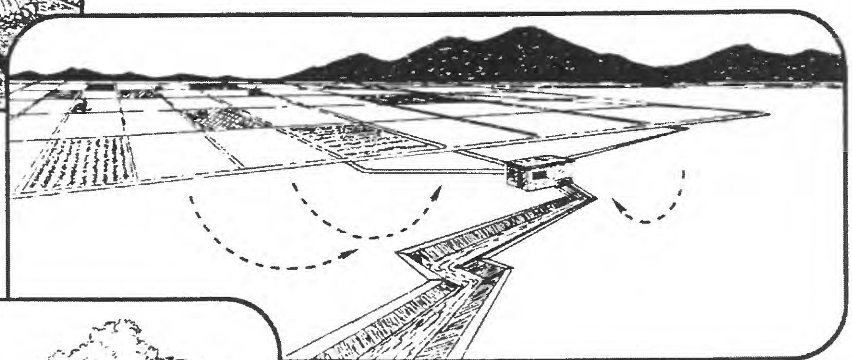
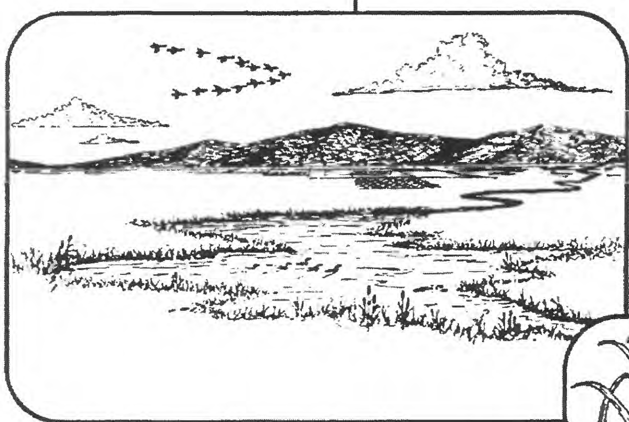
Field Verification Study of Water Quality, Bottom Sediment, and Biota Associated With Irrigation Drainage in and near Humboldt Wildlife Management Area, Churchill and Pershing Counties, Nevada, 1996





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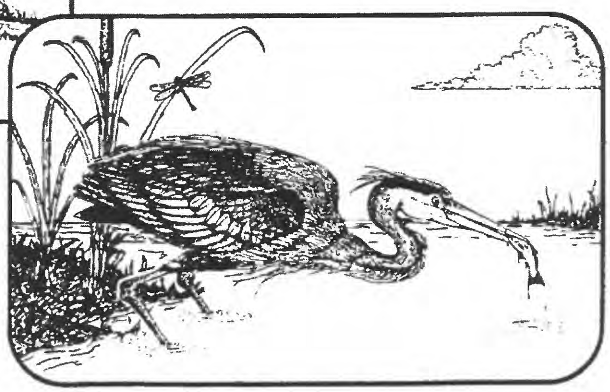

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Field Verification Study of Water Quality, Bottom Sediment, and Biota Associated with Irrigation Drainage in and near Humboldt Wildlife Management Area, Churchill and Pershing Counties, Nevada, 1996

By Ralph L. Seiler, U.S. Geological Survey, and
Peter L. Tuttle, U.S. Fish and Wildlife Service

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Carson City, Nevada
1997

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U.S. DEPARTMENT OF THE INTERIOR
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CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
acre	4,047	square meter
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
inch (in.)	25.40	millimeter
mile (mi)	1.609	kilometer

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929, formerly called "Sea-Level Datum of 1929"), which is derived from a general adjustment of the first-order leveling networks of the United States and Canada.

For temperature, degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) by using the formula °F=[1.8(°C)]+32. Degrees Fahrenheit may be converted to degrees Celsius by using the formula °C=5/9(°F-32).

ABBREVIATED WATER QUALITY UNITS

µS/cm	microsiemens per centimeter at 25 degrees Celsius
mL	milliliter
mg/L	milligram per liter
µg/g	microgram per gram
µg/L	microgram per liter

For those who wish to convert dry-weight concentrations to wet-weight concentrations for biological samples, the equation is:

wet weight = dry weight [1-(percent moisture/100)]

Field Verification Study of Water Quality, Bottom Sediment, and Biota Associated with Irrigation-Drainage in and near Humboldt Wildlife Management Area, Churchill and Pershing Counties, Nevada, 1996

By Ralph L. Seiler, U.S. Geological Survey, and Peter L. Tuttle, U.S. Fish and Wildlife Service

ABSTRACT

Physical, chemical, and biological data were collected from the Lovelock agricultural area during 1986-90 as part of reconnaissance investigations into the effects of irrigation drainage on fish and wildlife in the Humboldt Wildlife Management Area (WMA), Nevada. Arsenic, boron, dissolved solids, mercury, molybdenum, sodium, un-ionized ammonia, and selenium exceeded biological effect levels or Nevada standards for the protection of aquatic life. Causes of contamination in the wetlands were identified as irrigation drainage, hydrogeologic setting, historical mining activities, and drought. The Humboldt River Basin underwent an extended drought during and immediately after data collection for the Humboldt reconnaissance investigation in 1990.

A limited field verification was made in 1996 to determine if contaminant concentrations in water and birds during the drought conditions of the Humboldt reconnaissance investigation were representative of more normal climatic conditions. Salinity and boron concentrations in water samples from most sites were lower during the 1996 verification study than during 1987-90. Selenium and arsenic concentrations in water samples from most sites were about the same as those measured during 1987-90. In Humboldt Lake, salinity and concentrations of arsenic, boron, molybdenum, and selenium were generally higher than concentrations in samples collected during 1987-90. Most selenium and arsenic concentrations in water samples fall below the Nevada chronic criterion for the protection of aquatic life. Concentrations of arsenic, chromium, mercury, and selenium in aquatic vegetation, aquatic invertebrates, and avian eggs and livers were generally higher in 1996 than during 1986-90. Arsenic, boron, mercury, and selenium in one or more biological matrices exceeded concentrations associated with adverse effects to avian species.

INTRODUCTION

Background

During 1990-91, a reconnaissance investigation was made in the Humboldt Wildlife Management Area (WMA), within the Lovelock Valley Hydrographic Area,[1] Nev., as part of the Department of the Interior National Irrigation Water Quality Program (NIWQP; Seiler and others, 1993). Data were collected in the area during 1986-88 as part of the Stillwater reconnaissance investigation of the nearby Stillwater WMA, Nev. (Hoffman and others, 1990). The Humboldt WMA was selected for a reconnaissance investigation by NIWQP, in part, because of its hydrological and ecological similarity to Stillwater WMA where irrigation drainwater was known to have caused significant harmful effects to fish and wildlife.

[1]Formal hydrographic areas in Nevada were delineated systematically by the U.S. Geological Survey and Nevada Division of Water Resources in the late 1960's (Rush, 1968; Cardinalli and others, 1968) for scientific and administrative purposes. The official hydrographic-area names, numbers, and geographic boundaries continue to be used in Geological Survey scientific reports and Division of Water Resources administrative activities.

Detailed information about the hydrology, climate, and land use near Lovelock is provided by Seiler and others (1993). Rye Patch Reservoir, which impounds flow from the Humboldt River, is used to store water for delivery to farmers in Lovelock Valley during the growing season. The 39,600 acres of irrigable land near Lovelock (fig. 1) are used primarily to grow hay and seed alfalfa.

Wetlands in the Humboldt WMA have been identified as one of the most important wildlife habitats in Nevada (R. Hallock, U.S. Fish and Wildlife Service, written commun., 1981). These wetlands provide foraging, nesting, and staging habitat for waterfowl, shorebirds, and colonial nesting birds on the Pacific Flyway. Species assemblage is similar to that of Lahontan Valley, where more than 200 avian species, most of which are migratory, have been identified. The only threatened, endangered, or candidate species potentially exposed to irrigation drainage in the Humboldt WMA are bald eagles (*Haliaeetus leucocephalus*), American peregrine falcons (*Falco peregrinus anatum*), and mountain plovers (*Charadrius montanus*). Bald eagles winter in Nevada, most frequently near wetlands, including areas in the lower Humboldt River Basin (Herron and others, 1985). Peregrine falcons have been reported in Lahontan Valley (Alcorn, 1988) and also may occur infrequently in the lower Humboldt River Basin. Mountain plovers rarely have been seen in Lahontan Valley (Alcorn, 1988) and may be found in the lower Humboldt River basin.

The reconnaissance investigation (Seiler and others, 1993) concluded that (1) arsenic, boron, mercury, and selenium concentrations are of primary concern to human health and to fish and wildlife in and near the Humboldt WMA and (2) un-ionized ammonia, sodium, and dissolved-solids concentrations may approach concern levels. During the reconnaissance investigation, contamination existed in wetland areas that received irrigation drainage. In addition to irrigation drainage, however, historical mining activities, regional drought, and the hydrogeologic setting were identified as potential contributors to the observed contamination in wetland areas.

Although selenium concentrations in water were low in comparison with some other areas in the western United States affected by irrigation drainage (Seiler and others, 1993), they equalled or exceeded concentrations associated with food chain bioconcentration (Skorupa and Ohlendorf, 1991). Selenium concentrations in livers of juvenile migratory birds greatly exceeded selenium concentrations in their food sources. The median selenium concentration in livers of juvenile black-necked stilts (*Himantopus mexicanus*) was 29 μg/g, which approaches the threshold for toxicity (30 μg/g) in juvenile and adult birds (Heinz, 1996). The level of selenium in one of three duck muscle samples was near the Nevada public health advisory criterion of 1 μg/g wet weight (Seiler and others, 1993).

The Humboldt WMA underwent an extended drought during and immediately after data collection for the reconnaissance investigation in 1990. Rye Patch Reservoir, the source of irrigation water used in the study area, was emptied to provide water to irrigators in the year following the reconnaissance investigation. In the Humboldt WMA, Toulon Lake went dry in 1990 and Humboldt Lake went dry the following year. During the drought, severe desiccation and cracking of the soils occurred in the area. During the post-irrigation season in 1993, farmers blocked drains to the wetlands and pumped drainwater into dry canals to wet the bottoms, thereby reducing future canal seepage losses.

Above-average runoff in the Humboldt River Basin in 1993 and near average runoff in 1995 refilled Rye Patch Reservoir and left standing water in Humboldt Lake for the first time in 4 years. Toulon Lake remained dry from 1990 until the 1996 irrigation season when it began receiving water once again.

Objectives and Scope of Verification Study

The principal objective of the verification field study in 1996 was to determine if contaminant concentrations measured in water and biota during the drought conditions—when the Humboldt reconnaissance investigation was done—were more representative of normal climatic and hydrologic conditions.

The scope of the verification study focused on collecting a limited number of water-quality and biological samples from sites previously identified as potentially contaminated during the earlier reconnaissance investigations. Funding was not sufficient to allow more extensive sampling.

This report describes data-collection activities and compares chemical concentrations in water and biota from the verification study and the earlier reconnaissance investigations. For the convenience of investigators studying the effects of land-use changes in the upper Humboldt River Basin on the Humboldt WMA, all chemical data collected during the verification study are presented along with selected chemical data collected during previous investigations.

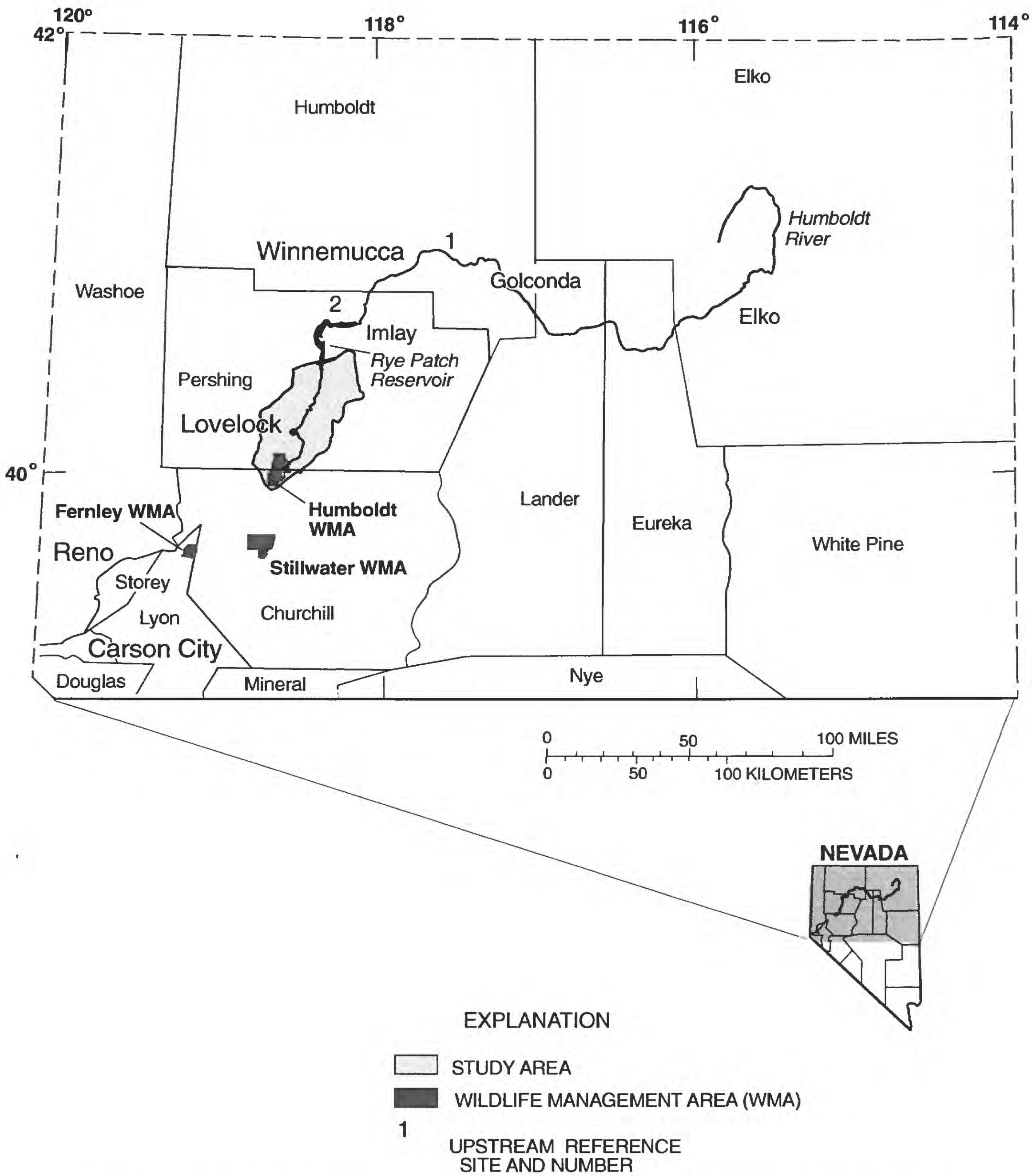


Figure 1. Location of study area, Wildlife Management Areas, and upstream reference sites in relation to Humboldt River and other geographic features in Nevada. For site information, see table 1.

STUDY APPROACH AND METHODS

Water samples were collected by the U.S. Geological Survey (USGS) from nine sites in and near the Humboldt WMA in late May 1996. Six of the nine sites had been sampled during the reconnaissance investigation. Two previously unsampled drain sites were sampled to obtain chemical analyses of water that bio-assay results had identified as toxic during the Humboldt reconnaissance investigation (Seiler and others, 1993). A sample of water used for irrigation was collected at a streamflow-gaging station immediately below Rye Patch Dam. During the earlier reconnaissance investigations, samples of water were collected prior to irrigation use at an ungaged location about 10 miles downstream.

All water samples were analyzed for major ion and trace-element concentrations at the USGS National Water Quality Laboratory in Arvada, Colo., by the same analytical methods used during the reconnaissance study (Seiler and others, 1993, p. 22-23). These data reside in the USGS National Water Information System and the U.S. Environmental Protection Agency (USEPA) STORET databases. As part of quality-assurance practices, a blank water sample was prepared at one of the sites to assess the potential for contamination of major constituents and trace elements during sample collection and processing activities.

