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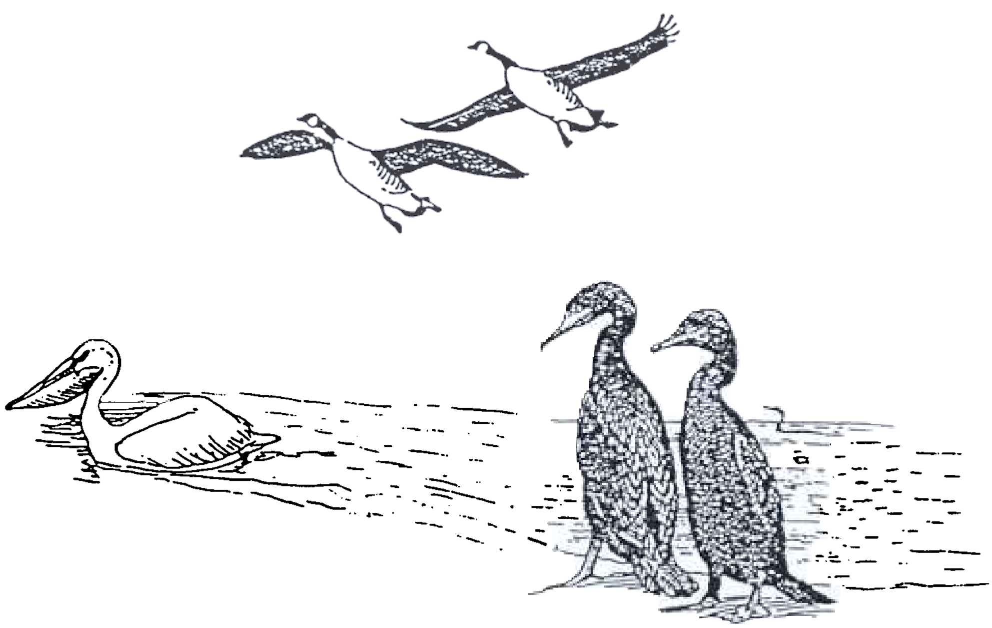
AN INVESTIGATION OF TRACE ELEMENT CONTAMINATION AT BAMFORTH NATIONAL WILDLIFE REFUGE

By
Kimberly Dickerson and Pedro Ramirez, Jr



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ABSTRACT

Bamforth National Wildlife Refuge (Bamforth) located in southeast Wyoming serves as an important resting area for several species of migratory waterbirds. Surveys were conducted in the summer months of 1992 to determine bird use at Bamforth. Sediment, water, and biota were collected from Bamforth to identify wetlands with potential contaminant problems that may be affecting migratory waterbirds. Mercury and lead in water samples were above criteria for the protection of aquatic life. Selenium levels in vegetation and sediment were elevated above concentrations documented to bioaccumulate and cause adverse reproductive effects in waterfowl. Selenium levels in waterbird eggs were slightly greater than background concentrations but no deformities in embryos were found. Arsenic concentrations in aquatic invertebrates and vegetation were elevated to levels that may be harmful to waterfowl who consume these items Water from Bamforth Lake, South Pond, and the southeast seep were hypersaline brines. Salt toxicosis in waterbirds was not observed in this study, but maintaining existing freshwater sources such as a nearby stock pond may reduce the likelihood of salt toxicosis in the numerous waterbirds that come to rest, feed, or nest at Bamforth. Periodic monitoring of trace elements and the occurrence of salt toxicosis in waterbirds at Bamforth is recommended.

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INTRODUCTION

Wildlife refuges nationwide are threatened by environmental contaminants. Problems associated with irrigation drainwater and resulting selenium contamination in refuges have been documented extensively in the western United States (Ohlendorf et al. 1986; Peterson et al. 1988: Stephens et al 1988). In 1987, aquatic birds were collected by the U.S. Fish and Wildlife Service (Service) at Bamforth Lake, Bamforth National Wildlife Refuge in southeast Wyoming to assess if harmful concentrations of trace elements were present in waterbird tissues. American avocet (*Recurvirostra americana*) and eared grebe (*Podiceps nigricollis*) livers had elevated levels of selenium, 80 μg/g and 42 μg/g dry weight, respectively (unpub. U.S. Fish and Wildlife data 1987). Selenium concentrations greater than 30 μg/g dry weight in waterfowl livers are associated with detrimental effects, including reproductive impairment and deformities in embryos (Ohlendorf et al. 1986). One eared grebe liver also had a mercury concentration of 5.2 μg/g dry weight (unpub. U.S. Fish and Wildlife data 1987). Mercury concentrations in livers greater than 4.0 μg/g dry weight are indicative of an environmental mercury problem (Eisler 1987)

