severity of external or histological lesions.	No. No statistically significant increases in frequency or severity of external or histological lesions.			The native population of trout in LRC does not appear to have lesions associated with asbestos exposure	High. An adequate number of fish were evaluated, and neither external nor histological examination provided an indication of asbestos related effects..

Table 5-1. Physical Characteristics of Site and Reference Sediments

Parameter	BTT-R1	NSY-R1	CC-1	TP-TOE2
Moisture (wt %)	41.2	24.8	26.8	37.4
Organic Carbon (wt %)	1.35	0.31	0.36	0.76
Total Solids (wt %)	58.5	75.2	73.2	62.6
pH	7.8	6.8	7.5	7.6
% Gravel	66	40	50	30
% Sand	15	52	43	64
% Silt	13	3	4	1
% Clay	5	5	4	5

Data Source: Parametrix 2009b, 2009c

Table 5-2. Concentration Data for Site-Specific Sediments

Analyte (a)	Units	BTT-R1	NSY-R1	CC-2	TP-TOE2
LA	mass %	ND	ND	5%	3%
Aluminum	mg/kg	8540	7350	10700	17600
Arsenic	mg/kg	5	5	<2	4
Barium	mg/kg	263	53	430	1160
Chromium	mg/kg	8	6	91	358
Cobalt	mg/kg	8	5	16	32
Copper	mg/kg	14	11	22	34
Iron	mg/kg	18900	14000	22000	28200
Lead	mg/kg	12	9	7	14
Manganese	mg/kg	1810	267	687	7670
Nickel	mg/kg	11	9	31	66
Vanadium	mg/kg	9	6	39	64
Zinc	mg/kg	42	37	18	37

(a) Concentrations of antimony, beryllium, boron, cadmium, selenium, mercury, silver and thallium were below the limit of detection in all samples. In addition, chlorinated herbicides, organochlorine pesticides, organophosphate pesticides, and semi-volatile organics were below the limit of detection for the BTT-R1 and NSY-R1 samples.

Data Source: Parametrix 2009

Table 5-3. Concentration of LA in Sediment Porewater

Replicate	Treatment 1 Control Sediment		Treatment 5 NSY-R1 Sediment		Treatment 6 CC-1 Sediment		Treatment 7 TP-TOE2 Sediment	
	Start	End	Start	End	Start	End	Start	End
H	ND	ND	ND	ND	28.9	3.9	35.9	2.7
I	ND	ND	ND	ND	3.4	3.9	27.2	3.8
J	ND	ND	ND	ND	44.8	3.5	20.8	0.8
K	ND	ND	ND	ND	16.2	3.0	ND	1.9
L	ND	ND	ND	ND	0.4	0.4	43.2	4.7

Concentrations are reported in units of billion fibers per liter (BFL).
Non-detects were < 0.4 BFL.

Data Source: Parametrix 2009b

Table 5-4 Kick Net Benthic Maroinvertebrate Community Data

Metric	Description	Year	Off-Site Reference		Upper Rainy Creek		Lower Rainy Creek				
			BTT-R1	NSY-R1	URC-1A	URC-2	TPTOE2	LRC-1	LRC-2	LRC-3	LRC-5
1	Taxa Richness (Number of Taxa)	2008	30	31	29	28	26	23	19	19	15
		2009	23	52	26	31	26	22	22	30	24
2	Total Density (number of organism	2008	2375	1065	1256	707	538	5610	2618	304	5221
		2009	2548	4560	1833	276	2825	3782	5236	1745	1771
3	EPT Index (number of EPT taxa)	2008	13	26	21	21	9	7	8	12	10
		2009	12	26	19	20	8	7	8	12	9
4	Shannon -Weaver Diversity	2008	3.42	2.63	3.54	3.41	2.90	3.07	2.73	2.53	2.04
		2009	3.34	4.69	3.17	3.92	2.54	3.08	2.88	2.77	2.85
5	% Ephemeroptera	2008	22.2	64.2	43.2	34.0	31.4	4.0	3.2	20.1	30.2
		2009	15.0	25.0	44.0	29.0	21.0	11.0	14.0	11.0	16.0
6	% Tolerant organisms	2008	16.7	3.2	3.5	3.6	11.5	34.8	21.1	10.5	6.7
		2009	17.0	6.0	4.0	3.0	15.0	18.0	18.0	10.0	13.0
7	% Contribution Dominant Taxon	2008	26.9	59.7	25.1	25.3	31.0	23.0	45.8	50.3	49.1
		2009	26.0	11.0	35.0	16.0	41.0	24.0	46.0	55.0	43.0
8	% Scrapers	2008	30.7	60.6	26.9	25.6	0.0	40.6	59.4	12.2	3.5
		2009	25.0	22.0	35.0	16.0	0.0	40.0	55.0	3.0	8.0
9	% Clingers	2008	64.0	74.0	58.0	61.0	35.0	90.0	89.0	24.0	59.0
		2009	71.0	35.0	66.0	49.0	48.0	91.0	79.0	20.0	66.0

Data Source: Parametrix 2009d, 2010

Table 5-5 RBP BCS Calculations Based on Kick Net Data

2008 Data	BTT-R1		NSY-R1		URC-1A		URC-2		TPTOE2		LRC-1		LRC-2		LRC-3		LRC-5	
	%	Score	%	Score	%	Score	%	Score	%	Score	%	Score	%	Score	%	Score	%	Score
1. Taxa Richness (site / reference)	100%	6	100%	6	94%	6	90%	6	87%	6	77%	4	63%	4	63%	4	50%	2
2. Total Density (site / reference)	100%	6	100%	6	50%	2	60%	2	113%	6	96%	6	96%	6	130%	6	104%	6
3. EPT Index (site / reference)	100%	6	100%	6	118%	6	66%	0	23%	0	236%	6	110%	6	13%	0	220%	6
4. Shannon –Weaver Diversity (site / reference)	100%	6	100%	6	40%	0	6%	0	111%	6	148%	6	205%	6	68%	2	70%	2
5. % Ephemeroptera (site / reference)	100%	6	100%	6	81%	6	81%	6	69%	6	54%	6	62%	6	92%	6	77%	6
6. % tolerant organisms (reference / site)	100%	6	100%	6	137%	6	130%	6	150%	6	171%	6	150%	6	100%	6	133%	6
7. % Contribution of Dominant Taxon	3%	6	3%	6	4%	6	3%	6	3%	6	3%	6	3%	6	3%	6	2%	6
8. % scrapers (site / reference)	100%	6	100%	6	68%	6	84%	6	76%	6	92%	6	86%	6	83%	6	85%	6
9. % clingers (site / reference)	100%	6	100%	6	67%	6	53%	6	142%	6	18%	0	14%	0	91%	6	136%	6
Biological Condition Score (BCS)		54		54		44		38		48		46		46		42		46
BCS(site) / BCS(reference) **					**82%**		**71%**		**90%**		**86%**		**86%**		**79%**		**86%**	
Biological Condition Category					**Not impaired**		**Slightly impaired**		**Not impaired**		**Not impaired**		**Not impaired**		**Slightly impaired**		**Not impaired**	

2009 Data	BTT-R1		NSY-R1		URC-1A		URC-2		TPTOE2		LRC-1		LRC-2		LRC-3		LRC-5	
	%	Score	%	Score	%	Score	%	Score	%	Score	%	Score	%	Score	%	Score	%	Score
1. Taxa Richness (site / reference)	100%	6	100%	6	50%	2	60%	2	113%	6	96%	6	96%	6	130%	6	104%	6
2. Total Density (site / reference)	100%	6	100%	6	40%	2	6%	0	111%	6	148%	6	205%	6	68%	4	70%	4
3. EPT Index (site / reference)	100%	6	100%	6	73%	2	77%	2	67%	0	58%	0	67%	0	100%	6	75%	2
4. Shannon –Weaver Diversity (site / reference)	100%	6	100%	6	68%	2	84%	4	76%	4	92%	6	86%	6	83%	4	85%	6
5. % Ephemeroptera (site / reference)	100%	6	100%	6	176%	6	116%	6	140%	6	73%	6	93%	6	73%	6	107%	6
6. % tolerant organisms (reference / site)	100%	6	100%	6	150%	6	200%	6	113%	6	94%	6	94%	6	170%	6	131%	6
7. % Contribution of Dominant Taxon	26%	4	11%	6	35%	2	16%	6	41%	2	24%	4	46%	2	55%	2	43%	2
8. % scrapers (site / reference)	100%	6	100%	6	159%	6	73%	6	0%	0	160%	6	220%	6	12%	0	32%	2
9. % clingers (site / reference)	100%	6	100%	6	189%	6	140%	6	68%	6	128%	6	111%	6	28%	2	93%	6
Biological Condition Score (BCS)		52		54		34		38		36		46		44		36		40
BCS(site) / BCS(reference) **					**64%**		**71%**		**67%**		**86%**		**82%**		**67%**		**75%**	
Biological Condition Category					**Slightly impaired**		**Slightly impaired**		**Slightly impaired**		**Not impaired**		**Not impaired**		**Slightly impaired**		**Slightly impaired**	

** BCS Reference score = mean of BTT and NSY for 2008 and 2009 = 53.5
Slightly impaired = 0.5 to 0.8 * Mean of reference = 26.8 to 42.8
Moderatley impaired = 0.2 to 0.5 * Mean of reference = 10.7 to 26.8

Table 5-6 Surber Benthic Maroinvertebrate Community Data

Metric	Description	Year	Off-Site Reference		Upper Rainy Creek		Lower Rainy Creek				
			BTT-R1	NSY-R1	URC-1A	URC-2	TPTOE2	LRC-1	LRC-2	LRC-3	LRC-5
1	Taxa Richness	2008	24	34	10	36	30	20	27	17	20
	(Number of Taxa)	2009	28	42	40	45	27	16	23	24	32
2	EPT Index	2008	9	26	6	22	11	6	10	10	12
	(number of EPT taxa)	2009	9	29	18	18	10	5	8	13	16
3	HBI Score	2008	4.86	1.30	2.46	1.45	4.51	5.30	5.44	4.07	3.42
		2009	4.80	1.81	1.95	1.73	4.50	5.57	5.51	3.63	3.41
4	% Contribution	2008	54	27	69	22	35	24	40	34	57
	Dominant Taxon	2009	55	26	21	22	62	30	34	45	24
5	Collecter Gatherer	2008	11	16	72	21	37	3	10	25	61
	(% Abundance)	2009	8	15	36	22	21	5	10	12	51
6	EPT	2008	32	91	26	80	44	35	26	59	92
	(% Abundance)	2009	23	83	74	78	32	16	26	83	88
7	Scraper and Shredder	2008	18	64	5	51	15	37	29	35	29
	(% Abundance)	2009	12	57	49	59	13	50	37	57	40

Data Source: Parametrix 2009b, 2010

Table 5-7 Mountain MMI Scores Based on Surber Data

2008 Data	Off-Site Reference		Upper Rainy Creek		Lower Rainy Creek				
	BTT-R1	NSY-R1	URC-1A	URC-2	TPTOE2	LRC-1	LRC-2	LRC-3	LRC-5
1) Taxa Richness (Number of Taxa)	2	3	0	3	3	1	2	0	1
2) EPT Index (number of taxa at station)	0	3	0	3	0	0	0	0	0
3) HBI Score	1	3	3	3	1	0	0	1	2
4) % Contribution Dominant Taxon	0	2	0	3	1	3	1	2	0
5) Collecter Gatherer, % Abundance	3	3	1	3	3	3	3	3	2
6) EPT Abundance	0	3	0	3	1	0	0	2	3
7) Scraper and Shredder, % Abundance	0	3	0	2	0	1	1	1	1
Total Score	6	20	4	20	9	8	7	9	9

2009 Data	Off-Site Reference		Upper Rainy Creek		Lower Rainy Creek				
	BTT-R1	NSY-R1	URC-1A	URC-2	TPTOE2	LRC-1	LRC-2	LRC-3	LRC-5
1) Taxa Richness (Number of Taxa)	2	3	3	3	2	0	1	2	3
2) EPT Index (number of taxa at station)	0	3	2	2	0	0	0	0	1
3) HBI Score	1	3	3	3	1	0	0	2	2
4) % Contribution Dominant Taxon	0	2	3	3	0	2	2	1	3
5) Collecter Gatherer, % Abundance	3	3	3	3	3	3	3	3	3
6) EPT Abundance	0	3	3	3	0	0	0	3	3
7) Scraper and Shredder, % Abundance	0	3	2	3	0	2	1	3	1
Total Score	6	20	19	20	6	7	7	14	16

Table 5-8 Benthic Habitat Quality Data and Scores

Panel A: Data from 2008

Habitat Parameter		Perfect Score	Off-Site Reference		Upper Rainy Creek		Lower Rainy Creek				
			BTT-R1	NSY-R1	URC-1A	URC-2	TP-TOE2	LRC-1	LRC-2	LRC-3	LRC-5
Epifaunal Substrate/ Available Cover		20	18	16	18	17	15	13	16	17	16
Embeddedness		20	17	19	17	16	15	16	17	18	16
Velocity/Depth Regime		20	12	12	14	12	13	10	10	17	11
Sediment Deposition		20	15	17	16	13	16	14	16	16	17
Channel Flow Status		20	18	13	18	17	17	17	18	18	17
Channel Alteration		20	18	18	17	16	16	14	14	17	14
Frequency of Riffles (or bends)		20	15	15	14	15	14	14	17	12	14
Bank Stability	Left Bank	10	9	8	9	9	9	7	9	9	9
	Right Bank	10	9	8	9	9	9	7	9	9	8
Vegetative Protection	Left Bank	10	9	9	9	9	9	8	8	9	9
	Right Bank	10	9	9	9	9	9	7	8	9	7
Riparian Vegetative Zone Width	Left Bank	10	8	9	9	9	8	6	7	9	5
	Right Bank	10	9	9	9	9	9	6	7	9	9
HABITAT QUALITY SCORE		200	166	162	168	160	159	139	156	169	152

Panel B: Data from 2009

Habitat Parameter		Perfect Score	Off-Site Reference		Upper Rainy Creek		Lower Rainy Creek				
			BTT-R1	NSY-R1	URC-1A	URC-2	TP-TOE2	LRC-1	LRC-2	LRC-3	LRC-5
Epifaunal Substrate/ Available Cover		20	15	18	18	16	13	11	14	15	15
Embeddedness		20	18	18	16	13	15	13	13	15	13
Velocity/Depth Regime		20	11	12	14	12	12	9	15	14	11
Sediment Deposition		20	15	18	16	12	16	12	15	13	16
Channel Flow Status		20	18	12	17	14	16	15	17	16	16
Channel Alteration		20	18	18	17	17	13	10	12	15	12
Frequency of Riffles (or bends)		20	16	15	14	15	13	14	17	11	14
Bank Stability	Left Bank	10	8	9	9	9	6	6	8	8	9
	Right Bank	10	8	9	9	9	7	6	8	8	7
Vegetative Protection	Left Bank	10	9	9	9	9	7	7	7	9	9
	Right Bank	10	9	9	9	9	8	7	7	9	6
Riparian Vegetative Zone Width	Left Bank	10	8	9	9	9	7	5	5	9	7
	Right Bank	10	8	9	9	9	7	5	5	9	3
HABITAT QUALITY SCORE		200	161	165	166	153	140	120	143	151	138

Data Source: Parametrix 2009b, 2010

Table 5-9 Weight of Evidence Summary for Benthic Invertebrates

Study Type	Exposure Pathways	Endpoint	Was a Difference Observed?	Is the Difference Attributable to LA ?	Is the Difference Judged to be Ecologically Significant ?	Conclusion	Confidence and Limitations
Site-specific sediment toxicity tests in *H. azteca*	Direct contact with sediment and porewater; ingestion of sediment and detritus	Survival	Yes: A marginally significant decrease occurred for organisms exposed to Carney Creek sediment but not TPTOE sediment	Unknown. Analytical limitations (PLM) do not allow the results to be confidently interpreted as dose-responsive or not.	No. Overall survival rates are high (>85%) and differences between site and reference are small.(4-6%)	Adverse effects from LA cannot be ruled out but they are deemed too small to be ecologically significant and are inconsistent with the observed increased growth and reproduction observed with LA containing sediments.	Medium-High. Although results are available for two species, neither is native to mountain streams, and native species might have differing sensitivity.
		Growth	No. Organisms exposed to OU3 sediments were larger than those exposed to reference sediments				
		Reproduction	No. Reproduction was higher in organisms exposed to OU3 sediments than reference sediments				
Site-specific sediment toxicity tests in *C. tentans*	Direct contact with sediment and porewater; ingestion of sediment and detritus	Survival and emergence	Yes: A statistically significant decrease occurred in organisms exposed to TPTOE sediment and a marginally significant decrease occurred for Carney Creek sediment	Unknown. Analytical limitations (PLM) do not allow the results to be confidently interpreted as dose-responsive or not.	Possibly. Adverse effects of site sediments on a single benthic species may or may not be representative of the benthic community and should be interpreted with additional lines of evidence. Additionally, this study cannot assess potential effects at lesser contaminated locations.	LA in sediments of LRC might be causing effects on *C. tentans* in locations with maximal contamination, but effects at other locations and other species in LRC cannot be determined without additional lines of evidence.	
		Growth	Yes A marginally significant decrease was noted for organisms exposed to Carney Creek sediment but not TPTOE sediment.	Unknown. Analytical limitations (PLM) do not allow the results to be confidently interpreted as dose-responsive or not.			
		Number of eggs	No. The average number of eggs was higher for both Carney Creek and TPTOE sediments than for reference sediments.				
		Reproduction	Yes. A very small but statistically significant decrease was observed for TPTOE sediment.	Unknown. Analytical limitations (PLM) do not allow the results to be confidently interpreted as dose-responsive or not.	No. Hatch success was high (97%), and differences between OU3 and reference were very small (<2%).		
Site-specific benthic community studies	All pathways, including direct contact with sediment., pore water, surface water, ingestion of sediment and detritus	RBP BCS	Yes. LRC stations sometimes rank as slightly impaired, depending on sampling year and location.	Unlikely. Numerous differences in habitat exist. Although correlation with habitat is low, habitat is nevertheless likely to account for at least some of the apparent differences.	No. Differences are small and the benthic communities remain relatively close to expected density and diversity	LA in LRC water and sediment does not appear to be causing effects on the benthic community.	Medium. Although community surveys often tend to be variable between years, results were relatively consistent over two years.
		Mountain MMI	No. MMI scores tend to be within the normal range.				

Table 6-1. Growth and Survival Endpoints for Ambhibian Laboratory Study

Measurement Endpoint	Treatment 1 Control Sed.		Treatment 2 Ref. Sed.		Treatment 3 Carney Creek Sed.		Statistical Significance		
	Mean	Stdev	Mean	Stdev	Mean	Stdev	Test	3 vs 1	3 vs 2
Survival (%)	81.3%	2.5%	61.3%	18.0%	70.0%	12.2%	FET	0.070	0.909
Weight at termination (mg)	354	52	254	30	703	88	t-test	0.999	1.000
SVL (mm)	17.6	1.4	15.6	1.0	20.8	0.6	t-test	0.993	1.000
Food intake (g/organism/day)	0.113	0.017	0.130	0.014	0.125	0.010	t-test	0.868	0.293

[Yellow highlight] Marginally significantly lower than comparison ($0.05 < p \leq 0.20$)

FET = Fisher exact test (one tailed)

Data Source: FEL 2013

Table 6-2.
Measurement Endpoints for Amphibian Field Study

Developmental Window	Endpoints
Egg mass	Structure Cleavage
Larval (Field Stages 1-6)	Mouth Gills Eyes Skin Tail Limbs
Larval (Field Stages 3-6)	Hind limb length (HLL) Snout-vent length (SVL)
Metamorphosed young (Field Stage 8)	Mouth Eyes Skin Limbs Size (weight and SVL)

Data Source: Golder 2014c

Table 6- 3. Estimated Concentrations of LA in Sediment

Category	Location	LA Concentration (%) (a)	
		Initial	Final
On-site	Carney Pond	Bin C (5%)	Bin C (4%)
	Fleetwood Pond	Bin C (1.5%)	Bin C (3%)
	Mill Pond	Bin B2 (0.2-1%)	Bin B1 (< 0.2%)
	Tailings Pond	Bin B2 (0.2-1%)	Bin C (1.5%)
Reference	Tepee Pond	Bin A (ND)	Bin A (ND)
	Schrieber Lake	Bin A (ND)	Bin A (ND)
	Banana lake	Bin A (ND)	Bin A (ND)
	Bobtail Pond	Bin A (ND)	Bin A (ND)

(a) As discused in Section 2, sediment is analyzed by PLM and results are semiquantitative:
Bin A = Non-detect (ND)
Bin B1 = detected at a concentration judged to be less than 0.2%
Bin B2= Detected at a concentration judged to be between 0.2% and 1%
Bin C = 1% or greater

Data Source: CDM Smith 2013a

Table 6-4. Exposure Conditions in Water

Panel A. LA Concentrations Measured in Water

Group	Location	Number of samples	Concentration (MFL)	
			Mean	Range
OU3	Carney Pond	15	7.9	0.03 - 270
	Fleetwood Pond	15	26	0.09 - 110
	Mill Pond	15	6.7	ND - 52
	Tailings Pond	15	8.7	ND - 53
Reference	Bobtail Pond	2	ND	ND - ND
	Banana Lake	2	< 0.1	ND - 0.09
	Teepee Pond	2	ND	ND - ND

Panel B. Water Temperature

Group	Location	Number of measurements	Temperature (ºC)	
			Mean	Range
OU3	Carney Pond	29	16.5	8.6 - 22.1
	Fleetwood Pond	29	18.6	10.6 - 24.3
	Mill Pond	26	15.5	7.8 - 23.9
	Tailings Pond	24	18.0	5.7 - 26.2
Reference	Bobtail Pond	27	17.6	7.8 - 24.9
	Banana Lake	26	14.4	7.1 - 20.6
	Teepee Pond	25	19.1	8.1 - 25.5

Data Source: Golder 2014c

Table 6-5. Amphibians Collected During Field Study

Species	Developmental Stage	Target number of specimens	OU3 Ponds				Reference Ponds		
			Carney Pond	Fleetwood Pond	Mill Pond	Tailings Pond	Bobtail Pond	Banana Lake	Tepee Pond
Northern Tree Frog	Egg	4	4	0	0	0	0	0	0
	Premetamorphs	40	35	40	0	77	0	36	40
	Prometamorphs	40	11	40	0	41	0	1	13
	Metamorphs	20	2	20	0	1	6	0	15
Columbia Spotted Frog	Egg	4	0	0	0	0	0	0	0
	Premetamorphs	40	66	0	0	6	41	4	40
	Prometamorphs	40	13	0	0	10	9	9	40
	Metamorphs	20	20	1	0	20	20	20	20
Western Toad	Egg	4	0	0	0	0	0	0	0
	Premetamorphs	40	30	0	0	40	0	0	1
	Prometamorphs	40	0	0	0	0	0	0	0
	Metamorphs	20	0	0	0	0	0	0	0

Data Source: Golder 2014c

Table 6-6.
Metamorphs Sent for Histological Examination

Group	Location	Columbia Spotted Frog	Northern Tree Frog
OU3	Carney Pond	20	2
	Fleetwood Pond	1	20
	Tailings Pond	20	1
	OU3 Total	41	23
Reference	Bobtail Pond	20	6
	Banana Lake	20	
	Teepee Pond	20	15
	Reference Total	60	21
Grand Total		101	44

Data source: Golder 2014c

Table 6-7. List of Tissues Examined Histologically

Skin	Head
	Dorsum
	Ventrum
	Leg
	Feet
Adipose	
Skeletal Muscle	
Bones	Flat
	Long
	Vertebrae
	Digits
Endolymphatic sacs	
Ears	
Eyes	
Nervous system	Brain
	Spinal cord
Coelomic cavity	
GI Tract	Mouth
	Tongue
	Esophagus
	Stomach
	Duodenum
	Small intestine
	Large intestine
	Cloaca

Organs	Pancreas
	Liver
	Gall bladder
Resp System	Nasal cavity
	Larnyx
	Trachea/Bronchi
	Lungs
	Gills
Cardiovascular system	Heart
	Large vessels
	Small vessels
Renal System	Kidney
	Ureter
	Bladder
Reproductive Organs	Ovaries/Testes
Endocrine system	Pituitary
	Adrenals
	Thyroid
	Parathyroid
Hematopoetic tissues	Bone marrow
	Thymus
	Spleen

Data Source: Golder 2014c

Table 6-8. Frequency of Histologic Lesions in Field-Collected Metamorphs

Panel A: Columbia Spotted Frog

Tissue	OU3			Reference			FET
	Normal	Abnormal	Total	Normal	Abnormal	Total	(1-T)
Dorsum skin	39	2	41	60	0	60	0.162
Ventrum skin	39	2	41	57	3	60	0.679
Skeletal muscle	41	0	41	52	8	60	1.000
Vertebrae	39	2	41	57	3	60	0.679
Brain	40	1	41	60	0	60	0.406
Spinal cord	38	0	38	58	1	59	1.000
Coelomic cavity	22	19	41	47	13	60	0.008
Mouth	41	0	41	59	1	60	1.000
Tongue	39	2	41	56	4	60	0.784
Duodenum	36	1	37	56	2	58	0.777
Small intestine	37	4	41	46	14	60	0.981
Large intestine	39	2	41	28	32	60	1.000
Cloaca	19	0	19	44	2	46	1.000
Pancreas	41	0	41	52	5	57	1.000
Liver	3	38	41	0	60	60	1.000
Gall bladder	38	2	40	59	0	59	0.161
Nasal	40	1	41	60	0	60	0.406
Lungs	39	2	41	42	18	60	1.000
Heart	41	0	41	48	12	60	1.000
large vessels	38	0	38	59	1	60	1.000
Kidney	2	39	41	0	60	60	1.000
Bladder	35	2	37	41	15	56	0.999
Pituitary	20	1	21	17	0	17	0.553

Panel B: Northern Tree Frog

Tissue	OU3			Reference			FET
	Normal	Abnormal	Total Organisms	Normal	Abnormal	Total Organisms	(1-T)
Ventrum skin	21	2	23	21	0	21	0.267
Adipose	22	1	23	19	2	21	0.900
Skeletal muscle	22	1	23	18	3	21	0.956
Vertebrae	22	1	23	21	0	21	0.523
Endolymphatic	22	1	23	21	0	21	0.523
Brain	22	1	23	21	0	21	0.523
Coelomic cavity	17	6	23	13	8	21	0.881
Tongue	23	0	23	17	4	21	1.000
Large Intestine	23	0	23	15	6	21	1.000
Liver	9	14	23	9	11	20	0.468
Lungs	19	4	23	16	5	21	0.816
Heart	21	2	23	16	5	21	0.964
Large vessels	22	1	23	21	0	21	0.523
Kidney	3	19	22	0	21	21	1.000
Bladder	22	0	22	19	1	20	1.000
Thyroid	6	1	7	11	0	11	0.389

(pink)	OU3 significantly greater than Reference ($p \leq 0.05$)
(yellow)	OU3 marginally greater than Reference ($0.05 < p \leq 0.20$)

Data Source: Golder 2014c

Table 6-9. Severity of Histologic Lesions in Field-Collected Metamorphs

Panel A: Columbia Spotted Frog

Tissue	OU3			Reference			WRS p Value	
	Abnormal	Sum of Scores	Mean Score	Abnormal	Sum of Scores	Mean Score	2-tail	1-tail
Dorsum skin	2	3	1.50	0	0	--	--	--
Ventrum skin	2	4	2.00	3	6	2.00	1.000	0.500
Skeletal muscle	0	0	--	8	27	3.38	--	--
Vertebrae	2	2	1.00	3	5	1.67	0.182	0.909
Brain	1	1	1.00	0	0	--	--	--
Spinal cord	0	0	--	1	3	3.00	--	--
Coelomic cavity	19	48	2.53	13	21	1.62	0.005	0.003
Mouth	0	0	--	1	4	4.00	--	--
Tongue	2	4	2.00	4	14	3.50	0.134	0.933
Duodenum	1	4	4.00	2	2	1.00	0.157	0.079
Small intestine	4	12	3.00	14	35	2.50	0.434	0.217
Large intestine	2	6	3.00	32	136	4.25	0.151	0.925
Cloaca	0	0	--	2	4	2.00	--	--
Pancreas	0	0	--	5	12	2.40	--	--
Liver	38	155	4.08	60	261	4.35	0.074	0.963
Gall bladder	2	4	2.00	0	0	--	--	--
Nasal	1	4	4.00	0	0	--	--	--
Lungs	2	4	2.00	18	59	3.28	0.022	0.989
Heart	0	0	--	12	47	3.92	--	--
large vessels	0	0	--	1	2	2.00	--	--
Kidney	39	190	4.87	60	274	4.57	0.282	0.141
Bladder	2	5	2.50	15	39	2.60	1.000	0.500
Pituitary	1	1	1.00	0	0	--	--	--

Panel B: Northern Tree Frog

Tissue	OU3			Reference			WRS p Value	
	Abnormal	Sum of Scores	Mean Score	Abnormal	Sum of Scores	Mean Score	2-tail	1-tail
Ventrum skin	2	4	2.00	0	0	--	--	--
Adipose	1	2	2.00	2	4	2.00	1.000	0.500
Skeletal muscle	1	3	3.00	3	3	1.00	0.083	0.042
Vertebrae	1	2	2.00	0	0	--	--	--
Endolymphatic	1	2	2.00	0	0	--	--	--
Brain	1	2	2.00	0	0	--	--	--
Coelomic cavity	6	11	1.83	8	10	1.25	0.106	0.053
Tongue	0	0	--	4	14	3.50	--	--
Large Intestine	0	0	--	6	15	2.50	--	--
Liver	14	40	2.86	11	27	2.45	0.511	0.256
Lungs	4	11	2.75	5	15	3.00	1.000	0.500
Heart	2	3	1.50	5	15	3.00	0.105	0.948
Large vessels	1	2	2.00	0	0	--	--	--
Kidney	19	71	3.74	21	108	5.14	0.022	0.989
Bladder	0	0	--	1	3	3.00	--	--
Thyroid	1	1	1.00	0	0	--	--	--

(pink)	OU3 significantly greater than Reference ($p \leq 0.05$)
(yellow)	OU3 marginally greater than Reference ($0.05 < p \leq 0.20$)

Data Source: Golder 2014c

Table 6-10 Weight of Evidence Summary for Amphibians

Study Type	Exposure Pathways	Endpoint	Was a Difference Observed?	Is the Difference Attributable to LA ?	Is the Difference Judged to be Ecologically Significant ?	Conclusion	Confidence and Limitations
Site-specific sediment toxicity test using developing tadpoles of the southern leopard frog	Direct contact with sediment and overlying water; ingestion of sediment and detritus	Survival	No. Survival was higher for organisms exposed to OU3 sediment that for organisms exposed to an off-site reference sediment			Frog larvae exposed to OU3 sediment are not impacted by LA	Medium-High. The sediments tested were selected to be at the high end of the range observed on-site. Most sediments from LRC have lower concentrations, so risk of effect would be even lower.
		Growth	No. Organisms exposed to OU3 sediment were larger than organisms exposed to either control or reference sediment				
		Development	Yes. About half of all organisms exposed to OU3 sediment did not complete full metamorphosis by study termination	Unknown. Study design was intended to evaluate potential effects of maximally exposed organisms and does not allow assessment of dose-responsiveness.	Unlikely. Development was nearly complete, with most lagging organisms having reached Gosner stages 43-45.		
Site-specific survey of lesion frequency in native species (northern tree frog, Columbia spotted frog)	All pathways, including direct contact with sediment., surface water, ingestion of sediment and detritus	Size and weight	No. There is no consistent pattern of decreases in either size or weight for organisms collected from OU3 compared to organisms from reference locations.			Native amphibian species captured in OU3 do not have lesions attributable to LA in water or sediment.	High. Results are based on two species (tree frog, spotted frog), although insufficient numbers of toads were captured to allow evaluation.
		External lesions	No. No lesions were observed in organisms captured in OU3.				
		Histological lesion prevalence	No. Histological lesions were not more frequent in amphibians from OU3 than expected based on organisms from Reference areas	No. Nearly all of the tissue lesions observed in organisms from both OU3 and Reference areas were inflammatory in nature and were attributed to parasitism			
		Histological lesion severity	No. There is no apparent tendency for tissue lesions to be more severe in OU3 that in Reference areas				

Table 7-1 Small Mammal Species Captured

Location	Trap Line	Deer Mouse	Western jumping mouse	Yellow-pine chipmunk	Bushy tailed woodrat
Reference	A	23		5	
	B	1		2	1
	C	5		1	1
	D	5			2
	Total	34	0	8	4
OU3	A	15	1	7	
	B	5			
	C	4			1
	D	7			
	E	2		2	
	F	5		1	
	Total	38	1	10	1

Data Source: Golder 2010

Table 7-2. Size Data for Deer Mice

Location	Trap Line	Body Weight (g)		Length (cm)	
		Females	Males	Females	Males
Reference	A	15.7	15.7	16.2	16.4
	B	16.5	--	16.5	--
	C	14.9	15.4	16.6	16.5
	D	13.3	14.3	16.1	16.5
	Mean	15.1	15.1	16.4	16.5
	Stdev	1.4	0.7	0.2	0.1
OU3	A	15.9	16.2	16.4	16.2
	B	15.0	12.2	15.6	14.7
	C	13.5	17.6	14.8	15.9
	D	12.8	15.6	14.5	16.2
	E	--	17.5	--	17.5
	F	12.6	16.3	15.6	16.4
	Mean	14.0	15.9	15.4	16.2
	Stdev	1.4	2.0	0.7	0.9
Stat. Signif. (t-test)		0.265	0.429	0.042	0.430

(pink box) Statistically sifgnificant ($p \leq 0.05$)

Data Source: Golder 2010

Table 7-3. Gender Distribution of Mice

Location	Trap Line	Number			Percent	
		Females	Males	Total	Female	Male
Reference	A	13	10			
	B	1	0			
	C	4	1			
	D	4	1			
	Total	22	12	34	65%	35%
OU3	A	6	9			
	B	2	3			
	C	3	1			
	D	5	2			
	E	0	2			
	F	1	4			
	Total	17	21	38	45%	55%

Stat. Signif. (2-tail FET) 0.103

Marginally statistically significant ($0.05 < p \leq 0.20$)

Data Source: Golder 2010

Table 7-4. Estimated Age of Mice

Location	Trap Line	Estimated Age (days)	
		Females	Males
Reference	A	180	218
	B	161	--
	C	155	316
	D	139	113
	Mean	159	216
	Stdev	17	102
OU3	A	165	137
	B	214	105
	C	96	136
	D	142	163
	E	--	226
	F	105	186
	Mean	144	159
	Stdev	48	43
Stat. Signif. (t-test)		0.560	0.438