Biological samples were collected in May and July 1996 by the U.S. Fish and Wildlife Service (USFWS). Pondweed (*Potamegeton spp.*) was collected by hand, rinsed with water from the site, and placed in pre-cleaned 60 mL glass jars with Teflon-lined closures. Water boatmen (a nektonic Hemipteran insect) were collected with a kick net and placed in pre-cleaned 60 mL glass jars with Teflon lined closures. Aquatic vegetation and invertebrate samples were stored on ice in the field and frozen upon return to the laboratory. American coot (*Fulica americana*) and American avocet (*Recurvirostra americana*) eggs were collected by hand, stored on ice in the field, and refrigerated upon return to the laboratory. Eggs were later opened using pre-cleaned stainless steel instruments. Contents were placed in pre-cleaned 60 mL glass jars with Teflon-lined closures, then frozen. Pre-flight juvenile coots and avocets were collected using a shotgun with steel shot. Individual birds were placed in plastic bags and stored on ice in the field. Birds were later dissected in the laboratory using pre-cleaned stainless steel instruments. Livers were placed in pre-cleaned 60 mL glass jars with Teflon-lined closures and frozen. Black-necked stilts were collected during the reconnaissance investigations (1986-90) to evaluate shorebirds. However, only a few individuals of this species were observed at Humboldt Lake in 1996, so avocets were collected as a surrogate.

Biological samples were shipped frozen to the Research Triangle Institute, Research Triangle Park, N.C., for trace-element analysis. Tissue samples were homogenized using a food processor. A portion of the tissue sample was freeze dried for determination of moisture content. Arsenic and selenium concentrations were determined using graphite furnace atomic absorption. Mercury concentrations were determined using cold vapor atomic absorption. Other trace elements were determined using inductively coupled plasma emission spectroscopy. Laboratory analytical quality-assurance and quality-control procedures are described in a reference manual prepared by the Patuxent Analytical Control Facility (1990).

RESULTS

Sample Collection Sites

Locations of sites where water-quality and biological data have been collected in the study area are shown in figures 1 and 2. A list of the sites used in this and the earlier reconnaissance investigations and the rationale for their selection are presented in table 1. For data analysis, the sites were classified in three groups. River and reservoir sites on the Humboldt River above the Lovelock agricultural area were classified as irrigation source water sites. The Toulon Lake site and sites ultimately discharging to Toulon Lake were classified as Toulon Lake system sites. The Humboldt Lake site and sites ultimately discharging to Humboldt Lake were classified as Humboldt Lake system sites.

Six sites (4, 5, 7, 8, 10, and 11) were sampled during the earlier reconnaissance investigations and the verification study. Data from four new sites were collected also. A site on the Humboldt River immediately below Rye Patch Dam (site A, fig. 2) was selected to replace site 3 from the earlier reconnaissance investigations because site A is gaged, whereas site 3 is not. Both sites (A and 3) are upstream of irrigated areas.

A spring at Toy, Nev. (site B, fig. 2), was identified as a possible source of contaminants to Toulon Lake in the Humboldt reconnaissance report

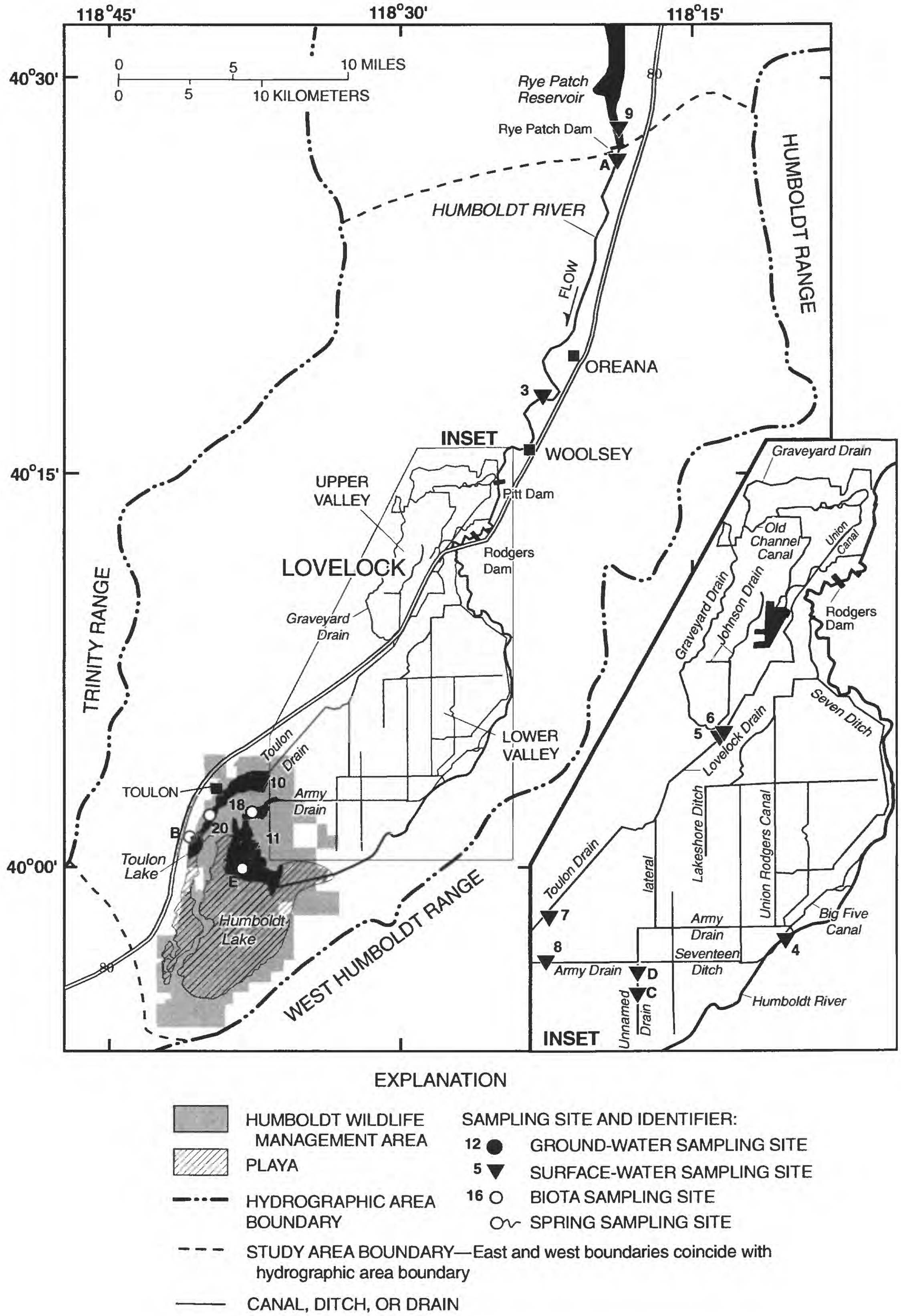


Figure 2. Location of sampling sites for analyses of water, bottom sediment, and biota during verification and reconnaissance studies (Seiler and others, 1993).

Table 1. Sampling sites for collection of water and biota in and near Humboldt Wildlife Management Area, 1987-96

[Abbreviations: M, miscellaneous measurement, 1992; R, reconnaissance investigations, 1986-90; V, verification study, 1996]

Site no. (figs. 1 and 2)	Site location	U.S. Geological Survey site identification [1]	Period of data collection	Rationale for site selection
		Irrigation source water		
1	Humboldt River near Golconda	10327800	R	Reference site
2	Humboldt River near Imlay	10333000	R	Reference site
9	Rye Patch Reservoir	10334500	R	Reference site
A	Humboldt River near Rye Patch	10335000	V	Reference site, discharge from reservoir
3	Humboldt River at Upper Valley Road	10335300	R	Initial source water
		Toulon Lake system		
5	Graveyard Drain at railroad	10335800	R,V	Inflow from Upper Valley
6	Lovelock Drain	10335750	R,V	Contains Lovelock sewage effluent
7	Toulon Drain	10336035	R,V	Inflow with high arsenic concentration
B	Toy Spring	400103118400701	M	Possible source of contaminants to Toulon Lake
10	Toulon Lake	400407118363001	R,V	Terminal drainage, wildlife concerns
		Humboldt Lake system		
4	Humboldt River near Lovelock	10336000	R,V	Inflow, high arsenic concentrations, historical data
C	Unnamed Drain	400229118330501	V	Inflow, probably site identified as toxic in reconnaissance investigation
D	Army Drain Inflow	400234118330501	V	Inflow, probable contaminant source
8	Army Drain	10336040	R,V	Inflow
11	Upper Humboldt Lake	400009118372001	R,V	Terminal drainage, wildlife concerns
E	Upper Humboldt Lake at islands	--	V	Nesting area for birds

[1] Many sample sites are assigned a unique identification number on the basis of geographic location. The eight-digit numbers are station numbers that follow the downstream order system. The first two digits, or part number, refers to the drainage basin.The following six digits is the downstream-order number, which is assigned according to the geographic location of the site in the drainage basin; larger number stations are downstream from smaller number stations. The 15-digit numbers are based on the grid system of latitude and longitude. The first six digits denote degrees, minutes, and seconds of latitude; the next seven digits denote the degrees, minutes, and seconds of longitude; the last two digits, assigned sequentially, identify the sites within a 1-second grid. For example, site 400407118363001, is at 40°04'07" latitude and 118°36'30" longitude and is the first site recorded in that 1-second grid.

(Seiler and others, 1993, p. 9). This spring discharges through old mine tailings into Toulon Lake. A water sample from the spring, as it issues from the tailings, was collected for chemical analysis in June 1992 and the results are included here. This site is referred to as Toy spring in this report.

Bioassays made during the Humboldt reconnaissance investigation using water from sites identified by Seiler and others (1993) as Rennie Road Drains 1, 2, and 3 (sites 14-16 in fig. 2) indicated complete mortality of test organisms within 2 days and had specific conductance values ranging from 7,600 to 22,500 µS/cm (Seiler and others, 1993, tables 6-7). However, in 1996, the drain along Rennie Road contained extensive growths of cattails (*Typha latifolia*) and had specific conductance values of about 2,400 µS/cm. Therefore, these sites probably were misnamed and mislocated during the reconnaissance investigation because cattails are typically found in water with a specific conductance less than 5,000 µS/cm (Stewart and Kantrud, 1971).

An unnamed drain, herein called Unnamed Drain, is 1 mile west of Rennie Road drain (fig. 2) and is believed to be the site where the toxic water samples were actually collected during the Humboldt reconnaissance investigation. During the verification study, specific conductance ranging from 10,500 to 13,500 µS/cm was measured along Unnamed Drain. Water from Unnamed Drain, a long deep trench without a natural outlet, is mixed with water from Seventeen Ditch (fig. 2) and pumped into Army Drain where it eventually discharges to Humboldt Lake. Water samples were collected from Unnamed Drain (site C, fig. 2) and the pipe discharging the mixture of water to Army Drain (site D, fig. 2).

Biological samples from Humboldt Lake were collected in a different location than the water samples. Water samples were collected near the east edge of the lake (fig. 2) at the site where samples were collected during the earlier reconnaissance investigations. Biological samples were collected from the center of the lake where the birds nest on islands the Nevada Division of Wildlife constructed to provide a protected breeding area for shorebirds. The site where water samples were collected was reached by wading from the shore; the site where biological samples were collected was reached by airboat. Water and biota collection sites were shallow and feeding shorebirds were abundant in both areas.

Chemical Analyses

Water

The Humboldt River below Rodgers Dam and wetlands in Humboldt WMA are designated as class D waters of the State (Nevada Administrative Code 445A.127). Beneficial uses of class D waters include recreation not involving contact with water, aquatic life, propagation of wildlife, irrigation, watering of livestock, and industrial supply except for food-processing purposes. Therefore, standards for municipal and domestic supply do not apply to most areas investigated in 1996.

Results of chemical analyses of water samples collected during the verification study in the Humboldt WMA are presented in the Supplemental Data section at the back of this report. The Supplemental Data section also includes selected data from the reconnaissance investigation and data for a miscellaneous sample collected from Toy spring in 1992. Concentrations of constituents in water were compared with Nevada water-quality standards and criteria (table 2).

In this study, a volume of deionized water was treated as a sample in all aspects, including exposure to water-sample containers, filtration apparatus, chemical preservatives, holding times, and laboratory processing. Chromium and zinc were detected in this field blank at concentrations of 1.2 and 9 µg/L; no other constituents were detected at concentrations exceeding the reporting level. The exceedances for chromium and zinc are unexplained.

In general, dissolved-solids concentrations in water samples collected in 1996 were at the low end of the range of concentrations measured during 1987-90 (fig. 3). The only exception was in Humboldt Lake (site 11) where the dissolved-solids concentration in 1996 was nearly twice the highest measurement in 1987-90. The reason for the difference is not known. The arm of the lake where the sample was collected apparently is more saline than the rest of the lake. Field specific conductance of water near the bird nesting site (site E) was 7,500 µS/cm on July 12, 1996, when the juvenile birds were collected. This value is greater than any measurement made between 1987-90. Three samples for dissolved solids exceeded 3,000 mg/L, the State standard for watering of livestock.

Boron concentrations show a pattern similar to dissolved solids. The lowest boron concentrations were measured during the 1996 verification study, except at Humboldt Lake where boron concentrations were substantially higher than previous measurements.

Although boron concentrations in water typically were lower in 1996 than during 1987-90, almost all were greater than 1,000 µg/L, which would have exceeded the Nevada aquatic life criterion for boron (550 µg/L). That criteria was eliminated in 1995. Boron in all samples collected from sites affected by irrigation-drainage exceeded the Nevada standard for irrigation water (750 µg/L; table 2). Boron concentrations in water samples collected in 1996 from Toy spring, Unnamed Drain, Army Drain, and Humboldt Lake exceeded the Nevada standard for watering of livestock (5,000 µg/L; table 2).

The molybdenum concentration in the irrigation source water was near the Nevada chronic criterion for the protection of aquatic life (19 µg/L). Molybdenum concentrations in samples from most of the other sites exceeded the criterion (table 6). The molybdenum concentration from Humboldt Lake in 1996 was substantially higher than previous measured concentrations.

Like dissolved solids and boron, arsenic concentrations in water samples collected in 1996 generally were at the low end of observed concentrations (fig. 4). However, the arsenic concentration measured in Humboldt Lake in 1996 (190 µg/L) was the second highest observed in these studies. For most sites, arsenic concentrations did not exceed criteria because arsenic concentrations were less than the Nevada chronic criterion of 180 µg/L for As(III). At two sites, it cannot be determined if arsenic concentrations exceeded criteria because arsenic species were not measured as part of the verification study. Although arsenic concentrations at Humboldt Lake (190 µg/L) and Unnamed Drain (270 µg/L) exceeded 180 µg/L, it is not known if the amount of As (III) in the samples exceeded criteria. At these two sites it is possible, but unlikely, that arsenic concentrations exceeded criteria for As (III).

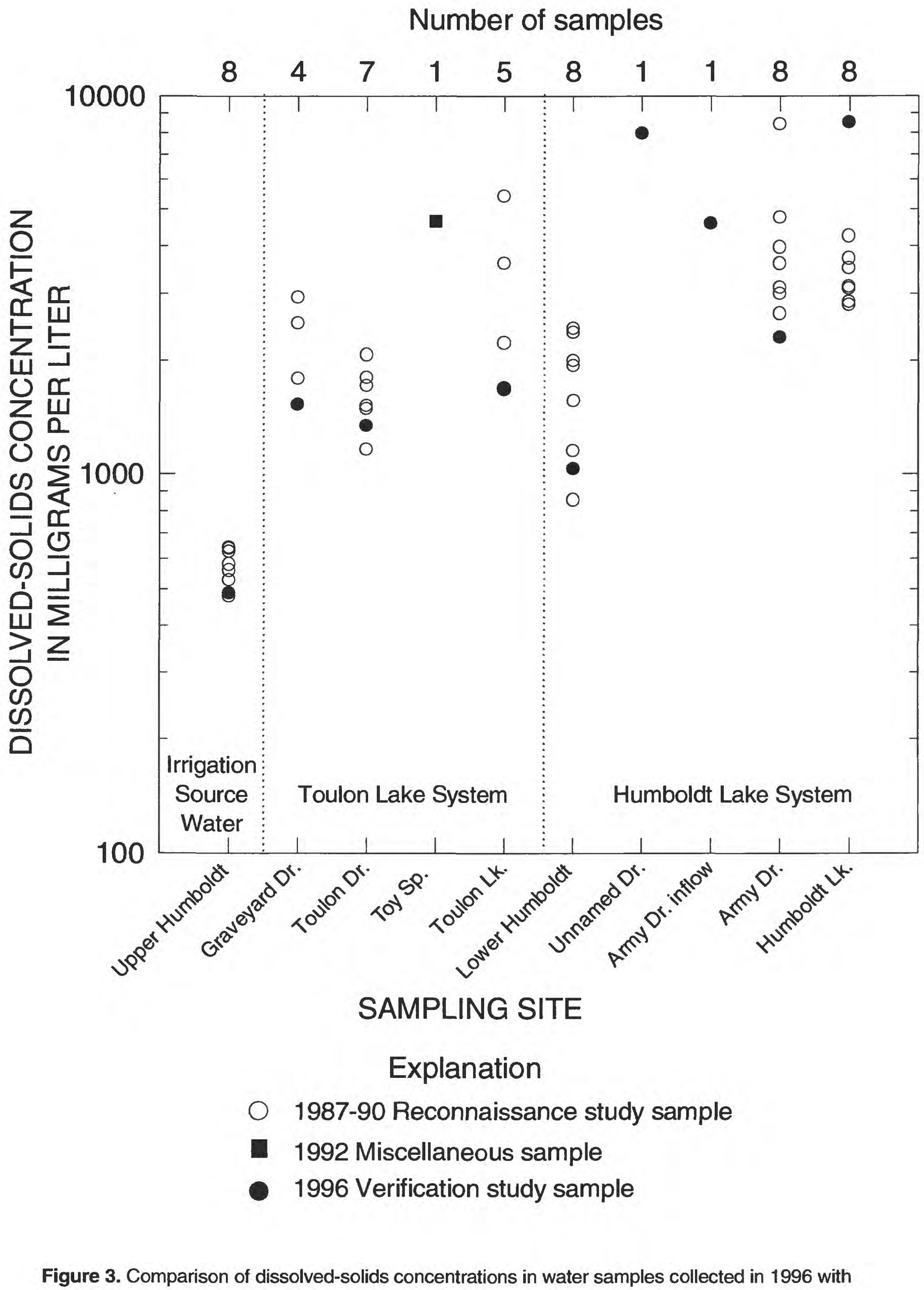


Figure 3. Comparison of dissolved-solids concentrations in water samples collected in 1996 with samples collected during 1987-92.

