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BIOAVAILABILITY AND EXPOSURE ASSESSMENT OF PETROLEUM HYDROCARBONS AND TRACE ELEMENTS IN BIRDS NESTING NEAR THE NORTH PLATTE RIVER, CASPER, WYOMING

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ABSTRACT

The objectives of this study were to compare refinery-related petroleum hydrocarbon concentrations in nestling tree swallows (*Tachycineta bicolor*) and nestling house wrens (*Troglodytes aedon*) at sites along the North Platte River Casper, Wyoming in 1997 and 1998; and to determine if contaminants were present in concentrations that could adversely affect the birds. Because trace element concentrations, mixed function oxidase activity, and the variation in DNA are often associated with petroleum hydrocarbon concentrations in birds, each was measured as indicators of petroleum contamination. Sediment and aquatic invertebrates were also sampled for characterizing a possible contaminant source to the birds. Sampling areas included sites upstream (Game & Fish, Patterson-Zonta Park), adjacent to (Amoco Park, Texaco Refinery), and downstream (EKW State Park) of the former Amoco and Texaco oil refineries. We also sampled one site between the Amoco and Texaco Refineries (Crossroads Park). Additional samples were taken using adult cliff swallows (*Hirundo pyrrhonota*) nesting under various bridges along the North Platte River in 1998.

Several aliphatic hydrocarbons were detected in sediment, aquatic invertebrates, and carcasses and gastrointestinal contents of house wren and tree swallow nestlings and adult barn and cliff swallows from all sites but differences among sites were not significant. The low pristane to n-C_{17} ratio in avian diet and tissues did not suggest chronic or acute exposure of birds to petroleum at any of the locations. However, the high phytane to n-C_{18} ratios of the gastrointestinal contents may indicate that some of the dietary items consumed by the birds were recently or chronically exposed to petroleum products.

Most polycyclic aromatic hydrocarbons (PAHs) were not detected in aquatic insect larvae but some were detected in sediments. Concentrations of total PAHs were detected in nestling carcasses of tree swallows, house wrens, and a bank swallow. Differences in PAH concentrations were not significant among sites for tree swallow nestlings but were for house wren nestlings. In gastrointestinal contents of both tree swallow and house wren nestlings, PAH concentrations tended to be higher at the Texaco Refinery site when compared to the Game & Fish site. Two hepatic monooxygenase activities, benzyloxyresorufin-O-dealkylase (BROD) and ethoxyresorufin-O-dealkylase (EROD), in tree swallow livers also tended to be higher at the Texaco Refinery site than at the Game & Fish sites and their induction may be related to PAH exposure. Because of the small sample size, results of the flow cytometry analysis, which measured DNA content, were inconclusive. Adult cliff swallow carcasses showed significant differences in total PAHs among sites with the highest concentrations occurring at the Texaco Refinery site and the upstream Patterson-Zonta Park site. PAHs were not detected in gastrointestinal contents of the cliff swallows. The predominance of unsubstituted PAHs and the general lack of alkyl-PAHs in all samples suggests that most of the PAHs were combustion-derived.

Most trace elements were not elevated in any of the samples. Chromium and selenium were elevated in aquatic insect larvae but differences among sites were not significant. Chromium was not detected in avian eggs or most nestling livers but was detected in nestling tree swallow and wren carcasses and one adult barn swallow carcass. Mercury was detected in one bank swallow egg and all tree swallow eggs. Mercury was significantly higher in tree swallow eggs collected at the EKW State Park site when compared to the Game & Fish site. Mercury was detected in wren eggs from EKW State Park but was not detected in eggs from the Game & Fish site or in two of the three eggs

from the Texaco Refinery site. In tree swallow and wren nestling livers from EKW State Park and the Texaco Refinery site, mercury concentrations were significantly higher than from the Game & Fish site. Mercury was also detected in tree swallow nestling carcasses from both the Texaco Refinery and EKW State Park but not from the Game & Fish site or in any of the house wrens. Differences were not significant among sites and the source of the mercury is unknown. Concentrations of mercury were detected in adult barn and cliff swallow livers and carcasses. Selenium was detected in house wren and tree swallow eggs, livers, and nestling carcasses. Selenium was also detected in adult barn and cliff swallow livers and carcasses. Differences were not significant but selenium concentrations, probably the result of irrigation return flows, tended to decrease downstream.

