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ENVIRONMENTAL CONTAMINANTS PROGRAM

Lead Shot Availability to Birds Using the North Platte River Near a Trap and Skeet Range

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Abstract

A trap and skeet shooting range gun club is located on the North Platte River, below the Guernsey Reservoir in Wyoming. In 1999, we obtained sediment samples to determine if lead shot from shooting activities was present and potentially available to waterfowl and bald eagles. We collected 25 sediment samples, each consisting of the upper 10 cm of sediment, every 1.5 meters along transects that paralleled the river bank and skeet range. Sediment was sorted using a series of sieves. Nineteen of the 25 samples contained at least one lead shot (range = 1-14 lead shot/sample). Samples nearest the bank where the range is located contained no shot but as we moved across the river, the number of samples with shot present increased. Clay target fragments also littered the riverbed. In 2003, we intensified our efforts by taking 300 sediment samples as described above, but we also recorded each sample location by GPS and plotted the data using Asset Surveyor to show the distribution and density of lead shot. We analyzed sediment, biofilm, crayfish, and white suckers to determine if lead and other metals were accumulating in the food chain and to assess potential threats to waterfowl and bald eagles feeding from the river. Samples of clay target fragments were also collected and analyzed because the paint of the targets may contain elevated concentrations of some metals, which could leach into the river. Lead shot was present and available to waterfowl but it was not present at a density associated with bird die-offs. We found that clay target fragments and shot were transported downstream and that greater concentrations of arsenic, cadmium, mercury, and selenium were associated with orange-colored clay targets. However, except for selenium concentrations, trace metals including lead were not greatly elevated in sediment and biota. Elevated selenium concentrations in biota were most likely the result of sources upstream. Regulatory concerns associated with the discharge of lead shot and clay targets into a water of the United States are discussed.

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INTRODUCTION

A trap and skeet shooting range gun club (Gun Club) is located on the North Platte River (river), below the Guernsey Reservoir, in Wyoming. The Gun Club has existed since 1949 and is oriented so that shooting occurs directly over the river. Although not used heavily, the location of the Gun Club is a concern because spent shot usually remains in the top 10 cm of sediment where it is available for ingestion by waterfowl (Scheuhammer and Norris 1996). Waterfowl use this stretch of the river for resting and feeding, particularly during the fall migration when water levels are low (Larry Roberts, Wyoming Game & Fish Dept, pers. comm. 1/22/01). Waterfowl can easily ingest shot by mistaking the pellets for grit.

Waterfowl poisoned from lead shot ingestion is thoroughly documented (Szymczak and Adrian 1978; Kendall and Driver 1982; Driver and Kendall 1984; Zwank et al. 1985; Wingingstad and Hinds III 1987). The U.S. Fish and Wildlife Service estimates that between 1.6 and 2.4 million waterfowl are poisoned each year by lead shot (Friend 1989). This number may slowly be declining with the conversion from lead shot to non-toxic shot for waterfowl hunting; but, poisoning from lead shot deposited before the ban is still available in the environment and is being ingested by waterfowl in appreciable amounts (Anderson et al. 2000). Additionally, the amount of lead shot at trap and skeet ranges is unlikely to follow a similar decreasing pattern. Lead is used almost exclusively at shooting ranges, primarily because it is much less expensive than non-toxic shot. For example, 25 shells of lead shot can be reloaded for about $3.00, whereas the cost for non-toxic shot ranges from $8.00 to $25.00 for 20 shells (U.S. Environmental Protection Agency (U.S. EPA) 2003). The Gun Club uses almost exclusively lead shot.

Furthermore, the bioavailability of lead originating from lead shot may be altered in the environment. Elemental lead shot will break down into finer particles and molecular species. Although this breakdown is normally a slow process (100-300 years for total breakdown; Eisler 1988b), it can result in elevated concentrations in the water and sediment (Scheuhammer and Norris 1996) and may expose other organisms including invertebrates and fish. Contaminated sediments also can serve as another exposure route for waterfowl, which ingest sediments while they forage (Beyer et al. 1994). Lead shot can also contain trace concentrations of arsenic that can be incorporated into the bones of water birds (Hall and Fisher, Jr. 1985).

Large waterfowl die-offs can potentially occur at a site when birds ingest lead shot (Szymczak and Adrian 1978; Kendall and Driver 1982; Wingingstad and Hinds III 1987); but, chronic poisoning is more common and can take days to weeks before birds succumb (Friend 1985). Birds, particularly during migration, may exhibit symptoms of lead poisoning, but determining the location of lead shot ingestion may be impossible. Also, the individual response of a bird to lead shot may vary because of the number and size of shot retained, amount of lead eroded, and the individual's susceptibility (e.g. health, age) and diet (Bellrose 1976; Chasko et al. 1984; Wobeser 1981). Typically, birds suffering from chronic lead poisoning are weak, fly erratically, or may be reluctant to fly. They may act crippled with drooping wings, be emaciated, and tend to seek protective cover as their illness progresses (Friend 1989). These birds often die from a secondary cause such as predation or disease (Franson 1986; Scheuhammer and Norris 1996).

Because consuming lead-sickened prey can result in secondary lead poisoning of predators, raptors may be at risk. Specifically, bald eagles may be exposed to lead by ingesting lead-poisoned waterfowl or fish inhabiting this stretch of river (USFWS, unpubl. data). There are documented cases where raptors were poisoned when they ingested waterfowl tissues that contained lead from lead shot (Benson et al. 1974; Jacobsen et al. 1977). Furthermore, bottom-dwelling fish such as white suckers and carp that inhabit this stretch of the river (Al Conder, Wyoming Game & Fish Dept., pers. comm. 1/22/01) may accumulate lead when they ingest sediments and aquatic invertebrates. These fish could provide another pathway to further expose eagles to lead. Eagles that suffer from lead poisoning are often weak and may ultimately die from another cause such as predation, disease, or starvation (Jacobsen et al. 1977).

In addition to lead shot, clay targets litter the bottom of the river as a result of shooting activities from the Gun Club. Clay targets are composed of dolomitic limestone and petroleum pitch with bright fluorescent orange or yellow paint covering the surface of the target for high visibility (Baer et al. 1995). Petrogenic hydrocarbons, which comprise the majority of the pitch, are relatively insoluble in water and acute toxicity of these hydrocarbons is low (Baer et al. 1995). At the Gun Club site, there is the potential for aquatic organisms to be chronically exposed to polynuclear aromatic hydrocarbons (PAHs) leaching from the pitch. However, it is unlikely that bald eagles or waterfowl are being chronically exposed because once the aquatic organisms ingest PAHs, the PAHs are rapidly metabolized. PAHs also do not bioaccumulate or biomagnify through the food chain to affect upper trophic levels (Albers 1995). Rather, upper trophic levels may be affected by metals leaching from the fluorescent paint, which can include arsenic, cadmium, mercury, and selenium (Tom Maurer, U.S. Fish and Wildlife Service, pers. comm. 1/16/01). These trace metals can bioaccumulate (and biomagnify in the case of mercury and selenium) in aquatic organisms, thereby posing a potential threat to upper trophic levels (waterfowl, bald eagles) (Eisler 1985, Eisler 1987, Eisler 1988a, Lemly 2002).

The purpose of the present study was to determine if lead shot density in the river is sufficient to threaten the health of waterfowl and eagles and determine if trace elements are leaching from spent targets and accumulating through the food chain. Our objectives were to: (1) determine the distribution and density of lead shot by collecting sediments from the North Platte River upstream, adjacent to, and downstream of the Gun Club; (2) determine the availability of lead shot and subsequent threat to waterfowl by documenting waterfowl use and behavior and comparing lead shot density results with published literature values; (3) determine if lead from spent shot and arsenic, cadmium, mercury, and selenium from clay targets are leaching into the sediment and posing a threat to waterfowl (from incidental sediment ingestion) and to bald eagles through food chain bioaccumulation in benthic fish; (4) determine if periphyton, benthic aquatic invertebrates, and benthic fish are bioaccumulating lead from spent shot and other trace elements from clay targets that would pose a threat to bald eagles, and compare these results with samples collected upstream of the Gun Club; and (5) use geographic information system (GIS) to map the distribution of lead shot (shooting trajectory) including downstream areas to determine lead mobility and lead shot concentration areas (slow water areas) that may be associated with the river's flushing flows.

METHODS

Study Sites

The shooting range is located on the west side of the North Platte River, in the town of Guernsey, Wyoming (Figure 1). The shooting range is not used frequently but has operated since 1949. The shooting of clay targets is aimed directly over the river towards the opposite bank (Figures 2, 3, and 4). The property on the opposite bank of the river is Camp Guernsey, a training site for the Army National Guard. No shooting activities occur at Camp Guernsey near the river.

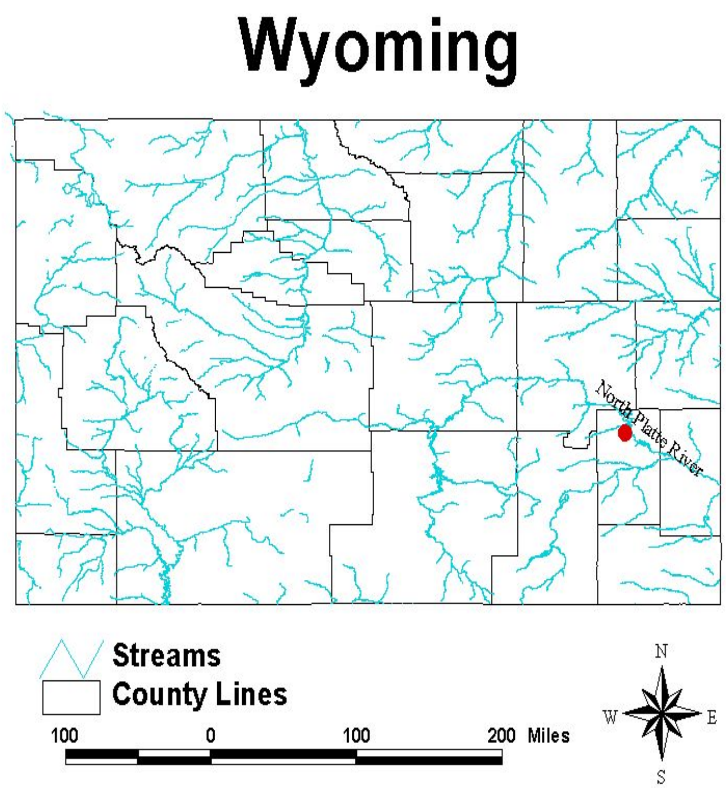

Figure 1. General location of study area on the North Platte River, Platte County, Wyoming.

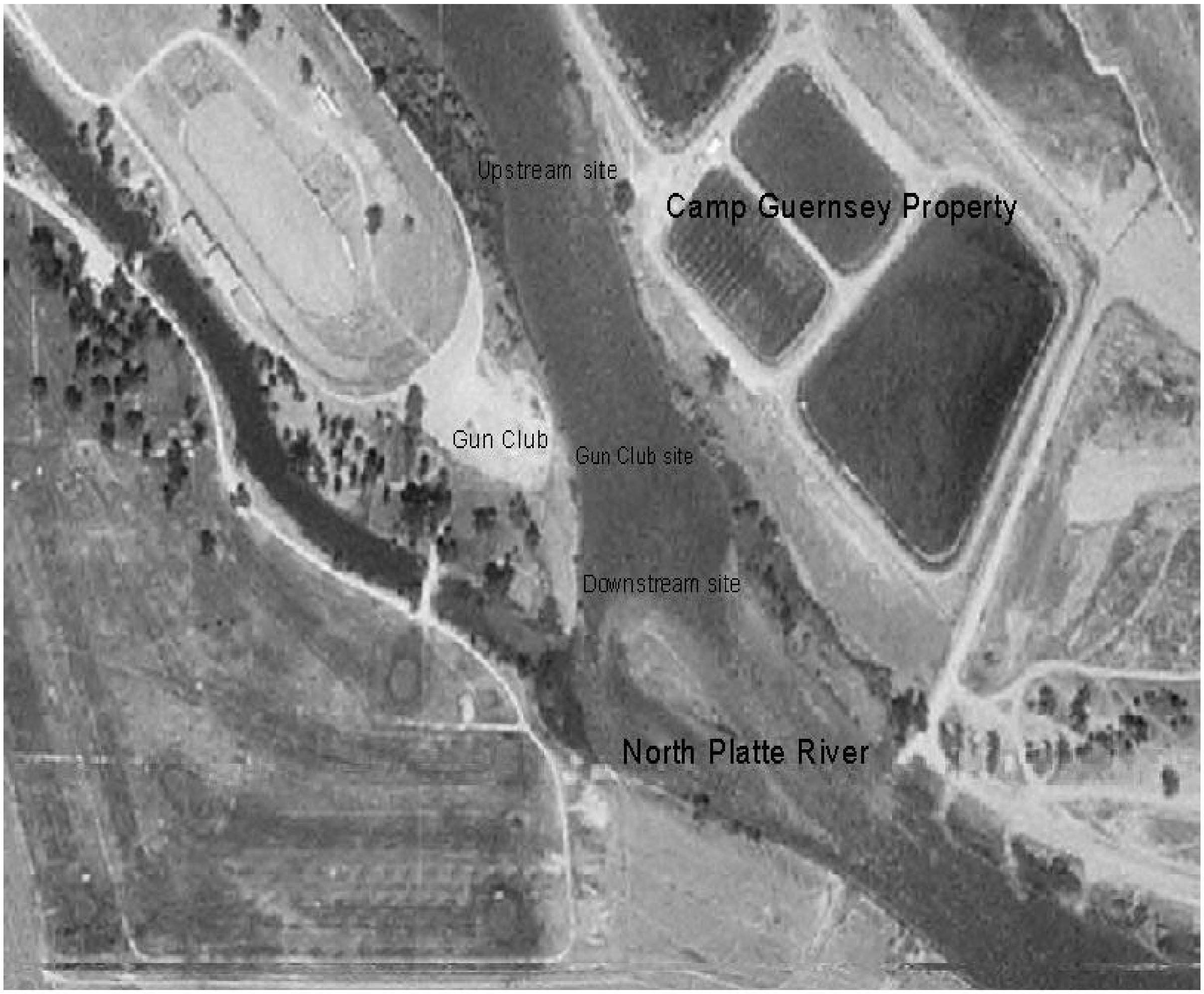

Figure 2. Aerial photograph illustrating the location of the Gun Club property, Camp Guernsey property, and sampling sites along the North Platte River, Wyoming.