Data Source: Golder 2010

Table 7-5. Small Mammal Lesion Frequency and Severity

System	Tissue	Frequency					Severity (a)		
		Reference		Site		FET p	Reference	Site	WRS p
Upper airway	Larynx	15/33	45%	24/38	63%	0.104	1.33	1.75	0.021
	Trachea	26/34	76%	28/38	74%	0.706	1.96	1.89	0.563
	Left Mainstem Bronchus	21/32	66%	28/34	82%	0.102	1.57	1.68	0.301
	Right Mainstem Bronchus	20/29	69%	22/33	67%	0.678	1.70	1.95	0.167
Lung	Left Cranial Lung	24/33	73%	30/37	81%	0.292	2.96	2.63	0.837
	Left Middle Lung	23/33	70%	27/37	73%	0.484	3.17	2.93	0.784
	Left Caudal Lung	29/33	88%	32/37	86%	0.700	3.03	2.88	0.705
	Right Cranial Lung	29/34	85%	33/38	87%	0.558	3.07	3.24	0.330
	Right Middle Lung	26/34	76%	32/38	84%	0.298	2.92	3.16	0.334
	Right Caudal Lung	33/34	97%	35/38	92%	0.928	4.00	4.57	0.240
	Post Caval Lung	29/33	88%	31/37	84%	0.796	4.03	4.39	0.302
Upper GI	Esophagus	2/34	6%	3/38	8%	0.553	1.50	1.33	0.500
	Cardiac Stomach	8/34	24%	3/38	8%	0.986	1.63	2.67	0.075
	Fundus	1/34	3%	2/38	5%	0.542	1.00	1.50	0.500
	Pylorus	5/34	15%	4/37	11%	0.802	1.00	1.00	0.500
Lower GI	Duodenum	27/34	79%	34/38	89%	0.196	1.07	1.00	0.940
	Jejunum	28/34	82%	35/38	92%	0.186	1.25	1.23	0.574
	Ileum	32/34	94%	35/38	92%	0.785	1.22	1.14	0.787
	Cecum	25/34	74%	30/38	79%	0.396	1.24	1.10	0.912
	Colon	19/34	56%	19/38	50%	0.769	1.32	1.11	0.935
	Rectum	2/34	6%	2/38	5%	0.734	2.00	1.50	0.500
	Anus	2/26	8%	1/28	4%	0.895	1.00	1.00	0.500
Other tissues	Adrenal	6/34	18%	5/38	13%	0.804	2.33	2.40	0.500
	Thryoid	1/32	3%	2/36	6%	0.545	2.00	2.50	0.500

(a) Mean severity score for animals with lesions

(pink)	Site statistically higher than Reference (p ≤ 0.05)
(yellow)	Site marginally higher than Reference (0.05 < p ≤ 0.20)

Data Source: Golder 2010

Table 7-6 Weight of Evidence Summary for Mammals

Study Type	Exposure Pathways	Endpoint	Was a Difference Observed?	Is the Difference Attributed to LA ?	Is the Difference Judged to be Ecologically Significant?	Conclusion	Confidence and Limitations
Site-specific survey of lesion frequency in mice	All pathways, including inhalation exposure while foraging, ingestion of LA from food or soil, and direct contact.	External lesions	No. No deformities or other gross abnormalities were observed in any of the animals, and all animals appeared to be in good health.			Small mammals residing in the forest area of OU3 are not impacted by exposure to LA.	High. However, extrapolation of this conclusion to other mammals is limited by several uncertainties including a) differences in lifespan, b) differences in area usage, and c) differences between the forest and the mine area.
		Histological lesion prevalence	Yes. The frequency of lesions was marginally significantly higher in animals from the site than from the reference area for larynx, left mainstem bronchus, duodenum, and jejunum.	No. None of the lesions were judged to be consistent with asbestos exposure, but rather were attributed to parasitism or infectious disease.	No. None of the lesions would be expected to affect survival or reproduction.		
		Histological lesion severity	Yes. The median severity of lesions was significantly higher ($p<0.05$) for larynx, and marginally significantly higher for right mainstem bronchus and cardiac stomach				

ATTACHMENT A

WILDLIFE SPECIES THAT MAY OCCUR IN OU3

Attachment A-1. Amphibian Species Occuring within the Libby OU3 Site

		Habitat Group											Observation in Lincoln, Co., Montana		
Group	**Common Name (Genus/species)**	**Foraging**	**Nesting**	**General Habitat Description**	**Feeding Guild**	**Food**	**Migration/ Hibernation**	**Longevity**	**Size**		**Global Rank**	**State Rank**	**Oldest**	**Most Recent**	**Number**
Chorus Frogs (Hylidae)	Pacific Treefrog (*Pseudacris regilla*)	Aquatic	Aquatic	Regularly found in the water only during the breeding period in spring. In western Montana they breed in temporary ponds in lower elevation forests and intermountain valleys shortly after snowmelt. Eggs hatch in 2 to 3 weeks and tadpoles take 8 to 10 week	NA	NA	NA/NP	NA	NA		G5	S4	1946	2006	101
Family Woodland Salamanders (Plethodontidae)	Coeur d'Alene Salamander (*Plethodon idahoensis*)	Aquatic	Aquatic	Springs and seeps, waterfall spray zones, and stream edges. More specifically, primary habitats are seepages and streamside talus; they also inhabit talus far from free water (deep talus mixed with moist soil on well-shaded north-facing slopes). In wet w	Invertivore	When above ground, Coeur d'Alene salamanders feed primarily on insects (11 orders documented) and other invertebrates, including millipeds, mites, spiders, harvestmen, snails, and segmented worms. They appear to be opportunistic feeders and generally rest	NA	NA	NA		G4	S2	1962	2006	102
Tailed Frogs (Ascaphidae)	Rocky Mountain Tailed Frog (*Ascaphus montanus*)	Aquatic	Aquatic	Small, swift, cold mountain streams. Eggs are laid during late summer and take approximately 4 weeks to hatch. Tadpoles take 1 - 4 years to metamorphose, depending on water temperature. Sexual maturity in Montana is attained at 6 or 7 years of age (the la	Insectivore	Larva feed almost exclusively on diatoms, though also pollen opportunistic; forage at night. Adults in forest near streams. Prey on invertebrates, mainly terres. but also aquatic forms	NA/NP	NA	NA		G4	S4	1949	2006	43
True Frogs (Ranidae)	Columbia Spotted Frog (*Rana luteiventris*)	Aquatic	Aquatic	Spotted frogs are regularly found at water's edge in or near forest openings. Wetlands at or near treeline are also used, but populations are uncommon in large, open intermountain valleys. Breeding takes place in lakes, ponds (temporary and permanent), sp	NA	Larvae: veg (Callitriche/Spirogyra) in Yellowstone. Adults: mainly ground insects in W MT: coleoptera 35%, hymenoptera 22%, arachnid 15%; others < 10%	NA	NA	NA		G4	S4	1922	2007	309
True Salamanders Plethodontidae)	Long-toed Salamander (*Ambystoma macrodactylum*)	Aquatic	Aquatic	Variety of habitats from sagebrush to alpine. They typically breed in ponds or lakes, usually those without fish present.	Insectivore	Larv: ostracods/cyclops; also red water mites, insect egg masses, algae. Adult: terres. arthropods (mostly formicid coleop, diptera) 74%; aq. insect larv. (mostly tri- chop) 37%	NA	NA	NA		G5	S4	1962	2007	246
True Frogs (Ranidae)	Northern Leopard Frog (*Rana pipiens*)	Aquatic	Aquatic	Low elevation and valley bottom ponds, spillway ponds, beaver ponds, stock reservoirs, lakes, creeks, pools in intermittent streams, warm water springs, potholes, and marshes. There is no evidence that this species in Montana has occupied high elevation wetlands, in contrast to Wyoming and Colorado	Invertivore	Metamorphosed frogs eat various small invertebrates, including various insects, spiders, leeches, and snails obtained along the water's edge or in nearby meadows or fields. They rarely eat small vertebrates. Larvae eat algae, plant tissue, organic debris, and probably some small invertebrates. In Montana, adults have been documented feeding on 10 orders of insects, spiders, mites, harvestmen, centipedes, millipedes, snails, and newly metamorphosed boreal toads	NA	NA	NA		G5	S1S3	1922	2006	14
True Toads (Bufonidae)	Western Toad (*Bufo boreas*)	Aquatic	Aquatic	Habitats used by boreal toads in Montana are similar to those reported for other regions, and include low elevation beaver ponds, reservoirs, streams, marshes, lake shores, potholes, wet meadows, and marshes, to high elevation ponds, fens	Insectivore	Five insect orders; spiders, daddy longlegs, and millipeds	NA/NP	NA	NA		G4	S2	1949	2006	126

Montana Species Ranking Codes: Montana employs a standardized ranking system to denote global (G - range-wide) and state status (S) (NatureServe 2003). Species are assigned numeric ranks ranging from 1 (critically imperiled) to 5 (demonstrably secure), reflecting the relative degree to which they are "at-risk". Rank definitions are given below. A number of factors are considered in assigning ranks - the number, size and distribution of known "occurrences" or populations, population trends (if known), habitat sensitivity, and threat.

G1 S1
At high risk because of extremely limited and potentially declining numbers, extent and/or habitat, making it highly vulnerable to global extinction or extirpation in the state.

G2 S2
At risk because of very limited and potentially declining numbers, extent and/or habitat, making it vulnerable to global extinction or extirpation in the state.

G3 S3
Potentially at risk because of limited and potentially declining numbers, extent and/or habitat, even though it may be abundant in some areas.

G4 S4
Uncommon but not rare (although it may be rare in parts of its range), and usually widespread. Apparently not vulnerable in most of its range, but possibly cause for long-term concern.

G5 S5
Common, widespread, and abundant (although it may be rare in parts of its range). Not vulnerable in most of its range.

Common Name (Genus/species)	Habitat Group: Foraging	Habitat Group: Nesting	General Habitat Description	Feeding Guild	Food	Migration	Longevity	Size	Home Range	Global Rank	State Rank	Observations in Lincoln, Co.,: Oldest	Most Recent	Number
American Bittern (*Botaurus lentiginosus*)	Riparian	Riparian	Freshwater wetlands with tall, emergent vegetation. Sparsely vegetated wetlands occasionally, tidal marshes rarely.	Aquatic Invertivore	Mainly insects, amphibians, crayfish and small fish and mammals.	Migratory	NA	706 g	NA	G4	S4B	1991	2006	3
American Coot (*Fulica americana*)	Riparian	Riparian	Marshy borders of ponds	Herbivore	Grains, grasses, and agricultural crops on land; however, it generally forages in or under water, where it is almost exclusively an herbivore	Migratory	NA	724 g	NA	G5	S5B	1991	2006	9
American Crow (*Corvus brachyrhynchos*)	Scavenger	NA	One of the most widespread of North American birds. Found in a wide variet of habitats, particularly in open landscapes, with scattered trees and small woodlots. Uses both natural habitats and those created by humans (logged, areas, agricultural fields, cities, and villages). Generally avoids large areas of forest	Omnivore	Wide variety of invertebrates (terrestrial and intertidal marine); amphibians; reptiles; small birds and mammals; birds' eggs, nestlings and fledglings; grain crops ; seeds and fruits; carrion; and discarded human food	Migratory	NA	316-575 g	spring-summer home range averaged 2.6 sq km	G5	S5B	1992	2006	40
American Dipper (*Cinclus mexicanus*)	Riparian	Riparian	Prefers fast-moving, clear streams along with waterfalls. Species prefers sand, pebble, or rocky stream bottoms, which provide sufficient aquatic invertebrates. Shorelines with large boulders, fallen trees, and rubble provide good shelter and protection from predators.	Aquatic Invertivore	aquatic invertebrates, insects, and insect larvae. Occ	Non-Migratory	NA	6 g	reported defense of up to 320 meters of stream in breeding season, and from 46-820 meters in nonbreeding season. Year-round density was 1.3 to 2.9 birds per kilometer of stream.	G5	S5	1991	2005	20
American Goldfinch (*Carduelis tristis*)	Arboreal/Shrub/Ground	NA	Widely distributed in temperate North America. Common in weedy fields, river flood plains, early second growth forest, and also cultivated lands, roadsides, orchards and gardens. in shaded locations under canopy of leaves or dense cluster of needles.	Grainivore	Feeds on seeds (e.g., birches, alders, conifers, thistles, goldenrod, etc.); eats some berries and insects. Small seeds of various trees. Insects only as encountered.	Migratory	NA	13 g	NA	G5	S5B	1991	1998	15
American Kestrel *(Falco sparverius*)	Ground	Arboreal/Cliffs/Cavity	found in nearly all habitats in Montana. Nests are often located in cavities in trees, banks, cliffs, and buildings. They also use man-made nest boxes. They usually hunt in open habitat. Kestrels often perch on overhead wires or posts while looking for prey, or hover in midair. In Bozeman area, summer birds are concentrated in the valley, but some birds are found far up mountain canyons; wintering birds tend to frequent irrigated areas	Carnivore	During the summer, kestrels feed heavily on large insects such as grasshoppers. Other prey includes small birds, rodents, and snakes. During winter they feed primarily on small birds and rodents.	Migratory	NA	160 g	Average territory size was 109.4 ha and 129.6 ha in two western U.S. studies (Cade 1982); home range diameter during the breeding season ranged from about 0.5 to 2.4 km in different region:	G5	S5B	1991	2006	49
American Redstart (*Setophaga ruticilla*)	Arboreal	Shrub	prefers second growth, deciduous woodlands usually near water. Often found in shrubby areas, along with alder and willow thickets	Invertivore	mainly of insects. In late summer months, small berries and fruits. Eats mostly forest tree insects, also spiders and some fruits and seeds	Migratory	NA	9 g	Less than 2 ha	G5	S5B	1991	2005	38
American Robin (*Turdus migratorius*)	Ground	Arboreal/Shrub	Most widespread North American thrush. Frequents forest, woodland, and gardens, breeding primarily where lawns and other short-grass areas are interspersed with shrubs and trees, such as residential areas, towns, farmyards, and parks	Invertivore	Eats worms, insects, and other invertebrates (mostly obtained on ground), and small fruits	Migratory	NA	77 g	Territory sizes average 3.65 acres in Douglas fir forests in western Montana.	G5	S5B	1991	2006	828
American Three-toed Woodpecker (*Picoides dorsalis*)	Arboreal	Dead tree - Cavity	Nesting habitat includes coniferous forests (with spruce, larch, or fir trees), or logged areas and swamps. A cavity nest is dug by both sexes and is placed 1.5 to 15 meters (5 to 50 feet) high in a stump or other dead or dying trees, often near water.	Invertivore	larvae of bark beetles. Also, tree sap and insects.	NA	NA	NA	breeding density hit 13.5 birds per 100 acres in lodgepole pine during a pine beetle epidemic, probably due to the ability of birds to nest in lodgepole pine. In Oregon, home ranges for 3 radioed individuals were 751, 351, and 131 acres.	G5	S3S4	1992	2005	57
American Wigeon (*Anas americana*)	Riparian	Riparian	Breeds near shallow, freshwater wetlands: sloughs, ponds, small lakes, marshes, and rivers. For nesting prefers areas with upland cover of brush/grass vegetation in the vicinity of lakes or marshy sloughs.		During winter and migration almost entirely vegetarian - stems and leafy parts of acquatic plants, leafy parts of upland grasses and leafy parts and seeds of various agricultural crops. During breeding season there is a shift toward a greater proportion of seeds and fruits and a substgantial shift toward more nonplant foods - insects, mollusks and crustaceans.	Migratory	NA	792 g	NA	G5	S5B	1986	2005	5

Common Name (Genus/species)	Habitat Group: Foraging	Habitat Group: Nesting	General Habitat Description	Feeding Guild	Food	Migration	Longevity	Size	Home Range	Global Rank	State Rank	Observations in Lincoln, Co.: Oldest	Most Recent	Number
Bald Eagle (*Haliaeetus leucocephalus*)	Riparian	Arboreal	Riparian and lacustrine habitats (forested areas along rivers and lakes), especially during the breeding season. Important year-round habitat includes wetlands, major water bodies, spring spawning streams, ungulate winter ranges and open water areas. Nesting sites are generally located within large forested areas near large lakes and rivers where nests are usually built in the tallest, oldest, large diameter trees. Nesting site selection is dependent upon maximum local food availability and minimum disturbance from human activity	Piscivore	The majority of diet is comprised of fish. Important prey for Bald Eagles are waterfowl, especially in the winter, salmonids, suckers, whitefish, carrion and small mammals and birds	Non Migratory	First breeds in 5-6 yr	5244 g	Defended territories are 11-45 hectares and average 23 ha and territory radius around active nests averaged 0.6 km. Feeding home ranges 7 square kilometers breeding home ranges averaged 21.6 square kilometers	G5	S3	1983	2005	325
Bank Swallow (*Riparia riparia*)	Riparian	Ground	Breeds primarily in lowland areas along ocean coasts, rivers, streams, lakes, reservoirs, and wetlands. Nesting colonies also found in artificial sites such as sand and gravel quarries and road cuts. Most rivers and streams with nesting habitats are low-gradient, meandering waterways with eroding streamside banks.	Aquatic Invertivore	Takes flying or jumping insects almost exclusively on the wing. Occasionally eats terrestrial and aquatic insects or larvae. Rare consumption of vegetable matter appears to be accidental.	Migratory	1 -2 yr	15 g	Most foraging flights within 0.8 kilometers of colony	G5	S5B	1993	1999	8
Barn Swallow (*Hirundo rustica*)	Aerial	Buildings	Originally nesting primarily in caves, it has almost completely converted to breeding under the eves of or inside artificial structures such as buildings and bridges. Presently found in various habitats, including agricultural areas, cities, suburbs, and along highways. Breeding habitat usually contains open areas (fields and meadows) for foraging, a nest site that includes a vertical or	Aerial Invertivore	Flying insects. Flies over open land and water and forages on insects; forages nearer to the ground than other swallows (usually not greater than 10 meters and often less than 1 meter above the ground) Feeds opportunistically on a wide variety of flying insects;	Migratory	NA	17-20 g	Usually forages within a few hundred meters of nest when breeding.	G5	S5B	1991	2005	14
Barred Owl (*Strix varia*)	Carnivore	NA	Restricted to forested areas, ranging from swamps and riparian areas to upland regions. Large, unfragmented blocks of forests preferred. Throughout its range, found in association with mature and old growth forests, typically of mixed deciduous-coniferous compositio	Carnivore	An opportunistic predator, consuming small mammals and rabbits, birds up to the size of grouse, amphibians, reptiles, and invertebrates	Non-Migratory	NA	801 g	Home range usually is less than 400 ha (but up to 760 ha) over 2-7 months, average 273 hectares	G5	S4	1995	2004	13
Barrow's Goldeneye (*Bucephala islandica*)	Riparian	NA	Chiefly a bird of the western montane region of North America. This species is generally restricted to areas west of the Continental Divide. Prefers alkaline to freshwater lakes in parkland areas; to lesser extent, subalpine and alpine lakes, beaver ponds, and small sloughs. In summer usually found in small, scattered groups. In winter often seen in large flocks.	Aquatic Invertivore	Aquatic invertebrates (insects, mollusks, crustaceans) and fish eggs. Seeds and tubers provide a small fraction of the diet	Non Migratory	NA	1090 g	NA	G5	S5B	1987	1995	6
Belted Kingfisher (*Megaceryle alcyon*)	Riparian	Riparian - Burrow	Inhabits streams, rivers, ponds, lakes, and estuaries or calm marine waters in which prey are clearly visible. Availability of suitable nesting sites - earthen banks where nesting burrows can be excavated - appears critical for the distribution and local abundance of this species. Prefers to excavate a nesting burrow near its fishing territory. Needs clear still waters for fishing.	Piscivore	Chiefly fish. Also mollusks, crustaceans, insects, amphibians, reptiles, young birds, small mammals, even berries.	Migratory	NA	148 g	Regularly forages up to 8 km from the nest	G5	S5B	1991	2006	15
Black-backed Woodpecker (*Picoides arcticus*)	Arboreal	Arboreal	Early successional, burned forest of mixed conifer, lodgepole pine, Douglas-fir, and spruce-fir (Hutto 1995a, 1995b), although they are more numerous in lower elevation Douglas-fir and pine forest habitats than in higher elevation subalpine spruce forest habitats	Invertivore	Bulk of the diet is wood-boring beetle larvae (including Monochamus spp. and Englemann spruce beetle, Dendroctonus englamanni), but they also feed on other insects (e.g., weevils, beetles, spiders, ants). Occasionally they will eat fruits, nuts, sap, and cambium. obtain food by flaking bark from trees (usually dead conifers) and logs, sometimes by picking gleaning. They feed primarily on logs and low on large-diameter tree trunks (more than 7.5 centimeter diameter at breast height; but most often 15-25 centimeter dbh)	Non Migratory	NA	72 g	178, 307, and 810 acres	G5	S2	1987	2005	37
Black-billed Magpie (*Pica hudsonia*)	Ground	Arboreal	Historically, it frequently followed Native Americans and lived on the refuse of their hunts. In breeding season will be found in thickets in riparian areas, often associated with open meadows, grasslands, or sagebrush for foraging. Less specific in its habitat requirements in nonbreeding season. Frequently numerous near human habitats such as livestock feedlots, barnyards, landfills, sewage lagoons, and grain elevators. Nests are durable, domed structures of sticks, with mud cup and anchor. Generally prefers high trees. Have been know to nest on utility poles.	Omnivore	Ground-dwelling arthropods, seeds, and carrion	Non Migratory	NA	189 g	NA	G5	S5	1993	1998	12

Common Name (Genus/species)	Habitat Group: Foraging	Habitat Group: Nesting	General Habitat Description	Feeding Guild	Food	Migration	Longevity	Size	Home Range	Global Rank	State Rank	Observations in Lincoln, Co.,: Oldest	Most Recent	Number
Black-capped Chickadee (*Poecile atricapillus*)	Arboreal/ Shrubs	Arboreal - Cavity	Deciduous and mixed deciduous/coniferous woodland, open woods and parks willow thickets, and cottonwood groves. Also disturbed areas such as old fields or suburban areas. Generally more common near edges of wooded areas. Nests in cavities. Natural sites typically in trees, especially dead snags or rotten branches, sometimes old woodpecker holes or even in bird boxes.	Invertivore	Eats mainly insects and other small invertebrates, and their eggs and immature stages, and seeds and fruits; forages mainly on woody twigs, branches, and stems	Non Migratory	NA	11 g	Territory size averaged about 8 9 ha	G5	S5	1992	2006	316
Black-chinned Hummingbird (*Archilochus alexandri*)	Shrub/Groun d	Riparian	In the arid western portion of range, nests in environments that often include cottonwood, sycamore, willow, salt-cedar, sugar-berry, and oak. In most regions, its preferred habitat is a canyon or flood-plain riparian community. Nests typically in riparian habitats. Nest is a cup shape, primarily composed of plant down.	Nectarivore	Main foods taken include nectar from flowers; small insects and spiders; sugar water from feeders provided by humans	Migratory	NA	4 g	NA	G5	S4B	1993	2006	19
Black-headed Grosbeak (Pheucticus melanocephalus)	Arboreal	Arboreal	Occupies diverse habitats. Cottonwood/willow groves and other riparian habitats in desert and dry grassland; openings in mature pine forest; aspen groves; deciduous growth especially in mountain valleys/canyons; pinyon-juniper woodlands; oak savanna; gardens; orchards. Relatively tolerant of human disturbance. Nests widely reported to be so thinly constructed that eggs can be seen through bottom. Nests are generally well concealed among foliage of branches.	Omnivore	Insects and spiders; cultivated fruit, wild fruit, weed seeds, and grains. During breeding season, gleans insects high in trees and in understory.	Migratory	NA	47 g	NA	G5	S5B	1993	2002	38
Blue Jay (*Cyanocitta cristata*)	Ground	Arboreal	Primarily inhabits deciduous, coniferous, and mixed forests and woodlands. Common in towns and residential areas, especially those having large oaks or other mast-producing trees.	Omnivore	Arthropods, acorns and other nuts, soft fruits, seeds, small vertebrates.	Migratory	NA	87 g	NA	G5	S5N	1988	2002	5
Blue-winged Teal (*Anas discors*)	Riparian	Riparian	Main habitat consists of shallow ponds with adequate supplies of aquatic invertibrates. Prefers to nest in grass or herbaceous vegetation and rarely uses brushy nesting cover.	Omnivore	Diet consists of aquatic inveritbrates, seeds, vegetative parts of aquatic plants, duckweeds, algae, and occasional grains from agricultural crops. Animal matter dominates diet of laying females.	Migratory	NA	409 g	NA	G5	S5B	1992	1998	6
Bohemian Waxwing (*Bombycilla garrulus*)	Arboreal	Arboreal	Prefers open coniferous or mixed-coniferous and deciduous forests. Often found in recently burned areas or near lakes and streams, beaver ponds, and swamps.	Frugivore, Invertivore	Sugary fruits and insects. During spring, also tree sap and budding flowers.	Migratory	NA	56 g	NA	G5	SHB, S5N	1920	1993	4
Boreal Chickadee (*Poecile hudsonica*)	Arboreal	Arboreal	boreal coniferous and mixed forests, muskeg bogs, in the vicinity of white cedar and hemlock swamps, birches and streamside willows. The species nests in natural cavities or abandoned woodpecker holes, or in a cavity dug by a pair in a rotten tree stub, usually within 1 meter of the ground (but up to 3.7 m).	Omnivore	conifer and birch seeds, and the eggs, larval stages, and adults of insects. It forages mainly on twigs and branches of trees.	Non-Migratory	NA	10 g	NA	G5	S1S2	1994	2005	13
Boreal Owl (*Aegolius funereus*)	Carnivore	Arboreal	High elevation spruce/fir forest, with lodgepole pine sometimes present. Mature spruce/fir forests with multilayered canopies and a highly complex structure, at elevations greater than 1500m with a mosaic of openings or meadows. roost at sites scattered throughout their home range, rarely in the same stand on consecutive nights or the same tree more than 2X per year. Roost alone, usually far from their nest and mate	Carnivore	Predominately small mammals, with a few birds and insects	Non-Migratory	NA	167 g	NA	G5	S4	1986	1996	35
Brewer's Blackbird (*Euphagus cyanocephalus*)	Ground	NA	Open, human-modified habitats such as residential lawns, golf courses, cemeteries, mowed urban parks and campus areas. Also found in large clearcut forests and plowed fields	Omnivore	During breeding season, diet consists of insects and other invertebrates, along with grains and weed seeds. During migration and winter, diet consists of primarily vegetarian such as waste grains, weed and grass seeds.	Migratory	NA	67 g	NA	G5	S5B	1991	2006	11
Brown Creeper (*Certhia americana*)	Arboreal	Arboreal	Late successional stages of coniferous forests and mixed coniferous-deciduous forest. Especially common in unlogged, old-growth stands. The consistent factor appears to be the need for large trees and snags (dead trees) for foraging and nesting microsites. Breeding season is the same as winter, but possible no vegetable matter is eaten. Nest built in 2 parts, base and nest cup, behind a piece of peeling bark.	Invertivore	Forages primarily on trunks of live trees. In winter main foods taken include a variety of insects and larvae, spiders and their eggs, ants, and pseudeoscorpions; a small amount of seeds and other vegetable matter.	Altitudinal	NA	8 g	Territories ranged from 2.3 to 6.4 ha	G5	S4	1992	2004	225
Brown-headed Cowbird (*Molothrus ater*)	Ground	Brood parasite	Areas with low or scattered trees among grassland vegetation€"woodland edges, brushy thickets, prairies, fields, pastures, orchards, or even residential areas. Species is a brood parasite; nests are chosen by females, but are that of another species. Care given to cowbird eggs and young is provided by the host and reflects characteristics of that species.	Omnivore	Mainly of anthropods and seeds.	Migratory	NA	adult male is 39-57 g, female is smaller	NA	G5	S5B	1992	2006	102

Common Name (Genus/species)	Habitat Group: Foraging	Habitat Group: Nesting	General Habitat Description	Feeding Guild	Food	Migration	Longevity	Size	Home Range	Global Rank	State Rank	Observations in Lincoln, Co.,: Oldest	Observations in Lincoln, Co.,: Most Recent	Observations in Lincoln, Co.,: Number
Bufflehead (*Bucephala albeola*)	Riparian	Riparian	Freshwater, permanent ponds with no outlet or only seasonal outflow, and small lakes. Large lakes are avoided except by molting flocks. habit of nestin in the holes of the Northern Flicker. Will also nest in boxes.	Aquatic Invertivore	Main foods taken are aquatic invertebrates (insects, crustaceans, mollusks). Will take some seeds.	Migratory	NA	473 g	NA	G5	S5B	1995	2006	5
Bullock's Oriole (*Icterus bullockii*)	Arboreal	Arboreal	Prefers open woodland areas, especially riparian (river) woodlands with large cottonwoods, sycamores, and willows. During spring and fall migration it is found in a variety of open woodland and urban parklands and tall shrubland. Nests are typically pensile, often suspended from a few thin branches.	Invertivore	Mostly insects, especially butterfly and moth larvae and pupae, grasshoppers and crickets, beetles and other insects.	Migratory	NA	34 g	Females foraged regularly more than 200 meters from nest, and up to 1 kilometer	G5	S5B	1993	2004	2
California Gull (*Larus californicus*)	Riparian	Riparian	Prefers larger lakes, but also occurs on ponds and rivers, especially in spring and fall. Nests varied in shape from depressions in the ground to constructed mounds; they were located 2 to 75 feet apart	Aquatic Invertivore	Insects, oligochaetes, crustaceans, amphibians and birds, and plant material believed to be ingested incidentally to consuming animals	Migratory	NA	609 g	Breeding pairs in MT foraged an average of 17.4 km (maximum 61 km) from colony. At another colony, maximum foraging distance was 32 km	G5	S5B	1991	1995	3
Calliope Hummingbird (*Stellula calliope*)	Aerial	Arboreal	Mountains; along meadows, canyons and streams. Open montane forest, mountain meadows, and willow and alder thickets, gardens; in migration and winter also in chaparral, lowland brushy areas, deserts. Nests in tree (frequently conifer) at edge of meadow or in canyon or thicket along stream. Nests <1-21 m above ground (usually low, with branch or foliage above). Nectar supply unimportant in location of male's breeding territory In Bozeman area occurs on thickety hillsides and in forest openings to moderate elevations in the mountains.	Aerial Invertivore	Floral nectar and small insects. Like other hummingbirds, it forages aerially for small insects.	Migratory	NA	3 g	NA	G5	S5B	1991	2004	40
Canada Goose (*Branta canadensis*)	Ground	Riparian	Various habitats near water, from temperate regions to tundra. In migration and winter, coastal and freshwater marshes, lakes, rivers, fields, etc. Breeds i open or forested areas near lakes, ponds, large streams, inland and coastal marshes. The nest is built on the ground or on an elevated place (muskrat house, abandoned heron's nest, rocky cliffs, etc.). Usually returns to nesting territory used in previous year.	Herbivore	Grazes on marsh grasses, sprouts of winter wheat (spring), grain (fall); eats clover, cattails, bulrushes, algae, pond- weed, and other plants. Feeds in shallows, marshes, fields. Also eats mollusks and small crustaceans	Migratory	Begin breeding at 2 years, most by age 3 years.	4741 g	NA	G5	S5B	1991	2006	33
Canvasback (*Aythya valisineria*)	Riparian	Riparian	Breeds in small lakes, deep-water marshes, sheltered bays of large fresh wate and alkali lakes, permanent and semi permanent ponds, sloughs, potholes, an shallow river impoundments. In aspen parklands and mixed-grass prairie, prefers wetlands bordered by dense emergent vegetation. In boreal forest, utilizes open marshes. Nest is a large bulky structure. May be overtopped by vegetation and may have one or more well-maintained ramps.	Omnivore	Foods vary depending upon availability. During winter and migration, mainly plants (winter buds, rhizomes, and tubers or aquatic plants. When plant food is limited, may take small clams and snails.	Migratory	NA	1248 g	NA	G5	S5B			2
Canyon Wren (*Catherpes mexicanus*)	Ground	Ground/Cliffs and Rock Outcops	Limited to cliffs, steep-sided canyons, rocky outcrops, and boulder piles, usually in arid regions. Inhabits the same territories year-round. Also sometimes found in towns, around houses and barns, on old stone buildings. Nests on canyon walls; may also nest around human-built structures.	Invertivore	Uses its long, decurved bill and flattened head to probe for spiders and insects in rock crevices	Non-Migratory	NA	39 g	NA	G5	S4	1995	1995	2
Cassin's Finch (*Carpodacus cassinii*)	Arboreal	Arboreal	Prefers open coniferous forests of interior western mountains along with mature forests of lodgepole pine. Nests in conifer, 3-25 m above ground, on outer end of limb; may sometimes nest in deciduous tree or in shrub. May return to same nesting area in successive years, though this may be unusual	Herbivore	Consists of mostly vegetable matter, particularly buds, seeds, berries and other fruits, along with some insects.	Migratory	Breeds at 1-2 yr	27 g	NA	G5	S5	1990	2004	155
Cassin's Vireo (*Vireo cassinii*)	NA	NA	Prefer dry, open forests. Occupies coniferous, mixed-coniferous/deciduous, and deciduous forests in mountains and foothills.	Omnivore	Diet consists almost exclusively of arthropods, spring through autumn. Winter diets consists of fleshy fruits.	NA	NA	NA	NA	G5	S4B	1994	2005	733
Cedar Waxwing (*Bombycilla cedrorum*)	Arboreal	NA	Habitats include deciduous, coniferous, and mixed woodlands6”especially open forests and riparian areas of deserts and grasslands; farms, orchards, conifer plantations, and suburban gardens also popular.	Frugivore, Invertivore	Diet consists of fleshy fruits and insects. Feeds opportunistically on small fruits, in spring and summer also various insects. May consume maple tree sap and flower petals. Apparently cannot maintain positive energy balance when feeding solely on high-sucrose fruits.	Migratory	NA	33 g	NA	G5	S5B	1992	2006	61

