Environmental Contaminants in Biota from the San Juan River and Selected Tributaries in Colorado, New Mexico, and Utah

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Table of Contents

	Page
List of Figures	iii
List of Tables	vi
Abbreviations and Conversions	vii
Acknowledgments	viii
Introduction	1
Study Area	4
Methods	7
Inorganic Results	11
Organic Results	50
Discussion \ Conclusions	55
Literature Cited	58

List of Figures

Page

Figure 1. Sample collection sites in the San Juan River basin 5

Figure 2. An annotated boxplot 12

Figure 3. Arsenic in biota from different habitats in the San Juan River basin 1988-1994 13

Figure 4. Arsenic in whole fish from the San Juan River mainstem 1988-1994 (NCBP comparison) 14

Figure 5. Arsenic in different species of whole fish from the San Juan River mainstem 1988-1994 15

Figure 6. Arsenic concentrations in biota from the San Juan River mainstem 1988-1994 16

Figure 7. Cadmium in biota from different habitats in the San Juan River basin 1988-1994 18

Figure 8. Cadmium in whole fish from the San Juan River mainstem 1988-1994 (NCBP comparison) 19

Figure 9. Cadmium in different species of whole fish from the San Juan River mainstem 1988-1994 20

Figure 10. Cadmium concentrations in biota from the San Juan River mainstem 1988-1994 21

Figure 11. Copper in biota from different habitats of the San Juan River basin 1988-1994 23

Figure 12. Copper in whole fish from the San Juan River mainstem 1988-1994 (NCBP comparison) 24

Figure 13. Copper in different species of whole fish from the San Juan River mainstem 1988-1994 25

Figure 14. Copper concentrations in biota from the San Juan River mainstem 1988-1994 26

List of Figures (Continued)

Page

Figure 15. Lead in biota from different habitats of the San Juan River basin 1988-1994 28

Figure 16. Lead in whole fish from the San Juan River mainstem 1988-1994 (NCBP comparison) 29

Figure 17. Lead in whole fish from the San Juan River mainstem 1988-1994 (NCBP comparison with y-axis scale changed) 30

Figure 18. Lead in different species of whole fish from the San Juan River mainstem 1988-1994 31

Figure 19. Lead concentrations in biota from the San Juan River mainstem 1988-1994 32

Figure 20. Mercury in biota from different habitats of the San Juan River basin 1988-1994 34

Figure 21. Mercury in whole fish of the San Juan River mainstem 1888-1994 (NCBP comparison) 35

Figure 22. Mercury in different species of whole fish from the San Juan River mainstem 1988-1994 36

Figure 23. Mercury concentrations in biota from the San Juan River mainstem 1988-1994 37

Figure 24. Selenium in biota from different habitats of the San Juan River basin 1988-1994 39

Figure 25. Selenium in whole fish of the San Juan River mainstem 1888-1994 (NCBP comparison) 40

Figure 26. Selenium in different species of whole fish from the San Juan River mainstem 1988-1994 41

Figure 27. Selenium concentrations in biota from the San Juan River mainstem 1988-1994 42

List of Figures (Continued)

Page

Figure 28. Selenium concentrations in whole fish collected during different seasons from the San Juan River basin 1988-1994 43

Figure 29. Zinc in biota from different habitats of the San Juan River basin 1988-1994 46

Figure 30. Zinc in whole fish from the San Juan River mainstem 1988-1994 (NCBP comparison) 47

Figure 31. Zinc in different species of whole fish from the San Juan River mainstem 1988-1994 48

Figure 32. Zinc concentrations in biota from the San Juan River mainstem 1988-1994 49

Figure 33. Corrected total PAH SPMD concentrations above field blanks by site for March through April 1994 52

Figure 34. Corrected total PAH SPMD concentrations above field blanks by site for September through October 1994 53

List of Tables

Page

Table 1. Discreet river miles (RM), site description, site name, and habitat characteristics of each sample collection site 6

Table 2. Scientific names, common names, fish species abbreviations used in this report, and average moisture content (standard deviation) of plant, invertebrate, and fish samples collected in the San Juan River Basin, 1988-1994. 11

Table 3. The concentrations of arsenic (mg/kg dry weight) in plants, invertebrates and whole fish collected from the San Juan River basin, 1988-94. 12

Table 4. The concentrations of cadmium (mg/kg dry weight) in plants, invertebrates and whole fish collected from the San Juan River basin, 1988-94. 17

Table 5. The concentrations of copper (mg/kg dry weight) in plants, invertebrates and whole fish collected from the San Juan River basin, 1988-94. 22

Table 6. The concentrations of lead (mg/kg dry weight) in plants, invertebrates and whole fish collected from the San Juan River basin, 1988-94. 27

Table 7. The concentrations of mercury (mg/kg dry weight) in plants, invertebrates and whole fish collected from the San Juan River basin, 1988-94. 33

Table 8. The concentrations of selenium (mg/kg dry weight) in plants, invertebrates and whole fish collected from the San Juan River basin, 1988-94. 44

Table 9. The concentrations of zinc (mg/kg dry weight) in plants, invertebrates and whole fish collected from the San Juan River basin, 1988-94. 45

Table 11. PAH metabolite concentrations (ng/g wet weight) in fish bile from the San Juan River, 1994 and interpretation 51

Abbreviations, Equivalent Units, and Conversions

Abbreviations

centimeter	cm
gram	g
kilogram	kg
kilometer	km
meters per second	m/s
micrograms per gram	μg/g
milligram per kilogram	mg/kg
nanograms per gram	ng/g
parts per million	ppm
parts per billion	ppb
parts per trillion	ppt

Equivalent Units

micrograms per gram	ppm
milligrams per kilogram	ppm
nanograms per gram	ppb
milligrams per kilogram	μg/g

Conversions

1 mile . . . . . 1.609 km

Wet weight concentration = (dry weight concentration)×(1 - (percent moisture/100))

Dry weight concentration = (wet weight concentration)÷(1 - (percent moisture/100))

Integrated whole body contaminant concentrations were calculated using the equation:

[(fillet mass ÷ whole fish mass) × (contaminant concentration in fillet)] + [(whole body mass - fillet mass {i.e., remnant body mass} ÷ whole fish mass) × (contaminant concentration in partial body)].

Example:

fillet mass	= 20 g	concentration = 0.50 μg/g
remnant body mass	= 180 g	concentration = 0.80 μg/g

[(20g ÷200g) × 0.50μg/g] + [(180g ÷ 200g) × 0.80 μg/g] = 0.77 μg/g

The integrated whole body concentration would be 0.77 μg/g.

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INTRODUCTION

The San Juan River Recovery Implementation Program (Program) was initiated October 1992. The Program was authorized in a cooperative agreement originally signed by the Department of the Interior, the State of Colorado, the State of New Mexico, the Ute Mountain Ute Tribe, the Southern Ute Tribe, and the Jicarilla Apache Tribe. The Programs' primary objective was to collect data in order to assist the U.S. Bureau of Reclamation develop and comply with "reasonable and prudent alternatives" (as defined in section 7 of the Endangered Species Act of 1973) in connection with their proposal to construct the Animas-LaPlata Irrigation Project in southwestern Colorado. This objective included a 7-year commitment of funding and personnel from state and federal natural resource management agencies with interests in the San Juan River Basin. Following the original cooperative agreement, the U.S. Bureau of Indian Affairs (BIA), the U.S. Bureau of Land Management (BLM), and the National Park Service became cooperators in the Program's research to determine which natural resources may be affected by proposed water development and to facilitate the development of Section Seven-related reasonable and prudent alternatives for land and water development activities under their jurisdiction.

The Program's 7-year research plan was designed to gather and interpret scientific data useful for the conservation and recovery of the endangered and native fish populations concomitant with further water development activities in the San Juan River basin. As such, the Program's Biology Committee approved and funded investigations of most aspects of the San Juan River ecosystem believed to correlate with the conservation requirements of the endangered Colorado squawfish (*Ptychocheilus lucius*) and the razorback sucker (*Xyrauchen texanus*). Early funding was used to investigate the responses of native fish populations to manipulations in the San Juan River's flow regime designed to mimic the natural hydrograph (water releases are controlled at Navajo Dam in New Mexico). Early investigations also explored the connection of the physical aspects of San Juan River habitats (stage, areal extent, etc.), fish community structure and dynamics, and the life history requirements of fish (San Juan River Recovery Implementation Program 1993, Biology Committee and Researchers 1994).

Early studies (Kidd and Potter 1978, Eiceman et al. 1985, O'Brien 1987, Butler et al. 1993, Blanchard et al. 1993) identified inorganic and hydrocarbon contamination within the San Juan River Basin. Thus, researchers realized at the outset that the quality of aquatic habitats (e.g., soils, water, and food quality) was an integral line of investigation to be pursued during the Program's 7-year research plan. In 1992, several proposals to investigate contaminants in the San Juan River Basin and a draft comprehensive work plan were prepared. This work plan identified a need to summarize the existing water quality data and determine trends and data gaps as a basis for refining the contaminants' research plan. A final report summarizing water quality and other contaminant information from the San Juan River Basin was completed by the University of New Mexico (Abell 1994) in April 1994.

In 1993, the U.S. Department of the Interior (DOI), under the administration of the U.S. Geological Survey (USGS), launched a National Irrigation Water Quality Program (NIWQP) Detailed Study in the San Juan River Basin. Personnel with the USGS, BIA, and the U.S. Fish and Wildlife Service (FWS) collected samples during the summer months in 1993 and 1994. Sampling sites were primarily centered on areas receiving irrigation water. Water, sediment, and biota were collected and analyzed for both inorganic and organic contaminants, but the focus was on selenium and other contaminants generally associated with irrigation drainwater. The San Juan River, between Navajo Dam and Blanco, New Mexico, was evaluated as part of the NIWQP Detailed Study. The final draft report for the NIWQP Detailed Study is expected in October 1995. Data collected for this study were useful to supplement the Program's research efforts and are included in this report.

In 1994, three new contaminant investigations were launched to meet Program objectives. These investigations included: 1) a BLM study of oil and gas-related contamination, 2) a National Biological Survey (NBS) study of the toxicity of irrigation return water to larval endangered fish, and 3) a comprehensive survey of contaminants in biota from the San Juan River mainstem and three tributaries (herein called the Synoptic Study).

In 1994, personnel of the BLM in Farmington, New Mexico, conducted a sampling program of the presence, distribution, and concentrations of polycyclic aromatic hydrocarbons (PAHs) in water, sediment, and soils to determine impacts of oil and gas production. After analysis of 235 samples, Odell (1995) concluded that impacts from oil and gas development on BLM leased land are minimal. The BLM plans to sample additional areas in 1995.

In 1994, the NBS Midwest Science Center in Columbia, Missouri, conducted laboratory studies to determine the sensitivity and toxicity of PAHs to aquatic organisms, especially endangered fish species (D. Mount, 1995). This study demonstrated: 1) that juvenile fish exposed simultaneously to PAHs in water and ultraviolet radiation (PAH/UV), exhibit greater adverse effects than those exposed to PAHs in water and regular lighting, 2) juvenile Colorado squawfish were more sensitive to PAH/UV exposure than juvenile razorback suckers and both were more sensitive than juvenile fathead minnows, and 3) larval fathead minnows are more sensitive to PAH/UV than juvenile fathead minnows.

In 1994, the NBS Midwest Science Center Field Research Station in Yankton, South Dakota, initiated studies of the toxicity of reconstituted irrigation return water (synthesized to reflect the measured concentrations of major ions in the San Juan River) to juvenile Colorado squawfish and razorback suckers. Hamilton and Buhl (in press), found that razorback suckers were, in general, more sensitive than larval Colorado squawfish. Hamilton and Buhl also suggested that copper was the principal toxic component in synthesized irrigation drainage water.

Until 1994, no comprehensive study of contaminant concentrations in the biota of the San Juan River ecosystem had been conducted. Several investigations limited in their scope (e.g., fish only) or in their geographic extent had been conducted (Blanchard et al. 1993, Butler et al. 1993, Keller-Bliesner Engineering and Ecosystems Research Institute 1991, and Waddell and Wiens 1993). In 1994, Synoptic Survey investigators collected biota (plants, invertebrates, and fish) from 17 mainstem and major tributary sites of the San Juan River between Blanco, New Mexico, and the headwaters of Lake Powell. The primary purpose of the Synoptic Survey was to identify any mainstem reaches or tributaries with inorganic contaminant concentrations that may present a risk (e.g., reproductive impairment) to endangered fish or other wildlife populations. We also used semi-permeable membrane devices (Huckins et al. 1990) at 10 locations along the San Juan River and in selected tributaries to assay the bioavailability of PAHs in water to fish. Additionally, the bile from fish gall bladders of selected channel catfish and carp was collected and tested for the metabolic byproducts resulting from exposure to PAHs.

Study Area

The San Juan River Basin comprises a drainage area of 64,460 km^2 (Figure 1) within the Four Corners region of northwestern New Mexico, southwestern Colorado, southeastern Utah, and northeastern Arizona. It forms a major portion of the upper Colorado River watershed. The approximate center of the San Juan Basin is located near the Four Corners region.[1]

Ranching, farming, and mineral extraction and processing are the predominant land uses within the Basin. During the late Cretaceous age, this area was part of a productive, shallow inland sea (Stone et al. 1983). Rich deposits of organic matter (now found as petroleum, coal, and gas) in the Basin are found associated with these Cretaceous formations. Soils weathered from some of the sedimentary deposits laid down during this age would be expected to be rich in nutrients (e.g., phosphorus, copper, selenium) and organic material (natural gas, coal, oil).

For the purposes of this study, the sample area extended from the San Juan arm of Navajo Reservoir in the upper portion of the Basin downstream all the way to the upper portion of the San Juan arm of Lake Powell, a distance of about 350 miles. Major tributaries to the San Juan River include the Navajo, Piedra, Los Pinos, Animas, La Plata, Chaco, and Mancos rivers; McElmo, Montezuma, and Chinle creeks; Cottonwood Wash and Cañon Largo. The primary drainage contributions come from Colorado, New Mexico, and Utah. Arizona contains only the headwaters of Chinle Creek (Abell 1994).

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[1]The only area in the United States where the boundaries of four States (New Mexico, Utah, Arizona, and Colorado) come together in a single point is referred to as the "Four Corners region."

Figure 1. Sample Collection Sites in the San Juan River Basin (see Table 1)

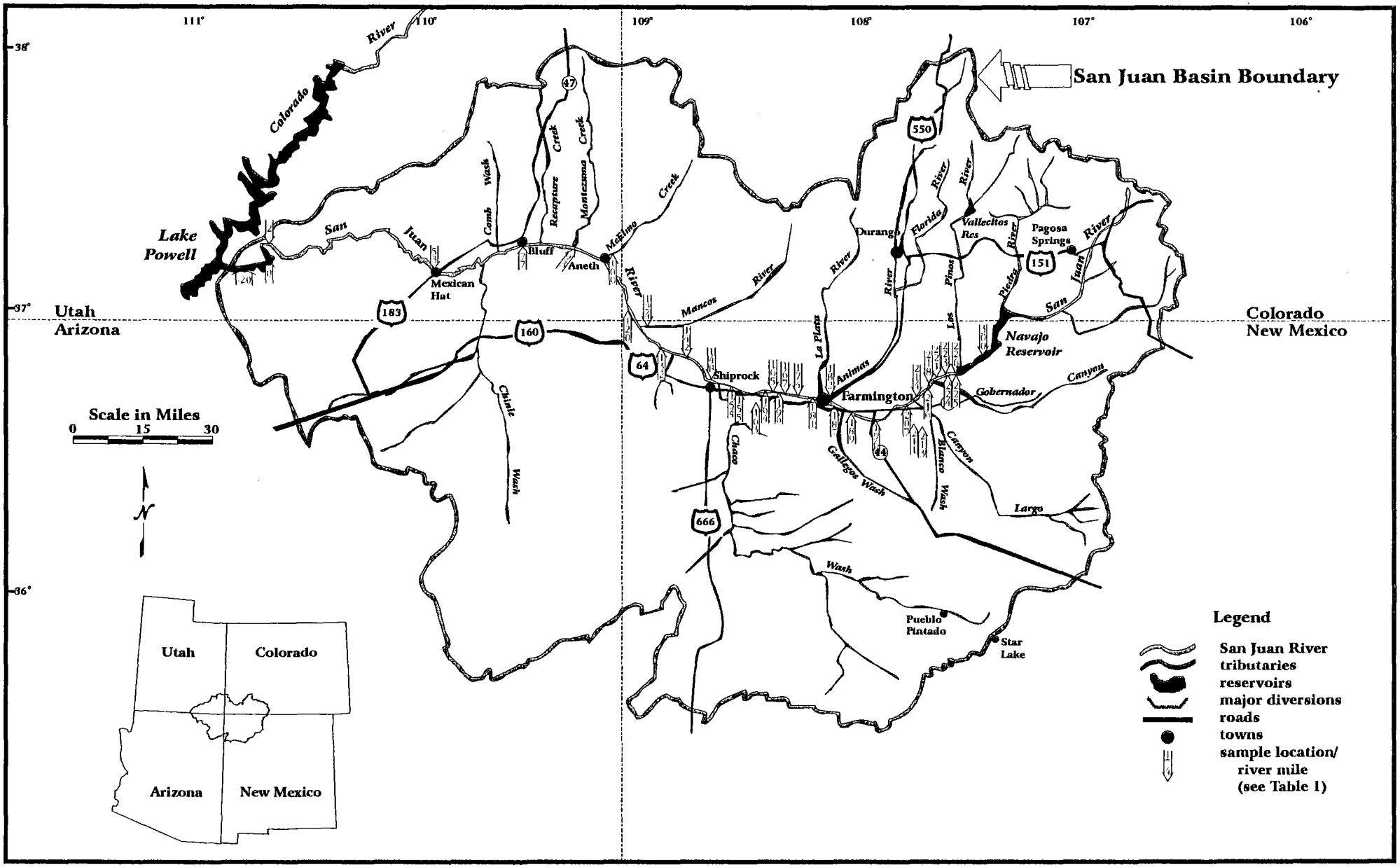

Table 1. Discreet river miles (RM), site description, site name, and habitat characteristics of each sample collection site. [Note: SJR = San Juan River].

RM	Site description	Site Abbreviation	Habitat type
300	Navajo Reservoir	Navajo Res.	Reservoir
250	Piedra River*	Piedra	Tributary mainstem
226	perched wetland at dam	perched wtlnd	Isolated wetland
225	south side muddy backwater	s. side bkwtr	SJR backwater
224	south side wetland+	s. side wtlnd	SJR backwater
223	SJR at Texas Hole+	Tex. Hole	SJR mainstem
221	SJR below Simon Canyon+	Simon Can.	SJR mainstem
218	SJR above Pump Canyon+	Pump Can.	SJR mainstem
216	SJR at Shriner's building+	Shriner's	SJR mainstem
214	RM 214	RM 214	SJR mainstem
213	East Hammond wetland+	E. Hmnd wtlnd	Isolated wetland
211	West Hammond pond+	W. Hmnd pond	Isolated wetland
207	SJR at Blanco	Blanco	SJR mainstem
196	SJR at Bloomfield*	Bloomfield	SJR mainstem
189	RM 189	RM 189	SJR mainstem
187	RM 187	RM 187	SJR mainstem
182	Animas River*	Animas	Tributary mainstem
181	SJR at Farmington	Farmington	SJR mainstem
174	RM 174	RM 174	SJR mainstem
167	RM 167	RM 167	SJR mainstem
166	SJR near Kirtland High School+	Kirtland	SJR mainstem
165	RM 165	RM 165	SJR mainstem
164	RM 164	RM 164	SJR mainstem
163	Fruitland Irrigation Return+	Fruitland	SR irrigation return
158	E. Hogback irrigation drain+	E. Hgbk irr drain	SJR irrigation return
155	Hogback backwater+	Hogback	SJR backwater
154	Fruitland Irrigation Return at Hogback+	Fruit. Drain	SJR irrigation return
148	SJR at Shiprock	Shiprock	SJR mainstem
144	Cudei irrigation drainage	Cudei irr drain	SJR irrigation return
143	Cudei diversion	Cudei diversion	SJR irrigation delivery
142	SJR at Cudei	Cudei	SJR mainstem
132	SJR "Mixer"*	Mixer	SJR mainstem
124	Mancos River	Mancos	Tributary mainstem
120	SJR at 4 Corners	4 Corners	SJR mainstem
100	McElmo Creek	McElmo	Tributary mainstem
93	SJR at Montezuma Creek *	Montezuma	SJR mainstem
77	SJR at Bluff*	Bluff	SJR mainstem
53	SJR at Mexican Hat*	Mex. Hat	SJR mainstem
2	SJR at Clay Hills*	Clay Hills	SJR mainstem
1	Piute Farms	Piute Farms	Reservoir
0	Zahn Bay *	Zahn Bay	Reservoir

* indicates sites sampled with semipermeable membrane devices
+ indicates sites sampled for organochlorine compounds

Methods

Collection Methods for Inorganic Analyses

We attempted to collect samples of plants, macroinvertebrates, large (≥ 15 cm) and small fish (≤ 15 cm) from 12 San Juan River mainstem reaches and three selected tributaries (Table 1) during February 28 to March 4, 1994, and September 12-15, 1994. Teams consisting of personnel from the BIA, Keller-Bliesner Engineering, Ecosystems Research Institute, and FWS collected biological samples, moving downstream to preestablished study reaches.

Investigators hand-collected one sample of aquatic plants (usually filamentous algae) per site where available. Attempts were made to collect a minimum of approximately 10g of plant material. Plants were collected from three (or more) sub-sites to reduce variability. Plants were washed in site water to eliminate sediment contamination.

Invertebrates were collected by kick-net or hand picked from rocks removed from the bottom of the stream. Investigators obtained approximately 10g of invertebrates if they were available. We collected composites of single species, large invertebrates (e.g., crayfish), and also multi-species composites of smaller aquatic invertebrates (e.g., caddisflies, midges, etc.) for analyses.

Samples of large fish (≥ 15 cm) were collected from the mainstem San Juan River using raft-mounted electrofishing gear and from Navajo Reservoir using boat-mounted electrofishing equipment, seines, or gill nets (Butler et al. 1993). Where possible, we obtained more than one species of large fish from each site. Generally, individual large fish were weighed, measured for total length, and composited into samples of three to five similarly sized fish. Small fish, consisted of approximately 3-25 fish, were weighed as a group. In instances where a single species was not present in sufficient quantities to meet analysis requirements, composites of similar species were taken (e.g., rainbow trout and brown trout, small fish).

All samples collected were either double-bagged in food-quality plastic bags or placed in chemically clean jars with Teflon-lined lids. Large fish samples collected for the NIWQP Detailed Study and used in this report were wrapped in aluminum foil before bagging. Aluminum foil was used for these selected samples to reduce plastic contamination of samples analyzed for organochlorine compounds. Samples were labeled by location, species, date collected. In the field, all samples were cooled in insulated chests containing either wet or dry ice and then stored frozen until shipment to analytical laboratories.

The New Mexico Department of Game and Fish manages the San Juan River immediately downstream from Navajo Dam as a trophy trout fishery ("Quality Waters"). This segment of the San Juan River receives over 70,000 angler-use days per year (L. Ahlm, pers. comm.). To estimate the risks of contaminants in fish consumed by people, if any, fillets were collected separately in addition to the rest of the fish from six sites (four main channel and two backwater/wetland sites) within the Quality Waters. Fish samples from this Quality Waters reach were collected for the NIWQP Detailed Study in August 1993 and July 1994.

