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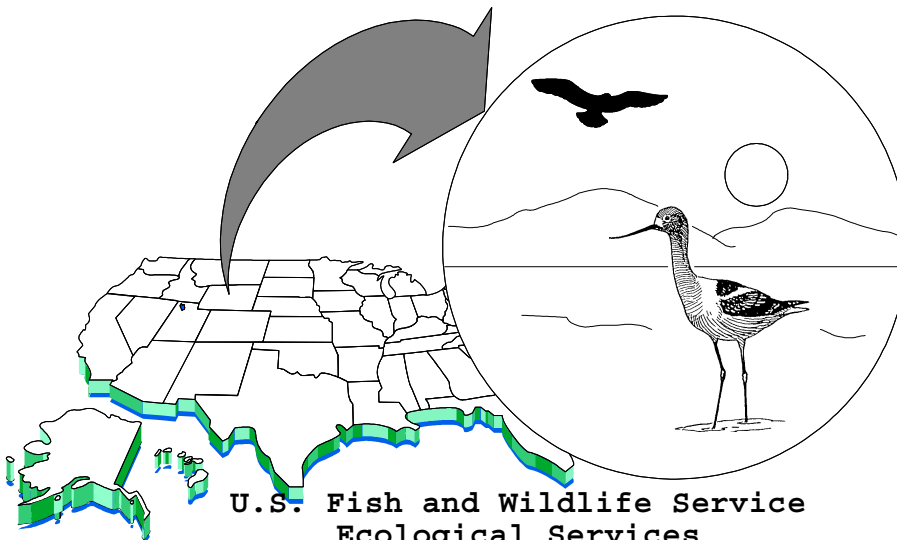
TRACE ELEMENT CONCENTRATIONS
IN WATER, SEDIMENT AND BIOTA FROM
PATHFINDER NATIONAL WILDLIFE REFUGE,
NATRONA AND CARBON COUNTIES, WYOMING

BY

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ABSTRACT

Pathfinder National Wildlife Refuge (Pathfinder NWR), located in Natrona and Carbon Counties, is 50 miles southwest of Casper, Wyoming. Pathfinder NWR, established in 1936, is a refuge and breeding area for migratory waterfowl. The refuge initially encompassed the entire Pathfinder Reservoir, an impoundment of the North Platte River. In 1965, the U.S. Fish and Wildlife Service reduced it to four smaller units to allow more intensive management: the Sweetwater Arm, Goose Bay Unit, DeWeese Creek Unit, and the Sage Creek-Platte Unit. We collected water, sediment and biota samples for trace element analyses in May, June and July 1993 from wetlands next to and including Steamboat Lake in the Sweetwater Arm Unit of Pathfinder NWR. High salinity occurs at all ponds ($> 30,000 \mu\text{mho/cm}$). Sodium is the most abundant cation and carbonates and sulfates are the most abundant anions in these ponds. Hypersaline wetlands (conductivity $> 77,000 \mu\text{mho/cm}$) can be lethal to waterfowl. Sodium toxicity occurs when sources of freshwater are not available nearby. We did not find any major trace element problems at the Sweetwater Arm Unit of Pathfinder NWR except for arsenic and chromium in brine shrimp. Although elevated, arsenic and chromium concentrations do not appear to pose a threat to aquatic birds. Major cations and anions, specific conductance and total alkalinity are typical of shallow alkaline wetlands in the arid western United States. Waterfowl nesting should not be encouraged at these ponds due to the potential for sodium toxicity in ducklings or goslings. Nesting enhancement measures could be carried out at the southeast ponds closest to the Sweetwater Arm of the reservoir where freshwater is available. Refuge managers should consider water quality analyses at these ponds before intensive management for waterfowl production. The alkaline ponds, however, do provide good nesting habitat for American avocets.

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INTRODUCTION

Wildlife refuges nationwide are threatened by environmental contaminants. Since 1984, the U.S. Fish and Wildlife Service (Service) has conducted biological investigations in national wildlife refuges throughout the United States to identify existing contaminant problems and baseline conditions. In Wyoming, the Service has completed baseline environmental contaminant investigations at Seedska-dee, National Elk, Hutton Lake and Bamforth National Wildlife Refuges (Ramirez and Armstrong 1992, Dickerson and Ramirez 1993). In 1993 the Service collected water, sediment and biota from Pathfinder National Wildlife Refuge (Pathfinder NWR) and submitted the samples for trace element analyses.

