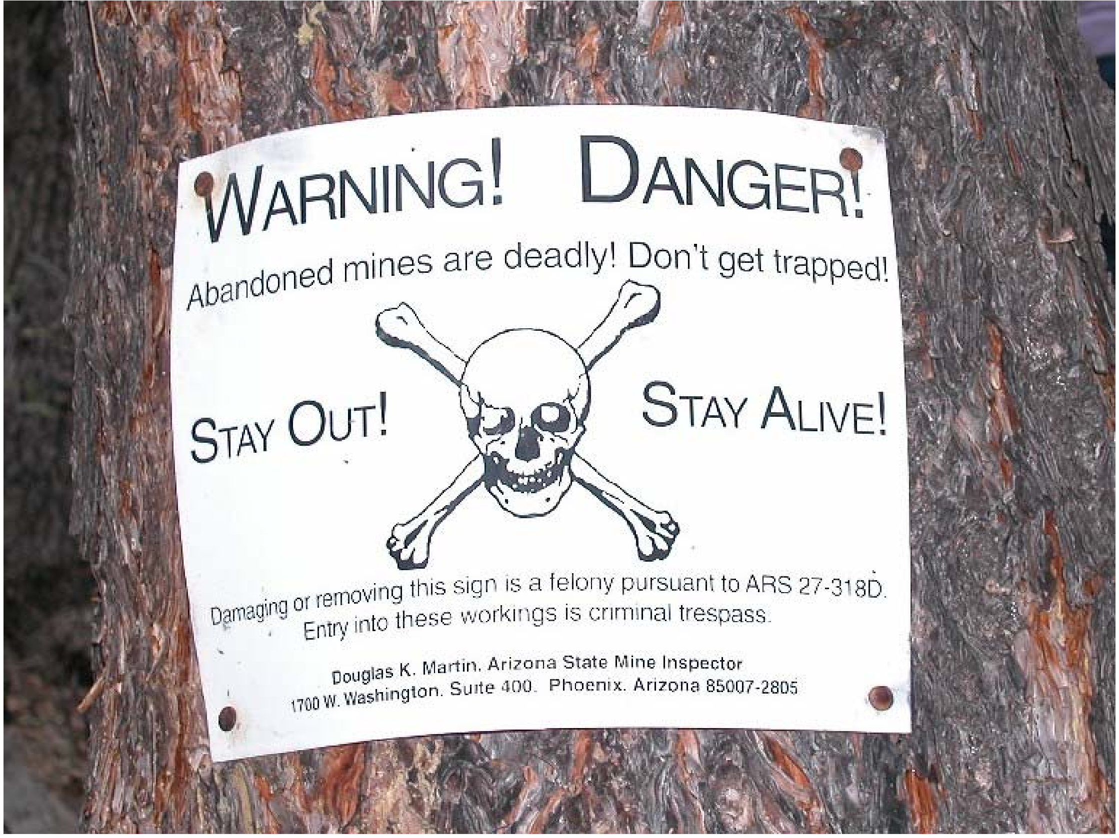
DEPARTMENT OF THE INTERIOR
U.S. FISH AND WILDLIFE SERVICE
REGION 2

Contaminants in Fish and Wildlife of Lynx Lake, Arizona

Final Report



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ABSTRACT

Sediment, water, crayfish, and fish were collected at Lynx Creek and Lynx Lake, Arizona in 2004 and 2005. Granite Basin Lake was used as a reference site. Both sites are located in the the Prescott National Forest. Concentrations of arsenic, copper, manganese, mercury, lead, and zinc in sediments from Lynx Creek exceeded sediment toxicity thresholds. Sediment toxicity tests were conducted in 2005 with sediments from Lynx Creek. Sediments in Lynx Creek were consistently toxic to *Hyallela azteca*. There were no exceedances of Arizona's water quality standards in Lynx Lake, but exceedances of acute water quality standards were found for cadmium, copper, and zinc in Lynx Creek. Chronic exceedances of water quality standards for cadmium, chromium, copper, lead and zinc were found in Lynx Creek. Low pHs were detected in Lynx Creek. Crayfish from Lynx Creek had concentrations of aluminum, barium, cadmium, and magnesium greater than potential toxic thresholds. Carp and catfish from Lynx Lake had elevated concentrations of cadmium, copper, lead, and zinc. Mercury in fish from Granite Basin Lake was elevated compared to other studies and to EPA's water quality criterion guideline for methylmercury for human health.

A conservative risk screening was conducted to assess the potential risk to bald eagles. Bald eagles at Lynx Lake are at risk from exposure to lead in fish.

The Forest Service remediated the abandoned Blue John Mine on Lynx Creek where lead and arsenic were elevated in tailings in 2006. The EPA also plans to remediate the abandoned Sheldon Mine on Lynx Creek in 2008. These actions will decrease loading of contaminants into the Lynx Creek watershed, but contaminated sediments in the watershed will remain in the creek and lake until scouring or dredging remove them or uncontaminated sediments dilute or accumulate over the contaminated sediments.

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ACRONYMS/ABBREVIATIONS

AAC	Arizona Administrative Code
ACF	Analytical Control Facility
ADEQ	Arizona Department of Environmental Quality
AGFD	Arizona Game and Fish Department
Al	Aluminum
ANOVA	Analysis of Variance
As	Arsenic
AWQC	Ambient Water Quality Criteria
AZ WQS	Arizona Water Quality Standard
B	Boron
Ba	Barium
BAF	Bioaccumulation Factor
Be	Beryllium
BTAG	Biological Technical Assistance Group
BW	Body Weight
Cd	Cadmium
CERCLIS	Comprehensive Environmental Response, Compensation, and Liability Information System
CDRB	Colorado River Basin
Cr	Chromium
Csoil (Cwater, Cfish)	Concentration in soil, water, or fish
Cu	Copper
D	Dissolved
DW	Dry Weight
EPA	U.S. Environmental Protection Agency
Fe	Iron
FIR	Food Ingestion Rate
FWS	U.S. Fish and Wildlife Service
GB	Granite Basin
GSI	Gonado-somatic index
Hg	Mercury
HDPE	High density polyethylene
HNO_3	Nitric acid
HSI	Hepato-somatic index
HQ	Hazard quotient
ICP	Inductively Coupled Plasma Atomic Emission Spectroscopy
INT	Intermediate
LC, LL	Lynx Creek, Lynx Lake
LET	Laboratory and Environmental Testing, Inc.
LOD	Limit of Detection
Mg	Magnesium
Mn	Manganese
Mo	Molybdenum
NCBP	National Contaminant Biomonitoring Program
N	Sample Size
NA	Not Analyzed
ND	Non Detect or No Data
Ni	Nickel
NOAA	National Oceanic Atmospheric Administration
NOAEL	No Adverse Effect Level
PA/SI	Preliminary Assessment/Site Investigation
Pb	Lead
PEC	Probable Effect Concentration
PPB	Parts Per Billion
PPM	Parts Per Million
QA/QC	Quality Analysis/Quality Control
RBSL	Risk-based screening level
Se	Selenium
SIR	Soil Ingestion Rate
SPLP	Synthetic Precipitation Leaching Procedure
Sr	Strontium
TEC	Threshold Effect Concentration
TRVs	Toxicity reference values
U	Undissolved
V	Vanadium
WW	Wet Weight
Z	Zinc

KEYWORDS

Acid mine drainage, sediment toxicity, fish tissue concentrations, coots, FFS#1130-2F42, DEC ID # 200420003.3, Congressional District 1

INTRODUCTION

Background and Justification

Abandoned mining operations in the Lynx Creek watershed above Lynx Lake southeast of Prescott, Arizona polluted fish and wildlife with arsenic, cadmium, copper, lead, manganese, and zinc. Lynx Lake was created by the Arizona Game and Fish Department (AGFD) in the 1960s and receives water solely from the Lynx Creek watershed. This watershed had active copper, silver, and gold mines from the late 1800s to early 1900s. At least six abandoned hard rock mines and one placer mine (Follett and Wilson 1969) are present in the Lynx Creek drainage. The Lynx Creek watershed is listed as a potential hazardous waste site in the Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS website). Lynx Creek and Lynx Lake were also listed on Arizona's 303(d) List prior to 1994 for exceeding mercury standards and for lack of monitoring data, respectively (ADEQ 1994). Neither is currently on the 303(d) list but they are on the planning list due to inconclusive data for the Aquatic and Wildlife-coldwater use for several trace metals (ADEQ 2005). The status of Lynx Creek did not change in the draft 2006 303(d) list (ADEQ 2007). The Blue John Wash was added to this report, but is also listed as inconclusive for Aquatic and Wildlife-ephemeral use for zinc. Lynx Lake attained its Aquatic and Wildlife-cold designated use in the draft 2006 303(d) report. During the winter of 2000-2001, a 19 foot-high gabion constructed in Lynx Creek to contain contaminated sediment was breached and an estimated 2,700 cubic yards of metals-contaminated sediment flowed towards Lynx Lake. Contamination in fish was documented before the gabion failure (Rector 1993).

Drainage and runoff from six abandoned mines in the watershed have polluted Lynx Creek with six metals (EPA 1994). These abandoned mines are in the headwaters of Lynx Creek, where there are many first- and second-order streams (EPA 1994). Lynx Lake has a surface area of 55 acres and is in the Agua Fria watershed. Lynx Lake pH varied between 7.41 - 8.53 (AGFD 2001a). Since its creation, numerous studies have been conducted on Lynx Lake to assess how the abandoned mines have affected the water quality. Follett and Wilson (1969) suggested that the reason Lynx Lake cannot sustain a renewable sport fishery is due to the levels of trace metals present in the water and sediment. Results from previous analyses of sediment are presented in Table 1, as are results from analyses done by the Arizona Department of Environmental Quality (ADEQ) and U.S. Environmental Protection Agency (EPA). Lynx Creek is an ephemeral creek, so sediments are not saturated year round. Therefore, sediment concentrations from Lynx Creek were compared against soil background, Arizona soil remediation levels (AAC 2006), and sediment quality guidelines (MacDonald et al. 2000). Concentrations of arsenic, cadmium, copper, lead and zinc concentrations exceeded Arizona soil remediation levels and/or protective levels for benthic invertebrates.

The abandoned Sheldon Mine is located at the headwaters of Lynx Creek, approximately seven miles upstream from Lynx Lake. Arsenic, copper, and zinc concentrations exceeded Arizona mean background concentrations, human health remediation standard, and/or probable effect level for aquatic invertebrates (Table 1). The Sheldon Mine appears to be a source of contamination in Lynx Creek since metal concentrations in sediment were greatest close to the mine and decreased as the creek approached the lake (Rector 1994).

Lynx Lake consistently has low numbers of aquatic invertebrates and scarce phytoplankton and zooplankton populations, which may be due to high copper and zinc concentrations (EPA 1994). A lack of nutrients may be indirectly related to metal loading. Rathbun (1971) reported that phytoplankton growth was inhibited after storm events associated with simultaneously increased copper and zinc concentrations, decreased phosphorus concentrations, and increased water turbidity in Lynx Lake. Crane and Sommerfeld (1977) reported that phytoplankton standing crop and diversity were low, which could explain in part why the fishery has been poor at Lynx Lake. A subsequent study by Lampkin and Sommerfeld (1982) revealed that algal species richness was reduced in Lynx Creek where acid mine drainage entered the creek.

The habitat surrounding Lynx Lake is part of the Montane Conifer Forest biotic community (Brown 1994). This provides suitable habitat bald eagles (*Haliaeetus leucocephalus)*. A pair of bald eagles nested on Lynx Lake in 2002. Lynx Lake is important waterfowl wintering habitat. The lake shore had cattails and willows in the past, although drought conditions recently may have reduced emergent vegetation around the lake perimeter. Waterfowl species observed during visits to Lynx Lake included ring-necked ducks (*Aythya collaris*), goldeneyes (*Bucephala clangula*), coots (*Fulica americana*), and canvasbacks (*Aythya valisineria*). The threatened Mexican spotted owl (*Strix occidentalis lucida*) also occurs in the watershed. Eight or nine pairs of Mexican spotted owls nest in the Prescott National Forest and may opportunistically use water in the Lynx Creek watershed to drink or bathe (EPA 1994).

Granite Basin Lake was used as a reference location. It was chosen because of its proximity to Lynx Lake and lack of significant historical mining in its drainage. It is located approximately 11.5 miles northwest of Lynx Lake, in Yavapai County, Arizona. Situated on the Prescott National Forest, Granite Basin Lake is in the Verde River watershed and is in the Plains Grassland biotic community (Brown 1994).

Table 1. Trace metal pollutants in sediment (ppm dry weight) from previous studies.

	Arizona Background[1]	Human Health Guideline[2]		Sediment Quality Guidelines[3]		Lynx Creek Watershed						
	Mean	Residential	Non-Residential	Threshold Effect Concentration	Probable Effect Concentration	Lynx Creek			Lynx Lake			Sheldon Mine Drainage[7]
						ADEQ[4]	EPA[5]	Weston[6]	ADEQ	EPA	Weston	
Antimony	<1	31	680	ND[8]	ND	7.2	NA	1.6	7.9	NA	1.7	NA
Arsenic	9.8	10	10	9.79	33	33.9	39	13.1	25.1	22	21.2	84.4
Beryllium	0.52	1.4	11	ND	ND	0.76	NA	0.37	0.49	NA	0.31	0.69
Cadmium	ND	38	850	0.99	4.98	8.7	2.8	1.1	2.3	3.4	2.7	NA
Chromium	61.3	2,100	4500	43.4	111	39.5	NA	5.3	23.4	20	17.4	9.5
Copper	30	2,800	63,000	31.6	149	408	618	415	270	310	182	181
Lead	23.4	400	2,000	35.8	128	280	667	99.1	176	160	146	27.9
Manganese	ND	3,200	43,000	ND	ND	NA	NA	191	NA	NA	559	NA
Mercury	0.1	6.7	180	0.18	1.06	0.24	NA	0.07	0.1	0.043	0.07	NA
Nickel	27.5	1,500	34,000	22.7	48.6	NA	NA	5.5	NA	14	10	NA
Selenium	0.3	380	8,500	ND	ND	0.29	NA	0.9	0.26	NA	0.91	NA
Silver	ND	380	8,500	ND	ND	NA	NA	0.89	NA	NA	2.2	NA
Zinc	62.1	23,000	510,000	121	459	NA	NA	256	NA	420	357	159

[1] Boerngen and Shacklette (1981) as found in Earth Technology (1991).

[2] AAC 2006.

[3] MacDonald et al. 2000.

[4] Rector 1993.

[5] EPA 1994.

[6] Weston 2002 (Table 4-5 and 4-6).

[7] Rector 1994.

[8] ND = No data. NA = Not analyzed.

▨ Values in bold exceeded protective levels for humans and/or fish and wildlife.

Scientific Objectives

1. Examine trace metal concentrations in sediment, water, invertebrates, fish, and waterfowl that occur in Lynx Creek and Lynx Lake.
2. Assess the potential for contaminant-induced effects on fish and wildlife.
3. Present data for future management decisions by regulatory agencies.

METHODS

Data Collection and Analysis

The majority of sediment, water, fish and invertebrate samples were collected between May and August 2004. Additional sediment was collected at eight locations in May 2005 for toxicity testing. Analytical chemistry results were available for four of the eight locations, so analytical chemistry was not repeated in 2005 at these locations. The EPA performed the analytical chemistry for the other four locations in 2005. Samples were collected according to U.S. Fish and Wildlife Service (FWS) protocols (FWS 1984, 1996; NCTC 2002), preserved, and stored until shipment for analysis. Sediment and water sampling locations are identified in Figures 1, 2, and 3.

Sediment was sampled in 2004 and 2005 in Lynx Creek and both Granite Basin Creeks. Composite samples were collected according to Shelton and Capel (1994), placed in a pre-cleaned high density polyethylene (HDPE) bottles, kept on ice in a cooler in the field, and refrigerated at -4°C until shipment to the analytical laboratory. The 2005 sediment samples were analyzed by an EPA Region 9 analytical lab for trace metals. American Aquatic Consulting, Inc. conducted the *Hyallela azteca* sediment toxicity tests. Sediment, water, invertebrates, and fish were collected from a reference location, Granite Basin Lake. Every effort was made to collect the same number of samples from both sites. Analytical results were compared to threshold and probable effects concentrations (MacDonald et al. 2000).