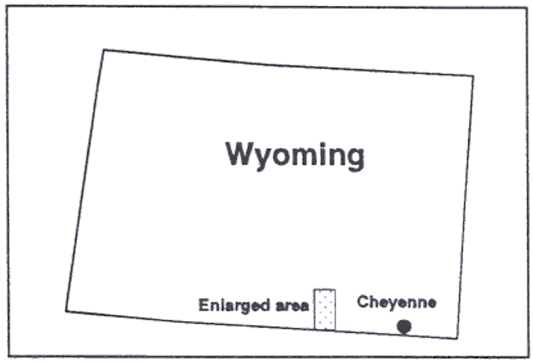
These elevated concentrations of selenium and mercury in waterbird tissues prompted a closer study to determine trace element levels not only in waterbird tissues but water, sediment, vegetation, aquatic invertebrates, and waterbird eggs at Bamforth. We also evaluated avian reproductive success and waterbird use at Bamforth Lake by conducting weekly surveys of waterbirds and their broods during April through September 1992. The reproductive success of waterbirds can be greatly affected by elevated concentrations of trace elements, particularly selenium (Ohlendorf et al. 1986). We made observations to document the occurrence of deformities in waterbirds, possibly resulting from elevated trace element levels. Observations were also made to determine the occurrence of salt toxicosis in waterbirds because the water in the wetlands of Bamforth is very saline due to high evaporation rates and the absence of an outflow to flush the system. Additional salts may be deposited in the wetlands from irrigation return flows.

Hutton Lake National Wildlife Refuge (Hutton Lake) was used as a reference site in this study because of its proximity to Bamforth. However Ramirez and Armstrong (1992) showed that selenium, mercury, and boron were elevated in biota at Hutton Lake and worthy of periodic monitoring.

STUDY AREA DESCRIPTION

Bamforth National Wildlife Refuge is located in Albany County near Laramie, Wyoming (Figure 1). Bamforth was established in 1932 as a refuge and breeding area for migratory waterfowl. The refuge is vitally important to many bird species due to the lack of open water on the Laramie Plains. The refuge consists of 1,166 acres of national refuge lands, 2,126 acres of state lands, and 2,744 acres of private lands. Bamforth is situated in a closed basin and contains Bamforth Lake, which is the primary wetland, and several smaller ponds and ditches. All wetlands are saline and receive surface irrigation return flows with the exception of a freshwater stock pond. Upland habitat consists of short-grass prairie and shrubland. Cattle grazing and irrigated pasture lands are the primary uses of the land. Geological makeup of the refuge consists of quaternary alluvial deposits. Cretaceous Niobrara Formations occur 0.5 miles east of Bamforth Lake. These formations are components of Cody Shale that can contain high concentrations of selenium. The selenium can be readily leached by irrigation return flows (Love and Christiansen 1985) and collect in closed basins reaching elevated concentrations.

The reference site, Hutton Lake, is 12 miles south of Bamforth. This refuge was established in 1932 as a refuge for migratory waterfowl. The 1,428 acres contains the freshwater lakes of Creighton, George, Rush, Hutton, and Hoge. Short-grass prairie surrounds the lakes, and livestock grazing is the primary land use. The refuge is underlain by the Frontier Formation which can contain high concentrations of boron (Love and Christiansen 1985).