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STUDY AREA DESCRIPTION

Pathfinder NWR, located in Natrona and Carbon Counties, is 50 miles southwest of Casper, Wyoming (Figure 1). Pathfinder NWR, established in 1936, is a refuge and breeding area for migratory waterfowl. The refuge initially encompassed the entire Pathfinder Reservoir, an impoundment of the North Platte River. In 1965, the Service reduced the refuge to four smaller units to allow more intensive management: the Sweetwater Arm, Goose Bay Unit, DeWeese Creek Unit, and the Sage Creek-Platte Unit. Pathfinder NWR encompasses 16,807 acres.

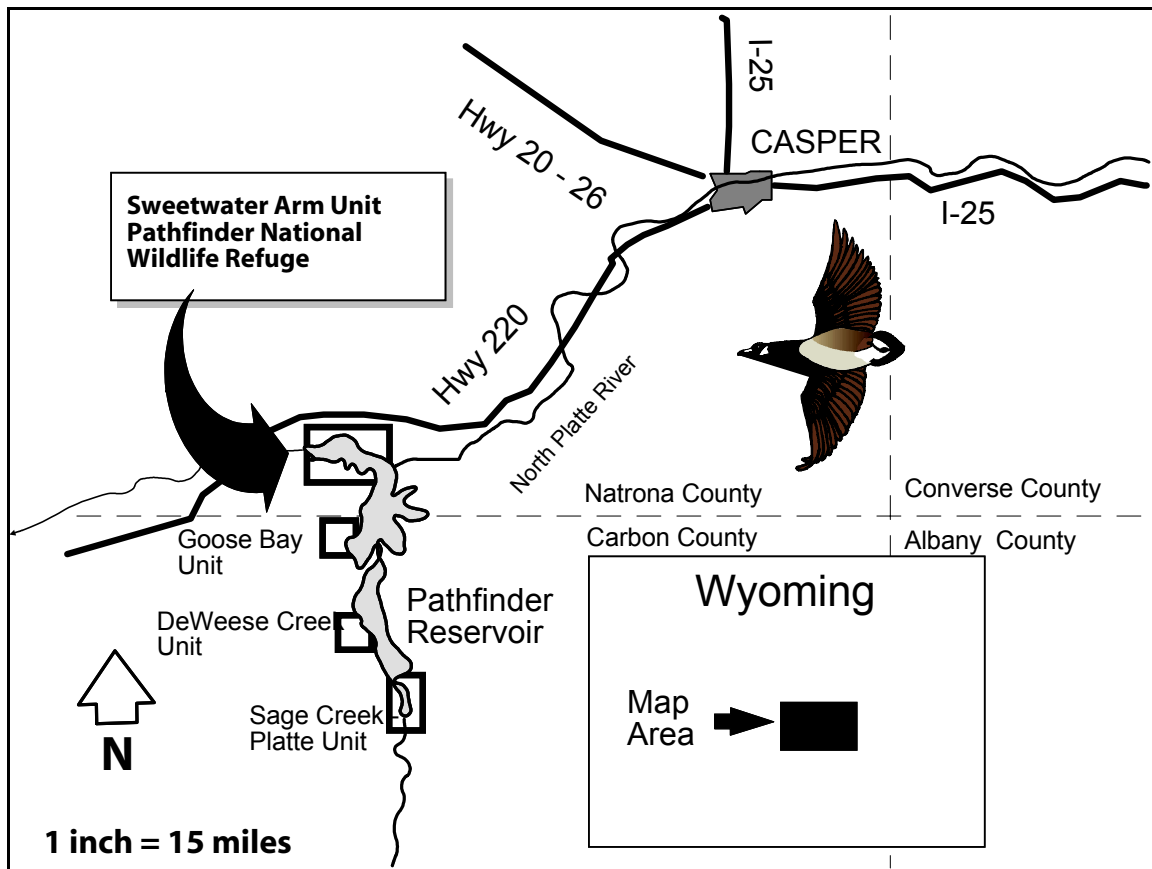


Figure 1. Location of Sweetwater Arm Unit of Pathfinder National Wildlife Refuge, Wyoming.

