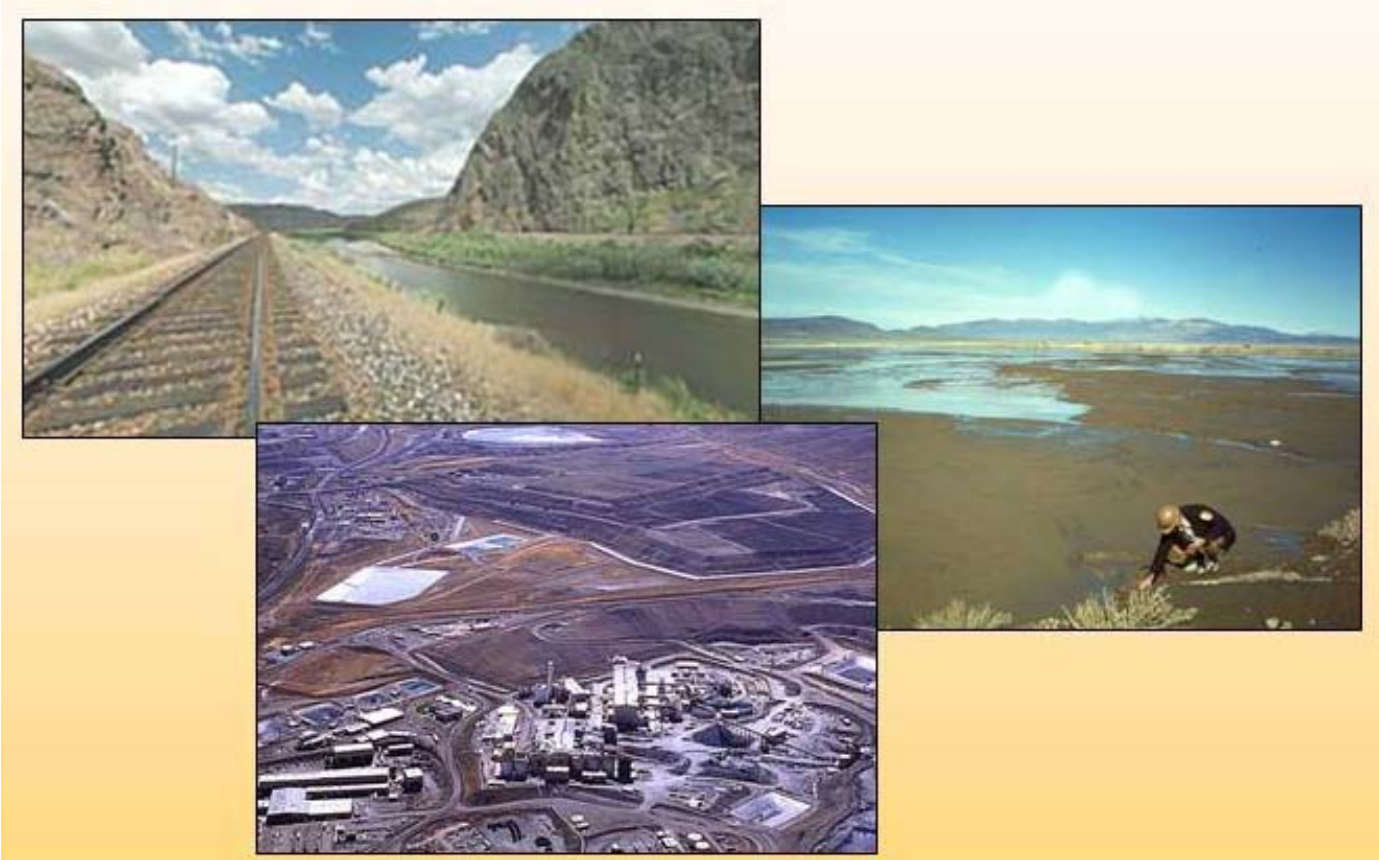
Aquatic Biota Monitoring on the Humboldt River, Nevada, in Relation to Mine Dewatering Discharges



U.S. Fish and Wildlife Service
Division of Environmental Quality
Nevada Fish and Wildlife Office
Reno, Nevada

Aquatic Biota Monitoring on the Humboldt River, Nevada, in Relation to Mine Dewatering Discharges

by

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Executive Summary

Anthropogenic sources of contamination have the potential to adversely affect the Humboldt River and its terminal wetlands at the Humboldt Wildlife Management Area, Nevada. The latter area provides important habitat for migratory birds. Previous investigations of irrigation drainage in this area found that fish and wildlife had been exposed to elevated concentrations of several elements and total dissolved solids. Discharges to the Humboldt River of additional loads of such contaminants from mine dewatering was cause for concern. Therefore, this study was initiated to: provide a baseline on surface water quality and elements in biota in the mid to lower Humboldt River basin and to evaluate trends; determine if water quality standards were protective of fish, wildlife, and habitat; and attempt to determine relative loads of contaminants entering the Humboldt Wildlife Management Area that originated from mine dewatering and irrigation drainage. Mine dewatering discharges to the Humboldt River or its tributaries occurred from the Newmont Gold Quarry and Lone Tree Mines and the Barrick Goldstrike Mine.

Aquatic vegetation, macroinvertebrates, and fish were collected from eight sites along the Humboldt River, including sites both upstream and downstream of mine dewatering discharge points. Sediment, aquatic vegetation, macroinvertebrates, fish, and bird eggs and livers were collected from the Humboldt Wildlife Management Area. Sampling at all sites was conducted in 1998 and 1999, and four sites along the river in 2000. Samples were analyzed for an array of elements. Data on water quality in the Humboldt River as well as mine dewatering discharges were evaluated. The U.S. Geological Survey conducted an associated study on water and sediment quality in the lower portion of the basin, and estimated loads of contaminants in the river from various sources, with results provided in a separate report.

Element concentrations in algae varied widely among sample locations and years. Magnesium and strontium concentrations in algae tended to increase in a downstream direction. Molybdenum concentrations were markedly higher downstream of the Lone Tree Mine discharge point than at all other locations; however, the source is unclear. Element concentrations in dragonfly larvae often varied among years, with some being significantly different among sites. Concentrations of some elements (e.g., aluminum and chromium) often declined from 1998 to 2000. Manganese concentrations in dragonfly larvae tended to decline in a downstream direction. Concentrations of some elements in crayfish also varied widely among collection sites and years, whereas others tended to be more stable in relation to these variables. Chromium and mercury concentrations in crayfish tended to be higher in 1998 than in later years, with the opposite being true for magnesium and strontium. Zinc concentrations in crayfish tended to be higher in 1999 than in other years. Manganese concentrations in crayfish tended to decline in a downstream direction. Concentrations of a number of elements in Lahontan redsides, a small shiner, varied widely among collection sites and years. Data are also provided for other species of fish that were not consistently found at all sites.

Concentrations of some elements in American coot eggs varied among years and collection locations. Mercury and selenium concentrations in eggs from Humboldt Lake were the highest in 1996, in a previous study, and declined in 1998 and 1999. Arsenic concentrations in livers of juvenile coots were highest in 1999, and lowest in 1988 in a previous study. Mercury

concentrations also varied greatly among years, with the lowest and highest mean concentrations occurring in 1988 and 1996, respectively.

Flows in the Humboldt River varied widely among the years of this study, with the highest flow occurring in 1998, declining in 1999, and further declining in 2000. Long-term water quality in the Humboldt River tended to decline in a downstream direction, characterized by increased concentrations of arsenic, boron, iron, and total dissolved solids. Suspended solids declined markedly below the dam at Rye Patch Reservoir, probably due to settling of solids during storage which may have been related to a marked decrease in iron in water at this site.

The National Pollution Discharge Elimination System permit limit for total dissolved solids at the Newmont Gold Quarry mine was commonly exceeded and arsenic concentrations were frequently higher in the discharge than that found upstream. Discharge limits for the Barrick Goldstrike Mine were nearly always met with the exception of one pH reading; however, boron concentrations in the discharge were much higher than in the river at both upstream and downstream sites. Discharge limits for the Lone Tree Mine were occasionally exceeded for arsenic, boron, and total dissolved solids. Arsenic and boron concentrations in the discharge tended to be higher than those found in the river, both upstream and downstream of the discharge point.

Concentrations of elements in sediment from the Humboldt Wildlife Management Area were evaluated in relation to threshold and probable effect concentrations or concern levels that were related to biological effects in freshwater ecosystems. The threshold effect concentration for arsenic was consistently exceeded, whereas the threshold effect concentrations or concern levels for cadmium, copper, iron, manganese, mercury, nickel, and selenium were exceeded in one of eight samples.

Concentrations of elements in biota from this study were evaluated in relation to direct effects on aquatic invertebrates and fish, where possible, and avian dietary effect levels. Concentrations in invertebrates and fish did not exceed concentrations associated with known effects concentrations. However, concentrations of some elements in some fish samples exceeded the 85th percentile concentrations in 1984 in a national fish monitoring program. Boron concentrations in aquatic vegetation often exceeded a concentration associated with reduced duckling weight gain; however, boron concentrations in aquatic invertebrates and fish were not elevated. Chromium concentrations in algae in 1998 and 1999 commonly exceeded a threshold concentration associated with potential health and reproductive effects in birds, with a few samples of other biota exceeding the concentration. Mercury concentrations in several species of fish commonly exceeded a reproductive effects criterion for ducks. Some samples of aquatic macroinvertebrates and fish had concentrations of selenium that exceeded a threshold associated with reproductive effects in birds. Zinc in some fish samples exceeded a level for prevention of marginal sublethal effects in birds that may consume fish. Concentrations of elements in avian eggs and livers in this study were nearly always below known effect levels for health or reproduction. In general, concentrations of elements in biota were usually below effect levels.

Recommendations are made for future sampling, which include information on sample types, locations, elements analyzed, frequency of sampling, and a possible more holistic study approach.

Sufficient data were obtained to begin to assess trends in surface water quality and elements in aquatic vegetation, invertebrates, fish, and bird eggs and livers in the mid to lower Humboldt River basin. For the period from June 1998 through September 1999, only about 6 percent of the loads of total dissolved solids and arsenic in the Humboldt River were contributed by mine dewatering discharges. The relative load contributed by the mines was not evaluated during later periods of lower river flows. During periods of high flow or no irrigation, the river generally carried greater loads of sodium, chloride, dissolved solids, arsenic, boron, molybdenum, and uranium to the Humboldt Wildlife Management Area than did the agricultural drains. However, the reverse was true during other periods. There is no clear evidence that mine dewatering discharges had an adverse effect on biological resources in the Humboldt River. The adequacy of water quality standards was not evaluated.

Introduction

Anthropogenic sources of contaminants in the Humboldt River and its terminal wetlands at the Humboldt Wildlife Management Area (WMA), Nevada, include irrigation drainage, mine dewatering, abandoned mines, livestock grazing, and municipal wastewater effluent. A better understanding of the relative sources of contaminants in the Humboldt River basin, especially irrigation drainage and mine dewatering, was needed. Other sources of contaminants were not addressed due to funding constraints.

The Humboldt River drains the largest watershed in Nevada and terminates in the Humboldt Sink in Pershing and Churchill Counties, except in years when the Humboldt Sink floods and discharges into the Carson Sink, such as occurred in 1998. Wetlands in and near the Humboldt Sink provide important nesting, foraging, and resting habitat to large numbers of migratory birds. These wetlands, now contained within the Humboldt WMA, have been identified as one of the most important wildlife habitats in Nevada (Hallock et al. 1981). In unusual years, such as 1977, the Humboldt WMA may be the most important wetland in Nevada as determined by waterfowl-use days (Hallock et al. 1981). Shorebird use of the area is also significant.

Wetlands near the terminus of the Humboldt River were included in a reconnaissance study in 1990-91 under the National Irrigation Water Quality Program (Seiler et al. 1993). A field verification study, under that program, was conducted in the same area in 1996 (Seiler and Tuttle 1997). The reconnaissance investigation in 1990-91 found that irrigation drainage from the Lovelock area may have caused harmful effects to fish and wildlife. Levels of arsenic (As), boron (B), chromium (Cr), copper (Cu), dissolved solids (TDS), lithium, mercury (Hg), molybdenum (Mo), selenium (Se), uranium, and zinc (Zn) in water sediment, and/or biota in some cases exceeded one or more of the following: geochemical baseline values; biological effect levels; and/or Nevada water quality standards for the protection of aquatic life or the propagation of wildlife. Because of high concentrations in water and/or biological tissues, As, B, Hg, and Se were of primary concern. Dissolved solids in Toulon Lake of the Humboldt WMA were high enough to cause an adverse effect on duckling survival, based on data provided by Mitcham and Wobeser (1988). Selenium concentrations in water met or exceeded effect levels for fish and wildlife bioaccumulation. Selenium biomagnification occurred, with median concentrations in livers of juvenile black-necked stilts (*Himantopus mexicanus*) being about three times higher than the effect level (i.e., 9 µg/g dry weight; Heinz et al. 1987). Also, the public advisory criterion for selenium in edible tissue (i.e., approximately 7.2 µg/g dry weight) was exceeded in one of three adult duck muscle samples.

Concentrations of As, Cr, Hg, and Se in aquatic vegetation, aquatic invertebrates, and avian eggs and livers were generally higher in the 1996 field verification study than in the 1990-91 reconnaissance study (Seiler et al. 1993; Seiler and Tuttle 1997). Arsenic, B, Hg, and Se in one or more biological matrices exceeded concentrations associated with adverse effects to avian species. However, the causes of changes in concentrations over time were unknown. The mean As concentration (i.e., 28.7 µg/g) in aquatic vegetation collected in 1996 approached a 30 µg/g dietary concentration associated with effects on growth, development, and physiology of mallards (*Anas platyrhynchos*; Camardese et al. 1990). All vegetation samples exceeded a 100

µg/g B concentration associated with delayed growth and biochemical effects in mallards (Hoffman et al. 1990), with one sample exceeding 1000 µg/g, a concentration associated with reduced duck egg hatching success, hatch weight, duckling weight gain, and duckling survival (Smith and Anders 1989). Mercury concentrations in aquatic invertebrates were greater than dietary concentrations associated with reduced production and behavioral effects in mallards (Heinz 1979). The mean Hg concentration (i.e., 0.89 µg/g wet weight) in American coot (*Fulica americana*) eggs exceeded a 0.83 µg/g egg concentration (wet weight) associated with reduced hatch rate and juvenile survival in mallards (Heinz 1979), with one of seven American avocet (*Recurvirostra americana*) eggs exceeding this effect concentration. Selenium in all invertebrate samples exceeded a 5 µg/g critical avian dietary threshold identified by Skorupa et al. (1996). During both the reconnaissance investigation and the field verification studies (Seiler et al. 1993; Seiler and Tuttle 1997), mean Se concentrations in coot livers exceeded a 10 µg/g concentration at which the possibility of reproductive impairment and sublethal effects increase (Heinz 1996). During both periods, juvenile shorebird hepatic concentrations of Se were near a 30 µg/g concentration indicative of an increased risk of adverse biological effects (Skorupa et al. 1996). Seiler (1995) showed that the likelihood of a Se problem at the Humboldt WMA would change from possible to probable with the addition of a major upstream source.

Several mining operations in the Humboldt River basin have pumped groundwater around open pits to facilitate mining below the water table. Three mines discharged this water to the Humboldt River. These operations were the Newmont Mining Corporation Gold Quarry and Lone Tree Mines (the latter previously owned by the Santa Fe Pacific Gold Corporation) and the Barrick Goldstrike Mines Inc., Goldstrike Mine. Collectively, these mines were permitted to discharge 313,000 acre-feet per year, which exceeded the long-term average annual flow of the main-stem Humboldt River; however, actual discharges were below permitted limits. The long-term (1895-2000) average flow at the Comus gage equals 246,000 acre-feet per year (Allander et al. 2001).

Although the mine dewatering discharges were required by regulation to be in compliance with State and Federal water quality standards, TDS concentrations and several elements were of concern because they could exceed concentrations currently existing in the Humboldt River near discharge points. Dissolved solids, As, and Se were of particular concern. Between 1982 and 1992, geometric mean levels of TDS and dissolved As at a U.S. Geological Survey (USGS) gage near Carlin, Nevada (upstream of all areas of dewatering discharges) were 283 mg/L (extremes 178 and 414 mg/L) and 6.6 µg/L (extremes 3 and 12 µg/L), respectively (http://nwis.waterdata.usgs.gov/nwis/qwdata). During the same period, dissolved Se was below a 1 µg/L detection limit in 41 of 43 samples. The limits for discharge were 500 mg/L for TDS, 50 µg/L and 5 µg/L for total As and Se, respectively. Because of the dewatering magnitude and permitted discharge limitations, inorganic contaminant concentrations, including TDS and elements, and loads in the Humboldt River basin had the potential to increase.

The objectives of this study were to: 1) obtain sufficient data to begin to assess trends in surface water quality and elements in aquatic vegetation, invertebrates, fish, and bird eggs and livers in the mid to lower Humboldt River basin; 2) assess the adequacy of State and Federal water quality standards for TDS and elements to protect fish and wildlife resources in the lower Humboldt River basin, and the possible need for the establishment of total maximum daily loads;

and 3) attempt to determine the relative proportions of TDS and elements entering the Humboldt WMA that originate from mine dewatering and from agricultural drainwater in the Lovelock area. The U.S. Geological Survey was provided with funds to obtain data in relation to the third objective; the results of their study have been provided in a separate report (Paul and Thodal 2003). The early detection of potential biological effects was critical because of the terminal nature of the Humboldt River system, the persistence of trace elements in the environment, and the previous identification of potential adverse effects caused by inorganic contaminants in wetlands at the terminus of the river.

Methods

Monitoring Sites

Monitoring of elements in aquatic biota was conducted at the following sites along the Humboldt River, listed in an upstream to downstream order (Figure 1). Information is provided on the general location of each site and the criteria for sampling at each.

Osino - about 1 mile east of Osino, immediately downstream of railroad bridge (Figure 2). This site is upstream of all dewatering discharges as well as possible municipal effects from Elko. The Nevada Division of Environmental Protection (NDEP) monitors water quality at or near this site.

Carlin - near the USGS gage in the canyon downstream of the I-80 highway tunnels, upstream of Carlin (Figure 3). This site is the first site downstream of Elko and upstream of the confluence with Maggie Creek. NDEP monitors water quality at or near this site.

Palisade - near the USGS gage at Palisade (Figure 4). This is downstream of the confluence of Maggie Creek. The Newmont Gold Quarry Mine dewatering discharge is to Maggie Creek. NDEP monitors water quality at this site.

Argenta - near the bridge on the road to the TS Ranch, about 1.5 miles north of Mosel and about 5.5 miles east-northeast of Argenta (Figure 5). This site is downstream of the Barrick Goldstrike Mine dewatering discharge point on the Humboldt River.

Emigrant - near the highway bridge at Preble, about 4.6 miles east- northeast of Golconda (Figure 6). This site is downstream of the Newmont Lone Tree Mine dewatering discharge point on the Humboldt River. NDEP monitors water quality somewhat upstream of this site.

Imlay - immediately downstream of the diversion dam for the Pitt-Taylor Canal, about 2 miles north of Mill City and 4.5 miles northeast of Imlay (Figure 7). This site is downstream of all mine dewatering discharge points and upstream of any influences of water storage in Rye Patch Reservoir. NDEP monitors water quality on the Humboldt

River just north of Imlay, which is downstream of this site.

Rye Patch - immediately downstream of Rye Patch Dam (Figure 8). This site is downstream of influences of water storage in Rye Patch Reservoir. NDEP monitors water quality at this site.

Lovelock - near a bridge across the Humboldt River about 4.5 miles north of Colado and about 3 miles southwest of Oreana (Figure 9). This site is upstream of all agricultural drainwater inflows.

Sampling occurred at all of the above sites in 1998 and 1999 and at the Carlin, Palisade, Argenta, and Emigrant sites in 2000. In 1998, the majority of samples from sites along the Humboldt River were collected on September 1-3, with supplemental sampling at Argenta, Emigrant, Imlay, and Lovelock on September 24 (Appendix 1). In 1999, sampling at sites along the river was conducted from August 30 to September 1, except for Lovelock, where sampling occurred on September 28. Supplemental sampling occurred at the Emigrant site on October 12 and 29 due to flooding of the sampling site from impounded water during the normal sampling period for most other sites. In 2000, all sampling occurred on September 18 and 19. Sampling of sites along the river was normally conducted in late August and early September because flows were low, thereby making sampling less difficult. In 1998, eggs were collected from the Humboldt WMA between May 21 and June 8, whereas eggs were collected at the upstream end of Rye Patch Reservoir on June 4 and July 2, and upstream of the Emigrant site on June 30. Sediment, vegetation, invertebrates, and fish were collected at the Humboldt WMA on August 28 and October 7, 1998. Eggs were collected at the Humboldt WMA on June 7 and 23, 1999. The collection of birds (for the harvesting of livers) on this area occurred on August 5 and 28, 1998, and July 23 and August 2 and 23, 1999. Sediment, vegetation, invertebrates, and fish were collected at the Humboldt WMA on August 23, 1999.

Information on approximate coordinates of all collection points is provided in Appendix 2, including generally minor deviations that occurred between years in some cases for sites along the Humboldt River. Information on the total number of samples that was collected is provided in Appendix 3. Field measurements of water quality were also obtained (Appendix 4).

Sediment

Sediment quality was monitored because sediment represents both a repository for elements and a potential pathway of fish and wildlife exposure. Sediment samples were collected on Humboldt Lake within the Humboldt WMA in both 1998 and 1999. At each sampling point, a composite of three (1998) or five (1999) samples was collected with a Wildco model number 2422 H12 core sampler and placed in a clean nalgene container. Samples included the top 5 cm of each core. The samples from each point were thoroughly mixed with a stainless steel instrument and a sub-sample placed in a chemically clean jar with Teflon-lined lid (hereafter referred to as clean jar), stored on ice in the field, and frozen upon return to the laboratory. Between each sampling site, sediment sampling equipment was washed with a brush

and mild detergent, rinsed with dilute nitric acid, and triple rinsed with deionized water.

Biological Samples

Biological samples were collected to assess bioaccumulation of elements and their implications to fish and wildlife health (Appendix 3). *Chara*, pondweed (*Potamogeton* spp.), and filamentous algae were collected with gloved hand and placed in clean jars in the field. Dragonfly larvae (Odonata), water boatmen (Corixidae), and backswimmers (Notonectidae) were collected with kick nets, sorted from substrate materials with gloved hand or clean forceps, and placed in clean jars in the field. Crayfish were collected with nets (kick nets or seine) or by gloved hand, generally sorted by size, and pooled samples placed in clean jars with or in clean plastic bags in the field.

Fish were collected with a seine, sorted by species and often by size, and pooled samples placed in clean jars in the field. Fish of selected species, including those retained for analysis, were individually weighed (grams; g) and measured (total length in millimeters; mm) to determine general condition. Fish not needed for chemical analysis were released at point of capture. Fulton Condition Factor (Anderson and Neumann 1996) was calculated for each species and location for a given year. Fish in better condition have higher scores. The following equation was used where K = the Fulton Condition Factor, W = weight in grams, and L = total length in millimeters:

$$K = (W/L^3) \times 100{,}000$$

All samples for chemical analysis were placed on ice in the field and were frozen upon return to the laboratory. Minimum sample weights were as follows: sediment 58 g; vegetation 11 g, with the majority exceeding 20 g; dragonfly larvae 8 g, with the majority exceeding 10 g; crayfish 25 g, with many exceeding 100 g; other invertebrates 4.3 g; and fish 9.2 g with the majority exceeding 20 g. Between sampling sites, kick nets were washed with a brush and mild detergent, rinsed with deionized water, and submerged in site water for at least 1 minute prior to use. The seine was rinsed in site water for at least 2 minutes prior to use at each sampling site.

Avian eggs, one per nest, were collected with gloved hand, placed in clean egg cartons, placed on ice in the field, and refrigerated upon return to the laboratory. Egg length, breadth, volume, and weight were recorded. Eggs were opened with clean stainless steel instruments in the laboratory by scoring and then cutting through the shell at the equator. Egg contents were placed in clean jars and contents were examined for embryonic development and gross abnormalities. Egg contents were then frozen. Sample weights always exceeded 17 g. Attempts to determine the reproductive success of sampled nests in 1998 were unsuccessful and therefore, were not monitored in 1999.

Birds were usually collected by shooting with steel shot. An outbreak of avian botulism occurred on the Humboldt WMA in 1999 during a collection trip. Therefore, some avocets that were collected that year were found dead or moribund (killed in the field). Bird carcasses were placed in plastic bags on ice in the field. Livers were removed in the laboratory with clean stainless steel instruments and placed in clean jars and frozen. Weights of American coot livers

generally exceeded 10 g, whereas American avocet liver weights ranged from 7 to 11 g, and one black-necked stilt liver weighed 5.7 g.

Chemical Analysis

All samples were analyzed at Research Triangle Institute, Research Triangle Park, North Carolina. All samples were homogenized prior to analysis using a food processor. A portion of the sample was then freeze-dried for determination of moisture content and ground to 100 mesh with a mill. A portion of each freeze-dried sample was digested with 5 ml of Baker Instra-Analyzed nitric acid in a microwave oven. The residue was then diluted to 50 ml with laboratory pure water. Aluminum (Al), B, barium (Ba), beryllium (Be), cadmium (Cd), Cr, Cu, iron (Fe), magnesium (Mg), manganese (Mn), Mo, nickel (Ni), lead (Pb), strontium (Sr), vanadium (V), and Zn measurements were made using inductively coupled plasma (ICP), using a Leeman Labs Plasma Spec I sequential or ES2000 simultaneous spectrometer. Arsenic and Se measurements were made using graphite furnace atomic absorption (GFAA). GFAA instruments were a Perkin-Elmer Zeeman 3030 or 4100ZL atomic absorption spectrometer. Mercury measurements were conducted using $SnCl_4$ as the reducing agent. Cold vapor atomic absorption (CVAA) was employed, using a Leeman PS200 Hg Analyzer.

For the samples collected in 1998, the following numbers of samples were analyzed for quality assurance/quality control (QA/QC) purposes: procedural blanks - eight animal tissue, two plant tissue, and one soil/sediment; duplicates - three egg, two each of invertebrate, liver, vegetation, and fish, and one sediment; standard reference materials - two vegetation (peach leaves), eight animal tissue (lobster hepatopancreas), and one sediment; and spike recoveries - two each of egg, invertebrate, and vegetation, three fish, and one sediment. The limits of detection for a number of samples of animal tissue (Al [n = 8], As [n = 40], and Pb [n = 83]) were slightly higher than the contract norm. The variability of Zn in vegetation was slightly high based on a duplicate result in one sample and the recovery of Zn in one spiked vegetation sample was high. Also, the recovery of Cd in one animal tissue sample of standard reference materials was slightly high. None of these anomalies should have any effect on data interpretation. Analytical results and QA/QC were approved by the Patuxent Analytical Control Facility (PACF) of the U.S. Fish and Wildlife Service (FWS) for all years of sampling.

For the samples collected in 1999, the following numbers of samples were analyzed for QA/QC purposes: procedural blanks - 10 animal tissue, two plant tissue, and one soil/sediment; duplicates - one each of egg and sediment, two each of invertebrate and liver, and three each of vegetation and fish; standard reference materials - two vegetation (peach leaves), eight animal tissue (lobster hepatopancreas), and one sediment; and spike recoveries - two each of egg, vegetation, and liver, one each of invertebrate and sediment, and three fish. The limit of detection for Cr in one sample was slightly higher than the contract norm. Variability in Cd results in three duplicate analyses was slightly high. Spike recoveries for single elements (Al, Cd, Mn) in three samples were slightly high. Recovery for three elements (Al, Cd, Pb) in seven samples of standard reference materials were slightly outside the normal range. None of these anomalies should have any effect on data interpretation.

For the samples collected in 2000, the following numbers of samples were analyzed for QA/QC purposes: procedural blanks - 2 animal tissue and one plant tissue; duplicates - one each of invertebrate, vegetation, and fish; standard reference materials - one vegetation (peach leaves) and two animal tissue (lobster hepatopancreas); and spike recoveries - one each of invertebrate, vegetation, and fish. The limit of detection for Pb was higher than the contract norm in 22 animal tissue samples. The variability of Cd and Hg each in one sample for duplicate analyses was slightly high. The recovery of Al and Cd in one sample each of standard reference materials was slightly outside the normal range. None of these anomalies should have any effect on data interpretation.

Detection limits varied among years (Appendix 5). Changes in detection limits must be taken into account when analyzing data where some samples have non-detectable concentrations.

Water Quality Data

Data on water quality at various sites in the Humboldt River Basin were obtained from the NDEP. Data sets for total elements generally began in 1975 and included data through February 2002, whereas data for total dissolved solids and total suspended solids generally began in February 1989 and continued through April 2002. Concentrations were for total elements in non-filtered samples. Limited data for dissolved elements (filtered samples) were also obtained from NDEP. Data on both total and dissolved metals were also obtained from USGS for several years. Data from USGS where concentrations were below detection limits, but where detection limits were not reported were excluded from data analysis.

Data were obtained from NDEP or Barrick Goldstrike Mines Inc. on water quality of mine dewatering discharges to the Humboldt River or Maggie Creek in the case of the Newmont Mining Corporation Gold Quarry Mine. Concentrations were for total elements in non-filtered samples. Latitude and longitude coordinates for the NDEP and USGS sampling locations and mine dewatering discharge points are provided in Appendix 6.