	Habitat Group											Observations in Lincoln, Co.,		
Common Name (Genus/species)	**Foraging**	**Nesting**	**General Habitat Description**	**Feeding Guild**	**Food**	**Migration**	**Longevity**	**Size**	**Home Range**	**Global Rank**	**State Rank**	**Oldest**	**Most Recent**	**Number**
Chestnut-backed Chickadee (*Poecile rufescens*)	Arboreal	Arboreal	humid coastal and interior forests from southeastern Alaska to southern California. Year-round resident throughout its range. Occurs within the densest coniferous forests, or along edges, where temperature is even and there is considerable shade. Nests in tree cavities and readily colonizes available nest boxes.	Invertivore	Insects and arthropods make up approximately 65% of the diet. Seeds and plant material make up the rest. Eats mainly insects gleaned from twigs, branches, and trunks of trees and shrubs; in the breeding season, forages often on outer foliage (needles, leaves, or buds); also eats spiders, some fruit, conifer seeds	Non-Migratory	NA	10 g	NA	G5	S4	1991	2005	119
Chestnut-sided Warbler (*Dendroica pensylvanica*)	Arboreal	Shrub	Nesting in shrubby habitat close to the ground, sometimes deciduous trees. In new, second-growth thickets of alder and other deciduous bushes growing in scrubby clearings and brushy areas or along the margins of streams, in orchards, pasturelands, forest edges, cut-over forests, roadsides, in open deciduous woodlands and in powerline corridors. Becomes most common in deciduous second growth or large forest clearings. Avoids deep woods.	Invertivore	Eats primarily the larvae and some adults of Lepidoptera and Diptera, some spiders, and some seeds and fruit as well . Usually forages alone. Gleans the undersurfaces of leaves at the low to medium levels in shrubs and the lower branches of small trees, but may feed in the upper canopy	Migratory	NA	10 g	NA	G5	SNA	1972	1993	2
Chipping Sparrow (*Spizella passerina*)	Ground	Arboreal	Prefers open woodlands, the borders of natural forest openings, edges of rivers and lakes, and brushy, weedy fields. It has a preference for nesting in open glades of coniferous forests, and for foraging in brushy open areas making it suited to human-modified habitats. Nests in a wide variety of trees and shrubs; has a distinct preference for conifers. Nest is a loosely woven cup.	Herbivore	Feeds primarily on seeds of grasses and various annual plants, infrequently supplementing this diet with small fruits. Adds insects and other invertebrates when breeding. Mainly forages on the ground, but also in foliage.	Migratory	NA	NA	Territory sizes of 1.1 to 1.8 acres	G5	S5B	1989	2006	969
Cinnamon Teal (*Anas cyanoptera*)	Riparian	Riparian	Prefers wetlands including large marsh systems, natural basins, reservoirs, sluggish streams, ditches, and stock ponds. Well-developed basins with emergent vegitation common habitat.	Omnivore	Seeds and aquatic vegetation, aquatic and semi-terrestrial insects, snails, and zooplankton.Feeds on aquatic plants in shallow water areas; especially on rush seeds, pondweed seeds and leaves, and salt grass seeds. Also eats small amounts of animal food especially insects and mollusks	Migratory	NA	408 g	NA	G5	S5B	1991	1993	3
Clark's Nutcracker (*Nucifraga columbiana*)	Arboreal	Arboreal	Found in close association with ponderosa pine, Douglas fir, and white-bark pine. Usually nests at elevations between 1800 and 2500 m. Nests on outer end of branch of a conifer, 2-45 m above ground.	Grainivore	Fresh and stored pine seeds. Also eats insects, acorns, berries, snails, carrion; sometimes eats eggs and young of small birds.	Non Migratory	NA	141 g	Foraging 0.8 to 2.4 km from nest, summer home range of 1500 ha (4.4. km in diameter). Year-round home ranges are much larger: 15,000 ha in areas of good food	G5	S5	1991	2005	130
Clay-colored Sparrow (*Spizella pallida*)	Ground	NA	Prefers open shrubland, thickets along edges of waterways, second-growth areas, and forest edges and burns	Omnivore	Feeds on a wide variety of seeds; during the summer eats insects. Forages on or near the ground. When breeding, feeds in area separate from nesting territory	Migratory	NA	NA	Nesting territories about 0.1 to 0.5 ha and 0.04-0.1 ha.	G5	S4B	1995	2004	24
Cliff Swallow (*Petrochelidon pyrrhonota*)	Aerial	Cliffs/Eaves	Open to semiwooded habitat, cliffs, canyons, farms; near meadows, marshes, and water. Builds bottle shaped mud nest in colonies on cliffs, eaves of buildings, under bridges, etc. Prefers sites with overhang.	Aerial Invertivore	Flying insects at all times of the year. Insects taken reflect local availability.	Migratory	NA	22 g	Forages usually within 0.5 km of colony	G5	S5B	1992	2005	13
Common Goldeneye (*Bucephala clangula*)	Riparian	Riparian	Breeding birds usually are found in forested wetland habitats	Aquatic Invertivore	During breeding season, primarily insectivorous and prefers lakes (often fishless) with abundant aquatic invertebrates. Fish, crustaceans, and mollusks become a more important part of the diet in winter.	Migratory	NA	1000 g	NA	G5	S5	1977	2006	10
Common Merganser (*Mergus merganser*)	Riparian	Riparian	Occur on large lakes and large rivers. During migration, most birds are on lakes	Piscivore	Eats primarily small fish, but will also eat insects, mollusks, crustaceans, worms, frogs, small mammals, birds, and plants	Migratory	Breeds at end of 2nd yr	1709 g	NA	G5	S5B	1977	2000	21
Common Nighthawk (*Chordeiles minor*)	Aerial	NA	Coastal sand dunes and beaches, woodland clearings, prairies and plains, and flat gravel rooftops of city buildings. During times of migration, habitat includes farmlands, river valleys, marshes, and coastal dunes.	Invertivore	Diet consists solely of flying insects	Migratory	NA	64 g	NA	G5	S5B	1992	2006	39

Common Name (Genus/species)	Habitat Group: Foraging	Habitat Group: Nesting	General Habitat Description	Feeding Guild	Food	Migration	Longevity	Size	Home Range	Global Rank	State Rank	Observations in Lincoln, Co.,: Oldest	Observations in Lincoln, Co.,: Most Recent	Observations in Lincoln, Co.,: Number
Common Raven (*Corvus corax*)	Ground	NA	Broad range of habitats: boreal, conifer, and deciduous forests; tundra; prairies and grasslands; isolated settlements, towns, and cities; deserts; sea coasts and islands; agricultural fields; Arctic ice floes; and the highest mountains. It is one of the most widespread naturally occurring birds in the world.	Omnivore	Diverse diet includes arthropods (even scorpions), amphibians, reptiles, birds (adults, chicks, and eggs), small mammals, carrion, grains, buds, and berries.	Non Migratory	NA	689-1,625 g.	Home range size of breeding birds reported at 0.2-4.4, 6.6, 9.4 and 40.5 sq km.	G5	S5	1991	2006	592
Common Redpoll (*Carduelis flammea*)	Ground/Trees	Arboreal	Open subarctic, largely coniferous forest and scrub, on dry, rocky, or damp substrates; level or steeply sloped; avoids dense forest; occurs on tundra and above timberline only where shrubby deciduous and sometimes coniferous vegetation occurs in hollows and sheltered places. Nests are built on loose foundation of small twigs laid across adjacent branches out from trunk of small spruce or in crotch of alder or willow. Forages in trees or on the ground.	Grainivore, Invertivore	Very small seeds and other plant material throughout the year. Also arthropods, particularly in summer when feeding young	Migratory	NA	13 g	move up to 20 km while foraging	G5	S5N	1990	1990	3
Common Yellowthroat (*Geothlypis trichas*)	Ground	Ground	Occupies thick vegetation in wide range of habitats from wetlands to prairie to pine forest. Nests just above ground or over water, in weeds, reeds, cattails, tules, grass tussocks, brier bushes, and similar situations; often at base of shrub or sapling, sometimes higher in weeds or shrubs up to about 1 m.	Invertivore	Eats various small invertebrates obtained among low plants	Migratory	NA	10 g	NA	G5	S5B	1992	2006	37
Cooper's Hawk (*Accipiter cooperii*)	NA	Arboreal	Nest in dense deciduous and coniferous forest cover, often in draws or riparian areas. They hunt in these areas or in adjacent open country	Carnivore	Small to medium-sized birds comprise most of the diet of Cooper's hawks, although they also eat small mammals	Migratory	NA	529 g	3.2 km from nest	G5	S4B	1991	2005	11
Cordilleran Flycatcher (*Empidonax occidentalis*)	Aerial/ Arboreal	Ground/Arboreal	Coolness, shade, and nest sites" are requisites, and this species, from Alberta to n. Mexico, "invariably associated with water courses, and thus openings, in the timber. Has been know to nest in rocky outcroppings near water, in natural nest cavities in live trees (quaking aspen, Douglas fir), tree stumps, and about mountain cabins.	Invertivore	Feeds almost exclusively on insects caught in the air or gleaned from foliage of trees and shrubs.	Migratory	NA	NA	NA	G5	S5	1993	2004	22
Dark-eyed Junco (*Junco hyemalis*)	Ground	Ground-Cavity	Occurs across the continent from northern Alaska south to northern Mexico. Conspicuous ground-foraging flocks are often found in suburbs (especially at feeders), at edges of parks and similar landscaped areas, around farms, and along rural roadsides and stream edges. Most often in small cavity on sloping bank or rock face, under protruding rock, among roots (especially on vertical surface of root ball of large trees topple by wind), and in sloping road cut (especially if overhung by grass or other vegetation).	Omnivore	Seeds and arthropods; occasionally fruit and waste grain in agricultural fields. Most food obtained from ground and leaf litter	Migratory	NA	2 g	Territory sizes form of 1.7 to 2.6 acres	G5	S5B	1991	2006	1977
Dark-eyed Junco (Oregon) (*Junco hyemalis oreganus*)	Ground	Ground/Rock/Cavity	Occurs across the continent from northern Alaska south to northern Mexico. Conspicuous ground-foraging flocks are often found in suburbs (especially at feeders), at edges of parks and similar landscaped areas, around farms, and along rural roadsides and stream edges. Nest site highly variable. Most often in small cavity on sloping bank or rock face, under protruding rock, among roots (especially on vertical surface of root ball of large trees topple by wind) and in sloping road cut (especially if overhung by grass or other vegetation).	Omnivore	Seeds and arthropods; occasionally fruit and waste grain in agricultural fields. Most food obtained from ground and leaf litter	NA	NA	NA	NA	G5T5	SNR	1994	2000	11
Downy Woodpecker (*Picoides pubescens*)	Arboreal	Arboreal	Open riparian and deciduous woodlands throughout its entire range. Also use wooden human-made structures in urban areas. Nests mostly in hole dug by both sexes in dead stub of tree, also in live tree (especially dead part), fenceposts; 1-15 m above ground.	Invertivore, Frugivore	Insects, including adults, larvae, pupae, and eggs, obtained from bark of trees; also eats berries and nuts	Non Migratory	NA	27 g	NA	G5	S5	1991	2004	43
Dusky Flycatcher (*Empidonax oberholseri*)	Aerial	Shrub	Open coniferous forest, mountain chaparral, aspen groves, streamside willow thickets and brushy open areas. In MT, Nests were in small bush crotches; the average nest height was 5 fee	Aerial Invertivore	aerial forager - a sit and wait predator. It eats flying insects, occasionally pounces on prey on the ground	Migratory	NA	10 g	NA	G5	S5B	1993	2005	316
Dusky Grouse (*Dendragapus obscurus*)	Ground	NA	Winter at high elevations in conifer stands. In early spring, they descend to lower altitudes, where they prefer forest edges and openings	Omnivore	In winter they eat mainly conifer needles. In summer they eat a mixed diet of insects, green plants and berries. The young eat mainly insects	Altitudinal	NA	1188 g	Brood movement in summer is generally less than 0.5 mile	G5	S5	1977	2006	21
Eared Grebe (*Podiceps nigricollis*)	Riparian	Riparian	Shallow lakes and ponds with vegetation and macro invertebrate communities rarely on ponds with fish. They prefer saline habitats at all seasons, allowing them to escape fish predators and have an abundant of invertebrates.	Aquatic Invertivore	large variety of aquatic prey, mainly invertebrates, small crustations, insects, and less often small fish, mollusks, amphibians.	Migratory	NA	297 g	NA	G5	S5B	1993	1995	4

Common Name (Genus/species)	Habitat Group: Foraging	Habitat Group: Nesting	General Habitat Description	Feeding Guild	Food	Migration	Longevity	Size	Home Range	Global Rank	State Rank	Observations in Lincoln, Co.,: Oldest	Observations in Lincoln, Co.,: Most Recent	Observations in Lincoln, Co.,: Number
Eastern Kingbird (*Tyrannus tyrannus*)	Aerial	NA	Open environments along forest edges and fields. Also orchards and scattered shrubs and trees favorable.	Aerial Invertivore	Eats mainly insects obtained by flycatching from perch; also eats seeds and small fruits, and may pick food from ground or water surface	Migratory	NA	40 g	NA	G5	S5B	1991	2006	13
European Starling (*Sturnus vulgaris*)	Ground	Ground/Arboreal	Exotic species. Non-Native. Owing to their close association with man and behavioral plasticity, starling inhabit a wide variety of areas if a few crucial needs are met. They forage in open country on short, mown, or grazed fields - abundantly available in urban as well as agricultural areas. These areas also provide the necessary food resources, nesting cavities, and water. Nests can be found virtually anywhere a cavity can be found. Preferred sites include cavity-like openings in buildings, nest-boxes, cavities usurped from woodpeckers, and natural cavities in trees. Found occasionally without a cavity in dense vegetation in trees or on the ground.	Omnivore	Extremely diverse diet that varies geographically, with the age of individuals, and with season. Generally will eat invertebrates when available, fruits and berries, grains and certain seeds during other times of the year. Most foraging time is spent in open areas with short vegetation.	Non Migratory	NA	85 g	NA	G5	SNA	1991	2006	18
Evening Grosbeak (*Coccothraustes vespertinus*)	Arboreal	Arboreal	Common in mixed-conifer and spruce-fir forests, less common in pine-oak, pinon, Cascadian, ponderosa pine and aspen forests. Less closely tied to coniferous tree species than other carduelines-also uses deciduous species for nesting and food. Nests primarily in trees but also in shrubs, a spare structure, shaped like flattened saucer.	Omnivore	Invertebrates, especially spruce budworm and other larvae; wide variety of small fruits and seeds, especially maples	Migratory	NA	60 g	NA	G5	S5	1992	2003	154
Flammulated Owl (*Otus flammeolus*)	Ground	Arboreal	Associated with mature and old-growth xeric ponderosa pine/Douglas-fir stands and in landscapes with higher proportions of suitable forest and forest with low to moderate canopy closure. They are absent from warm and humid pine forests and mesic ponderosa pine/Douglas-fir. Most often nests in an abandoned tree cavity made by Pileated Woodpecker , flicker, sapsucker or other large primary cavity nester, at heights from 1 to 16 meters	Invertivore	Hunt at night and eat nocturnal arthropods. Feeds on various insects (e.g., moths, beetles, grasshoppers, crickets, caterpillars;	Migratory	NA	47 g	Territory size about 5.2 sq km	G4	S3B	1992	2005	32
Fox Sparrow (*Passerella iliaca*)	Ground	NA	Areas of thick cover, usually around forest edges and brushy woodland edges. Also found in grown-up fields, cut-over woodland, and scrubby woods.	Omnivore	Forages on the ground for seeds (e.g., smartweed, ragweed). Also eats berries (e.g., blueberries, elderberries) grapes and other fruits. Diet consists mainly of insects. Other food sources include seeds, fruit and plant matter.	Migratory	NA	30 g	NA	G5	S5B	1991	2005	192
Gadwall (*Anas strepera*)	Riparian	Riparian	Nest density was highest in saline lowlands, followed by dense nesting cover, panspots, and silty/ shallow clay. Nest success was highest in saline lowlands, then clay, panspots, silty sites and dense cover	Herbivore	Mainly of submerged aquatic vegitation, seeds and aquatic invertibrates.	Migratory	NA	990 g	NA	G5	S5B	1995	2006	4
Golden Eagle (*Aquila chrysaetos*)	Carnivore	Arboreal/Cliffs	Nest on cliffs and in large trees (occasionally on power poles), and hunt over prairie and open woodlands.	Carnivore	Primarily jackrabbits, ground squirrels, and carrion (dead animals). They occasionally prey on deer and antelope (mostly fawns), waterfowl, grouse, weasels, skunks, and other animals.	Migratory	NA	4,692 g	Territory size in several areas of the western U.S. averaged 57-142 sq km	G5	S4	1997	2000	4
Golden-crowned Kinglet (*Regulus satrapa*)	Arboreal	Arboreal	Nests in forests with closed or open canopies, edges of clearings, or near water	Invertivore	Feeds primarily on insects and their eggs (e.g., bark beetles, scale insects, aphids). Also drinks tree sap and eats some fruit and seeds (rare). Young are fed various insects and other small arthropods and sometimes small snails	Migratory	NA	6 g	Territory size in northern Minnesota was 2.1-6.2 acres (mean 4.1 acres)	G5	S5	1991	2005	818
Gray Catbird (*Dumetella carolinensis*)	Shrub	Shrub	Throughout range found in dense shrubs or vine tangles; most abundant in shrub-sapling-stage successional habitats. Also found in forest edges and clearings, roadsides, fencerows, abandoned farmland and home sites, pine plantations, streamsides, and some residential areas. Uncommon in areas dominated by conifers.	Omnivore	Main foods taken include insects and small fruits	Migratory	NA	37 g	NA	G5	S5B	1994	2005	16

Common Name (Genus/species)	Habitat Group: Foraging	Habitat Group: Nesting	General Habitat Description	Feeding Guild	Food	Migration	Longevity	Size	Home Range	Global Rank	State Rank	Observations in Lincoln, Co.,: Oldest	Observations in Lincoln, Co.,: Most Recent	Observations in Lincoln, Co.,: Number
Gray Jay (*Perisoreus canadensis*)	Arboreal	Arboreal	A widespread resident of North America's boreal and sub-alpine coniferous forests. Nests of low to moderate height, often 1 or 2 trees north of north edge of open bog, road allowance, or other break in the forest.	Omnivore	Arthropods, berries, carrion, nestling birds, fungi. Copious sticky saliva from enlarged salivary glands is used to fasten food items in trees, food that is used extensively by pairs throughout the winter and even during other times of the year.	Non Migratory	NA	71 g	NA	G5	S5	1991	2006	328
Gray Partridge (*Perdix perdix*)	Ground	NA	Exotic species. Non-native. Habitat consists of a mixture of cultivated and noncultivated land; grasslands interspersed with wheat fields, weed patches, and brushy cover. Optimum conditions are a cool, moderately dry climate an a mixture of cultivated and noncultivated land. Grain fields and winter wheat stubble are also used. Field edges provide escape and winter cover	Grainivore	Waste grain is a staple fall and winter food. Weed seeds and insects are summer food. Feeds primarily on seeds of wheat, corn, barley, oats, smartweeds, lambs's quarters, crabgrass, etc. Also eats leaves of clover, alfalfa, bluegrass, dandelion, etc. Chicks feed on insects for first few weeks of life.	Non Migratory	NA	398 g	In New York, home range size was 82-672 ha, did not differ by season	G5	SNA			2
Great Blue Heron (*Ardea herodias*)	Riparian	Riparian	Nested primarily in cottonwoods in riparian zones, and also in drier, coniferous sites. Nesting trees are the largest available. Active colonies are farther from rivers than inactive colonies. The number of nests in the colony corresponded to the distance from roads	Piscivore	Feeds mostly in slow moving or calm freshwater. Eats mostly fish but also amphibians, invertebrates, reptiles, mammals, and birds.	Migratory	NA	2,576	NA	G5	S3S4	1981	2006	36
Great Gray Owl (*Strix nebulosa*)	Carnivore	Dead Trees	Use lodgepole pine/Douglas-fir in Montana. Habitat is dense coniferous and hardwood forest, especially pine, spruce, paper birch, poplar, and second-growth, especially near water. They forage in wet meadows, boreal forests and spruce-tamarack bogs in the far north, and coniferous forest and meadows in mountainous areas. Nest in the tops of large broken-off tree trunks (especially in the south), in old nests of other large birds (e.g., hawk nest) (especially in the north), or in debris platforms from dwarf mistletoe, frequently near bogs or clearings.	Carnivore	Small mammals, especially rodents (i.e. voles) dominate prey over most of the range. Pocket gophers also dominate the diet of Great Gray Owls in North America. They usually forage in open areas where scattered trees or forest margins provide suitable sites for visual searching.	Migratory	NA	1,298	NA	G5	S3	2000	2000	5
Great Horned Owl (*Bubo virginianus*)	Carnivore	Arboreal/Cliffs/Cavity	Occurs from river bottoms to timberline throughout the state. Nests in stick nests made by other birds, broken-topped snags, hollow trees, and cliff cavities.	Carnivore	small to medium-sized mammals and birds.	Non Migratory	NA	1,769	Home range size varies seasonally and geographically. Breeding territories in southwest Yukon 230-883 ha, averaging 483 ha; nonterritorial floaters averaged 725 ha	G5	S5	1992	2005	10
Green-winged Teal (Anas crecca)	Riparian	Riparian	Highest densities in wooded ponds of deciduous parklands, with additional breeding in boreal forests, arctic deltas, and mixed prairie regions. Often inhabits grasslands or sedge meadows with brush thickets or woodlands next to a marsh or pond. Often inhabits beaver ponds in wooded areas. Ground nester. Nests typically in sedge meadows, grasslands, brush thickets, or woods near a pond. Eggs are elliptical to subelliptical.	Omnivore	Broad diet. Seeds of sedges, grasses, and aquatic vegetation; aquatic insects and larvae, molluscs, crustaceans	Migratory	NA	364 g	NA	G5	S5B	1986	2005	6
Hairy Woodpecker (*Picoides villosus*)	Arboreal	Arboreal - Cavity	Primarily a forest bird; widely distributed in regions where mature woodlands prevalent. Also occurs in small woodlots, wooded parks, cemeteries, shaded residential areas, and other urban areas with mature shade trees, but often scarce within these habitats. Cavity nester. In western North America, more often in large dead stubs or in some areas in aspen with fungal decay.	Omnivore	Tree surface and subsurface arthropods and a diversity of fruits and seeds. Readily comes to feeders	Migratory	NA	70 g	Territory size 0.6-15 hectares; varies with habitat quality. In central Ontario, breeding territories averaged 2.8 hectares, range 2.4 to 3.2 ha	G5	S5	1991	2005	237
Hammond's Flycatcher (*Empidonax hammondii*)	Aerial	Arboreal	Inhabits cool forest and woodland, breeding primarily in dense fir, mature coniferous or mixed forests to near timberline. nests were saddled on limbs o mature conifers, 10.5 to 40 feet high.	Aerial Invertivore	Diet consists of insects. The Hammond's Flycatcher is primarily an aerial forager, capturing most of its insect diet on the wing. On occasion it may forage from leaf surfaces or from the ground	Migratory	NA	10 g	Territory sizes of 1.6 to 3.2 acres in Douglas fir or lodgepole forests in western Montana	G5	S4B	1992	2006	355
Harlequin Duck (*Histrionicus histrionicus*)	Riparian	Riparian	Inhabit fast moving, low gradient, clear mountain streams. Overstory in Montana does not appear to affect habitat use	Aquatic Invertivore	95% of the material in droppings in Grand Teton National Park consisted of Stoneflies, Mayflies, and Caddisflies	Migratory	NA	687 g	NA	G4	S2B	1972	2005	76

Common Name (Genus/species)	Habitat Group: Foraging	Habitat Group: Nesting	General Habitat Description	Feeding Guild	Food	Migration	Longevity	Size	Home Range	Global Rank	State Rank	Observations in Lincoln, Co.,: Oldest	Most Recent	Number
Harris's Sparrow (*Zonotrichia querula*)	Ground	Ground	Frequents streams, hedgerows, shelterbelts, and brushy ravines dominated by deciduous trees and shrubs. Feeds primarily on the ground, scratching and kicking away ground litter with its feet; forages less frequently among branches of trees. Nests are located on the ground, typically under a shrub that is on top of, or next to, a hummock. May also be located beneath rock or turf overhangs. In Northwest Territories, most nests are concealed amid dwar birch, alder, spruce, and Labrador tea. Nest entrances are often oriented to the southeast, opposite the direction of prevailing storms	Omnivore	Diet consists of seeds, fruits, arthropods, and young conifer needles.	Migratory	longest 11yr 8mo	39 g	Territories averaged 2 hectares, but birds foraged up to 500 meters outside territories	G5	SNA			2
Hermit Thrush (*Catharus guttatus*)	Ground	NA	Species prefers interior forest edges such as margins of ponds and edges of meadows in forested areas.	Omnivore	During breeding diet consists mostly of animal matter, especially insects and other small invertebrates. During migration and winter, diet supplemented by wide variety of fruits. Forages from ground.	Non Migratory	NA	31 g	Territory sizes of 5.1 to 5.6 acres in Douglas fir or lodgepole pine forests in western MT	G5	S5B	1991	2005	355
Herring Gull (*Larus argentatus*)	Riparian	Riparian	Mainly islands and areas around water. Sometimes found in rocky or sandy cliffs; occasionally on rooftops near water.	Scavenger	Diet consists of marine invertebrates, fishes, insects, other seabirds, and adults, eggs, and young of congeners. Feeds opportunistically mostly on various animals and garbage. Often a scavenger around bays and harbors.	Migratory	Adult plumage in 4 yr	1226 g	NA	G5	SNA	1995	1995	3
Hoary Redpoll (*Carduelis hornemanni*)	Ground	Ground	Open forest and scrub, extending farther onto tundra than Common Redpoll, but still requiring shrub, at least in sheltered hollows; substrate damp or dry. During migration and in winter, often joins with Common Redpolls. Occurs i open woodland and shrub, along field edges and week patches and in towns and villages. Nest sites similar to Common Redpoll but may be closer to water, often over shallow water; in willows, alder, spruce, tamarack, birch. Where otherwise suitable sites unavailable, nests in cavities in driftwood.	Herbivore	Small seeds of various trees, shrubs, weeds and grasses, along with other plant parts, supplemented with invertebrates in summer	Migratory	NA	13 g	NA	G5	SNA			2
Hooded Merganser (*Lophodytes cucullatus*)	Riparian	Riparian	Hooded Mergansers are generally found in river areas bounded by woods and supporting good fish populations associated with clear water	Aquatic Invertivore	Main foods taken are primarily aquatic insects, fish, and crustaceans (particularly crayfish).	Migratory	First breed at 2 yr	680 g	NA	G5	S4B	2006	2006	3
Horned Grebe (*Podiceps auritus*)	Riparian	Riparian	Breeding Range is on shallow freshwater ponds an marshes with beds of emergent vegetation, especially sedges, rushes and cattails. In spring and fall the Horned Grebe is mainly on large sized bodies of water, including rivers and small lakes. The floating nest is usually concealed in the vegetation.	Aquatic Invertivore	Aquatic arthropods in the summer, & fish and crustaceans in winter, especially amphipods, crayfish, and polychaetes.	Migratory	NA	453 g	NA	G5	S4			2
Horned Lark (*Eremophila alpestris*)	Ground	Ground - Cavity	Open, gerally barren country; avoids forests. Prefers bare ground to grasses taller than a few cm. May nest on marshy soil but generally prefers, throughout its range, bare ground such as plowed or fall-planted fields. Digs a nest cavity or may use a natural depression. Food obtained from ground.	Grainivore	In winter, mostly seeds. During the breeding season adults eat mostly seeds but feed insects to their young. Adults take more insects during the spring and fall than at other times, perhaps to compensate for the energetic demands of breeding and molt	Migratory	NA	32 g	Territory size varies with habitat and population density; ranges from means of 3.5 ha in higher latitude heath, 1.6 ha in the agricultural Midwest to a range of 0.3-14 ha in Colorado shorstgrass prairie	G5	S5			2
House Finch (*Carpodacus mexicanus*)	Ground	NA	A common backyard bird throughout most of the contiuguous United States. In its native west, this species occupies a wide range of open or semi-open habitats from undisturbed desert to highly urbanized areas. In the east, it is rarely found far from urban or suburban areas.	Herbivore	In all seasons, 97% of diet is vegetable matter including buds, seeds, and fruits. Primary weed seeds eaten include Napa thistle, black mustard, wild mustard, Amaranth, knotweed and turkey mullen, plus some 21 additional seed varieties. In late summer it will eat fruits.	Non Migratory	NA	21 g	NA	G5	S5	1995	1998	2
House Sparrow (*Passer domesticus*)	Ground	Arboreal	Exotic. Non-Native. Breeding habitat is mostly associated with human modified environments such as farms, and residential and urban areas. Absen from extensive woodlands, forests, grasslands, and deserts. Nest often in enclosed spaces. If they nest in trees the nest usually is a globular structure with a side entrance and may share a wall with a neighboring nest.	Grainivore	Have been known to eat livestock feed. Grains, wee seeds, relatively few insects. Urban birds eat commercial birdseed.	Non Migratory	NA	28 g	NA	G5	SNA	1995	2005	4

Common Name (Genus/species)	Habitat Group: Foraging	Habitat Group: Nesting	General Habitat Description	Feeding Guild	Food	Migration	Longevity	Size	Home Range	Global Rank	State Rank	Observations in Lincoln, Co.,: Oldest	Most Recent	Number
House Wren (*Troglodytes aedon*)	Ground/Shrub	Cavity	Affinity for open, shrubby woodlands, mimicked so well by small town and suburban backyards and city parks; has a preference for human-made "bird houses" . Nests usually in cavities (natural, abandoned woodpecker holes, bird boxes, and within various human artifacts). Male starts several nests, female finishes nest.	Invertivore	Feeds primarily on small, terrestrial invertebrates	Migratory	NA	11 g	NA	G5	S5B	1992	1998	16
Killdeer (*Charadrius vociferus*)	Ground	Ground	Frequents open areas, especially sandbars, mudflats, heavily grazed pastures, and such human-modified habitats as cultivated fields, athletic fields, airports golf courses, graveled or broken-asphalt parking lots, and graveled rooftops	Invertivore	Main foods taken include terrestrial invertebrates, especially earthworms, grasshoppers, beetles, and snails; infrequently small vertebrates and seeds	Migratory	NA	101 g	NA	G5	S5B	1992	2007	17
Lark Sparrow (*Chondestes grammacus*)	Ground	Ground/Arboreal/Cavity	Widespread in open habitats such as shrub-steppe, pinion-juniper edges, grasslands, roadsides, farmlands, and pastures. Nests on bare ground, in hollow depression, or in shrub or tree up to 2.75 m from ground. May use unusual nest sites such as a natural cavity of a dead tree. Nest either on the ground or close to the ground (within 4 meters) in woody vegetation	Omnivore	Categorized as a ground-foraging omnivore during the breeding season, and a ground-gleaning granivore during the nonbreeding period. In breedin season, eats more insects than seeds. During colder periods, when insects are less readily available, seeds may be primary diet.	Migratory	NA	29 g	Territories around immediate nest site (Martin and Parrish 2000), 66-248 sq. m in extent	G5	S5B	2004	2004	2
Lazuli Bunting (*Passerina amoena*)	Ground	Arboreal/Shrub	Arid brushy areas in canyons, riparian thickets, chaparral and open woodland; in migration and winter also in open grassy and weedy areas Nests in small trees, shrubs, or vines, 0.3-3 m above ground	Omnivore	Feeds on insects (grasshopper, caterpillars, beetles, ants, etc) and seeds (wild oats, canary grass, needlegrass, etc.).	Migratory	NA	16 g	NA	G5	S5B	1991	2006	35
Least Flycatcher (*Empidonax minimus*)	Aerial	NA	Semi-open, second-growth, and mature deciduous and mixed woods; occasionally conifer groves, burns, swamp and bog edges, orchards, and shrubby fields. Often found near open spaces such as forest clearings and edges, water, roads, and cottage clearings. Nest is a neat compact cup, generally not protected or only partially protected by surrounding vegetation.	Aerial Invertivore	Feeds almost exclusively on insects caught by hawking from the air or gleaned from foliage of trees and shrubs. Fruits and seeds taken occasionally.	Migratory	NA	10 g	NA	G5	S5B	1994	1998	13
Lesser Scaup (*Aythya affinis*)	Riparian	Ground	In the Bozeman area, habitat is generally restricted to lakes and ponds. Throughout fall and winter this species forms large flocks on rivers, lakes, and large wetlands. Pairs and broods typically associated with fresh to moderately brackish, seasonal and semipermanent wetlands and lakes with emergent vegetation such as bulrush, cattail and river bulrush . builds nest or the ground near or over water, as well as in uplands	Aquatic Invertivore	Mainly aquatic invertebrates such as insects, crustaceans, and mollusks. Seeds and vegetative parts of aquatic plants are important in certain areas	Migratory	NA	850 g	NA	G5	S5B	1993	1995	4
Lewis's Woodpecker (*Melanerpes lewis*)	Aerial	Arboreal	Occur in river bottom woods and forest edge habitats. Nest in a natural cavity, abandoned northern flicker hole, or previously used cavity, 1-52 meters above ground. Sometimes will excavate a new cavity in a soft snag (standing dead tree), dead branch of a living tree, or rotting utility pole	Aerial Invertivore	Adult emergent insects (e.g., ants, beetles, flies, grasshoppers, tent caterpillars, mayflies) in summer, and ripe fruit and nuts in fall and winter. They are opportunistic and may respond to insect outbreaks and grasshopper swarms by increasing breeding densities.	Migratory	NA	116 g	NA	G4	S2B	1991	1995	8
Lincoln's Sparrow (*Melospiza lincolni* i)	Ground	Ground	Found mainly in boggy, willow, sedge, and moss-dominated habitats, particularly where shrub cover is dense. At lower elevations, also prefers mesic willow shrubs, but can be found in mixed deciduous wood groves such as aspen and cottonwoods. Nests on the ground, most often inside a low willow shrub or mountain birch that also contains fairly dense sedge cover.	Omnivore	Winter: small seeds, terrestrial invertebrates when available. Occasionally uses feeders. Breeding season: mostly arthropods, also small seeds when available. Forages on ground under grass and brush	Migratory	NA	17 g	Breeding territory about 0.4 ha	G5	S5B	1992	1998	10
Long-eared Owl (*Asio otus*)	Carnivore	Arboreal	Most often observed in hedgerows, woody draws, and juniper thickets, although they do occur within the forest edge. They are predominantly open-country hunters; however, they are seldom seen because of their nocturnal habits. Nests in a stick nest built by other raptors, magpies, crows, or ravens.	Carnivore	Depends heavily on small rodents.	Migratory	NA	279 g	in Siberia, nesting pairs remained in an area about 100-300 meters in diameter	G5	S5	2003	2003	3
MacGillivray's Warbler (*Oporornis tolmiei*)	Riparian-Ground	Shrub	Commonly found in riparian habitat and clearcuts of northern coniferous forests along the Rocky Mountains. Forages along streams or in dense second growth. Commonly found in deciduous, shrubby riparian habitats. Usually nests low, 0.6-1.5 meters above ground, in bushes, saplings, clump of ferns, etc.	Invertivore	Main food is insects. Feeds on or just above the ground.	Migratory	NA	10 g	NA	G5	S5B	1991	2005	488