Pathfinder NWR is an important feeding, resting and nesting area for aquatic birds. The refuge is administered from the Arapaho NWR in Walden, Colorado, 200 miles to the south. As a result, management activities are severely limited. Water levels within the reservoir fluctuate as much as 50 feet per year and are controlled by the Bureau of Reclamation for the primary benefit of

irrigation users. The study area focused on wetlands in the Sweetwater arm of Pathfinder Reservoir, specifically wetlands including and next to Steamboat Lake (Figure 2).

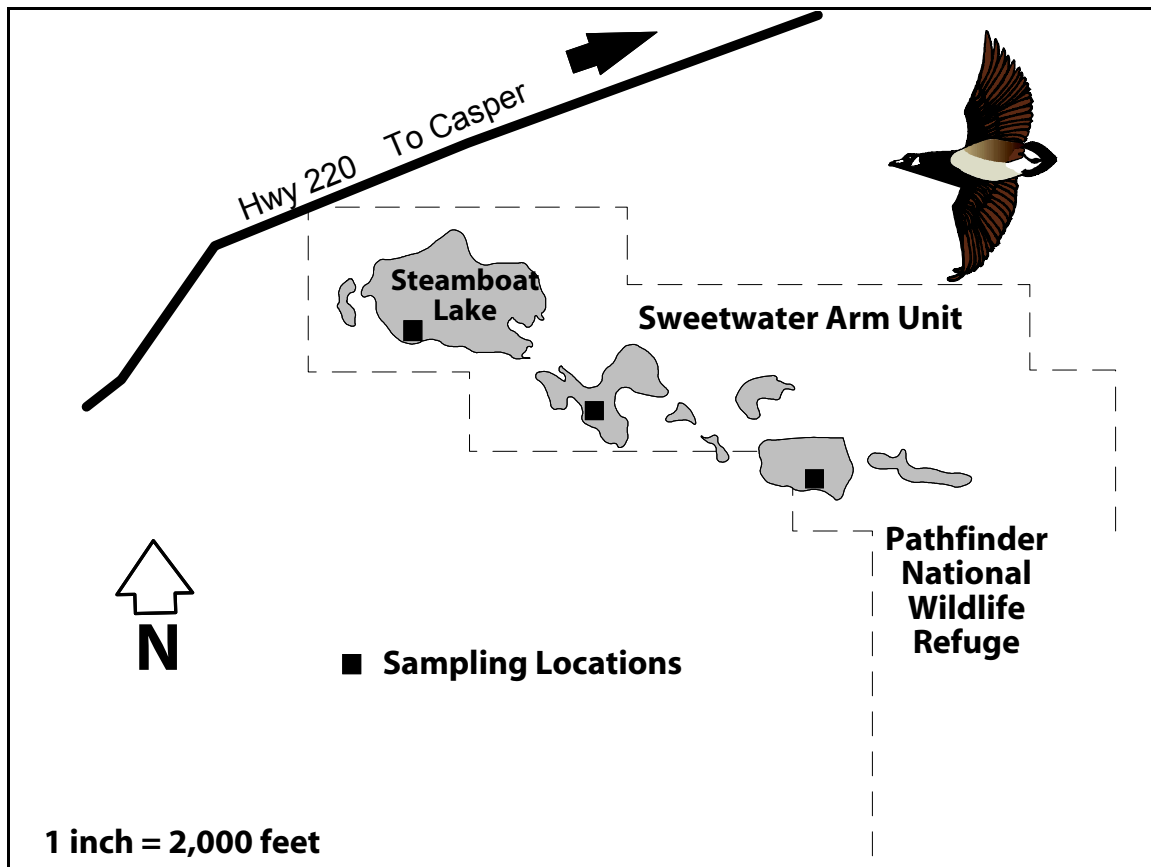


Figure 2. Sampling sites at the Sweetwater Arm Unit of Pathfinder National Wildlife Refuge, Wyoming.