Figure 3. Aerial photograph depicting the shooting direction towards the North Platte River, Wyoming.

Figure 4. The Guernsey Gun Club, Guernsey, Wyoming.

Waterfowl Counts

Prior to our study, Dan Moss, an environmental analyst with the Wyoming Army National Guard at Camp Guernsey, performed weekly waterfowl counts from October 2000 until November 2001. The counts were used to indicate the number and species of waterfowl that use the river during low flow when lead shot is most accessible to birds.

Waterfowl counts were resumed in the fall of 2003 using methods as described in Ralph et al. (1995). We also canvassed the river banks and surrounding area for the presence of any sick or dying waterfowl and for the presence of bile-stained feces, an indicator of lead poisoning. Two people surveyed the areas corresponding with the lead shot sediment collection areas (120 m x 80 m) using transects that parallel the river. Surveys were started at the river bank and progressed upland. Sick waterfowl, carcasses, or bile-stained feces were collected and sent to the National Wildlife Health Lab (NWHL) in Madison, Wisconsin, to determine if the cause of sickness or death was the result of lead poisoning.

Lead Shot and Clay Target Fragments in Sediments

We collected sediment samples using transects in the river adjacent the Gun Club (120 m x 80 m), upstream of the Gun Club (120 m x 80 m), and downstream of the Gun Club (120 m x 80 m). Transects paralleled the river, beginning along the bank nearest the Gun Club and progressed across at 5 m intervals to the opposite bank. At the upstream and downstream sites, transects were spaced at 10 m intervals. We used a Trimble Pro XRS GPS unit with real time precision of 0.3 m to mark sample locations.

We forced a 30.5 x 30.5 x 10 cm (12 x 12 x 4-inch) frame into the sediment and collected all sediment within the frame area to a depth of 10 cm using a chemically-cleaned stainless steel spoon (acetone and nitric acid rinsed). All sediment within one frame was considered one sample. Sediment was placed in a Whirl-Pak7 bag. Upon returning to the laboratory, we sorted the shot and clay target fragments from the sediment by using a series of sieves.

Shot found in the remaining sediment was removed for identification. We used a magnet to identify steel shot and we used pliers to crimp the remaining shot to differentiate between lead and bismuth (lead shot compresses and bismuth shot fractures). Clay target fragments were removed and weighed for each sample.

For QA/QC purposes, every 10^{th} sediment sample was recounted. This was done by placing recovered shot and clay target fragments back into the sediment sample, re-labeling the sample, and having the technician (without their knowledge) recount the sample.

Using GIS and Asset Surveyor, we plotted the distribution and density of lead shot from the sediment samples we collected at the sampling sites along the river. Similarly, we plotted the distribution and density of clay target fragments at each of the sampling sites along the river.

Sediment and Clay Target Samples

Four composite sediment samples were collected from each of the three sites using a chemically-cleaned stainless steel spoon (acetone and nitric acid rinsed), which was decontaminated between samples. Sediments were placed in Whirl-pak bags®, frozen, and submitted for analyses of arsenic, cadmium, and selenium to determine if constituents from the orange paint on the clay targets were ending up in the sediments. Lead was also analyzed to determine if leaching from lead shot was occurring. Analyses of the sediments were performed by U.S. Geological Survey Columbia Environmental Research Center (CERC) in Columbia, Missouri.

We collected three random composite samples of clay target fragments littering the river bed for analysis of arsenic, cadmium, and selenium to determine if these constituents might be greatly elevated in the paint on the targets. Due to budgetary limitations, mercury was not measured in sediment as sediment is usually a poor predictor of mercury contamination in biota (D'Intri 1990). We compared these analytical results to analytical results of three composite samples of five each of newly purchased clay targets. Analysis of the clay targets was also performed by CERC.

Biofilm (Periphyton), Aquatic Invertebrate, and Fish Samples

Biofilm, benthic aquatic invertebrates, and benthic fish data were collected to determine if bald eagles could be exposed to lead from dietary pathways apart from that of waterfowl (direct ingestion) and if bald eagles were ingesting contaminants leaching from the shot and/or clay targets that may have bioaccumulated in fish tissue via the food web.

Biofilm is primarily an accumulation of periphyton (epilithic algae) and associated fauna that accumulates on submerged rocks and stones (Wetzel 1983). Biofilm can also contain dead and abiotic material such as fine sediments (Unrine and Jagoe 2004). The biofilm community is sessile providing a constant biological detector of contamination and is consumed by benthic fish and some benthic invertebrates. We collected four composite samples of biofilm by scraping rocks at each of the three sampling sites. Biofilm samples were placed in 40 ml clear glass vials and frozen for trace element analyses.

Originally, we began collecting *Odonata* sp. but we could not obtain enough biomass for sample analysis. Therefore, we collected crayfish (*Orconectes* sp.) using kick nets as described in the U.S. Fish and Wildlife Service QA/QC protocols (USFWS 1996) at each of the three sites. We were able to collect four composite samples at the Gun Club but only three composite samples at both the upstream and downstream sites. Samples were placed in chemically-clean 40 ml clear glass vials and frozen for trace element analyses.

Benthic fish were collected using electrofishing equipment according to standard methods of the U.S. Geological Survey - Biological Research Division (USGS-BRD). We collected twenty suckers (*Catostomus* sp.) at both the downstream/Gun Club and upstream sites. The downstream and Gun Club sites were not separated enough to be considered two distinct sites for sampling fish. Therefore, these sites were combined as one site and labeled as the downstream site. Fish were weighed and measured. Ten fish (63 – 82 mm, 1 - 5 g) at each site were frozen for trace element analyses. The remaining ten fish (82 – 182mm, 6-64 g) were dissected and the livers frozen in chemically clean glass jars for trace element analyses. Due to budgetary limitations, mercury was only measured in ten whole fish (five each above and below) and it was not measured in fish livers. All biological samples were submitted to CERC for trace element analysis.

Analysis for Trace Elements

All samples were homogenized before analysis; the methods varied according to sample type. Whole-body fish were cut into 1-cm^2 pieces with a titanium meat cleaver, lyophilized (freeze-dried), then further homogenized by cryogenic (liquid nitrogen immersion) grinding using a Spex 6850 Freezer Mill. Samples were once again lyophilized to remove any residual moisture obtained during cryogenic grinding. Similarly, invertebrate samples were lyophilized as received, cryogenically ground, and re-lyophilized. Fish livers were simply lyophilized as received without any further homogenization. Biofilm and sediment samples were lyophilized as received then mechanically pulverized in a glass vial with a glass rod to produce a coarse powder. Clay targets were cryogenically ground as received, then lyophilized. All final dried and homogenized sample products were stored in glass vials in a desiccator until sub-samples were weighed for chemical digestion and analysis.

Three separate chemical digestion methods were used depending upon sample type and instrumental method. For analysis by inductively-coupled plasma mass spectrometry (ICP-MS), tissues were digested by one of two methods depending upon available sample mass. For most samples, a microwave-assisted digestion was used as follows: an aliquant of each dried sample (<0.15 g, fish liver; ~0.25 g, biofilm; ~0.2 g invertebrates and clay targets) was heated with 6 mL nitric acid (HNO_3) in a sealed low pressure Teflon vessel in a laboratory microwave oven. The cooled digestate liquid was transferred into a 125 mL polyethylene bottle with ultrapure water (>10 megOhm/cm) to a final weight of 101.5 g (100 mL). The final acid matrix for these samples was 6% HNO_3 (v/v). Digestion of sediment (~0.5 g) followed the same procedure, except that 5.5 mL HNO_3 and 0.5 hydrochloric acid (HCl) was used, giving a final acid matrix of 5.5% HNO_3 and 0.5% HCl. For samples in which the available mass was limited, a test tube-hot block digestion was used. For these, a 0.05g subsample was added to a pre-cleaned borosilicate glass test tube, 0.5 mL HNO_3 was added, and the sample was allowed to predigest for 1 hour at room temperature. The sample tube was capped and then heated for 30 minutes in a heating block at 110^o-120^oC. After cooling, 0.2 mL of hydrogen peroxide was added and the mixture heated again for 30 minutes. The resulting digestate was diluted to 5 mL with ultra-pure water for a final HNO_3 matrix of 10% (v/v).

For the determination of selenium in all samples except sediments, a combination wet ash/dry ash beaker digestion was performed because the analysis method used for that element (hydride atomic absorption spectrophotometry) does not tolerate high levels of HNO_3 and the selenium must be present in the +4 valence state. The procedure includes three heating steps: 1) boiling to near dryness with nitric acid for solubilization and partial oxidation, 2) ashing at 500^oC with magnesium nitrate to complete the oxidation of remaining organic matter, and 3) heating with HCl to dissolve the ash and reduce selenium to the $selenium^{+4}$ +4 valence state. The sample weights analyzed included 0.1 g for fish and 0.5 g for other matrices. Following the HCl-reduction step, digestates were diluted to 25 mL (fish) or 100 mL (other matrices) with deionized water, yielding a final acid matrix of 1-% HCl. For the determination of mercury in fish samples, there was no chemical preparation (digestion) because the dried sample was thermally decomposed during instrumental analysis (see below).

Instrumental analysis was conducted by ICP-MS for arsenic, cadmium, and lead in all samples; and for selenium for sediments only. The semi-quantitative scan mode (TotalQuant) was used for arsenic, cadmium, and selenium, whereas the quantitative mode was used for lead. The semi-quant scanning mode has a manufacturer's reported accuracy of $\pm$30% to $\pm$50% (depending upon analyte), but in most instances the accuracy is within $\pm$20%. For the quantitative analysis mode used for lead, accuracy is expected to be within $\pm$10%. For this mode of operation, multiple standard concentrations of lead, multiple standard concentrations of lead were used to calibrate the instrument and the instrument performance was regularly monitored specifically for lead throughout the analysis run. For both quantitative analysis, all samples were diluted 10x by a CETAC ASD-500 autodiluter as part of the analytical sequence. Internal standards were scandium (10 ppb), rhodium (10 ppb), and thorium (10 ppb), and the external standard consisted of a NIST traceable reference solution (Trace Metals in Drinking Water; High Purity Standards, Charleston, SC) to which five elements (praseodymium, terbium, thulium, tantalum, and gold) were added for improved calibration in the rare earth region of the mass spectral range. For quantitative analysis of lead, the following standards (ppb) were used to produce a calibration line: lead – 1.5, 3, 6, 12. After the 10x predilution, any sample over the upper calibration standard for lead was automatically diluted 10x in a serial fashion until concentrations were within the confines of the standard line. The internal standard was bismuth (10 ppb) which was metered into the sample line via peristaltic pump. Masses reported for lead were Pb^{206+}, Pbd^{207+}, and Pb^{208+}.

Mercury was determined with a direct mercury analyzer in accordance with U.S. EPA method 7473. With this method, a dried fish sample (30-50 mg) was combusted in a stream of oxygen. All mercury in the sample was volatilized and trapped by amalgamation on a gold substrate and was thermally desorbed and quantitated by atomic absorption spectrophotometry. The entire sequence was conducted with a Milestone DMA-80 analyzer equipped with an automated sample carousel.

Except for sediment samples, the determination of selenium was accomplished by flow injection hydride generation atomic absorption spectroscopy similar to U.S. EPA method 7741A. In this procedure, the digestate is mixed with a HCl-carrier solution and then reduced by sodium tetrahydridoborate which has been stabilized with sodium hydroxide. The resulting volatile hydrogen selenide is transferred with argon carrier gas into a heated quartz cell mounted on an atomic absorption spectrophotometer for decomposition and measurement.

Quality Assurance

Quality assurance measures followed U.S. EPA guidelines and the specific quality control samples included with each sample digestion group depended on the final instrumental approach. For digestion of all matrices for the ICP-MS semi-quantitative scan, quality control included digestion blanks, reference solutions and materials, samples replicate, and sample spikes. Quality control parameters for sample analysis by ICP-MS scan included running the single calibration standard as a sample, a measurement of precision by repeated runs of a reference solution, the analysis of independent-source laboratory control samples, and within run monitoring of changes in the internal standards. For samples analyzed by flow injection atomic absorption (selenium), pre-digestion quality control included digestion blanks, replicates, spikes, and reference solutions/materials. Analytical quality control for selenium included calibration verification solutions and analysis spikes. For analysis of mercury in tissue by thermal combustion, amalgamation, and atomic absorption spectroscopy (DMA-80), quality control included calibration verification checks, reference tissues, replicates, method spikes, and blanks. All quality control results wee considered acceptable according to CERC guidelines.

Statistical Analysis

Dr. Ken Burnham and Paul Lukacs (a graduate student) of the Colorado Cooperative Fish and Wildlife Research Unit, Fort Collins, Colorado, reviewed and provided guidance regarding the design of the study and statistical analysis. Statistical analysis of the metal sample data consisted of non-parametric Wilcoxon statistics because of the small sample sizes ($n<20$). One-half the detection limit was used for metal concentrations below the detection limit. Waterfowl count data and clay fragment data were used only qualitatively with no statistical analysis performed. An overall average was taken for determining the number of lead shot obtained per sample.

