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ASSESSMENT OF SELENIUM AND ATRAZINE EXPOSURE AND EFFECTS TO WILDLIFE AT THE NORTH PLATTE NATIONAL WILDLIFE REFUGE, SCOTTSBLUFF, NEBRASKA.

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ABSTRACT

This study evaluated selenium and atrazine exposure and effects to fish and wildlife at North Platte National Wildlife Refuge (Refuge) in Scotts Bluff County, Nebraska. Atrazine was detected in 2 of 54 water samples and at low concentrations that are not of concern. However, concentrations of selenium and strontium exceeded toxicity guidelines in water, sediment, invertebrates, whole-body fish and wood duck eggs. Concentrations of selenium in water at Refuge sites frequently exceeded a 2 µg/L total recoverable threshold for selenium bioaccumulation and were greatest at Stateline Island (9.7 µg/L) and Little Lake Alice (24 µg/L). In sediments, strontium concentrations were elevated above background (49 mg/kg) at all sites but were greatest at Stateline Island (858 mg/kg). Selenium in sediments was greatest at Stateline Island (mean = 9.6 ± 2.1 mg/kg) and exceeded a 4 mg/kg toxicity guideline at which adverse effects to some fish and wildlife species may occur. Concentrations of selenium in aquatic invertebrates averaged 10 ± 2 mg/kg at Stateline Island and 6 ± 2 mg/kg at Winters Creek Lake and exceeded a 3 - 8 mg/kg dietary benchmark for reproductive impairment in birds. Fish from all sites had tissue selenium concentrations above a 4 mg/kg effects threshold for protecting fish health and reproduction. Twenty-nine of 40 fish sampled also exceeded a 2 mg/kg wet weight human health advisory for limited consumption. Concentrations of selenium in wood duck eggs at Lake Alice and Lake Minatare averaged 5.9 ± 0.6 and 6.4 ± 0.3 mg/kg, respectively, and 20 of 42 eggs exceeded a 6 mg/kg toxicity threshold for reduced hatchability. An aquatic hazard assessment of selenium for each Refuge subunit was derived using a protocol that considers selenium concentrations in water, sediments, invertebrates, fish and bird eggs. This assessment indicates high risk to Refuge biota from selenium exposure at Winters Creek Lake and Stateline Island and moderate risk at Lake Alice and Lake Minatare. Recommendations to reduce selenium exposure include management actions aimed at increasing selenium volatilization and phytoremediation.

Keywords: North Platte National Wildlife Refuge, Nebraska, selenium, atrazine, wood ducks, waterfowl, elemental contaminants, metals.

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ACRONYMS AND ABBREVIATIONS

<	less than	NOAA	National Oceanic and Atmospheric Administration
ACF	Analytical Control Facility	NWR	National Wildlife Refuge
Al	aluminum	^{o}C	degrees Celsius
As	arsenic	p	level of significance
B	boron	Pb	lead
Ba	barium	PEC	probable effect concentration
Be	beryllium	pers. comm.	personal commentary
BEST	Biomonitoring of Environmental Status and Trends	PRBE	Platte River Basin Environments, Inc.
BR	Bureau of Reclamation	QA/QC	quality Assurance/quality Control
Cd	cadmium	Refuge	North Platte National Wildlife Refuge
Cr	chromium	SAS	Statistical Analysis System
Cu	copper	SE	standard error
dw	dry weight	Se	selenium
ELISA	enzyme-linked immunosorbent assay	Service	U.S. Fish and Wildlife Service
et al.	and others	SL	Stateline Island
Fe	iron	SOPs	standard operating procedures
Hg	mercury	sp	species
i.e.	in explanation	Sr	strontium
ID	identification	TEC	threshold effect concentration
LA	Lake Alice	USDA	U.S. Department of Agriculture
LM	Lake Minatare	USDOI	U.S. Department of the Interior
Mg	magnesium	USEPA	U.S. Environmental Protection Agency
mg/kg	milligrams per kilogram	USFWS	U.S. Fish and Wildlife Service
mg/L	milligrams per liter	USGS	U.S. Geological Survey
mm	millimeter	V	vanadium
Mn	manganese	WC	Winters Creek Lake
Mo	molybdenum	ww	wet weight
n	sample size	Zn	zinc
NDEQ	Nebraska Department of Environmental Quality	µg/g	micrograms per gram
NEFO	Nebraska Ecological Services Field Office	µg/L	micrograms per liter
Ni	nickel	µS/cm	microsiemens per centimeter

INTRODUCTION

North Platte National Wildlife Refuge (Refuge) is located 8 miles northeast of Scottsbluff, in Nebraska's Panhandle. It was established by Executive Order in 1916, and was managed by the Bureau of Reclamation (BR) until 1986, when primary jurisdiction was granted to the U.S. Fish and Wildlife Service (Service). The primary purpose of the Refuge is to provide sanctuary for migratory birds, but habitat for migrating bald eagles, waterfowl production, and compatible recreation are important management goals (USFWS, 2001). Twenty bald eagles and over 200,000 waterfowl concentrate on the Refuge during migration and over 200 species of birds have been observed on the Refuge.

The 2,909 acre Refuge includes three reservoirs: 1) Lake Alice, 2) Winters Creek Lake, and 3) Lake Minatare (Figure 1). Water levels in all three reservoirs are managed by BR for irrigation and Lake Minatare is managed as a State Recreation Area under a lease agreement with the Nebraska Game and Parks Commission. The Refuge also manages property on the North Platte River (Figure 2). The Service assumed management of Stateline Island, a 135-acre diversion project on the North Platte River, in 1990. Stateline Island is also subject to BR uses. Horse Creek and Spotted Tail subunits are currently owned by the Platte River Basin Environments, Inc. (PRBE); however, plans to transfer these units to the Service have been initiated. The goal of PRBE is to preserve, conserve, enhance and restore vital wildlife habitat and natural areas within the North Platte River basin (http://www.nebwild.org/).

Irrigation supply water from the North Platte River is the primary source of water for all three Refuge reservoirs, which are interconnected by a canal system. Lake Alice receives water from the Interstate and Highline canals, and discharges to the Supply canal and Hersche drain. Winters Creek Lake is fed by the Supply Canal and also discharges to the Supply Canal, with the inflow and outflow separated by approximately 200 meters. Lake Minatare receives water primarily from the Supply Canal with secondary input from the Highline Canal and discharges into the Lowline Canal and Alliance Drain. Land use in the drainage is primarily agricultural; with wheat, corn, soybeans, and sugar beet production the predominant row crops. In addition, alfalfa production and grazing areas support cattle ranching within the Refuge's watershed.

Although the most common crops in the study area include wheat and sugar beets, corn is also produced. Atrazine is the most heavily applied herbicide for corn agriculture in Nebraska. Previous studies have linked atrazine to adverse effects in a wide spectrum of wildlife including periphyton (Nelson et al., 1999), invertebrates (Dewey, 1986), fish (Kettle et al., 1987), and amphibians (Hayes et al., 2002, 2010).

Selenium is an essential element in animals and some plants (Ohlendorf, 2003); however, the narrow margin of safety between selenium deficiency and toxicity make it one of the most toxic trace elements (USDOI, 1998). Nutritionally optimal dietary selenium exposure is generally reported as 0.1 to 0.3 milligrams per kilogram (mg/kg) dry weight (dw) whereas threshold values for dietary toxicity in animals are generally reported as 2 to 5 mg/kg dw (USDOI, 1998). Reproductive effects to fish and waterfowl from exposure to selenium are well documented by laboratory and field investigations (reviewed by USDOI, 1998 and Hamilton, 2004). Fish and aquatic birds are the most sensitive animals to selenium toxicity and are most vulnerable at early life stages (Ohlendorf, 2003). Selenium exposure to fish and/or avian species can result in teratogenic defects in developing offspring, decreased hatchability, reduced growth, reproductive failure, and mortality (Lemly, 1996; USDOI, 1998).

Previous surveys at the Refuge identified elevated levels of selenium in fish (Schwarz et al., 2005) and water (Druliner et al., 1999), but there are no previous data for atrazine exposure. The primary objective of this study was to evaluate selenium and atrazine exposure and effects to fish, amphibians, and waterfowl that utilize the Refuge. Refuge biota exposure to selenium was evaluated by measuring concentrations of selenium in sediments, water, whole body fish, waterfowl food items (invertebrates and plants) and wood duck eggs. Water samples from four Refuge subunits were measured for atrazine, pH, temperature, dissolved oxygen, and conductivity.

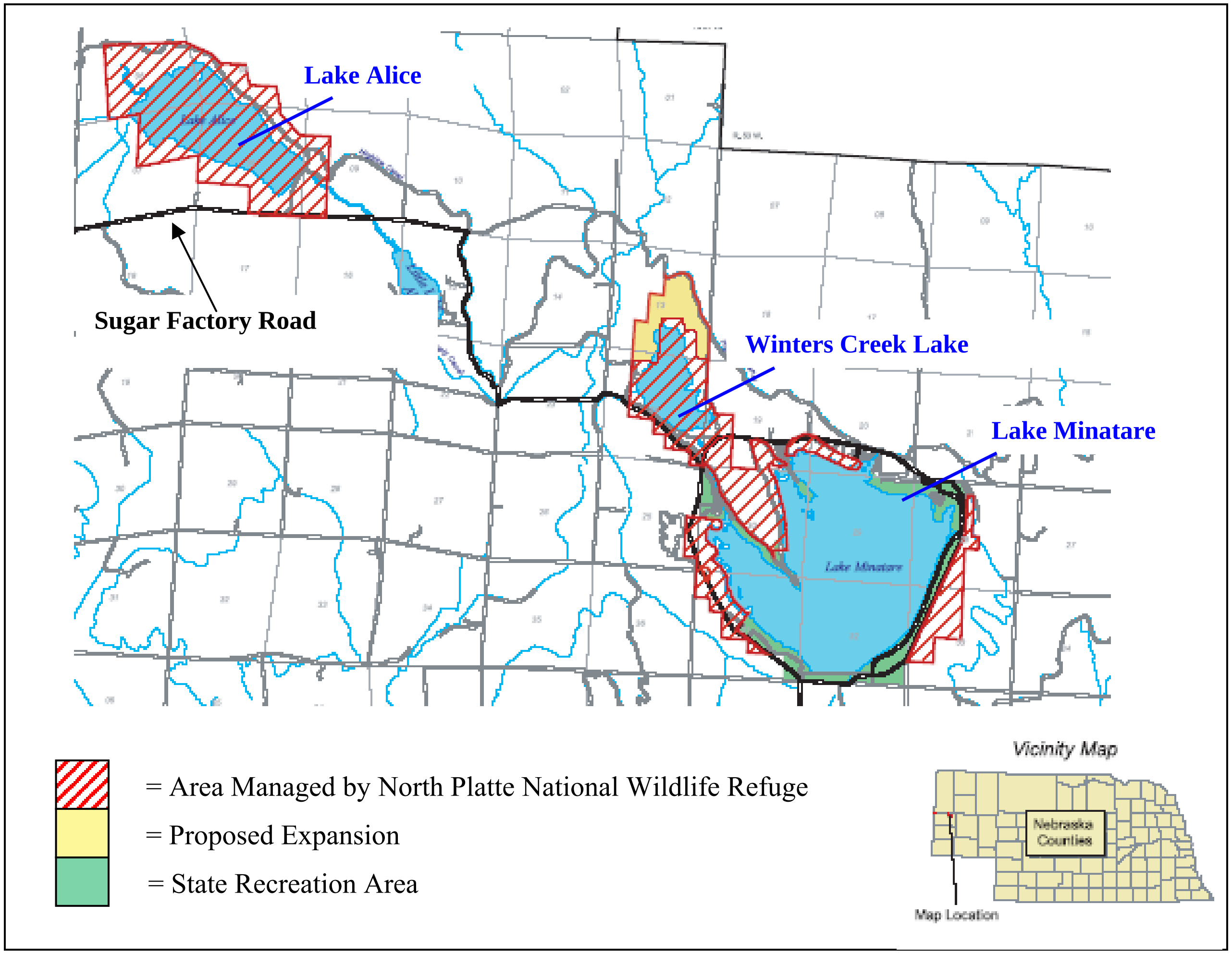

Figure 1. Location of Lake Alice, Lake Minatare, and Winters Creek Lake subunits at North Platte National Wildlife Refuge in Clay County, Nebraska. Note: Map overlay is from USFWS (2001).

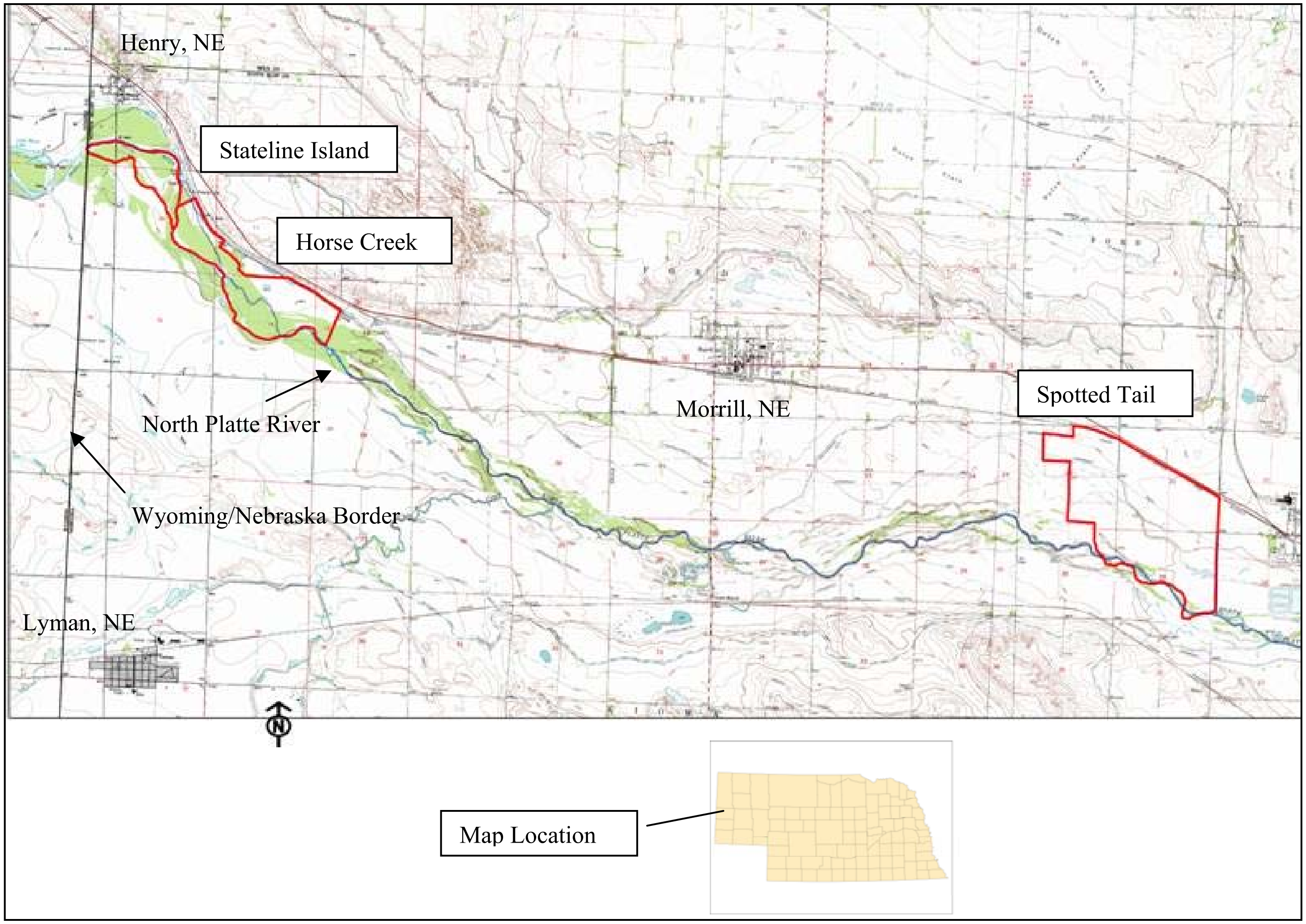

Figure 2. Location of Stateline Island subunit, Horse Creek site, and Spotted Tail site at North Platte National Wildlife Refuge in Scotts Bluff County, Nebraska.

METHODS

Sample Collections

All samples were collected by Service personnel from the Nebraska Ecological Services Field Office (NEFO). Fish were collected by electrofishing in collaboration with staff from the Nebraska Game and Parks Commission and included use of boat, barge and backpack electrofishing equipment. Fish were collected both as individuals and as composite samples of 2 or more fish depending on size and number collected. Aquatic invertebrates for elemental analysis were captured with light traps and a 1 millimeter (mm) mesh sieve bucket. Waterfowl eggs were collected by hand from nest boxes and placed in egg cartons for transfer to the NEFO lab. In the laboratory, intact eggs were washed with distilled water and allowed to dry at room temperature. Volume, length, and mass were measured for each egg in accordance to standard operating procedures (SOPs) developed by the Service's Environmental Contaminants Program in Fairbanks, Alaska (Matz, 2001). Egg contents were transferred into precleaned containers for elemental contaminant analysis by cutting the eggshell at the equator with a clean surgical blade. To measure wood duck eggshell thickness, eggshells were washed with distilled water and the inner shell membrane was removed by gently rubbing. Eggshells were air-dried and thickness was measured to the nearest 0.01 mm with a digital caliper (Model 3415, Control Company, Friendswood, TX). Average eggshell thickness for each egg was determined by taking four measurements near the equator of each half of the egg. All samples for analytical analysis were kept cold in the field and then stored in a freezer at -20 degrees Celsius (^{o}C) at the Refuge or NEFO lab. Samples were stored frozen until shipped to the Analytical Control Facility (ACF), for analytical analysis.

Water Quality

Dissolved oxygen, pH, conductivity and temperature were measured periodically from May 5, 2005 to June 19, 2006 by NEFO personnel (Appendix Tables A.1 and A.2). Water quality was measured at multiple sites within the Stateline, Winters Creek Lake, Lake Alice, and Lake Minatare Refuge subunits (Appendix Figures B.1 – B.4). In 2005, temperature, dissolved oxygen, conductivity (YSI® model 85), and pH (Accument® AP61) were measured from May 4 – July 28. However, the number of sampling occasions was not equal across sites. For example, sample site one at Winters Creek Lake (WC1) was only measured on one occasion in 2005 due to dryness. In 2006, the same parameters were measured at the same four Refuge subunits using an In-Situ® Inc., Troll 9500 water quality multimeter. Water quality sampling in 2006 occurred between April 19 – July 19, with more sampling occasions at Stateline Island than at other refuge subunits. The additional sampling at Stateline Island was in response to results from 2005 that indicated selenium contamination.

Atrazine

Water samples for atrazine analysis were collected in precleaned amber glass containers, immediately cooled on ice and refrigerated until analysis. Atrazine concentrations in water were quantified by Enzyme Linked Immuno Sorbent Assay (ELISA) procedure (RaPID atrazine test kit, Strategic Diagnostics Inc., Newark, DE, USA). In brief, samples were mixed with an enzyme conjugate (enzyme labeled atrazine) followed by paramagnetic particles attached with antibodies specific to atrazine. Atrazine and other related triazine herbicides in the sample compete with the enzyme labeled atrazine for antibody binding sites on the magnetic particles. At the end of a 15 minute incubation period, a magnetic field was applied and unbound reagents were decanted. The presence of atrazine was detected by adding a color reagent. The color developed was quantified by a spectrophotometer (Ohmicron RPA-I™ Photometric Analyzer) and was inversely proportional to the concentration of atrazine in the sample. The range of atrazine detection was 0.05 to 5 micrograms per liter (µg/L). Samples with more than 5 µg/L atrazine were rerun following a 10-fold serial dilution.

Elemental Contaminants

Elemental contaminants were measured in water, sediment, aquatic invertebrate, amphibian, fish, and waterfowl egg samples collected from multiple sites within each refuge subunit (Appendix Table A.3). All samples for elemental contaminant analysis were collected into precleaned certified (PC Class) high density polyethylene plastic containers obtained from Environmental Sampling Supply (http://www.essvial.com/). Sampling equipment was decontaminated between sites by following standard operating procedures developed by the Service. Water samples were collected for total recoverable analysis and were preserved at a pH near 2 using certified clean nitric acid. Sediments were collected by using a cleaned stainless steel spoon. All samples were collected by NEFO personnel and submitted to ACF. Detailed descriptions of lab methods including sample preparation, sample digestion, Quality Assurance/Quality Control (QA/QC) results, and detection limits are provided in ACF catalogs which are available upon request (http://chemistry.fws.gov/). In brief, the analysis of duplicate samples, spiked samples, and standard reference materials generally indicated acceptable levels of precision and accuracy, and limits of detection were within ACF contract requirements (ACF, 2005). For elemental contaminants analyses, all samples were freeze dried, percent moisture was determined, and results were provided as wet weight (ww) and dry weight (dw) concentrations. Inductively coupled plasma atomic emission spectrometry was used to determine concentrations of aluminum (Al), boron (B), barium (Ba), beryllium (Be), cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), magnesium (Mg), manganese (Mn), molybdenum (Mo), nickel (Ni), lead (Pb), strontium (Sr), vanadium (V), and zinc (Zn). Mercury (Hg) concentrations were determined by cold vapor atomic absorption, and graphite furnace atomic absorption was used to measure arsenic (As), selenium (Se), and small concentrations of Pb and Cd.

Selenium Aquatic Hazard Assessment

Risk to aquatic life from exposure to selenium is best evaluated by measuring concentrations of selenium in multiple biotic and abiotic receptors. For this study we measured selenium in water, sediment, benthic invertebrates, amphibians, waterfowl plant food items, whole-body fish, and waterfowl eggs. However, not all of these matrices were tested at all sites. A hazard profile for each component was assigned based on a selenium hazard protocol developed by Lemly (1995). The Lemly (1995) protocol scores the selenium hazard for multiple environmental components (i.e., dissolved water, sediment, benthic invertebrates, fish eggs, and bird eggs) and then provides an overall hazard rating based on the component scores. Gravid fish ovaries were not obtained from Refuge fish; therefore, concentrations of selenium in whole-body fish were converted to fish egg selenium by using a multiplier of 3.3 (Lemly, 1995).