Table 2. Regulatory standards applicable to designated waters in Nevada. Standards are from Nevada Administrative Code (NAC) 445A.119 and 445A.144 (Nevada Environmental Commission, 1991)

Constituent	Municipal or domestic supply	Aquatic life	Irrigation	Watering of livestock	Propagation of wildlife
pH	5.0-9.0	6.5-9.0	4.5-9.0	6.5-9.0	7.0-9.2
Dissolved solids (mg/L)	1,000	--	--	3,000	--
Chloride (mg/L)	400	--	--	1,500	1,500
Arsenic (μg/L)	50	180[a,b]	100	200	--
Barium (μg/L)	2,000	--	--	--	--
Beryllium (μg/L)	0	--	100	--	--
Boron (μg/L)	--	--	750	5,000	--
Cadmium (μg/L)	5	(b,c)	10	50	--
Chromium (μg/L)	100	(b,c,d)	100	1,000	--
Copper (μg/L)	--	(b,c)	200	500	--
Fluoride (μg/L)	--	--	1,000	2,000	--
Iron (μg/L)	--	1,000	5,000	--	--
Lead (μg/L)	50	(b,c)	5,000	100	--
Manganese (μg/L)	--	--	200	--	--
Mercury (μg/L)	2	0.012[e]	--	10	--
Molybdenum (μg/L)	--	19	--	--	--
Nickel (μg/L)	13.4	(b,c)	200	--	--
Selenium (μg/L)	50	5[e]	20	50	--
Uranium (μg/L)	20[f]	--	--	--	--
Zinc (μg/L)	--	(b,c)	2,000	25,000	--

[a] Arsenic chronic criteria for aquatic life are specific for As^{+3}. The 96-hour average aquatic life criterion is given.

[b] Criterion applies to dissolved fraction only.

[c] Criteria for aquatic life are based on water hardness, which is expressed in milligrams per liter as $CaCO_3$. Formulas for 96-hour average criteria for specific elements are as follows:

Cadmium:	0.85exp[0.7852 ln(hardness)-3.490]
Chromium (III):	0.85exp[0.8190 ln(hardness)+1.561]
Copper:	0.85exp[0.8545 ln(hardness)-1.465]
Lead:	0.25exp[1.273 ln(hardness)-4.705]
Nickel:	0.85exp[0.8460 ln(hardness)-1.1645]
Zinc:	0.85exp[0.8473 ln(hardness)+0.7614]

[d] The 96-hour average aquatic-life criterion for chromium (VI) is given.

[e] The 96-hour average aquatic-life criterion is given.

[f] Proposed maximum contaminant level in drinking water (U.S. Environmental Protection Agency, 1991b).

Selenium concentrations in water for most of the sites ranged from 1 to 3 μg/L (fig. 5). Unlike dissolved solids, the boron, arsenic, and selenium concentrations determined for water samples collected in 1996 were on the high end of the range. In Humboldt Lake, the selenium concentration measured in 1996 (2 μg/L) was higher than all but one value measured at the site during 1987-90. The Nevada chronic criterion for selenium for the protection of freshwater aquatic life (5 μg/L) was exceeded in only one sample, that being from Unnamed Drain (8 μg/L). However, six of eight samples collected in 1996 were within the range or exceeded 1.5 to 3 μg/L, the Lowest Observed Adverse Effect Level (LOAEL) for fish and wildlife by bioaccumulation (Joseph P. Skorupa, U.S. Fish and Wildlife Service, written commun., 1997).

Elevated concentrations of dissolved solids and trace elements were found in the new site at Unnamed Drain. Nevada chronic criteria for the protection of aquatic life (table 2) were exceeded for molybdenum, selenium, and possibly arsenic. Inflow of the mixture of water from Unnamed Drain and Seventeen Ditch has a large effect on water quality in Army Drain. The specific conductance of the water in Unnamed Drain was

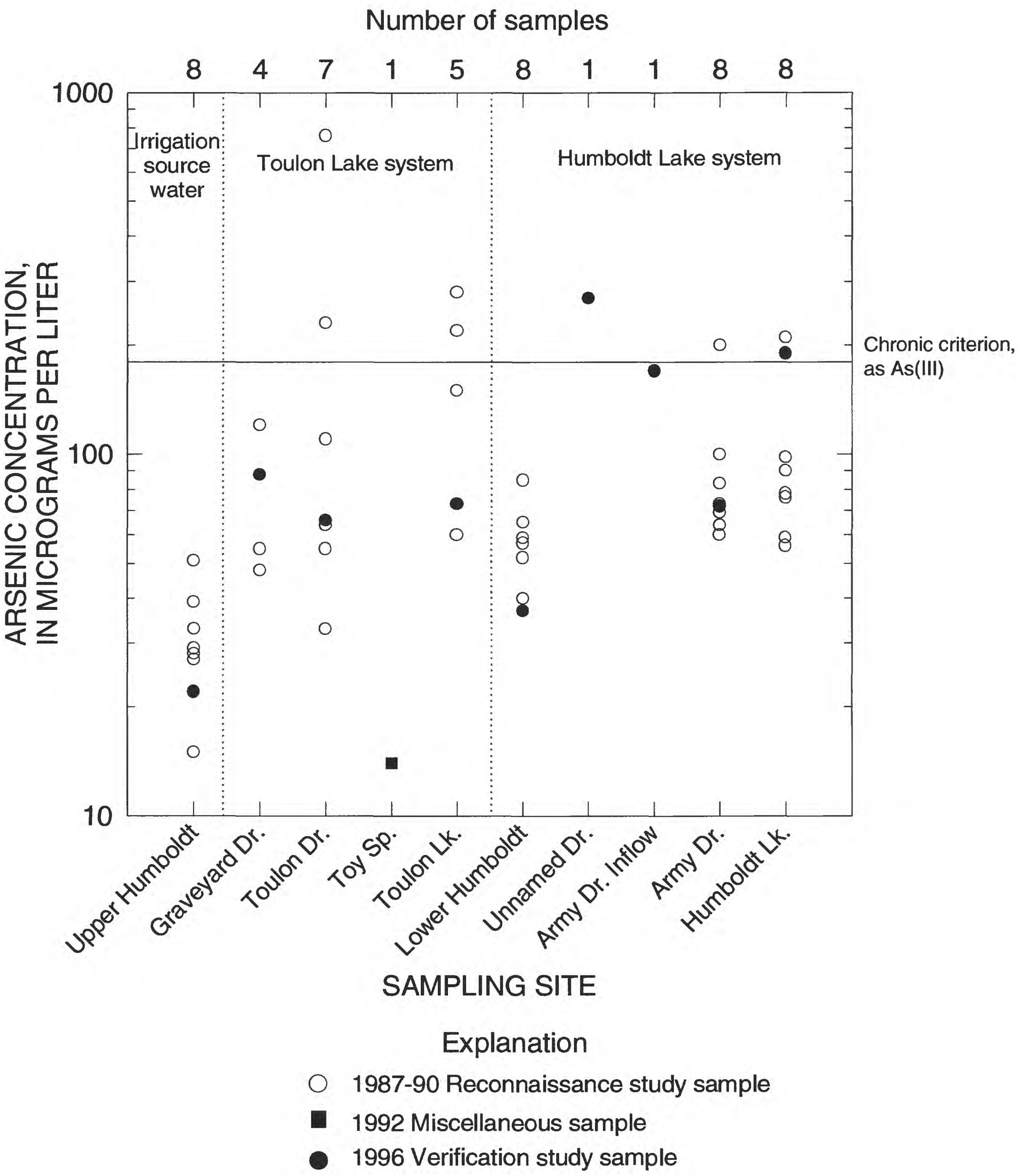


Figure 4. Comparison of arsenic concentrations in water samples collected in 1996 with samples collected during 1987-92.

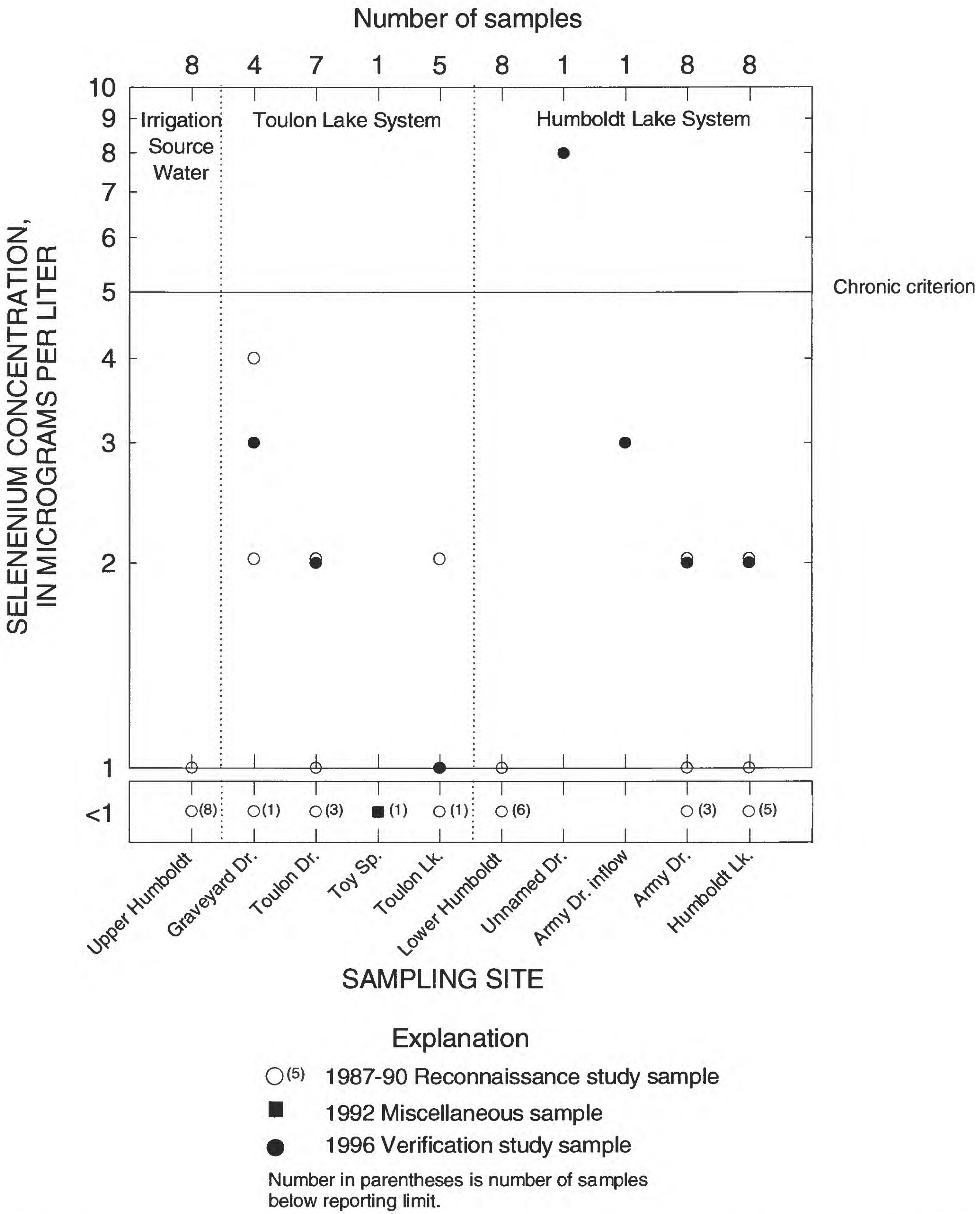


Figure 5. Comparison of selenium concentrations in water samples collected in 1996 with samples collected during 1987-92.

13,200 µS/cm (table 4), in Seventeen Ditch (which is near Unnamed Drain) it was 4,900 µS/cm, and in the water that was a mixture of the two discharged into Army Drain it was 8,100 µS/cm (table 4). The effect of the inflow is demonstrated by specific conductance measurements in Army Drain above and below the inflow. Above the inflow, specific conductance in Army Drain was 3,500 µS/cm and below the inflow, where the water was fairly well mixed, the specific conductance was 4,800 µS/cm. This last value is similar to what was measured at the Army Drain sampling site the day before (4,300 µS/cm).

During the drought, when Humboldt and Toulon Lakes were dry, Toy spring (site B) probably was an important source of water to wildlife because it continued to flow and was one of the few water sources still available in the Humboldt Sink. Data collected in 1992 indicate that, although the water was moderately saline and contained elevated boron concentrations, it did not contain particularly high concentrations of other trace elements. The source of the water issuing from Toy spring has not been conclusively identified, but probably is flow from recharge in the Trinity Range to the west (fig. 2).

Bottom Sediment

The USGS collected a bottom-sediment sample from Humboldt Lake (site 11) in November 1990 and the USFWS collected a bottom-sediment sample in May 1996. The USGS and USFWS samples were collected in different parts of the lake using different sampling methods, and were analyzed by different laboratories using different sample preparation and analytical methods. As an example, the USGS samples were sieved (0.062 mm), whereas the USFWS samples were whole samples. Contaminant concentrations in the two samples were relatively similar, considering the differences in protocols. Arsenic and selenium concentrations were 7.3 and 1.1 µg/g, respectively, in the 1990 USGS sample and were 19 and <0.5 µg/g in the 1996 USFWS sample.

Biota

The Humboldt reconnaissance investigation (Seiler and others, 1993) identified concerns with arsenic, boron, chromium, copper, mercury, selenium, and zinc in biological tissues. Paucity of samples, differences in collection sites, and differences in species limited statistical comparisons for most of the sample matrices. Therefore, qualitative comparisons of differences between time periods for most sample matrices are offered. Additionally, no coot or shorebird eggs were collected from Humboldt Lake during the earlier investigations, thus concentrations of several elements in coot eggs collected in 1996 are compared with elements in coot eggs collected from Toulon Lake. A review of 1996 sample data did not reveal additional concerns with other trace elements.

Concentrations of trace elements in biological material were compared with concern and effect levels (table 3). Concern levels are those associated with relatively minor effects or are unusually high compared with background levels, thereby being indicators of potential contaminant exposure in the food chain, and are not associated with major known adverse biological effects. Effect levels are those associated with substantial biological effects such as reduced survival and reproduction (including teratogenic effects), and include levels of dietary exposure.

Arsenic

The Humboldt reconnaissance investigation identified concerns with arsenic in aquatic vegetation (based on avian dietary exposure) and fish. Arsenic concentrations were about the same in avian dietary items collected in 1996 as in samples collected during 1986-90 (fig. 6). One sample of pondweed collected in 1996 had a concentration that exceeded 30 µg/g, a dietary concentration associated with adverse effects on mallards (*Anas platyrhynchos*; Camardese and others, 1990). Arsenic concentrations were slightly higher in coot livers collected in 1996 than in 1986-88 (fig. 7), but concentrations were about the same in coot eggs during these periods (fig. 8). During 1986-87, arsenic concentrations were less than the reporting limit in black-necked stilt livers; no eggs from stilts were collected during 1986-90. Arsenic concentrations in liver and egg samples from American avocets were almost always less than the reporting limit (figs. 7 and 8).

Selenium

The reconnaissance investigation identified concerns with selenium in aquatic invertebrates, avian livers, and avian muscle tissue. Selenium concentrations were greater in aquatic vegetation, invertebrates, and coot eggs collected in 1996 than in the reconnaissance investigation (figs. 6 and 8). Selenium in all invertebrate samples collected in 1996 were within or

Table 3. Selected concern and effect concentrations for metals and trace elements in biological samples. Concentrations are in dry weight unless otherwise noted.

