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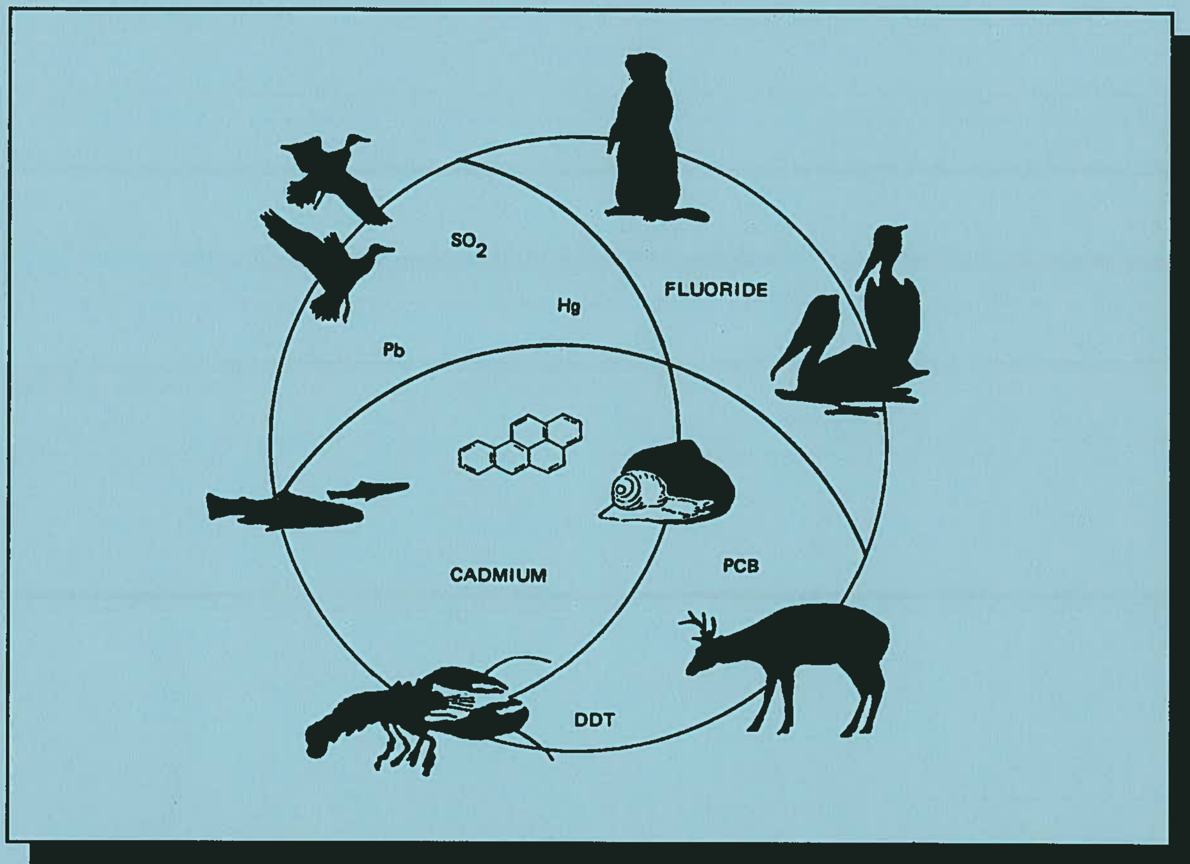
CONTAMINANT CONCERNS FOR WEST RIVER NATIONAL WILDLIFE REFUGES SLOPE AND DUNN COUNTIES, NORTH DAKOTA



July 1998

Prepared by

U.S. FISH AND WILDLIFE SERVICE
Ecological Services
North Dakota Field Office
1500 Capitol Avenue
Bismarck, North Dakota 58501