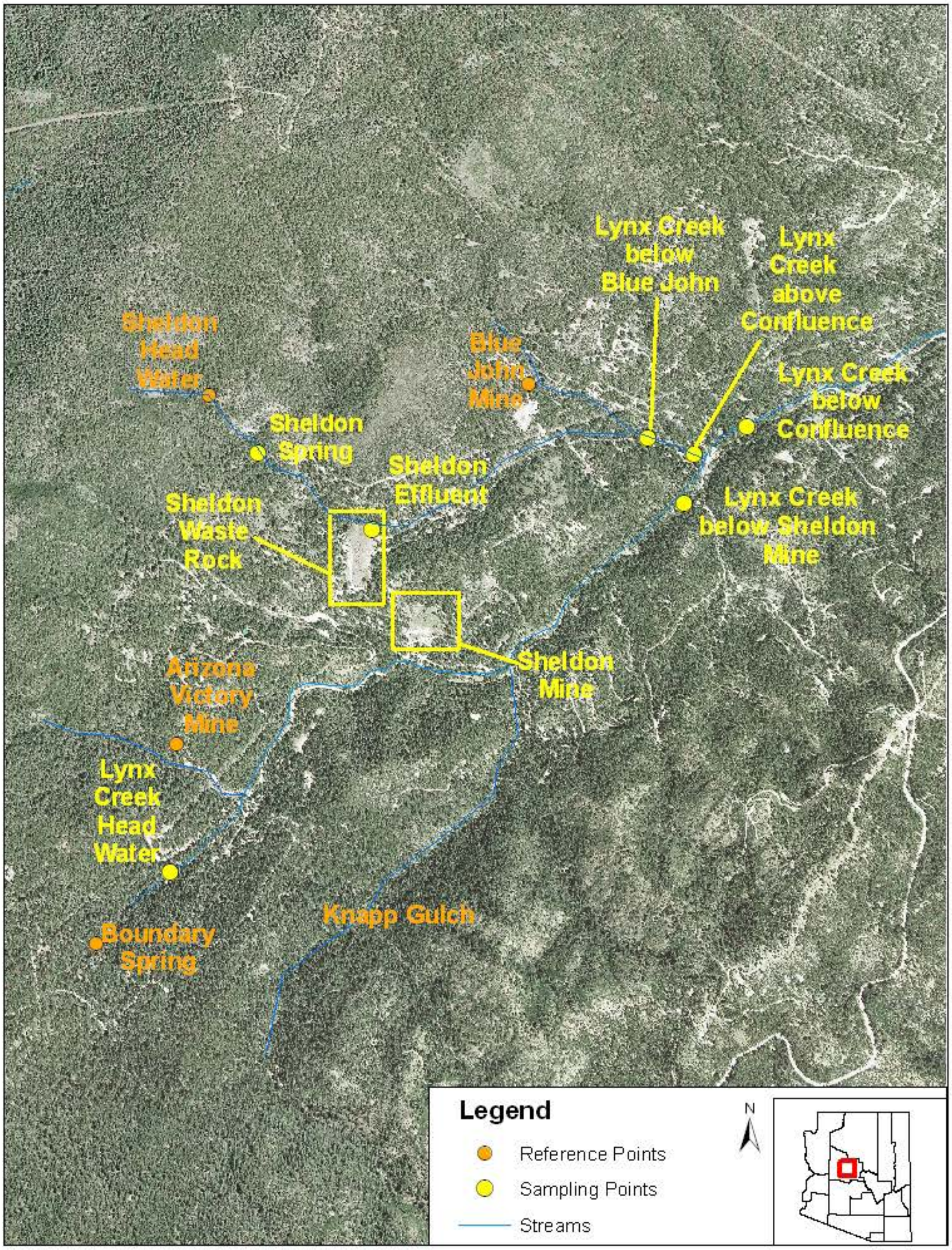


Figure 1. Map of sampling sites along the headwaters of the Lynx Creek watershed, Arizona in 2004 and 2005.

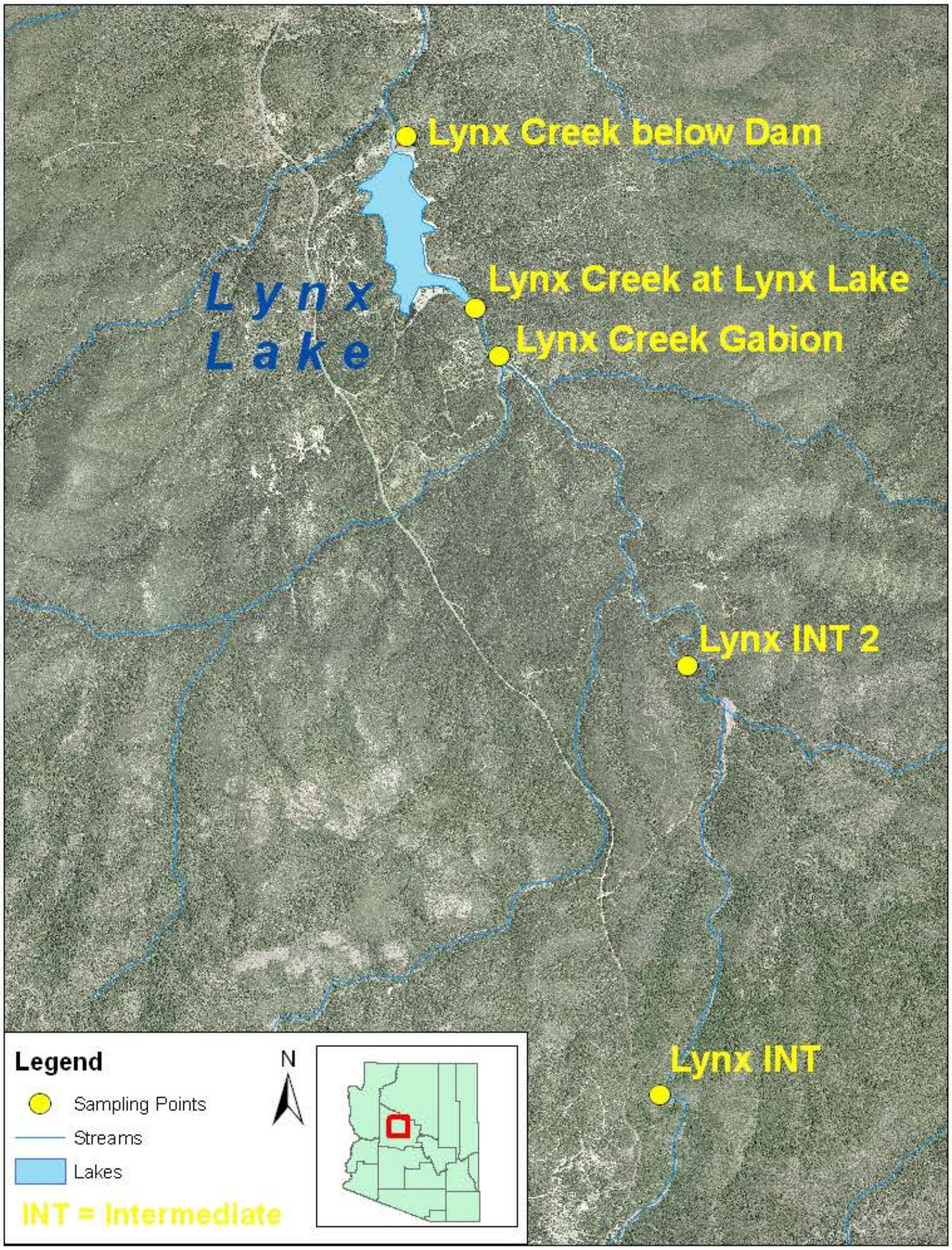


Figure 2. Map of sampling sites along Lynx Creek as it approaches Lynx Lake, Arizona in 2004 and 2005.

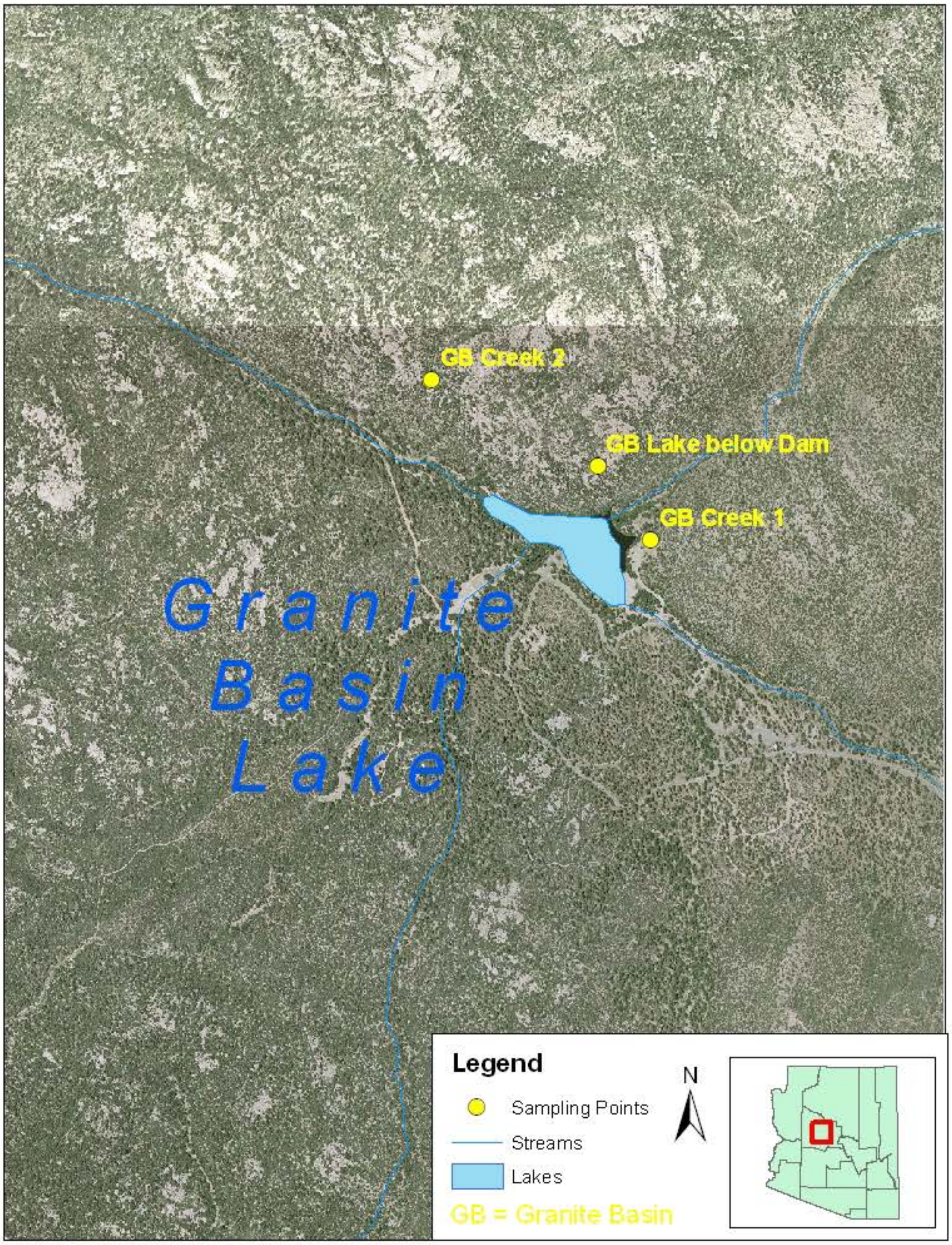


Figure 3. Map of sampling sites near Granite Basin Lake, Arizona, the reference location, in 2004.

Specific conductance, pH, DO, temperature, and hardness were measured in water at each site concurrently with sample collection. Lynx Creek water samples were collected according to Shelton (1994). Water samples were preserved with HNO_3 to pH<2 for trace metals analysis. No water was available for collection from the tributaries into Granite Basin Lake.

Water samples from Lynx Lake and Granite Basin Lake were collected by boat. Samples were taken once along the width of the lake after sampling five times in equal-width increments. Subsamples were collected using ½ of a Kemmerer bottle from the top 1 meter of the lake and the bottom 1 meter of the lake and composited into a plastic churn splitter. One filtered sample and unfiltered sample were collected for analysis from this transect. This step was repeated for all subsequent water collections. Samples were taken across the length of the lake after subsampling 10 times along this transect in equal-width increments. Two composite samples were created: one from the first five subsamples and another from the last five subsamples. A total of six samples at Lynx Lake and six samples at Granite Basin Lake were collected for trace metal analysis. These methods were used to decrease variability between samples as much as possible. The sampling design was not intended to capture seasonal, vertical, or horizontal variation in the lake. Lake water samples were also preserved with HNO_3 to pH<2. Filtered water samples were compared to Arizona Water Quality Standards (AZ WQS) for the Aquatic and Wildlife-cold water designated use because most of the inorganic standards are presented as dissolved metals (ADEQ 2003). Unfiltered water samples were collected for qualitative comparison against filtered water samples and sediment samples.

Crayfish were collected using baited minnow traps. All crayfish samples were collected and preserved using general methods described in the FWS's Field Operational Manual for the Resource Contaminant Assessment (FWS 1984, Staley and Rope 1993, FWS 1996). Crayfish were collected at the Lynx Creek Gabion, near the mouth of Lynx Lake, Lynx Creek below Dam, and below the Granite Basin Dam. All crayfish were submitted for analysis with their exoskeletons and gastrointestinal tracts intact. Crayfish were submitted as individual samples from Lynx Lake and Lynx Creek Gabion because the crayfish were large (7.6 – 53.0 g). Crayfish were submitted as composite samples from Lynx Creek below Dam and Granite Basin Lake. The composite sample from Granite Basin Lake included crayfish from the lake and from below the dam.

At Lynx Lake, seven common carp (*Cyprinus carpio*), twelve yellow bullhead catfish (*Ameiurus natalis*) and channel catfish (*Ictalurus punctatus*), one largemouth bass (*Micropterus salmoides*), and one bluegill (*Lepomis macrochirus*) were collected by electrofishing in May 2004 and by trammel and gill nets in July and August 2004. At Granite Basin Lake, eight largemouth bass and twelve bluegills were collected by electrofishing in May 2004. Samples were processed according to Schmitt et al. (1999). Fish were held no longer than 12 hours in nets or in live wells prior to tissue collection. Fish were sacrificed with a blow to the head and necropsied. Samples of scales, liver, spleen were collected. Then, the whole body was wrapped in aluminum foil and placed in a cooler for transport back to the laboratory until shipment for analyses. Liver and spleen were weighed, measured, and then discarded with the rest of the gastrointestinal and reproductive tracts. Gonado-somatic indices (GSIs) and hepato-somatic indices (HSIs) were also calculated as an indicator of fish health (Schmitt et al. 1999). All efforts were taken to collect and process fish in the same age class based on field measurements of total length and weight.

Analysis

Sample analysis, laboratory quality assurance, and quality control were under the general supervision of the FWS Analytical Control Facility (ACF), a field station of the Division of Environmental Quality located at the National Conservation Training Center in Shepherdstown, West Virginia. The ACF contracted Laboratory and Environmental Testing, Inc. (LET), Columbia, Missouri to conduct analyses. Sediment, water, crayfish, and whole body fish were analyzed for trace metals by LET. The following elements are included in standard testing by ACF and were quantified in all water (mg/L), sediment, crayfish, and fish tissue (mg/kg [ppm] dry weight) samples: Al, As, Ba, Be, B, Cd, Cr, Cu, Fe, Pb, Hg, Mg, Mn, Mo, Ni, Se, Sr, V and Z.

Arsenic and selenium concentrations were determined by hydride generation atomic absorption (EPA 1987). Mercury was quantified by cold vapor atomic absorption (EPA 1984). Lead was analyzed in water and animal tissue using graphite furnace atomic absorption (EPA 1987). All other elements were analyzed by inductively coupled plasma (ICP) atomic emission spectroscopy (Dahlquist and Knoll 1978, EPA 1987) or ICP. The lower limits of quantification varied by element and by sample. Detection limits for trace metals in water ranged from 0.0002 – 0.05 ppm wet weight in water, from 0.1-10 ppm dry weight in sediment, and from 0.1-5 ppm dry weight in tissues.

The sediment samples analyzed by the EPA Region 9 analytical lab were processed according to EPA Method 6010B for trace metals (EPA 1996) and EPA Method 7473 for total mercury (EPA 1998b) (Table 2). Detection limits for trace metals in sediment ranged from 0.26 ppm dry weight for beryllium to 350 ppm dry weight for aluminum. Detection limits for mercury in sediment ranged from 0.02 – 0.044 ppm dry weight.