METHODS

We collected water, sediment and biota samples between May and July 1993 from wetlands next to and including Steamboat Lake. Water samples for trace element analyses were collected in polyethylene jars and preserved with nitric acid to a pH # 2. For major ion and basic water chemistry analyses, duplicate water samples were collected and refrigerated. Sediment samples were collected in whirl-pak bags with a chemically-clean stainless-steel spoon. Sediment and biota samples were kept in an ice-filled cooler immediately after collection and frozen within eight hours. We collected brine shrimp (*Artemia sp.*), by dipping a chemically-clean stainless steel strainer into the water. Brine shrimp samples were stored in 40 ml chemically-clean glass vials. We collected American avocet (*Recurvirostra americana*) eggs, dissected them and examined the embryos to determine age and condition. Adult and juvenile avocets, gadwall (*Anas strepera*) and cinnamon teal (*A. cyanoptera*) were collected with a shotgun and steel shot. We dissected the birds and removed the livers for trace element analyses. Livers were placed in whirl-pak bags and frozen immediately.

Sediment and biota samples were submitted to Research Triangle Institute Laboratory through the National Biological Survey's Patuxent Analytical Control Facility (PACF) in Laurel, Maryland. The laboratory analyzed samples for mercury by cold vapor atomic absorption spectroscopy, selenium and arsenic by graphic furnace absorption spectroscopy, and the remaining trace elements by inductively coupled plasma emission spectroscopy (ICP Scan). Quality assurance and quality control (QA/QC) procedures were confirmed with procedural blanks, duplicate analyses, test recoveries of spiked materials and reference material analyses. The Wyoming Department of Agriculture Analytical Services Laboratory (WDAASL) in Laramie, Wyoming analyzed water samples for major ions, total alkalinity, hardness, total dissolved solids (TDS), and conductivity. QA/QC procedures involved daily calibration of instrumentation, analysis of reagent blanks, duplicate analysis, and analysis of laboratory control standards, instrument QC standards and blind performance samples. Laboratory methods used by the (WDAASL) for major ions, total alkalinity, hardness, total dissolved solids (TDS), and conductivity follow Methods for the determination of inorganic substances in water and fluvial sediments, Book 5, Laboratory Analysis Chapter A1, 1979 and Standard methods for the examination of water and waste water, 18th edition, APHA, AWWA and WEF, Washington, DC, 1992. PACF did not review the work of this laboratory for QA/QC.

RESULTS AND DISCUSSION

Water Quality

Based on specific conductance, high salinities occurred at all ponds (> 30,000 $\mu\text{mho/cm}$) (Table 1). Cowardin et al. (1979) classified wetlands as polysaline if specific conductances ranged from 30,000 to 45,000 $\mu\text{mho/cm}$ and hypersaline for conductance greater than 60,000 $\mu\text{mho/cm}$. Sites 2 and 3 are hypersaline with salinities greater than seawater. In these ponds, sodium is the most abundant cation and carbonates and sulfates are the most abundant anions.

Table 1. Water quality data from three ponds in the Sweetwater Arm Unit of Pathfinder National Wildlife Refuge, Wyoming.

Cations (mg/l)	Site 1 Steamboat Lake		Site 2 Middle Pond		Site 3 SE Pond	
	PF1a	PF1b	PF2a	PF2b	PF3a	PF3b
Ca	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Mg	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Na	10,500	9,840	76,100	75,800	37,700	39,200
K	150	130	770	740	1,400	1,400
Anions (mg/l)						
Carbonate	7,900	8,100	62,100	68,600	33,500	33,300
Bicarbonate	3,500	3,400	18,200	17,000	9,800	9,600
Sulfates	4,900	4,600	33,500	34,500	20,100	20,280
Chloride	2,200	2,100	23,600	18,900	4,700	4,700
Conductance ($\mu\text{mho/cm}$)	33,400	33,400	117,500	117,000	84,300	84,200
pH	10.2	10.2	10.3	10.4	10.4	10.4
Total Alkalinity as CaCO ₃ (mg/l)	16,100	16,200	118,500	128,300	64,000	63,400

Waterfowl mortalities resulting from salt crystallization and/or toxicity have been documented in hypersaline (conductivity > 77,000 $\mu\text{mho/cm}$) wetlands in Canada and North Dakota (Wobeser and Howard 1987, Mitcham and Wobeser 1988, Windingstad et al. 1987). Sodium toxicity occurs when freshwater sources are not available nearby. Cooch (1964) found that aquatic birds ingesting water with large salt concentrations can increase their susceptibility to avian botulism.

