Contaminant Report Number: R6/114K/94

T060002.3

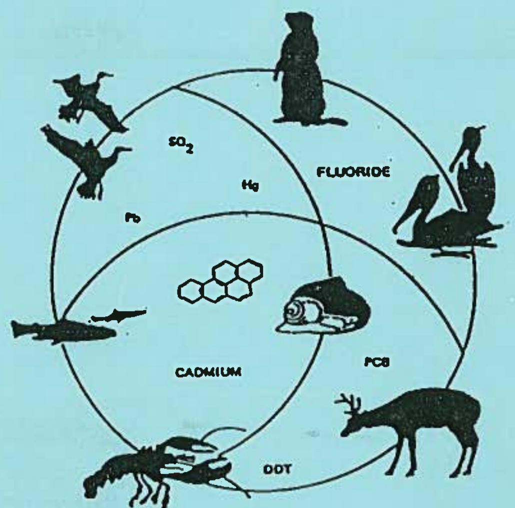
10-6-... 91-6-6110 92-6-6N05

U.S. FISH & WILDLIFE SERVICE
REGION 6

CONTAMINANTS PROGRAM

on-Refuge 6N05

TRACE ELEMENT CONCENTRATIONS IN BIOTA AND SEDIMENTS AT TEWAUKON NATIONAL WILDLIFE REFUGE SARGENT COUNTY, NORTH DAKOTA



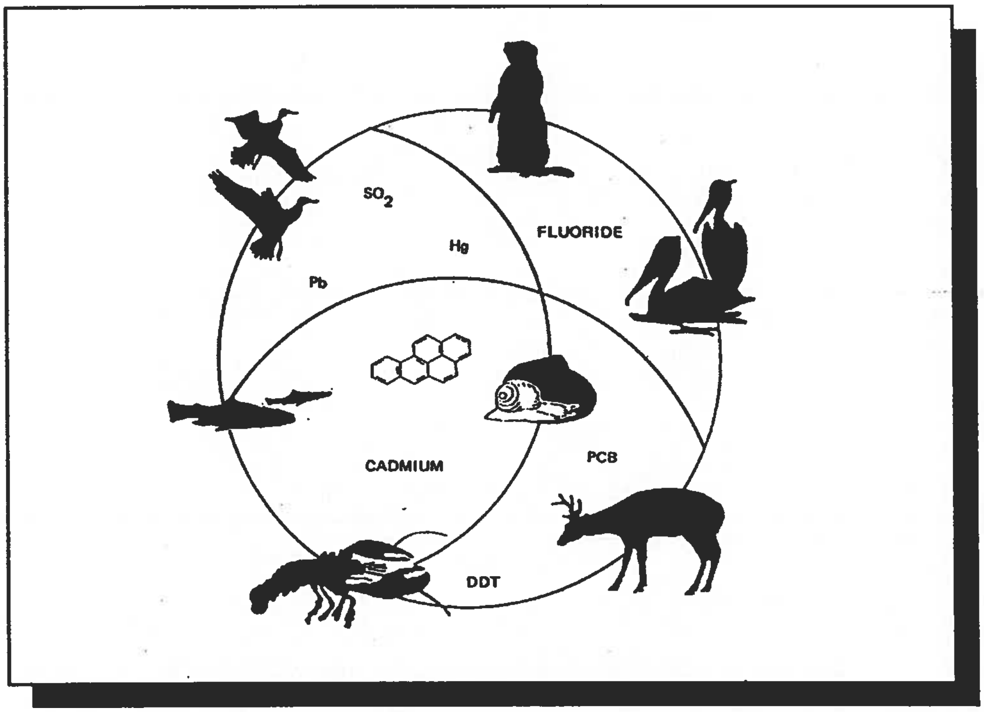
U.S. FISH AND WILDLIFE SERVICE
Ecological Services
1500 Capitol Avenue
Bismarck, North Dakota 58501

June 1994

2

Project Numbers Covered by this Report
90-6-105
91-6-6110
92-6-6N05

TRACE ELEMENT CONCENTRATIONS IN BIOTA AND SEDIMENTS AT TEWAUKON NATIONAL WILDLIFE REFUGE SARGENT COUNTY, NORTH DAKOTA



by
Mike Olson

Prepared by

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

TABLE OF CONTENTS

LIST OF FIGURES

5

LIST OF APPENDICES

6

ACKNOWLEDGEMENTS

Barry Sova and Selena Werdon of the U.S. Fish and Wildlife Service assisted with sample collections. Fred Giese, Refuge Manager, and Jack Lalor, Refuge Operation Specialist, assisted with site selection and sample storage. Quality of this report was improved thanks to reviews by Pete Ramirez and Brent Esmoil. Sharon Schweigert typed numerous drafts and assisted with creation of the tables. We thank all of these individuals for their assistance.

ABSTRACT

Tewaukon National Wildlife Refuge (Tewaukon) is located near one of only two designated Superfund sites in North Dakota. Extensive use of arsenic trioxide during the 1930's and 1940's caused contamination of local groundwater and resulted in Superfund designation for a 430 hectare area located adjacent to the refuge boundary. This study assessed arsenic and other potentially harmful trace element concentrations in fish and wildlife utilizing Tewaukon refuge from 1990 to 1992. A total of 53 bird liver samples, 32 fish samples, 19 sediment samples, 14 plant samples, 8 coot eggs, and 3 crayfish were chemically analyzed. Arsenic concentrations were low in sediments and biota collected from the refuge. Seven of 53 (13 percent) of the bird livers analyzed were at or exceeded selenium concentrations considered to be elevated. Other elements were at or near background concentrations for North Dakota Refuges.

8

INTRODUCTION

Tewaukon National Wildlife Refuge (Tewaukon) is located near the Lidgerwood Superfund site, one of only two designated Superfund sites in the State of North Dakota. In 1979, arsenic was detected at elevated levels in the groundwater in the area (Figure 1). Arsenic was detected at or exceeding the Maximum Contaminant Level (MCL) of 0.05 mg/l as set by the U.S. Environmental Protection Agency (EPA) in public drinking water supplies of three neighboring cities (Lidgerwood, Rutland, and Wyndmere) in southeast North Dakota (Roberts et al. 1985). Subsequent sampling of 558 ground-water supplies from an area of 557 square miles, enclosing the three cities, revealed arsenic concentrations ranging from 0 to 1.56 mg/l. The investigation showed that 1,719 persons living in the study area were at an increased risk of chronic arsenosis from the contaminated ground water. In the 1930's and 1940's, inorganic arsenicals such as arsenic trioxide (AsO_3) were used widely in the southeastern part of the State as insecticides to combat grasshopper infestations. Area wells indicate concentrations which could be detrimental to aquatic organisms. The North Dakota State Department of Health has designated 190 mg/l as the water quality standard for protection of aquatic life from chronic toxic effects of arsenic (North Dakota State Department of Health 1991). Arsenic accumulates in a variety of organisms, however, there is no evidence of magnification along the aquatic food chain (Woolson 1975).

Historical records indicate large amounts of arsenic-laced bait were used in and around Tewaukon National Wildlife Refuge to combat grasshopper infestations. Investigation of bait disposal methods and interviews with area residents indicate that ground water contamination from disposed bait could have taken place, but no disposal sites were confirmed (Roberts et al. 1985). The most likely disposal site was located in the Sheyenne National Grasslands approximately 40 kilometers north of Tewaukon Refuge.