Statistical Analyses

All statistical calculations were performed with JMP® Version 5 software (SAS Institute, 2002). Where means are provided, the "±" refers to a standard error (SE) unless otherwise noted. Data were typically nonparametric; therefore, a Kruskal-Wallis nonparametric one-way analysis of variance was used to test significance among three groups and a Wilcoxon rank sums test was used to test significance between groups. If more than 50 percent of the sample size (n) was above the detection limit for a particular contaminant, then half the detection limit was used in place of those below the detection limit for statistical analyses, unless otherwise noted. If 50 percent or more of the samples were below the detection limit, then results were not analyzed statistically. Use of the term "significant" in this report indicates statistical analysis using a p-value of 0.05.

Data Interpretation

Concentrations of contaminants in samples were compared to literature established benchmarks or toxicity thresholds. Benchmarks developed by the National Oceanic and Atmospheric Administration (NOAA) were used to evaluate elemental contaminant concentrations in water and sediment. Elemental contaminants in fish tissues were evaluated using interpretative guidance by the U.S. Department of Interior (USDOI, 1998) and a database developed by the U.S. Geological Survey (USGS) Biomonitoring of Environmental Status and Trends (BEST) program (http://www.cerc.usgs.gov/data/best/search/).

RESULTS AND DISCUSSION

Raw data for field measurements are in Appendix A or are available from NEFO upon request. For elemental contaminants, raw analytical results for each catalog (see Appendix Table 3) are available from ACF upon request (http://chemistry.fws.gov/).

Water Quality

Mean dissolved oxygen concentrations in water were not significantly different among sites within each Refuge subunit or among subunits. Mean dissolved oxygen for all subunits ranged from 5.5 milligrams per liter (mg/L) at Stateline Island to 16.8 mg/L at Stateline Island (Appendix Table A.4). None of the DO measurements were below Nebraska's water quality standard of 5 mg/L.

Mean water temperature was not significantly different among sites or Refuge subunits and ranged from 5.5 ^{o}C at Winter Creek Lake on April 10, 2006, to 27.5 at Lake Alice on July 19, 2006. Nebraska's water quality standard for temperature (i.e., a maximum of 32 ^{o}C was not exceeded in any of the measurements taken.

With the exception of Stateline Island (SL), there were no significant differences in pH among the sites within each subunit. At SL1, pH was significantly lower than SL2 or SL3. For the Refuge subunits, pH measurements ranged from 6.0 at Stateline Island (site SL4) to 11.6 at Winter Creek Lake (site WC5). The mean pH at Winters Creek Lake was significantly greater than at Lake Minatare or Stateline Island. Lake Alice also had a significantly greater mean pH than Stateline Island. The impoundments at Stateline Island (i.e., sites SL1, SL3, and SL4) had a significantly lower pH than the North Platte River at Stateline Island. Nebraska's water quality standard range for pH (6.5 – 9) was exceeded on 15 occasions total and included readings at all sites but Lake Minatare. The only pH reading below 6.5 occurred on one occasion at SL4 (pH = 6.01). The highest pH readings were at Winters Creek Lake, where pH ranged from 7.1 – 11.6. Nebraska's water quality standard of 9.0 for pH was exceeded on 4 occasions at Lake Alice and 9 occasions at Winters Creek Lake. The higher pH at Winters Creek Lake may be a result of higher primary productivity and is not necessarily a cause for concern. In wetlands, the carbon dioxide fixation by submerged macrophytes and algae during the day can result in pH values greater than 10 (Lewis et al., 1999).

With the exception of Winters Creek Lake, there were no significant differences in conductivity among the sites within each subunit. At Winters Creek Lake, the isolated pond site (WC1) had a significantly greater conductivity than the other sites at Winters Creek Lake or other Refuge subunits. Conductivity at WC1 averaged 3,060 ± 637 microsiemens per centimeter (µS/cm) and exceeded Nebraska's agricultural water quality standard (2,000 µS/cm) in 4 of the 5 samples collected in 2005 and 2006. The main waterbody of Winters Creek Lake also had a significantly greater mean conductivity than Lake Minatare or Lake Alice, and Lake Alice had a significantly lower conductivity than Stateline Island or the North Platte River at Stateline Island. The high conductivity of WC1 is likely a result of its isolation from the main waterbody of Winters Creek Lake. WC1 has a surface water connection with the other sites at WC only during times of high water and was isolated during the sampling occasions in 2005 and 2006.

<u>Atrazine</u>

Atrazine was detected in only 2 of 54 water samples collected from Refuge subunits between May and July, 2005. Both atrazine detections were at very low concentrations (i.e., 0.05 and 0.09 µg/L) that did not approach Nebraska's 12 µg/L chronic aquatic life water quality standard. Eight water samples from Crescent Lake National Wildlife Refuge (NWR), a reference site, were also analyzed for atrazine. Atrazine was detected in 2 of 8 samples from Crescent Lake NWR at 0.08 and 0.13 µg/L. In comparison, atrazine concentrations in 20 water samples from Nebraska's Rainwater Basin that were collected between May and August, 2005, averaged 9.1 ± 2 µg/L and ranged from 0.82 - 33 µg/L. Although the Refuge subunits receive irrigation drainage water, our results indicate that atrazine is not heavily used within the subunits' watersheds. Atrazine is commonly applied to corn and sorghum crops in Nebraska. The most common crops in the study area include wheat and sugar beets, and atrazine is typically not applied to those crops.

Elemental Contaminants

Water. Concentrations of elemental contaminants in water were generally low and frequently below the detection limit (Appendix Tables A.5 and A.6). However, Nebraska aquatic life water quality criteria (NDEQ, 2009) were exceeded for aluminum, cadmium, iron and selenium.

The highest concentrations of total Al were at Lake Minatare and Lake Alice, where they averaged 2,854 ± 857 µg/L and 2,464 ± 1,539 µg/L, respectively. Nebraska's acute aquatic life criterion (750 µg/L) was exceeded in 4 of 5 samples from Lake Alice and 7 of 8 samples from Lake Minatare. Nebraska's chronic aquatic life criterion (87 µg/L) was exceeded in all samples from Lake Alice, 7 of 8 samples from Lake Minatare, and 2 of 5 samples from Winters Creek Lake. The comparison of Al concentrations detected in this study with Nebraska water quality criteria may not accurately evaluate whether wetland plant and invertebrate species are at risk. Total recoverable Al was measured in this study, whereas Nebraska's water quality standard is for dissolved Al. Water samples are filtered before an analysis for dissolved metals, whereas total recoverable analysis includes microorganisms and suspended particulates that are not filtered and can result in higher concentrations. Total recoverable is a more appropriate measurement than dissolved when particulate aluminum is found primarily as aluminum hydroxide particles; however, the total recoverable procedure also measures aluminum bound to clay particles, which might be less toxic than aluminum hydroxide (USEPA, 2002). Aluminum toxicity and bioavailability to aquatic biota is largely dependent on its solubility and generally increases as pH decreases (Gensemer and Playle, 1999). The pH at Lake Alice and Lake Minatare averaged 8.8 and 8.4, respectively. Aluminum bioavailability and toxicity to aquatic species at Lake Alice and Lake Minatare are not a concern based on the relatively high pH at these sites.

Concentrations of cadmium exceeded Nebraska's chronic aquatic life criterion of 0.25 µg/L at all four Refuge subunits. However, the criterion is based on dissolved concentrations of cadmium and not total recoverable concentrations. For total recoverable cadmium, concentrations should not exceed 1.5 and 3.0 µg/L at a water hardness of 50 and 100 mg/L, respectively (Eisler, 1985). Total recoverable concentrations of cadmium did not exceed 1 ug/L in any of the samples from the Refuge and is not a concern for aquatic life.

Selenium exceeded Nebraska's chronic aquatic life water quality criterion (5.0 µg/L total recoverable concentration) in one sample (9.7 µg/L) from Stateline Island and one sample from Little Lake Alice (24 µg/L). In addition, concentrations of selenium in surface waters at Stateline Island, Lake Alice and Lake Minatare frequently exceeded a 2 µg/L total recoverable selenium threshold for bioaccumulation and reproductive failure for fish and wildlife (Lemly, 1996; USDOI, 1998) (Appendix Tables A.5 and A.6). Fifteen water samples from Winters Creek Lake all had selenium concentrations less than 2 µg/L.

It is unclear why concentrations of selenium were consistently lower at Winters Creek Lake but it may be a result of the site's hydrology and biological activity. Winters Creek Lake provides wetland habitat whereas the lakes and ponds sampled at the other Refuge subunits function more as permanent waterbodies. The dry and wet cycles at Winters Creek Lake may reduce waterborne selenium concentrations by increasing selenium volatilization (USGS, 2003). Wetlands also typically have high biological productivity and increased biological uptake can result in lower waterborne selenium concentrations (Ohlendorf, 2003).

Sediments. A total of 72 and 54 sediment samples were analyzed for selenium and other routine elemental contaminants, respectively (Appendix Tables A.7 and A.8). At Lake Alice, Lake Minatare, and Winters Creek Lake, mean concentrations of elemental contaminants in sediments were below or near background concentrations and did not exceed toxicity benchmarks (Appendix Table A.9). Concentrations of elemental contaminants were also generally near background at Stateline Island, Horse Creek, and Spotted Tail, with a few exceptions for arsenic, cadmium, selenium, and strontium. (Appendix Table A.10.)

Concentrations of arsenic in sediment were above background at all three Platte River subunit sites but did not exceed any toxicity benchmarks (Appendix Table A.8). Cadmium and copper were only elevated at Stateline Island where they exceeded the Threshold Effect Concentration (TEC), a concentration below which adverse effects are not expected to occur (McDonald et. al., 2000). However, concentrations of cadmium and copper did not exceed the Probable Effect Concentration (PEC), above which adverse effects are expected to occur more often than not (McDonald et. al., 2000) (Appendix Table A.8). Concentrations of strontium were elevated above background (49 mg/kg) at all sites but were greatest at Winters Creek Lake, Stateline Island, Horse Creek and Spotted Tail with a maximum concentration of 858 mg/kg dw at SL4. In comparison, average concentrations of strontium in sediment at two locations along the North Platte River near Casper, Wyoming, were 63 and 84 mg/kg dw (Custer et al., 2001). We did not find sediment based toxicity thresholds for strontium in the literature to evaluate potential toxicity; however, strontium exposure may be associated with decreased hatching success in passerines (Mora, 2003). Synthesis of data from the National Irrigation Water Quality Program (Seiler et al., 2003) indicates that strontium is strongly associated with selenium and high concentrations at the sites may be due to seepage from naturally high levels in the soil or reused agricultural water.

Mean concentrations of selenium exceeded an ecological sediment guideline of 2 mg/kg dw (Seiler et al., 2003) at Stateline Island and Horse Creek (Figure 3). The mean concentration of selenium at Stateline Island (9.6 ± 2.1mg/kg) was significantly greater than at Horse Creek, Spotted tail, and Winters Creek Lake and also exceeded a 4 mg/kg toxicity guideline at which adverse effects to some fish and wildlife species may occur (USDOI, 1998). Concentrations of selenium in sediments at Stateline Island were greater at the water impoundment sampling locations (i.e., SL1, SL3, SL4,) than at the stream site (SL2) or North Platte River. Selenium concentrations at Horse Creek and Spotted Tail showed a similar response, with the highest selenium concentrations at the terminal end of the pools (See Appendix Figures B.5 and B.6).

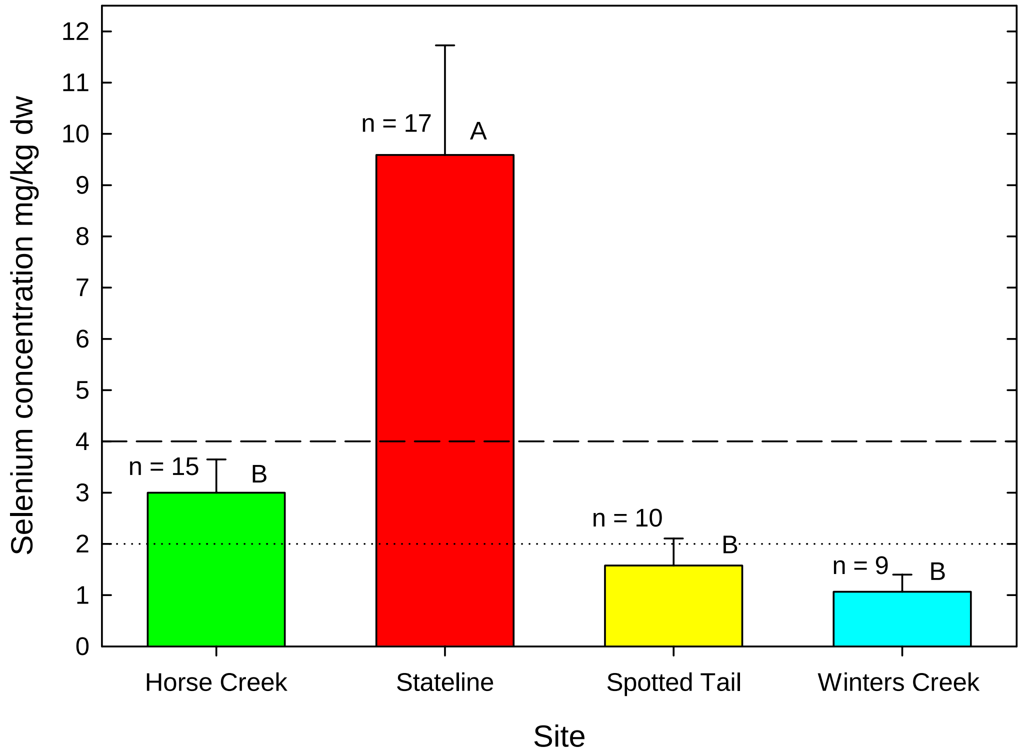

Figure 3. Mean concentrations of selenium in sediment from North Platte National Wildlife Refuge subunit sites, Scotts Bluff County, Nebraska, 2006 and 2007.

Note: n = sample size, letters above each bar indicate significant differences ($p < 0.05$) as determined by a Kruskal -Wallis test followed by pairwise Wilcoxon rank sums tests. Reference lines are for a 2 mg/kg ecological sediment guideline (Seiler et al., 2003) and a 4 mg/kg toxicity guideline at which adverse effects to some fish and wildlife species may occur (USDOI, 1998).

Vegetation. Waterfowl plant food items were only found in abundance at the Winters Creek Lake subunit. A total of 5 composite samples of seeds from standing smartweed (*Polygonum* sp) were analyzed from Winters Creek Lake in July, 2005 (Appendix Table A.11). Concentrations of arsenic, beryllium, cadmium, chromium, lead, molybdenum and vanadium were below detection limits in all samples. Concentrations of selenium in seeds averaged 1.1 ± 0.25 mg/kg dw and all samples were within a 0.1 – 2.0 mg/kg dw background range for freshwater macrophytes, (Appendix Table A.12) (USDOI, 1998).

Aquatic Invertebrates. Aquatic invertebrates were not available in sufficient numbers for elemental contaminant analysis at Lake Alice or Lake Minatare. Our observations indicate that Lake Alice and Lake Minatare provide loafing habitat for waterfowl but may not be important as feeding areas. Aquatic invertebrates were readily available as waterfowl food items at Winters Creek Lake and Stateline Island. A total of 10 composite aquatic invertebrate samples, 6 at Stateline Island and 4 at Winters Creek Lake, were collected in 2006 for analytical analysis (Appendix Table A13).

Differences in sampling method success resulted in differences in aquatic invertebrate species sampled from each subunit. Light traps were used at both sites but worked better at Stateline Island by catching predominately water boatman (Coroxidae). At Winters Creek Lake there appeared to be fewer Coroxidae and instead of using light traps, dragonfly larvae were opportunistically collected when trammel nets were set to collect fish.

Concentrations of elemental contaminants at Winters Creek Lake and Stateline Island were below all known dietary toxicity thresholds for waterfowl, with the exception selenium. Concentrations of selenium in aquatic invertebrates averaged 10 ± 2 at Stateline Island and 6 ± 2 mg/kg at Winters Creek Lake and at both sites exceeded a 3 – 8 mg/kg dietary benchmark for reproductive impairment in birds (USDOI, 1998). Selenium concentrations were greatest at two samples from the SL1 pond at Stateline Island (i.e., 15 and 13 mg/kg selenium) and were within a dietary 10 – 15 mg/kg dw selenium toxicity threshold range for nonbreeding birds exposed to winter-stress (USDOI, 1998).

Amphibians. Amphibians were too scarce for sampling at many of the Refuge subunits and only four composite whole-body tadpole samples were collected in 2006 for elemental analysis (Appendix Table A14). Species sampled included bullfrogs (*Rana catesbeiana*) from Horse Creek and Stateline Island, Woodhouse's toad (*Bufo woodhousii*) from Lake Alice and tiger salamander (*Ambystoma* sp) from Winters Creek Lake. Concentrations of selenium in amphibian samples exceeded expected background limits of 1 – 3 mg/kg dw (USDOI, 1998) in samples from all sites except Lake Alice. Bullfrogs from Stateline Island and Horse Creek had the highest concentrations of selenium at 16 and 8.8 mg/kg, respectively. Concentrations of selenium in amphibians did not exceed a presumptive amphibian adverse effects threshold of 20 mg/kg (USDOI, 1998). However, amphibians from Horse Creek, Stateline Island and Winters Creek Lake had concentrations of selenium within or above a 3 – 8 mg/kg dietary benchmark range for reproductive impairment in birds and may present a detrimental exposure pathway to avian species that feed on them (USDOI, 1998).

Fish. Forty whole-fish samples, comprised of both individual and composite samples, were analyzed for elemental contaminants (Appendix Tables A.15 - A.19). Fish analyzed included common carp (*Cyprinus carpio*), white sucker (*Catostomus commersoni*), creek chub (*Semotilus atromaculatus*), green sunfish (*Lepomis cyanellus*), and channel catfish (*Ictalurus punctatus*). Carp from the Refuge had concentrations of cadmium, selenium, and zinc that exceeded the 85th percentile concentration for carp as determined by a national fish tissue monitoring program (Schmitt and Brumbaugh, 1990) (Appendix Table A.19). The mean concentration of cadmium in carp from the North Platte River (0.39 mg/kg ww) was 4 times greater than in carp collected by the USGS BEST program (http://www.cerc.usgs.gov/data/best/search/) but did not exceed a 2 mg/kg benchmark for probable cadmium contamination (Appendix Table A.19). Concentrations of selenium in fish were frequently above known toxicity thresholds for protecting wildlife and human health (Appendix Table A.19). Fish from all sites sampled had tissue concentrations of selenium above the 4.0 µg/g dw effects threshold for protecting fish health and reproduction (Lemly, 1996; USDOI, 1998) (Table A.18). Twenty-nine of the 40 fish sampled also had concentrations of selenium above a 2 mg/kg ww human health advisory concentration for no consumption by children and pregnant women (Fan et al, 1988). Selenium in common carp from the North Platte River site averaged 26 ± 3 ug/L and was significantly greater than those from Lake Minatare and Lake Alice (Figure 4). The highest concentration of selenium in whole-body fish (563 mg/kg) was for a white sucker collected at Stateline Island and was an anomaly for the site. Concentrations of selenium in other fish samples from Stateline Island ranged from 8 – 17 mg/kg. Furthermore, the QA/QC report for the analysis of this sample (i.e., ACF catalog 6050129) indicated that recovery of selenium from the standard reference material (134 percent) was outside the normal range and results may be biased high. Previous fish samples analyzed (i.e., ACF catalog 6050120) had standard reference material results were within normal limits.

Concentrations of selenium in fish reported in the current study are similar to those reported for the area previously but may be increasing. A survey by the Service in 1993 (Schwarz et al., 2005) reported selenium concentrations in single carp composite samples of 7.3 and 11.5 mg/kg for Lake Minatare and Lake Alice, respectively. In the current study, concentrations of selenium in carp from Lake Minatare and Lake Alice ranged from 8 – 11 mg/kg and 13 – 17 mg/kg, respectively. An irrigation drainage water quality survey conducted near the Refuge in 1995 (Druliner et al., 1999) reported that selenium concentrations in thirteen composite samples of various fish species ranged from 2.7 - 7 mg/kg dw, and eight samples (62 percent) had concentrations of selenium above the 4.0 mg/kg level of concern. For all the fish sampled in the current study, 36 of 40 (90 percent) had a selenium concentration above 4.0 mg/kg.