Statistical Analysis

Residue concentrations were transformed to log values to correct for skewness and to equalize variance among groups. Re-transformed values (i.e., geometric means) are reported. Values less than the lower limit of detection were set to one-half that limit. Geometric means are only reported when 50% or more of the samples contained detectable concentrations. SYSTAT® programs (versions 5.0 or 10; SYSTAT 2000) were used in statistical analyses. One-way analysis of variance (ANOVA) was used to examine differences among years or areas when three or more groups were involved. When significant differences were found, Bonferroni tests were used to determine which groups were different from one another. T-tests were used when examining differences between two groups; separate variance P values were used from t-tests. Two-way ANOVA was used to examine effects among sites and years. All statistical comparisons were conducted at a significance level of $\propto = 0.05$.

Results

Sediment

Concentrations of elements in sediment are presented in Table 1. Differences between years are likely related to natural variability in concentrations among sampling sites. Therefore, no statistical analyses were conducted. Differences between studies may be due in part to sample processing methods (i.e., type and fraction sieved), as well as differences in sample locations.

Vegetation

Algae

Element concentrations in algae varied widely among sample locations and years (Table 2). Types of algae that were collected were not identified; therefore, some differences among years and sites might be due to differing taxa that may have been collected. A two-way ANOVA examining site and year effects for 1998 and 1999 data only was conducted, excluding Imlay due to no data and Hg due to frequent non-detection. Significant site-year interactions were present for all elements, except for B, Mg, Se, and Zn. Therefore no attempt was made to determine which sites and years were significantly different from one another. Significant differences among sites were present for all elements, except Cr and Zn. Years were significantly different from one another only for Ba, Cd, Cr, Mn, and Ni, with concentrations in 1999 being higher in all cases, except Cr.

A two-way ANOVA of site and year effects for 1998, 1999, and 2000 for Carlin, Palisade, Argenta, and Emigrant was also conducted. Site-year interactions were not significant only for Cd, Mg, and Zn; therefore, no attempt was made to determine which groups were significantly different from one another. Significant differences among sites occurred for all elements, except B, Cr, Ni, and Zn. Differences among years were significant for all elements, except As, Ba, Mo, Ni, and Se.

The data indicate much lower concentrations of B at Rye Patch and Lovelock than at the other sites in both 1998 and 1999 (Figure 10). Magnesium and Sr concentrations tended to increase in a downstream direction (Figures 11 and 12). Molybdenum concentrations were markedly higher at Emigrant than other sites in all years (Figure 13).

Pondweed and Chara

Concentrations of elements in pondweed and *Chara* are provided in Table 3. Statistical comparison could not be made for sample sizes < 3. For pondweed in 1999, concentrations of Al ($P = 0.012$), As ($P = 0.001$), Ba ($P = 0.004$), Fe ($P = 0.009$), and Sr ($P = 0.001$) were significantly higher at Rye Patch, and B ($P < 0.001$), Mn ($P < 0.001$), Mo ($P = 0.035$), and Zn ($P = 0.047$) were higher at Lovelock. For *Chara* at Osino, B and Ni were significantly higher in 1998 than 1999 ($P = 0.014$ and 0.001, respectively).

Aquatic Invertebrates

Dragonfly larvae

Concentrations of elements in dragonfly larvae are reported in Table 4. A two-way ANOVA of site and year effects for 1998 and 1999 only was conducted, using data from all riverine sites, except for Emigrant and Rye Patch due to lack of data. Data for Be, Hg, Mo, and Pb were not included in the analysis due to > 50% non-detectable concentrations. Site-year interactions were significant for all elements, except Cu, Ni, Sr, V, and Zn. Differences among sites were significant for all elements with the exception of Cr, Ni, V, and Zn. Significant differences occurred between years for all elements, except Mg, Mn, and Sr. Overall, Al, B, Ba, Cr, Fe, Ni, and V concentrations were higher in 1998 with the remainder, where significant differences were present, having higher concentrations in 1999.

A two-way ANOVA of site and year effects for 1998, 1999, and 2000 for Carlin, Palisade, and Argenta was also conducted. Site-year interactions were significant for all elements, except Cd, and Cr. Concentrations were significantly different among sites for all elements, except As, Cr, Cu, and Se. Significant differences among years occurred for all elements, except Cu and Sr.

An examination of the data reveal that concentrations often declined from 1998 to 2000, data for selected sites for Al being one example (Figure 14). Chromium concentrations were much higher in 1998, except at Lovelock (Figure 15). Manganese concentrations tended to decline in a downstream direction (Figure 16).

Crayfish

Concentrations of some elements in crayfish varied widely among collection sites and years, whereas others tended to be more stable (Table 5). A two-way ANOVA of site and year effects for 1998 and 1999 data only was conducted, excluding data from Argenta, Imlay, and Lovelock due to lack of data. The average weight of the crayfish in each sample was included as a covariate due to concerns that some contaminant concentrations may increase with the age (i.e., associated with size) of the individuals. Beryllium was not detected in any samples and Mo and V were not included in the analysis due to frequent non-detections. Average weight was a significant covariate only for Cd, Hg, Mg, and Sr. No significant differences occurred among sites, between years, or for the site-year interaction for average weight. Significant site-year interactions occurred for Cd, Cr, Cu, Hg, Pb, and Se. All elements were significantly different among sites, except Pb and all but Al, B, Ba, Cd, Cu, and Ni were significantly different between years. Concentrations of Cr, Fe, and Hg were higher in 1998 than 1999, whereas concentrations were higher in 1999 for the remaining constituents where significant differences occurred between years.

A two-way ANOVA of site and year effects for 1998, 1999, and 2000 for Carlin, Palisade, and Emigrant was conducted. Average weight was again included as a covariate. Average weight was a significant covariate for As, Ba, Cd, Mg, Se, and Sr. Site-year interactions were significant for all elements, except B, Cd, Ni, and Pb. Significant differences among sites occurred for all elements, except Pb and Zn, whereas differences among years occurred for all elements, except B and Pb. There were no significant site, year, or site-year interaction effects

for average weight.

Concentrations of Ba were much lower at Rye Patch and Lovelock than at other sites (Figure 17). Both Cr and Hg concentrations tended to be higher in 1998 than in later years (Figures 18 and 19). Concentrations of Mg and Sr tended to be lower in 1998 than in later years (Figures 20 and 21). Concentrations of Mn tended to decline in a downstream direction (Figure 22). Concentrations of Zn tended to be higher in 1999 than in other years (Figure 23).

Corixids

Concentrations of Se (P = 0.004) and Zn (P = 0.037) were higher in corixids from Humboldt Lake in 1999 than 1998 (Table 6), whereas the opposite was true for Cr (P = 0.042) and Hg (P = 0.015). Data from a single sample of notonectids from Humboldt Lake in 1998 are also provided in Table 6.

Fish

Lahontan redside

Concentrations of a number of elements in Lahontan redsides (*Richardsonius egregius*) varied widely among collection sites and years (Table 7). A two-way ANOVA of site and year effects for 1998 and 1999 data only was conducted using data from all sites, except Rye Patch and Lovelock where this species was uncommon. The average weight of the fish in each sample was included as a covariate due to concerns that some contaminant concentrations may increase with the age (i.e., associated with size) of the individuals. Average weight was a significant covariate for Al, Hg, Mg, Mn, Sr, and Zn. Average weight was not significantly different among sites nor was there a significant site-year interaction; however, average weight was significantly lower in 1999. Year-site interactions were significant for all constituents, except Cd and Cr. There were significant differences among sites for all constituents, except Fe. Significant differences occurred between years for all elements, except Ba, Cd, Fe, and Mn. Where significant differences occurred between years, Al and Hg concentrations were lower in 1999 than in 1998, with the opposite being true for the remaining elements.

A second two-way ANOVA of site and year effects for 1998, 1999, and 2000 for Carlin, Palisade, Argenta, and Emigrant was conducted, with average weight as a covariate. The covariate was significant only for Zn. Average weight was not significantly different among sites nor was there a significant site-year interaction. However, average weight was significantly different among years, being the highest in 1998. Site-year interactions were significant for all constituents, except Cd, Cr, Fe, and Hg. There were significant differences among sites for Al, Cd, Cu, Mn, Se, Sr, and Zn, and among years for all constituents, except for Ba, Hg and Mn.

An examination of the data show that Cd concentrations tended to be lower at Emigrant than other sites (Figure 24), as well as a marked increase in Sr (Figure 25) from 1998 to 2000 occurred at Emigrant, with similar increases for Mg, and Ba.

Tahoe sucker

The average weights of Tahoe suckers (*Catostomus tahoensis*) collected in 1999 at Osino and Rye Patch were similar (Table 8); therefore, the data were examined to determine if residue

concentrations were different between the sites. Concentrations of the following elements differed significantly: Ba (P = 0.031), Fe (P = 0.044), Hg (P = 0.009), and Mn (P = 0.024). The small number of samples per site precluded further statistical comparisons. However, concentrations of Al, Ba, Mg, Mn, Sr, and V appeared to decline between 1998 and 1999 at Osino and Palisade, with no overlap in the residue ranges between years, although the small shifts in fish size between years may have been a factor.

Carp

The average weights of carp collected in 1998 at Imlay and Rye Patch were not significantly different; therefore, the data were examined to determine if residue concentrations were different between sites (Table 9). Only Ba was significantly higher at Imlay (P = 0.020). The small number of samples per site precluded further statistical comparisons and the large differences in fish size between years at Imlay and Rye Patch precluded even more general comparisons.

Other species

Concentrations of elements in small numbers of samples of other species of fish that were collected at various sites in 1998 and 1999 are reported in Table 10. The small number of samples per site for a given species precluded statistical comparisons. However, concentrations of Al, Ba, Fe, and Mn in walleye (*Stizostedion vitreum*) in 1998 were much higher at Lovelock than Rye Patch, with only a slight difference in fish size between sites. Also, concentrations of many elements in Sacramento blackfish (*Orthodon microlepidotus*) were lower at Rye Patch than Imlay in 1999, even though the Rye Patch fish were larger.

Fish condition

Data on total length, weight, and Fulton condition factor are provided in Tables 11-13 for several species of fish in each year of the study. Condition factor data should be limited to fish of similar length and not compared among species (Anderson and Neumann 1996). Length and weight of Lahontan redsides tended to be lower in 1999 and 2000 than in 1998 for all sites where samples were collected in more than one year (Table 11). However, Fulton condition factor was more variable, with no consistent trend among sites. Data for Tahoe suckers were limited and varied considerably among sites and between years (Table 12), making interpretation difficult. Data for other species (Table 13) were more sparse, but is provided for future reference.

Avian Eggs

Concentrations of some elements in coot eggs varied among years and collection locations (Table 14). Although concentrations of B were seldom detected in eggs from most areas, it was found in most eggs from Toulon Lake, with concentrations in 1988 (Seiler et al. 1993) significantly higher than in 1999 (P < 0.0001). Barium concentrations differed significantly among years for eggs from Humboldt Lake and between 1988 and 1999 for Toulon Lake (P = 0.026), with no differences among sites in 1998. Concentrations of Cu were not significantly different among years for Humboldt Lake and among areas in 1998; however,

concentrations were higher in 1988 than in 1999 for eggs from Toulon Lake (P = 0.004). Concentrations of Fe and Mg were similar among areas and between years. Concentrations of Hg in coot eggs from Humboldt Lake differed significantly among years, with concentrations being the highest in 1996 and declining in 1998 and 1999. Concentrations of Hg also differed significantly among sites in 1998, with eggs from the Emigrant site having the highest concentrations. Concentrations of Hg in eggs from Toulon Lake were similar in 1988 and 1999 (P = 0.089). Concentrations of Mn were similar in 1999 and 1988 for eggs from Toulon Lake (P = 0.091); there were no differences among sites in 1998 and among years for Humboldt Lake. Concentrations of Se were significantly different among years for eggs from Humboldt Lake, with eggs collected in 1996 having higher concentrations than in either 1998 or 1999. Concentrations of Se were higher in eggs from Humboldt Lake and Rye Patch Reservoir than for eggs from the Emigrant site in 1998. The mean Se concentration for eggs from Toulon Lake between 1988 and 1999 did not change (P = 0.964). Concentrations of Sr were significantly higher in eggs from Humboldt Lake than those from Rye Patch Reservoir and Emigrant in 1998 and higher in 1988 than 1999 for eggs from Toulon Lake (P < 0.0001). Concentrations of Zn were generally similar among sites and years, with the exception that concentrations were higher in 1988 than 1999 for eggs from Toulon Lake (P = 0.014). No significant differences in concentrations were found between Toulon Lake and Humboldt Lake for eggs collected in 1999 (P > 0.05) for the following elements: Ba, Cu, Fe, Hg, Mg, Mn, Se, Sr, and Zn.

Avian Livers

American coot

Concentrations of elements in livers of juvenile coots were compared among years, including data from earlier studies (Table 15). Significant differences in As concentrations were found among years, with the highest mean concentration occurring in 1999 and the lowest in 1988. Concentrations of B were significantly higher in 1986 than in all other years. Concentrations of Cd varied among years with the highest concentration occurring in 1988. Concentrations of Cu and Zn were significantly lower in 1988 and 1996 than in 1986, 1998, and 1999. Concentrations of Fe were similar in 1996, 1998, and 1999, but significantly lower in 1986 and higher in 1988. Mercury concentrations also varied greatly among years, with the lowest mean concentration occurring in 1988 and the highest in 1996. Concentrations of Mg were similar in 1988, 1996 and 1998, but were significantly higher in 1986 and 1999. Concentrations of both Mn and Mo did not differ among years. Concentrations of Se were similar in 1986, 1988, 1996, and 1999, but significantly lower in 1998. Concentrations of Sr were the highest in the last years of sampling.

Concentrations of elements in livers of adult coots in 1999 did not differ by sex (Table 16); therefore, the data were combined prior to comparisons with juvenile coots in the same year. Concentrations of Cd, Fe, and Mo were significantly higher in livers of adults than juveniles (P < 0.0001, 0.002, and 0.012, respectively), whereas the opposite was true for Cu, Sr, and Zn (P = 0.006, 0.025, and 0.015, respectively). No significant differences were found for the remaining elements.

Avocets and stilts

Elemental concentrations in livers of avocets and stilts previously collected in 1996 (Seiler and Tuttle (1997) and in this study are provided in Table 17. Comparisons among groups should be viewed with caution because the effects of botulism, if any, on residue concentrations are unknown. Iron ($P < 0.0001$) and Zn ($P = 0.008$) concentrations were significantly higher in livers of juvenile avocets in 1999 than in 1996, all of which were collected on Humboldt Lake. Chromium and Ni were detected in all juvenile avocet livers collected on Humboldt Lake in 1996, but in none in 1999. Concentrations in juvenile and adult avocets that were collected on Humboldt Lake in 1999 did not differ. Inadequate samples of avocets from Toulon Lake and stilts from Humboldt Lake, both collected in 1999, were available for comparisons with previously collected data.

Discussion

Humboldt River Flows

Flows in the Humboldt River varied widely among the years of study, with the total annual runoff in water years 1998, 1999, and 2000 being 615,400, 344,200, and 158,100 acre feet, respectively at the Comus gage (Preissler et al. 1999; Jones et al. 1999; Allander et al. 2001), a site which was considered representative of general runoff in the basin. The long-term average flow at the Comus gage equals 246,000 acre-feet per year (Allander et al. 2001). Therefore, 1998 may be characterized as a very wet year, 1999 as somewhat above normal, and 2000 as a dry year. Flows peaked in June of each year, with the exception of 1998, when it occurred on May 28 (Figure 26). Sediment loads generally increase with greater river flows (Linsley et al. 1949). Concentrations of elements that are associated with suspended sediment may, therefore, also vary in relation to flows, thus affecting exposure to biotic resources.

Humboldt River Water Quality

Nevada Division of Environmental Protection - Total

Long-term water quality for total concentrations (i.e., unfiltered) in the Humboldt River, as measured by NDEP, tends to decline as one proceeds in a downstream direction (Appendix 7). Concentrations of As, B, and Fe increased between the Battle Mountain and Comus sampling sites, with a lesser increase in TDS. The As concentration at the Maggie Creek site was somewhat elevated from that found at the Carlin and Palisade sites, which are the first upstream and downstream sites, respectively, from the confluence of Maggie Creek with the Humboldt River. Total suspended solids (TSS) declined markedly below Rye Patch Reservoir, probably due to settling of solids during storage, and were lower at the site above the Humboldt Sink than the Battle Mountain, Comus, and Imlay sites that are upstream of the reservoir. The concentration of Fe also declined by nearly 50% below Rye Patch reservoir from that found at Imlay, which is just upstream of the reservoir. This may be related to the change in TSS between these sites.

Concentrations of B in one or more NDEP samples from Comus, Imlay, Rye Patch, and above Humboldt Sink exceeded the irrigation standard (i.e., 750 µg/L), with the geometric means for the latter site exceeding the standard. The aquatic life standard for Fe (i.e., 1,000 µg/L) was exceeded in at least one sample from all sites except Maggie Creek and Rye Patch. The standard was exceeded by an order of magnitude in at least one sample each from Comus and Imlay. The 96-hour aquatic life standard for Se (i.e., 5 µg/L) was occasionally equaled or exceeded in samples from a number of sites, but mean concentrations were well below the standard. Overall geometric means for TSS for all sites from Osino through Rye Patch did not exceed the beneficial use standard (annual median <80 mg/L). There are no standards for TSS for the site above the Humboldt Sink; however, the mean concentration at this site was also lower than the standard for upstream sites. Water quality standards do not appear to apply to Toulon Drain. The single value requirements to maintain existing higher quality (RMHQ; standards for reaches given in parentheses) for TDS were occasionally exceeded at Osino (≤385 mg/L), Carlin and Palisade (≤400 mg/L), Battle Mountain (≤520 mg/L), Comus (≤560 mg/L), Imlay (≤590 mg/L), and Rye Patch (≤700 mg/L); however, the geometric mean concentrations over the long-term period analyzed for these sites were all below the annual average concentrations related to RMHQ as well as the standards for beneficial uses. Generally a water body is identified on Nevada's 303(d) list if more than 10% of the samples exceed the water quality standard.

Nevada Division of Environmental Protection - Dissolved

Short-term (1997-2002) water quality data for dissolved (i.e., filtered) constituents monitored by NDEP are provided in Appendix 8. A degree of caution should be taken in interpretation of these data due to the short period of record. Arsenic and B concentrations tend to increase in a downstream direction, with a near doubling of concentrations between Battle Mountain and Comus. Iron showed a general increase downstream, with a sizeable increase at Battle Mountain and a slight decline below Rye Patch. Concentrations of Cu, Se, and Zn were more variable, with no strong trends. Cadmium, Cr, Hg, and Pb were seldom, if ever, detected. The Nevada Division of Environmental Protection compared Humboldt River water quality (1997-2001) to the hardness dependent standards for Cd, Cr, Cu, Pb, and Zn and found no evidence for 303(d) listing (L. Drozdoff, pers. comm.).

U.S. Geological Survey - Total

The USGS monitored water quality for total constituents (i.e., unfiltered) at Carlin and below Rye Patch Dam on the Humboldt River (Appendix 9). At Carlin element data were collected in 1979-82 and TSS data in 1979-95. At Rye Patch, most data were collected in the period 1975-82, except for Ba and Ni where data collection did not start until 1978 and 1979, respectively. At Rye Patch, data for TSS were collected during 1974-86. Data were obtained from the USGS web site (http://nwis.waterdata.usgs.gov/nwis/qwdata). The mean As concentration at Rye Patch was much higher than at Carlin, similar to the downstream trend found in the NDEP data set. Iron, Mn, Zn, and TSS concentrations at Rye Patch were much lower than at Carlin which may indicate transport of these metals with suspended solids. Concentrations of As, Cu, Fe, Hg, Pb, and Zn at Carlin were slightly higher to much higher than those reported by NDEP. At Rye Patch, concentrations were slightly higher to much higher for

Cu, Fe, and Zn, with higher frequencies of detection for Cd, Cr, Hg, Pb, and Se than data reported by NDEP. However, some differences between the two data sets may be due to variations in periods of sampling, detection limits, sampling techniques, and flows and seasons at the time of sample collection.

U.S. Geological Survey - Dissolved

The USGS monitored water quality for dissolved constituents (i.e., filtered) at several stations on the Humboldt River for varying periods of time (Appendix 10). The earliest and latest years sampled are given in Appendix 10. The USGS data sets for Maggie Creek, Palisade, and Dunphy were limited; therefore, no comparisons using these sites are appropriate. Arsenic concentrations increased by more than three times between Battle Mountain and Rye Patch, similar to the downstream increases seen in both the NDEP and USGS data sets for total As. Concentrations of Mo also increased between Battle Mountain and Rye Patch. Barium declined between Battle Mountain and Rye Patch. The average Mn concentration at Battle Mountain was about one-half that found at Carlin, with an additional decline at Rye Patch. Sampling periods for the NDEP data set for dissolved concentrations were short; therefore, comparisons between the two data sets are not appropriate. Additional information on water quality in the lower Humboldt River basin for 1998-2000 may be found in Paul and Thodal (2003).

Water Quality of Discharges

Newmont Gold Quarry

The Newmont Gold Quarry Mine began discharging groundwater to Maggie Creek in the spring of 1994. Quarterly discharge monitoring reports were provided to the Nevada Division of Environmental Protection from April 1994 through July 1996 and monthly thereafter. Discharge limits were dependent, in part, on water quality conditions in the creek; therefore, water quality in Maggie Creek 3 meters upstream from the point of discharge was also monitored. Data on the following parameters of interest to this study included: pH, and concentrations of TDS, TSS, As, Cd, Fe, Hg, Mn, and Se. Data on National Pollution Discharge Elimination System (NPDES) permit limits were as follows. The 30-day average concentrations for the following constituents were not to exceed the concentration at the upstream site or 50 µg/L for As, 2 µg/L for Cd, 1000 µg/L for Fe, 0.012 µg/L for Hg, 100 µg/L for Mn, 5 µg/L for Se, and 20 mg/L for TSS, whichever concentration was greater for each constituent. The 30-day average concentration for TDS was not to exceed 350 mg/L or 1.33 times the concentration at the upstream site, whichever was less. Concentrations of various constituents for both the discharge and the upstream site are provided in Appendix 11. Discharge flow varied throughout the period of interest which began at the initiation of discharge and ran through September 2000, a point in time consistent with the last collection of biota samples. Discharge flow rates ranged from 0.84 to 27.5 million gallons per day (MGD), with a mean of 15.2 MGD. Permit limits were exceeded during one reporting period for Cd and for 34 reporting periods for TDS. The discharge concentration exceeded the upstream concentration during the following number of reporting periods: As 51, Cd 4, Fe 8, Hg 0, Mn 1, Se 2, TSS 3, and TDS 50. The total number of reporting periods was 60 in each case.

Barrick Goldstrike

Discharges to the Humboldt River by Barrick Goldstrike Mines occurred for 17 months, from September 17, 1997 to February 5, 1999. Monthly monitoring reports were provided by the mine to NDEP throughout the period of discharge. Thirty-day average discharge limits were: As 50 µg/L, B 750 µg/L, Cu 14 µg/L, Fe 1000 µg/l, Pb 4 µg/L, Zn 120 µg/L, TSS 20 mg/L, TDS 425 mg/L, and pH from 7.0 to 8.5. Mean monthly discharge flow ranged from 2.8 to 91.6 MGD, with an average of 49.4 MGD. Concentrations of various constituents for the discharge are provided in Appendix 12. The pH level was below the lower limit in one month. No other permit limits were exceeded.

Lone Tree

Discharges to the Humboldt River by the Lone Tree mine began in July 1991 and continued beyond September 2000, the date of the last collection of biota samples for this study. Monthly monitoring reports were provided to NDEP throughout the period of discharge. Four different outfalls were used for varying periods of time to discharge waters to the Humboldt River. Discharge points were via an unnamed ditch or the Iron Point Relief Canal, which flows to Herrin and Gonzales Sloughs. During this study, discharges from the four numbered outfalls occurred during the following periods: 001 - July 1991 to June 1993; 003 - May to June 1993; 004 - September 1992 to September 1993; 005 - July 1993 to September 2000, the later date being the time of the last collection of samples for this study. Flow rates from July 1991 through August 1992 (all through outfall 001) ranged from 2.13 to 15.7 MGD, with a mean of 9.1 MGD. Flow rates from September 1992 through June 1993 (combined from outfalls 001, 003 and 004) ranged from 21.6 to 25.6 MGD, with a mean of 23.7 MGD. For the period of July 1993 through September 2000, flow rates (all from outfall 005) ranged from 21.9 to 44.6 MGD, with a mean of 36.5 MGD.

Permit limits (maximum 30-day averages or daily maximums listed where averages were not applicable) for the Lone Tree Mine were first established in July 1991 and were modified in April 1994 and November 1995. The As limit for the period of November 1995 until April 1996 or until completion and activation of an As treatment plant, whichever was sooner, did not have to be met until 1.7 miles below the confluence of the Iron Point Relief Canal and the Humboldt River (Comus Gage location) during high flows only if a point 3260 feet below the same confluence was not accessible. Thereafter, the compliance point was at the confluence of the Pipeline Ditch and the Canal, the same point as for other constituents. Limits for the three periods, respectively, were: As - 50 µg/L in all periods; B - 750 µg/L starting in April 1996 and presumably continuing through September 2000; Cu - 26, 21, and 14 µg/L; Fe - 1000 µg/L applicable to only the last two periods; Mn - 200 µg/L presumably applicable only from April 1994 through October 1996; Pb - 50, 8, and 4 µg/L; Zn - 230, 191, and 120 µg/L; pH - not to exceed a range of 6.5 to 9.0 in the first period, followed by 7.0 to 9.0 in the second period, and 7.0 to 8.5 in the third period; TSS - 20 mg/L in all periods; and TDS - 500 mg/L in all periods. Concentrations of various constituents for the discharge are provided in Appendix 13. The 30-day average permit limits were exceeded at outfall 005 the following number of times for the periods given: As - six times in the second period and once in the third; B - six times in the third period; Cu and Fe - once each in the second period; Zn - once in the third period; TSS - four

times in the third period; TDS - nine times in the third period; and pH - 13 times in the third period, all exceeding the upper limit.

Each mine facility that discharged water to either Maggie Creek or the Humboldt River was also required by NDEP to annually monitor a wider variety of elements in their discharges. These results are reported in Appendix 14.

Discharge vs. Humboldt River or Maggie Creek Water Quality

Concentrations of various elements in discharges were compared to concentrations in water from the Humboldt River or Maggie Creek at stations near points of discharge. Caution in interpretation may be needed due to possible differences in sampling frequencies, dates, and periods of record.

Newmont Gold Quarry

The mean As concentration in the discharge to Maggie Creek, a tributary to the Humboldt River, was slightly higher than the mean concentration measured by NDEP (Appendix 7), and more than two times higher than the mean concentration measured upstream of the discharge point as part of permit conditions (Appendix 11). Cadmium, Hg, and Se were seldom detected in samples in the discharge or in Maggie Creek. The concentration of Fe was much lower in the discharge than that found in Maggie Creek. Total suspended solids were lower in the discharge than in upstream samples from Maggie Creek. Total dissolved solids in the discharge were only slightly higher than that found in Maggie Creek by NDEP (Appendix 7) as well as in upstream samples collected as part of permit conditions. For constituents sampled only annually (i.e., B, Cr, Cu, Mg, Pb, and Zn), only B and Zn concentrations were slightly higher than that reported by NDEP (Appendix 7), with Cr, Cu and Pb seldom detected in samples from either source.

Barrick Goldstrike

Concentrations found in the discharge by Barrick (Appendix 12) were compared to long-term mean concentrations found in the Humboldt River at Palisade, the first water quality monitoring site upstream of the discharge point and Battle Mountain, the first sampling site downstream of the discharge point (Appendix 7). The Palisade monitoring station is approximately 20 miles upstream of the Barrick discharge point, whereas the Battle Mountain monitoring station is approximately 20 miles downstream of the discharge point. Arsenic concentrations were far lower in the discharge than in the river. The mean B concentration in the discharge was 3.2 times higher than at Palisade and 2.6 times higher than the mean concentration found at Battle Mountain; however, Barrick was in full compliance with the B effluent limit in the NPDES permit. Copper was detected in only one of 18 samples in the discharge and only in slightly more than 50% of the samples from Palisade. Iron was detected in five of 18 samples in the discharge, but was always found in samples from Palisade; the ranges in concentrations for the two sources barely overlapped, with concentrations at Palisade being much higher than those in the discharge. Lead was seldom detected in samples from the discharge and Palisade. Zinc was detected in 29% of the discharge samples and in 77% of samples from Palisade, with both sets of samples having similar detection limits. Concentrations of TSS in the discharge were

much lower than in the river. The mean TDS concentration in the discharge was 19% higher than at Palisade, but only 3% higher than that found at Battle Mountain.