RESULTS

Waterfowl Counts

The most commonly observed waterfowl species during the fall of 2003 were wood ducks (*Aix sponsa*) with overall bird use by various waterfowl being low (Table 1). Data obtained during the 2000-2001 observations are in Appendix A. The observation period was for an entire year and shows a more diverse array of waterfowl species with dabbling ducks and Canada geese (*Branta canadensis*) most commonly observed. Wood ducks were not observed during 2001.

Density of Lead Shot and Clay Target Fragments in Sediments

In sediment samples taken adjacent the Gun Club, we recovered lead shot within the 10 cm depth available to feeding waterfowl (0-16 shot per sample; $\bar{x} = 0.71$ shot/sample) (see Appendix B-1 for the number of shot in each sediment sample). Most lead shot occurred in the shot trajectory zone. The density of shot increased toward the opposite bank and samples nearest the Gun Club contained little or no shot (Figure 5). No other types of shot (steel, bismuth) were found. We found several sediment concretions, which resemble corroded shot but when compressed with pliers, the concretions disintegrated.

In some sediment samples taken downstream of the Gun Club, we occasionally found a lead shot (Appendix B-2) indicating that some shot does get swept downstream during high water flows (Figure 5). No shot were found at the upstream site (Appendix B-3). Sediment samples collected adjacent the Gun Club, contained clay target fragments (0 -386.4 g) (Figures 6 and 7). Most of the clay fragments occurred nearest the bank by the Gun Club and decreased in density towards the opposite bank (Appendix B-1). Clay target fragments were also found downstream of the Gun Club, indicating transport downstream via high water flows (Appendix B-2). At the upstream site, no clay target fragments were found.

Table 1. Bird observations on North Platte River, Guernsey, Wyoming, 2003.

		Species of Waterfowl Observed			
Site	**Date**	**Wood Duck**	**Common Merganser**	**Unidentified**	**Total Observed**
Upstream	September 18	2			2
Gun Club		7			7
Downstream				3	3
Upstream	September 24				0
Gun Club		25			25
Downstream					0
Upstream	October 9	8			8
Gun Club		17			17
Downstream		2			2
Upstream	October 16				0
Gun Club					0
Downstream					0
Upstream	October 23				0
Gun Club		3	1		4
Downstream					0

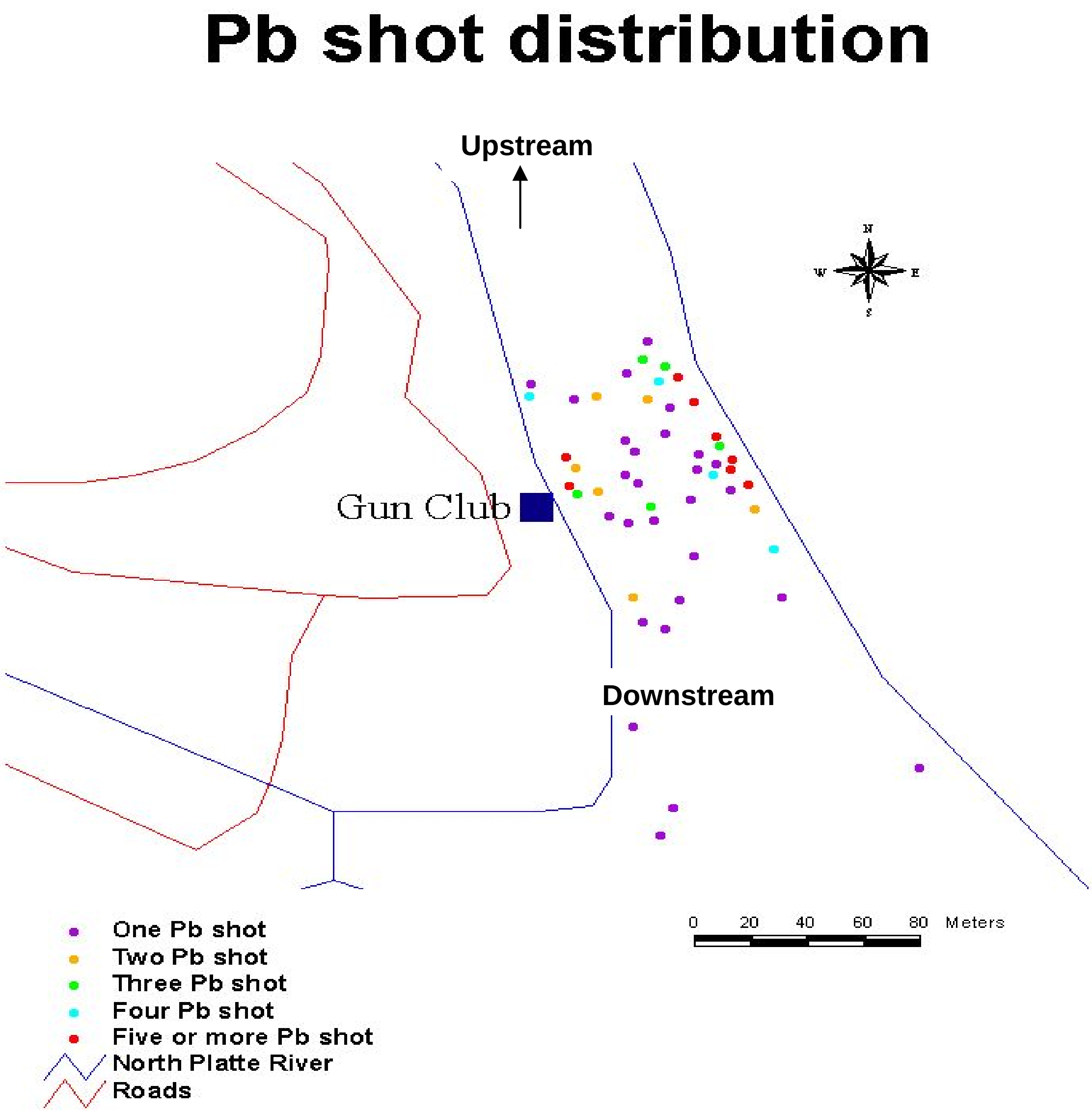

Figure 5. Distribution of lead shot found in sediment samples, North Platte River, Guernsey, Wyoming, 2003.

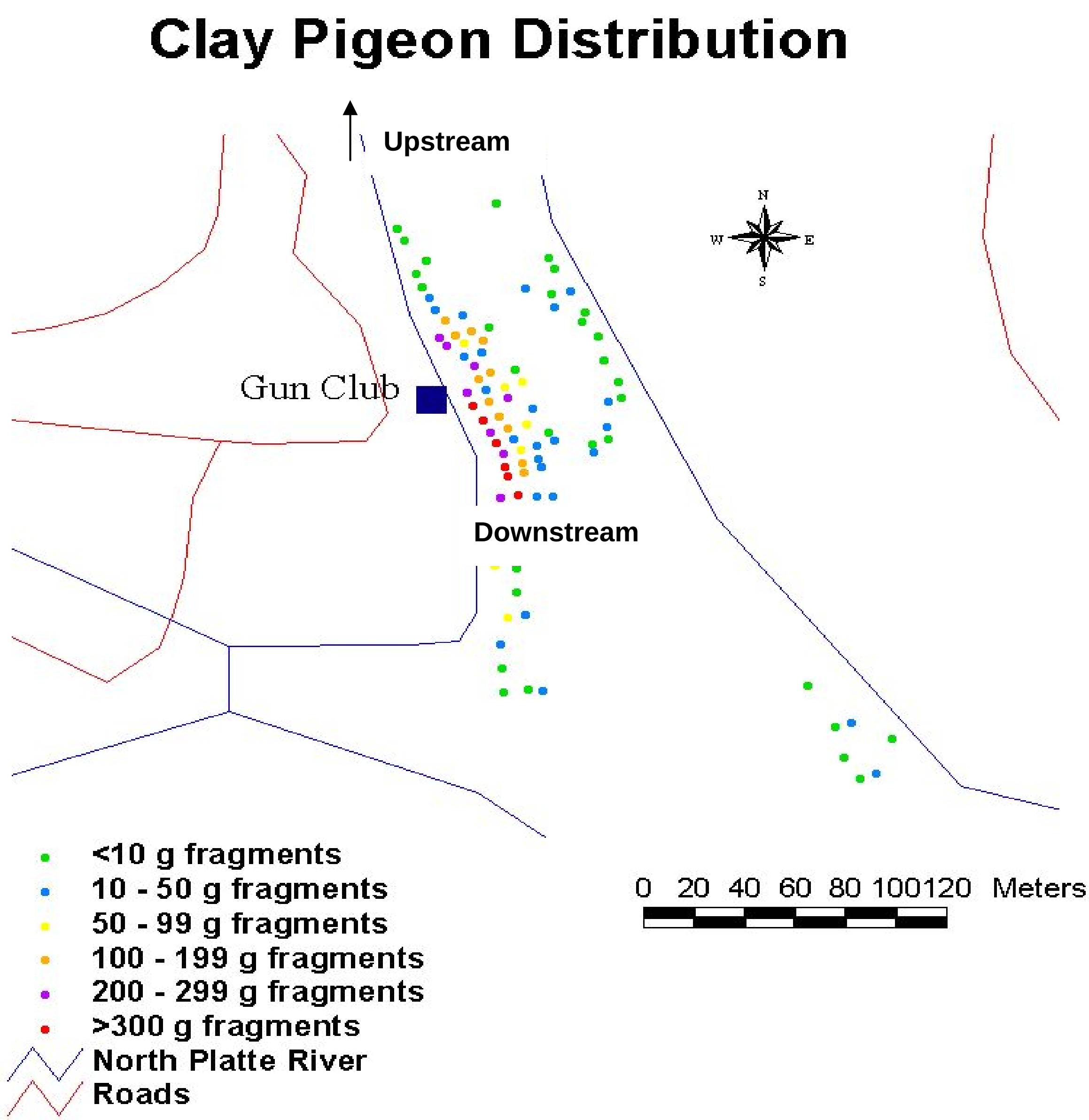

Figure 6. Distribution of clay target fragments found in sediment samples, North Platte River, Guernsey, Wyoming, 2003.

Figure 7. Photo showing clay target fragments littering the riverbed, North Platte River, Guernsey, Wyoming, 2003.

Sediment and Clay Target Analyses

Arsenic and lead were detected in sediment samples from all three sites (Table 2) but cadmium and selenium were below reporting limits for the semi-quantitative scan. Lead concentrations were slightly higher in sediment adjacent the Gun Club; whereas, arsenic was higher in concentration in sediment samples from the upstream site. Differences were not significant ($p<0.05$) among sites.

New clay targets and weathered clay target fragments collected from the river below and adjacent the Gun Club did not have elevated metal levels. Additionally, weathered clay fragments were not significantly lower in metal concentrations than the control (new) targets ($p<0.05$) (Table 3). Interestingly, the sample of new targets with yellow paint was lower in metals than new targets with orange paint. Weathered clay fragment samples contained fragments with both yellow and orange paint, but fragments with orange paint were the most common.

Table 2. Trace metal concentrations (µg/g dry weight) in sediment samples collected from the North Platte River near Guernsey, Wyoming, 2003.

Site	Sample #	Arsenic	Cadmium	Lead	Selenium
Upstream	NPRFSD01	3.0	<0.1	2.3	<1
Upstream	NPRFSD02	3.5	<0.1	2.8	<1
Upstream	NPRFSD03	4.1	<0.1	2.5	<1
Upstream	NPRFSD04	2.3	<0.1	2.8	<1
Gun Club	NPPBSD01	2.9	<0.1	3.7	<1
Gun Club	NPPBSD02	2.3	<0.1	3.0	<1
Gun Club	NPPBSD03	2.4	<0.1	2.4	<1
Gun Club	NPPBSD04	3.7	<0.1	2.9	<1
Downstream	NPDSSD01	2.1	<0.1	3.3	<1
Downstream	NPDSSD02	2.0	<0.1	3.0	<1
Downstream	NPDSSD03	2.0	<0.1	2.7	<1
Downstream	NPDSSD04	2.2	<0.1	3.4	<1

Table 3. Trace metal concentrations (µg/g dry weight) in control (new) clay targets and clay target fragment samples collected from the North Platte River near Guernsey, Wyoming, 2003.

Sample #	Arsenic	Cadmium	Lead	Mercury	Selenium
Clay Target Fragments Composite 1 - Gun Club	0.68	0.19	2.2	0.37	0.11
Clay Target Fragments Composite 2 - Gun Club	0.86	0.23	2.8	0.32	0.12
Clay Target Fragments Composite 3 - Gun Club	0.82	0.13	1.9	0.34	0.16
Control Composite 1 (Clay Targets with Yellow Paint)	0.40	0.22	0.7	0.16	0.05
Control Composite 2 (Clay Targets with Orange Paint)	0.72	0.29	2.6	0.57	0.12
Control Composite 3 (Clay Targets with Orange Paint)	0.91	0.23	3.3	0.55	0.12

Biofilm (Periphyton), Aquatic Invertebrate, and Fish Analysis

Arsenic
The concentrations of arsenic in biologic tissues decreased as the level of food chain complexity increased. The arsenic concentrations generally followed the pattern of biofilm>crayfish>whole fish>fish livers. Although there was a trend of greater arsenic concentrations in biologic samples collected from the Gun Club site (e.g. biofilm upstream $\bar{x}$ = 4.2 µg/g dw, biofilm at Gun Club site $\bar{x}$ = 5.0 µg/g dw, and downstream $\bar{x}$ = 3.8 µg/g dw), the ranges of concentrations in sample at each site were not great and concentrations were not significantly different among sites for any biologic samples (Table 4; Appendix C).