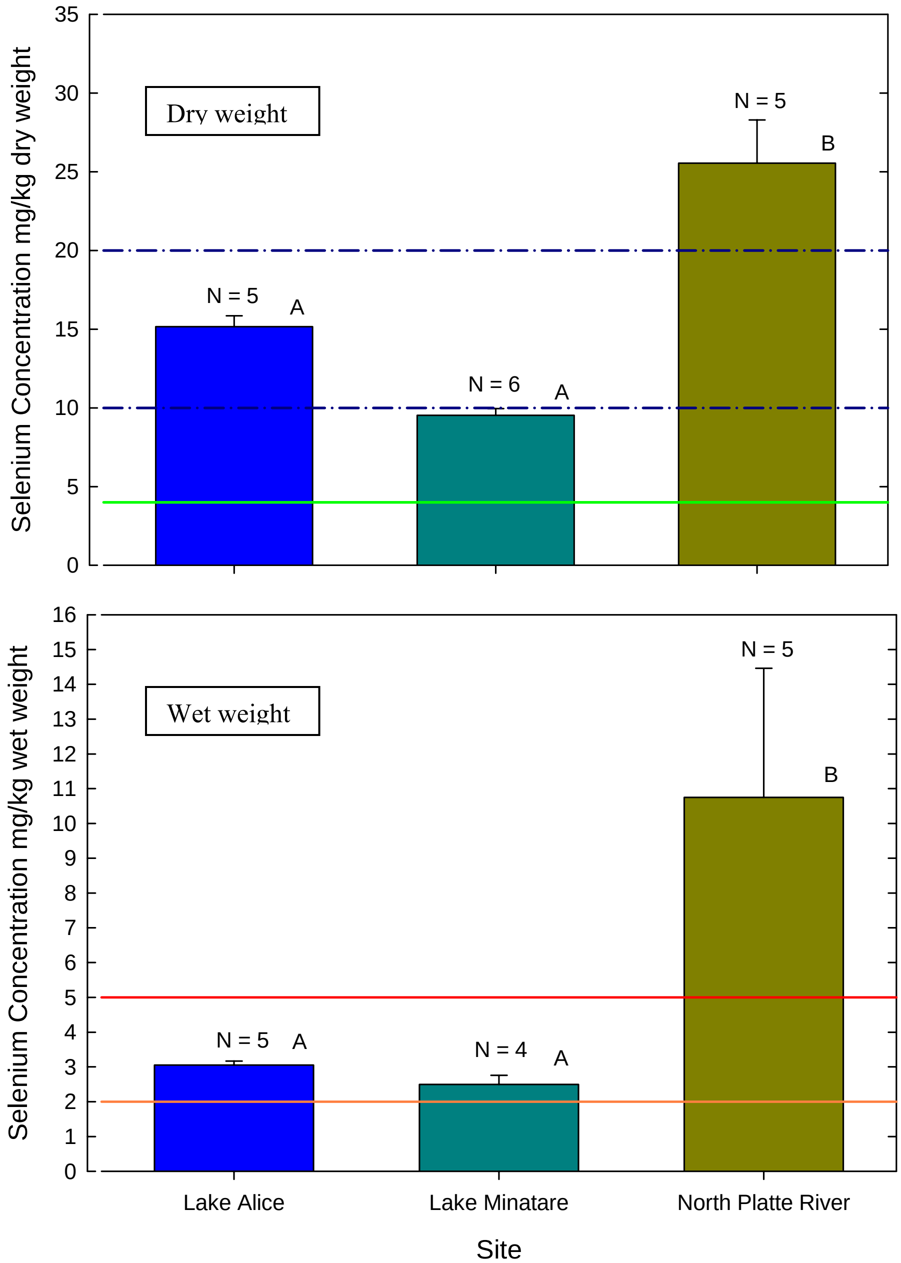

Figure 4. Mean ± SE dry weight and wet weight concentrations of selenium in common carp from North Platte National Wildlife Refuge subunit sites, Scotts Bluff County, Nebraska, 2006 and 2007.

Note: n = sample size, letters above each bar indicate significant differences ($p < 0.05$) as determined by a Kruskal -Wallis test followed by pairwise Wilcoxon rank sums tests. Horizontal reference lines for dry weight are for a 4.0 µg/g effects threshold for protecting fish health and reproduction (Lemly, 1996) and a 10 – 20 µg/g range for fish teratogenesis (USDOI, 1998). Reference lines for wet weight are for a 2 mg/kg human health advisory concentration for no consumption by children and pregnant women (Fan et al, 1988) and a 5 mg/kg recommended complete ban on human consumption (USDOI, 1998).

Waterfowl Eggs. A total of 42 wood duck (*Aix sponsa*) and 15 Canada goose (*Branta Canadensis*) eggs were collected between 2005 and 2007 for analysis of elemental contaminants (Appendix Tables A.20 and A.21). Wood duck eggs were collected in 2005 and 2006 from Lake Minatare (n = 26) and Lake Alice (n = 16). No eggs were collected from wood duck nest boxes at Stateline Island (n = 5) or Winters Creek Lake (n = 12). Drought conditions may have resulted in the lack of nest box use at Winters Creek Lake as Refuge records indicate previous wood duck use in 2002 and the late 1990s. At Stateline Island, only plastic wood duck nest boxes were available in 2005 and plastic wood duck nest boxes have not been productive at any of the Refuge subunits (Brad McKinney, Refuge Manager, pers. comm., 2006). Twelve new wooden nest boxes of the same design successfully used at Lake Minatare were placed at Stateline Island in 2006 but were also not successful, possibly indicating an abundance of natural habitat. Canada goose eggs were collected only from goose nest boxes at Winters Creek Lake in 2007.

Elemental contaminants of concern in wood duck and Canada goose eggs from North Platte NWR include strontium and selenium. Concentrations of selenium in wood duck eggs at Lake Alice and Lake Minatare averaged 5.9 ± 0.6 and 6.4 ± 0.3 mg/kg dw, respectively (Appendix Table A.20). There were no significant differences in selenium concentrations among wood duck nest boxes. Concentrations of selenium in 20 of 42 eggs exceeded a 6 mg/kg dw toxicity threshold for reduced hatchability (Seiler et al., 2003) and 30 of 42 eggs exceeded a 3 – 5 mg/kg dw natural background range (USDOI, 1998). Selenium concentrations in goose eggs were lower than in wood duck eggs and averaged 2.6 mg/kg dw and ranged from 1.6 – 3.8 mg/kg dw (Appendix Table A.21). In comparison, concentrations of selenium in Canada goose eggs (n = 29) collected from a selenium contaminated site (i.e., Rasmus Lee Lake near the town of Casper, Wyoming), averaged 7.7 mg/kg and ranged from 3.8 – 29.9 mg/kg (Ramirez and Dickerson, 1999).

Concentrations of strontium in wood duck eggs at Lake Alice and Lake Minatare averaged 81 ± 38 and 186 ± 82 micrograms per gram (μg/g), respectively (Appendix Table A.20). These concentrations are among the highest reported in avian eggs according to the Service's Environmental Contaminants Data Management System

(Christopher Latty, Service Contaminants Specialist, pers. comm., 2010). Strontium concentrations in Canada goose eggs (n = 15) from Winters Creek Lake were much lower with a mean of 12 ± 2 mg/kg and a range of 6 to 31 mg/kg. However, strontium concentrations in both wood duck and Canada goose eggs from North Platte NWR are high compared to background concentrations reported elsewhere. Background concentrations of strontium in eggs of colonial waterbirds nesting on the National Audubon Sanctuary Islands of the lower Laguna Madre, Texas, ranged from 0.75 - 1.9 μg/g (Mora, 1996). Mean concentrations of strontium in eggs reported in the literature as elevated in waterbirds ranged from 14 - 23 μg/g for tree swallows and wrens in Wyoming (Custer et al., 2001) and from 23 - 30 μg/g for common eiders in Alaska (Franson et al., 2004).

Eggshell thickness was measured in 34 wood duck eggs from Lake Alice and Lake Minatare (Appendix Table A. 22). Wood duck eggshell thickness was not significantly different between sites and averaged 0.28 ± 0.004 mm and ranged from 0.23 - 0.34 mm. In our study there was no significant correlation between the concentration of strontium and eggshell thickness.

Some previous studies have reported a significant inverse relationship between strontium concentration and avian eggshell thickness (Weber et al 1973; Matz and Rocque, 2007), whereas others have found no relationship (Mora, 2003; Mora et al., 2007). Strontium in Lesser Scaup (*Aythya affinis*) eggs (n = 10) averaged 10.90 mg/kg dw and was significantly negatively correlated with eggshell thickness (Matz and Rocque, 2007). Eggshell thickness of the Lesser Scaup eggs was 18 percent lower than in museum specimens, a percentage associated with population declines in other species, and was not correlated with other contaminants (Matz and Rocque, 2007). Mean concentrations of strontium in eggs from eleven passerine bird species in Arizona ranged from 3.2 ± 1.8 to 224 ± 173 μg/g dw and were not significantly correlated with eggshell thickness for any species (Mora, 2003; Mora et al., 2007). However, the authors concluded that high eggshell concentrations of strontium could affect later-stage embryos by possible interference with calcium metabolism and bone growth, possibly resulting in reduced hatching success and potential minor beak deformities (Mora et al., 2007).

Previous studies indicate that dietary exposure to strontium may result in adverse reproductive effects to avian species (Ridgway and Karnofsky, 1952; Mraz et al., 1967; Mora et al., 2007). Strontium is likely mobilized from the bone along with calcium and deposited into the egg during egg formation (Braune and Simon, 2004). High concentrations of strontium may interfere with the calcium transport from the eggshell to the embryo and could result in increased egg breakage, decreased hatching success, and deformities related to insufficient transport of Ca for bone formation (Ridgway and Karnofsky, 1952; Mraz et al., 1967; Mora et al., 2007).

Higher concentrations of strontium in wood duck eggs than Canada goose eggs from the Refuge are likely due to differences in dietary exposure. Wood ducks consume a variety of plant and animal foods typically by feeding from the water surface with subsurface and bottom feeding occurring rarely (Dugger and Fredrickson, 1992). The typical diet of adult female wood ducks during egg laying is comprised of 80 percent invertebrates to meet daily protein needs during egg laying and changes to nearly 100 percent of plant foods (e.g., acorns) during the winter (Dugger and Fredrickson, 1992). Dietary exposure of strontium to wood ducks in the study area may include aquatic invertebrates food items and incidental ingestion of sediments. Study results indicate that strontium is elevated in both invertebrates and sediments. Canada geese in the area likely feed more on terrestrial grasses and corn which may contain lower concentrations of strontium. Differences in egg strontium concentrations as a result of diet have been suggested elsewhere (Franson et al., 2004). Concentrations of strontium in eggs were about 10 times higher in common eiders (*Somateria mollissima*) feeding on invertebrates than in eggs of lesser snow geese (*Anser caerulescens*) feeding on vegetation (Franson et al., 2004).

Nest boxes at Lake Minatare and Lake Alice provided nesting habitat for wood ducks and other species; however, most of the wood duck eggs recovered from the nest boxes were addled and 25 of 49 eggs collected were fertile but never hatched. During the study, there were no observations of broods near any of the nest boxes and no indication that nest boxes produced any viable ducklings. Poor habitat conditions from drought may be partially to blame for the nesting failures observed during this study. Nest box monitoring results for the Refuge prior to this study indicate that wood duck nest box use was greater and more widespread in the mid 1990s during non-drought conditions. Previous monitoring data by the Refuge and the results of this study also indicate that many of the wood duck eggs found in nest boxes do not hatch. Reduced hatchability of wood duck eggs may be a result of exposure to strontium and/or selenium.

Selenium Aquatic Hazard Assessment

The aquatic hazard to Refuge fish and wildlife from exposure to selenium ranges from moderate to high, depending on the subunit (Table 1). Lake Alice and Lake Minatare had moderate hazard ratings with the majority of risk attributed to fish data. Fish sampled from these reservoirs may have received the majority of their exposure to selenium in the North Platte River. Therefore, the moderate rating for the reservoirs may not accurately relate selenium risk to other biotic receptors. Selenium hazards to biota at Stateline Island and Winters Creek Lake were high and are of concern.

Stateline Island had high hazard scores for all of the components analyzed and adverse effects to biota are likely occurring. Groundwater seepage into SL4 was observed and may be an important source of selenium to the State Island ponds. More study is needed to evaluate whether or not selenium accumulation at Stateline Island is attributed to a deep groundwater source or bank infiltration of North Platte River water.

Component scores for Winters Creek Lake were high for invertebrates and fish but low to minimal for water, sediments, plant food items and Canada goose eggs. Only one composite sample of fish minnows was available for the selenium assessment of Winters Creek Lake as the waterbody was mostly dry for two years prior to sampling. In past years, Winters Creek Lake provided good recreational fishing for perch and other species and future assessments should include a more robust analysis of adult fish. The assessment for Winters Creek Lake would also have been more robust had wood ducks used nest boxes on site. Refuge records indicate that nest boxes at Winters Creek Lake have been successful in the past. Observations indicate that wood ducks utilize Winters Creek Lake and Stateline Island and future assessments should try to include use of nest boxes and nest searches to obtain wood duck eggs for selenium analysis.

Table 1. Aquatic hazard assessment of selenium at North Platte National Wildlife Refuge subunits, Scotts Bluff County, Nebraska, 2005 - 2007.

	Evaluation by component					Site Totals	
Refuge Subunit	Component	Sample Size	Maximum Selenium Concentration	Score	Hazard	Total Site Score	Site Hazard Rating
Lake Alice	Water	6	2.6 ug/L	3	low		
	Sediment	5	0.6 mg/kg	1	none		
	Bird eggs	16	9.8 mg/kg	3	low		
	Fish whole-body to eggs	5	17 X 3.3 = 56.1 mg/kg	5	high	12	Low - Moderate
Lake Minatare	Water	13	3.6 ug/L	4	moderate		
	Sediment	7	1 mg/kg	2	minimal		
	Bird eggs	26	9.7 mg/kg	3	low		
	Fish whole-body to eggs	16	11 X 3.3 = 36.3 mg/kg	5	high	14	Low - Moderate
Stateline Island	Water	11	9.7 ug/L	5	high		
	Sediment	17	34 mg/kg	5	high		
	Invertebrate	6	15 mg/kg	5	high		
	Fish whole-body to eggs	7	17 X 3.3 = 56.1 mg/kg	5	high	20	High
Winters Creek Lake	Water	15	1.6 ug/L	2	minimal		
	Sediment	9	2.9 mg/L	3	low		
	Invertebrate	4	8.3 mg/kg	5	high		
	Plants: waterfowl food	5	1.5 mg/kg	2	minimal		
	Bird eggs	15	3.8 mg/kg	2	minimal		
	Fish whole-body to eggs	1	9 X 3.3 = 29.7 mg/kg	5	high	19	High

Note: Component hazard scores were determined by comparing concentrations of selenium to hazard profiles in Figures 1 - 5 of Lemly (1995). Site Hazard Ratings were based on the following criteria by Lemly (1995) that depend on the number of evaluation criteria available. Sites with four evaluation criteria (i.e., Lake Alice, Lake Minatare and Stateline Island) had the following scoring: less than 4 = no hazard, 5 - 7 = minimal hazard, 8 - 10 = low hazard, 11 - 14 = moderate hazard, 15 - 20 = high hazard. Winters Creek Lake had more than 6 evaluation criteria and was scored as follows: less than 5 = no hazard, 6 - 8 = minimal hazard, 9 - 11 = low hazard, 12 - 15 = moderate hazard, 15 - 25 = high hazard). For water, total recoverable selenium was used instead of dissolved selenium and may bias high the site hazard rating for Lake Alice and Lake Minatare, thus site hazard range is provided. The overall site hazard ratings for Stateline Island and Winters Creek Lake are unaffected by the hazard score for water.

Recommendations

Management actions are needed to reduce the exposure of selenium and strontium to aquatic wildlife on the Refuge, especially at sites that include wetlands or isolated ponds such as Winters Creek Lake and Stateline Island. Strategies to reduce selenium exposure to Refuge habitats include introducing water sources that are low in selenium and reducing selenium concentrations in the existing water source. A combination of both strategies may be needed and should be further evaluated. For example, pumping groundwater into Winters Creek Lake may reduce waterborne selenium concentrations; but removal of selenium from sediments and biota may require technologies to reduce selenium. There are many technologies to reduce selenium loading in agricultural drainage water including physical, chemical, and biological methods (Frankenberger et al., 2004). Techniques that may be most economically practical for the Refuge include volatilization, phytoremediation and use of constructed wetlands.

Volatilization is a naturally occurring component of selenium cycling in the environment and is a primary mechanism of removing selenium out of water and sediments (Frankenberger et al., 2004). The lower sediment concentrations of selenium at Winters Creek Lake compared to impoundments at Stateline Island may be due to drying and flooding. Others have focused on increased volatilization to remove selenium from surface waters (Lin and Terry, 2003; USGS, 2003; Frankenberger et al., 2004). At Stewart Lake, Utah, annual flooding and drying cycles were initiated in 1997 to increase volatilization of selenium and to discharge oxidized selenium to the Green River (USGS, 2003). However, the flood and drain cycle at Stewart Lake has not been effective in reducing sediment concentrations of selenium to a remediation goal of 4 mg/kg dw and additional efforts such as the use of soil amendments and source removal are needed (USGS, 2003).

Plants can remove selenium by biological uptake and accumulation in plant tissues in addition to volatilization. Rhizofiltration occurs when plants (primarily their root systems) absorb selenium from soil and water and then translocate the selenium to stems and leaves. Selenium can then be removed by phytoextraction, the process of harvesting plant parts that have accumulated selenium for disposal. Indian mustard and other *Brassica* species have a high capacity to both volatilize and bioaccumulate selenium and has been used to reduce selenium levels in agricultural soil (USDA, 1996; Frankenberger et al., 2004).

Constructed wetlands have been used to treat wastewater from municipalities and agricultural runoff at many sites across Europe and the USA; however, their use to treat selenium contamination needs further study (Frankenberger et al., 2004). Mechanisms for selenium removal by constructed wetlands include reduction of selenium to insoluble forms that are then trapped in sediments, accumulation by plants, and volatilization to the atmosphere (Frankenberger et al., 2004). A concern with the use of constructed wetland systems in selenium treatment is the potential to produce harmful habitat for aquatic life and this concern should be addressed through proper design, operation, and maintenance.

The selenium remediation methods discussed above should be further evaluated to develop a strategy to reduce selenium exposure and effects to Refuge biota. It is recommended that the impoundments at Stateline Island be converted into flow-through wetlands that could be manipulated to allow for flooding and drying cycles. Allowing for the impoundments to be dried and flushed could reduce selenium from becoming trapped on the Refuge. Ducks Unlimited recently added water control structures to restore flow-through wetland meadow habitat at the Spotted Tail site (Steve Donovan, Manager of Conservation Programs, Ducks Unlimited, pers. comm., 2010). Post restoration monitoring at Spotted Tail is recommended to evaluate whether or not restoration efforts have reduced selenium in sediments, water and biota compared to previous sediment data and data from Stateline Island.

If converting the impoundments into flow-through wetlands is not enough to reduce selenium exposure, then a tiered approach using constructed wetlands may be needed. For example, a subsurface flow constructed wetland could be designed to accumulate selenium in thick stands of bulrush and cattails which would be periodically dried and the vegetation harvested for proper disposal. Surface flow or subsurface flow wetland cells could be used as water enters the property with outflows to wetlands designed more for habitat. Funding for selenium remediation at the Refuge may be acquired by submitting a Refuge Cleanup Project Proposal to develop and implement a restoration plan. Post restoration monitoring to evaluate the effectiveness of decreasing selenium accumulation in the food chain should be included in the restoration plan.

Drought conditions did not allow for an adequate assessment of wood duck hatchability or survival to fledge. However, study results indicate that concentrations of selenium in wood duck eggs may be resulting in decreased hatchability. Wood duck nesting should be further evaluated during years with favorable nesting conditions to evaluate hatchability and brood success. If hatching success is determined to be a result of exposure to selenium, then the source of selenium should be thoroughly investigated and means to reduce selenium exposure and effects should be implemented. Further study should include an analysis of wood duck diet to determine potential sources of selenium and could include use of radio telemetry to identify feeding areas. If wood duck nesting is not further evaluated then the Refuge should consider removing the nest boxes to avoid attracting birds to an environment that is potentially not conducive to successful reproduction.

Winters Creek Lake did not contain adult game fish for sampling during the time of this study. However, if recreational fishing returns to Winters Creek Lake, then concentrations of selenium in adult game fish fillets should be determined to evaluate whether or not human health advisories are needed. Potential human health advisory concentrations include a 2 mg/kg ww no consumption by children and pregnant women (Fan et al, 1988) and a 5 mg/kg ww recommended complete ban on human consumption (USDOI, 1998).

Conclusions

This study evaluated selenium and atrazine exposure and effects to fish, amphibians, and waterfowl at the Refuge. Refuge biota exposure to selenium was evaluated by measuring concentrations of selenium in Refuge sediments, water, whole body fish, waterfowl food items (invertebrates and plants) and wood duck eggs. Water samples from the four Refuge subunits were measured for atrazine, pH, temperature, dissolved oxygen, and conductivity.

Water quality was generally similar among Refuge subunits with an exception of higher pH and conductivity at Winters Creek Lake. Atrazine was detected in only 2 of 54 water samples collected from the Refuge and at concentrations well below Nebraska's 12 ug/L chronic aquatic life water quality standard. Water quality parameters measured during this study were within normal limits and are not of concern.

Elemental contaminants of concern include selenium and strontium. Concentrations of selenium at the Refuge exceeded toxicity thresholds and/or recommended guidelines in water, sediment, invertebrates, whole-body fish and wood duck eggs. An aquatic hazard assessment of selenium indicates a high risk to Refuge biota at Winters Creek Lake and Stateline Island and a moderate risk at Lake Alice and Lake Minatare. Concentrations of strontium were elevated in wood duck eggs, invertebrates, and sediments and may be resulting in decreased wood duck hatchability. However, we found no relationship between strontium concentrations and eggshell thickness, as reported by others. Wood duck nesting should be further evaluated during years with favorable nesting conditions to evaluate hatchability and brood success. Concentrations of selenium in adult game fish from Winters Creek Lake may also need to be measured to identify risk to human health from fish consumption.

Management actions are recommended to reduce the exposure of selenium and strontium to aquatic wildlife on the Refuge, especially at sites that include wetlands or isolated ponds such as Winters Creek Lake and Stateline Island. It is recommended that funding be sought to characterize selenium sources (i.e., soil deposits in groundwater or infiltration of river water) and design and implement selenium removal techniques that are most economically practical for the Refuge. Such techniques include use of water control structures to manipulate flood and drain cycles, and vegetation management to increase selenium volatilization and phytoremediation. Constructed wetlands designed to remove selenium and limit exposure to waterfowl and birds may be needed to treat water prior to use in habitat wetlands for waterfowl and fish. Post restoration monitoring at

Spotted Tail is also recommended to evaluate whether or not restoration and development of a flow-through wetland system decreases selenium concentrations in sediment and biota.

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APPENDIX A: ADDITIONAL TABLES

Table A.1. Measurements of water temperature, pH, dissolved oxygen, and conductivity from North Platte Refuge Subunits, Scotts Bluff County, Nebraska, 2005.