Composite samples of three to five trout (approximately same size and weight) were collected from five of the six sites within the Quality Waters. One backwater site contained no trout. A skinless fillet was removed from the right side of each trout using a stainless steel blade. Fillets were weighed, composited, placed in chemically clean glass jars, labeled, and stored on wet ice until they could be frozen upon returning from the field. The corresponding composite samples of the three to five whole fish (minus the right-side fillet) were measured for total length, weighed, wrapped in aluminum foil, double-bagged, labeled and stored on wet ice until they could be frozen.

The composite fillets were analyzed separately from the corresponding remnant (minus right-side fillets) whole fish. Processing fish samples in the previously described manner provides data that are useful in two ways. First, contaminant concentrations observed in fillets can be used to estimate public health risks related to fish consumption. Secondly, whole body contaminant concentration was back-calculated using the weighted average of the contaminant concentrations in fillets and recombining those values with the composite samples of remnant fish to calculate an "integrated whole fish" concentration for estimating ecological risks to piscivorous predators, such as the bald eagle, and comparing to other whole fish data.

Inorganic chemical analyses were conducted at two laboratories: Geochemical & Environmental Research Group Laboratory at Texas A&M, and Environmental Trace Substances Research Center in Columbia, Missouri. Analyses were conducted according to procedures outlined by the FWS (1990). Generally, arsenic, and selenium were analyzed by graphite furnace atomic absorption, mercury was analyzed by cold vapor atomic absorption, and other inorganics were analyzed by inductively coupled plasma spectroscopy. About 10% of plant, invertebrate, and fish samples were also submitted for quality assurance/quality control samples. These samples consisted of split, duplicate, method blanks, and standard reference materials.

Inorganic Data Evaluation

The inorganic results in this report were derived from several different data sets in order to provide a more comprehensive view of contaminants in the San Juan River ecosystem (from Navajo Reservoir to the upper reaches of Lake Powell). Approximately 70 percent of the data evaluated in this report came from the Synoptic Study's March and September collections of aquatic plants, benthic invertebrates, and fish. Other data included to supplement this data set were from: the NIWQP Detailed Study (22.6%), the DOI Reconnaissance Investigation of the Pine River Project Area (Butler et al. 1993), which contained data for Navajo Reservoir (5.3%), and other FWS unpublished data (2.1%). After combining data, we were able to evaluate 23 San Juan River mainstem reaches, three backwater sites, two irrigation return sites, three isolated wetlands, three reservoir sites, and three tributaries. In total, contaminant data from over 400 samples of plants (15%), invertebrates (18%), and whole fish (67%) were evaluated in this report.

The concentrations of elements in plants, invertebrates, and fish were not normally distributed, nor were the variances' equivalent. All data were transformed using the natural logarithm, and 1/2 the limit of detection (LOD) was used if any element was less than the LOD in the evaluation of the data. Calculations of geometric means and other statistical analyses were performed with Statistical Packages for the Social Sciences 6.0 for Windows. An analysis of

variance and the range test (Tukey's "honestly significantly different" test) were used to determine if the range and geometric mean concentrations were different. References to significance refer to a 5% error rate. Reference to "average" concentrations in the text are equivalent to the geometric mean concentrations.

Data were evaluated by season, date collected, species, and habitat characteristics. The discreet river mile most closely associated with the collection of samples in a river reach or other collection site was paired with a site name and identified by habitat characteristics (Table 1). Habitats were divided arbitrarily into: 1) the mainstem of the San Juan River, 2) the tributaries (Animas River, Mancos River, and McElmo Creek), 3) backwater environments (connected to the San Juan River by a clearly identifiable inlet/outlet), 4) isolated wetlands (not directly connected to San Juan River), and 5) irrigation drainage return areas along the San Juan River.

Collection and Analytical Methods for Organic Contaminants

Organochlorine analyses were performed on the same fish samples collected in the Quality Waters reach of the San Juan River and other sites (as indicated by a "+" on Table 1). Organochlorine analyses were conducted at the Mississippi State Chemical Laboratory and at Geochemical & Environmental Research Group at Texas A & M. Generally, a sample of fish was mixed with sodium sulfate and hexane extracted prior to partitioning in ether, and glass chromatographic column cleanup. Residues were quantified using electron capture gas chromatography.

During the same periods that Synoptic Study investigators collected biological samples for inorganic contaminants, semipermeable membrane devices (SPMDs) were placed at nine test sites and one reference site throughout the San Juan Basin (as indicated by a "*" on Table 1). The stainless steel mesh canister containing the SPMD was suspended in place between two fence posts or 8-foot sections of rebar pounded into the streambed. Sometimes an additional post or rebar section was used in front of the sample set to provide protection from debris moving with the current. Wire or plastic locking ties were used to connect the canister to the posts. Water velocities were measured at the SPMD sampling sites using a Marsh-McBirney pygmy flow meter to ensure the installation of all of the SPMDs was in water of approximately equivalent current velocities (0.5 m/s). Water temperatures also were recorded during installation.

The SPMDs were retrieved in April and October 1994, approximately 30 days following their deployment. The membrane bags containing the triolein analyte were removed from their protective canisters by hand (polyethylene gloves were worn to prevent contamination from human skin oil or other foreign organic contaminants that might be on the researcher's hand), and placed in chemically cleaned jars. The jars were labeled with site identifiers, date, and water temperature at the time of collection. After sealing the lids with multiple wraps of Teflon tape, the jars containing the membrane samplers were wrapped in several layers of Saran-brand plastic wrap, placed in a locking seal plastic bag and stored in a cooler containing dry ice while in the field. The jars from all sites remained on dry ice while in the field and were shipped to the analytical laboratory immediately upon returning to headquarters. The SPMDs were shipped to Dr. Harry Prest, an organic chemist at Long Marine Laboratory, at the University of California, Santa Cruz, for preparation and analysis.

Synoptic Study investigators removed the bile from common carp and channel catfish gall bladders to analyze for PAH metabolites[2]. Bile was collected using chilled needles and vacuum tubes, placed on dry ice while in the field, and stored frozen until laboratory analysis. Analysis was accomplished by Geochemical and Environmental Research Group, Texas A&M, College Station, Texas, using high performance liquid chromatography.

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[2] Polycyclic Aromatic Hydrocarbon (PAH) compounds are enzymatically metabolized in the liver and do not accumulate in fish tissue. Therefore, bile collected from a fish's gallbladder is assayed for certain characteristic metabolic byproducts to determine if PAH exposure has occurred.

Inorganic Results

Data Presentation and Moisture Content

The scientific names and name codes for fish species collected used figures throughout this document are found in Table 2. Moisture content varied by species of fish and biota type (Table 2). Native sucker species had the highest dry mass content. Figure 2 is an annotated boxplot. Boxplots without whiskers usually have few samples or all observed data are contained within the 75th percentile interquartile box.

Arsenic

The highest average arsenic concentrations were found in plants collected from the San Juan mainstem (Table 3). Arsenic was highest in invertebrates collected from irrigation returns (Figure 3). Arsenic was highest in fish from the Mancos River; however, only two samples were collected at this site. In the San Juan River mainstem, only fish from Zahn Bay had average arsenic concentrations that were above the 85th percentile arsenic concentration for fish sampled nationwide (Schmitt and Brumbaugh 1990) (Figure 4). Comparing all fish species, the bony fish seemed to have higher average arsenic concentrations (Figure 5). Average arsenic concentrations increased in plants from San Juan River sites after Blanco, New Mexico (Figure 6). There was no concomitant increase in invertebrates or whole fish.

Table 2. Scientific names, common names, fish species abbreviations used in this report, and average percent moisture content (standard deviation) of plant, invertebrate, and fish samples collected in the San Juan River Basin, 1988-1994.

Scientific Name	Common Name	Name Code	Moisture Content
Ictalurus melas	black bullhead	bullhead	78.9 (1.9)
Ictalurus punctatus	channel catfish	ch catfish	72.5 (3.8)
Salmo trutta	brown trout	br trout	73.3 (3.4)
Oncorhynchus mykiss	rainbow trout	rb trout	73.5 (3.4)
Catostomus commersoni	white sucker	wh sucker	74.1 (1.0)
Catostomus discobolus	bluehead sucker	bh sucker	68.9 (3.2)
Catostomus latipinnis	flannelmouth sucker	fm sucker	68.9 (4.4)
Cyprinus carpio	common carp	carp	72.9 (4.3)
Gambusia affinis	mosquitofish	mosquitofish	74.5 (3.8)
Cottus bairdi	mottled sculpin	sculpin	78.9 (2.0)
Stizostedion vitreum	walleye	walleye	70.2 (0.8)
Morone saxatalis	striped bass	st bass	73.3 (2.2)
Lepomis cyanellus	green sunfish	gr sunfish	76.6 (2.4)
all whole fish			71.8 (4.5)
all plants			79.6 (9.1)
all invertebrates			74.8 (7.5)

Table 3. The concentrations of arsenic (mg/kg dry weight) in plants, invertebrates, and whole body fish collected from the San Juan River Basin, 1988-94. [Note: Tributaries Combined is the averages of all three tributaries, San Juan River Basin combined all data; SJR = San Juan River; N, number of samples; gM, geometric mean, 95% CI, the 95 percent confidence interval for the geometric mean; <, less than; and ---, data unavailable.]

SITE TYPE	Plants			Invertebrates			Whole Body Fish		
	N	gM	95% CI	N	gM	95% CI	N	gM	95% CI
SJR Mainstem	33	3.46	2.00 - 4.62	40	0.94	0.68 - 1.31	188	0.30	0.27 - 0.34
SJR Backwaters	11	1.33	0.76 - 2.31	9	0.88	0.47 - 1.65	23	0.43	0.34 - 0.55
SJR Irrigation Drains	10	1.11	0.26 - 4.84	7	3.14	1.57 - 6.28	10	0.33	0.23 - 0.47
SJR Reservoirs	---	---	---	---	---	---	41	0.38	0.29 - 0.51
SJR Wetlands	10	0.33	0.20 - 0.57	13	0.45	0.20 - 1.00	4	0.15	<.06 - 0.69
Tributaries Combined	1	3.0	---	5	1.18	0.83 - 1.67	15	0.27	0.17 - 0.42
Animas River	1	3.0	---	2	1.34	<.06 - 28.6	6	0.20	<.06 - 0.49
Mancos River	---	---	---	2	1.03	<.06 - 26.8	2	0.51	<.06 - 333.6
McElmo Creek	---	---	---	1	1.20	---	7	0.29	0.14 - 0.60
San Juan River Basin	65	1.72	1.23 - 2.41	74	0.94	0.73 - 1.21	281	0.32	0.29 - 0.35

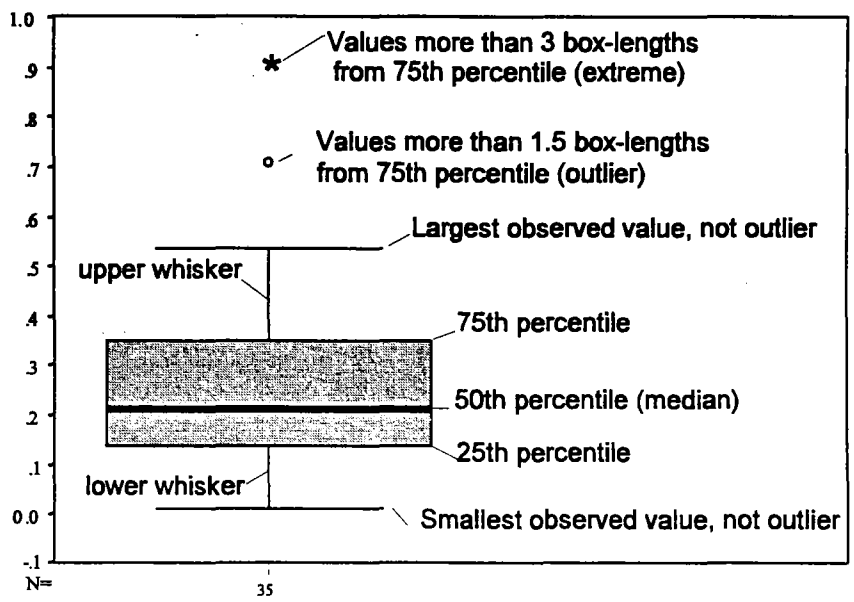


Figure 2. An annotated boxplot.

Figure 3. Arsenic in biota from different habitats in the San Juan River basin 1988-1994.

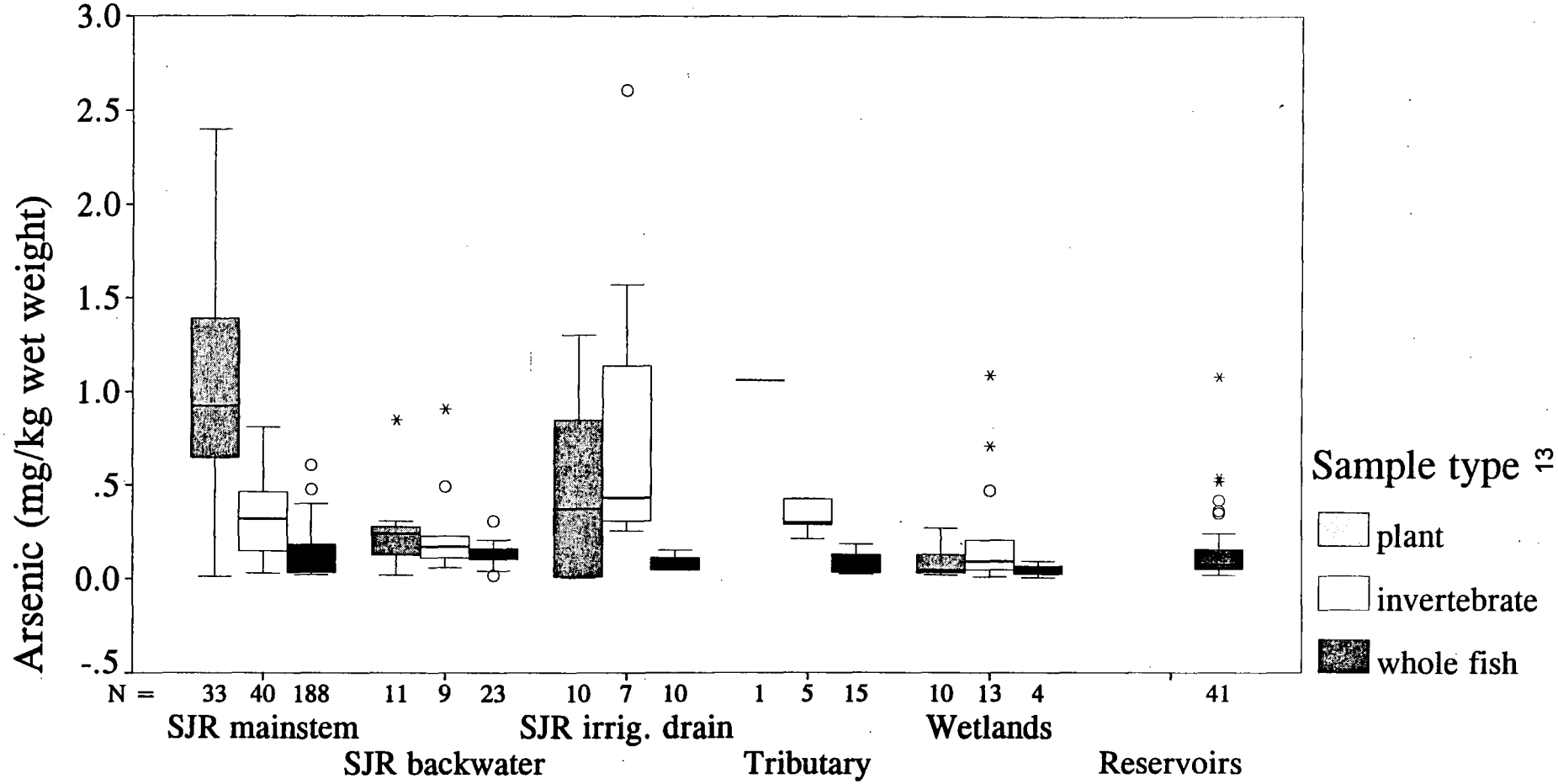


Figure 4. Arsenic in whole fish from the San Juan River mainstem 1988-1994.

[See Table 1 & Fig. 2 notes; line is NCBP 85th percentile (0.27 mg/kg)]

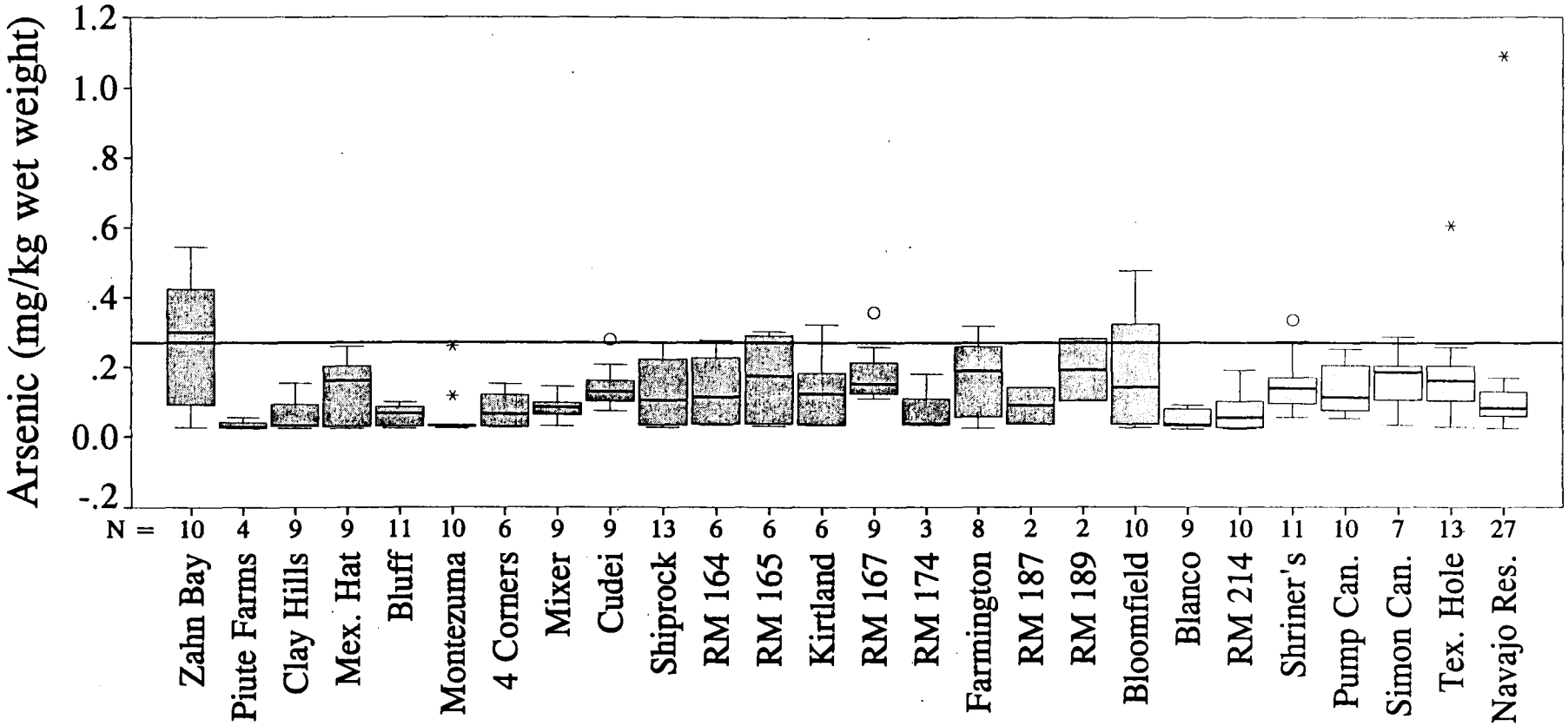


Figure 5. Arsenic in different species of whole fish from the San Juan River mainstem 1988-1994.