Common Name (Genus/species)	Habitat Group: Foraging	Habitat Group: Nesting	General Habitat Description	Feeding Guild	Food	Migration	Longevity	Size	Home Range	Global Rank	State Rank	Observations in Lincoln, Co.: Oldest	Observations in Lincoln, Co.: Most Recent	Observations in Lincoln, Co.: Number
Mallard (*Anas platyrhynchos*)	Riparian	Riparian	In North America, the Mallard is the most abundant duck species. Its success in the wild reflects its adaptability to varied habitats, its hardiness in cold climates, and tolerance of human activities. Usual nest site is in uplands close to water. Nests in wide variety of situations with dense cover, including grasslands, marshes, bogs, riverine floodplains, dikes, roadside ditches, pastures, cropland, shrubland, fence lines, rock piles, forests, and fragments of cover around farmsteads	Omnivore	Very flexible in food choice; diet composition depends on stage of annual cycle, hydrological conditions, invertebrate behavior, and crop-harvesting schedule	Migratory	NA	1,082 g	NA	G5	S5	1977	2006	34
Marsh Wren (*Cistothorus palustris*)	Riparian	Riparian	Freshwater and brackish marshes in cattails, tule, bulrush, and reeds. Nests in marsh vegetation; female finishes one of several nests started by male; male may continue to build nests even after female begins incubation. Nesting success may be greatest in marshes with relatively dense vegetation and deep water	Aquatic Invertivore	Eats mainly insects and other invertebrates	Migratory	NA	12 g	NA	G5	S5B	1991	2006	7
Merlin (*Falco columbarius*)	Carnivore	Arboreal	Breeding pairs in eastern Montana usually use sparse conifer stands adjacent to prairie habitats, but sometimes use shelterbelts and river bottom forests. In western Montana, they use open stands of conifers and river bottom forests. Merlins sometimes nest in urban areas	Carnivore	Bulk of diet usually consists of small to medium-sized birds, often flocking species. Large flying insects (e.g., dragonflies) may be important for young learning to hunt. Also eats toads, reptiles, and mammals	Migratory	NA	244 g	NA	G5	S4			3
Mountain Bluebird (*Sialia currucoides*)	Ground	Arboreal	Subalpine meadows, grasslands, shrub-steppe, savanna, and pinyon-juniper woodland; in south usually at elevations above 1500 m. In winter and migration also inhabits desert, brushy areas and agricultural lands. Nests are built in natural tree cavities, or abandoned woodpecker holes. May also use bird box, old swallow's nest, rock crevice, or old mammal burrow.	Invertivore/Omnivore	Insectivorous. Feeds on beetles, ants, bees, wasps, caterpillars, grasshoppers, etc. Also consumes some berries and grapes seasonally. Hovers and drops to ground while foraging or darts out from a low perch to catch prey.	Migratory	NA	28 g	NA	G5	S5B	1991	2006	147
Mountain Chickadee (*Poecile gambeli*)	Shrub	Ground/Arboreal	Year round resident of montane coniferous forests of west North America, primarily in areas dominated by pine, spruce-fir and pinon juniper. Occurs in mixed coniferous-deciduous forests. Nests in a natural tree cavity, woodpecker hole, hole in the ground, or under a rock in a bank. Nest height usually is low, but may be up to 25 m.	Invertivore	Insects during warm seasons augmented with spiders. Conifer seeds during cool seasons.	Non Migratory	NA	12 g	Mean territory size 1.5 ha in Arizona;	G5	S5	1991	2006	875
Mourning Dove (*Zenaida macroura*)	Ground	Ground	tremendous adaptability. Generally shuns deep woods or extensive forest and selects more open woodlands and edges between forest and prairie biomes for nesting. Human alteration of original vegetations is generally beneficial for this species, with creation of opening in extensive forest and plowing of grasslands for cereal-grain production. Additional habitat created with planting of trees and shrubs in cities, towns, and suburbs. Nests primarily at woodland or grassland edge, usually in trees but readily on ground in absence of suitable trees or shrubs.	Grainivore	Mostly seeds (99%). Insignificant amounts of animal matter and green forage may be acquired incidentally. Principal food items vary by region and immediate locale. Feeds almost entirely on ground	Migratory	NA	123 g	Average home range in Missouri was 3200 ha, but most activity was within 1.6 kilometers	G5	S5B	1993	2006	24
Myrtle Warbler (*Dendroica coronata auduboni*)	NA	NA	NA	NA	NA	NA	NA	NA	NA	G5T5	S5B	1994	2000	10
Nashville Warbler (*Vermivora ruficapilla*)	Ground/Arboreal	Ground	Forest-bordered bogs, second growth, open deciduous and coniferous woodland, forest edge and undergrowth, cutover or burned areas; in migration and winter in various woodland, scrub, and thicket habitats. Nests on ground at base of bush, small tree, sapling, or clump of grass, or in hollow in moss.	Invertivore	Eats insects; forages from ground to treetop, but mainly low in trees and thickets at edge of forest	Migratory	NA	9 g	NA	G5	S5B	1991	2005	58
Northern Flicker (*Colaptes auratus*)	Ground	Arboreal	A common, primarily ground-foraging woodpecker that occurs in most wooded regions of North America. Prefers forest edge and open woodlands. Yellow-shafted Flickers reported nesting in most tree species in the wide range of woodlands it inhabits. Red-shafted Flickers are particularly common in quaking aspen stands and cottonwoods in riparian woodlands and in burned woodlands. Cavities excavated by flickers are used by many species of secondary cavity users.	Invertivore	Insects, primarily ants; fruits and seeds, especially in winter. Feeds on the ground or catches insects in the air.	Migratory	NA	142 g	NA	G5	S5	1991	2006	572

Common Name (Genus/species)	Habitat Group: Foraging	Habitat Group: Nesting	General Habitat Description	Feeding Guild	Food	Migration	Longevity	Size	Home Range	Global Rank	State Rank	Observations in Lincoln, Co.: Oldest	Most Recent	Number
Northern Flicker (Red-shafted) (*Colaptes auratus cafer*)	Ground	Arboreal	A common, primarily ground-foraging woodpecker that occurs in most wooded regions of North America. Prefers forest edge and open woodlands. Yellow-shafted Flickers reported nesting in most tree species in the wide range of woodlands it inhabits. Red-shafted Flickers are particularly common in quaking aspen stands and cottonwoods in riparian woodlands and in burned woodlands. Cavities excavated by flickers are used by many species of secondary cavity users.	Invertivore	Insects, primarily ants; fruits and seeds, especially in winter. Feeds on the ground or catches insects in the air.	Migratory	NA	142 g	NA	G5T5	SNRB	1994	2000	11
Northern Goshawk (*Accipiter gentilis*)			Goshawks in Montana tend to nest predominately in mature large-tract conifer forests with a high canopy cover (69%), relatively steep slope (21%) and little to sparse undergrowth. Nests were constructed an average 10.9 meters above the ground and were usually located near water (232 m) or a clearing (85 m)	Carnivore	Forage during short flights alternating with brief prey searches from perches. They also hunt by flying rapidly along forest edges, across openings, and through dense vegetation. An opportunistic hunter, Northern Goshawks prey on a wide variety of vertebrates and, occasionally, insects. Prey is taken on the ground, in vegetation, or in the air.	Non Migratory	Breed at 1-2 yr	1137 g	NA	G5	S3	1924	2005	153
Northern Pintail (*Anas acuta*)	Riparian	Riparian	prefer large lakes . Breeders favor shallow wetlands interspersed throughout prairie grasslands or arctic tundra. An early fall migrant, the species arrives on wintering areas beginning in August, after wing molt, often forming large roosting and feeding flocks on open, shallow wetlands and flooded agricultural fields	Grainivore	Grain (rice, wheat, corn, barley), moist-soil and aquatic plant seeds, pond weeds, aquatic insects, crustaceans, and snails	Migratory	NA	1035 g	NA	G5	S5B	1995	2006	4
Northern Pygmy-owl (*Glaucidium gnoma*)	Carnivore		most often seen in mixed fir forests, but can be found form river bottoms to timberline.	Carnivore	Small birds, mammals, insects, and probably a few reptiles and amphibians. Small birds may be an important part of its diet.	Non Migratory	NA	73 g	NA	G5	S4	1994	2005	12
Northern Rough-winged Swallow (*Stelgidopteryx serripennis*)	Aerial	Ground	Long-distance migrant in the U.S. and Canada. Breeding populations from the lowlands and central interior of Mexico southward are generally sedentary, though they may make local elevational migrations to coastal areas in winter.	Invertivore	Flys through air and catches insects (e.g., flies, wasps, bees, beetles). Swoops low over open ground or water. Occasionally may scavenge on ground.	Migratory	NA	16 g	NA	G5	S5B	1991	2006	18
Northern Saw-whet Owl (*Aegolius acadicus*)	Carnivore	Arboreal	Most common in coniferous forests; however, they can be found in deciduous trees along watercourses. Nests in woodpecker holes and possibly natural cavities.	Carnivore	Eats mainly small mammals sometimes birds and insects.	Non Migratory/Elevational	NA	91 g	NA	G5	S4	1994	2005	8
Olive-sided Flycatcher (*Contopus cooperi*)	Aerial	Ground	Generally breeds in the montane and boreal forests in the mountains of western North America, highly adapted to the dynamics of a landscape frequently altered by fire. They are more often associated with post-fire habitat than any other major habitat type, but may also be found in other forest openings (clear cuts and other disturbed forested habitat), open forests with a low percentage of canopy cover, and forest edges near natural meadows, wetlands, or canyons. Nests are placed most often in conifers (Harrison 1978, 1979), on horizontal limbs from two to 15 meters from the ground.	Invertivore	hovering or sallying forth, concentrating on prey available via aerial attack. They generally launch these aerial attacks from a high, exposed perch atop a tree or snag. Like others in the flycatching guild, this bird is a passive searcher, looking for easy to find prey, but is also an active pursuer, attacking prey difficult to capture	Migratory	NA	32 g	NA	G4	S3B	1992	2005	332
Orange-crowned Warbler (*Vermivora celata*)	Arboreal	Ground	Prefers habitats with shrubs and low vegetation, often in aspen forest or in riparian or chaparral areas which provide cover for its nest. Nests well concealed, often on or near ground or in small crevices or depression in ground/rock, along shady hillside, on slopes or steep banks, sheltered by overhanging vegetation. Also found in shrubby bushes, ferns, vines. Nest is a small open cup.	Invertivore	Gleans insects from leaves, blossoms, and the tips of boughs, but also eats some berries and fruit and is attracted to suet feeders in the winter.	Migratory	NA	9 g	NA	G5	S5B	1992	2004	608
Pileated Woodpecker (*Dryocopus pileatus*)	Arboreal	Arboreal	Late success ional stages of coniferous or deciduous forest, but also younger forests that have scattered, large dead trees. Dead trees provide favored sites in which to excavate nest cavities. Only large- diameter trees have enough girth to contain nest.	Invertivore	Diet consists primarily of wood-dwelling ants and beetles that are extracted from down woody material and from standing live and dead trees. Fruit and mast of wild nuts when available.	Non-Migratory	9 years	308 g	NA	G5	S4	1991	2005	256
Pine Grosbeak (*Pinicola enucleator*)	Arboreal	NA	Open coniferous forests of north-western mountain ranges and in coastal and island rain forests of Alaska and British Columbia. Always most common in places where forest is open.	Omnivore	During most of the year 99% of diet is vegetable matter, especially buds, seeds and fruits. Feeds young a diet of mainly insects and spiders often mixed with vegetable matter	Migratory	NA	56 g	NA	G5	S5	1988	2004	59

Common Name (Genus/species)	Habitat Group: Foraging	Habitat Group: Nesting	General Habitat Description	Feeding Guild	Food	Migration	Longevity	Size	Home Range	Global Rank	State Rank	Observations in Lincoln, Co.,: Oldest	Most Recent	Number
Pine Siskin (*Carduelis pinus*)	Ground	NA	Forests and woodlands, parks, gardens and yards in suburban areas; in migration and winter in a variety of woodland and forest habitats, partly open situations with scattered trees, open fields, pastures and savanna.	Herbivore	Forages in trees and on the ground for seeds (e.g., of alder, birches, pines, maples, thistles) and insects. Also eats flower buds of elms, drinks nectar from eucalyptus blossoms and sap from sapsucker's holes	Migratory	NA	15 g	NA	G5	S5	1991	2006	1243
Pygmy Nuthatch (*Sitta pygmaea*)	Arboreal	Arboreal	long-needled pine forests - principally ponderosa pines. Reaches its highest densities in mature pine forests little affected by logging, firewood collection, and snag removal. A cavity nester, can excavate own cavity, but will use woodpecker holes and natural cavities	Invertivoe	Feeds mainly on weevils and leaf and bark beetles, but also eats pine seed. At feeders, eats suet and sunflower seeds	Non-Migratory	NA	11 g	NA	G5	S4	1993	2004	11
Red Crossbill (*Loxia curvirostra*)	Arboreal	Arboreal	Coniferous and mixed coniferous-deciduous forests; also pine savanna and pine-oak habitat. In migration and winter may also occur in deciduous forest, and more open scrubby areas. Nests in conifers, 1.5-25 m above ground, toward outer end of branch	Omnivore	Eats seeds, buds, and insects. Forages in trees; also picks up seeds from the ground.	Non-Migratory	NA	37 g	NA	G5	S5	1989	2004	692
Red-breasted Nuthatch (*Sitta canadensis*)	Arboreal	Arboreal	Prefers forests that have a strong fir and spruce component. May also breed in mixed woodland when a strong coniferous component is associated with deciduous trees such as aspen, oak and poplar. The nests are open and built up from a variety of grasses, strips of bark and pine needles.	Invertivore	Eats mainly arboreal arthropods during the breeding season and a large number of conifer seeds outside the breeding season.	Migratory	NA	10 g	NA	G5	S5	1991	2005	1724
Red-eyed Vireo (*Vireo olivaceus*)	Arboreal	NA	Breeds in deciduous and mixed deciduous-coniferous forest. Absent from site where understory shrubs are sparse or lacking. Often found near small openings in forest canopy. Can occur in residential areas, city parks, and cemeteries where large trees grow. During spring and fall migration uses a greater variety of forested habitats than during breeding season, but still prefers deciduous woodland over conifers. Winter range finds them present in various forested habitats from sea level up to 3000 m elevation.	Invertivore	Consumes mostly insects, particularly caterpillars. During breeding season most often observed foraging in canopy vegetation. Also eats various small fruits, most frequently in late summer and fall. In winter, mostly frugivorous	Migratory	NA	17 g	NA	G5	S5B	1993	2000	25
Red-naped Sapsucker (*Sphyrapicus nuchalis*)	Arboreal	Arboreal	nesting in broken-top larch; optimum habitat is old-growth larch, particularly near wet areas. Nest cavities made in dead trees or dead portions of live trees. Pure white, moderately glossy eggs are ovate to elliptical-ovate or rounded-ovate.	Herbivore	Sap wells in the bark of woody plants and feed on sap that appears there. Often drill sap wells in the xylem of conifers and aspens. Once the temperature increase and sap begins to flow, theses birds switch to phloem wellls in aspen or willow, if available. Insects, also bast (inner bark), fruit, and seeds.	Migratory	NA	NA	NA	G5	S5B	1992	2006	189
Red-tailed Hawk (*Buteo jamaicensis*)	Carnivore	Arboreal/Cliffs	nest in trees and on cliffs, and hunt over grasslands, open woodlands, and agricultural areas.	Carnivore	primarily ground squirrels and other small rodents, but also feed on a wide variety of other animals. Red tailed hawks often eat snakes, including rattlesnakes.	Migratory	NA	1,224 g	NA	G5	S5B	1989	2006	73
Red-winged Blackbird (*Agelaius phoeniceus*)	NA	NA	Breeds in a variety of wetland and upland habitats. Wetland habitats include freshwater marsh, saltwater marsh, and rice paddies. Upland breeding habitats commonly include sedge meadows, alfalfa fields and other crop land and old fields. Roosts in habitats with dense cover.	Omnivore	During the nonbreeding season, diet is primarily plant matter. During breeding season, diet is primarily animal matter with some plant matter.	Migratory	NA	64 g	NA	G5	S5B	1993	2006	21
Ring-billed Gull (*Larus delawarensis*)	Riparian	Riparian	Spring and fall migration prefers fresh water (lakes, river marshes, reservoirs, irigation and agricultural areas). Occurs inland more often than other species of gulls - near landfill sites, golf courses, farm fields. Winter range mostly on or near coast. Common around docks, wharves, harbors; scarce in pelagic waters; inland on reservoirs, lakes, ponds and streams, landfill sites, and shopping malls in large metropolitan centers.	Invertivore	fish, insects, earthworms, rodents, and grain.. At Freezeout Lake, stomach contents included insects, oligochaetes, crustaceans, birds and mammals, and plant material believed to be consumed incidentally to consuming animals	Migratory	NA	566 g	NA	G5	S5B	1991	2006	5
Ring-necked Duck (*Aythya collaris*)	Riparian	Riparian	Freshwater wetlands, especially marshes, fens, and bogs that are generally shallow with fringes of flooded or floating emergents, predominantly sedges interspersed with other vegetation and shrubs; also open water zones vegetated with abundant submerged or floating aquatic plants (Hohman and Eberhardt 1998). In the Bozeman area, habitat is restricted to lakes and ponds.	Omnivore	Moist-soil and aquatic plant seeds and tubers; aquatic invertebrates	Migratory	NA	730 g	NA	G5	S5B	1992	2006	9
Rock Wren (*Salpinctes obsoletus*)	Ground	NA	Rock also found in nonrocky habitats, as long as there exists areas "rich in crevices, interstices, passageways, recesses, and nooks and crannies of diverse shapes and sizes"	Invertivore	Insects and other arthropods	Migratory	NA	17 g	NA	G5	S5B	1991	2004	11

	Habitat Group											Observations in Lincoln, Co.,		
Common Name (Genus/species)	**Foraging**	**Nesting**	**General Habitat Description**	**Feeding Guild**	**Food**	**Migration**	**Longevity**	**Size**	**Home Range**	**Global Rank**	**State Rank**	**Oldest**	**Most Recent**	**Number**
Ruby-crowned Kinglet (*Regulus calendula*)	Arboreal	Arboreal	In the west, nests in spruce-fir, lodgepole pine and Douglas-fir forests. Spring and fall migration includes a broad range of habitats: coniferous and deciduous forests, floodplain forests, willow shrubs, abandoned homesteads in rangeland, old fields, and suburban yards. Nest globular or elongated, usually pensile but may be placed on limb. In all cases nests protected from above by overhanging foliage.	Invertivore	Winter: spiders and their eggs, a variety of insects and their eggs, psuedoscorpions, small amounts of fruit, seeds and other vegetable matter. Breeding season: same as winter except no vegetable matter eaten	Migratory	NA	7 g	NA	G5	S5B	1992	2006	500
Ruddy Duck (*Oxyura jamaicensis*)	Riparian	Riparian	Breeding is usually on overgrown, shallow marshes with abundant emergent vegetation and some open water. Non-breeding birds are found on large, generally deeper waters with silty/muddy bottoms	Invertivore	primarily aquatic insects, crustaceans, zooplankton, and other invertebrates. Typically consumes small amount of aquatic vegetation and seeds. Forage almost exclusively by diving but occasionally forage by "skimming" water surface, straining food from water	Migratory	NA	590 g	NA	G5	S5B	1992	1993	4
Ruffed Grouse (*Bonasa umbellus*)	Ground	Arboreal/Shrub	found in dense, brushy, mixed-conifer and deciduous tree cover, often along stream bottoms. In the Bozeman area they are mostly in deciduous thickets in the foothills and mountains; also in riparian areas to the lowest elevation says they inhabit the denser cover of mixed conifer and deciduous trees and brush, and are often along stream bottoms.	Omnivore	In winter deciduous tree buds and shrubs. In summer, a mixed diet of insects, green plants and berries, with young birds eating primarily insect	Migratory	NA	NA	NA	G5	S5	1977	2006	148
Rufous Hummingbird (*Selasphorus rufus*)	Riparian	Riparian	primarily aquatic insects, crustaceans, zooplankton, and other invertebrates. Typically consumes small amount of aquatic vegetation and seeds. Forage almost exclusively by diving but occasionally forage by "skimming" water surface, straining food from water	Invertivore	primarily aquatic insects, crustaceans, zooplankton, and other invertebrates. Typically consumes small amount of aquatic vegetation and seeds. Forage almost exclusively by diving but occasionally forage by "skimming" water surface, straining food from water	Migratory	NA	3 g	NA	G5	S5B	1991	2007	49
Savannah Sparrow (*Passerculus sandwichensis*)	Ground	Arboreal	widespread and abundant in open habitats throughout North America. During the breeding season its persistent buzzy song can be heard in agricultural fields, meadows, marshes, coastal grasslands, and tundra. During spring and fall migration it can be found in open fields, roadsides, dune vegetation, coastal marshes, edges of sewage ponds and other ponds in open country.	Omnivore	The main foods taken in winter include small seeds, fruits, and insects when available. During breeding season they eat adult insects, larval insects, insect eggs, small spiders, millipedes, isopods, amphipods, decapods, mites, small mollusks, seeds, and fruits.	Migratory	NA	25 g	Territories are small, ranging from 0.05 to 1.25 hectares	G5	S5B	1992	2004	12
Say's Phoebe (*Sayornis saya*)	Aerial	NA	Open country, prairie ranches, sagebrush plains, badlands, dry barren foothills, canyons, and borders of deserts	Invertivore	Primarily flying or terrestrial insects, most frequently wild bees and wasps but also flies, beetles, and grasshoppers. Little vegetable matter	Migratory	NA	21 g	NA	G5	S5B			2
Sharp-shinned Hawk (*Accipiter striatus*)	Carnivore	NA	commonly use heavy timber, especially even-aged stands of conifers, but sometimes hunt in open areas	Carnivores	almost entirely on songbirds, although they occasionally take small mammals and insects	Non-Migratory	NA	174 g	NA	G5	S4B	1991	2003	17
Solitary Vireo (*Vireo solitarius*)	Arboreal	NA	Mixed coniferous-deciduous woodland, humid montane forest; in migration and winter also in "a variety of wooded habitats, but favors tall woodland with live oaks and pines in the temperate zone.	Invertivore	Eats mostly insects, some spiders and small fruits; forages among foliage and branches of trees and shrubs. Eats fruits and insects in about equal proportions	Migratory	NA	17 g	NA	G5	SNR	1993	1994	9
Song Sparrow (*Melospiza melodia*)	Arboreal	NA	Wide range of forest, shrub, and riparian habitats, but limited to those adjacent to fresh water more often in arid environments	Omnivore	In nonbreeding period, primarily seeds, fruits, and invertebrates, as available. During breeding, primarily insects and other small invertebrates; some seeds and fruit	Migratory	NA	21 g	NA	G5	S5B	1991	2006	80
Sora (Porzana carolina)	Riparian	Riparian	Primarily shallow freshwater emergent wetlands (e.g., marshes of cattail, sedge, blue-joint, or bulrush), less frequently in bogs, fens, wet meadows, and flooded fields, sometimes foraging on open mudflats adjacent to marshy habitat.	Omnivore	Eats mollusks, insects, seeds of marsh plants, duckweed	Migratory	NA	NA	NA	G5	S5B	1991	2000	9
Spotted Sandpiper (*Actitis macularius*)	Riparian	Riparian	Shores of lakes, ponds, and streams, sometimes in marshes; prefers shores with rocks, wood, or debris; also mangrove edges in Caribbean. Nests near freshwater in both open and wooded areas, less frequently in open grassy areas away from water; on ground in growing herbage or low shrubby growth, or against log or plant tuft	Aquatic Invertivore	Eats mainly small invertebrates obtained from surface or by probing along shores or some distance inland if insects are abundant there	Migratory	NA	40 g	NA	G5	S5B	1992	2006	29

Common Name (Genus/species)	Habitat Group: Foraging	Habitat Group: Nesting	General Habitat Description	Feeding Guild	Food	Migration	Longevity	Size	Home Range	Global Rank	State Rank	Observations in Lincoln, Co., Oldest	Most Recent	Number
Spotted Towhee (*Pipilo maculatus*)	Ground	NA	Uses a wide variety of shrubby habitats characterized by deep litter and humus on ground, and sheltering vegetation overhead. Undergrowth of open woodland, forest edge, second growth, brushy areas, chaparral, riparian thickets, woodland	Invertivore	Forages on the ground beneath shrubs and undergrowth, using a two-footed scratching maneuver to find food among loose debris. Eats various invertebrates, seeds, small fruits, some smal vertebrates	Migratory	NA	42 g	NA	G5	S5B	1991	2006	78
Spruce Grouse (*Falcipennis canadensis*)	Ground	NA	dense forest types such as alpine fir, Engelmann spruce, or lodgepole pine. Winter home ranges northeast of Missoula are covered by Douglas fir, ponderosa pine, lodgepole pine and larch. Douglas fir provided the most important cover; the average size being 24.1 hectars	Herbivore	Conifer needles (larch, ponderosa pine, lodgepole pine) were the main food in late fall through early spring. In summer, herbaceous vegetation and insects were utilized.	Migratory	NA	492 g	NA	G5	S4	1992	2004	16
Steller's Jay (*Cyanocitta stelleri*)	Ground	Arboreal	Coniferous and mixed coniferous-deciduous forest, open woodland, orchards, and gardens including humid coniferous forest in nw. North America. Habituates readily to humans and is well known at feeders, picnic areas, and campgrounds. Nests typically placed on horizontal branches close to trunk, often close to top of tree. When nesting close to human habitation, frequently nests close to a window, building, or path, above ground in bushes or trees.	Omnivore	Consumes wide variety of animal and plant food including arthropods, nuts, seeds, berries, fruits, small vertebrates, and eggs and young of smaller birds. At feeders, picnic areas and campgrounds, consumes wide variety of foods such as suet, sunflower seeds, peanuts, meat, cheese, bread, and cookies	Non Migratory	NA	106 g	NA	G5	S5	1987	2005	83
Swainson's Thrush (*Catharus ustulatus*)	Arboreal	Arboreal	Coniferous and mixed coniferous-deciduous forest, open woodland, orchards, and gardens including humid coniferous forest in nw. North America. Habituates readily to humans and is well known at feeders, picnic areas, and campgrounds. Nests usually in small tree, close to trunk, often 2 m or less above ground; often in conifer, sometimes deciduous tree or shrub.	Omnivore	Berries and insects. Breeding and spring migrating populations tend to be insectivorous; fall migrating and wintering populations more frugivorous	Non Migratory/ Altitudinal	NA	23-45 g	Territory sizes of 1.7 to 3.3 acres	G5	S5B	1991	2005	1387
Tennessee Warbler (*Vermivora peregrina*)	Arboreal	Arboreal	Openings of northern woodland, edges of dense spruce forests, cleared balsar tamarack bogs, grassy places of open aspen and pines, alder and willow thickets, open deciduous second growth. In migration and winter generally in single species flocks in tops of trees of various woodland types--not typically in continuous mature forest; in winter prefers semi-open, second growth, coffee plantations, gardens. Nests in hollow of moss in bog, or on higher level ground or hillside, in thickets or in open at base of grass or shrub	Invertivore	Eats insects and spiders, seeds, fruit juices; forages over terminal twigs and leaves of trees and in dense patches of weeds	Migratory	NA	10 g	NA	G5	S2S4 B	1991	2000	10
Townsend's Solitaire (*Myadestes townsendi*)	Ground	Ground	Open woodland, pinyon-juniper association, chaparral, desert and riparian woodland nest sites were in cutbanks and 2 were in open woodlands	Invertivore	In Missoula, insects were the primary summer food, obtained primarily by ground predation. Rocky Mountain juniper cones were the primary food during late winter. Feeds on insects (e.g., caterpillars, beetles, wasps, ants, bugs) and fruit (e.g., juniper berries, and berries of rose, cedar mistletoe, madrona); also pine seeds. Flies out from a perch and catches insects in the air.	Migratory	NA	34 g	NA	G5	S5	1991	2004	515
Townsend's Warbler (*Dendroica townsendi*)	Arboreal	Arboreal	Tall coniferous and mixed coniferous-deciduous forest at various elevations, from wet coastal forest at sea level to dry subalpine forest. Most abundant in unlogged, old-growth forest, but also common in late successional stages. Uncommon in logged forest. Appears to prefer conifers; may nest 2.7-4.5 m above ground, maybe higher	Invertivore	Insects. Honeydew excreted by scale insects in low-latitude cloud forests. Winter: gleans small insects and caterpillars in foliage at all heights, occasionally hovers and plucks them from undersides of leaves; hawks flying insects	Non Migratory	NA	9 g	NA	G5	S5B	1991	2005	1306
Tree Swallow (*Tachycineta bicolor*)	Aerial	Arboreal	Open fields, meadows, marshes, beaver ponds, lakeshores and other wetland margins. Uses trees only for nesting and occasional roosting.	Invertivore	Mostly flying insects, though vegetable matter is eaten during unfavorable weather conditions. Forage over open water, marshes, ponds, and fields, as well as in shrubby habitat.	Migratory	NA	20 g	NA	G5	S5B	1992	2006	27
Turkey Vulture (*Cathartes aura*)	Carnivore	Cliffs	Turkey vultures forage in a variety of habitats, including grasslands, badlands, open woodlands, and farmlands. Nesting in the northern Rockies is usually done on cliff ledges under overhangs, or in rock crevices, often in river valleys	Carnivore	Carrion is the primary food, but they sometimes prey on small mammals.	Migratory	NA	1467 g	NA	G5	S4B	1992	2006	18

Common Name (Genus/species)	Habitat Group: Foraging	Habitat Group: Nesting	General Habitat Description	Feeding Guild	Food	Migration	Longevity	Size	Home Range	Global Rank	State Rank	Observations in Lincoln, Co., Oldest	Most Recent	Number
Varied Thrush (*Ixoreus naevius*)	Ground	Arboreal	Humid coastal and interior montane coniferous forest, deciduous forest with dense understory, and tall shrubs (especially alder); in migration and winter also open woodland and chaparral. Usually nests in a small conifer, sometimes a deciduous tree, 3-4.5 m above ground	Omnivore	Feeds in trees or forages on the ground for insects, earthworms, seeds, and berries.	Non Migratory	NA	78 g	NA	G5	S5B	1990	2005	619
Vaux's Swift (*Chaetura vauxi*)	Aerial	Arboreal	During breeding prefer late stages of coniferous forests and deciduous forests mixed with coniferous. More common in old-growth forests than in younger stands. During spring and fall migrations prefer forests and open areas; roost trees and chimneys important as they allow swifts to avoid exposure and conserve body heat. Hollow trees are its favored nesting and roosting sites. Nest in hollow trees in the forest; less commonly in chimneys.	Invertivore	Almost entirely insects and spiders. Catches its prey from the air.	Non Migratory	NA	17 g	NA	G5	S4B	1991	2002	12
Veery (*Catharus fuscescens*)	Ground	Riparian	Generally inhabits damp, deciduous forests. Has a strong preference for riparian habitats in several regions, including the Great Plains. Prefers disturbed forest, probably because denser understory is not found in undisturbed forests. Breeds in early-successional, damp, deciduous forests, often nesting near streamside thickets or swamps. Nest are typically on or near the ground, most often elevated in or at the base of a bush or small tree.	Omnivore	Primarily a ground forager, with a diet fairly evenly divided between insects and fruit. Roughly 60% insects, 40% fruit, feeding primarily on insects as breeders and on fruit late summer and fall.	Migratory	NA	31 g	NA	G5	S4B	1994	1995	7
Vesper Sparrow (*Pooecetes gramineus*)	Ground	Ground	In central Montana they nest on the ground under big sagebrush, but concealment of the nest is not greatly important. They are found in areas where vegetation was short and dense, with a high percentage of cover	Omnivore	In central Montana, 70-90% of food was animal (mostly Coleopterans), while 3 to 23% was plant (mostly grass seeds)	Migratory	NA	27 g	NA	G5	S5B	1991	2006	73
Violet-green Swallow (*Tachycineta thalassina*)	Aerial	Arboreal	Occurs principally in montane coniferous forests. Breeding range includes open deciduous, coniferous, and mixed woodlands. Often perches on wires and exposed tree branches.	Invertivore	Flying insects exclusively. Not known to feed on seeds or berries.	Migratory	NA	14 g	NA	G5	S5B	1991	2006	27
Warbling Vireo (Vireo gilvus)	Ground	Arboreal	Throughout range, shows a strong association with mature mixed deciduous woodlands especially along streams, ponds, marshes, and lakes but sometime in upland areas away from water. Also found in young deciduous stands that emerge after a clear-cut. In general, overall habitat structure consists of large trees with semi-open canopy. Other habitats include urban parks and gardens orchards, farm fencerows, campgrounds, deciduous patches in pine forests, mixed hardwood forests, and rarely, pure coniferous forests. Usually nests at end of branch in a deciduous tree, 9-18 m above ground, or 1-3.5 m above ground, in shrub or orchard tree	Invertivore	Insects, throughout the year. Some fruit in winter	Migratory	NA	12 g	Territory sizes of 3.4 to 5.6 acres	G5	S5B	1992	2006	435
Western Bluebird (*Sialia mexicana*)	Ground		Can usually be found in open coniferous and deciduous woodlands, parklike forests, edge habitats, burned areas and where moderate amounts of logging have occurred, provided a sufficient number of larger trees and snags remain to provide nest sites and perches. Nests usually found in rotted or previously excavated cavities in trees and snags, or between trunk and bark.	Invertivore	Insects during the warmer months, but forages primarily on berries and fruits through the winter. Forages by flycatching and by dropping from perch to ground.	Non Migratory	NA	29 g	averaged 0.43 hectares and 0.56 hectares	G5	S4B	1991	2003	11
Western Grebe (Aechmophorus occidentalis)	Riparian-Opportunist		Lives on fresh water lakes and marshes which have large areas of open water and vegetation around it.	Piscivore, invertivore	Feeds mainly on fish, but will also eat salamanders, crustaceans, polychaete worms, and insects. They tend to be opportunists.	Migratory	NA	1477 g	20 hectares or more open water	G5	S4B	1987	1991	4
Western Kingbird (Tyrannus verticalis)	Aerial/Ground	Arboreal/ Shrub	Open and partly open country, especially savanna, agricultural lands, and areas with scattered trees, also desert.	Invertivore	Primarily insectivorous; feeds on wasps, beetles, moths, caterpillars, grasshoppers, true bugs. Also eats spiders, millipedes, and some fruit. May occasionally take tree frogs	Migratory	NA	40 g	Foraging range at least 400 meters from nest	G5	S5B	1991	2006	8
Western Meadowlark (Sturnella neglecta)	Ground	Ground	Most common in native grasslands and pastures, but also in hay and alfalfa fields, weedy borders of croplands, roadsides, orchards, or other open areas; occasionally desert grassland. Preference shown for habitats with good grass and litter cover.	Grainivore, Invertivore	Grain and weed seeds, and insects. Favorite insect foods include beetles, weevils, wireworms, cutworms, grasshoppers, and crickets. Seasonal differences: grain during winter and early spring, insects late spring and summer, weed seeds in fall .	Migratory	NA	106 g	4-13 hectares	G5	S5B	1992	2006	45