Project ID# 92-6-6N11
93-6-6N11

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NATIONAL WILDLIFE REFUGES
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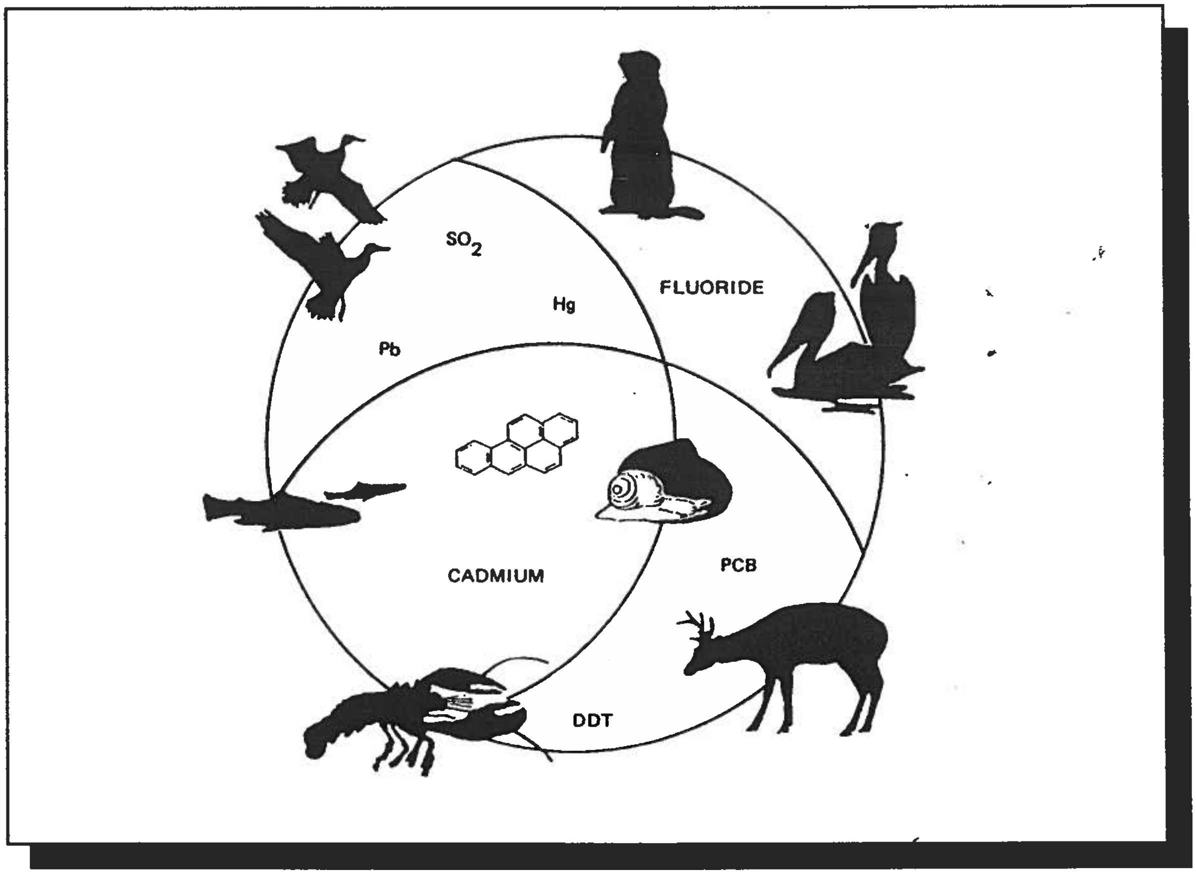

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ABSTRACT

From 1990 to 1993 three National Wildlife Refuges (NWRs) located west of the Missouri River in North Dakota were surveyed for contaminants. Trace element concentrations were determined in water, sediment, fish, and bird tissues collected from Stewart Lake, White Lake, and Lake Ilo NWRs. Selenium levels in young-of-the-year waterfowl livers from Stewart Lake ranged from 4.3 to 40 µg/g dry wt., with a mean of 18.5. This concentration is considered elevated. Waterfowl livers from White Lake and Lake Ilo were not elevated. Selenium in 41 eared grebe (*Podiceps nigricollis*) eggs, from Stewart Lake NWR averaged 4.5 *u*g/g dry weight (range 2.9-6.5 *u*g/g), and is above the 85th percentile of mean concentrations in background investigations of selenium in eggs from the wetern United States. All other contaminant concentrations were within normal ranges. Management strategies to improve water quality and reduce erosion would be beneficial to Stewart Lake NWR.

INTRODUCTION

National Wildlife Refuges (NWRS) west of the Missouri River in North Dakota are critical to resident wildlife and migratory birds. Because of the aridity of this region, migratory aquatic birds depend on wetlands in these areas for staging, brood rearing, and migratory resting areas.

This study focused on three refuges; Stewart Lake and White Lake in Slope County, and Lake Ilo in Dunn County. Results of a Level II Contaminant Survey performed in 1990 indicated potentially elevated selenium concentrations in livers of young-of-the-year waterfowl from the Stewart Lake NWR. Level II Surveys are performed to either confirm or disprove the presence of contaminants on a site. Sample analyses are usually first conducted at this level to determine the presence and magnitude of contaminants. Therefore, this study emphasized a more extensive analysis of contaminants in biota utilizing this refuge.

Based on United States Department of Agriculture records, soils adjacent to Stewart Lake NWR have the potential for biologically significant selenium concentrations (U.S. Soil Conservation Service 1978). The majority of the soils in Slope County developed from sedimentary material deposited millions of years ago when this area was covered by oceans and inland seas. This type of geologic history has established potentially elevated concentrations of selenium in area soils (U.S. Soil Conservation Service 1978). The source of selenium is thought to be pyritic material found within the vast lignite coal resources, or the marine shales which underlie some of the western landscape. The largest lignite coal reserves in North Dakota are located in Dunn County. Although abandoned coal mines exist in the county, the nearest active mine is located near Beulah, about 32 miles east of Lake Ilo NWR. Dunn County soils have similar selenium concentrations and have similar origins as Slope County soils (U.S. Soil Conservation Service 1982).

This report summarizes contaminant data for water, sediment, and bird eggs, and livers from young-of-the-year waterfowl collected at Stewart Lake from 1990 through 1993, White Lake from 1992 to 1993, and Lake Ilo from 1992 and 1993.

STUDY AREA

Stewart Lake is located about 12 km southwest of Amidon in Slope County, North Dakota (Figure 1). Stewart Lake NWR contains approximately 1,000 surface ha of water and is surrounded by over 4,400 ha of upland. The lake is spring fed and receives runoff from two tributaries. The lake is impounded by an earthen dam with a rock and concrete spillway. The refuge was widely used for recreation prior to the construction of larger reservoirs in the area.

