1995

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

Pedro Ramirez Jr.
*U.S. Fish and Wildlife Service*

Kimberly Dickerson
*U.S. Fish and Wildlife Service*

Mary Jennings
*U.S. Fish and Wildlife Service*

CONTAMINANT REPORT NUMBER: R6/708C/95

U.S. FISH & WILDLIFE SERVICE
REGION 6

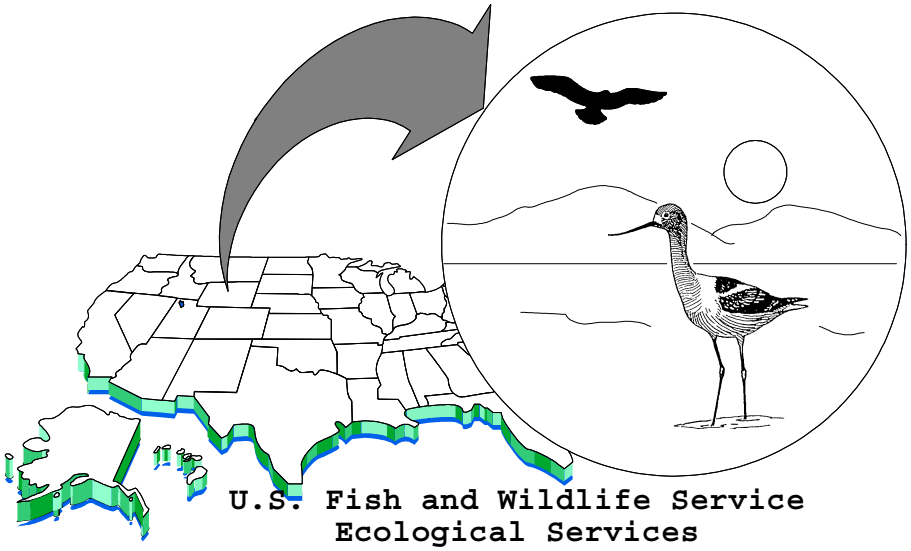
CONTAMINANTS PROGRAM

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


BY
PEDRO RAMIREZ, JR.,
KIMBERLY DICKERSON,
AND MARY JENNINGS



Project #'s
93-6-61411 1261
93-6-60120 1261
93-6-60120 4600


U.S. Fish and Wildlife Service
Ecological Services
Wyoming Field Office
4000 Morrie Avenue
Cheyenne, Wyoming 82001
1995

# 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 µmho/cm). Sodium is the most abundant cation and carbonates and sulfates are the most abundant anions in these ponds. Hypersaline wetlands (conductivity > 77,000 µmho/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.

# TABLE OF CONTENTS

# List of Figures and Tables

# 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 Seedskadee, 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.

**Acknowledgements -** We would like to thank Gene Patton, Tom Jackson and Gene Hansmann of the Service. Mike Lessard and Steve Brockmann helped with bird collections. Our appreciation is also extended to Andrew Archuleta, Brent Esmoil, and Don Palawski of the Service for reviewing this manuscript.