Sediment toxicity tests using the amphipod *Hyalella azteca* were conducted by American Aquatic Testing, Inc. according to procedures in Ingersoll et al. (2000) and Nally (2005).

Data were censored using one-half the detection limit as a substitute for non-detects. Standard deviations of crayfish and fish are reported to evaluate the variability in biota between sites (Gad 2001, Hayek and Buzas 1997).

QA/QC

ACF has a stringent quality assurance and quality control (QA/QC) program and handled the laboratory QA/QC through its contract labs (PACF 1997). Environmental-sample and associated blank-sample QC collection, preservation, and handling was conducted according to standard FWS protocols. The laboratories maintained QA/QC by analyzing blanks, duplicates, and spiked samples. Field quality control samples were also collected. We collected two field duplicate water samples at a frequency of 8% of all water samples. Two equipment blanks and two field blanks were collected – one each for Lynx Lake and for Granite Basin Lake. The laboratory provided and analyzed all required matrix spike duplicates, except when noted elsewhere. Duplicates of percent moisture could not be performed on Lynx Creek Crayfish 5 and Lynx Lake Crayfish 8 due to insufficient quantity. Duplicate results were within normal limits. The QA/QC report noted that other elements had very good precision and spike recoveries (ACF 2006).

Inorganic analytical methods were reported by LET (2007). All blank and duplicate analyses were within normal limits. The spike recovery for WATERLC11 was outside the normal range, but should not affect the interpretation of the data. Two standard reference material anomalies were detected. The standard was Buffalo River Sediment and the analytes were aluminum and strontium. Recovery of these analytes was low and may have biased aluminum and strontium concentrations in sediment low. Otherwise, analytical methodology and values met ACF QA/QC contract limits.

EPA conducted analysis on a laboratory blanks, matrix spikes, and reference materials as part of its QA/QC procedure for four sediment samples. All of the sediment samples analyzed by EPA were extracted past the holding time for mercury analysis. Some of the EPA analytical results were J-flagged to indicate that the values were estimated.

RESULTS and DISCUSSION

Sediment

Arsenic, cadmium, copper, manganese, mercury, lead, selenium, and zinc concentrations in sediment were compared against Arizona mean background concentrations in soil (Shacklette and Boerngen 1984; Boerngen and Shacklette 1981), Threshold Effect Concentrations (TEC; MacDonald et al. 2000) and Probable Effect Concentrations (PEC; MacDonald et al. 2000) (Table 2). Sediments are compared against both soil and sediment values because Lynx Creek is an ephemeral creek and the sediments do not stay saturated year-round. Background concentrations of Arizona sediments are not available, and Lynx Creek sediments are not exactly the same as sediments that are saturated year-round. The sediments in the toxicity tests that the TECs and PECs are calculated from are saturated year-round and the invertebrates used in these tests may not be native in Arizona.

The background concentration for arsenic in Arizona soil was exceeded in 64% of the Lynx

Creek sediments. The arsenic TEC (9.79 ppm) was exceeded in 82% of Lynx Creek sediments. The PEC (33 ppm) was exceeded in 27% of the Lynx Creek sediments.

There is no background concentration for cadmium in Arizona soils. The cadmium TEC (0.99 ppm) was exceeded in 82% of Lynx Creek sediments. The PEC (4.98 ppm) was exceeded in 36% of the Lynx Creek sediments.

The background concentration for copper in Arizona soil was exceeded in 100% of the Lynx Creek sediments. The copper TEC (31.6 ppm) was exceeded in 100% of Lynx Creek sediments. The PEC (149 ppm) was exceeded in 91% of the Lynx Creek sediments.

Only sediments in Lynx Creek close to Lynx Lake (both above and below) had mercury concentrations greater than the TEC (0.18 ppm). The background concentration for mercury in Arizona soil was exceeded in 21% of the Lynx Creek sediments. The mercury TEC (0.18 ppm) was exceeded in 27% of Lynx Creek sediments. The PEC (1.06 ppm) was not exceeded.

The background concentration for manganese in Arizona soil was exceeded in 73% of the Lynx Creek sediments. There are no TECs or PECs for manganese.

The background concentration for lead in Arizona soil was exceeded in 71% of the Lynx Creek sediments. The lead TEC (35.8 ppm) was exceeded in 82% of Lynx Creek sediments. The PEC (128 ppm) was exceeded in 36% of the Lynx Creek sediments.

The background concentration for selenium in Arizona soil was exceeded in 18% of the Lynx Creek sediments. There is no TEC or PEC for selenium.

The background concentration for zinc in Arizona soil was exceeded in 100% of the Lynx Creek sediments. The zinc TEC (121 ppm) was exceeded in 82% of Lynx Creek sediments. The PEC (459 ppm) was exceeded in 64% of the Lynx Creek sediments.

Concentrations of arsenic, cadmium, copper, lead and zinc exceeded PECs in the Lynx Creek watershed. The copper PEC had the greatest number of exceedances (91%). The zinc PEC had the second greatest number of (64%). Five different metals in Lynx Creek had elevated concentrations in sediment greater than PECs compared to one at Granite Creek (arsenic). This is probably a reflection of the historical mining in the Lynx Creek watershed, despite the natural mineralization that is present in both areas.

Table 2. Sediment from Lynx Creek, Granite Basin Creeks, and below the dams on Granite Basin Lake and Lynx Lake (ppm dry weight), Arizona in 2004 and 2005.

	Mean Bkgd[1]	TEC[2]	PEC	Lynx Creek Head Water	Sheldon Spring	Lynx Creek below Sheldon Mine	Lynx Creek below Blue John	Lynx Creek above Confluence	Lynx Creek below Confluence	Lynx INT[4]	Lynx INT 2	Lynx Creek Gabion	Lynx Creek at Lynx Lake	Lynx Creek below Dam	Granite Basin Creek-1	Granite Basin Creek-2	Granite Basin Lake-below Dam
				EPA[3]	EPA	SED8	SED9	SED1	SED10	EPA	EPA	SED7	SED6	SED5	SED3	SED4	SED2
% Moist[5]				22	43	2.3	0.4	21.2	0.5	23	22	19.5	1.00	74.3	0.4	0.2	73.4
As	9.8	9.79[6]	33	6.2	25	9	17	71	21	32	25	35	29	160	11	1.00	320
Cd	NA[7]	0.99	4.98	0.99	5.5	3.60	1.10	<0.2	4.00	5.9	3.9	5.90	6.20	6.70	<0.2	<0.2	<0.2
Cu	30	31.6	149	280	390	194	548	140	601	180	250	461	460	182	7	3	12
Hg	0.10	0.18	1.06	<0.03	0.072	<0.1	0.10	0.10	0.10	0.09	0.03	0.20	0.20	0.20	<0.1	<0.1	0.10
Mn	380[8]	NA	NA	240	780	600	246	288	482	1,000	950	783	633	>5,000	800	207	5,940
Pb	23.4	35.8	128	17	29	70	71	41	110	150	220	250	220	73	10	10	25
Se	0.30	NA	NA	NA	NA	<0.5	<0.5	<0.5	<0.5	NA	NA	1	<0.5	1	<0.5	<0.5	1
Zn	62.1	121	459	96	500	507	243	90	596	550	450	620	523	620	32	21	65

[1] Bkgd = background; Boerngen and Shacklette (1981) as found in Earth Technology (1991).

[2] TEC= Threshold Effect Concentration; PEC= Probable Effect Concentration (MacDonald et al. 2000).

[3] Most data were collected in 2004 except for the EPA data which were collected in 2005.

[4] INT = Intermediate.

[5] % Moist = Percent Moisture.

[6] Bold numbers indicate exceedance above TEC and PEC.

[7] NA= Not available or not analyzed.

[8] Shacklette and Boerngen (1984) concentration for western U.S.

Boron was not detected in any samples. Aluminum, barium, beryllium, chromium, iron, magnesium, molybdenum, nickel, strontium, and vanadium are not shown here, but are in Appendix 1.

▓ Denotes an exceedance of a PEC.

▒ Denotes an exceedance of a TEC.

░ Denotes an exceedance of background.

Al, Ba, Be, Cr, Fe, Mg, Mo, Ni, Sr, and V results are presented in Appendix 1. None of the background concentrations for aluminum, chromium, nickel, strontium, or vanadium in Arizona soils were exceeded by Lynx Creek sediments. None of the Lynx Creek sediments exceeded chromium or nickel TECs or PECs. There are no TECs or PECs for the other contaminants of concern. There are no background concentrations in Arizona for iron or magnesium. One sediment sample at Lynx Creek below Dam (1,090 ppm) exceeded the background concentration for barium in Arizona soil (565 ppm). Two sediment samples, Lynx Creek Gabion and Lynx Creek at Lynx Lake, exceeded the background concentration for beryllium in Arizona soil (0.52 ppm). One sediment sample at Lynx Creek below Dam (5 ppm) exceeded the background concentration for molybdenum in Arizona soil (3 ppm).

The geology of the Lynx Creek watershed contains extensive mineralization (Stephens 1990). Massive sulfide deposits containing veins of arsenic, copper, lead, gold, silver, and zinc formed during the Precambrian to mid-Tertiary period (Tetra Tech 2003). Miners were attracted to this area because of this geology and mineralization. Although some prospecting took place near Granite Basin, there are no abandoned mines in its watershed. Some trace metals were elevated at Granite Basin when compared to Lynx Creek. For example, the greatest concentration of arsenic in sediment (320 ppm) was found below Granite Basin Lake Dam. An elevated concentration of arsenic in sediment was found below the dam at Lynx Lake also (160 ppm). The greatest concentrations of manganese were found below the Granite Basin Lake Dam (5,940 ppm) and below the Lynx Lake Dam (>5,000 ppm). The phenomena of elevated arsenic and manganese in sediment below the dams did not occur for other contaminants of concern.

Sediment concentrations of cadmium, copper, mercury, lead, and zinc were all greatest in Lynx Creek. Maximum concentrations of cadmium, mercury, and zinc were all detected below the Lynx Lake Dam. It is unknown how far the elevated concentrations of trace metals below Lynx Lake Dam continue since only one sediment sample was collected there. On a smaller scale, elevated concentrations of arsenic, cadmium, copper, mercury, lead and zinc were detected in the Lynx Creek Gabion sample. Sedimentation plays a large role in deposition and availability of trace metals in the Lynx Creek watershed.

Elevated concentrations of trace metals were found in sediment samples from the background locations, Lynx Creek Headwater and Sheldon Spring. The Lynx Creek Headwater sediment had elevated concentrations of copper and zinc and Sheldon Spring sediment had elevated concentrations of arsenic, cadmium, copper, lead, and zinc.

The maximum copper concentration in Lynx Creek was 4.0-times greater than the PEC. The maximum copper concentration was detected in a sediment sample from the Lynx Creek below Confluence, below the confluence where one Lynx Creek tributary drains the Sheldon Mine and the other one receives runoff from the Blue John Mine and Sheldon Waste Rock. Stephens (1990) concluded that metals would be mobile in soils downstream of the Blue John Mine because of low neutralization potential and cation exchange capacity. However, the tailings piles at the Blue John Mine were moved to an on-site repository in 2005 and the EPA may proceed with a removal action at the Sheldon Mine in 2008. Concentrations of copper in Lynx Creek may decrease as a result of these remedial efforts since creek sediments will continue to be transported downstream. Monitoring will be necessary at the Lynx Creek Gabion and in Lynx Lake to ensure that sediments with high metal concentrations do not continue to affect the watershed, even after the source has been remediated.

Hyallela azteca Toxicity Tests

As a complement to the sediment and water chemistry conducted in 2004, sediment toxicity tests with *Hyallela azteca* were conducted in 2005. Sediment was collected at eight sites in 2005 for toxicity testing. Since analytical results were available for four of these sites, no new chemistry was performed for these sites. However, four locations did not have analytical chemistry available, so EPA analyzed these sediments for trace metals. Two of the four new locations were chosen as background locations on Lynx Creek and the other two locations were situated between the abandoned mines and Lynx Lake. American Aquatic Testing, Inc. was contracted to conduct the sediment toxicity tests.

Sediment was collected at six sites below the influence of mining; five had significantly lowered survival compared to the laboratory control. Sediment was collected at two background locations. Both background locations had elevated metal concentrations compared to sediment toxicity thresholds. However, only Lynx Creek Headwater sample exhibited a significant decrease in *Hyallela* survival compared to control. Topographical maps do not show any mines near either background location, but digital aerial photos do show some surface disturbance close to the Lynx Creek Headwater site.

Table 3. Results of sediment toxicity tests from Lynx Creek, Arizona in 2005. Percent survival of *H. azteca* by replicate chamber and mean survival using control sample.

	Sample Location								
Rep.	Control	Lynx Head Water	Sheldon Spring	Sheldon Effluent	Lynx Creek below Blue John[1]	Lynx Creek below Confluence	Lynx INT[2]	Lynx INT 2	Lynx Creek Gabion
A	100	70	90	70	0	20	10	60	90
B	90	70	80	40	0	0	10	10	100
C	100	80	100	40	0	0	40	30	100
D	100	80	90	50	0	0	30	30	100
E	100	70	100	20	0	40	40	20	90
Mean Survival	98	74	92	44	0	12	26	30	96
Statistically Different From Control[3]		**Yes**	No	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	No

[1] Sample not included in ANOVA due to 100 % mortality.

[2] INT = Intermediate.

[3] ANOVA hypothesis that all sites were the same was rejected at $p<0.0001$. Dunnett's pairwise comparisons were performed to determine differences in survival of organisms in all samples versus the control.

Two conclusions of the *Hyallela* toxicity tests were contradictory to the expected outcome: toxicity observed in a background location in a headwater above any mining influence and an absence of toxicity in the Lynx Creek Gabion. Given the metal concentrations in sediments from Lynx Creek Headwater and Sheldon Spring, we would have expected more toxicity in the Sheldon Spring sediment, but the Lynx Creek Headwater sediment was more toxic. Metal concentrations in the Sheldon Spring background sediment were comparable to the metals in the Lynx Creek gabion sediment. Metal concentrations at the gabion (Table 2) were elevated enough to cause toxicity. The gabion acts as a lake microcosm, capturing sediment from upstream and preventing excessive sedimentation in the lake downstream. Since it is a sink for all sediment deposition from the former mines, toxic concentrations were expected to occur here. Sediment oxygenation, sediment pH, simultaneously extractable metals, and acid volatile sulfides were not analyzed, and perhaps explain the differences in metal concentrations, bioavailability, and toxicity between sites. Metal bioavailability varies with the metal species present, metal concentrations, sulfide concentrations, particle size, organic matter, and anoxic conditions (Newman 1998). Rule and Alden (1996) found that sulfides may not complex all of the available metal in an anaerobic environment depending on the input of new metals into the sediment, potentially increasing cadmium bioavailability and toxicity. It may also be possible that oxygen was introduced when samples were collected and affected the outcome of the toxicity tests by altering metal bioavailability. Variability between the sediments collected for chemical analyses and the sediments collected for toxicity testing could also account for the difference between observed versus expected toxicity because there is uncertainty with the actual metal concentrations to which organisms were exposed. The complex association of at least six metals at this site and other unknown conditions may also explain the differences observed in toxicity.

Water

Filtered and unfiltered water samples were collected to determine dissolved versus total metal concentrations. Concentrations of metals in filtered water samples were necessary to compare against AZ WQS, which, for most metals, are dissolved. Unfiltered water samples were collected in order to examine to what benthic invertebrates (e.g., crayfish) and fish are exposed through ingestion.

Concentrations of cadmium, chromium, copper, lead, and zinc in filtered water samples in Lynx Creek exceeded AZ WQS. Neither Lynx Lake nor Granite Basin Lake showed any exceedances of AZ WQS. Exceedances of acute AZ WQS occurred for cadmium and copper in Lynx Creek below Blue John and Lynx Creek above Confluence. At Lynx Creek below Blue John and Lynx Creek above Confluence, acute AZ WQS for cadmium were exceeded by a factor of 3.1 and 17.9, respectively, and for copper were exceeded by a factor of 33.7 and a factor of 1,201, respectively. The acute and chronic AZ WQS for zinc are the same number. Therefore, acute exceedances of the zinc standards are also chronic exceedances. Exceedances of chronic AZ WQS occurred for cadmium, chromium, copper, lead, and zinc. Additionally, exceedances of chronic AZ WQS occurred in Lynx Creek below the Sheldon Mine and at Lynx Creek below Confluence. The two highest exceedances of chronic AZ WQS occurred at Lynx Creek above Confluence (by a factor of 63.9 the chronic zinc standard) and at Lynx Creek below Blue John (by a factor of 11.1 the chronic zinc standard). The two sites that were the most contaminated based on exceedances of AZ WQS were Lynx Creek below Blue John and Lynx Creek above Confluence. The same two locations, Lynx Creek below Blue John and Lynx Creek above Confluence, had the greatest number of exceedances, regardless of filtering protocol.

