Metals and Trace Elements in Pondweed and Aquatic Invertebrates at Ruby Lake National Wildlife Refuge, June 2002

by

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January 2003

Introduction

The Nevada Division of Wildlife operates the Gallagher Fish Hatchery in the Ruby Lake National Wildlife Refuge (NWR) in Ruby Valley, Nevada. The results of previous sampling of water, sediment, and aquatic vegetation that was conducted in September 1993 (Wiemeyer and Tuttle 1995), suggested that copper and zinc concentrations in vegetation and/or sediment samples from a ditch downstream of the fish hatchery were elevated above concentrations in samples from a water collection ditch upstream of the hatchery. Copper sulfate is occasionally used by fish hatchery personnel to control algal blooms, usually in August and September of each year (Martha Collins, personal communication). These applications may be conducted both at the north fish-rearing facility, about 1.5 miles north of refuge headquarters, and at the main hatchery complex, approximately 1.1 miles south of refuge headquarters. Concentrations of several metals and trace elements also appeared to be somewhat elevated in water, sediment, and vegetation samples collected at the south end of the South Marsh, at least when compared to other locations on the refuge.

The Refuge Manager of the Ruby Lake NWR requested that the Nevada Fish and Wildlife Office collect various samples downstream of hatchery operations to determine if the fish hatchery could be a possible source of metals and if they could have an adverse effect on refuge resources. Information was also needed on concentrations of metals and trace elements in aquatic invertebrates from the refuge as food items for fish and wildlife on the refuge.

Methods

Five samples of biota, two pondweed (*Potomogeton pectinatus*) and three aquatic invertebrate, were collected at the Ruby Lake NWR on June 11, 2002 (Table 1), and were analyzed for an array of metals and trace elements. The samples that were collected just downstream from the main hatchery outflow were taken in the oxbow, which is similar to site 10 near marsh unit 21, in the report by Wiemeyer and Tuttle (1995). The samples that were collected just downstream from the north fish-rearing facility were taken near site 1 in Wiemeyer and Tuttle (1995), upstream of the inflow to marsh unit 10. The corixid (water boatmen) sample that was taken at the Narciss boat ramp near the south end of the South Marsh is near site 14 in the report of Wiemeyer and Tuttle (1995). Sample locations were determined with use of global position equipment. We also attempted to collect an aquatic invertebrate sample near the inlet of marsh unit 14; however, we were unable to collect an adequate sample due field conditions and lack of time.

Pondweed samples were collected with gloved hand and placed in chemically clean glass jars, chilled on ice in the field and frozen upon return to the laboratory. Aquatic invertebrate samples were collected with a kick net and placed in a clean stainless steel pan for sorting from debris. Invertebrates were placed in chemically clean glass jars, chilled on ice in the field and frozen upon return to the laboratory. All samples were kept frozen through delivery to the analytical laboratory.

Samples were analyzed for metals and trace elements at Laboratory and Environmental Testing, Inc., Columbia, Missouri. Quality control and quality assurance (QA/QC) included the analysis of procedural blanks, duplicates, reference materials, and spike recoveries. All QA/QC and analytical results were approved by John Moore of the U.S. Fish and Wildlife Service, Patuxent Analytical Control Facility, Laurel, Maryland. Information on analytical methods are on file in the Nevada Fish and Wildlife Office, along with all analytical results.

All residue concentrations are reported on a µg/g (synonymous to parts per million) on a dry weight basis, unless otherwise noted.

Results and Discussion

Aquatic Invertebrates and Pondweed

Concentrations of metals and trace elements in aquatic invertebrates and pondweed are provided in Tables 2 and 3, respectively. Aquatic invertebrates from Ruby Lake NWR had not been previously collected for analysis; therefore, no comparisons to previous data are possible. Comparisons between amphipods and corixids collected in 2002 should be done with caution because different invertebrate types might accumulate metals and trace elements at different rates. The cause for the higher concentration of nickel in the corixid sample from the site downstream of the north fish-rearing facility is unknown(Table 2).

Samples of aquatic vegetation were collected in 1993 (Wiemeyer and Tuttle 1995). However, the identification of most samples was uncertain. Therefore, comparisons between the 1993 and 2002 data should be conducted with caution. Concentrations of aluminum in the 2002 pondweed samples were higher than in vegetation samples collected throughout the refuge in 1993, as well as higher than samples from similar sites (Table 3). Arsenic concentrations in 2002 samples were similar to the overall mean in 1993, but slightly higher than samples from similar sites in 1993. Boron concentrations in 2002 were similar to concentrations found in samples from similar sites in 1993 and lower than the overall mean for all sites sampled in 1993. Barium and manganese concentrations in 2002 were similar to concentrations in samples from similar sites in 1993 as well as the overall mean in 1993. Beryllium concentrations in 2002 were slightly higher than those found in samples from similar sites in 1993 and the overall 1993 mean. Cadmium, chromium, copper, iron, nickel, and zinc concentrations in samples collected in 2002 were somewhat higher than those found in samples from similar sites in 1993 as well as the overall 1993 respective means, and concentrations in 2002 samples exceeded the extreme values found in 1993 throughout the refuge. The site sampled downstream of the hatchery in 1993 had the highest concentration of zinc. Mercury concentrations were not detected in 2002 samples and the detection limit in 2002 was much higher than in 1993. Therefore, comparisons between the two years are not possible. Magnesium concentrations in 2002 were somewhat higher than in samples from similar sites in 1993, but the 2002 sample from the oxbow downstream from the fish hatchery was similar to the overall 1993 mean. The magnesium concentration in the 2002 sample from the north fish-rearing facility was slightly higher than the extreme value in 1993. The magnesium concentration in sediment at site 1 in 1993 was the third highest. Molybdenum was not detected in samples in both 1993 and 2002. The lead concentration in the 2002 sample from the oxbow was higher than that found in the vegetation sample from a similar site in 1993. The 2002 sample from the north fish-rearing facility contained a lead concentration similar to that found in a sample from a similar site in 1993. The selenium and vanadium concentrations found in samples collected in 2002 were slightly higher than the respective extreme concentrations found in 1993. Site 10 in 1993 had the second highest concentration of selenium in sediment.