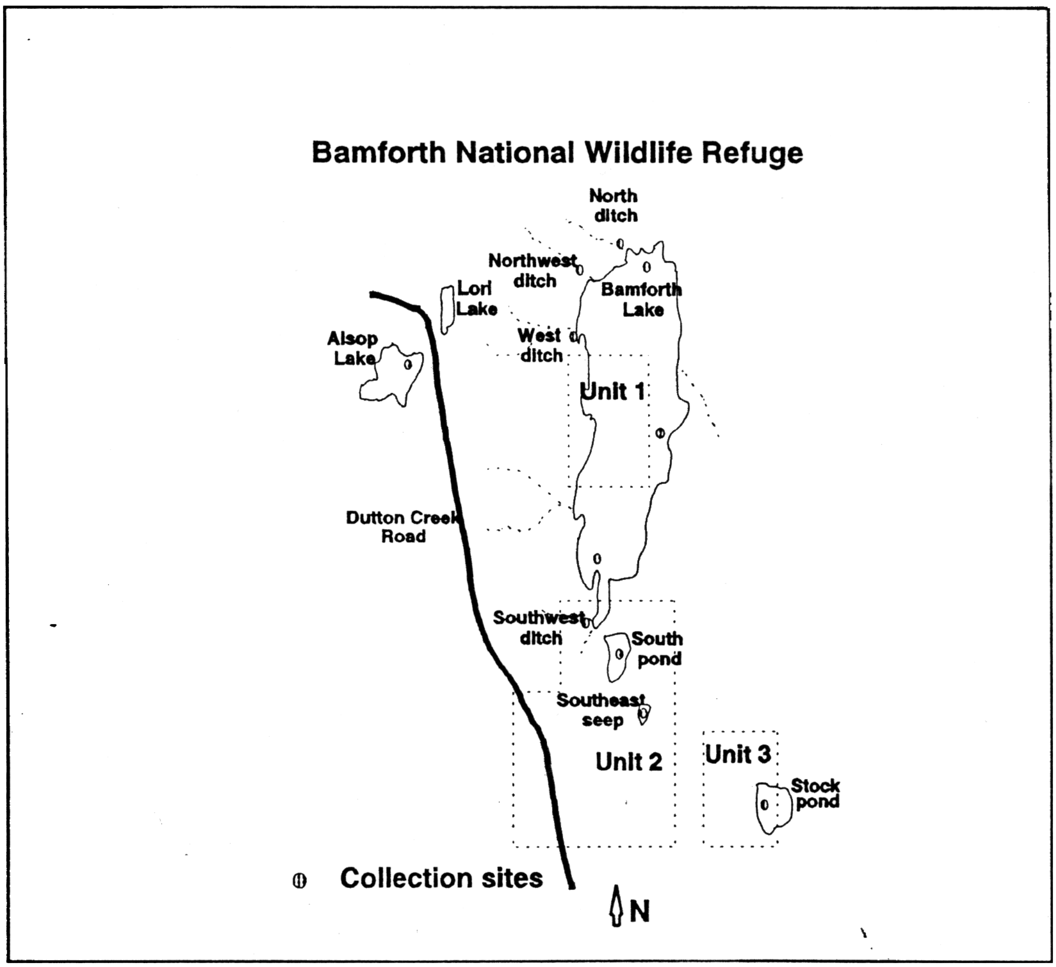


Figure 1. Sampling locations for Bamforth National Wildlife Refuge, Wyoming.

METHODS

We conducted a weekly census from March through October 1992 to determine waterbird use at the primary wetland, Bamforth Lake. Our observations were made between 7:30 a.m. and 11:30 a.m. using a 15 to 60 power zoom spotting scope and binoculars. We collected water, sediment, and biota samples in 1990 and 1991 using chemically-cleaned utensils and containers. The locations and dates that samples were collected are in Appendix A. All samples with the exception of water were frozen within eight hours of collection. Water samples were collected in polyethylene jars. For trace element analyses, water samples were preserved by lowering the pH to < 2 with nitric acid. For major ion and basic water quality analyses, duplicate water samples were collected and refrigerated Two additional water samples were collected from Bamforth Lake to perform assays using the Microtox System (Microbics Corporation, California). Sediment samples were collected with a stainless steel spoon and placed in whirl-pak bags Aquatic vegetation was collected by hand and stored in whirl-pak bags. We used light traps, similar to those describe by Espinosa and Clark (1972), to collect aquatic invertebrates, which were stored in 40 ml glass vials. We collected waterbird eggs, dissected them, and examined the embryos for deformities. The egg contents were placed into chemically-cleaned glass jars. Adult and juvenile birds were collected with a shotgun using steel shot and stored in plastic bags In our lab, we dissected the carcasses, removed the liver and brain, and stored them in chemically-cleaned glass jars.

Water, sediment, and biota samples were submitted for trace element analyses to the U.S Fish and Wildlife Service Patuxent Analytical Control Facility (PACF) in Maryland. Mercury was analyzed by cold vapor atomic absorption spectroscopy, selenium and arsenic were analyzed by graphite furnace absorption spectroscopy, and the remaining trace elements were analyzed by inductively coupled plasma emission spectroscopy (ICP scan) In this report all discussion of analytical results for sediment and biota samples and toxicity criteria or adverse effects levels are given in dry weight unless otherwise specified Quality assurance and quality control procedures were confirmed with procedural blanks, duplicate analyses, test recoveries of spiked materials, and reference material analyses.

Duplicate water samples were analyzed for major ions, total alkalinity, hardness, total dissolved solids (TDS), and conductivity by the Wyoming Department of Agriculture Analytical Services in Laramie. The work of this laboratory was not reviewed for quality assurance or quality control by PACF but is certified by the State of Wyoming.