More than 80 percent of the arsenic trioxide produced worldwide is used to manufacture products with agricultural applications, such as insecticides, herbicides, fungicides, algicides, sheep dips, wood preservatives, and the medicines for eradication of tapeworm in sheep and cattle (National Academy of Science 1977). Agricultural applications provide the largest anthropogenic source of arsenic in the environment (Woolson 1975). However, most registered uses of arsenic trioxide as an agricultural insecticide have been cancelled or voluntarily withdrawn in recent years.

The State Department of Health concluded that arsenic from bait application has had an impact on the quality of the ground water, but cannot in itself be the sole source of contamination. Glacial till and subcropping shale contain sufficient arsenic to account for the high concentrations found in the ground water. However, available hydrogeologic information is insufficient to indicate if these materials are the major source of contamination.

A baseline study of the refuge was initiated because of the potential threat of arsenic exposure to trust resources. The project took place from 1990 to 1992.

OBJECTIVES

The main objective of this work was to determine if arsenic concentrations were elevated in sediments or biota on the refuge. Other trace metals of concern, such as selenium, mercury, cadmium, chromium, and lead, were also investigated to serve as baseline information against which to measure future conditions.

STUDY AREA

Tewaukon is located in Sargent County, North Dakota (Figure 2). The refuge encompasses approximately 3400 hectares which serve as nesting, feeding, and resting areas for migratory waterfowl in the Central Flyway. A total of 235 species of birds have been recorded on Tewaukon. Principal bird use includes nesting colonies of western grebes and double-crested cormorants. Up to 1500 white pelicans, 2,000 Franklin's and ring-billed gulls, and 50,000 snow and Canada geese have also been documented on the refuge. Fall concentrations of ducks can exceed 60,000. Bitterns, herons, and egrets are also numerous in late summer. The refuge also plays an important role during spring migration. During the spring of 1991, an estimated 100,000 snow geese used the refuge. Principle resident upland species include ring-necked pheasant and gray partridge.

Important habitats at Tewaukon include: natural and impounded wetlands, deep marsh habitats, and the Wild Rice River. Three major drainages, in addition to the Wild Rice River, contribute flows to the refuge's pools and main channels. From its headwaters in western Sargent County, the Wild Rice River flows easterly through the county to the refuge where it is controlled by a series of dams and impoundments. The river is considered to be a Class I stream downstream from its headwaters to the refuge. This designation means the quality of waters in this stream permits the propagation or life of resident fish species and other aquatic biota. Water flowing out of drained wetland basins and runoff from agricultural lands both adversely effect Tewaukon's environmental quality.

Samples collected in 1984 by the State Department of Health showed arsenic concentrations ranging from 15 to 30 µg/l in water samples collected at three refuge wells. The U.S. Geological Survey database for the area indicates an arsenic concentration of 55 µg/l in a well just north of Tewaukon Lake. The Environmental Protection Agency's maximum contaminant level for arsenic in drinking water is 50 µg/l (EPA 1984). The chronic arsenic standard for aquatic organisms is 190 µg/l in the most recent State water quality standards (NDSDHCL 1991).

MATERIALS AND METHODS

The study design, sampling protocol, and bioindicators for this study were patterned after other baseline sampling efforts in North Dakota. Eleven sampling sites were selected via consultation with refuge staff. Sites remained consistent in 1990 and 1991. In 1992, sampling efforts were reduced on the refuge to supplement information obtained in the previous 2 years. In 1990, 11 sediment samples, 9 coot livers, 4 blue-winged teal livers, 8 algae composites, 3 crayfish, 4 carp, and 8 forage fish composites of various species were analyzed. In 1991, 8 sediment, 16 coot livers, 2 eared grebe livers, 2 gadwall livers, 1 pheasant liver, 1 wood duck liver, 1 mallard liver, 1 mourning dove liver composite, 3 coot eggs, 3 pondweed composites, 3 duckweed composites, 4 carp composites, 4 fathead minnow composites, 4 walleye muscle, 4 walleye livers, and 4 walleye gonads were analyzed. During 1992, 14 coot livers, 1 eared grebe liver and 5 coot eggs were analyzed.

The samples were collected using standard sample collection techniques. The sediment samples were collected using an Eckman dredge or a stainless steel trowel, were placed in polyethylene containers and were placed on ice before frozen. Birds were collected with number 6 steel shot and dissected with stainless steel instruments. Livers were placed in Whirl-pacs and placed on ice before frozen. Aquatic plants were placed into polyethylene bags and placed on ice before frozen. Samples were shipped in coolers with dry ice to analytical laboratories via overnight delivery. All samples arrived at the laboratory facility in good condition.

RESULTS AND DISCUSSION

Arsenic

The nationwide arsenic concentrations in whole common carp averaged 0.05 mg/kg wet weight (Eisler 1988a). Concentrations of arsenic less than 0.4 ppm dry weight represent background concentrations (Eisler 1988a). In 1990, three common carp and four walleyes were analyzed for arsenic with a range of <0.2 to 0.5 ppm dry weight. In 1991, four composites of common carp representing four distinct length classes and four composites of fathead minnows were analyzed. Arsenic concentrations in these fish ranged from 0.2 to 0.9 ppm dry weight. Walleye livers, muscle, and gonads from Sprague Lake were also analyzed in 1991 and all were below 0.3 ppm dry weight (Appendices H,I,J). These concentrations suggest that arsenic is not a concern in fish from Tewaukon Lake and Sprague Lake.

Arsenic concentrations in sediment from Tewaukon NWR in 1990 and 1991 were near 5.5 ppm dry weight, the level considered background for soils of the western United States (Shacklette and Boerngen 1984). Soil arsenic concentrations ranged from 1.0 to 6.4 ppm dry weight. Higher arsenic concentrations (14.2 to 44.2 ppm dry weight) in soil have been detected in North Dakota in the Fort Clark and Heart Butte irrigation districts (Welsh and Olson 1991). Arsenic concentrations in sediment at Tewaukon do not indicate contamination.

Bird livers analyzed for arsenic in 1990 all showed concentrations below detection limits (0.1 ppm dry weight). In 1991, concentrations ranged from 0.07 to 0.37 ppm dry weight. The 1992 concentrations ranged from ≤0.1 to 0.3

ppm dry weight. The natural background concentration of arsenic in all tissues of ducks is <0.4 ppm (Eisler 1988). Based on these concentrations, there is not a problem with arsenic in waterfowl utilizing Tewaukon.

Plants analyzed at Tewaukon in 1990 and 1991 had arsenic concentrations ranging from 1.0 to 12.6 ppm dry weight. The background concentration of arsenic in freshwater plants is considered to be less than 6 ppm dry weight (Eisler 1988). Based on this, there are slightly elevated levels of arsenic in some aquatic plants. Pondweed at geothermal areas, a known arsenic source, contained 11 to 436 ppm dry weight arsenic (Eisler 1988). Arsenic is accumulated from the water by a variety of organisms, however, there is no evidence of magnification along the aquatic food chain (Woolson 1975). Our data for arsenic are consistent with Woolson's observation.

The median arsenic concentrations in sediments collected at Tewaukon was below the 5.5 ppm concentration considered background for soils of the western United States (Shacklette and Boerngen 1984). Arsenic concentrations in sediments from Tewaukon ranged from 1.0 to 6.1 ppm (Appendices A, B).