The concentrations of metals and trace elements found in the samples collected in 2002 were evaluated in relation to known concern or effect concentrations in the foods of migratory birds and wildlife. A concentration of 5000 µg/g aluminum was considered an adverse dietary effect level in waterfowl (Sparling 1990). All concentrations in 2002 were below this level. Dietary concentrations of 30 µg/g arsenic and boron were associated with reduced weight gain in mallard (*Anas platyrhynchos*) ducklings (Camardese et al. 1990; Smith and Anders 1989). This concentration of arsenic and boron was not exceeded in this study. Cain et al. (1983) established a concern level of 20 µg/g cadmium in mallard ducklings. Cadmium concentrations in this study were far lower. Eisler (2000a) proposed a threshold concentration of 10 µg/g chromium in the diet of wildlife, above which one might expect potential adverse effects on health and reproduction. No chromium concentrations in this study exceeded this level. Poultry diets containing < 200 µg/g copper were considered safe (Eisler 2000a). Copper concentrations in this study were far lower. The mercury dietary effect level for adverse reproductive effects in mallards is 0.5 µg/g (Heinz 1979). No mercury concentrations in this study exceeded this level. The lower dietary effect concentration of molybdenum associated with a reduction in growth of birds is 200 µg/g (Eisler 2000b). Molybdenum was not detected in the samples from this study. A nickel concentration of 800 µg/g wet weight was associated with adverse effects to adult mallards (Eisler 2000a). Concentrations in this study were far lower. An avian dietary concentration of < 5 µg/g lead was proposed to be protective (Eisler 2000a). Lead concentrations in this study did not exceed 5 µg/g. A concentration of 3 µg/g selenium is the lower dietary threshold for reproductive effects in birds (U.S. Department of the Interior 1998). All selenium concentrations in this study were lower than this level. White and Dieter (1978) established an avian dietary concern level of 100 µg/g for vanadium. Vanadium concentrations in this study were far lower. Dietary effect levels for zinc proposed by Eisler (2000a) for the protection of birds were not exceeded in this study.

Reinterpretation of 1993 Sediment Data

Mac Donald et al. (2000) have published consensus-based sediment quality guidelines for freshwater ecosystems. These include threshold effect concentrations (TEC) below which adverse effects are not likely to occur and probable effect concentrations (PEC) above which adverse effects are expected to occur. Data were provided for arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc. None of the PECs were exceeded in sediment samples collected from the Ruby Lake NWR in 1993. The TEC for arsenic (i.e., 9.79 µg/g) was exceeded for three samples (sites 2, 6, and 14 in Wiemeyer and Tuttle 1995; 11, 16, and 13 µg/g, respectively). The TEC for zinc (i.e., 121 µg/g) was exceeded at site 10 where the sediment sample contained 134 µg/g. The toxicity threshold for selenium in sediment in relation to adverse effects for fish and wildlife is ≥ 4 µg/g (Lemly and Smith 1987; U.S. Department of the Interior 1998). All sediment samples collected in 1993 contained less than 4 µg/g selenium. Persaud et al. (1993) established concern levels of 21,200 and 460 µg/g for iron and manganese in sediment, respectively. These concentrations were not exceeded in sediment samples collected in 1993.

Conclusions and Recommendations

The limited sampling that was conducted in June 2002 did not provide any clear indication that fish hatchery operations were the source of metals or trace elements in areas downstream of hatchery facilities. However, the collection of water samples immediately following discharges of copper sulfate-contaminated water should be conducted to determine if the copper concentrations are high enough to cause adverse acute effects to aquatic resources, including fish. Water collections should including sampling of both upstream and downstream sites for comparative purposes.