Cadmium
Cadmium concentrations in biologic tissues generally followed the pattern of fish livers>biofilm>crayfish> whole body fish. As was the case with arsenic, concentrations of cadmium in biologic samples were not significantly different among sites. Concentrations of cadmium in biofilm at the Gun Club were variable with two of the four biofilm samples from the site having cadmium concentrations of 1.2 and 2.5 µg/g dw, concentrations that were greater than any of the other biofilm samples (biofilm from Gun Club site range = 0.4 – 2.5 µg/g dw, biofilm downstream range = 0.2 – 0.7 µg/g dw, and biofilm upstream range = all 0.2 µg/g dw. The concentrations of cadmium were greatest in fish livers, but the concentrations were variable (fish livers upstream range = 0.2 – 13.0 µg/g dw and fish livers downstream range = 0.1 – 7.2 µg/g dw) and reflect one fish liver sample from upstream that had a cadmium concentration of 13.0 µg/g dw and one fish liver sample from downstream that had a cadmium concentration of 7.2 µg/g dw (Table 5; Appendix C).

Lead
Concentrations of lead in biofilm samples were at least 10x the concentrations measured in crayfish, whole fish, or fish livers. For example, the highest mean lead concentration in biofilm at the Gun Club was $\bar{x}$ = 6.5 µg/g dw, whereas the highest mean lead concentration for crayfish at the Gun Club was $\bar{x}$ = 0.6 µg/g dw. As with the other metals, concentrations of lead were not significantly different from the upstream or downstream sites, but there was a trend of greater concentrations of lead in biofilm and crayfish collected from the Gun Club site. Lead concentrations in whole body fish were generally small but there was a trend of greater concentrations at the upstream site ($\bar{x}$ = 0.5 µg/g dw) compared to whole body fish collected downstream ($\bar{x}$ = 0.3 µg/g dw) (Table 6; Appendix C).

Mercury
The concentrations of mercury measured in biologic samples were generally small and there is no discernable pattern among levels of biological organization. There were no significant differences for concentrations of mercury among sites and within a sample type. However, there was a trend of greater concentrations in samples collected from the Gun Club site (e.g. biofilm $\bar{x}$ = 0.012 µg/g dw versus $\bar{x}$ = 0.009 and 0.06 µg/g dw downstream and upstream respectively). Several whole body fish had no detectable mercury. However, whole body fish from the upstream site had higher mercury concentrations ($\bar{x}$ = 0.13 µg/g dw) than at the downstream site ($\bar{x}$ = 0.09 µg/g dw) (Table 7; Appendix C).

Selenium
The concentration of selenium generally increased as the level of biologic organization increased

and indicates that selenium is bioaccumulating through the food chain. The general pattern for selenium concentrations was fish livers>whole fish>crayfish>biofilm. There were no significant differences in selenium concentrations among sites within a sample type. However, the concentrations of selenium were large in whole fish and fish livers at both the upstream and downstream sites (whole body fish upstream $\bar{x}$ = 13.5 µg/g dw); downstream $\bar{x}$ = 12.4 µg/g dw; fish livers upstream $\bar{x}$ = 17.0 µg/g dw; downstream $\bar{x}$ = 18.0 µg/g dw) (Table 8; Appendix C).

Table 4. Mean concentrations and ranges of arsenic (µg/g dry weight) in biota samples collected from the North Platte River near Guernsey, Wyoming, 2003.

Matrix	Site	Number of Samples	Mean (µg/g dw)	Range (µg/g dw)
Biofilm	Upstream	4	4.2	4.0 – 4.4
	Gun Club	4	5.0	4.3 – 5.3
	Downstream	4	3.8	3.6 – 4.0
Crayfish	Upstream	3	3.5	3.4 – 3.6
	Gun Club	4	3.2	1.8 – 4.5
	Downstream	3	3.8	3.4 – 4.3
Whole body fish	Upstream	10	1.3	0.4 – 3.7
	Downstream	10	1.4	1.1 – 1.8
Fish livers	Upstream	10	1.8	<0.1 – 4.7
	Downstream	10	1.0	0.2 – 2.8

Table 5. Mean concentrations and ranges of cadmium (µg/g dry weight) in biota samples collected from the North Platte River near Guernsey, Wyoming, 2003.

Matrix	Site	Number of Samples	Mean (µg/g dw)	Range (µg/g dw)
Biofilm	Upstream	4	0.2	All 0.2
	Gun Club	4	1.2	0.4 – 2.5
	Downstream	4	0.5	0.2 – 0.7
Crayfish	Upstream	3	0.13	0.11 – 0.16
	Gun Club	4	0.13	<0.1 – 0.16
	Downstream	3	0.25	0.22 – 0.28
Whole body fish	Upstream	10	0.15	<0.1 – 0.17
	Downstream	10	0.13	<0.1 – 0.15
Fish livers	Upstream	10	1.6	0.2 – 13.0
	Downstream	10	1.0	0.1 – 7.2

Table 6. Mean concentrations and ranges of lead (µg/g dry weight) in biota samples collected from the North Platte River near Guernsey, Wyoming, 2003.

Matrix	Site	Number of Samples	Mean (µg/g dw)	Range (µg/g dw)
Biofilm	Upstream	4	4.3	4.0 – 5.1
	Gun Club	4	6.5	5.6 – 7.0
	Downstream	4	5.1	4.4 – 5.8
Crayfish	Upstream	3	0.1	<0.1 – 0.1
	Gun Club	4	0.6	0.4 – 0.8
	Downstream	3	0.1	<0.1 – 0.2
Whole body fish	Upstream	10	0.5	<0.1 – 1.0
	Downstream	10	0.3	0.2 – 0.5
Fish livers	Upstream	10	0.3	0.1 – 0.5
	Downstream	10	0.3	<0.1 – 0.8

Table 7. Mean concentrations and ranges of mercury (µg/g dry weight) in biota samples

collected from the North Platte River near Guernsey, Wyoming, 2003.

Matrix	Site	Number of Samples	Mean (µg/g dw)	Range (µg/g dw)
Biofilm	Upstream	4	0.006	0.006 – 0.007
	Gun Club	4	0.012	0.010 – 0.016
	Downstream	4	0.009	0.008 – 0.010
Crayfish	Upstream	3	0.04	0.036 – 0.053
	Gun Club	4	0.07	0.052 – 0.09
	Downstream	3	0.04	0.043 – 0.046
Whole body fish	Upstream	5	0.13	0.10 – 0.16
	Downstream	5	0.09	0.07 – 0.11
Fish livers	Upstream	10	Not measured	--
	Downstream	10	Not measured	--

*ND – Not Detected.

Table 8. Mean concentrations and ranges of selenium (µg/g dry weight) in biota samples collected from the North Platte River near Guernsey, Wyoming, 2003.

Matrix	Site	Number of Samples	Mean (µg/g dw)	Range (µg/g dw)
Biofilm	Upstream	4	3.8	3.4 – 4.0
	Gun Club	4	3.7	3.4 – 3.8
	Downstream	4	4.5	4.2 – 4.8
Crayfish	Upstream	3	8.1	6.0 – 9.5
	Gun Club	4	5.2	3.2 – 8.1
	Downstream	3	7.4	6.9 – 7.9
Whole body fish	Upstream	10	13.5	11.5 – 16.0
	Downstream	10	12.4	10.9 – 16.0
Fish livers	Upstream	10	17.0	<10.0 – 25.0
	Downstream	10	18.0	<10.0 – 23.0

DISCUSSION

During our study, we observed very few waterfowl species using the river. Typical low flow conditions occur in autumn and the winter for this part of the river making lead shot available to dabbling waterfowl but, because of a continuing drought, water levels were very low (0.15 – 0.20 m), which may have contributed to the minimal waterfowl use. The wood ducks observed at the site feed primarily at the water's surface on aquatic plants and rarely dabble or feed on the bottom. Therefore, they are unlikely to suffer lead toxicosis from ingesting lead shot in the river's sediment. However, we also observed (but did not count) many other waterfowl species landing on water retention ponds, located adjacent the river at Camp Guernsey, rather than heading to the river, indicating that waterfowl do frequent the area. Additionally, our data show that most waterfowl use was during the winter months in 2000 and 2001 when waterfowl would be able to reach the lead shot due to low water levels. Migration in the fall and exposure to cold and limited food sources in the winter can stress waterfowl making them more susceptible to lead impacts if they ingest lead shot. Additionally, some of these bird species (e.g. mallards) are considered resident birds (http://gf.state.wy.us/downloads/pdf/nongame/WYBirdMammHerpAtlas04.pdf) and spend a considerable amount of time on and near the river. The amount of time birds spend at a site is positively correlated to their potential exposure.

Lead shot in a flowing system with a cobbly bottom substrate is often assumed to pose little threat to water birds because the shot is unavailable as it is buried underneath the cobble. But where spent shot remains in the top 10 cm of soils/sediments, it is available for ingestion by dabbling waterfowl (Scheuhammer and Norris 1996). We did find lead shot within the sediment depth available to waterfowl (Anderson 1982). We estimated that there were 1,075 shot/ha (2,656 ac) of river bottom, which falls far below the suggested density threshold for lead poisoning problems. According to Anderson (1982), the suggested density threshold for waterfowl is 4.94×10^5 lead shot/ha (>20,000 lead shot pellets/ac). We did not find any sick or dying waterfowl, but the highest number of lead shot (16) found in a sample could pose a threat to waterfowl considering the ingestion of just one lead pellet can adversely affect a mallard (Bellrose 1959).

With the lead shot, we found soil concretions in the sediment during this study. Such concretions can be mistaken for lead shot as previous research has revealed that soil concretions appeared on fluoroscopes as fairly round and very similar to oxidized shot. Soil concretions are primarily comprised of iron, with varying amounts of magnesium, aluminum, silicon, sodium, and manganese (Oates 1989), and disintegrated when compressed by pliers. These concretions are not the result of lead shot and would pose little threat to waterfowl. We are confident that we made accurate delineations between lead shot and soil concretions because soil concretions crumble when pressed with a pair of pliers, whereas lead shot compresses but does not fall apart.

Contaminant Assessment

Because of the changing flow regimes from irrigation and flushing in this stretch of the North Platte River, it is difficult to completely evaluate the effects of contaminants on biota. Storm events and seasonal weather events further complicate contaminant evaluations because pulses of water may flush contaminants and/or organisms downstream (McIntosh 1991) and as a result, cause conservative estimates in an area of concern.

The small number of samples collected during this study provides a brief glimpse of the potential exposure to organisms and indicate potential exposure routes. None of the mean concentrations of contaminants associated with the Gun Club activities (other than the lead shot itself) were elevated.

Arsenic

Arsenic concentrations in sediments and biologic samples were not significantly elevated and all, except whole fish, were below suggested guidelines for exposure to arsenic. The sediment concentrations were below sediment quality guidelines (9.79 µg/g dw). These guidelines reflect threshold effect concentrations (TEC) (Ingersoll and MacDonald 2002). A TEC is a concentration below which harmful effects are unlikely to be observed in organisms (MacDonald et al. 2000). Biofilm had the highest arsenic concentrations of all the biota sampled. Guidelines for interpreting concentrations of trace elements in biofilm, that may be harmful to organisms consuming the biofilm or to the biofilm itself, do not exist. But, because biofilm consists of algae and fine sediment, these data would provide insight about the transfer of contaminants from abiotic to biotic components in the river. Crayfish had arsenic concentrations lower than the level of concern (30-50 µg/g dw) (USDOI 1998). Whole body fish at both sites had concentrations of arsenic that were slightly above the USDOI (1998) guideline of 1.0 µg/g dw for no effect to fish but these concentrations were well below dietary concentrations that would affect birds that consumed these fish.

Cadmium

Cadmium typically accumulates more rapidly in the sediments than in living organisms (Wren et al. 1995), so it is interesting that the mean cadmium concentration was higher in biota than sediment. However, the sediments in our study were typically sandy, cobbly, and rather low in organic matter, which would tend to reduce adsorption of trace elements by sediments (Eisler 1985). In particular, two of the four biofilm samples collected at the Gun Club had cadmium concentrations of 1.2 and 2.5 µg/g dw. Concentrations of cadmium typically found in periphyton from river systems were not found in the literature; but, filamentous algae from Canadian lakes with various cadmium concentrations contained cadmium concentrations ranging from 1.4 to 3.9 µg/g dw (Wren et al 1995). According to Eisler (1985), a conservative estimate of 100 ppb of cadmium in the diet of fish or wildlife cause probable or pronounced adverse effects. None of the biological samples we collected exceeded this conservative estimate and are unlikely to pose a threat to birds consuming crayfish or fish. The source of cadmium in this system in unknown but may be associated with municipal wastewater discharges (Eisler 1985) entering the system upstream.

Lead

Lead concentrations in sediment (<3.7 µg/g dw) were below the sediment quality guideline of 35.8

μg/g dw which reflects the threshold effect concentration (Ingersoll and MacDonald 2002). Lead concentrates primarily in sediments containing large amounts of clay and organic matter (D'Itri 1990), but sediments in the North Platte River were primarily sandy and cobbly. Biofilm, however, had higher lead concentrations than either sediment or any of the other biotic samples. Lead can accumulate in plants where spent lead shot has accumulated; but, this typically occurs where acidic soils and sediments are present (Pain 1995). Lead can also become more mobile when alkaline (pH>8) conditions exist. According to U.S. EPA (2003), lead will precipitate out of solution and adsorb to soil when moderately alkaline (pH 7 – 8.5) conditions exist. The adsorption inhibits the mobility of lead. The average pH of the river water is 7.9 (http://www.usgs.gov/state/state.asp?State=WY). Therefore, sediments in the river may bind some of the dissolved lead but because of flushing flows, the sediments and adsorbed lead may be distributed downstream. Additionally, biofilm is sessile, often acting as a filter, and consists of small sediment fines (D'Itri 1990). Therefore, the biofilm may be more representative of the amount of lead that is being adsorbed at a particular site.