Lone Tree

The concentrations of various constituents from this mine (Appendix 13) were compared to the long-term averages found in the Humboldt River at Battle Mountain, the first sampling point upstream of the point of discharge, and Comus, the first sampling point downstream from the discharge point (Appendix 7). Concentrations of various constituents in the discharge from the Lone Tree mine varied in relation to the outfall used which was associated with the time of the discharges. The As concentration in discharge from outfalls 001 and 004 were lower than both points on the Humboldt River. However, the mean concentration of As in the discharge from the 005 outfall was 2.7 times that at Battle Mountain and 1.3 times that at Comus. The B concentration in the discharge from the 005 outfall was 3.4 times that at Battle Mountain and 1.7 times that at Comus. Copper was only detected in discharges from the 005 outfall, but only in 38% of the samples, whereas it was found in > 50% of the samples from the two sites on the river. Iron concentrations were much lower in the 005 outfall than either the Battle Mountain or Comus sites. Lead was only detected in discharges from the 005 outfall (38% of the samples) and was found in 30 and 26% of the samples at Battle Mountain and Comus, respectively. Zinc concentrations in samples from outfall 005 were only about one-half that found in samples from the two sites on the river. Concentrations of TSS were lower in the discharge than in the river. Concentrations of TDS were 24 to 33% higher in the discharges than in samples from the Battle Mountain site on the river; however, the concentrations in the discharges were similar to those found at Comus. Cadmium, Cr, Hg, and Se were not detected in samples collected annually from the discharge and were seldom detected in samples from the river. Concentrations of Mg in the annually collected discharge samples were slightly lower than those found at Battle Mountain or Comus.

Overall Loading

Although As concentrations in the discharge from Barrick were lower than those found in the river, the period of discharge was relatively brief when compared with discharges from the Newmont Gold Quarry and Lone Tree mines. Therefore, its influence on total loading would be relatively minor. On the other hand, As concentrations in discharges from the Newmont Gold Quarry and Lone Tree mines were higher than those found near the points of discharge. Concentrations of B were not routinely measured at the Newmont Gold Quarry mine. However, B concentrations in the discharges from both the Barrick and Lone Tree mines were much higher than those found near points of discharge. Concentrations of TDS in the discharges from each mine were slightly higher than those found in upstream sites. The presence of higher concentrations of these constituents in discharges than in upstream sites indicates that total loading would increase. These constituents have the potential to adversely effect wildlife and their habitats in the Humboldt WMA that may suffer from contaminant induced stress.

Paul and Thodal (2003) estimated the cumulative permitted mine-dewatering discharges to surface waters of the Humboldt River and its tributaries ranged from 61 to 206 cubic feet/second from June 1998 through September 1999. Median dissolved solids and total As in

the discharges were about 25 and 0.0010 tons per day, respectively, whereas the median dissolved solids and dissolved As loads for this period for the Humboldt River near Imlay were 440 and 0.016 tons per day, respectively. The total As load in the river would have been somewhat higher than that estimated in the dissolved fraction. The proportion of the loads of As and dissolved solids contributed by the three mines would have been only about 6 percent of the total loads, at most. However, the proportion of the loads contributed by Newmont Gold Quarry and Lone Tree during later periods of lower flows in the river (i.e., 2000) may have been far different when the proportion of discharge to river flows would have been greater. Additional information on the proportion of loads in the Humboldt River contributed by the mines would have been possible if all mines had been required to monitor for the same list of constituents.

Paul and Thodal (2003) stated that "During periods of high flow (greater than 130 ft^3/s) or no irrigation, the river near Lovelock generally carried greater loads of sodium, chloride, dissolved solids,...arsenic, boron, molybdenum, and uranium to the HWMA [Humboldt Wildlife Management Area] than did the agricultural drains....In September 1998 and during sampling from April through September 1999, Toulon and Army Drains [both agricultural drains] carried larger amounts of sodium, chloride, dissolved solids,...arsenic, boron, molybdenum, and uranium than did the river near Lovelock."

Elements in Sediment

Sediment provides both a repository for environmental contaminants and a potential pathway for exposure of fish and wildlife. Concentrations of elements in sediment from Humboldt Lake that were collected in 1990, 1996, and 1999-2000 that were previously reported (Seiler et al. 1993; Tuttle and Seiler 1997; Paul and Thodal 2003) were generally similar to those found in 1998-99 (Table 1). However, direct comparisons may not be appropriate due to differences in sample preparation (i.e., sieving) among years. Concentrations of some elements were highly variable among sites in a given year.

MacDonald et al. (2000) provided consensus-based sediment quality guidelines, specifically threshold effect concentrations (TEC) and probable effect concentrations (PEC), for several elements in relation to biological effects in freshwater ecosystems. A TEC is a concentration below which harmful effects are not likely to be observed and a PEC is a concentration above which harmful effects are likely to be observed, both of which are expressed on a dry weight basis. The TEC and PEC for As are 9.79 µg/g and 33.0 µg/g, respectively. The As TEC was consistently exceeded in all sediment samples from Humboldt Lake in this study, whereas the PEC was not exceeded. The TEC and PEC for Cd are 0.99 µg/g and 4.98 µg/g, respectively. The Cd PEC was not exceeded in any samples in this study, but the TEC was exceeded in one sample in 1998; however, the geometric mean was well below the TEC. The TEC for Cr (i.e., 43.4 µg/g) was not exceeded in any sediment samples in this study. The TEC and PEC for Cu are 31.6 µg/g and 149 µg/g, respectively. The Cu TEC was exceeded in only one sample in 1998 and all concentrations in this study were far below the PEC. The TEC and PEC for Hg are 0.18 µg/g and 1.06 µg/g, respectively. The Hg TEC was exceeded in only one sample in 1998 and all concentrations in this study were far below the PEC. The TEC and PEC for Ni are 22.7 µg/g and 48.6 µg/g, respectively. The Ni TEC was exceeded in one sample

collected in 1998, whereas all concentrations in this study were far below the PEC. The TEC for Pb (i.e., 35.8 µg/g) was not exceeded in any samples. The TEC for Zn (i.e., 121 µg/g) was not exceeded in any samples in this study.

Persaud et al. (1993) identified a concern level for Fe in sediment of 21,200 µg/g (dry weight). This was exceeded in one sample collected in 1998. Persaud et al (1993) also identified a concern level for Mn in sediment of 460 µg/g. This concentration was exceeded in one sample each collected in 1998 and 1999. The toxicity threshold for Se in relation to adverse effects for fish and wildlife was identified as ≥ 4 µg/g (dry weight; Lemly and Smith 1987; U.S. Department of the Interior 1998). This concentration was exceeded in one sample collected in 1999; however, geometric mean Se concentrations in both 1998 and 1999 were below this threshold. Only one sediment sample was involved where the above TECs or other thresholds were exceeded in 1998.

Paul and Thodal (2003) provided additional information on concentrations of As, Cd, Cr, Cu, Hg, and Ni in sediments from the Humboldt River, selected agricultural drains, and Humboldt WMA that were collected in 1999-2000 that exceeded various effects criteria. They concluded that concentrations of Cr, Cu, and Ni generally were higher in sediments collected in 1999-2000 than those collected in previous investigations in 1990 and 1996 (Seiler et al. 1993: Seiler and Tuttle 1997).

Losses of sediments from Humboldt Lake may occur through the exposure of unconsolidated saline playa sediments to wind erosion (Young and Evans 1986; Blank et al. 1999). Therefore, various elements may be removed with the sediments with wind erosion from Humboldt Lake during periods of drought when the area is not flooded. The magnitude and significance of such removal is unclear. Humboldt Lake occasionally overflows to the Carson Sink (Paul and Thodal 2003). Water soluble elements and possibly sediments also may be removed from Humboldt Lake during these periods.

Elements in Vegetation and Aquatic Invertebrates

Sparling and Lowe (1996) reviewed Al accumulation in plants and aquatic invertebrates and indicated that a variety of factors may be involved including ambient concentrations and pH in the growing medium. They reported concentrations of 2,800 µg/g (dry weight) in *Chara* and 2,670-6,480 µg/g (dry weight) in *Potamogeton* sp., which are in the general range of concentrations found in this study. They reported Al concentrations under typical ambient levels frequently exceed 1,000 µg/g (dry weight) in aquatic invertebrates, with concentrations as high as 4,900 µg/g (dry weight) in free-living freshwater insects. Concentrations of Al in dragonfly larvae and crayfish in this study are consistent with the above findings.

Concentrations of elements in aquatic vegetation were also evaluated in relation to those found in other studies. Concentrations of As in pondweeds from a control site (i.e., < 6 µg/g dry weight; Eisler 2000b) were somewhat lower than those from this study. Concentrations of Cd in pondweed in this study were lower than that reported by Eisler (2000a). Concentrations of Cu in algae, pondweed, and *Chara* in this study were near the low range of concentrations reported in freshwater macrophytes (i.e., 2.5 - 256 µg/g dry weight) by Eisler (2000a), with a similar range of concentrations (i.e., 5.0-102.9 µg/g dry weight) in pondweed from Pennsylvania. Nickel

concentrations in algae and macrophytes from reference sites were usually < 15 µg/g dry weight; Eisler 2000a) which is similar to that found in this study. Concentrations of Se in freshwater algae were previously reported to be < 2.0 µg/g dry weight with filamentous algae from a control area having < 0.5 µg/g dry weight (Eisler 2000b), which are generally similar to or somewhat lower than that found in this study.

Jarvinen and Ankely (1999) compiled a database linking effects of various contaminants to tissue residues in a variety of aquatic organisms from controlled studies. The length and route of exposure in the studies cited likely affected test results, whereas tissue residues may have been secondary. In long-term studies with crayfish, whole body residues of Cd, Cu, and Zn that were associated with adverse effects on growth, survival, and/or reproduction appeared to be considerably higher than those found in this study.

Elements in Fish

Schmitt and Brumbaugh (1990) reported geometric mean, 85th percentile, and maximum concentrations (wet weight basis) of As, Cd, Cu, Hg, Pb, Se, and Zn in freshwater fish from a United States national monitoring program conducted in 1984. These data are used here as a general benchmark for residue concentrations in fish. The detection limit for As in this study was higher than the 85th percentile (i.e., 0.27 µg/g) in 1998, similar to the 85th percentile in 1999, and below the 85th percentile in 2000. Detectable As concentrations in fish from this study in 1998 all exceeded the 85th percentile. In 1999, As concentrations in mosquitofish (*Gambusia affinis*) at Humboldt Lake and in some Tahoe sucker samples at all sites sampled for this species exceeded the 85th percentile. The As concentration in carp at Carlin in 2000 equaled the 85th percentile. The maximum concentration of As in 1984 (i.e., 1.5 µg/g) was not exceeded in any samples in this study.

Cadmium concentrations in 1998 in most fish samples from this study at nearly all sites exceeded the 85th percentile (i.e., 0.05 µg/g), with the concentration in one sample at Argenta approaching the maximum concentration (i.e., 0.22 µg/g) reported for 1984. In 1999, the Cd detection limit in this study was slightly higher than the geometric mean for 1984 (i.e., 0.03 µg/g), with concentrations in fish of several species exceeding the 85th percentile. The 1984 maximum concentration was exceeded at Argenta. In 2000, the Cd detection limit in this study was near the 1984 geometric mean; concentrations in Lahontan redsides from all sites equaled or exceeded the 1984 geometric mean, with none greater than the maximum.

The 1984 85th percentile for Cu (i.e., 1.0 µg/g) was often exceeded in fish from this study in 1998, especially in carp and Tahoe suckers, with the 1984 geometric mean (i.e., 0.65 µg/g) very often being exceeded. In 1999, the Cu geometric mean for 1984 was exceeded in almost all samples from this study, with the 85th percentile often exceeded. In 2000, the 1984 Cu geometric mean was exceeded in all fish samples from this study, with none exceeding the 85th percentile. The 1984 maximum Cu concentration (i.e., 23.1 µg/g) was not exceeded in any samples from this study.

The 1984 geometric mean Hg concentration (i.e., 0.10 µg/g) was exceeded in most species of fish from this study from most sites in 1998, with the 85th percentile (i.e., 0.17 µg/g) being exceeded in some samples for certain species. The 1984 maximum (i.e., 0.37 µg/g) was

exceeded in Lahontan redsides at Emigrant and Imlay and in Tahoe suckers at Imlay in 1998. The 1984 geometric mean was again exceeded in 1999 samples of some species of fish from certain sites in this study, with the 85th percentile being exceeded in Lahontan redsides from Argenta, Emigrant, and Osino, and in bluegill (*Lepomis macrochirus*) at Imlay. The 1984 maximum was equaled at Imlay in bluegill. In 2000, the 1984 85th percentile was exceeded in Lahontan redsides at Emigrant and Carlin and the 1984 geometric mean was exceeded in most samples; the 1984 maximum was not equaled or exceeded.

The detection limit for Pb in all years of this study was usually above the 85th percentile (i.e., 0.22 µg/g) reported in 1984. Detectable concentrations reported in 1999 were well above the 85th percentile. No Pb concentrations in this study were near the 1984 maximum concentration for Pb (i.e., 4.88 µg/g).

The 1984 geometric mean concentration for Se (i.e., 0.42 µg/g) was exceeded by the concentrations found in many fish samples from this study in 1998, with the 85th percentile (i.e., 0.73 µg/g) being exceeded in samples of Lahontan redsides from Argenta and pumpkinseed (*Lepomis gibbosus*) from Humboldt Lake. In 1999, at least one sample of each species from each site exceeded the 1984 geometric mean, with the 85th percentile being exceeded in Lahontan redsides from Argenta, Carlin, Emigrant, Imlay, Osino, and Palisade, and in mosquitofish from Humboldt Lake, and equaled by the concentration found in the bluegill sample from Imlay. The 1984 geometric mean was exceeded in all fish samples from this study that were collected in 2000, with the 85th percentile being exceeded in one or more samples of Lahontan redsides from Argenta, Carlin, and Palisade. The 1984 maximum concentration for Se (i.e., 2.3 µg/g) was not approached or exceeded in any samples from this study.

The 1984 85th percentile for Zn (i.e., 34.2 µg/g) was exceeded in 1998 in at least one sample of Lahontan redsides from each site as well as in all samples of carp; however, the 1984 Zn maximum concentration (i.e., 118.4 µg/g) was not approached. The 1984 geometric mean (i.e., 21.7 µg/g) was exceeded by Zn concentrations in almost all samples collected in 1998. The 1984 geometric mean was exceeded in all samples of fish collected in 1999, with the 85th percentile being exceeded in: all samples of Lahontan redsides and carp; some samples of Tahoe sucker at Osino, Palisade, and Rye Patch; in all Sacramento blackfish; and one walleye sample. The 1984 maximum Zn concentration was exceeded in at least one sample each of Lahontan redside at Argenta and Tahoe sucker at Osino. In 2000, the 85th percentile for Zn was consistently exceeded in all fish samples from this study; however, the 1984 maximum concentration was not approached.

Jarvinen and Ankely (1999) compiled a database linking effects of various contaminants to tissue residues in a variety of aquatic organisms from controlled studies. The length and route of exposure in the studies cited likely affected test results, whereas tissue residues may have been secondary. Concentrations of Cd, Cu, Hg, Se, and Zn in whole bodies of fish in this study appeared to be lower than those associated with adverse effects on survival, growth, and/or reproduction in long-term studies that were cited.

Differences in residue concentrations among species are likely due to their respective trophic levels and feeding habits. The Lahontan redside feeds opportunistically on invertebrates, whereas the Tahoe sucker utilizes a broader food base which includes invertebrates, algae, and vascular plants, with littoral bottom feeding being common (Sigler and Sigler 1987). Carp

primarily feed on aquatic invertebrates, with algae being used if more desirable invertebrates are lacking (Sigler and Sigler 1987). Young walleye feed primarily on aquatic invertebrates and small fish, becoming piscivorus as they grow (Sigler and Sigler 1987). The food habits of the Sacramento blackfish differs greatly from those listed above, being primarily a filter feeder on planktonic algae and zooplankton (Sigler and Sigler 1987). These relationships may account for the generally higher concentrations of Hg and Se in species such as the Lahontan redside due to high rates of biomagnification (i.e., Hg; Wiener et al. 2003) or bioaccumulation (i.e., Se; Ohlendorf 2003). Higher concentrations of other metals such as Al and Fe in Tahoe suckers than in the Lahontan redside may be due to suckers feeding on aquatic vegetation, including algae, which had elevated concentrations of these elements, as well as bottom feeding which may include the ingestion of sediment.

The accumulation of elements in fish was evaluated, in part, in relation to invertebrate food sources. Aluminum accumulates in fish, but does not appear to result in toxic effects (Hamilton and Hoffman 2003). Arsenic biomagnifies in invertebrates, but not in fish (Hamilton and Hoffman 2003). The data from this study, where As was seldom detected in fish but was found in both dragonfly larvae and crayfish, are consistent with this information. Cadmium concentrations have generally been found to be higher in aquatic invertebrates than fish (Hamilton and Hoffman 2003). In this study, Cd concentrations were highest in dragonfly larvae and lowest in crayfish, with Lahontan redsides being intermediate. The biochemical regulation of copper in fish prevents toxic effects at low concentrations, in the range found in this study, because it is an essential element to fish (Hamilton and Hoffman 2003). Lead accumulation in fish was reported to be lowest in piscivores, intermediate in predators of macroinvertebrates, and highest in grazers or detritus feeders (Hamilton and Hoffman 2003). This may explain the higher Pb concentrations in Tahoe suckers than Lahontan redsides in this study. Adverse effects in fish associated with manganese exposure have not been reported (Hamilton and Hoffman 2003). Dietary Zn concentrations far higher than those found in aquatic invertebrates in this study had no effects on fish, probably due to zinc being an essential element which is efficiently regulated in fish from a dietary route (Hamilton and Hoffman 2003).

Elements in Biological Samples in Relation to Avian Dietary Effects

Concentrations of elements in biota were evaluated as a potential food source to migratory birds. Effects concentrations for Ba, Be, Fe, Mg, Mn, and Sr are not known and are not discussed further. Comparisons of dietary effect concentrations from studies with mallards to concentrations found in algae in this study should be viewed with caution, especially for ducklings, as waterfowl consumption of algae in the wild is likely to be minimal.

Aluminum

An Al concentration of 5,000 µg/g (dry weight) was considered an adverse dietary effect level in waterfowl (Sparling 1990), with diets less than 1,000 µg/g (dry weight) considered to be not harmful (Sparling and Lowe 1996). However, interactions with calcium and phosphorus are likely important. The higher concentration above was commonly exceeded in algae in all three years, sometimes by three times, with concentrations at Palisade being the only site where

concentrations were consistently lower. Mean concentrations of Al in pondweed and *Chara* did not exceed 5,000 µg/g. Aluminum concentrations in aquatic macroinvertebrates and fish from this study were far below this criterion.

Arsenic

An As concentration of 30 µg/g (dry weight) in the diet of mallard ducklings was associated with reduced weight gain (Camardese et al. 1990). The mean concentration of As in algae exceeded the value associated with reduced weight gain only at Emigrant in 1998, with the mean at Osino in 1999 approaching this concentration. The mean As concentration in pondweed at Humboldt Lake in 1999 also exceeded 30 µg/g, with concentrations in pondweed and *Chara* at other sites and years being considerably lower. Arsenic concentrations in aquatic macroinvertebrates were generally about an order of magnitude below the above effect level, with levels in fish being well below the effect level.

Boron

Weight gain of mallard ducklings whose parents received a diet containing 30 µg/g (dry weight) B and the reproductive success of adult mallards that received a diet containing 1,000 µg/g (dry weight) were significantly reduced (Smith and Anders 1989). All B concentrations in algae were far below the concentration associated with reduced reproductive success, but exceeded the level associated with reduced weight gain in ducklings. All B concentrations in pondweed exceeded the duckling weight gain effect level and mean concentrations at Humboldt Lake in 1998 and Lovelock in 1999 approached the reproductive effect level. Concentrations in *Chara* were considerably lower than those in algae and pondweed, with only the concentrations at Osino in 1998 exceeding the duckling effect level. Aquatic macroinvertebrates in this study had B concentrations below the effect level related to duckling weight gain. Only mosquitofish from Humboldt Lake in 1998 had a mean B concentration exceeding the duckling effect concentration, with concentrations in the 1999 sample and the pumpkinseed sample in 1998 from this site being about one-half of the criterion. Boron was seldom detected in fish samples from other sites.

Cadmium

All Cd concentrations in algae, pondweed, and *Chara* were far below a level of concern in mallard ducklings of 20 µg/g (dry weight; Cain et al. 1983). Cadmium concentrations in dragonfly larvae were generally an order of magnitude lower than this criterion, whereas concentrations in crayfish were often two orders of magnitude lower, with concentrations in corixids and notonectids being somewhat intermediate between the two. Mean Cd concentrations in fish were all < 1 µg/g, thereby being well below the concern level for ducklings.

Chromium

One might expect potential adverse effects on health and reproduction of wildlife when Cr in the diet exceeds 10 µg/g (dry weight; Eisler 2000a). Mean concentrations of Cr in algae in 1998 and 1999 commonly exceeded this threshold, but were lower than the threshold in 2000.

Mean Cr concentrations in pondweed and *Chara* did not exceed the threshold, except for the single sample of *Chara* from Carlin in 1998. Mean Cr concentrations in dragonfly larvae from Palisade, Argenta, and Imlay in 1998 exceeded the above criterion, but were lower than the criterion in all remaining samples in both dragonfly larvae and crayfish. The Cr concentration in one sample of corixids from Humboldt Lake equaled the criterion, with the remainder of concentrations in both corixids and notonectids from this site being lower. The mean Cr concentration in Lahontan redsides from Palisade in 1999 exceeded the above criterion and was approached in the sample from Argenta (excluding the high outlier) the same year. Chromium concentrations in Tahoe suckers were somewhat higher, with means for samples from Osino in 1998 and 1999, and Lovelock in 1999 exceeding the criterion. The mean concentration in carp from Emigrant in 1998 exceeded the criterion. Individual samples from several species of fish and from several sites also exceeded the criterion.

Copper

Eisler (2000a) considered poultry diets containing < 200 µg/g (dry weight) of Cu to be safe. Copper concentrations in all vegetation and fish from this study were far lower than this criterion. Aquatic macroinvertebrates from this study contained Cu concentrations that were lower than this criterion.

Mercury

Adverse reproductive effects in mallards were associated with a dietary concentration of 0.5 µg/g (dry weight; Heinz 1979). Mercury was rarely detected in vegetation samples from this study, with all concentrations being well below the effects concentration. Mean Hg concentrations in dragonfly larvae were lower than the reproductive effects concentration, with the exception of the samples from Emigrant and Imlay in 1998, whereas the only samples of crayfish containing concentrations of Hg that exceeded the criterion were from Emigrant in 1998. All samples of corixids and notonectids from Humboldt Lake had concentrations below the criterion. Mean Hg concentrations in Lahontan redsides, carp, and walleye commonly exceeded the reproductive effects criterion, whereas concentrations in other species of fish were generally lower. Mercury in fish would be of concern if piscivorus birds are as sensitive to mercury as mallards.

Molybdenum

Growth reduction in birds was associated with dietary concentrations of Mo of 200-300 µg/g (dry weight; Eisler 2000b). All vegetation and aquatic macroinvertebrate samples from this study had far lower Mo concentrations than this threshold. All Mo concentrations in fish were < 1.5 µg/g, thereby being far lower than the criterion.

Nickel

A dietary concentration of 800 µg/g (fresh weight) of Ni has been associated with adverse effects to adult mallards (Eisler 2000a). All Ni concentrations in vegetation, aquatic macroinvertebrates, and fish from this study were far lower than this effects concentration.

Lead

An avian dietary concentration of < 5 µg/g (dry weight) of Pb was proposed to be protective by Eisler (2000a). Mean Pb concentrations in most algae samples exceeded this level. The mean Pb concentration in pondweed at Humboldt Lake in 1998 equaled this concentration, whereas the criterion was slightly exceeded in *Chara* samples from Osino in both 1998 and 1999. All mean Pb concentrations in aquatic macroinvertebrate samples, with the exception of Lovelock in 1999, were below this criterion, although a few individual samples from selected sites had concentrations exceeding the criterion. All Pb concentrations in fish were below the above criterion, with only the Lahontan redsides sample from Lovelock in 1998 approaching this level.

Selenium

The lower threshold of dietary exposure associated with reproductive effects in birds is 3 µg/g (dry weight; U.S. Department of the Interior 1998). Mean Se concentrations in vegetation samples did not exceed this threshold. Mean Se concentrations in dragonfly larvae from Palisade, Argenta, and Lovelock in 1999, and from Carlin and Palisade in 2000 equaled or exceeded the threshold effects concentration, whereas all crayfish samples contained concentrations lower than the threshold. Corixid samples from Humboldt Lake in 1999 contained Se concentrations that exceeded the threshold. The threshold criterion was slightly exceeded in some samples of Lahontan redsides in all years and was lower than the criterion in all other fish samples, except for mosquitofish and pumpkinseed from Humboldt Lake in 1998 and 1999, and Sacramento blackfish and bluegill from Imlay in 1999.

Vanadium

The avian dietary concern level for V is 100 µg/g (dry weight; White and Dieter 1978). All V concentrations in vegetation, aquatic macroinvertebrates, and fish from this study were far below this level.

Zinc

The dietary effect levels proposed for the protection of birds are < 178 µg/g to prevent marginal sublethal effects and < 2000 µg/g to prevent the death of chicks and ducklings (Eisler 2000a). Mean Zn concentrations in vegetation samples from this study did not exceed the concentration protective of marginal sublethal effects; however, concentrations in individual samples of algae and pondweed from some sites collected in 1998 and 1999 exceeded this criterion. Mean Zn concentrations in dragonfly larvae occasionally approached the level established to prevent marginal sublethal effects, with concentrations in a few individual samples exceeding that level. Concentrations in crayfish were below this criterion in all samples. The mean Zn concentration in corixids from Humboldt Lake in 1999 exceeded the level established to prevent marginal sublethal effects. Mean Zn concentrations in the majority of Lahontan redsides and carp samples exceeded the level established to prevent marginal sublethal effects, with concentrations generally being lower in other species of fish. The above criterion to prevent death of ducklings and chicks was not exceeded in any fish samples.

Avian Eggs - Trends and Relations to Effects

Four coot eggs and 12 black-necked stilt eggs were collected in 1987 from the Humboldt Wildlife Management Area and analyzed for B, Hg, and Se (Henny et al. 2000). Geometric mean concentrations (dry weight) were as follows: B - coot 5.5 µg/g, stilt 2.9 µg/g; Hg - coot 0.19 µg/g, stilt 0.25 µg/g; and Se - coot 2.3 µg/g, stilt 3.7 µg/g. The B concentration in coot eggs was slightly lower than that found in coot eggs in 1996 at Humboldt Lake by Seiler and Tuttle (1997), but higher than that found in 1998 and 1999 (Table 14). The mean B concentrations in the stilt eggs in 1987 and 1999 were similar. The Hg concentration in coot eggs in 1987 was similar to that found at Toulon Lake in both 1988 and 1999 as well as at Humboldt Lake in 1999, but much lower than in eggs from Humboldt Lake in 1996 and 1998. The Hg concentration in stilt eggs in 1987 was much lower than that found in stilt eggs from Toulon Lake in 1999. Mean Se concentrations in coot eggs in 1987 were generally lower than those found in eggs from Humboldt Lake in 1996-99, and the mean concentration in stilt eggs in 1987 was also lower than that found in 1999. Comparisons using data from stilt eggs collected in 1999 should be viewed with caution due to the small sample size.

Mercury concentrations at Lead Lake at Stillwater National Wildlife Refuge tended to be higher following re-flooding after a period of drought (Tuttle et al. 2000). This phenomenon (i.e., reflooding) may account in part for the elevated concentration of Hg in coot eggs from Humboldt Lake in 1996, with a decline in 1998 and 1999.

Seiler et al. (2003) provided information on background levels and toxic thresholds for contaminants in avian eggs (all on a dry weight basis). The no observed effect level of inorganic As in avian eggs was 1.8 µg/g. All As concentrations in eggs from this study were below this concentration. The highest B concentration in an egg from this study was 6.8 µg/g which is well below the no observed effect level of B of 22 µg/g. The background level of Cd was listed as 0.15 µg/g and no information was provided on a no observed effect level. Cadmium was seldom detected in eggs from this study, with detection limits usually being near or below 0.15 µg/g. Concentrations of Cu in eggs from this study were somewhat below the listed background level of 5.5 µg/g. The no observed effect level and the dose-response threshold in avian eggs for Hg were both listed as 3.0 µg/g, with the background level being 0.1 µg/g. The geometric mean Hg concentration for coot eggs collected at Humboldt Lake in 1996, prior to this study, was 3.2 µg/g, which is slightly higher than the threshold for adverse effects, which was based on the mallard reproductive study by Heinz (1979). Concentrations of Hg in all eggs collected for this study were far below the threshold concentration. The background level, no observed effect level, and lowest observed effect level for Mo in avian eggs were 0.25 µg/g, 23 µg/g, and 23 µg/g, respectively. The detection limit for Mo in eggs from this study was above the background level and the highest concentration (i.e., 7.3 µg/g) was far below the lowest observed effect level. The background level for Se in avian eggs was listed as 1.9 µg/g, with the dose response threshold for toxic effects being 6.0 µg/g. Although the geometric mean Se concentrations in eggs from this study were generally greater than the background level, no eggs had a concentration exceeding the threshold level for toxic effects. The background level for Zn in avian eggs was listed as 50 µg/g, with no information on concentrations related to toxic thresholds. Geometric mean Zn concentrations in eggs from this study were slightly above the background concentration, with

the highest concentration (i.e., 210 µg/g) being four times this level. In summary, concentrations of elements in eggs from this study were below thresholds for toxic effects.