Refuge Subunit	Site	Lat	Long	Collection Date M/D/YYYY	Time	Temp. (°C)	pH	Disolved Oxygen (mg/L)	Actual Conductivity (µs/cm)
Lake Alice	LA1	41.985364°	-103.597960°	6/9/2005	8:55	17.9	8.4	5.6	661
Lake Alice	LA1	41.985364°	-103.597960°	7/6/2005	18:08	25.9	8.5	NC	NC
Lake Alice	LA2	41.985364°	-103.597960°	7/6/2005	18:27	23.5	8.5	NC	NC
Lake Minatare	LM1	41.937573°	-103.503176°	5/5/2005	14:27	14.0	8.7	10.7	606
Lake Minatare	LM3	41.920109°	-103.487958°	5/5/2005	13:52	20.0	8.4	13.2	680
Lake Minatare	LM1	41.937573°	-103.503176°	5/20/2005	9:20	19.6	8.6	NC	NC
Lake Minatare	LM2	41.935711°	-103.511468°	5/20/2005	8:30	18.1	8.4	6.1	679
Lake Minatare	LM3	41.920109°	-103.487958°	5/20/2005	10:20	22.3	8.5	NC	NC
Lake Minatare	LM1	41.937573°	-103.503176°	6/8/2005	16:32	18.7	8.6	9.4	659
Lake Minatare	LM2	41.935711°	-103.511468°	6/8/2005	15:11	19.7	8.6	9.7	681
Lake Minatare	LM1	41.937573°	-103.503176°	7/6/2005	17:25	25.5	8.5	NC	NC
Lake Minatare	LM2	41.935711°	-103.511468°	7/6/2005	7:12	22.1	8.6	NC	NC
Stateline Island	SL1	41.989375°	-104.049850°	5/4/2005	13:59	22.0	8.8	11.0	750
Stateline Island	SL2	41.988545°	-104.043466°	5/4/2005	16:44	16.5	8.5	9.2	742
Stateline Island	SL1	41.989375°	-104.049850°	5/19/2005	15:00	25.8	8.2	5.5	801
Stateline Island	SL2	41.988545°	-104.043466°	5/19/2005	15:00	19.6	8.3	16.8	790
Stateline Island	SL1	41.989375°	-104.049850°	6/7/2005	16:28	23.0	8.3	8.4	NC
Stateline Island	SL2	41.988545°	-104.043466°	6/7/2005	15:34	21.3	8.2	14.5	821
Stateline Island	SL1	41.989375°	-104.049850°	7/6/2005	15:01	19.1	8.2	NC	NC
Stateline Island	SL2	41.988545°	-104.043466°	7/6/2005	15:28	20.0	8.2	NC	NC
Stateline Island	SL1	41.989375°	-104.049850°	7/28/2005	7:58	12.1	7.8	NC	NC
Stateline Island	SL2	41.988545°	-104.043466°	7/28/2005	8:40	12.2	7.8	NC	NC
Stateline Island	NPR1	41.990334°	-104.049781°	7/28/2005	8:24	21.0	8.3	NC	NC
Winters Creek Lake	WC1	41.949149°	-103.520460°	7/6/2005	9:19	23.1	8.3	7.3	2024

Table A.2. Measurements of water temperature, pH, dissolved oxygen, and conductivity from North Platte Refuge Subunits, Scotts Bluff County, Nebraska, 2006.

Refuge Subunit	Site	Lat	Long	Collection Date M/D/YYYY	oximate	Temp. (°C)	pH	Disolved Oxygen (mg/L)	Conductivity (µs/cm)
Lake Alice	LA1	41.985364°	-103.597960°	5/3/2006	12:27	15.5	8.5	8.9	586
Lake Alice	LA1	41.985364°	-103.597960°	5/17/2006	11:07	17.7	8.3	8.9	637
Lake Alice	LA1	41.985364°	-103.597960°	7/19/2006	12:50	25.1	9.9	9.3	618
Lake Alice	LA2	41.980053°	-103.600910°	5/3/2006	12:14	14.8	8.4	9.4	582
Lake Alice	LA2	41.980053°	-103.600910°	5/17/2006	10:38	18.2	8.2	8.6	642
Lake Alice	LA2	41.980053°	-103.600910°	7/19/2006	12:43	25.7	9.6	9.2	626
Lake Alice	LA3	41.996966°	-103.615939°	5/3/2006	12:40	15.3	8.5	9.2	585
Lake Alice	LA3	41.996966°	-103.615939°	5/17/2006	11:37	17.7	8.3	8.9	637
Lake Alice	LA3	41.996966°	-103.615939°	7/19/2006	13:03	26.0	9.9	9.7	557
Lake Alice	LA4	41.986876°	-103.625076°	5/3/2006	13:09	16.8	8.4	9.3	637
Lake Alice	LA4	41.986876°	-103.625076°	5/17/2006	12:27	21.3	8.2	11.2	561
Lake Alice	LA4	41.986876°	-103.625076°	7/19/2006	13:57	27.4	10.2	8.2	647
Lake Alice	LA5	41.992632°	-103.625159°	5/3/2006	13:29	16.8	8.5	9.0	647
Lake Alice	LA5	41.992632°	-103.625159°	5/17/2006	12:41	18.7	8.4	9.5	622
Lake Alice	LA5	41.992632°	-103.625159°	7/19/2006	13:32	24.7	9.0	8.5	584
Lake Minatare	LM1	41.937573°	-103.503176°	4/20/2006	9:50	9.2	8.5	10.7	545
Lake Minatare	LM1	41.937573°	-103.503176°	5/3/2006	10:33	11.6	8.4	10.0	574
Lake Minatare	LM1	41.937573°	-103.503176°	5/17/2006	14:40	19.1	8.2	9.0	687
Lake Minatare	LM1	41.937573°	-103.503176°	7/17/2006	16:24	26.5	8.4	8.0	949
Lake Minatare	LM2	41.935711°	-103.511468°	4/20/2006	10:07	7.2	8.6	11.3	471
Lake Minatare	LM2	41.935711°	-103.511468°	5/3/2006	10:44	14.1	8.4	9.1	604
Lake Minatare	LM2	41.935711°	-103.511468°	5/17/2006	15:10	19.6	8.2	8.7	662
Lake Minatare	LM2	41.935711°	-103.511468°	7/17/2006	16:36	26.6	8.7	8.4	934
Lake Minatare	LM3	41.920109°	-103.487958°	5/3/2006	11:02	12.9	8.5	9.7	580
Lake Minatare	LM3	41.920109°	-103.487958°	5/17/2006	16:56	23.1	8.2	7.6	754
Lake Minatare	LM3	41.920109°	-103.487958°	7/17/2006	16:56	25.4	8.6	8.3	934
Lake Minatare	LM4	41.942530°	-103.477636°	5/3/2006	11:18	12.1	8.4	9.9	593
Lake Minatare	LM4	41.942530°	-103.477636°	5/17/2006	16:16	22.2	8.1	7.8	736
Lake Minatare	LM4	41.942530°	-103.477636°	7/17/2006	17:07	25.3	8.5	7.4	930
Lake Minatare	LM5	41.947078°	-103.491000°	5/3/2006	11:34	12.9	8.5	9.8	583
Lake Minatare	LM5	41.947078°	-103.491000°	5/17/2006	16:55	20.5	8.2	8.0	685
Lake Minatare	LM5	41.947078°	-103.491000°	7/17/2006	17:19	25.9	8.8	8.5	834
Stateline Island	NPR1	41.990334°	-104.049781°	4/19/2006	11:25	5.4	8.6	12.6	630
Stateline Island	NPR1	41.990334°	-104.049781°	5/2/2006	11:32	14.7	8.3	9.7	714
Stateline Island	NPR1	41.990334°	-104.049781°	6/14/2006	15:41	27.6	8.0	9.3	935
Stateline Island	NPR1	41.990334°	-104.049781°	6/26/2006	17:59	22.7	8.8	8.8	641
Stateline Island	NPR1	41.990334°	-104.049781°	7/17/2006	20:11	24.2	9.3	7.8	780
Stateline Island	NPR2	41.986180°	-104.035388°	5/2/2006	12:27	19.3	8.4	9.9	811
Stateline Island	NPR2	41.986180°	-104.035388°	6/14/2006	14:52	29.4	8.4	9.0	961
Stateline Island	NPR2	41.986180°	-104.035388°	6/26/2006	18:32	23.1	8.3	8.8	651
Stateline Island	NPR2	41.986180°	-104.035388°	7/17/2006	20:25	24.0	9.0	7.9	782

Table A.2. Continued.

Refuge Subunit	Site	Lat	Long	Collection Date M/D/YYYY	oximate	Temp. (^{o}C)	pH	Disolved Oxygen (mg/L)	Conductivity (µs/cm)
Stateline Island	SL1	41.989375°	-104.049850°	4/19/2006	11:14	11.2	7.9	8.3	715
Stateline Island	SL1	41.989375°	-104.049850°	5/2/2006	11:16	17.5	8.1	8.2	716
Stateline Island	SL1	41.989375°	-104.049850°	5/16/2006	19:49	12.9	7.9	8.5	517
Stateline Island	SL1	41.989375°	-104.049850°	6/14/2006	15:18	23.4	6.5	15.3	821
Stateline Island	SL1	41.989375°	-104.049850°	6/26/2006	17:38	15.8	7.8	7.7	711
Stateline Island	SL1	41.989375°	-104.049850°	7/17/2006	20:04	12.3	6.5	8.1	786
Stateline Island	SL2	41.988545°	-104.043466°	4/19/2006	11:40	10.9	8.4	11.2	653
Stateline Island	SL2	41.988545°	-104.043466°	5/2/2006	11:47	16.4	8.4	11.4	662
Stateline Island	SL2	41.988545°	-104.043466°	5/16/2006	20:54	15.3	8.1	8.1	710
Stateline Island	SL2	41.988545°	-104.043466°	6/14/2006	12:16	21.1	8.3	8.3	789
Stateline Island	SL2	41.988545°	-104.043466°	6/26/2006	18:44	17.1	8.0	10.1	746
Stateline Island	SL2	41.988545°	-104.043466°	7/17/2006	20:33	15.3	8.5	8.8	872
Stateline Island	SL3	41.989288°	-104.051782°	4/19/2006	11:01	8.8	8.0	9.3	542
Stateline Island	SL3	41.989288°	-104.051782°	5/2/2006	10:57	16.1	8.9	12.4	626
Stateline Island	SL3	41.989288°	-104.051782°	5/16/2006	19:10	21.3	8.0	10.8	789
Stateline Island	SL3	41.989288°	-104.051782°	6/14/2006	10:57	24.1	8.7	6.6	789
Stateline Island	SL3	41.989288°	-104.051782°	6/26/2006	17:20	26.2	8.3	9.4	908
Stateline Island	SL3	41.989288°	-104.051782°	7/17/2006	19:29	26.3	8.5	11.1	1028
Stateline Island	SL4	41.989069°	-104.051880°	5/2/2006	10:47	14.1	8.0	7.9	696
Stateline Island	SL4	41.989069°	-104.051880°	5/16/2006	19:26	17.5	8.1	9.9	753
Stateline Island	SL4	41.989069°	-104.051880°	6/14/2006	10:47	20.8	8.3	6.7	770
Stateline Island	SL4	41.989069°	-104.051880°	6/26/2006	17:15	20.3	7.6	9.9	789
Stateline Island	SL4	41.989069°	-104.051880°	7/17/2006	19:25	20.9	6.0	13.5	962
Winters Creek Lake	WC1	41.949149°	-103.520460°	4/20/2006	10:30	5.5	8.3	12.0	1150
Winters Creek Lake	WC1	41.949149°	-103.520460°	5/17/2006	17:45	21.7	7.4	11.1	4482
Winters Creek Lake	WC1	41.949149°	-103.520460°	6/15/2006	10:52	20.5	9.8	10.2	3493
Winters Creek Lake	WC1	41.949149°	-103.520460°	7/19/2006	11:58	22.2	9.7	8.3	4151
Winters Creek Lake	WC2	41.952335°	-103.528537°	4/20/2006	10:47	6.7	8.5	11.8	1168
Winters Creek Lake	WC2	41.952335°	-103.528537°	5/2/2006	18:20	17.6	8.7	9.2	654
Winters Creek Lake	WC2	41.952335°	-103.528537°	5/17/2006	18:20	20.5	8.3	9.0	797
Winters Creek Lake	WC2	41.952335°	-103.528537°	6/15/2006	11:17	21.0	11.5	10.0	740
Winters Creek Lake	WC2	41.952335°	-103.528537°	7/19/2006	11:50	25.0	10.5	10.7	852
Winters Creek Lake	WC3	41.955045°	-103.531474°	5/2/2006	18:32	18.1	8.7	9.4	652
Winters Creek Lake	WC3	41.955045°	-103.531474°	5/17/2006	19:30	20.2	8.0	7.4	788
Winters Creek Lake	WC3	41.955045°	-103.531474°	6/15/2006	11:33	22.1	10.9	10.3	760
Winters Creek Lake	WC3	41.955045°	-103.531474°	7/19/2006	11:37	25.0	7.1	10.6	837
Winters Creek Lake	WC4	41.963780°	-103.525902°	5/2/2006	18:49	17.4	8.8	9.6	946
Winters Creek Lake	WC4	41.963780°	-103.525902°	5/17/2006	18:59	20.8	7.9	6.9	830
Winters Creek Lake	WC4	41.963780°	-103.525902°	6/15/2006	11:48	21.2	11.2	11.1	756
Winters Creek Lake	WC4	41.963780°	-103.525902°	7/19/2006	12:10	24.3	10.5	11.5	829
Winters Creek Lake	WC5	41.957712°	-103.522835°	5/2/2006	19:03	18.2	8.8	9.0	1000
Winters Creek Lake	WC5	41.957712°	-103.522835°	5/17/2006	18:40	21.7	8.3	9.0	834
Winters Creek Lake	WC5	41.957712°	-103.522835°	6/15/2006	12:08	21.1	11.6	10.3	748
Winters Creek Lake	WC5	41.957712°	-103.522835°	7/19/2006	12:17	25.5	10.6	10.6	891

Table A.3. Samples analyzed for contaminant residues through the U.S. Fish and Wildlife Service's Analytical Control Facility.

Analysis	Sample ID	Sample Matrix	Sample Mass (grams)	Percent moisture
Catalog 6050121	LMNB2301	Egg	0.488	68.0
Elemental Contaminants	LMNB2302	Egg	0.486	67.9
Wood duck eggs and	LMNB2303	Egg	0.493	68.1
hatched duckling	LMNB2304	Egg	0.482	68.1
	LMNB2305	Egg	0.475	68.0
	LMNB0501	Wholebody	0.473	65
Catalog 6050128	LA14E1	Egg	0.498	85.5
Elemental Contaminants	LA14E2	Egg	0.497	81.0
Wood duck eggs	LA14E3	Egg	0.479	69.1
	LA14E4	Egg	0.472	70.3
	LA14E5	Egg	0.494	84.5
	LA3E1	Egg	0.488	84.1
	LA3E2	Egg	0.485	80.2
	LA3E3	Egg	0.488	80.9
	LA3E6	Egg	0.481	81.0
	LA3E7	Egg	0.471	71.5
	LA3E8	Egg	0.491	41.7
	LA4E1	Egg	0.477	86.0
	LA4E2	Egg	0.480	77.7
	LA4E3	Egg	0.492	80.8
	LA4E4	Egg	0.498	76.0
	LA4E5	Egg	0.488	92.2
	LM14E1	Egg	0.473	61.6
	LM14E2	Egg	0.482	83.9
	LM14E3	Egg	0.500	69.0
	LM14E4	Egg	0.496	80.3
	LM14E5	Egg	0.488	85.1
	LM14E6	Egg	0.479	82.0
	LM15E1	Egg	0.490	96.5
	LM15E2	Egg	0.495	73.8
	LM15E3	Egg	0.494	78.5
	LM15E4	Egg	0.491	80.4
	LM15E5	Egg	0.499	81.9
	LM15E6	Egg	0.495	95.7
	LM26E1	Egg	0.470	81.7
	LM26E2	Egg	0.492	79.5
	LM26E3	Egg	0.495	83.3
	LM26E4	Egg	0.476	84.0
	LM30E1	Egg	0.499	91.7
	LM30E2	Egg	0.492	86.6
	LM30E3	Egg	0.492	80.2
	LM30E4	Egg	0.495	85.5
	LM30E5	Egg	0.487	88.6
Catalog 6050132	GBWC1A	Egg	NR	69.2
Elemental Contaminants	GBWC1B	Egg	NR	69.1
Canada Goose eggs	GBWC2A	Egg	NR	38.3
	GBWC2B	Egg	NR	71.4
	GBWC2C	Egg	NR	61.1
	GBWC2D	Egg	NR	68.9
	GBWC2E	Egg	NR	69.7
	GBWC2F	Egg	NR	70.7
	GBWC2G	Egg	NR	40.1
	GBWC3A	Egg	NR	56.5
	GBWC4A	Egg	NR	68.1
	GBWC4B	Egg	NR	69.8
	GBWC4C	Egg	NR	69.3
	GBWC4D	Egg	NR	70.9
	GBWC5A	Egg	NR	68.7

Table A.3. Continued.

Analysis		Sample ID	Sample Matrix	Percent Total Organic Carbon	Percent moisture
Catalog 6050125		LASED01	Sediments	0.600	28
Elemental Contaminants		LASED02	Sediments	0.400	21
Sediments		LASED03	Sediments	0.700	24
		LASED04	Sediments	0.800	30
		LASED05	Sediments	1.200	34
		LM1	Sediments	0.700	29
		LM2	Sediments	0.400	21
		LM3	Sediments	1.000	28
		LMSED01	Sediments	0.900	27
		LMSED02	Sediments	0.500	25
		LMSED03	Sediments	2.600	48
		LMSED04	Sediments	0.800	29
		SL1	Sediments	5.000	76
		SL2	Sediments	3.500	64
		SLSED01	Sediments	4.400	75
		SLSED02	Sediments	2.600	64
		SLSED03	Sediments	5.200	81
		SLSED04	Sediments	1.900	53
		SLSED05	Sediments	1.500	34
		WCSED01	Sediments	4.200	59
		WCSED02	Sediments	2.100	60
		WCSED03	Sediments	0.900	37
		WCSED04	Sediments	3.000	57
		WCSED05	Sediments	0.900	28.6
Catalog 6050127		NP1SED1	Sediments	0.100	17
Elemental Contaminants		NP1SED2	Sediments	0.100	17
Sediments		NP2SED1	Sediments	0.100	17
		NPR2SED2	Sediments	0.100	17
		SL2A	Sediments	3.100	69
		SL2B	Sediments	0.400	23
		SL2C	Sediments	2.600	66
		SL2D	Sediments	1.000	42
		SL2E	Sediments	4.300	70
		SL3	Sediments	0.200	18
		SL4A	Sediments	1.600	58
		SL4B	Sediments	2.900	77
		SPL1SED1	Sediments	1.900	53
		SPL1SED2	Sediments	1.300	47
		WC1S	Sediments	3.300	58
		WC2S	Sediments	0.600	27
		WC3S	Sediments	0.800	36
		WC4S	Sediments	5.100	62
Catalog 6050120	c	LAcarp01	*Cyprinus carpio*	0.496	79.1
Elemental Contaminants	c	LAcarp02	*Cyprinus carpio*	0.484	80.7
Individual (I) and composite	c	LAcarp03	*Cyprinus carpio*	0.480	80.5
(c) fish samples	c	LAcarp04	*Cyprinus carpio*	0.486	78.1
	c	LAcarp05	*Cyprinus carpio*	0.484	80.6
	I	LMcarp01	*Cyprinus carpio*	0.494	73.3
	I	LMcarp02	*Cyprinus carpio*	0.480	72.6
	I	LMcarp03	*Cyprinus carpio*	0.482	72.6
	I	LMcarp04	*Cyprinus carpio*	0.483	75.1
	I	LMcarp05	*Cyprinus carpio*	0.499	65.0
	I	LMcarp06	*Cyprinus carpio*	0.489	83.4
	I	LMcat01	*Ictalurus punctatus*	0.483	74.1
	I	LMcat02	*Ictalurus punctatus*	0.494	70.7
	I	LMcat03	*Ictalurus punctatus*	0.571	0.2
	I	LMcat04	*Ictalurus punctatus*	0.491	72.0
	I	LMcat05	*Ictalurus punctatus*	0.496	73.8
	I	LMwsuc01	*Catostomus commersoni*	0.482	79.1
	I	LMwsuc02	*Catostomus commersoni*	0.474	XD
	I	LMwsuc03	*Catostomus commersoni*	0.484	XD
	I	LMwsuc04	*Catostomus commersoni*	0.485	75.3
	I	LMwsuc05	*Catostomus commersoni*	0.481	80.1

Table A.3. Continued.