[Abbreviations: µg/g, microgram per gram]

Constituent	Category	Concentration (micrograms per gram)		
		Avian diet	Avian liver	Avian egg
Arsenic	Concern	-	-	-
	Effect	[a]30	[b]4.5	-
Boron	Concern	[c]30	[c]3	[c]3
	Effect	[c]1,000	[c]51	[c]49
Chromium	Concern	[d]10	[e]4	-
	Effect	[d]50	-	-
Mercury	Concern	-	-	-
	Effect	[f]0.5	[e,f]11.3	[e,f]0.83
Selenium	Concern	-	[g]10	-
	Effect	[h]3-8	[g]30	[i]10
Zinc	Concern	[j]178	-	-
	Effect	[k]3,000	[k]401	-

[a] Camardese and others (1990); growth, development, and physiology of mallard ducklings affected.

[b] Stanley and others (1994); reduced growth of mallard ducklings

[c] Smith and Anders (1989); reduced weight gain of mallard ducklings through 21 days at 30 µg/g in diet (3µg/g in juvenile liver); reduced body weight of hatchlings at 300 µg/g in diet (13 µg/g in eggs and 17 µg/g in juvenile liver); reduced hatching success, hatch weight, duckling survival, and duckling weight gain at 1,000 µg/g in diet (49 µg/g in egg and 51 µg/g in juvenile liver).

[d] Haseltine and others (1985); survival of ducklings depressed for those receiving 50 µg/g.

[e] Wet weight basis.

[f] Heinz (1979); diet (7 percent moisture) concentration associated with reduced reproduction and duckling behavioral effects. Egg concentrations associated with reduced hatch rate. Hen mallards, across generations had a mean of 1.3 µg/g (wet weight) in liver, whereas males had a mean of 4.4 µg/g. Nicholson and Osborn (1984); nephrotoxic lesions in European starlings (*Sturnus vulgaris*) fed a diet containing 1.1 µg/g mercury; liver contained 6.55 µg/g (dry weight).

[g] Joseph Skorupa (U.S. Fish and Wildlife Service, written commun., 1997); baseline concentrations rarely exceed 10 µg/g in avian liver. Heinz (1996); reproductive impairment is possible when the liver of egg laying females contains > 3 µg/g (wet weight); important sublethal effects may occur when the liver of young or adults contains > 10 µg/g (wet weight) and survival may be jeopardized when the concentration in liver is > 20 µg/g (wet weight); these would be about 12, 40, and 80 µg/g on a dry weight basis. Joseph Skorupa (written commun., 1997); the threshold liver concentration for juvenile and adult toxicity is 30 µg/g. Heinz and Hoffman (in press); dietary exposure to mercury alone in mallards greatly increased selenium residues in the liver, thus making the interpretation of residues difficult.

[h] Joseph Skorupa (U.S. Fish and Wildlife Service, written commun., 1997); avian reproductive impairment threshold range. See also Heinz (1996).

[i] Heinz (1996) estimated embryotoxic threshold for selenium in bird eggs is 10 µg/g. Skorupa and Ohlendorf (1991) estimated lower boundary for individual black-necked stilts with impaired embryo viability at 10 µg/g; critical embryotoxic and teratogenic threshold between 13 and 24 µg/g in aquatic bird eggs.

[j] Stahl and others (1989); immuno-suppression in domestic chickens.

[k] Gasaway and Buss (1972); reduced mallard survival.

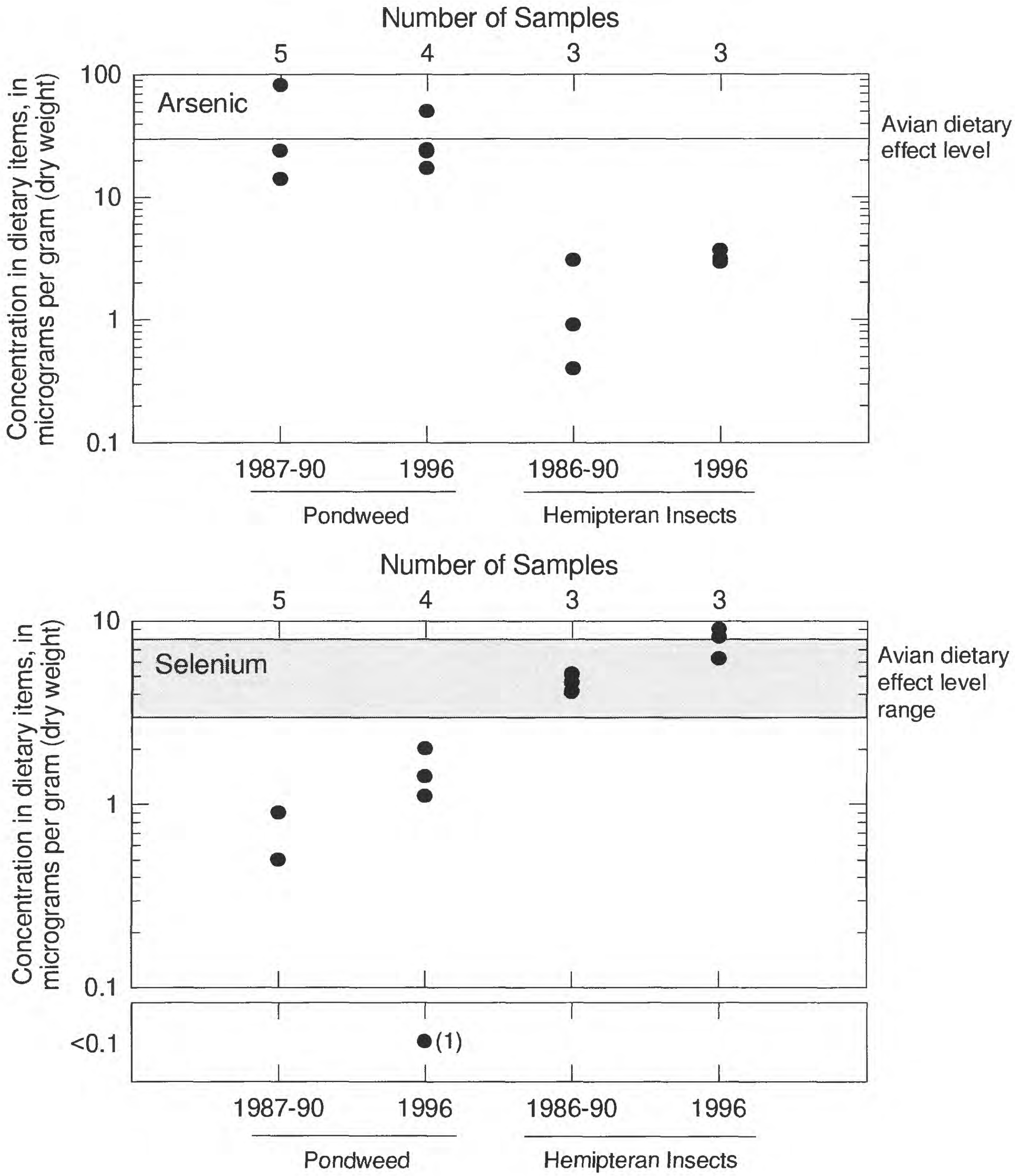


Figure 6. Arsenic and selenium concentrations in avian dietary items collected from Humboldt Wildlife Management Area, 1986-96. Avian dietary effect level for arsenic from Camardese and others (1990) and from selenium from Joseph Skorupa (U.S. Fish and Wildlife Service, written commun., 1997) and Heinz (1996).

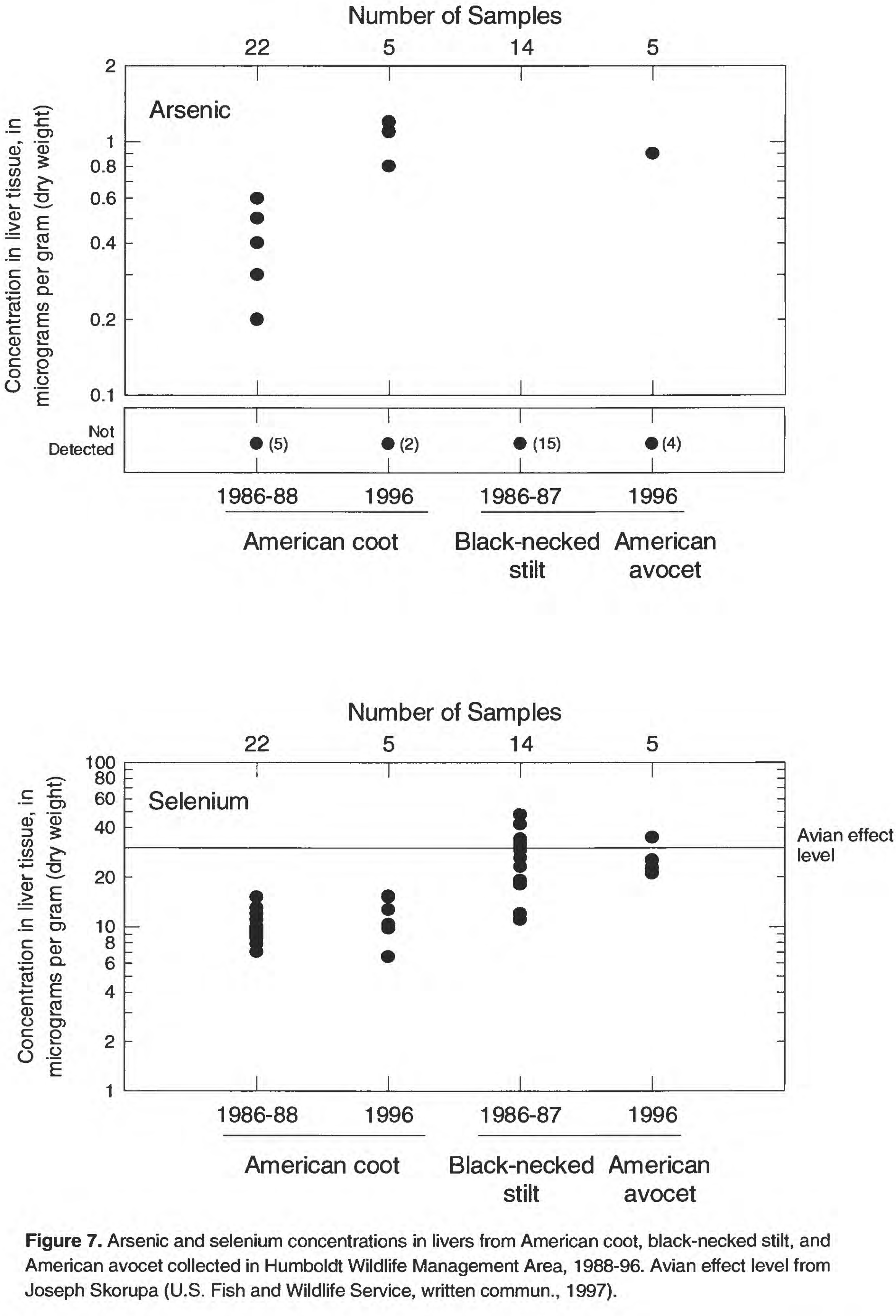


Figure 7. Arsenic and selenium concentrations in livers from American coot, black-necked stilt, and American avocet collected in Humboldt Wildlife Management Area, 1988-96. Avian effect level from Joseph Skorupa (U.S. Fish and Wildlife Service, written commun., 1997).

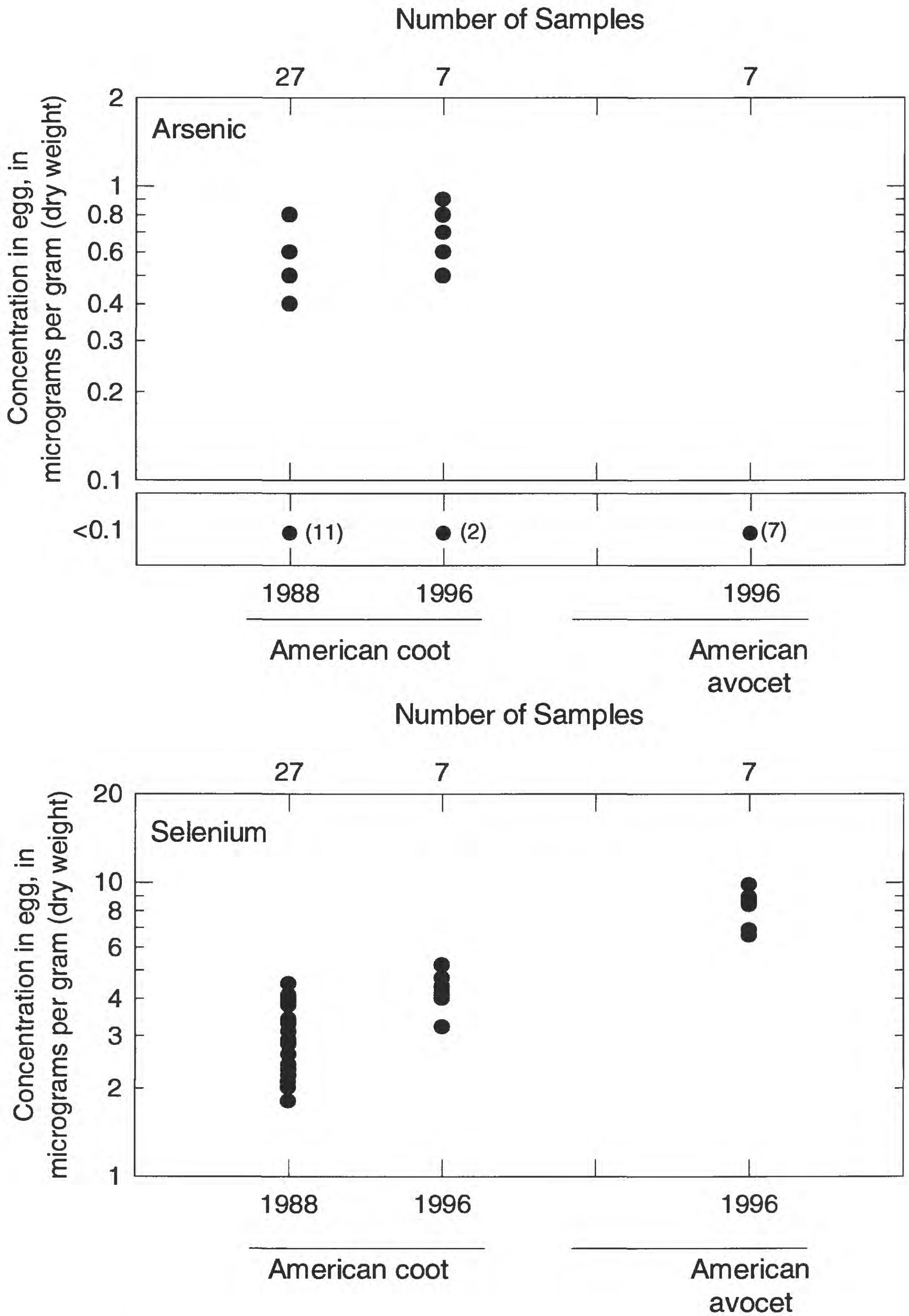


Figure 8. Arsenic and selenium concentrations in eggs from American coot and American avocet collected in Humboldt Wildlife Management Area, 1988-96.

exceeded the dietary reproductive impairment threshold range of 3-8 µg/g. Mean selenium concentrations in livers of coots collected during 1986-88 and in 1996 were not statistically different (table 7). During both periods, mean selenium concentrations in liver tissue from coots exceeded 10 µg/g, a concentration at which the possibility of reproductive impairment and sublethal effects increases (Heinz, 1996). Selenium concentrations in juvenile shorebird livers were near 30 µg/g, a concentration that approximates the threshold for toxicity in both juvenile and adult birds (Heinz, 1996). However, the elevated liver concentrations may be explained, in part, by elevated exposure to mercury (Heinz and Hoffman, in press).

In 1996, the selenium concentration in avocet eggs ranged from 6.6 to 9.8 µg/g (fig. 8). The sample of American avocet eggs collected in 1996 is particularly useful for assessing risk because of the detailed interpretive standards available for avocet eggs (Skorupa, in press). Additionally, the risk to black-necked stilts, a more sensitive species of shorebird, can be inferred directly from avocet exposure data because stilt and avocet eggs contain similar concentrations of selenium when these closely related species co-exist at a study site (Ohlendorf and Skorupa, 1989; Skorupa and Ohlendorf, 1991; Ohlendorf and Hothem, 1994). For a selenium-tolerant species like the American avocet, 6.6 to 9.8 µg/g of selenium in eggs would not be expected to have direct embryotoxic effects. Using a more sensitive standard, such as a "stilt response standard," this amount of selenium in stilt eggs would be expected to cause a 5-10 percent depression in nesting proficiency, even though it would not be sufficient to induce embryo teratogenesis (Skorupa, in press). Although selenium-induced embryotoxicity may not be expected in avocets at the Humboldt WMA, black-necked stilts and other moderately to highly sensitive species of waterbirds may be at risk of selenium-induced reproductive depression.