# 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.

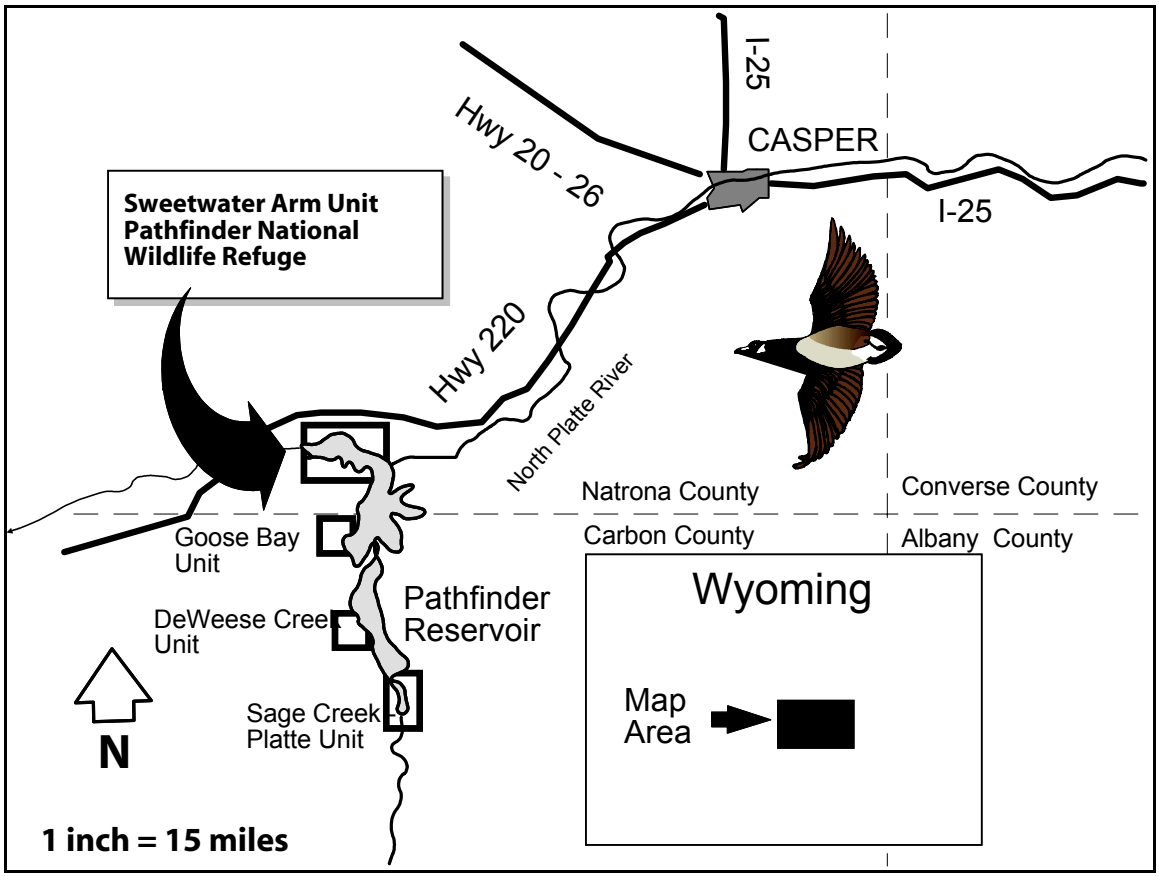



Figure 1. Location of Sweetwater Arm Unit of Pathfinder National Wildlife Refuge, Wyoming.

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).