Additional sampling of dietary items throughout the refuge to determine exposure of fish and wildlife to metals and trace elements does not appear to be necessary, as the concentrations found in both vegetation and very limited sampling of aquatic invertebrates to date has not revealed concentrations that exceed avian dietary effect concentrations, except for boron in most vegetation samples collected in 1993. The reproductive success of mallards that received a diet containing 1000 µg/g boron was significantly reduced, whereas there were no significant effects at a dietary concentration of 300 µg/g (Smith and Anders 1989). The lowest observable adverse effect concentration for reproductive effects is not known. The arithmetic mean boron concentration in aquatic vegetation samples collected in 1993 was 337 µg/g, which is only slightly above a concentration shown to have no reproductive effects. As indicated above, a dietary concentration of 30 µg/g boron caused reduced weight gain in ducklings (Smith and Anders 1989); however, there did not appear to be any consistent adverse effects on duckling survival through 21 days of age. Nine of 15 vegetation samples collected in 1993 had boron concentrations higher that 30 µg/g. A full understanding of the overall diet of ducklings as well as boron concentrations in different components of the diet would be needed to better evaluate the significance of the elevated boron concentrations in vegetation at Ruby Lake NWR.

Acknowledgments

I thank Kevin Kritz for assistance with collection of samples in 2002. Martha Collins and Jeff Mackay reviewed a draft of the report.

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Table 1. Collection data for samples of aquatic invertebrates and pondweed from the Ruby Lake National Wildlife Refuge, June 11, 2002.

	Coordinates		Location	Sample
Sample Type	North	West	Description	Weight (g)
Invertebrates				
Amphipods	40° 10' 54"	115° 29' 23"	Hatchery oxbow	14.7
Corixids	40° 13' 17"	115° 29' 06"	North fish-rearing facility	4.7
Corixids	40° 04' 52"	115° 30' 49"	Narciss boat ramp	7.5
Vegetation				
Pondweed	40° 10' 54"	115° 29' 23"	Hatchery oxbow	17.9
Pondweed	40° 13' 17"	115° 29' 06"	North fish-rearing facility	29.6

Table 2. Concentrations (parts per million, dry weight) of metals and trace elements in aquatic invertebrates from Ruby Lake National Wildlife Refuge, June 2002.

Element	Hatchery oxbow Amphipods	North facility Corixids	Narciss boat ramp Corixids
Aluminum	568.	120.	170.
Arsenic	3.6	0.70	1.0
Boron	<2.00	<2.00	4.0
Barium	233.	74.1	31.6
Beryllium	<0.100	< 0.100	<0.100
Cadmium	0.30	0.10	0.20
Chromium	1.0	0.50	<0.500
Copper	60.1	20.0	12.0
Iron	387.	180.	170.
Mercury	<0.100	<0.100	0.31
Magnesium	2930.	1310.	2690.
Manganese	26.	22.	19.
Molybdenum	<2.00	<2.00	<2.00
Nickel	0.70	4.7	0.80
Lead	0.40	<0.200	<0.200
Selenium	1.8	1.2	0.70
Strontium	92.2	6.5	15.0
Vanadium	1.0	0.50	0.70
Zinc	79.9	111.	132.

Table 3. Concentrations (parts per million, dry weight) of metals and trace elements in pondweed (*Potomogeton pectinatus*) from Ruby Lake National Wildlife Refuge, June 2002, with comparisons to vegetation samples collected in September 1993 (Wiemeyer and Tuttle 1995).

	2002		1993			
Element	Hatchery oxbow	North facility	Site 10[a]	Site 1[b]	Overall mean[c]	(extremes)
Aluminum	2710.	4410.	51.	1870.	383.	(19-1870)
Arsenic	1.6	2.7	0.30	1.0	2.1	(0.30-21)
Boron	12.	17.	13.	12.	337.	(12-1240)
Barium	209.	433.	224.	362.	310.	(131-562)
Beryllium	0.10	0.20	<0.01	0.11	0.024	(<0.01-0.11)
Cadmium	0.30	0.37	0.03	0.14	0.06	(0.03-0.14)
Chromium	4.2	8.3	0.51	2.5	0.83	(0.20-2.5)
Copper	10.	8.4	3.8	3.3	2.2	(0.40-4.3)
Iron	2150.	4320.	101.	1630.	378.	(101-1630)
Mercury	<0.100	<0.100	<0.005	0.01	0.009	(<0.005-0.024)
Magnesium	5740.	19000.	2790.	8890.	6756.	(2790-16100)
Manganese	95.6	105.	80.3	179.	129.	(13.0-391)
Molybdenum	<2.00	<2.00	<1.0	<1.0	-[d]	(<0.9-<1.0)
Nickel	3.0	4.0	0.74	1.8	0.66	(0.30-1.8)
Lead	1.8	3.1	<0.40	3.5	-[d]	(<0.4-3.5)
Selenium	0.60	0.69	0.30	0.50	0.27	(<0.2-0.5)
Strontium	54.7	208.	42.6	147.	74.6	(33.2-170)
Vanadium	8.7	8.5	0.40	4.1	1.4	(<0.3-7.1)
Zinc	109.	53.1	41.	34.	18.	(5.7-41)

[a] Similar to or near hatchery oxbow; possibly widgeongrass (*Ruppia maritima*).
[b] Similar to or near North facility; marestail (*Hippurus vulgaris*).
[c] Arithmetic means for 15 sample sites, throughout the refuge.

[d] More than 50% of samples with non-detectable residues.