Selenium

At elevated concentrations, selenium is toxic to wildlife. Irrigation return flows are a potential source of selenium, and were responsible for wildlife mortality at Kesterson National Wildlife Refuge in California (Ohlendorf 1989). Selenium concentrations in livers of American coots from Kesterson ranged from 28 to 140 ppm dry weight (Ohlendorf 1989). Toxic effects of selenium at Kesterson included deformed embryos, reduced hatching rates, and adult mortality (Ohlendorf 1989).

The median selenium concentrations in livers of 263 coots collected as part of contaminant investigations on North Dakota refuges from 1986-1992 was 2.7 ppm dry weight (Welsh and Olson 1993).

Selenium concentrations in bird livers from this study ranged from 0.7 to 26 ppm dry weight with a median of 5.4 (Appendices C,D,E,N,O). Aquatic birds from areas where selenium concentrations are not elevated usually contain less than 10 ppm dry weight selenium in livers (Ohlendorf 1989). Seven of the 53 (13 percent) livers analyzed from Tewaukon were at or exceeded the 10 ppm dry weight selenium concentration.

Selenium concentrations in aquatic sediments from freshwater lakes in Canada ranged from 0.2 to 14.5 ppm. Selenium concentrations in the aquatic sediments collected at Tewaukon ranged from <0.2 to 1.5 ppm (Appendices A,B), therefore, the selenium concentrations are not considered elevated.

Mercury

The geological cycle of mercury involves a strong atmospheric component which tends to distribute mercury widely across the globe (Eisler 1987). In addition, seeds treated with organomercury fungicides were used in agriculture

12

for decades in many parts of the world, including the Northern Great Plains (Swanson et al. 1972, Krapu et al. 1973).

The median mercury concentration and interquartile range in livers of 263 coots collected as part of contaminant investigations on North Dakota Refuges from 1986-1992 was 0.67 (0.40 to 1.30) ppm dry weight (Welsh and Olson 1993). The coot liver mercury concentrations from this study ranged from 0.03 to 5.6 ppm dry weight with a median of 1.37. A potential source is mercury residue remaining as a result of mercury seed treatments during the 50's, 60's and early 70's.

The mean mercury concentration in sediment samples from Tewaukon was 0.034 ppm (Appendix A,B). This concentration is below the geometric mean (0.046 ppm) for soils from Western United States (Shacklette and Boerngen 1984).

Lead

Lead concentrations in livers from coots from this study were at or below detection limits in all samples.

Worldwide, the median concentration of lead in surface sediments is 10 ppm (Eisler 1988b). The range of concentration of lead in sediments collected from this study was <4 to 23 ppm with a median of 11 ppm, therefore, the lead concentration was not considered elevated.

Other Elements

Concentrations of the other inorganic analytes for were below levels of concern (Appendices A - O).

13

SUMMARY

Results of sampling of biota and sediments at Tewaukon indicate wildlife on the refuge is not threatened by arsenic concentrations in the environment. Selenium concentrations in bird livers from this study were elevated in 13 percent of the livers analyzed, but were below levels associated with a high risk of toxicity. Mercury concentrations in birds were slightly higher than the statewide median, but were also below levels associated with a high risk of toxicity. This information will serve as useful baseline dataset for Tewaukon.

1d

LITERATURE CITED

Eisler, R. 1987. Mercury hazards to fish, wildlife, and invertebrates: a synoptic review. U. S. Fish Wildl. Serv. Biol. Rep. 85 (1.10). 90pp.

Eisler, R. 1988a. Arsenic hazards to fish, wildlife, and invertebrates: a synoptic review. U. S. Fish Wildl. Serv. Biol. Rep. 85 (1.12). 92pp.

Eisler, R. 1988b. Lead hazards to fish, wildlife, and invertebrates: a synoptic review. U. S. Fish Wildl. Serv. Biol. Rep. 85 (1.14). 134pp.

Krapu, G. L., Swanson, G. A., and H. K. Nelson. 1973. Mercury residues in pintails breeding in North Dakota. J. Wildl. Manage. 37:395-399.

National Academy of Science. 1977. Medical and biological effects of environmental pollutants - arsenic. National Academy of Sciences. Washington, D. C., 332pp.

North Dakota State Department of Health. 1991. Standards of water quality for the State of North Dakota. Rule 33-16-02. 29pp.

Ohlendorf, H. M. 1989. Bioaccumulation and effects of selenium in wildlife. Soil Science Society of America. Selenium in Agriculture and the Environment. Special Publication No. 23 pp.137-177.

Roberts, K., B. Sterns, and R. L. Francis. 1985. Investigation of arsenic in southeastern North Dakota ground water, a superfund remedial investigation report. North Dakota State Department of Health, Bismarck North Dakota. Superfund Agreement No. V008414-01.

Shacklette, H. T., and J. G. Boerngen. 1984. Element concentrations in soils and other surficial materials of the conterminous United States. U. S. Geological Survey Professional Paper 1270, 105pp.

Skorupa, J. P., H. M. Ohlendorf., and R. L. Hothem. In Review. Interpretive guidelines for field studies of selenium-exposed waterbirds.

Swanson, G. A., Krapu, G. L., and H. K. Nelson. 1972. Mercury levels in tissues of ducks collected in South-Central North Dakota. Proc. North Dakota Academy of Science. 25:84-93.

U.S. Environmental Protection Agency. 1984. Health Assessment Document for Inorganic Arsenic. Final report. Research Triangle Park, NC. Publication number EPA-600/8-83-021F.

Welsh, D. and M. Olson. 1991. A pre-reconnaissance investigation of trace elements and organic contaminants in biota and sediments at Fort Clark and Heart Butte irrigation units. U.S. Fish and Wildlife Service. 33pp.

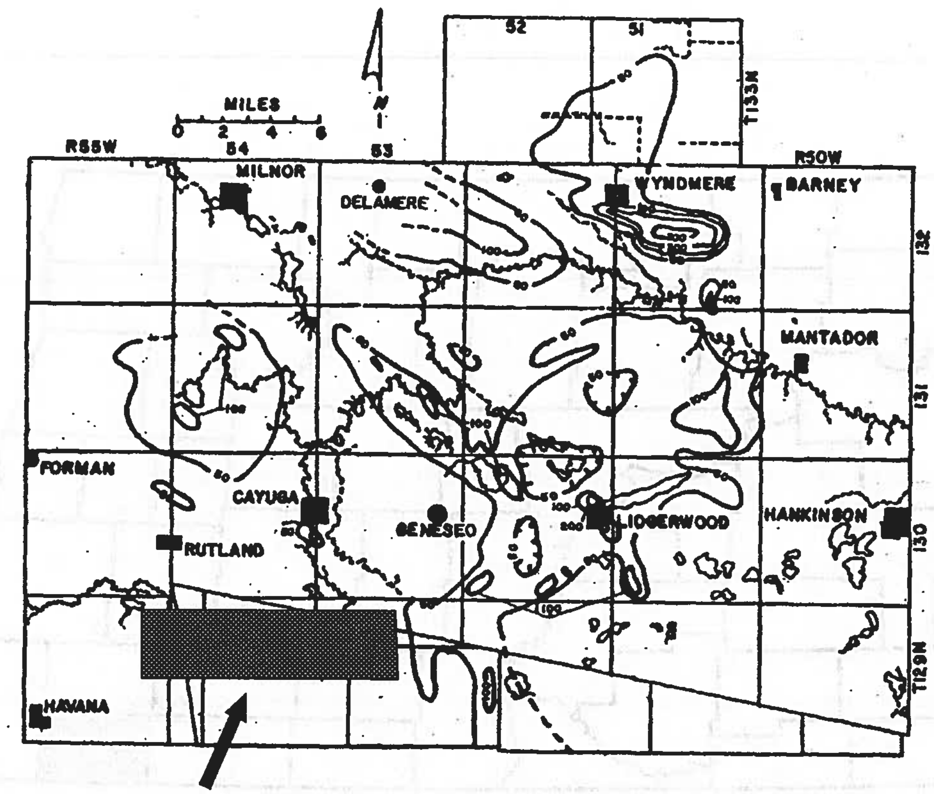
Welsh, D. and M. Olson. 1991. An investigation of trace element concentrations in biota and sediments in relation to avian botulism at Long Lake National Wildlife Refuge, North Dakota. U.S. Fish and Wildlife Service. 32pp.