RESULTS AND DISCUSSION

Bird Use

Bird surveys in 1992 revealed that bird use at Bamforth Lake was highest between late April through mid-August (Figure 2 and Appendix B). White pelicans (*Pelecanus erythrorhynchos*) were in greatest abundance (58% of the total individuals counted) followed by double-crested cormorants (*Phalacrocorax auritus*) (23%) Phalaropes (*Phalaropus* sp. were the next most abundant (5%) followed by American avocets (2.5%) and Canada geese (*Branta canadensis*) (2.5%) Bird species that comprised <2% of total bird species were grouped together and constituted 9.0% of the total abundance (Figure 3)

As many as 403 broods were observed at any one time during the survey period in July and August 1992 (Figure 4 and Appendix C). Bamforth Lake is an important rearing area for pelicans (71% of the total broods observed) and double-crested cormorants (23.6%) (Figure 5). Because of the amount of bird use at Bamforth, elevated contaminant levels could have detrimental effects on local populations of waterbirds

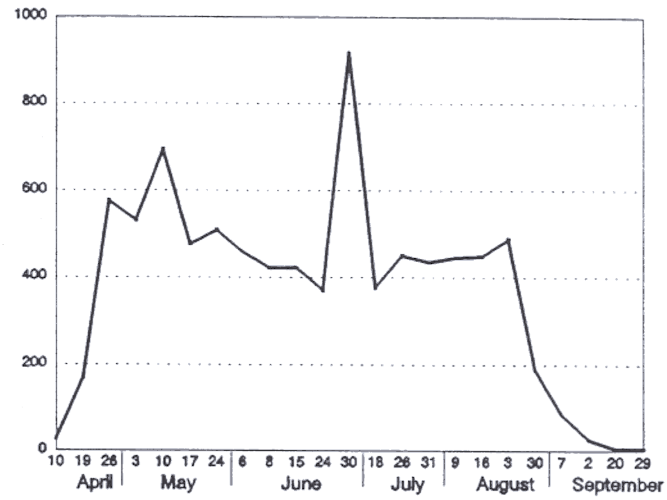


Figure 2. Number of birds observed at Bamforth Lake, Bamforth National Wildlife Refuge, Wyoming, during weekly counts in 1992.

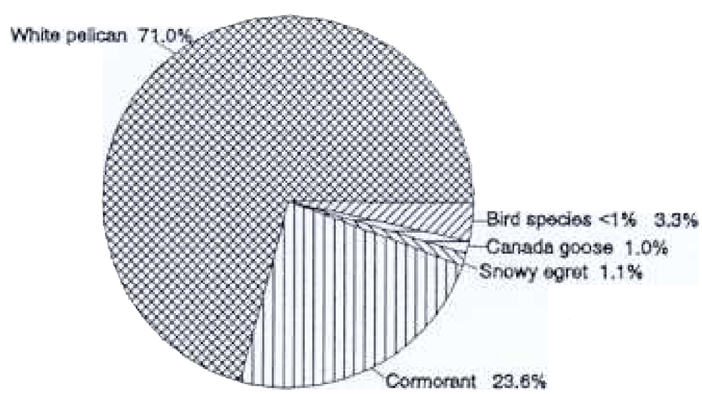


Figure 3. Percent contribution of individual species to the total number of birds observed at Bamforth Lake, Bamforth National Wildlife Refuge, Wyoming during weekly counts, April - September, 1992.

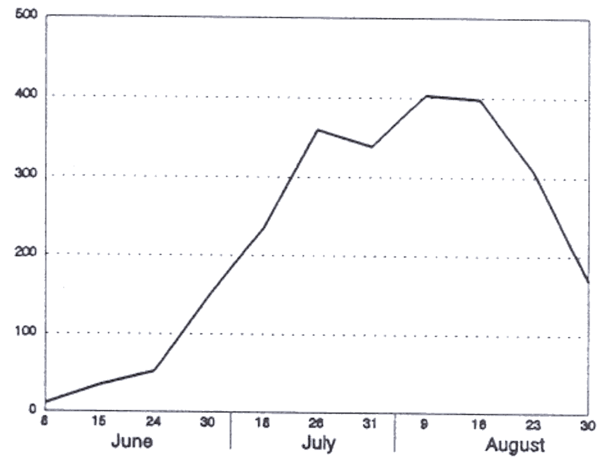


Figure 4. Number of broods observed at Bamforth Lake, Bamforth National Wildlife Refuge, Wyoming, during weekly counts in 1992.

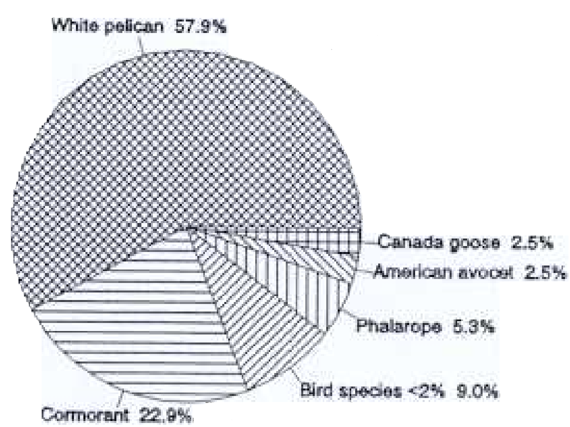


Figure 5. Percent contribution of individual species to the total number of broods observed at Bamforth Lake, Bamforth National Wildlife Refuge during weekly counts, April - September, 1992.