	Habitat Group											Observations in Lincoln, Co.,		
Common Name (Genus/species)	Foraging	Nesting	General Habitat Description	Feeding Guild	Food	Migration	Longevity	Size	Home Range	Global Rank	State Rank	Oldest	Most Recent	Number
Western Tanager (Piranga ludoviciana)	NA	Arboreal	Favors open woodlands, but occasionally extends into fairly dense forests. During migration, frequents a wide variety of forest, woodland, scrub and partly open habitats and various human-made environments such as orchards stands of trees in suburban areas, parks, and gardens.	Frugivore, Invertivore	Feeds predominantly on insects during the breeding season, but it also incorporates fruits and berries in its diet whenever it can	Migratory	NA	28 g	NA	G5	S5B	1991	2006	1158
Western Wood-pewee (Contopus sordidulus)	Aerial	Arboreal	Seen wherever there are clearings or groves of deciduous trees along the river valleys	Invertivore	Flying insects, especially flies, ants, bees, wasps, and beetles, moths and bugs.	Migratory	NA	13 g	NA	G5	S5B	1992	2006	34
White-breasted Nuthatch (Sitta carolinensis)	Arboreal	Arboreal	A common resident of deciduous forests in North America. Also in mixed deciduous and coniferous forests. Favors woodland edges over more central locations, prefering open areas. Over much of its range the presence of some oaks seems to be a requirement.	Grainivore, Invertivore	Feeds on a variety of insects and plant matter (acorns, nuts, etc).	Migratory	NA	21 g	10-20 hectares feeding territory	G5	S4	1992	2006	58
White-crowned Sparrow (Zonotrichia leucophrys)	Ground	Ground/Shrub/Arboreal	Necessary habitat features of breeding territories include grass, either pure or mixed with other plants; bare ground for foraging; dense shrubs or small conifers thick enough to provide a roost and conceal a nest; standing or running water on or near territory; and tall coniferous trees, generally on periphery of territory.	Grainivore, Invertivore	Main foods taken in winter include seeds, buds, grass, fruits, and arthropods, when available. During breeding season arthropods (principally insects) and seeds are taken.	Migratory	NA	29 g	NA	G5	S5B	1989	2003	41
White-throated Sparrow (Zonotrichia albicollis)	Ground	Ground	Coniferous and mixed forest, forest edge, clearings, bogs, brush, thickets, open woodland. In migration and winter also in deciduous forest and woodland, scrub, shrubbery, gardens, parks, cattail marshes.	Frugivore, Granivore, Invertivore	Eats mostly weeds seeds, also small fruits, buds, and insects.	Migratory	NA	26 g	NA	G5	SNA	1994	1994	3
White-winged Crossbill (Loxia leucoptera)	NA	Arboreal	Coniferous forest (especially spruce, fir or larch), mixed c oniferous-deciduous woodland, and forest edge; in migration and winter also may occur in deciduous forest and woodland	Granivore, Invertivore	Eats seeds (e.g., of conifers, birches, grasses, junipers, etc.) and insects; mainly conifer seeds, which also comprise diet of nestlings	Non-Migratory	NA	28 g	NA	G5	S4	1991	2000	28
Wild Turkey (Meleagris gallopavo)	Ground	Ground	Open ponderosa pine forest in rugged terrain, interspersed with grassland and brushy draws is the preferred habitat (FWP). Open ponderosa pine-grassland cover types are most widely used in the Longpine Hills during summer and early fall; canyon bottoms at lower elevations, grain fields and livestock feeding areas are utilized in late fall and winter.	Frugivore, Granivore, Herbivore, Invertivore	Summer foods include insects (primarily grasshoppers), bearberry, snowberry and skunkbrush sumac fruits, grass leaves and stems, and Carex seeds; winter foods are grains, hawthorn and snowberry fruits, and grass leaves, stems and heads.	Non-Migratory	NA	7400 g	260 to 520 hectares	G5	SNA	1994	2005	12
Williamson's Sapsucker (Sphyrapicus thyroideus)	Arboreal	Arboreal	Coniferous forest, especially fir and Lodgepole Pine; in migration and winter also in lowland forest.	Invertivore	Drills holes in trees and consumes sap, cambium and insects. Ants may comprise 86% of its animal food; also eats wood-boring larvae, moths of spruce budworms, etc.	Migratory	NA	48 g	Reported territory sizes vary from 4 hectares to 6-7 hectares	G5	S3S4B	1991	2002	39
Willow Flycatcher (Empidonax traillii)	Aerial	Riparian	Strongly tied to brushy areas of willow (SALIX spp.) and similar shrubs. Found in thickets, open second growth with brush, swamps, wetlands, streamsides, and open woodland. Common in mountain meadows and along streams; also in brushy upland pastures (especially hawthorn) and orchards. The presence of water (running water, pools, or saturated soils) and willow, alder (ALNUS spp), or other deciduous riparian shrubs are essential habitat elements.	Invertivore	Eats mainly insects and occasionally berries, 96 percent of diet is animal matter, most of which is flying insects.	Migratory	NA	14 g	0.1 to 0.9 hectares	G5	S5B	1991	2006	26
Wilson's Phalarope (Phalaropus tricolor)	Riparian	Riparian - ground	During spring, the species is widespread in the valley in lakes, ponds and flooded fields. Summer birds are restricted to marshy borders of lakes and ponds	Invertivore	Small aquatic invertebrates in freshwater or hypersaline environments; also some terestrial invertebrates.	Migratory	NA	68 g	Usually nests less than 100 meters from shoreline	G5	S4B	1995	1995	2
Wilson's Snipe (Gallinago delicata)	Ground	Ground	During summer birds are widely distributed in the valley in moist meadows. In winter, they occur along warm, bog-bordered streams in the valley. Requires soft organic soil rich in food organisms just below surface, with clumps of vegetation offering both cover and good view of approaching predators. Avoids marshes with tall, dense vegetation (cattails, reeds, etc.).	Invertivore	Eats mostly larval insects, but also takes crustaceans, earthworms, and mollusks. Stomachs contain as much as 66% plant material, but probably little or no energy is obtained from plants	Migratory	NA	128 g	Common Snipes breed throughout the state. Most wintering records are for western Montana.	G5	S5	1991	2006	54
Wilson's Warbler (Wilsonia pusilla)	Arboreal/Aerial	Ground	Breeding territories are usually located in riparian habitat or wet meadows with extensive deciduous shrub thickets. Likes edeges of beaver ponds, lakes bogs and overgrown clear-cuts of montane and boreal zones.	Invertivore	Bees, flies, mayflies, spiders, beetles and caterpillars. Occasionally eats berries.	Migratory	NA	7 g	Ranges from about 0.2 to 2.0 hectares.	G5	S5B	1991	2005	349

Common Name (Genus/species)	Habitat Group: Foraging	Habitat Group: Nesting	General Habitat Description	Feeding Guild	Food	Migration	Longevity	Size	Home Range	Global Rank	State Rank	Observations in Lincoln, Co.,: Oldest	Most Recent	Number
Winter Wren (*Troglodytes troglodytes*)	Ground/Shrubs	Arboreal - Cavity	Coniferous forest, primarily with dense understory and near water, and in open areas with low cover along rocky coasts, cliffs, islands, or high mtn. areas, logged areas with large amounts of slash; in winter and migration also in deciduous woods with understory, thickets, brushy fields.	Invertivore	Eats almost entirely insects (beetles, Diptera, caterpillars) and spiders.	Migratory	NA	9 g	NA	G5	S4	1991	2005	487
Wood Duck (*Aix sponsa*)	Riparian/Ground	Arboreal - Cavity	Wide variety of habitats: creeks, rivers, overflow, bottomlands, swamps, marshes, beaver and farm ponds.	Omnivore	Omnivore with a broad diet. Seeds, fruits and aquatic and terrestrial invertebrates are main foods taken.	Migratory	NA	681 g	Home ranges of of fledged broods range up to 12.8 kilometers.	G5	S5B	1996	2006	6
Yellow Warbler (*Dendroica petechia*)	Arboreal/Aerial	Arboreal/Shrub	Found throughout much of North America in habitats categorized as wet, deciduous thickets. Found especially in those dominated by willows.	Invertivore	Main foods include insects and other arthropods. May take wild fruits occasionally.	Migratory	NA	10 g	Breeding territories are as small as 0.16 hectares.	G5	S5B	1991	2006	51
Yellow-breasted Chat (*Icteria virens*)	Arboreal	Arboreal/Shrub	Found in low, dense vegetation without a closed tree canopy, including shrubby habitat along stream, swamp, and pond margins; forest edges, regenerating burned-over forest, and logged areas; and fencerows and upland thickets of recently abandoned farmland	Frugivore, Invertivore	Adults feed on small invertebrates (mainly insects and spiders), fruit and berries when available.	Migratory	NA	26 g	Territory size averages 1.24 hectares.	G5	S5B	1991	1993	4
Yellow-headed Blackbird (*Xanthocephalus xanthocephalus*)	Ground	Riparian	Primarily prairie wetlands, but also common in wetlands associated with quaking aspen parklands, mountain meadows, and arid regions. Scattered colonies occur on forest edges and on larger lakes in mixed-wood boreal forest.	Granivore, Invertivore	During breeding season specializes in "aquatic" prey; feeds aquatic insects to nestlings. Consumes primarily cultivated grains and weed seeds during the postbreeding season.	Migratory	NA	80 g	Forages up to 1.6 kilometers from nesting area.	G5	S5B	1993	2006	6
Yellow-rumped Warbler (*Dendroica coronata*)	Arboreal/Aerial/Ground	Arboreal	Nests in forests or open woodlands. In migration and winter found in open forests, woodlands, savanna, roadsides, pastures, and scrub habitat.	Invertivore	Feeds on insects (ants, wasps, flys, beetles, mosquitoes, etc.), spiders, some berries and seeds.	Migratory	NA	13 g	NA	G5	S5B	1991	2005	1716

	Habitat Group											Observation in Lincoln, Co.,		
Common Name (Genus/species)	Foraging	Breeding, Resting	General Habitat Description	Feeding Guild	Food	Migration/ Hibernation	Longevity	Size	Home Range	Global Rank	State Rank	Oldest	Most Recent	Number
Beaver (*Castor canadensis*)	Riparian	Riparian	Ponds, small lakes, meandering streams, and rivers. Requires water and associated woody vegetation.	Herbivore	variety of woody and herbaceous species. Willows, mountain alder, and aspen	Non-migratory	11 years in wild	Adults 16-23 kg (35-50 pounds), Kits 0.5 kg or less (1 pound) at birth, when they are about 38 cm (15 inches) long	NA	G5	S5	1947	2006	4
Black Bear (*Ursus americanus*)	Ground/Shrub/Arboreal	Ground	Dense forests; riparian areas; open slopes or avalanche chutes during spring green-up (FWP). Habitat use tied to seasonal food avail./plant phenology. Dry mtn meadows in early spring, snow slides,stream bottoms, wet meadows early & mid-summer. May concentrate in berry & whitebark pine areas in fall. Sympatric with grizzly bear but more prone to occupying closed canopy areas. Natural cub and adult mortality low, sub-adult mortality higher. Dens beneath downed trees, hollow trees, roots or other shelter.	Omnivore	Grasses, sedges, berries, fruits, inner bark of trees, insects, honey, eggs, carrion, rodents, occassional ungulates (especially young and domestic), and (where available) garbage. Varies. Spring--primarily vegetation (grasses, umbels, & horsetails). Summer--herbaceous & fruits. Fall--berries & nuts, some begetation. Insects a frequent bomponent of diet. Also mammals, birds, & carrion	Non-migratory/Semi-hibernates in winter	NA	90 - 240+ kg	NA	G5	S5	1917	2006	20
Bobcat (*Lynx rufus*)	Carnivore	NA	Utilizes wide variety of habitats; known to be an animal of "patchy" country. Prefers rimrock and grassland/shrubland areas. Often found in areas with dense understory vegetation and high prey densities. Natural rocky areas are preferred den sites May be active during all hours but is primarily nocturnal. Solitary animal that is difficult to observe in the wild. In Central MT selected for cover types (52+% canopy cover) corrected with high prey densities. In W. MT den sites within caves, btwn boulders, in hollow logs, or abandon mine shafts.	Carnivore	Snowshoe hares and jackrabbits are the most common prey. Also feeds heavily on medium-sized rodents. Will eat carrion.	Non-migratory/ NA	NA	6.7 - 15.7 kg	In LA about 5 sq km for males and 1 sq km for females. In Idaho, home ranges averaged 42 sq km for males and 19 sq km for females	G5	S5	1997	1997	365
Bushy-tailed Woodrat (*Neotoma cinerea*)	Ground	Dens - rock crevices, logs	Occurs in crevices where there are large amounts of sticks, leaves & other debris used to build nest. Rockslides, rocky slopes, abandoned homesites, badlands. Occas. lodges nest in tree forks high above ground	Herbivore	Not selective in its diet of foliage, fruits and seeds of shrubs & forbs, conifer & fungi.	Non-migratory/NA	NA	NA	NA	G5	S5	1975	2006	4
Columbian Ground Squirrel (*Spermophilus columbianus*)	Ground	NA	Intermontane valleys, open woodland, subalpine meadows, even alpine tundra . Subalpine basins, clearcuts, and other disturbed areas. At high elevations, may use rockslides/forage in meadows. Prefers g-lands & sedges.	Herbivore	Grasses, leafy vegetation, and bulbs. May increase use of fruits and seeds as season progresses. Uses a small amount of animal matter: insects, fish, carrion.	Non-migratory/ Dormacy	NA	340 - 812 g	NA	G5	S5	1922	2006	12

	Habitat Group											Observation in Lincoln, Co.,		
Common Name (Genus/species)	**Foraging**	**Breeding, Resting**	**General Habitat Description**	**Feeding Guild**	**Food**	**Migration/ Hibernation**	**Longevity**	**Size**	**Home Range**	**Global Rank**	**State Rank**	**Oldest**	**Most Recent**	**Number**
Coyote (*Canis latrans*)	Scavenger	NA	Utilizes almost any habitat, including urban areas, where prey is readily available. Prefers prairies, open woodlands, brushy or boulder-strewn areas. Coyote abundance is tied to food availability. Mainly nocturnal, true scavenger, territorial. Occupies diverse habitats.	Omnivore	Will eat almost anything, plant or animal. Emphasizes small mammals, fawns, plants, birds, and invertebrates. During winter, often preys on deer. Commonly preys on domestic sheep. Rodents & rabbits imp. year round. Grasshoppers, crickets, fruits may be used in summer & fall. Food habits vary bet- ween seasons & areas. May take adult deer in winter. Young deer, elk, & pronghorn in spring.	Non-migratory / NA	NA	9 - 22 kg	NA	G5	S5	1999	2006	3
Deer Mouse (*Peromyscus maniculatus*)	Ground	Ground-Burrows	In virtually all habitats - sagebrush desert, grasslands, riparian areas, montane, subalpine coniferous forests & alpine tundra. Usually not seen in wetlands. In forest areas densities peak about 2-5 years after clear-cutting, then decline as succession advances. 15 yrs. after cut, uncut & cut densities similar. On prarie production may be linked to precipitation. Nests in burrow in ground in trees, stumps and buildings	Omnivore	Omnivorous diet although dentition is adapted for seed eating. Invertebrates important in warm months, green plant material a minor but important component. Stores some food in burrow	Non-migratory/No hibernation	Rarely lives more than 2 years in wild and from 5-8 years in captivity	18 - 35 g	NA	G5	S5	1895	2006	60
Dusky or Montane Shrew (*Sorex monticolus*)	Ground	Ground - Beneath stumps, logs, trees	High altitude spruce-fir forest, alpine tundra. Non-breeders territorial. Breeders apparently not territorial. First-year animals may not be reproductively active. Nests in stumps, logs, beneath trees.	Invertivore	Similar to other long-tailed shrews: eats mostly invertebrates	Non-migratory/NA	NA	NA	NA	G5	S5	2006	2006	7
Elk (Cervus canadensis)	Ground/Grazer	NA	Mainly coniferous forests interspersed with natural or man-made openings (mountain meadows, grasslands, burns, and logged areas) (FWP). Varies btwn pops. & areas. Basic habitat components: securi ty, shelter (may use to maintain thermal equil.) & forage prod. Moist sites preferred in sum.	Herbivore	Grasses, sedges, forbs, deciduous shrubs (especially williow and serviceberry) and young trees (especially chokecherry and maple), some conifers (FWP). Varies between ranges.	Migratory in some areas (Sun River, North Yellowstone) moving between seasonal ranges, non-migratory in others.	14 years in the wild (25 years in captivity)	Males (315 - 450 kg); Females (225 - 270 kg)	NA	G5	S5	1977	2006	5
Fisher (*Martes pennanti*)	Carnivore	Ground/Arboreal	Although they are primarily terrestrial, fishers are well adapted for climbing. When inactive, they occupy dens in tree hollows, under logs, or in ground or rocky crevices, or they rest in branches of conifers (in the warmer months). Fishers occur primarily in dense coniferous or mixed forests, including early successional forests with dense overhead cover. Dens in hollow tree or on ground	Carnivore	Mammals (small rodents, shrews, squirrels, hares, muskrat, beaver, porcupine, raccoon, deer carrion); also birds and fruit. Snowshoe hares are an important dietary item for fishers in Montana, as is deer carrion. known for their skill at killing porcupines	Fishers are non-migratory, but may make extensive movements up to a maximum of 40 kilometers in 3 days / NA	More than 9 years in captivity	Males (2.7 - 5.4 kg); Females (1.4 - 3.2 kg)		G5	S3	1965	1992	18

Common Name (Genus/species)	Habitat Group: Foraging	Habitat Group: Breeding, Resting	General Habitat Description	Feeding Guild	Food	Migration/ Hibernation	Longevity	Size	Home Range	Global Rank	State Rank	Observation in Lincoln, Co.,: Oldest	Most Recent	Number
Golden-mantled Ground Squirrel (*Spermophilus lateralis*)	Ground	Ground-Burrows	Occurs throughout the montane and subalpine forests, where- ever the rocky habitat it dwells in (outcrops and talus slopes) is present. It will range above timberline and even (in summer at least) into alpine tundra. Short, simple, concealed burrows--entrance near rock, stump, log, or bush	Omnivore	Seeds, fruits, insects, eggs, meat (Burt and Grossenheider, 1952)	Non-migratory/ Hibernates	NA	170 - 276 g	NA	G5	S4	1966	1966	2
Gray Wolf (*Canis lupus*)	Carnivore	NA	No particular habitat preference except for the presence of native ungulates within its territory on a year round basis. Wolves establishing new packs in Montana have demonstrated greater tolerance of human presence and disturbance than previously thought characteristic of this species. They have established territories where prey are more abundant at lower elevations than expected, especially in winter.	Carnivore	Opportunistic carnivores that predominantly prey on large ungulates. Main prey in Montana include deer, elk, and moose. Also alternative prey, such as rodents, vegetation and carrion. Hunt in packs, but lone wolves and pairs are able to kill prey as large as adult moose.	Not migratory but may move seasonally following migrating ungulates within its territory.	NA	31.5 - 54 kg	NA	G4	S3	1974	2000	47
Grizzly Bear (*Ursus arctos horribilis*)	Ground/Shrub	NA	In Montana, grizzlies primarily use meadows, seeps, riparian zones, mixed shrub fields, closed timber, open timber, sidehill parks, snow chutes, and alpine slabrock habitats. Habitat use is highly variable between areas, seasons, local populations, and individuals	Omnivore	large vegetative component (more than half) to their diet and have evolved longer claws for digging and larger molar surface area to better exploit vegetative food sources	No true migration occurs, although grizzly bears often exhibit discrete elevational movements from spring to fall, following seasonal food availability/ Hibernates	25 years or more in captivity	146 - 282 kg	NA	G4	S2S3	1912	2003	14
Heather Vole (*Phenacomys intermedius*)	Ground	Ground-Burrows	Most common in subalpine spruce-fir forest w/ evergreen shrub ground cover, also in timberline krummholz, alpine tundra. Sometimes in montane yellowpine-doug fir forests w/ bearberry-twinflower understory. Winter nest is a hollow sphere of twigs & lichens about 6 inches diam., above ground in protected spot. Summer nest 4-10 in. underground (Banfield 1974). Does not tend to construct runways.	Herbivore	Twigs, berries	Non-migratory/NA	NA	NA	NA	G5	S4	1948	2006	15
Hoary Marmot (*Marmota caligata*)	Ground	NA	Talus slopes, alpine meadows, high in mountains near timberline	Herbivore	herbs, grasses, sedges	Hibernates	NA	3.6 - 9 kg	NA	G5	S3S4	1949	2006	12
Long-tailed Vole (*Microtus longicaudus*)	Ground	Ground-Burrows	Riparian valley bottoms to alpine tundra, sagebrush-grassland semi-desert to subalpine coniferous forests. In forested areas may not make runways. Subordinate to other species of voles. Streambanks and occasionally in dry situations. Nests above ground in winter and in burrows in summer.	Herbivore	Grasses, bulbs, bark of small twigs.	NA/NA	NA	37 - 57 g	NA	G5	S4	1895	1993	13

Common Name (Genus/species)	Habitat Group: Foraging	Habitat Group: Breeding, Resting	General Habitat Description	Feeding Guild	Food	Migration/ Hibernation	Longevity	Size	Home Range	Global Rank	State Rank	Observation in Lincoln, Co.,: Oldest	Observation in Lincoln, Co.,: Most Recent	Observation in Lincoln, Co.,: Number
Long-tailed Weasel (*Mustela frenata*)	Carnivore	Ground- Burrows	Found in almost all land habitats near water. Has the broadest ecological and geographical range of the North American weasels. Prefers areas with abundant prey. Avoids dense forest, most abundant in late seral ecotones. Primarily nocturnal, but sometimes active during the day. Quite fearless and curious. Mainly terrestrial but can climb and swim well. Nests in old burrows of other animals . Occupies a diverse range of habitats. More prone to open country and forest openings than *M. erminea* . Common in intermontane valleys and open foresets where M. erminea is absent. May occur up to alpine tundra	Carnivore	More of a generalist than the short-tailed and least weasels. Feeds mostly on small mammals up to rabbit-sized, but eats birds and other animals as well	Non-migratory/No hibernation	NA	Males (198 - 340 g); Females (85 - 198 g)	NA	G5	S5	1940	1992	3
Lynx (*Lynx canadensis*)	Carnivore	NA	Subalpine forests between 1,220 and 2,150 meters in stands composed of pure lodgepole pine but also mixed stands of subalpine fir, lodgepole pine, Douglas-fir, grand fir, western larch and hardwoods. In extreme northwestern Montana, primary vegetation may include cedar-hemlock habitat types	Carnivore	The primary winter food for lynx throughout their range is the snowshoe hare, comprising 35 to 97% of their diet. Red squirrels are also an important prey item, particularly when snowshoe hare populations are reduced. Summer diets are not as well known but are probably more varied. Lynx in Montana probably prey on a wider variety of species throughout the year because of generally lower snowshoe hare densities and available alternate prey	Non-migratory, but movements of 90 to 125 miles have been recorded between Montana and Canada / NA	NA	6.7 - 13.5 kg	NA	G5	S3	1941	2005	215
Marten (*Martes americana*)	Carnivore	NA	Primarily a boreal animal preferring mature conifer or mixed wood forests. Severe forest disturbance can significantly reduce habitat value. Uses deadfall and snags as den sites. Spends much time in trees but will also forage on the ground.	Carnivore	Opportunistic feeder that primarily feeds on small mammals. Meadow voles and red-backed voles were staples in Glacier NP. Also used Cricetidae, jumping mice, shrews, ground squirrels, and snowshoe hares. Use of birds, insects, and fruit variable by season.	Non-migratory/NA	17 years in captivity	Males (754 - 1248 g); Females (681 -851 g)	NA	G5	S4	1945	1966	78
Masked Shrew (*Sorex cinereus*)	Ground	Ground	Coniferous forest. In western Montana, where *S. vagrans* also occurs, *S. cinereus* is usually restricted to drier coniferous forest habitat. Moist situations in forests, open country, brushland. Nest of dry leaves or grasses, in stumps or under logs or piles of brush.	Invertivore	Invertebrates, salamanders, small mice. In winter, seeds may be main item in diet.	Non-migratory/NA	NA	3 - 6 g	NA	G5	S5	1966	2006	16
Meadow Vole (*Microtus pennsylvanicus*)	Ground	Ground- Burrows	Wet grassland habitat but not above timberline in grassy alpine tundra. Where *M. montanus* not present, M. pennsyvanicus may inhabit drier grasslands. Makes extensive runways. In E MT mean home range was 0.13 ac. for females, 0.14 ac. for lactating females, 0.23 ac. for males (McCann 1976). Low longevity, high juvenile mortality.	Herbivore	Grasses, sedges & herbaceous plants. May use fungi, particularly endogone. Will use insects. Occasionally will use carrion. Reported to feed on apple trees (bark and vascular tissues of lower trunk and roots)	Non-migratory/NA	1 to 3 years in wild	28 - 70 g	NA	G5	S5	1895	2006	57

Common Name (Genus/species)	Habitat Group: Foraging	Habitat Group: Breeding, Resting	General Habitat Description	Feeding Guild	Food	Migration/ Hibernation	Longevity	Size	Home Range	Global Rank	State Rank	Observation in Lincoln, Co.,: Oldest	Observation in Lincoln, Co.,: Most Recent	Observation in Lincoln, Co.,: Number
Mink (*Mustela vison*)	Riparian	Ground	Usually found along streams and lakes. Commonly occurs in marshes and beaver ponds. Permanence of water and dependable source of food are most important habitat components. Often uses den sites of other animals and is commonly found in association with muskrats. Semi-aquatic forager. Can kill prey larger than itself. Chiefly nocturnal, territorial, and secretive. Dens underneath piles of brush or driftwood, under rocks, in hollow logs, and in houses or dens abandoned by beavers or muskrats.	Piscivore	Preys primarily on small mammals, birds, eggs, frogs, and fish. Its diet is almost entirely animal. During summer preys on waterfowl. Order of importance varies.	Non-migratory. Males make extensive movements and juveniles disperse / NA	NA	Males (681 - 1362 g); Females (567 - 1089 g)	NA	G5	S5	1939	1943	2
Moose (*Alces alces*)	Ground/Grazer	NA	Variable; in summer, mountain meadows, river valleys, swampy areas, clearcuts; in winter, willow flats or mature coniferous forests; best ability of any Montana ungulate to negotiate deep snow	Herbivore	Browse, including large saplings; aquatic vegetation (FWP). Varies btwn ranges. Winter: willow, servicebry, chokecherry & redosier dogwood. Spring/sum--incr. forb use (up to70% of diet). Some pop.s use aquat. veg. overall	Often uses separate summer/winter ranges. Movements prompted by temperature & snow depth/ No hibernation	20 or more years in the wild	Males (382.5 - 531 kg); Females (270 -360 kg)	NA	G5	S5	1977	2006	10
Mountain Cottontail (*Sylvilagus nuttallii*)	Ground	NA	Primarily dense shrubby undergroth, riparian areas in Cen- tral and Eastern MT. In mountains, it uses shrubby gulleys, and forest edges.	Herbivore	Sagebrush may be a principal food. Grasses also a preferred food. Juniper sometimes used. May prefer grasses in spring and summer	Non-migratory/No hibernation	NA	0.7 - 1.3 kg	NA	G5	S4	NA	NA	NA
Mountain lion (*Puma concolor)*	Carnivore	NA	Mostly mountains and foothills, but any habitat with sufficient food, cover and room to avoid humans. In W MT spring-fall ranges at higher elev than winter areas. Cover types in winter: 42% pole stands, 30% selectively logged (pole or mature), 18% seral brushfields	Carnivore	Deer, elk, and pocupines most important in Montana, but may take prey ranging in size from grasshoppers to moose (FWP).	Non-migratory/NA	NA	36 - 90 kg	NA	G5	S4	1975	2007	182
Mule deer (*Odocoileus hemionus*)	Ground/Grazer	NA	Grasslands interspersed with brushy coulees or breaks; riparian habitat along prairie rivers; open to dense montane and subalpine coniferous forests, aspen groves (FWP). Varies between areas & seasons.	Herbivore	Bitterbush, mountain mahogany, chokecherry, serviceberry, grasses and forbs	Migratory in mountain-foothill habitats/ No hibernation	Normal in wild 16 years	Males (56.2 -180 kg) Females (45 - 67.5 kg)	NA	G5	S5	1977	1978	4
Muskrat (*Ondatra zibethicus*)	Riparian	Riparian	Marshes, edges of ponds, lakes, streams, cattails, and rushes are typical habitats. An essential habitat ingredient is water of sufficient depth or velocity to prevent freezing. The presence of herbaceous vegetation, both aquatic and terrestrial, is another essential ingredient. In general, has very flexible habitat requirements and often coexists in habitats used by beavers (FWP). Lentic or slightly lotic water containing vegetation. Typha spp. (cattails) & Scirpus spp. (bulrushes) usually present. Constructs bank dens, lodges, feeding huts, platforms, pushups & canals	Herbivore	Primarily herbivorous and will eat virtually any vegetable matter. Utilizes shoots, roots, bulbs, and leaves of aquatic plants. Cattails and bulrush are preferred foods. Will also consume cultivated crops. On occasion will eat animal matter. Food is stored in the burrow or den and during winter may even eat part of its own lodge	Non-migratory/NA	NA	908 - 1,816 g	NA	G5	S5	1940	2006	3

	Habitat Group											Observation in Lincoln, Co.,		
Common Name (Genus/species)	**Foraging**	**Breeding, Resting**	**General Habitat Description**	**Feeding Guild**	**Food**	**Migration/ Hibernation**	**Longevity**	**Size**	**Home Range**	**Global Rank**	**State Rank**	**Oldest**	**Most Recent**	**Number**
North American Wolverine (*Gulo gulo luscus*)	Carnivore	Caves/Cavity/Ground/Rock	Wolverines are limited to alpine tundra, and boreal and mountain forests (primarily coniferous) in the western mountains, especially large wilderness areas. They are usually in areas with snow on the ground in winter. Riparian areas may be important winter habitat. When inactive, wolverines occupy dens in caves, rock crevices, under fallen trees, in thickets, or similar sites. Wolverines are primarily terrestrial but may climb trees. In Montana, most wolverine use in medium to scattered timber, while areas of dense, young timber were used least.	Omnivore	Wolverines are opportunistic. They feed on a wide variety of roots, berries, small mammals, birds' eggs and young, fledglings, and fish. They may attack moose, caribou, and deer hampered by deep snow. Small and medium size rodents and carrion (especially ungulate carcasses) often make up a large percentage of the diet. Prey is captured by pursuit, ambush, digging out dens, or climbing into trees. They may cache prey in the fork of tree branches or under snow	Wolverines in northwestern Montana and Alaska tend to occupy higher elevations in summer and lower elevations in winter / NA	More than 15 years in captivity	7 - 32 kg	NA	G4	S3	1938	1995	56
Northern Flying Squirrel (*Glaucomys sabrinus*)	Arboreal	Arboreal	Montane and subalpine coniferous forests. Also in riparian Cottonwood forests. Nests are constructed either within natural cavities or abandoned woodpecker holes in dead standing trees, or they are built over limbs or within witches' brooms	Omnivore	Seeds, fruits, flowers, insects, tree sap, fungus. Perhaps eggs and meat.	Non-migratory	NA	113-185 g	NA	G5	S4	1941	1969	5
Northern Pocket Gopher (*Thomomys talpoides*)	Ground	Ground-Burrows	Cultivated fields and prairie to alpine meadows. Avoids dense forests, shollaow rocky soils and areas with poor snow cover.	Herbivore	underground plant parts	Non-migratory	18 to 24 months average in wild		NA	G5	S5	1966	1966	1
Pika (*Ochotona princeps*)	Ground	NA	Talus slides, boulder fields, rock rubble (with interstitial spaces adeq. for habitation) near meadows. Usually at high elevation but mid elevation possible if suitable rock cover and food plants present	Herbivore	Animals feed on hay individually, stored in small clumps under rocks, boulders.	Non-migratory/No hibernation	Maximum 7 yr	113 - 180 g	0.3-0.5 ha and mean 0.26 ha	G5	S4	1949	2006	12
Porcupine (*Erethizon dorsatum*)	Ground/ Shrub	Dens - rock crevices, trees	Common in montane forests of Western Montana, also occurs in brushy badlands, sagebrush semi-desert and alon streams and rivers. Rockfall caves, ledge caves, hollow trees, or brushpiles for dens,	Herbivore	In winter uses cambium, phloem, & foliage of woody shrubs & trees--Ponderosa Pine, Lodgepole Pine, perhaps spruce & fir. In spring & summer uses reprod. parts & foliage of aspen, forbs, grasses, sedges & succulent wetland vegetation	Non-migratory. In mountainous areas seasonal alti- tudinal migration may occur	NA	4.5 - 12.7 kg	NA	G5	S4	1917	1966	3
Pygmy Shrew (*Sorex hoyi*)	Ground	Ground/Cavity	Dry, open coniferous forests (ponderosa pine, western larch)	Invertivore	Primarily on invertebrates	Non-migratory/NA	NA	3 - 4 g	NA	G5	S4	1978	2006	4
Raccoon (*Procyon lotor*)	Riparian	NA	Inhabits stream and lake borders near wooded areas or rocky cliffs. Most abundant in riparian and wetland habitats. Uses hollow logs, trees, and rock crevices as den sites. Forested riparian habitat--river & stream valleys. Although tree dens are most common, burrows & crevices, etc. also used.	Omnivore	Carrion, mammals, birds, reptiles, insects, amphibians, grains, nuts, and fruits.	Non-migratory / No hibernation	NA	900 - 1130 g	NA					