Welsh, D. and M. Olson. 1993. Contaminant levels in waterfowl on National Wildlife Refuges in North Dakota. Presentation given at - Prairie Ecosystems: Wetland Ecology, Management and Restoration. Jamestown, ND.

Woolson, E. A. (ed.), 1975. Arsenical pesticides. Am. Chem. Soc. Symp. Ser. 7, 176pp.

16

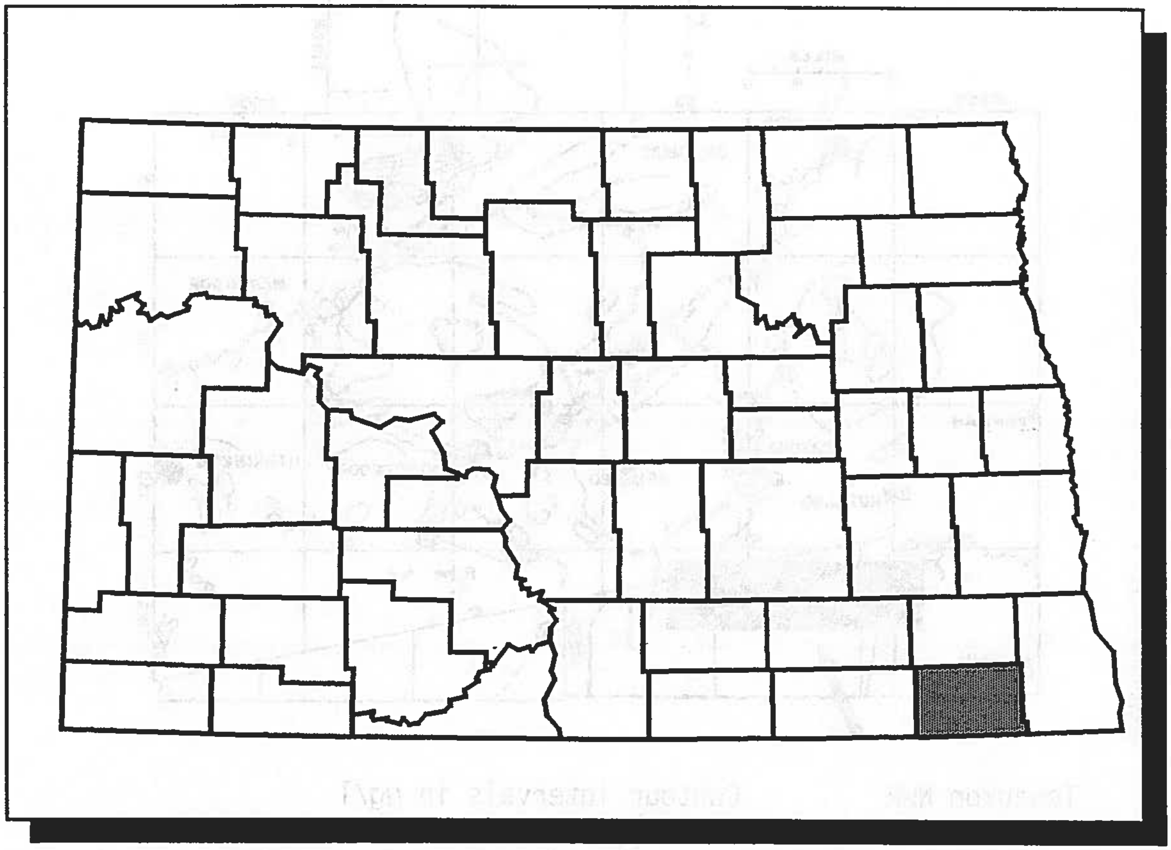
Figure 1. Isoconcentration map of observed arsenic levels in ground water near Tewaukon NWR (Roberts et al. 1985).



Tewaukon NWR

Contour intervals in $\mu g/l$

Figure 2. Sargent County, North Dakota



Appendix A. Element concentration (ppm, dry weight) in sediments collected at Tewaukon NWR in 1990.

	Sediment Identification Number													
	S-SL	S-ML	S-UWR	S-HS	S-TL	S-CNL-TM	S-PB	S-MAR	S-P2	S-WWL	S-HL	MIN	MAX	MEAN
Element														
Ag	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	*
Al	28100	25100	29900	30500	23000	30200	29200	13100	18700	9710	7370	7370	30500	22300
As	5.0	6.1	3.4	4.3	5.5	4.3	6.4	4.3	4.3	4.1	3.0	3.0	6.4	4.6
B	22	24	27	31	18	25	26	8.0	12	11	5	5	31	19
Ba	212	223	269	228	197	227	211	130	185	99.2	81.2	81.2	269	187
Be	1.3	1.2	1.3	1.3	1.1	1.5	1.4	0.73	1.0	0.65	0.39	0.39	1.5	1.08
Cd	0.7	0.8	0.5	0.90	0.3	0.5	0.6	0.6	0.7	0.5	0.4	0.3	0.9	0.6
Cr	33	28	34	32	25	33	27	18	22	14	10	10	34	25
Cu	21	24	20	23	17	23	23	17	18	15	8.1	8.1	24	19
Fe	20900	21300	21600	20100	18700	23000	20300	14700	19000	11200	7710	7710	21600	18000
Hg	0.03	0.03	0.03	0.03	0.04	<0.02	0.03	0.03	0.03	<0.02	<0.02	<0.02	0.04	0.03
Mg	11800	11500	16100	8770	13900	10300	11300	9850	10900	6230	6790	6230	16100	10670
Mn	538	598	673	450	601	484	668	535	734	345	287	345	734	538
Mo	0.36	0.95	0.39	0.2	0.2	0.35	0.78	0.32	0.2	0.99	0.53	0.2	0.99	0.48
Ni	26	29	25	26	25	32	31	19	23	20	11	11	32	24
Pb	20	23	16	19	17	16	16	15	18	13	8	8	23	16
Se	0.79	1.3	0.4	0.6	0.69	0.94	1.5	0.72	0.3	0.92	0.4	0.3	1.5	0.77
Sr	95.5	147	99.3	63.1	131	89.4	160	87.2	107	108	83.9	63.1	160	107.4
Tl	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	*
V	79.2	65.9	74.4	72.2	62.5	69.6	65.8	34	46	29	20	20	79.2	56.2
Zn	74.8	82.1	66.5	459	59.4	78.8	77.4	55.7	68.8	48.7	30.5	30.5	459	100.2
% MOIST	63.1	38.6	39.9	65.9	56.9	55.7	62.8	55.3	46.1	66.2	39.7	38.6	66.2	53.7

* Not Quantifiable

19

Appendix B. Element concentration (ppm, dry weight) in sediments collected at Tewaukon NWR in 1991.