Water Quality

High salinities were measured in Bamforth Lake (78,800 and 83,200 µmhos/cm), South Pond (80,800 and 81,000 µmhos/cm), and the southeast seep (66,900 µmhos/cm) (Table 1 and Appendix D) Water from these sites are a sodium sulfate brine due to the large concentrations of sodium sulfate ions and conductivities that are much greater than seawater (i.e. conductivities >35,000 µmhos/cm) (Cowardin et al. 1979) Hypersaline wetlands (conductivity 77,000 to 90,000 µmhos/cm) can be lethal to waterfowl. In Canada, approximately 300 Canada geese were rendered flightless in September 1985 due to heavy encrustation of sodium sulfate crystals on their feathers One hundred forty five of the geese died from aspirating the brine water (Wobeser and Howard 1987). Waters with conductivities greater than 35,000 µmhos/cm have been shown to be toxic to mallard ducklings (*Anas platyrhynchos*) hatching on saline wetlands unless a source of freshwater is nearby (Mitcham and Wobeser 1988). Water samples from Bamforth also had high total alkalinities as $CaCO_3$ >1300 mg/L) and high total dissolved solids that ranged from 127,000 to 214,000 mg/L.

Water samples from the southwest and northwest ditches at Bamforth were the sodium sulfate type and categorized as mesohaline, with conductivities of 15,400 and 15,100 µmhos/cm. Total alkalinities were 590 and 300 mg/L as $CaCO_3$ and total dissolved solids were 17,300 and 16,000

Table 1. Water quality results from Bamforth National Wildlife Refuge, September 1991.

	Conductivity	Total Alkalinity	Total Dissolved Solids	Sodium	Sulfate
Site #	(μmho/cm)	(mg/L as CaCO3)	(mg/L)	(mg/L)	(mg/L)
South Pond	80,800	1,500	191,000	28,000	117,000
South Pond (Duplicate)	81,000	1,500	195,000	28,000	120,000
Southwest ditch - Bamforth Lake	15,400	590	17,300	2,500	11,000
Northwest ditch -Bamforth Lake	15,100	300	16,000	2,700	9,500
Bamforth Lake -main	83,200	1,500	214,000	26,000	120,000
Bamforth Lake -south	78,800	1,300	184,000	21,000	99,000
Southeast Seep	66,900	520	127,000	19,000	74,000
Stock pond	1,450	63	1,140	160	880

mg/L for the southwest and northwest ditches, respectively. The stock pond had the freshest water but also was the sodium sulfate type, with a conductivity of 1,450 μmhos/cm and a total alkalinity of 63 mg/L as $CaCO_3$. The stock pond may be vitally important in providing waterfowl the necessary freshwater needed to offset the effects of saline water.

Microtox

Microtox (Microbics Corporation 1992) is a procedure using photoluminescent bacteria to measure the toxicity of a sample. Suppression of light output by the bacteria is the toxic endpoint measured The greater the light suppression of the bacteria the more toxic the sample is Most commonly, four dilutions of the sample are tested to generate a dose-response curve from which the effective concentration (EC50) is found.

Results of the Microtox assays using Bamforth Lake water were inconclusive. Using the Microtox statistical software (Microbics Corporation 1992), EC50 values could not be calculated for the Bamforth Lake water samples because three of the four dilutions had a gamma less than 0.05 Gamma is the ratio of light lost to light remaining after exposure of the reagent to the samples (Microbics Corporation 1992). Consequently, data points from the three dilutions were deleted because they fell outside the set range of 0.05 to 100 gammas This left insufficient data to do the statistics. The observed reduced light levels emitted from the bacteria with increasing concentrations of Bamforth Lake sample water was probably a result of the high alkalinity of the water.

Trace Elements

Water

Water that collects in closed basins can have high salt concentrations and elevated trace element concentrations (Finger et al. 1989). Concentrations of most trace elements in water samples collected from Bamforth in the summers of 1990 and 1991 were within acceptable limits (Appendix E) Standard means are given where the sample size was ≤ 3. Aluminum concentrations were elevated above the EPA acute criteria of 0.755 mg/L (EPA 1988) in nine samples from Bamforth (Table 2). These concentrations were comparable to those found at Hutton Lake (1.40 mg/L) (Ramirez and Armstrong 1992) with the exceptions of the northwest ditch site (3.03 mg/L) and southwest ditch site (2.54 mg/L) at Bamforth which had higher concentrations. Aluminum toxicity is greatest in waters with an acidic pH (Miles et al. 1993); however, water in both refuges is very alkaline. Five samples at Bamforth NWR slightly exceeded the EPA acute criterion for iron (1.0 mg/L) (EPA 1980a) but only one of these five samples was greater than the iron concentration of 1.74 mg/L found in Hutton Lake (Ramirez and Armstrong 1992). Elevated iron levels in the water samples are probably the result of geological formations containing naturally high iron concentrations. Two Bamforth Lake samples exceeded acute lead criterion (EPA 1980b). However, lead is not biomagnified through the food chain and levels in water alone are not great enough to cause adverse effects to waterfowl (Eisler 1980b).