This study demonstrates that some refinery-related contaminants are bioavailable and birds are being exposed. However, the data do not exhibit any pattern that can be linked to the refineries. Our small sample size and limited statistical power do not allow us to determine if any of the contaminants are adversely affecting the birds; and, the data collected on adult birds are inconclusive because exposure to contaminants may have occurred outside the sampling area. Additionally, for several contaminants detected, the upstream Game & Fish site appears to have concentrations similar to the study sites. Finally, we were unable to determine the influence of yearly variation on the results of the petroleum hydrocarbon or trace element analyses from 1997 and 1998; but, the 1997 data from the EKW State Park were not critical to the overall conclusions of the manuscript.

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INTRODUCTION

The Little America, former Amoco, and former Texaco oil refineries are located along the North Platte River (River) near Casper, Wyoming. Historically, a light non-aqueous phase liquid plume of petroleum hydrocarbon contamination in groundwater extended from the former Amoco plant to the River (ThermoRetec Consulting Corporation 1999). Additionally, historic oil seeps into the River adjacent to the former Texaco refinery were documented by EPA (Schmelzer 1995) and others (TRC Environmental Corporation 1994; EPA 1995). Sediment samples from the River where the oil seeps were located contained elevated concentrations of polycyclic aromatic hydrocarbons (PAHs), including the carcinogenic compounds benzo[a]pyrene, benzo[b]fluoranthene, chrysene, and benzo[a]anthracene (Schmelzer 1995).

Because of the petroleum contamination entering the River, both the Amoco and Texaco Refineries have installed barrier walls to prevent further contamination from entering the River (TriHydro Corporation 1998; ThermoRetec Consulting, Inc. 1999). However, residual contamination may exist between the barrier walls and the River. Such contamination can have adverse effects on wildlife as this reach provides wintering and feeding habitat for bald eagles (*Haliaeetus leucocephalus*), American white pelicans (*Pelecanus erythrorhynchos*), double-crested cormorants (*Phalacrocorax auritus*), great blue herons (*Ardea herodias*), swallows (*Hirundo* spp.), and a variety of other birds protected under the Migratory Bird Treaty Act (U.S. Fish and Wildlife Service 1981). In addition, any contamination may also have widespread effects on endangered species inhabiting the river and associated wetlands downstream into Nebraska.

PAHs are not biomagnified through the food chain but chronic ingestion of oil-contaminated diets (insects, fish) can affect the health of birds feeding along the River. Researchers documented that PAHs can accumulate and may cause reduced body weight, impaired reproduction, and increased susceptibility to disease in birds (Szaro et al. 1978; Eastin and Murray 1981; Rocke et al. 1984; Eisler 1987a;). Szaro et al. (1978) documented that chronic ingestion of oil resulted in depressed growth, impaired behavior, liver hypertrophy, and splenic atrophy in mallard ducklings (*Anas platyrhnchos*). Several of these pathological changes observed in the ducklings were the result of ingesting environmentally realistic concentrations of oil (i.e. the oil ingested was 0.25% of the diets). The study also stated that injury resulted regardless if the oil was ingested directly or indirectly by the birds.