During the 4 years of this study, North Dakota experienced a drought and the lake water level was 1 to 3 m below normal pool elevation. Maximum depth was approximately 1.5 m. Much of the eastern end of the lake was dry or less than 10 cm deep during the course of the study. Highway crews exacerbated drought effects in 1991 by pumping water from the lake to control dust at a local highway construction site.

White Lake is located about 6 km east of Amidon in Slope County, North Dakota (Figure 1). White Lake NWR contains approximately 76 surface ha of water and is surrounded by just over 331 ha of upland. The lake is spring fed and receives runoff from two tributaries to the Cannonball River. The lake produces a large number of Canada geese (Branta canadensis) each year, largely due to the artificial nest program administered by the refuge.

Lake Ilo NWR is located approximately 3 km west of Dunn Center, North Dakota (Figure 1), and is approximately 1,200 ha in size. Lake Ilo was formed by an earth-filled dam constructed in 1937. The surface area of the lake is approximately 162 ha at maximum pool elevation. Lake Ilo is fed primarily by Spring Creek which is a major tributary to the Knife River.

The mission of Stewart Lake, White Lake, and Lake Ilo NWRS, based on their established purposes, is to improve and maintain habitat for breeding and maintenance needs of migratory waterfowl and other wildlife. The Service conducts a number of programs aimed at providing the requirements of waterfowl and other migratory birds occurring on the refuges to carry out this mission.

The land surrounding all of the refuges is used almost exclusively for agriculture, with cropland occupying approximately 35 percent of the area (U.S. Soil Conservation Service 1978). Wheat, barley, and sunflowers are the major crops grown in the area. Another 40 percent remains in native prairie and is used for grazing and haying. Approximately 8 percent of the surrounding area is covered with introduced grasses and legumes, primarily crested wheatgrass, smooth brome, and alfalfa.

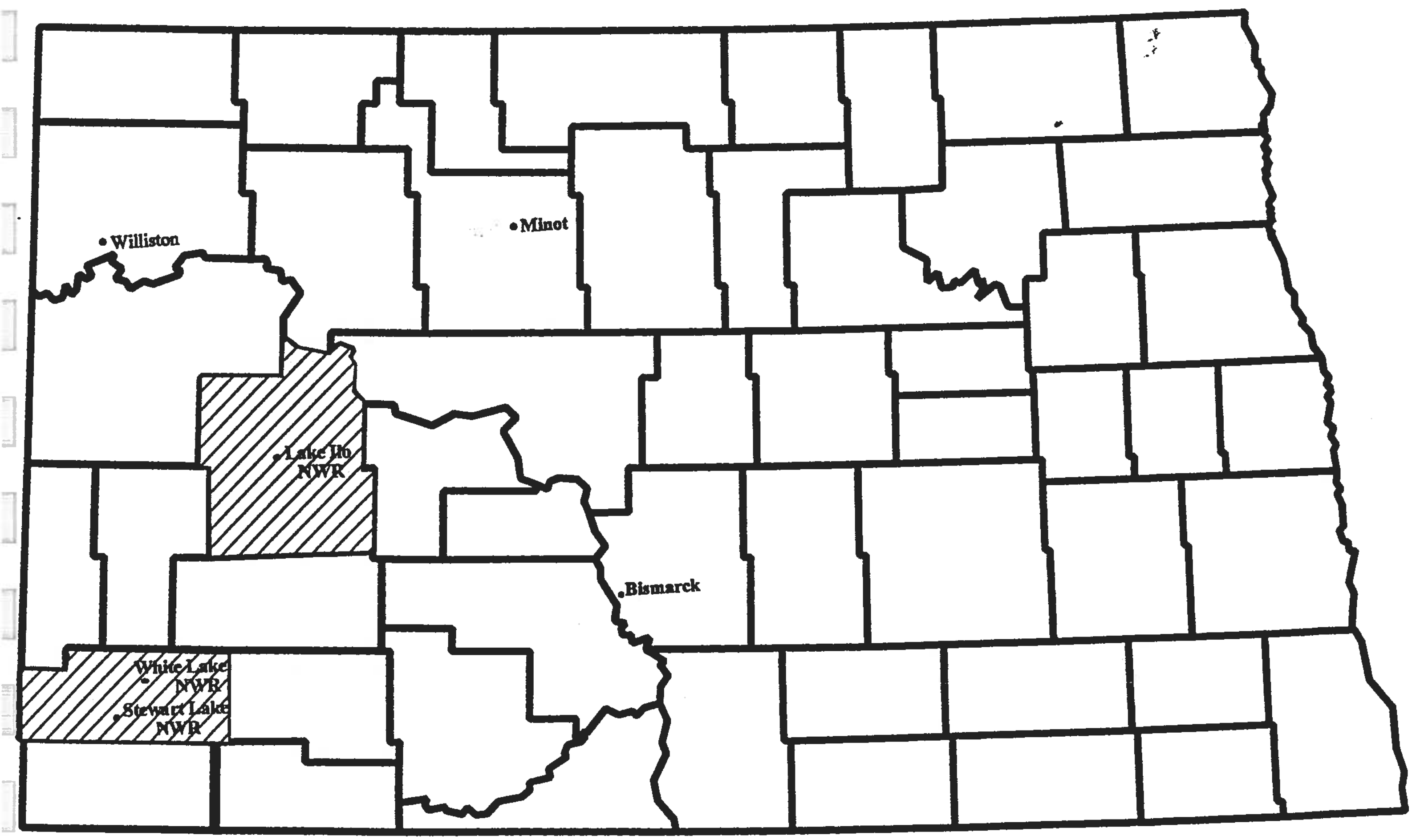

Figure 1. Study site locations, White Lake NWR, Stewart Lake NWR, and Lake Ilo NWR, relative to major cities in North Dakota.