Most metal concentrations in unfiltered water samples were greater than the filtered water samples by only a few thousandths or hundredths. Few differences between metal concentrations in filtered and unfiltered water samples implied that metals were available in the water column and were not complexed with suspended sediments. Since only small amounts of metals were filtered out, most of the metals were dissolved in solution.

Water from Lynx Lake was not elevated with any metals, but Lynx Creek had elevated arsenic, cadmium, copper, manganese, and zinc. Unfiltered water samples had greater metals concentrations than filtered water samples. Some of the highest metal concentrations in water compared to background (Weston 2002) or AZ WQS (arsenic, cadmium, copper, lead, and zinc) were found below the Sheldon Mine and the Blue John Mine.

The lowest pHs in Lynx Creek in 2004 were 2.60 at Lynx Creek above Confluence and 5.51 at

Lynx Creek below Blue John. The locations with the lowest pHs also had the highest concentrations of cadmium, chromium, copper, lead, and zinc in 2004. The pHs were tested again in 2008 and ranged from lowest to highest 4.35 at the Lynx Creek above Confluence to 7.00 at the Lynx Creek Gabion.

Table 4. Surface Water from Lynx Creek, Granite Basin Lake, and Lynx Lake (ppm), Arizona in 2004.[1]

		pH			Hardness (ppm)	As	Cd	Cr[4]	Cu	Mn	Ni	Pb	Se	Zn
AZ WQS	Acute[2]					0.360	0.02	0.016	0.050	NNS	1.513	0.281	0.020	0.379
	Chronic	2004	2005[3]	2008		0.190	0.006	0.011	0.029	NNS	0.168	0.011	0.002	0.379
Filtered														
LC18	LC[5] below Sheldon Mine	7.64	6.7	5.76	500	0.001	0.009	ND	0.014	0.110	ND	ND	ND	0.72
LC19	LC below Blue John	5.51		4.40	500	0.001	0.061	ND	1.67	0.619	0.01	0.024	0.0002	4.22
LC11	LC above Confluence	2.60	6.4	4.35	>1,000	0.100	0.352	0.016	59.6	14.6	0.11	ND	ND	24.2
LC20	LC below Confluence	7.40	6.7	5.64	500	ND	0.011	ND	0.031	0.227	ND	ND	0.0002	0.72
LC17	LC Gabion	7.45	7.5	7.00	250	0.003	0.002	ND	0.009	0.405	ND	ND	ND	0.03
LC15	Below LL Dam	7.22			300	0.004	ND	ND	0.006	0.407	ND	ND	ND	0.03
LL4	Lynx Lake	Top=8.0 Bottom=7. 9			200	0.005	ND	ND	0.005	0.015	ND	ND	ND	0.02
LL5	Lynx Lake	Top=8.1 Bottom=8.0			200	0.005	ND	ND	0.005	0.013	ND	ND	ND	0.02
LL6	Lynx Lake	Top=8.1 Bottom=8.0			200-225	0.005	ND	ND	0.005	0.015	ND	ND	ND	ND
GB4	GB Lake	Top=9.1[6]			110	0.008	ND	ND	ND	0.773	ND	ND	0.000	ND
GB5	GB Lake	Top=8.3			110	0.008	ND	ND	ND	0.846	ND	ND	ND	ND
GB6	GB Lake	Top=8.9			120	0.009	ND	ND	ND	1.710	ND	ND	ND	ND
GB12F	Below GB Dam	7.2			800	0.014	ND	ND	ND	5.760	ND	ND	ND	ND

[1] Mercury and molybdenum were not detected in any samples. Al, B, Ba, Be, Fe, Mg, Sr, V were not included here. Data for these metals can be found in Appendix 2.

[2] Acute and chronic criteria are shown for Arizona's Aquatic &Wildlife- cold water designated use (ADEQ 2003); criteria for hardness dependent metals are shown using hardness >400 ppm. Hardness-dependent metals include cadmium, trivalent chromium, copper, nickel, lead, and zinc. For samples where hardness <400 ppm, no exceedances were found.

[3] pH was also collected at Lynx Creek Headwater (6.2), Sheldon Spring (7.2), Lynx INT (7.8, and Lynx INT2 (7.9) in 2005.

[4] The AZ WQS shown here are for hexavalent chromium. None of the samples exceeded the trivalent chromium hardness dependent criteria.

[5] LC = Lynx Creek; LL = Lynx Lake; GB = Granite Basin.

[6] Granite Basin Lake was too shallow to collect deep samples. GB4 water quality was collected at the surface, but GB5 and GB6 were collected ½ way down since the lake was so shallow.

▓ Denotes an exceedance of an acute AZ WQS or pH standard.

░ Denotes an exceedance of a chronic AZ WQS.

Sediment and water samples were collected in Lynx Creek in 2004 and 2005 prior to the remedial work conducted at the Blue John Mine. Until this time, continued erosion from the Blue John Mine added metals to Lynx Creek, decreasing stream water quality (Stephens 1990). The Forest Service completed its remedial work at the Blue John Mine in 2006. It stabilized the contaminated tailings from the Blue John Mine in an on-site repository. Elevated metals may still be present in Lynx Creek until scouring flows move sediments downstream.

The samples collected immediately downstream from the Blue John Mine (Lynx Creek below Blue John and Lynx Creek above Confluence) had the lowest pH and the highest concentrations of metals in solution. However, locations where sediments had more than one type of metal greater than TECs were further downstream (Table 2): Lynx Creek Gabion, Lynx Creek above Lynx Lake, and Lynx Creek below Lynx Lake Dam. Tetra Tech (2003) conducted paste pH and synthetic precipitation leaching procedure (SPLP) tests in Lynx Creek downstream of the Blue John Mine and concluded that although paste pHs were very acidic, SPLP extract concentrations were very low compared to the total concentration in soils/tailings and did not show a direct relationship with paste pH. Based on the relationship Tetra Tech found in the SPLP extracts and cessation of acidic mine drainage from the Blue John Mine, water quality in Lynx Creek is expected to improve.

Crayfish

Insects such as mayflies, stoneflies, and caddisflies that are typically associated with forest streams were not observed in Lynx Creek in 1990 (Weston 2002). No aquatic invertebrates were detected in Lynx Creek in a follow-up trip in 2005. All of the invertebrates collected were terrestrial invertebrates that had fallen into the creek (Rich Henry, FWS, pers. comm.). Laboratory sediment toxicity tests confirmed the lack of benthic invertebrate diversity in Lynx Creek was due to the toxicity of the sediments.

Metal concentrations were compared with potential toxic threshold concentrations from King et al. (2000) and effects residue concentrations (Army Corps of Engineers 2008) to see if any risk due to toxic body burden existed (Table 5). Two crayfish from Lynx Creek had aluminum concentrations greater than the potential toxic threshold concentration (931-1,150 ppm vs 800 ppm, respectively). All of the crayfish collected had barium concentrations greater than the potential toxic threshold. All of the crayfish from Lynx Creek and Lynx Lake had cadmium concentrations greater than the 0.4 ppm potential toxic threshold concentration, but none of them were greater than the effects residue concentration of 84.4 ppm. Crayfish from Lynx Creek below Dam had a greater mean concentration of copper (253 ppm) than an effects residue concentration (250 ppm) based on a no observed effect dose. Three crayfish collected from Lynx Lake had magnesium greater than the 3,000 ppm potential toxic threshold (3,050-3,460 ppm; Appendix 3). Although some metal concentrations in crayfish from the Lynx Creek watershed were greater than potential toxic threshold concentrations, these data are based on toxicology studies on other species, so the comparison to crayfish toxicity is assumed and may not be accurate. Crayfish effects data were available from the Army Corps of Engineers (2008), but it was limited to cadmium, copper, and zinc. None of the metal concentrations in crayfish from the Lynx Creek watershed were greater than lowest observed effects doses or lethal doses in toxicology studies. Therefore, toxicity is not likely to be occurring in crayfish in the Lynx Creek watershed.

Metal uptake patterns were not similar in crayfish from Lynx Creek, Lynx Lake, and Granite Basin Lake. Manganese concentrations were noticeably greater in two individuals from Lynx Creek (1,120 and 1,560 ppm) than the other crayfish from Lynx Creek (Appendix 3). Similarly, two individuals had much higher manganese concentrations in Lynx Lake (1,350 and 1,430 ppm) than the other crayfish from Lynx Lake. Crayfish from Lynx Creek and Lynx Lake had greater concentrations of cadmium, copper, and lead than Granite Basin Lake, but the opposite was noted for barium, mercury, and zinc. Higher aluminum, arsenic, and iron concentrations were found in Lynx Creek compared to other sites. Differences in metal concentrations between the Lynx Creek watershed and the Granite Basin watershed may be explained by different geological parent material, the presence (or absence) of historical mines in the area, and/or unassimilated metals present in sediments in crayfish gastrointestinal tracts.

Table 5. Metal concentrations (mean ± standard deviation) in crayfish from Lynx Creek above Lynx Lake, Lynx Lake, Lynx Creek below Lynx Lake, and Granite Basin Lake (ppm dry weight), Arizona in 2004.

	N[2]	Al[3]	As	Ba	Cd	Cr	Cu	Hg	Mn	Pb	Se	Zn
Potential Toxic Threshold[1]		800	30	80	0.4	10	300	0.33	2,000	400	3	178
Army Corps of Engineers (2008)[4]		--	--	--	84.4	--	250	--	--	--	--	237
Lynx Creek	6	788 ±216	5.78 ±1.21	101 ±19.7	3.45 ±1.68	2.57 ±1.81	240 ±63.2	0.15 ±0.05	800 ±460	13.3 ±7.69	0.66 ±0.11	109 ±14.7
Lynx Lake	12	225 ±83.0	1.41 ±0.49	196 ±31.9	2.93 ±1.04	0.98 ±0.69	195 ±50.5	0.08 ±0.06[5]	549 ±405	5.56 ±2.93	0.55 ±0.11	86.4 ±12.7
Lynx Creek below Dam	2	241 ±19.8	2.95 ±1.20	85.2 ±7.35	1.95 ±1.34	0.55 ±0.07	253 ±51.6	0.15 ±0.07	910 ±84.9	1.3 ±0.28	0.64 ±0.06	124 ±19.1
Granite Basin Lake[6]	1	305	4.5	303	<0.1	0.5	31.2	0.2	939	0.5	0.5	152

[1] Potential toxic threshold = concentration potentially toxic to upper trophic level feeders such as fish-eating birds including the bald eagle. Data from Eisler 1985, 1987, 1988, Gearhart and Waller 1994, Scheuhammer 1987, USDI 1998, and USGS 1998 (*in* King et al. 2000). [2] N = sample size; LC and LL samples consisted of individual crayfish. One composite sample from Below LL consisted of 4 crayfish and the other consisted of 10 crayfish. The GB composite samples consisted of 4 crayfish. [3] Beryllium and molybdenum were not detected in any crayfish samples. Nickel was detected in one sample from Granite Basin Lake at 0.8 ppm dry weight. Concentrations of boron, iron, manganese, strontium, vanadium are not shown. [4] Mean effect concentrations were calculated from lowest observed effect dose or lethal dose data for freshwater crayfish species. Only one data point, a no observed effect dose, was available for copper. Data were available as wet weight; they were converted to dry weight using a factor of 0.2 (Stephen et al. 1985). [5] ½ LOD was used if the sample was a non-detect. Nine out of the 12 mercury results were non-detect. [6] The composite sample from Granite Basin Lake included crayfish from the lake and from below the dam.

▓ Denotes an exceedance of a potential toxic threshold.

░ Denotes an exceedance of an effects residue concentration.

Fish

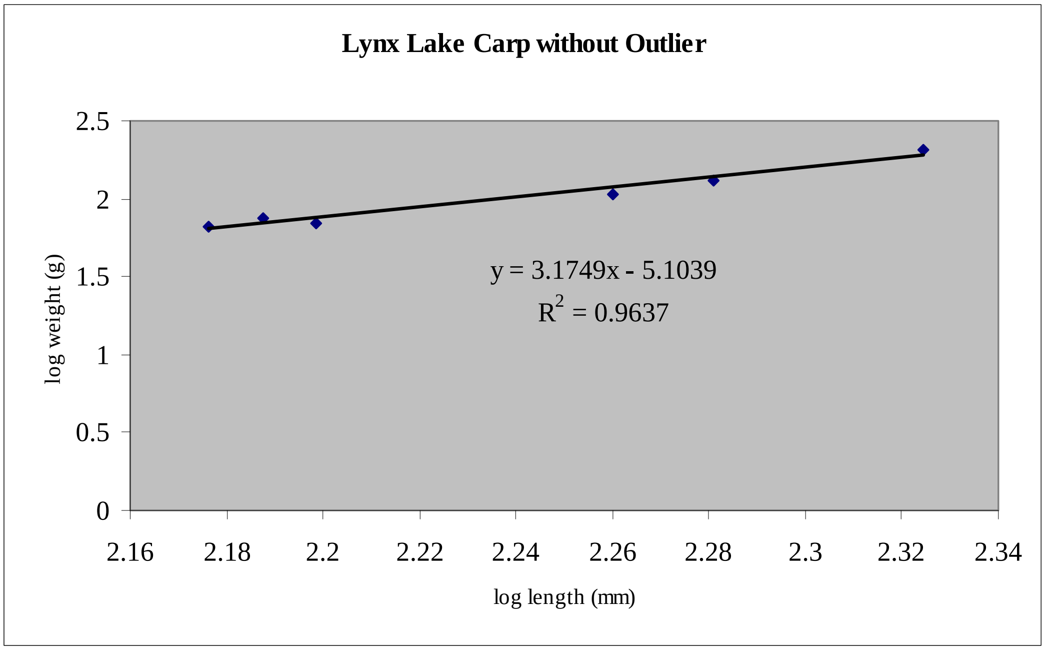
Although similar species occur at both lakes, mostly catfish and carp were collected at Lynx Lake and only largemouth bass and bluegill were collected at Granite Basin Lake. Despite efforts to collect even sex ratios, these results were also skewed. Therefore, no statistical comparisons were done.

Due to differences in collection techniques and sampling times, sex ratios, reproductive stages, and length/weight were not similar (Figures 4 and 5). Electrofishing selects for larger fish of a species (Reynolds 1996, Hinck 2006) and this was noticeable in bass at Granite Basin Lake and in one large carp from Lynx Lake.

Anderson and Neumann (1996) note that the relationship of $\log_{10}W = a + b * \log_{10}L$, where

W = Weight
L = Length
a and b are parameters,

that describes the body shape of individual fish. For most species, b is equal to 3.0. For all fish except bluegill at Granite Basin Lake, b was around 3.0. One carp and one catfish at Lynx Lake were determined to be outliers and were removed from the regression. Data are available for these fish in Appendices 4 and 5.