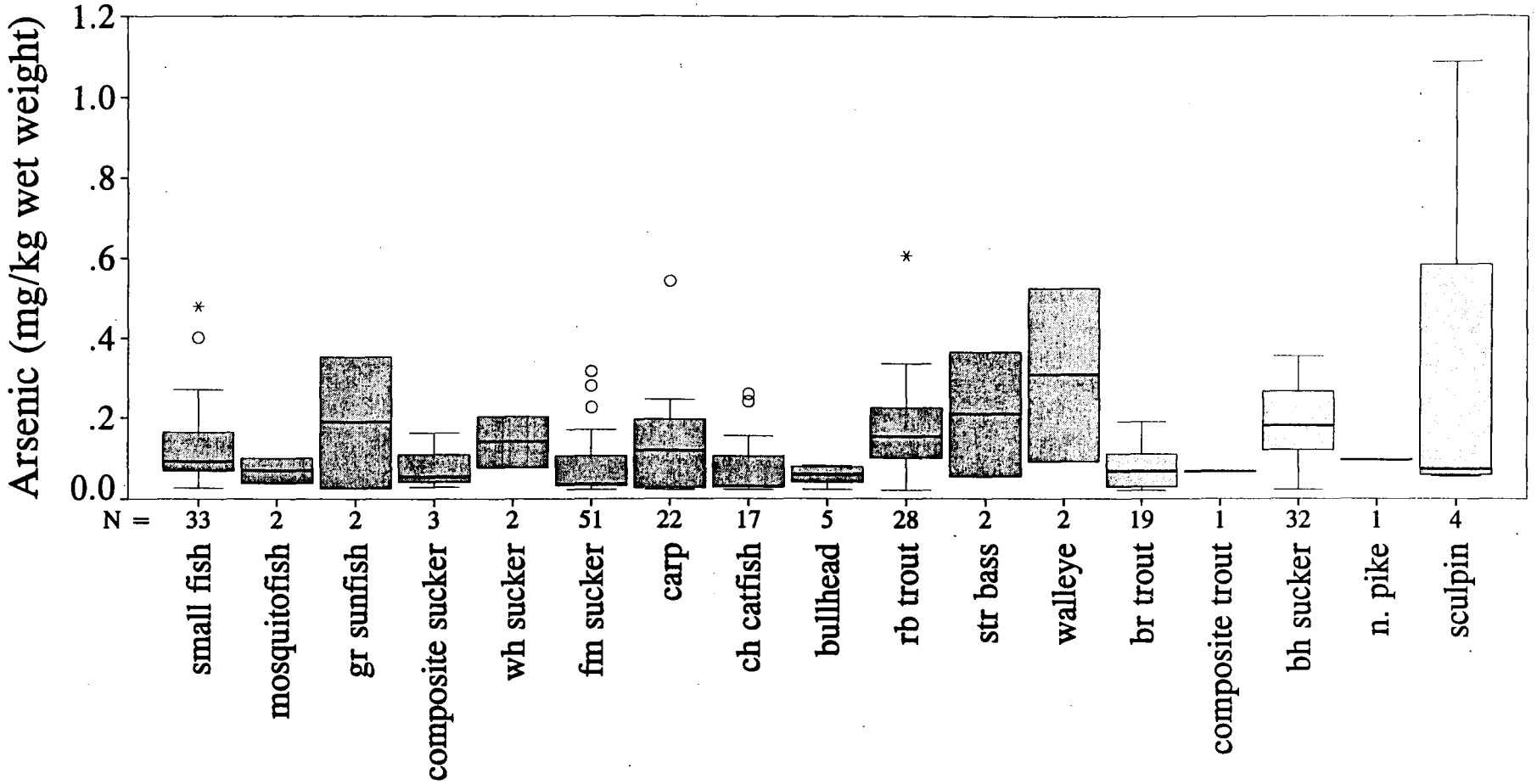
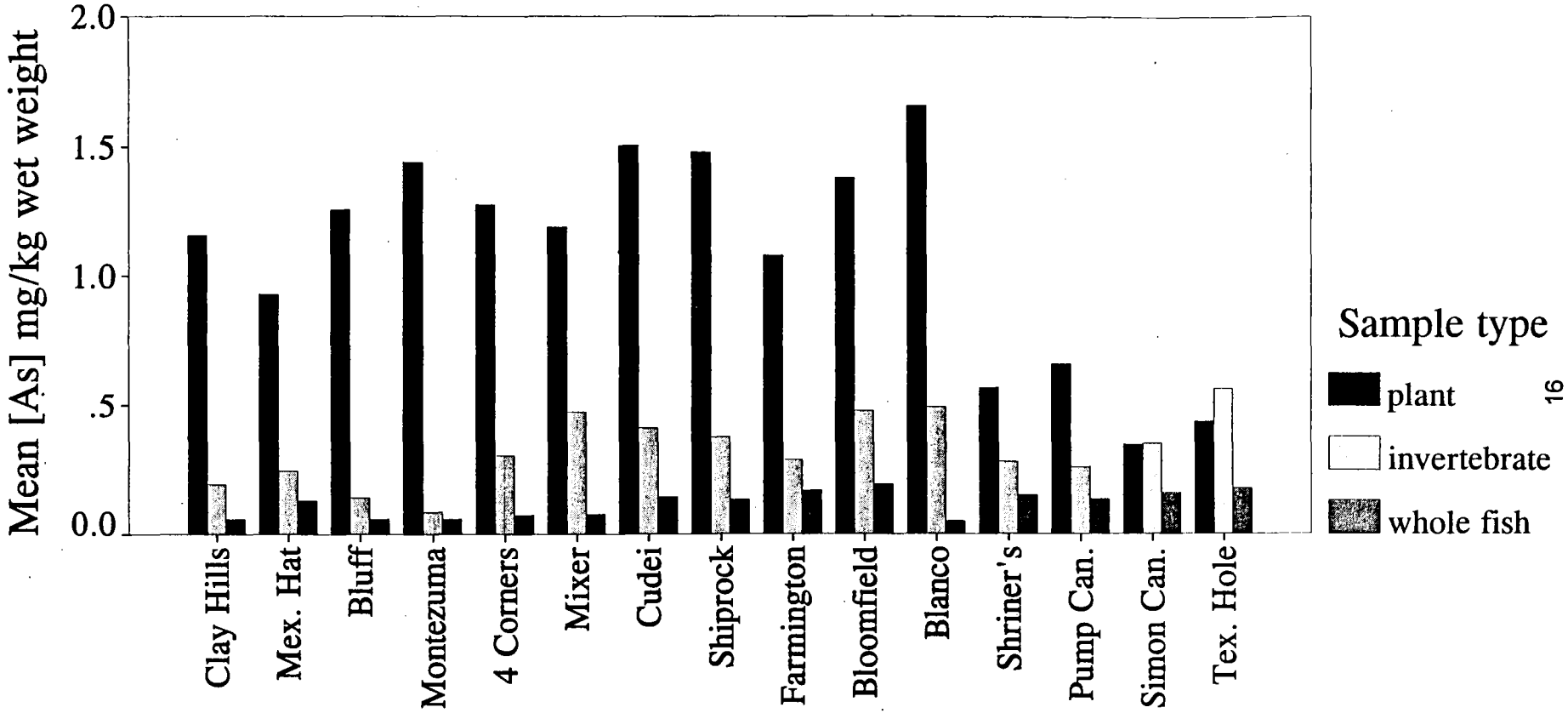


Figure 6. Arsenic concentrations in biota from the San Juan River mainstem 1988-1994.

[only sites with all three sample types are shown]



Cadmium

The highest cadmium concentrations in plants were found in the Animas River (Table 4). Invertebrates from the Animas River were also elevated, but the highest average concentrations were in invertebrates from San Juan River backwaters (Figure 7). However, fish from the reservoir sites, particularly Navajo Reservoir, contained the highest average cadmium concentrations. Unfortunately, plants and invertebrates were not sampled in the reservoirs.

Fish from Navajo Reservoir had an average cadmium concentration that was above the 85th percentile concentration for fish sampled nationwide (Figure 8). Most of the fish from Navajo Reservoir were carp that may accumulate cadmium to a greater extent than other species, perhaps in their scales (Schmitt and Brumbaugh 1990). Composite suckers and green sunfish also contained elevated cadmium concentrations compared to other species (Figure 9). No site had consistently elevated cadmium concentrations in all trophic levels (plants, invertebrates, and whole fish) (Figure 10).

Table 4. The concentrations of cadmium (mg/kg dry weight) in plants, invertebrates, and whole body fish collected from the San Juan River Basin, 1988-94. [Note: Tributaries Combined is the average of all three tributaries, San Juan River Basin combined all data; SJR = San Juan River; N, number of samples; gM, geometric mean, 95% CI, the 95 percent confidence interval for the geometric mean; <, less than; and ---, data unavailable.]

SITE	Plants			Invertebrates			Whole Body Fish		
	N	gM	95% CI	N	gM	95% CI	N	gM	95% CI
SJR Mainstem	33	0.28	0.22 - 0.35	40	0.17	0.13 - 0.23	188	0.05	0.04 - 0.05
SJR Backwaters	11	0.21	0.10 - 0.47	9	0.35	0.19 - 0.64	23	0.05	0.04 - 0.07
SJR Irrigation Drains	10	0.11	0.04 - 0.28	7	0.18	0.08 - 0.37	10	0.03	<.01 - 0.05
SJR Reservoirs	---	---	---	---	---	---	41	0.17	0.11 - 0.27
SJR Wetlands	10	0.06	0.03 - 0.10	13	0.07	0.03 - 0.13	4	0.03	<.01 - 0.07
Tributaries Combined	1	0.86	---	5	0.18	0.08 - 0.43	15	0.12	0.08 - 0.17
Animas River	1	0.86	---	2	0.31	<.01 - 1136	6	0.08	0.04 - 0.16
Mancos River	---	---	---	2	0.15	0.07 - -0.31	2	0.09	<.01 - 0.57
McElmo Creek	---	---	---	1	0.09	---	7	0.17	0.09 - 0.34
San Juan River Basin	65	0.18	0.14 - 0.24	74	0.16	0.12 - 0.20	281	0.06	0.05 - 0.07

Figure 7. Cadmium in biota from different habitats in the San Juan River basin 1988-1994.

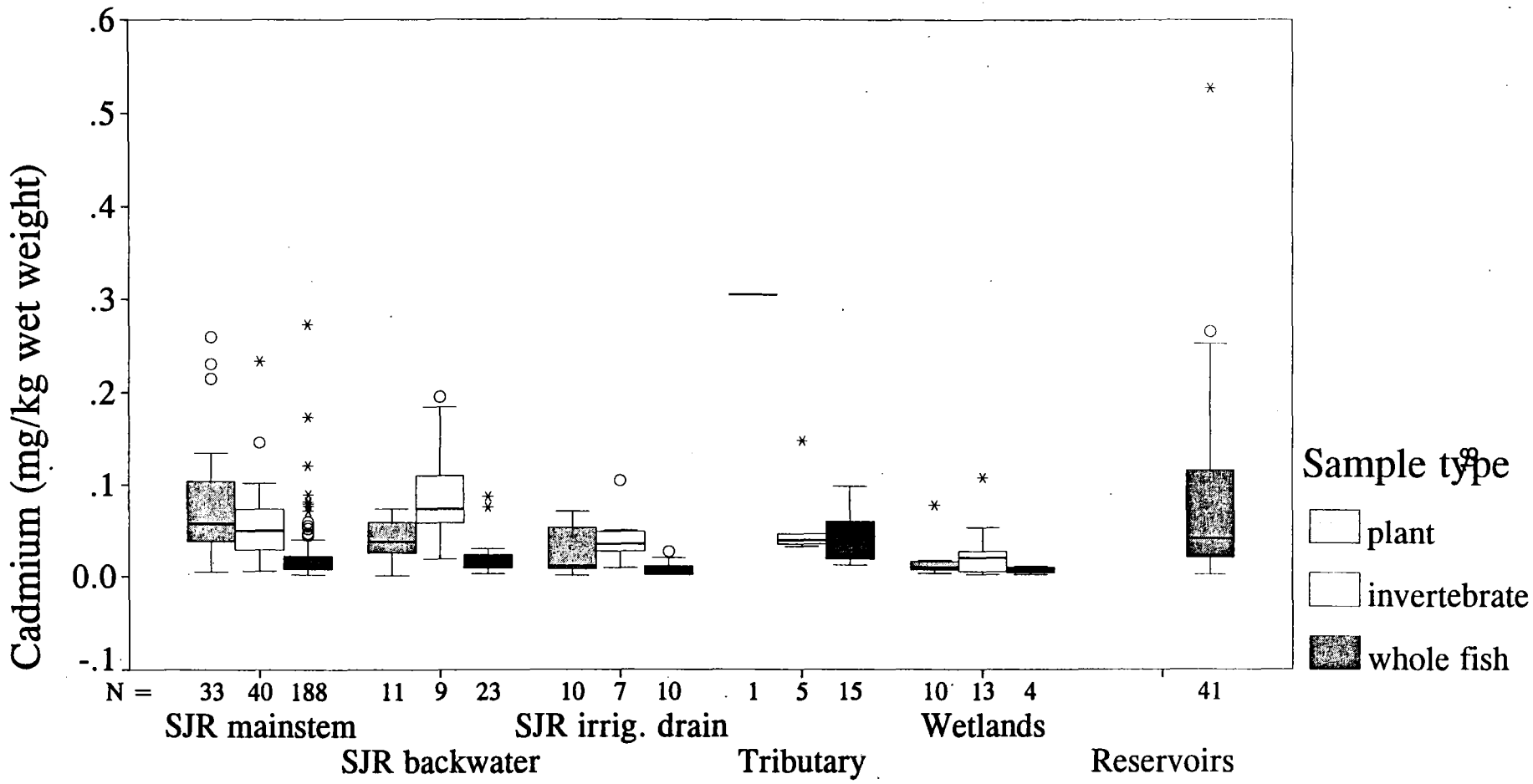


Figure 8. Cadmium in whole fish from the San Juan River mainstem 1988-1994.

[See Table 1 & Fig. 2 notes; line is NCBP 85th percentile (0.05 mg/kg)]

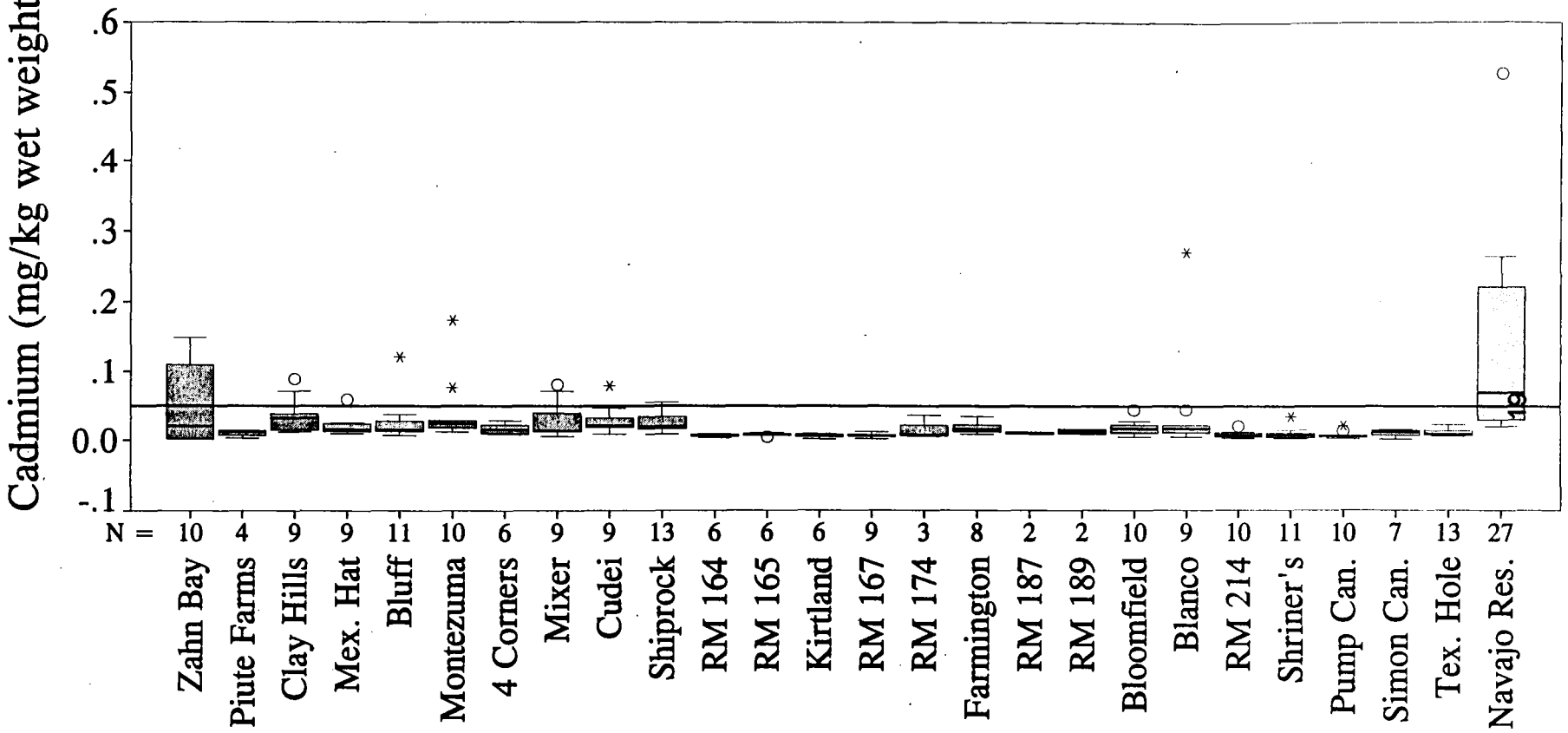


Figure 9. Cadmium in different species of whole fish from the San Juan River mainstem 1988-1994.

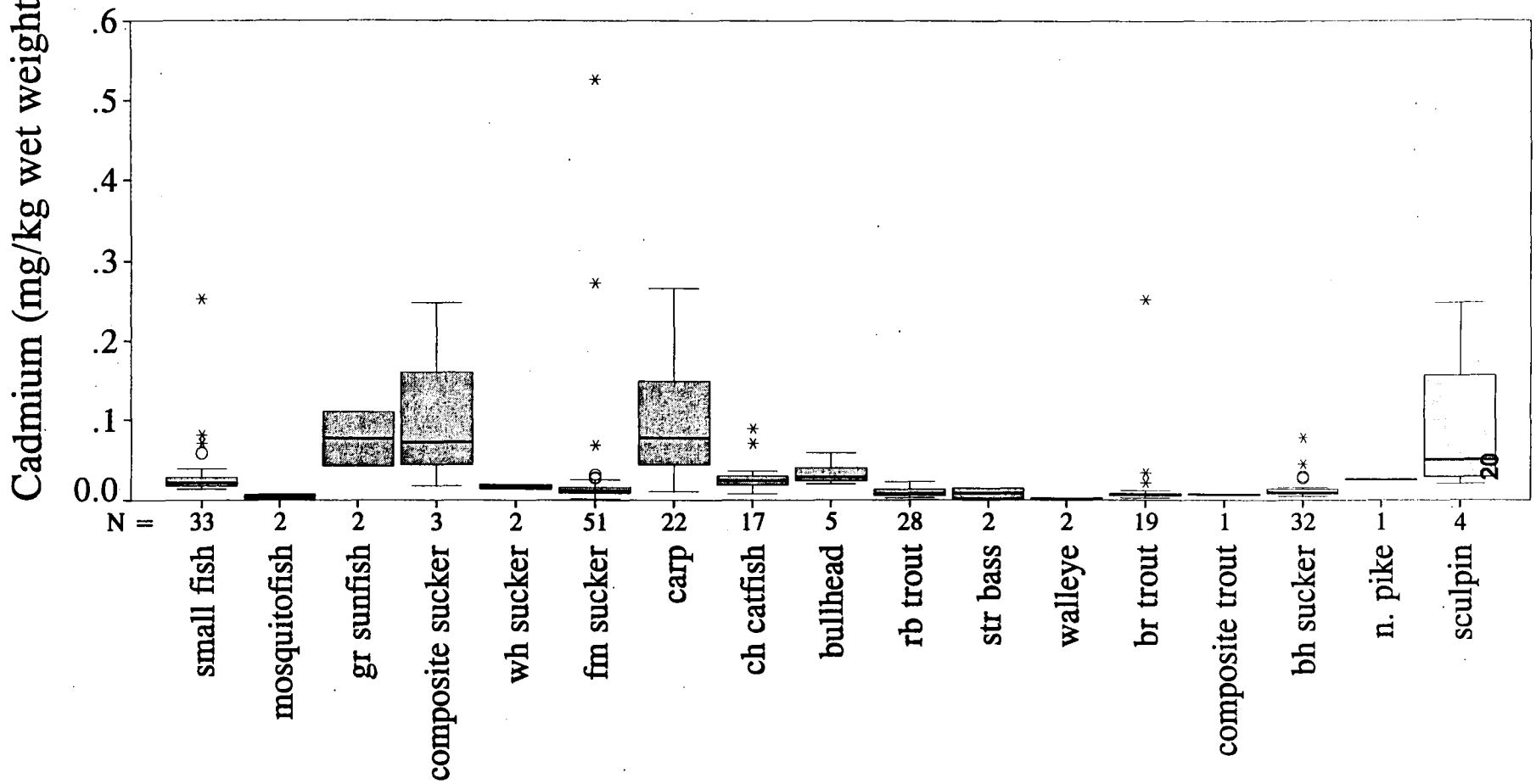
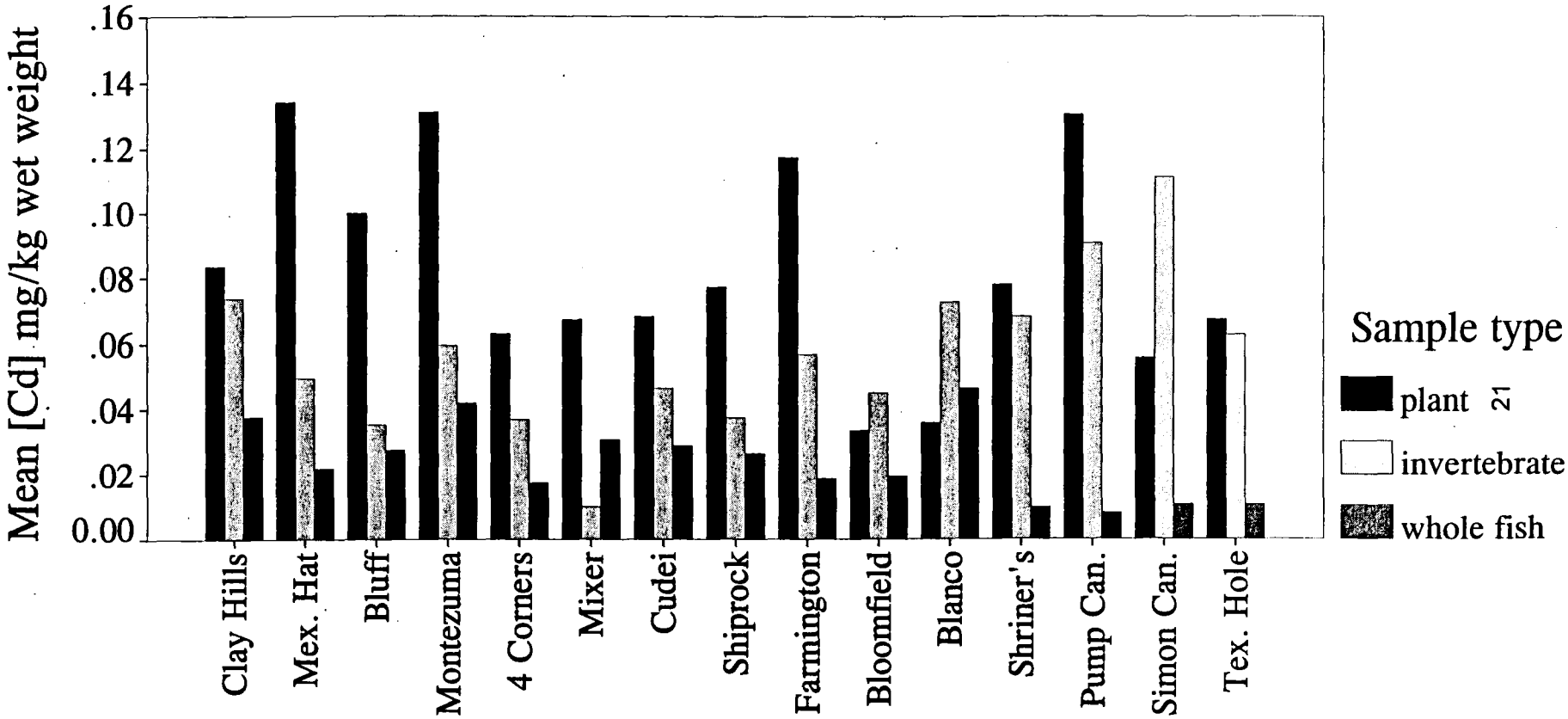


Figure 10. Cadmium concentrations in biota from the San Juan River mainstem 1988-1994.

[only sites with all three sample types are shown]



Copper

The average copper concentrations were highest in plants and invertebrates from the tributaries, particularly invertebrates from McElmo Creek. However, fish from isolated wetlands had the highest average copper concentrations (Table 5). Hamilton and Buhl (1995) found copper to be a principal component contributing to the toxicity of synthesized irrigation drainage water to fish. However, plant, and invertebrate copper concentrations were not significantly different at irrigation return sites compared to other habitat types (Figure 11). Perhaps as dietary copper is a nutrient, residue levels in biota are physiologically regulated.

Average copper concentrations were higher in fish collected from sites above River Mile 214, compared to other sites (Figure 12) and compared to the 85th percentile concentration of fish sampled nationwide. Copper concentrations varied immensely by species, which may account for an upstream trend as trout species were collected mostly upstream (above RM 214) and have higher average copper concentrations compared to other species (Figure 13). Average copper concentrations generally increase downstream in plants and invertebrates (Figure 14).

Table 5. The concentrations of copper (mg/kg dry weight) in plants, invertebrates, and whole body fish collected from the San Juan River Basin, 1988-94. [Note: Tributaries Combined is the average of all three tributaries, San Juan River Basin combined all data; SJR = San Juan River; N, number of samples; gM, geometric mean, 95% CI, the 95 percent confidence interval for the geometric mean; <, less than; and ---, data unavailable.]