METHODS

The study design, sampling protocol, and bioindicators for this study were patterned after other U.S. Fish and Wildlife Service contaminant baseline studies in North Dakota (U.S. Fish and Wildlife Service 1991; U.S. Fish and Wildlife Service 1994). Sampling sites were selected after consultation with refuge staff. Sites remained consistent throughout the study.

The types of samples collected are listed in Table 1. The sediment samples were collected using an Eckman dredge or a stainless steel trowel, placed in chemically-cleaned polyethylene containers, and placed on ice before being frozen. Dabbling ducks were collected with a shotgun and number 6 steel shot and dissected with stainless steel instruments. Livers were placed in Whirl-pac bags and placed on ice before being frozen. Fish were collected only from Lake Ilo. At Lake Ilo NWR, fish were collected using experimental gill nets set for 1 hour. Below the dam at Lake Ilo, fish were collected using a seine. Fish samples were placed on ice before freezing. All specimens were frozen within 24 hours of collection. Samples were shipped in coolers with dry ice to analytical laboratories via overnight delivery. All samples arrived at the laboratory facility in good condition.

Eared grebes are a common nester at all three refuge, thus eared grebe eggs were collected for examination of embryo deformities and chemical analysis. Eared grebe nests were located by searching suitable habitat via canoe. We collected one egg from each nest on the first visit. Eggs that failed to hatch were collected on subsequent visits. Eggs were placed on ice in a cooler and transported to Bismarck, North Dakota, for processing the following day. We measured length and width of each egg to the nearest 0.05 mm with vernier calipers. Shells were removed and egg contents placed in chemically clean glass jars. Eared grebe (Podiceps nigricolis) eggs were aged by flotation (Westerskov 1950) and numbered with a permanent marker for individual identification, we examined embryos for age, viability, and gross external deformities.

The Service's Patuxant Analytical Control Facility (Patuxant) contracted with The Environmental Trace Substances Research Center, Columbia, Missouri, to chemically analyze the samples. All samples were analyzed for arsenic, selenium, and mercury using atomic absorption spectrophotometry (AAS). Arsenic and selenium were analyzed using graphite furnace AAS, and mercury using cold vapor AAS.

Analyses for other elements were done using an inductively-coupled plasma emission (ICP) scan with preconcentration to pH 6. Because AAS is a more accurate technique than ICP, AAS results take precedence over ICP results for arsenic and selenium.

Samples analyzed for quality assurance/quality control (QA/QC) purposes included procedural blanks, National Bureau of Standards (NBS) standard reference materials, spiked samples, and duplicate samples. Procedural blanks were analyzed to verify that contamination of lab equipment did not produce spurious results. Standard reference materials and spiked samples (samples to which known amounts of trace elements were added) were analyzed to verify the accuracy of analytical techniques. Duplicate samples (samples which were analyzed twice) were analyzed to verify the precision (repeatability) of analytical methods.

This study was not designed to make statistical comparisons of trace element concentrations among sites and years, between adult and young-of-the-year, or between species. Analyses of the data in this report were limited to calculation of arithmetic means and ranges. In calculations of means, concentrations below detection limits of analytical techniques were assumed to be equal to one-half the detection limit. Detection limits for analytes (Table 2) were the same for water, sediment, and biota.

All analytical results reported here are expressed on a dry-weight basis unless indicated otherwise. Where necessary for comparative purposes, element concentrations from published literature were converted from wet-weight to dry-weight values assuming a moisture content of 75 percent.

RESULTS AND DISCUSSION

Selenium is the major contaminant concern for refuges located in western North Dakota. There is a high probability that the source of selenium affecting Stewart Lake and White Lake NWRS is the association with marine shales geology. While Lake Ilo NWR is located near selenium rich coal deposits. The eastern and northern parts of Dunn County have remnants of glacial till that cover about 75 percent of the county. These deposits consist mainly of soft shale, sandstone, and lignite. The erosion of this soft shale is thought to be a major contributing source of selenium (U.S. Soil Conservation Service 1978). Drainages transport selenium to the west river refuges and their water quality may also have an influence on the availability of selenium to migratory birds.

Water

Trace elements in water collected from Stewart Lake, White Lake, and Lake Ilo are summarized in Table 3. Selenium concentrations in water greater than 2 to 5 μg/L can cause reproductive failure in fish and waterfowl (Lemly and Smith 1987). Selenium concentrations in water analyzed from the three refuges ranged from below detection limits to 4 μg/L at both White Lake and Stewart Lake and from below detection limits to 0.006 μg/L at Lake Ilo. The selenium concentration in water from Stewart Lake in 1992 ranged from 2 to 4 with a mean of 3.3 μg/L. Arsenic levels for Stewart Lake in 1992 ranged from below detection limits to 21.5 ug/L, levels for Lake Ilo in 1993 were 0.003 to 0.009 ug/L, and for White Lake in 1992 the range was from 0.009 to 106.0 ug/L. The level of lead in the water for Stewart Lake and Lake Ilo ranged from below detection limits to 13.3 and 0.011 ug/L respectively and for White Lake the levels were 0.003 to 12.7 ug/L. Mercury levels for Stewart Lake and Lake Ilo were below detection limits, while White Lake Mercury levels ranged from below detection limits to 0.00004 ug/L.