Avian Livers - Relations to Effects

Concentrations of elements were compared to known effect concentrations from various published sources. No data for interpretation were found for Ba, Be, Fe, Mg, Mn, and Sr; therefore, they are not discussed further.

Arsenic is rapidly excreted from avian tissues (Eisler 2000b) and concentrations in all livers from this study were well below concentrations in livers clearly associated with adverse effects such as reduced weight gain and diminished reproductive success (Camardese et al. 1990; Stanley et al. 1994). Concentrations of B in livers of both juvenile and adult birds from this study were usually similar to or only slightly higher than concentrations in control mallards in experimental studies and were lower than concentrations associated with elevated exposures of B that were related to adverse effects (Smith and Anders 1989; Hoffman et al. 1990).

Cadmium concentrations > 3 µg/g (dry weight) in liver were considered indicative of increased environmental exposure, whereas adverse effects were expected at concentrations > 40 µg/g (dry weight; Eisler 2000a). Juvenile birds in this study all had Cd concentrations in liver that were less than the level associated with increased exposure. However, a few adults had concentrations exceeding this level, but far below the adverse effects level. Chromium concentrations in tissues of wildlife > 4 µg/g (dry weight) were associated with probable exposure (Eisler 2000a). Chromium concentrations in bird livers from this study were generally lower than this level, with none greatly exceeding it. The no effect level of Cu in bird liver is < 60 µg/g (dry weight), with the toxicity threshold being > 540 µg/g (dry weight; U.S. Department of the Interior 1998). Few birds from this study had levels exceeding the no effect level, with none more than twice this concentration.

Mercury concentrations in bird livers between 1 to 10 µg/g (wet weight) were considered normal; however, concentrations of > 5 to 6 µg/g (wet weight) may be toxic to sensitive species, which would include mallards and other waterbirds (Heinz 1979; U.S. Department of the Interior 1998; Eisler 2000a). Comparable concentrations on a dry weight basis for comparison with the results of this study would be approximately 3 to 30 µg/g as normal and > 15 µg/g for sensitive species. Mean Hg concentrations in all birds from Humboldt Lake 1998 and 1999 were below the toxic threshold for sensitive species.

Molybdenum concentrations in liver of birds of 22-36 µg/g (dry weight) have been associated with toxic effects (U.S. Department of the Interior 1998). The highest Mo concentration in a bird liver in this study was 20 µg/g, with mean concentrations being far lower. Adverse effects to birds were associated with Ni concentrations in liver > 3 µg/g (dry weight; Eisler 2000a). Nickel was rarely detected in bird livers in 1998 and 1999, with all concentrations being below this level. Lead concentrations in livers of waterfowl > 6 µg/g (dry weight) were considered elevated (Eisler 2000a). Concentrations of Pb in bird livers from this study in 1998 and 1999 did not exceed this level.

Median background concentrations of Se in bird livers were 3.3, 7.5, and 8.2 µg/g (dry weight) for herbivores, omnivores, and carnivores, respectively (U.S. Department of the Interior

1998) with concentrations < 5.2-<10 µg/g (dry weight) classified as being acceptable and concentrations > 10 µg/g (dry weight) being associated with adverse effects (Eisler 2000a). The mean Se concentration in juvenile (both sexes) and adult female coots in 1999 marginally exceeded 10 µg/g (dry weight). Selenium concentrations were somewhat higher in avocets and stilts 1999, usually exceeding 10 µg/g (dry weight), but all but one were below the effect level of 30 µg/g (dry weight; Seiler et al. 2003). American avocets (Robinson et al. 1997) and black-necked stilts (Robinson et al. 1999) are primarily carnivores, with the bulk of their foods being invertebrates. Therefore, they would be expected to have higher concentrations of Se in their livers than American coots because of their relative position in the food chain. American coots are primarily herbivores (Brisbin and Mowbray 2002).

Information on the interpretation of V concentrations in livers of birds is very limited. The lipid metabolism of mallard hens fed 100 µg/g (dry weight) V was altered (White and Dieter 1978). The birds on this dietary concentration had a mean of 0.657 µg/g (wet weight) in their livers, with only 0.019 µg/g (wet weight) in livers of controls; therefore the higher concentration was considered a level of concern. Vanadium concentrations in bird livers from Humboldt Lake in 1998 and 1999 were generally between these concentrations.

Liver concentrations of Zn in various species of birds of 21-33 µg/g (dry weight) were considered normal, whereas livers of Zn-poisoned birds had 75-156 µg/g (dry weight; Eisler 2000a). However, liver concentrations < 210 µg/g (dry weight) were considered to be of no effect by the U.S. Department of the Interior (1998), with concentrations > 2,100 being the toxicity threshold. Mean Zn concentrations in this study were ≤ 200 µg/g (dry weight), with the highest concentration being 256 µg/g.

Relations Among Water and Biota Concentrations

Relations between water and biota

Data on concentrations of elements in biota in relation to specific sampling locations were compared to long-term data on concentrations in water (total) that were reported by NDEP.

Algae - The general increase in As concentrations in algae between Carlin and Palisade is consistent with the As input from Maggie Creek for 1998-99; however, the increase in As concentrations in water between Carlin and Palisade was very minor. The additional increase in As in algae at Emigrant is consistent with the increase in As concentrations in water between Battle Mountain and Comus. However, no additional increases were seen in As concentrations in algae downstream at Rye Patch and Lovelock, unlike the As concentration increases in water between Imlay and above the Humboldt Sink.

No consistent change in B in algae was seen between Carlin and Palisade that would reflect the contribution of B to the river from Maggie Creek. A modest increase in B in algae between Argenta and Emigrant, but not consistent in all years, corresponds with an increase in B concentrations in water between Battle Mountain and Comus. In locations further downstream, changes in B concentrations in algae did not parallel those seen in water. Copper concentrations generally increased in a downstream direction for both water and algae.

Major increases in Fe concentrations in algae in 1999 and 2000 between Palisade and Argenta, with an additional increase at Emigrant, paralleled increases in Fe concentrations in water from Palisade to Battle Mountain, continuing to Comus. However, Fe concentrations decreased between Carlin and Palisade. Iron concentrations in algae below Rye Parch Dam declined slightly from that found at Emigrant, but the relative change was far smaller than that reported in water for similar sites. The declines in Fe concentrations seen in algae between Carlin and Palisade were not observed in water for these two stations. For other elements, no major shifts in concentrations in water were seen between stations with similar results for concentrations in algae.

The concentrations of Mo in algae at Emigrant in 1998-2000 were far higher than those found at other sites. Little or no data were available on Mo concentrations in water for this reach of the river for this period. Seiler and Tuttle (1997) reported 5 and <1 µg/L dissolved Mo at Golconda and 6 and <1 µg/L at Imlay in July and November 1990, respectively. Dissolved Mo concentrations in water from the Humboldt River near Lovelock in 1987 to 1990 ranged from 2 to 12 µg/L. Molybdenum was detected in four of 12 samples collected below Rye Patch Reservoir in 1975-86 and in only three of 29 samples collected at Battle Mountain in 1991-98, with the maximum concentration being 20 µg/L in both cases (Appendix 10). The detection limit was generally 10 µg/L in these samples. Seiler and Tuttle (1997) reported 17 µg/L at Rye Patch in May 1996. Molybdenum concentrations in surface water from the lower Humboldt River in 1998-2000 frequently (i.e., > 50%) exceeded the State water quality standard (19 µg/L) for the protection of aquatic life near Imlay, Rye Patch, and near Lovelock (Paul and Thodal 2003). The detection limit was 1 µg/L in these samples. Paul and Thodal (2003) found a maximum Mo concentration of 115 µg/L (October 7, 1998) among samples collected from the Humboldt River near Imlay. Concentrations of Mo at Rye Patch (range 13-37 µg/L) appear to have increased in recent years.

Aquatic invertebrates and fish - In general, changes in water quality among stations were not reflected in concentrations of various elements in dragonfly larvae. Evaluations included As, B, Cr, Cu, Fe, Mg, Pb, Se, and Zn. An increase in B in crayfish at Emigrant reflects an increase in B concentrations in water between Battle Mountain and Comus; however, there was no further increase in crayfish downstream despite further increases in B concentrations in water. An increase in Fe concentrations in crayfish between Palisade and Emigrant paralleled that found in water for the reach of the river between Palisade and Comus. Decreases in Fe concentrations in water, crayfish, and Tahoe suckers were seen below Rye Patch Dam.

Boron was rarely detected in fish, with the highest concentration in one sample of Lahontan redsides from Lovelock. The highest B concentration in water from the river occurred at the site above the Humboldt Sink, which is consistent with this finding. No other consistent relationships between element concentrations in fish and water were noted.

Relations between river and discharge water quality and residues in biota

Data on mine discharge and river water quality for the years of the study were examined to determine if water quality was associated with changes in residues in biota for the same years. The data on the discharge from the Barrick Goldstrike mine were too brief to be included in the

analysis. Few trends in concentrations of metals or trace elements in discharges from the Newmont Gold Quarry and Lone Tree mines were noted for 1998 to 2000, except for Fe being higher in 1999 than 1998 or 2000 for the Gold Quarry mine and Fe tending to decline throughout the period in the discharge from the Lone Tree mine. No similar trends in Fe residues were noted in algae, aquatic invertebrates or Lahontan redsides at Palisade or Emigrant, the first stations downstream from these sites. Changes in concentrations during 1998-2000 of selected elements (e.g., As, B, Fe, Zn) in water seldom paralleled those found in algae, aquatic invertebrates, and Lahontan redsides during the same years.

Potential effects of mine dewatering discharges on biota

Many of the elements that were analyzed for in biota samples were not consistently included in the list of elements analyzed by the mines as part of their discharge permits, precluding a detailed assessment of potential mine dewatering impacts.

The consistently high concentrations of Mo in algae at Emigrant that were present at no other site that was sampled may have been due to an unreported discharge of this element by the Lone Tree Mine. Results of the 1998 sampling were provided to a number of stakeholders, including personnel from this mine. The Lone Tree Mine subsequently submitted a request to NDEP for a mixing zone for Mo downstream of their discharge point.

Macroinvertebrate sampling in the Humboldt River was conducted between Battle Mountain and Golconda in relation to the Lone Tree mine discharge from 1995 through 2002, with the exception of 1997 and 2001 (Queen of the River Fish Co. undated; Queen of the River Consultants 2000, 2001, 2002). Some sampling stations changed from year to year due to lack of flows at some sites. The ecological condition of the river, based on various indices, varied among stations and years. Biological Condition Index scores provided in these study reports, which are used to assess benthic community health, with higher scores indicating less impacted environments, tended to improve over the years sampled for both sites upstream and downstream from the point of discharge. Biological Condition Index scores tended to be lower at downstream sites. However, a variety of factors other than dewatering discharges might account for these differences as no pre-discharge data were collected.

Macroinvertebrate communities have been monitored on the Humboldt River in relation to discharges from the Barrick Goldstrike Mine, beginning in 1995 and continuing through 2002 (JBR Environmental Consultants, Inc. [JBR] 2002). Biotic Condition Index scores have varied widely among sampling stations both upstream and downstream of the discharge point, with scores at upstream sites declining in the fall of 2001 and spring of 2002. Scores at downstream sites have been more stable during this latter period. Data on water chemistry were also provided in this and previous reports (JBR 1997, 2001a, b); this information was not included or evaluated herein.

Other potential mining-related sources

Nevada is well known for its variety of mineral resources. The following sources of various minerals were noted near the Humboldt River. However, it is unknown if any of these contributed to contaminant burdens in this study.

Molybdenum deposits are known to occur in the Humboldt River basin near the river in the general vicinity of the Lone Tree Mine, including the Golconda mining district, Sonoma Mountain mining district, and Winnemucca (Schilling 1964). Therefore, it is conceivable that Mo deposits may occur at the Lone Tree Mine or that the source of Mo found in algae at the Emigrant site, which is near Golconda, could be in part from other sources. The Battle Mountain mining district is an additional source of Mo (Tuttle et al. 2003); however, it is unclear as to whether flows from this area consistently reach the Humboldt River.

A Hg mine was located immediately to the east of the southern end of Rye Patch Reservoir (Bailey 1964), which potentially could be a source to downstream areas. Air emissions of Hg may occur from Hg retorts at the Lone Tree Mine (Bureau of Land Management 1995), Newmont South Operations Area (Bureau of Land Management 2000), and the Betze Project of Barrick Goldstrike Mines Inc. (Bureau of Land Management1991). Fallout from such emissions would have the potential to adversely affect aquatic resources in the Humboldt River basin. Other Hg sources may exist.

Arsenic widely occurs in ore deposits in Nevada, with known occurrences in the Humboldt River basin including the Getchell Mine in Humboldt County and an area south of Battle Mountain (La Heist 1964). Copper deposits are also present in the Battle Mountain area (Kirkemo 1964) A beryllium source in hot springs deposits has been reported in the Golconda area, with additional varied sources to the east of the river in downstream areas (Griffiths 1964). However, beryllium was not detected (< 5 µg/L) in a water sample from the Golconda Hot Springs in 1974 (http://nwis.waterdata.usgs.gov/nwis/qwdata). A manganese deposit was also reported in the Golconda area (Crittenden 1964). A lead and zinc source was reported near Winnemucca (Kleinhampl 1964).

Recommendations and Conclusions

If future sampling is conducted along the Humboldt River in relation to mine dewatering discharges, data on water quality in the river should be collected immediately upstream and downstream of discharge points to better characterize changes in quality related to the discharges. Similar sampling points for biota would be helpful. Monetary limitations and suitable access points precluded such an approach in this study. The large changes in concentrations of some elements in biota among years, possibly in relation to major changes in river flows, were unexpected. Therefore, any future monitoring, if conducted, should span a longer series of years to capture extreme flow events or at least be conducted during flow regimes similar to that of this study.

Future sampling locations, at a minimum, should include those named Carlin, Palisade, Argenta (if Barrick discharges resume), and Emigrant in this study, as well as the Humboldt WMA. Sampling of each major biota type should be continued with the following recommendations. Algae sampling should continue, but a sub-sample should be retained from each site for identification. *Chara* should no longer be sampled due to its restricted distribution and pondweed should only be sampled at the Humboldt WMA. Both dragonfly larvae and crayfish should be sampled at sites on the river and corixids should be sampled at the Humboldt WMA. Lahontan redsides should be the primary fish species sampled at sites along the river,

with the possibility of only one additional species at downstream sites if Lahontan redsides are not present. An additional fish species could be sampled at the Humboldt WMA. Both bird eggs and livers of coots should be sampled on the Humboldt WMA, with emphasis on pre-flighted juvenile coots for livers, as the residues in such liver samples represent local exposure. All biota samples should be analyzed for a full suite of elements, similar to that of this study. The analysis of a shorter list of elements may not result in reduced costs as many of them are analyzed using the same method (i.e., ICP). An expanded more holistic study should be considered, which would include an evaluation of water and bed sediment chemistry in the river, flows, physical habitat qualities, an assessment of biological communities, and concentrations of elements in biota. Such a study would require the cooperation of multiple partners due to high costs.

The mines are currently required to routinely report concentrations of a very restricted number of elements in their discharges. It would be helpful to expand the number of constituents monitored on a more frequent basis (i.e., more frequently than annually), although it is recognized that increased costs may be a factor in such a decision. The data on Mo in this study demonstrate the need to include it in future monitoring of mine discharges to the river.

A larger array of elements should be monitored in surface waters by NDEP, to at least include all those having State standards, including aquatic life standards (e.g., Mo and silver). These changes were made in February 2004, with minor exceptions (L. Drozdoff, pers. comm.).

The first objective of the study was met, which was to obtain sufficient data to begin to assess trends in surface water quality and trace elements in aquatic vegetation, invertebrates, fish, and bird eggs and livers in the mid to lower Humboldt River basin.

The second objective was to assess the adequacy of State and Federal water quality standards for TDS and elements to protect fish and wildlife resources in the lower Humboldt River basin, and the possible need to establish total maximum daily loads (TMDLs). We did not assess the adequacy of water quality standards and now view this objective as having been overly ambitious. None of the reaches of the Humboldt River or Maggie Creek have been included on the 303(d) list of impaired waters due to arsenic. NDEP has approved TMDLs on the Humboldt River for TDS at Comus and Imlay. The boron standard was exceeded at Battle Mountain and Rogers Dam to the Humboldt Sink, resulting in its inclusion on the 303(d) list. Boron TMDL development for these areas has been assigned a low priority (L. Drozdoff, pers. comm.). There is no clear evidence that mine dewatering discharges had an adverse effect on biological resources in the Humboldt River.

The third objective of the study, which was to attempt to determine the relative proportions of TDS and elements entering the Humboldt WMA that originate from mine dewatering and from agricultural drainwater in the Lovelock area, was only partially met due to differences among mines in reporting requirements (e.g., list of elements monitored), which limited loading estimates to only two constituents. The fulfillment of this objective was further complicated by mines reporting total concentrations in comparison to USGS reporting dissolved (i.e., filtered) concentrations of elements (Paul and Thodal 2003).

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The U.S. Fish and Wildlife Service is solely responsible for the content of this report. The content may not be in agreement with the views of some study cooperators.

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TABLES

Table 1. Geometric mean concentrations [ppm dry weight] (extremes) of elements in sediment samples collected from Humboldt Lake, Humboldt Wildlife Management Area, 1990-99.

	This study[a]		Seiler et al. (1993)[b]	Seiler and Tuttle (1997)[a]	Paul and Thodal (2003)[c]
Element	1998 (n=5)	1999 (n=3)	1990 (n = 1)	1996 (n = 1)	1999-2000 (n = 6)
Al	10608. (6579-22200)	7465. (5238-9617)	na[d]	10400.	34220. (22000-56000)
As	19. (15-28)	22. (19-31)	20.	19.	23. (21-25)
B	69. (39-94)	54. (33-71)	21.	87.	45.[e] (40-50)
Ba	234. (198-331)	203 (179-233)	400.	237.	435. (340-530)
Be	0.33 (0.12-1.1)	0.21 (<0.21-0.38)	< 1	< 0.2	0.97 (0.44-1.8)
Cd	0.44 (0.15-1.4)	0.46 (0.37-0.63)	< 2	0.3	0.19 (<0.1-0.81)
Cr	8.6 (4.7-21)	4.9 (<5.2-7.6)	17.	7.	31. (22-46)
Cu	15. (6.9-33)	13. (8.3-21)	16.	8.	24. (16-36)
Fe	9731. (4286-26620)	6868. (4435-9485)	na	4810.	1809. (1200-2900)
Hg	nd[f] (<0.10-0.20)	0.027 (<0.021-0.05)	0.02	< 0.1	0.06 (0.05-0.11)
Mg	12372. (8746-14750)	9367. (8136-11096)	na	13200.	1419. (1200-1800)

Table 1. (concluded)

Element	This study[a] 1998 (n=5)	This study[a] 1999 (n=3)	Seiler et al. (1993)[b] 1990 (n = 1)	Seiler and Tuttle (1997)[a] 1996 (n = 1)	Paul and Thodal (2003)[c] 1999-2000 (n = 6)
Mn	376. (222-667)	579. (421-1078)	1100.	304.	717. (430-1600)
Mo	1.9 (1.0-3.2)	nd (<5.0-6.3)	4.	<5.1	4.1 (2.0-6.7)
Ni	11. (5.1-26)	8.6 (5.7-12)	8.	6.9	21. (18-26)
Pb	14. (7.5-24)	10. (7.7-12)	7.	8.0	11. (6.4-22)
Se	1.8 (0.67-3.8)	3.3 (2.4-4.6)	1.1	< 0.5	1.2 (1.0-1.5)
Sr	638. (287-976)	1077. (870-1203)	1200.	1400.	817. (510-1100)
V	35. (19-59)	30. (18-63)	52.	22.	72. (49-110)
Zn	39. (18-105)	26. (16-38)	43.	20.	62. (36-100)

[a] Bulk sediment, not sieved.
[b] Sieved, < 2 mm fraction.
[c] Sieved, < 62 µm fraction.
[d] Not analyzed.
[e] n = 2.
[f] nd = not detected in > 50% of samples.

Table 2. Geometric mean concentrations [ppm dry weight] (extremes} of elements in algae collected from the Humboldt River basin, 1998-2000[a].

Element	Year	Osino	Carlin	Palisade	Argenta	Emigrant	Rye Patch	Lovelock	HWMA[b]
Al	1998	5173.	10678.	8030.	7835.	10242.	8346.	15869.	4333.
		(5096-5251)	(7617-14410)	(6833-9323)	(2177-14120)	(9634-11100)	(7405-9203)	(15660-16000)	(2942-6382)
	1999	9255.	6861.	2809.	6920.	10990.	9385.	10835.	5771.
		(7872-10230)	(5912-7807)	(2167-3799)	(4114-12830)	(10280-12090)	(6560-11300)	(10600-11000)	
	2000		5445.	1312.	5082.	5495.			
			(4736-6631)	(1137-1522)	(4754-5260)	(4340-8437)			
As	1998	21.	11.	14.	12.	31.	17.	16.	18.
		(20-22)	(10-13)	(12-15)	(11-14)	(24-36)	(15-22)	(12-18)	(14-24)
	1999	28.	13.	25.	8.7	21.	16.	12.	26.
		(23-35)	(8.7-17)	(22-27)	(7.5-9.4)	(17-24)	(15-17)	(11-13)	
	2000		17.	17.	14.	17.			
			(15-19)	(15-19)	(13-14)	(14-21)			
B	1998	196.	148.	154.	184.	230.	67.	56.	167.
		(184-209)	(114-224)	(111-221)	(132-244)	(217-245)	(36-98)	(33-76)	(109-256)
	1999	187.	219.	199.	155.	179.	59.	51.	102.
		(145-264)	(92-380)	(166-245)	(122-188)	(93-283)	(53-69)	(49-53)	
	2000		292.	324.	223.	151.			
			(258-334)	(312-339)	(200-246)	(131-178)			
Ba	1998	127.	301.	198.	217.	233.	188.	395.	152.
		(122-133)	(238-346)	(147-267)	(125-335)	(205-270)	(176-213)	(295-692)	(138-167)
	1999	398.	359.	128.	306.	283.	183.	1596.	544.
		(332-466)	(244-437)	(109-152)	(281-339)	(233-397)	(167-214)	(1371-1898)	
	2000		238.	179.	346.	151.			
			(185-315)	(152-224)	(329-356)	(124-193)			
Be	1998	0.33	0.47	0.37	0.41	0.44	0.30	0.55	0.14
		(0.23-0.47)	(0.32-0.64)	(0.29-0.47)	(0.21-0.63)	(0.42-0.47)	(0.25-0.37)	(0.54-0.55)	(<0.19-0.20)
	1999	0.55	0.36	0.22	0.36	0.67	0.42	0.53	0.18
		(0.50-0.66)	(0.21-0.47)	(0.19-0.26)	(0.30-0.46)	(0.56-0.79)	(0.35-0.50)	(0.51-0.56)	
	2000		0.35	nd[c]	0.32	0.38			
			(0.29-0.47)	(<0.10-0.10)	(0.29-0.36)	(0.33-0.49)			
Cd	1998	0.58	0.65	0.65	1.0	0.54	0.35	0.73	nd
		(0.50-0.67)	(0.48-0.81)	(0.48-0.83)	(0.92-1.2)	(0.41-0.83)	(0.28-0.42)	(0.63-0.89)	(<0.19)
	1999	0.88	0.53	0.48	0.85	0.68	0.67	2.3	0.38
		(0.78-1.1)	(0.21-0.75)	(0.40-0.62)	(0.75-1.0)	(0.54-0.78)	(0.61-0.74)	(1.8-2.7)	

Table 2. (continued)

Element	Year	Osino	Carlin	Palisade	Argenta	Emigrant	Rye Patch	Lovelock	HWMA
Cd	2000		0.47	0.24	0.71	0.37			
			(0.43-0.51)	(0.20-0.27)	(0.67-0.73)	(0.27-0.63)			
Cr	1998	15.	15.	25.	27.	17.	16.	17.	6.7
		(12-18)	(11-27)	(21-30)	(16-45)	(13-22)	(10-21)	(14-22)	(5.2-8.5)
	1999	15.	11.	9.9	8.4	12.	14.	14.	6.3
		(7.9-29)	(3.9-19)	(6.9-14)	(6.5-11)	(10-15)	(8.9-20)	(10-19)	
	2000		9.0	3.4	9.6	9.8			
			(8.7-9.1)	(3.0-3.8)	(8.5-11)	(6.5-13)			
Cu	1998	9.0	11.	9.9	13.	14.	13.	17.	9.9
		(8.5-9.6)	(8.8-14)	(7.9-14)	(11-17)	(13-15)	(12-15)	(17-18)	(8.0-12)
	1999	12.	8.9	6.7	14.	19.	16.	18.	13.
		(11-14)	(6.3-11)	(5.8-7.4)	(12-15)	(16-24)	(14-19)	(18-19)	
	2000		7.4	3.6	8.7	9.2			
			(6.6-9.3)	(3.1-4.3)	(8.6-8.9)	(7.8-12)			
Fe	1998	4582.	8732.	7157.	7740.	8901.	7700.	14415.	3533.
		(4573-4591)	(5976-12080)	(5904-8457)	(3008-12640)	(8459-9537)	(6625-9111)	(14130-14640)	(2211-5645)
	1999	9455.	6415.	3616.	6704.	11806.	10766.	12285.	5063.
		(8258-10350)	(5043-7638)	(2994-4534)	(4804-10060)	(11370-12730)	(8669-12650)	(11990-12480)	
	2000		5610.	1563.	5236.	6339.			
			(4840-7056)	(1351-1789)	(4931-5439)	(4995-8707)			
Hg	1998	nd	nd	nd	nd	nd	nd	nd	nd
		(<0.19)	(<0.19)	(<0.19)	(<0.19)	(<0.19)	(<0.18)	(<0.19)	(<0.19)
	1999	0.09	0.05	0.05	nd	0.11	0.06	0.12	0.12
		(0.07-0.14)	(<0.04-0.08)	(0.04-0.05)	(<0.04-0.04)	(0.10-0.13)	(0.04-0.11)	(0.11-0.12)	
	2000		0.07	0.05	0.05	0.05			
			(0.06-0.08)	(0.04-0.06)	(0.04-0.05)	(0.04-0.05)			
Mg	1998	3193.	4929.	3686.	4836.	6544.	8289.	8676.	8663.
		(3085-3304)	(4783-5188)	(3297-4638)	(2927-6256)	(6129-7110)	(6718-11400)	(8158-8959)	(7523-9975)
	1999	4611.	4485	3206.	5105.	6768.	7695.	7371.	9590.
		(3964-5058)	(3966-5120)	(2946-3523)	(4489-5918)	(6118-7157)	(7040-8432)	(7171-7531)	
	2000		3342.	2449.	3420.	4345.			
			(3116-3746)	(2338-2576)	(3308-3611)	(3600-5418)			
Mn	1998	1420.	1890.	1299.	669.	904.	1253.	419.	279.
		(1268-1590)	(1260-2191)	(844-2857)	(429-841)	(824-997)	(628-3420)	(378-507)	(126-618)

Table 2. (continued)

Element	Year	Osino	Carlin	Palisade	Argenta	Emigrant	Rye Patch	Lovelock	HWMA
Mn	1999	3225.	1947.	907.	647.	2936.	378.	743.	845.
		(2857-3486)	(1267-2616)	(841-946)	(521-789)	(2204-4339)	(323-426)	(709-779)	
	2000		2506.	2404.	2218.	560.			
			(1839-3658)	(1922-3279)	(1998-2358)	(455-698)			
Mo	1998	3.8	nd	1.0	1.2	18.	nd	nd	1.9
		(3.8)	(<0.94)	(<0.96-2.3)	(<0.98-2.7)	(15-21)	(<0.95-1.2)	(<0.96-1.5)	(1.8-1.9)
	1999	2.2	1.0	1.6	nd	12.	0.83	0.82.	1.4
		(1.9-2.4)	(<0.95-1.7)	(1.4-1.9)	(<0.50-1.4)	(11-13)	(<0.96-1.2)	(<0.93-0.94)	
	2000		1.2	1.5	1.4	9.6			
			(0.74-1.8)	(1.2-2.0)	(0.96-1.8)	(7.5-13)			
Ni	1998	6.8	8.8	9.5	11.	13.	10.	15.	6.8
		(6.3-7.4)	(7.3-11)	(7.2-11)	(7.8-15)	(12-14)	(9.4-12)	(14-15)	(5.4-8.4)
	1999	13.	8.4	7.6	9.8	13.	14.	21.	9.1
		(10-17)	(4.5-12)	(5.8-9.1)	(9.0-11)	(12-15)	(13-16)	(19-23)	
	2000		6.8	3.7	9.8	11.			
			(6.0-8.0)	(3.3-4.2)	(9.5-10)	(9.4-14)			
Pb	1998	4.6	8.2	6.2	5.4	7.6	6.7	14.	6.4
		(3.9-5.4)	(6.0-9.8)	(5.6-7.2)	(2.1-8.1)	(6.0-8.9)	(5.4-8.0)	(14-15)	(5.0-8.2)
	1999	7.3	7.7	3.8	7.2	9.4	9.4	12.	7.4
		(6.5-8.8)	(5.9-9.4)	(3.8-3.9)	(6.4-9.3)	(8.7-9.9)	(7.4-11)	(11-13)	
	2000		8.1	2.8	6.5	5.4			
			(6.7-12)	(2.3-3.4)	(6.2-6.7)	(3.8-8.3)			
Se	1998	1.1	1.4	0.86	0.93	1.8	2.5	1.0	2.4
		(1.0-1.3)	(<0.94-2.1)	(<0.96-1.7)	(<0.98-1.8)	(1.2-2.9)	(1.6-3.2)	(<0.99-1.8)	(1.7-3.4)
	1999	1.2	1.9	nd	nd	0.91	1.6	0.86	1.8
		(0.75-1.5)	(1.1-3.4)	(<0.50-0.72)	(<0.97-1.4)	(<0.93-1.4)	(1.1-1.9)	(<0.93-1.2)	
	2000		1.4	1.7	0.88	0.36			
			(1.1-1.6)	(1.5-2.0)	(0.77-1.1)	(<0.42-0.52)			
Sr	1998	102.	243.	111.	108.	278.	341.	297.	669.
		(98-107)	(180-309)	(87-170)	(96-120)	(217-381)	(280-443)	(231-336)	(524-854)
	1999	146.	285.	111.	317.	204.	268.	200.	737.
		(138-160)	(185-439)	(103-119)	(280-344)	(188-234)	(245-307)	(194-207)	
	2000		163.	139.	155.	179.			
			(151-187)	(118-159)	(139-189)	(151-221)			

Table 2. (concluded)

Element	Year	Osino	Carlin	Palisade	Argenta	Emigrant	Rye Patch	Lovelock	HWMA
V	1998	8.6	13.	13.	15.	16.	19.	29.	13.
		(8.1-9.1)	(9.1-18)	(11-15)	(8.5-22)	(15-17)	(19-20)	(27-30)	(12-15)
	1999	15.	10.	6.2	13.	18.	21.	21.	20.
		(13-16)	(8.7-12)	(5.2-7.5)	(9.3-19)	(15-21)	(16-25)	(19-23)	
	2000		11.	4.7	13.	11.			
			(9.2-13)	(3.8-5.9)	(12-14)	(9.3-15)			
Zn	1998	59.	87.	110.	79.	95.	74.	68.	71.
		(34-102)	(60-126)	(62-204)	(47-116)	(81-116)	(66-80)	(59-87)	(69-74)
	1999	140.	104.	157.	59.	122.	98.	91.	146.
		(39-282)	(20-361)	(107-280)	(35-118)	(53-213)	(45-189)	(47-239)	
	2000		48.	25.	49.	45.			
			(44-52)	(25-26)	(45-57)	(38-60)			

[a] Number of samples collected in 1998, 1999, and 2000, respectively were as follows: Osino - 2, 3, 0; Carlin - 4, 5, 3; Palisade - 5, 3, 3; Argenta - 5, 5, 3; Emigrant - 5, 3, 3; Rye Patch - 3, 3, 0; Lovelock - 3, 3, 0; HWMA - 2, 1, 0. No sampling was conducted at Osino, Imlay, Rye Patch, Lovelock, and HWMA in 2000. Algae, in sufficient quantities for sampling, was not found at Imlay in any of the 3 years.