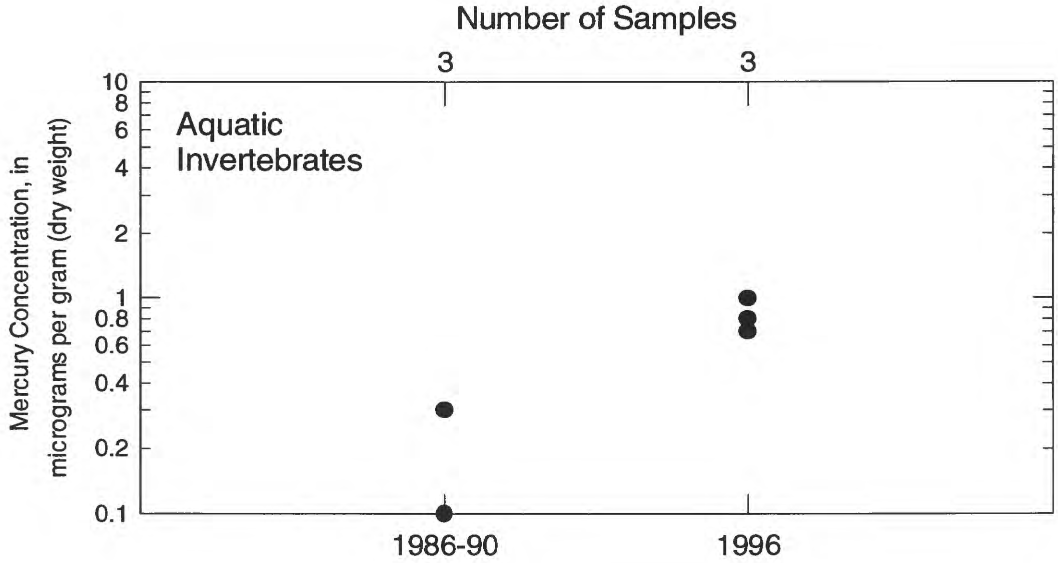
Boron, Chromium, Mercury, and Zinc

The Humboldt reconnaissance investigation identified concerns with boron, chromium, mercury, and zinc. The boron concentrations in aquatic vegetation samples collected in 1996 exceeded a 30 µg/g dietary concentration given to adult mallards and their hatchlings that resulted in reduced weight gain of the ducklings (Smith and Anders, 1989). One vegetation sample collected in 1996 exceeded 1,000 µg/g boron (table 7), a concentration associated with reduced egg hatching success and duckling survival in mallards (Smith and Anders, 1989). In coot livers collected in 1996, all boron concentrations were greater than 3 µg/g (table 7), a concentration associated with reduced duckling weight gain (Smith and Anders, 1989). Two of five avocet livers collected in 1996 also had greater than 3 µg/g (table 7).

The Humboldt reconnaissance investigation identified a concern with chromium in fish collected from Humboldt Lake. Chromium concentrations in aquatic invertebrates and coot livers tended to be greater in samples collected in 1996 than during the reconnaissance investigations. However, in 1996, concentrations in pondweed and aquatic invertebrates were below 10 µg/g, a dietary concentration associated with adverse effects to juvenile black ducks (*Anas rubripes*; Haseltine and others, 1985). The mean chromium concentrations in coot liver (4.2 µg/g) and avocet liver (4.9 µg/g) exceeded 4.0 µg/g, a concentration identified as presumptive evidence of chromium contamination (Eisler, 1986). However, the biological significance of this concentration is uncertain.

The Humboldt reconnaissance investigation identified concerns with mercury in aquatic vegetation and fish. Mercury concentrations in aquatic invertebrates, avian eggs, and avian livers were less than concentrations associated with adverse effects in other studies. Generally, mercury concentrations in biological samples were greater in 1996 than during 1986-90 (fig. 9). Mercury concentrations in aquatic invertebrates collected in 1996 were greater than 0.5 µg/g (table 7), a dietary concentration associated with reduced production in mallard ducks and behavioral effects in mallard ducklings (Heinz, 1979). Mercury concentrations in juvenile coots and avocets livers were less than a concentration (1.3 µg/g, wet weight) associated with reduced reproduction and survival (Heinz, 1979). The mercury concentration in three of seven coot eggs exceeded a concentration associated with reduced hatch rate in mallards (0.83 µg/g, wet weight; Heinz, 1979). Only one of seven avocet eggs exceeded this concentration.

The Humboldt reconnaissance investigation identified a concern with zinc in fish collected from the Humboldt River and one agricultural drain. Zinc concentrations in liver tissue samples collected in 1996 were well below concentrations associated with reduced mallard survival (Gasaway and Buss, 1972).



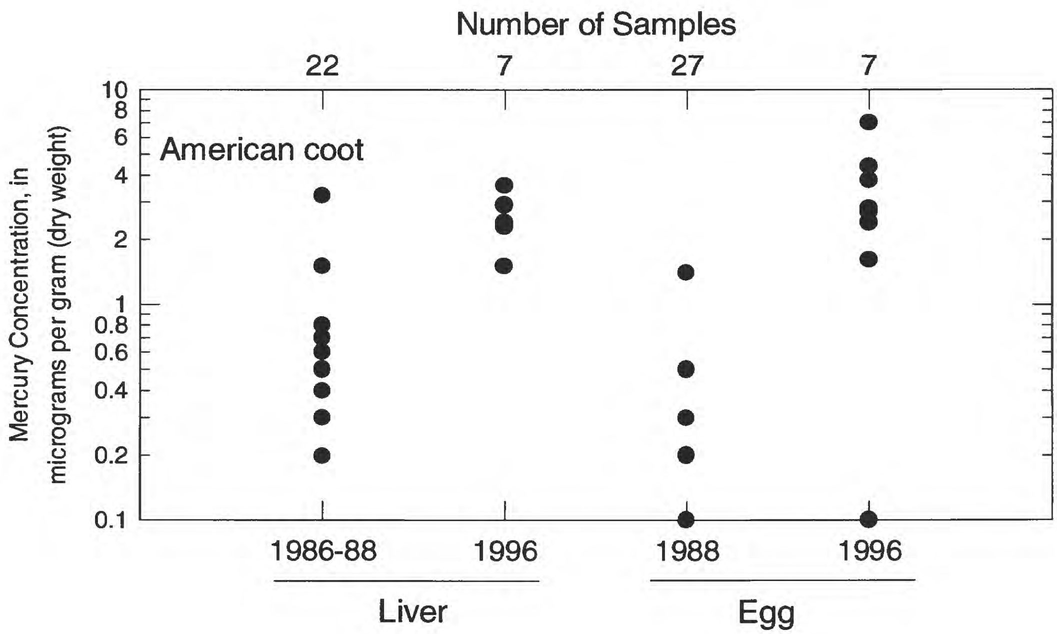


Figure 9. Mercury concentrations in aquatic invertebrates and American coot liver and eggs collected from Humboldt Wildlife Management Area, 1986-96.

SUMMARY AND CONCLUSIONS

Data were collected at the Humboldt WMA in 1986-88 and 1990 as part of reconnaissance investigations made by the Department of the Interior National Irrigation Water Quality Program. Arsenic, boron, mercury, molybdenum, selenium, sodium, uranium, total dissolved solids, and un-ionized ammonia exceeded State or Federal criteria or proposed criteria, State water-quality standards, or concentrations associated with adverse effects to aquatic organisms or wildlife. However, the fact that these earlier investigations were made partly during drought conditions may have affected study results. Therefore, a field verification study was undertaken in 1996 to determine if the results of the earlier reconnaissance investigations were representative of normal climatic and hydrologic conditions.

During the verification study, samples of water were collected in which molybdenum, selenium, and dissolved solids exceeded State water-quality standards or concentrations associated with adverse effects to aquatic organisms or wildlife. Salinity and boron concentrations were lower at most sites during the 1996 study than during 1987-90, whereas selenium and arsenic concentrations at most sites were similar during the two studies. An exception occurred at Humboldt Lake, where concentrations of dissolved solids and arsenic, boron, molybdenum, and selenium in water were higher in 1996 than during 1987-90.

With the exception of molybdenum, trace-element concentrations at most sites in 1996 were less than chronic criteria for the protection of aquatic life. At two sites it is possible, but unlikely, that arsenic concentrations exceeded criteria for As (III). Total arsenic concentrations were greater than the criterion for arsenic (III), but arsenic speciation was not done, therefore it cannot be determined if the concentrations exceeded the criterion. The chronic criterion for the protection of aquatic life for selenium was exceeded in one water sample from a deep drain that ultimately discharges to Humboldt Lake. The selenium concentration in Humboldt Lake in 1996 (2 μg/g) was near 3 μg/g, a level considered to be harmful to some birds under some circumstances (Skorupa and Ohlendorf, 1991), but was below the Nevada chronic criterion for the protection of aquatic life.

Concentrations of arsenic, boron, chromium, mercury, and selenium in biological samples collected from Humboldt Lake in 1996 were similar to, or slightly higher than in samples collected during 1986-90. The mean arsenic concentration in vegetation in 1996 approached the dietary effect level for birds. Selenium concentrations in 1996 in aquatic invertebrates equaled or exceeded the avian dietary effect range. Selenium concentrations in livers of juvenile coots and avocets in 1996 approached concentrations associated with toxicity. Boron concentrations in aquatic vegetation and livers of coots and avocets in 1996 exceeded concentrations associated with reduced weight gain in birds. Mercury concentrations in aquatic invertebrates and coot eggs in 1996 exceeded concentrations associated with reduced production.

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SUPPLEMENTAL DATA

Table 4. Field measurements of physical properties and laboratory analyses of chemical constituents for surface-water samples in and near the Humboldt Wildlife Management Area and upstream sites, 1987-96

[Specific conductance, pH, bicarbonate, and carbonate measured in field, except those marked 'L' that were measured in laboratory. Abbreviations and symbols: E, estimated; ft^3/s; cubic feet per second; mg/L, milligrams per liter; µg/L, micrograms per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; --, not determined; <, less than]

Site (figs. 1 and 2)	Station name	Date sampled	Time	Discharge instantaneous (ft^3/s)	Specific conductance (µS/cm)	pH (standard units)	Air temperature (°C)	Water temperature (°C)	Oxygen, dissolved (mg/L)	Oxygen, dissolved (percent saturation)
1	Humboldt River Nr Golconda Nv	07-10-90	0900	75 E	610	8.2	28.0	21.3	7.3	96
		11-27-90	0830	2.0 E	926	8.5	-8.0	2.0	12.2	103
2	Humboldt River Nr Imlay	02-05-90	1015	--	790	--	--	.5	--	--
		03-20-90	1440	--	540	--	--	11.5	--	--
		05-07-90	1645	--	674	--	--	16.5	--	--
		07-10-90	1245	106	653	8.5	31.0	25.9	6.5	92
		09-11-90	1455	--	854	--	--	26.5	--	--
		11-14-90	1410	--	823	--	--	6.0	--	--
		11-27-90	1200	14	888	8.7	0.0	1.0	12.1	98
A	Humboldt River Nr Rye Patch	05-21-96	1600	--	877	8.1	--	14.0	9.4	107
3	Humboldt River At Upper Valley Rd Nr Lovelock	10-07-87	1500	158 E	1,010	8.5	27.0	18.0	8.7	107
		03-18-88	0900	--	916 L	8.3 L	--	--	--	--
		08-24-88	0730	247 E	1,060	8.1	19.0	18.7	8.0	100
		03-29-89	0750	.50	895	8.6	5.5	7.0	9.7	93
		03-27-90	0730	.33	863	8.7	--	7.4	8.6	83
		07-10-90	1545	147 E	1,110	8.5	36.0	24.2	7.2	99
		11-20-90	1400	.50 E	1,120	8.7	--	8.3	11.1	110
5	Graveyard Drain At Lovelock Drain Nr Lovelock	03-27-90	1030	.33	4,110	8.5	--	11.2	10.5	113
		07-11-90	0800	.03	3,180	8.7	24.0	18.8	2.5	31
		11-20-90	0715	.01 E	5,300	7.9	4.0	4.9	6.8	61
		11-20-90	0720	.01 E	5,300	7.9	4.0	4.9	6.8	61
		05-21-96	0800	5.0 E	2,490	8.1	16.0	15.5	4.6	54
6	Lovelock Drain Abv Graveyard Drain Nr Lovelock	03-27-90	1030	--	2,740	8.1	--	12.0	--	--
		07-11-90	0805	--	2,410	8.1	--	18.5	--	--
		11-20-90	0730	1.0 E	2,380	7.8	--	4.5	--	--
		05-21-96	0800	--	2,300	--	--	--	--	--

Table 4. Field measurements of physical properties and laboratory analyses of chemical constituents for surface-water samples in and near the Humboldt Wildlife Management Area and upstream sites, 1987-96—Continued

Site (figs. 1 and 2)	Station name	Date sampled	Time	Discharge instant-aneous (ft^3/s)	Specific conduct-ance (μS/cm)	pH (standard units)	Air temper-ature (°C)	Water temper-ature (°C)	Oxygen, dissolved (mg/L)	Oxygen, dissolved (percent saturation)
7	Toulon Drain At Derby Field Rd Nr Toulon	10-06-87	1300	11	2,420	8.5	26.0	18.0	13	159
		03-17-88	0830	--	3,630 L	7.9 L	--	--	--	--
		08-23-88	1730	5.7	1,950	8.4	34.0	26.0	10.6	153
		03-27-89	1500	1.2	2,840	9.1	12.5	17.0	20	242
		03-26-90	1030	1.6	3,010	8.6	--	14.0	15	170
		07-09-90	1230	.20	2,540	9.6	36.0	27.3	14.9	217
		05-20-96	1030	10 E	2,200	8.4	--	15.5	11.3	132
10	Toulon Lake-Westegard Pond	10-07-87	1200	--	2,600	8.8	23.5	18.0	8.2	101
		03-17-88	1330	--	3,820 L	8.2 L	--	--	--	--
		03-28-89	1230	--	5,930	9.4	--	15.5	9.6	113
		03-26-90	1630	--	8,370	9.0	--	18.2	8.5	107
		05-20-96	1245	--	2,800	9.0	21.0	26.0	18.4	--
A	Toy Spring	06-25-92	1315	--	7,930	8.6	--	17.0	--	--
4	Humboldt River Nr Lovelock	10-07-87	0730	2.9	2,720	8.4	9.0	14.0	7.9	89
		03-17-88	1530	--	3,620 L	8.1 L	--	--	--	--
		08-24-88	0930	14	1,520	8.4	27.5	23.0	7.9	107
		03-28-89	1400	3.2	4,270	8.8	--	16.0	9.8	116
		03-27-90	1230	.40	3,950	8.8	--	15.1	10.7	125
		07-18-90	1540	6.8	2,030	8.9 L	36.0	29.3	10.1	153
		11-19-90	1400	8.5	3,690	8.6	13.0	7.9	11.8	118
		05-21-96	1330	--	1,890	8.4	--	15.5	9.5	112
C	Unnamed Drain	05-21-96	1000	--	13,200	7.8	--	15.1	13.3	--
D	Discharge Pipe Outlet Into Army Drain Nr Derby Fld	05-21-96	1120	--	8,100	8.0	--	16.5	--	--
8	Army Drain At Iron Bridge Nr Toulon	10-06-87	1500	19	7,900	8.3	28.0	18.5	11.3	142
		03-16-88	1530	--	13,700 L	7.9 L	--	--	--	--
		08-24-88	1230	19	4,370	8.2	33.0	24.0	5.7	79
		03-28-89	0800	1.7	5,900	8.4	15.0	10.0	6.0	63
		03-26-90	1415	4.4	5,010	8.5	--	15.5	12.9	152

Table 4. Field measurements of physical properties and laboratory analyses of chemical constituents for surface-water samples in and near the Humboldt Wildlife Management Area and upstream sites, 1987-96—Continued

Site (figs. 1 and 2)	Station name	Date sampled	Time	Discharge instant-aneous (ft^3/s)	Specific conduct-ance (μS/cm)	pH (standard units)	Air temper-ature (°C)	Water temper-ature (°C)	Oxygen, dissolved (mg/L)	Oxygen, dissolved (percent saturation)
8	Army Drain At Iron Bridge Nr Toulon	07-18-90	1215	3.3	6,550	7.9 L	35.0	30.1	10.8	167
		11-19-90	1110	.71	5,420	8.5	10.0	5.2	13.1	122
		05-20-96	1420	--	4,060	8.3	--	17.0	13.6	165
11	Upper Humboldt Lk Nr Center	10-07-87	1030	--	5,960	8.2	23.5	15.0	6.1	71
		03-17-88	1030	--	5,320 L	8.1 L	--	--	--	--
		08-24-88	1130	--	5,490	8.6	32.5	29.5	12.3	189
		03-28-89	1045	--	7,140	8.8	15.0	18.0	8.6	107
		03-26-90	1500	--	5,840	8.6	--	22.1	10.5	142
		07-09-90	1500	--	4,700	8.2	37.0	36.5	7.4	129
		11-26-90	1200	--	5,440	8.6	3.0	9.0	--	--
		05-20-96	1630	--	12,900	8.4	--	29.0	9.7	--

Table 5. Water hardness and concentrations of major dissolved chemical constituents in surface-water samples in and near Humboldt Wildlife Management Area and upstream sites, 1987-96.