Sediments

Sediment samples were collected from Lake Ilo, White Lake, and Stewart Lake NWRS (Tables 4 and 5). Selenium levels in Lake Ilo sediments ranged from below detection limits to 0.3 μg/g in 1992. At White Lake selenium ranged from below detection limits to 0.4 μg/g in 1992 and below detection limits to 0.45 μg/g in 1993. Stewart Lake NWR was sampled each year from 1990 through 1993. Mean concentrations of selenium ranged from below detection limits in 1990 to 0.5 μg/g in 1991. All samples were below the mean concentration (0.89 μg/g) of selenium in the Northern Prairie Pothole Region (Martin and Hartman 1984).

Mean concentrations of arsenic in sediment from Stewart Lake NWR ranged from 1.7 µg/g in 1990 to 4.8 µg/g in 1992. Lake Ilo NWR sediment had mean arsenic concentrations of 4.3 µg/g and 3.3 µg/g in 1992 and 1993, respectively. White Lake NWR sediment had mean concentrations of arsenic that were 3.7 µg/g and 4.2 µg/g in 1992 and 1993. Martin and Hartman (1984) reported that the mean concentration of arsenic in sediments from the Northern Prairie Pothole Region was listed as 4.4 µg/g. All sample locations, with the exception of Stewart Lake NWR, exhibited arsenic levels below the regional mean concentration (Martin and Hartman 1984). Little data exists on arsenic effects to soil biota, but arsenic appears to have minimal impacts on soil organisms at levels up to 150 µg/g (Eisler 1988a).

Lake Ilo sediment had a mean lead concentration of 33 µg/g in 1992 and was not detected in 1993. White Lake NWR exhibited the same trend with 24 µg/g in 1992 and below detection limits in 1993. Sediment from Stewart Lake NWR had a mean lead concentration of 31 µg/g in 1992 and was also below detection limits in 1993. Martin and Hartman (1984) list the mean lead concentration to be 13 µg/g in sediment from the Northern Prairie Region. Although plants take up lead and growth inhibition can appear with lead levels of 12 to 312 µg/g in soil, it is not believed that vegetation is important in food chain biomagnification of lead (Eisler 1988b).

Mercury in sediment was below detection limits at both Lake Ilo NWR and White Lake NWR. Sediments from Stewart Lake NWR ranged from below detection limits in 1990 and 1993 to 0.04 µg/g in 1991. Mean concentrations of mercury in sediment from the Northern Prairie Region reported by Martin and Hartman (1984) were 0.03 µg/g.

Fish

White sucker (Catostomus commersoni), black bullhead (Ameiurus melas), common carp (Cyprinus carpio), northern pike (Esox lucius), and yellow perch (Perca flavescens) were collected. Selenium concentrations in whole body fish ranged from 1.3 to 2.9 µg/g dry weight (Table 6). The mean concentration of selenium in fish from Lake Ilo was above the NCBP-85th percentile concentrations, 0.73 µg/g (Schmitt and Brumbaugh 1990). Toxic effects of selenium on fish includes reproduction impairment and mortality (Lemly and Smith 1987). Fish having selenium concentrations greater than 2-3 µg/g wet-weight, may suffer reproductive impairment (Hermanutz et.al. 1992).

Mean lead and arsenic concentrations were found to be below detection limits in 1992 and 1993. Lead, arsenic, and mercury concentrations were below the

NCBP-85th percentile; 0.88, 1.08, and 0.68 µg/g respectively (Schmitt and Brumbaugh 1990).

Young-of-the-Year Waterfowl Livers

Trace element concentrations in young-of-the-year waterfowl livers collected from Stewart Lake, White Lake, and Lake Ilo are summarized in Tables 7 and 8. Thirty-three young-of-the-year waterfowl livers were analyzed from Stewart Lake, 4 from Lake Ilo, and 11 from White Lake. Selenium concentrations in young-of-the-year waterfowl livers from the three refuges ranged from 2.5 to 40.0 ug/g dry weight, with the highest concentrations occurring at Stewart Lake. The mean selenium concentrations in young-of-the-year waterfowl livers collected from Stewart Lake for four separate years (1990-1993) ranged from 9.6 to 26.0 ug/g dry wt. The median selenium concentrations in livers of 263 young-of-the-year American coots collected as part of contaminant investigations on North Dakota refuges from 1986-1992 was 2.7 ug/g dry wt. (Olson and Welsh 1993). Selenium concentrations in livers of young-of-the-year American coots found dead or debilitated at Kesterson ranged from 28 to 140 ug/g dry wt. (Ohlendorf 1989). According to Lemely (1993), embryo mortality and teratogenic effects in hatchlings may be seen when tissue concentrations exceed 3 ug/g dry wt. in eggs and 10 ug/g dry wt. in liver tissue and mortality and deformities increase markedly (affecting 50 percent or more of all birds) above 10 ug/g dry wt. in eggs and 30 ug/g dry wt. in adult livers. In aquatic birds from areas where selenium concentrations are not elevated in the environment, mean concentrations usually are less than 10.0 µg/g in livers and 3.0 µg/g in eggs (Ohlendorf and Skorupa 1989; Skorupa and Ohlendorf 1991).