[b] Humboldt Wildlife Management Area, Humboldt Lake.

[c] nd = not detected in > 50% of samples.

Table 3. Geometric mean concentrations [ppm dry weight] (extremes) of elements in pondweed and *Chara* collected from the Humboldt River basin, 1998 and 1999.

	Pondweed					*Chara*		
	Rye Patch		Lovelock	Humboldt Lake		Osino		Carlin
	1998	1999	1999	1998	1999	1998	1999	1998
Element	(n = 2)	(n = 3)	(n = 3)	(n = 2)	(n = 2)	(n = 3)	(n = 3)	(n = 1)
Al	3196.	2088.A [a]	875.B	2766.	2336.	3810.A	3675.A	4766.
	(2752-3711)	(2011-2174)	(728-1050)	(2562-2987)	(1745-3127)	(3243-4259)	(2990-5495)	
As	9.0	10.A	4.2B	16.	33.	9.0A	9.3A	8.0
	(7.4-11)	(9.6-12)	(4.1-4.5)	(13-21)	(25-44)	(7.6-11)	(8.2-11)	
B	453.	277.A	944.B	904.	360.	50.A	15.B	16.
	(371-553)	(255-308)	(883-1013)	(835-979)	(296-437)	(40-68)	(11-22)	
Ba	89.	118.A	65.B	101.	113.	370.A	372.A	288.
	(81-97)	(113-122)	(59-72)	(97-106)	(94-135)	(322-401)	(324-437)	
Be	nd[b]	0.09	nd	nd	0.08	nd	0.12	< 0.19
	(<0.19)	(<0.10-0.12)	(<0.10)	(<0.19)	(0.10-0.12)	(<0.18)	(<0.20-0.17)	
Cd	0.15	0.24A	0.34A	0.14	0.22	0.27A	0.21A	0.56
	(<0.19-0.24)	(0.20-0.30)	(0.24-0.43)	(<0.19-0.20)	(0.22-0.23)	(0.20-0.44)	(0.15-0.27)	
Cr	5.3	3.1A	3.0A	4.7	4.7	7.3A	3.3A	45.
	(5.2-5.4)	(2.6-4.3)	(2.7-3.5)	(4.4-4.9)	(4.3-5.2)	(4.6-14)	(3.0-3.7)	
Cu	9.1	9.2A	9.1A	6.5	14.	8.2A	6.0A	7.5
	(8.8-9.3)	(8.2-9.8)	(8.6-9.7)	(6.3-6.7)	(11-17)	(6.9-11)	(5.6-6.3)	
Fe	2917.	2536.A	1215.B	2214.	2708.	2910.A	3202.A	5348.
	(2537-3355)	(2388-2661)	(1036-1419)	(1998-2454)	(1984-3697)	(2381-3407)	2633-4071)	
Hg	nd	0.02A	0.03A	nd	0.04	nd	0.02	< 0.19
	(<0.19)	(<0.02-0.03)	(0.02-0.03)	(<0.19)	(0.03-0.05)	(<0.18)	(<0.04-0.03)	
Mg	5370.	5523.A	7342.A	6534.	10083.	5247.A	6508.A	3022.
	(5336-5404)	(5465-5576)	(6423-7974)	(6431-6639)	(8551-11890)	(4703-6248)	(6332-6744)	
Mn	440.	147.A	440.B	149.	237.	2653.A	1798.A	822.
	(329-589)	(138-162)	(416-467)	(99-224)	(178-316)	(622-6056)	(1184-3972)	

Table 3. (concluded)

	Pondweed					*Chara*		
	Rye Patch		Lovelock	Humboldt Lake		Osino		Carlin
	1998	1999	1999	1998	1999	1998	1999	1998
Element	(n = 2)	(n = 3)	(n = 3)	(n = 2)	(n = 2)	(n = 3)	(n = 3)	(n = 1)
Mo	1.6	1.4A	3.8B	2.7	5.7	nd	nd	< 0.94
	(1.1-2.4)	(0.99-2.1)	(3.3-4.2)	(2.5-2.9)	(3.2-10)	(<0.92-1.2)	(<0.50-0.84)	
Ni	7.0	7.9A	6.7A	5.5	6.3	5.7A	3.7B	8.1
	(6.8-7.2)	(7.3-8.6)	(6.2-7.1)	(5.2-5.7)	(5.5-7.3)	(5.5-6.2)	(3.5-3.9)	
Pb	4.4	3.1A	2.8A	5.0	4.4	6.0A	6.5A	4.1
	(4.2-4.7)	(2.7-3.4)	(2.5-3.1)	(4.1-6.0)	(3.8-5.2)	(4.3-7.8)	(6.1-7.1)	
Se	1.6	1.5A	0.97A	2.1	1.4	1.8A	1.2A	< 0.94
	(1.3-2.0)	(1.4-1.8)	(0.63-1.3)	(1.7-2.7)	(1.3-1.4)	(1.3-2.4)	(0.64-1.9)	
Sr	240.	526.A	230.B	511.	628.	495.A	754.A	247.
	(212-272)	(493-593)	(214-259)	(474-551)	(458-861)	394-679)	(672-832)	
V	10.	12.A	10.A	18.	12.	4.9A	4.6A	9.4
	(9.8-11)	(12-13)	(9.3-12)	(12-25)	(9.9-15)	(3.5-6.7)	(3.9-5.7)	
Zn	128.	61.A	128.B	115.	57.	71.A	36.A	30.
	(88-187)	(46-91)	(109-168)	(72-184)	(55-58)	(52-93)	(17-63)	

[a] Means followed by a common capital letter indicate that there was no significant difference (P > 0.05) between Rye Patch and Lovelock in 1999 for pondweed or between 1998 and 1999 for *Chara* at Osino.

[b] nd = not detected in > 50% of samples.

Table 4. Geometric mean concentrations [ppm dry weight] (extremes) of elements in dragonfly larvae collected from the Humboldt River, 1998-2000[a].

Element	Year	Osino	Carlin	Palisade	Argenta	Emigrant	Imlay	Lovelock
Al	1998	1814.	1029.	1333.	2286.	1144.	916.	969.
		(1699-1937)		(1153-1540)	(1609-3121)	(944-1387)	(915-916)	(936-1003)
	1999	1249.	652.	671.	738.		1061.	991.
		(955-1640)	(498-797)	(613-718)	(576-1205)			(921-1067)
	2000		505.	434.	662.	1387.		
			(398-730)	(328-618)	(641-707)	(1002-1782)		
As	1998	2.1	1.7	2.4	1.5	1.2	1.1	1.2
		(2.1-2.2)		(2.3-2.4)	(1.4-1.6)	(1.1-1.3)	(1.0-1.2)	(1.1-1.4)
	1999	2.3	2.1	2.2	2.4		1.5	2.2
		(2.0-2.5)	(1.7-2.4)	(2.1-2.3)	(1.9-2.9)			(2.0-2.5)
	2000		1.8	2.0	2.0	1.9		
			(1.7-2.2)	(1.8-2.2)	(1.8-2.4)	(1.8-2.0)		
B	1998	5.5	< 3.7	4.6	6.5	5.5	5.7	4.5
		(5.5-5.6)		(4.6-4.7)	(5.3-8.4)	(4.5-6.8)	(5.0-6.5)	(4.3-4.8)
	1999	nd[b]	nd	nd	5.0		12.	3.3
		(<3.9)	(<3.7)	(<4.0)	(4.3-6.7)			(<3.9-5.8)
	2000		nd	nd	nd	9.3		
			(<3.9)	(<3.9)	(<3.9)	(8.3-11)		
Ba	1998	38.	22.	134.	46.	34.	34.	22.
		(36-41)		(51-354)	(32-59)	(28-40)	(28-42)	(22-23)
	1999	36.	20.	22.	27.		29.	21.
		(34-37)	(16-24)	(19-28)	(24-30)			(21)
	2000		22.	25.	27.	33.		
			(18-26)	(21-33)	(26-30)	(27-39)		
Be	1998	nd	nd	nd	nd	nd	nd	nd
		(<0.19)	(< 0.18)	(<0.18)	(<0.18)	(<0.19)	(<0.20)	(<0.19)
	1999	nd	nd	nd	nd		nd	nd
		(<0.20)	(<0.19)	(<0.20)	(<0.19)		(< 0.20)	(<0.19)
	2000		nd	nd	nd	nd		
			(<0.20)	(<0.20)	(<0.19-0.23)	(<0.20-0.22)		

Table 4. (continued)

Element	Year	Osino	Carlin	Palisade	Argenta	Emigrant	Imlay	Lovelock
Cd	1998	1.4	1.0	1.6	1.6	0.23	0.64	0.66
		(1.4-1.5)		(1.4-1.7)	(1.1-2.0)	(0.21-0.26)	(0.55-0.75)	(0.62-0.70)
	1999	1.5	0.75	1.5	2.1		1.6	1.2
		(1.3-1.7)	(0.52-1.0)	(1.4-1.6)	(1.9-2.4)			(1.1-1.5)
	2000		0.30	0.75	1.4	1.3		
			(0.26-0.34)	(0.69-0.82)	(1.1-1.5)	(1.1-1.4)		
Cr	1998	8.8	4.9	48.	21.	7.9	11.	4.7
		(5.9-13)		(39-60)	(7.5-79)	(4.2-15)	(7.7-16)	(4.4-5.0)
	1999	4.5	2.9	2.9	1.9		3.9	4.3
		(3.5-5.5)	(2.2-3.5)	(1.9-4.8)	(1.5-2.2)			(4.2-4.4)
	2000		1.8	0.98	1.7	3.7		
			(1.1-3.6)	(<0.97-1.7)	(1.4-1.9)	(2.7-5.4)		
Cu	1998	22.	21.	21.	20.	17.	19.	22.
		(22)		(20-21)	(18-22)	(16-17)	(19-20)	(22)
	1999	27.	20.	22.	20.		24.	26.
		(26-28)	(18-21)	(22-23)	(19-21)			(25-27)
	2000		19.	21.	22.	18.		
			(18-20)	(19-23)	(20-23)	(16-19)		
Fe	1998	1512.	815.	2072.	2061.	1035.	1011.	961.
		(1479-1545)		(1816-2365)	(1420-2992)	(832-1287)	(997-1026)	(949-974)
	1999	990.	613.	602.	744.		935.	976.
		(947-1054)	(453-750)	(590-617)	(633-996)			(944-1010)
	2000		547.	507.	684.	1514.		
			(442-752)	(412-706)	(659-710)	(1142-1952)		
Hg	1998	0.15	nd	nd	nd	0.88	0.66	0.32
		(<0.20-0.22)	(< 0.18)	(<0.18)	(<0.18-0.21)	(0.87-0.89)	(0.64-0.68)	(0.31-0.33)
	1999	0.17	0.14	0.14	0.13		0.16	0.20
		(0.17-0.18)	(0.14-0.15)	(0.12-0.15)	(0.11-0.14)			(0.18-0.22)
	2000		0.31	0.25	0.23	0.10		
			(0.22-0.40)	(0.21-0.27)	(0.22-0.25)	(0.09-0.10)		

Table 4. (continued)

Element	Year	Osino	Carlin	Palisade	Argenta	Emigrant	Imlay	Lovelock
Mg	1998	1159. (1139-1180)	909.	1116. (1096-1136)	1244. (997-1480)	1075. (971-1190)	997. (967-1027)	958. (956-959)
	1999	1263. (1166-1358)	908. (818-971)	1074. (1055-1094)	1062. (937-1203)		1425.	1181. (1150-1212)
	2000		726. (671-837)	809. (715-959)	973. (917-1029)	1337. (1055-1569)		
Mn	1998	440. (383-506)	204.	464. (461-468)	204. (147-240)	150. (103-217)	80. (71-90)	50. (50)
	1999	623. (593-677)	180. (169-194)	266. (261-274)	168. (147-181)		79.	59. (52-66)
	2000		288. (261-338)	423. (308-591)	171. (163-182)	140. (120-154)		
Mo	1998	nd (<0.93)	nd (< 0.92)	0.73 (<1.0-1.1)	nd (<0.91-1.7)	1.3 (1.3)	nd (<0.97)	nd (<0.94)
	1999	nd (<0.97)	nd (<0.93)	nd (<0.99)	nd (<0.93)		nd (< 0.99)	nd (<0.97)
	2000		nd (<1.0-1.6)	nd (<0.97-1.5)	0.86 (<1.0-1.2)	nd (<1.0-1.5)		
Ni	1998	2.7 (2.6-2.8)	2.5	4.5 (4.3-4.7)	3.7 (2.4-7.0)	3.5 (3.1-3.9)	2.7 (2.3-3.1)	3.2 (3.1-3.4)
	1999	2.5 (1.9-3.6)	1.4 (1.3-1.7)	2.6 (1.9-4.3)	2.7 (2.4-2.9)		3.4	2.3 (2.0-2.5)
	2000		1.2 (1.0-1.5)	1.5 (1.4-1.9)	2.1 (1.6-2.7)	3.5 (2.8-4.5)		
Pb	1998	nd (<1.9)	nd (< 1.8)	2.8 (<1.8-8.7)	nd (<1.8-1.9)	nd (<1.9)	nd (<2.0)	nd (<1.9)
	1999	2.4 (1.5-4.5)	0.97 (<0.93-1.7)	1.4 (<1.0-3.6)	nd (<0.93)		1.2	5.9 (5.7-6.2)
	2000		nd (<2.0)	nd (<2.0)	nd (<1.9-2.3)	nd (<1.8)		

Table 4. (concluded)

Element	Year	Osino	Carlin	Palisade	Argenta	Emigrant	Imlay	Lovelock
Se	1998	2.3	2.9	2.2	2.5	1.5	1.6	2.1
		(2.1-2.5)		(2.0-2.5)	(2.2-2.9)	(1.4-1.7)	(1.5-1.6)	(2.1)
	1999	2.5	2.8	3.2	3.0		2.5	4.3
		(2.3-2.7)	(2.4-3.1)	(3.0-3.4)	(2.5-3.4)			(3.8-4.9)
	2000		3.6	3.2	2.8	2.2		
			(3.6-3.8)	(3.0-3.3)	(2.6-3.2)	(2.1-2.4)		
Sr	1998	19.	15.	20.	25.	21.	42.	18.
		(18-20)		(18-21)	(19-32)	(17-25)	(28-63)	(16-19)
	1999	17.	17.	13.	20.		46.	18.
		(15-19)	(14-21)	(13-14)	(19-22)			(18-19)
	2000		17.	17.	18.	43.		
			(16-18)	(15-19)	(17-20)	(32-59)		
V	1998	2.9	1.8	3.6	4.9	2.2	1.8	2.3
		(2.8-3.0)		(3.2-4.0)	(3.0-10)	(1.7-2.9)	(1.8-1.9)	(2.2-2.3)
	1999	2.0	0.98	1.6	1.7		2.2	2.4
		(1.8-2.3)	(<0.96-1.5)	(1.5-1.7)	(1.5-2.0)			(2.3-2.6)
	2000		0.94	1.3	1.5	2.5		
			(<1.0-1.6)	(1.0-1.5)	(1.4-1.7)	(1.9-3.3)		
Zn	1998	128.	131.	155.	121.	139.	116.	112.
		(127-130)		(140-172)	(113-134)	(137-142)	(114-118)	(107-117)
	1999	169.	143.	176.	124.		171.	172.
		(152-202)	(120-189)	(148-208)	(108-148)			(155-190)
	2000		108.	128.	129.	108.		
			(103-118)	(116-141)	(123-136)	(96-117)		

[a] Number of samples for 1998, 1999, and 2000 were as follows: Osino - 2, 3, 0; Carlin - 1, 3, 3; Palisade - 2,3,3; Argenta - 3,3,3; Emigrant - 2, 0, 3; Imlay - 2, 1, 0; Lovelock - 2, 2, 0. Sampling at Osino, Imlay, and Lovelock was not conducted in 2000. Adequate numbers of dragonfly larvae were not present for sampling at Rye Patch.

[b] nd = not detected in > 50% of samples.

Table 5. Geometric mean concentrations [ppm dry weight] (extremes) of elements and arithmetic mean weight per individual [grams] in crayfish collected from the Humboldt River, 1998-2000[a].

Weight or Element	Year	Osino	Carlin	Palisade	Argenta	Emigrant	Imlay	Rye Patch	Lovelock
Mean weight	1998	17.	25.	16.	42.	19.		25.	6.1[b]
		(2.5-30)	(16-38)	(6.3-26)		(5.2-32)		(12-39)	(1.2-17)
	1999	21.	21.	23.		17.	13.	32.	10.
		(8.9-38)	(13-30)	(13-29)		(7.2-31)		(14-58)	(1.5-19)
	2000		21.	21.		6.2			
			(13-32)	(11-35)		(2.1-10)			
Al	1998	617.	425.	279.	527.	487.		304.	644.
		(560-709)	(333-547)	(234-311)		(398-716)		(241-414)	(368-1378)
	1999	513.	177.	320.		589.	338.	213.	478.
		(329-699)	(146-250)	(294-339)		(518-683)		(156-293)	(289-724)
	2000		122.	60.		457.			
			(107-145)	(52-70)		(418-500)			
As	1998	1.5	1.4	3.1	< 0.97	1.3		2.4	1.9
		(1.2-1.7)	(0.97-2.0)	(3.0-3.4)		(1.1-1.6)		(1.6-3.5)	(1.5-2.8)
	1999	2.0	1.9	2.1		1.7	1.4	2.5	3.6
		(1.6-2.6)	(1.7-2.0)	(2.0-2.2)		(1.4-1.8)		(2.4-2.7)	(2.9-5.0)
	2000		2.3	2.2		2.4			
			(2.3-2.5)	(2.0-2.5)		(2.1-2.6)			
B	1998	9.9	3.7	nd[c]	3.9	6.1		6.7	8.7
		(9.1-10)	(<3.7-5.7)	(<3.7-6.1)		(5.9-6.3)		(4.6-8.1)	(7.5-11)
	1999	3.3	4.0	nd		11.	18.	7.0	7.3
		(<4.0-4.6)	(<3.8-7.3)	(<4.0)		(9.9-13)		(6.0-8.1)	(7.2-7.6)
	2000		nd	nd		8.2			
			(<4.0)	(<3.9)		(7.4-9.0)			
Ba	1998	157.	203.	181.	146.	162.		100.	122.
		(129-190)	(188-233)	(158-202)		(150-174)		(91-107)	(97-140)
	1999	197.	201.	175.		281.	200.	86.	107.
		(189-203)	(179-232)	(145-196)		(261-294)		(75-99)	(102-115)
	2000		269.	260.		306.			
			(261-285)	(208-325)		(295-318)			
Cd	1998	0.36	0.19	0.40	0.22	0.24		0.18	0.36
		(0.28-0.53)	(<0.18-0.31)	(0.28-0.49)		(<0.19-0.46)		(<0.18-0.29)	(0.35-0.39)

Table 5. (continued)

Weight or Element	Year	Osino	Carlin	Palisade	Argenta	Emigrant	Imlay	Rye Patch	Lovelock
Cd	1999	0.24	0.21	0.63		nd	0.29	0.31	0.56
		(<0.20-0.44)	(<0.19-0.36)	(0.58-0.75)		(<0.19-0.21)		(0.27-0.35)	(0.54-0.61)
	2000		nd	nd		0.16			
			(<0.20)	(<0.20-0.23)		(<0.20-0.27)			
Cr	1998	3.1	1.9	2.6	3.9	5.0		2.8	3.1
		(3.0-3.4)	(1.6-2.3)	(2.3-3.2)		(3.2-9.2)		(2.1-4.0)	(2.3-5.2)
	1999	1.0	nd	1.4		1.3	1.3	1.5	1.6
		(<0.99-1.7)	(<0.91-0.96)	(1.2-1.9)		(1.2-1.4)		(1.3-2.1)	(1.0-3.1)
	2000		nd	nd		1.2			
			(<0.99)	(<0.97)		(1.2-1.3)			
Cu	1998	55.	67.	73.	70.	80.		56.	93.
		(49-68)	(48-82)	(57-94)		(73-85)		(51-59)	(75-117)
	1999	71.	50.	91.		94.	124.	71.	90.
		(58-84)	(49-51)	(78-105)		(77-123)		(52-87)	(82-98)
	2000		34.	31.		72.			
			(31-41)	(30-32)		(62-84)			
Fe	1998	372.	273.	212.	350.	358.		272.	494.
		(332-422)	(207-351)	(168-249)		(267-494)		(204-367)	(293-963)
	1999	282.	102.	191.		392.	225.	181.	351.
		(181-386)	(89-129)	(189-195)		(339-432)		(105-295)	(256-503)
	2000		74.	45.		283.			
			(66-82)	(43-48)		(258-311)			
Hg	1998	0.24	0.21	0.25	0.55	0.56		0.32	0.34
		(<0.19-0.42)	(0.20-0.23)	(0.21-0.29)		(0.50-0.62)		(0.28-0.38)	(0.32-0.40)
	1999	0.17	0.11	0.20		0.29	0.19	0.21	0.16
		(0.13-0.22)	(0.10-0.12)	(0.16-0.24)		(0.24-0.34)		(0.13-0.31)	(0.14-0.18)
	2000		0.19	0.12		0.29			
			(0.17-0.23)	(0.09-0.18)		(0.24-0.36)			
Mg	1998	2222.	2357.	2245.	2361.	2216.		2775.	2673.
		(1985-2717)	(2185-2553)	(2029-2420)		(1883-2419)		(2204-3193)	(2407-3149)
	1999	2981.	2769.	2742.		4298.	3975.	3671.	3204.
		(2820-3223)	(2427-3333)	(2492-2981)		(4051-4546)		(3096-4453)	(2786-3728)

Table 5. (continued)

Weight or Element	Year	Osino	Carlin	Palisade	Argenta	Emigrant	Imlay	Rye Patch	Lovelock
Mg	2000		2812. (2642-2989)	2649. (2299-3302)		3119. (3018-3222)			
Mn	1998	203. (172-248)	116. (103-132)	169. (165-175)	95.	153. (140-180)		49. (43-55)	52. (44-69)
	1999	438. (356-487)	183. (169-205)	132. (117-143)		189. (154-214)	238.	34. (29-44)	61. (54-77)
	2000		257. (239-280)	225. (205-250)		101. (96-106)			
Mo	1998	nd (<0.89)	nd (<0.89)	nd (<0.92-1.0)	< 0.97	nd (<0.91)		nd (<0.90)	nd (<0.91)
	1999	nd (<0.98)	nd (<0.91)	nd (<0.99-1.2)		nd (<0.94-0.94)	< 0.94	nd (<0.98)	nd (<0.98-5.2)
	2000		nd (<0.99)	nd (<0.97)		nd (<0.96)			
Ni	1998	1.1 (1.1-1.2)	nd (<0.89-1.3)	1.5 (1.5-1.7)	1.2	1.6 (1.4-1.9)		1.5 (1.2-1.9)	1.1 (<0.93-2.4)
	1999	nd (<0.98-1.5)	nd (<0.91-1.1)	1.8 (1.4-2.4)		1.5 (1.4-1.6)	1.4	2.1 (1.8-2.2)	1.9 (1.5-2.3)
	2000		nd (<0.99)	nd (<0.98-1.1)		0.86 (<1.0-1.5)			
Pb	1998	1.8 (<1.9-3.0)	1.9 (1.9-2.0)	1.8 (<1.9-3.2)	< 1.9	nd (<1.9-1.9)		nd (<1.8-2.0)	1.8 (<1.9-2.7)
	1999	4.8 (3.2-7.3)	1.1 (<0.91-2.0)	4.0 (1.8-10)		3.5 (2.8-4.9)	2.5	4.7 (4.0-5.9)	1.9 (<0.99-3.7)
	2000		2.3 (2.0-2.6)	2.4 (2.2-2.8)		2.4 (2.2-2.7)			
Se	1998	nd (<0.93-0.91)	nd (<0.89)	1.1 (0.99-1.3)	1.3	nd (<0.91)		1.3 (0.94-1.6)	0.92 (<0.91-1.4)
	1999	nd (<0.99-1.0)	nd (<0.94-0.92)	1.3 (1.2-1.5)		nd (<0.93)	1.3	1.9 (1.3-2.3)	1.7 (1.5-2.0)
	2000		1.2 (1.1-1.4)	1.2 (0.84-1.4)		0.99 (0.95-1.0)			

Table 5. (concluded)

Weight or Element	Year	Osino	Carlin	Palisade	Argenta	Emigrant	Imlay	Rye Patch	Lovelock
Sr	1998	368. (334-424)	464. (391-554)	436. (411-476)	403.	453. (351-550)		479. (397-562)	473. (406-538)
	1999	563. (505-650)	645. (560-817)	531. (466-590)		1323. (1210-1390)	556.	562. (505-688)	659. (598-754)
	2000		746. (731-768)	776. (713-840)		1466. (1277-1682)			
V	1998	nd (<0.93-1.1)	nd (<0.89)	nd (<0.92)	< 0.97	nd (<0.91-1.2)		nd (<0.90-0.94)	nd (<0.93-2.3)
	1999	nd (<0.98-1.2)	nd (<0.91)	nd (<0.99)		nd (<0.93-1.3)	< 0.94	nd (<0.98)	nd (<0.98-1.5)
	2000		nd (<0.99)	nd (<0.97)		0.72 (<1.0-1.0)			
Zn	1998	70. (67-77)	79. (68-86)	79. (68-87)	80.	77. (70-83)		90. (87-93)	79. (69-89)
	1999	112. (98-129)	82. (73-96)	122. (116-134)		125. (103-176)	126.	147. (131-160)	154. (144-171)
	2000		62. (58-68)	51. (45-55)		73. (65-82)			

[a] Sample numbers for 1998, 1999, and 2000, respectively, were as follows: Osino - 3, 3, 0; Carlin - 3, 3, 3; Palisade - 3, 3, 3; Argenta - 1, 0, 0; Emigrant - 3, 3, 2; Imlay - 0, 1, 0; Rye Patch - 3, 3, 0; Lovelock 3, 3, 0. No sampling was conducted at Osino, Imlay, Rye Patch, and Lovelock in 2000. Beryllium was not detected in any samples.