Sediments and Aquatic Invertebrates

Trace element concentrations in sediments were within the ranges reported by Harms et al. (1990) for the northern Great Plains (Table 2). Brine shrimp samples contained elevated concentrations of arsenic and chromium (Table 3). However, the toxicity of arsenic is dependent on the form or species. Arsenicals are toxic to birds at concentrations ranging from 17 to 48 $\mu\text{g/g}$ (Eisler 1988). Mallards do not show adverse effects until dietary levels of arsenic reach 200 $\mu\text{g/g}$ as sodium arsenate (Eisler 1988). Chromium concentrations in biota greater than 4 $\mu\text{g/g}$ are considered elevated (Eisler 1986). Selenium concentrations in four of five brine shrimp samples were less than the 3 $\mu\text{g/g}$ dietary level considered adverse to aquatic birds (Lemly 1993). One sample had a selenium concentration of 3.47 $\mu\text{g/g}$. No other trace elements were elevated in the brine shrimp.

Bird Livers and Eggs

All six avocet liver samples had elevated selenium concentrations (Table 4). Concentrations greater than 10 $\mu\text{g/g}$ are considered adverse to aquatic birds (Lemly 1993). One of two gadwall liver samples and two of the three cinnamon teal liver samples also had elevated selenium. Based on sediment and invertebrate samples, it is unlikely that the elevated selenium resulted from Pathfinder NWR. It is possible that these birds accumulated the selenium at another site. Most trace elements in avocet eggs were below detection limits or were present at levels not considered adverse to aquatic birds (Table 5). Selenium concentrations in avocet eggs were above the 3 $\mu\text{g/g}$ level considered background but were below the 8 $\mu\text{g/g}$ level known to cause reproductive impairment (Skorupa et al. 1991).

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Table 2. Trace element concentrations (in ug/g) in sediments from the Sweetwater Arm, Pathfinder National Wildlife Refuge, Natrona County, Wyoming.

Sample ID	% Moisture	Al	As	B	Ba	Be	Cd
PFP2SED1	37.03	14210	4.38	43.79	133.6	0.5193	<0.1988
PFSED01	26.35	6543	4.21	32.83	87	0.2165	<0.2
PFSED02	27.05	5501	2.9	24.03	76.36	<0.2008	<0.2008
PFSED03	34.98	13750	4.57	62.1	104.5	0.4986	<0.2
PFSED04	25	7239	3.67	37.62	92.93	0.228	<0.1988
PFSED05	39.58	11350	5.81	58.77	120	0.4071	<0.1992
PFSESD01	32.17	8824	5.33	51.31	117.3	0.2678	<0.2008
PFSESD02	29.57	6156	4.1	33.41	81.37	<0.2004	<0.2004
PFSESD03	49.87	13350	10.44	95.33	94.76	0.511	<0.1992
PFSESD04	29.27	6387	4.23	30.29	101.6	<0.1996	<0.1996
PFSESD05	39.39	9426	4.71	47.7	91.07	0.2856	<0.2004
PFSLSD01	30.35	4714	3.02	13.62	67.54	<0.1992	<0.1992
PFSLSD02	18.59	1094	0.88	<5.0607	26.27	<0.2024	<0.2024
PFSLSD03	27.76	10190	2.98	24.44	131	0.3214	<0.2028
PFSLSD04	23.46	4877	2.17	15.75	66.75	<0.2028	<0.2028
PFSLSD05	45.34	6460	3.21	30.43	62.77	<0.2	<0.2
PFSLSED1	34	5835	2.5	12.84	81.16	<0.2037	<0.2037
PFSLSED2	37.79	6796	3.66	31.25	83.66	0.6803	0.4032