Eared Grebe Eggs

In 1991, a large colony of eared grebes nested at Stewart Lake. An investigation of eggs from the colony indicated that the embryos did not contain elevated concentrations of selenium (Olson and Welsh 1993). Eared grebes in North Dakota typically lay 2-8 eggs (Stewart 1975). Nests monitored in 1991 contained 1-5 eggs. The mean concentration of selenium in the grebe eggs collected in 1991 was 4.5 µg/g dry weight and ranged from 2.9 to 6.5 µg/g. These concentrations were consistent with eared grebe eggs collected at Bowdoin NWR in Montana from 1986 through 1989 (Palawski et al. 1991). Randomly collected eared grebe eggs from Kesterson, an area of known high selenium concentration, had a mean selenium concentration of 69.7 µg/g dry weight (Ohlendorf et al. 1986). Toxic effects of selenium in aquatic birds at Kesterson included deformed embryos, reduced hatching rates, and adult mortality (Ohlendorf 1989).

Results of trace element concentrations in eggs collected from Stewart Lake in 1991 and 1993, and White Lake and Lake Ilo NWRS in 1992 and 1993 are summarized in Table 9. Selenium concentrations were at or exceeded 3.0 µg/g dry weight in 45 of 47, 5 of 56, and 0 of 11 eggs analyzed from Stewart Lake, Lake Ilo, and White Lake NWRS respectively. A concentration of 3.0 µg/g is the 85th percentile of the mean selenium concentrations in eggs from uncontaminated non-marine wetlands in western states (U.S. Fish and Wildlife Service 1990), and indicates that nesting eared grebes at Stewart Lake NWR have recently been exposed to selenium levels above normal background concentrations. The mean concentration of 4.5 µg/g dry weight found at Stewart Lake falls into a range (3-20 µg/g) where "reasonably conclusive interpretation of biological significance is not possible without associated studies of reproductive performance" (U.S. Fish and Wildlife Service 1990), however, 8.0 ppm is the threshold level indicating potential reproductive impairment (Skorupa and Ohlendorf 1991). There were no embryo deformities in the grebe eggs collected from Stewart Lake, although 16 percent of the embryos were dead. The lack of deformities and low mortality suggests selenium concentrations in grebe eggs at this site were neither embryotoxic nor teratogenic.

Toxic effects of selenium are influenced by environmental factors, including interaction with other trace elements, including arsenic, cadmium, copper, and mercury (Eisler 1985). No other elements analyzed in grebe embryos were elevated. Arsenic and cadmium concentrations were all below detection limits. Mercury concentrations ranged from 0.38 to 2.09 with a mean of 0.648 µg/g dry weight. Copper concentrations ranged from 2.2 to 3.9 with a mean of 2.9 µg/g dry weight. Though selenium concentrations in grebe eggs and water samples from Stewart Lake were considered elevated, sediment sample concentrations were not elevated. Further investigation is required to determine the source of selenium in grebe eggs and the effect on grebes nesting at Stewart Lake.

RECOMMENDATIONS

Management practices should be implemented to reduce erosion, runoff, and resultant transport of selenium entering Stewart Lake. Reduction or elimination of cattle grazing and establishment of dense nesting cover in the lands in the watershed could help achieve that goal.

Construction of a water control structure on the earthen dam will provide water management capabilities that are currently not available. Stewart Lake flushes only in years of high precipitation and associated runoff that causes the pool level to overflow through the emergency spillway. A control structure would provide the opportunity to flush the system even during years of low inflow or to provide a total drawdown of the lake.

Any mechanism to increase the quantity of good quality water to Stewart Lake would be beneficial. Development of groundwater wells or enhancement of existing natural springs or artisan well on the property should be assessed as potential sources of water. The availability of contaminant clean-up funds for National Wildlife Refuge System lands may further support the implementation of management options.

Although reproductive effects to nesting waterfowl have not been documented at Stewart Lake, Lake Ilo, or White Lake NWRS, selenium levels in water and eggs of eared grebes at Stewart Lake and in water at White Lake are approaching potentially hazardous levels. Precautions should be initiated now to prevent selenium levels from increasing at Stewart and White Lakes in the future.

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TABLES

Table 1. Type of sample collected at each National Wildlife Refuge.

Sample Matrix	Stewart Lake NWR	White Lake NWR	Lake Ilo NWR
Water	X	X	X
Sediment	X	X	X
Fish			X
Young-of-the-year-waterfowl livers (mallard, pintail, greenwing teal, gadwall and blue winged teal)	X	X	X
Eared Grebe Eggs	X	X	X

Table 2. Detectable limits of each analyte.