[b] n = 2.

[c] nd = not detected in > 50% of samples.

Table 6. Geometric mean concentrations [ppm dry weight] (extremes) of elements in corixids and notonectids collected from Humboldt Lake, Humboldt Wildlife Management Area, 1998-99.

	Corixids				Notonectids
Element	1998 (n = 4)		1999 (n = 3)		1998 (n = 1)
Al	417.	(143-1375)	190.	(98-296)	84.
As	2.8	(1.8-3.8)	1.8	(1.5-2.1)	2.2
B	21.	(18-27)	11.	(7.2-20)	21.
Ba	19.	(5.6-56)	6.6	(3.6-9.8)	5.7
Be	nd[a]	(<0.19)	nd	(<0.19)	< 0.19
Cd	0.23	(<0.20-0.35)	0.60	(0.34-1.0)	0.40
Cr	7.4	(5.3-10)	1.2	(<0.97-2.0)	5.5
Cu	17.	(14-20)	22.	(15-29)	13.
Fe	617.	(294-1389)	276.	(194-356)	237.
Hg	0.25	(0.19-0.38)	0.06	(0.04-0.10)	0.27
Mg	1552.	(1145-2167)	1498.	(1310-1759)	1281.
Mn	40.	(21-70)	35.	(23-56)	23.
Mo	2.6	(1.7-3.9)	2.6	(1.9-3.4)	1.2
Ni	2.2	(<0.97-3.8)	0.86	(<0.97-1.3)	< 0.94
Pb	nd	(<1.9)	nd	(<0.96-1.7)	< 1.9
Se	1.3	(1.1-2.1)	3.6	(3.3-3.9)	2.4
Sr	56.	(31-107)	24.	(19-34)	35.
V	1.6	(<0.97-3.8)	nd	(<0.96-1.4)	< 0.94
Zn	122.	(93-157)	196.	(174-226)	157.

[a] nd = not detected in > 50% of samples.

Table 7. Geometric mean concentrations [ppm dry weight] (extremes) of elements and arithmetic mean weight per fish [grams] of Lahontan redsides collected from the Humboldt River, 1998-2000[a].

Weight or Element	Year	Osino	Carlin	Palisade	Argenta	Emigrant	Imlay	Lovelock
Mean weight	1998	4.1	4.0	4.9	7.2	5.4	8.4	1.8
		(2.3-5.4)	(2.6-5.1)	(3.8-6.2)	(1.9-15)	(1.9-7.6)	(1.5-14)	
	1999	1.2	2.5	1.5	1.8	2.7	4.0	
		(0.91-1.5)	(1.4-5.1)	(1.1-1.9)	(0.95-3.3)	(2.0-3.1)		
	2000		1.2	1.9	1.7	2.2		
			(1.2)	(0.72-3.3)	(0.82-2.9)	(1.4-3.0)		
Al	1998	159.	317.	191.	84.	230.	66.	2827.
		(72-252)	(199-543)	(138-299)	(39-133)	(150-499)	(41-107)	
	1999	37.	127.	115.	246.	189.	43.	
		(29-42)	(48-306)	(72-180)	(151-386)	(111-500)		
	2000		32.	73.	19.	157.		
			(30-35)	(65-99)	(17-24)	(116-200)		
As	1998	nd[b]	nd	nd	nd	nd	nd	2.0
		(<1.8)	(<1.9)	(<1.8)	(<1.9)	(<1.8)	(<1.8)	
	1999	nd	nd	nd	nd	nd	< 1.0	
		(<0.98)	(<0.98)	(<0.98)	(<0.98-1.0)	(<1.0)		
	2000		nd	nd	nd	0.69		
			(<0.78)	(<0.74)	(<0.74)	(<0.79-1.1)		
B	1998	nd	nd	nd	nd	nd	nd	5.3
		(<3.7)	(<3.8)	(<3.7)	(<3.8)	(<3.7)	(<3.6)	
	1999	nd	nd	nd	nd	nd	< 4.0	
		(<3.9)	(<3.9)	(<3.9)	(<3.9-5.0)	(<4.0)		
	2000		nd	nd	nd	nd		
			(<3.9)	(<3.7)	<3.7)	(<3.8)		
Ba	1998	15.	27.	13.	10.	10.	6.1	59.
		(13-16)	(15-45)	(11-16)	(6.5-14)	(7.2-18)	(4.5-8.5)	

Table 7. (continued)

Weight or Element	Year	Osino	Carlin	Palisade	Argenta	Emigrant	Imlay	Lovelock
Ba	1999	17.	22.	10.	23.	17.	7.1	
		(15-18)	(11-46)	(9.3-10)	(21-26)	(15-23)		
	2000		16.	23.	19.	21.		
			(16)	(17-38)	(16-23)	(20-22)		
Cd	1998	0.53	0.53	0.47	0.66	0.18	0.42	< 0.20
		(0.40-0.64)	(0.35-0.79)	(0.40-0.57)	(0.49-0.88)	(<0.18-0.26)	(0.36-0.48)	
	1999	0.48	0.46	0.53	0.89	0.22	0.50	
		(0.41-0.54)	(0.37-0.54)	(0.46-0.65)	(0.81-1.0)	(<0.20-0.45)		
	2000		0.26	0.27	0.53	0.26		
			(0.24-0.27)	(0.23-0.30)	(0.41-0.73)	(0.22-0.34)		
Cr	1998	2.2	5.9	4.8	3.7	1.8	3.6	38.
		(1.9-2.8)	(2.9-15)	(4.0-6.6)	(1.9-9.7)	(<0.94-4.2)	(1.2-8.4)	
	1999	4.6	7.8	16.	20.	2.7	2.5	
		(2.9-5.8)	(3.5-20)	(2.1-51)	(2.8-339[c])	(1.6-4.2)		
	2000		1.3	1.6	1.4	2.1		
			(1.3)	(1.3-1.8)	(1.3-1.5)	(1.5-3.2)		
Cu	1998	2.9	3.4	2.9	2.5	1.8	2.1	6.2
		(2.8-2.9)	(3.0-4.0)	(2.7-3.2)	(2.4-2.8)	(1.6-2.1)	(1.9-2.5)	
	1999	2.7	3.5	3.2	4.1	3.1	2.7	
		(2.7)	(2.9-4.9)	(3.2-3.4)	(3.4-6.3)	(2.7-4.1)		
	2000		2.8	3.9	3.0	3.2		
			(2.7-2.8)	(3.4-4.4)	(2.8-3.2)	(3.1-3.3)		
Fe	1998	198.	284.	196.	116.	195.	107.	2382.
		(115-361)	(165-419)	(150-266)	(99-130)	(135-374)	(100-112)	
	1999	102.	213.	309.	510.	256.	102.	
		(91-114)	(114-446)	(121-560)	(233-3285[d])	(165-560)		

Table 7. (continued)

Weight or Element	Year	Osino	Carlin	Palisade	Argenta	Emigrant	Imlay	Lovelock
Fe	2000		80.	118.	62.	188.		
			(79-80)	(107-134)	(59-64)	(155-220)		
Hg	1998	1.1	0.70	0.81	1.6	1.8	2.0	0.63
		(0.98-1.2)	(0.64-0.83)	(0.76-0.92)	(1.2-1.8)	(1.8)	(1.5-2.5)	
	1999	0.87	0.40	0.40	1.0	1.2	0.42	
		(0.81-0.91)	(0.34-0.46)	(0.37-0.42)	(0.69-1.3)	(1.2-1.3)		
	2000		0.79	0.64	0.52	0.27		
			(0.76-0.81)	(0.62-0.67)	(0.46-0.60)	(<0.04-1.0)		
Mg	1998	1465.	1439.	1294.	1167.	826.	1057.	2109.
		(1395-1538)	(1284-1553)	(1198-1449)	(1016-1233)	(727-1012)	(947-1244)	
	1999	1362.	1353.	1263.	1668.	1601.	1164.	
		(1269-1453)	(1224-1545)	(1209-1308)	(1586-1815)	(1411-1789)		
	2000		1535.	1849.	1626.	1919.		
			(1495-1578)	(1798-1878)	(1529-1686)	(1758-2142)		
Mn	1998	31.	30.	24.	11.	17.	9.3	55.
		(16-67)	(23-40)	(20-31)	(6.3-15)	(12-29)	(7.4-14)	
	1999	16.	34.	18.	32.	26.	8.3	
		(15-18)	(15-70)	(13-24)	(20-92)	(25-30)		
	2000		31.	53.	13.	20.		
			(21-44)	(47-62)	(11-14)	(18-22)		
Mo	1998	nd	nd	nd	nd	nd	nd	< 0.99
		(<0.92)	(<0.96-1.7)	(<0.91)	(<0.94)	(<0.92)	(<0.90)	
	1999	nd	nd	nd	nd	nd	< 1.0	
		(<0.98)	(<0.98)	(<0.98)	(<0.98-1.8)	(<1.0)		
	2000		nd	nd	nd	nd		
			(<0.97)	(<0.92)	(<0.93)	(<0.95-1.3)		

Table 7. (continued)

Weight or Element	Year	Osino	Carlin	Palisade	Argenta	Emigrant	Imlay	Lovelock
Ni	1998	nd	nd	nd	nd	nd	nd	3.0
		(<0.92-1.1)	(<0.96)	(<0.96-0.99)	(<0.94)	(<0.92)	(<0.90)	
	1999	nd	nd	2.3	2.8	nd	< 1.0	
		(<0.98)	(<0.98-2.2)	(<1.0-6.1)	(<0.99-28[e])	(<1.0)		
	2000		nd	nd	nd	nd		
			(<0.97)	(<0.92)	(<0.93)	(<0.95)		
Pb	1998	nd	nd	nd	nd	nd	1.8	4.2
		(<1.8)	(<1.9-2.5)	(<1.8)	(<1.9)	(<1.8-2.6)	(<2.0-2.9)	
	1999	nd	1.3	nd	2.1	1.5	< 1.0	
		(<0.98-1.4)	(<0.99-2.4)	(<0.98)	(1.6-2.8)	(1.2-2.0)		
	2000		nd	nd	nd	nd		
			(<1.94)	(<1.9-2.0)	(<1.9)	(<1.9)		
Se	1998	2.5	2.5	2.4	2.6	1.2	2.0	1.3
		(2.4-2.8)	(2.1-3.0)	(2.2-2.8)	(2.3-2.8)	(1.0-1.3)	(1.8-2.2)	
	1999	2.9	4.2	4.2	3.7	2.8	4.1	
		(2.5-3.4)	(3.6-4.7)	(3.8-4.7)	(3.3-4.4)	(2.7-2.8)		
	2000		4.0	3.1	3.6	2.2		
			(3.8-4.1)	(2.8-3.5)	(3.4-4.0)	(2.1-2.3)		
Sr	1998	60.	66.	58.	54.	52.	59.	109.
		(57-62)	(55-72)	(54-64)	(44-61)	(45-69)	(52-71)	
	1999	64.	65.	61.	83.	124.	69.	
		(62-65)	(60-75)	(55-65)	(68-98)	(115-137)		
	2000		76.	91.	89.	159.		
			(75-78)	(83-100)	(86-92)	(154-162)		
V	1998	nd	nd	nd	nd	nd	nd	4.4
		(<0.92)	(<0.96)	(<0.91)	(<0.94)	(<0.92)	(<0.90)	

Table 7. (concluded)

Weight or Element	Year	Osino	Carlin	Palisade	Argenta	Emigrant	Imlay	Lovelock
V	1999	nd (<0.98)	nd (<0.98)	nd (<0.98)	nd (<0.98-1.6)	nd (<1.0-1.1)	< 1.0	
	2000		nd (<0.97)	nd (<0.92)	nd (<0.93)	nd (<0.95)		
Zn	1998	217. (210-222)	220. (198-255)	168. (151-185)	162. (126-197)	108. (84-138)	133. (104-176)	145.
	1999	274. (267-278)	214. (183-249)	301. (262-328)	369. (303-709)	255. (236-281)	194.	
	2000		266. (262-270)	263. (254-279)	255. (251-259)	271. (256-291)		

[a] Numbers of samples collected in 1998, 1999, and 2000 respectively were as follows: Osino - 3, 3, 0; Carlin - 5, 5, 2; Palisade - 3, 3, 3; Argenta - 5, 5, 3; Emigrant - 3, 3, 3; Imlay - 4, 1, 0; Lovelock - 1, 0, 0. No sampling was conducted at Osino, Imlay, and Lovelock in 2000. Lahontan redsides were not found at locations not listed. Beryllium was not detected in any samples.

[b] nd = not detected in > 50% of samples.

[c] Outlier; geometric mean 9.7 ppm without this value.

[d] Outlier; geometric mean 320 ppm without this value.

[e] Outlier; geometric mean 1.6 ppm without this value.

Table 8. Geometric mean concentrations [ppm dry weight] (extremes) of elements and arithmetic mean weight per fish [grams] of Tahoe suckers collected from the Humboldt River, 1998-99[a].

	Osino		Palisade		Imlay	Rye Patch	Lovelock
Weight or Element	1998 (n = 2)	1999 (n = 3)	1998 (n = 2)	1999 (n = 1)	1998 (n = 1)	1999 (n = 3)	1999 (n = 2)
Mean weight	4.1 (3.2-5.0)	3.4 (2.7-4.7)	5.3 (4.3-6.2)	3.7	16.3	2.7 2.3-3.1	8.7 (1.8-16)
Al	1886. (1738-2047)	830. (815-841)	2184. (2130-2240)	438.	1716.	158. (86-339)	542. (412-712)
As	1.5 (<1.8-2.4)	1.2 (1.0-1.5)	2.3 (1.9-2.7)	2.1	< 1.9	0.90 (<0.97-1.5)	1.8 (1.6-2.1)
Ba	86. (84-89)	59. (55-67)	81. (78-85)	39.	66.	8.5 (4.9-17)	20. (17-22)
Cd	0.59 (0.49-0.69)	0.30 (0.24-0.38)	0.37 (0.34-0.40)	0.53	0.28	0.32 (0.30-0.34)	0.25 (0.22-0.29)
Cr	19. (15-23)	16. (4.0-118*)	9.2 (9.2-9.3)	133.*	19.	2.5 (<0.97-13)	15. (9.8-22)
Cu	5.6 (5.3-6.0)	4.6 (4.2-5.6)	5.7 (5.4-6.0)	3.7	4.7	3.5 (2.8-4.0)	4.5 (4.2-4.9)
Fe	1552. (1445-1667)	1120. (872-1832)	1669. (1613-1727)	1487.	1392.	226. (128-524)	759. (646-892)
Hg	0.24 (0.20-0.29)	0.47 (0.36-0.60)	0.14 (<0.18-0.22)	0.13	2.3	0.10 (0.10)	0.28 (0.25-0.32)
Mg	1949. (1888-2013)	1773. (1677-1841)	1852. (1786-1920)	1449.	1968.	1453. (1261-1620)	1729. (1707-1752)
Mn	250. (207-301)	114. (110-121)	153. (149-158)	76.	71.	12. (7.5-21)	38. (37-39)
Mo	nd[b] (<0.91)	nd (<1.0)	0.78 (<0.92-1.3)	< 0.96	< 0.97	nd (<0.90)	nd (<1.0)

Table 8. (concluded)

Weight or Element	Osino 1998 (n = 2)	Osino 1999 (n = 3)	Palisade 1998 (n = 2)	Palisade 1999 (n = 1)	Imlay 1998 (n = 1)	Rye Patch 1999 (n = 3)	Lovelock 1999 (n = 2)
Ni	2.2 (1.9-2.6)	3.9 (1.7-14*)	1.6 (1.5-1.7)	11.	1.5	nd (<0.90-3.1)	3.0 (2.7-3.4)
Pb	1.7 (<1.9-3.0)	1.8 (1.6-2.3)	3.4 (3.1-3.7)	0.97	3.3	nd (<0.90-1.9)	0.81 (<1.0-1.3)
Se	0.69 (<0.97-0.99)	1.9 (1.6-2.2)	nd (<0.92)	1.6	1.0	1.8 (1.7-2.3)	2.3 (2.3)
Sr	90. (87-92)	82. (80-86)	81. (79-83)	75.	113.	61. (44-77)	88. (87-90)
V	2.6 (2.4-2.8)	1.6 (1.5-1.7)	3.1 (3.1)	1.1	2.9	nd (<0.90-1.1)	1.6 (1.3-1.9)
Zn	129. (128-131)	255. (135-582)	108. (104-113)	273.	119.	176. (121-272)	103. (102-104)

[a] Boron and beryllium were not detected in any samples.

[b] nd = not detected in > 50% of samples.

* Likely outliers: Osino 1999 geometric means with outliers removed are: Cr 5.8 and Ni 2.0.

Table 9. Geometric mean concentrations [ppm dry weight] (extremes) of elements and arithmetic mean weight per fish [grams] of carp collected from the Humboldt River, 1998-99[a].

	Carlin	Emigrant	Imlay		Rye Patch	
Weight or Element	2000 (n = 1)	1998 (n = 2)	1998 (n = 3)	1999 (n = 1)	1998 (n = 3)	1999 (n = 2)
Mean weight	5.5	9.1 (8.1-10)	17.3 (16-18)	31.	16.3 (12-20)	81. (79-83)
Al	29.	373. (223-624)	158 (111-231)	62.	303. (235-389)	49. (49-50)
As	1.2	nd[b] (<1.9)	nd (<1.9)	nd (<1.0)	nd (<1.9)	nd (0.90)
Ba	20.	25. (19-31)	18. (17-20)	15.	11. (9.1-13)	9.1 (8.5-9.8)
Cd	< 0.20	0.39 (0.24-0.66)	0.60 (0.36-0.85)	0.43	0.49 (0.41-0.55)	0.14 (<0.19-0.21)
Cr	1.3	16. (8.2-31)	5.2 (4.6-5.6)	48.[c]	2.9 (2.0-4.5)	4.6 (2.2-9.5)
Cu	4.4	6.1 (5.8-6.3)	6.1 (5.8-6.5)	6.8	5.7 (5.3-6.4)	6.1 (5.4-6.9)
Fe	100.	452. (283-723)	219. (184-265)	477.	326. (275-400)	152. (133-173)
Hg	0.27	1.6 (1.5-1.8)	1.1 (1.0-1.3)	0.74	0.95 (0.85-1.0)	0.42 (0.35-0.51)
Mg	1761.	1812. (1766-1859)	1538. (1425-1756)	1750.	1703. (1601-1811)	1623. (1508-1746)
Mn	50.	28. (26-30)	15. (14-19)	26.	14. (12-17)	9.9 (9.0-11)
Mo	< 0.99	nd (<0.95)	nd (<0.96)	< 1.0	nd (<0.95-1.1)	nd (<0.90)

Table 9. (concluded)

Weight or Element	Carlin 2000 (n = 1)	Emigrant 1998 (n = 2)	Imlay 1998 (n = 3)	Imlay 1999 (n = 1)	Rye Patch 1998 (n = 3)	Rye Patch 1999 (n = 2)
Ni	< 0.99	0.77 (<0.95-1.2)	nd (<0.96)	4.4	nd (<0.94)	1.6 (<0.95-5.5)
Pb	< 2.0	nd (<1.9)	nd (<1.9-2.9)	< 1.0	nd (<1.9-2.9)	nd (<0.90)
Se	2.3	2.0 (1.8-2.2)	1.8 (1.6-2.1)	2.8	1.9 (1.5-2.1)	2.2 (1.9-2.5)
Sr	133.	142. (126-159)	195. (159-252)	149.	123. (106-136)	163. (156-171)
V	< 0.99	0.84 (<0.95-1.5)	nd (<0.96)	< 1.0	nd (0.94)	nd (<0.90)
Zn	223.	197. (191-204)	208. (178-257)	448.	229. (221-243)	243. (206-287)

[a] Boron and beryllium were not detected in any samples.

[b] nd = not detected in > 50% of samples.

[c] Likely outlier.

Table 10. Geometric mean concentrations [ppm dry weight] (extremes) of elements and arithmetic mean weight per fish [grams] of various species of fish collected from the Humboldt River basin, 1998-99[a].

	Walleye			Sacramento blackfish		Mosquitofish		Bluegill	Pumpkinseed
	Rye Patch		Lovelock	Imlay	Rye Patch	Humboldt Lake		Imlay	Humboldt Lake
Weight or Element	1998 (n = 2)	1999 (n = 3)	1998 (n = 4)	1999 (n = 1)	1999 (n = 3)	1998 (n = 3)	1999 (n = 1)	1999 (n = 1)	1998 (n = 1)
Mean weight	5.3 (5.2-5.4)	15. (4.6-36)	3.5 (2.9-3.9)	14.	25. (24-25)	–[b]	–	47.	–
Al	59. (52-68)	65. (35-93)	486. (407-552)	599.	114. (94-134)	110. (91-122)	162.	55.	54.
As	nd[c] (<1.9)	nd (<0.93)	nd (<1.9)	< 0.99	nd (<0.93)	5.4 (3.8-9.1)	1.5	< 1.0	< 1.9
B	nd (<3.7)	nd (<3.7)	nd (<3.8)	< 4.0	nd (<3.7)	49. (36-64)	15.	< 4.0	17.
Ba	4.2 (3.6-4.9)	6.1 (4.4-7.4)	17. (14-19)	40.	6.3 (5.7-7.0)	33. (25-39)	16.	14.	7.3
Cd	0.15 (<0.19-0.23)	nd (<0.19)	0.30 (0.26-0.35)	0.33	nd (<0.19)	0.20 (<0.18-0.44)	< 0.20	< 0.20	0.47
Cr	0.81 (<0.93-1.4)	5.0 (1.5-28[d])	6.4 (4.4-12)	3.0	0.94 (<0.98-1.4)	1.7 (1.3-2.4)	7.2	2.6	1.9
Cu	1.7 (1.6-1.9)	2.1 (1.5-2.9)	2.6 (2.4-2.9)	12.	4.9 (4.7-5.0)	5.8 (5.5-6.3)	6.8	2.8	2.6
Fe	70. (59-84)	141. (53-447)	384. (322-544)	657.	137. (121-157)	123. (115-129)	237.	93.	84.
Hg	0.52 (0.49-0.56)	0.10 (0.07-0.16)	0.63 (0.47-0.75)	0.28	0.14 (0.12-0.19)	0.27 (0.24-0.32)	0.10	1.6	0.28
Mg	1405. (1399-1411)	1325. (1244-1403)	1629. (1528-1814)	1992.	1475. (1418-1575)	2202. (2004-2513)	2078.	2065.	1857.
Mn	11. (11-12)	11. (8.2-15)	23. (19-27)	36.	5.8 (5.0-7.4)	43. (29-87)	20.	23.	10.
Mo	nd (<0.93)	nd (<0.93)	nd (<0.94)	< 0.99	nd (<0.93)	nd (<0.92-1.4)	< 0.98	< 1.0	< 0.95
Ni	0.71 (<1.0-1.0)	nd (<0.93-2.2)	nd (<0.94)	< 0.99	nd (<0.93)	0.92 (<0.92-1.4)	1.1	< 1.0	1.1
Pb	1.5 (<1.9-2.4)	nd (<0.93)	1.5 (<1.9-2.7)	1.6	nd (<0.93)	nd (<1.8)	< 0.98	1.4	2.7

Table 10. (concluded)

	Walleye			Sacramento blackfish		Mosquitofish		Bluegill	Pumpkinseed
	Rye Patch		Lovelock	Imlay	Rye Patch	Humboldt Lake		Imlay	Humboldt Lake
Weight or Element	1998 (n = 2)	1999 (n = 3)	1998 (n = 4)	1999 (n = 1)	1999 (n = 3)	1998 (n = 3)	1999 (n = 1)	1999 (n = 1)	1998 (n = 1)
Se	2.1 (2.0-2.3)	2.4 (2.1-2.7)	1.8 (1.6-2.0)	3.1	1.7 (1.6-1.9)	4.3 (4.2-4.4)	4.2	3.2	5.9
Sr	69. (69-70)	73. (61-88)	74. (69-81)	151.	52. (34-68)	285. (250-345)	297.	166.	285.
V	nd (<0.93)	nd (<0.93)	nd (<0.94-1.0)	2.1	nd (<0.93)	1.3 (1.1-1.6)	< 0.98	< 1.0	< 0.95
Zn	79. (78-80)	111. (97-134)	101. (94-108)	260.	156. (152-164)	158. (155-162)	172.	134.	124.

[a] Beryllium was not detected in any samples.

[b] – = not weighed.

[c] nd = not detected in > 50% of samples.

[d] Likely outlier; geometric mean without this value is 2.1.

Table 11. Mean total length, weight, and Fulton condition factor (FCF) [ranges in parentheses] for Lahontan redsides sampled from the Humboldt River, Nevada, 1998-2000.

Site	Year	n	Total length (mm)	Weight (g)	FCF
Osino	1998	254	54.1	1.4	0.77
			(25-105)	(0.1-11.0)	(0.42-1.07)
	1999	39	50.8	1.3	0.91
			(39-73)	(0.4-3.0)	(0.59-1.36)
Carlin	1998	51	68.4	3.3	0.94
			(49-98)	(0.9-9.0)	(0.54-1.15)
	1999	44	57.9	2.0	0.91
			(37-85)	(0.4-5.8)	(0.67-1.10)
	2000	34	50.1	1.1	0.85
			(35-70)	(0.4-3.2)	(0.54-0.99)
Palisade	1998	25	76.0	4.8	0.98
			(54-102)	(1.0-11.0)	(0.64-1.09)
	1999	35	53.9	1.5	0.91
			(47-71)	(0.8-3.2)	(0.72-1.08)
	2000	38	53.1	1.6	0.90
			(33-78)	(0.3-4.7)	(0.72-1.43)
Argenta	1998	19	84.7	6.6	0.98
			(68-119)	(3.0-19.0)	(0.77-1.13)
	1999	50	58.6	1.8	0.82
			(41-81)	(0.5-4.8)	(0.38-1.28)
	2000	43	52.9	1.4	0.86
			(29-91)	(0.2-6.3)	(0.61-1.48)
Emigrant	1998	51	72.6	4.4	0.95
			(41-102)	(0.4-12.9)	(0.44-1.27)
	1999	51	66.5	2.4	0.78
			(39-91)	(0.6-6.5)	(0.46-1.02)
	2000	43	63.9	2.2	0.78
			(48-88)	(0.9-5.7)	(0.57-0.96)
Imlay	1998	10	90.0	9.0	0.94
			(48-119)	(0.7-17.0)	(0.63-1.07)
	1999	5	74.6	4.6	1.08
			(67-79)	(2.9-7.9)	(0.89-1.60)
Lovelock	1998	5	53.6	1.9	1.25
			(47-63)	(1.5-2.6)	(1.04-1.44)

Table 12. Mean total length, weight, and Fulton condition factor (FCF) [ranges in parentheses] for Tahoe suckers sampled from the Humboldt River, Nevada, 1998-1999.

Site	Year	n	Total length (mm)	Weight (g)	FCF
Osino	1998	25	69.4	3.4	0.98
			(54-103)	(1.5-10.0)	(0.77-1.33)
	1999	29	66.7	3.4	0.98
			(41-113)	(0.7-14.6)	(0.77-1.26)
Carlin	1998	5	48.4	0.94	0.82
			(42-55)	(0.6-1.2)	(0.72-0.94)
	1999	19	58.9	2.2	1.04
			(35-73)	(0.5-3.9)	(0.91-1.28)
Palisade	1998	13	78.4	5.2	1.01
			(50-98)	(1.0-10.0)	(0.80-1.17)
	1999	7	68.7	3.7	1.01
			(48-111)	(1.1-10.8)	(0.79-1.20)
Argenta	1999	11	55.2	1.6	0.91
			(48-69)	(0.9-2.9)	(0.72-1.06)
Imlay	1998	4	123.0	16.2	0.83
			(107-143)	(10-26)	(0.75-0.89)
Rye Patch	1999	27	69.4	4.7	1.04
			(50-142)	(1.3-33.1)	(0.90-1.35)
Lovelock	1999	13	69.2	5.0	1.01
			(50-128)	(1.2-21.8)	(0.81-1.49)

Table 13. Mean total length, weight, and Fulton condition factor (FCF) [ranges in parentheses] for common carp, walleyes, Sacramento blackfish, pumpkinseeds, and white crappies sampled from the Humboldt River, Nevada, 1998-2000.

Species and Site	Year	n	Total length (mm)	Weight (g)	FCF
Common carp					
Carlin	2000	3	72.7 (66-77)	5.3 (4.0-6.0)	1.38 (1.31-1.42)
Emigrant	1998	6	89.7 (81-98)	9.0 (5.6-12.0)	1.20 (1.05-1.28)
Imlay	1998	7	108.9 (100-124)	17.4 (12.1-23.0)	1.35 (1.14-1.84)
Rye Patch	1998	36	98.4 (82-117)	15.1 (8.5-23.5)	1.56 (1.32-1.77)
	1999	5	176.8 (163-196)	81.0 (59.4-116.6)	1.43 (1.30-1.55)
Lovelock	1998	3	56.0 (52-63)	2.6 (1.9-3.3)	1.51 (1.28-1.92)
HWMA[a]	1998	20	64.9 (43-183)	9.2 (1.3-74)	1.59 (1.21-1.99)
Walleye					
Rye Patch	1998	50	74.0 (64-83)	5.1 (3.3-7.9)	1.25 (1.11-1.46)
	1999	35	123.8 (70-157)	27.2 (4.1-53.3)	1.23 (1.01-1.50)
Lovelock	1998	32	67.0 (49-80)	3.5 (1.4-6.0)	1.13 (0.87-1.31)
Sacramento blackfish					
Imlay	1999	5	117.6 (55-138)	14.0 (1.7-20.0)	0.78 (0.68-1.02)
Rye Patch	1999	32	135.3 (105-160)	25.2 (11.1-42.0)	0.99 (0.91-1.08)
Pumpkinseed					
Rye Patch	1998	20	80.9 (59-97)	11.0 (4.1-19.4)	1.99 (1.69-2.23)
White crappie					
HWMA	1998	11	96.5 (50-190)	23.0 (1.7-102)	1.30 (1.13-1.68)

[a] Humboldt Wildlife Management Area.