Table 2. Samples from Bamforth National Wildlife Refuges containing concentrations of trace elements at levels that may adversely affect fish and wildlife.

Matrix	Element	Adverse Effect Level[1]	Reference	Site #	Concentration
Water	Al	0.755 mg/L	EPA 1988	Bamforth Lake,south	1.79 mg/L
				Bamforth Lake,north	1.05 mg/L
				Bamforth Lake,north	1.94 mg/L
				Bamforth Lake,north	1.76 mg/L
				Northwest ditch	3.03 mg/L
				Stock Pond	0.94 mg/L
				Southeast seep	1.99 mg/L
				South Pond	1.80 mg/L
				Southwest ditch	2.54 mg/L
Water	Fe	1 mg/L	EPA 1980a	Bamforth Lake, main	1.10 mg/L
				Bamforth Lake,north	1.91 mg/L
				Northwest ditch	1.08 mg/L
				Southeast seep	1.42 mg/L
				South Pond	1.30 mg/L
Water	Pb	0.082 mg/L	EPA 1980b	Bamforth Lake,south	0.143 mg/L
				Bamforth Lake,north	0.164 mg/L
Vegetation	Al	<5000 μg/g	Miles et al. 1993	Stock Pond	9710.0 μg/g
-	As[2]	17-48 μg/g	Eisler 1988a	Bamforth Lake	27.6 μg/g
				Stock Pond	49.2 μg/g
				South Pond	24.5 μg/g
Vegetation	B	300 μg/g	Eisler 1990	South Pond	303.0 μg/g
Vegetation	Cr[3]	5.1-10.0 μg/g	Eisler 1986	Stock Pond	13.0 μg/g
Vegetation	Pb	50-75 μg/g	Eisler 1988b	Stock Pond	10.7 μg/g
Vegetation	Se	<3 μg/g	Ohlendorf et al. 1986	Southeast seep	4.08 μg/g
				South Pond	3.48 μg/g
				South Pond	3.28 μg/g
				South Pond	4.26 μg/g
Sediment	Al	12000 μg/g	Harms et al. 1990	North seep	17100 μg/g

Sediment	Al	12000 µg/g	Harms et al. 1990	North seep	24500 µg/g
				North ditch	16600 µg/g
				Bamforth Lake,north	13000 µg/g
				Bamforth Lake, main	15700 µg/g
				Bamforth Lake,south	21900 µg/g
				South Pond	22100 µg/g
Sediment	Cd	2.5 µg/g	Hart et al. 1988	Southeast seep	3.41 µg/g
Sediment	Fe	5900 µg/g	Hart et al. 1988	Most samples from Bamforth	>6380 µg/g
Sediment	Se	<20 µg/g	Harms et al. 1990	Southeast seep	28.6 µg/g
Invertebrates	Al	<5000 µg/g	Miles et al. 1993	Bamforth Lake,north	1560 µg/g
				Bamforth Lake,south	2380 µg/g
				Stock Pond	2480 µg/g
Invertebrates	As[2]	17-48 µg/g	Eisler 1988a	Bamforth Lake,north	23.1 µg/g
				Bamforth Lake,south	33.1 µg/g
Invertebrates	Se	3 µg/g	Lemly and Smith 1987	Lake George	5.45 µg/g
				Bamforth Lake,north	4.59 µg/g
				Bamforth Lake,south	7.26 µg/g
Invertebrates	Se	3 µg/g	Ohlendorf et al. 1986	Stock Pond	8.63 µg/g
Liver	Cu	<603 µg/g	Parslow et al. 1982	Bamforth Lake	183 µg/g
				Bamforth Lake	260 µg/g
				Bamforth Lake	221 µg/g
Egg	Se	<8 µg/g	Skorupa and Ohlendorf 1991	Bamforth Lake	4.10 µg/g
				Bamforth Lake	4.80 µg/g
				Bamforth Lake	5.30 µg/g
				Bamforth Lake	3.10 µg/g
				Bamforth Lake	3.60 µg/g

[1] Concentrations are levels that adversely affect waterfowl with the exception of water where EPA has set criteria to protect aquatic life. Trace element EPA criteria listed in the table are acute values.
[2] Toxicity is dependent on the form of arsenic.
[3] Toxicity is dependent of the form of chromium.