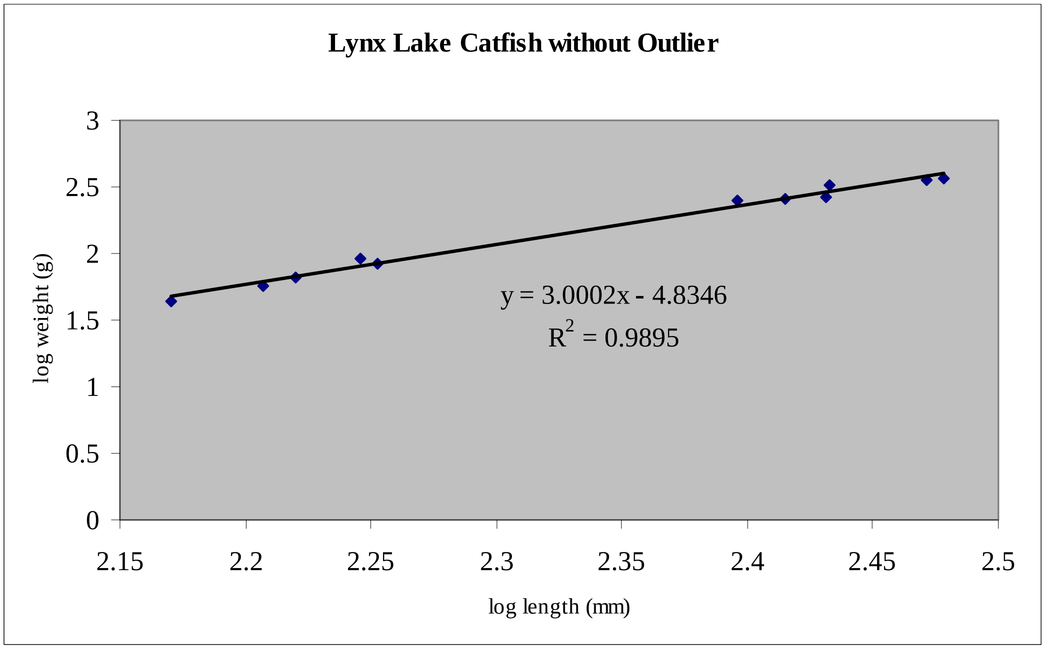


Figure 4. Regression analysis of logarithmic total length (mm) and logarithmic weight (g) of carp and catfish from Lynx Lake, Arizona in 2004. Outliers are identified in Appendix 4.

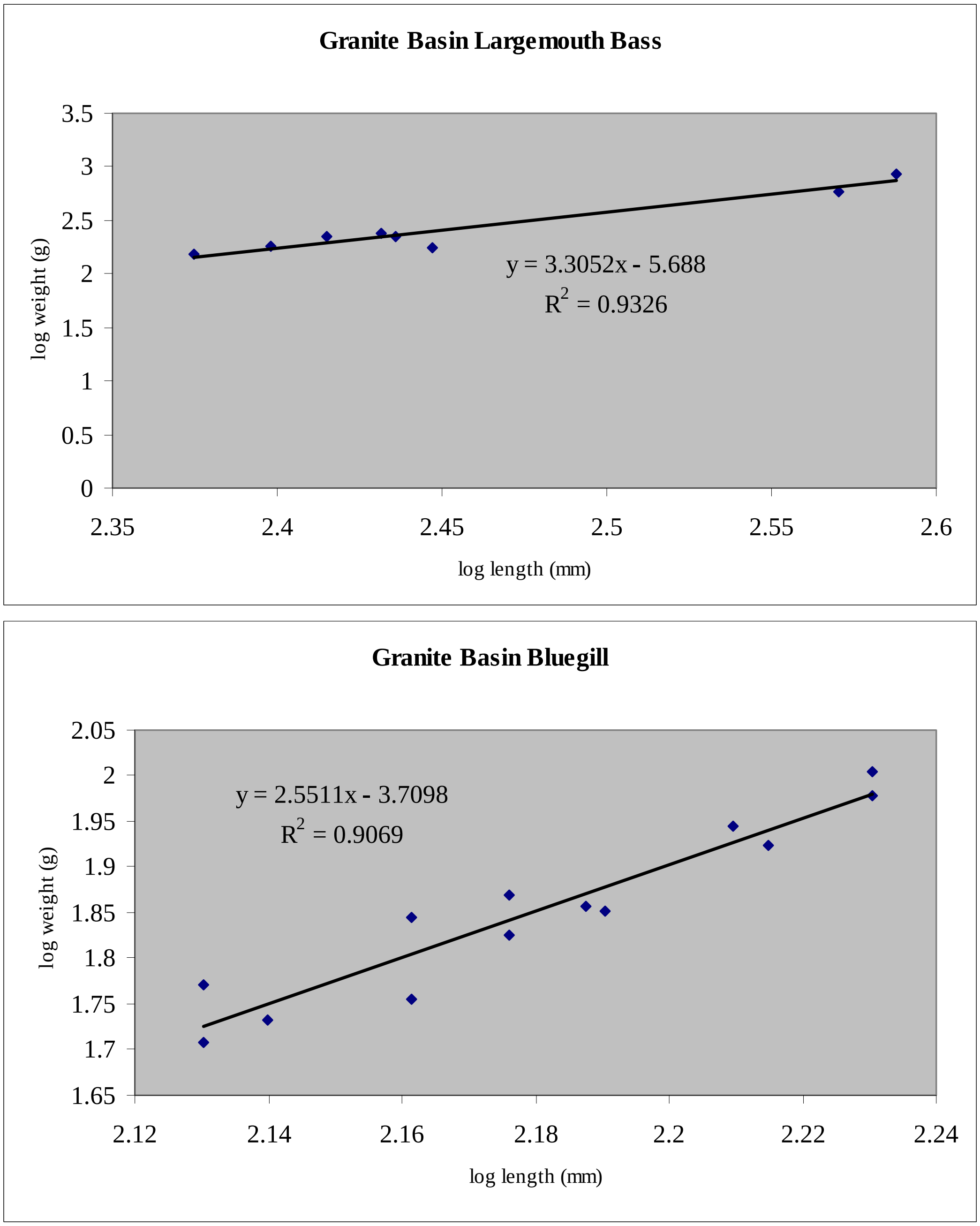


Figure 5. Regression analysis of logarithmic total length (mm) and logarithmic weight (g) of bluegill and bass from Granite Basin Lake, Arizona in 2004.

A general fish health assessment was conducted in the field. No extreme cases of infection or lesions were noted. Condition factors, hepato-somatic indices (HSIs) and gonado-somatic indices (GSIs) were calculated as follows:

CF = body weight (g)/ length (mm)^3* 100,000,
HSI= liver weight (g)/ body weight (g)*100, and
GSI = gonad weight (g)/ body weight (g)*100 and are shown in Figures 4, 5, and 6.

Although condition factors (CF) allow biologists to compare the overall health and nutritional status of individual fish, they do vary between taxa and between species at different locations (Schmitt and Dethloff 2000). Condition factors for fish collected at Lynx Lake and Granite Basin Lake were similar (Figure 6). Correlations between metals and condition factors for all fish at Lynx Lake were analyzed. No correlations were significant except for the positive relationships between at selenium (R^2=0.73, p=0.014) and zinc (R^2=0.72, p=0.016) in carp at Lynx Lake. Since these trace metals are also essential nutrients, they had a positive effect on the growth of carp in Lynx Lake.

Although age was not determined for fish, bluegills at Granite Basin Lake were most likely less than two years old and channel catfish were probably stocked into Lynx Lake less than one year before sampling occurred (Andy Clark, AGFD Region 3 Fisheries Program Manager, 2004, pers. comm.). Carp and yellow bullhead catfish spawn on their own at Lynx Lake (Andy Clark, AGFD Region 3 Fisheries Program Manager, 2004, pers. comm.). For comparison, average CFs in the Colorado River Basin were 1.17 for carp, 0.79 for channel catfish, and 1.34 for bass in 2003 (Hinck et al. 2006). Averages in this study were very similar to the Colorado River Basin.

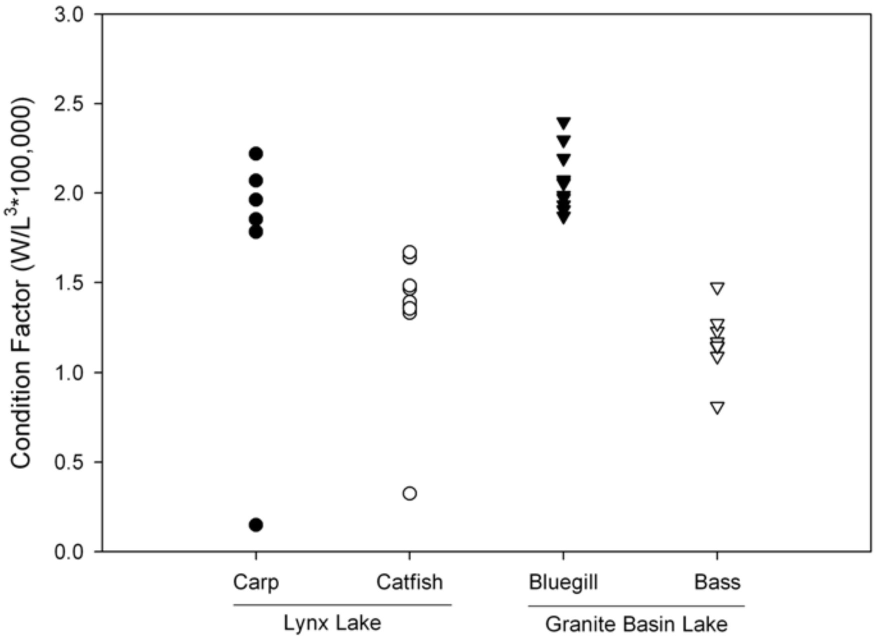


Figure 6. Condition factors for fish in Lynx Lake and Granite Basin Lake, Arizona in 2004.

Similarly, HSIs or GSIs can be used to determine organ health. An average HSI is 2% for teleost fishes (Gingerich 1982, Schmitt and Dethloff 2000) even though it does vary with seasonal fluctuations due to nutritional status, gonadal status, and differences between sexes. Almost all of the HSIs at Lynx Lake and Granite Basin Lake were below the 2% average (Figure 7). Results did not differ when the sexes were separated. Therefore, contaminant burden may play a role in the reduction of HSIs below the 2% average.

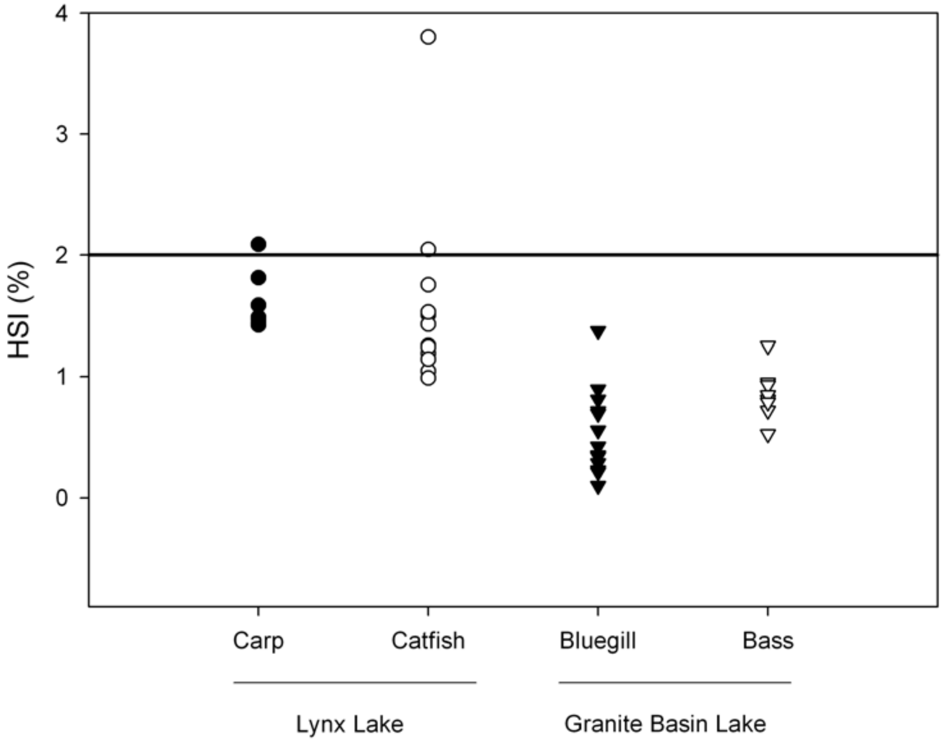


Figure 7. HSIs for fish in Lynx Lake and Granite Basin Lake, Arizona in 2004.

Gonado-somatic indices vary seasonally in response to reproductive stage, environmental dynamics, and/or contaminant exposure (Schmitt and Dethloff 2000). Gonado-somatic indices, along with other metrics, can determine reproductive maturity. Gonadal stage was approximated during the internal fish exam, but gonadal histology was not performed. Male GSIs were very similar at both sampling locations although only 2 males were collected at Granite Basin Lake (Figure 8; Appendix 4). Seventy-seven percent of the testes were not enlarged; one of the largest male carp collected at Lynx Lake was reproductively mature. Female GSIs were more variable because they were ripe. Results were similar for female catfish, bluegill, and bass despite the location or species. Too few female carp were collected for comparison. For contrast, average GSIs in the Colorado River Basin were 5.6% for male carp and 10.7% for female carp, 0.2% for male channel catfish and 0.7% for female channel catfish, and 0.3% for male bass and 0.9% for female bass in 2003 (Hinck et al. 2006). Averages from Lynx Lake and Granite Basin Lake were all similar to these except for male carp (12%). However, the Colorado River fish were all collected post-spawn whereas fish from this study were collected mid-spawn. Also, fish from the Colorado River were from lotic systems whereas fish from this study were from lentic systems.

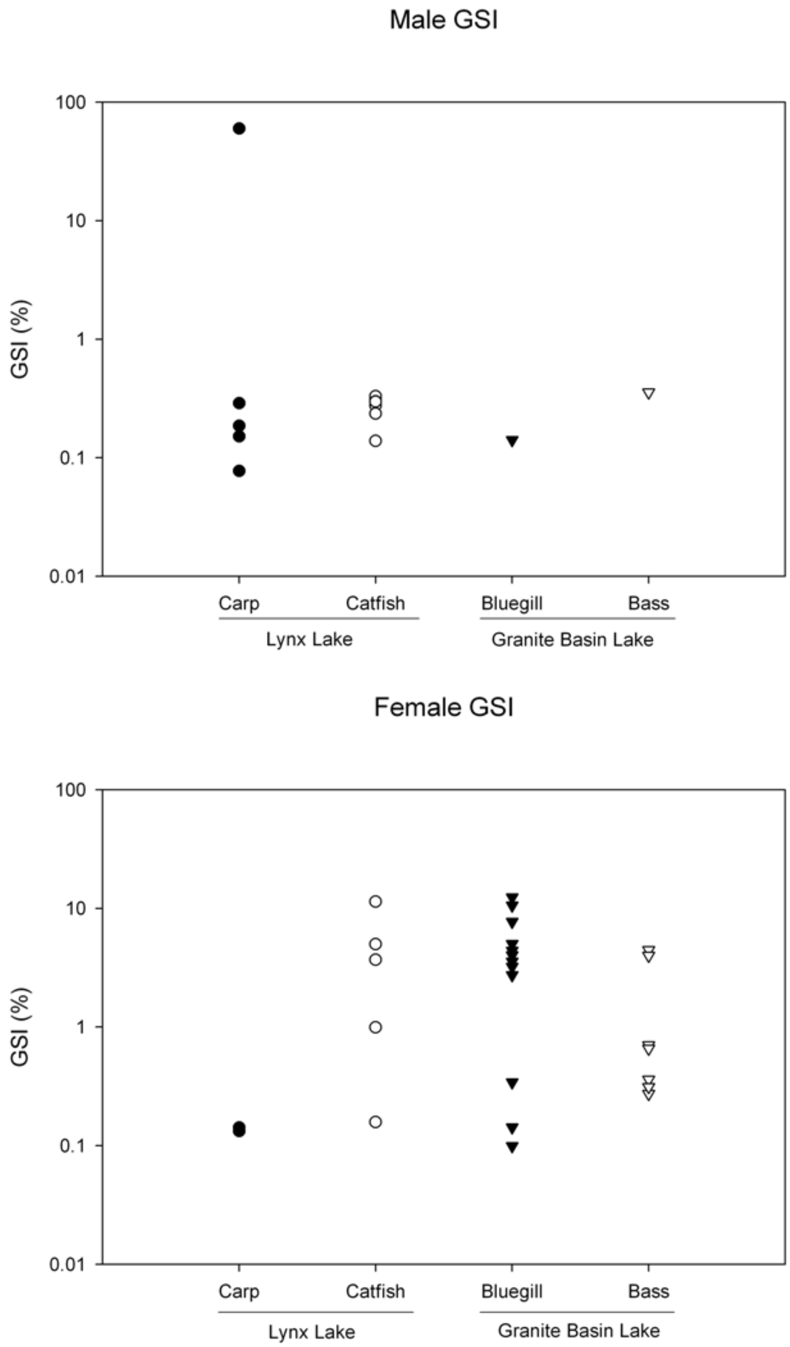


Figure 8. GSIs for fish at Lynx Lake and Granite Basin Lake, Arizona in 2004.