SITE	Plants			Invertebrates			Whole Body Fish		
	N	gM	95% CI	N	gM	95% CI	N	gM	95% CI
SJR Mainstem	33	14.7	12.8 - 16.7	40	18.7	15.6 - 22.3	188	3.3	3.1 - 3.5
SJR Backwaters	11	9.7	7.4 - 15.6	9	20.7	14.0 - 30.5	23	4.2	3.4 - 5.3
SJR Irrigation Drains	10	9.3	5.4 - 15.8	7	24.1	12.3 - 47.5	10	4.5	3.6 - 5.6
SJR Reservoirs	---	---	---	---	---	---	41	3.2	2.6 - 4.0
SJR Wetlands	10	5.7	2.4 - 13.6	13	10.0	6.2 - 16.2	4	6.5	4.5 - 9.4
Tributaries Combined	1	18.6	---	5	43.4	13.8 - 136.2	15	3.7	3.0 - 4.6
Animas River	1	18.6	---	2	20.7	12.3 - 34.9	6	3.6	2.2 - 6.1
Mancos River	---	---	---	2	63.3	<0.1 - 3 x	2	3.8	0.5 - 30.5
McElmo Creek	---	---	---	1	89.4	---	7	3.7	2.6 - 5.4
San Juan River Basin	65	11.1	9.3 - 13.2	74	18.4	15.6 - 21.7	281	3.4	3.2 - 3.6

Figure 11. Copper in biota from different habitats of the San Juan River basin 1988-1994.

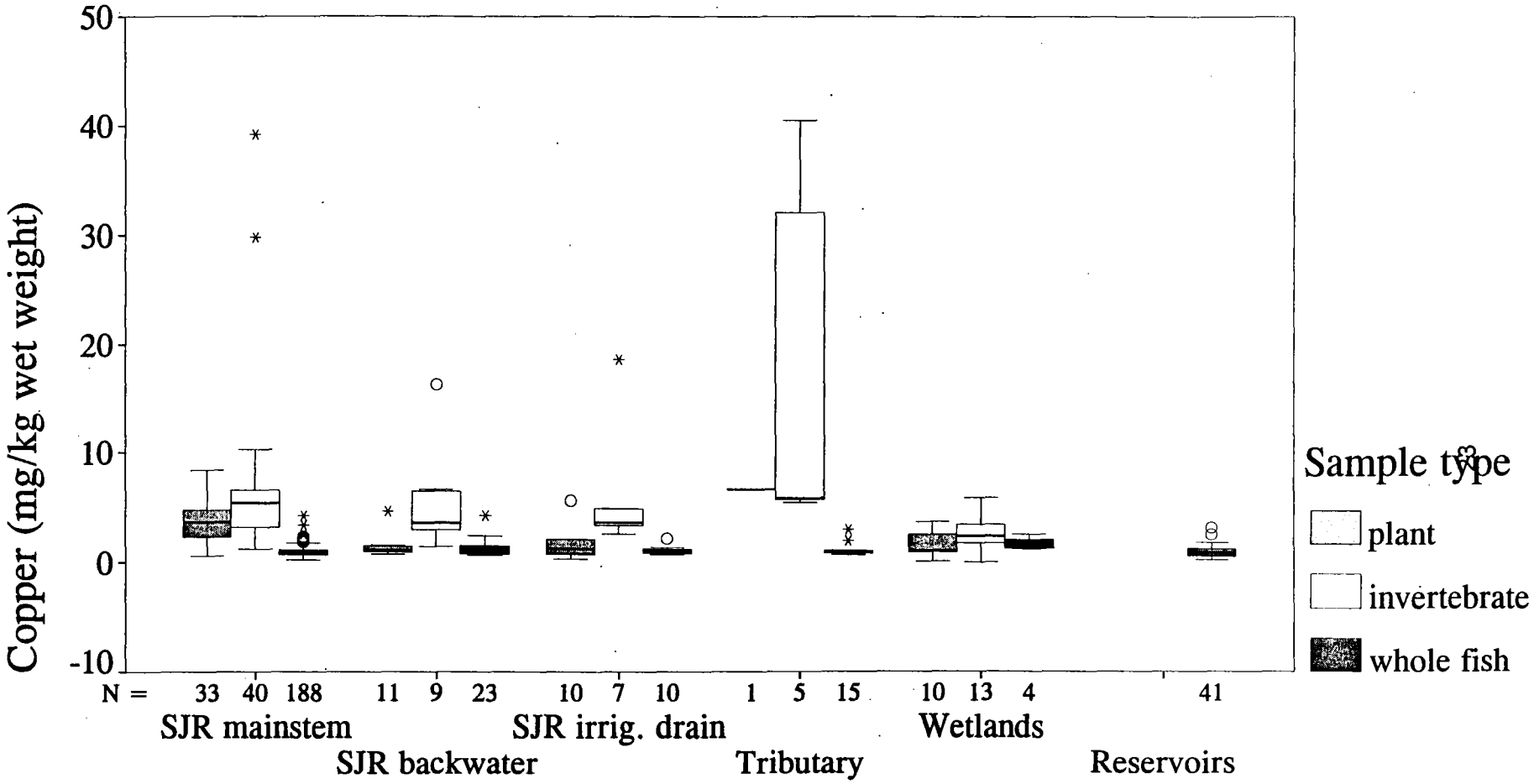


Figure 12. Copper in whole fish from the San Juan River mainstem 1988-1994.

[See Table 1 & Fig. 2 notes; line is NCBP 85th percentile (1.0 mg/kg)]

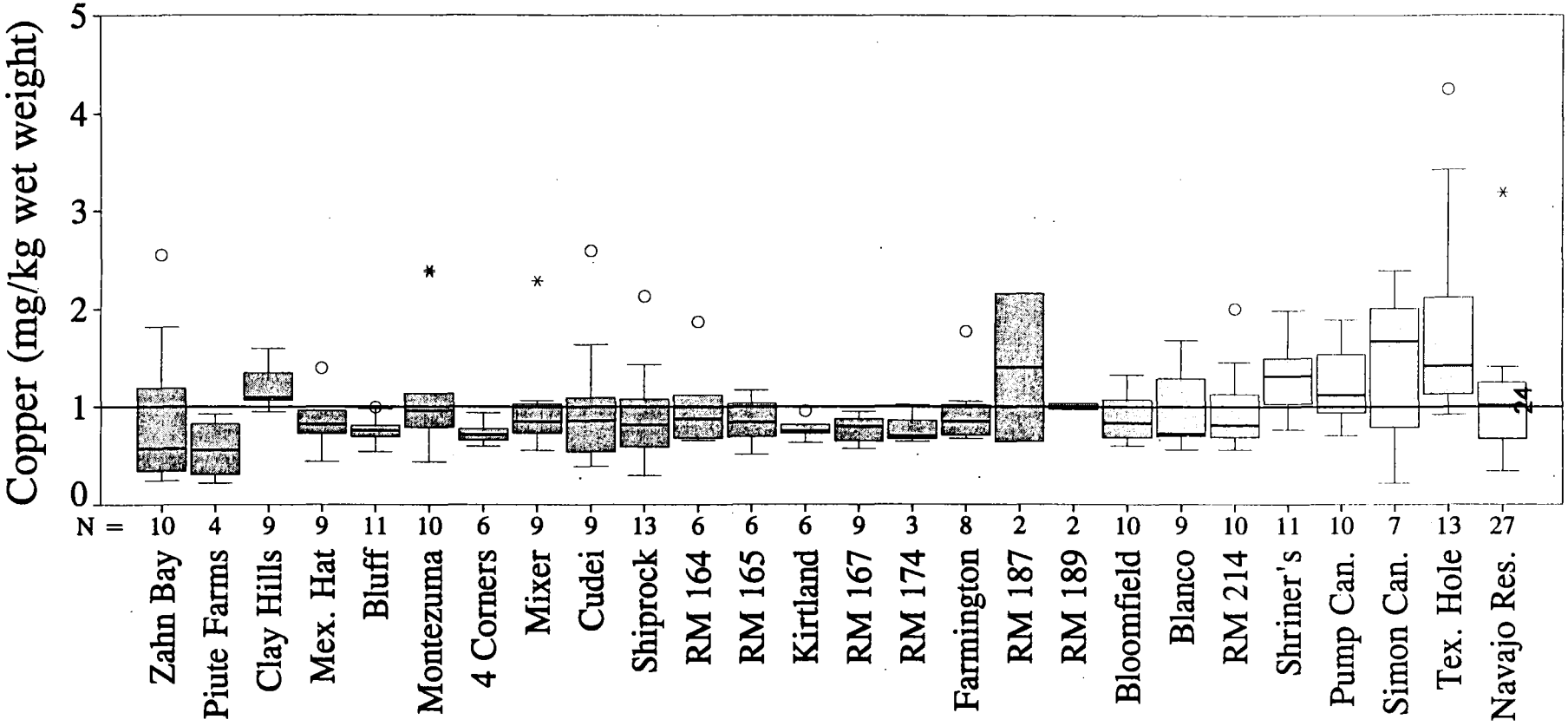


Figure 13. Copper in different species of whole fish from the San Juan River mainstem 1988-1994.

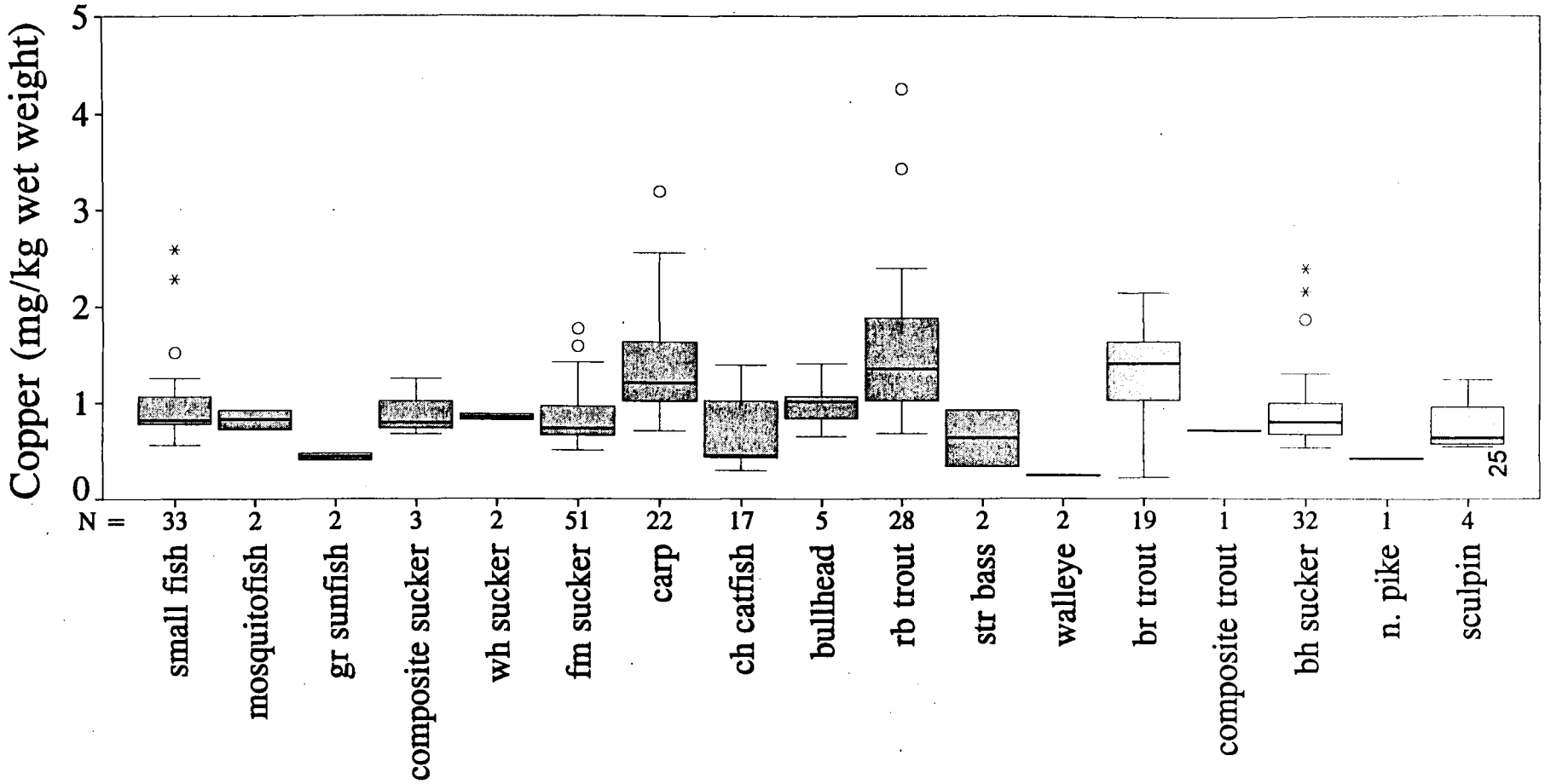
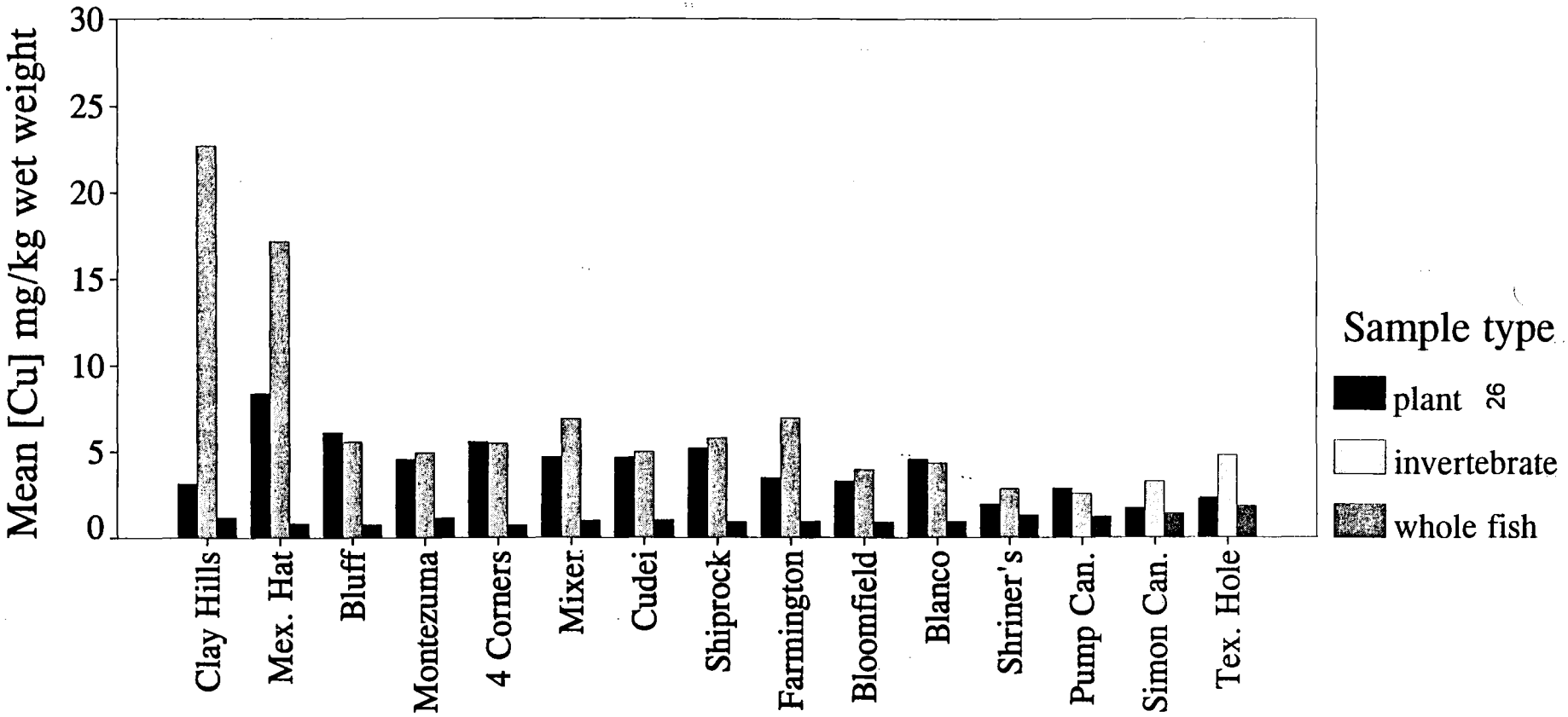


Figure 14. Copper concentrations in biota from the San Juan River mainstem 1988-1994.

[only sites with all three sample types are shown]



Lead

The highest average lead concentrations were in plants, invertebrates, and fish collected from the Animas River (Table 6). However, lead was elevated in plants and invertebrates from irrigation returns and in fish from reservoirs (Figure 16). Plants and invertebrates were not collected at reservoir sites. The 95% confidence interval for average lead concentrations in samples from the tributaries was large because not enough samples were collected there to refine the expected average concentrations with certainty (Table 6).

Fish from Navajo Reservoir had average lead concentrations greater than the 85th percentile concentration in fish nationwide (Figure 17). Most fish species had similarly low average lead concentrations (Figure 18). Average lead concentrations in fish are elevated in fish from Navajo Reservoir, but fall and are low until rising near municipalities and then falling again after Cudei, New Mexico (Close up of Figure 17). Biota reflect similar patterns (Figure 19).

Table 6. The concentrations of lead (mg/kg dry weight) in plants, invertebrates, and whole body fish collected from the San Juan River Basin, 1988-94. [Note: Tributaries Combined is the average of all three tributaries, San Juan River Basin combined all data; SJR = San Juan River; N, number of samples; gM, geometric mean, 95% CI, the 95 percent confidence interval for the geometric mean; <, less than; and ---, data unavailable.]

SITE	Plants			Invertebrates			Whole Body Fish		
	N	gM	95% CI	N	gM	95% CI	N	gM	95% CI
SJR Mainstem	33	2.4	1.0 - 5.9	40	0.9	0.6 - 1.3	188	0.3	0.3 - 0.4
SJR Backwaters	11	0.1	<.01 - 1.0	9	0.5	0.1 - 1.6	23	0.2	0.1 - 0.3
SJR Irrigation Drains	10	1.3	0.3 - 5.5	7	2.2	1.1 - 4.3	10	0.2	0.1 - 0.6
SJR Reservoirs	---	---	---	---	---	---	41	1.0	0.6 - 1.6
SJR Wetlands	10	0.1	<.01 - 0.2	13	0.1	<.01 - 0.2	4	0.04	<.01 - 1.9
Tributaries Combined	1	34.5	---	5	1.8	0.3 - 10.2	15	0.6	0.4 - 0.9
Animas River	1	34.5	---	2	6.4	1.1 - 39.2	6	1.3	0.9 - 1.7
Mancos River	---	---	---	2	1.3	<.01 - 3 x 10^6	2	0.5	<.01 - 3 x 10^6
McElmo Creek	---	---	---	1	0.3	---	7	0.4	0.2 -0.6
San Juan River Basin	65	0.8	0.4 - 1.6	74	0.6	0.4 - 0.9	281	0.4	0.3 - 0.4

Figure 15. Lead in biota from different habitats of the San Juan River basin 1988-1994.

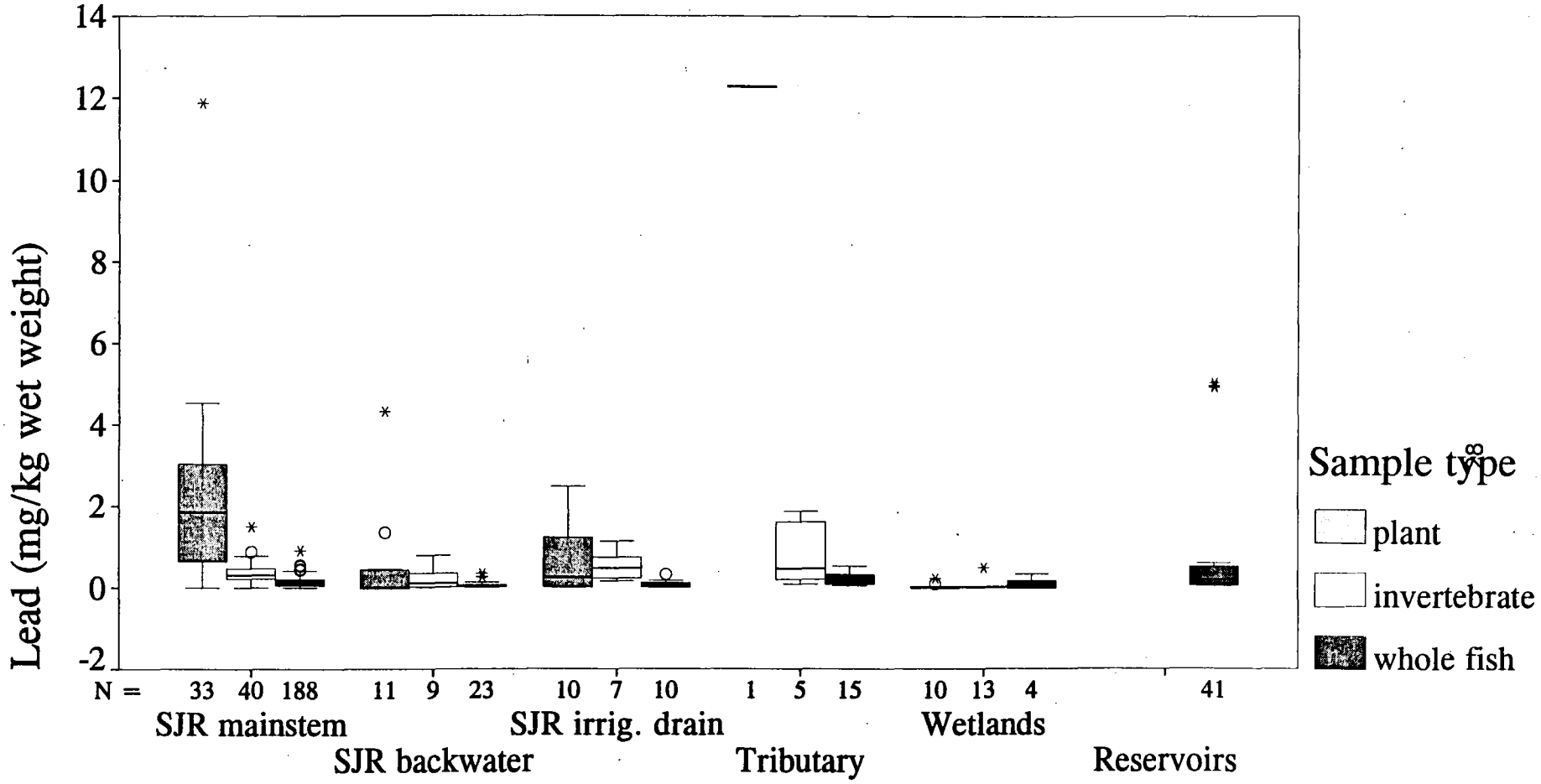


Figure 16. Lead in whole fish from the San Juan River mainstem 1988-1994

[See Table 1 & Fig. 2 note; line is NCBP 85th percentile (0.22 mg/kg)]