[Alkalinity, bicarbonate, and carbonate measured in field, except those marked 'L' that were measured in laboratory. Abbreviations and symbols: °C, degrees Celsius; mg/L, milligrams per liter; --, not determined; <, less than]

Site (fig. 2)	Date	Hardness (mg/L as $CaCO_3$)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Alkalinity (mg/L as $CaCo_3$)	Bicarbonate, (mg/l as HCO_3)	Carbonate, (mg/L as CO_3)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Flouride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO_2)	Solids, dissolved, residue at 180°C (mg/L)	Solids, dissolved sum of constituents (mg/L)
1	07-10-90	170	50	12	65	7.5	230	270	4	48	37	--	--	384	356
	11-27-90	220	59	17	130	9.2	330	390	5	89	67	0.8	--	588	569
2	07-10-90	190	53	14	72	8.9	240	270	10	59	43	--	--	425	393
	11-27-90	210	51	20	110	8.2	230	280	0	100	82	.6	--	520	509
A	05-21-96	170	44	15	110	14	230	280	0	85	81	1.0	--	543	488
3	10-07-87	190	44	20	140	16	250	260	22	96	130	.8	41	624	638
	03-18-88	220	57	18	110	10	190 L	240 L	0 L	97	110	.5	39	552	560
	08-24-88	180	39	21	140	13	230	280	0	100	130	--	--	641	581
	03-29-89	210	51	20	120	11	180 L	210 L	0 L	93	130	--	--	544	528
	03-27-90	190	49	17	99	12	180	210	4	85	110	--	--	520	479
	07-10-90	190	44	20	150	16	230	270	10	110	160	--	--	652	643
	11-20-90	200	48	20	150	13	180	210	5	96	190	.6	--	666	626
5	03-27-90	370	73	45	750	40	490	580	7	450	860	--	--	2,530	2,510
	07-11-90	250	39	36	540	24	300	340	15	370	600	--	--	1,910	1,790
	11-20-90	580	110	73	870	40	320	390	0	540	1,100	1.0	--	3,040	2,930
	11-20-90	570	110	72	850	36	320	390	0	550	1,200	1.4	--	3,010	3,010
	05-21-96	390	100	35	410	28	430	530	0	300	390	1.5	--	1,650	1,530
7	10-06-87	310	75	30	420	24	490	530	29	280	360	1.3	44	1,500	1,520
	03-17-88	430	100	43	680	23	500 L	610 L	0 L	430	450	1.4	41	2,210	2,070
	08-23-88	280	69	25	320	25	420	450	31	190	280	--	--	1,210	1,160
	03-27-89	320	82	29	510	23	440	410	62	250	560	--	--	1,710	1,720
	03-26-90	400	100	36	500	25	430	480	22	290	590	--	--	1,870	1,800
	07-09-90	260	58	27	420	22	360	210	110	260	490	--	--	1,570	1,490
	05-20-96	360	97	29	340	25	420	490	12	250	340	1.3	--	1,420	1,340

Table 5. Water hardness and concentrations of major dissolved chemical constituents in surface-water samples in and near Humboldt Wildlife Management Area and upstream sites, 1987-96—Continued

Site (fig. 2)	Date	Hardness (mg/L as $CaCO_3$)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Alkalinity (mg/L as $CaCo_3$)	Bicarbonate, (mg/l as HCO_3)	Carbonate, (mg/L as CO_3)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Flouride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO_2)	Solids, dissolved, residue at 180°C (mg/L)	Solids, dissolved sum of constituents (mg/L)
10	10-07-87	210	45	23	540	27	440	490	26	170	560	1.2	42	1,560	1,680
	03-17-88	380	78	44	760	26	510 L	620 L	0 L	440	550	1.4	26	2,310	2,230
	03-28-89	260	36	41	1,200	50	490	380	110	690	1,300	--	--	3,690	3,610
	03-26-90	300	26	57	1,800	73	750	720	100	900	2,100	--	--	5,420	5,410
	05-20-96	330	71	37	480	28	450	370	89	320	480	1.3	--	1,730	1,690
B	06-25-92	41	5.7	6.5	1,700	21	750 L	920 L	0 L	400	1,900	5.6	--	4,650	4,490
4	10-07-87	240	36	36	530	25	320	400	0	290	430	1.2	27	1,590	1,570
	03-17-88	250	61	23	670	35	310 L	380 L	0 L	210	710	1.7	44	2,050	1,940
	08-24-88	190	44	20	240	27	290	320	17	120	230	--	--	907	855
	03-28-89	230	50	26	830	43	370	400	26	210	1,000	--	--	2,420	2,380
	03-27-90	200	39	24	800	41	370	370	41	200	1,100	--	--	2,360	2,430
	07-18-90	120	18	19	350	30	280 L	350 L	0 L	150	410	--	--	1,140	1,150
	11-19-90	250	59	26	630	37	310	380	2	180	880	1.8	--	2,090	2,000
	05-21-96	200	51	18	300	19	280	350	0	120	350	1.3	--	1,130	1,030
C	05-21-96	1,100	270	110	2,100	79	520	630	0	1,400	3,200	2.0	--	7,980	7,470
D	05-21-96	780	190	74	1,300	54	410	510	0	800	1,900	1.8	--	5,010	4,570
8	10-06-87	900	210	91	1,300	49	460	560	0	700	2,100	1.5	37	5,040	4,760
	03-16-88	1,200	250	130	2,900	63	450 L	550 L	0 L	1,200	3,600	1.7	28	8,580	8,440
	08-24-88	490	120	47	800	24	560	690	0	360	970	--	--	2,560	2,660
	03-28-89	570	130	59	1,100	34	550	620	24	450	1,500	--	--	3,530	3,600
	03-26-90	470	110	47	900	40	410	460	22	450	1,200	--	--	2,990	3,000
	07-18-90	610	140	64	1,200	44	450 L	550 L	0 L	450	1,800	--	--	3,740	3,970
	11-19-90	330	70	38	1,000	41	350	430	0	250	1,500	2.1	--	3,120	3,110
	05-20-96	500	130	42	600	35	410	500	0	390	860	1.5	--	2,510	2,300

Table 5. Water hardness and concentrations of major dissolved chemical constituents in surface-water samples in and near Humboldt Wildlife Management Area and upstream sites, 1987-96—Continued

Site (fig. 2)	Date	Hardness (mg/L as $CaCO_3$)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Alkalinity (mg/L as $CaCo_3$)	Bicarbonate, (mg/l as HCO_3)	Carbonate, (mg/L as CO_3)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Flouride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO_2)	Solids, dissolved, residue at 180°C (mg/L)	Solids, dissolved sum of constituents (mg/L)
11	10-07-87	540	100	71	1,200	42	350	420	0	560	1,500	1.4	29	3,540	3,710
	03-17-88	450	75	64	980	28	230 L	280 L	0 L	460	1,100	1.3	11	3,070	2,860
	08-24-88	390	57	61	1,000	44	340	380	19	560	1,200	--	--	3,140	3,130
	03-28-89	530	83	78	1,300	47	360	380	26	630	1,900	--	--	4,300	4,250
	03-26-90	360	53	56	1,100	50	310	350	19	540	1,500	--	--	3,430	3,490
	07-09-90	460	100	51	890	36	310	370	0	340	1,200	--	--	2,680	2,800
	11-26-90	310	63	36	1,000	41	300	350	5	270	1,500	1.5	--	2,900	3,090
	05-20-96	2,100	390	270	3,800	94	460	560	2	1,900	3,200	1.3	--	8,520	9,930

Table 6. Concentrations of trace elements in surface-water samples in and near Humboldt Wildlife Management Area and upstream sites, 1987-96

[Abbreviations and symbols: µg/L, micrograms per liter; --, not determined; <, less than]

Site (figs. 1 and 2)	Date	Aluminum dissolved (µg/L as Al)	Antimony, dissolved (µg/L as Sb)	Arsenic, dissolved (µg/L as As)	Barium, dissolved (µg/L as Ba)	Boron, dissolved (µg/L as B)	Cadmium, dissolved (µg/L as Cd)	Chromium, dissolved (µg/L as Cr)	Copper, dissolved (µg/L as Cu)	Iron, dissolved (µg/L as Fe)	Lead, dissolved (µg/L as Pb)	Lithium, dissolved (µg/L as Li)	Manganese, dissolved (µg/L as Mn)	Mercury, dissolved (µg/L as Hg)	Molybdenum, dissolved (µg/L as Mo)	Nickel, dissolved (µg/L as Ni)	Selenium, dissolved (µg/L as Se)	Silver, dissolved (µg/L as Ag)	Vanadium, dissolved (µg/L as V)	Zinc, dissolved (µg/L as Zn)
1	07-10-90	--	--	14	--	270	1	2	2	--	<1	--	--	<0.1	5	--	<1	--	9	<3
	11-27-90	--	--	18	--	610	<1	<1	1	--	<1	--	--	<.1	<1	--	<1	--	4	<3
2	07-10-90	--	--	17	--	350	<1	2	2	--	<1	--	--	<.1	6	--	<1	--	11	3
	11-27-90	--	--	16	--	650	<1	<1	1	--	<1	--	--	<.1	<1	--	<1	--	5	<3
A	05-21-96	--	--	22	--	480	<1	1.1	2	--	<1	--	--	<.1	17	--	<1	--	11	5
3	10-07-87	<10	7	39	59	550	<1	<10	<10	--	<5	140	2	<.1	11	3	1	<1	15	16
	03-18-88	<10	1	33	--	350	1	<1	<1	<10	<5	90	20	<.1	7	--	1	--	8	<10
	08-24-88	--	--	51	--	620	--	<1	--	--	--	170	--	<.1	11	--	1	--	16	<3
	03-29-89	--	--	29	--	400	--	<1	--	--	--	110	--	<.1	9	--	1	--	6	7
	03-27-90	--	--	15	--	380	2	<5	<10	--	<10	--	--	.2	<10	--	1	--	<6	13
	07-10-90	--	--	27	--	730	<1	1	3	--	<1	--	--	<.1	12	--	1	--	17	6
	11-20-90	--	--	28	--	660	<1	<1	3	--	<1	--	--	<.1	2	--	<1	--	10	5
5	03-27-90	--	--	120	--	4,200	<1	1	2	--	<1	--	--	<.1	48	--	2	--	32	20
	07-11-90	--	--	55	--	2,900	<1	1	4	--	<1	--	--	<.1	15	--	2	--	23	<10
	11-20-90	--	--	48	--	4,000	<1	<1	1	--	<1	--	--	<.1	17	--	4	--	24	<10
	11-20-90	--	--	48	--	3,900	<1	<1	1	--	<1	--	--	<.1	20	--	5	--	25	<10
	05-21-96	--	--	88	--	1,900	<1	1.2	2	--	<1	--	--	<.1	26	--	3	--	27	<9
7	10-06-87	<10	11	230	100	1,900	<1	<10	<10	--	<5	340	<10	.1	23	1	<1	<1	27	<10
	03-17-88	<10	12	110	--	3,200	1	<1	<1	10	<5	400	110	<.1	32	--	2	--	34	10
	08-23-88	--	--	33	--	1,400	--	<1	--	--	--	270	--	<.1	10	--	<1	--	19	<3
	03-27-89	--	--	55	--	2,600	--	<1	--	--	--	300	--	<.1	21	--	1	--	30	<10
	03-26-90	--	--	64	--	2,700	<1	2	2	--	<1	--	--	<.1	20	--	2	--	24	10
	07-09-90	--	--	760	--	2,300	<1	1	4	--	<1	--	--	<.1	12	--	<1	--	23	<10
	05-20-96	--	--	66	--	1,500	<1	1.3	2	--	<1	--	--	<.1	19	--	2	--	22	<9

Table 6. Concentrations of trace elements in surface-water samples in and near Humboldt Wildlife Management Area and upstream sites, 1987-96—Continued

Site (figs. 1 and 2)	Date	Alu-minum dis-solved (µg/L as Al)	Anti-mony, dis-solved (µg/L as Sb)	Arsenic, dis-solved (µg/L as As)	Barium, dis-solved (µg/L as Ba)	Boron, dis-solved (µg/L as B)	Cad-mium, dis-solved (µg/L as Cd)	Chro-mium, dis-solved (µg/L as Cr)	Copper, dis-solved (µg/L as Cu)	Iron, dis-solved (µg/L as Fe)	Lead, dis-solved (µg/L as Pb)	Lith-ium, dis-solved (µg/L as Li)	Manga-nese, dis-solved (µg/L as Mn)	Mercury, dis-solved (µg/L as Hg)	Molyb-denum, dis-solved (µg/L as Mo)	Nickel, dis-solved (µg/L as Ni)	Sele-nium, dis-solved (µg/L as Se)	Silver, dis-solved (µg/L as Ag)	Vana-dium, dis-solved (µg/L as V)	Zinc, dis-solved (µg/L as Zn)
10	10-07-87	<10	13	60	100	2,300	<1	2	<10	--	<5	350	<10	0.1	12	<1	<1	<1	21	<10
	03-17-88	<10	16	150	--	3,400	1	<1	<1	10	<5	420	<10	<.1	35	--	1	--	41	10
	03-28-89	--	--	220	--	5,700	--	<1	--	--	--	490	--	<.1	140	--	2	--	91	10
	03-26-90	--	--	280	--	7,700	<1	<1	2	--	5	--	--	<.1	76	--	2	--	59	<10
	05-20-96	--	--	73	--	2,200	<1	1.3	2	--	<1	--	--	<.1	16	--	1	--	22	<9
B	06-25-92	--	--	14	--	8,300	<1	1	2	--	<1	--	--	<.1	47	--	<1	--	34	<10
4	10-07-87	10	<1	85	100	2,200	<1	<40	<10	--	<5	390	<10	<.1	17	<1	1	<1	22	<10
	03-17-88	<10	3	52	--	3,500	1	<1	<1	<10	<5	740	40	<.1	12	--	1	--	21	<10
	08-24-88	--	--	57	--	1,100	--	<1	--	--	--	270	--	<.1	10	--	<1	--	18	15
	03-28-89	--	--	40	--	4,500	--	<1	--	--	--	730	--	<.1	13	--	<1	--	15	<10
	03-27-90	--	--	65	--	4,200	<1	1	2	--	<1	--	--	.1	13	--	<1	--	23	<10
	07-18-90	--	--	52	--	2,000	1	1	4	--	<1	--	--	<.1	13	--	<1	--	24	<3
	11-19-90	--	--	59	--	3,600	<1	<1	1	--	<1	--	--	<.1	9	--	<1	--	28	<10
	05-21-96	--	--	37	--	1,400	<1	1.4	2	--	<1	--	--	<.1	17	--	<1	--	16	<3
C	05-21-96	--	--	270	--	9,400	<1	1.3	2	--	<4	--	--	<.1	200	--	8	--	120	52
D	05-21-96	--	--	170	--	5,500	<1	1.4	2	--	<2	--	--	<.1	110	--	3	--	69	19
8	10-06-87	<10	10	100	100	5,000	<1	<10	<10	--	<5	760	160	<.2	58	1	2	<1	62	20
	03-16-88	<10	28	200	--	10,000	1	<1	<1	30	<5	920	440	<.1	100	--	<1	--	69	10
	08-24-88	--	--	83	--	3,000	--	<1	--	--	--	520	--	<.1	20	--	2	--	45	<10
	03-28-89	--	--	73	--	3,700	--	<1	--	--	--	540	--	.5	22	--	<1	--	38	10
	03-26-90	--	--	69	--	3,600	<1	2	1	--	<1	--	--	<.1	24	--	1	--	40	20
	07-18-90	--	--	64	--	3,600	<1	2	2	--	<1	--	--	.1	25	--	<1	--	38	20
	11-19-90	--	--	60	--	4,100	<1	<1	2	--	<1	--	--	<.1	13	--	<1	--	24	10
	05-20-96	--	--	72	--	3,000	<1	1.7	2	--	<1	--	--	<.1	38	--	2	--	28	<9