Another exposure pathway of oil and PAHs in birds is topical. Birds can carry petroleum products on their feathers back to the nest. Microliter quantities of petroleum products on eggs can be toxic to the embryos and result in death (Hoffman and Gay 1981; Albers 1983). Additionally, PAHs applied to mallard eggs have been shown to reduce growth and increase deformities particularly in the eye, brain, bill, and liver of the embryos (Albers 1983; Hoffman and Gay 1981). One study suggests that PAHs may impact waterfowl embryos more than adults because the embryonic enzymes metabolize PAHs to more toxic intermediates such as benzo[a]pyrene and chrysene (Hoffman and Gay 1981).

The use of indicator species to determine if residual contamination accumulates in aquatic invertebrates or organisms that feed on aquatic invertebrates is important. Swallows, especially tree swallows (*Tachycineata bicolor*), are widely used as indicators of local contamination (Bishop et al. 1995; Nichols et al. 1995; King et al. 1994; Ankley et al. 1993; Kraus 1989; Shaw 1983). Tree swallows readily use nest boxes, so study sites can be established at specific locations of interest. They feed most frequently within 400 m of their boxes (Quinney and Ankney 1985) on emergent aquatic insects (Blancher and McNicol 1991), so chemical residues in swallow tissues reflect sediment contamination from a very localized area (Fairchild et al. 1992). Reproductive parameters are well understood and can be used as endpoints in contaminant evaluations. Additionally, in areas where there are chronic low levels of pollution, emerging aquatic invertebrates (the primary food of swallows) are better indicators of local PAH contamination than fish; and aquatic invertebrates can accumulate petroleum hydrocarbons in parts per million concentrations (Szaro et al. 1978). Aquatic invertebrates are also a primary exposure pathway of petroleum hydrocarbons to dabbling ducks, goslings, and other bird species that rely heavily on a high protein diet. Birds can be adversely affected if oil contamination reduces the quantity and quality of the aquatic invertebrates.

Exposure and effects of PAHs have been documented in barn swallows (*Hirundo rustica*) near Indiana Harbor, Indiana. Aromatic hydrocarbons were significantly higher in barn swallow eggs and chicks from Indiana Harbor than in those from a reference location (Custer and Sparks 1996). Reduced reproductive success, smaller clutch sizes, and extended incubation time were associated with aromatic PAH contamination at Indiana Harbor (Dan Sparks, USFWS, unpublished data).

Other studies have demonstrated contaminant accumulation in nestling swallows and suggest negative reproductive and behavioral effects. For example: a) trace element accumulation has been documented in barn swallows nesting near a selenium-contaminated lake (mercury and selenium) (King et al. 1994) and a contaminated river/canal in Indiana (iron, chromium, manganese, nickel and selenium) (Custer and Sparks 1996); b) organochlorine accumulation has been documented in tree swallows in several studies (Ankley et al. 1993; Custer et al. 1995; Custer et al. 1998); and, c) organochlorine concentrations in tree swallow eggs were correlated with abandonment and behavioral abnormalities near the Upper Hudson River, New York (McCarty and Secord 1999a,1999b).

Alterations at the biochemical or molecular level in organisms are useful biomarkers to show detectable and quantifiable responses to environmental contaminants and are often more sensitive indicators than alterations at a higher level of biological organization (Stegeman et al. 1992). The use of ethoxyresorufin-O-dealkylase (EROD) activity in bird livers is an indicator of PCB (Bellward et al. 1990) and petroleum contamination (Custer et al. 2000; Stegeman et al. 1992). EROD is a liver detoxification enzyme and part of the protein family of cytochrome P450 monooxgenases or mixed function oxygenase (MFO). EROD activity can be used as a sensitive indicator of PAH exposure while reproductive parameters (including hatching success, percent deformities, etc.) are used to document injury.

Field and laboratory studies have documented the relationship between PAH exposure and MFO activity. For example, three hepatic monooxygenase activities in lesser scaup (*Aythya affinis*), collected on the heavily petroleum-polluted Indiana Harbor Canal, Indiana, were significantly correlated with PAH concentrations in the carcasses of the birds (Custer et al. 2000). In the laboratory studies, hepatic naphthalene-metabolizing activities of mallard ducks (*Anas platyrhynchos*) increased almost four times following exposure to food dosed with South Louisiana crude oil (Gorsline and Holmes 1981); and similarly, EROD activity was induced in adult Atlantic puffins (*Fratercula arctica*) after a single dose of Prudhoe Bay crude oil (Peakall et at. 1987).