Element	TS001	TS002	TS003	TS004	TS005	TS006	TS007	TS008	MIN	MAX	MEAN
Al	4470	2440	4740	15100	17900	14500	17700	20800	2440	20800	12210
As	1.8	1.0	1.4	4.1	5.66	3.4	4.1	4.1	1.0	5.66	3.2
B	3	4	6	8.7	14	6.2	9.5	20	3	20	8.9
Ba	66.8	49.2	101	123	154	115	138	163	49.2	163	114
Be	0.2	0.1	0.2	0.61	0.68	0.67	0.73	0.72	0.1	0.73	0.49
Cd	<0.2	<0.2	<0.2	0.3	0.5	0.3	0.65	0.5	<0.2	0.65	0.3
Cr	7.6	3.2	6.2	19	10	16	25	15	3.2	25	12.8
Cu	5.6	1.9	4	15	17	14	16	19	1.9	19	11.6
Fe	5910	2580	5780	14400	16500	14100	17000	16800	2580	17000	11600
Hg	0.03	<0.01	0.03	0.045	0.059	0.045	0.045	0.072	<0.01	0.072	0.042
Mg	8290	3150	8300	10800	11500	9000	8940	8130	3150	11500	8510
Mn	243	137	179	488	754	356	567	575	137	754	412
Mo	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	*
Ni	8.1	3	6.7	20	21	17	19	19	3	21	14
Pb	<4	<4	<4	7	8	9	9	18	<4	18	8
Se	0.3	<0.2	0.4	0.3	0.3	0.3	0.5	0.64	<0.2	0.64	0.4
Sr	52.2	27.4	39.1	47.7	53.9	45.6	56.1	60.7	27.4	60.7	47.8
V	14	6.5	16	42.1	45.7	32.6	40.1	48.7	6.5	48.7	30.7
Zn	47.2	9.9	16	49.3	65.9	93.3	67.1	81.2	9.9	93.3	53.7
% MOIST	18.1	21.3	13.4	47.3	50.6	34.4	39.6	58.7	13.4	58.7	35.4

As, Hg, and Se analyzed differently than ICP

Appendix C. Element concentration (ppm, dry weight) in coot livers collected at Tewaukon NWR in 1990.

Coot Liver Identification Number

Element	B-HS-1	B-HS-2	B-HS-3	B-HS-4	B-HS-7	B-HS-8	B-PB-1	B-WWL-1	B-WWL-2	MIN	MAX	MEAN
Al	5.1	10	5.3	14	1.9	1.6	3.5	0.6	9.1	0.6	10	5.7
As	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	*
Be	<0.01	<0.01	<0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.02	*
Cd	<0.01	<0.04	<0.97	<0.04	0.05	<0.04	<0.04	0.04	0.1	<0.01	0.1	*
Cr	<0.2	<0.2	<0.3	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.3	<0.2
Cu	53.8	35.4	65.3	26.7	65.0	51.5	68.2	32.3	86.6	26.7	86.6	53.9
Fe	3300	1870	589	361	1520	181	1440	738	485	181	3300	1165
Hg	0.33	0.31	0.50	8.25	0.18	0.23	0.93	1.2	1.2	0.18	8.25	1.45
Mn	16.1	11.6	18.2	7.1	22.2	14.4	30.6	9.27	12.0	7.1	30.6	15.72
Mo	2.7	1.8	2.3	1.6	2.1	1.2	2.4	1.2	1.1	1.1	2.7	1.8
Ni	<0.2	<0.2	<0.4	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.4	*
Pb	0.8	<0.5	<0.9	<0.5	0.5	<0.5	<0.5	<0.4	<0.5	<0.4	<0.9	*
Se	1.3	1.5	1.7	0.94	1.5	0.9	3.6	2.7	3.9	0.9	3.9	2.0
Tl	<0.5	<0.5	<1	<0.5	<0.5	<0.5	<0.5	0.6	<0.5	<0.5	<1	*
Zn	128	135	186	84.7	138	89.9	176	102	145	84.7	186	131.6
% Moist	75.1	74.9	76.5	71.4	69.7	70.1	72.6	72.9	75.5	69.7	76.5	73.2

* Not Quantifiable

21

Appendix D. Element concentration (ppm, dry weight) in coot livers collected at Tewaukon NWR in 1991.

Coot Liver Identification Number

Elmt	TB004	TB005	TB006	TB007	TB008	TB009	TB010	TB011	TB012	TB013	TB014	TB017	SC001	SC002	SC003	P3C001	MIN	MAX	MEAN
Al	6	5	10	9	6	7	12	7	5	6	5	9.3	<3	3	4	<3	<3	12	6.1
As	0.07	0.1	0.31	0.2	0.26	0.22	0.2	0.37	0.2	0.17	0.23	0.15	0.09	0.15	0.07	0.1	0.07	0.31	0.18
B	<2	<2	<4	<2	<2	<2	<2	<2	<2	<2	<2	<2	2	<2	<2	2	<2	<4	*
Ba	<0.1	<0.1	<0.2	0.1	<0.1	0.2	0.31	<0.1	0.1	<0.1	<0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.31	*
Be	<0.01	<0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	<0.01	<0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	*
Cd	<0.04	0.21	2.0	0.78	2.1	0.47	0.28	1.3	0.23	0.56	0.81	1.2	<0.03	2.2	1.1	0.59	<0.03	2.2	0.87
Cr	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	*
Cu	112	18	66.7	52.5	44.1	131	24.7	68.8	35.9	52.6	69.7	18	84.4	35.8	13	20.8	13	131	53
Fe	159	3340	2460	2260	4370	1430	2370	3410	3890	4810	2400	3130	222	695	179	264	159	4810	2211
Hg	0.809	0.46	2.71	2.71	1.00	2.36	1.30	1.88	1.89	5.62	1.58	1.10	0.81	1.30	0.38	0.572	0.38	5.62	1.66
Mg	669	658	718	706	686	695	755	667	667	674	580	708	702	671	511	592	511	755	666
Mn	19.8	13	13	14	9.4	13	17	11	50.8	14	9.6	15	27.2	17	13	14	9.4	50.8	16.9
Mo	2	3.8	3	3.7	5.8	4.3	4.4	5.1	7.7	5.8	3.9	4.4	2	3.5	2	3	2	7.7	4.0
Ni	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	*
Pb	<0.5	<0.5	<0.9	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.5	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.9	*
Se	2.9	2.8	8.4	7.0	4.2	7.6	4.8	9.8	3.9	4.8	6.0	3.5	1.6	2.9	1.5	2.3	1.5	9.8	4.6
Sr	0.2	0.2	0.2	0.2	0.1	0.2	0.97	0.1	0.2	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.97	0.2
V	<0.3	<0.3	2.5	0.7	0.3	<0.3	<0.3	0.6	<0.3	0.5	0.4	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	2.5	*
Zn	157	156	179	145	210	236	123	174	164	205	158	147	245	145	89.5	120	89.5	245	166
%Mst	73.6	73.4	73.2	72.5	74.3	81.1	73.1	73.7	75.6	71.5	70.5	71.4	74.2	73.0	71.2	71.5	70.5	81.1	73.3

Appendix E. Element concentration (ppm, dry weight) in coot livers collected at Tewaukon NWR in 1992.