Sample ID	Cr	Cu	Fe	Hg	Mg	Mn	Mo	Ni
PFP2SED1	21.15	11.12	11400	<0.0994	13160	306.2	<4.9702	12.25
PFSED01	54.72	5.408	5908	<0.1	5666	136	<5	7.572
PFSED02	47.88	<5.0201	4154	<0.1004	4217	96.93	<5.0201	6.341
PFSED03	28.39	10.01	11150	<0.1	18900	283.2	<5	12.07
PFSED04	53.73	6.797	6230	<0.0994	6880	154.6	<4.9702	7.73
PFSED05	32.17	10.11	9583	<0.0996	10650	250.1	<4.9801	11.34
PFSESD01	95.02	7.778	7523	<0.1004	7237	169.7	<5.0201	10.01
PFSESD02	29.5	6.287	5484	<0.1002	6182	140.8	<5.01	6.3
PFSESD03	16.77	12.63	10250	<0.0996	17200	306.2	<4.9801	11.33
PFSESD04	43.47	5.977	5370	<0.0998	5981	148.8	<4.99	5.724
PFSESD05	13.33	7.934	7484	<0.1002	11880	211.1	<5.01	7.892
PFSLSD01	16.46	<4.9801	4067	<0.0996	3942	114.3	<4.9801	5.33
PFSLSD02	10.96	<5.0607	1111	<0.1012	715	45.82	<5.0607	<5.0607
PFSLSD03	17.35	7.6	8033	<0.1014	9565	242	<5.071	8.324
PFSLSD04	8.641	<5.071	3844	<0.1014	4388	96.68	<5.071	<5.071
PFSLSD05	12.88	5.357	5642	<0.1	6047	146.7	<5	6.127
PFSLSED1	10.05	<5.0916	5292	<0.1018	5095	168.1	<5.0916	5.398
PFSLSED2	9.391	5.794	5304	<0.102	5622	150.4	<5.102	7.507

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Table 2. Trace element concentrations (in ug/g) in sediments from the Sweetwater Arm, Pathfinder National Wildlife Refuge, Natrona County, Wyoming.

Sample ID	Pb	Se	Sr	V	Zn
PFP2SED1	12.39	<0.497	157.5	39.13	40.04
PFSED01	7.483	<0.5	70.27	19.86	18.45
PFSED02	5.314	<0.502	118.6	12.82	31.15
PFSED03	19.75	<0.5	253	39.72	39.72
PFSED04	14.59	<0.497	125.3	19.47	22.03
PFSED05	13.44	0.5	78.52	31.35	34.04
PFSESD01	12.16	<0.502	116.6	26.46	24.8
PFSESD02	9.94	<0.501	111	19.89	18.62
PFSESD03	18.04	<0.498	215.3	47.87	41.67
PFSESD04	11.68	<0.499	148.5	18.67	18.66
PFSESD05	8.123	<0.501	161.9	27.97	27.3
PFSLSD01	<4.9801	<0.498	103.2	17.61	14.3
PFSLSD02	<5.0607	<0.5061	60.93	<5.0607	<5.0607
PFSLSD03	9.112	<0.5071	224.1	35.48	28.65
PFSLSD04	8.014	<0.5071	98.39	13.31	12.55
PFSLSD05	9.359	0.74	91.13	23.83	20.76
PFSLSED1	12.53	<0.5092	122.1	15.19	18.54
PFSLSED2	14.84	0.88	118.2	24.25	20.07

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Table 3. Trace element concentrations (in ug/g) in brine shrimp collected from alkaline ponds in the Sweetwater Arm, Pathfinder National Wildlife Refuge, Natrona County, Wyoming.

Sample ID	% Moisture	Al	As	B	Ba	Be	Cd
PFAQI01	92.35	7427	17.94	75.96	55.29	0.2875	0.8527
PFAQI02	90.88	4731	18.56	69.99	37.63	<0.2008	0.8351
PFAQI03	85.83	2979	23.25	76.81	23.87	<0.1976	0.9029
PFAQI04	88.79	4209	20.78	82.44	27.18	<0.2	0.8669
PFAQI05	88.06	4356	22.82	98.29	26.9	<0.2	0.9002

Sample ID	Cr	Cu	Fe	Hg	Mg	Mn	Mo	Ni
PFAQI01	9.812	12.58	7468	<0.1984	10260	182.5	4.047	7.807
PFAQI02	6.371	10.23	4750	<0.2	5822	110.2	4.104	5.158
PFAQI03	4.403	8.846	3079	<0.2024	3558	71.86	5.114	3.832
PFAQI04	5.342	9.172	3658	<0.2033	4233	77.18	4.672	3.868
PFAQI05	5.352	9.509	3962	<0.1976	4106	82.78	5.653	5

Sample ID	Pb	Se	Sr	V	Zn
PFAQI01	14.65	2.47	66.57	25.69	42.69
PFAQI02	7.579	2.59	39.89	18.61	37.76
PFAQI03	6.578	3.47	22.41	12.39	35.1
PFAQI04	8.039	2.85	29.07	14.7	36.26
PFAQI05	7.699	2.39	18.23	15.95	36.6

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Table 4. Trace element concentrations (in ug/g) in livers from aquatic birds collected from the Sweetwater Arm, Pathfinder National Wildlife Refuge, Natrona County, Wyoming.