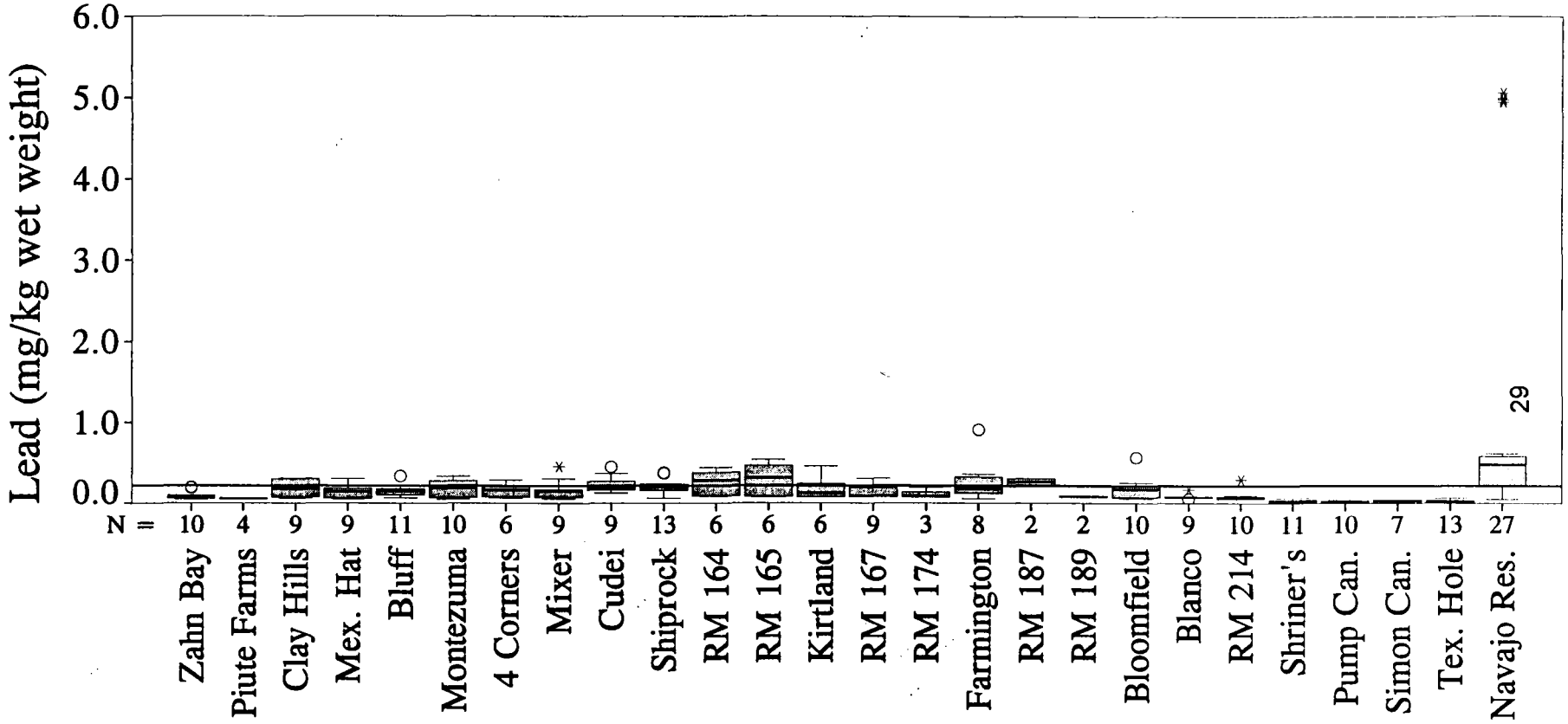


Figure 17. Lead in whole fish from the San Juan River mainstem 1988-1994 (y-axis scale changed)

[See Table 1 & Fig. 2 note; line is NCBP 85th percentile (0.22 mg/kg)]

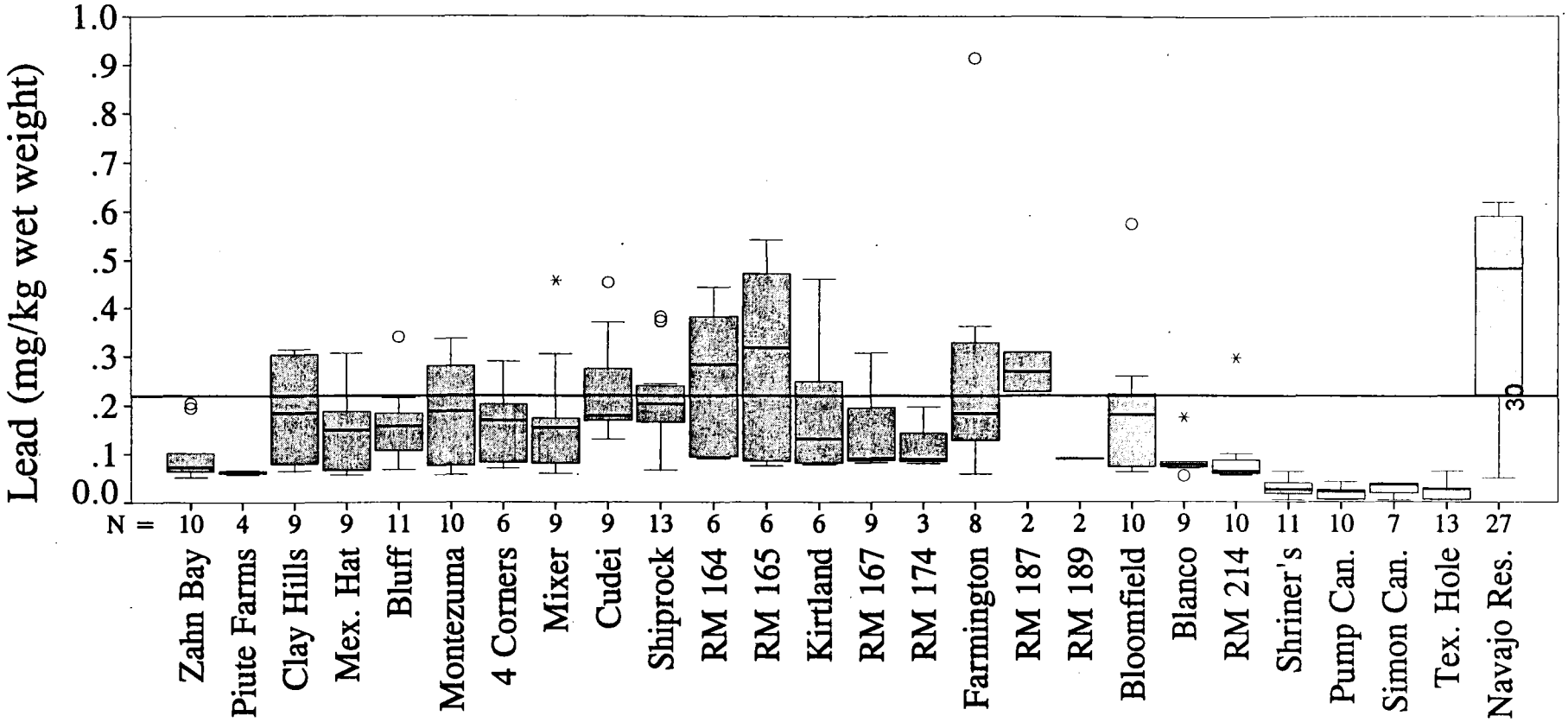


Figure 18. Lead in different species of whole fish from the San Juan River mainstem 1988-1994.

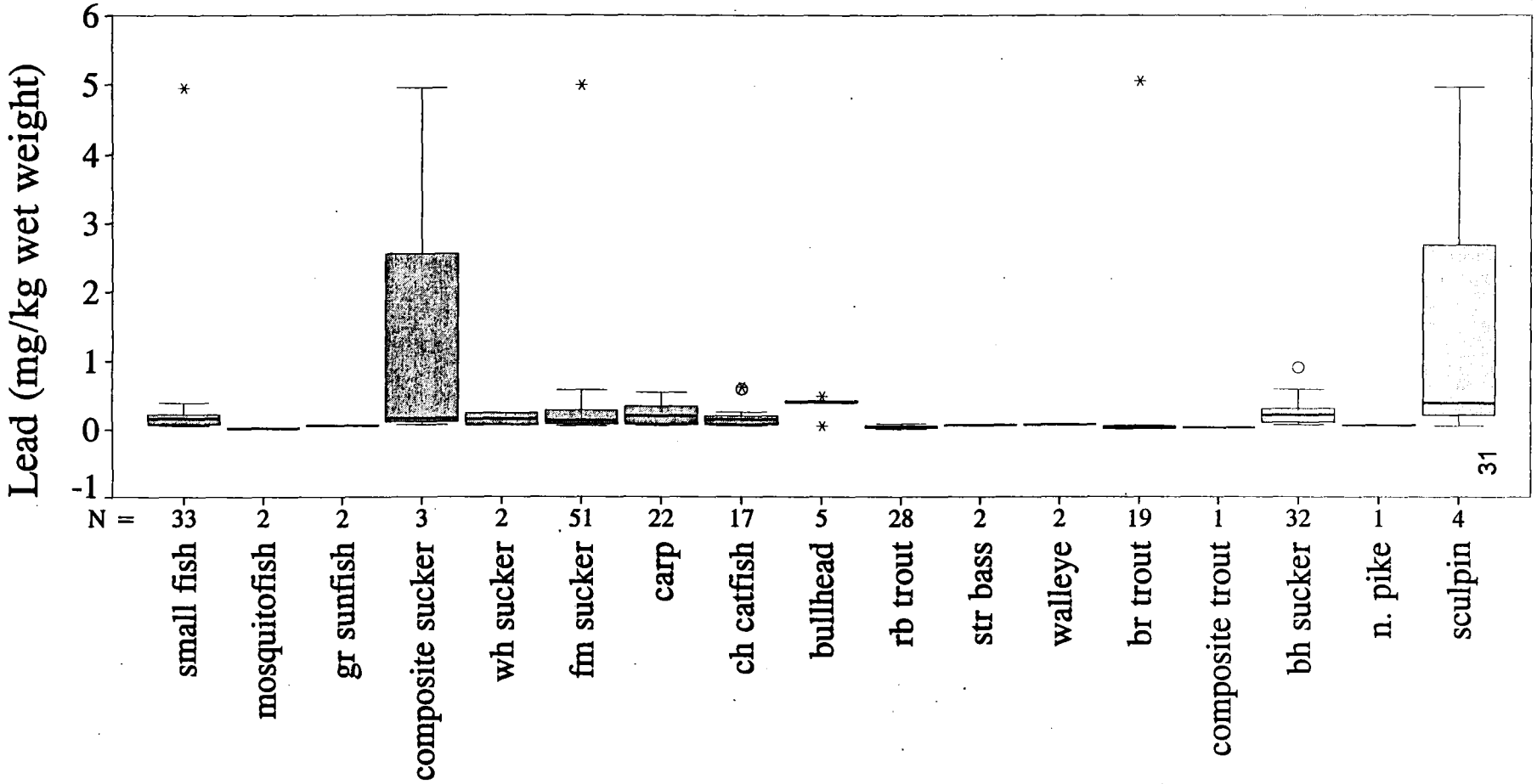
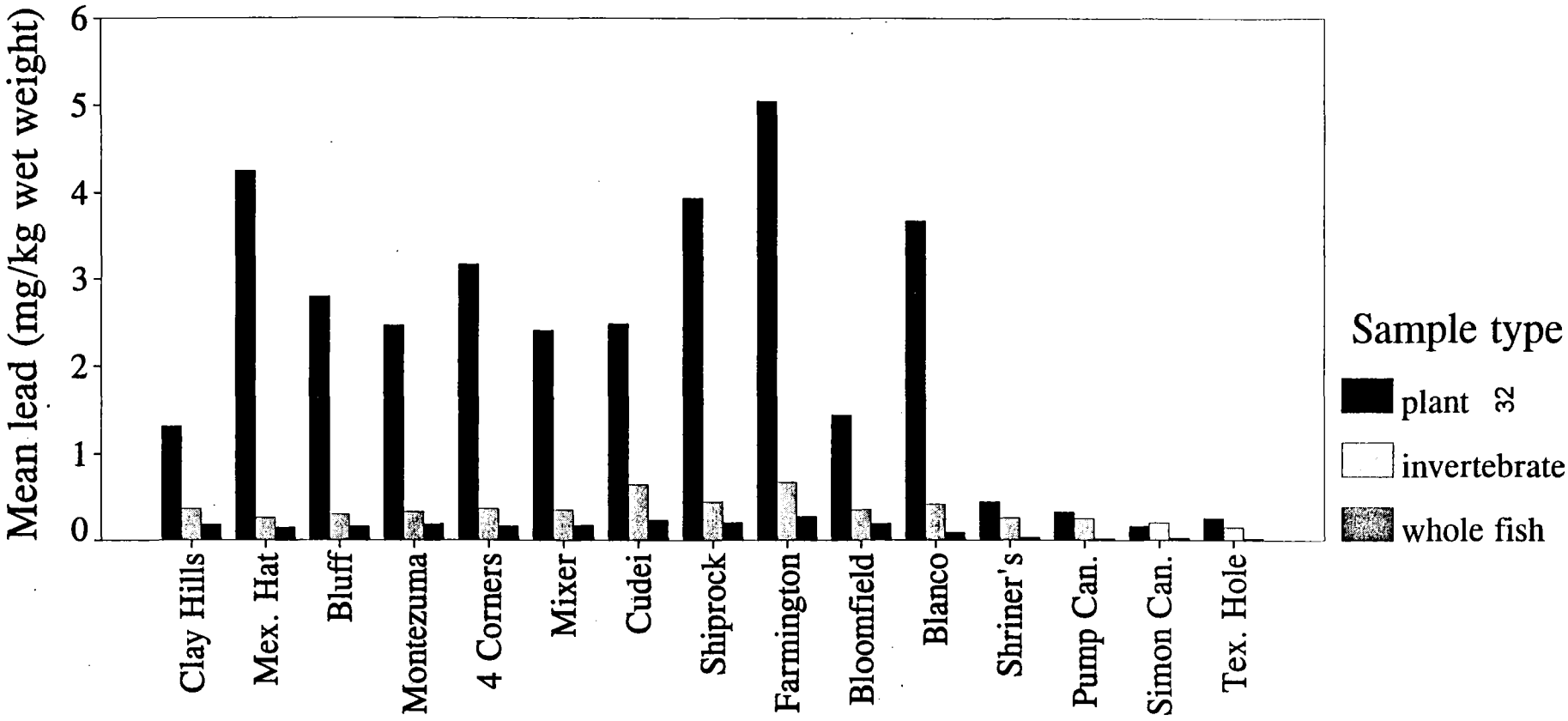


Figure 19. Lead concentrations in biota from the San Juan River mainstem 1988-1994.

[only sites with all three sample types are shown]



Mercury

Backwater habitats and reservoirs had the highest average mercury concentrations in plants, invertebrates and fish (Table 7 and Figure 20). Average mercury concentrations in fish did not exceed the 85th percentile of mercury in fish sampled nationwide (Figure 21). Average mercury concentrations in whole fish were elevated in the upper reaches of the river. Although there was variation in a fish's propensity to accumulate mercury (Figure 22), we did not attribute the elevated concentrations upstream to a trout bias in samples collected because mercury concentrations in trout were similar to those in carp and catfish. Among fish species, the highest mercury concentrations were in predatory striped bass and walleye from the reservoirs, and black bullhead.

We compared sites on the San Juan River for which we had all three ecological trophic levels sampled (plant, invertebrate, and fish) (Figure 23). The Texas Hole, a site renowned for its trophy trout, had consistently elevated concentrations of mercury in plants, invertebrates, and whole fish. Some fish collected from the upper reach of the San Juan River (Figure 23) and at reservoir sites had average mercury concentrations that exceed the predator protection limit suggested by Eisler (1987a) to protect piscivorous wildlife from mercury toxicity.

Table 7. The concentrations of mercury (mg/kg dry weight) in plants, invertebrates, and whole body fish collected from the San Juan River Basin, 1988-94. [Note: Tributaries Combined is the average of all three tributaries, San Juan River Basin combined all data; SJR = San Juan River; N, number of samples; gM, geometric mean, 95% CI, the 95 percent confidence interval for the geometric mean; <, less than; and ---, data unavailable.]

SITE	Plants			Invertebrates			Whole Body Fish		
	N	gM	95% CI	N	gM	95% CI	N	gM	95% CI
SJR Mainstem	33	0.08	0.05 - 0.11	40	0.08	0.06 - 0.11	188	0.21	0.19 - 0.24
SJR Backwaters	11	0.20	0.07 - 0.58	9	0.17	0.07 - 0.38	23	0.32	0.22 - 0.44
SJR Irrigation Drains	10	0.02	0.01 - 0.03	7	0.05	0.02 - 0.09	10	0.08	0.05 - 0.12
SJR Reservoirs	---	---	---	---	---	---	41	0.45	0.32 - 0.55
SJR Wetlands	10	0.11	0.02 - 0.48	13	0.12	0.05 - 0.32	4	0.13	0.01 - 1.82
Tributaries Combined	1	0.04	---	5	0.06	0.04 -0.11	15	0.15	0.12 - 0.20
Animas River	1	0.04	---	2	0.05	<0.01 - 0.75	6	0.13	0.09 - 0.18
Mancos River	---	---	---	2	0.06	<0.01 - 0.81	2	0.12	0.01 - 1.25
McElmo Creek	---	---	---	1	0.12	---	7	0.19	0.12 - 0.32
San Juan River Basin	65	0.07	0.05 - 0.11	74	0.09	0.07 - 0.12	281	0.23	0.21 - 0.25

Figure 20. Mercury in biota from different habitats of the San Juan River basin 1988-1994.

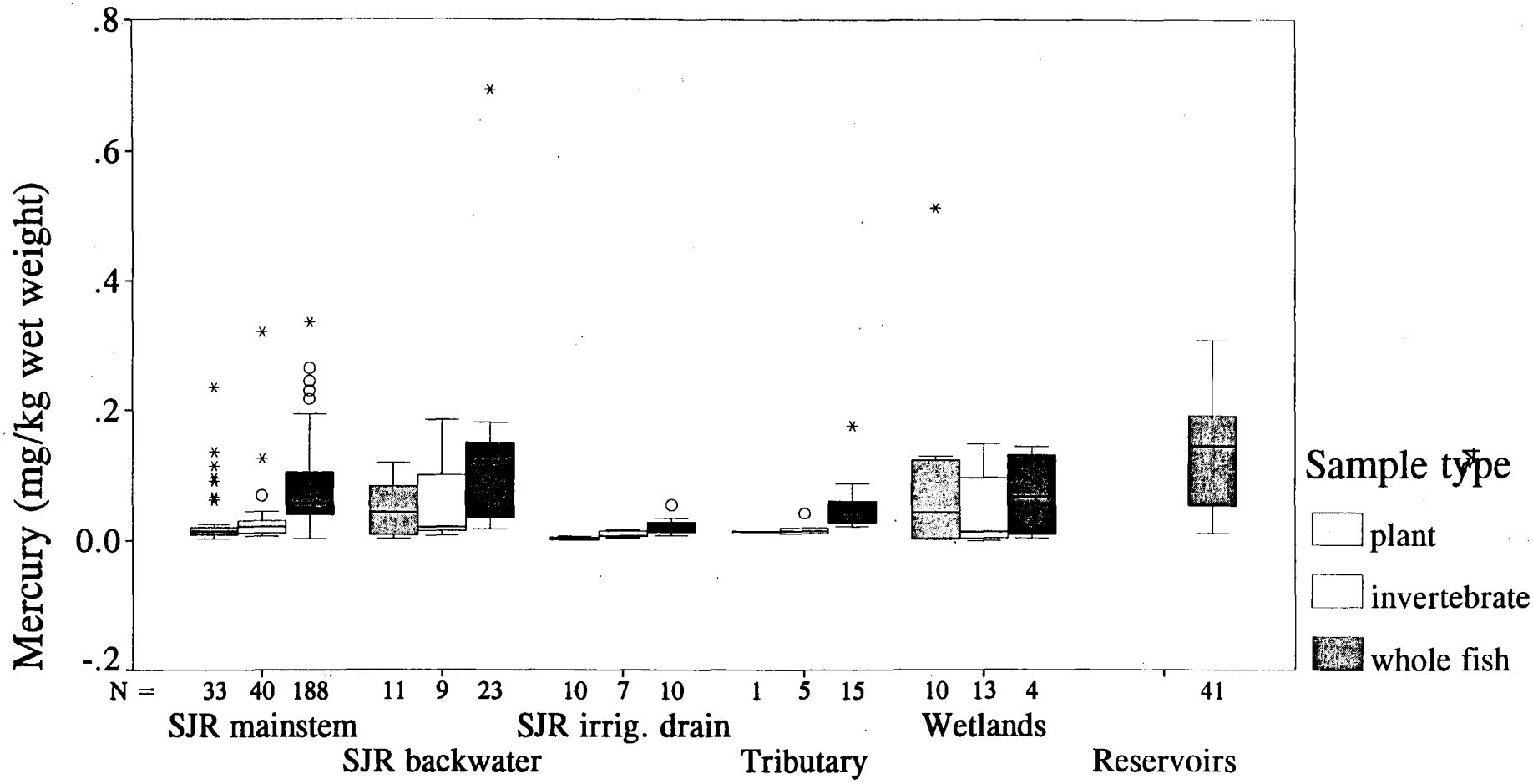


Figure 21. Mercury in whole fish from the San Juan River mainstem 1988-1994.