Common Name (Genus/species)	Habitat Group: Foraging	Habitat Group: Breeding, Resting	General Habitat Description	Feeding Guild	Food	Migration/ Hibernation	Longevity	Size	Home Range	Global Rank	State Rank	Observation in Lincoln, Co.,: Oldest	Most Recent	Number
Red fox (*Vulpes vulpes*)	Carnivore	Ground	Wide range of habitats. Often associated with agricultural areas. Prefers mixture of forest and open country near water. Uses dens for shelter during severe weather and when pups are being reared. Usually uses dens made by other animals. Seldom found far from permanent water. Thrive in bushy successional area where small mammals are most abundant. Occupies diverse habitats. In forest situations uses edge. Burrow den-sites comprised of sub-dens (10-40 holes). Some dens in open and some in brush.	Carnivore	Opportunistic predator that sometimes eats carrion. Preys on small mammals, birds, eggs, game birds. Varies according to avail. in W. MT. During spring: microtus spp., birds, muskrats, rabbits, grnd squirrels, deer carrion (in decreasing order of importance). In winter microtus spp., birds, N. pocket gophers. Also uses vegetation.	Non-migratory / NA	NA	18 - 31.5 kg	NA					
Red Squirrel (*Tamiasciurus hudsonicus*)	Ground	NA	Most common in Montane (Yellow Pine and Douglas Fir) and subalpine (subalpine fir--Englemann Spruce) forests in W. MT. Annual fluctuations in density are large. Correlated with size of seed and cone crops	Herbivore	Conifer cone crops, including serotinous cones. Opportun- istic. Uses terminal buds, seeds, sap, berries, bark of a variety of plants. Also uses fungi. Occasionally carnivorous	Non-migratory/No hibernation	NA	198 - 250 g	NA	G5	S5	1945	2006	19
Red-tailed Chipmunk (*Tamias ruficaudus*)	Arboreal	NA	Coniferus forests, talus slides, mountains up to timberline. Most abundant in edge openings. Sometimes ranges into alpine	Herbivore	Primarily seeds and fruits. Leaves and flowers in spring, less so in summer. Occasionally uses arthropods	Non-migratory	NA	NA	NA	G5	S4	1949	1978	13
Short-tailed Weasel (*Mustela erminea*)	Carnivore	Ground-Burrows	Inhabits brushy or wooded areas, usually not far from water. Tends to avoid dense forests. Prefers areas with high densities of small mammals. Most abundant in ecotones. Mostly nocturnal but will hunt during the day. Active throughout the year. Dens in ground burrows, under stumps, rock piles, or old buildings. In Montana apparently prone to montane forest associations.	Carnivore	Weasels prey on a variety of small mammals and birds, they specialize in hunting voles. Mostly small warm-blooded vertebrates, primarily cricetidae. Hunts under snow in winter. Females generally eat smaller prey. May use invertebrates.	Non-migratory/No hibernation	NA	Males (71 - 170 g); Females (28 - 85 g)	NA	G5	S5	1939	1969	4
Snowshoe Hare (*Lepus americanus*)	Ground	NA	In W. MT, apparently preferred fairly dense stands of young pole-sized timber with some use of more open stands, openings, and edges.	Herbivore	Spring and summer: forbs and grasses. Fall and winter: more shrubs and sometimes conifer needles. Occasionally reingests feces. Sometimes eats sand	Non-migratory/No hibernation	Few live more than 3 years in the wild.	0.9 - 1.8 kg	NA	G5	S4	1986	1986	1
Southern Red-backed Vole (*Clethrionomys gapperi*)	Ground	Ground	Common in dense subalpine forests, also occurs in more open forest types, even alpine tundra. A favored prey of marten in NW MT. Populations fluctuate. Typically does not construct runways. Simple globular nests (75-100 mm. diam.), lined w/ grass, stems, leaves or moss.	Herbivore	Vegetative portions of plants, nuts, seeds, berries, mosses, lichens, ferns, fungi & arthropods	Non-migratory/NA	NA	14 - 40 g	NA	G5	S4	1949	2006	35
Striped Skunk (*Mephitis mephitis*)	Ground	Ground/Cavity	Variety of habitats including semi-open country, mixed woods, brushland, and open prairie. Most abundant in agricultural areas where there is ample food and cover. Usually absent where water table is too high for making ground dens. Forest edges, open woodland, brushy grassland, riparian vegetation, cultivated lands. Dens in ground burrows, beneath abandoned buildings, boulders, or wood, or rock piles.	Omnivore	Omnivorous, eating more animal than plant matter. Propor- tional composition of diet varies. Small mammals, reptiles, amphibians, berries, fruit, garbage, cariion, bird eggs, & arthropods.	Non-migratory / No hibernation	NA	2.7 - 6.3 kg	NA	G5	S5	1895	1999	3
Vagrant Shrew (*Sorex vagrans*)	Ground	NA	At elevations below 5000 ft, usually Doug. Fir, Lodgepole Pine, W. Larch, Grand Fir, W. Red Cedar forests. Often found in moist sites. Marshes, bogs, wet meadows, and along streams in forests. Uses echolocation to orient in darkness.	Carnivore	Insects, annelida, shrews, vegetable matter, insect larvae. Also uses plant seeds, carrion, and some mushrooms	Non-migratory/NA	Few live more than 16 months.	7 g	NA	G5	S4	1895	2006	39

	Habitat Group											Observation in Lincoln, Co.,		
Common Name (Genus/species)	**Foraging**	**Breeding, Resting**	**General Habitat Description**	**Feeding Guild**	**Food**	**Migration/ Hibernation**	**Longevity**	**Size**	**Home Range**	**Global Rank**	**State Rank**	**Oldest**	**Most Recent**	**Number**
Water Shrew (*Sorex palustris*)	Riparian	Ground	Streamside habitat in coniferous forests, particularly in or under overhanging banks or crevices--good cover. However, also found in seasonal streams and small seeps. Also above timberline. Nests of dried sticks and leaves.	Invertivore	Aquatic insect larvae, also some vegetable matter, oligo- chaetes, other shrews, arachnids, and small fish	Non-migratory/NA	NA	9 - 14 g	NA	G5	S4	1966	1992	4
Water Vole (*Microtus richardsoni*)	Riparian	Ground-Burrows	Semi-aquatic. Near streams & lakes in subalpine and alpine zones. Normally above 5000 ft. in western mountains. Moist grass & sedge areas, streamside hummocks overhung w/ willows. Burrows, runways & cuttings are conspicuous in summer	Omnivore	Possible heavy use of graminoids. Composite data from a variety of areas suggest forbs & willows also eaten. Use of vaccinium, erythronium bulbs, conifer seeds, insects	Non-migratory/NA	NA	71 - 100 g	NA	G5	S4			
Western Jumping Mouse (*Zapus princeps*)	Ground	Ground	tall grass along streams, with or without a brush or tree canopy. Also dry grasslands in N. Central MT. Mesic forests with sparse understory herbage in W. MT. From valley floors to timberline & alpine wet sedge meadows. Nests are in mounds or banks elevated above surrounding ground (well-drained) usually 2 feet underground, shredded vegetation insulative core.	Herbivore	Seeds	Non-migratory/ Hibernates	As long as 6 years in wild if survive first hibernation (half of all juveniles die during first hibernation)	18 to 37 grams	NA	G5	S4	1949	2006	17
White-tailed deer (*Odocoileus virginianus*)	Ground/Grazer	NA	River and creek bottoms; dense vegetation at higher elevations; sometimes open bitterbush hillsides in winter (FWP). In W MT mature subclimax coniferous forest, cool sites, diversity & moist sites important in summer (Leach 1982). In winter prefer dense canopy classes, moist habitat types, uncut areas & low snow depths (Berner 1985).	Herbivore	Leaves, twigs, fruits, and berries of browse plants such as chokecherry, serviceberry, snowberry, and dogwood; some forbs during summer (FWP). Browse most imp. statewide - yr. round, particularly so in winter. Graminoid use increases in spring, forb use in late spring & sometimes in fall.	Uses summer range, winter range in W MT may be 8.69-15 mi. apart.	Up to 16.5 years in the wild.	Males (33.7 - 180 kg); Females (22.5 - 112.5 kg)	NA	G5	S5	1978	2006	3
Yellow pine chipmunk (*Tamias amoenus*)	Ground	Ground-Burrows	Open stands of ponderosa pine and Douglas fir. Nest chamber in burrow averaging 11 inches below surface. Open coniferous forests, chaparral, rocky areas with brush or scattered bines, burned over areas.	Herbivore	Fruits and seeds and a few insects	Non-migratory/ Hibernates	5 years or more in the wild	38 - 71 gram	NA	G5	S5	1860	2006	10
Yellow-bellied Marmot (*Marmota flaviventris*)	Ground/Rock Slopes	Dens - Talus slopes, rock outcrops	Semi-fossorial. Inhabits talus slopes or rock outcrops in meadows. Abundant herbaceous & grassy plants nearby. Rocks support burrows & serve as sunning & observ. posts. Avoids dense forests. Rarely in holl riv bot fld pln c-wood trees. Occurs from valley bottoms to alpine tundra where suitable habitat exists. Where *Marmota caligata* occurs, *M. flavi* - ventris is restricted to lower elevations.	Herbivore	Grasses, flowers, forbs--in late summer eats seeds. Mode- rate grazing by ungulates may favor marmots. Likes alfalfa	Non-migratory, although dispersal movements may be observed/ Hibernates	NA	2.2 - 4.5 kg	NA	G5	S4	1949	1949	3

Attachment A-4. Fish Species Occuring within the Libby OU3 Site

Common Name (Genus/species)	General Habitat Description	Food Habits	Global Rank	State Rank	Observation in Lincoln, Co., Montana: Oldest	Most Recent	Number
Black Bullhead (*Ameirurus melas*)	Turbid, mud bottomed lakes and ponds; also pools and backwaters of streams. Tolerates high water temperatures and low levels of dissolved oxygen.	Omnivorous. Mostly aquatic insects, crustaceans, mollusks, fish, and vegetation matter. Young feed during day, while adults feed at night.	G5	SNA	1996	1996	1
Brook Trout (*Salvelinus fontinalis*)	Prefers small spring fed streams and ponds with sand or gravel bottom and vegetation. Clear, cool water . Spawns over gravel in either streams or lakes with percolation;spring areas in lakes.	Feed mainly on aquatic insects and other small aquatic invertebrates throughout life. Larger individuals may eat small fish	G5	SNA	1960	2006	86
Brown Trout (*Salmo trutta*)	Valley portions of larger rivers where gradients are low and Summer temperatures range from 60-70 degrees F. Also reservoirs and lakes at similar elevation with suitable spawning trib.	Feeds largely on underwater aquatic insects. Also uses many other small organisms available and large individuals eat many small fish	G5	SNA	2006	2006	2
Bull Trout (*Salvelinus confluentus*)	Sub-adult and adult fluvial bull trout reside in larger streams and rivers and spawn in smaller tributary streams, whereas adfluvial bull trout reside in lakes and spawn in tributaries. They spawn in headwater streams with clear gravel or rubble bottom.	Young feed on aquatic insects. The adults are piscivorous.	G3	S2	1960	2004	40
Burbot (*Lota lota*)	Large rivers and cold, deep lakes and reservoirs. Spawn in shallow water, usually in rocky areas.	Young feed on aquatic invertebrates. Adults are piscivorous	G5	SNA	1993	1993	1
Channel Catfish (*Ictalurus punctatus*)	Prefers large rivers and lowland lakes. Thrives at water temperatures above 70 degrees. Tolerates turbid water.	Omnivorous feeder. Uses almost any living or dead organisms available.	G5	S5	2006	2006	1
Common Carp (*Cyprinus carpio*)	Primarily lakes and reservoirs, moderately warm water and shallows. Also rivers, pools and backwaters. Congregates in areas of organic enrichment. Tolerates turbid water and low dissolved oxygen; avoids cold and swift, rocky streams. Spawns in shallow weedy areas	An omnivorous feeder with vegetation and detritus making up bulk of diet. May feed on any available aquatic organism including eggs.	G5	SNA	2006	2006	2
Fathead Minnow (*Pimephales promelas*)	Habitat is highly variable but found mostly in small turbid creeks and shallow ponds of flatlands. Very tolerant of extreme conditions found in a prairie environment (turbid water, high temperature, and low dissolved oxygen).	Variety of minute aquatic plants and animals.	G5	S4S5	1998	1998	1
Kokanee Salmon (*Oncorhynchus nerka*)	Cold, clear lakes and reservoirs and Kokanee Salmon are found at all depths. They spawn over loose rubble, gravel, and sand in lower portions of tributary streams or along lake shores	The diet consists mostly of plankton. Micro-crustacea are most important, but midges and other aquatic insects are often taken	G5	SNA	2002	2002	1
Largescale Sucker (*Catostomus macrocheilus*)	Found in both streams and lakes. Spawns in gravel riffles with strong current or along lake margins	Almost any available organism found on the substrate	G5	S5	1993	2003	3
Longnose Dace (*Rhinichthys cataractae*)	Habitat variable. Found in lakes, streams, springs. Preferred habitat is riffles with a rocky substrate	Eats mostly immature aquatic insects picked off the rocks. Small amounts of algae and a few fish eggs are also eaten	G5	S5	2000	2006	8
Longnose Sucker (*Catostomus catostomus*)	Cold, clear streams and lakes; sometimes moderately warm waters and turbid waters. Spawns over loose gravel beds in riffle areas.	Considerable algae, midge larvae, and most aquatic invertebrates	G5	S5	1996	2006	3
Mottled Sculpin (*Cottus bairdi*)	Prefer riffle areas of fast-flowing streams that are clear and have rocky bottoms.	Variety of immature aquatic organisms, but midge and acddis larvae are by far the most important. A study in southwest Montana showed bottom-dwelling aquatic insects comprising 99.7% of the diet.	G5	S5	1953	1991	5
Mountain Whitefish (*Prosopium williamsoni*)	Medium to large cold mountain streams. Also found in lakes and reservoirs. Normally a stream spawner in riffles over gravel or small rubble but has been seen spawning along lake shorelines.	Mostly on aquatic insects but also takes terrestrial insects which fall into water. May eat fish eggs, but rarely fishes Feeds actively in Winter. Zooplankton important in lakes.	G5	S5	1969	2006	14

Common Name (Genus/species)	General Habitat Description	Food Habits	Global Rank	State Rank	Observation in Lincoln, Co., Montana: Oldest	Most Recent	Number
Northern Pikeminnow (*Ptychocheilus oregonensis*)	Prefers lakes and slow - flowing streams of moderate size. Young usually school in shallow water near lake shores and in quiet backwaters of streams	Most kinds of aquatic invertebrates. Adults frequently eat small fish. Considered a serious predator on young salmon and trout	G5	S5	1952	2006	3
Peamouth (*Mylocheilus caurinus*)	Shallow weedy zones of lakes or rivers.	Young feed mainly on micro-crustaceans. Adults eat micro-crustaceans, snails, adult aquatic and terrestrial insects. Occasionally small fish.	G5	S5	2006	2006	1
Rainbow Trout (*Oncorhynchus mykiss*)	Cool clean streams, lakes, res., farm ponds. Able to withstand wider range of temperatures than most trout. Spawns in streams over gravel beds.	Feed mainly on aquatic insects but eat what is available to them. Large adults also eat fish. River populations mostly insect eaters while zooplankton and forage fish are important in Lake Koocanusa.	G5	S5	1976	2006	80
Redside Shiner (*Richardsonius balteatus*)	Lakes, ponds, and larger rivers where current is weak or lacking.	Young feed mainly on plankton and adults eat mostly aquatic insects and snails.	G5	S5	2002	2006	4
River Carpsucker (*Carpiodes carpio*)	Reservoirs and the pools and backwaters of rivers. Spawn in larger streams with backwater areas.	Mostly diatoms, desmids, and filamentous algae. Also aquatic invertebrate larvae.	G5	S5	2006	2006	1
Slimy Sculpin (*Cottus cognatus*)	Rocky riffles of cold, clear streams, but it is sometimes found along the rubble beaches of lakes, especially near the mouths of inlet streams	Mostly immature aquatic insects and invertebrates, but also includes any small fish available	G5	S5	1950	2006	58
Smallmouth Bass (*Micropterus dolomieu*)	Prefers clear cool water and rocky substrates in both rivers and lakes. In streams, it prefers riffle areas with clean bottoms. In lakes, it prefers rocky shorelines, reefs, out- croppings, gravel bars, etc.	Feeds on most available item. Fry feed on zooplankton and small mayflies. Adults feed heavily on fish, frogs, and aquatic invertebrates. Seems to prefer crayfish, if available.	G5	SNA	2006	2006	2
Torrent Sculpin (*Cottus rhotheus*)	Riffles of cold, clear streams, but are also taken in lakes. They hide near stones on the bottom.	The fry eat mostly plankton. Adults feed mainly on aquatic insects and a variety of invertebrates, but also include plankton. Larger individuals often eat small fish.	G5	S3	1950	2006	89
Westslope Cutthroat Trout (*Oncorhynchus clarkii lewisi*)	Spawning and rearing streams tend to be cold and nutrient poor. Seek gravel substrate in riffles and pool crests for spawning. Sensitive to fine sediment. Require cold water. Thrive in streams with more pool habitat and cover than uniform, simple habitat. Juveniles overwinter in the interstitial spaces of large stream substrate. Adult need deep, slow moving pools that do not fill with anchor ice in order to survive the winter.	NA	G4T3	S2	1960	2006	60
White Sturgeon - *Acipenser transmontanus*							

Data are taken from: http://fieldguide.mt.gov/

Montana Species Ranking Codes: Montana employs a standardized ranking system to denote global (G - range-wide) and state status (S) (NatureServe 2003). Species are assigned numeric ranks ranging from 1 (critically imperiled) to 5 (demonstrably secure), reflecting the relative degree to which they are “at-risk”. Rank definitions are given below. A number of factors are considered in assigning ranks - the number, size and distribution of known “occurrences” or populations, population trends (if known), habitat sensitivity, and threat.

G1 S1
At high risk because of extremely limited and potentially declining numbers, extent and/or habitat, making it highly vulnerable to global extinction or extirpation in the state.

G2 S2
At risk because of very limited and potentially declining numbers, extent and/or habitat, making it vulnerable to global extinction or extirpation in the state.

G3 S3
Potentially at risk because of limited and potentially declining numbers, extent and/or habitat, even though it may be abundant in some areas.

G4 S4
Uncommon but not rare (although it may be rare in parts of its range), and usually widespread. Apparently not vulnerable in most of its range, but possibly cause for long-term concern.

G5 S5
Common, widespread, and abundant (although it may be rare in parts of its range). Not vulnerable in most of its range.

Attachment A-5. Reptile Species Occuring within the Libby OU3 Site

Common Name (Genus/species)	General Habitat Description	Food Habits	Global Rank	State Rank	Observation in Lincoln, Co., Montana: Oldest	Most Recent	Number
Common Gartersnake (*Thamnophis sirtalis*)	Found in nearly all habitats, but most commonly at lower elevations around water. Prefer moist habitats and are found most often along the borders of streams, ponds and lakes. They may travel long distances (4 to 17 kilometers) from hibernacula to forage in preferred habitat	Variety of vertebrates and invertebrates.	G5	S4	1954	2006	55
Eastern Racer (*Coluber constrictor*)	Associated with relatively open habitats either in shortgrass prairie or forested areas. Very fast and active, prey on insects and small vertebrates such as mice and frogs. Females lay a clutch of three to seven eggs in summer. In the NW racers generally absent from dense forest/hi mtns.	Orthopterans can form a major part of diet and have been re- ported as food in NC MT. Small mammals, lizards, orthopterans, anurans are all major components of diet.	G5	S5	1991	1991	4
Gophersnake (*Pituophis catenifer*)	Dry habitats, including open pine forests. Occasionally climb trees.	Rodents, rabbits, ground-dwelling birds, and to a lesser extent lizards.	G5	S5	1993	1994	3
Northern Alligator Lizard (*Elgaria coerulea*)	Little specific information on habitat associations in Montana. South-facing slopes in fine to course talus, sometimes in the open, but often with some canopy cover of Douglas-fir, ponderosa pine, a variety of shrubby species (serviceberry, ninebark, mock orange), and a litter layer of dried leaves and conifer needles .	An invertivore, northern alligator lizards feed on insects, ticks, spiders, centipedes, millipedes, slugs and snails.	G5	S3	1949	2006	12
Painted Turtle (*Chrysemys picta*)	NA (web page not available)	NA (web page not available)	G5	S4	1955	2006	44
Rubber Boa (*Charina bottae*)	Usually found under logs and rocks in either moist or dry forest habitats. They are primarily nocturnal, but occasionally may be observed sunning on roads, trails, or in open areas.	Feed primarily on small mice but also take shrews, salamanders, snakes, and lizards.	G5	S4	1980	2004	15
Terrestrial Gartersnake (*Thamnophis elegans*)	Found in nearly all habitats, but most commonly at lower elevations around water. Common near water but also found away from water. At high elev. common on rocky cliffs/ brushy talus .	They eat a variety of vertebrates and invertebrates.	G5	S5	1952	2006	51

Data are taken from: http://fieldguide.mt.gov/

Montana Species Ranking Codes: Montana employs a standardized ranking system to denote global (G - range-wide) and state status (S) (NatureServe 2003). Species are assigned numeric ranks ranging from 1 (critically imperiled) to 5 (demonstrably secure), reflecting the relative degree to which they are “at-risk”. Rank definitions are given below. A number of factors are considered in assigning ranks - the number, size and distribution of known “occurrences” or populations, population trends (if known), habitat sensitivity, and threat.

G1 S1
At high risk because of extremely limited and potentially declining numbers, extent and/or habitat, making it highly vulnerable to global extinction or extirpation in the state.

G2 S2
At risk because of very limited and potentially declining numbers, extent and/or habitat, making it vulnerable to global extinction or extirpation in the state.

G3 S3
Potentially at risk because of limited and potentially declining numbers, extent and/or habitat, even though it may be abundant in some areas.

G4 S4
Uncommon but not rare (although it may be rare in parts of its range), and usually widespread. Apparently not vulnerable in most of its range, but possibly cause for long-term concern.

G5 S5
Common, widespread, and abundant (although it may be rare in parts of its range). Not vulnerable in most of its range.

Common Name (Genus/species)		General Habitat Description	Global Rank	State Rank	Observation in Lincoln, Co., Montana: Oldest	Most Recent	Number
Freshwater Sponge (*Heteromeyenia baileyi*)	Aquatic	NA	G5	S1S3	1997	1997	1
Stonefly (*Utacapnia columbiana*)	Aquatic	The larvae occur on the upper surfaces and sides of cobbles and boulders in moderate gradient, fast flowing, foothills to mountain streams. Inhabits streams with moreintermediate characteristics between the higher elevation, cold mountain streams (more likely to find Glossosoma & Anagapetus), and the large warmer transitional rivers downstream (more likely to find Prototila). Generally the riparian canopy of the occupied streams is mostly (>50%) open, and less shaded than mountain streams. In clear streams and rivers during low flows, it is typical to be able to locate & identify *Agapetus* larvae on the tops of rocks. In relation to trophic status, A. montanus larvae scrape, graze and digest algae and diatoms from the surfaces of rocks.	G4	S2			1
Banded Tigersnail (*Anguispira kochi*)	Terrestrial	NA	G5	SNR	2005	2007	39
Blue Glass (*Nesovitrea binneyana*)	Terrestrial	NA	G5	SNR	2007	2007	7
Brown Hive (*Euconulus fulvus*)	Terrestrial	NA	G5	SNR	2005	2007	17
Coeur d'Alene Oregonian (*Cryptomastix mullani*)	Terrestrial	NA	G4	SNR	2005	2007	20
Land Snail, Cross Vertigo (*Vertigo modesta*)	Terrestrial	NA	G5	SNR	2006	2007	5
Land Snail, Fir Pinwheel (*Radiodiscus abietum*)	Terrestrial	NA	G4	S2S3	1959	2007	32
Land Snail, Forest Disc (*Discus whitneyi*)	Terrestrial	NA	G5	SNR	2005	2007	12
Slug, Giant Gardenslug (*Limax maximus*)	Terrestrial	Common in gardens and buildings, and margins of native forests, does not seem to penetrate far into undistrubed forests, although it can be abundant in modified forest remnants and secondary forests. This nocturnal slug feeds primarily on decaying plant material and fungi, but because it shows aggresive behavior towards other slugs, it is often erroneously regarded as a predator	G5	SNA	2005	2005	1
Slug, Gray Fieldslug (*Deroceras reticulatum*)	Terrestrial	NA	G5	SNA	2007	2007	1
Land snail, Hedgehog Arion (*Arion intermedius*)	Terrestrial	Often locally abundant in pastures, hedgerows, plantation forests, and in native forests. It can penetrate deep into undisturbed forest from areas disturbed by humans	G5	SNR	2007	2007	3
Land snail, Idaho Forestsnail (*Allogona ptychophora*)	Terrestrial	NA	G5	SNR	2005	2007	15
Slug, Magnum Mantleslug (*Magnipelta mycophaga*)	Terrestrial	Low- to mid-elevation sites, often with water in the general vicinity. Moist, cool sites in relatively undisturbed forest with an intact duff layer, such as are found in moist valleys, ravines, and talus areas, are preferred. Forest canopy composition at sites includes *Picea engelmannii*, *Pseudotsuga menziesii*, *Pinus ponderosa*, *Pinus albicaulis*, *Larix occidentalis*, *Abies lasiocarpa* , and *Abies grandis* , often with *Alnus* present; spruce-fir appears to be the most frequent forest association. Often found on the ground under pieces of loose bark, logs, loose stones, and in rotted wood; surface active on cool (10-16wet and overcast days, probably most active at night.	G3	S1S3	2005	2007	8
Slug, Meadow Slug (*Deroceras laeve*)	Terrestrial	Cliff, Cropland/hedgerow, Forest - Conifer, Forest - Hardwood, Forest - Mixed, Forest Edge, Forest/Woodland, Grassland/herbaceous, Old field, Savanna, Shrubland/chaparral, Suburban/orchard, Urban/edificarian, Woodland - Conifer, Woodland - Hardwood, Woodland - Mixed	G5	SNA	2005	2007	5
Land snail, Multirib Vallonia (*Vallonia gracilicosta*)	Terrestrial	NA	G5Q	SNR	2007	2007	1
Land snail, Orange-banded Arion (*Arion fasciatus*)	Terrestrial	Damp areas and wet meadows adjacent to streams	GNR	SNR	2007	2007	3

Common Name (Genus/species)		General Habitat Description	Global Rank	State Rank	Observation in Lincoln, Co., Montana: Oldest	Most Recent	Number
Darner damselfly, Paddle-tailed Darner (*Aeshna palmata*)	Terrestrial	Found in most habitats, including warm springs; found far from water	G5	S5	1994	1994	1
Slug, Pale Jumping-slug (*Hemphillia camelus*)	Terrestrial	NA	G4	S1S3	2005	2007	10
Slug, Pygmy Slug (*Kootenaia burkei*)	Terrestrial	Forest - Mixed, Fallen log/debris, forested and adjacent to a perennial water body. Found on forest floor mostly, either on or under woody debris, mats of moss, or deciduous tree leaves; two specimens collected 0.2 m aboveground on moss-covered tree trunk along stream edge	G2	S1S2	2005	2007	17
Land Snail, Quick Gloss (*Zonitoides arboreus*)	Terrestrial	NA	G5	SNR	2005	2007	26
Land Snail, Robust Lancetooth (*Haplotrema vancouverense*)	Terrestrial	NA	G5	S1S2	2006	2006	16
Land Snail, Rocky Mountainsnail (*Oreohelix strigosa*)	Terrestrial	Composition of the plant community appears to be of little importance, dominant plant species ranges from sagebrush to a wide variety of deciduous shrubs and trees and a similarly wide variety of coniferous shrubs and trees. Substrate, however, is of great importance, the presence of exposed limestone being almost critical for occurrence; exceptions, however, are well known, there being documented occurrences on sandstone, and occurrences on other substrates probably exist. Slope, too, has been considered to be of importance. Herbivorous.	G5	SNR	2005	2006	6
Slug, Sheathed Slug (*Zacoleus idahoensis*)	Terrestrial	Moist microsites in relatively intact *Pseudotsuga menziesii*, *Pinus ponderosa*, and *Picea engelmannii* forests in moist valleys, ravines, and talus on both north- and south-facing slopes. Meadows and cedar swamps, white pine stands, spruce valleys, rockslides, and near springs.	G3G4	S2S3	1959	2007	18
Land Snail, Smoky Taildropper (*Prophysaon humile*)	Terrestrial	NA	G3	S1S3	2005	2007	22
Land Snail, Spruce Snail (*Microphysula ingersolli*)	Terrestrial	NA	G4G5	SNR	2005	2007	29
Land Snail, Striate Disc (*Discus shimekii*)	Terrestrial	Found most often in litter in rich lowland forest, generally on shaded, north-facing slope bases, often bordering or ranging slightly onto stream floodplain. Usually on limestone soils. Species will crawl on downed wood and is sometimes seen on rock surfaces. Primarily feeds on partially decayed deciduous tree leaves and degraded herbaceous vegetation.	G5	S1	1959	1959	1
Land Snail, Subalpine Mountainsnail (*Oreohelix subrudis*)	Terrestrial	NA	G5	SNR	2007	2007	6
Western Pearlshell (*Margaritifera falcata*)	Aquatic	Cool-coldwater running streams that are generally wider than 4 m, perferrable habitat is stable sand or gravel substrates. Found in hard as well as soft water. This species occurs in sand, gravel and even among cobble and boulders in low to moderate gradient streams up to larger rivers.	G4	S2S4	1992	1996	7

Data are taken from: http://fieldguide.mt.gov/
Inc

G1 S1
At high risk because of extremely limited and potentially declining numbers, extent and/or habitat, making it highly vulnerable to global extinction or extirpation in the state.
G2 S2
At risk because of very limited and potentially declining numbers, extent and/or habitat, making it vulnerable to global extinction or extirpation in the state.
G3 S3
Potentially at risk because of limited and potentially declining numbers, extent and/or habitat, even though it may be abundant in some areas.
G4 S4
Uncommon but not rare (although it may be rare in parts of its range), and usually widespread. Apparently not vulnerable in most of its range, but possibly cause for long-term concern.
G5 S5
Common, widespread, and abundant (although it may be rare in parts of its range). Not vulnerable in most of its range.

ATTACHMENT B

SUMMARY OF SITE-SPECIFIC SURFACE WATER TOXICITY TESTS

ATTACHMENT B
SITE-SPECIFIC TOXICITY TESTS IN FISH

1.0 OVERVIEW

As discussed in Section 3 of the main text, site-specific toxicity studies are often a useful line of evidence in ecological risk assessment. At OU3, EPA, working in concert with the Libby OU3 BTAG, determined that site-specific studies of the toxicity of LA-contaminated water would provide one valuable line of evidence to evaluate risks to fish in OU3. Several alternative study designs were pursued, as described below.

2.0 EXPOSURE OF FISH TO SITE WATER

The first study that was implemented to evaluate risks to fish from LA in water involved exposure of rainbow trout fry to water collected directly from the site. The study is described in detail in Parametrix (2009a). A summary is provided below.

Study Design

The study design was specified in the Phase II Part A Sampling and Analysis Plan (SAP) of the RI for OU3 (EPA 2008c). The water sample used for testing was collected from the tailings impoundment in OU3. Triplicate analysis of LA in this sample (measured before the toxicity test began) showed that the concentration was about 21 MFL. This concentration is in the middle to upper end of the range of LA concentrations that have been observed in surface water samples from OU3.

The test was conducted with newly hatched larval (sac fry) rainbow trout (*Oncorhynchus mykiss*) under static renewal conditions for an exposure duration of 6 weeks. Organisms were exposed to the undiluted site water (21 MFL) as well as five serial 1:10 dilutions of the site water. A control group (no LA) was also evaluated. During the test, the water was renewed every ten days during the sac-fry exposure (days 0-20) and every three days following swim-up of the organisms (days 20-42). Survival, behavior, and growth were observed during the exposure period. At the end of the test, fish were sacrificed and examined for the occurrence of pathological lesions.

Results from this study showed no significant change in any measure of effect in fish exposed to site water when compared to controls (Parametrix 2009a). However, analysis of water samples taken from the test aquaria during the study revealed that asbestos concentrations were significantly lower than expected. For example, the concentration of LA in the aquaria containing undiluted site water at the end of the first exposure cycle (day 10) had fallen from the expected value of 21 MFL to below the analytical detection level (0.05 MFL). Further investigations (detailed in Parametrix 2009a) indicated that the most likely reason for the low concentrations was that LA in the water tended to become clumped with organic material in the water, and that a substantial fraction of the LA became bound to the walls of the aquaria and/or the stock bottle. Based on this, EPA concluded that the exposure of the fish to LA in these toxicity tests could not be reliably quantified, and therefore the results of this study could not be used to draw reliable conclusions about risks to fish exposed to LA in site waters.

3.0 EXPOSURE OF FISH TO WATER SPIKED WITH LA

EPA and the BTAG then considered performing toxicity tests using LA added to laboratory water, rather than using site water. The hope was that laboratory water would contain lower levels of the organic material and microbial organisms that likely were responsible for the losses observed in the site water studies. An initial pilot study was performed by Oregon State University (OSU 2011) to evaluate the maximum duration that LA fibers added to laboratory water could remain in a free (un-bound) state before fiber "loss" due to clumping, binding, settling, etc. occurred. Rainbow trout fry were exposed in four different LA asbestos concentrations, plus a dilution water control, for a period of 3 days. The nominal test concentrations were 10 billion LA fibers per liter (BFL), 1 BFL, 0.1 BFL, 0.01 BFL and the control. Samples for both total LA and free-fiber LA analyses were sampled from each concentration and each replicate on each day of the test. Subsequent analysis of some of the samples indicated that concentration were substantially lower than the expected nominal concentrations (OSU 2011, SRC 2011). Based on this, EPA and the BTAG concluded that spiking studies with normal laboratory water were subject to the same problems as studies with site waters.

EPA and the BTAG next evaluated an alternative study design in which exposure would occur to ozonated laboratory water spiked with LA. Ozonation is known to destroy living organisms and biological materials in water, and helps improve the precision of analyses of asbestos in water (EPA 1994). The logic was that if LA was added to sterile water that was entirely free from living organisms and organic material, the problems of clumping and binding of LA could be minimized. However, the design of such a study is complicated by two key issues, as discussed below.

Issue 1: Form of LA in Site Water

Examination of site waters indicates that LA may occur in both a free form (individual fibers), and as "clumps" in which multiple LA fibers exist bound to an organic material. This was first recognized by TEM analyses of site waters in which occasional clumps of LA were observed on the filters. The presence of clumps in site waters was further demonstrated by noting that treatment of site waters with ozone in accord with EPA Method 100.1 tended to increase the apparent concentration by several fold (EPA 2013b). Consequently, if a study was successfully implemented with exposure to "free" (un-clumped) fibers, this might or might not provide a useful basis for estimation of hazards to fish exposed to a mixture of free and clumped fibers in site waters.

Issue 2: Potential Loss of Fibers During Laboratory Tests

> The second factor that complicated the design of a spiked water toxicity test was a concern that LA spiked into laboratory water might still be subject to clumping and binding due to growth of bio-films in bottles and tubing and on aquaria walls as the study progressed. If uncontrolled, this could lead to a tendency for decreased exposure levels to LA as the bio-films formed and grew, similar to the problem encountered in the first study. If so, this could make it difficult to interpret the results of such a study.

EPA and the BTAG met several times to discuss the best approach for measuring free and clumped fibers in water samples, and for designing a toxicity study using LA-spiked ozonated laboratory water. With regard to the first issue, the BTAG decided that, if it were possible to evaluate the toxicity of free fibers, those data could be used to provide a bounding estimate of risks from site water by assuming that the toxicity of free and clumped fibers was equal. However, before committing to the implementation of such a study, EPA and the BTAG decided to perform a series of pilot tests to evaluate the second issue and determine if exposures to controlled levels of free fibers could be achieved in ozonated water.

The pilot studies that were performed are summarized in SRC (2011). In brief, these studies demonstrated that even when water was treated by ozonation to provide initially sterile conditions, decreases in LA concentrations still occurred during subsequent storage and dilution of the water, and that LA was also lost over time when the water was placed into aquaria. Based on this, EPA and the BTAG decided that implementation of a study using spiked ozonated water would be unlikely to provide reliable data, and the effort was not pursued further.

4.0 CONCLUSION

Based on the studies described above, EPA and the BTAG concluded that exposure of fish to LA under laboratory conditions, using either site water or laboratory water spiked with LA, was subject to technical difficulties that precluded the ability to reliably control and maintain the exposure levels. Consequently, this approach was not used at OU3.

ATTACHMENT C

AVIAN RESPIRATORY SYSTEM
Overview of Anatomy and Function as Related to Particulate Inhalation

Report prepared for EPA by

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AVIAN RESPIRATORY SYSTEM:
Overview of Anatomy and Function as Related to Particulate Inhalation

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INTRODUCTION

The avian respiratory system performs the following functions: gas exchange; thermoregulation; phonation; olfaction; air filtration/cleansing; blood filtration; regulation of acid-base balance; and, production and metabolism of blood-borne molecules. This summary will focus first on the macroscopic and microscopic anatomy of the extra- and intra-pulmonary airways and their connections to the air sacs. Patterns of air flow during inspiration and expiration then can be summarized. Finally the defense mechanisms that protect the respiratory system from inhaled particulates and the evidence pertinent to avian particulate inhalation will be reviewed. Extensive reviews of avian respiratory structure and function have been published elsewhere (Jukes, 1971; King and Molony, 1971; Duncker, 1974; Nickel et al., 1977; McLelland and Molony, 1983; King and McLelland, 1984; Fedde, 1986, 1998; Brackenbury, 1987; Scheid and Piiper, 1987; King, 1993; Brown et al., 1997). Animated images of air flow patterns through the lungs and air sacs can be found at: http://people.eku.edu/ritchisong/birdrespiration.html. The descriptions contained in the present overview pertain primarily to the respiratory system of the domestic fowl.