Table 6. Concentrations of trace elements in surface-water samples in and near Humboldt Wildlife Management Area and upstream sites, 1987-96—Continued

Site (figs. 1 and 2)	Date	Alu-minum dis-solved (μg/L as Al)	Anti-mony, dis-solved (μg/L as Sb)	Arsenic, dis-solved (μg/L as As)	Barium, dis-solved (μg/L as Ba)	Boron, dis-solved (μg/L as B)	Cad-mium, dis-solved (μg/L as Cd)	Chro-mium, dis-solved (μg/L as Cr)	Copper, dis-solved (μg/L as Cu)	Iron, dis-solved (μg/L as Fe)	Lead, dis-solved (μg/L as Pb)	Lith-ium, dis-solved (μg/L as Li)	Manga-nese, dis-solved (μg/L as Mn)	Mercury, dis-solved (μg/L as Hg)	Molyb-denum, dis-solved (μg/L as Mo)	Nickel, dis-solved (μg/L as Ni)	Sele-nium, dis-solved (μg/L as Se)	Silver, dis-solved (μg/L as Ag)	Vana-dium, dis-solved (μg/L as V)	Zinc, dis-solved (μg/L as Zn)
11	10-07-87	<10	7	210	100	3,900	<1	<10	<10	--	<5	660	<10	0.2	31	1	2	<1	43	10
	03-17-88	<10	2	56	--	3,500	1	<1	<1	10	<5	560	<10	<.1	27	--	<1	--	33	20
	08-24-88	--	--	90	--	4,300	--	<1	--	--	--	700	--	<.1	38	--	<1	--	41	10
	03-28-89	--	--	98	--	5,400	--	<1	--	--	--	710	--	<.1	44	--	<1	--	45	10
	03-26-90	--	--	78	--	4,500	<1	1	2	--	<1	--	--	<.1	26	--	<1	--	48	<10
	07-09-90	--	--	59	--	2,700	<1	2	1	--	<1	--	--	.2	24	--	1	--	37	<10
	11-26-90	--	--	76	--	3,800	<1	<1	2	--	<1	--	--	<.1	19	--	<1	--	19	<10
	05-20-96	--	--	190	--	9,600	<1	1.3	3	--	<4	--	--	<.1	310	--	2	--	100	<30

Table 7. Selected trace-element concentrations (dry weight) in sediment and biological samples in and near Humboldt Wildlife Management Area, 1986-96

[Symbols: <, less than; --, not determined]

Matrix	Site	Date	Moisture (percent)	Concentration (micrograms per gram)							
				Aluminum	Arsenic	Barium	Beryllium	Boron	Cadmium	Chromium	Copper
Sediment (<2 mm)	Humboldt Lake	11/26/90	--	--	7	400	<1	21	<2	17	16
Sediment	Humboldt Lake	05/30/96	52.3	10,400	19	237	<.2	87	.3	7	8
Pondweed leaf	Toulon Lake	07/02/87	90.3	--	14	82	<.5	561	<.50	5	17
Pondweed leaf	Toulon Lake	07/02/87	90.3	--	82	82	<.5	431	<.50	14	18
Pondweed leaf	Toulon Lake	06/11/90	87.8	3,280	14	119	<.1	180	<.2	3	7
Pondweed leaf	Toulon Lake	05/25/90	89.3	1340	24	45	<.1	432	<.2	1	6
Pondweed leaf	Humboldt Lake	06/15/90	85.8	734	14	40	<.1	620	<.2	1	6
Pondweed leaf	Humboldt Lake	07/12/96	89.9	47	17	17	<.2	416	<.2	4	6
Pondweed leaf	Humboldt Lake	07/12/96	89.4	117	24	28	<.2	1,116	<.2	3	5
Pondweed leaf	Humboldt Lake	07/12/96	87.4	155	24	91	<.2	323	<.2	<1	6
Pondweed leaf	Humboldt Lake	07/12/96	89.1	229	50	42	<.2	776	<.2	2	6
Hemipteran insect	Humboldt Lake	08/05/86	81.5	260	.9	9	<.5	<27	<.5	<2	20
Hemipteran insect	Toulon Lake	06/23/87	86.1	180	.4	7	<.1	9.5	.6	<1	23
Hemipteran insect	Humboldt Lake	06/15/90	86.4	498	3.0	16	.1	29	1.9	<1	26
Hemipteran insect	Humboldt Lake	07/12/96	88.2	75	3.1	7	<.2	58.6	4.1	4	37
Hemipteran insect	Humboldt Lake	07/12/96	86.8	112	2.9	11	<.2	32.7	2.1	3	24
Hemipteran insect	Humboldt Lake	05/30/96	87.7	456	3.6	20	<.2	49.2	1.4	2	21
American coot egg	Toulon Lake	05/17/88	72.2	<6.3	.50	12	.14	9.0	<.4	<.5	6.4
American coot egg	Toulon Lake	05/17/88	74.5	<6.3	.55	1.6	.08	4.5	.4	<.5	5.5
American coot egg	Toulon Lake	05/17/88	75.4	<6.3	.42	3.9	.07	6.4	<.4	<.5	3.6
American coot egg	Toulon Lake	05/17/88	73.1	<6.3	.49	3.6	<.03	6.9	.4	<.5	4.5
American coot egg	Toulon Lake	05/17/88	74.0	<6.3	.46	4.9	.21	6.7	1.2	.9	5.2
American coot egg	Toulon Lake	06/08/88	73.4	<6.3	.76	3.7	.15	7.1	.9	<.5	4.6
American coot egg	Toulon Lake	06/08/88	74.0	<6.3	<.3	11	.17	9.5	.9	<.5	4.0
American coot egg	Toulon Lake	06/08/88	77.2	<6.3	<.3	6.0	.19	14	.8	.5	5.6
American coot egg	Toulon Lake	05/25/88	72.2	<6.3	<.3	1.3	.13	5.1	1.0	<.5	4.3
American coot egg	Toulon Lake	05/17/88	73.5	<6.3	<.3	7.4	.11	8.7	.6	<.5	3.8

Table 7. Selected trace-element concentrations (dry weight) in sediment and biological samples in and near Humboldt Wildlife Management Area, 1986-96—Continued

Matrix	Site	Date	Moisture (percent)	Concentration (micrograms per gram)							
				Aluminum	Arsenic	Barium	Beryllium	Boron	Cadmium	Chromium	Copper
American coot egg	Toulon Lake	05/17/88	73.5	<6.3	<0.3	3.4	<0.03	7.8	0.7	0.9	5.8
American coot egg	Toulon Lake	05/17/88	72.7	<6.3	.6	3.1	<.03	7.2	<.4	<.5	4.9
American coot egg	Toulon Lake	05/25/88	66.5	<6.3	.5	3.2	<.03	4.4	<.4	<.5	3.9
American coot egg	Toulon Lake	05/25/88	63.6	<6.3	.5	9.1	<.03	9.8	<.4	<.5	4.2
American coot egg	Toulon Lake	05/25/88	63.7	<6.3	.6	3.9	<.03	14	<.4	<.5	6.6
American coot egg	Toulon Lake	05/17/88	65.4	<6.3	.5	4.0	.1	9.1	.4	<.5	5.7
American coot egg	Toulon Lake	05/17/88	63.3	<6.3	.5	2.9	.3	5.2	<.4	<.5	3.4
American coot egg	Toulon Lake	05/17/88	59.8	<6.3	<.3	1.0	<.03	5.4	<.4	.9	4.0
American coot egg	Toulon Lake	05/17/88	65.5	<6.3	<.3	4.2	.03	7.7	<.4	.6	3.4
American coot egg	Toulon Lake	05/17/88	62.4	<6.3	.5	5.4	<.03	8.6	<.4	<.5	4.0
American coot egg	Toulon Lake	05/17/88	54.0	<6.3	.4	8.9	<.03	8.5	<.4	<.5	3.3
American coot egg	Toulon Lake	05/25/88	55.8	<6.3	<.3	6.0	<.03	4.5	<.4	.6	3.7
American coot egg	Toulon Lake	05/26/88	59.7	<6.3	<.3	6.2	.04	5.5	<.4	.6	4.5
American coot egg	Toulon Lake	05/25/88	77.8	<6.3	.5	3.8	<.03	10	<.4	<.5	5.0
American coot egg	Toulon Lake	05/25/88	75.3	<6.3	<.3	7.3	<.03	8.6	<.4	<.5	4.7
American coot egg	Toulon Lake	05/26/88	75.6	<6.3	<.3	6.3	<.03	6.8	<.4	<.5	5.1
American coot egg	Toulon Lake	06/01/88	74.9	<6.3	.4	2.2	<.03	5.7	<.4	<.5	3.2
American coot egg	Humboldt Lake	05/30/96	74.1	10	.5	3.5	<.1	7.8	<.1	1.7	3.1
American coot egg	Humboldt Lake	05/30/96	74.4	7.0	.7	0.9	<.1	10.6	<.1	<.5	3.6
American coot egg	Humboldt Lake	05/30/96	74.0	6.8	.8	2.9	<.1	7.5	<.1	<.5	2.9
American coot egg	Humboldt Lake	05/30/96	74.0	9.0	.9	1.5	<.1	8.0	<.1	<.5	3.6
American coot egg	Humboldt Lake	05/30/96	76.1	6.5	.7	1.8	<.1	7.8	<.1	<.5	3.6
American coot egg	Humboldt Lake	05/30/96	76.2	9.5	.9	0.7	<.1	7.4	<.1	.6	3.5
American coot egg	Humboldt Lake	05/30/96	74.0	8.9	.6	2.6	<.1	7.2	<.1	1.0	3.2
American avocet egg	Humboldt Lake	05/30/96	72.9	12	<.5	1.1	<.1	2.3	<.1	<.5	3.3
American avocet egg	Humboldt Lake	05/30/96	72.8	6.3	<.5	2.6	<.1	2.6	<.1	<.5	3.3
American avocet egg	Humboldt Lake	05/30/96	75.7	9.7	<.5	2.8	<.1	<2.0	<.1	<0.5	3.4
American avocet egg	Humboldt Lake	05/30/96	71.2	9.7	<.5	1.5	<.1	2.2	<.1	.5	3.8
American avocet egg	Humboldt Lake	05/30/96	76.1	<5.0	<.5	1.0	<.1	2.0	<.1	<.5	4.6
American avocet egg	Humboldt Lake	05/30/96	74.1	<5.1	<.5	2.0	<.1	2.0	<.1	<.5	3.5
American avocet egg	Humboldt Lake	05/30/96	72.9	6.7	<.5	2.7	<.1	3.1	<.1	.5	3.7

Table 7. Selected trace-element concentrations (dry weight) in sediment and biological samples in and near Humboldt Wildlife Management Area, 1986-96—Continued

Matrix	Site	Date	Moisture (percent)	Concentration (micrograms per gram)							
				Aluminum	Arsenic	Barium	Beryllium	Boron	Cadmium	Chromium	Copper
American coot liver	Humboldt Lake	08/04/86	76.9	8	0.4	<0.4	<0.4	11	<0.4	<1	63
American coot liver	Humboldt Lake	08/04/86	75.7	9	.4	<.4	<.4	39	<.4	<1	29
American coot liver	Humboldt Lake	08/04/86	72.8	13	.4	<.4	<.4	73	<.4	<1	80
American coot liver	Humboldt Lake	08/04/86	76.6	12	.7	<.4	<.4	47	<.4	<1	77
American coot liver	Humboldt Lake	08/04/86	74.9	12	.4	<.4	<.4	51	<.4	<1	110
American coot liver	Toulon Lake	07/02/87	74.3	<3	<.2	.1	.1	2	<.2	<1	81
American coot liver	Toulon Lake	07/02/87	77.5	<3	<.2	<.1	<.1	3	<.2	<1	60
American coot liver	Toulon Lake	07/02/87	76.9	<3	<.2	<.1	<.1	<2	<.2	<1	135
American coot liver	Toulon Lake	07/02/87	76.8	3	<.2	<.1	<.1	4	<.2	<1	71
American coot liver	Toulon Lake	07/02/87	80.2	<3	<.2	<.1	<.1	3	<.2	<1	135
American coot liver	Humboldt Lake	08/09/88	68.1	4	.3	<.1	<.1	5	.8	<2	13
American coot liver	Humboldt Lake	08/09/88	68.6	<3	.5	<.1	<.1	8	.7	<2	26
American coot liver	Humboldt Lake	08/09/88	69.0	3	.2	<.1	<.1	5	<.4	<2	28
American coot liver	Humboldt Lake	08/09/88	70.9	<3	.2	<.1	<.1	5	<.4	<2	27
American coot liver	Humboldt Lake	08/09/88	69.6	4	.4	.1	<.1	4	1.0	<2	35
American coot liver	Humboldt Lake	08/09/88	70.3	<3	.2	.1	<.1	3	<.4	<2	33
American coot liver	Humboldt Lake	08/09/88	66.8	3	.2	<.1	<.1	4	1.0	<2	32
American coot liver	Humboldt Lake	08/09/88	68.8	<3	.4	.1	<.1	6	.5	<2	18
American coot liver	Humboldt Lake	08/09/88	69.6	4	.5	<.1	<.1	3	.9	<2	13
American coot liver	Humboldt Lake	08/09/88	71.2	4	.3	<.1	<.1	<2	1.0	<2	26
American coot liver	Humboldt Lake	08/09/88	69.0	4	.4	<.1	<.1	5	.7	<2	17
American coot liver	Humboldt Lake	08/09/88	69.4	<3	.4	<.1	<.1	5	<.4	<2	15
American coot liver	Humboldt Lake	07/12/96	72.5	<5	1.1	<.5	<.1	14	.1	3.2	13
American coot liver	Humboldt Lake	07/12/96	73.6	<5	<.5	<.5	<.1	5	.1	7.6	56
American coot liver	Humboldt Lake	07/12/96	72.5	<5	<.5	<.5	<.1	8	.2	6.6	28
American coot liver	Humboldt Lake	07/12/96	75.7	<5	1.2	<.5	<.1	9	.2	2.5	22
American coot liver	Humboldt Lake	07/12/96	69.8	<5	.8	<.5	<.1	8	.5	4.7	15
Black-necked Stilt liver	Humboldt Lake	08/04/86	72.4	7	<.2	<.4	<.4	24	<.4	<1	18
Black-necked Stilt liver	Humboldt Lake	08/04/86	74.2	7	<.2	<.4	<.4	25	2.7	1.4	18
Black-necked Stilt liver	Humboldt Lake	08/04/86	72.2	25	<.2	<.4	<.4	190	<.4	1.9	17
Black-necked Stilt liver	Humboldt Lake	08/04/86	72.4	21	<.2	<.4	<.4	110	<.4	1.4	18
Black-necked Stilt liver	Humboldt Lake	08/04/86	71.9	10	<.2	<.5	<.5	45	<.5	2.6	19

Table 7. Selected trace-element concentrations (dry weight) in sediment and biological samples in and near Humboldt Wildlife Management Area, 1986-96—Continued

Matrix	Site	Date	Moisture (percent)	Concentration (micrograms per gram)							
				Aluminum	Arsenic	Barium	Beryllium	Boron	Cadmium	Chromium	Copper
Black-necked Stilt liver	Toulon Lake	08/12/87	69.4	<3	<0.2	0.4	<0.1	<2	<0.2	<1	16
Black-necked Stilt liver	Toulon Lake	08/12/87	70.7	<3	<.2	.2	<.1	<2	<.2	<1	22
Black-necked Stilt liver	Toulon Lake	08/12/87	71.6	<3	<.2	.1	<.1	<2	<.2	<1	20
Black-necked Stilt liver	Toulon Lake	08/12/87	71.4	<3	<.2	.2	<.1	<2	.2	<1	20
Black-necked Stilt liver	Humboldt Lake	07/30/87	74.9	<3	<.2	.2	<.1	2	.4	<1	22
Black-necked Stilt liver	Humboldt Lake	07/30/87	73.3	<3	<.2	.1	<.1	<2	<.2	<1	24
Black-necked Stilt liver	Humboldt Lake	07/30/87	76.2	5	<.2	.2	<.1	<2	3.3	<1	16
Black-necked Stilt liver	Humboldt Lake	08/12/87	71.1	<3	<.2	.1	.1	<2	.2	<1	23
Black-necked Stilt liver	Humboldt Lake	08/12/87	71.2	<3	<.2	.2	<.1	<2	1.8	<1	33
American avocet liver	Humboldt Lake	07/12/96	72.7	<5	.9	<.5	<.1	3	.2	7.4	28
American avocet liver	Humboldt Lake	07/12/96	72.7	<5	<.5	<.5	<.1	2	.4	4.4	24
American avocet liver	Humboldt Lake	07/12/96	71.9	<5	<.5	<.5	<.1	2	.9	3.7	20
American avocet liver	Humboldt Lake	07/12/96	72.6	<5	<.5	<.5	<.1	3	.3	2.6	29
American avocet liver	Humboldt Lake	07/12/96	71.5	<5	<.5	<.5	<.1	<2	.6	3.0	29