Analysis		Sample ID	Species	Sample Mass (grams)	Percent moisture
Catalog 6050129	I	NPR1CARP	*Cyprinus carpio*	0.486	21.8
Elemental Contaminants	I	NPRC2	*Cyprinus carpio*	0.467	68.9
Individual (I) and composite	I	NPRC3	*Cyprinus carpio*	0.471	73.1
(c) fish samples	I	NPRC4	*Cyprinus carpio*	0.497	65.9
	c	NPRF1	composite minnows	0.483	73.0
	i	NPRGS1	*Lepomis cyanellus*	0.499	69.9
	i	NPRGS2	*Lepomis cyanellus*	0.483	71.1
	c	NPRGS3	*Lepomis cyanellus*	0.501	58.1
	c	NPRWS1	*Ictalurus punctatus*	0.492	75.5
	c	NPRWS2	*Ictalurus punctatus*	0.492	72.6
	c	NPRWS3	*Ictalurus punctatus*	0.499	76.7
	c	SL2	Cyprinidae minnows	0.492	74.5
	c	SL2CC1	Semotilus atromaculatus	0.494	66.3
	c	SL2CC2	Semotilus atromaculatus	0.499	54.7
	c	SL2WS1	*Ictalurus punctatus*	0.476	74.7
	c	SL2WS2	*Ictalurus punctatus*	0.481	75.9
	c	SL3	Cyprinidae minnows	0.495	74.4
	c	SL4	Cyprinidae minnows	0.471	72.1
	c	WCFish	Cyprinidae minnows	0.490	78.5
Catalog 6050119		WCPL01	Polygonum Spp	NA	60
Elemental Contaminants		WCPL02	Polygonum Spp	NA	65
Smartweed composite		WCPL03	Polygonum Spp	NA	62
samples		WCPL04	Polygonum Spp	NA	63
		WCPL05	Polygonum Spp	NA	60.7
Catalog 6050130		SL1IA	Mixed Aquatic Invertebrates	NA	85
Elemental Contaminants		SL1IB	Mixed Aquatic Invertebrates	NA	79
Composite Invertebrate		SL2Corox	Coroxidae Spp	NA	86
and amphibian samples		SL2I	Mixed Aquatic Invertebrates	NA	77
		SL4I	Mixed Aquatic Invertebrates	NA	81
		SL4I297	Mixed Aquatic Invertebrates	NA	93
		WCIA	Mixed Aquatic Invertebrates	NA	86
		WCIB	Mixed Aquatic Invertebrates	NA	86
		WCIC	Mixed Aquatic Invertebrates	NA	87
		WCPFL	Dragon fly larvae	NA	79
		HCTAD	*Rana catesbeiana*	NA	84.4
		LA2TAD	*Bufo woodhousii*	NA	89.1
		SL3BFT	*Rana catesbeiana*	NA	91.0
		WC1TS	*Ambystoma tigrinum*	NA	87.1

Table A.4. Summary statistics for water quality measurements at North Platte National Wildlife Refuge, Scotts Bluff County, Nebraska, 2005 and 2006.

		Dissolved Oxygen (mg/L)			pH			Conductivity (microsiemens per cm)		
Year	Site	N	Mean ± S.E.	Range	N	Mean ± S.E.	Range	N	Mean ± S.E.	Range
2006	Lake Alice	15	9.2 ± 0.2	8.2 - 11.2	15	8.8 ± 0.2	8.2 - 10.2	15	611 ± 8	557 - 647
	Lake Minitare	17	9.0 ± 0.3	7.4 - 11.3	19	8.4 ± 0	8.1 - 8.8	17	709 ± 38	471 - 949
	North Platte River	9	9.3 ± 0.5	7.8 - 12.6	9	8.6 ± 0.1	8.0 - 9.3	9	767 ± 41	630 - 961
	Stateline Island	23	9.6 ± 0.4	6.6 - 15.3	23	7.9 ± 0.1	6.0 - 8.9	23	754 ± 25	517 - 1028
	Winters Creek Lake	21	9.9 ± 0.3	6.9 - 12.0	21	9.3 ± 0.3	7.1 - 11.6	21	1303 ± 254	652 - 4482
2005	Lake Alice	1	5.6	NA	3	8.5 ± 0	8.4 - 8.5	1	661	NA
	Minitare	5	9.8 ± 1.1	6.1 - 13	9	8.5 ± 0	8.4 - 8.7	5	661 ± 14	606 - 681
	Stateline	6	10.9 ± 1.7	5.5 - 17	11	8.2 ± 0.1	7.8 - 8.8	6	651 ± 131	0.8 - 821
	Winters Creek Lake	1	7.3	NA	1	8.3	NA	1	2024	NA

Note: S.E. = standard error, NA = not applicable.

Table A.5. Concentrations of elemental contaminants in water samples from North Platte National Wildlife Refuge, Scotts Bluff County, Nebraska, 2005.

		Element Concentration in mg/L											
Site	**Sample ID**	**Al**	**As**	**B**	**Ba**	**Cd**	**Cu**	**Fe**	**Mg**	**Mn**	**Se**	**Sr**	**V**
Lake Alice	LAWAT01	0.42	< 0.001	0.09	0.07	0.001	< 0.001	0.26	23	0.01	0.0025	0.59	0.003
Lake Alice	LAWAT02	0.93	0.002	0.08	0.06	< 0.00025	< 0.001	0.57	21	0.02	0.0024	0.53	0.004
Lake Alice	LAWAT03	0.98	0.002	0.09	0.07	0.001	< 0.001	0.57	23	0.02	0.0026	0.59	0.005
Lake Alice	LAWAT04	1.40	0.002	0.09	0.07	0.001	< 0.001	0.89	22	0.03	0.0025	0.56	0.006
Lake Alice	LAWAT05	8.59	0.003	0.09	0.14	0.001	0.005	5.81	23	0.15	0.0024	0.56	0.021
Lake Minatare	LM1	2.83	0.003	0.10	0.14	0.001	0.002	1.70	29	0.08	0.0034	0.79	0.014
Lake Minatare	LM2	1.20	0.002	0.09	0.09	0.001	< 0.001	0.73	22	0.05	0.0017	0.54	0.007
Lake Minatare	LM3	5.16	0.004	0.10	0.15	0.001	0.004	3.30	25	0.13	0.0036	0.76	0.017
Lake Minatare	LMinlet	7.23	0.004	0.10	0.13	0.001	0.004	4.50	24	0.09	0.0028	0.63	0.021
Lake Minatare	LMWAT01	0.92	0.002	0.10	0.07	< 0.00025	< 0.001	0.54	23	0.02	0.0025	0.62	0.005
Lake Minatare	LMWAT02	3.81	0.002	0.10	0.11	0.001	0.003	2.30	26	0.08	0.0022	0.68	0.009
Lake Minatare	LMWAT03	0.08	< 0.001	0.10	0.09	0.001	< 0.001	0.10	28	0.11	0.0011	0.73	0.002
Lake Minatare	LMWAT04	1.60	0.003	0.10	0.09	0.001	< 0.001	0.93	24	0.05	0.0022	0.63	0.006
Stateline Island	SL1	< 0.01	< 0.001	0.10	0.08	0.001	0.002	0.05	24	0.02	0.0050	0.64	0.007
Stateline Island	SL2	< 0.01	< 0.001	0.08	0.06	< 0.00025	< 0.001	< 0.03	16	0.01	0.0023	0.43	0.002
Stateline Island	SLWAT01	< 0.01	0.002	0.10	0.18	0.001	< 0.001	0.09	22	0.06	0.0021	0.63	0.002
Stateline Island	SLWAT02	< 0.01	< 0.001	0.09	0.08	< 0.00025	< 0.001	< 0.03	17	0.17	0.0008	0.55	0.001
Stateline Island	SLWAT03	< 0.01	0.002	0.10	0.09	< 0.00025	< 0.001	0.23	23	0.57	0.0005	0.63	< 0.0005
Stateline Island	SLWAT04	< 0.01	< 0.001	0.10	0.07	< 0.00025	< 0.001	< 0.03	23	0.02	0.0022	0.64	0.002
Stateline Island	SLWAT05	0.07	< 0.001	0.10	0.09	0.001	< 0.001	0.15	31	0.04	0.0097	0.86	< 0.0005
Winters Creek Lake	WCWAT01	< 0.01	0.003	0.86	0.03	< 0.00025	< 0.001	< 0.03	244	0.21	< 0.0002	5.09	< 0.0005
Winters Creek Lake	WCWAT02	< 0.01	0.007	0.40	0.07	< 0.00025	< 0.001	< 0.03	96	0.02	0.0008	4.44	0.004
Winters Creek Lake	WCWAT03	0.09	0.007	0.37	0.08	< 0.00025	< 0.001	0.17	91	0.03	0.0009	4.42	0.007
Winters Creek Lake	WCWAT04	0.20	0.005	0.32	0.07	0.001	< 0.001	0.41	75	0.04	0.0007	3.56	0.003
Winters Creek Lake	WCWAT05	0.13	0.006	0.33	0.07	0.001	< 0.001	0.42	81	0.12	0.0010	3.83	0.003

Note: < = less than the detection limit.

Table A.6. Concentrations of selenium in water samples from North Platte National Wildlife Refuge, Scotts Bluff County, Nebraska, 2006.

Site	Sample ID	Date Collected	Selenium Concentration (mg/L)
Lake Alice	LA5WAT	6/28/2006	0.0023
Little Lake Alice	LLA1	4/20/2006	0.0240
Lake Minatare	LM05	4/20/2006	0.0021
Lake Minatare	LM5WAT	6/28/2006	0.0024
Lake Minatare	LMHC	7/19/2006	0.0024
Lake Minatare	LMLCI	4/20/2006	0.0021
Lake Minatare	LMSR	4/20/2006	0.0019
North Platte River	NPR1	6/27/2006	0.0027
North Platte River	NPR2	6/26/2006	0.0026
Stateline Island	SL1	6/26/2006	0.0038
Stateline Island	SL2	6/26/2006	0.0026
Stateline Island	SL3	6/26/2006	0.0009
Stateline Island	SL4	6/26/2006	0.0036
Winter Creek Lake	WC1A	4/20/2006	0.0012
Winter Creek Lake	WC1B	6/27/2006	0.0005
Winter Creek Lake	WC2A	4/20/2006	0.0011
Winter Creek Lake	WC2B	6/27/2006	0.0011
Winter Creek Lake	WC3A	4/20/2006	0.0012
Winter Creek Lake	WC3B	6/27/2006	0.0015
Winter Creek Lake	WC4A	4/20/2006	0.0013
Winter Creek Lake	WC4B	6/27/2006	0.0014
Winter Creek Lake	WC5A	4/20/2006	0.0014
Winter Creek Lake	WC5B	6/27/2006	0.0016

Table A.7. Concentrations of elemental contaminants in sediment samples from North Platte National Wildlife Refuge, Scotts Bluff County, Nebraska, 2005 – 2007.

			Element Concentration in mg/kg															
Site	Sample ID	Date Col.	Al	As	Ba	Be	B	Cd	Cr	Cu	Fe	Pb	Mg	Mn	Ni	Se	Sr	V	Z
Horse Creek	HC2	10/16/2007	1140	3	49	0.1	4	0.1	2	4	1990	1.5	1420	29	2.9	2.98	235	11	6
Horse Creek	HC3	10/16/2007	1190	1	31	0.1	3	0.0	1	2	1910	1.6	781	21	1.7	0.77	83	5	5
Horse Creek	HC4	10/16/2007	7730	7	129	0.6	12	0.5	10	16	10600	10.1	5470	166	12.4	9.71	407	39	51
Horse Creek	HC7	10/17/2007	2160	2	66	0.1	4	0.2	4	4	4140	3.0	1540	1420	7.3	2.13	84	11	11
Horse Creek	HC8	10/17/2007	4570	2	87	0.3	9	0.1	5	5	6800	5.3	2720	238	5.7	0.89	106	13	19
Horse Creek	HC9	10/17/2007	2140	2	62	0.1	3	0.2	3	4	4580	2.8	1540	292	4.7	1.48	122	9	11
Lake Alice	LASED01	7/27/2005	12300	2	113	0.5	10	0.3	10	7	10700	10.0	4530	150	7.0	<0.25	89	24	30
Lake Alice	LASED02	7/27/2005	8360	2	69	0.3	< 5	0.4	8	5	7740	7.0	3110	110	5.0	<0.25	46	18	21
Lake Alice	LASED03	7/27/2005	11400	2	102	0.4	< 5	< 0.1	9	7	10700	7.0	4140	140	6.0	<0.25	63	22	27
Lake Alice	LASED04	7/27/2005	12800	3	166	0.6	10	0.4	12	9	12500	10.0	6000	223	9.0	<0.25	93	25	38
Lake Alice	LASED05	7/27/2005	14300	3	180	0.7	20	0.4	13	9	13600	10.0	6720	302	10.0	0.60	113	28	41
Lake Minatare	LM1	5/21/2005	9520	2	109	0.4	< 5	< 0.1	9	5	10200	7.0	3680	140	5.0	<0.25	53	23	26
Lake Minatare	LM2	5/21/2005	6110	1	68	0.2	< 5	< 0.1	5	3	5580	< 2.5	2050	92	< 2.5	<0.25	32	12	13
Lake Minatare	LM3	5/21/2005	13700	2	136	0.6	10	0.2	11	8	12800	10.0	5090	190	7.0	0.70	71	27	35
Lake Minatare	LMSED01	7/27/2005	12000	1	140	0.4	10	0.2	10	6	11100	8.0	4040	160	6.0	<0.25	61	26	30
Lake Minatare	LMSED02	7/28/2005	11200	2	100	0.4	10	0.3	10	7	12200	7.0	3970	190	6.0	<0.25	49	29	30
Lake Minatare	LMSED03	7/28/2005	24800	2	187	1.0	20	0.4	19	20	18700	10.0	8670	241	10.0	1.00	88	40	70
Lake Minatare	LMSED04	7/27/2005	10200	3	89	0.4	10	< 0.1	9	6	11500	8.0	4130	180	5.0	<0.25	48	27	29
NPR	NP1SED1	6/14/2006	3190	1	83	< 0.1	< 5	0.2	2	2	3540	6.0	660	110	< 2.5	<0.25	19	7	7
NPR	NP1SED2	6/14/2006	3310	1	57	0.2	< 5	0.4	4	2	5090	9.0	1480	334	< 2.5	<0.25	37	10	13
NPR	NP2SED1	6/14/2006	1010	2	16	< 0.1	< 5	0.3	2	2	2980	5.0	510	110	< 2.5	<0.25	8	4	6
NPR	NPR2SED2	6/14/2006	1040	1	10	< 0.1	< 5	0.3	1	1	2110	6.0	340	64	< 2.5	<0.25	7	4	4
Spotted Tail	ST16	10/17/2007	6790	3	196	0.4	43	0.3	7	10	9670	7.9	12400	1800	6.5	2.10	541	13	54
Spotted Tail	ST18	10/17/2007	8340	4	190	0.6	19	0.3	10	10	10700	8.9	7490	850	10.3	2.12	487	31	51
Spotted Tail	ST20	10/17/2007	6350	9	196	0.4	39	0.3	7	11	9080	8.4	8700	1970	7.6	5.49	537	35	50
Spotted Tail	ST26	10/17/2007	9320	5	214	0.6	20	0.4	11	11	11700	10.2	8240	921	11.4	2.12	539	33	54
Spotted Tail	ST28	10/17/2007	1870	1	52	0.1	2	0.0	2	2	2230	2.2	954	98	1.9	0.12	41	5	6
Spotted Tail	ST30	10/17/2007	4640	3	109	0.3	5	0.1	4	4	5190	4.2	2540	361	4.3	0.21	83	13	18
Stateline Island	SL1	5/19/2005	6100	6	787	0.4	10	3.0	9	117	7670	18.0	4400	190	10.0	21.00	416	39	28
Stateline Island	SL2	5/19/2005	6910	3	228	0.3	20	0.7	8	14	6090	9.0	4090	243	6.0	4.90	420	21	18
Stateline Island	SL2A	6/14/2006	4640	3	388	0.3	10	3.1	7	86	5590	18.0	3390	244	10.0	12.00	405	31	21
Stateline Island	SL2B	6/14/2006	1290	1	41	< 0.1	< 5	0.6	2	4	1820	8.0	640	69	< 2.5	1.00	55	5	5
Stateline Island	SL2C	6/14/2006	2830	2	196	< 0.1	< 5	1.6	3	29	3470	10.0	1820	200	7.0	6.10	230	13	11
Stateline Island	SL2D	6/14/2006	1360	1	82	< 0.1	< 5	2.6	3	27	2180	8.0	650	91	7.0	3.20	52	24	7
Stateline Island	SL2E	6/14/2006	6080	4	559	0.4	20	2.6	9	87	6940	22.0	3840	170	10.0	18.00	384	34	26
Stateline Island	SL3	6/14/2006	2160	2	35	< 0.1	< 5	0.3	3	3	4300	6.0	1030	37	< 2.5	1.60	16	8	9
Stateline Island	SL4A	6/27/2006	1880	2	203	0.2	10	1.7	3	20	4410	10.0	2430	220	7.0	34.00	475	20	14
Stateline Island	SL4B	6/27/2006	1790	2	265	0.2	< 5	2.0	4	28	3540	10.0	3660	271	< 2.5	13.00	858	18	11
Stateline Island	SLSED01	7/28/2005	5210	4	409	0.3	10	2.5	7	83	6140	10.0	3690	278	10.0	14.00	397	42	21
Stateline Island	SLSED02	7/28/2005	2600	3	217	< 0.1	< 5	2.3	3	24	3730	7.0	1730	220	10.0	5.20	180	17	12
Stateline Island	SLSED03	7/28/2005	4070	4	667	0.3	20	1.7	5	55	6840	10.0	3520	222	9.0	15.00	513	34	18
Stateline Island	SLSED04	7/28/2005	5770	2	157	0.3	< 5	0.8	6	11	5280	8.0	3210	190	< 2.5	4.50	257	16	17
Stateline Island	SLSED05	7/28/2005	15800	4	182	0.9	10	0.7	17	14	15600	16.0	7020	247	16.0	3.60	111	31	61
Stateline Island	SPL1SED1	6/14/2006	4460	2	142	0.3	< 5	1.0	5	9	4420	10.0	2620	200	< 2.5	2.90	258	12	15
Stateline Island	SPL1SED2	6/14/2006	7070	2	178	0.4	10	0.8	8	8	6440	10.0	3500	190	7.0	3.00	193	17	21
Winters Creek Lake	WC1S	6/27/2006	10100	3	152	0.4	30	0.8	7	6	9640	16.0	6040	1270	6.0	<0.25	473	17	32
Winters Creek Lake	WC2S	6/27/2006	8540	2	112	0.4	< 5	0.5	7	4	7900	6.0	2780	120	< 2.5	1.00	59	19	22
Winters Creek Lake	WC3S	6/27/2006	11700	2	100	0.5	10	0.3	9	6	10900	10.0	4170	140	6.0	<0.25	81	21	30
Winters Creek Lake	WC4S	6/27/2006	11700	4	133	0.5	20	0.4	9	7	11100	10.0	4110	140	6.0	2.20	195	28	32
Winters Creek Lake	WCSED01	7/27/2005	12400	2	164	0.5	36	0.5	10	8	11900	10.0	7790	1350	6.0	<0.25	468	23	37
Winters Creek Lake	WCSED02	7/27/2005	12000	4	198	0.5	20	0.4	9	7	10900	9.0	5470	269	6.0	1.80	469	29	31
Winters Creek Lake	WCSED03	7/27/2005	7090	3	116	0.3	10	0.3	6	4	7850	7.0	3320	160	< 2.5	0.70	214	21	19
Winters Creek Lake	WCSED04	7/27/2005	13900	5	231	0.5	20	0.3	11	9	13600	10.0	6640	288	7.0	2.90	626	36	38
Winters Creek Lake	WCSED05	7/27/2005	10100	2	111	0.4	10	0.2	8	6	10300	7.0	3730	120	< 2.5	<0.25	109	21	26

Note: < = less than the detection limit.

Table A.8. Concentrations of selenium in sediment samples from Horse Creek and Spotted Tail sites, Scotts Bluff County, Nebraska, 2007.

Site	Sample ID	Date Collected	Selenium Concentration (mg/kg) dw
Horse Creek	HC1	10/16/2007	2.02
Horse Creek	HC5	10/16/2007	6.12
Horse Creek	HC6	10/17/2007	< 0.75
Horse Creek	HC10	10/17/2007	1.10
Horse Creek	HC11	10/17/2007	1.28
Horse Creek	HC12	10/17/2007	2.95
Horse Creek	HC13	10/17/2007	3.92
Horse Creek	HC14	10/17/2007	4.19
Horse Creek	HC15	10/17/2007	5.08
Spotted Tail	ST17	10/17/2007	0.86
Spotted Tail	ST19	10/17/2007	2.34
Spotted Tail	ST21	10/17/2007	< 0.42
Spotted Tail	ST22	10/17/2007	< 0.45
Spotted Tail	ST23	10/17/2007	< 0.43
Spotted Tail	ST24	10/17/2007	< 0.46
Spotted Tail	ST25	10/17/2007	< 0.47
Spotted Tail	ST27	10/17/2007	< 0.39
Spotted Tail	ST29	10/17/2007	< 0.42

Note: < = less than the detection limit. Samples shown above were analyzed for selenium only. Additional samples from these sites were analyzed for selenium and other elemental contaminants (see table A.7)

Table A.9. Summary statistics for concentrations of elemental contaminants in sediments from Lake Alice, Lake Minatare, and Winters Creek Lake compared to background and toxicity threshold benchmarks.