Another useful indicator of petroleum hydrocarbon exposure is the measure of variation of DNA content (DNA CV) in blood, which is measured by flow cytometry (McBee and Bickham 1988; McBee et al. 1987). Higher DNA CV in blood from black-crowned night-heron *(Nycticorax nycticorax*) embryos suggested cytogenetic damage at sites contaminated with petroleum (Custer et al. 2000; Custer et al. 1994).

The objective of this study was to compare petroleum hydrocarbon concentrations in tree swallows and house wrens nesting at locations along the River that were upstream of, adjacent to, or downstream from the oil refineries. Because trace element concentrations, MFO activity, and DNA CV are often associated with petroleum hydrocarbon concentrations in birds (Stegeman et al. 1992; Custer et al. 2000), each was measured as indicators of petroleum contamination. The collection of sediment and aquatic insect larvae for PAH and trace element analysis allowed us to characterize a possible contaminant source. Sediments serve as a sink for PAHs and are part of the exposure route from the benthic stage of aquatic insects to insectivorous birds like tree swallows that use the river extensively (Long and Morgan 1990).

STUDY SITES

The headwaters of the North Platte River originate in North Park, Colorado (Figure 1). A series of dams regulate the River as it flows north and then east to Casper, Natrona County, Wyoming. The River continues east and flows into Nebraska. Cottonwood (*Populus* spp.), Russian olive (*Elaeagnus angustifolia*), willows (*Salix* spp.), and riparian grasses border the River as it flows through Casper.

Study sites (Figure 2) along the River were: the Wyoming Game and Fish Department (1) and Patterson-Zonta City Park/Bridge (2). Both of these sites are upstream of the refineries and used as reference sites. The remaining study locations were: Amoco Park adjacent to the former Amoco Refinery (3); Crossroads City Park (4) and the Bryan Stocktrail Bridge (5), both of which are downstream of the former Amoco Refinery but upstream of the Texaco Refinery; the former Texaco Refinery and Bridge (6); and Edness K. Wilkens State Park (7), which is downstream from all refineries.