Both crayfish and fish had some detectable lead concentrations but these concentrations were low. Additionally, crayfish may not be a good biological indicator for lead accumulation in benthic organisms. Crayfish exposed to contaminated sediment can accumulate lead primarily through adsorption to the exoskeleton; but then lose most of the lead through molting (Knowlton et al. 1983). In general, the toxicity effects of lead on aquatic organisms is extremely varied based on physical, chemical, and biological variables (Eisler 1988b); but, the moderate alkaline conditions, binding of lead to biofilm, and low lead concentrations in the biological samples suggest that any lead that becomes dissolved is bound readily and not available. Therefore, the most likely threat of lead toxicity to waterfowl and eagles at this site is from the primary or secondary ingestion of shot rather through sediment ingestion or dietary items.

Mercury

Mercury was higher in the new clay targets than in the weathered fragments and the new targets with orange paint were higher in mercury than the new yellow-painted targets. Although mercury was not measured in sediments, if mercury was leaching from the paint of clay targets it did not appear to be greatly accumulating in biota. This may be attributed to the average pH of the river being 7.9 (http://www.usgs.gov/state/state.asp?State=WY). A pH less than this would tend to promote mercury bioaccumulation in organisms (USDOI 1998). Data from this study suggest that waterfowl and eagles are not at risk from mercury concentrations in either the sediments or dietary items.

Selenium

Selenium was elevated in some biological samples but not in sediment samples. In selenium-normal (background/unpolluted sites) sediments, the average concentrations are usually <1.0 μg/g. This is based on samples no deeper than the upper 7.6 cm (3 inches) of whole-bed sediment (USDOI 1998). The sediment samples we collected were cobbly and did not consist of significant amounts of organic matter, which may explain why the apparent lack of significant amounts of selenium in the sediments compared to the biological samples (USDOI 1998).

We did not collect water during this study, but upstream irrigation return flows elevated in selenium are most likely the source of selenium as local geological formations are not selenium-bearing (http://www.usgs.gov/state/state.asp?State=WY). The river has annual flushing flows that could transport potentially selenium-contaminated irrigation water downstream. Selenium readily accumulates in biological tissues (USDOI 1998). No guidelines exist for selenium concentrations in biofilm, but background selenium concentrations for freshwater algae range from 0.1 – 1.5 µg/g dw with the background sediment concentrations for selenium averaging <1.0 µg/g dw (USDOI 1998). Because biofilm consists of periphyton and fine sediment, it is likely that the periphyton fraction of the samples were responsible for the elevated concentration measurements of selenium at all three sampling sites.

The background selenium concentrations for aquatic invertebrates ranges between 0.4 – 4.5 µg/g dw with values typically <2.0 µg/g dw (USDOI 1998). The lowest observed adverse effect level (LOAEL) for sublethal effects in crayfish is 30 µg/g dw selenium. Therefore, adverse effects may not occur in the crayfish, but birds that consume dietary items containing 3-8 µg/g selenium may suffer reproductive impairment (USDOI 1998). Non-breeding adult birds can tolerate higher concentrations of selenium in dietary items, but concentrations of selenium in dietary items for these birds should not exceed 10-15 µg/g dw (USDOI 1998). Additionally, chronic effects from elevated selenium in the diet manifest to suppress the immune system in birds (Fairbrother et al. 1994) and can render the affected birds more susceptible to disease and predation.

Whole-body (10.9 – 16.0 µg/g dw) and liver (<10 – 25 µg/g dw) concentrations of selenium in fish were elevated at both the upstream and downstream sites although these concentrations were lower than fish collected at the upstream Kendrick Project, where contaminated irrigation return flows enter directly into the river (See et al. 1992). Background concentrations of selenium in whole body fish range from <1 – 4 µg/g dw with the typical background concentration being <2 µg/g dw (USDOI 1998). Background hepatic concentrations of selenium range from 2 – 8 µg/g dw with the typical background concentration being <5 µg/g dw (USDOI 1998). The estimated true threshold range (approximately IC10) for reproductive impairment in sensitive species of fish is 4-6 µg/g dw, with an experimental LOAEL for total reproductive failure being 15-20 whole body µg/g dw (USDOI 1998).

The U.S. EPA currently has a draft fish tissue criterion of 7.9 µg/g dw for selenium. The whole-body white suckers were above this criterion. Additionally, sensitive species of fish such as salmonids can experience significant mortality when whole-body tissue concentrations exceed 4 µg/g (Lemly 2002). These effects can go undetected because the "primary point of impact is the egg" which receives the selenium from the female (Lemly 2002). Selenium effects to internal organs can also cause an increase in energy requirements thus making fish more susceptible to Winter Stress Syndrome which occurs when the water temperature drops in the autumn and causes increased metabolism (Lemly 2002). Mortality of fish usually occurs as a result of Winter Stress Syndrome. Chronic exposure to selenium can damage gill and internal organs and/or result in teratogenic deformities in offspring (Lemly 2002).

Furthermore, in their "Notice of draft aquatic life criteria for selenium and request for scientific information, data, and views" (Federal Register. 69(242):75541-75546), the U.S. EPA states that "*the draft selenium recommendation is not designed to protect birds or terrestrial wildlife*." Therefore, the fish-tissue criterion of 7.9 µg/g dry weight would not protect sensitive migratory aquatic birds. This is because birds that consume fish containing 3-8 µg/g selenium may suffer reproductive impairment (USDOI 1998). Selenium, at high concentrations, can cause mortality (acute effects) in birds; however, chronic effects manifest themselves in immune suppression to birds (Fairbrother et al. 1994), which can make affected birds more susceptible to disease and predation. Selenium toxicity will also cause deformities and mortality in embryos and chicks (Skorupa 1991; See et al. 1992; Ohlendorf 2002). However, selenium concentrations in biotic samples appear to be the result of upstream sources rather than the paint on the clay targets.

Regulatory Concerns and Management Recommendations

Currently, there are no specific federal environmental regulations specific for outdoor shooting ranges (NSSF 1997). However, several of the sediment samples we collected contained lead shot or clay target fragments. According to U.S. EPA (2003), "expended shot and target debris, including steel shot, left in the water are pollutants as defined by the Clean Water Act" (CWA).

The CWA Aprohibits the discharge of any pollutant by any person into the waters of the United States without a National Pollution Discharge and Elimination System (NPDES) permit.@ A permit must be obtained before spent ammunition is discharged into the water, or a violation has been committed. As stated by the U.S. EPA (U.S. EPA 2003), AIt is recommended that these ranges change direction of shooting, to avoid shooting over or into wetlands or other navigable waters of the United States, and initiate lead removal and recycling activities.@ The range must be operating for the CWA regulations to apply. Although the Gun Club we examined in this study is not extremely active, it is an operating range and the CWA regulations would apply.

Lead management must also comply with Resource Conservation and Recovery Act (RCRA), which applies to both operating and non-operating ranges. Although shooting lead shot is not regulated by RCRA, according to the U.S. EPA (2003), "lead shot/bullets, if abandoned, may be a solid and/or a hazardous waste and may present an actual or potential imminent and substantial endangerment." For example, a court ruling (Connecticut Coastal Fishermen=s Association v. Remington Arms Company, Inc., 989 F.2d 1305, 2d Cir. 1993) stated that gun clubs are not considered RCRA facilities but concluded that lead shot and clay targets are considered solid waste because they are Adiscarded material@ and Aleft to accumulate@ (U.S. EPA 2003). Additionally, the court stated that the discharged lead shot was considered Ahazardous waste@ (U.S.EPA 2003). RCRA sections 7002 and 7003 can be used to compel clean up.

Lead is also considered a Ahazardous substance@ under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). CERCLA applies to clean up of a contaminated site, although this is the least preferable alternative when encouraging clean up. Additionally, the shooting range may be liable for costs associated with damage to natural resources and other expenses, which can be substantial.

Owners and/or operators of shooting ranges need to implement an environmental stewardship plan (NSSF 1997) or best management practices (BMPs) to manage lead (U.S. EPA 2003). The implementation of BMPs depends on several factors including the range size, shooting patterns and volume of shooting, and physical characteristics (e.g. soil characteristics, presence of water, etc.) of the surrounding environment. Sound management of lead reduces environment and health risks, is a good business practice, and may help to avoid costly remediation activities.

Furthermore, alternatives for preventing additional lead from entering the environment should be investigated by the Gun Club. Alternatives may include changing the direction of shooting or relocating the Gun Club. The costs and benefits of removing the lead shot from the river should also be investigated. Most management actions such as discing, tilling, or use of vegetative management practices are used to remove/bury lead shot to eliminate the availability to waterfowl in wetland areas (Sporting Arms and Ammunition Manufacturer=s Institute (SAAMI) 1996). Although the shotfall zone impacts water at this site, this situation presents a unique challenge because it is a riverine system rather than a wetland. Therefore, cleanup of the river from target shooting activities at this time may not be appropriate. Clean up activities such as dredging would probably do more harm than good ecologically; but, continued shooting activities at the Gun Club are additive and will continue to degrade this section of river. In lieu of a river cleanup, the only other reasonable recommendation may be for the Gun Club to cease activities that continue to pollute the North Platte River.

The Gun Club can receive assistance by contacting SAAMI for implementing a proper range management program. SAAMI has programs to help sportsmen=s clubs and commercial shooting facilities to manage their facilities with regard to lead shot and water quality (SAAMI 1996). This service is available to clubs at little or no charge (National Association of Shooting Ranges (NASR) http://www.rangeinfo.org/).

Conclusions

We found that lead shot was not at a density threshold which can result in bird die-offs based on known mortality events that have occurred. We did not find any dead or dying waterfowl and the analytical results of trace elements in the samples revealed that concentrations were generally low with the exception of selenium (which was not related to shooting activities). However, there was lead shot present at a depth available to waterfowl. Consequently, dabbling ducks may still ingest shot and become sick or die and eagles may ingest shot by eating sickened ducks. Additionally, both the shot and the target fragments are considered solid waste (U.S. EPA 2003).

Although the focus of this study was to investigate lead in the aquatic environment as it was deemed more of an immediate threat to birds and other wildlife than in terrestrial areas; it is very likely that lead shot from shooting activities at the Gun Club is present in the terrestrial areas along the banks of the river. A future study to investigate if lead shot from the Gun Club is impacting terrestrial birds and wildlife along the river is warranted.

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LITERATURE CITED

Albers, P.H. 1995. Petroleum and individual polycyclic aromatic hydrocarbons. In: *Handbook of Ecotoxicology*, Hoffman, D.J., B.A. Rattner, G.A. Burton, Jr., and J. Cairns, Jr., eds. Lewis Publishers, Boca Raton, FL. Pp. 330-355.

Anderson, W.L. 1982. Potential for lead poisoning die-offs among waterfowl at Rend Lake. Illinois Department of Conservation, Division of Fish and Wildlife Periodic Report No. 36.

Anderson, W.L., S.P. Havera, and B.W. Zercher. 2000. Ingestion of lead and nontoxic shotgun pellets by ducks in the Mississippi Flyway. J. Wildl. Manage. 64(3): 848-857.

Baer, K.N., D.G. Hutton, R.L. Boeri, T.J. Ward, and R.G. Stahl, Jr. 1995. Toxicity evaluation of trap and skeet shooting targets to aquatic test species. Ecotoxicol. 4: 385-392.

Bellrose, F.C. 1976. *Ducks, Geese, and Swans of North America*. Stackpole Pub. Harrisburg, PA. 543 pp.

Bellrose, F.C. 1959. Lead poisoning as a mortality factor in waterfowl populations. Illinois Natural History Survey Bull. 27: 236-287.

Benson, W.W., B. Pharoah, and P. Miller. 1974. Lead poisoning in a bird of prey. Bull. Environ. Contam. Toxicol. 11: 105-108.

Beyer, W.N., E.E. Conner, and S. Gerould. 1994. Estimates of soil ingestion by wildlife. J. Wildl. Manage. 58: 375-382.

Chasko, G.C., T.R. Hoehn, and P. Howell-Heller. 1984. Toxicity of lead shot to wild black ducks and mallards fed natural foods. Bull. Environ. Contam. Toxicol. 32: 417-428.

D'Itri, F.M. 1990. The biomethylation and cycling of selected metals and metalloids in aquatic sediments. In: *Sediments: Chemistry and Toxicity of In-Place Pollutants*, R. Baudo, J. Giesy, and H. Muntau, eds. Lewis Publishers, Inc. Chelsea, MI. Pp.163-214.

Driver, C.J. and R.J. Kendall. 1984. Lead shot ingestion in waterfowl in Washington State, 1978-1979. Northw. Sci. 58: 103-107.

Eisler, R. 1985. Cadmium hazards to fish, wildlife, and invertebrates: A synoptic review. U.S. Fish and Wildlife Service Biological Report 85 (1.2).

Eisler, R. 1987. Mercury hazards to fish, wildlife, and invertebrates: A synoptic review. U.S. Fish and Wildlife Service Biological Report 85 (1.10).

Eisler, R. 1988a. Arsenic hazards to fish, wildlife, and invertebrates: A synoptic review. U.S. Fish and Wildlife Service Biological Report 85 (1.12).

Eisler, R. 1988b. Lead hazards to fish, wildlife, and invertebrates: A synoptic review. U.S. Fish and Wildlife Service Biological Report 85 (1.14).

Fairbrother, A., M. Fix, T. O'Hara, and C. A. Ribic. 1994. Impairment of growth and immune function of avocet chicks from sites with elevated selenium, arsenic, and boron. J. Wildl. Diseas. 30: 222-233.

Franson, C.J. 1986. Immunosuppressive effects of lead. In: *Lead Poisoning in Wild Waterfowl: A Workshop*, J.S. Feierabend and A.B. Russell, eds. National Wildlife Federation. Washington D.C. Pp. 106-109.

Friend, M. 1985. Interpretation of criteria commonly used to determine lead poisoning problem areas. U.S. Fish and Wildlife Service Leaflet 2. Washington D.C. 5 pp.

Friend, M. 1989. Lead poisoning: The invisible disease. U.S. Fish and Wildlife Leaflet 13. Washington D.C. 5 pp.