Sample ID	Species	% Moisture	Al	As	B	Ba
PFSLAA01	Am. Avocet	69.75	<5.0403	1.38	0.8939	<0.504
PFSLAA02	Am. Avocet	70	26.92	2.89	1.058	<0.5
PFSLAA03	Am. Avocet	67.78	5.156	3.21	<0.501	<0.501
PFSLAA04	Am. Avocet	68.2	<5.0505	2.22	<0.5051	<0.5051
PFSLAA05	Am. Avocet	76.9	<5	3.04	<0.5	<0.5
PFSLAA06	Am. Avocet	50.2	8.356	2.83	3.039	<0.501
PFSECT01	Cinnamon Teal	71.67	<5	<0.5	1.692	<0.5
PFSECT02	Cinnamon Teal	72.82	<5	<0.5	3.359	<0.5
PFSECT03	Cinnamon Teal	69.33	<5	<0.503	1.373	<0.5
PFSEGW01	Gadwall	73.94	<5.0201	0.62	2.791	<0.502
PFSEGW02	Gadwall	72.24	55.21	1	4.472	0.8063

Sample ID	Species	Be	Cd	Cr	Cu	Fe	Hg
PFSLAA01	Am. Avocet	<0.1008	2.297	0.7318	19.7	1816	0.6746
PFSLAA02	Am. Avocet	<0.1	3.248	1.053	16.58	2235	0.6466
PFSLAA03	Am. Avocet	<0.1002	2.083	0.8605	19.62	1489	0.7838
PFSLAA04	Am. Avocet	<0.101	2.395	0.6536	10.25	1206	0.3649
PFSLAA05	Am. Avocet	<0.1	1.523	0.7128	14.99	1621	1.157
PFSLAA06	Am. Avocet	<0.1002	1.35	1.597	16.24	2363	0.7823
PFSECT01	Cinnamon Teal	<0.1	2.181	1.291	88.94	1398	1.906
PFSECT02	Cinnamon Teal	<0.1	0.6922	0.8865	31.69	1860	0.8426
PFSECT03	Cinnamon Teal	<0.1	0.554	0.7754	17.24	1602	0.5134
PFSEGW01	Gadwall	<0.1004	1.379	1.048	168.2	967.7	0.5684
PFSEGW02	Gadwall	<0.1	1.6	0.8446	83.91	1452	1.309

Sample ID	Species	Mg	Mn	Mo	Ni	Pb	Se
PFSLAA01	Am. Avocet	621.7	14.23	2.674	<0.504	0.5165	91.5
PFSLAA02	Am. Avocet	684.6	11.95	2.227	<0.5	1.163	57
PFSLAA03	Am. Avocet	666.3	12.79	1.406	<0.501	<0.501	66.5
PFSLAA04	Am. Avocet	480	9.868	1.387	<0.5051	<0.5051	59.4
PFSLAA05	Am. Avocet	663.9	11.7	1.516	<0.5	<0.5	89.4
PFSLAA06	Am. Avocet	921.4	11.77	2.83	<0.552	2.054	72.2
PFSECT01	Cinnamon Teal	776.1	15.8	4.969	<0.5	0.7909	21.1
PFSECT02	Cinnamon Teal	839.4	11.41	2.564	<0.5	<0.5	6.6
PFSECT03	Cinnamon Teal	622.3	11.45	2.206	<0.5	<0.5	17.9
PFSEGW01	Gadwall	648.4	8.065	4.418	<0.502	<0.502	8.8
PFSEGW02	Gadwall	820.6	17.28	3.437	<0.5	0.6379	35.4

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Table 4. Trace element concentrations (in ug/g) in livers from aquatic birds collected from the Sweetwater Arm, Pathfinder National Wildlife Refuge, Natrona County, Wyoming.