Trace Element	MDL	Lake Alice			Lake Minitare			Winters Creek Lake			Published Background or Threshold Concentrations (mg/kg)
			Dry Weight Concentration (mg/kg)			Dry Weight Concentration (mg/kg)			Dry Weight Concentration (mg/kg)		
		N_D/N_A	Mean ± S.E.	Range	N_D/N_A	Mean ± S.E.	Range	N_D/N_A	Mean ± S.E.	Range	
Aluminum	10	5/5	11832 ± 987	8360 - 14300	7/7	12504 ± 2234	6110 - 24800	9/9	10837 ± 698	7090 - 13900	74000[1], 25519[3]
Arsenic	0.5	5/5	2.4 ± 0.3	1.8 - 3.3	7/7	1.9 ± 0.3	1.0 - 3.2	9/9	3.0 ± 0.3	1.9 - 4.6	1.1[2], 9.8[3]
Barium	0.5	5/5	126 ± 21	69 - 180	7/7	118 ± 15	68 - 187	9/9	146 ± 15	100 - 231	670[1]
Beryllium	0.1	5/5	0.5 ± 0.1	0.3 - 0.7	7/7	0.5 ± 0.1	0.2 - 1.0	9/9	0.4 ± 0.0	0.3 - 0.5	1[1]
Boron	5.0	3/5	10 ± 3	5 - 20	5/7	10 ± 2	5 - 20	8/9	18 ± 3	5 - 36	30[5]
Cadmium	0.2	4/5	0.3 ± 0.2	0.1 - 0.4	4/7	0.2 ± 0.0	0.2 - 0.4	9/9	0.4 ± 0.1	0.2 - 0.8	0.1 - 0.3[2], 0.99[3], 4.98[4]
Chromium	1.0	5/5	10 ± 1	8 - 13	7/7	10 ± 2	5 - 19	9/9	8 ± 1	6 - 11	7 - 13[2], 43[3]
Copper	1.0	5/5	7 ± 1	5 - 9	7/7	8 ± 2	3 - 20	9/9	6 ± 1	4 - 9	10 - 25[2], 32[3]
Iron	10.0	5/5	11048 ± 995	7740 - 13600	7/7	11726 ± 1468	5580 - 18700	9/9	10454 ± 610	7850 - 13600	26000[1]
Lead	5.0	5/5	9 ± 1	7 - 10	6/7	8 ± 1	3 - 10	9/9	9 ± 1	6 - 16	4 - 17[2], 36[3]
Magnesium	10.0	5/5	4900 ± 650	3110 - 6720	7/7	4519 ± 772	2050 - 8670	9/9	4894 ± 559	2780 - 7790	400[2]
Manganese	2.0	5/5	185 ± 35	110 - 302	7/7	170 ± 18	92 - 241	9/9	429 ± 168	120 - 1350	480[1]
Nickel	5.0	5/5	7 ± 1	5 - 10	6/7	6 ± 1	5 - 10	6/9	5 ± 1	5 - 7	9.9[2], 23[3]
Selenium	0.5	1/5	NA	0.6	2/7	NA	0.7 - 1.0	5/9	1 0.3	0.5 - 2.9	0.29[2]
Strontium	1.0	5/5	81 ± 12	46 - 113	7/7	57 ± 7	32 - 88	9/9	299 ± 70	59 - 626	49[2]
Vanadium	1.0	5/5	23 ± 2	18 - 28	7/7	26 ± 3	12 - 40	9/9	24 ± 2	17 - 36	50[2]
Zinc	2.0	5/5	31 ± 4	21 - 41	7/7	33 ± 7	13 - 70	9/9	30 ± 2	19 - 38	7 - 38[2], 121[3]

Note: MDL = method detection limit, N_D = number of samples above detection, N_A = number of samples analyzed, S.E. = standard error, < = less than MDL, NA = not applicable. For “Background or Threshold Concentration” column: 1 = background (Shakette et al., 1984), 2 = background (Buchman, 2008); 3 = Threshold Effects Concentration below which adverse effects are not expected to occur (McDonald et. al., 2000); 4 = Probable Effect Concentration above which adverse effects are expected to occur more often than not (McDonald et. al., 2000), 5 = United States mean concentration in soil (Eisler, 1990).

Table A.10. Summary statistics for concentrations of elemental contaminants in sediments from Stateline Island, Horse Creek, and Spotted Tail compared to background and toxicity threshold benchmarks.

		Stateline Island	Dry Weight Concentration (mg/kg)		Horse Creek	Dry Weight Concentration (mg/kg)		Spotted Tail	Dry Weight Concentration (mg/kg)		
Trace Element	MDL	N_D/N_A	Mean ± S.E.	Range	N_D/N_A	Mean ± S.E.	Range	N_D/N_A	Mean ± S.E.	Range	Published Background or Threshold Concentrations (mg/kg)
Aluminum	10.0	17/17	4707 ± 842.4	1290 - 15800	6/6	3155 ± 1047	1140 - 7730	6/6	6218 ± 1093	1870 - 9320	74000[1], 25519[3]
Arsenic	0.5	17/17	2.8 ± 0.3	0.9 - 5.9	6/6	3.0 ± 0.8	1.5 - 6.7	6/6	4.1 ± 1.0	1.2 - 8.7	1.1[2], 9.8[3]
Barium	0.5	17/17	279 ± 52	35 - 787	6/6	71 ± 14	31 - 129	6/6	159 ± 26	52 - 214	670[1]
Beryllium	0.2	12/17	0.28 ± 0.05	0.10 - 0.90	6/6	0.22 ± 0.08	0.06 - 0.56	6/6	0.39 ± 0.08	0.12 - 0.63	1[1]
Boron	10.0	9/17	9 ± 1	5 - 20	6/6	6 ± 2	3 - 12	6/6	21 ± 7	2 - 43	30[5]
Cadmium	0.2	17/17	1.6 ± 0.2	0.3 - 3.1	6/6	0.2 ± 0.1	0.0 - 0.5	6/6	0.2 ± 0.1	0.0 - 0.4	0.1 - 0.3[2], 0.99[3], 4.98[4]
Chromium	1.0	17/17	6 ± 1	2 - 17	6/6	4 ± 1	1 - 10	6/6	7 ± 1	2 - 11	7 - 13[2], 43[3]
Copper	1.0	17/17	36 ± 9	3 - 117	6/6	6 ± 2	2 - 16	6/6	8 ± 2	2 - 11	10 - 25[2], 32[3,] 149[4]
Iron	10.0	17/17	5556 ± 747	1820 - 15600	6/6	5003 ± 1343	1910 - 10600	6/6	8095 ± 1484	2230 - 11700	26000[1]
Lead	5.0	17/17	11 ± 1	6 - 22	6/6	4 ± 1	2 - 10	6/6	7 ± 1	2 - 10	4 - 17[2], 36[3]
Magnesium	10.0	17/17	3014 ± 384	640 - 7020	6/6	2245 ± 694	781 - 5470	6/6	6721 ± 1730	954 - 12400	400[2]
Manganese	2.0	17/17	193 ± 17	37 - 278	6/6	361 ± 216	21 - 1420	6/6	1000 ± 307	98 - 1970	480[1]
Molybdenum	5.0	3/17	4.2 ± 1.2	2.5 - 23.0	6/6	0.9 ± 0.1	0.5 - 1.3	6/6	0.7 ± 0.3	0.1 - 1.9	5 - 57[5]
Nickel	5.0	12/17	7 ± 1	3 - 16	6/6	6 ± 2	2 - 12	6/6	7 ± 1	2 - 11	9.9[2], 23[3]
Selenium	0.5	17/17	9.6 ± 2.1	1.0 - 34.0	14/15	3.0 ± 0.6	0.4 - 9.7	8/15	1.1 ± 0.4	0.1 - 5.5	0.29[2]
Strontium	1.0	17/17	307 ± 51	16 - 858	6/6	173 ± 52	83 - 407	6/6	371 ± 98	41 - 541	49[2]
Vanadium	1.0	17/17	22 ± 3	5 - 42	6/6	15 ± 5	5 - 39	6/6	22 ± 5	5 - 35	50[2]
Zinc	2.0	17/17	19 ± 3	5 - 61	6/6	17 ± 7	5 - 51	6/6	39 ± 9	6 - 54	7 - 38[2], 121[3]

Note: MDL = method detection limit, N_D = number of samples above detection, N_A = number of samples analyzed, S.E. = standard error, < = less than MDL, NA = not applicable. For "Background or Threshold Concentration" column: 1 = background (Shakette et al., 1984), 2 = background (Buchman, 2008); 3 = Threshold Effects Concentration below which adverse effects are not expected to occur (McDonald et. al., 2000); 4 = Probable Effect Concentration above which adverse effects are expected to occur more often than not (McDonald et. al., 2000), 5 = United States mean concentration in soil (Eisler, 1990).

Table A.11. Concentrations of elemental contaminants in plants (*Polygonum* sp) from Winters Creek Lake, North Platte National Wildlife Refuge, Scotts Bluff County, Nebraska, 2005.

		Element Concentration in mg/L										
Sample ID	Date Col.	Al	Ba	B	Cu	Fe	Mg	Mn	Ni	Se	Sr	Z
WCPL01	7/27/2005	45	1	17	0.8	60	2170	117	0.60	< 0.1	17	28
WCPL02	7/27/2005	63	8	17	7.4	82	2400	161	1.00	1.1	47	36
WCPL03	7/27/2005	45	3	17	7	66	2350	134	0.70	1.3	49	33
WCPL04	7/27/2005	38	2	15	5.2	56	2220	97	< 0.25	1.4	42	25
WCPL05	7/27/2005	38	4	13	3.9	53	2140	74	< 0.25	1.5	43	26

Note: < = less than detection limit.

Table A.12. Summary statistics for concentrations of elemental contaminants in plants (*Polygonum* sp) from Winters Creek Lake, North Platte National Wildlife Refuge, Scotts Bluff County, Nebraska, 2005.

			Dry Weight Concentration (mg/kg)	
Trace Element	MDL (mg/kg)	N_D/N_A	Mean ± S.E.	Range
Aluminum	3.0	5/5	46 ± 5	38 - 63
Barium	0.2	5/5	4 ± 1	1 - 8
Boron	2.0	5/5	16 ± 1	13 - 17
Copper	0.3	5/5	5 ± 1	1 - 7
Iron	2.0	5/5	63 ± 5	53 - 82
Magnesium	3.0	5/5	2256 ± 51	2140 - 2400
Manganese	0.5	5/5	117 ± 15	74 - 161
Mercury	0.1	1/5	NA	0.1 - 0.1
Nickel	0.3	3/5	0.6 ± 0.1	0.3 - 1.0
Selenium	0.1	4/5	1.1 ± 0.3	0.1 - 1.5
Strontium	0.2	5/5	40 ± 6	17 - 49
Zinc	0.5	5/5	30 ± 2	25 - 36

Note: MDL = method detection limit, N_D = number of samples above detection, N_A = number of samples analyzed, S.E. = standard error, NA = not applicable.

Table A.13. Dry weight concentrations of elemental contaminants in aquatic invertebrate samples from Stateline Island and Winters Creek Lake, North Platte National Wildlife Refuge, Scotts Bluff County, Nebraska, 2006.

			Element Concentration in mg/kg dry weight															
Site	Speices	Sample ID	Al	As	Ba	B	Cd	Cr	Cu	Fe	Pb	Mg	Mn	Ni	Se	Sr	V	Z
Stateline Island	Mixed	SL1IA	1120	4	137	7	2.30	1.7	139	1150	1.2	1510	225	1.0	15.0	369	4.9	61
Stateline Island	Mixed	SL2I	546	4	75	13	1.70	1.0	45	552	0.7	1300	303	0.6	6.5	381	1.9	37
Stateline Island	Mixed	SL4I297	250	5	328	3	1.60	< 0.3	14	556	1.0	1910	83	1.0	6.6	241	4.1	61
Stateline Island	Mixed	SL1IB	1460	4	115	8	2.30	2.1	87	1600	1.8	1550	219	4.1	13.0	285	6.5	84
Stateline Island	Mixed	SL4I	120	2	87	3	1.20	< 0.3	22	474	0.3	1110	564	1.0	6.3	83	1.0	89
Stateline Island	Coroxidae	SL2Corox	130	2	220	1	4.70	< 0.3	62	231	1.5	1130	63	0.8	3.7	15	0.7	122
Winters Creek Lake	Mixed	WCIA	240	1	17	21	0.32	< 0.3	10	672	< 0.1	1860	1190	< 0.3	1.3	215	< 0.3	59
Winters Creek Lake	Mixed	WCIB	130	2	5	7	0.20	< 0.3	13	388	0.4	1150	220	0.6	8.3	25	1.0	80
Winters Creek Lake	Mixed	WCIC	648	2	13	6	0.10	0.7	11	749	0.3	1670	171	0.9	7.3	28	2.1	87
Winters Creek Lake	Anisoptera	WCPFL	62	1	1	2	0.05	< 0.3	11	120	< 0.1	1200	11	0.5	5.4	7	0.3	83

Note: < = less than detection limit.

Table A.14. Dry weight concentrations of elemental contaminants in tadpoles from North Platte National Wildlife Refuge, Scotts Bluff County, Nebraska, 2006.

			Element Concentration in mg/kg dry weight								
Site	Speices	Sample ID	Al	As	B	Ba	Be	Cd	Cr	Cu	Fe
Horse Creek	*Rana catesbeiana*	HCTAD	3540	3.6	7.9	94.7	0.2	0.3	8.7	4.1	3000
Lake Alice	*Bufo woodhousii*	LA2TAD	9430	3.1	11	102	0.41	0.31	8.6	8	7290
Stateline Island	*Rana catesbeiana*	SL3BFT	666	3.1	5	78.2	< 0.05	0.5	1.9	5.8	1920
Winters Creek Lake	*Ambystoma* sp	WC1TS	64	0.5	3	5.4	< 0.05	0.1	0.9	4.8	241

Site	Speices	Sample ID	Hg	Mg	Mn	Ni	Pb	Se	Sr	V	Z
Horse Creek	*Rana catesbeiana*	HCTAD	< 0.05	2820	201	4.6	2.1	8.8	229	8.1	59.6
Lake Alice	*Bufo woodhousii*	LA2TAD	< 0.05	4350	172	6	4.8	4.7	75	20	58.1
Stateline Island	*Rana catesbeiana*	SL3BFT	< 0.05	1540	543	3.5	0.63	16	57.3	3	165
Winters Creek Lake	*Ambystoma* sp	WC1TS	0.2	1600	91.1	< 0.25	< 0.1	1.7	69.3	< 0.25	165

Note: < = less than detection limit.

Table A.15. Fish samples collected for elemental contaminant analysis, North Platte National Wildlife Refuge, Scotts Bluff County, Nebraska, 2005 -2006.

Refuge subunit	Date Collected	Species	Age	No. Composite	No. Individuals
Lake Alice	7/26/2005	Common Carp	sub-adult	5	0
Lake Minitare	7/26/2005	Common Carp	adult	0	6
		Channel Catfish	adult	0	5
		White Sucker	adult	0	5
North Platte River	7/18/2006	Common Carp	adult	0	4
		Cyprinidae Minnows	sub-adult	1	0
		Green sunfish	adult	0	2
		Green sunfish	adult	1	0
		White Sucker	adult	3	0
Stateline Island	6/14/2006	Minnows	unknown	3	0
	7/18/2006	Creek chub	adult	2	0
		White Sucker	adult	2	0
Winters Creek Lake	7/18/2006	Minnows	unknown	1	0

Table A.16. Dry weight concentrations of elemental contaminants in fish from North Platte National Wildlife Refuge, Scotts Bluff County, Nebraska, 2005 and 2006.

			Date	Element Concentration in mg/kg dry weight																	
Site	Sample ID	Species	Collected	Al	As	Ba	B	Cd	Cr	Cu	Fe	Hg	Mg	Mn	Mo	Ni	Pb	Se	Sr	V	Z
Lake Alice	LAcarp01	Common Carp	7/26/2005	141	< 2.5	7	< 8	< 0.8	< 2.5	< 2.5	218	< 0.2	1505	12	< 1.5	< 1.5	< 2.60	16	106	< 2.6	221
Lake Alice	LAcarp02	Common Carp	7/26/2005	150	< 2.5	8	< 8	< 0.8	< 2.5	< 2.5	218	< 0.2	1647	12	< 1.5	< 1.5	< 2.60	15	152	< 2.6	257
Lake Alice	LAcarp03	Common Carp	7/26/2005	207	< 2.5	8	< 8	< 0.8	< 2.5	< 2.5	265	< 0.2	1629	12	< 1.5	< 1.5	< 2.60	17	132	< 2.6	226
Lake Alice	LAcarp04	Common Carp	7/26/2005	209	< 2.5	9	< 8	< 0.8	< 2.5	< 2.5	274	< 0.2	1592	18	< 1.5	< 1.5	< 2.60	13	126	< 2.6	229
Lake Alice	LAcarp05	Common Carp	7/26/2005	169	< 2.5	9	< 8	< 0.8	< 2.5	< 2.5	253	< 0.2	1716	14	< 1.5	< 1.5	< 2.60	14	163	< 2.6	188
Lake Minatare	LMcarp01	Common Carp	7/26/2005	183	< 2.5	10	< 8	< 0.8	< 2.5	< 2.5	264	< 0.2	1721	11	< 1.5	< 1.5	< 2.60	9	163	< 2.6	275
Lake Minatare	LMcarp02	Common Carp	7/26/2005	132	< 2.5	10	< 8	< 0.8	< 2.5	< 2.5	187	< 0.2	1645	11	< 1.5	< 1.5	< 2.60	8	201	< 2.6	159
Lake Minatare	LMcarp03	Common Carp	7/26/2005	178	< 2.5	7	< 8	< 0.8	< 2.5	< 2.5	233	< 0.2	1633	10	< 1.5	< 1.5	< 2.60	10	148	< 2.6	187
Lake Minatare	LMcarp04	Common Carp	7/26/2005	241	< 2.5	15	< 8	< 0.8	< 2.5	< 2.5	229	< 0.2	1913	18	< 1.5	< 1.5	< 2.60	9	214	< 2.6	309
Lake Minatare	LMcarp05	Common Carp	7/26/2005	80	< 2.5	5	< 8	< 0.8	< 2.5	< 2.5	156	< 0.2	1149	< 5	< 1.5	< 1.5	< 2.60	10	55	< 2.6	133
Lake Minatare	LMcarp06	Common Carp	7/26/2005	85	< 5.0	22	< 8	< 0.8	< 2.5	< 2.5	154	< 0.2	2209	19	< 1.5	< 1.5	< 2.60	11	289	< 2.6	238
Lake Minatare	LMcat01	Channel Catfish	7/26/2005	98	< 6.0	4	< 8	< 0.8	< 2.5	< 2.5	132	< 0.2	1468	12	< 1.5	< 1.5	< 2.60	4	98	< 2.6	64
Lake Minatare	LMcat02	Channel Catfish	7/26/2005	159	< 8.0	8	< 8	< 0.8	< 2.5	< 2.5	135	< 0.2	1354	24	< 1.5	< 1.5	< 2.60	3	110	< 2.6	56
Lake Minatare	LMcat03	Channel Catfish	7/26/2005	130	< 8.0	9	< 8	< 0.8	< 2.5	< 2.5	202	< 0.2	1118	8	< 1.5	< 1.5	< 2.60	5	68	< 2.6	63
Lake Minatare	LMcat04	Channel Catfish	7/26/2005	92	< 8.0	18	< 8	< 0.8	< 2.5	< 2.5	138	< 0.2	1102	6	< 1.5	< 1.5	< 2.60	3	66	< 2.6	56
Lake Minatare	LMcat05	Channel Catfish	7/26/2005	47	< 2.5	18	< 8	< 0.8	< 2.5	< 2.5	74	< 0.2	1824	17	< 1.5	< 1.5	< 2.60	4	175	< 2.6	75
Lake Minatare	LMwsuc01	White Sucker	7/26/2005	96	< 2.5	12	< 8	< 0.8	< 2.5	< 2.5	152	0.4	2000	16	< 1.5	< 1.5	< 2.60	7	115	< 2.6	64
Lake Minatare	LMwsuc02	White Sucker	7/26/2005	80	< 2.5	6	< 8	< 0.8	< 2.5	< 2.5	131	0.3	1565	6	< 1.5	< 1.5	< 2.60	8	70	< 2.6	72
Lake Minatare	LMwsuc03	White Sucker	7/26/2005	77	< 2.5	8	< 8	< 0.8	< 2.5	< 2.5	80	< 0.2	1687	11	< 1.5	< 1.5	< 2.60	8	112	< 2.6	55
Lake Minatare	LMwsuc04	White Sucker	7/26/2005	71	< 2.5	9	< 8	< 0.8	< 2.5	< 2.5	112	0.3	2147	11	< 1.5	< 1.5	< 2.60	7	141	< 2.6	79
Lake Minatare	LMwsuc05	White Sucker	7/26/2005	289	< 2.5	13	< 8	< 0.8	< 2.5	< 2.5	277	< 0.2	2026	12	< 1.5	< 1.5	< 2.60	8	106	< 2.6	74
North Platte River	NPR1CARP	Common Carp	7/18/2006	6	0.2	0	2	0.37	<0.5	12.6	428	0.1	472	3	0.3	0.1	0.07	32	1	0.4	1155
North Platte River	NPRC2	Common Carp	7/18/2006	18	0.3	1	1	1.70	<0.5	12.0	309	0.1	709	7	0.4	0.2	0.21	32	3	0.7	2909
North Platte River	NPRC3	Common Carp	7/18/2006	4	0.1	0	< 8	0.08	<0.5	2.2	50	0.4	1196	1	0.2	< 1.5	0.05	21	5	< 0.05	83
North Platte River	NPRC4	Common Carp	7/18/2006	41	0.8	5	3	3.28	0.5	20.8	166	0.1	1042	25	1.1	0.2	0.29	20	47	1.3	986
North Platte River	NPRF1	Cyprinidae minnows	6/15/2006	511	0.6	12	4	<0.04	0.9	2.2	468	0.1	1429	66	0.3	0.5	0.38	21	67	0.9	138
North Platte River	NPRGS1	Green Sunfish	7/18/2006	16	0.3	3	1	<0.04	0.9	< 0.5	22	0.1	1674	10	0.2	0.1	<0.05	12	102	< 0.05	74
North Platte River	NPRGS2	Green Sunfish	7/18/2006	5	0.3	2	< 8	<0.04	0.7	1.0	21	0.1	1641	5	0.3	0.1	<0.05	16	80	< 0.05	90
North Platte River	NPRGS3	Green Sunfish	7/18/2006	5	0.3	4	< 8	0.05	0.8	1.4	27	0.1	1410	26	0.5	0.3	0.37	15	88	< 0.05	115
North Platte River	NPRWS1	White Sucker	7/18/2006	< 1	0.2	3	< 8	0.06	0.5	1.4	24	0.2	1410	12	0.2	0.1	<0.05	25	46	< 0.05	40
North Platte River	NPRWS2	White Sucker	7/18/2006	3	0.4	9	1	<0.04	1.0	1.0	21	0.1	1849	33	0.2	0.1	0.07	19	148	< 0.05	76
North Platte River	NPRWS3	White Sucker	7/18/2006	< 1	0.4	6	< 8	<0.04	0.9	1.5	24	0.2	1799	21	0.3	0.2	0.09	10	196	< 0.05	69
Stateline Island	SL2	Cyprinidae minnows	6/19/2006	44	0.7	13	3	0.13	0.7	6.1	115	0.1	1322	18	0.2	0.3	0.19	10	83	0.1	144
Stateline Island	SL2CC1	Creek chub	7/18/2006	< 1	0.5	2	1	0.09	<0.5	3.1	34	0.2	1180	15	0.4	0.2	<0.05	17	37	< 0.05	73
Stateline Island	SL2CC2	Creek chub	7/18/2006	< 1	0.2	3	< 8	<0.04	<0.5	1.5	13	0.1	857	5	0.1	0.1	<0.05	8	36	< 0.05	68
Stateline Island	SL2WS1	White Sucker	7/18/2006	< 1	0.4	5	2	0.36	0.9	3.2	73	0.1	1485	46	0.5	0.9	<0.05	16	61	0.2	68
Stateline Island	SL2WS2	White Sucker	7/18/2006	< 1	26.9	4	< 8	<0.04	<0.5	1.2	10	19.3	1163	22	<0.03	< 0.04	2.31	563	73	< 0.05	33
Stateline Island	SL3	Cyprinidae minnows	6/14/2006	5	0.6	14	2	<0.04	0.8	2.7	56	0.1	1662	22	0.3	0.2	<0.05	9	132	< 0.05	188
Stateline Island	SL4	Cyprinidae minnows	6/14/2006	4	0.6	11	2	0.07	0.7	6.7	98	0.1	1378	22	0.3	0.1	<0.05	11	81	< 0.05	155
Winters Creek Lake	WCFish	Cyprinidae minnows	7/18/2006	175	2.0	8	4	0.53	1.3	3.3	218	0.4	1675	9	0.9	1.6	0.13	9	205	0.9	136

Note: < = less than detection limit.