Vegetation

One vegetation sample from the Stock Pond at Bamforth was high in aluminum (9710 μg/g) (Table 2). Aluminum levels in diet above 5,000 μg/g can produce significant harmful effects in starling eggshells and bone, and high levels of aluminum in the form of aluminum sulfate can cause rickets in ducklings (Miles et al. 1993) However, the toxicity of aluminum is dependent on pH, with acidic pH causing aluminum to become more toxic, and toxicity can vary according to the species and age of the bird (Miles et al. 1993)

Total recoverable arsenic concentrations were higher in vegetation samples from Alsop Lake (27.9 μg/g), Stock Pond (49.2 μg/g), and South Pond (24.5 μg/g) than at other sites. Arsenic can be accumulated by organisms from their diet (Spehar et al. 1980), but the toxicity of arsenic depends on the form. Significant toxic effects on mallard duckling growth have not occurred until the arsenic concentration, as sodium arsenate, in food items is 200 μg/g (Hoffman et al. 1992). Sodium arsenite was toxic to 50% of mallards at a dose of 500 μg/g in the diet but adverse effects of various forms of arsenic ranged from 17 to 48 μg/g in several bird species (Eisler 1988a)

The boron concentration (303 μg/g) in one vegetation sample from South Pond at Bamforth was slightly above 300 μg/g, the concentration that has been found to reduce growth in mallard ducklings (Eisler 1990). However, boron concentrations in vegetation from Hutton Lake ranged from 391 to 820 μg/g

(Ramirez and Armstrong 1992) The Frontier Formation, which occurs in the area and has naturally high levels of boron, may explain the elevated levels in the vegetation (Ramirez and Armstrong 1992)

Vegetation from the Stock Pond at Bamforth contained high levels of copper (22.6 μg/g) and nickel (31.3 μg/g) when compared to the other sites, but were below dietary levels shown to cause adverse effects to birds by Poupoulis and Jensen 1976) and Eastin and O'Shea (1981). The Stock Pond vegetation also had high levels of chromium (13.0 μg/g) and lead (10.7 μg/g) The toxicity of chromium is dependent on the form, either Cr +3 or Cr +6, with Cr +6 being the most toxic form. Chromium in biological materials however, is usually in the trivalent +3) state and not readily available to organisms (Eisler 1986) The lead concentration in the vegetation may not be a critical concern as consumption of vegetation with biologically incorporated lead is not likely to cause clinical lead poisoning in wildlife and lead is not readily transferred through the food chain (Eisler 1988b) Selenium levels in the vegetation are of greater concern. Concentrations of selenium in vegetation from the stock pond (4.08 ug/g) and the South Pond concentrations (3.48, 3.28, 4.26 μg/g) were elevated. Lemly and Smith 1987) found that concentrations of selenium in food >3.0 μg/g can bioaccumulate through the food chain leading to reproductive effects in waterfowl (Ohlendorf et al. 1986).

Sediment

No formal criteria have been developed for trace elements in sediments; although, sediment quality guidelines were proposed by Hart et al. 1988). Several sediment samples from Bamforth had concentrations of aluminum greater than background concentrations of 3,400 to 12,000 µg/g in soils of the Northern Great Plains region given by Harms et al. 1990). However, the concentration in sediment samples from Bamforth were comparable to those found at Hutton Lake (Ramirez and Armstrong 1992). One sediment sample from the Southeast seep at Bamforth had high levels of cadmium (3.41 µg/g) in comparison to 2.5 µg/g in Hart et al 1988) (Table 2). At 28.6 µg/g, selenium also was elevated in this sample. Concentrations were similar to those found in sediments from Goose Lake in the Kendrick Reclamation Project area in Wyoming (Harms et al. 1990), where selenium levels are suspected to cause deformities in shorebirds (Peterson et al. 1988).

Aquatic Invertebrates

Invertebrate samples from Bamforth Lake (1560 and 2380 µg/g) and the southeast stock pond (2480 µg/g) also were high in aluminum compared to other sites at Bamforth and Hutton Lake; although, these concentrations did not exceed the 5,000 µg/g documented as causing adverse effects in birds by Miles et al. 1993). Arsenic (23.1 and 33.1 µg/g) was elevated in invertebrate samples from Bamforth Lake. However, the toxicity of arsenic is dependent on the form. It is reported that arsenicals are toxic to birds at dietary concentrations ranging from 17.0 to 48.0 μg/g (Eisler 1988a) but mallards do not exhibit adverse effects until arsenic concentrations reach 200 μg/g as sodium arsenate (Hoffman et al. 1992) and 500 μg/g as sodium arsenite (Eisler 1988a). Aquatic invertebrates from Bamforth Lake (4.59 and 7.26 μg/g) and the Stock Pond (8.63 μg/g) had elevated selenium concentrations (Table 2). Lemly and Smith (1987) found that concentrations >3.0 μg/g in the diet bioaccumulate and are detrimental to fish and wildlife. Deformities in waterfowl caused by dietary selenium levels ranging from 5.9 to 180.0 μg/g have been documented at Kesterson National Wildlife Refuge (Schuler et al 1990), the Kendrick Project in Wyoming (Peterson et al. 1988), and the Middle Green River in Utah (Stephans et al. 1988).