Table 14. Geometric mean concentrations [ppm dry weight] (extremes) of elements in American coot and black-necked stilt eggs collected from the Humboldt River basin, 1988-99.

	Coot							Stilt[a]
	Humboldt Lake			Rye Patch Reservoir[a]	Emigrant[a]	Toulon Lake		Toulon Lake
Element	1996[b] (n = 7)	1998[a] (n=19)	1999[a] (n=12)	1998 (n=3)	1998 (n=5)	1988[c] (n = 27)	1999[a] (n=10)	1999 (n=2)
Al	8.1	nd[d]	nd	10.	nd	nd	nd	11.
	(6.5-10)	(<8.5-32)	(<5.0-23)	(<7.7-21)	(<9.3-24)	(<6.3)	(<5.0-77)	(6.3-20)
As	0.71	nd	nd	nd	nd	0.31	nd	nd
	(0.5-0.9)	(<0.85)	(<0.50-0.98)	(<0.76)	(<0.93)	(<0.3-0.76)	(<0.50)	(<0.50)
B	8.0	nd	nd	nd	nd	7.3A[e]	1.8B	2.6
	(7.2-10.6)	(<3.4-5.6)	(<2.0-3.0)	(<3.1)	(<3.7)	(4.4-14)	(<2.0-2.9)	(<2.0-6.8)
Ba	1.7A	4.5Ba[f]	3.5AB	4.7a	3.0a	4.3A	2.8B	3.4
	(0.7-3.5)	(1.9-10)	(1.3-9.6)	(2.2-14)	(1.9-4.8)	(1.0-12)	(1.5-5.6)	(3.0-3.8)
Be	nd	nd	nd	nd	nd	nd	nd	nd
	(<0.10)	(<0.17)	(<0.10)	(<0.15)	(<0.19)	(<0.03-0.32)	(<0.10)	(<0.10)
Cd	nd	nd	nd	nd	nd	nd	nd	nd
	(<0.10)	(<0.17)	(<0.10)	(<0.15)	(<0.19)	(<0.4-1.2)	(<0.10)	(<0.10)
Cr	nd	2.0	nd	nd	nd	nd	nd	nd
	(<0.5-1.7)	(<0.95-9.9)	(<0.50-11)	(<0.76-7.7)	(<0.93-3.8)	(<0.5-0.91)	(<0.50)	(<0.50)
Cu	3.3A	3.7Aa	3.8A	3.2a	3.1a	4.5A	3.5B	3.4
	(2.9-3.6)	(2.9-5.3)	(2.6-5.0)	(2.8-3.5)	(2.5-3.6)	(3.2-6.6)	(2.3-4.4)	(3.3-3.5)
Fe	93.A	131.Aa	118.A	132.a	111.a	100.A	115.A	147.
	(81-107)	(61-207)	(46*-232)	(93-178)	(91-146)	(74-153)	(78-223*)	(121-179)
Hg	3.2A	0.77Ba	0.29C	0.69ab	1.2b	0.16A	0.21A	0.70
	(1.6-7.0)	(0.50-1.4)	(0.12-0.86*)	(0.33-1.5)	(0.61-2.0)	(0.08-1.4*)	(0.12-0.31)	(0.51-0.96)
Mg	511.A	576.Aa	579.A	541.a	558.a	542.A	512.A	413.
	(387-571)	(464-749)	(446-962*)	(378-775)	(471-660)	(300*-728)	(419-645)	(378-451)

Table 14. (concluded)

	Coot							Stilt
	Humboldt Lake			Rye Patch Reservoir	Emigrant	Toulon Lake		Toulon Lake
Element	1996 (n = 7)	1998 (n=19)	1999 (n=12)	1998 (n=3)	1998 (n=5)	1988 (n=27)	1999 (n=10)	1999 (n=2)
Mn	1.4A (0.80-2.2)	2.3Aa (0.82-6.0)	2.1A (1.0-5.0)	3.6a (2.5-4.6)	1.8a (1.3-2.2)	0.95A (<0.4-2.2)	1.5A (0.77-12*)	2.9 (1.6-5.3)
Mo	1.2 (0.80-1.7)	nd (<0.85-2.0)	0.57 (<0.50-1.9)	nd (<0.94-0.90)	nd (<0.93)	nd (<7.0-7.3)	nd (<0.50-1.3)	nd (<0.50)
Ni	nd (<0.5-1.0)	nd (<0.85-1.1)	nd (<0.50-1.8)	nd (<0.76)	nd (<0.93-1.1)	nd (<4.5-7.4)	nd (<0.50)	0.37 (<0.51-0.53)
Pb	nd (<1.0)	nd (<1.7)	nd (<0.50-0.80)	nd (<1.5)	nd (<1.9)	nd (<9-13)	nd (<0.50-0.92)	nd (<0.50)
Se	4.2A (3.2-5.2)	3.1Ba (1.3*-4.2)	2.8B (2.0-3.5)	3.1a (2.6-3.7)	1.4b (1.1-1.7)	2.8A (1.8-4.5)	2.8A (2.1-4.7)	4.6 (4.3-4.8)
Sr	13.A (8-20)	15.Aa (8.3-24)	15.A (8.6-43*)	8.8b (4.8-13)	8.1b (5.8-13)	26.A (9.8-47)	13.B (8.2-17)	19. (18-20)
V	nd (<0.50)	nd (<0.85)	nd (<0.50)	nd (<0.76)	nd (<0.93)	nd (<0.57-0.91)	nd (<0.50)	nd (<0.50)
Zn	65.A (45-93)	57.Aa (45-83)	67.A (45-210*)	64.a (44-104)	60.a (50-72)	63.A (52-80)	56.B (43-66)	49. (47-51)

[a] This study.
[b] Seiler and Tuttle (1997).
[c] Seiler et al. (1993).
[d] nd = not detected in > 50% of samples.
[e] Means followed by a common capital letter within an area (between or among years) are not significantly different (P > 0.05).
[f] 1998 means followed by a common lower case letter (between or among areas) are not significantly different (P > 0.05).
Note: Values marked with an asterisk (*) were identified as outliers in statistical analyses; however, they were retained.

Table 15. Geometric mean concentrations [ppm dry weight] (extremes) of elements in juvenile American coot livers collected from Humboldt Lake, Humboldt Wildlife Management Area, 1986-99[a].

	Seiler et al. (1993)		Seiler and Tuttle (1997)	This study	
Element	1986 (n = 5)	1988 (n = 12)	1996 (n = 5)	1998 (n = 6)	1999 (n = 6)
Al	11. (8-13)	2.5 (<3-4)	nd[b] (<5)	nd (<15)	nd (<5)
As	0.42AB[c] (0.36-0.65)	0.31A (0.20-0.52)	0.58AB (<0.5-1.2)	0.43AB (<0.51-0.90)	0.89B (0.53-1.6)
B	38.A (11-73)	4.1B (<2-8)	8.3B (5-14)	4.1B (2.9-6.1)	4.7B (<2.0-12)
Ba	nd (<0.36-<0.43)	nd (<0.1-0.1)	nd (<0.50)	nd (<0.51-1.8)	nd (<0.50)
Cd	ndABC (<0.36-<0.43)	0.51C (<0.4-1.0)	0.18AB (0.1-0.5)	0.26BC (0.13-0.46)	ndA (<0.10-0.17)
Cr	nd (<1.1-<1.3)	nd (<2)	4.5 (2.5-7.6)	1.9 (<0.51-5.8)	nd (<0.50)
Cu	66.B (29-110)	22.A (13-35)	23.A (13-56)	54.B (31-79)	65.B (37-108)
Fe	374.A (250-470)	4335.C (2330-6490)	1256.B (771-2408)	1151.B (336-3434)	1143.B (334-1909)
Hg	0.52AB (0.35-0.75)	0.49A (0.21-3.2)	2.4C (1.5-3.6)	1.8BC (0.21-5.7)	0.58AB (0.24-1.3)
Mg	832.B (800-870)	632.A (557-716)	652.A (557-724)	695.A (6.5-805)	839.B (733-962)
Mn	14.A (9.3-24)	11.A (7.7-15)	9.0A (7.2-12.4)	12.A (7.8-31)	8.8A (6.4-11)
Mo	4.3A (3.4-5.5)	4.2A (3.0-6.0)	3.1A (2.0-4.3)	4.9A (3.0-7.5)	4.0A (2.6-5.3)
Ni	nd (<1.1-<1.3)	nd (<3)	2.5 (1.2-4.4)	nd (<0.51-1.1)	nd (<0.50)
Pb	nd (<0.72-<0.85)	nd (<4)	nd (<1.0-1.2)	nd (<1.0)	nd (<0.50)
Se	11.B (9.0-15)	10.B (7.8-13)	10.B (6.6-15)	4.5A (2.4-6.7)	11.B (5.1-15)
Sr	ndA (<0.36-2.7)	0.49AB (0.3-0.7)	1.1BC (0.7-1.8)	2.0C (0.87-4.6)	1.9C (1.0-2.6)
V	nd (<0.40-0.87)	0.71 (<0.5-2.4)	nd (<0.50)	nd (<0.50)	nd (0.50)
Zn	208.B (170-240)	109.A (81-144)	120.A (97-147)	178.B (155-206)	200.B (181-256)

Table 15. (concluded)

[a] Beryllium was not detected in any samples.
[b] nd = not detected in > 50% of samples.
[c] Means for a given element not followed by a common capital letter were significantly different from one another (Bonferroni tests; $P < 0.05$).

Table 16. Geometric mean concentrations [ppm dry weight] (extremes) of elements in adult American coot livers collected from Humboldt Lake, Humboldt Wildlife Management Area, 1998-99[a].

	Female		Male	Combined sexes[b]
Element	1998 (n = 2)	1999 (n = 4)	1999 (n = 4)	1999 (n = 8)
Al	nd[c]	5.4	4.5	4.9
	(<15)	(<5.0-13)	(<5.0-9.0)	(<5.0-13)
As	0.64	0.93	0.76	0.84
	(<0.51-1.6)	(0.71-1.3)	(<0.50-1.4)	(<0.50-1.4)
B	6.3	7.8	6.3	7.0
	(5.7-7.0)	(5.4-12)	(3.2-8.9)	(3.2-12)
Ba	nd	nd	nd	nd
	(<0.51)	(<0.50-0.67)	(<0.50)	(<0.50-0.67)
Cd	0.91	0.92	0.98	0.95*
	(0.79-1.0)	(0.45-2.6)	(0.29-4.5)	(0.29-4.5)
Cr	1.5	nd	nd	nd
	(1.4-1.5)	(<0.50)	(<0.50)	(<0.50)
Cu	23.	32.	36.	34.*
	(20-26)	(22-50)	(27-49)	(22-50)
Fe	3236.	5093.	4345.	4699.*
	(2508-4176)	(2207-10210)	(3512-5320)	(2207-10210)
Hg	0.42	0.66	0.68	0.67
	(0.32-0.55)	(0.35-2.9)	(0.25-2.0)	(0.25-2.9)
Mg	688.	826.	726.	774.
	(675-701)	(748-888)	(662-804)	(662-888)
Mn	9.5	8.6	9.2	8.9
	(8.6-11)	(6.9-12)	(8.2-11)	(6.9-12)
Mo	4.2	8.7	5.8	7.1*
	(3.7-4.7)	(6.1-20)	(4.3-8.4)	(4.3-20)
Se	4.6	12.	7.5	9.5
	(4.2-5.1)	(8.5-18)	(5.7-10)	(5.7-18)
Sr	0.71	1.2	0.96	1.1*
	(0.55-0.93)	(0.55-2.9)	(0.83-1.2)	(0.55-2.9)
V	0.26	0.58	1.1	0.81
	(<0.50-0.75)	(<0.50-1.0)	(<0.51-2.9)	(<0.50-2.9)
Zn	131.	152.	178.	164.*
	(122-141)	(137-168)	(161-200)	(137-200)

[a] The following elements were not detected in any samples: beryllium, nickel, and lead.
[b] There were no sex differences for adults in 1999. Means for combined sexes in 1999 followed by an asterisk (*) were significantly different from those of juvenile coot livers collected in 1999 from Humboldt Lake.
[c] nd = not detected.

Table 17. Geometric mean concentrations [ppm dry weight] (extremes) of elements in American avocet and black-necked stilt livers collected from Humboldt Wildlife Management Area, 1996 and 1999[a].

	Avocet				Stilt
	Humboldt Lake			Toulon Lake	Humboldt Lake
	Juvenile[b]	Juvenile[c]	Adult[d]	Adult[b]	Unknown[e]
	1996	1999	1999	1999	1999
Element	(n = 5)	(n = 3)	(n = 3)	(n = 1)	(n = 1)
Al	nd	nd[f]	9.0	9.5	< 5.0
	(<5.0)	(<5.1-8.1)	(2.5-26)		
As	nd	nd	nd	< 0.50	< 0.50
	(<0.5-0.9)	(<0.51)	(<0.50)		
B	2.0	nd	nd	2.9	< 2.0
	(<2-3)	(<2.0)	(<2.0)		
Ba	nd	nd	nd	1.0	< 0.50
	(<0.5)	(<0.51-0.61)	(<0.50-0.66)		
Cd	0.42	0.44	1.8	3.6	0.14
	(0.2-0.9)	(0.25-0.67)	(0.24-5.9)		
Cr	3.9	nd	nd	< 0.50	< 0.50
	(2.6-7.4)	(<0.51)	(<0.50)		
Cu	26.	21.	11.	20.	15.
	(20-29)	(14-34)	(14-24)		
Fe	463.	2376.*	1519.	1841.	1064.
	349-613)	(2078-2597)	(617-3007)		
Hg	2.6	0.81	0.76	2.0	1.3
	(1.7-4.1)	(0.40-1.3)	(0.34-1.6)		
Mg	708.	694.	739.	849.	651.
	(653-791)	(622-812)	(608-882)		
Mn	12.	11.	10.	14.	11.
	(11-14)	(6.7-16)	(7.8-12)		
Mo	2.0	2.9	2.0	2.3	2.5
	(1.7-2.5)	(2.3-4.5)	(1.7-2.5)		
Ni	2.3	nd	nd	< 0.50	< 0.50
	(1.5-4.7)	(<0.51)	(<0.50)		
Pb	nd	nd	nd	< 0.50	5.0
	(<1.0)	(<0.51)	(<0.50-4.8)		
Se	24.	18.	13.	25.	38.
	(21-34)	(11-24)	(8.9-18)		
Sr	1.3	0.56	0.37	1.4	0.39
	(0.8-1.7)	(0.32-1.2)	(<0.20-2.1)		
V	nd	nd	nd	< 0.50	< 0.50
	(<0.50)	(<0.51-1.1)	(<0.50-<0.51)		

Table 17. (concluded)

	Avocet				Stilt
	Humboldt Lake			Toulon Lake	Humboldt Lake
	Juvenile[b] 1996	Juvenile[c] 1999	Adult[d] 1999	Adult[b] 1999	Unknown[e] 1999
Element	(n = 5)	(n = 3)	(n = 3)	(n = 1)	(n = 1)
Zn	101. (90-116)	128.* (119-136)	111. (81-180)	102.	78.

[a] 1996 data from Seiler and Tuttle (1997); remaining data from this study. Beryllium was not detected in any samples. Means for 1999 juveniles followed by an asterisk (*) were significantly different from 1996 means for juveniles. There were no significant differences between juveniles and adults in 1999.

[b] Shot.

[c] Two botulism, one shot.

[d] Two shot, one botulism.

[e] Botulism.

[f] nd = not detected in > 50% of samples.

APPENDICES

Appendix 1. Sampling dates for monitoring of contaminants in the Humboldt River basin, 1998-2000.

Site	Year	Sample types	Dates
Osino	1998	All	1 September
	1999	All	31 August
Carlin	1998	All	1 September
	1999	All	30 August
	2000	All	18 September
Palisade	1998	All	1 September
	1999	All	31 August
	2000	All	18 September
Argenta	1998	Algae, dragonfly larvae, fish	2 September
		Crayfish	24 September
	1999	All	30 August
	2000	All	19 September
Emigrant	1998	Crayfish, dragonfly larvae (1), fish	2 September
		Algae, dragonfly larvae (1)	24 September
		Eggs	30 June
	1999	Algae	31 August
		Crayfish, fish (1)	12 October
		Fish (2)	29 October
	2000	All	19 September
Imlay	1998	Dragonfly larvae (1), fish	2-3 September
		Dragonfly larvae (1)	24 September
	1999	All	1 September
Rye Patch	1998	All, except eggs	3 September
		Eggs	4 June & 2 July
	1999	All	1 September
Lovelock	1998	Algae (1), crayfish (2), fish	3 September
		Algae (2), crayfish (1), dragonfly larvae	24 September
	1999	All	28 September
HWMA[a]	1998	Eggs	21 May-08 June
		Livers	5-28 August
		Sediment, veg., invert., fish	28 August & 7 October
	1999	Eggs	7 & 23 June
		Livers	23 July - 23 August
		Sediment., veg., invert., fish	23 August

[a] Humboldt Wildlife Management Area.

Appendix 2. Approximate coordinates of collection locations for sediment, aquatic biota, and bird eggs and livers from the Humboldt River basin, 1998-2000.

Site	Year	Sample types	Latitude	Longitude
Osino	1998-99	All	40°N 55' 55"	115°W 37' 50"
Carlin	1998-99	All	40°N 43' 10"	116°W 00' 35"
	2000	Fish	40°N 43' 40"	116°W 01' 00"
	2000	Veg., Invert.	40°N 43' 40"	116°W 00' 35"
Palisade	1998-2000	All	40°N 36' 30"	116°W 12' 05"
Argenta	1998	Veg.	40°N 40' 32"	116°W 43' 44"
	1998	Invert., Fish	40°N 40' 40"	116°W 39' 05"
	1999-2000	All	40°N 40' 40"	116°W 39' 05"
Emigrant	1998	Veg., DFL[a] (1)[b]	40°N 58' 25"	117°W 23' 40"
	1998	Crayfish, Fish, DFL (1)	40°N 58' 20"	117°W 23' 55"
	1998	Eggs (averaged)[c]	40°N 59' 30"	117°W 22' 00"
	1999	Veg., Fish	40°N 57' 21"	117°W 26' 57"
	1999	Crayfish	40°N 58' 25"	117°W 23' 40"
	2000	Algae, Fish	40°N 58' 25"	117°W 23' 40"
	2000	Invertebrates	40°N 58' 20"	117°W 23' 55"
Imlay	1998	Invertebrates	40°N 42' 25"	118°W 04' 50"
	1998	Fish	40°N 41' 37"	118°W 05' 33"
	1999	All	40°N 42' 25"	118°W 04' 50"
Rye Patch	1998-99	All except eggs	40°N 28' 05"	118°W 18' 15"
	1998	Eggs	40°N 41' 00"	118°W 14' 00"
Lovelock	1998	Algae (2), DFL (2), Crayfish (1)	40°N 18' 50"	118°W 21' 10"
	1998	Algae (1), Crayfish (2), Fish	40°N 18' 40"	118°W 22' 15"
	1999	Algae	40°N 18' 50"	118°W 21' 10"
	1999	Pondweed, Invert., Fish	40°N 18' 40"	118°W 22' 15"
Humboldt WMA[d]				
Humboldt Lake				
	1998	Egg (extremes)[c]	39°N 57' 53"	118°W 35' 23"
			39°N 59' 49"	118°W 36' 21"
	1998	Livers (averaged)	40°N 01'	118°W 36'
	1998	All remaining (averaged)	39°N 59'	118°W 36'
	1999	One each: Sed., Pondweed., Invert., Fish	39°N 59' 15"	118°W 36' 15"
	1999	One each: Sed., Algae, Invert.	40°N 01' 15"	118°W 37' 25"
	1999	One each: Sed., Pondweed, Invert.	40°N 00' 00"	118°W 37' 40"

Appendix 2. (concluded)

Site	Year	Sample types	Latitude	Longitude
Humboldt WMA				
Humboldt Lake (continued)				
	1999	Stilt liver	39°N 59' 15"	118°W 36' 15"
	1999	Avocet liver (extremes)	39°N 59' 00"	118°W 36' 00"
			40°N 03' 35"	118°W 37' 35"
	1999	Coot liver (averaged)	39°N 59' 15"	118°W 36' 15"
	1999	Coot egg (averaged)	39°N 59' 15"	118°W 36' 15"
Toulon Lake				
	1999	Egg (averaged)	40°N 03' 30"	118°W 37' 00"

[a] DFL = dragonfly larvae.
[b] Number of samples in parentheses.
[c] Extremes of coordinates (individually within latitude or longitude, not combined coordinates for individual sites) shown or averages provided.
[d] Humboldt Wildlife Management Area.

Appendix 3. Number of samples, by type, location, and year, collected in the Humboldt River basin, 1998-2000.

																					Humboldt WMA		
	Osino		Carlin			Palisade			Argenta			Emigrant			Imlay		Rye Patch		Lovelock		Humboldt Lake		Toulon Lake
Sample type	98	99	98	99	00	98	99	00	98	99	00	98	99	00	98	99	98	99	98	99	98	99	99
Sediment																					5	3	
Vegetation																							
Algae	2	3	4	5	3	5	3	3	5	5	3	5	3	3			3	3	3	3	2	1	
Pondweed																	2	3		3	2	2	
Chara	3	3	1																				
Invertebrates																							
Dragonfly larvae	2	3	1	3	3	2	3	3	3	3	3	2		3	2	1			2	2			
Crayfish	3	3	3	3	3	3	3	3	1			3	3	2		1	3	3	3	3			
Corixid																					4	3	
Notonectid																					1		
Fish																							
Lahontan redside	3	3	5	5	2	3	3	3	5	5	3	3	3	3	4	1			1				
Tahoe sucker	2	3				2	1								1			3		2			
Carp					1							2			3	1	3	2					
Walleye																	2	3	4				
Mosquitofish																					3	1	
Sacramento blackfish																1		3					
Bluegill																1							
Pumpkinseed																					1		
Bird eggs																							
American coot												5					3				19	12	10
Black-necked stilt																							2
Bird livers																							
American coot																					8[a]	14[b]	
American avocet																						6[c]	1[d]
Black-necked stilt																						1	

[a] Two adult, six juvenile.
[b] Eight adult, six juvenile.
[c] Three adult, three juvenile.
[d] Adult.

Appendix 4. Field measurements of water quality taken at sampling sites for the Humboldt River aquatic biota monitoring study, 1998-2000.

Site	Date	Time	Specific Conductance (µS/cm)	Dissolved Oxygen (mg/L)	pH (SU)	Salinity (ppt)	Temperature (° C)	Turbidity (NTU)
Osino	9/1/98	1100	425	8.1	8.2	0.2	20	-
	8/31/99	0830	440	7.9	8.1	0.8	11	-
Carlin	9/1/98	1230	450	9.1	8.5	0.2	23	-
	8/30/99	1600	490	9.1	8.5	0.5	23	6.4
	9/18/00	1315	420	9.5	7.8	0.2	20	-
Palisade	9/1/98	1530	550	9.2	8.5	0.8	24	-
	8/31/99	1300	485	8.8	8.0	0.7	16	3.4
	9/18/00	1615	490	10.5	8.2	0.2	21	-
Argenta	9/2/98	1000	510	8.4	8.6	0.2	20	-
	8/30/99	1300	600	8.7	8.5	0.5	22	3.8
	9/19/00	0840	600	6.8	7.2	0.3	15	-
Emigrant	9/2/98	-	810	15.7	8.4	0.5	25	-
	8/31/99[a]	1615	800	6.6	8.0	0.8	20	-
	10/12/99[b]	1100	700	7.8	8.8	0.9	13	-
	9/19/00	1200	960	8.0	8.5	0.5	19	-
Imlay	9/2/98	1600	880	9.2	8.7	0.6	25	-
	9/1/99	0820	900	8.2	8.3	1.2	7	16
Rye Patch	9/3/98	1000	700	8.3	8.5	0.7	19	-
	9/1/99	1145	800	7.6	8.4	0.8	20	24
Lovelock	9/3/98	1200	710	8.2	8.4	0.5	20	-
	9/28/99	1020	700	8.5	8.3	0.9	12	-
HWMA[c]	8/28/98[d]	1130-1400	2780	7.3	8.5	1.8	25	-
			(2100-3500)	(5.1-9.1)	(8.4-8.6)	(1.3-2.1)	(24-26)	
	10/7/98[e]	1410	810	-	8.5	0.5	15	35
	8/23/99[f]	-	3200	5.5	8.1	2.5	28	90
HWMA	8/23/99[g]	-	11000	10.2	8.8	7.0	28	52
	8/23/99[h]	-	5000	7.6	8.3	3.0	28	62

Appendix 4. (concluded)

[a] Downstream of diversion dam downstream of highway bridge.
[b] Downstream of dam upstream of highway bridge.
[c] Humboldt Wildlife Management Area.
[d] Means (extremes) for five sites. Depths ranged from 15-30 cm to 1.5 m.
[e] Northeast shore area.
[f] End of Army Drain in wetland.
[g] West of cattail area.
[h] Central area.

Appendix 5. Detection limits (ppm dry weight) for elements in samples collected in 1998-2000 as part of the Humboldt River aquatic biota monitoring study.