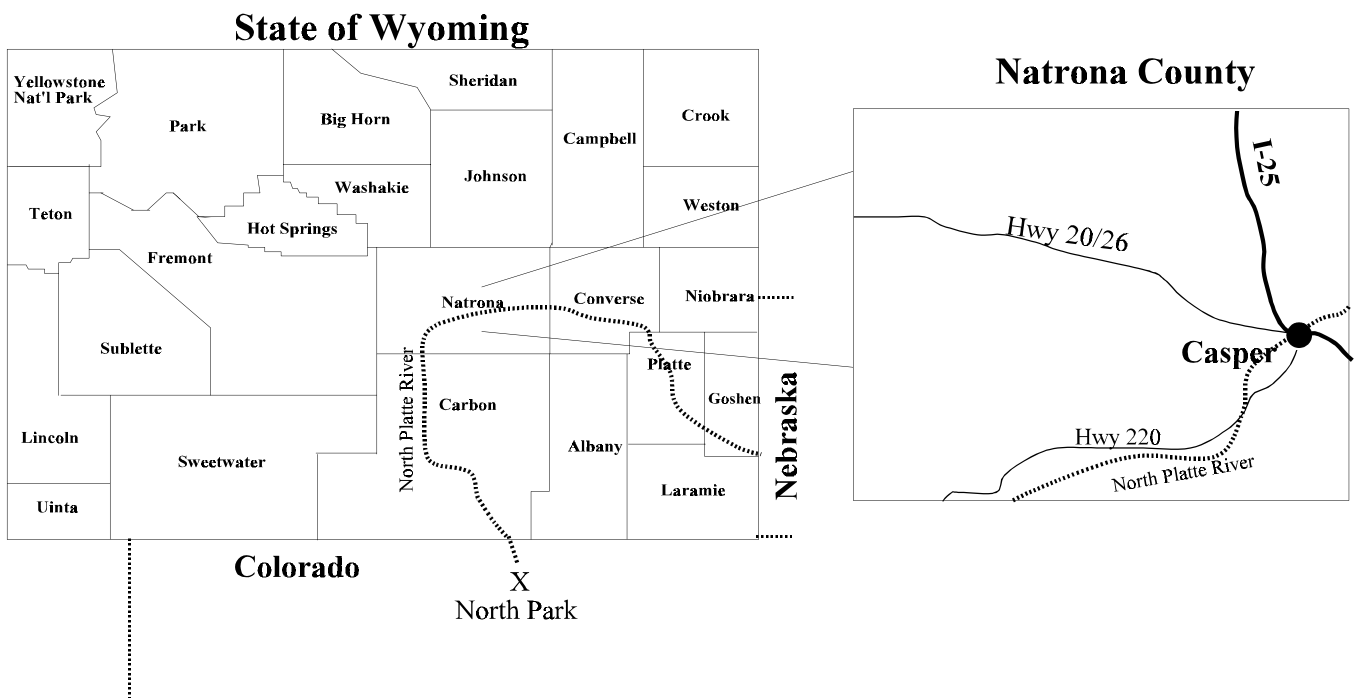

Figure 1. General location of study area, Casper, Natrona County, Wyoming.