Element	Detectable Limit (ppm)
Al	3.0
As	0.4
B	2.0
Ba	0.1
Be	0.01
Cd	0.2
Cr	0.1
Cu	0.2
Fe	1.0
Hg	0.01
Mg	0.6
Mn	0.2
Mo	0.9
Ni	0.1
Pb	0.4
Se	0.2
Sr	0.1
V	0.3
Zn	0.2

Table 4. Mean, minimum, and maximum trace element concentrations ($\mu g/g$ dry weight) in sediments from Lake Ilo Lake NWR and White Lake NWR, North Dakota.

	Lake Ilo NWR		White Lake NWR	
Element	1992 n=3	1993 n=5	1992 n=3	1993 n=7
Al	17700 16600-19000	13770 7760-19400	12300 6300-22200	12050 4050-19900
As	4.3 3.4-5.6	3.3 2.5-4.0	3.7 3.2-4.4	4.2 3.1-5.7
B	5.8 5.0-6.2	BDL[1] BDL	9 3-15	BDL BDL
Ba	263 254-275	201 136-313	170 132-203	196 9B05-2B9
Be	0.86 0.82-0.92	BDL BDL	0.48 0.20-0.95	BDL BDL
Cd	0.96 0.77-1.10	BDL BDL	0.58 0.40-0.B3	BDL BDL
Cr	26 23-29	21 10-32	18 9-31	20 BDL-36
Cu	31.7 30.9-33.4	19 14-29	17.8 5.6-36.9	16 BDL-31.0
Fe	19600 18500-21700	16980 12100-23100	13990 6460-24100	18020 9630-26600
Hg	BDL BDL	BDL BDL	BDL BDL	BDL BDL
Mg	7200 7100-7400	5326 3710-8350	7200 2610-12900	11090 5660-14400
Mn	375 351-408	221 120-326	308 98.0-528	525.5 190-861
Mo	BDL BDL	BDL BDL	BDL BDL	BDL BDL
Ni	30 29-31	26 20-32	18.5 8.4-35.0	28 10-47
Pb	33 31-35.0	BDL BDL	24 15-42	BDL BDL
Se	0.3 BDL-0.3	0.2 0.1-0.3	0.3 BDL-0.4	0.2 BDL-0.45
Sr	80.2 75.1-83.3	49 37-66	60.4 35.5-82.2	111 33-239
V	37.7 35.5-41.8	24 15-31	26.4 13-44.3	27 14-39
Zn	74.2 71-79.6	66 46-84	45.9 20-84.7	60 24-95

[1] Below detectable levels

Table 6. Mean, minimum, and maximum trace element concentrations (µg/g dry weight) in fish from Lake Ilo Lake NWR, North Dakota.

Element	1992 n=5	1993 n=5
Al	301 180-382	194 32-150
As	BDL[1] BDL-0.6	BDL BDL-0.50
B	BDL BDL	BDL BDL
Ba	11.1 5.4-16.4	7.3 3.5-14.9
Be	BDL BDL	BDL BDL-0.1
Cd	BDL BDL	0.07 0.05-0.13
Cr	0.55 0.20-0.96	0.3 0.2-0.4
Cu	4.1 3.4-5.0	2.7 2-3.9
Fe	262 199-314	138 85-174
Hg	0.077 0.052-0.110	0.23 0.15-0.27
Mg	1210 1020-1310	1216 1030-1420
Mn	10.3 5.7-13.0	13.4 4.3-38
Mo	BDL BDL	BDL BDL
Ni	0.78 0.30-2.20	BDL BDL-0.2
Pb	BDL BDL-.07	BDL BDL-0.5
Se	2.5 2.3-2.7	2.0 1.3-2.9
Sr	107.1 59.8-153.0	107 53.3-162
V	2.0 0.7-6.1	0.8 0.3-1.8
Zn	210 154-297	122 49.5-253

[1] Below detectable levels

Table 7. Mean, minimum, and maximum trace element concentrations ($\mu g/g$ dry weight) of dabbling duck livers from Stewart Lake NWR, North Dakota.

Element	1990 n=6	1991 n=7	1992 n=15	1993 n=5
Al	NS[1]	BDL[2] BDL	BDL BDL	6.8 BDL-20
As	BDL BDL	BDL BDL	BDL BDL-0.6	0.25 0.25
B	NS	BDL BDL	BDL BDL	0.14 BDL-2.0
Ba	NS	BDL BDL	BDL BDL	BDL BDL
Be	NS	BDL BDL	BDL BDL	BDL BDL
Cd	NS	1.02 0.09-1.6	0.04 BDL-0.05	0.39 0.95-1.4
Cr	NS	BDL BDL	BDL BDL	0.1 BDL-0.2
Cu	NS	59 18-130	132 105-159	84 21-145
Fe	NS	2725 1570-3720	870 982-1200	1476 662-3180
Hg	0.24 0.16-0.37	1.68 0.95-2.49	0.38 0.14-0.92	1.05 0.33-1.2
Mg	NS	666 319-776	823 750-933	761 696-B13
Mn	NS	13.1 7.1-16.0	12 10-14	12.1 9.1-15.0
Mo	NS	3.7 2.0-5.1	3.4 3.0-3.7	3.0 2.0-3.7
Ni	NS	0.22 BDL-0.3	0.2 BDL-0.39	BDL BDL
Pb	BDL BDL	BDL BDL	0.43 BDL-0.6	0.86 BDL-1.2
Se	26 15-40	20 11-32	9.6 6.9-15	14.2 4.3-23
Sr	NS	0.2 BDL-0.53	0.39 0.2-0.54	0.28 BDL-0.44
V	NS	BDL BDL	BDL BDL	0.5 BDL-0.9
Zn	NS	134.8 64.7-173	160.8 145-187	167 120-220

[1] Not sampled
[2] Below detectable levels

Table 8. Mean, minimum, and maximum trace element concentrations (μg/g dry weight) in dabbling duck livers from Lake Ilo Lake NWR and White Lake NWR, North Dakota.