Table A.17. Wet weight concentrations of elemental contaminants in fish from North Platte National Wildlife Refuge, Scotts Bluff County, Nebraska, 2005 and 2006.

Site	Sample ID	Species	Date Collected	Element Concentration in mg/kg wet weight																	
				Al	As	Ba	B	Cd	Cr	Cu	Fe	Hg	Mg	Mn	Mo	Ni	Pb	Se	Sr	V	Z
Lake Alice	LAcarp01	Common Carp	7/26/2005	30	< 0.5	1.4	< 1.6	< 0.16	< 0.5	< 0.5	46	< 0.04	314	2	< 0.3	< 0.3	< 0.5	3	22	< 0.5	46
Lake Alice	LAcarp02	Common Carp	7/26/2005	29	< 0.5	1.6	< 1.5	< 0.15	< 0.5	< 0.5	42	< 0.04	318	2	< 0.3	< 0.3	< 0.5	3	29	< 0.5	50
Lake Alice	LAcarp03	Common Carp	7/26/2005	40	< 0.5	1.6	< 1.5	< 0.15	< 0.5	< 0.5	52	< 0.05	318	2	< 0.3	< 0.3	< 0.5	3	26	< 0.5	44
Lake Alice	LAcarp04	Common Carp	7/26/2005	46	< 0.6	2.1	< 1.7	< 0.17	< 0.6	< 0.6	60	< 0.05	349	4	< 0.3	< 0.3	< 0.6	3	28	< 0.6	50
Lake Alice	LAcarp05	Common Carp	7/26/2005	33	< 0.5	1.7	< 1.5	< 0.15	< 0.5	< 0.5	49	< 0.04	333	3	< 0.3	< 0.3	< 0.5	3	32	< 0.5	37
Lake Minatare	LMcat01	Channel Catfish	7/26/2005	25	< 1.7	1.0	< 2.0	< 0.20	< 0.7	< 0.7	34	< 0.06	380	< 2	< 0.4	< 0.4	< 0.7	1	25	< 0.7	17
Lake Minatare	LMcat02	Channel Catfish	7/26/2005	47	< 2.2	2.5	< 2.2	< 0.22	< 0.7	< 0.7	40	< 0.07	397	3	< 0.5	< 0.5	< 0.7	1	32	< 0.7	16
Lake Minatare	LMcat03	Channel Catfish	7/26/2005	37	< 2.5	2.7	< 2.2	< 0.22	< 0.7	< 0.7	58	< 0.07	322	7	< 0.4	< 0.4	< 0.7	2	20	< 0.7	18
Lake Minatare	LMcat04	Channel Catfish	7/26/2005	26	< 2.7	5.0	< 2.1	< 0.21	< 0.7	< 0.7	39	< 0.07	309	2	< 0.4	< 0.4	< 0.7	1	18	< 0.7	16
Lake Minatare	LMcat05	Channel Catfish	7/26/2005	12	< 0.7	4.7	< 2.0	< 0.20	< 0.7	< 0.7	19	< 0.06	478	2	< 0.4	< 0.4	< 0.7	1	46	< 0.7	20
Lake Minatare	LMcarp01	Common Carp	7/26/2005	49	< 0.7	2.6	< 2.0	< 0.20	< 0.7	< 0.7	70	< 0.07	460	5	< 0.4	< 0.4	< 0.7	2	44	< 0.7	74
Lake Minatare	LMcarp02	Common Carp	7/26/2005	36	< 0.7	2.8	< 2.1	< 0.21	< 0.7	< 0.7	51	< 0.07	451	3	< 0.4	< 0.4	< 0.7	2	55	< 0.7	44
Lake Minatare	LMcarp03	Common Carp	7/26/2005	49	< 0.7	2.0	< 2.1	< 0.21	< 0.7	< 0.7	64	< 0.06	447	3	< 0.4	< 0.4	< 0.7	3	40	< 0.7	51
Lake Minatare	LMcarp04	Common Carp	7/26/2005	60	< 0.7	3.6	< 1.9	< 0.19	< 0.6	< 0.6	57	< 0.05	476	3	< 0.4	< 0.4	< 0.6	2	53	< 0.6	77
Lake Minatare	LMcarp05	Common Carp	7/26/2005	28	< 1.23	1.6	< 2.6	< 0.26	< 0.9	< 0.9	55	< 0.08	402	5	< 0.5	< 0.5	< 0.9	4	19	< 0.9	47
Lake Minatare	LMcarp06	Common Carp	7/26/2005	14	< 0.92	3.6	< 1.3	< 0.13	< 0.4	< 0.4	26	< 0.04	367	3	< 0.3	< 0.3	< 0.4	2	48	< 0.4	39
Lake Minatare	LMwsuc01	White Sucker	7/26/2005	20	< 0.52	2.4	< 1.7	< 0.16	< 0.5	< 0.5	32	< 0.07	418	3	< 0.3	< 0.3	< 0.5	2	24	< 0.5	13
Lake Minatare	LMwsuc02	White Sucker	7/26/2005	18	< 0.6	1.3	< 1.8	< 0.18	< 0.6	< 0.6	30	< 0.04	354	1	< 0.4	< 0.4	< 0.6	2	16	< 0.6	16
Lake Minatare	LMwsuc03	White Sucker	7/26/2005	18	< 0.6	1.9	< 1.8	< 0.18	< 0.6	< 0.6	19	0.08	396	3	< 0.4	< 0.4	< 0.6	2	26	< 0.6	13
Lake Minatare	LMwsuc04	White Sucker	7/26/2005	18	< 0.6	2.2	< 1.9	< 0.19	< 0.6	< 0.6	28	0.07	530	3	< 0.4	< 0.4	< 0.6	2	35	< 0.6	19
Lake Minatare	LMwsuc05	White Sucker	7/26/2005	58	< 0.5	2.5	< 1.6	< 0.16	< 0.5	< 0.5	55	0.08	403	2	< 0.3	< 0.3	< 0.5	2	21	< 0.5	15
North Platte River	NPR1CARP	Common Carp	7/18/2006	4	0.12	0.2	1.20	0.29	< 0.4	9.83	335	0.04	369	2	0.22	0.06	0.05	25	1	0.35	903
North Platte River	NPRC2	Common Carp	7/18/2006	6	0.08	0.3	0.44	0.53	< 0.2	3.71	96	0.03	220	2	0.14	0.06	0.07	10	1	0.22	904
North Platte River	NPRC3	Common Carp	7/18/2006	1	0.04	0.1	< 0.3	0.02	< 0.1	0.58	13	0.11	321	0	0.05	< 0.01	0.01	6	1	< 0.01	22
North Platte River	NPRC4	Common Carp	7/18/2006	14	0.28	1.7	1.04	1.12	0.18	7.07	57	0.03	355	9	0.36	0.07	0.10	7	16	0.43	336
North Platte River	NPRF1	Cyprinidae minnows	6/15/2006	138	0.17	3.1	0.96	< 0.01	0.24	0.60	126	0.03	386	18	0.08	0.13	0.10	6	18	0.24	37
North Platte River	NPRGS1	Green Sunfish	7/18/2006	5	0.10	0.9	0.36	< 0.01	0.28	< 0.2	7	0.03	504	3	0.07	0.03	< 0.02	3	31	< 0.01	22
North Platte River	NPRGS2	Green Sunfish	7/18/2006	1	0.09	0.5	< 0.3	< 0.01	0.22	0.29	6	0.04	475	1	0.10	0.02	< 0.02	5	23	< 0.02	26
North Platte River	NPRGS3	Green Sunfish	7/18/2006	2	0.14	1.8	< 0.4	0.02	0.33	0.59	12	0.06	591	11	0.21	0.14	0.15	6	37	< 0.02	48
North Platte River	NPRWS1	White Sucker	7/18/2006	< 0.3	0.05	0.7	< 0.3	0.01	0.13	0.35	6	0.04	346	3	0.05	0.02	< 0.01	6	11	< 0.01	10
North Platte River	NPRWS2	White Sucker	7/18/2006	1	0.11	2.4	0.34	< 0.01	0.28	0.26	6	0.03	507	9	0.04	0.03	0.02	5	40	< 0.01	21
North Platte River	NPRWS3	White Sucker	7/18/2006	< 0.2	0.10	1.4	< 0.2	< 0.01	0.21	0.34	6	0.04	420	5	0.08	0.04	0.02	2	46	< 0.01	16
Stateline Island	SL2	Cyprinidae minnows	6/19/2006	11	0.19	3.4	0.80	0.03	0.18	1.57	29	0.03	337	5	0.06	0.07	0.05	3	21	0.04	37
Stateline Island	SL2CC1	Creek chub	7/18/2006	< 0.3	0.15	0.8	0.39	0.03	< 0.2	1.04	11	0.05	398	5	0.14	0.06	< 0.02	6	12	< 0.02	24
Stateline Island	SL2CC2	Creek chub	7/18/2006	< 0.5	0.08	1.3	< 0.45	< 0.01	< 0.2	0.70	6	0.04	389	2	0.03	0.05	< 0.02	4	16	< 0.02	31
Stateline Island	SL2WS1	White Sucker	7/18/2006	< 0.3	0.09	1.3	0.41	0.09	0.22	0.81	18	0.02	376	12	0.13	0.24	< 0.01	4	16	0.05	17
Stateline Island	SL2WS2	White Sucker	7/18/2006	< 0.3	6.48	0.9	< 0.3	< 0.01	< 0.13	0.28	2	4.66	281	5	< 0.01	< 0.01	0.56	136	18	< 0.01	8
Stateline Island	SL3	Cyprinidae minnows	6/14/2006	1	0.14	3.5	0.43	< 0.01	0.20	0.68	14	0.02	425	6	0.09	0.04	< 0.01	2	34	< 0.01	48
Stateline Island	SL4	Cyprinidae minnows	6/14/2006	1	0.17	3.1	0.44	0.02	0.19	1.87	27	0.02	384	6	0.09	0.04	< 0.02	3	23	< 0.01	43
Winters Creek Lake	WCFish	Cyprinidae minnows	7/18/2006	38	0.43	1.8	0.94	0.11	0.28	0.72	47	0.09	360	2	0.19	0.34	0.03	2	44	0.18	29

Note: < = less than detection limit.

Table A.18. Summary statistics for dry weight concentrations of elemental contaminants in common carp (*Cyprinus carpio*) from Lake Alice, Lake Minatare, and the North Platte River, Scotts Bluff County, Nebraska, 2005 and 2006.

		Lake Alice			Lake Minitare			North Platte River near Stateline Island		
			Dry Weight Concentration (mg/kg)			Dry Weight Concentration (mg/kg)			Dry Weight Concentration (mg/kg)	
Trace Element	MDL	N_D/N_A	Mean ± S.E.	Range	N_D/N_A	Mean ± S.E.	Range	N_D/N_A	Mean ± S.E.	Range
Aluminum	13	5/5	175 ± 14	141 - 209	6/6	150 ± 26	80 - 241	5/5	116 ± 99	4 - 511
Arsenic	6	0/5	NA	1.3 - 1.3	0/6	NA	1.3 - 2.8	5/5	0.4 ± 0.1	0.1 - 0.8
Barium	1	5/5	8.3 ± 0.4	6.8 - 9.4	6/6	11.4 ± 2.5	4.6 - 21.9	5/5	3.6 ± 2.2	0.2 - 11.6
Boron	8	0/5	NA	NA	0/6	NA	NA	4/5	2.0 ± 0.6	0.5 - 3.6
Cadmium	1	0/5	NA	NA	0/6	NA	NA	4/5	1.09 ± 0.63	0.02 - 3.28
Chromium	3	0/5	NA	NA	0/6	NA	NA	2/3	NA	0.26 - 0.90
Copper	3	0/5	NA	NA	0/6	NA	NA	5/5	9.9 ± 3.5	2.2 - 20.8
Iron	5	5/5	246 ± 12	218 - 274	6/6	204 ± 18	154 - 264	5/5	284 ± 79	50 - 468
Lead	3	0/5	NA	NA	0/6	NA	NA	5/5	0.2 ± 0.1	0.1 - 0.4
Magnesium	26	5/5	1618 ± 35	1505 - 1716	6/6	1712 ± 143	1149 - 2209	5/5	970 ± 171	472 - 1429
Manganese	5	5/5	14 ± 1	12 - 18	5/6	12 ± 2	3 - 19	5/5	20 ± 12	1 - 66
Mercury	0	0/5	NA	NA	0/6	NA	NA	5/5	0.15 ± 0.06	0.05 - 0.40
Molybdenum	2	0/5	NA	NA	0/6	NA	NA	5/5	0.5 ± 0.2	0.2 - 1.1
Nickel	2	0/5	NA	NA	0/6	NA	NA	4/5	0.2 ± 0.1	0.03 - 0.5
Selenium	3	5/5	15 ± 1	13 - 17	6/6	10 ± 0	8 - 11	5/5	26 ± 3	20 - 32
Strontium	3	5/5	136 ± 10	106 - 163	6/6	178 ± 32	55 - 289	5/5	25 ± 14	1 - 67
Vanadium	3	0/5	NA	NA	0/6	NA	NA	4/5	0.7 ± 0.2	0.03 - 1.3
Zinc	5	5/5	224 ± 11	188 - 257	6/6	217 ± 28	133 - 309	5/5	1054 ± 512	83 - 2909

Note: MDL = maximum method detection limit, N_D = number of samples above detection, N_A = number of samples analyzed, S.E. = standard error.

Table A.19. Summary statistics for concentrations of elemental contaminants in fish from Stateline Island, Horse Creek, and Spotted Tail compared to background and toxicity threshold benchmarks, Scotts Bluff County, Nebraska, 2005 and 2006.

			Fish from North Platte NWR							BEST program*					
Common name	Site	Analyte	N_D	N_A	MDL	Mean	S.E.	Min.	Max.	N_D	N_A	Mean	S.E.	NCBP**	Toxicity Benchmarks
Channel Catfish	LM	Selenium	5	5	0.7	1.0	± 0.1	0.8	1.5	15.0	15.0	0.6	± 0.1		2[1], 5[1]
		Strontium	5	5	0.7	28	± 5	18	46	15	15	25	± 3		NA
Common Carp	LA	Selenium	5	5	0.5	3.1	± 0.1	2.8	3.4	152.0	152.0	0.9	± 0.1	0.70 - 0.73	2[1], 5[1]
		Strontium	5	5	0.5	27	± 2	22	32	152	152	21	± 1		NA
	LM	Selenium	6	6	0.4	2.5	± 0.3	1.8	3.7	152.0	152.0	0.9	± 0.1	0.70 - 0.73	2[1], 5[1]
		Strontium	6	6	0.4	43	± 5	19	55	152	152	21	± 1		
	NPR	Cadmium	5	5	0.0	0.393	± 0.205	0.004	1.118	121	152	0.109	± 0.009	0.05 - 0.11	2[2]
		Copper	5	5	0.1	4.36	± 1.82	0.58	9.83	152.00	152.00	1.17	± 0.04		11[3]
		Selenium	5	5	0.1	10.7	± 3.7	5.8	25.3	152	152	0.9	± 0.1	0.70 - 0.73	2[1], 5[1]
		Zinc	5	5	0.3	440	± 197	22	904	152	152	74	± 2	34 - 46	
White Sucker	LM	Magnesium	5	5	5.2	420	± 29	354	530	4	4	343	± 38		
		Selenium	5	5	0.5	1.8	± 0.1	1.5	2.0	3	4	0.6	± 0.2		2[1], 5[1]
		Strontium	5	5	0.5	24	± 3	16	35	4	4	7	± 2		
	NPR	Magnesium	3	3	1.2	424	± 47	346	507	4	4	343	± 38		
		Selenium	3	3	0.0	4.6	± 1.2	2.3	6.2	3	4	0.6	± 0.2		2[1], 5[1]
		Strontium	3	3	0.0	33	± 11	11	46	4	4	7	± 2		
	SL	Arsenic	2	2	0.0	3.29	± 3.20	0.09	6.48	3.00	4.00	0.10	± 0.05		5.4[4]
		Selenium	2	2	0.1	70.0	± 65.9	4.2	135.9	3.0	4.0	0.6	± 0.2		2[1], 5[1]
		Strontium	2	2	0.0	17	± 1	16	18	4	4	7	± 2		

Note: LM = Lake Minatare, LA = Lake Alice, NPR = North Platte River at Stateline Island, SL = Stateland Island, MDL = maximum method detection limit, N_D = number of samples above detection, N_A = number of samples analyzed, S.E. = standard error. * = Data from Biomonitoring of Environmental Status and Trends Program (http://www.cerc.usgs.gov/data/best/search/index.htm). ** = 85 percentile concentration from National Contaminant Biomonitoring Program 1976-1984 (Schmitt and Brumbaugh, 1990). For "Toxicity Benchmarks" column: 1 = human health advisory recommendations for no consumption by children and pregnant women (Fan et al, 1988) and complete ban on human consumption (USDOI, 1998); 2 = evidence of probable cadmium contamination (Eisler, 1985); 3 = reduced survival of carp larvae (Stouthart et al., 1996); 4 = increased mortality in rainbow trout (McGreachy and Dixon, 1990).

Table A.20. Summary statistics for concentrations of elemental contaminants in wood duck eggs from Lake Alice and Lake Minatare at North Platte National Wildlife Refuge, Scotts Bluff County, Nebraska, 2005 and 2006.

		Lake Alice			Lake Minitare		
			Dry Weight Concentration (mg/kg)			Dry Weight Concentration (mg/kg)	
Trace Element	MDL (mg/kg)	N_D/N_A	Mean ± S.E.	Range	N_D/N_A	Mean ± S.E.	Range
Aluminum	1.0	3/16	NA	29 - 73	6/26	NA	2 - 29
Arsenic	0.1	3/16	NA	0.1 - 0.2	0/25	NA	NA
Barium	0.2	16/16	5.7 ± 0.8	1.0 - 11.5	25/26	10.6 ± 0.1	4.7 - 11.5
Beryllium	0.03	0/16	NA	NA	2/26	NA	0.1 - 0.3
Boron	1.0	1/16	NA	1.1 - 1.1	1/26	NA	1.5 - 1.5
Cadmium	0.03	0/16	NA	NA	2/26	NA	0.1 - 0.2
Copper	0.5	16/16	3.3 ± 0.3	1.7 - 6.3	25/26	2.8 ± 0.2	0.3 - 5.2
Lead	0.1	0/16	NA	NA	2/26	NA	0.15 - 0.15
Iron	5.0	16/16	1346 ± 693	25 - 8001	26/26	730 ± 310	47 - 6015
Magnesium	5.0	16/16	3783 ± 1855	64 - 21388	26/26	4012 ± 1717	292 - 25809
Manganese	0.1	16/16	3.3 ± 0.7	0.5 - 9.4	21/26	1.7 ± 0.2	0.1 - 3.3
Mercury	0.02	13/16	0.07 ± 0.01	0.01 - 0.20	18/26	0.09 ± 0.01	0.01 - 0.22
Molybednum	0.05	16/16	0.19 ± 0.02	0.10 - 0.30	20/26	0.32 ± 0.05	0.03 - 0.79
Nickel	0.05	15/16	0.09 ± 0.01	0.03 - 0.19	20/26	0.26 ± 0.06	0.03 - 0.79
Selenium	0.2	16/16	5.9 ± 0.6	0.6 - 9.8	26/26	6.4 ± 0.3	3.8 - 9.7
Strontium	0.05	16/16	81 ± 38	4 - 566	26/26	186 ± 82	9 - 1486
Vanadium	0.05	0/16	NA	NA	2/26	NA	NA
Zinc	1.0	16/16	59 ± 5	10 - 92	25/26	62 ± 3	1 - 88

Table A.21. Summary statistics for concentrations of elemental contaminants in Canada goose eggs from Winters Creek Lake, North Platte National Wildlife Refuge, Scotts Bluff County, Nebraska, 2005 and 2006.

Trace Element	MDL	N_D/N_A	Dry Weight Concentration (mg/kg)	
			Mean ± S.E.	Range
Aluminum	3.0	1/15	NA	< 3 - 7
Barium	0.2	15/15	9 ± 1	1 - 16
Boron	2.0	3/15	NA	< 2 - 5
Copper	0.3	15/15	3.0 ± 0.1	2.6 - 3.6
Iron	2.0	15/15	101 ± 6	37 - 130
Magnesium	2.0	15/15	418 ± 10	311 - 471
Manganese	0.5	12/15	1.1 ± 0.2	< 0.5 - 2.6
Selenium	0.1	15/15	2.6 ± 0.2	1.6 - 3.8
Strontium	0.2	15/15	12 ± 2	6 - 31
Zinc	0.5	15/15	64 ± 2	45 - 74

Table A.22. Mean egg width and strontium concentration in wood duck eggs from Lake Alice and Lake Minatare subunits of North Platte National Wildlife Refuge, Scotts Bluff County, Nebraska, 2005 and 2006.