[See Table 1 & Fig. 2 notes; line is NCBP 85th percentile (0.17 mg/kg)]

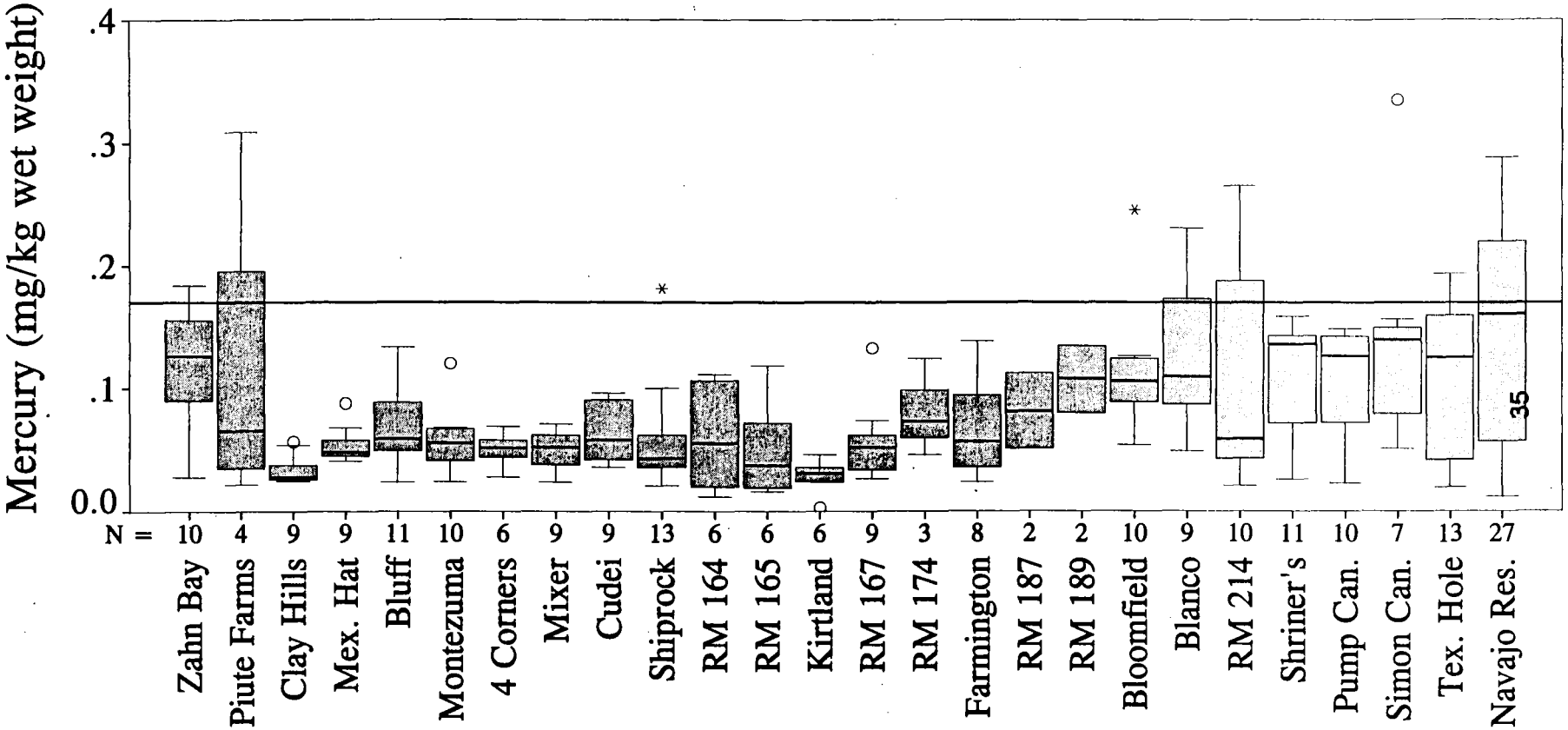


Figure 22. Mercury in different species of whole fish from the San Juan River mainstem 1988-1994

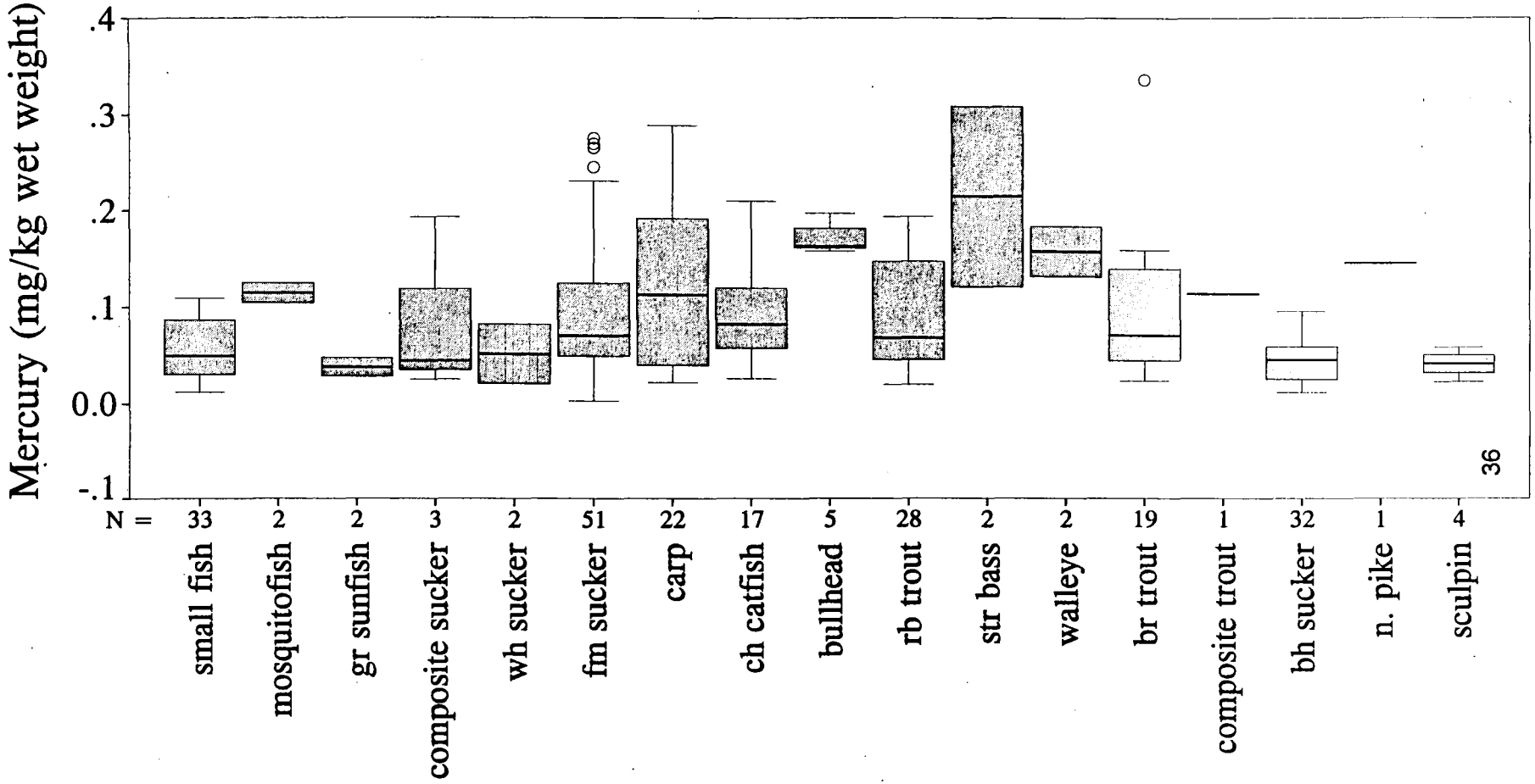
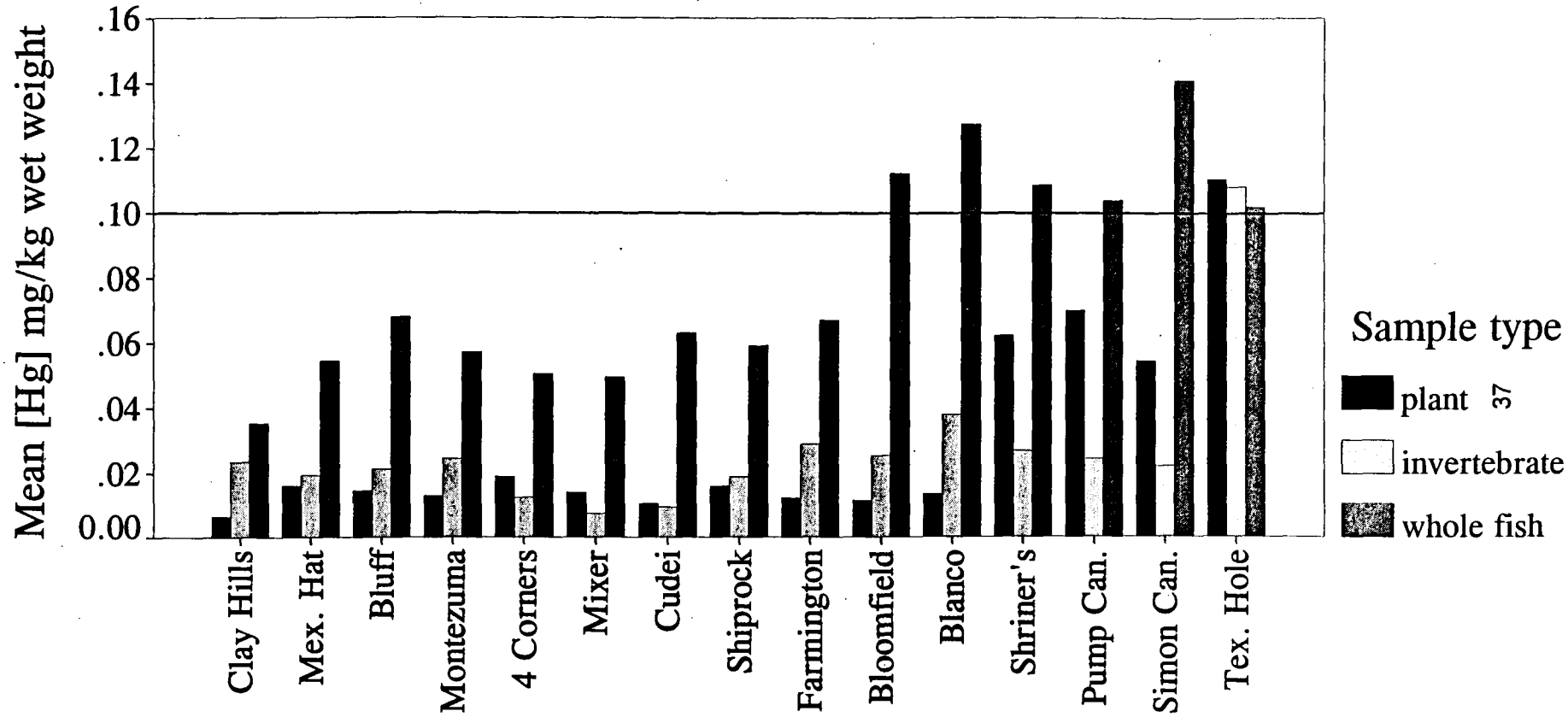


Figure 23. Mercury concentrations in biota from the San Juan River mainstem 1988-1994.

[sites selected with 3 sample types; line is predator protection limit]



Selenium

The highest average selenium concentrations in plants were in those collected from the San Juan River mainstem and backwater habitats (Table 8 and Figure 24). Invertebrates from the Mancos River had the highest average selenium concentration. Only two invertebrate samples were collected there. The highest average selenium concentrations in fish were those in fish collected from irrigation drainage habitats (Table 8 and Figure 24).

When we compared selenium in fish only from the San Juan River mainstem, the highest average concentrations were in fish from sites in the upper reach (Figure 25). The average selenium concentrations in fish collected at sites below Shiprock, New Mexico were also higher than the 85th percentile of selenium in fish sampled nationwide. The range of average selenium concentrations in different fish species (Figure 26) was below the whole fish concentration associated with reproductive effects (i.e., 2 mg/kg wet weight; Baumann and May 1984).

We compared sites on the San Juan River for which we had all three ecological trophic levels sampled (Figure 26). The highest average selenium concentrations in invertebrates and fish were found at the Blanco, New Mexico, and Bloomfield, New Mexico sites. Most invertebrate and fish samples had average selenium concentrations that exceeded the dietary level of concern (0.75 mg/kg wet weight; converted from dry weight using moisture content = 75%) that Lemly (1993) suggested would pose a risk to higher trophic level predators (Figure 27). However, only those fish and invertebrates collected from the Blanco and Bloomfield sites had average selenium concentrations that were above the dietary toxicity threshold (1.5 mg/kg wet weight, converted using 75% moisture) that the Interagency Technical Team of the National Irrigation Water Quality Program (Gober 1993) suggested is associated with adverse reproductive effects to the wildlife that consistently consumes these organisms.

One of our initial goals was to determine the variation of selenium by season. However, sampling efforts were not equal for all samples at all sites or sampling periods. The majority (80%) of these data were collected in spring and summer, 20% were collected in the fall, and only two samples (0.4%) were collected in the winter. Furthermore, samples collected during the spring season were analyzed separately from samples collected in the fall, summer, and winter seasons. Seasonal trends then, may be obscured by the variation between laboratory batches. Quality assurance samples had adequate recovery, but varied within the allowable range of acceptability (average relative percent difference $\leq$ 11.5 %). The lowest average percent recovery of selenium was from the spring batch. This batch effect may confound the variation of selenium in whole fish by season (Figure 28). Given that one sample batch contributes the majority (96%) of fish collected during the spring season, a batch effect may confound the lower average of selenium concentrations compared to selenium concentrations in fish collected during the other seasons. Without the spring data, no differences were found between the fall and summer seasons.

Figure 24. Selenium in biota from different habitats of the San Juan River basin 1988-1994.

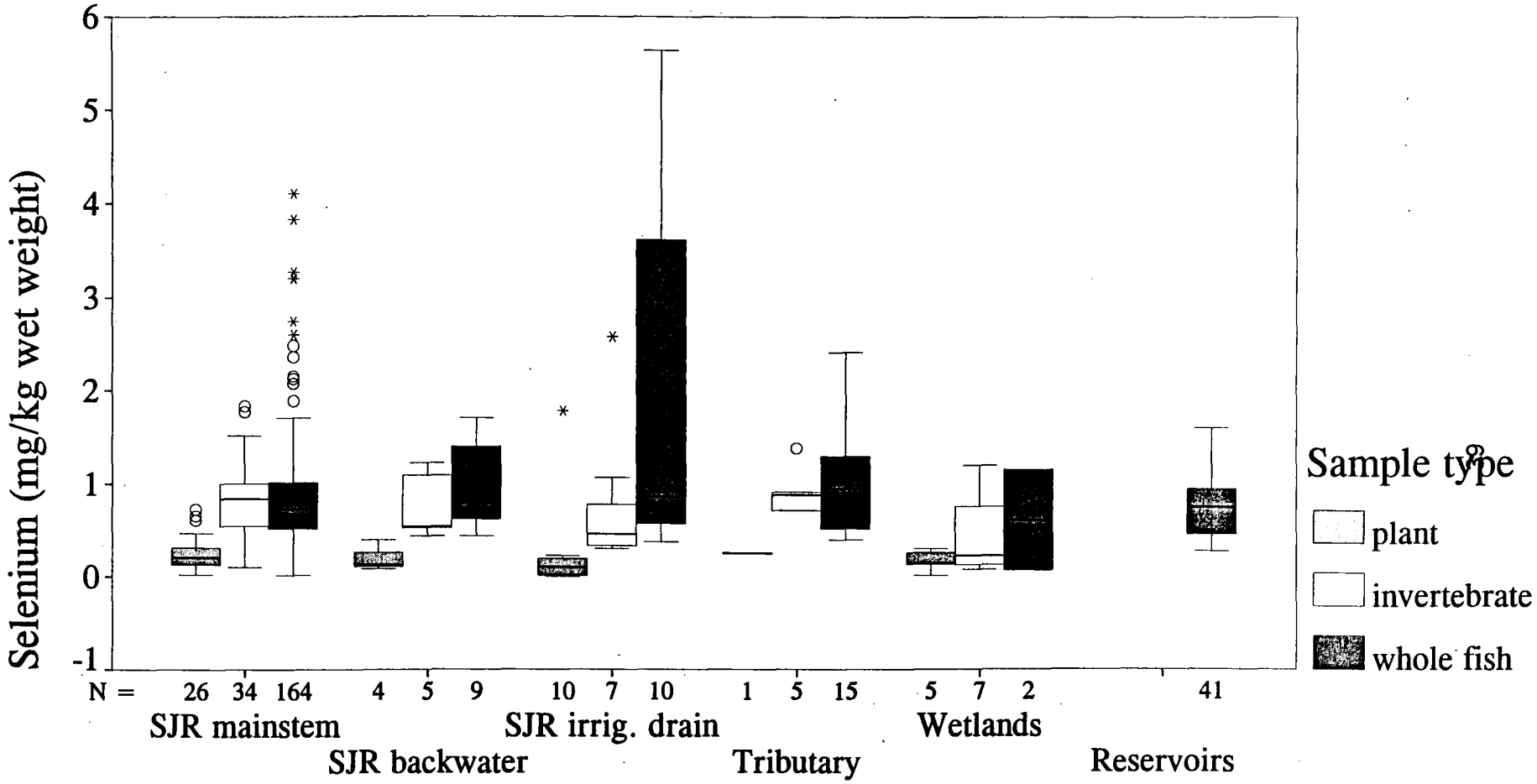


Figure 25. Selenium in whole fish from the San Juan River mainstem 1988-1994.

[See Table 1 & Fig. 2 notes; line is NCBP 85th percentile (0.73 mg/kg)]

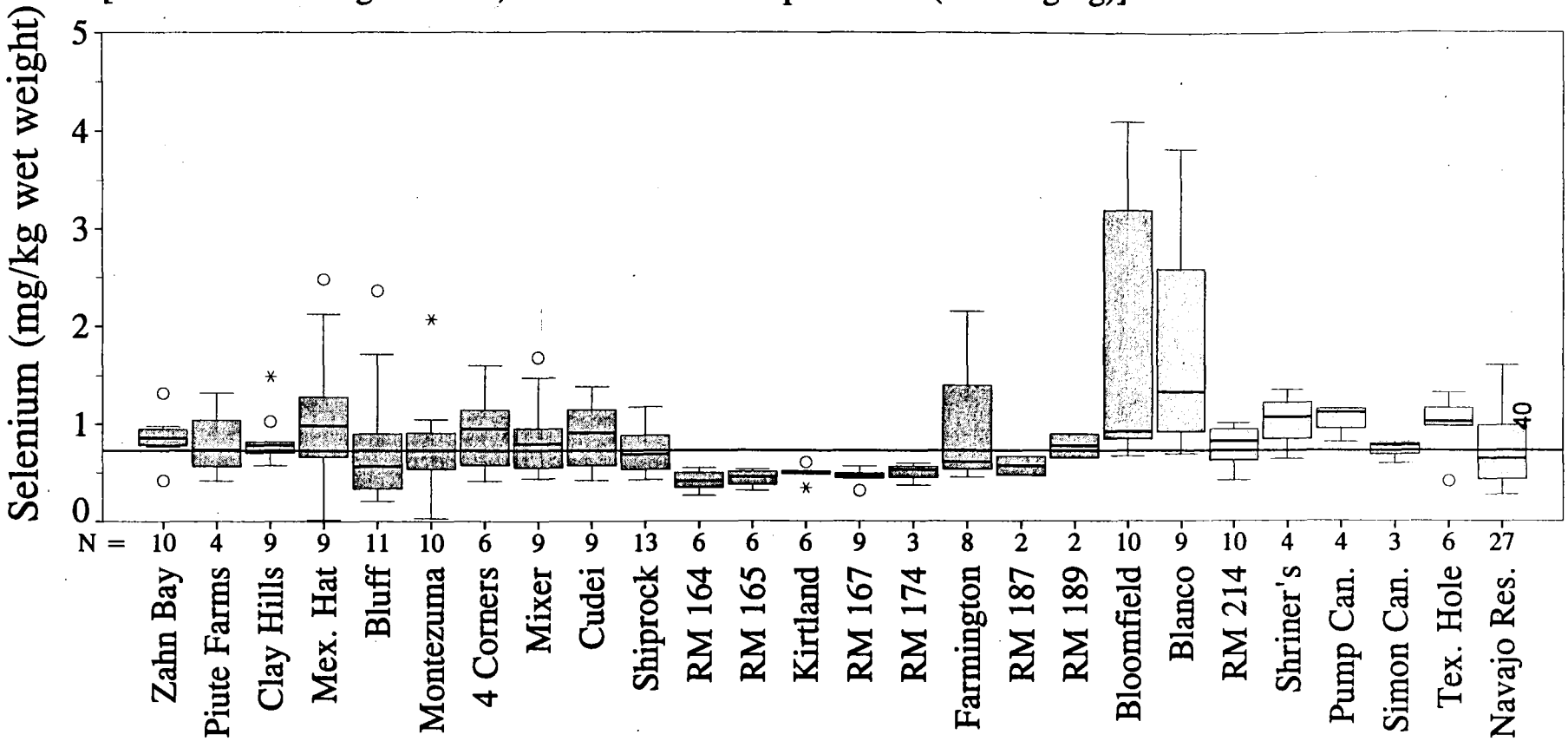


Figure 26. Selenium in different species of whole fish from the San Juan River mainstem 1988-1994.

[line is whole fish residue (2.0 mg/kg) reproductive toxicity threshold]

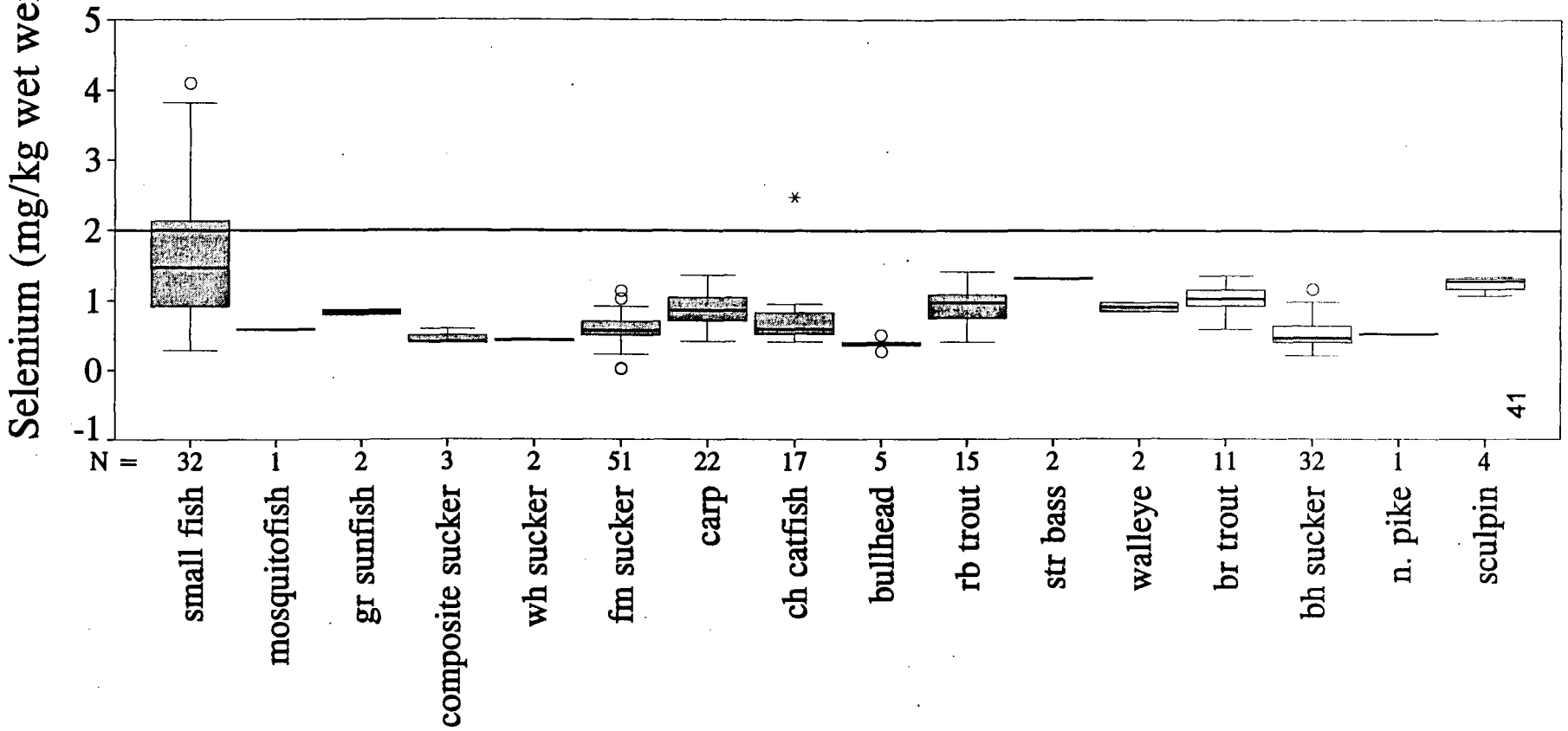
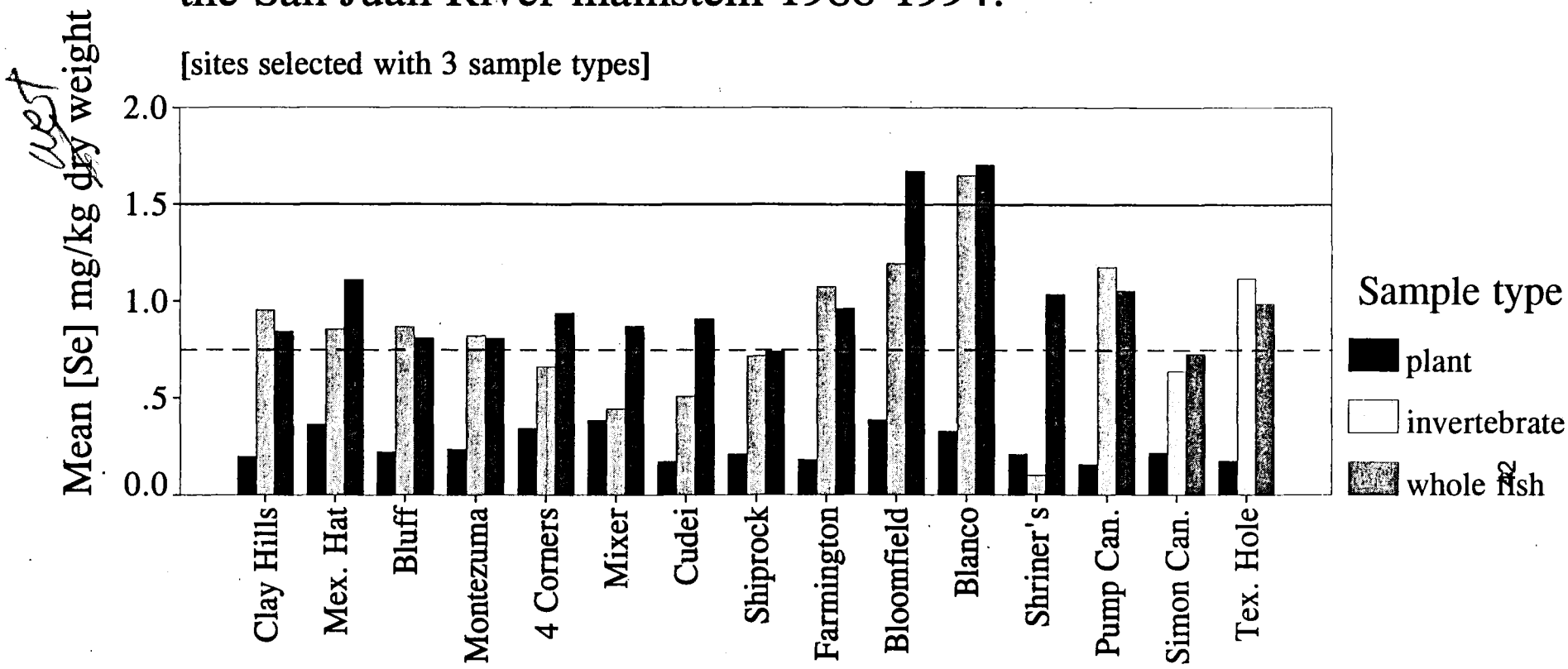


Figure 27. Selenium concentrations in biota from the San Juan River mainstem 1988-1994.