Sample ID	Species	Sr	V	Zn
PFSLAA01	Am. Avocet	0.2092	<0.504	96.77
PFSLAA02	Am. Avocet	0.9812	<0.5	88.19
PFSLAA03	Am. Avocet	0.3087	<0.501	97.67
PFSLAA04	Am. Avocet	<0.202	<0.5051	79.5
PFSLAA05	Am. Avocet	0.2651	<0.5	89.18
PFSLAA06	Am. Avocet	1.028	<0.501	93.6
PFSECT01	Cinnamon Teal	0.2016	0.5222	165.2
PFSECT02	Cinnamon Teal	0.4008	<0.5	123.8
PFSECT03	Cinnamon Teal	<0.2	<0.5	79.7
PFSEGW01	Gadwall	0.2148	<0.502	144
PFSEGW02	Gadwall	1.085	<0.5	223.9

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Table 5. Trace element concentrations (in ug/g) in American Avocet eggs collected from the Sweetwater Arm, Pathfinder National Wildlife Refuge, Natrona County, Wyoming.

Sample ID	% Moisture	Al	As	B	Ba	Be	Cd
PFAAE01	74.64	8.84	<0.499	0.5894	1.18	<0.0998	<0.0998
PFAAE02	71.77	8.779	<0.501	<0.504	1.661	<0.1008	<0.1008
PFAAE03	73.23	8.443	<0.5061	<0.5	2.3	<0.1	<0.1
PFAAE04	73.75	6.569	<0.5051	1.086	1.846	<0.1004	<0.1004
PFAAE05	74.25	7.918	<0.504	1.831	2.871	<0.1002	<0.1002
PFAAE06	73.87	<5.0403	<0.5071	0.6961	2.527	<0.1008	<0.1008
PFAAE07	73.2	<5.0403	<0.502	<0.504	2.473	<0.1008	<0.1008
PFAAE08	71.61	4.99	<0.504	<0.499	2.806	<0.0998	<0.0998

Sample ID	Cr	Cu	Fe	Hg	Mg	Mn	Mo	Ni
PFAAE01	<0.499	3.045	97.73	0.1011	375.4	1.8	0.7889	<0.499
PFAAE02	<0.504	2.738	129.7	0.1185	370.9	1.885	<0.504	<0.504
PFAAE03	<0.5	2.823	100.6	0.2446	373.3	1.282	<0.5	<0.5
PFAAE04	<0.502	2.958	106.1	0.5231	418.7	1	1.074	<0.502
PFAAE05	<0.501	2.324	121.6	0.1145	402.1	0.9117	<0.501	<0.501
PFAAE06	<0.504	3.242	121.1	0.234	405	1.428	0.9845	<0.504
PFAAE07	<0.504	2.392	135.5	0.1603	414.5	1.434	<0.504	<0.504
PFAAE08	<0.499	3.233	138.1	0.1407	460.3	1.479	0.6895	<0.499

Sample ID	Pb	Se	Sr	V	Zn
PFAAE01	<0.499	4.75	12.7	<0.499	40.4
PFAAE02	<0.504	4.84	7.992	<0.504	57.92
PFAAE03	<0.5	5.03	10.78	<0.5	47.6
PFAAE04	<0.502	5.31	5.51	<0.502	48.16
PFAAE05	<0.501	5.55	5.385	<0.501	46.56
PFAAE06	<0.504	5.84	7.234	<0.504	46.82
PFAAE07	<0.504	5.03	6.843	<0.504	45.3
PFAAE08	<0.499	5.46	9.061	<0.499	52.43

MANAGEMENT RECOMMENDATIONS

We did not find any major trace element problems at the Sweetwater Arm Unit of Pathfinder NWR with the possible exception of arsenic and chromium in brine shrimp. Although elevated, arsenic and chromium concentrations do not pose a threat to aquatic birds. Major cations and anions, specific conductance and total alkalinity are typical of shallow alkaline wetlands in the arid western United States. We did not find any evidence of sodium toxicity in ducklings or goslings; however, waterfowl nesting should not be encouraged at these ponds due to the potential for sodium toxicity. Nesting enhancement measures could be carried out at the southeast ponds closest to the Sweetwater Arm of the reservoir where freshwater is available. Refuge managers should consider water quality analyses at these ponds before intensive management for waterfowl production. The alkaline ponds do provide good nesting habitat for American avocets. If possible, aquatic bird surveys should be conducted during the breeding season to determine productivity and use.

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