Element	Year	Sediment	Vegetation	Invertebrate	Fish	Avian Egg	Avian Liver
Aluminum (Al)	1998	5.08-5.14	8.83-9.92	8.90-9.96	8.96-10.2	7.65-9.88	15.1-15.5
	1999	100-103	4.97-9.92	9.06-10.0	9.03-10.1	4.99-5.19	5.01-5.10
	2000		4.99-5.56	9.12-10.3	9.19-10.3		
Arsenic (As)	1998	0.508-0.514	0.883-0.992	0.890-0.996	1.79-2.03	0.764-0.988	0.503-0.518
	1999	0.502-0.516	0.497-0.992	0.906-1.00	0.902-1.01	0.499-0.519	0.501-0.510
	2000		0.399-0.444	0.730-0.823	0.735-0.826		
Boron (B)	1998	2.03-2.06	3.53-3.97	3.56-3.98	3.58-4.06	3.06-3.95	2.01-2.07
	1999	2.01-2.07	1.99-3.97	3.62-4.00	3.61-4.03	2.00-2.07	2.00-2.04
	2000		2.00-2.22	3.65-4.12	3.68-4.13		
Barium (Ba)	1998	0.508-0.514	0.883-0.992	0.890-0.996	0.896-1.02	0.764-0.988	0.503-0.518
	1999	3.01-3.10	0.497-0.992	0.906-1.00	0.902-1.01	0.499-0.519	0.501-0.510
	2000		0.499-0.556	0.912-1.03	0.919-1.03		
Beryllium (Be)	1998	0.102-0.103	0.177-0.198	0.178-0.199	0.179-0.203	0.153-0.198	0.101-0.104
	1999	0.201-0.207	0.0994-0.198	0.181-0.200	0.180-0.202	0.0998-0.104	0.100-0.102
	2000		0.0998-0.111	0.182-0.206	0.184-0.207		
Cadmium (Cd)	1998	0.102-0.103	0.177-0.198	0.178-0.199	0.179-0.203	0.153-0.198	0.101-0.104
	1999	0.201-0.207	0.0994-0.198	0.181-0.200	0.180-0.202	0.0998-0.104	0.100-0.102
	2000		0.0998-0.111	0.182-0.206	0.184-0.207		
Chromium (Cr)	1998	0.508-0.514	0.883-0.992	0.890-0.996	0.896-1.02	0.764-0.988	0.503-0.518
	1999	5.02-5.17	0.497-0.992	0.906-1.00	0.902-1.01	0.499-0.519	0.501-0.510
	2000		0.499-0.556	0.912-1.03	0.919-1.03		
Copper (Cu)	1998	0.508-0.514	0.883-0.992	0.890-0.996	0.896-1.02	0.764-0.988	0.503-0.518
	1999	5.02-5.17	0.497-0.992	0.906-1.00	0.902-1.01	0.499-0.519	0.501-0.510
	2000		0.499-0.556	0.912-1.03	0.919-1.03		
Iron (Fe)	1998	10.2-10.3	17.7-19.8	17.8-19.9	17.9-20.3	15.3-19.8	20.1-20.7
	1999	100-103	9.94-19.8	18.1-20.0	18.1-20.2	9.98-10.4	10.0-10.2
	2000		9.98-11.1	18.2-20.6	18.4-20.7		
Mercury (Hg)	1998	0.102-0.103	0.177-0.198	0.178-0.199	0.179-0.203	0.153-0.198	0.101-0.104
	1999	0.0201-0.0207	0.0199-0.397	0.0362-0.0400	0.0361-0.0403	0.0200-0.0207	0.0200-0.0204
	2000		0.0200-0.0218	0.0365-0.0412	0.0368-0.0413		

Appendix 5. (continued)

Element	Year	Sediment	Vegetation	Invertebrate	Fish	Avian Egg	Avian Liver
Magnesium (Mg)	1998	10.2-10.3	17.7-19.8	17.8-19.9	17.9-20.3	15.3-19.8	20.1-20.7
	1999	100-103	9.94-19.8	18.1-20.0	18.1-20.2	9.98-10.4	10.0-10.2
	2000		9.98-11.1	18.2-20.6	18.4-20.7		
Manganese (Mn)	1998	0.406-0.412	0.707-0.794	0.712-0.797	0.717-0.813	0.612-0.790	2.41-2.48
	1999	4.02-4.08	0.398-0.794	0.725-0.800	0.722-0.806	0.399-0.415	0.401-0.408
	2000		0.399-0.444	0.730-0.823	0.735-0.826		
Molybdenum (Mo)	1998	0.508-0.514	0.883-0.992	0.890-0.996	0.896-1.02	0.764-0.988	0.503-0.518
	1999	5.02-5.17	0.497-0.992	0.906-1.00	0.902-1.01	0.499-0.519	0.501-0.510
	2000		0.499-0.556	0.912-1.03	0.919-1.03		
Nickel (Ni)	1998	0.508-0.514	0.883-0.992	0.890-0.996	0.896-1.02	0.764-0.988	0.503-0.518
	1999	5.02-5.17	0.497-0.992	0.906-1.00	0.902-1.01	0.499-0.519	0.501-0.510
	2000		0.499-0.556	0.912-1.03	0.919-1.03		
Lead (Pb)	1998	1.02-1.03	1.77-1.98	1.78-1.99	1.79-2.03	1.53-1.98	1.01-1.04
	1999	5.02-5.17	0.497-0.992	0.906-1.00	0.902-1.01	0.499-0.519	0.501-0.510
	2000		0.998-1.11	1.82-2.06	1.84-2.07		
Selenium (Se)	1998	0.508-0.514	0.883-0.992	0.890-0.996	0.896-1.02	0.764-0.988	0.503-0.518
	1999	0.502-0.516	0.497-1.02	0.906-1.00	0.902-1.01	0.499-0.519	0.501-0.510
	2000		0.399-0.444	0.730-0.823	0.735-0.826		
Strontium (Sr)	1998	0.203-0.206	0.353-0.397	0.356-0.398	0.358-0.406	0.306-0.395	0.201-0.207
	1999	2.01-2.07	0.199-0.397	0.362-0.400	0.361-0.403	0.200-0.208	0.200-0.204
	2000		0.200-0.222	0.365-0.412	0.368-0.413		
Vanadium (V)	1998	0.508-0.514	0.883-0.992	0.890-0.996	0.896-1.02	0.764-0.988	0.503-0.518
	1999	5.02-5.17	0.497-0.992	0.906-1.00	0.902-1.01	0.499-0.519	0.501-0.510
	2000		0.499-0.556	0.912-1.03	0.919-1.03		
Zinc (Zn)	1998	1.02-1.03	1.77-1.98	1.78-1.99	1.79-2.03	1.53-1.98	1.01-1.04
	1999	5.02-5.17	0.944-1.98	1.81-2.00	1.81-2.02	0.988-1.04	1.00-1.02
	2000		0.998-1.11	1.82-2.06	1.84-2.07		

Appendix 6. Coordinates of water quality sampling sites in the Humboldt River basin referred to in this study and of mine dewatering discharge points.

Site Name	Latitude	Longitude
NDEP sampling sites		
Osino	40°N 55' 52"	115°W 38' 19"
Carlin	40°N 43' 12"	116°W 00' 33"
Maggie Creek	40°N 43' 11"	116°W 05' 40"
Palisade	40°N 35' 35"	116°W 11' 55"
Battle Mountain	40°N 40' 03"	116°W 55' 49"
Comus	40°N 58' 24"	117°W 23' 51"
Imlay	40°N 41' 31"	118°W 13' 00"
Below Rye Patch	40°N 28' 11"	118°W 18' 23"
Above Humboldt Sink	40°N 30' 10"	118°W 28' 00"
Toulon Drain	40°N 05' 02"	118°W 34' 40"
U.S. Geological Survey sampling sites		
Carlin	40°N 43' 40"	116°W 00' 30"
Maggie Creek	40°N 42' 59"	116°W 05' 32"
Palisade	40°N 36' 27"	116°W 12' 03"
Dunphy	40°N 42' 20"	116°W 31' 48"
Battle Mountain	40°N 40' 04"	116°W 55' 49"
Below Rye Patch	40°N 28' 03"	118°W 18' 24"
Mine dewatering discharge points		
Newmont Gold Quarry	40°N 46' 45"	116°W 09' 00"
Barrick Goldstrike	40°N 42' 16"	116°W 34' 46"
Lone Tree	40°N 51' 30"	117°W 10' 30"

Appendix 7. Long-term average water quality (total) for selected sites in the Humboldt River basin from data collected by the Nevada Division of Environmental Protection. See Appendix 6 for site coordinates. Sampling years for most elements were 1975-2002, except Maggie Creek and Below Rye Patch where they were 1994 or 1995 to 2002. Sampling years for TDS and TSS were 1989-2002, except for Maggie Creek and Rye Patch were they were 1995-2002.

Constituent	Osino	Carlin	Maggie Creek	Palisade	Battle Mountain	Comus	Imlay	Below Rye Patch	Above Humboldt Sink	Toulon Drain
As (µg/L)	6.7[a] [22][b] (4-12)[c]	6.6 [22] (3-10)	18.6 [13] (14-24)	7.7 [24/25] (<3-16)	9.7 [22/23] (<3-19)	20.4 [25] (9-49)	19.5 [23] (11-34)	30.5 [12] (22-45)	48.1 [25] (25-85)	63.2 [13] (45-115)
B (µg/L)	171. [21/22] (<50-500)	143. [21/22] (<50-300)	249. [13] (192-400)	177. [24/25] (<50-300)	216. [23] (100-300)	428. [25] (200-1000)	447. [23] (300-900)	514. [12] (400-900)	1726. [25] (400-6100)	1917. [13] (1200-3000)
Cd (µg/L)	-[d] [1/44] (<1-2)	- [0/45] (<1-<10)	- [0/13] (<1)	- [3/48] (<1-2)	- [3/46] (<1-2)	- [3/46] (<1-3)	- [2/46] (<1-1)	- [0/12] (<1)	- [6/47] (<1-7)	- [7/35] (<1-10)
Cr (µg/L)	- [1/44] (<1-8)	- [3/45] (<2-8)	- [0/13] (<2-<5)	- [2/48] (<2-8)	- [7/46] (<2-11)	- [8/46] (<2-6)	- [5/46] (<2-11)	- [0/12] (<2-<5)	- [5/47] (<2-12)	- [5/35] (<2-10)
Cu (µg/L)	- [18/39] (<2-30)	- [18/40] (<2-30)	- [4/10] (<2-10)	5.7 [24/43] (<2-30)	6.4 [26/42] (<2-30)	5.8 [24/42] (<2-30)	6.7 [26/44] (<2-30)	5.8 [8/10] (<2-20)	6.6 [26/44] (<5-30)	9.6 [24/34] (<5-60)
Fe (µg/L)	280. [32] (60-2880)	230. [33] (80-2980)	182. [13] (30-540)	197. [36] (30-2820)	590. [34] (50-5420)	960. [35] (90-10200)	727. [35] (70-11240)	384. [12] (130-973)	632. [36] (30-6560)	664. [24] (50-14500)
Hg (µg/L)	- [1/44] (<0.1-8)	- [3/45] (<0.1-0.5)	- [0/13] (<0.5)	- [2/48] (<0.1-0.5)	- [1/46] (<0.1-0.4)	- [2/46] (<0.1-0.6)	- [1/46] (<0.1-0.4)	- [0/12] (<0.1-<-0.5)	- [1/47] (<0.1-0.9)	- [2/35] (<0.1-0.6)
Mg (µg/L)	13100 [18] (10000-17000)	11800 [18] (9000-14000)	20500 [13] (18000-26000)	13600 [20] (9000-16000)	14600 [18] (10000-17000)	14300 [19] (12000-17000)	16700 [19] (14000-21000)	16800 [12] (14000-24000)	21000 [21] (15000-30000)	38000 [12] (26000-50000)
Pb (µg/L)	- [2/44] (<0.9-9)	- [5/45] (<0.9-9)	- [2/13] (<0.9-5)	- [8/48] (<2-28)	- [14/46] (<0.9-15)	- [12/46] (<0.9-19)	- [13/46] (<1-46)	- [1/12] (<0.9-0.6)	- [13/47] (<2-19)	- [8/35] (<0.9-22)
Se (µg/L)	- [5/32] (<0.6-1)	- [2/33] (<0.6-3)	- [6/13] (<0.9-2)	- [11/36] (<1-6)	- [8/34] (<0.9-7)	- [8/35] (<0.6-5)	- [12/35] (<0.8-6)	- [2/12] (<0.7-2)	- [16/36] (<1-38)	2.5 [14/24] (<1-28)

Appendix 7. (concluded)

Constituent	Osino	Carlin	Maggie Creek	Palisade	Battle Mountain	Comus	Imlay	Rye Patch	Above Humboldt Sink	Toulon Drain
Zn (µg/L)	7.1 [28/44] (<5-20)	7.5 [30/44] (<5-37)	10.7 [10/12] (<5-40)	8.5 [36/47] (<5-40)	11.1 [37/45] (<5-50)	12.1 [37/46] (<5-60)	11.0 [35/46] (<5-70)	10.7 [11/12] (<5-60)	10.0 [37/47] (<5-70)	12.9 [30/35] (<1-120)
TDS[e] (mg/L)	313. [58] (212-474)	283. [63] (200-500)	331. [42] (207-997)	307. [65] (216-550)	354. [61] (228-560)	461. [67] (302-1140)	460. [64] (314-730)	541. [37] (340-1050)	1281. [66] (478-4638)	1686. [41] (516-2592)
TSS[f] (mg/L)	31.3 [57] (4-542)	27.7 [63] (1-314)	19.2 [42] (2-160)	23.3 [64] (2-1060)	75.5 [61] (4-2776)	68.3 [66] (5-568)	65.4 [63] (4-700)	12.4 [37] (1-44)	43.5 [66] (5-312)	46.3 [40] (1-900)

[a] Geometric mean. One-half of less than values (non-detectable) were used in calculating means.
[b] Number of samples with detectable residues/total number of samples analyzed. If only one number is given, all samples had detectable residues.
[c] Extremes.
[d] Less than 50% of samples with detectable residues.
[e] Total dissolved solids.
[f] Total suspended solids.

Appendix 8. Short-term average water quality (dissolved) for selected sites in the Humboldt River basin from data collected by the Nevada Division of Environmental Protection (1997-2002). Concentrations are in µg/L. See Appendix for site coordinates.

Constituent	Osino	Carlin	Maggie Creek	Palisade	Battle Mountain	Comus	Imlay	Below Rye Patch	Above Humboldt Sink	Toulon Drain
As	6.5[a] [7][b]	5.7 [6]	17.5 [5]	7.9 [7]	9.9 [9]	22.0 [10]	20.2 [9]	33.2 [6]	46.0 [8]	71.0 [5]
	(4-10)[c]	(3-8)	(13-21)	(6-10)	(8-14)	(13-48)	(14-26)	(26-42)	(29-80)	(61-85)
B	219. [7]	204. [6]	270. [5]	248. [7]	275. [9]	528. [10]	524. [9]	592. [6]	1431. [8]	2343. [5]
	(100-500)	(100-300)	(200-400)	(200-400)	(200-392)	(300-1200)	(300-700)	(500-800)	(595-4200)	(1700-3000)
Cd	-[d] [0/7]	- [0/6]	- [0/5]	- [0/7]	- [0/9]	- [0/10]	- [0/9]	- [0/6]	- [0/8]	- [0/5]
	(<1)	(<1)	(<1)	(<1)	(<1)	(<1)	(<1)	(<1)	(<1)	(<1)
Cr	- [0/7]	- [0/6]	- [0/5]	- [0/7]	- [0/9]	- [0/10]	- [0/9]	- [0/6]	- [0/8]	- [0/5]
	(<1-<5)	(<2-<5)	(<2-<5)	(<2-<5)	(<2-<5)	(<2-<5)	(<2-<5)	(<2-<5)	(<2-<5)	(<2-<5)
Cu	10. [2]	na[e]	10. [2]	10. [1]	4.1 [4/6]	4.3 [4/6]	5.8 [3/5]	10. [1]	10.2 [3/4]	10. [2]
	(10)		(10)	(10)	(<2-10)	(<2-20)	(<2-130)	(10)	(<2-110)	(10)
Fe	59.0 [7]	60.5 [6]	32.7 [5]	51.3 [7]	100. [9]	158. [10]	128. [9]	89.0 [6]	118. [8]	94.6 [5]
	(10-130)	(30-570)	(10-50)	(20-200)	(30-250)	(100-350)	(30-373)	(20-190)	(30-680)	(60-150)
Hg	- [0/7]	- [0/6]	- [0/5]	- [0/7]	- [0/9]	- [0/10]	- [0/9]	- [0/6]	- [0/8]	- [0/5]
	(<0.5)	(<0.5)	(<0.5)	(<0.5)	(<0.1-<0.5)	(<0.1-<0.5)	(<0.1-<0.5)	(<0.5)	(<0.1-<0.5)	(<0.5)
Pb	- [0/7]	- [0/6]	- [0/5]	- [0/7]	- [0/9]	- [1/10]	- [1/9]	- [0/6]	- [0/8]	- [0/5]
	(<2-<5)	(<2-<5)	(<2-<5)	(<2-<5)	(<0.5-<5)	(<0.9-0.6)	(<0.9-2)	(<2-<5)	(<1-<5)	(<2-<5)
Se	2.2 [4/7]	- [1/6]	- [2/5]	- [0/7]	- [2/9]	- [1/10]	- [4/9]	- [0/6]	2.1 [5/8]	3.9 [3/5]
	(<2-6)	(<2-2)	(<2-3)	(<2-<6)	(<0.7-3)	(<0.6-3)	(<0.7-4)	(<2-<6)	(<2-5)	(<6-6)
Zn	34.6 [7]	31.0 [5]	16.4 [5]	29.9 [6]	34.4 [9]	24.1 [9/10]	35.3 [9]	22.6 [6]	19.4 [7]	46.2 [5]
	(10-70)	(10-80)	(10-30)	(10-50)	(10-90)	(<10-40)	(20-110)	(10-50)	(10-70)	(30-70)

[a] Geometric mean. One-half of less than values (non-detectable) were used in calculating means.

[b] Number of samples with detectable residues/total number of samples analyzed. If only one number is given, all samples had detectable residues.

[c] Extremes.

[d] Less than 50% of samples with detectable residues.

[e] Not analyzed

Appendix 9. Long-term water quality data (total) from the U.S. Geological Survey (http://nwis.waterdata.usgs.gov/nwis/qwdata) for two stations on the Humboldt River. Years of record are provided in the text. See Appendix 6 for site coordinates.

	Carlin			Below Rye Patch		
Constituent	Mean[a]	N[b]	Extremes	Mean	N	Extremes
As (µg/L)	8.9	15/15	5-13	35.1	31/31	23-60
Ba (µg/L)	138.	14/15	<100-400	99.1	11/18	<100-300
Cd (µg/L)	nd[c]	2/6	<1-1	nd	4/21	<2-40
Cr (µg/L)	nd	4/9	<10-10	nd	6/14	<10-30
Cu (µg/L)	10.0	14/14	2-100	8.9	21/31	<20-40
Fe (µg/L)	1271.	15/15	200-8700	654.	31/31	230-1800
Hg (µg/L)	0.13	14/14	<0.1-0.4	0.20	16/30	<0.1-2.6
Mn (µg/L)	101.	15/15	50-280	19.4	26/31	<10-70
Ni (µg/L)	4.0	12/12	1-10	3.7	12/12	2-8
Pb (µg/L)	4.3	13/14	<1-24	nd	11/24	<2-30
Se (µg/L)	nd	2/7	<1-2	0.89	24/29	<1-1
Zn (µg/L)	35.6	15/15	10-80	19.9	22/30	<20-60
TSS[d] (mg/L)	71.9	98/98	9-2440	37.3	106/106	14-136

[a] Geometric means. Data for samples with non-detectable concentrations that had unknown detection limits were excluded from the calculations and data set.

[b] Number with detectable concentrations/total analyzed.

[c] Not detected; < 50% of samples with detectable concentrations.

[d] Total suspended solids.

Appendix 10. Water quality data (dissolved; filtered) for several stations on the Humboldt River from the U.S. Geological Survey (http://nwis.waterdata.usgs.gov/nwis/qwdata). Site coordinates are provided in Appendix 6. Years of data collection, except for magnesium and total dissolved solids (see footnote), are provided in parentheses under each site name.

Constituent	Carlin (1979-98)	Maggie Creek (1993-94)	Palisade (1990-91)	Dunphy (1991-94)	Battle Mountain (1991-98)	Below Rye Patch (1975-99)
Al (µg/L)	13.6[a] [42/64][b]	- [1/4]	8.4 [2/4]	8.6 [5/9]	9.7 [16/30]	5.9 [20/27]
	(<5-180)[c]	(<10-10)	(<10-20)	(<10-20)	(<5-60)	(<1-60)
As (µg/L)	6.8 [63]	12.7 [4]	8.3 [3]	8.6 [8]	8.1 [26]	29.0 [57]
	(3-14)	(6-25)	(7-9)	(7-9)	(5-11)	(16-60)
Ba (µg/L)	86. [76/77]	99. [4]	103. [4]	93. [9]	82. [30]	41.8 [40/43]
	(<100-140)	(91-110)	(93-110)	(78-110)	(61-110)	(<100-82)
Be (µg/L)	- [2/47]	- [0/4]	- [0/3]	- [1/8]	- [0/26]	- [½4]
	(<0.5-0.7)	(<0.5)	(<0.5)	(<0.5-0.7)	(<0.5-<1)	(<0.5-0.5)
Cd (µg/L)	- [4/61]	- [1/4]	- [1/3]	- [2/8]	- [4/26]	- [2/42]
	(<1-2)	(<1-1)	(<1-1)	(<1-3)	(<1-2)	(<1-2)
Cr (µg/L)	- [11/52]	1.2 [2/4]	- [1/3]	- [2/8]	- [4/26]	- [14/35]
	(<1-7)	(<1-8)	(<1-2)	(<1-8)	(<1-7)	(<1-20)
Cu (µg/L)	2.3 [55/62]	1.1 [2/4]	1.0 [2/3]	0.92 [4/8]	1.7 [22/26]	2.8 [53/58]
	(<1-13)	(<1-3)	(<1-2)	(<1-2)	(<1-6)	(<1-9)
Fe (µg/L)	12.5 [69/77]	5.5 [4]	7.5 [4]	4.5 [8/9]	6.9 [23/30]	9.9[34/58]
	(<3-130)	(3-9)	(5-10)	(<3-9)	(<3-40)	(<3-130)
Hg (µg/L)	- [9/56]	- [0/2]	- [0/3]	- [0/5]	- [0/22]	- [15/43]
	(<0.1-0.5)	(<0.1)	(<0.1)	(<0.1)	(<0.1)	(<0.1-1.8)
Mg[d] (mg/L)	11.1 [175]	23.6 [4]	11.4 [68]	13.2 [9]	12.7 [30]	17.3 [450]
	(5.4-17)	(21-26)	(5.4-17)	(11-15)	(7.9-18)	(7.8-53)
Mn (µg/L)	9.8 [77/78]	23.2 [4]	10.5 [4]	11.4 [9]	5.0 [28/30]	2.7 [28/55]
	(<1-160)	(7-130)	(8-15)	(5-21)	(<4-92)	(<1-40)
Mo (µg/L)	- [3/63]	- [1/4]	- [0/4]	- [1/9]	- [3/30]	12.3 [18/26]
	(<10-13.5)	(<10-10)	(<10)	(<10-10)	(<10-20)	(<10-37)

Appendix 10. (concluded)

Constituent	Carlin (1979-98)	Maggie Creek (1993-94)	Palisade (1990-91)	Dunphy (1991-94)	Battle Mountain (1991-98)	Below Rye Patch (1975-99)
Ni (µg/L)	1.0 [42/71] (<1-6)	1.2 [3/4] (<1-2)	0.71 [2/4] (<1-1)	- [2/9] (<1-1)	0.80 [16/30] (<1-3)	1.7 [30/35] (<1-9)
Pb (µg/L)	- [21-57] (<1-10)	- [0/4] (<1)	- [0/3] (<1)	- [0/8] (<1)	- [½6] - [17/43] (<1-5)	(<1-11)
Se (µg/L)	- [3/69] (<1-1)	2.0 [3/4] (<1-5)	- [0/4] (<1)	- [0/9] (<1)	- [3/30] (<1-1)	0.74 [30/54] (<1-1.5)
Zn (µg/L)	5.6 [41/62] (<3-130)	15.1 [4] (5-44)	- [0/3] (<3)	- [3/8] (<3-11)	- [10/26] (<3-52)	3.3 [24/47] (<1-25)
TDS[d,e] (mg/L)	297. [172] (178-444)	424. [4] (389-460)	317. [68] (226-416)	353. [9] (296-391)	345. [30] (237-484)	571. [395] (364-2190)

[a] Geometric mean. - = < 50% with detectable concentrations. Data for samples with non-detectable concentrations that had unknown detection limits were excluded from the calculations and data set.

[b] Number of samples with detectable concentration/total number of samples. Where only one number is given all samples had detectable concentrations.

[c] Extremes.

[d] Years sampled, where they deviate from column headings, were as follows: Carlin 1965-98; Palisade 1962-91; Rye Patch 1951-99, but with a gap in 1972-73 for TDS only.

[e] Total dissolved solids.

Appendix 11. Concentrations[a] of selected constituents in Maggie Creek upstream of the discharge point and in waters discharged to Maggie Creek by the Newmont Gold Quarry Mine, April 1994 through September 2000. Site coordinates for discharge point provided in Appendix 6. From data provided to the Nevada Division of Environmental Protection.

Constituent	Maggie Creek (n = 60)	Discharge to Maggie Creek (n = 60)
As (µg/L)	9.8[b] [60][c] (1 - 30)[d]	21.3 [60] (4 - 32)
Cd (µg/L)	-[e] [6] (nd[f] - 3)	- [7] (nd - 3)
Fe (µg/L)	239 [59] (nd - 4025)	39.3 [57] (nd - 500)
Hg (µg/L)	- [3] (nd - 7)	- [0] (nd)
Mn (µg/L)	22.1 [55] (nd - 179)	2.35 [30] (nd - 19)
Se (µg/L)	- [18] (nd - 5)	- [15] (nd - 4)
TSS (mg/L)	1.4 [37] (nd - 630)	- [27] (nd - 13.7)
TDS (mg/L)	302 [60] (178-387)	350 [60] (220-463)
pH (SU)	not reported	8.01 [60] (7.03-8.40)

[a] Means are from quarterly or 30-day averages. For Fe, assumed that the detection limit for less than detectable (LTD) values was 20 µg/L, for Mn assumed that the detection limit for LTD values was 1 µg/L, and for TSS assumed that the detection limit for LTD values was 100 µg/L. One-half of these values was used in calculating means.

[b] Geometric mean.

[c] Number of samples with detectable concentration.

[d] Extremes.

[e] More than 50% of samples with non-detectable concentrations.

[f] Not detected; detection limits were not reported in many cases.

Appendix 12. Concentrations of selected constituents in waters discharged to the Humboldt River by the Barrick Goldstrike Mine, September 1997 through February 1999. Site coordinates for discharge point provided in Appendix 6. From data provided to the U.S. Fish and Wildlife Service.

Constituent	n	Concentration Mean[a]	Concentration Extremes	Number with detectable concentration
As (µg/L)	18	1.2	<1 - 7	10
B (µg/L)	18	570	493 - 633	18
Cu (µg/L)	18	-[b]	<4 - 6	1
Fe (µg/L)	18	-	<19 - 39	5
Pb (µg/L)	18	-	<1 - 3	3
Zn (µg/L)	17	-	<4 - 9	5
TSS (mg/L)	17	1.8	0 - 5	11[c]
TDS (mg/L)	17	364	313 - 412	17
pH (SU)	17	7.43	6.92 - 7.96	17

[a] Geometric means are based on 30-day averages. Non-detectable concentrations set to one-half of the detection limit when calculating means.

[b] More than 50% of the samples had non-detectable concentrations.

[c] Zeros (n = 5) considered not detectable, plus one at < 1.6 mg/L. Zeros used in calculation of the mean.

Appendix 13. Concentrations of selected constituents in waters discharged to the Humboldt River by the Lone Tree Mine, July 1991 through September 2000. Site coordinates for discharge point provided in Appendix 6. From data provided to the Nevada Division of Environmental Protection.

Constituent	Outfall Number 001 (n = 24)	003 (n = 2)	004 (n = 10)	005 (n = 87)[a]
As (µg/L)	7.1[b] [24][c] (3 - 21)[d]	40.6 [2] (33 - 50)	4.9 [9] (<5 - 8)	26.4 [86] (<5 - 96)
B (µg/L)				726 [54] (649 - 811)
Cu (µg/L)	-[e] [0] (<20 - <50)	- [0] (<20)	- [0] (<2 - <20)	- [33] (<2 - 49.1)
Fe (µg/L)				245 [78] (40 - 1300)
Mn (µg/L)				57.4 [29] (15 - 121)
Pb (µg/L)	- [0] (<3 - <100)	- [0] (<50)	- [0] (<50)	- [33] (<0.8 - 20[f])
Zn (µg/L)	- [6] (<10 - 30)	- [0] (<20)	- [0] (<20)	6.4 [50] (<2 -1400)
TSS (mg/L)	- [5] (<1-2)	9.9 [2] (7-14)	0.9 [8] (0-2)	3.8 [84] (<0.1-113)
TDS (mg/L)	446 [24] (405-500)	469 [2] (449-490)	438 [10] (403-456)	471 [87] (408-603)
pH (SU)	7.22 [24] (6.9-7.8)	7.88 [2] (7.8-7.96)	7.25 [10] (7.02-7.57)	8.18 [87] (6.97-9.45)

[a] Samples sizes were 54 for B, 78 for Fe, and 29 for Mn. Boron sampling was initiated in April 1996 and continued through September 2000. Iron sampling was initiated in April 1994 and continued through September 2000. Manganese sampling was initiated in April 1994 and continued through October 1996, with a lapse in November and December 1995.

[b] Geometric mean.

[c] Number of samples with detectable concentrations.

[d] Extremes.

[e] More than 50% of samples with non-detectable concentrations.

[f] Retested at <5 µg/L.

Appendix 14. Concentrations (µg/L) of a broader array of selected constituents in waters discharged by the Newmont Gold Quarry Mine, the Barrick Goldstrike Mine, and the Lone Tree Mine that were generally monitored annually. Site coordinates for discharge points provided in Appendix 6. From data provided to the Nevada Division of Environmental Protection or the U.S. Fish an Wildlife Service.

Element	Newmont (n = 5)	Barrick (n = 1)	Lone Tree (n = 7)
Ag	- [a] (<5 - 8)[b] [1][c]	<5	- (<2 - 5) [1]
Al	48.1[d,e] (<37 - 79) [2]	<37	no data
As	11.1 (<2 - 23) [4]	no data[f]	23.2 (16 - 37) [7]
B	267[e] (242 - 317) [3]	no data[f]	no data
Ba	104 (97 - 111) [5]	16	112 (98 - 150) [7]
Be	-[e] (<2) [0]	<2	no data
Cd	- (<1 - 2) [1]	2	- (<0.1 - <2.4) [0]
Cr	- (<1 - <8) [0]	<8	- (<5 - <8) [0]
Cu	- (<1 - 11) [1]	no data[f]	- (<0.2 - 6) [2]
Fe	37.5 (5 - 179) [5]	no data[f]	130 (<20 - 686) [6]
Hg	- (<0.2) [0]	<0.2	- (<0.2) [0]
Mg	19300 (15600 - 22000) [5]	1700	12200 (11600 - 12500) [7]
Mn	2.8 (<2 - 7) [4]	2	23.6 (6 - 113) [7]
Ni	-[e] (<16 - <23) [0]	<16	no data
Pb	- (<2 - 5) [2]	no data[f]	0.65 (<0.8 - 1) [4]
Sb	2.5[e] (2 - 4) [3]	<2	no data
Se	- (<0.2 - 5) [2]	<2	- (<1 - <10) [0]
Tl	-[e] (<1) [0]	<1	no data
Zn	10.9 (4 - 25) [5]	no data[f]	- (<2 - 15) [2]

[a] More than 50% of samples with concentrations below the detection limit, therefore no mean was calculated.
[b] Extremes.
[c] Number with detectable residues.
[d] Geometric mean. One-half of the detection limit used in calculating means in cases where non-detectable residues were reported.
[e] n = 3.
[f] These elements were monitored on a monthly basis by Barrick. See Appendix 12.

FIGURES