Table 7. Selected trace-element concentrations (dry weight) in sediment and biological samples from Humboldt Wildlife Management Area, 1986-96—Continued

Matrix	Site	Date	Concentration (micrograms per gram)										
			Iron	Lead	Magnesium	Manganese	Mercury	Molybdenum	Nickel	Selenium	Strontium	Vanadium	Zinc
Sediment (<2 mm)	Humboldt Lake	11/26/90	--	7	--	1,100	0.02	4	11	1.1	1,200	61	37
Sediment	Humboldt Lake	05/30/96	4,810	8.0	13,200	304	<.1	<5.1	6.9	<0.5	1,400	22	20
Pondweed leaf	Toulon Lake	07/02/87	--	10.0	--	103	.26	<5.1	5.3	.9	428	8.5	53
Pondweed leaf	Toulon Lake	07/02/87	--	<10.0	--	103	<.26	<5.1	5.3	.9	428	8.5	
Pondweed leaf	Toulon Lake	06/11/90	2,280	4.0	6,890	162	.4	<1	<1.0	.9	409	8.7	38
Pondweed leaf	Toulon Lake	05/25/90	1,080	4.0	7,840	74	.3	3.3	<1.0	.5	154	3.2	25
Pondweed leaf	Humboldt Lake	06/15/90	729	4.0	7,140	54	.03	3.1	2.0	.5	259	5.2	15
Pondweed leaf	Humboldt Lake	07/12/96	93	<2.0	9,370	33	<.2	6.2	4.3	1.4	149	1.4	42
Pondweed leaf	Humboldt Lake	07/12/96	186	<1.9	9,510	64	<.2	5.5	3.4	1.1	224	2.6	51
Pondweed leaf	Humboldt Lake	07/12/96	279	3.6	4,490	3,602	<.2	2.8	2.6	2.0	293	5.7	45
Pondweed leaf	Humboldt Lake	07/12/96	270	<2.0	7,340	116	<.2	13.4	3.1	<.5	371	2.8	44
Hemipteran insect	Humboldt Lake	08/05/86	4,630	6.0	6,650	245	.3	<1.0	8.3	2.5	200	16	--
Hemipteran insect	Toulon Lake	06/23/87	270	<4.0	--	18	.1	2.0	<1.0	4.1	20	.6	175
Hemipteran insect	Humboldt Lake	06/15/90	310	<1.1	--	43	.1	1.7	<1.6	5.1	22	1.1	170
Hemipteran insect	Humboldt Lake	07/12/96	182	<1.9	1,930	22	.7	1.8	3.0	9.0	84	<.9	194
Hemipteran insect	Humboldt Lake	07/12/96	185	<1.9	1,820	236	1.0	1.2	2.8	8.2	81	<.9	172
Hemipteran insect	Humboldt Lake	05/30/96	443	<1.9	2,280	42	.8	3.8	1.9	6.2	162	2.3	13
American coot egg	Toulon Lake	05/17/88	2	<9.0	481	1.1	.1	<7.0	<4.5	3.3	43	<.6	72
American coot egg	Toulon Lake	05/17/88	84	<9.0	604	1.3	.1	<7.0	<4.5	2.1	25	<.6	58
American coot egg	Toulon Lake	05/17/88	87	<9.0	681	1.4	.1	<7.0	<4.5	2.9	27	<.6	65
American coot egg	Toulon Lake	05/17/88	116	<9.0	519	1.4	.2	<7.0	<4.5	2.1	26	<.6	59
American coot egg	Toulon Lake	05/17/88	118	<9.0	607	1.7	.2	<7.0	7.4	2.8	29	<.6	64
American coot egg	Toulon Lake	06/08/88	114	<9.0	518	.7	.1	<7.0	<4.5	2.4	41	<.6	65
American coot egg	Toulon Lake	06/08/88	153	<9.0	483	1.1	.2	<7.0	<4.5	2.2	45	<.6	80
American coot egg	Toulon Lake	06/08/88	121	<9.0	569	1.5	.1	<7.0	<4.5	4.0	36	<.6	74
American coot egg	Toulon Lake	05/25/88	96	<9.0	598	1.1	.2	<7.0	<4.5	2.1	32	<.6	57
American coot egg	Toulon Lake	05/17/88	108	<9.0	603	1.1	.1	<7.0	<4.5	3.8	33	<.6	67

Table 7. Selected trace-element concentrations (dry weight) in sediment and biological samples from Humboldt Wildlife Management Area, 1986-96—Continued

Matrix	Site	Date	Concentration (micrograms per gram)										
			Iron	Lead	Magnesium	Manganese	Mercury	Molybdenum	Nickel	Selenium	Strontium	Vanadium	Zinc
American coot egg	Toulon Lake	05/17/88	80	<9.0	659	1.6	0.1	<7	<4.5	3.4	33	<0.6	60
American coot egg	Toulon Lake	05/17/88	98	<9.0	728	.8	.1	<7	<4.5	2.4	47	<.6	61
American coot egg	Toulon Lake	05/25/88	127	<9.0	703	1.2	.2	<7	<4.5	2.6	42	<.6	66
American coot egg	Toulon Lake	05/25/88	102	<9.0	598	1.0	.1	<7	<4.5	2.9	39	.9	67
American coot egg	Toulon Lake	05/25/88	103	<9.0	684	.6	.1	<7	<4.5	4.5	34	.6	57
American coot egg	Toulon Lake	05/17/88	130	13.0	627	1.6	.2	7.3	5.5	2.3	23	.9	68
American coot egg	Toulon Lake	05/17/88	90	<9.0	479	<.4	.2	<7	<4.5	1.8	22	<.6	57
American coot egg	Toulon Lake	05/17/88	77	<9.0	502	2.2	.2	<7	<4.5	2.4	10	.6	69
American coot egg	Toulon Lake	05/17/88	74	<9.0	480	<.4	.1	<7	<4.5	2.8	23	<.6	64
American coot egg	Toulon Lake	05/17/88	80	<9.0	495	.5	.1	<7	<4.5	3.3	14	<.6	56
American coot egg	Toulon Lake	05/17/88	100	<9.0	424	.7	1.4	<7	<4.5	2.6	23	.6	68
American coot egg	Toulon Lake	05/25/88	89	<9.0	300	.7	.5	<7	<4.5	2.0	23	<.6	74
American coot egg	Toulon Lake	05/26/88	89	<9.0	496	1.8	.3	<7	<4.5	4.1	13	.6	62
American coot egg	Toulon Lake	05/25/88	105	<9.0	455	.8	.1	<7	<4.5	3.1	17	<.6	52
American coot egg	Toulon Lake	05/25/88	112	<9.0	566	.5	.1	<7	<4.5	3.1	29	<.6	62
American coot egg	Toulon Lake	05/26/88	118	<9.0	493	1.5	.2	<7	<4.5	3.9	15	<.6	58
American coot egg	Toulon Lake	06/01/88	77	<9.0	526	1.1	.1	<7	<4.5	3.3	18	<.6	54
American coot egg	Humboldt Lake	05/30/96	103	<1.0	571	1.3	3.8	.8	1.0	5.2	20	<.5	71
American coot egg	Humboldt Lake	05/30/96	81	<1.0	501	2.0	2.8	1.6	<.5	4.1	11	<.5	45
American coot egg	Humboldt Lake	05/30/96	87	<1.0	387	.8	1.6	.8	<.5	3.2	15	<.5	50
American coot egg	Humboldt Lake	05/30/96	88	<1.0	522	1.1	7.0	1.7	<.5	4.0	15	<.5	90
American coot egg	Humboldt Lake	05/30/96	86	<1.0	565	1.3	2.4	1.1	<.5	4.4	12	<.5	50
American coot egg	Humboldt Lake	05/30/96	104	<1.0	561	2.2	4.4	1.7	<.5	4.2	8	<.5	75
American coot egg	Humboldt Lake	05/30/96	107	<1.0	500	1.4	2.7	1.0	.6	4.7	15	<.5	93
American avocet egg	Humboldt Lake	05/30/96	118	<1.0	389	3.6	3.0	1.0	<.5	8.4	7	<0.5	42
American avocet egg	Humboldt Lake	05/30/96	101	<1.0	342	1.6	2.0	.7	<.5	6.6	12	<.5	52
American avocet egg	Humboldt Lake	05/30/96	108	<1.0	409	3.0	1.3	1.1	<.5	8.9	17	<.5	73
American avocet egg	Humboldt Lake	05/30/96	130	<1.0	356	3.9	2.8	1.1	<.5	6.9	11	<.5	107
American avocet egg	Humboldt Lake	05/30/96	96	<1.0	327	2.8	1.9	3.0	<.5	9.8	7	<.5	31
American avocet egg	Humboldt Lake	05/30/96	116	<1.0	341	1.5	2.0	1.3	<.5	8.6	11	<.5	45
American avocet egg	Humboldt Lake	05/30/96	103	<1.0	432	2.7	2.3	.8	<.5	8.6	11	<.5	82

Table 7. Selected trace-element concentrations (dry weight) in sediment and biological samples from Humboldt Wildlife Management Area, 1986-96—Continued

Matrix	Site	Date	Concentration (micrograms per gram)										
			Iron	Lead	Magnesium	Manganese	Mercury	Molybdenum	Nickel	Selenium	Strontium	Vanadium	Zinc
American coot liver	Humboldt Lake	08/04/86	-	<0.8	840	9.8	0.4	5.5	<1	15	<0.4	<0.4	220
American coot liver	Humboldt Lake	08/04/86	470	<.8	870	9.3	.8	3.4	<1	9.3	<.4	<.4	170
American coot liver	Humboldt Lake	08/04/86	250	<.7	800	24.0	.4	4.4	<1	11	<.4	.9	240
American coot liver	Humboldt Lake	08/04/86	440	<.9	820	14.0	.7	3.9	<1	12	<.4	<.4	220
American coot liver	Humboldt Lake	08/04/86	380	<.8		18.0	.5	4.5	<1	9	2.7	.7	200
American coot liver	Toulon Lake	07/02/87	427	<4.0	784	8.2	.4	2.0	<1	7.0	.6	<.3	231
American coot liver	Toulon Lake	07/02/87	909	<4.0	738	10.0	.2	2.0	<1	9.6	.8	<.3	159
American coot liver	Toulon Lake	07/02/87	914	<4.0	776	10.0	.6	3.0	<1	10	.8	<.3	156
American coot liver	Toulon Lake	07/02/87	464	<4.0	776	12.0	.5	3.0	<1	10	.8	<.3	229
American coot liver	Toulon Lake	07/02/87	577	<4.0	775	9.6	.4	3.5	<1	9.1	1.2	<.3	234
American coot liver	Humboldt Lake	08/09/88	3,460	<4.0	585	13.0	1.5	4.0	<3	8.7	.3	<.5	93
American coot liver	Humboldt Lake	08/09/88	5,370	<4.0	595	8.1	.4	4.7	<3	9.1	.7	2.1	96
American coot liver	Humboldt Lake	08/09/88	4,340	<4.0	685	13.0	.4	4.0	<3	11	.5	1.0	121
American coot liver	Humboldt Lake	08/09/88	3,470	<4.0	716	12.0	3.2	4.3	<3	13	.4	<.5	137
American coot liver	Humboldt Lake	08/09/88	5,480	<4.0	678	9.7	.4	6.0	<3	11	.7	2.1	118
American coot liver	Humboldt Lake	08/09/88	4,370	<4.0	628	7.7	.3	4.3	<3	11	.4	<.5	111
American coot liver	Humboldt Lake	08/09/88	2,330	<4.0	586	9.9	.3	3.0	<3	8.5	.5	1.0	111
American coot liver	Humboldt Lake	08/09/88	4,460	<4.0	557	9.9	.3	4.6	<3	8.8	.7	<.5	98
American coot liver	Humboldt Lake	08/09/88	5,320	<4.0	625	11.0	.4	4.0	<3	9.8	.6	2.4	88
American coot liver	Humboldt Lake	08/09/88	4,770	<4.0	706	15.0	.4	4.0	<3	12	.7	1.0	132
American coot liver	Humboldt Lake	08/09/88	6,490	<4.0	700	12.0	.6	5.6	<3	7.8	.5	<.5	144
American coot liver	Humboldt Lake	08/09/88	3,840	<4.0	564	8.4	.2	3.0	<3	10	.3	1.6	81
American coot liver	Humboldt Lake	07/12/96	828	<1.0	557	7.2	1.5	2.8	1.8	6.6	1.0	<.5	96
American coot liver	Humboldt Lake	07/12/96	1,279	<1.0	721	12.4	3.6	4.3	4.4	9.7	1.1	<.5	147
American coot liver	Humboldt Lake	07/12/96	1,598	<1.0	683	9.1	2.9	3.5	3.8	13	1.8	<.5	124
American coot liver	Humboldt Lake	07/12/96	771	<1.0	644	7.1	2.3	2.0	1.2	10	1.4	<.5	118
American coot liver	Humboldt Lake	07/12/96	2,408	1.2	664	10.1	2.4	3.2	2.9	15	.7	<.5	122
Black-necked Stilt liver	Humboldt Lake	08/04/86	-	<.7	940	15.0	4.4	2.5	<1	34	<.4	<.4	110
Black-necked Stilt liver	Humboldt Lake	08/04/86	-	<.8	910	16.0	.5	2.1	<1	31	<.4	<.4	98
Black-necked Stilt liver	Humboldt Lake	08/04/86	890	<.8	890	17.0	.4	2.1	<1	29	<.4	<.4	81
Black-necked Stilt liver	Humboldt Lake	08/04/86	-	<.8	920	16.0	.6	2.3	<1	42	<.4	<.4	120
Black-necked Stilt liver	Humboldt Lake	08/04/86	730	<1.1	860	12.0	.4	1.7	<1	29	<.5	<.5	82

Table 7. Selected trace-element concentrations (dry weight) in sediment and biological samples from Humboldt Wildlife Management Area, 1986-96—Continued

Matrix	Site	Date	Concentration (micrograms per gram)										
			Iron	Lead	Magnesium	Manganese	Mercury	Molybdenum	Nickel	Selenium	Strontium	Vanadium	Zinc
Black-necked Stilt liver	Toulon Lake	08/12/87	918	<4.0	732	12	2.7	2.0	<1	12	1.2	<0.3	88
Black-necked Stilt liver	Toulon Lake	08/12/87	961	<4.0	728	15	2.8	2.0	<1	19	1.0	<.3	88
Black-necked Stilt liver	Toulon Lake	08/12/87	-	<4.0	723	14	3.1	3.0	<1	18	1.2	<.3	87
Black-necked Stilt liver	Toulon Lake	08/12/87	-	<4.0	700	13	2.2	2.0	<1	26	.7	<.3	88
Black-necked Stilt liver	Humboldt Lake	07/30/87	-	<4.0	822	14	2.5	2.0	<1	11	1.2	<.3	100
Black-necked Stilt liver	Humboldt Lake	07/30/87	798	<4.0	790	14	2.4	2.0	<1	31	.9	<.3	97
Black-necked Stilt liver	Humboldt Lake	07/30/87	-	<4.0	714	11	1.9	2.0	<1	48	.3	<.3	86
Black-necked Stilt liver	Humboldt Lake	08/12/87	771	<4.0	686	12	2.1	2.0	<1	32	.3	<.3	88
Black-necked Stilt liver	Humboldt Lake	08/12/87	941	<4.0	744	13	2.4	3.0	<1	23	.4	<.3	94
American avocet liver	Humboldt Lake	07/12/96	414	<1.0	653	11	1.7	1.7	4.7	25	1.7	<.5	97
American avocet liver	Humboldt Lake	07/12/96	613	<1.0	721	14	2.2	2.0	2.2	23	1.5	<.5	109
American avocet liver	Humboldt Lake	07/12/96	541	<1.0	713	13	2.9	2.5	2.3	34	.8	<.5	90
American avocet liver	Humboldt Lake	07/12/96	349	<1.0	791	12	2.6	1.8	1.5	21	1.4	<.5	116
American avocet liver	Humboldt Lake	07/12/96	445	<1.0	671	11	4.1	2.2	1.9	21	1.1	<.5	94