[sites selected with 3 sample types]



Solid line @ 1.5 dietary toxicity threshold

Dashed line @ 0.75 dietary concern threshold

Figure 28. Selenium concentrations in whole fish collected during different seasons from the San Juan River basin 1988-1994.

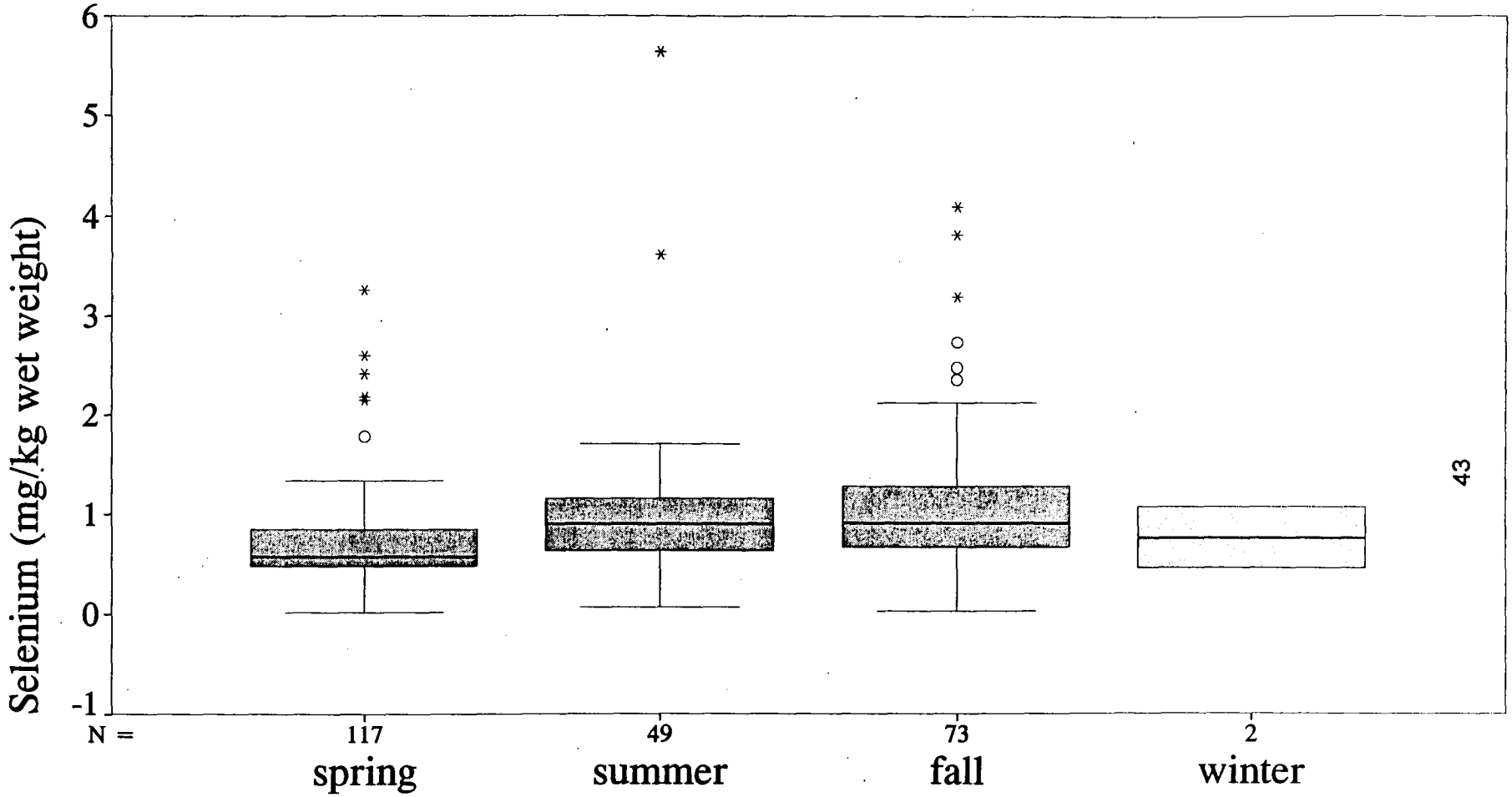


Table 8. The concentrations of selenium (mg/kg dry weight) in plants, invertebrates, and whole body fish collected from the San Juan River Basin, 1988-94. [Note: Tributaries Combined is the average of all three tributaries, San Juan River Basin combined all data; SJR = San Juan River; N, number of samples; gM, geometric mean, 95% CI, the 95 percent confidence interval for the geometric mean; <, less than; and ---, data unavailable.]

SITE	Plants			Invertebrates			Whole Body Fish		
	N	gM	95% CI	N	gM	95% CI	N	gM	95% CI
SJR Mainstem	33	0.86	0.60 - 1.24	40	2.97	2.31 - 3.82	188	2.73	2.47 - 3.01
SJR Backwaters	11	0.84	0.47 - 1.53	9	3.13	2.15 - 4.56	23	3.38	2.85 - 4.01
SJR Irrigation Drains	10	0.53	0.16 - 1.80	7	2.95	1.22 - 7.13	10	5.23	2.56 - 10.69
SJR Reservoirs	---	---	---	---	---	---	41	2.82	2.44 - 3.26
SJR Wetlands	10	0.53	0.22 - 1.27	13	0.92	0.46 - 1.86	4	0.90	0.13 - 6.33
Tributaries Combined	1	0.70	---	5	3.27	2.04 - 5.25	15	3.25	2.40 - 4.39
Animas River	1	0.70	---	2	2.96	0.35 - 25.2	6	3.06	1.41 - 6.62
Mancos River	---	---	---	2	4.93	1.27 - 16.8	2	3.63	<0.01 - 1,208
McElmo Creek	---	---	---	1	2.00	---	7	3.30	2.26 - 4.84
San Juan River Basin	65	0.74	0.55 - 0.98	74	2.45	1.97 - 3.04	281	2.83	2.62 - 3.07

Zinc

The highest average zinc concentrations in plants, invertebrates, and fish were from irrigation drainage habitats and from tributaries (Table 9 and Figure 29). Average zinc concentrations in fish from the San Juan River mainstem did not exceed the 85th percentile concentration in fish sampled nationwide (Figure 30). However, the ranges of zinc concentrations in fish seem to increase downstream of Shiprock, New Mexico. Carp had the highest average zinc concentrations of fish species sampled in the San Juan River mainstem (Figure 31). Zinc concentrations in invertebrates from the lower reaches of the San Juan River are elevated (Figure 32). Eisler (1993) said that zinc concentrations above 44.5 mg/kg wet weight (converted using 75% moisture) are associated with sublethal effects, such as reduced growth. This area is reported to be a potential spawning area for endangered fish species. The significance of elevated zinc in potential dietary foods for resident larval and adult fish should be considered in future research.

Table 9. The concentrations of zinc (mg/kg dry weight) in plants, invertebrates, and whole body fish collected from the San Juan River Basin, 1988-94. [Note: Tributaries Combined is the average of all three tributaries, San Juan River Basin combined all data; SJR = San Juan River; N, number of samples; gM, geometric mean, 95% CI, the 95 percent confidence interval for the geometric mean; <, less than; and ---, data unavailable.]

SITE	Plants			Invertebrates			Whole Body Fish		
	N	gM	95% CI	N	gM	95% CI	N	gM	95% CI
SJR Mainstem	33	38.4	24.6 - 59.9	40	65.9	43.6 - 99.4	188	35.2	26.3 - 47.0
SJR Backwaters	11	8.6	2.4 - 30.8	9	14.3	2.91 - 70.2	23	3.2	0.8 - 12.3
SJR Irrigation Drains	10	41.3	17.0 - 100.3	7	84.2	45.4 - 156.3	10	130.9	105.3 - 162.7
SJR Reservoirs	---	---	---	---	---	---	41	101.8	81.3 - 127.4
SJR Wetlands	10	1.7	0.4 - 8.1	13	4.23	0.9 - 20.7	4	4.0	<0.1 - 1636
Tributaries Combined	1	200	---	5	111.6	54.3 - 229.5	15	112.1	89.1 - 141.2
Animas River	1	200	---	2	200.6	14.4 - 2802	6	107.5	57.4 - 201.3
Mancos River	---	---	---	2	76.3	3.6 - 1620	2	129.7	2.2 - 7757
McElmo Creek	---	---	---	1	74.0	---	7	111.6	88.7 - 140.3
San Juan River Basin	65	19.1	11.9 - 30.8	74	35.8	22.8 - 56.3	281	36.4	28.3 - 46.8

Figure 29. Zinc in biota from different habitats of the San Juan River basin 1988-1994.

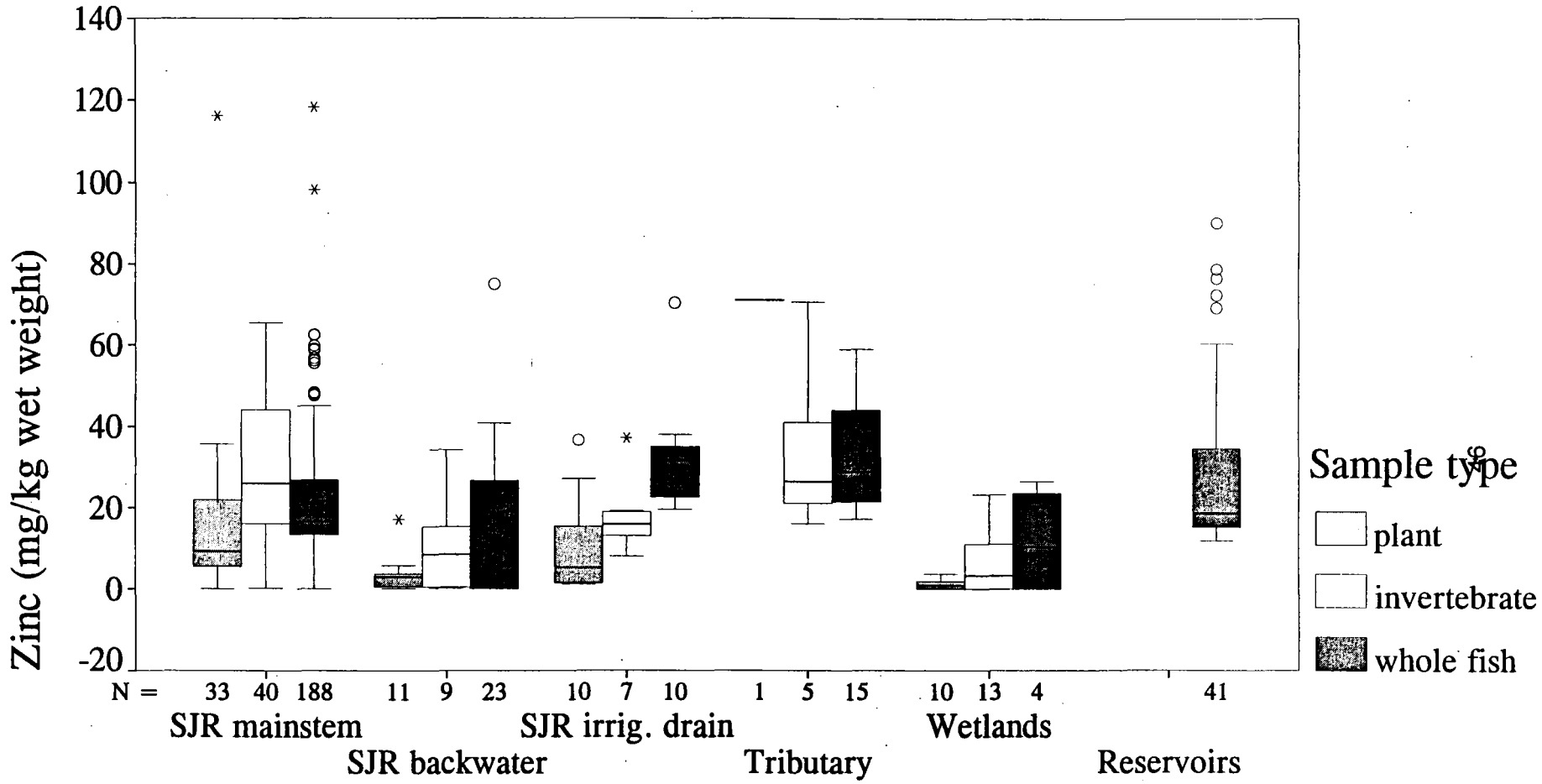


Figure 30. Zinc in whole fish from the San Juan River mainstem 1988-1994.

[See Table 1 & Fig. 2 notes; line is NCBP 85th percentile (34.2 mg/kg)]

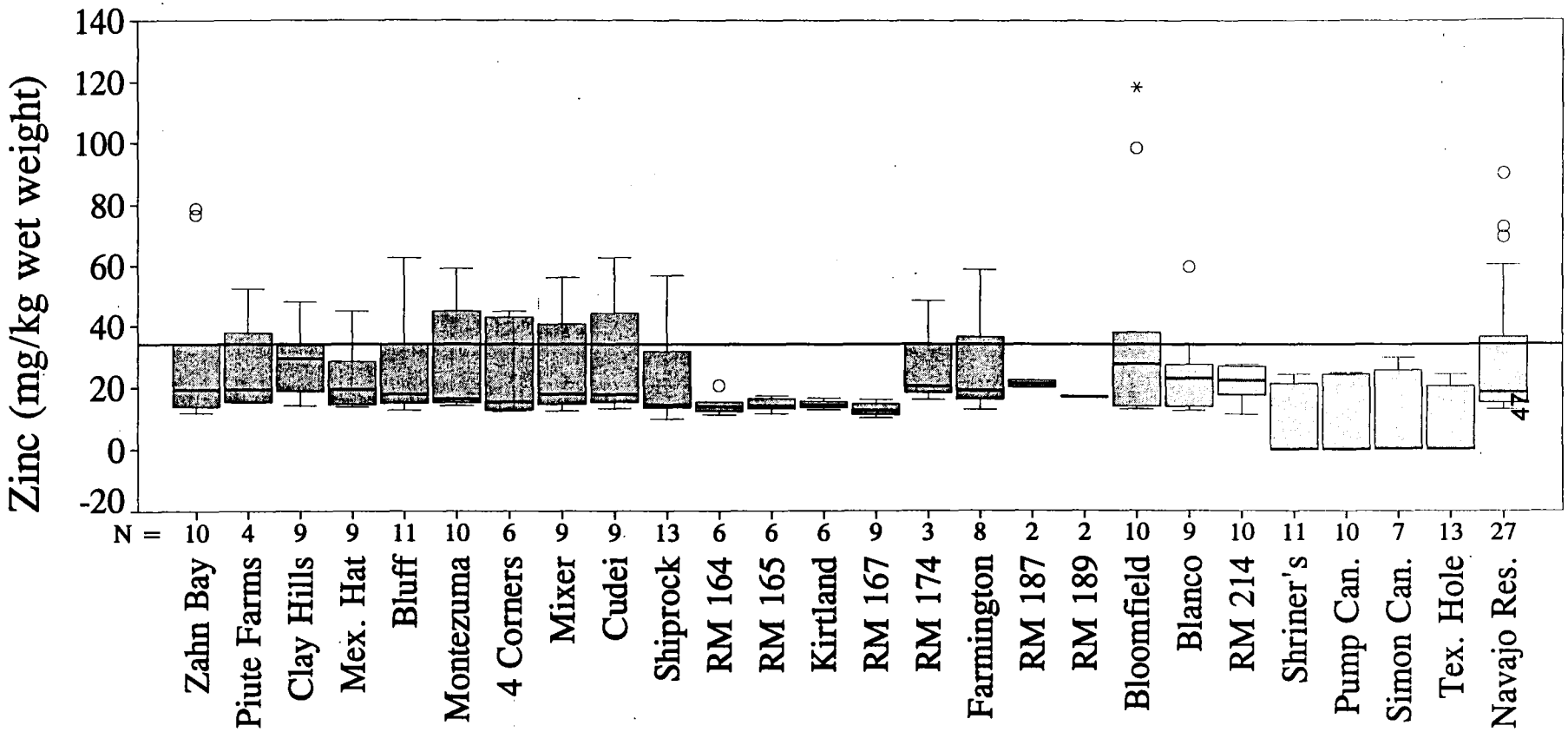


Figure 31. Zinc in different species of whole fish from the San Juan River mainstem 1998-1994.

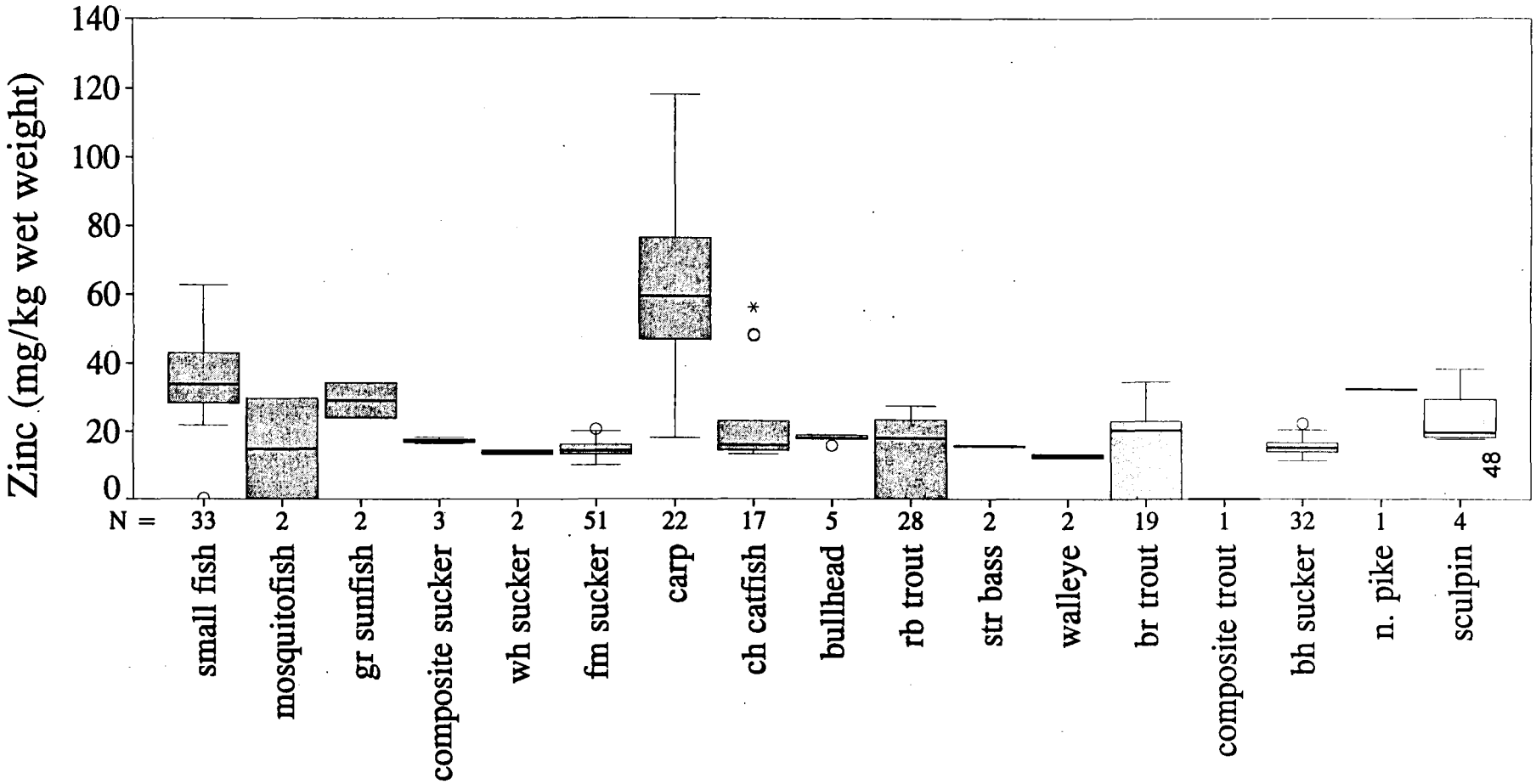
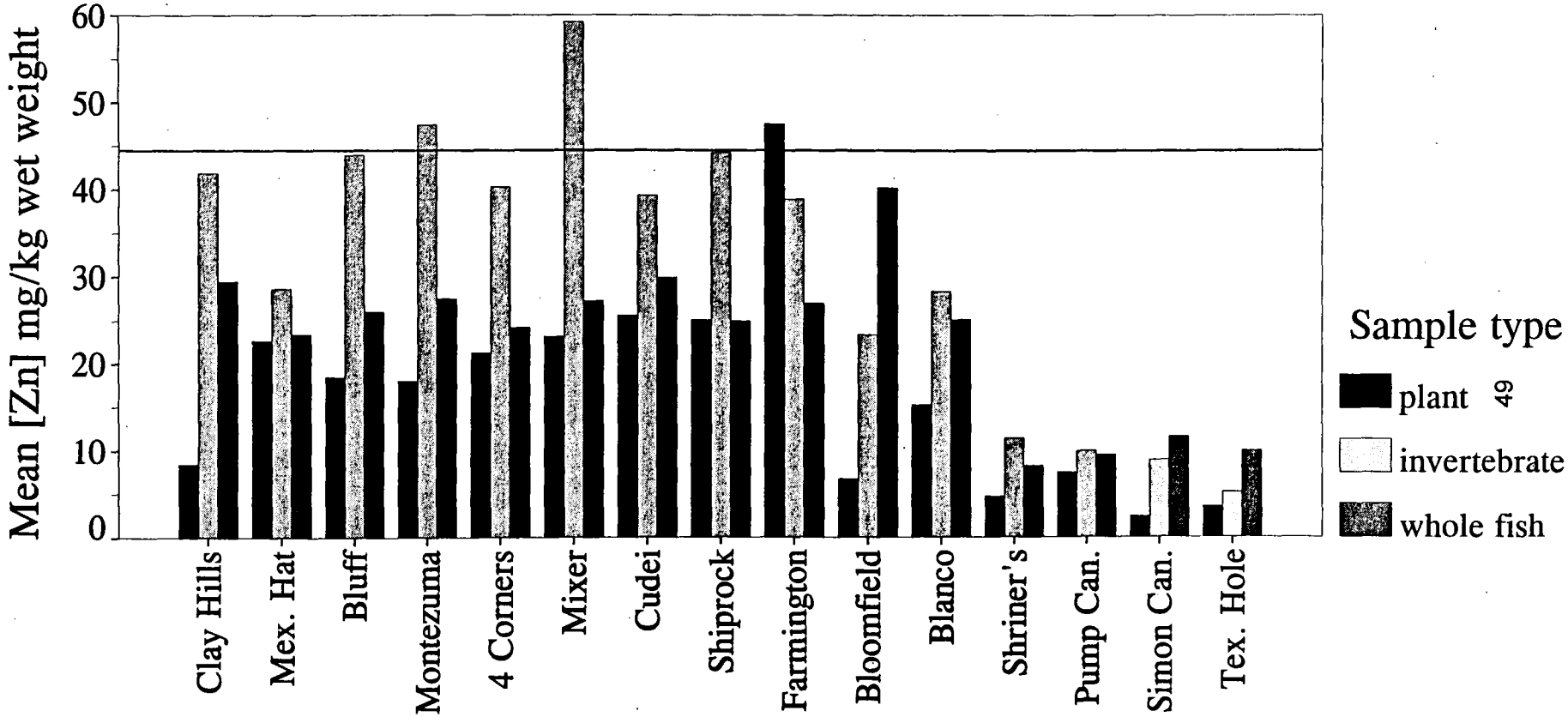


Figure 32. Zinc concentrations in biota from the San Juan River mainstem 1988-1994.