ANATOMY

*Nasal Passages***:** Depending on the species, the external nasal apertures (**nares**) at the base of the upper beak may be protected by **opercula** (partial or complete flaps) or **cere** and **ricti** (ridges of skin). Feathers arising from the cere may cover the nares. The nasal cavities contain **turbinate bodies** consisting of convoluted mucosa-covered cartilage. The nasal cavities open through the **choana** (medial fissure in the "hard" palate) into the **pharynx** (common passageway for food, water and air). The slit-like **glottis** guards the opening from the pharynx into the **larynx**, and prevents non-aerosol foreign matter (e.g., food and water) from entering the **trachea.**

Conducting Airways: the **trachea** conducts air into the thoracic cavity and bifurcates at the **syrinx** (the avian organ of phonation) to form the right and left **extrapulmonary primary bronchi**. These bronchi penetrate the respective lungs to become the **intrapulmonary primary bronchi** (**Figure 1**). The conducting airways up to this point are reinforced externally with cartilage rings that maintain flexibility while preventing airway collapse. The unilobar **lungs** are located lateral to the vertebral column in the dorsal thorax. The dorsal-lateral border of each lung interdigitates between 5 ribs, thus approximately 25% of the total lung volume is encased between the ribs (**Figures 2 and 3**). Within the lungs of domestic fowl, the **medioventral** (4 each), **mediodorsal** (8 each), **lateroventral** (8 each), and **laterodorsal secondary bronchi** (23-30 each) branch from the intrapulmonary primary bronchus (**Figures 1 and 2**). These secondary bronchi are not supported by external cartilage rings.

Gas Exchange Airways: Arching between the medioventral and mediodorsal secondary bronchi, arcades of long cylindrical **paleopulmonic parabronchi** (tertiary bronchi) (**Figures 2 and 4**) are layered adjacent to one another in a roughly hexagonal array (when viewed in cross section; Stearns et al., 1987). Individual parabronchi are separated from each other by a thin interparabronchial connective tissue septum containing interparabronchial arteries and veins (**Figures 5 and 6**). Approximately 500 paleopulmonic parabronchi are found in each lung of domestic fowl. They measure up to 4 cm long, have a uniform outside diameter of 1.5-2 mm and a lumen diameter of 0.5 mm. Between 100 and 300 freely anastomosing **neopulmonic parabronchi** connect the lateroventral and laterodorsal secondary bronchi (**Figure 4**). Neopulmonic parabronchi measure up to 1 cm long and comprise 20-25% of the total parabronchial volume.

A simple squamous epithelium lines the parabronchial lumen, but this epithelium is not the site of gas exchange. Instead, as shown in **Figures 5 and 6** thousands of **atria** 100-200µm in diameter form pockets projecting 50µm into the luminal wall. The epithelial cells lining the atria produce **surfactant**, which coats the inner surfaces of conducting airways and gas exchange membranes. Spiral bands of innervated smooth muscle underlie the parabronchial luminal epithelium and encircle the opening to each atrium (atrial muscle, **Figure 6**). Elastic fibers encase the walls (septa) and floor of the atria, presumably serving a support function. One or more funnel-shaped **infundibula** penetrate from the atrial floor into the parabronchial wall, with multiple freely anastomosing **air capillaries** originating from each infundibulum (**Figures 5 and 6**). The air capillaries average 8 to 15 µm in diameter and penetrate outward from the infundibulum, extending 200-500 µm to the outer periphery of the parabronchial wall adjacent to the interparabronchial septum (**Figure 6**). Each air capillary is surrounded by a profusion of **blood capillaries** derived from **intraparabronchial arterioles** that branch inward into the parabronchial wall from the **interparabronchial arteries**. Gas exchange occurs at the blood-gas barrier, at the interface between blood capillaries and air capillaries (**Figure 7**).

Air Sacs: Air enters and exits the air sacs via **ostea** that connect with the intrapulmonary primary bronchi, branches of the secondary bronchi, and terminal neopulmonic parabronchi (**Figures 1 and 2**). Domestic fowl possess eight air sacs, including one clavicular, one cervical, two cranial thoracic, two caudal thoracic, and two abdominal sacs (**Figures 1 and 3**). The thin, transparent nonstratified squamous epithelium of the air sacs is poorly vascularized and plays essentially no role in the gas exchange process. The air sac membrane contains small islands of ciliated and secretory cells, and is supported by diffuse elastin fibers (McLelland, 1989). Functionally, the air sacs serve as elastic, inflatable internal reservoirs for "fresh" and "stale" air. In conjunction with the thoracic and abdominal musculature, the air sacs also act in a bellows-like fashion to propel air through the parabronchi. The extensive penetration of air sacs throughout the thorax, abdomen and skeleton accounts for serious concerns regarding carcass contamination that arise when air sacculitis is detected during inspection of poultry at processing plants (King and McLelland, 1984). To simplify further discussion, it is convenient to group the clavicular, cervical and cranial thoracic sacs in the category of **cranial air sacs**, and the caudal thoracic and abdominal sacs in the category of **caudal air sacs**.

AIR FLOW DURING INSPIRATION AND EXPIRATION

Avian lungs remain essentially fixed in volume throughout the *respiratory cycle*, and thus the lungs neither appreciably inflate during inspiration nor deflate during expiration. The current consensus is that all intrapulmonary air channels remain open and relatively fixed in volume throughout the respiratory cycle. Consequently, air must be forced to flow through the intrapulmonary conducting airways by the bellows-like action of the air sacs. A saccopleural membrane is anchored by skeletal muscle (costoseptal muscle) to the internal thoracic wall and covers the ventral lung surface. This membranous structure is penetrated by the ostea to the caudal air sacs and, unlike the mammalian diaphragm, the avian saccopleural membrane does not contribute to the development of a negative intrathoracic pressure. The costoseptal muscles apparently contract during expiration to hold the ostea open (King and McLelland, 1984). Thus birds lack a functional diaphragm and must depend entirely on the contraction and relaxation of thoracic and abdominal muscles during inspiration and expiration.

During inspiration the rib cage and sternum expand to more cranial and ventral positions, increasing the thoracic volume and generating a negative intrathoracic pressure (suction). Simultaneous relaxation of the abdominal muscles coupled with the forward excursion of the sternum and gravitational pull on the visceral organs increases the volume of the abdominal cavity. The resulting negative thoraco-abdominal pressures (-1 cm H_2O) serve to inflate (draw air into) the cranial and caudal air sacs simultaneously (**Figure 8**, upper panel). "Fresh" air enters the trachea and is drawn through the extra- and intra-pulmonary primary bronchi toward the caudal air sacs. This incoming air does not enter the medioventral secondary parabronchi due to their acute caudally-directed angle of insertion along the intrapulmonary primary bronchus. Instead, the incoming fresh air is drawn caudally to: (a) mix with and carry end expiratory stale air from the trachea and primary bronchus, through the neopulmonic parabronchi and into the caudal air sacs; (b) supply the neopulmonic parabronchi and caudal air sacs with fresh air; and, (c) flow through the mediodorsal secondary bronchi, pushing the resident stale air out of the paleopulmonic parabronchi, through the medioventral secondary bronchi and into the cranial air sacs. Thus the caudal air sacs are inflated mainly with fresh air, and the cranial air sacs are inflated mainly with stale air from the paleopulmonic parabronchi (**Figure 8**, upper panel). Throughout the respiratory cycle, ongoing gas exchange occurs between the blood capillaries and air capillaries. Consequently, with the cessation of fresh air inflow at the end of inspiration, parabronchial air once again becomes stale (PCO_2 increases, PO_2 decreases).

During expiration the rib cage and sternum are drawn inward to more caudal and dorsal positions, reducing the thoracic volume and generating a positive intrathoracic pressure. Simultaneous contractions of the abdominal wall muscles reduce the volume of the abdominal cavity. The resulting positive thoraco-abdominal pressures (+1 cm H_2O) *partially* deflate the cranial and caudal air sacs (**Figure 8**, lower panel). The stale air from the cranial air sacs flows through the medioventral secondary bronchi, into the primary bronchus and then cranially out through the trachea. The relatively fresh air in the caudal air sacs is forced cranially, and due to aerodynamic valving most of the air exiting the caudal air sacs first perfuses the neopulmonic parabronchi and then flows through the mediodorsal secondary bronchi. After entering the mediodorsal secondary bronchi, the relatively fresh air flows through the paleopulmonic parabronchi. The stale air that is displaced from the paleopulmonic parabronchi flows, along with stale air from the cranial air sacs, through the medioventral secondary bronchi into the primary bronchus and out through the trachea (**Figure 8**, lower panel). Aerodynamic valving within the conducting airways insures that the cranial air sacs always serve as a reservoir for *stale* air exiting the parabronchi during inspiration, whereas the caudal air sacs mainly serve as a reservoir for *fresh* air to supply the parabronchi during expiration. This flow of "fresh" air during inspiration and expiration always is unidirectional in the paleopulmonic parabronchi (mediodorsal secondary bronchus to medioventral secondary bronchus), but is bidirectional in the neopulmonic parabronchi (e.g., air flow cessation and reversal occur in the neopulmonic parabronchi during each respiratory cycle, as well as in all air sacs).

As shown in **Figures 6 and 7**, each parabronchus can be modeled as a long tube with air capillaries (resembling the bristles of a bottle brush) radiating outward at right angles from the parabronchial lumen. During inspiration and expiration, rapid convective air flow occurs along the lumen of the parabronchus. Convective air flow may carry air as deep as the infundibula (Stearns et aI., 1987). However, O_2 must move through the gas exchange region of the parabronchus by the relatively slow process of diffusion from the infundibulum to the periphery of the air capillaries, across the **blood-gas barrier**[1], through the plasma, and into the red blood cells (Powell, 1982; Scheid and Piiper, 1987). Blood capillaries carry deoxygenated blood inward (convective blood flow) following the air capillaries back to their junction with the infundibulum near the parabronchus lumen. Because convective air flow occurs longitudinally down the lumen of the parabronchus, whereas blood flow and gas exchange occur in a transverse path across the radius of the parabronchial wall, the pattern of blood flow and air flow in avian lungs has been labeled a cross-current exchange system. When compared with mammalian respiratory systems, the cross-current avian respiratory system permits a higher degree of removal of O_2 from respiratory air, and provides exceptional advantages at low atmospheric pressure (low PO_2), as confirmed by the exceptional tolerance of birds to high altitude. Sparrows are able to fly at an atmospheric pressure of 349 mmHg, corresponding to an altitude of 6100 m, while mice are comatose and nearly unable to crawl under identical conditions (Schmidt-Nielsen, 1975).

RESPIRATORY SYSTEM DEFENSES

Nasal Passages: Feathers covering the nares serve to coarsely filter the incoming air. Turbulent air flow within the nasal passageways forces the inhaled air to swirl over the mucosal surfaces of the turbinate bodies. The air becomes humidified (fully saturated with water vapor), warmed to the bird's body temperature, and cleansed of larger particulates that adhere to the mucus. Additional particulate entrapment is likely to occur as the inhaled air flows through the moist, narrow choanal slit in the hard palate and flows over the moist surfaces of the pharynx and glottis (Hayter and Besch, 1974; Fedde, 1998; Brown et al., 1997).

Conducting Airways: The avian trachea, primary bronchi, and initial roots of secondary bronchi are lined with a **mucociliary epithelium** (a pseudostratified, longitudinally folded ciliated epithelium with mucous-secreting goblet cells). Pathogens and airborne particles become trapped

[1] The blood-gas barrier is composed of the blood capillary endothelium and its basal lamina, the thin air capillary epithelium, and a thin layer of surfactant. In chickens, the endothelium comprises 67% of the barrier thickness, the basal lamina comprises 21%, and the epithelium plus surfactant comprise only 12% of the barrier thickness.

in the mucus, and ciliary action sweeps the mucous cranially (at a rate of 10 mm/min; Fedde, 1998) to the oral cavity where it is swallowed or expectorated (King and Molony, 1971; King and McLelland, 1984). In addition to mucus, the fluids lining avian conducting airways contain antioxidants and surfactant binding proteins that assist in binding and neutralizing inhaled pathogens and antigens (Bottje et al., 1998; Zeng et al., 1998; Johnston et al., 2000). When mammals and birds of similar sizes are compared, the avian trachea is approximately 2.7X longer and has a 1.3X larger radius, which yields a 4X greater tracheal volume. (King and McLelland, 1984). Accordingly, the **mucociliary escalator** has a substantially enhanced opportunity to trap pathogens and particulates in birds when compared with mammals. The mucociliary escalator is an active and highly important line of defense in birds, preventing many aerosol particulates and pathogens from entering the gas exchange parenchyma. For example, poultry reared on floor litter are chronically challenged with air-borne dust, bacteria, and potent antigens (Anderson et al., 1966; Hayter and Besch, 1974; Gross, 1990; Whyte, 1993; Brown et al., 1997; Zucker et al., 2000; Bakutis et al., 2004; Lai et al., 2009). Only modest changes in respiratory function can be detected when broiler chickens (meat-type chickens bred for extremely fast growth and breast muscle accretion) reared on floor litter are compared with broilers reared in much cleaner environments (Bottje et al., 1998; Wang et al., 2002; Lorenzoni and Wideman, 2008). Commercial poultry populations reared on floor litter typically grow rapidly, thrive and reproduce while exhibiting minimal mortality levels. Furthermore, necropsies of clinically healthy broilers reared on floor litter overwhelmingly reveal healthy tracheas, almost pristine air sacs (e.g., uniformly clear and transparent membranes), and macroscopically unremarkable lungs (Wideman et al., 2011).

In commercial poultry the respiratory system becomes dramatically more susceptible to damage if mucociliary transport is inhibited by exposure to noxious gasses (e.g., ammonia) and pathogens such as infectious bronchitis virus (IBV), infectious laryngotracheitis (ILT), avian influenza (AI), Newcastle disease virus (ND), and *Mycoplasma gallisepticum*. For example, IBV causes ciliostasis and distinctive symptoms of upper airway distress (gasping, coughing, gurgling) attributable to obstruction of the trachea by mucus accumulation. Inhibition of the mucociliary escalator in combination with distressed patterns of breathing apparently allow pathogenic bacteria and aerosolized respirable particles to penetrate more readily into the lung parenchyma and air sacs. The ensuing pulmonary inflammation and air sacculitis (infection of the air sacs) are profoundly deleterious (Gross, 1961, 1990; Tottori et al., 1997; Yamaguchi et al., 2000).

Bronchus-associated lymphoid tissues (BALT) constitutively develop in the bronchial mucosa at the junctions of primary and secondary bronchi, and at the ostea to the air sacs of clinically healthy birds (Reese et al., 2006). BALT contain lymphocytes (B cells and T cells), lymphoid nodules, and epithelial cells. The mucosal BALT tissues may functionally compensate for the absence of fully formed lymph nodes in birds, although their specific role remains to be elucidated (Reese et al., 2006).

Gas Exchange Airways and Air Sacs: Whereas the overwhelming majority of airborne particles exceeding 5 µm in diameter are trapped in the nasal cavities and trachea, some of the smaller respirable particles averaging <5 µm in diameter do reach the avian parabronchi and abdominal air sacs (Hayter and Besch, 1974; Mensah and Brain, 1982; Stearns et al., 1987; Fulton et al., 1990). Respirable particles can be heavily contaminated with a wide range of immunogenic substances including pathogens and toxins (Bakutis et al., 2004). Macrophages and neutrophils play a central role in the mammalian responses to aerosolized particulates, and intra-alveolar macrophages serve as a first line of defense at mammalian gas exchange surfaces. In contrast, healthy birds do not appear to maintain large populations of resident macrophages or other resident leukocytes at their gas exchange surfaces (air capillaries) or within their air sacs, although some macrophages have been detected in the atria and infundibula of the parabronchi, as well as in the larger conducting airways (Maina and Cowley, 1998; Nganpiep and Maina, 2002). The primary phagocytic function within avian parabronchi apparently resides within the epithelial cells lining the atria and infundibula (the same cells that secrete surfactant). These phagocytic endothelial cells engulf particles encountered on their luminal (air space) surface. The internalized particles then may be degraded/digested intracellularly, or they undergo exocytosis to the underlying interstitium. There they are engulfed by resident macrophages located in the spaces between the atrial and infundibular epithelial cells (Stearns et al., 1987; Brown et al., 1997; Reese et al., 2006). Large numbers of macrophages can be induced to enter the air sacs by injecting appropriate antigens or pathogens into the air sac lumen (Fedde, 1998; Reese et al., 2006). During respiratory infection or aspiration of particulates, phagocytic macrophages and heterophils (analogous to mammalian neutrophils) can be found in lavage fluid from the avian respiratory tract, indicating mechanisms do exist that allow substantial populations of phagocytic leukocytes to enter the gas filled spaces when necessary (Ficken et al., 1986; Toth and Siegel, 1986; Toth et al., 1987, 1988; Qureshi et al., 1993; Klika et al., 1996; Lorenzoni et al., 2009; Maina and Cowley, 1998; Nganpiep and Maina, 2002). Intratracheal instillation of *C. parvum or E. coli* effectively increased the number of phagocytes collected by lung lavage within 24 h (Toth et al., 1987). Additionally, macrophages have been reported to migrate into air capillaries in a variety of infectious diseases, including toxoplasmisis, fatal viral hydropericardium syndrome, highly pathogenic infectious bursal disease and highly pathogenic avian influenza (Hower, 1985; Abe et al., 1998; Nakamura et al., 2001). Pathways by which macrophages that have engulfed pathogens or foreign particles are cleared from the lung parenchyma and air sacs remain to be elucidated. Phagocytosed materials may be transported and presented to the local BALT, or they may be transported to peripheral lymphoid organs (e.g., the spleen) (Fedde, 1998; Reese et al., 2006).

Vascular Defenses: Blood-borne particulates and antigens also trigger intrapulmonary immune responses. In addition to particles or pathogens entering the blood stream directly, materials engulfed by lymphatic capillaries subsequently flow through major lymph trunks that empty into the vena cava. Thus the lungs perform the important function of filtering and clearing the returning venous blood of micro- and macro-particulates including bacteria and thrombi, as well as other potent antigens translocated from pathogens resident in the intestine or from sites of infection (Weidner and Lancaster, 1999). In some mammalian species blood-borne antigens are primarily removed from the blood stream by pulmonary intravascular macrophages (PIMs), which are large mature macrophages bound to the pulmonary capillary endothelium. However, resident PIMs are not present in chickens (Lund et al., 1921; Winkler, 1988; Staub, 1994; Warner et al., 1994; Brain et al., 1999; Weidner and Lancaster, 1999). The absence of PIMs does not leave chicken's lungs immunologically unresponsive to blood-borne antigens because the entire blood volume and thus all of the circulating leukocytes flow through the lungs (e.g., the lungs receive 100% of the cardiac output via the pulmonary circulation). For example, intravenously injected cellulose microparticles (30µm diameter) become entrapped in inter- and intra-parabronchial pulmonary arterioles of broiler lungs. Within 20 minutes post-injection the microparticles trigger marked pulmonary inflammatory responses, including perivascular infiltration of mononuclear cells in combination with luminal accumulations of macrophages. During the ensuing 48 hours occlusive particles are surrounded by granulomatous tissue consisting primarily of macrophages, giant cells, and fibrous tissue. Subsequently virtually all of the microparticles are cleared from the lungs within approximately 3 weeks post-injection, the inflammatory response subsides, and the lung parenchyma again returns to an entirely normal (e.g., non-inflamed, unobstructed) histological appearance (Wideman et al., 2002, 2007, 2011a,b; Wang et al., 2003; Hamal et al., 2008, 2010). Avian lungs possess an impressive ability to eliminate (digest), clear (remove), or segregate (wall off) offending particulates.

DISTRIBUTION, DEPOSITION AND CLEARANCE OF INHALED PARTICULATES: RELEVANT RESEARCH SYNOPSIS

Peacock and Peacock (1965) injected finely ground asbestos fibers suspended in tributyrin (a triglyceride ester of glycerol and butyric acid) into the clavicular air sacs of adult White Leghorn chickens. The injected material spread throughout the air sac and entered the lung parenchyma. Immediate responses were inflammatory, with macrophages engulfing the asbestos fibers and clearing them from the air sacs (presumably into sub-epithelial spaces). Neoplastic and granulomatous tumors formed near the site of injection in 4 out of 30 injected birds. The granulomatous tumor contained asbestos fibers. Evidently the majority of injected birds lived for >3 years. Necropsies conducted 4 years post-injection revealed asbestos fibers remaining in the lung parenchyma, and "asbestos bodies" (asbestos fibers engulfed by macrophages or encased in mineralized connective tissue) were indentified in the "interalveolar septa" (presumably the interatrial septa where clusters of resident macrophages have been demonstrated in chickens by Reese et al., 2006).

Hayter and Besch (1974) evaluated the distribution of aerosolized spherical particles in spontaneously breathing adult roosters. Larger particles (≥3.7µm diameter) primarily were deposited in the nasal passageways and cranial segment of the trachea, although a portion of these particles also entered the caudal air sacs. Smaller particles (≤1.1µm diameter) tended to avoid entrapment in the upper airways and instead were distributed to the lungs and caudal air sacs. Particles were considered to accumulate preferentially at locations where branching of the conducting airways (e.g., rapid amplification of the cumulative luminal cross-sectional area caudal to the syrinx) caused abrupt reductions in air flow velocities, or where reversal of air flow occurred (e.g., in the caudal air sacs) (Hayter and Besch, 1974).

Brambilla et al. (1979) retrospectively evaluated pulmonary lesions in tissues saved during routine necropsies of 11 mammalian and 8 avian species that had chronically inhaled air containing high levels of silicate particles (1 to 10µm in length) while residing at the San Diego Zoo. All of the avian species exhibited severe silicate dust deposition in the tertiary bronchi (parabronchi), accompanied in some individuals by the formation of large granulomas composed of crystal laden macrophages. Fibrosis and necrosis were absent, and none of the birds had been reported to have respiratory problems. Particles deposited in the conducting airways evidently were effectively cleared by mucociliary escalator, whereas those engulfed by parabronchial epithelial cells or macrophages were much more difficult to clear and, consequently, triggered ongoing immunological responses. When compared with mammals, all of the avian species evaluated in this study appeared to be more susceptible to parenchymal silicate dust retention and granuloma formation (birds were less capable of clearing particulates reaching the non-ciliated secondary and tertiary bronchi), but birds were significantly less susceptible to pulmonary fibrosis (Brambilla et al., 1979).

Mensah and Brain (1982) evaluated the deposition and clearance rates for aerosolized particles (< 0.8μm diameter) in unanesthetized spontaneously breathing hens. Particles of this size were only sparsely deposited in the trachea but considerable deposition was detected in both lungs. More particles accumulated in caudal than cranial portions of the lungs, presumably reflecting preferential particle deposition in the neopulmonic parabronchi where air flow velocities decrease and then abruptly reverse direction. Almost half of the particles had been cleared from the lungs within 1 hour post-inhalation, and 65% of the particles were cleared from the lungs within 12 hours. This rapid phase of clearance presumably reflects the activity of the mucociliary escalator, which appears to be considerably more vigorous in birds than the more sluggish clearance rate for similarly sized particles deposited in mammalian lungs. As particles were cleared from the lungs they accumulated in the gastrointestinal tract (presumably after the tracheal mucus was swallowed) and were eliminated in the feces. Approximately 35% of the particles persisted in the lung parenchyma through the end of the study (36 hours), presumably reflecting the proportion engulfed by parabronchial epithelial cells and interstitial macrophages. Particles also accumulated in pneumatized bones that are penetrated by cranial air sacs, indicating significant numbers of particles streamlined completely through the paleopulmonic parabronchi and thus were dispersed into the cervical and clavicular air sacs (Mensah and Brain, 1982).

Nakaue, Pierson and Helfer (1982) and Bland, Nakue, Goeger and Helfer (1985) evaluated the performance and health responses of broiler chickens exposed to Mount St. Helen's volcanic ash (VA; particles ranging from 0.5 to 10 μm diameter). The VA was applied directly to the wood shavings litter on the pen floor, or was blown daily (for 20 consecutive days) into pens with resident birds. When compared with unexposed control birds, none of the modes of VA exposure altered any of the routine indices of broiler performance, including final body weights, feed conversion, carcass quality, and cumulative mortality. Litter moisture and ammonia levels also were unaffected by VA, suggesting the absence of significant damage to the kidneys and gastrointestinal tract. Aerosol induction of VA did not alter the histological appearance of the turbinate bodies or the trachea, but pathological changes within the lungs were detected in a portion of the birds beginning 4 days post-exposure. Macrophages initially phagocytized the VA dust within secondary and tertiary bronchi. More chronically, a mild lymphoid hyperplasia developed, including the formation of granulomas containing giant cells surrounding phagocytized crystalline material (Nakaue et al., 1982; Bland et al., 1985).

Stearns et al. (1987) exposed spontaneously breathing adult female ducks to aerosolized iron oxide (0.18μm diameter). The ducks were euthanized 24 hours post-exposure, and transmission electron microscopy was used to evaluate particle deposition within the parabronchial parenchyma. Particle clearance from the parabronchial lumen followed a distinctive sequence:

(a) entrapment in the relatively thick layer of surfactant; (b) phagocytosis by the luminal surface membranes of atrial and infundibular epithelial cells (the same cells that secrete surfactant); (c) movement of the phagosome to the basal-lateral surfaces of the epithelial cells; (d) exocytosis of the particles into the interstitial spaces; and, (e) phagocytosis of the particle by atrial and infundibular interstitial macrophages (macrophages were not seen on the epithelial/luminal surface). The disposition of the particles after their phagocytosis by interstitial macrophages was not assessed. Relatively few particles were observed in the air capillaries *per se*, leading to the interpretation that aerosolized particles were distributed to the atria and infundibula primarily by convective air flow (Stearns et al., 1987).

Brown et al. (1997) reviewed the structure and function of avian respiratory system in relation to its susceptibility to damage by inspired particles and toxins. Deposition patterns for aerosolized particles of different sizes and shapes were predicted based on the anatomy of the airways and the physical forces acting on the particles (e.g., inertial forces, gravitational sedimentation, and Brownian diffusion). Inertial impaction was predicted to clear larger particles primarily in the nasal passageways, pharynx, larynx, trachea, syrinx, and points where secondary bronchi branch from intrapulmonary primary bronchi. Gravitational sedimentation and Brownian diffusion were predicted to occur where air velocities are low and particle residence time is prolonged, particularly within the air sacs and parabronchi (Brown et al., 1997).

SYNTHESIS FROM THE AVAILABLE INFORMATION

1. Particle size distributions for the Libby Amphibole (LA) in duff (**Figure 9**) indicate that, <u>if suitably aerosolized</u>, well over half of these particles are small enough to be distributed throughout the avian respiratory system, including to the level of the parabronchial atria and infundibula.

- Ground foraging birds are likely to stir up the duff and kick LA particles into the air; the worst case scenario is created by dust-bathing birds.
- The LA particles may not be easily aerosolized during foraging or dust bathing, but some of the smallest particles may adhere to other inspirable "dust" that more readily becomes suspended as a colloid in the air when the duff is disturbed.

2. Over a period of months or years some of the LA particles are likely to be inspired by ground dwelling/foraging birds.

- Particles trapped in the protective mucus of the nasal passageways, pharynx and ciliated conducting airways will have little biological impact on those structures, and will be cleared rapidly by the mucociliary escalator. Mucus containing particles cleared from the upper airways will be swallowed, enter the gastrointestinal tract, and excreted in the feces. Evaluation of LA content within the core matrix of avian fecal pellets collected within the zone of contamination may constitute the simplest way to directly quantify the possibility that a threat exists.
- Particles deposited in the parabronchi will be phagocytized predominately by epithelial cells that line the atria and infundibula, but also by resident macrophages in the lumen and interstitial macrophages. Engulfed particulates composed of substances that cannot be degraded or digested intracellularly by the epithelial cells and interstitial macrophages

appear to pose a specific problem for birds: the epithelial cells (and apparently the interstitial macrophages) remain *in situ*, presumably emitting modulators (cytokines and chemokines) that provoke ongoing focal inflammatory reactions. The result in some birds appears to be granuloma and giant cell formation at sites where engulfed particulates cannot be cleared from the secondary and tertiary bronchi.

- The pattern of response to embedded particulates does not include fibrosis in birds; mild focal fibrosis would have little functional impact on the non-inflating avian lung, but fibrosis might modestly increase respiratory effort if the air sacs are affected.
- Particles deposited in air sacs are likely to be engulfed by macrophages and cleared from the air sacs. The fate of the responding macrophages, and thus sites to which they might redistribute the LA particles, is not known.

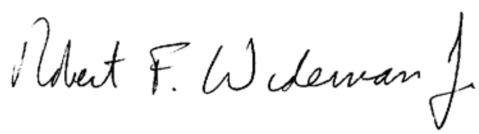
3. There is no evidence that the lungs of wild avian species are anatomically, physiologically or immunologically more susceptible to inhaled particulates than mammalian lungs.

- Published assertions that "avian" lungs are more susceptible to particulate or pathogen damage than mammalian lungs consistently cite examples of the susceptibility of poultry (particularly broiler chickens and modern hybrid turkeys) to respiratory pathogens or to extremely challenging air quality when commercial growout facilities are poorly managed. Indeed, chickens bred for extremely rapid growth and meat production (broiler chickens) provide an excellent model of genetically-imposed cardio-pulmonary and immunological inadequacies. Broiler chicks typically hatch at a weight of 40 g and grow to 4 kg within 8 weeks. Thus in two months a broiler's body weight doubles and redoubles almost 7 times. If human infants grew at the same rate, their body weight would increase from 3 kg (6.6 lb) at birth to 310 kg (690 lb) by 2 months of age. The consequences are obvious: extremely rapid early growth in broilers imposes proportional challenges to their developmentally immature pulmonary, cardiovascular and immunological systems. Rapid growth triggers a suite of "metabolic diseases" attributable primarily to "outgrowing cardio-pulmonary capacities" or "impaired immuno-competency". Wild birds and the progenitors of modern poultry breeds are uniformly found to be considerably more robust than modern broiler chickens and hybrid turkeys (Wideman, 2000, 2001; Nganpiep and Maina, 2002; Wideman et al. 2004, 2007).
- Particulate deposition due to gravitational sedimentation and Brownian diffusion most likely will occur where air velocities are low, particle residence time is prolonged, and at sites of air flow reversal. Accordingly, particles are highly likely to be deposited throughout the alveoli of mammalian lungs, precisely at the level where gas exchange must occur, and where membrane fibrosis is highly detrimental due to the loss of elasticity (alveoli must inflate and deflate during the respiratory cycle; fibrosis significantly increases respiratory effort in birds). In contrast, convective air flow does not penetrate the gas exchange capillaries of avian lungs, thus particle deposition within the air capillaries should be minimal or non-existent. Within the avian lung parenchyma, air flow is bidirectional in neopulmonic parabronchi which comprise 25%, at most, of the lung volume.
- Interstitial inflammation, granuloma development and giant cell formation are normal patterns of avian responses to pulmonary entrapment of particulates delivered either via the inspired air or via the bloodstream. Absent respiratory disease attributable to

pathogens, all available evidence indicates these intrapulmonary inflammatory responses have minimal impact on the function or viability of affected birds.

- Assuming equal levels of "exposure", the above considerations indicate that otherwise healthy mammals are likely to be *more* sensitive to particle inhalation than clinically healthy birds.

4. Conclusion: The experiments conducted by Nakaue, Pierson and Helfer (1982) and Bland, Nakue, Goeger and Helfer (1985) are highly instructive: 20 consecutive days of intensive aerosol exposure to volcanic ash particles of a respirable size did elicit intrapulmonary histological changes but failed to alter any routine indices of broiler performance, nor was mortality affected. Broiler chickens are considerably less robust than wild birds (*vide supra*). Peacock and Peacock (1965) demonstrated that most adult Leghorn chickens survived several years after milligram quantities of asbestos fibers were instilled directly into their air sacs and (presumably) into the lung parenchyma. It is my opinion that some birds in the affected area are likely to exhibit histological evidence of intrapulmonary LA particulate exposure, but that little or no impact on the physiological function or viability of resident avian populations will be discernable.