Hall, S.L. and F.M. Fisher, Jr. 1985. Lead concentrations in tissues of marsh birds: Relationship of feeding habits and grit preference to spent shot ingestion. Bull. Environ. Contam. Toxicol. 35: 1-8.

Ingersoll, C.G. and D.D. MacDonald. 2002. A Guidance Manual to Support the Assessment of Contaminated Sediments in Freshwater Ecosystems. Volume III – Interpretation of the results of sediment quality investigations. U.S. EPA Rep. EPA-905-B02-001-C. Chicago, IL. 207 pp.

Jacobson, E., J.W. Carpenter, M. Novilla. 1977. Suspected lead toxicosis in a bald eagle. J. Amer. Vet. Med. Assoc. 171: 952-954.

Kendall, R.J. and C.J. Driver. 1982. Lead poisoning in swans in Washington State. J. Wildl. Diseas. 18: 385-387.

Knowlton, M.F., T.P. Boyle, and J.R. Jones. 1983. Uptake of lead from aquatic sediment by submersed macrophytes and crayfish. Arch. Environ. Toxicol. Contam. 12: 535-541.

Lemly, A.D. 2002. Selenium assessment in aquatic ecosystems – a guide for hazard evaluation and water quality criteria. Springer. New York. 161 pp.

MacDonald, D.D., C.G. Ingersoll, and T.A. Berger. 2000. Development and evaluation of consensus-based sediment quality guidelines for freshwater ecosystems. Arch. Environ. Toxicol. Chem. 39: 20-31.

McIntosh, A. 1991. Trace metals in freshwater sediments: A review of the literature and an assessment of research needs. In: *Metal Ecotoxicology: Concepts and Applications*, Newman, M.C. and A.W. McIntosh, eds. Lewis Publishers, Inc., Chelsea, MI. Pp. 243-260.

National Shooting Sports Foundation (NSSF). 1997. Environmental aspects of construction and management of outdoor shooting ranges. Facility Development Series, No. 2. Newtown, CT.

Oates, D.W. 1989. Incidence of lead shot in the Rainwater Basin of south central Nebraska. Prairie Nat. 21: 137-146.

Ohlendorf, H.M. 2002. Ecotoxicology of selenium. In: *Handbook of Ecotoxicology*, 2nd ed., D.J. Hoffman, B.A. Rattner, G.A. Burton, Jr., and J. Cairns, Jr., eds. Lewis Publishers. Boca Raton, FL. Pp. 465-500.

Pain, D.J. 1995. Lead in waterfowl. In: *Environmental Contaminants in Wildlife*: *Interpreting Tissue Concentrations*, W.N. Beyer, G.H. Heinz, and A.W. Redmon-Norwood, eds. CRC Press, Inc. Boca Raton, FL. Pp. 251-264.

Ralph, C.J., J.R. Sauer, and S. Droege, technical editors. 1995. *Monitoring Bird Populations by Point Counts*. Gen. Tech. Rep. PSW-GTR-149. Albany, CA, Pacific Southwest Research Station, Forest Service, U.S. Dept. of Agriculture. 187 pp.

Scheuhammer, A.M. and S.L. Norris. 1996. The ecotoxicology of lead shot and lead fishing weights. Ecotoxicol. 5: 279-295.

See, R.B., D.L. Naftz, D.A. Peterson, J.G. Crock, J.A. Erdman, R.C. Severson, P. Ramirez, Jr., and J.A. Armstrong. 1992. Detailed study of selenium in soil, representative plants, water, bottom sediments, and biota in the Kendrick Reclamation Project Area, Wyomng, 1988-90. U.S. Geological Survey Water Resources Inv. Rep. 91-4131.

Skorupa, J.P. 1991. Contaminants in drainage water and avian risk thresholds. In: *The Economics and Management of Water and Drainage in Agriculture*, A. Dinar and D. Zilberman, eds. Kluwer Academic Publishers, Boston, MA. Pp. 345-368.

Sporting Arms and Ammunition Manufacturer=s Institute, Inc. (SAAMI). 1996. Lead mobility at shooting ranges. SAAMI, Newtown, CT. Various pages.

Szymczak, M.R. and W.J. Adrian. 1978. Lead poisoning in Canada geese in Southeast Colorado. J. Wildl. Manage. 42: 299-306.

Unrine, J.M. and C.H. Jagoe. 2004. Dietary mercury exposure and bioaccumulation in southern leopard frog (*Rana sphenocephala*) larvae. Environ. Toxicol. Chem. 23: 2956-2963.

U.S. Department of Interior. (USDOI). 1998. Guidelines for Interpretation of the Biological Effects of Selected Constituents in Biota, Water, and Sediment. National Irrigation Water Quality Program Information Report No. 3. Denver, CO. 198 pp.

U.S. Environmental Protection Agency (U.S. EPA). 2003. Best management practices for lead at outdoor shooting ranges. Report #: EPA-902-B-01-001. New York, NY. Various pages.

U.S. Fish and Wildlife Service (USFWS). 1996. Standard operating procedures for environmental contaminant operations. Volume 1. Department of Interior, Washington D.C.

Wetzel, R.G. 1983. Limnology, 2nd ed. Saunders College Publishing. New York, NY. Pp. 134-156.

Windingstad, R.M. and L.S. Hinds III. 1987. Lead poisoning in Canada geese on Plum Island, Massachusetts. J. Wildl. Diseas. 23: 438-442.

Wobeser, G.A. 1981. *Diseases of Wild Waterfowl, Lead and Other Metals*. Plenum Press, New York, NY. Pp. 151-163.

Wren, C.D., S. Harris, and N. Harttrup. 1995. Ecotoxicology of mercury and cadmium. In: *Handbook of Ecotoxicology*, Hoffman, D.J., B.A. Rattner, G.A. Burton, Jr., and J. Cairns, Jr., eds. Lewis Publishers, Boca Raton, FL. Pp. 392-423.

Zwank, P.J., V.L. Wright, P.M. Shealy, and J.D. Newsom. 1985. Lead toxicosis in waterfowl on two major wintering areas in Louisiana. Wildl. Soc. Bull. 13: 17-26.

Appendix A. Waterfowl counts east of the Gun Club on the North Platte River near Guernsey, Wyoming, 2000-2001.

	10/11/2000	10/18/2000	10/25/2000	11/1/2000	11/8/2000	11/15/2000	11/22/2000	11/29/2000	12/6/2000	12/13/2000
Dabbling Ducks										
Mallard			2		4			4	16	8
Blue-winged Teal										
Northern Pintail										
Diving Ducks										
Canvasback								2		4
Common Goldeneye										
Other Species										
Snow goose										
Canada goose										
American coot	2	0	2	2	3	2	3	3	3	4
Gull sp.	1	3	0	2	2	1	0	2	4	0
Total	**3**	**3**	**4**	**4**	**9**	**3**	**3**	**11**	**23**	**14**

	12/20/2000	12/27/2000	1/3/2001	1/10/2001	1/17/2001	1/24/2001	1/31/2001	2/7/2001	2/14/2001	2/21/2001
Dabbling Ducks										
Mallard	10	21	15	11	4	1	6	3	1	4
Blue-winged Teal		2	2	1			2	1		2
Northern Pintail										
Diving Ducks										
Canvasback	3	2	2	2	4	2	1	2	2	
Common Goldeneye		4	4	2	8	3	4	3	8	15
Other Species										
Snow goose										
Canada goose	4	4	8	3	2	2	5	9	2	3
American coot	3	5	3	3	2	2	2	2	3	2
Gull sp.		2		3	2	1	4		2	6
Total	**20**	**40**	**34**	**25**	**22**	**11**	**24**	**20**	**18**	**32**

Appendix A cont.

	2/28/2001	3/7/2001	3/14/2003	3/21/2001	3/28/2001	4/4/2001	4/11/2001	4/18/2001	4/25/2001	5/2/2001
Dabbling Ducks										
Mallard	2	6	4	9	4	2	2	2	2	5
Blue-winged Teal	2	2		9					2	
Northern Pintail				2		4			2	2
Diving Ducks										
Canvasback										
Common Goldeneye	8	7	2	4		2		4	7	
Other Species										
Snow goose										
Canada goose	3	2		4		20				
American coot	1	3	3							
Gull sp.	1	4	2	8	14	3	1		3	9
Total	**17**	**24**	**11**	**36**	**18**	**31**	**3**	**6**	**16**	**16**

	5/9/2001	5/16/2001	5/23/2001	5/30/2001	6/6/2001	6/13/2001	6/20/2001	6/27/2001	7/4/2001	7/11/2001
Dabbling Ducks										
Mallard	2	8		6	6	1	2		4	1
Blue-winged Teal										
Northern Pintail										
Unidentified species						1	2	1		
Diving Ducks										
Canvasback										
Common Goldeneye										
Other Species										
Snow goose										
Canada goose	4	2		2						
American coot										
Gull sp.	2		1		1	1		2		2
Total	**8**	**10**	**1**	**8**	**7**	**3**	**4**	**3**	**4**	**3**

Appendix A cont.

	7/18/2001	7/25/2001	8/1/2001	8/8/2001	8/15/2001	8/22/2001	8/29/2001	9/5/2001	9/12/2001	9/19/2001
Dabbling Ducks										
Mallard	6	5	6	2			2	4	8	5
Blue-winged Teal								2	3	
Northern Pintail										
Unidentified Species	2	2	1	3						
Diving Ducks										
Canvasback										
Common Goldeneye										
Other Species										
Snow goose										
Canada goose									3	4
American coot						2		2		3
Gull sp.	1	1	2		12	2	7	4	2	
Total	**9**	**8**	**9**	**5**	**12**	**4**	**9**	**12**	**16**	**12**

	9/26/2001	10/3/2001	10/10/2001	10/17/2001	10/24/2001	10/31/2001	11/7/2001	11/14/2001	11/21/2001	11/28/2001
Dabbling Ducks										
Mallard	5	7	6	2	10	5	20	9	25	21
Blue-winged Teal	3	3	4		2			11	9	
Northern Pintail	2									
Unidentified Species								2		
Diving Ducks										
Canvasback										
Common Goldeneye			2		6	3	7		12	15
Other Species										
Snow goose										3
Canada goose	3	5	6	2	6	4	9	12	7	25
American coot	3	2			3					
Gull sp.	3	5		1	5			4		2
Total	**19**	**22**	**18**	**5**	**32**	**12**	**36**	**38**	**53**	**66**

Appendix B-1. Number of shot and weight (g) of clay target fragments in sediment samples collected from the North Platte River adjacent the Gun Club, Guernsey, Wyoming, 2003.

Transect Point	Primary Substrate Type	# Lead Shot	# Other Shot	Total # Shot	Target Fragment Weight (g)	Latitude	Longitude	Elevation	Comments
A1	Large cobble	1		1	0	42.2558	-104.7364	1312.386	
A2	Small cobble			0	0.9	42.2558	-104.7364	1312.387	
A3	Small cobble			0	0	42.2558	-104.7365	1312.637	
A4	Large cobble			0	0	42.2557	-104.7365	1312.354	
A5	Small cobble			0	0	42.2557	-104.7366	1312.196	
A6	Small cobble			0	0	42.2557	-104.7366	1312.134	
A7	Small cobble			0	0	42.2557	-104.7367	1312.406	
A8	Small cobble			0	0.7	42.2557	-104.7368	1312.265	
B1	Large cobble			0	0	42.2557	-104.7363	1312.825	
B2	Small cobble	3		3	0	42.2557	-104.7364	1312.537	
B3	Large cobble			0	0	42.2557	-104.7364	1311.748	
B4	Small cobble	1		1	0	42.2557	-104.7365	1312.003	Found 1 sediment concretion
B5	Small cobble			0	0	42.2557	-104.7365	1312.313	
B6	Small cobble			0	0	42.2557	-104.7366	1313.092	
B7	Small cobble			0	0	42.2556	-104.7367	1311.376	
B8	Small cobble	1		1	0.6	42.2556	-104.7367	1312.351	
C1	Large cobble	3		3	0	42.2557	-104.7363	1312.486	
C2	Large cobble			0	0	42.2557	-104.7364	1311.862	
C3	Large cobble	1		1	0	42.2557	-104.7364	1312.926	
C4	Small cobble			0	0	42.2557	-104.7365	1312.784	
C5	Small cobble			0	0	42.2556	-104.7365	1312.774	
C6	Small cobble			0	0	42.2556	-104.7366	1312.95	
C7	Small cobble			0	0	42.2556	-104.7367	1313.053	
C8	Small cobble	4		4	0	42.2556	-104.7367	1313.054	

Appendix B-1 cont.

Transect Point	Primary Substrate Type	# Lead Shot	# Other Shot	Total # Shot	Target Fragment Weight (g)	Latitude	Longitude	Elevation	Comments
D1	Large cobble	5		5	0	42.2557	-104.7363	1312.348	
D2	Large cobble	4		4	0	42.2556	-104.7363	1312.487	
D3	Large cobble			0	0	42.2556	-104.7364	1312.47	
D4	Small cobble			0	0	42.2556	-104.7365	1313.105	
D5	Small cobble	2		2	0	42.2556	-104.7365	1312.699	
D6	Small cobble	1		1	0	42.2556	-104.7366	1312.542	
D7	Small cobble			0	0.6	42.2556	-104.7367	1312.738	
D8	Small cobble			0	0	42.2555	-104.7367	1312.743	
E1	Large cobble			0	0	42.2556	-104.7362	1312.981	
E2	Large cobble			0	0	42.2556	-104.7363	1312.406	
E3	Small cobble	2		2	0	42.2556	-104.7364	1311.576	
E4	Small cobble			0	0	42.2556	-104.7364	1312.03	
E5	Small cobble			0	0	42.2555	-104.7365	1312.595	
E6	Large cobble			0	0	42.2555	-104.7366	1313.014	
E7	Large cobble			0	0	42.2555	-104.7366	1312.78	
E8	Large pebble			0	1.7	42.2555	-104.7367	1313.455	
F1	Large cobble	6		6	1.6	42.2556	-104.7362	1312.273	
F2	Small cobble	1		1	0	42.2555	-104.7363	1311.912	
F3	Large cobble			0	0	42.2555	-104.7363	1311.946	
F4	Small cobble			0	0	42.2555	-104.7364	1312.829	Found 1sediment concretion
F5	Small cobble			0	0	42.2555	-104.7365	1313.146	
F6	Large cobble			0	0	42.2555	-104.7365	1313.118	
F7	Small cobble			0	0	42.2555	-104.7366	1312.031	
F8	Small cobble			0	9.1	42.2555	-104.7367	1312.115	

Appendix B-1 cont.