Lynx Lake

All concentrations are presented as dry weight. Beryllium, molybdenum, nickel were not detected in any Lynx Lake fish.

The National Contaminant Biomonitoring Program (NCBP) 85% (Schmitt and Brumbaugh 1990) data and the Colorado River Basin Biomonitoring of Environmental Status and Trends (BEST) data (Hinck et al. 2006) were used as a comparison for metal concentrations at Lynx Lake and Granite Basin Lake. The NCBP 85% was derived from the geometric mean of metal concentrations from a nationwide sampling effort. Concentrations from the BEST report were geometric mean of metal concentrations from the Colorado River Basin. Exceedance of the NCBP 85% or the BEST concentration is an indicator that Lynx Lake and Granite Basin Lake is contaminated with metals. Limited data are available in the toxicology literature linking exposure to tissue concentrations. When available, this data is presented.

Lynx Lake fish had greater concentrations of cadmium, copper, lead and zinc compared to the NCBP 85% concentrations (Table 6; Appendix 4). All trace metal concentrations in Table 6 exceeded BEST geometric means from the Colorado River Basin. Copper concentrations in early life stages of carp with reduced survival ranged from 55.5 – 210 ug/g dry weight (converted to dry weight assuming 20% moisure (Stephen et al. 1985)) (Stouthart et al. 1996). Copper concentrations in carp from Lynx Lake were lower than these concentrations.

The dietary threshold for reproductive impairment due to selenium in nesting aquatic birds is 3 to 8 ppm dry weight (USDI 1998). None of the selenium in fish from Lynx Lake exceeded this threshold. Using the mean percent moisture content for carp and catfish, none of the fish from Lynx Lake exceeded the EPA’s water quality criterion for methylmercury for human health (0.3 mg/kg wet weight or 1.41-1.48 mg/kg dry weight; EPA 2001). Methylmercury concentrations from 0.2-0.3 ug/g wet weight in fish appear to be protective of bald eagles in most cases (Lusk et al. 2005, USFWS 2003). To make this comparison with data from the Lynx watershed, it was assumed that methylmercury comprises greater than 90 percent of the total mercury in a fish (EPA 2001). Comparing Lynx Lake data to the mercury burden in catfish from the literature showed that the mean mercury concentration in catfish from Lynx Lake was seven-times less. A mercury concentration of 1.7 ug/g dry weight (converted to dry weight assuming 20% moisure (Stephen et al. 1985)) caused a 49% reduction in survival in larval channel catfish (Birge et al. 1979).

Table 6. Metal concentrations (mean ± standard deviation) in fish collected from Lynx Lake (ppm dry weight), Arizona in 2004.

	N[2]	% Moisture	As	Cd	Cr	Cu	Hg	Pb	Se	Zn
NCBP 85%[1]			1.08	0.2	--[3]	4	0.68	0.88	2.92	137
BEST	Piscivore		0.05	0.02	0.36	0.56	0.11	0.16	1.11	18.1
CDRB	Benthivore		0.08	0.05	0.41	1.00	0.06	0.14	1.75	67.1
Carp	7	78.8 ±4.76	1.06 ±0.67	0.42 ±0.19	1.09 ±0.85	7.29 ±4.40	0.16 ±0.05	1.46 ±2.05	2.00 ±0.46	232 ±54.6
Catfish	12	79.7 ±2.62	0.23 ±0.12	0.81 ±0.50	1.40 ±1.27	14.3 ±28.16	0.24 ±0.14	1.59 ±1.46	1.36 ±0.23	61.5 ±6.02
Bass	1	78.8	0.30	0.20	0.90	2.50	0.20	0.64	1.90	84.8
Bluegill	1	74.7	0.20	0.20	1.80	1.90	0.20	6.40	1.20	86.1

[1] NCBP 85% - geometric mean wet weight values from this study were converted to dry weight using 75% moisture content; data from 1984 were used (Schmitt and Brumbaugh 1990).

[2] N = sample size.

[3] -- Data not available in Schmitt and Brumbaugh 1990 for these metals.

■ Denotes an exceedance of the NCBP 85th percentile.

▒ Denotes an exceedance of the BEST geometric mean from CDRB.

Granite Basin Lake

Beryllium, boron, cadmium, molybdenum, nickel were not detected in any Granite Basin Lake fish (Table 7; Appendix 5). Lead was only detected in two bluegill samples at 0.2 ppm dry weight and 0.6 ppm. The lead detection limit in fish tissue was 0.2 ppm.

Metal concentrations in bass and bluegill from Granite Basin Lake exceeded the NCBP 85% for mercury (Table 7, Appendix 5). Mercury was the only metal from Granite Basin Lake where an exceedance of the NCBP 85% occurred. Also, mercury concentrations in fish from Granite Basin Lake exceeded the EPA water quality criterion for methylmercury of 1.04-1.23 mg/kg dry weight (converted from EPA criterion of 0.3 mg/kg wet weight using the mean percent moisture from bass and bluegill at Granite Basin Lake; EPA 2001). Despite its derivation as a human health criterion, 0.3 ppm methylmercury in fish and shellfish is protective of bald eagles in most cases (Lusk et al. 2005, USFWS 2003). Concentrations of arsenic, chromium, copper, mercury, and zinc exceeded BEST geometric means from the Colorado River.

Arsenic concentrations from 11.2 - 58 ug/g dry weight (converted to dry weight assuming 20% moisure (Stephen et al. 1985)) were found in juvenile bluegills with reduced growth and survival (Gilderhaus 1966). Mercury concentrations from 32.5-185 ug/g dry weight (converted to dry weight assuming 20% moisure (Stephen et al. 1985)) were found in juvenile bluegills with reduced survival (Cember et al. 1978). Selenium concentrations from 5.4 – 7.7 ug/g dry weight (converted to dry weight assuming 20% moisure (Stephen et al. 1985)) were found in juvenile bluegills with reduced survival (Cleveland et al. 1993, Lemly 1993). None of the bluegills from

Granite Basin Lake had arsenic, mercury, or selenium concentrations approaching the concentrations in these studies.

Table 7. Metal concentrations (mean ± standard deviation) in fish collected from Granite Basin Lake (ppm dry weight), Arizona in 2004.

	N[2]	% Moisture	As	Cr	Cu	Hg	Se	Zn
NCBP 85%[1]			1.08	--[3]	4	0.68	2.92	137
BEST CDRB	Piscivore		0.05	0.36	0.56	0.11	1.11	18.1
Bass	8	75.6 ±0.88	0.66 ±0.21	2.08 ±2.50	1.40 ±0.27	2.81 ±0.65	0.74 ±0.07	73.0 ±6.33
Bluegill	13	71.2 ±1.73	0.35 ±0.11	0.77 ±0.67	1.19 ±0.27	1.35 ±0.32	0.81 ±0.14	77.7 ±5.13

[1] NCBP 85% - geometric mean wet weight values from this study were converted to dry weight using 75% moisture content; data from 1984 were used (Schmitt and Brumbaugh 1990).
[2] N = sample size.
[3] -- Data not available in Schmitt and Brumbaugh 1990 for these metals.

▓ Denotes an exceedance of the NCBP 85th percentile.

░ Denotes an exceedance of the BEST geometric mean from Colorado River Basin.

Different metal concentrations in fishes from Lynx Lake exceeded the NCBP 85% (cadmium, copper, lead, and zinc) compared to Granite Basin Lake (mercury). Also, none of the selenium in fish from Granite Basin Lake exceeded dietary threshold for reproductive effects to aquatic birds. Differences in metal species composition could definitely play a role in the accumulation patterns at both lakes, although geology and mining history also likely played a role.

Granite Basin Lake was the best reference site for this study because no active mining occurred there, and AGFD monitors the fish population at both lakes yearly. Although AGFD manages each lake differently, similar fish species occupy both lakes. Collection timing and methods probably skewed the species and sex of fishes that were collected. AGFD stocks Lynx Lake with trout and channel catfish, occasionally largemouth bass, and historically bluegill. AGFD stocks only bluegill in Granite Basin Lake. Although no active mining occurred near Granite Basin Lake, elevated concentrations of chromium and mercury in fish were found. These elements are probably elevated in the parent material surrounding the area. The geological parent material around Lynx Lake is made of Precambrian granodiorite (Langenheim et al. 2002, Weston 2002) and the parent material around Granite Basin Lake is Granite Dells granite (Langenheim et al. 2002).

Cadmium, lead, and mercury concentrations in fish appear to be stable over time. Previous studies of bluegill from Lynx Lake (Rector 1993) (Table 8) reported cadmium concentrations exceeding the NCBP 85th percentile. Concentrations in carp and catfish in 2004 continued to exceed the NCBP 85th percentile. Lead concentrations exceeded the NCBP in bluegill in 1993 and in carp and catfish in 2004. Mercury concentrations, either past or present, have never exceeded the NCBP 85th percentile. Selenium concentrations declined in fish over the past 10 years. Selenium in bluegill exceeded the NCBP 85th percentile in 1993, but not in largemouth bass in 2001 or carp or catfish in 2004.

Table 8. Comparison of metals in fish tissues (ppm dry weight) from Lynx Lake to NCBP 85th percentiles over time.

Element Concentration	Lynx Lake 1993	Lynx Lake 2001	Lynx Lake 2004		NCBP 85th Percentile[4]
	Bluegill[1]	Bass [2]	Carp[3]	Catfish[3]	
Cadmium	1	0.21	0.42	0.81	0.2
Lead	2.4	ND[5]	1.46	1.59	0.88
Mercury	0.24	0.20	0.16	0.24	0.68
Selenium	84	1.14	2.0	1.36	2.92

[1] *Lepomis macrochirus* fillets (Rector 1993).
[2] Mean concentrations in whole body *Micropterus salmoides* (FWS/AGFD, unpublished data).
[3] Whole body bluegill, this study.
[4] NCBP (Schmitt and Brumbaugh 1990). Numbers are 85th percentile concentrations from the 1984 sampling effort. NCBP data were presented as wet weight. Dry weight values were calculated assuming 75% moisture content.
[5] ND = Not detected.

▨ Denotes an exceedance of the NCBP 85th percentile.

Although elevated concentrations of arsenic, cadmium, chromium, mercury, lead, selenium, and zinc were found in fish at Lynx Lake, it is unknown how fish have responded to exposure to metals in sediment and water. The fishery in Lynx Lake was poor in the 1970s (Crane and Sommerfeld 1977) but recently carp and yellow bullhead catfish have been reproducing (Andy Clark, AGFD Region 3 Fisheries Program Manager, 2004, pers. comm). Given the uncertainty associated with fish response to metal exposure and fish reproductive dynamics in the lake, a risk assessment for bald eagles was designed.

Hazard Quotients (Risk Screening)

An ecological risk screening was completed using some of the data in Tables 2, 4, and 6 to determine the potential risk to a bald eagle. Toxicity reference doses (TRVs) for birds from the EPA Region 9 Biological Technical Assistance Group (BTAG) (EPA 1998a) were used to perform the screening.

The BTAG TRVs were developed using toxicity tests from the literature. The low TRV approximates a No Adverse Effect Level (NOAEL) for such endpoints as growth and reproduction.

The TRVs were used during the ecological risk screening to determine the potential risk to birds and mammals from contaminants at the Lynx Creek watershed. The screening was designed to be conservative to ensure that contaminants with estimated exposures below the low TRV could confidently be removed from further investigation. Contaminants with exposures above the low TRV will be recommended for further evaluation.

The receptor used for this ecological risk screening was the bald eagle. The contaminants considered included arsenic, cadmium, copper, lead, mercury, manganese, and zinc. Transport pathways were water, sediment, and fish consumption. Bald eagles are exposed to water when they catch fish and may occasionally drink water from the lake. They are exposed to sediments when they consume fish along the banks of the lake. Bald eagles are primarily piscivorous, so the fish are one main transport pathway for metal exposure.

A conservative screening was performed using data for water, sediment, and fish (Table 9). The ecological risk was calculated by taking the maximum concentration of water, sediment, or fish divided by the back-calculated TRV (from mg/kg-day to mg/kg; Appendix 6). The result was a hazard quotient (Appendix 7). Any hazard quotient (HQ) over one indicates that the contaminant poses a threat to fish and wildlife resources at Lynx Lake (EPA 1997).

Table 9. The potential risk[1] to bald eagles in the Lynx Creek watershed using low toxicity reference doses[2] (TRVs).

	Water [3]	Sediment-Lynx Creek[4]	Sediment-Lynx Lake[5]	Fish
Arsenic	0.0002	0.71	0.54	0.01
Cadmium	0.0013	7.13	4.57	1.01
Copper	0.0006	20.1	14.4	0.61
Lead	--	1,318	1,497	16.0
Mercury	--	0.39	0.24	0.69
Manganese	0.0001	1.05	0.94	0.05
Selenium	0.0002	0.57	0.33	0.89
Zinc	0.0002	3.39	2.95	0.91

[1] Risk is determined by [media]/backcalculated low TRV.

[2] EPA Region 9 BTAG Recommended TRVs for Birds (EPA 1998a). Risk is present if the hazard quotient is > 1.

[3] See Appendix 7 for calculation of potential risk.

[4] Lynx Creek data from this study.

[5] Lynx Lake data from Rector 1993, EPA 1994, and Weston 2002. Mean concentrations were calculated from all three studies and used here.

▨ Values in bold indicate HQ>1.

Mean concentrations of metals in water from Lynx Lake (Table 4) were used to calculate a HQ. For water, there was no potential risk from any contaminant of concern (Appendix 7). Mean sediment concentrations of metals in sediment from Tables 1 and 2 were used to calculated hazard quotients. Potential risks from cadmium, copper, lead, manganese, and zinc were found in sediment from Lynx Creek and Lynx Lake. Mean concentrations for each metal for all fishes collected in Lynx Lake from Table 6 were used in calculating hazard quotients. Bald eagles consuming fish from Lynx Lake could potentially be at risk due to lead exposure. Overall, the ecological risk screening identified cadmium, copper, lead, manganese, and zinc as contaminants of concern to bald eagles at Lynx Lake.

MANAGEMENT ACTIONS

The Forest Service completed a removal action at the Blue John Mine in September 2005. There were two portions to this action: 1) closing the mine shaft and adit and 2) spreading a cover of native topsoil on top of tailings and waste rock to decrease erosion and stop the release of metals from the tailings and waste rock piles. Also, in October 2005, the Forest Service completed the excavation of two tailings piles and as much of the waste rock as possible and placed into an on-site repository. The repository was created in an old pond that had been used to store water for mining operations at the upper end of the site. Lime and biosolids were mixed into the tailings as they were placed into the repository. The final repository was capped with biosolids, seeded with native plants, and then fenced. A road above the repository was graded to divert run-on. The areas where tailings and waste rock were excavated were filled in and graded to allow for drainage. The Forest Service will continue to monitor this site until 2009. This includes monitoring the condition of the repository and collecting water samples upstream and downstream of the site for arsenic and lead (Fischer 2007). Although the source of contamination at the Blue John Mine has been remediated, elevated concentrations of metals in the Lynx Creek and Lynx Lake sediments persist. Continued monitoring for adverse effects in the creek and lake is recommended.

The Forest Service will be able to use information obtained from this study to determine whether more remedial work is necessary for other abandoned mines in the Lynx Creek watershed. Information in this report can also be used to determine whether dredging the Gabion on Lynx Creek, Lynx Lake and/or Granite Basin Lake is necessary.

Direct management has been implemented by the Forest Service and will begin soon by the EPA. The results of this study will continue to aid decision-making in the future. There is a high probability of complete site remediation. A follow-up study should be conducted in this watershed after one or two storms have scoured Lynx Creek to see if any risk from exposure to metals remains.

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APPENDICES

Appendix 1. Metal concentrations in sediment (ppm dry weight) from Lynx Creek, Granite Basin Creeks, and below Granite Basin Lake and Lynx Lake dams.