Site	Egg ID	Mean egg width (mm)	Strontium concentration (mg/kg)	Site	Egg ID	Mean egg width (mm)	Strontium concentration (mg/kg)
Lake Alice	LA14E1	0.27	5	Lake Minatare	LM15E3	0.28	11
	LA14E2	0.26	4		LM15E4	0.28	12
	LA14E3	0.32	15		LM15E5	0.31	10
	LA14E4	0.23	7		LM15E6	0.26	16
	LA14E5	0.34	14		LM26E1	0.28	12
	LA4E1	0.28	11		LM26E2	0.28	12
	LA4E2	0.25	17		LM26E3	0.23	10
	LA4E3	0.25	21		LM30E1	0.27	993
	LA4E4	0.26	18		LM30E2	0.29	985
	LA4E5	0.26	6		LM30E3	0.29	1,486
Lake Minatare	LM14E1	0.27	13		LM30E4	0.29	1,042
	LM14E2	0.29	14		LM30E5	0.29	22
	LM14E3	0.24	35		LMNB2301	0.26	18
	LM14E4	0.25	16		LMNB2302	0.30	16
	LM14E5	0.26	10		LMNB2303	0.28	15
	LM15E1	0.30	10		LMNB2304	0.30	19
	LM15E2	0.30	9		LMNB2305	0.29	13

APPENDIX B: ADDITIONAL FIGURES

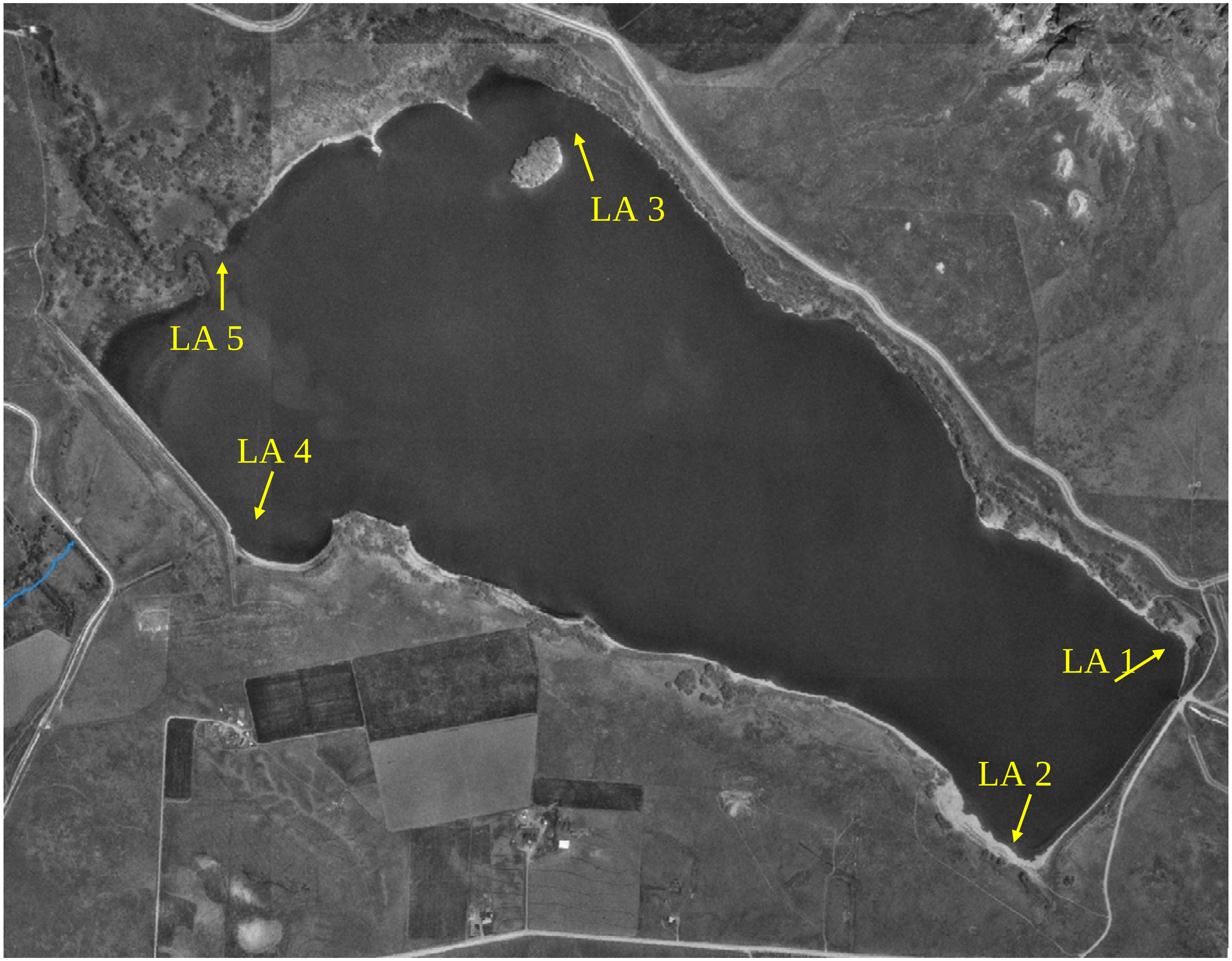


Figure B.1. Sample sites at Lake Alice subunit, North Platte National Wildlife Refuge, 2005 and 2006.

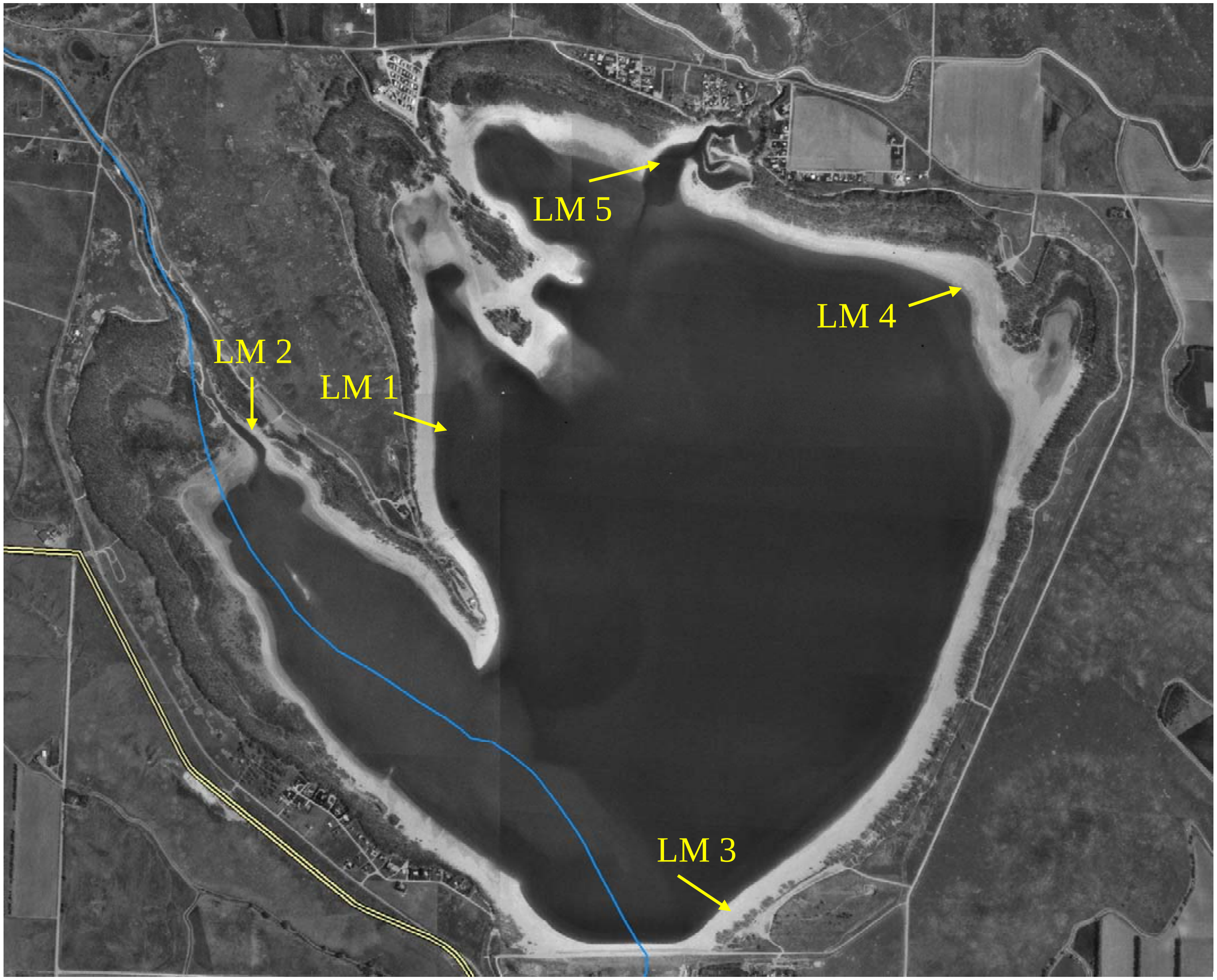


Figure B. 2. Sample sites at Lake Minatare subunit, North Platte National Wildlife Refuge, 2005 and 2006.

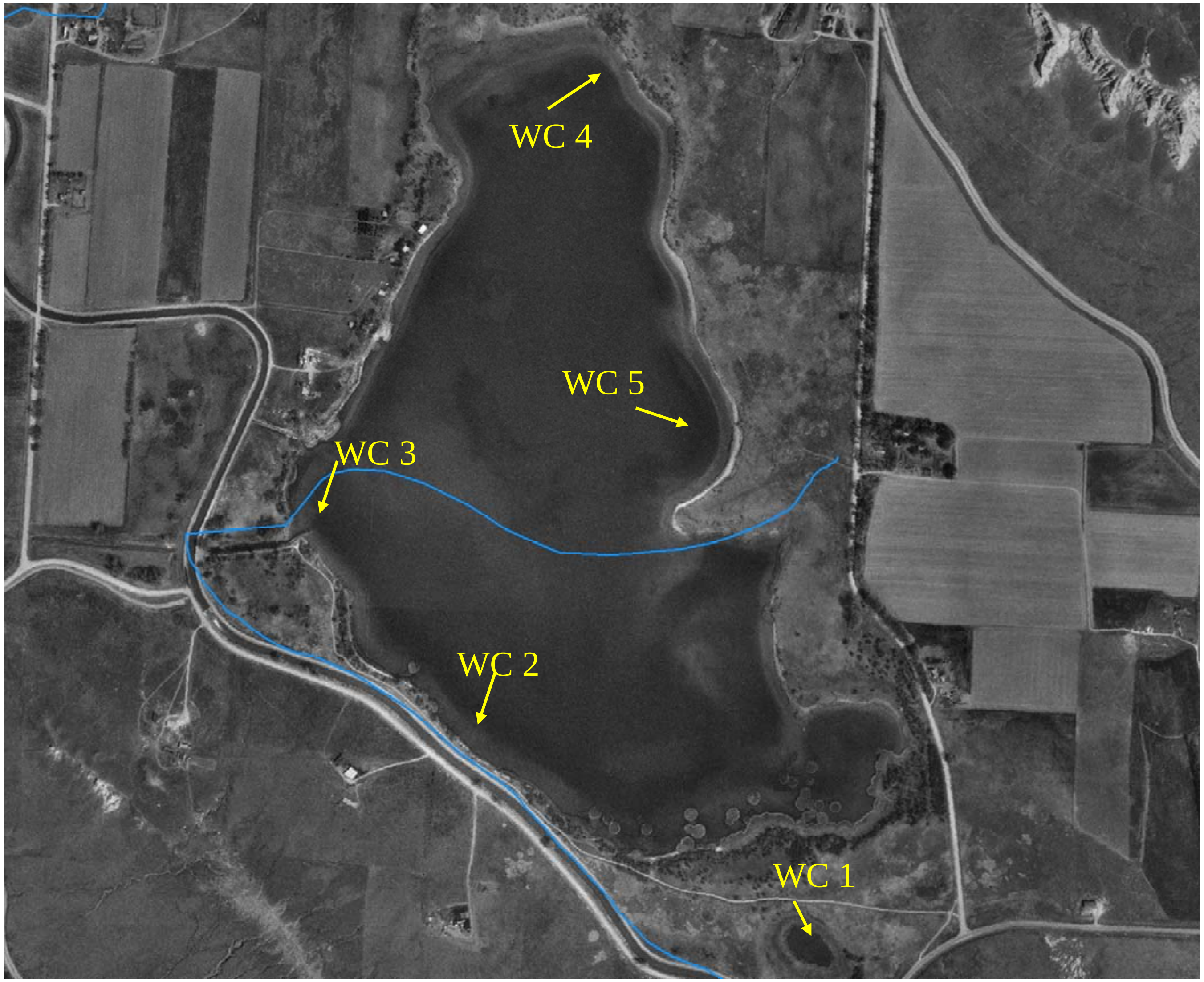
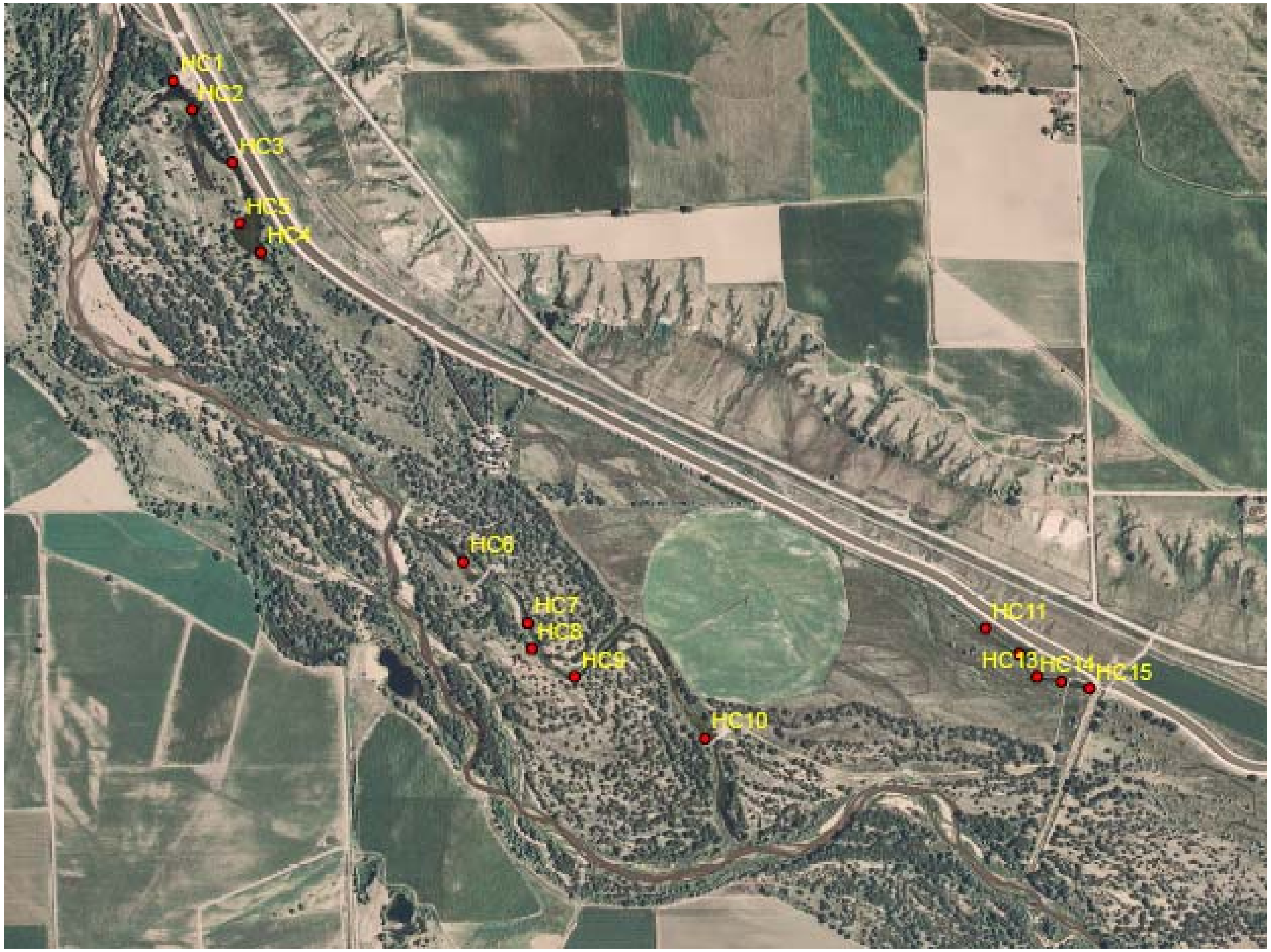


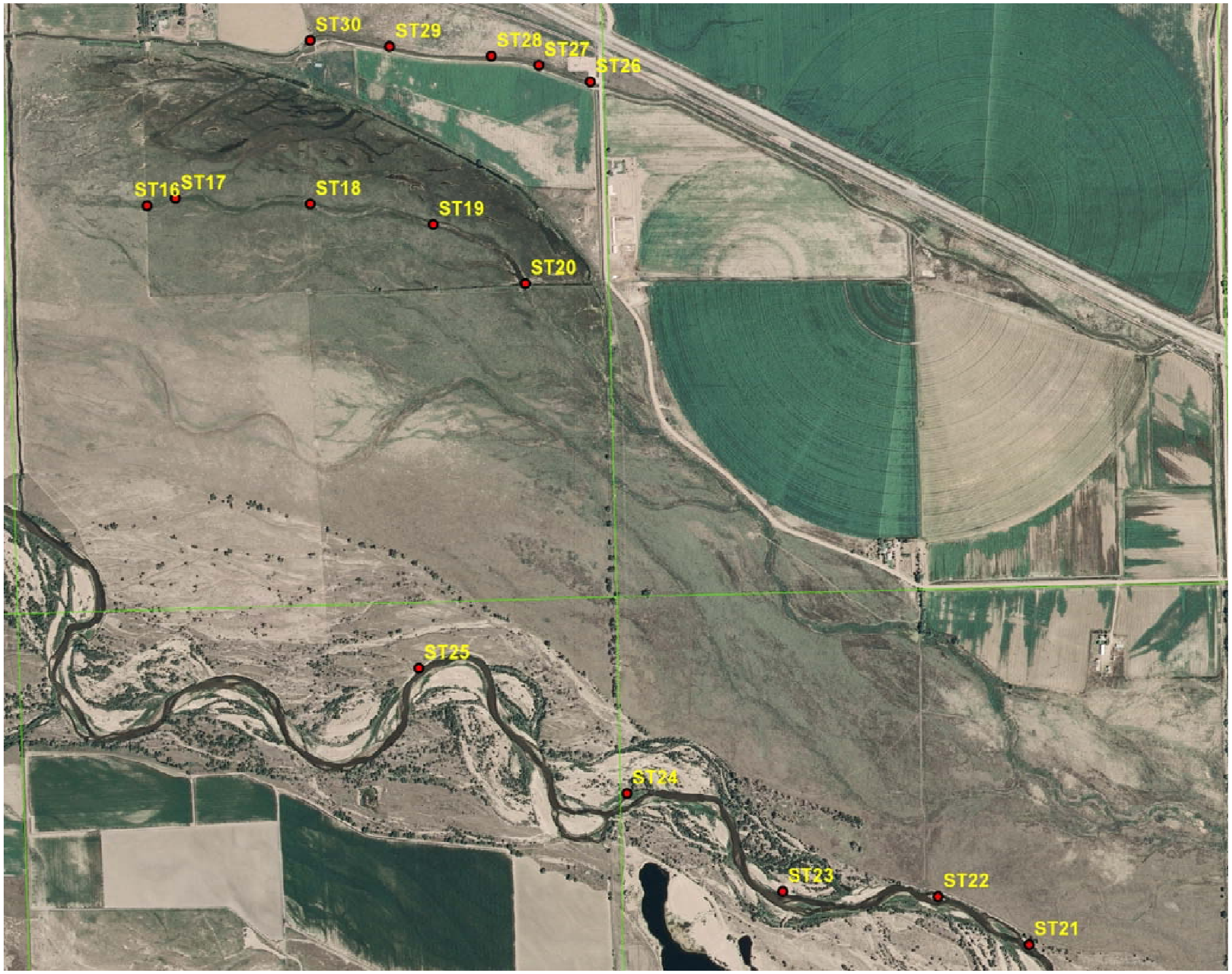
Figure B.3. Sample sites at Winters Creek Lake subunit, North Platte National Wildlife Refuge, 2005 and 2006.

Figure B.4. Sample sites at Stateline Island subunit, North Platte National Wildlife Refuge, 2005 and 2006.



Sample ID	Selenium Concentration mg/kg dw
HC1	2.02
HC2	2.98
HC3	0.771
HC4	9.71
HC5	6.12
HC6	< 0.754
HC7	2.13
HC8	0.89
HC9	1.48
HC10	1.1
HC11	1.28
HC12	2.95
HC13	3.92
HC14	4.19
HC15	5.08

Figure B.5. Sediment samples collected for elemental contaminant concentrations at Horse Creek site, Scotts Bluff County, Nebraska, 2007.



Sample ID	Selenium Concentration mg/kg dw
ST16	2.1
ST17	0.859
ST18	2.12
ST19	2.34
ST20	5.49
ST21	< 0.424
ST22	< 0.453
ST23	< 0.431
ST24	< 0.459
ST25	< 0.467
ST26	2.12
ST27	< 0.393
ST28	0.119
ST29	< 0.423
ST30	0.21

Figure B.6. Sediment samples collected for elemental contaminant concentrations at Spotted Tail site, Scotts Bluff County, Nebraska, 2007.