Element	Lake Ilo NWR 1993 n=4	White Lake NWR 1993 n=11
Al	4.75 BDL[1]-7	6.1 BDL-21
As	0.25 BDL-0.2	BDL BDL
B	3 3-4	BDL BDL
Ba	0.23 BDL-0.36	0.2 0.1-0.35
Be	BDL BDL	BDL BDL
Cd	0.26 0.11-0.42	0.2 0.08-0.39
Cr	0.12 BDL-0.3	0.12 BDL-0.3
Cu	177.9 96-277	77 35-106
Fe	577 455-777	594 150-1310
Hg	0.59 0.33-1.11	0.55 0.3B-1.21
Mg	725 678-754	752 635-853
Mn	21.9 20.3-25.3	10.5 7.8-13
Mo	3.3 3.1-3.6	2.0 2.0-3.1
Ni	BDL BDL	BDL BDL
Pb	1.1 0.6-1.7	1.1 BDL-2.8
Se	9.0 5.2-14.6	3.2 2.5-4.9
Sr	0.31 0.2-0.39	0.38 0.20-0.73
V	0.375 BDL-0.5	BDL BDL
Zn	133.5 13B-191	135 101-187

[1] Below detectable limits

Table 9. Mean, minimum, and maximum trace element concentrations ($\mu g/g$ dry weight) in eared grebe eggs from Stewart Lake NWR, Lake Ilo Lake NWR and White Lake NWR, North Dakota.

	Stewart Lake NWR		Lake Ilo NWR		White Lake NWR	
Element	1991 n=47	1993 n=8	1992 n=36	1993 n=20	1992 n=4	1993 n=7
Al	BDL[1]	BDL	BDL	BDL	BDL	BDL
	BDL	BDL	BDL-17	BDL-7	BDL	BDL
As	BDL	BDL	BDL	BDL	BDL	BDL
	BDL	BDL-0.2	BDL-0.3	BDL-0.2	BDL	BDL
B	BDL	BDL	BDL	BDL	BDL	BDL
	BDL	BDL	BDL-2	BDL	BDL-2	BDL
Ba	1.15	3.8	4.8	10.4	3.2	19.7
	0.44-2.20	0.78-15.40	1.B-10.3	1.7-22.3	1.B-6.1	2.5-45.9
Be	BDL	BDL	BDL	BDL	BDL	BDL
	BDL	BDL	BDL	BDL	8DL	BDL
Cd	BDL	BDL	BDL	BDL	BDL	BDL
	BDL	BDL-0.03	BDL	BDL-0.04	BDL	BDL-0.02
Cr	BDL	BDL	BDL	BDL	BDL	BDL
	BDL	BDL-0.1	BDL	BDL-0.1	BDL	BDL
Cu	2.9	3.1	4.1	3.3	3.2	3.1
	2.2-3.9	2.2-5.2	2-12	2.6-4.2	2.6-3.7	2.1-3.8
Fe	143	129	114	116	105	87
	38-195	B3-176	63-310	91-149	91-124	73-111
Hg	0.648	BDL	0.06	0.057	0.03	BDL
	0.34-2.09	BDL-2.2	BDL-0.66	BDL-0.20	BDL-0.06	BDL-0.14
Mg	483	330	430	294	301	304
	363-677	169-524	187-609	147-636	261-333	140-592
Mn	2.5	2.1	2.1	2.8	1.9	1.2
	0.75-4.5	0.98-4.8	0.9-4.4	1.2-5.0	1.4-2.4	0.86-1.5
Mo	BDL	BDL	BDL	BDL	BDL	BDL
	BDL	BDL	BDL	BDL	BDL	BDL
Ni	BDL	BDL	BDL	BDL	BDL	BDL
	BDL-0.73	BDL-0.2	BDL-1.2	BDL-1.1	BDL	BDL-0.48
Pb	BDL	BDL	BDL	BDL	BDL	BDL
	BDL	BDL	BDL	BDL-0.4	BDL	BDL-0.5
Se	4.5	2.1	2.1	2.1	1.4	1.5
	2.9-6.5	0.77-8.5	0.9-3.5	1.4-2.4	0.97-2.1	1.0-2.2
Sr	9.2	22.7	7.4	8.5	2.8	9.5
	3.8-22.9	6.2-39.2	2.6-21.3	4.3-13.7	1.8-3.9	2.8-19.5
V	BDL	BDL	BDL	BDL	BDL	BDL
	BDL	BDL	BDL	BDL	BDL	BDL
Zn	53.3	51.2	52.7	54.1	57.9	47.4
	38.6-79.4	46-57.2	32.1-65.4	38.5-68.8	51-66	41.4-59.0

[1] Below detectable levels