	% Moist.	Al	As	Ba	Be	Cd	Cr	Cu	Fe	Hg	Mg	Mn	Mo	Ni	Pb	Se	Sr	V	Zn
SED1	21.2	11,100	71	50	0.3	<0.2	13	140	24,200	0.1	3,380	288	<5	7	41	<0.5	56	35	90
SED2	73.4	12,400	320	1,260	1.3	<0.2	14	12	162,000	0.1	3,300	5940	<5	8	25	0.7	149	26	65
SED3	0.4	12,800	11	209	0.94	<0.2	27	7.4	19,900	<0.1	3,330	800	<5	23	10	<0.5	121	39	32
SED4	0.2	4,660	1	55.8	0.4	<0.2	8	3	13,900	<0.1	1,600	207	<5	<5	10	<0.5	14	20	21
SED5	74.3	15,900	160	1,090	0.5	6.7	19	182	40,200	0.2	6,540		5	10	73	0.8	143	58	620
SED6	1	16,700	29	116	0.72	6.2	23	460	26,800	0.2	6,140	633	<5	10	220	<0.5	38	52	523
SED7	19.5	17,400	35	136	0.77	5.9	23	461	26,200	0.2	6,300	783	<5	17	250	1	34	43	620
SED8	2.3	9,460	8.8	54.2	0.5	3.6	10	194	16,200	<0.1	3,400	600	<5	9	70	<0.5	45	35	507
SED9	0.4	11,000	17	55.4	0.5	1.1	9.9	548	14,000	0.1	3,130	246	<5	8	71	<0.5	46	26	243
SED10	0.5	8,660	21	56.5	0.5	4	11	601	16,000	0.1	3,340	482	<5	10	110	<0.5	32	30	596
Lynx Creek Head Water	22	7,200	6.2	43	0.32	0.99	2.6	280	20,000	<0.03	3,000	240	7.7	<13	17	NA	NA	40	96
Sheldon Spring	43	16,000	25	100	0.83	5.5	11	390	39,000	0.07	5,200	780	<17	12	29	NA	NA	93	500
Lynx INT	23	15,000	32	110	0.43	5.9	120	180	30,000	0.09	6,800	1,000	<13	29	150	NA	NA	69	550
Lynx INT 2	22	5,400	25	50	0.30	3.9	11	250	31,000	0.03	2,400	950	<13	8.7	220	NA	NA	66	450

% Moist. = Percent moisture content in the sediment; NA = not analyzed.
Sed1 was taken directly below the tailings pile.
Sed2-4 were taken from Granite Basin Lake, the reference site.
Sed5 was below the Lynx Lake dam.
Sed6 was at the mouth of Lynx Lake.
Sed7 was above the sediment dam on Lynx Creek.
Sed8 was about 2000' below the tailings pile.
Sed9 was on a tributary to Lynx Creek below another mine site.
Sed10 was below the confluence of the tributary and Lynx Creek.

Appendix 2. Metal concentrations in water (mg/L).

	F or U		Al	As	B	Ba	Be	Cd	Cr	Cu	Fe	Mg	Mn	Ni	Pb	Se	Sr	V	Zn
LC above Confluence	U	LC1	104	0.12	0.04	0.0042	0.013	0.364	0.016	60.8	128	76.2	14.3	0.11	0.007	<0.0002	0.523	0.003	24.1
LC below Confluence	U	LC10	0.34	0.001	0.04	0.07	<0.0005	0.011	<0.002	0.039	0.27	31.2	0.243	<0.005	<0.005	<0.0002	1.01	<0.001	0.7
LC above Confluence	F	LC11	102	0.1	0.04	0.002	0.013	0.352	0.016	59.6	120	77.1	14.6	0.11	<0.005	<0.0002	0.545	0.002	24.2
Below LL Dam	F	LC15	0.06	0.0038	0.04	0.039	<0.0005	<0.0005	<0.002	0.0062	<0.05	21	0.407	<0.005	<0.005	<0.0002	0.317	0.001	0.03
LC Gabion	F	LC17	<0.05	0.0032	0.04	0.069	<0.0005	0.0016	<0.002	0.0092	<0.05	15.4	0.405	<0.005	<0.005	<0.0002	0.334	0.002	0.03
LC below Sheldon Mine	F	LC18	<0.05	0.001	0.04	0.045	<0.0005	0.0092	<0.002	0.014	<0.05	32.1	0.11	<0.005	<0.005	<0.0002	1.08	0.002	0.72
LC below Blue John	F	LC19	0.8	0.0009	0.04	0.037	<0.0005	0.061	<0.002	1.67	<0.05	31.3	0.619	0.01	0.024	0.0002	0.758	<0.001	4.22
LC below Confluence	F	LC20	<0.05	<0.0008	0.04	0.066	<0.0005	0.011	<0.002	0.031	<0.05	31.2	0.227	<0.005	<0.005	0.0002	0.995	<0.001	0.72
Below LL Dam	U	LC5	0.08	0.0043	0.04	0.042	<0.0005	<0.0005	<0.002	0.0073	0.1	20.7	0.615	<0.005	<0.005	<0.0002	0.315	0.001	0.02
LC Gabion	U	LC7	0.53	0.0042	0.04	0.071	<0.0005	0.0017	<0.002	0.017	0.47	15.1	0.425	<0.005	<0.005	0.0003	0.33	0.003	0.035
LC below Sheldon Mine	U	LC8	0.23	0.001	0.04	0.045	<0.0005	0.0095	<0.002	0.02	0.23	31.8	0.13	<0.005	<0.005	<0.0002	1.09	0.002	0.74
LC below Blue John	U	LC9	2.4	0.0032	0.04	0.045	<0.0005	0.0615	0.003	1.6	1.6	31.9	0.547	0.01	0.035	0.0003	0.768	0.0033	4.41
Lynx Lake	U	LL1	0.09	0.0052	0.04	0.046	<0.0005	0.0006	<0.002	0.0079	0.08	14.2	0.039	<0.005	<0.005	<0.0002	0.284	0.0035	0.02
Lynx Lake	U	LL2	0.1	0.0051	0.04	0.045	<0.0005	<0.0005	<0.002	0.0089	0.1	14.1	0.037	<0.005	<0.005	<0.0002	0.283	0.003	0.02
Lynx Lake	U	LL3	0.1	0.0051	0.04	0.045	<0.0005	<0.0005	<0.002	0.007	0.1	14.2	0.04	<0.005	<0.005	0.0003	0.289	0.002	<0.01
Lynx Lake	F	LL4	<0.05	0.005	0.04	0.044	<0.0005	<0.0005	<0.002	0.005	<0.05	14	0.015	<0.005	<0.005	<0.0002	0.283	0.002	0.02
Lynx Lake	F	LL5	<0.05	0.0053	0.04	0.044	<0.0005	<0.0005	<0.002	0.005	<0.05	13.8	0.013	<0.005	<0.005	<0.0002	0.285	0.0036	0.02
Lynx Lake	F	LL6	0.08	0.005	0.04	0.044	<0.0005	<0.0005	<0.002	0.005	<0.05	13.9	0.015	<0.005	<0.005	<0.0002	0.287	0.0031	<0.01
GB Lake	U	GB1	0.2	0.011	0.05	0.099	<0.0005	<0.0005	<0.002	0.003	1.1	11	1.16	<0.005	<0.005	0.0002	0.234	0.001	<0.01
GB below Dam	F	GB12F	<0.05	0.014	0.05	0.238	<0.0005	<0.0005	<0.002	<0.002	7.27	13.8	5.76	<0.005	<0.005	<0.0002	0.395	0.001	<0.01
GB below Dam	U	GB12U	0.1	0.033	0.05	0.353	<0.0005	<0.0005	<0.002	0.01	22.4	14	5.98	<0.005	<0.005	<0.0002	0.412	<0.001	0.02
GB Lake	U	GB2	0.42	0.01	0.05	0.104	<0.0005	<0.0005	<0.002	<0.002	1.3	11.4	1.32	<0.005	<0.005	0.0003	0.245	0.003	<0.01
GB Lake	U	GB3	0.61	0.011	0.06	0.124	<0.0005	<0.0005	<0.002	<0.002	1.8	11.4	2.15	<0.005	<0.005	<0.0002	0.253	0.002	<0.01
GB Lake	F	GB4	<0.05	0.0078	0.05	0.085	<0.0005	<0.0005	<0.002	<0.002	0.21	11	0.773	<0.005	<0.005	0.0003	0.237	<0.001	<0.01
GB Lake	F	GB5	<0.05	0.008	0.07	0.089	<0.0005	<0.0005	<0.002	<0.002	0.22	11.1	0.846	<0.005	<0.005	<0.0002	0.239	<0.001	<0.01
GB Lake	F	GB6	<0.05	0.0086	0.06	0.105	<0.0005	<0.0005	<0.002	<0.002	0.23	11.2	1.71	<0.005	<0.005	<0.0002	0.25	<0.001	<0.01
		DUP1	0.09	0.0049	<0.04	0.046	<0.0005	0.0009	<0.002	0.0063	0.07	14.1	0.038	<0.005	<0.005	<0.0002	0.289	0.0036	0.02
		DUP2	0.27	0.01	0.05	0.098	<0.0005	0.0005	<0.002	<0.002	0.95	11	1.22	<0.005	<0.005	<0.0002	0.237	0.001	<0.01
		EB1	<0.05	<0.0008	<0.04	0.002	<0.0005	<0.0005	<0.002	0.015	<0.05	0.04	0.004	<0.005	0.01	<0.0002	0.001	<0.001	0.079

F or U		Al	As	B	Ba	Be	Cd	Cr	Cu	Fe	Mg	Mn	Ni	Pb	Se	Sr	V	Zn
	EQ2	<0.05	<0.0008	<0.04	<0.001	<0.0005	<0.0005	<0.002	0.019	<0.05	0.02	0.006	<0.005	0.009	0.0003	0.0007	<0.001	0.086
	FB1	<0.05	<0.0008	<0.04	<0.001	<0.0005	<0.0005	<0.002	0.0079	<0.05	0.03	<0.002	<0.005	0.007	<0.0002	0.0006	<0.001	0.043
	FB2	<0.05	<0.0008	<0.04	<0.001	<0.0005	<0.0005	<0.002	0.012	<0.05	<0.02	<0.002	<0.005	0.01	0.0003	<0.0005	<0.001	0.048

Mercury and molybdenum were not detected in any samples.

The water sample locations for Lynx Creek (1-10) correspond to sediment sampling locations. n_i corresponds to water taken from the same sampling site as sediment, where n_i ($_i$=1=10), n=unfiltered water, and n+10=filtered water.

The water sample locations for Lynx Lake and Granite Basin Lake (1-3) were collected as follows: n_i for unfiltered samples and n_i+3 for filtered samples where i= 1-3.

GB = Granite Basin

U = Unfiltered; F = Filtered.

Appendix 3. Metal concentrations in crayfish from the Lynx Creek Gabion, Lynx Lake, Lynx Creek below Dam, and Granite Basin Lake (ppm dry weight), Arizona in 2004.

	% Moist.	Al	As	B	Ba	Cd	Cr	Cu	Fe	Hg	Mg	Mn	Ni	Pb	Se	Sr	V	Zn
CRAYBLL1*	73.0	227	2.1	<2	90.4	1	0.6	216	359	0.2	1,960	970	<0.5	1.1	0.6	323	1	110
CRAYBLL2*	72.1	255	3.8	<2	80	2.9	0.5	289	667	0.1	1,860	850	<0.5	1.5	0.68	231	1	137
CRAYGB1*	75.1	305	4.5	<2	303	<0.1	0.5	31.2	582	0.2	2,270	939	0.8	0.5	0.5	544	1	152
CRAYLC01	75.9	614	4.4	<2	88.2	3.7	6.1	255	2030	0.1	1,640	737	<0.5	28	0.77	314	1.9	115
CRAYLC02	74.5	578	5.4	<2	82.8	2.9	1	155	1,710	0.2	1,390	401	<0.5	7.8	0.74	240	1.7	80.5
CRAYLC03	74.6	742	4.8	<2	93.7	1.7	1.5	294	2,340	0.1	1,620	385	<0.5	7.2	0.6	271	2.2	113
CRAYLC04	72.1	931	7.3	<2	136	6.3	2.4	165	3,220	0.1	1,820	1,560	<0.5	14	0.73	297	2.3	113
CRAYLC05	73.2	711	5.6	<2	112	4.1	2.4	286	2,620	0.2	1,980	1,120	<0.5	13	0.5	296	2.2	108
CRAYLC06	73.7	1,150	7.2	<2	94.3	2	2	283	3,150	0.2	1,910	595	<0.5	9.9	0.6	253	2.8	123
CRAYLL01	74.9	180	0.87	<2	186	3.7	0.7	204	256	<0.1	2,610	256	<0.5	3.2	0.4	479	1	83.8
CRAYLL02	76.5	340	2	<2	168	3.7	1	212	632	0.2	2,370	432	<0.5	6	0.5	459	2.1	101
CRAYLL03	75.8	170	0.93	<2	198	2.5	1.9	156	230	<0.1	2,900	383	<0.5	8.7	0.4	476	0.5	99.1
CRAYLL04	78.6	404	2.5	<2	202	4.5	1	252	602	0.2	2,930	1,350	<0.5	6	0.7	403	2.1	103
CRAYLL05	71.0	140	1.1	<2	234	1.7	<0.5	197	200	<0.1	3,460	563	<0.5	2.7	0.5	492	<0.5	73.6
CRAYLL06	74.5	140	1.4	<2	175	1.9	<0.5	135	285	<0.1	2,540	377	<0.5	3	0.6	477	<0.5	71.8
CRAYLL07	72.2	261	1.3	<2	250	3.7	0.7	177	399	<0.1	3,340	489	<0.5	4.3	0.5	487	0.8	83.2
CRAYLL08	74.3	239	1.9	<2	223	2	0.6	195	419	<0.1	3,050	1,430	<0.5	4.2	0.66	394	1	96
CRAYLL09	72.9	215	1.4	<2	177	1.2	0.7	113	371	<0.1	2,540	459	<0.5	3.6	0.4	538	1.6	62.5
CRAYLL10	75.5	241	1.3	<2	164	3.6	0.9	282	458	<0.1	2,150	261	<0.5	5.3	0.65	397	1.6	91.7
CRAYLL11	74.6	238	1.3	3	146	2.9	1	161	469	<0.1	2,800	259	<0.5	6.7	0.63	397	1.6	89.8
CRAYLL12	72.9	130	0.91	<2	225	3.7	2.7	254	210	0.1	2,940	332	<0.5	13	0.6	499	1	81.7

% Moist. = Percent moisture content in crayfish samples.

Beryllium and molybdenum were not detected in any crayfish samples.

*Composite samples. The composite sample from Granite Basin Lake included crayfish from the lake and from the creek below the dam.

Appendix 4. Fish data from Lynx Lake (fishll) and Granite Basin Lake (fishrf), including individual values for GSIs, HSIs, and CFs.