Transect Point	Primary Substrate Type	# Lead Shot	# Other Shot	Total # Shot	Target Fragment Weight (g)	Latitude	Longitude	Elevation	Comments
G1	Large cobble			0	1	42.2555	-104.7362	1312.135	
G2	Large cobble			0	0	42.2555	-104.7363	1312.665	
G3	Large cobble			0	0	42.2555	-104.7363	1311.727	
G4	Small cobble			0	0	42.2555	-104.7364	1311.237	
G5	Large cobble			0	0	42.2555	-104.7365	1311.862	
G8	Small cobble			0	14.8	42.2554	-104.7366	1312.588	
G7	Large cobble			0	0	42.2554	-104.7366	1312.762	
G6	Small cobble			0	0	42.2554	-104.7365	1312.79	
H1	Large cobble			0	0	42.2555	-104.7362	1312.758	
H2	Large cobble			0	0	42.2555	-104.7362	1312.651	
H3	Small cobble	1		1	14.6	42.2554	-104.7363	1312.794	
H4	Large cobble			0	0	42.2554	-104.7364	1312.296	
H5	Large cobble	1		1	0	42.2554	-104.7364	1312.617	
H6	Small cobble			0	0	42.2554	-104.7365	1312.147	
H7	Large cobble			0	0	42.2554	-104.7366	1312.08	
H8	Small cobble	7		7	41.4	42.2554	-104.7366	1312.744	
H9	Small cobble			0	0	42.2554	-104.7361	1313.207	
I1	Small cobble	5		5	10.7	42.2554	-104.7361	1313.022	
I2	Large cobble			0	1.4	42.2554	-104.7362	1312.272	
I3	Large cobble			0	0	42.2554	-104.7363	1312.406	
I4	Small cobble			0	0	42.2554	-104.7363	1312.269	
I5	Large cobble	1		1	0	42.2554	-104.7364	1311.834	
I6	Small cobble			0	0	42.2554	-104.7365	1312.513	
I7	Large cobble			0	32.4	42.2553	-104.7365	1312.436	
I8	Large cobble	2		2	195.5	42.2553	-104.7366	1312.99	

Appendix B-1 cont.

Transect Point	Primary Substrate Type	# Lead Shot	# Other Shot	Total # Shot	Target Fragment Weight (g)	Latitude	Longitude	Elevation	Comments
J1	Large cobble	3		3	0	42.2554	-104.7361	1312.484	
J2	Large cobble	1		1	10.8	42.2554	-104.7362	1312.063	
J3	Large cobble			0	0	42.2553	-104.7362	1311.906	
J4	Large cobble			0	0	42.2553	-104.7363	1311.74	
J5	Large cobble	1		1	0	42.2553	-104.7364	1311.653	Found 1sediment concretion
J6	Large cobble	1		1	3.8	42.2553	-104.7364	1312.032	
J7	Large cobble			0	107.5	42.2553	-104.7365	1312.296	
J8	Large cobble			0	151.1	42.2553	-104.7366	1312.612	
J9	Large pebble	7		7	292.4	42.2553	-104.7366	1312.831	
K1	Large cobble	8		8	4.4	42.2554	-104.7361	1312.387	Found 1 sediment concretion
K2	Large cobble	1		1	0	42.2553	-104.7361	1312.136	
K3	Large cobble	1		1	0	42.2553	-104.7362	1311.892	
K4	Large cobble			0	0	42.2553	-104.7363	1311.863	
K5	Large cobble			0	0	42.2553	-104.7363	1311.746	
K6	Large cobble	1		1	0	42.2553	-104.7364	1311.766	
K7	Large cobble			0	183.2	42.2552	-104.7365	1311.857	
K8	Large cobble	2		2	58.1	42.2552	-104.7365	1312.053	Found 1 sediment concretion
K9	Large cobble	3		3	285.8	42.2552	-104.7366	1312.222	
L1	Small cobble	16		16	5.2	42.2553	-104.7361	1312.454	
L2	Small cobble	4		4	0	42.2553	-104.7362	1312.265	
L3	Small cobble			0	0	42.2553	-104.7362	1312.003	
L4	Small cobble			0	0	42.2552	-104.7363	1311.895	
L5	Small cobble			0	0	42.2552	-104.7363	1311.701	
L6	Small cobble			0	0	42.2552	-104.7364	1311.851	
L7	Small cobble			0	33.5	42.2552	-104.7365	1312.187	
L8	Small cobble			0	48.8	42.2552	-104.7365	1312.208	

Appendix B-1 cont.

Transect Point	Primary Substrate Type	# Lead Shot	# Other Shot	Total # Shot	Target Fragment Weight (g)	Latitude	Longitude	Elevation	Comments
M1	Small cobble	5		5	2.5	42.2553	-104.7360	1312.193	Found 2 sediment concretions
M2	Large cobble	1		1	0	42.2552	-104.7361	1311.684	
M3	Large cobble			0	0	42.2552	-104.7362	1311.474	
M4	Large cobble	1		1	0	42.2552	-104.7362	1311.813	
M5	Small cobble			0	0	42.2552	-104.7363	1312.083	
M6	Small cobble	3		3	0	42.2552	-104.7364	1312.105	Found 1 sediment concretion
M7	Small cobble			0	0	42.2552	-104.7364	1312.027	
M8	Small cobble	1		1	298.2	42.2551	-104.7365	1312.274	
N1	Small cobble			0	0	42.2552	-104.7360	1312.242	
N2	Small cobble			0	0	42.2552	-104.7361	1312.082	
N3	Large cobble			0	0	42.2552	-104.7362	1311.935	
N4	Small cobble			0	0	42.2552	-104.7362	1311.797	
N5	Small cobble			0	0	42.2551	-104.7363	1311.835	
N6	Small cobble	1		1	1.6	42.2551	-104.7363	1311.638	
N7	Large cobble	1		1	180.8	42.2551	-104.7364	1311.874	
N8	Small cobble			0	158.4	42.2551	-104.7365	1312.521	
O1	Large cobble	2		2	1.5	42.2552	-104.7360	1312.524	
O2	Large cobble			0	0	42.2552	-104.7361	1312.319	
O3	Small cobble			0	0	42.2551	-104.7361	1312.335	
O4	Small cobble			0	0	42.2551	-104.7362	1312.261	
O5	Small cobble			0	0	42.2551	-104.7362	1312.567	
O6	Small cobble			0	51.3	42.2551	-104.7363	1312.635	
O7	Large cobble			0	61.8	42.2551	-104.7364	1312.679	
O8	Large cobble			0	33	42.2551	-104.7364	1312.694	
O9	Small cobble			0	222.4	42.2550	-104.7365	1312.599	

Appendix B-1 cont.

Transect Point	Primary Substrate Type	# Lead Shot	# Other Shot	Total # Shot	Target Fragment Weight (g)	Latitude	Longitude	Elevation	Comments
P1	Small cobble			0	0	42.2551	-104.7360	1312.523	
P2	Large cobble			0	0	42.2551	-104.7361	1311.772	
P3	Large cobble			0	0	42.2551	-104.7361	1311.731	
P4	Small cobble			0	0	42.2551	-104.7362	1311.461	
P5	Small cobble			0	0	42.2551	-104.7362	1311.51	
P6	Small cobble			0	0	42.2550	-104.7363	1311.73	
P7	Small cobble			0	200.5	42.2550	-104.7364	1311.81	
P8	Large cobble			0	130.5	42.2550	-104.7364	1312.079	
P9	Large pebble			0	367.9	42.2550	-104.7365	1312.371	
Q1	Small cobble			0	5.3	42.2551	-104.7360	1313.227	
Q2	Large cobble			0	0	42.2551	-104.7360	1312.322	
Q3	Large cobble			0	0	42.2550	-104.7361	1312.4	
Q4	Small cobble			0	0	42.2550	-104.7361	1311.483	
Q5	Small cobble	1		1	0	42.2550	-104.7362	1311.78	
Q6	Small cobble			0	26.5	42.2550	-104.7363	1311.451	
Q7	Large cobble			0	0	42.2550	-104.7363	1311.928	
Q8	Large cobble			0	114.7	42.2549	-104.7364	1312.424	
Q9	Large pebble			0	386.4	42.2549	-104.7364	1312.839	
R1	Large cobble	4		4	1.8	42.2550	-104.7360	1312.668	
R2	Large cobble			0	45.9	42.2550	-104.7360	1312.894	
R3	Large cobble			0	0	42.2550	-104.7361	1312.744	
R4	Small cobble			0	0	42.2550	-104.7361	1312.798	
R5	Small cobble			0	0	42.2550	-104.7362	1312.933	Found 1 sediment concretion
R6	Small cobble			0	0	42.2549	-104.7362	1313.206	
R7	Large cobble			0	88.3	42.2549	-104.7363	1313.55	
R8	Large cobble			0	194	42.2549	-104.7364	1313.254	
R9	Small cobble			0	271.5	42.2549	-104.7364	1313.363	

Appendix B-1 cont.

Transect Point	Primary Substrate Type	# Lead Shot	# Other Shot	Total # Shot	Target Fragment Weight (g)	Latitude	Longitude	Elevation	Comments
S1	Small cobble			0	0	42.2550	-104.7359	1312.557	
S2	Large cobble			0	0	42.2550	-104.7360	1312.289	
S3	Small cobble			0	0	42.2549	-104.7360	1312.27	
S4	Small cobble			0	0	42.2549	-104.7361	1312.267	
S5	Small cobble			0	0	42.2549	-104.7362	1312.223	
S6	Small cobble			0	9.2	42.2549	-104.7362	1312.282	
S7	Large cobble			0	0	42.2549	-104.7363	1312.395	
S8	Large cobble			0	46.2	42.2549	-104.7363	1312.382	Found 1 sediment concretion
S9	Small cobble	2		2	327.9	42.2548	-104.7364	1312.7	Found 2 sediment concretions
T1	Small cobble			0	0	42.2549	-104.7359	1312.218	
T2	Large cobble			0	0	42.2549	-104.7360	1312.348	
T3	Small cobble			0	11	42.2549	-104.7360	1312.543	
T4	Small cobble			0	0	42.2549	-104.7361	1312.568	
T5	Small cobble			0	0	42.2549	-104.7361	1312.633	Found 2 sediment concretions
T6	Small cobble			0	13	42.2549	-104.7362	1312.275	
T7	Small cobble	1		1	11.6	42.2548	-104.7363	1312.015	
T8	Small cobble			0	85.8	42.2548	-104.7363	1312.049	
T9	Small cobble			0	209.1	42.2548	-104.7364	1312.237	
U1	Large cobble			0	0	42.2549	-104.7359	1312.169	
U2	Small cobble			0	0	42.2549	-104.7359	1312.258	
U3	Large cobble			0	0.4	42.2549	-104.7360	1312.208	
U4	Large cobble			0	0.9	42.2548	-104.7361	1312.083	Found 3 sediment concretions
U5	Small cobble			0	0	42.2548	-104.7361	1312.16	
U6	Small cobble			0	0	42.2548	-104.7362	1312.115	Found 2 sediment concretions
U7	Large cobble			0	27.6	42.2548	-104.7363	1312.263	
U8	Large cobble			0	112.8	42.2548	-104.7363	1312.231	Found 1 sediment concretion
U9	Small cobble	1		1	352.9	42.2548	-104.7364	1312.329	

Appendix B-1 cont.

Transect Point	Primary Substrate Type	# Lead Shot	# Other Shot	Total # Shot	Target Fragment Weight (g)	Latitude	Longitude	Elevation	Comments
V1	Large cobble			0	0	42.2549	-104.7359	1312.602	
V2	Large cobble	1		1	0	42.2548	-104.7359	1312.471	
V3	Large cobble			0	0	42.2548	-104.7360	1312.363	
V4	Small cobble			0	10.7	42.2548	-104.7361	1312.452	
V5	Large cobble			0	0	42.2548	-104.7361	1312.425	
V6	Small cobble			0	0	42.2548	-104.7362	1312.48	
V7	Large cobble			0	18	42.2548	-104.7362	1312.227	
V8	Large cobble	1		1	106	42.2547	-104.7363	1312.033	
V9	Large pebble			0	424	42.2547	-104.7364	1312.533	Found 1 sediment concretion

Appendix B-2. Number of shot and weight (g) of clay target fragments in sediment samples collected from the North Platte River downstream of the Gun Club, Guernsey, Wyoming, 2003.