Coot Liver Identification Number

Elmt	CL01	CL02	CL03	CL04	CL05	CL06	CL07	CL08	CL09	CL10	CL11	CL12	CL13	CL14	MIN	MAX	MEAN
Al	11	7	9	4	47	7	130	<3	18	66	12	<5	<4	<3	<3	130	23
As	<0.2	<0.2	<0.2	<0.2	<0.2	0.3	<0.2	<0.2	<0.2	<0.2	<0.2	0.2	<0.3	<0.2	<0.2	0.3	*
B	3	4	5	3	8.4	3	17	<2	4	2	8.1	5	<3	<2	<2	17	4.9
Ba	0.2	0.58	0.2	0.1	0.63	0.2	0.59	<0.1	0.46	<0.1	0.2	0.52	0.4	0.69	<0.1	0.69	0.36
Be	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.04	<0.03	<0.05	<0.05	<0.03	<0.05	*
Cd	1.2	1.1	0.23	0.59	<0.06	0.09	<0.06	<0.06	<0.06	<0.06	0.1	1.9	<0.1	<0.09	<0.06	<1.2	*
Cr	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.5	<0.5	<0.5	<0.6	<0.9	<0.8	<0.5	<0.9	*
Cu	28.1	55.9	42	61.1	100	60.9	63	15	117	19	136	69.4	96.5	85.9	15	136	67.8
Fe	837	1800	1830	1060	352	176	527	434	141	257	227	2040	130	167	130	2040	712
Hg	0.663	1.6	0.89	2.7	1.1	2.2	0.734	1.5	0.92	1.7	2	2.9	1.14	0.96	0.663	2.9	1.5
Mg	696	675	594	650	828	790	816	765	757	747	778	713	771	818	594	828	742.7
Mn	31.1	52	31.2	40.3	73.2	54.2	36.5	18	37.8	21	24.6	80.5	161	68.1	18	161	52
Mo	3	3.6	3.3	5.4	2	3.2	2	<1	2	1	3	3.9	3	2	<1	5.4	2.7
Ni	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.4	<0.3	<0.5	<0.5	<0.3	<0.5	*
Pb	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<2	<2	<1	<2	*
Se	3.6	5.7	3.3	3.1	8.4	6.2	13	14	5.2	14	6.7	5.1	8.1	7.5	3.1	14	7.4
Sr	0.2	0.46	0.8	0.3	2.2	0.56	4.2	0.2	0.55	0.64	2.1	0.82	<0.2	<0.1	<0.1	4.2	0.9
V	1.7	2.9	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	1.8	<0.5	<0.4	<0.3	2.9	*
Zn	164	124	79.8	157	177	152	180	92.7	130	144	185	123	134	135	79.8	185	141
Mst	74.3	74.7	77.2	74.5	79.8	79.9	80.6	79	74.2	77.7	80.7	74.9	81.2	79	74.2	81.2	77.7

23

Appendix F. Element concentration (ppm, dry weight) in plants collected at Tewaukon NWR in 1990.

Plant Identification Number

Element	A·TL	A·PB	A·MAR	A·P2	A·WWL	A·HL	A·SL	A·HS	MIN	MAX	MEAN
Al	70.5	4630	7160	3160	3380	5010	2050	143	70.5	7160	3200
As	1.0	7.5	3.7	5.3	12.6	12	3.5	0.57	1.0	12.6	5.8
Be	<0.09	0.19	0.24	0.13	0.15	0.22	0.059	<0.01	<0.01	0.24	0.14
Cd	0.05	0.70	0.37	0.38	0.45	0.50	0.27	0.14	0.05	0.70	.036
Cr	0.5	17	13	8.5	6.5	7.8	7.0	4.0	0.5	17	8.0
Cu	7.24	12.0	11.4	5.43	10.0	7.24	11.5	3.13	3.13	12.0	8.5
Fe	301	4050	5150	2750	3230	5440	1930	342	301	5440	2900
Hg	0.02	0.03	0.02	0.02	0.07	0.035	0.02	0.01	0.01	0.07	0.03
Mn	29.5	9510	1220	4000	1620	7880	1170	2060	29.5	9510	3440
Mo	8.1	0.68	0.85	0.2	0.35	0.81	0.62	0.53	0.2	8.1	1.5
Ni	28.9	15	12	9.9	7.9	11	8.2	3.2	3.2	28.9	12
Pb	0.7	6.8	6.0	4.1	4.1	8.6	4.1	1	0.7	8.6	4.4
Se	0.2	0.97	1.2	0.5	1.1	8.6	0.87	<0.2	<0.2	8.6	1.7
Tl	<0.5	1	<0.7	<0.6	<0.6	0.9	<0.6	<0.6	<0.5	1	*
Zn	7.04	21.1	28.4	14.6	21.5	22.9	20.1	10.4	7.04	28.4	18.3
% Moist	96.8	91.9	89.3	77.3	85.4	81.8	81.5	87.5	77.3	96.8	86.4

24

Appendix G. Element concentration (ppm, dry weight) in plants collected at Tewaukon NWR in 1991.

Element	TP001	TP002	TP003	TP004	TP005	TP006	MIN	MAX	MEAN
Al	610.0	540.0	440.0	330.0	1220.0	120.0	120.0	1220.0	543
As	5.2	5.7	5.8	7.0	5.2	4.1	4.1	7.0	5.5
B	553.0	677.0	688.0	19.0	23.0	15.0	15.0	688.0	329.1
Ba	186.0	219.0	143.0	150.0	118.0	94.4	94.4	219.0	151.7
Be	<0.02	<0.04	<0.04	<0.02	0.04	<0.01	<0.01	0.04	*
Cd	0.28	0.30	0.20	0.38	0.58	0.30	0.20	0.58	0.34
Cr	0.99	1.0	1.0	1.3	2.4	0.48	0.48	2.4	0.86
Cu	5.4	7.1	5.4	4.2	6.4	3.1	3.1	7.1	5.2
Fe	989.0	1070.0	1010.0	804.0	1490.0	424.0	424.0	1490.0	964
Hg	0.051	0.053	<0.04	0.053	0.052	0.054	<0.04	0.054	0.05
Mg	5540.0	6390.0	8220.0	3320.0	3720.0	3330.0	3320.0	8220.0	5087
Mn	12000	14400	11600	8750	6310	5670	5670	14400	9788
Mo	<2.0	<2.0	<2.0	2.0	2.0	2.0	<2.0	2.0	*
Ni	4.4	5.0	7.3	5.1	5.4	3.8	3.8	7.3	5.2
Pb	<0.9	<2.0	<2.0	1.0	2.0	0.8	<0.9	2.0	*
Se	0.6	<0.3	<0.5	0.5	0.6	0.4	<0.3	0.6	0.43
Sr	142.0	158.0	120.0	83.7	82.3	79.1	79.1	158	110.8
V	5.4	6.0	5.1	5.2	6.7	2.8	2.8	6.7	5.2
Zn	46.5	48.8	52.5	17.0	22.0	15.0	15.0	52.5	33.6
% Moist	96.6	96.9	98.4	92.9	86.8	88.9	86.8	98.4	93.4

25

Appendix H. Element concentration (ppm, dry weight) in whole fish collected at Tewaukon NWR in 1990.