Fish ID	Species	Length (mm)	Weight (g)	Liver (g)	Spleen (g)	Sex	Sex organ wt (g)	GSI	HSI	CF
fishll4b	carp	154	75.6	1.2	0.2	f	0.1	0.13	1.59	2.07
fishll4g	carp	158	70.3	1	0.2	f	<0.1	0.14	1.42	1.78
fishll4a	carp	211	208.4	3	0.9	m	0.6	0.29	1.44	2.22
fishll4e	carp	182	107.6	1.6	0.3	m	0.2	0.19	1.49	1.78
fishll4f	carp	191	129.1	1.9	0.3	m	<0.1	0.08	1.47	1.85
fishll4h	carp	150	66.2	1.2	0.2	m	0.1	0.15	1.81	1.96
fishll1a	carp	614	345	7.2	21.4	m	206.2	59.77	2.09	0.15
fishll3f	bass	192	130.6	1.8	<0.1	f	0.5	0.38	1.38	1.85
fishll3c	bluegill	142.88	61.1	0.2	0.2	m	1.5	2.45	0.33	2.09
fishll2b	catfish	161	57	1	0.4	f	2.1	3.68	1.75	1.37
fishll2e	catfish	148	44	0.9	0.3	f	5	11.36	2.05	1.36
fishll3a	catfish	249	253.1	2.5	1.7	f	0.4	0.16	0.99	1.64
fishll3d	catfish	235	42.1	1.6	1.1	f	2.1	4.99	3.80	0.32
fishll3e	catfish	270	262.5	3	1.9	f	2.6	0.99	1.14	1.33
fishll4c	catfish	271	326.7	4.1	2.1	m	0.9	0.28	1.25	1.64
fishll4d	catfish	296	360.9	4.3	2.9	m	0.5	0.14	1.19	1.39
fishll2a	catfish	260	258	3.89	0.1	m	0.8	0.31	1.51	1.47
fishll2c	catfish	176	91	1.3	0.7	m	0.3	0.33	1.43	1.67
fishll2d	catfish	166	67	0.7	0.9	m	0.2	0.30	1.04	1.46
fishll2f	catfish	179	85	1.3	1	m	0.2	0.24	1.53	1.48
fishll3b	catfish	301	370	4.6	2.6	m	1.1	0.30	1.24	1.36
fishrf2c	bluegill	170	95	0.2	<0.1	f	2.6	2.74	0.21	1.93
fishrf3a	bluegill	154	72	0.5	0.1	f	3.6	5.00	0.69	1.97
fishrf3c	bluegill	170	101	<0.1	<0.1	f	0.1	0.10	0.10	2.06
fishrf3d	bluegill	162	88	0.2	<0.1	f	0.3	0.34	0.23	2.07
fishrf3e	bluegill	135	51	0.7	0.1	f	6.3	12.35	1.37	2.07
fishrf3f	bluegill	145	70	0.2	<0.1	f	0.1	0.14	0.29	2.30
fishrf4a	bluegill	135	59	0.2	<0.1	f	2.1	3.56	0.34	2.40
fishrf4b	bluegill	145	57	0.2	<0.1	f	2.5	4.39	0.35	1.87
fishrf4c	bluegill	164	84	0.6	0.1	f	2.7	3.21	0.71	1.90
fishrf4d	bluegill	150	67	0.6	0.1	f	2.7	4.03	0.90	1.99
fishrf4e	bluegill	150	74	0.6	0.1	f	5.7	7.70	0.81	2.19

Fish ID	Species	Length (mm)	Weight (g)	Liver (g)	Spleen (g)	Sex	Sex organ wt (g)	GSI	HSI	CF
fishrf4f	bluegill	138	54	0.3	<0.1	f	5.7	10.56	0.56	2.05
fishrf3b	bluegill	155	71	0.3	<0.1	m	<0.1	0.14	0.42	1.91
fishrf1a	bass	387	855	10.7	1.6	f	38.1	4.46	1.25	1.48
fishrf1c	bass	270	242	2.3	0.3	f	1.7	0.70	0.95	1.23
fishrf1d	bass	237	152	0.8	0.2	f	1	0.66	0.53	1.14
fishrf1e	bass	250	183	1.7	0.2	f	0.5	0.27	0.93	1.17
fishrf1f	bass	273	222	1.6	0.2	f	0.8	0.36	0.72	1.09
fishrf2a	bass	260	224	1.9	0.2	f	0.7	0.31	0.85	1.27
fishrf2b	bass	280	178	1.4	0.1	f	7.1	3.99	0.79	0.81
fishrf1b	bass	372	591	4.8	0.6	m	2.1	0.36	0.81	1.15

▨ Two outliers from Lynx Lake.

Appendix 5. Metal concentrations in Lynx Lake fish (ppm dry weight).

	Species	% Moist.	Al	As	B	Ba	Cd	Cr	Cu	Fe	Hg	Mg	Mn	Pb	Se	Sr	V	Zn
FISHLL1A	Carp	68.5	68	0.2	<2	3	0.3	0.5	5.1	160	0.1	947	13	0.85	1.1	34.9	0.7	132
FISHLL2A	Catfish	79.7	66	0.2	<2	10	0.66	0.8	7.3	150	0.2	1,540	75.9	0.99	1.5	68.6	0.6	64.7
FISHLL2B	Catfish	75.1	82	<0.2	<2	6.4	0.76	<0.5	6.6	140	0.1	1,550	67.6	0.5	1.3	61.1	0.8	68.8
FISHLL2C	Catfish	79.4	110	0.4	<2	23.6	2.1	1.9	103	209	<0.1	1,610	62.8	0.74	1.4	78.2	1	63.2
FISHLL2D	Catfish	76.8	78	0.3	<2	5.7	0.61	<0.5	7.8	130	<0.1	1,680	46	0.5	1.4	62.5	0.9	59
FISHLL2E	Catfish	77.1	69	0.4	<2	3.7	0.63	<0.5	5.4	130	0.1	1,820	40	0.61	1.9	62.2	0.8	74.1
FISHLL2F	Catfish	77.8	85	0.4	<2	17	1.1	0.7	15	160	0.2	1,630	50.9	0.66	1.2	77.5	1	55.2
FISHLL3A	Catfish	81.6	<2	0.2	<2	<0.2	<0.1	<0.5	<0.3	<2	0.33	<2	<0.5	5.1	1.4	<0.2	<0.5	<0.5
FISHLL3B	Catfish	82.1	25	<0.2	<2	4.3	0.86	3.6	5.7	180	0.45	1,510	18	2.7	1.3	53	0.9	70.6
FISHLL3C	Bluegill	74.7	86	0.2	8.7	4.6	0.2	1.8	1.9	69	0.2	1,550	26	6.4	1.2	78.9	0.5	86.1
FISHLL3D	Catfish	79.1	31	0.2	<2	3	1.1	2.3	3.6	97	0.37	1,900	28	3.6	1.5	87.9	1	83.8
FISHLL3E	Catfish	81.8	22	<0.2	<2	2.6	0.89	1.8	5.2	170	0.43	1,650	15	1.2	1	62.9	1	73.2
FISHLL3F	Bass	78.8	40	0.3	<2	2.4	0.2	0.9	2.5	100	0.2	1,540	9.9	0.64	1.9	37.3	<0.5	84.8
FISHLL4A	Carp	79.3	100	1.3	<2	5.4	0.3	2.9	7.3	222	0.1	1,360	13	0.96	2	47.6	0.8	273
FISHLL4B	Carp	80.7	793	2.2	<2	8.4	0.61	1	17	866	0.2	1,380	33	6.1	2.4	29.2	2.1	229
FISHLL4C	Catfish	83.9	80	0.3	<2	14	0.44	3.7	4.9	170	0.31	1,460	23	1.4	1.3	54.8	1	58.1
FISHLL4D	Catfish	81.6	55	<0.2	<2	5.4	0.52	1	6.3	150	0.3	1,590	28	1.1	1.1	62.7	0.8	66.7
FISHLL4E	Carp	79.9	68	0.96	<2	5.4	0.3	1	4.5	180	0.2	1,440	15	0.5	1.9	56.9	0.8	194
FISHLL4F	Carp	82.6	94	1.5	<2	5.3	0.36	1	6.1	221	0.2	1,440	18	0.72	2.5	46.1	1	252
FISHLL4G	Carp	78.5	83	0.6	<2	6.9	0.3	<0.5	4.6	180	0.2	1,460	19	0.62	1.9	62.7	1	252
FISHLL4H	Carp	82	70	0.64	<2	4.6	0.77	1	6.4	230	0.1	1,450	15	0.5	2.2	43	0.7	295

% Moist. = Percent moisture content in the samples.

Beryllium, molybdenum, nickel were not detected in any fish samples.

Appendix 6. Metal concentrations in Granite Basin Lake fish (ppm dry weight).

	Species	% Moist.	Al	As	Ba	Cr	Cu	Fe	Hg	Mg	Mn	Pb	Se	Sr	V	Zn
FISHRF1A	Bass	75.7	8.4	1	3.7	1	1.7	74	1.6	1,520	18	<0.2	0.62	81.2	<0.5	67.3
FISHRF1B	Bass	74.5	24	0.3	7.7	1	1.5	78	2.2	1,680	30	<0.2	0.74	100	<0.5	66.3
FISHRF1C	Bass	76.1	18	0.66	3.6	1.6	1.6	80	2.9	1,540	22	<0.2	0.72	62.3	<0.5	84.2
FISHRF1D	Bass	74.3	22	0.5	3.8	0.8	1.1	59	3.4	1,980	24	<0.2	0.72	93.2	<0.5	74.3
FISHRF1E	Bass	76.6	13	0.6	3.2	8.1	1.4	110	3.5	1,610	19	<0.2	0.72	58.6	<0.5	73.9
FISHRF1F	Bass	75.6	10	0.76	2.7	1	1	48	2.6	1,500	13	<0.2	0.85	54.8	<0.5	67.5
FISHRF2A	Bass	75.4	24	0.76	3.1	2.4	1.2	77	3	1,560	22	<0.2	0.74	62.1	<0.5	71
FISHRF2B	Bass	76.7	23	0.7	2.3	0.7	1.7	63	3.3	1,450	16	<0.2	0.82	41.2	<0.5	79.4
FISHRF2C	Bluegill	71.7	414	0.3	16	1	1.4	566	1.1	1,650	92.8	0.6	0.74	94.9	1	77.8
FISHRF3A	Bluegill	71.1	34	0.3	19	1	0.8	68	1.2	1,730	89.8	<0.2	0.68	145	0.6	85.5
FISHRF3B	Bluegill	70.9	44	0.3	9.1	2.8	1.2	110	1.3	1,600	55.2	<0.2	0.75	96.1	<0.5	77.9
FISHRF3C	Bluegill	72.1	73	0.3	11	0.8	1.5	170	1.4	1,420	117	0.2	0.84	74.2	<0.5	66.7
FISHRF3D	Bluegill	73.5	71	0.61	13	0.7	1.7	405	1.4	1,420	222	<0.2	0.97	68.3	<0.5	71.2
FISHRF3E	Bluegill	71.6	29	0.3	14	0.6	0.91	89	1.3	1,610	120	<0.2	0.71	110	0.6	77
FISHRF3F	Bluegill	71.6	40	0.4	9.8	<0.5	1.4	100	2.1	1,510	55.8	<0.2	1.1	91.3	0.5	83.3
FISHRF4A	Bluegill	71.1	63	0.3	9.3	<0.5	1.1	100	0.68	1,500	89.8	<0.2	0.98	78.5	0.5	77.4
FISHRF4B	Bluegill	71.2	140	0.5	14	0.6	1.1	333	1.2	1,590	76.6	<0.2	0.74	97.9	0.7	80.1
FISHRF4C	Bluegill	65.9	20	0.2	11	0.9	0.8	57	1.3	1,480	68.9	<0.2	0.64	106	<0.5	76.8
FISHRF4D	Bluegill	72.2	52	0.3	12	<0.5	1.2	110	1.6	1,650	93.6	<0.2	0.81	101	<0.5	74.4
FISHRF4E	Bluegill	71.6	12	0.4	11	0.6	1.2	56	1.5	1,680	133	<0.2	0.71	93.5	<0.5	78.2
FISHRF4F	Bluegill	71.2	22	0.4	10	<0.5	1.2	56	1.5	1,590	69.4	<0.2	0.85	94.2	<0.5	84.2

% Moist. = Percent moisture content in the samples.

Beryllium, boron, cadmium, molybdenum, nickel were not detected in any fish samples.

Appendix 7. Derivation of Risk-Based Screening Levels for sediments, water, and fish tissue.

$$\text{Csoil (or Cwater or Cfish)} = \frac{\underline{HQ * BW * TRV}}{(SIR + (FIR * BAF^{1}))}$$

Based on Sample et al. (1996), where
HQ = Hazard Quotient (unitless) = 1
BW (kg) = Body weight of an adult bald eagle = 3.9 kg (the average of male and female bald eagles in Arizona) (Hunt et al. 1992)
TRV (mg/kg/day) = Toxicity reference value = avian low TRV from EPA R9 BTAG values.
SIR (kg/day) = Soil (or water) Ingestion Rate = negligible amount based on Sample et al. (1997) for Cooper's hawk (=0.9%*FIR) or 0.16 L water /day based on EPA (1995).
FIR (kg/day) = Food Ingestion Rate = 0.5042 kg/day for bald eagles from EPA (1995).
BAF = Bioaccumulation Factor (unitless) = 1
[1] The BAF is not necessary for the tissue calculation.

Bald Eagle	RBSL Sediment mg/kg	HQ unitless	BW kg	TRV mg/kg bw-day	SIR kg/day	FIR kg/day	BAF kg tissue/ kg sediment
Chemical							
Arsenic	42.163	1	3.9	5.5	0.004538	0.5042	1
Cadmium	0.6133	1	3.9	0.08	0.004538	0.5042	1
Copper	17.632	1	3.9	2.3	0.004538	0.5042	1
Lead	0.1073	1	3.9	0.014	0.004538	0.5042	1
Manganese	594.88	1	3.9	77.6	0.004538	0.5042	1
Mercury	0.299	1	3.9	0.039	0.004538	0.5042	1
Selenium	1.7632	1	3.9	0.23	0.004538	0.5042	1
Zinc	131.86	1	3.9	17.2	0.004538	0.5042	1

Bald Eagle	RBSL Water mg/L	HQ unitless	BW kg	TRV mg/kg bw-day	SIR L/day	FIR kg/day	BAF L /kg tissue
Chemical							
Arsenic	32.29449	1	3.9	5.5	0.16	0.5042	1
Cadmium	0.469738	1	3.9	0.08	0.16	0.5042	1
Copper	13.50497	1	3.9	2.3	0.16	0.5042	1
Lead	0.082204	1	3.9	0.014	0.16	0.5042	1
Manganese	455.6459	1	3.9	77.6	0.16	0.5042	1
Mercury	0.228997	1	3.9	0.039	0.16	0.5042	1
Selenium	1.350497	1	3.9	0.23	0.16	0.5042	1
Zinc	100.9937	1	3.9	17.2	0.16	0.5042	1

Bald Eagle	RBSL Fish mg/kg	HQ unitless	BW kg	TRV mg/kg bw-day	SIR mg/kg bw-day	FIR kg/day
Chemical						
Arsenic	42.54264	1	3.9	5.5		0.5042
Cadmium	0.618802	1	3.9	0.08		0.5042
Copper	17.79056	1	3.9	2.3		0.5042
Lead	0.10829	1	3.9	0.014		0.5042
Manganese	600.238	1	3.9	77.6		0.5042
Mercury	0.301666	1	3.9	0.039		0.5042
Selenium	1.779056	1	3.9	0.23		0.5042
Zinc	133.0424	1	3.9	17.2		0.5042

Appendix 8. Calculation of Hazard Quotients for the Bald Eagle consuming water, sediment, and fish at Lynx Lake.

$$\text{Hazard Quotient (HQ)} = \frac{\text{Concentration of Metal in Water, Sediment, or Fish}}{\text{Risk-based Screening Level Concentration}}$$

	Water Conc Lynx Lake (mg/L)	RBSL* (mg/L)	HQ
Arsenic	0.005133	32.29449	0.000158954
Cadmium	0.0006	0.469738	0.001277308
Copper	0.007933	13.50497	0.000587438
Lead	ND	0.082204	--
Mercury	ND	0.228997	--
Manganese	0.038667	455.6459	8.48612E-05
Selenium	0.0003	1.350497	0.00022214
Zinc	0.02	100.9937	0.000198032

Unfiltered water; average of water results from 3 Lynx Lake water samples collected. If ND was present, disregarded.

*RBSL = risk based screening level = backcalculated TRV based on low EPA R9 BTAG TRVs

	Mean Sediment Concentration Lynx Creek (ppm dry weight)	RBSL* (ppm dry weight)	HQ
Arsenic	29.875	42.16317	0.708556726
Cadmium	4.371429	0.613283	7.127919725
Copper	354.25	17.63187	20.09145659
Lead	141.5	0.107324	1318.432211
Mercury	0.117143	0.298975	0.391814592
Manganese	622.75	594.884	1.046842668
Selenium	1	1.763187	0.567154738
Zinc	447.375	131.8557	3.392912541

	Mean Sediment Concentration Lynx Lake Other Studies (ppm dry weight)^	RBSL* (ppm dry weight)	HQ
Arsenic	22.76667	42.1631732	0.53996568
Cadmium	2.8	0.61328252	4.56559564
Copper	254	17.6318724	14.4057303
Lead	160.6667	0.10732444	1497.01843
Mercury	0.071	0.29897523	0.23747787
Manganese	559	594.884044	0.93967893
Selenium	0.585	1.76318724	0.33178552
Zinc	388.5	131.855742	2.94640184

^other studies = ADEQ (Rector 1993)+EPA (EPA 1994) +Weston 2002

	Mean Fish Concentration Lynx Lake (ppm dry weight)	RBSL* (ppm dry weight)	HQ
Arsenic	0.509524	42.54264	0.011976779
Cadmium	0.621905	0.618802	1.005014042
Copper	10.77857	17.79056	0.605859054
Lead	1.732857	0.10829	16.00195186
Mercury	0.209048	0.301666	0.692977051
Manganese	29.39762	600.238	0.048976604
Selenium	1.590476	1.779056	0.894000106
Zinc	120.7405	133.0424	0.907533514

Fish concentration from Lynx Lake is the arithmetic mean of all fish collected.