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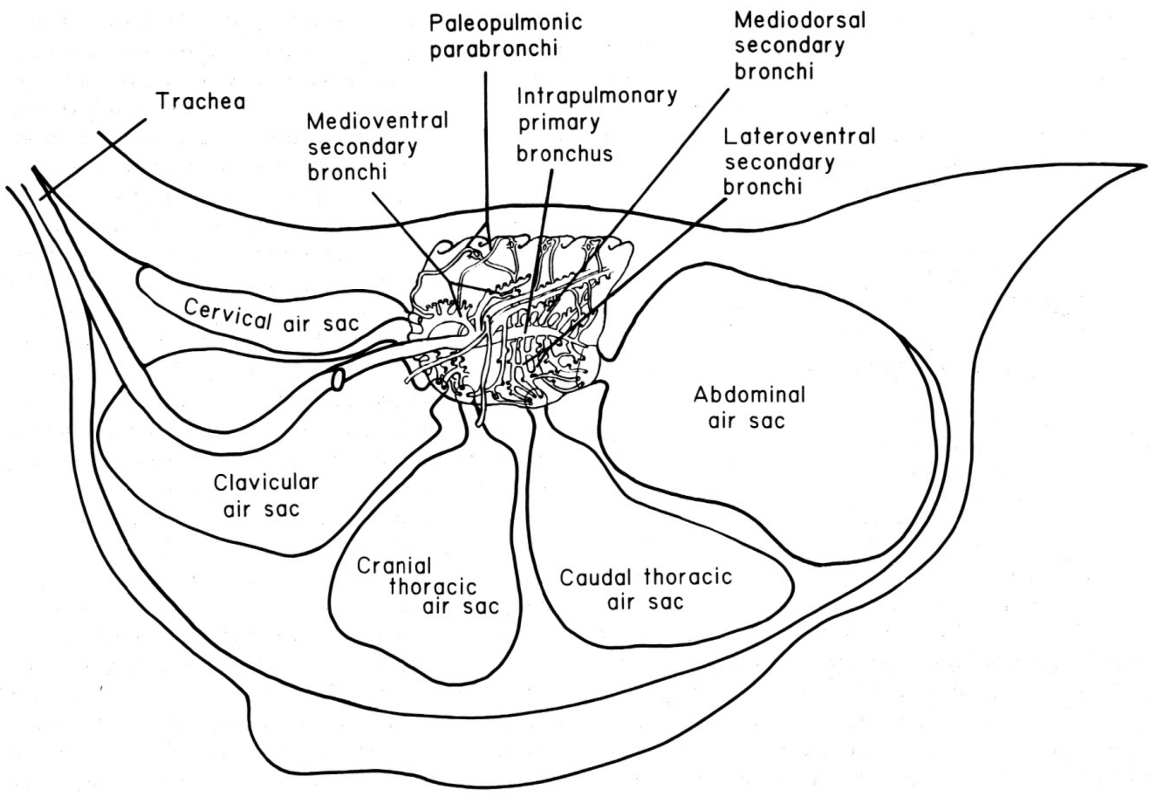
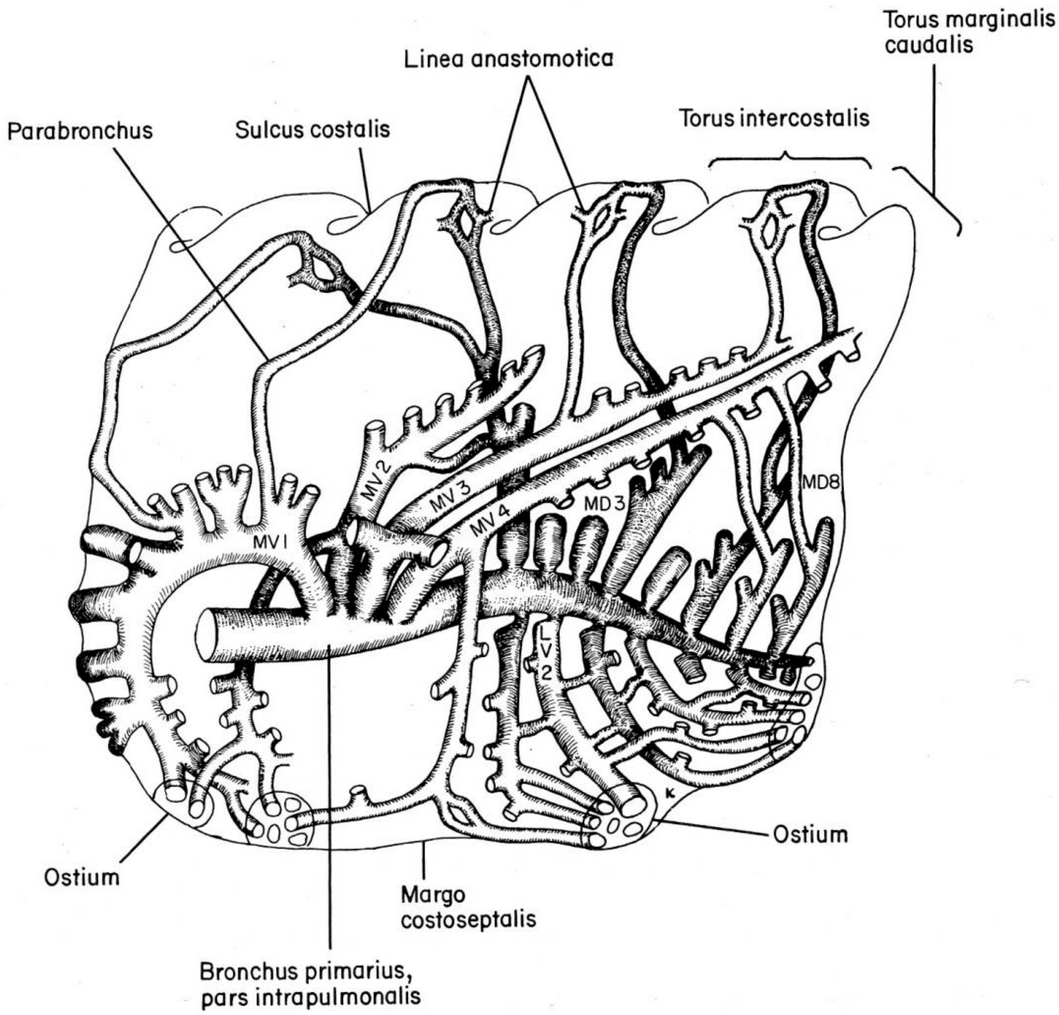
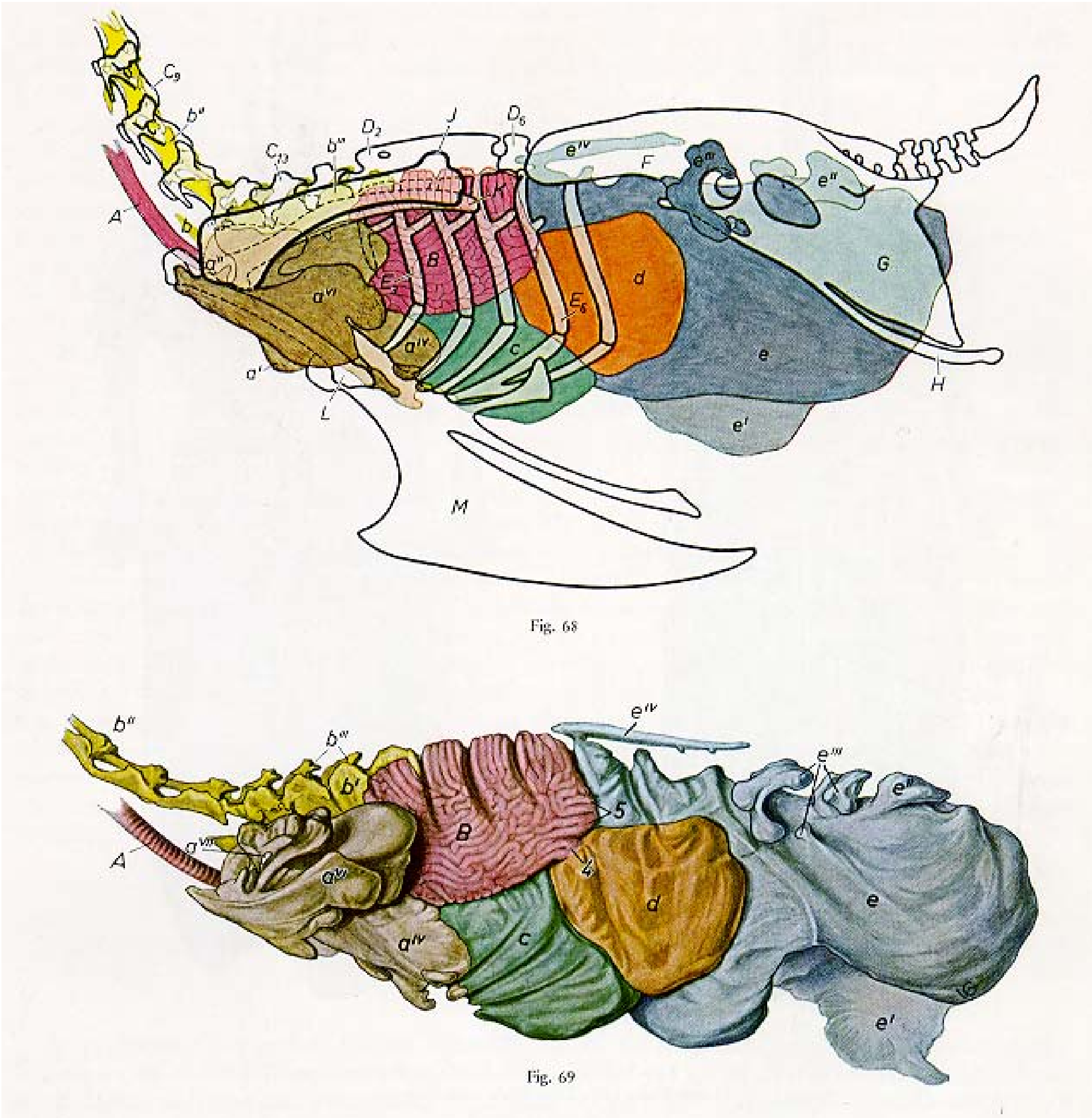


Figure 1. Schematic arrangement of avian lungs and air sacs. Deep within the thoracic cavity the **trachea** bifurcates at the syrinx (the avian organ of phonation) to form the right and left extrapulmonary primary bronchi. These bronchi penetrate the respective lungs to become the **intrapulmonary primary bronchi**. Within the lungs of domestic fowl, the **medioventral**, **mediodorsal**, **lateroventral**, and **laterodorsal secondary bronchi** branch from the intrapulmonary primary bronchus. The bronchi and air sacs connect via ostea.



Medial view of the right lung illustrating: the intrapulmonary primary bronchus; the medioventral (MV), mediodorsal (MD) and lateroventral (LV) secondary bronchi, paleopulmonic parabronchi (tertiary bronchi) connecting the MV and MD secondary bronchi; and, ostea (openings) to air sacs. The Costal sulcus represents a rib indentation.

Figure 2. Details of the primary and secondary bronchi within avian lungs. The **intrapulmonary primary bronchus** penetrates from the cranial to the caudal margins of the lung, opening caudally into the osteum of the abdominal air sac. Within the lungs the **secondary bronchi** branch from the intrapulmonary primary bronchus.



Air sac system of the fowl (Weik, 1963).

A: trachea, B: lung; C: cervical vertebrae; D: thoracic vertebrae; E: ribs; F: ilium; G: ischium, H: pubis; J: humerus; K: scapula; L: coracoid; M: sternum; a: clavicular air sac; b: cervical air sacs; c: cranial thoracic air sac; d: caudal thoracic air sac; e: abdominal air sac

Figure 3. The non-inflating avian lungs (B) are partially encased by 5 ribs (E) as indicated by the costal sulci (indentations) in the dorsal-lateral aspect of the lungs. The air sacs are shown in their anatomically correct positions.

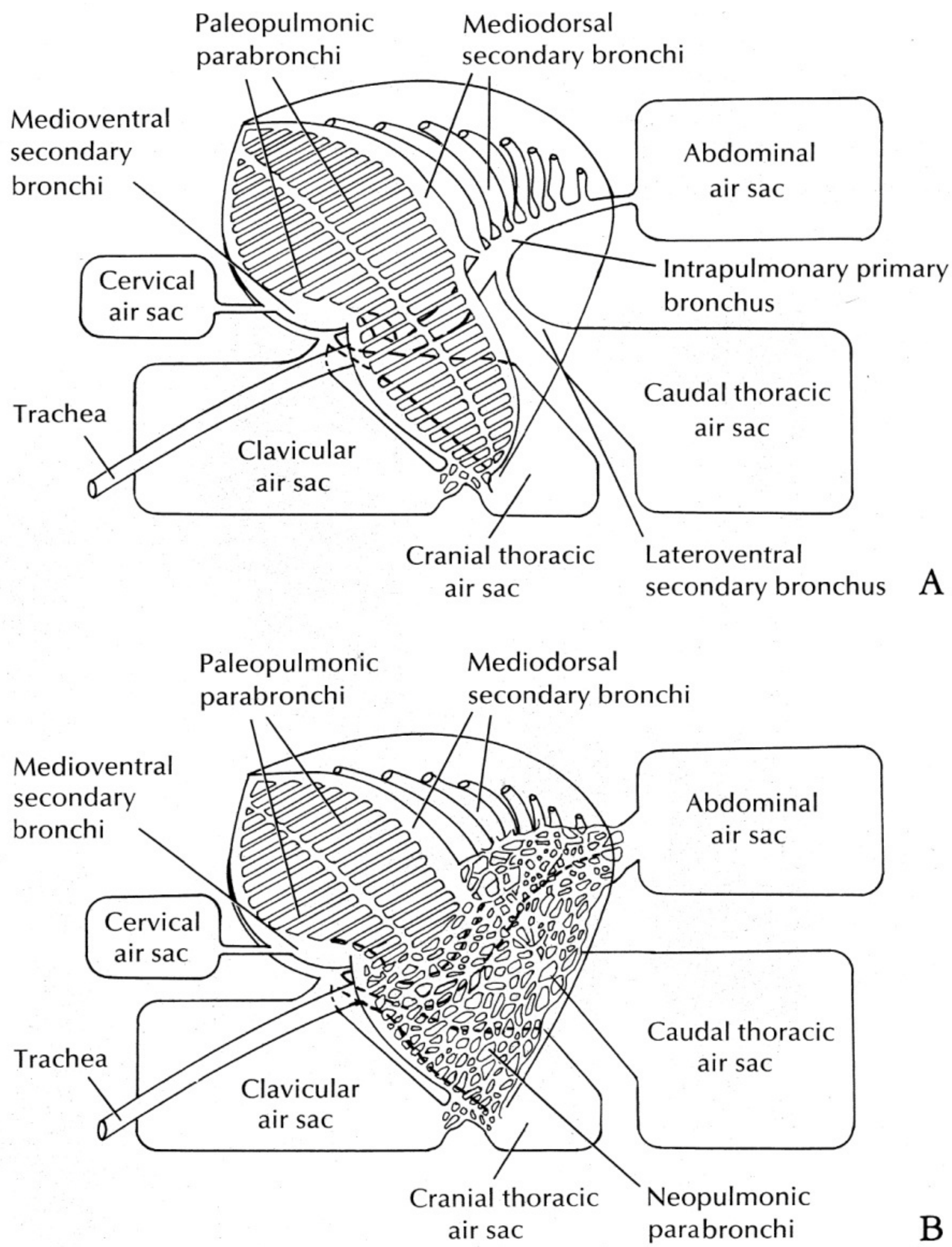


Figure 4. Scheme of the organization of the parabronchi in birds.
(A) Only paleopulmonic parabronchi are present in some birds (e.g., penguin and emu). (B) In addition to paleopulmonic parabronchi, a variably developed net of neopulmonic parabronchi is present in most birds (Duncker, 1972).

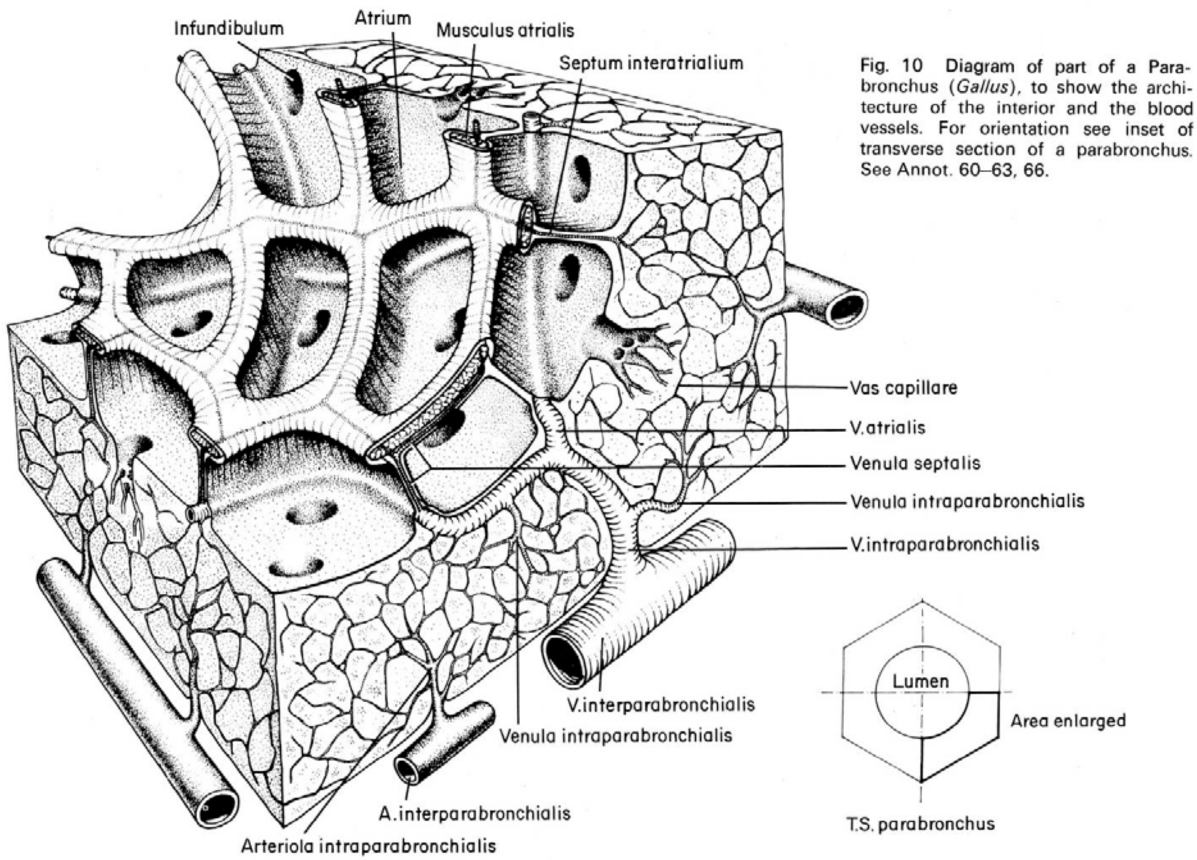


Fig. 10 Diagram of part of a Parabronchus (*Gallus*), to show the architecture of the interior and the blood vessels. For orientation see inset of transverse section of a parabronchus. See Annot. 60–63, 66.

Figure 5. Section through part of the wall of a parabronchus. A**tria** 100-200µm in diameter form pockets projecting 50µm into the luminal wall. Spiral bands of smooth muscle (Musculus atrialis) underlie the parabronchial luminal epithelium and encircle the opening to each atrium. One or more funnel-shaped **infundibula** penetrate from the atrial floor into the parabronchial wall, with multiple freely anastomosing **air capillaries** originating from each infundibulum and radiating outward toward the periphery (outer boundary) of the parabronchus.

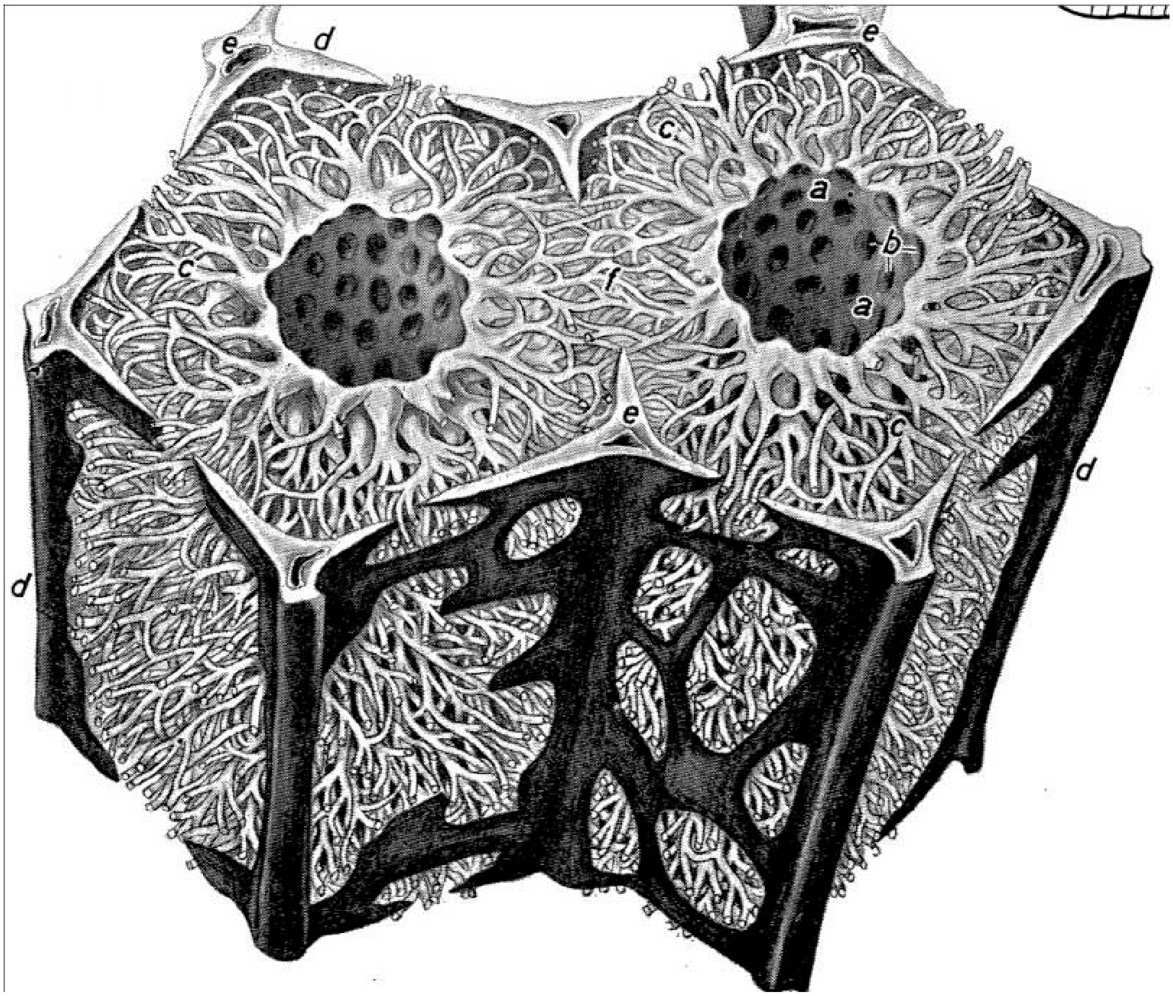


Figure 6. Section through two adjacent parabronchi. a: interatrial septa; b: atria; c: air capillaries; d: outer connective tissue septa; e: blood vessels; f: anastomotic connections between air capillaries. The **air capillaries** radiate outward toward the periphery (outer boundary) of the parabronchi.

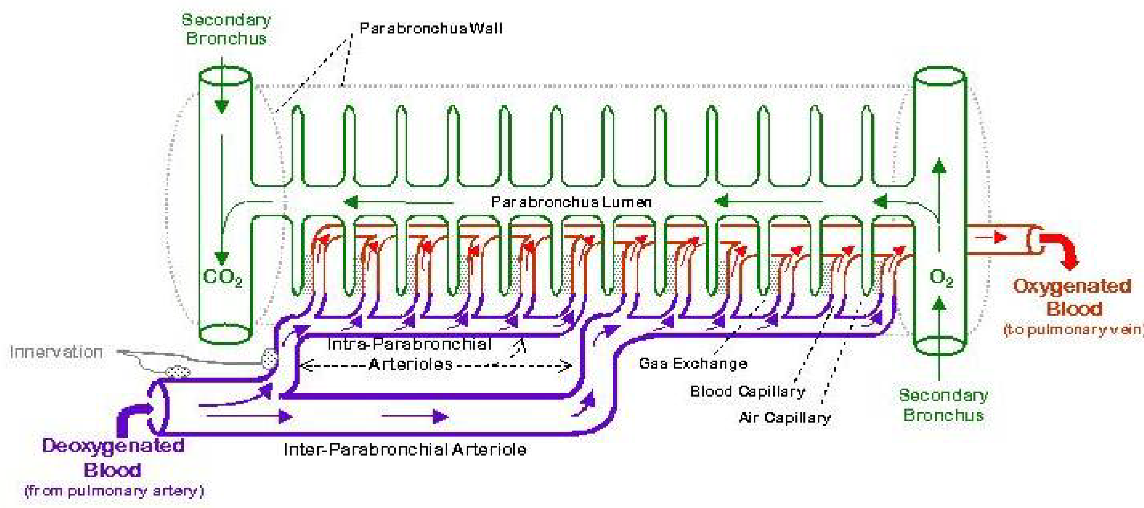


Figure 7. Interparabronchial arteries supply deoxygenated blood to Intraparabronchial arterioles branching inward into the parabronchial wall to form a net of blood capillaries surrounding each air capillary. Gas exchange occurs at the blood-gas barrier at the interface between blood capillaries and air capillaries. Venules collect the oxygenated blood at the base of the atria and infundibula adjacent to the parabronchial lumen.

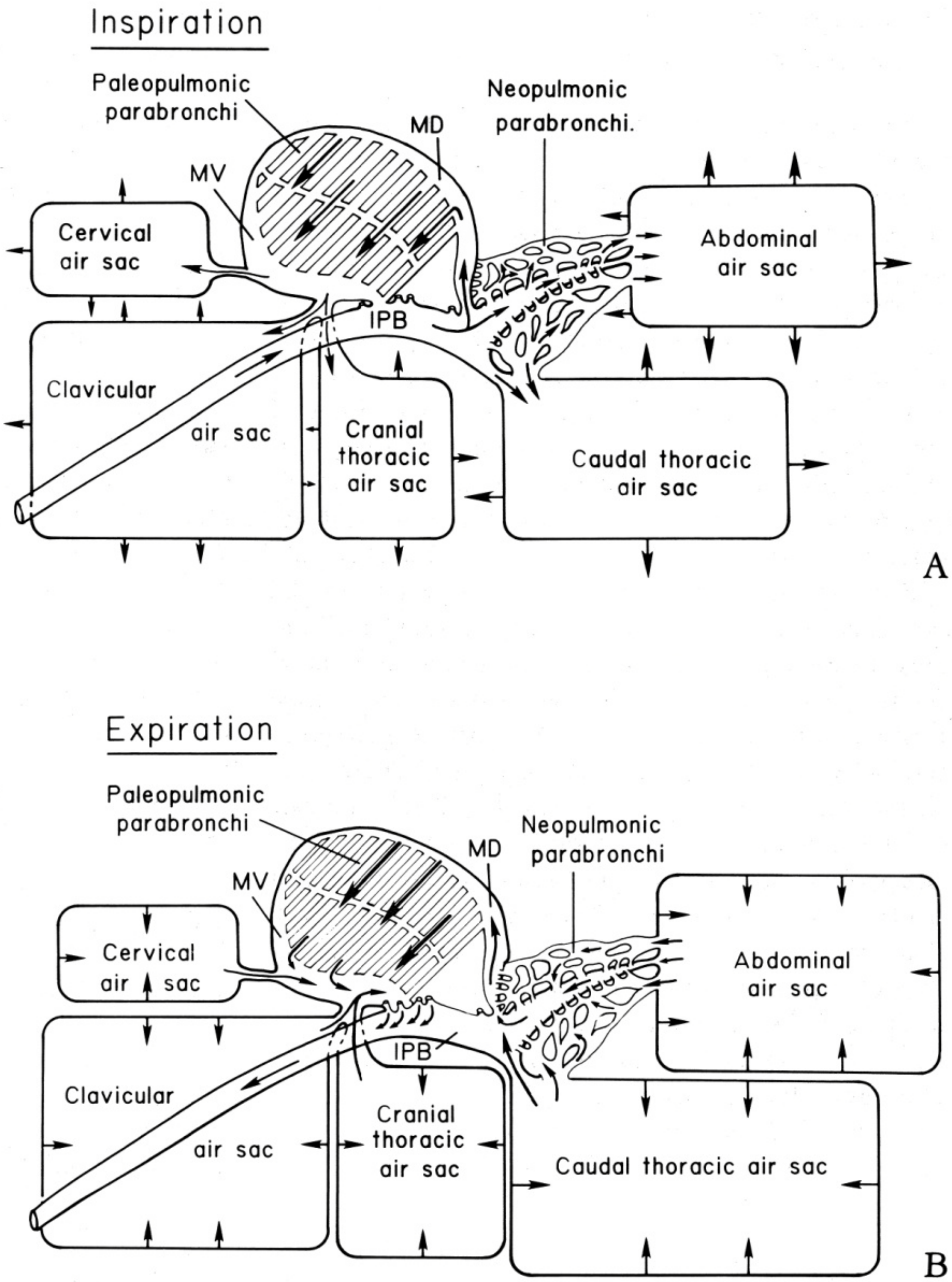


Figure 8. Schematic representation of the pathway of gas flow through the paleopulmonic and neopulmonic tertiary parabronchi during inspiration (A, upper panel) and expiration (B, lower panel). IPB: intrapulmonary primary bronchus; MD: mediodorsal secondary bronchi; MV: medioventral secondary bronchi. Outward arrows on air sacs (upper panel) = inflation caused by negative thoraco-abdominal pressures (suction); Inward arrows on air sacs (lower panel) = deflation caused by positive thoraco-abdominal pressures. Arrows in primary, secondary and tertiary parabronchi show directions of convective air flow.

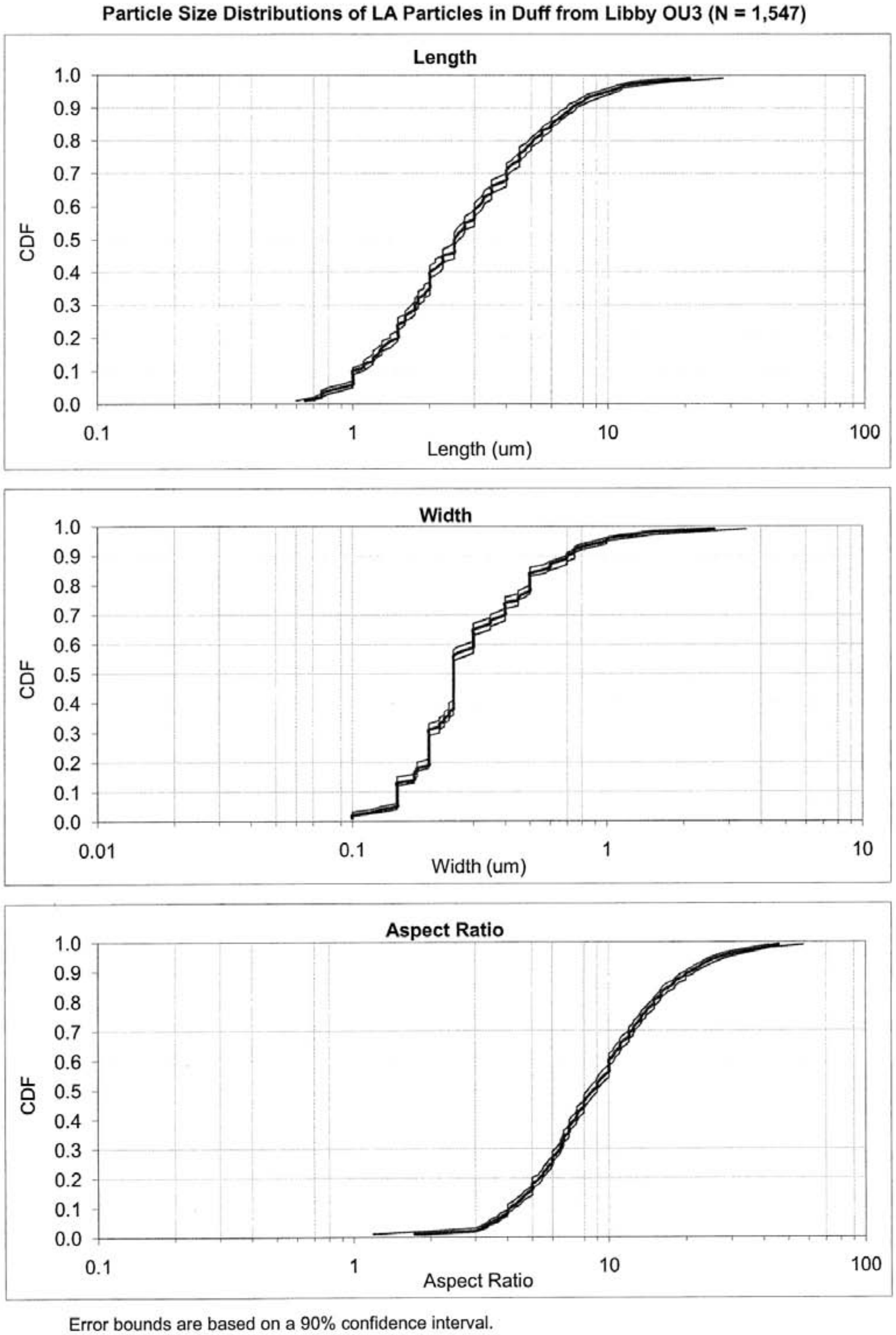


Figure 9. Particle size distributions for Libby Amphibole (LA) in duff.

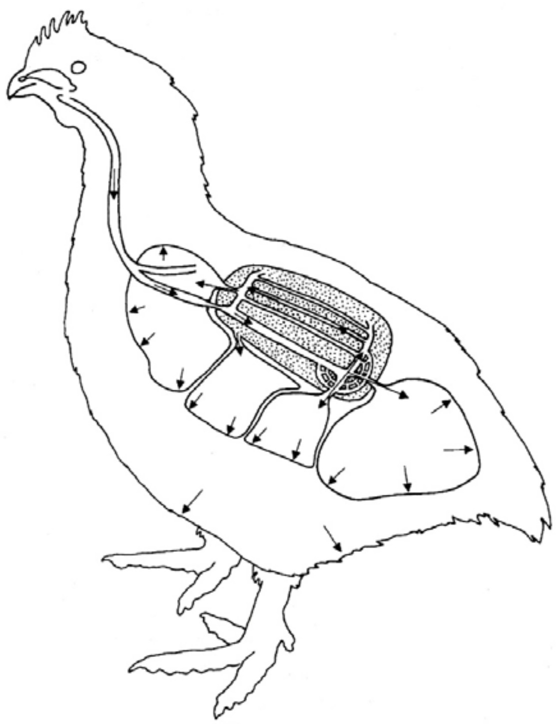


FIGURE 2. Pathway of gas flow in the avian respiratory system during inspiration. Enlargement of the body cavity by inspiratory muscle action lowers pressure in the air sacs relative to that in the atmosphere and gas flows into the system. Gas does not enter the medioventral secondary bronchi, but passes into the mediodorsal secondary bronchi. Some of the gas passes through the paleopulmonic parabronchi, and the remainder passes into the neopulmonic parabronchi and caudal air sacs.

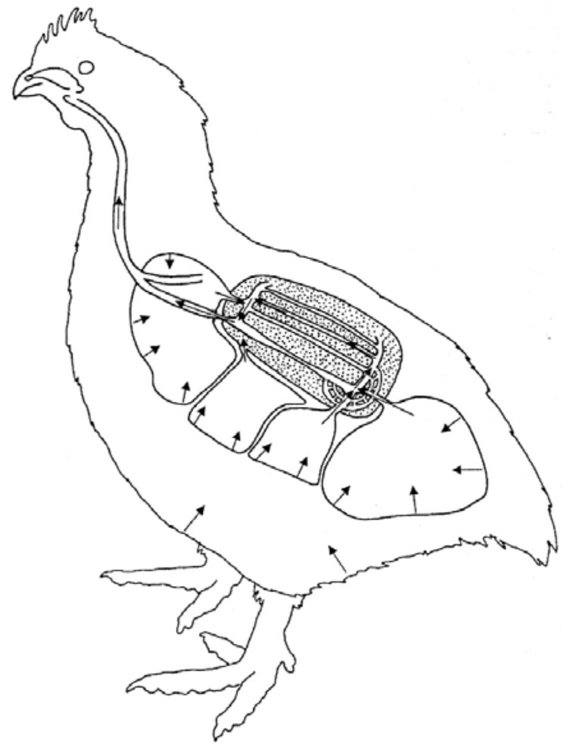


FIGURE 3. Pathway of gas flow in the avian respiratory system during expiration. Reduction in volume of the body cavity by expiratory muscle action increases pressure in the air sacs relative to that in the atmosphere and gas flows out of the system. Compression of intrapulmonary primary bronchus causes gas coming from the caudal air sacs to pass through neopulmonic parabronchi, into mediodorsal secondary bronchi and through the paleopulmonic parabronchi. Gas from the cranial air sacs does not pass through parabronchi on the way to the primary bronchus and trachea.

Figures from Fedde, 1998.

ATTACHMENT D

STUDY REPORTS

(See attached compact disk)