Transect Point	Primary Substrate Type	# Lead Shot	# Other Shot	Total # Shot	Target Fragment Weight (g)	Latitude	Longitude	Elevation	Comments
A1	Large pebble			0	15.5	42.2546	-104.7362	1311.644	
A2	Small cobble			0	20.9	42.2546	-104.7363	1311.432	
A3	Small cobble			0	301.6	42.2546	-104.7363	1312.536	
A4	Small cobble			0	284.6	42.2546	-104.7364	1312.522	
AA1	Large cobble	1		1	0	42.2542	-104.7355	1311.634	Found 1sediment concretion
AA2	Small cobble			0	0	42.2542	-104.7356	1311.723	Found 2 sediment concretions
B1	Small cobble			0	0	42.2545	-104.7363	1311.753	
B2	Large pebble			0	40.3	42.2546	-104.7363	1312.09	
BB1	Large cobble			0	0	42.2541	-104.7354	1311.568	
BB2	Large cobble			0	0	42.2541	-104.7355	1311.096	
C1	Small cobble			0	6.3	42.2545	-104.7363	1312.949	
C2	Large pebble			0	96	42.2545	-104.7364	1312.749	
CC1	Small cobble			0	0	42.2541	-104.7354	1311.365	
CC2	Small cobble			0	0	42.2540	-104.7354	1311.343	
D1	Small cobble			0	1.2	42.2544	-104.7363	1313.092	
D2	Large pebble	1		1	58.9	42.2544	-104.7364	1313.283	
DD1	Large cobble			0	0	42.2540	-104.7353	1311.449	
DD2	Large cobble			0	0	42.2540	-104.7353	1311.58	
DD3	Large cobble			0	0	42.2540	-104.7354	1311.767	
E1	Small cobble			0	5.8	42.2543	-104.7363	1311.929	
E2	Large pebble	1		1	0	42.2543	-104.7364	1311.707	
EE1	Large cobble			0	0	42.2539	-104.7352	1311.609	
EE2	Large cobble			0	2.8	42.2539	-104.7353	1311.472	
EE3	Small cobble			0	0	42.2539	-104.7354	1311.294	

Appendix B-2 cont.

Transect Point	Primary Substrate Type	# Lead Shot	# Other Shot	Total # Shot	Target Fragment Weight (g)	Latitude	Longitude	Elevation	Comments
F1	Small cobble			0	12.1	42.2542	-104.7363	1312.004	
F2	Small cobble			0	82.9	42.2542	-104.7364	1312.14	
FF1	Large cobble			0	0	42.2539	-104.7351	1311.756	
FF2	Large cobble			0	0	42.2538	-104.7352	1311.586	
FF3	Large cobble			0	0	42.2538	-104.7352	1311.668	
FF4	Large cobble			0	0	42.2538	-104.7353	1311.806	
G0	Small pebble			0	23.4	42.2541	-104.7364	1312.471	
G1	Small cobble	1		1	0	42.2541	-104.7363	1312.431	
G2	Small cobble			0	0	42.2541	-104.7363	1312.092	
GG1	Small cobble			0	0	42.2538	-104.7351	1312.077	
GG2	Large cobble			0	13.3	42.2538	-104.7351	1312.186	
GG3	Large cobble			0	7.2	42.2537	-104.7352	1312.149	
GG4	Large cobble			0	0	42.2537	-104.7353	1312.171	
H1	Small cobble			0	0	42.2540	-104.7363	1312.557	
H2	Small cobble	1		1	0	42.2540	-104.7363	1312.403	
H3	Small cobble			0	9.1	42.2540	-104.7364	1313.016	
HH1	Small cobble			0	3.5	42.2537	-104.7350	1311.874	
HH2	Large cobble			0	0	42.2537	-104.7350	1311.441	
HH3	Large cobble			0	0	42.2536	-104.7351	1311.6	
HH4	Large cobble			0	3	42.2536	-104.7352	1311.818	
I1	Small cobble			0	19	42.2539	-104.7362	1312.81	
I2	Small cobble			0	0.6	42.2539	-104.7363	1312.608	
I3	Small cobble			0	0.4	42.2539	-104.7364	1313.048	
II1	Large cobble			0	0	42.2536	-104.7349	1311.581	
II2	Large cobble			0	0	42.2536	-104.7350	1311.622	
II3	Large cobble			0	13.7	42.2536	-104.7351	1311.842	
II4	Small cobble			0	4.9	42.2535	-104.7351	1311.91	

Appendix B-3. Number of shot and weight (g) of clay target fragments in sediment samples collected from the North Platte River upstream of the Gun Club, Guernsey, Wyoming, 2003.

Transect Point	Primary Substrate Type	# Lead Shot	# Other Shot	Total # Shot	Target Fragment Weight (g)	Latitude	Longitude	Elevation	Comments
A1	Large cobble			0	0	42.2725	-104.7518	1316.173	
A2	Large cobble			0	0	42.2725	-104.7519	1315.807	
A3	Large cobble			0	0	42.2725	-104.7520	1315.656	
A4	Large cobble			0	0	42.2725	-104.7520	1315.628	
A5	Large cobble			0	0	42.2725	-104.7521	1315.559	
A6	Large cobble			0	0	42.2725	-104.7522	1315.452	
A7	Large cobble			0	0	42.2725	-104.7522	1315.756	
B1	Small cobble			0	0	42.2723	-104.7518	1316.076	
B2	Large cobble			0	0	42.2723	-104.7519	1315.687	
B3	Large cobble			0	0	42.2723	-104.7519	1315.452	
B4	Large cobble			0	0	42.2723	-104.7520	1315.332	
B5	Large cobble			0	0	42.2724	-104.7521	1315.194	
B6	Large cobble			0	0	42.2724	-104.7521	1315.206	
B7	Large cobble			0	0	42.2724	-104.7522	1315.3	
B8	Large cobble			0	0	42.2724	-104.7523	1315.771	
C1	Large cobble			0	0	42.2723	-104.7519	1315.306	
C2	Large cobble			0	0	42.2723	-104.7520	1315.556	
C3	Large cobble			0	0	42.2723	-104.7520	1315.409	
C4	Large cobble			0	0	42.2723	-104.7521	1315.37	
C5	Large cobble			0	0	42.2723	-104.7522	1315.364	
C6	Large cobble			0	0	42.2723	-104.7522	1315.774	
C7	Large cobble			0	0	42.2723	-104.7523	1315.845	
D1	Small cobble			0	0	42.2722	-104.7519	1315.409	
D2	Large cobble			0	0	42.2722	-104.7520	1315.216	
D3	Large cobble			0	0	42.2722	-104.7520	1314.752	
D4	Large cobble			0	0	42.2722	-104.7521	1314.817	
D5	Large cobble			0	0	42.2722	-104.7522	1314.829	
D6	Large cobble			0	0	42.2722	-104.7522	1315.243	Found 1 sediment concretion

Appendix B-3 cont.

Transect Point	Primary Substrate Type	# Lead Shot	# Other Shot	Total # Shot	Target Fragment Weight (g)	Latitude	Longitude	Elevation	Comments
E1	Large cobble			0	0	42.2721	-104.7520	1316.007	
E2	Large cobble			0	0	42.2721	-104.7520	1316.03	Found 1 sediment concretion
E3	Large cobble			0	0	42.2721	-104.7521	1316.021	
E4	Large cobble			0	0	42.2721	-104.7522	1316.122	
E5	Large cobble			0	0	42.2721	-104.7522	1316.305	
E6	Large cobble			0	0	42.2721	-104.7523	1316.421	
F1	Small cobble			0	0	42.2720	-104.7520	1315.957	
F2	Large cobble			0	0	42.2720	-104.7520	1315.921	
F3	Large cobble			0	0	42.2720	-104.7521	1316.042	
F4	Large cobble			0	0	42.2720	-104.7522	1316.005	Found 1 sediment concretion
F5	Small cobble			0	0	42.2720	-104.7522	1316.014	
F6	Large cobble			0	0	42.2720	-104.7523	1316.23	
G1	Large cobble			0	0	42.2719	-104.7520	1316.606	
G2	Large cobble			0	0	42.2720	-104.7521	1316.454	
G3	Large cobble			0	0	42.2720	-104.7521	1316.288	
G4	Large cobble			0	0	42.2720	-104.7522	1316.027	
G5	Large cobble			0	0	42.2720	-104.7522	1315.957	
G6	Small cobble			0	0	42.2720	-104.7523	1315.702	
H1	Small cobble			0	0	42.2719	-104.7520	1316.918	
H2	Large cobble			0	0	42.2719	-104.7520	1316.836	
H3	Large cobble			0	0	42.2719	-104.7521	1316.89	Found 1 sediment concretion
H4	Large cobble			0	0	42.2719	-104.7522	1316.475	
H5	Large cobble			0	0	42.2719	-104.7522	1316.763	
I1	Small cobble			0	0	42.2717	-104.7520	1316.485	Found 1 sediment concretion
I2	Small cobble			0	0	42.2717	-104.7520	1316.357	
I3	Large cobble			0	0	42.2718	-104.7521	1316.298	
I4	Large cobble			0	0	42.2718	-104.7522	1316.516	
I5	Large cobble			0	0	42.2718	-104.7522	1316.798	

Appendix C. Trace metal concentrations (µg/g dry weight) in biota collected from the North Platte River, near Guernsey, Wyoming, 2003.

Site	Sample Type	Sample #	Arsenic µg/g dw	Cadmium µg/g dw	Mercury µg/g dw	Lead µg/g dw	Selenium µg/g dw
Upstream	Biofilm	NPRFPE01	4.0	0.2	0.006	4.1	3.4
		NPRFPE02	4.1	0.2	0.006	4.0	4.0
		NPRFPE03	4.3	0.2	0.006	4.0	3.9
		NPRFPE04	4.4	0.2	0.007	5.1	3.8
Gun Club Site	Biofilm	NPPBPE01	5.1	2.5	0.012	7.0	3.4
		NPPBPE02	5.3	0.8	0.011	5.6	3.5
		NPPBPE03	5.2	0.4	0.016	6.9	3.8
		NPPBPE04	4.3	1.2	0.010	6.6	4.1
Downstream	Biofilm	NPDSPE01	4.0	0.6	0.008	4.8	4.6
		NPDSPE02	3.7	0.2	0.008	4.4	4.2
		NPDSPE03	3.9	0.3	0.010	5.8	4.6
		NPDSPE04	3.6	0.7	0.010	5.3	4.8
Upstream	Crayfish	NPRFCO5	3.5	0.11	0.053	0.1	9.5
		NPRFCO6	3.4	0.13	0.036	< 0.1	6.0
		NPRFCO7	3.6	0.16	0.039	0.1	8.7
Gun Club Site	Crayfish	NPPBCF03	2.4	< 0.1	0.074	0.6	4.9
		NPPBCF04	1.8	0.12	0.058	0.4	3.2
		NPPBCF05	3.9	0.12	0.09	0.5	8.1
		NPPBCF06	4.5	0.16	0.052	0.8	4.5
Downstream	Crayfish	NPDSCF05	3.4	0.22	0.043	< 0.1	7.3
		NPDSCF06	4.3	0.24	0.046	0.1	6.9
		NPDSCF07	3.8	0.28	0.045	0.2	7.9

Appendix C cont.

Site	Sample Type	Sample #	Arsenic µg/g dw	Cadmium µg/g dw	Mercury µg/g dw	Lead µg/g dw	Selenium µg/g dw
Upstream	White suckers Whole body	NP-AB-WB 21	0.8	< 0.1	--	< 0.1	12.0
		NP-AB-WB 22	1.3	0.17	0.14	1.0	12
		NP-AB-WB 23	1.2	0.16	0.16	0.5	11.5
		NP-AB-WB 24	1.4	0.11	--	0.5	15
		NP-AB-WB 25	0.6	< 0.1	0.12	0.1	13.6
		NP-AB-WB 26	0.8	< 0.1	0.15	< 0.1	15.1
		NP-AB-WB 27	1.4	0.16	--	0.4	12
		NP-AB-WB 28	1.6	0.16	0.10	0.5	15
		NP-AB-WB 29	0.4	< 0.1	--	0.2	16
		NP-AB-WB 30	3.7	< 0.1	--	0.9	12.6
Downstream	White suckers Whole body	NP-BL-WB 21	1.6	0.12	--	0.2	11.3
		NP-BL-WB 22	1.3	< 0.1	0.11	0.3	16
		NP-BL-WB 23	1.6	0.12	0.07	0.2	13.4
		NP-BL-WB 24	1.1	0.15	--	0.5	11
		NP-BL-WB 25	1.2	< 0.1	0.11	0.3	12.7
		NP-BL-WB 26	1.8	0.11	0.08	0.2	11.5
		NP-BL-WB 27	1.6	< 0.1	--	0.2	14
		NP-BL-WB 28	1.6	< 0.1	0.08	0.4	11
		NP-BL-WB 29	1.3	< 0.1	--	0.3	12
		NP-BL-WB 30	1.2	< 0.1	--	0.3	10.9
Upstream	White suckers Livers	NP-AB-LIV 1	4.7	13.0	--	0.3	13
		NP-AB-LIV 2	0.3	0.3	--	0.2	< 10
		NP-AB-LIV 3	1.8	0.5	--	0.2	17
		NP-AB-LIV 4	< 0.1	0.9	--	0.3	< 10
		NP-AB-LIV 5	< 0.1	0.2	--	0.2	11
		NP-AB-LIV 6	< 0.1	0.4	--	0.2	25
		NP-AB-LIV 7	< 0.1	0.2	--	0.4	< 10
		NP-AB-LIV 8	< 0.1	0.2	--	0.5	15
		NP-AB-LIV 9	1.3	0.3	--	0.1	14
		NP-AB-LIV 10	1.1	0.2	--	0.1	23

Appendix C cont.

Site	Sample Type	Sample #	Arsenic µg/g dw	Cadmium µg/g dw	Mercury µg/g dw	Lead µg/g dw	Selenium µg/g dw
Downstream	White suckers Livers	NP-BL-LIV 1	0.8	0.1	--	< 0.1	19
		NP-BL-LIV 2	0.5	0.1	--	< 0.1	17
		NP-BL-LIV 3	0.6	0.1	--	< 0.1	21
		NP-BL-LIV 4	0.8	0.3	--	0.2	21
		NP-BL-LIV 5	0.6	0.4	--	0.4	16
		NP-BL-LIV 6	1.2	7.2	--	0.8	18
		NP-BL-LIV 7	0.2	0.5	--	0.3	11
		NP-BL-LIV 8	2.8	0.4	--	0.3	21
		NP-BL-LIV 9	1.8	0.3	--	0.1	23
		NP-BL-LIV 10	1.1	0.2	--	0.1	10