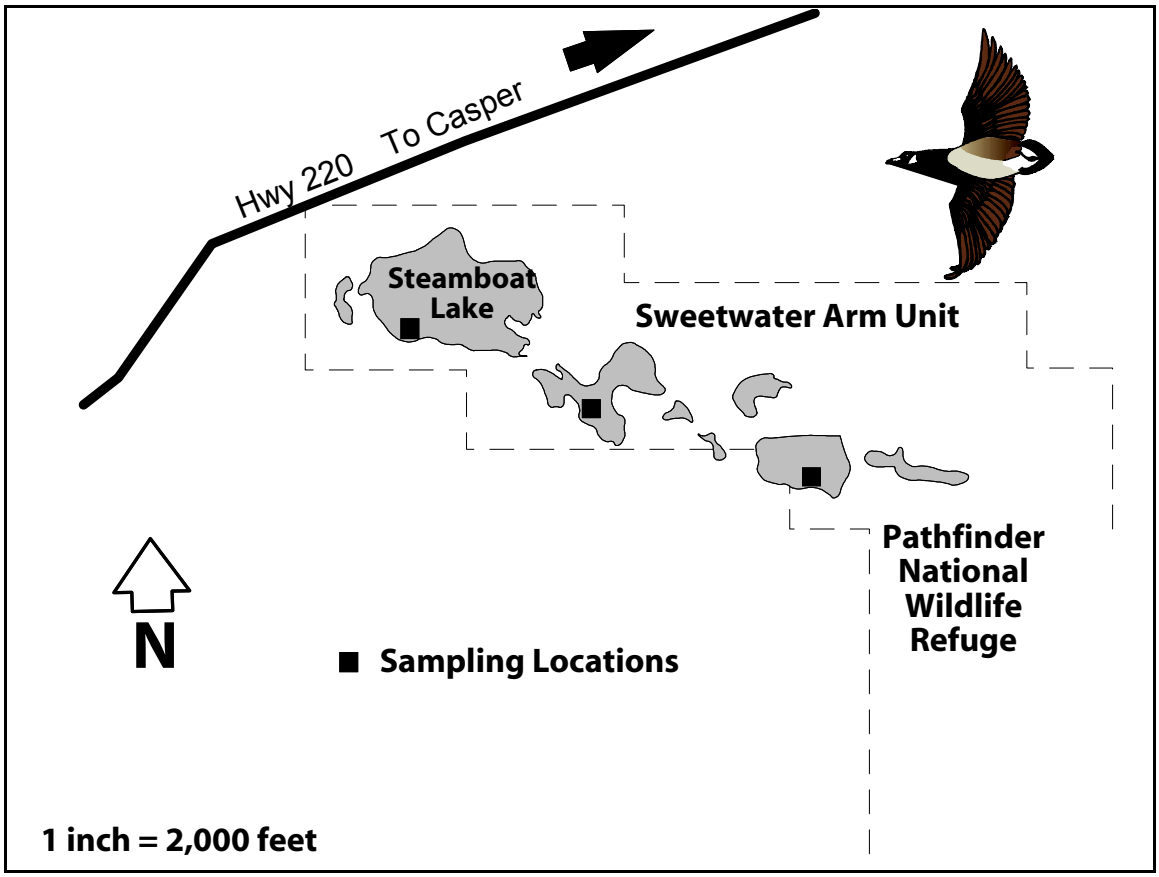



Figure 2. Sampling sites at the Sweetwater Arm Unit of Pathfinder National Wildlife Refuge, Wyoming.

# 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 Iinstitute 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 µmho/cm)(Table 1). Cowardin et al. (1979) classified wetlands as polysaline if specific conductances ranged from 30,000 to 45,000 µmho/cm and hypersaline for conductance greater than 60,000 µmho/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 (umho/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 CaCO3 (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 µmho/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 susceptiblity 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 µg/g (Eisler 1988). Mallards do not show adverse effects until dietary levels of arsenic reach 200 µg/g as sodium arsenate (Eisler 1988). Chromium concentrations in biota greater than 4 µg/g are considered elevated (Eisler 1986). Selenium concentrations in four of five brine shrimp samples were less than the 3 µg/g dietary level considered adverse to aquatic birds (Lemly 1993). One sample had a selenium concentration of 3.47 µg/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 µg/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 µg/g level considered background but were below the 8 µg/g level known to cause reproductive impairment (Skorupa et al. 1991).

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 |

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 |

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 |

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 |

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 |

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.

# LITERATURE CITED

**Cooch, F.G. 1964.** A preliminary study of the survival value of a functional salt gland in prairie Anatidae. Auk. 81:380-393.

**Cowardin, L.M., V. Carter, F.C. Golet and E.T. LaRoe. 1979.** Classification of wetlands and deepwater habitats of the United States. U.S. Fish and Wildlife Service Office of Biol. Serv. Rep. 31. Washington, D.C.

**Dickerson, K. and P. Ramirez, Jr. 1993.** An investigation of trace element contamination at Bamforth National Wildlife Refuge. U.S. Fish Wildl. Serv. Contam. Rep. R6/707C/93, Cheyenne, WY. 29 pp.

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

**Eisler, R. 1986.** Chromium hazards to fish, wildlife, and invertebrates: a synoptic review. U.S. Fish Wild. Serv. Biol. Rep. 85(1.6) 60 pp.

**Harms, T.F., K.C. Stewart, P.H. Briggs, P.L. Hageman and C.S.E. Papp. 1990.** Chemical results for bottom material for Department of the Interior irrigation drainage task group studies 1988 - 1989. U.S. Geological Survey, Open-File Report 90-50, Denver, CO. 47 pp.

**Lemly, A.D. 1993.** Guidelines for evaluating selenium data from aquatic monitoring and assessment studies. Environ. Monitor. Assess. 28:83-100.

**Mitcham, S.A. and G. Wobeser. 1988.** Toxic effects of natural saline waters on mallard ducklings. J. Wildl. Diseases 24:45-50.

**Ramirez, P. Jr. and J. Armstrong. 1992.** Environmental contaminant surveys in three national wildlife refuges in Wyoming. U.S. Fish Wildl. Serv. Contam. Rep. R6/702C/92. Cheyenne, WY. 35 pp.

**Skorupa, J.P. and H.M. Ohlendorf. 1991.** Contaminants in drainage water and avian risk thresholds. Pages 345-368 *in* A. Dinar and D. Zilberman, eds. The economics and management of water and drainage in agriculture. Kluwer Academic Publishers, Boston, MA

**Wobeser, G. and J. Howard. 1987.** Mortality of waterfowl on a hypersaline wetland as a result of salt encrustation. J. Wildl. Diseases 23:127-134.

**Windingstad, R.M., F.X. Kartch, R.K. Stroud and M.R. Smith. 1987.** Salt toxicosis in waterfowl in North Dakota. Jour. Wildl. Diseases 23(1):127-134.