[sites with all 3 sample types; line for predator protection 44.5 mg/kg]



Organic Results

A total of 32 fillet and 86 whole fish samples collected from 14 sites along the San Juan River were analyzed for the following organochlorine pesticides and polychlorinated biphenyls (PCBs): alpha-BHC, beta-BHC, delta-BHC, gamma-BHC (Lindane), Heptachlor, Aldrin, Heptachlor epoxide, Hexachlorobenzene, Endosulfan I, Dieldrin, 4,4'-DDE, Endrin, Endosulfan II, 4,4'-DDD, Endosulfan sulfate, 4,4'-DDT, Endrin aldehyde, Methoxychlor, Kepone, alpha-Chlordane, gamma-Chlordane, Toxaphene, Chloropyrifos, and Arochlors-1232, 1242/1016, 1248, 1254, and 1260.

All but one fish sample had DDT concentrations below the LOD (0.001 mg/kg wet weight), but 46.5% of the whole fish samples had detectable DDE concentrations (range = 0.003 - 0.02 mg/kg wet weight). There were no more recent additions of DDT to the San Juan River ecosystem as evidenced by the lack of DDT in biota and the slow degradation of DDT to DDE. PCBs were ubiquitous in the environment as over 60% had detectable PCBs (range = 0.002 - 0.14 mg/kg wet weight). Twenty-five percent of the fillets had detectable concentrations of DDE (range = 0.003 - 0.15 mg/kg wet weight), and 46 percent had detectable concentrations of PCBs (range 0.003 - 0.02 mg/kg wet weight). Compared to heavily contaminated sites, the concentrations of PCBs in biota from the San Juan River ecosystem are relatively low. However, individual forms of PCB (Arochlors) have the potential to act as "rogue hormones" with dramatic consequences at even low concentrations (Mac et al. 1993).

Polycyclic Aromatic Hydrocarbon Metabolites in Fish Bile

The bile from three carp and five channel catfish was collected at four locations on March 2-3, 1994, and concentrations of three PAHs were determined. Naphthalene and phenanthrene are 2- and 3-ring compounds typically associated with naturally occurring hydrocarbon sources such as oil and natural gas. These low molecular weight compounds are acutely toxic to some organisms but have not been identified as carcinogens (Eisler 1987b). The third PAH, benzo(a)pyrene, is a 5-ring compound generally associated with anthropogenic hydrocarbon sources related to oil and gas production and exhausts and wastes from coal-fired power plants, has been shown to be carcinogenic to wildlife and people (Eisler 1987b).

The largest concentration of benzo(a)pyrene (1,200 ng/g wet weight) was found in a carp downstream of the Cudei Diversion (Reach 09), suggesting significant anthropogenic pollution (Suzanne McDonald, personal communication) (Table 10). Carp from Bluff, Utah (Reach 15), and catfish from above the Cudei Diversion (Reach 08), and near Mexican Hat, Utah (Reach 16), had concentrations of benzo(a)pyrene indicating moderate pollution. The presence of PAH metabolites in bile of every fish sampled suggests some level of exposure to both natural and anthropogenic hydrocarbons. The sample size, however, is too small to determine relationships between river reaches or fish species. Table 10 presents PAH metabolite concentrations and general guidelines for interpreting exposure.

Table 10. PAH metabolite concentrations (ng/g wet weight) in fish bile from the San Juan River, 1994 and interpretation[1].

Species	Reach	Date	Naphthalene	Phenanthrene	Benzo(a)pyrene
Carp	09	3/2/94	400,000**	100,000***	1,200***
Carp	09	3/2/94	85,000*	28,000**	490**
Carp	15	3/3/94	56,000*	17,000**	300**
Catfish	08	3/2/94	28,000*	7,300*	180*
Catfish	08	3/2/94	30,000*	7,600*	170*
Catfish	08	3/2/94	200,000*	58,000***	620**
Catfish	16	3/3/94	33,000*	7,700*	150*
Catfish	16	3/3/94	28,000*	8,700*	200**

[1] General guidelines for interpreting concentrations of PAH metabolites in fish bile (Suzanne McDonald, Geochemical and Environmental Research Group, personal communication):

*** Highly polluted environment
- Naphthalene >500,000 ng/g
- Phenanthrene > 50,000
- Benzo(a)pyrene > 1,000

** Moderately polluted environment
- Naphthalene c.300,000 to 500,000 ng/g
- Phenanthrene c. 10,000 to 50,000
- Benzo(a)pyrene c. 200 to 1,000

* Low level pollution or background
- Naphthalene <100,000 to 300,000 ng/g
- Phenanthrene < 10,000
- Benzo(a)pyrene < 200

Bile data from this collection period was compared with bile data from Lake Powell collected in 1991-1994 (Waddell and Wiens 1993). All eight samples collected during the 1994 the San Juan Synoptic Study collections fell within the range of 19 samples collected for the same species at Zahn Bay, Lake Powell (Reach 18). Average concentrations for carp from the San Juan River Reach 09 substantially exceeded those from Zahn Bay for naphthalene, phenanthrene, and benzo(a)pyrene. A single carp sample from Reach 15 was less than the average for Zahn Bay for naphthalene and phenanthrene, but elevated for benzo(a)pyrene. The average concentration of benzo(a)pyrene was nearly four times that from Zahn Bay. For catfish, the average concentrations of naphthalene and phenanthrene were substantially lower than those from Zahn Bay, but benzo(a)pyrene was similar to or substantially higher for Reaches 16 and 08, respectively.

Large variability in concentrations of PAHs between species, sites, and sampling periods was noted in both the Lake Powell study and this study. Some variability may be due to how recently the fish fed, before the collection of the bile sample (Suzanne McDonald, personal communication). From the more extensive collections at Lake Powell, the data suggest that year, time of the year, and site may all be factors. For all samples from both studies, highest concentrations of PAHs were found in carp during March and May, and in catfish in July. The data are inadequate to determine whether these are seasonal differences or site differences. Variability in the Zahn Bay data may also be related to sediment redistribution in the San Juan River inflow area of Lake Powell.

Semipermeable Monitoring Devices

This Synoptic Study also used SPMDs, in March and September 1994, to assay for fat-soluble organic contaminants in water at 10 locations on the San Juan mainstem and selected tributaries. Analyses for PAHs demonstrated generally low concentrations in March 1994 samples (Prest and Hodgins 1995a). Sites were ranked from highest to lowest concentrations: Montezuma= Animas>> Bluff> Mixer> Bloomfield> Piedra >> Zahn Bay = Clay Hills = Mexican Hat = below Navajo Reservoir (Figure 33). Some anomalies in the sampling and analysis were identified for samples at the Montezuma site and sites downriver. The effects of these anomalies on the reported concentrations are unknown.

In September 1994, PAH levels were low except at the Animas site (Prest and Hodgins 1995b). Sites were ranked from highest to lowest as follows: Animas>> Mixer> Montezuma> Mexican Hat= Clay Hills. The following sites had lower total PAH concentrations: Piedra= Bloomfield> Navajo= Zahn Bay (Figure 34). The Zahn Bay SPMD was damaged during deployment or as a result of lake level fluctuation with resulting poor lipid recovery and low total PAHs. The Bluff sample deployed in September was misplaced by the laboratory and therefore, was not analyzed.

The San Juan River below Montezuma Creek, near Bluff, Utah, and in the Animas River had the highest concentrations of total PAHs (after field blanks were subtracted) in the deployed SPMDs during March. In the September deployment, these sites (without Bluff sample), and the Mixer site again had the highest concentrations of total PAHs (Figures 33 and 34). Individual PAH ratios at the Montezuma and Animas sites were generally similar, suggesting a common source and/or mixing of similar sources. These ratios demonstrated higher molecular weight components for the Montezuma site sample compared to the Animas site sample.

We did compare fish bile data with the SPMD data and found a general correlation, but sample sizes were insufficient to allow reliable conclusions.

Figure 33. Corrected Total PAH SPMD Concentrations above Field Blanks by Site for March through April 1994.

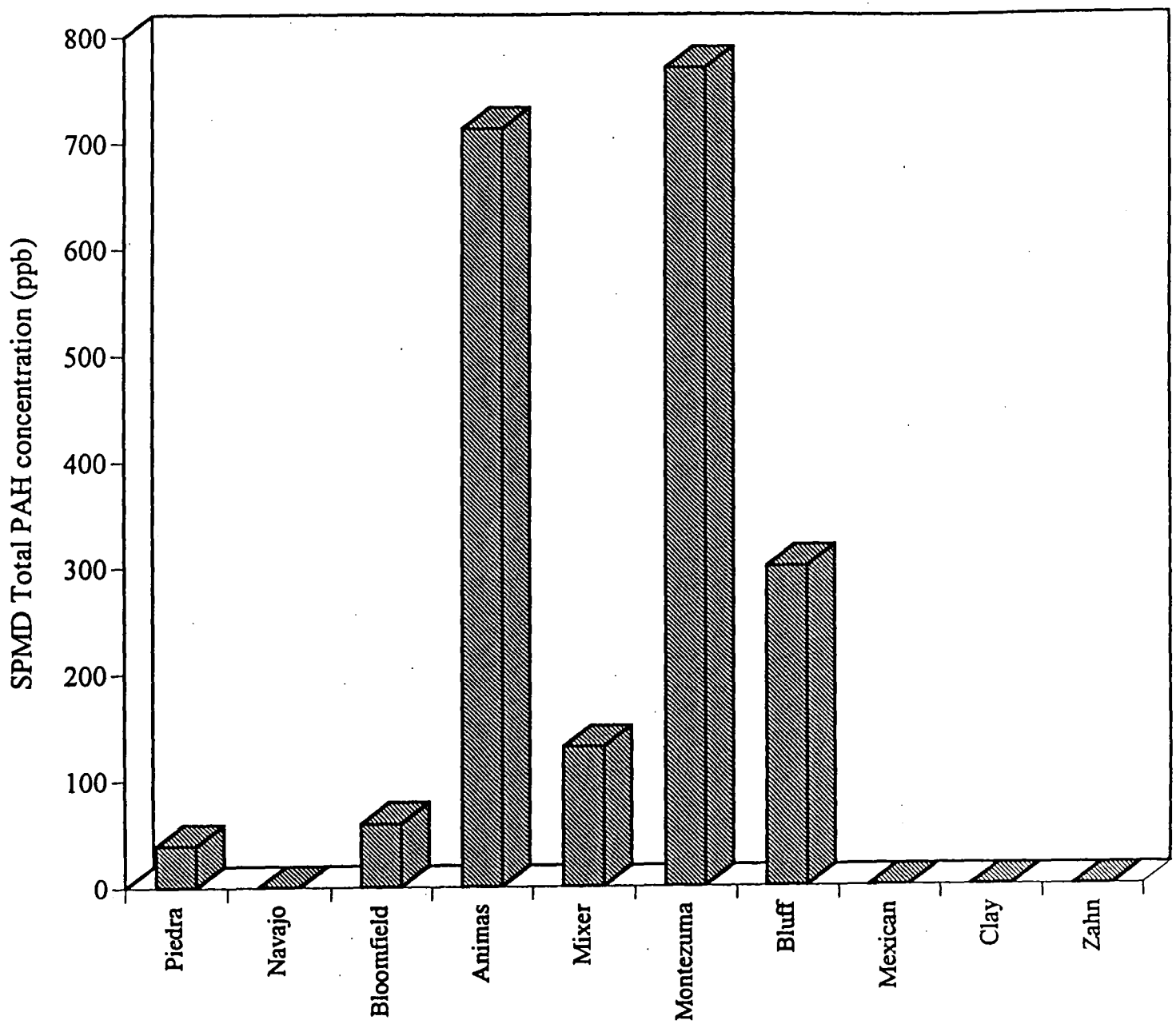
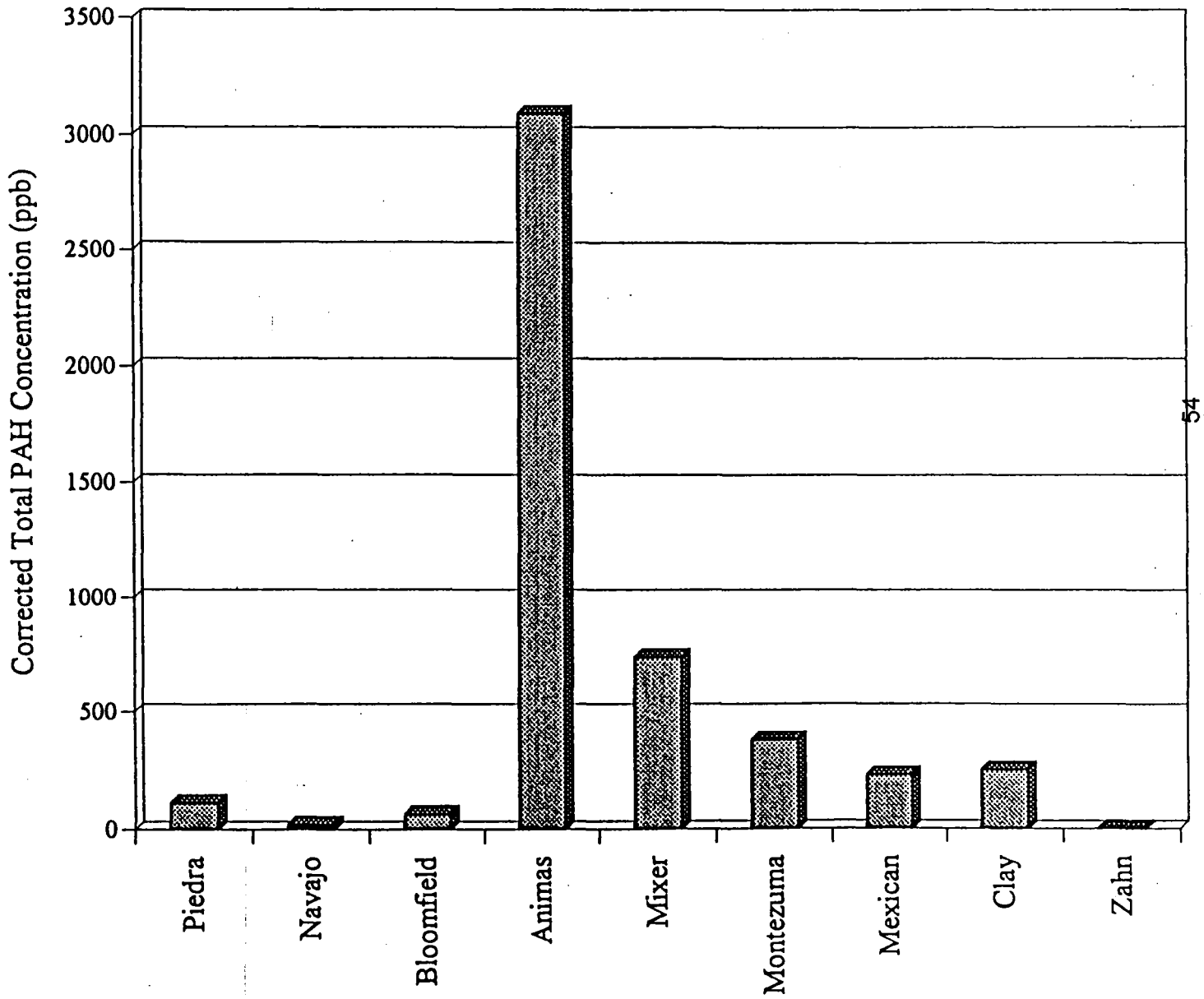


Figure 34. Corrected Total PAH Concentrations above Field Blanks by Site for September through October 1994.



Discussion / Conclusions

Compared to the San Juan River basin overall, arsenic was elevated in fish from Zahn Bay, Utah. Arsenic concentrations in plants and invertebrates increased by Blanco, New Mexico. On average, arsenic concentrations in fish from the San Juan River were less than those in fish sampled nationwide.

Copper was elevated in invertebrates from McElmo Creek and the Mancos River. Copper concentrations in plants and invertebrates generally increased downstream in the San Juan River. Fish showed the opposite trend. Average concentrations of copper in whole fish (mostly trout) were greater in the upper reaches (greater than in fish sampled nationwide) and greater than in whole fish from lower reaches.

Though few samples were collected from the Animas River, the relative concentrations of lead and cadmium in biota collected in this tributary are elevated compared to the average for the basin. As lead and cadmium are often associated with anthropogenic activities, we recommend that additional plant, invertebrate and whole fish be sampled from the Animas River mindful of the location of potential lead- or cadmium-generating activities (such as mining). Both reservoirs also contained whole fish with elevated lead and cadmium, but samples of plants and invertebrates were not collected in order to make definitive conclusions about contamination relative to the San Juan River Basin ecosystem. We suspect that lead and cadmium are also elevated in plants and invertebrates from reservoir sites, as evidenced by the concentrations in whole fish, and should be sampled to confirm or deny this concern.

Mercury concentrations in biota were higher in habitats that were characterized by large expanses of slow-moving water compared to riverine habitats. Predatory fish from reservoirs were likely to biomagnify the highest mercury concentrations. Even wetlands isolated from a direct surface water connection to the San Juan River were elevated. The data tends to support the premise that mercury is uniformly deposited from atmosphere and is more readily available to biota through biochemical processes (methylation) predominant in reservoirs, wetlands, and backwaters.

Selenium was elevated in biota collected from irrigation drainage return habitats and the Mancos River. Although we did not compare any quantitative measure of productivity with selenium accumulation, we suspect productive habitats in seleniferous regions would likely have elevated selenium in biota as it is a nutrient. Selenium concentrations in whole body fish occasionally exceeded concentrations reported to be associated with reproductive failure. Selenium concentrations in biota were elevated and may pose a threat to predatory fish and wildlife that consistently feed in the region. The relative contribution of selenium from the tributaries and irrigation projects needs to be evaluated and managed in a way similar to the management of salts in the Colorado River. The relative contributions of selenium (on a mass-basis) into the San Juan River Basin ecosystem could be evaluated using state-of-the-art

hydrological techniques to identify and manage those watersheds that contribute selenium disproportionately. A site-specific investigation to determine the relative risks to fish and wildlife species posed by elevated selenium concentrations in a diet related to whole body burdens and reproductive failure may eventually be necessary to utilize fully all information in this study.

Zinc concentrations were elevated in biota from the Animas River; from 3-to-10 times the average for the San Juan River basin overall. Carp species often contained the highest zinc concentrations compared to other fish species. Zinc concentrations in biota form the San Juan River increase by Farmington, New Mexico and remain elevated into Utah. High concentrations of zinc in invertebrates in the Mixer region of the San Juan River may cause stunting in fish that feed in this region exclusively.

There were some trends that should be considered preliminary and used with caution. For instance, there were differences in average copper and average mercury concentrations in whole fish from upper San Juan River sites compared to whole fish from lower San Juan River sites. Average copper concentrations in whole fish from the upper reaches differed from the average in whole fish from the lower reaches by only 0.3 mg/kg wet weight. The difference in average mercury concentrations was only 0.04 mg/kg wet weight. These are small differences. We cannot, as yet, ascribe these differences to any a particular factor. The San Juan River has very different water quality, habitat conditions, and fish assemblages (trout) in the upper reaches compared to the lower reaches. Subtle changes due to season, site, species, dietary composition, and analytical quality have likely influenced the variation within samples and will need to be extensively evaluated before definitive conclusions can be made about these differences.

Concentrations of organochlorine pesticides and PCBs are ubiquitous but declining in fish from the San Juan River. Based on SPMDs and analysis of fish bile, exposure to PAHs occurred in the San Juan River. However, the concentrations of PAHs in the Animas River were consistently elevated and warrant further study to determine if sources are generally associated with runoff from municipalities or other activities within the Animas River watershed. Further work is necessary to explain the "pulse phenomena" that occurred in the San Juan River below the confluence with Montezuma Creek and into Zahn Bay. PAH metabolites in fish bile are also inconsistent. Individual fish reflected exposure to an elevated source, while fish collected nearby reflected a lower level of exposure. Exposure to PAHs was documented, but the consequences to fish health and trends could not be determined from these data.

A tremendous amount of environmental data exists for the San Juan River Basin (O'Brien 1987; Keller-Bliesner Engineering and Ecosystems Research Institute 1991; Waddell and Wiens 1993; Blanchard et al. 1993; U.S. Bureau of Indian Affairs 1993, Abell 1994 to name but a few). Endangered species recovery would be enhanced if environmental data (water quality, soil and sediment quality, habitat characteristics, fish health and quality) could be

geographically and temporally referenced. A method will need to be established to assure a certain level of data quality and consistency is used in data incorporation, synthesis and interpretation. Using a data set with these features, data could be queried for regions that were less contaminated than others and identified as areas to emphasize recovery. Clear trends in environmental quality and data gaps could be identified, understood, and related to specific recovery goals.

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