Liver

Copper concentrations in three juvenile gull livers collected at Bamforth Lake were relatively high (>183 μg/g) when compared to other juvenile gulls at Bamforth (Table 2). However, copper concentrations in liver samples from unpolluted areas have been found as high as 603 μg/g without any documented toxic effects (Parslow et al. 1982).

Eggs

Eggs had selenium concentrations ranging from 3.1 to 5.3 μg/g (Table 2). These selenium concentrations are slightly greater than background levels found in avocet eggs (3.0 to 4.0 μg/g) (Skorupa and Ohlendorf 1991) cormorant eggs (<0.6 to 3.7 μg/g) (Skorupa, unpub. data), and common loon (*Gavia immer*) and red-breasted merganser (*Mergus serrator*) eggs (1.2 to 4.0 μg/g) (Eisler 1985). However, these concentrations are less than the mean egg selenium level of 8 μg/g associated with the onset of toxic effects, including reproductive impairment, in avocet and black-necked stilt populations (Skorupa and Ohlendorf 1991). Teratogenic effects in aquatic birds from western and plains states are documented when mean egg selenium concentrations reach 13 to 24 μg/g (Skorupa and Ohlendorf 1991). There were no deformed embryos found at Bamforth during this study

Salt Toxicosis

Conductivities at Bamforth Lake and South Pond were in the range of conductivities found to cause salt toxicosis in Canada geese (Wobeser and Howard 1987). However, sick or dying waterbirds, as a result of salt toxicosis, were not observed in 1992 at Bamforth. Three possibilities may explain the absence of toxic salt effects observed in waterbirds. First, pelicans and double-breasted cormorant were the major species using Bamforth Lake and South

Pond. Both species are salt tolerant as their winter ranges consist of salt bays and marshes along the Pacific coast (Peterson 1990). Second, pelicans and double-crested cormorants are fish eaters (Peterson 1990) Because there are no fish present at Bamforth Lake or South Pond these species must feed elsewhere and therefore, probably do not consume large quantities of salt. Finally, because of the shallow depth (approximate range of 0.2 to 0.5 m) and warm water temperatures (approximate average of 21° C) of Bamforth Lake and South Pond during the summer months (pers. comm., Gene Patten, Arapahoe National Wildlife Refuge Complex, Walden, Colorado) when bird use is heaviest, salt crystals remained dissolved in solution and did not form agglomerates on the birds' feathers. However, as describe in the study by Wobeser and Howard 1987), once water temperatures dropped below 3° C, the solution becomes supersaturated and salts begin to crystallize. Bird surveys were not conducted after September 29, 1992 but future surveys may be necessary to document the bird species present on Bamforth Lake and South Pond in the autumn months; and, to document if salt toxicosis may be occurring as water and air temperatures drop

Conclusions

Bamforth will continue to be an important resting and breeding ground for migratory birds because of the scarcity of waterbodies on the Laramie Plains. Selenium is the primary trace element of concern at Bamforth because of its effect on waterbird reproduction. Although selenium concentrations were elevated in vegetation, sediment, and eggs, reproductive success was not affected. The occurrence of salt toxicosis in bird species was not observed even though conductivities were high enough in the wetlands to cause such effects. Bird species, in particular juvenile birds that do not have fully developed salts glands and Canada geese, may be at the highest risk. During drought years, selenium, other trace elements, and salts may pose a greater threat to waterbirds as levels become more concentrated.

MANAGEMENT RECOMMENDATIONS

Monitoring of lead concentrations in water at Bamforth should continue. If the level of lead increases, the source should be investigated. Selenium levels in vegetation, sediment, and eggs should be monitored periodically at Bamforth because of the potential adverse effects related to bioaccumulation of selenium through the food chain. Observations of deformed waterbird embryos would indicate selenium contamination, although no deformities were found during this study. Arsenic concentrations in aquatic invertebrates and vegetation should be monitored because waterbirds can accumulate high levels of arsenic through their diet. The stock pond should be maintained as a freshwater source because its use reduces the likelihood of salt toxicosis occurring in waterbirds that come to feed or nest at the saline wetlands. We also recommend periodic monitoring for the occurrence of salt toxicosis in waterbirds, especially in juveniles that do not have fully developed salt glands and cannot excrete excess salts as readily as adults. The construction of additional freshwater ponds would help reduce the risk of salt toxicosis that may occur during drought years or months with cool water temperatures.

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