Fish Identification Numbers

Element	F-SL-W	F-SL-FH	F-TL-A	F-MAR-A	F-P2-A	F-P2-J	F-TL-J	F-MAR-J	MIN	MAX	MEAN
Al	12.0	66.7	62.8	55.8	101.0	34.0	104.0	163.0	12.0	163.0	74.9
As	<0.2	0.5	0.3	0.3	0.3	0.5	0.2	<0.4	<0.2	0.5	0.3
Be	<0.01	<0.01	<0.01	<0.009	<0.01	<0.01	<0.01	<0.01	<0.009	<0.01	*
Cd	<0.05	0.39	0.1	0.1	0.32	0.33	0.1	0.1	<0.05	0.39	0.18
Cr	1.0	1.8	3.8	2.6	1.2	0.80	4.4	5.3	1.0	4.4	2.6
Cu	1.3	6.83	2.79	2.59	4.10	6.95	3.72	390.0	1.3	390.0	52.2
Fe	36.1	138.0	128.0	104.0	147.0	114.0	204.0	253.0	36.1	253.0	140.5
Hg	0.92	0.11	0.14	0.15	0.24	0.31	0.42	0.10	0.10	0.92	0.29
Mn	3.81	11.4	6.45	6.02	12.0	7.98	30.6	41.2	3.81	41.2	14.9
Mo	0.1	0.62	0.45	0.2	0.2	0.2	0.2	0.1	0.1	0.62	0.26
Ni	0.5	2.0	3.5	1.4	1.0	0.7	2.7	2.1	0.5	3.5	1.7
Pb	<0.4	<0.5	<0.5	<0.4	<0.5	<0.5	<0.5	1.0	<0.4	1.0	*
Se	1.3	2.1	1.5	1.3	1.1	1.6	1.8	1.9	1.1	1.9	1.6
Tl	<0.7	<0.7	<0.6	<0.5	<0.7	<0.7	<0.7	<0.7	<0.5	<0.7	*
Zn	41.9	162.0	241.0	222.0	195.0	207.0	161.0	183.0	41.9	241.0	176.6
% Moist	69.0	79.2	75.6	76.0	73.8	81.3	82.4	81.9	69.0	82.4	77.4

2b

Appendix I. Element concentration (ppm, dry weight) in whole fish collected at Tewaukon NWR in 1991.

	Carp Identification Numbers			Fathead Identification Numbers							
Element	TF001	TF002	TF003	TF004	TF013	TF014	TF015	TF016	MIN	MAX	MEAN
Al	62.0	54.0	70.0	39.0	41.0	78.0	42.0	31.0	31.0	70.0	52.0
As	0.3	0.36	0.34	0.2	0.3	0.9	0.81	0.75	0.2	0.9	0.49
B	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	*
Ba	4.5	3.6	4.2	2.9	3.5	5.8	6.1	5.5	2.9	6.1	4.5
Be	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	*
Cd	<0.03	<0.03	0.04	0.09	<0.03	0.04	<0.03	0.04	<0.03	0.04	*
Cr	0.72	0.55	0.84	0.64	0.20	0.85	0.58	1.3	0.20	1.3	0.71
Cu	3.1	2.9	3.6	3.0	4.8	5.1	3.9	3.8	2.9	5.1	3.8
Fe	117	97	136	111	115	93	98	94	93	117	96
Hg	0.2	0.23	0.29	0.31	0.26	0.27	0.25	0.23	0.2	0.31	0.25
Mg	1120	1050	1260	1140	1100	1300	1330	1310	1050	1330	1201
Mn	6.0	4.7	8.1	5.5	14.0	20.0	24.3	22.0	4.7	22.0	13.0
Mo	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	*
Ni	0.4	0.4	0.59	0.71	0.3	0.88	0.6	0.88	0.3	0.88	0.59
Pb	<0.4	<0.4	<0.4	<0.4	<0.4	<0.5	<0.4	<0.4	<0.4	<0.5	*
Se	1.5	1.4	1.5	1.6	1.2	2.1	2.1	2.1	1.4	2.1	1.7
Sr	63.8	56.7	65.0	55.8	22.1	44.3	43.6	45.0	22.1	65.0	49.5
V	<0.3	0.6	0.6	0.7	<0.3	0.3	0.4	<0.3	<0.3	0.7	0.4
Zn	244	255	337	270	54	135	129	119	54	337	192
% Moist	70.5	70.8	71.0	71.5	79.5	77.7	77.3	77.2	70.5	79.5	74.4

27

Appendix J. Element concentration (ppm, dry weight) in walleye gonads, livers, and muscle collected at Tewaukon NWR in 1991.

	GONAD IDENTIFICATION NUMBERS				LIVER IDENTIFICATION NUMBERS				MUSCLE IDENTIFICATION NUMBERS						
Element	SL001	TF015	TF016	TF017	TF009	TF010	TF011	TF012	TF005	TF006	TF007	TF008	MIN	MAX	MEAN
Al	3	<3	<3	12	16	<3	<3	3	<3	<3	<3	7	<3	16	*
As	<0.2	<0.2	<0.2	<0.2	<0.2	0.3	0.3	0.3	0.2	0.3	0.3	<0.2	<0.2	0.3	*
B	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	*
Ba	0.1	<0.1	<0.1	0.2	<0.2	<0.1	<0.1	<0.1	<0.1	0.1	0.1	0.2	<0.1	0.2	*
Be	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	*
Cd	<0.03	<0.03	<0.03	<0.03	0.2	0.19	0.22	0.25	<0.03	<0.03	<0.03	<0.03	<0.03	0.25	*
Cr	0.2	0.35	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.41	0.48	0.48	0.48	<0.1	0.48	0.21
Cu	0.3	<0.2	<0.2	<0.2	18	13	13	27.5	1.9	0.67	2.4	2.4	<0.2	27.5	7.2
Fe	13	5.6	5.2	14	1030	711	978	1130	8.7	10	7.9	15	5.2	1130	327
Hg	0.009	0.009	<0.005	<0.005	0.28	0.43	0.35	0.34	0.713	0.868	0.774	0.78	<0.005	0.868	0.38
Mg	40	13.8	13.4	18.5	526	563	535	651	1370	1290	1330	1370	13.4	1370	643
Mn	1.8	<0.2	<0.2	1	8.4	6.5	6.7	6.3	0.8	1.3	0.92	1.5	<0.2	8.4	2.9
Mo	<0.9	<1	<1	<0.9	<1	<1	<1	<1	<1	<1	<1	<1	<0.9	<1	*
Ni	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	0.2	<0.2	<0.2	<0.2	0.3	<0.2	0.3	*
Pb	<0.4	<0.5	<0.4	0.8	<0.4	<0.5	<0.4	<0.4	<0.5	<0.5	<0.4	<0.4	<0.4	0.8	*
Se	<0.2	<0.2	<0.2	<0.2	3.5	3.3	3.4	4.2	1.8	2.1	1.7	1.9	<0.2	4.2	1.9
Sr	0.65	<0.1	<0.1	<0.09	0.34	0.32	0.36	0.62	0.4	0.56	1.1	0.49	<0.1	1.1	0.40
V	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	*
Zn	37.9	13	17	21.8	88.1	86.1	87.7	108	35	29	39.1	22.5	13	108	48.7
% MOIST	10.5	62.7	6	6.5	75.2	75.3	78.1	77.7	77.2	77.5	77.7	77.5	6	78.1	58.5

28

Appendix K. Element concentration (ppm, dry weight) in crayfish collected at Tewaukon NWR in 1990.

	Crayfish Identification Number					
	I-TL	I-MAR	I-P2	MIN	MAX	MEAN
ELEMENT						
Al	300	632	391	300	632	441
As	3.2	1.8	1.7	1.7	3.2	2.2
Be	0.02	0.03	0.02	0.02	0.03	0.02
Cd	0.08	0.1	0.2	0.08	0.2	0.12
Cr	1.4	1.7	0.98	0.98	1.7	1.36
Cu	63.1	86.4	68.2	63.1	86.4	72.6
Fe	253	477	319	253	477	349
Hg	0.072	0.056	0.31	0.056	0.31	0.146
Mn	80.8	96.8	226	80.8	226	134
Mo	0.30	0.59	0.2	0.2	0.59	0.96
Ni	2.1	2.9	1.9	1.9	2.9	2.3
Pb	1.7	4.4	1	1	4.4	2.3
Se	1.1	1.0	0.79	0.79	1.1	0.96
Tl	<0.7	<0.7	<0.7	<0.7	<0.7	*
Zn	134	246	71.2	71.2	246	150.4
% Moisture	75.8	74.1	70.6	70.6	75.8	73.5

Appendix L. Element concentration (ppm, dry weight) in coot eggs collected at Tewaukon NWR in 1991.

Coot Egg Identification Number

ELEMENT	SL1A	T1A	T2A	MIN	MAX	MEAN
Al	<3	<3	<3	<3	<3	*
As	<0.05	<0.05	0.05	<0.05	0.05	*
B	<2	<2	<2	<2	<2	*
Ba	2.4	4.8	2.3	2.3	4.8	*
Be	<0.01	<0.01	<0.01	<0.01	<0.01	*
Cd	<0.04	<0.03	<0.03	<0.03	<0.04	*
Cr	<0.1	<0.1	<0.1	<0.1	<0.1	*
Cu	3.2	3.6	3.6	3.2	3.6	3.4
Fe	121	100	76	76	121	99
Hg	0.47	0.584	0.644	0.47	0.644	0.566
Mg	432	487	552	432	552	490
Mn	2.1	1.7	1.5	1.5	2.1	1.8
Mo	<1.0	<1.0	<1.0	<1.0	<1.0	*
Ni	<0.2	<0.2	<0.2	<0.2	<0.2	*
Pb	<0.5	<0.4	<0.4	<0.4	<0.5	*
Se	1.7	2.1	2.1	1.7	2.1	2.0
Sr	4	4.5	3.4	3.4	4.5	4.0
V	<0.3	<0.3	<0.3	<0.3	<0.3	*
Zn	53.1	53.1	40.8	40.8	53.1	49.0
% Moisture	72.9	76.7	77.2	72.9	77.2	75.6

Appendix M. Element concentration (ppm, dry weight) in coot eggs collected at Tewaukon NWR in 1992.

	Coot Egg Identification Number							
ELEMENT	CE01	CE02	CE03	CE04	CE05	MIN	MAX	MEAN
Al	4	<3	<3	4	<3	<3	4	*
As	<1	<2	<1	<1	<1	<1	<2	*
B	<2	4	3	4	2	<2	4	3
Ba	1.1	0.98	9.64	7.2	7.6	0.98	9.64	5.3
Be	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	*
Cd	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	*
Cr	<0.1	<0.09	<0.1	<0.1	<0.1	<0.09	<0.1	*
Cu	1.6	3.2	2.5	2.3	2.6	1.6	3.2	2.4
Fe	64	121	93	61	98.3	61	121	87.5
Hg	0.601	0.542	0.539	0.654	0.44	0.44	0.601	0.55
Mg	306	867	673	401	522	306	867	553
Mn	2	2.4	4.6	2.4	3.2	2	4.6	2.9
Mo	<1	<0.9	<0.9	<1	<1	<0.9	<1	*
Ni	<0.1	<0.09	<0.9	<0.1	<0.1	<0.09	<0.1	*
Pb	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	*
Se	1.3	1	1.3	1	1.2	1	1.3	1.2
V	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	*
Zn	33.9	44.3	58.4	38.1	49	33.9	58.4	44.7
% Moisture	77.7	85.8	74.2	77.3	76	74.2	85.8	78.2

31

Appendix N. Element concentration (ppm, dry weight) in bird livers other than coots collected at Tewaukon NWR in 1990.

	Bird Liver Identification Number						
ELEMENT	B-HS-5	B-HS-6	B-TL-1	B-WWL-3	MIN	MAX	MEAN
Al	4.8	3.0	30	2.3	2.3	30	10
As	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	*
Be	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	*
Cd	<0.04	<0.04	<0.08	<0.07	<0.08	<0.04	*
Cr	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	*
Cu	40.6	64.8	81.1	65.2	40.6	81.1	62.9
Fe	313	251	883	926	251	883	593
Hg	0.15	0.17	0.648	1.1	0.15	1.1	0.52
Mn	16.3	19.1	17.1	14.6	14.6	19.1	16.8
Mo	2.4	2.7	2.3	2.1	2.1	2.7	2.4
Ni	<0.2	<0.3	2.3	<0.2	<0.2	2.3	*
Pb	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	*
Se	1.5	1.8	13.0	8.4	1.5	13.0	6.2
Tl	<0.5	<0.6	<0.5	<0.5	<0.5	<0.6	*
Zn	79.1	115	126	136	79.1	136	114
% Moisture	70.8	71.4	70.8	71.7	70.8	71.7	71.2

Appendix O. Element concentration (ppm, dry weight) in bird livers other than coots collected at Tewaukon NWR in 1991.

Bird Species and Liver Identification Numbers

ELEMENT	MALLARD TB001	EARED GREBES TB002	EARED GREBES TB003	GADWALLS TB015	GADWALLS TB016	MOURNING DOVE TB018	PHEASANT TB019	WOODDUCK TB020	MIN	MAX	MEAN
Al	3	6	5	4	3	4	<3	<3	<3	6	3.5
As	0.06	0.07	<0.05	<0.05	<0.05	<0.05	<0.05	0.25	<0.05	0.25	*
B	<2	<2	<2	<2	<2	<2	<2	3	<2	3	*
Ba	0.1	<0.1	<0.1	0.1	<0.1	<0.1	<0.1	0.2	<0.1	0.2	*
Be	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	*
Cd	<0.04	1.9	3	0.05	0.04	1.2	0.15	0.06	<0.04	3	0.8
Cr	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	*
Cu	79.9	13	11	146	154	13	17	14	11	154	56
Fe	196	802	1310	600	662	635	372	256	196	1310	604
Hg	0.06	8.91	11.5	0.34	0.35	0.01	0.12	0.79	0.01	11.5	2.8
Mg	773	591	660	717	708	707	792	746	591	792	712
Mn	18	15	16	16	19	8.8	13	53.4	8.8	53.4	19.9
Mo		3	1	1	3.3	3.3	3.1	3.4	1	3.4	2.4
Ni	<0.2	<0.2	<0.2	<0.2	<0.2	0.2	<0.2	0.2	<0.2	0.2	*
Pb	<0.4	<0.5	<0.5	<0.4	<0.4	<0.5	<0.5	<0.5	<0.4	<0.5	*
Se	3.2	16.0	10.0	3.2	3.7	3.1	3.9	6.3	3.1	16.0	6.2
Sr	0.4	0.1	0.2	0.33	0.2	0.1	0.1	1	0.1	0.33	0.30
V	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	*
Zn	141	84.9	69	147	175	79.7	86.6	107	69	175	111
% Moist	71.6	69.5	67.3	71.2	69.7	72.2	70.4	72.3	67.3	72.3	70.5