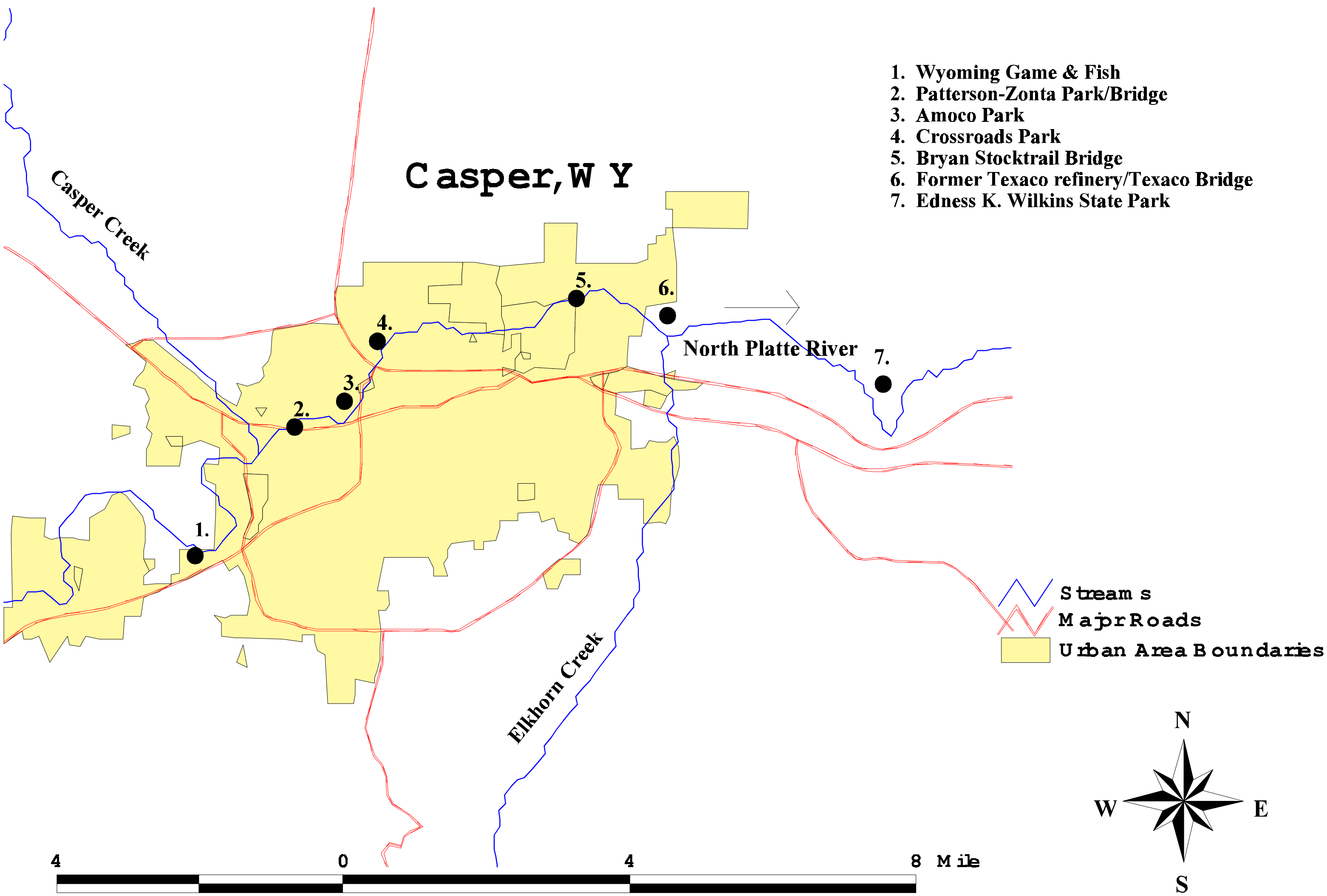

Figure 2. Locations of study sites along the North Platte River, Wyoming.

METHODS

Data Collection

Eggs and Nestlings

In May 1997, we attached 15 tree swallow nest boxes to metal posts and placed them approximately 40 yards apart along the shore of the North Platte River at Edness K. Wilkens State Park (EKW State Park). Because tree swallows and house wrens used the boxes readily for nesting we expanded our study and placed additional nest boxes in April 1998 along the shore of the River at the Wyoming Game and Fish Department (Game & Fish) (n=16), Patterson-Zonta Park (n=14), Amoco Park (n=21), Crossroads Park (n=24), and at the former Texaco Refinery (n=20). During both years, we checked boxes once per week until eggs were laid. Thereafter, the boxes were checked every three days until the eggs hatched and the nestlings fledged. We recorded the species nesting in each box and the number of eggs or young present during each visit. Nestlings were visually examined for morphological anomalies.

In 1997, we collected eggs from four house wrens (*Troglodytes aedon*) and three tree swallow nests at the EKW State Park; nestlings were collected from three wren and three tree swallow nests. In 1998, nest boxes at Patterson-Zonta Park, Amoco Park, and Crossroads Park were vandalized. As a result, tree swallow nesting was minimal and nesting wrens were unable to produce any eggs at these sites. The number of tree swallow eggs and 12-day old nestlings, respectively, that we collected are as follows: Game & Fish (3, 2), Patterson-Zonta Park (1, 1), Amoco Park (1, 1), Crossroads Park (0, 0) and the Texaco Refinery (4, 4). The number of house wren eggs and nestlings, respectively, that we collected included: Game & Fish (3, 3) and the Texaco Refinery (3, 3). One bank swallow (*Riparia riparia*) egg was collected from the Texaco Refinery site. Egg contents were placed into 120 ml chemically clean jars, frozen, and stored until trace element analysis. If more than one egg was collected from a nest, the eggs were pooled by nest.

Within two hours of collection, the 12-day old tree swallow and house wren nestlings from 1997 and 1998 were weighed ($\pm$0.1 g) and decapitated with a sharp pair of scissors. Blood from tree swallow nestlings collected in 1998 was obtained for flow cytometry analysis from the decapitated carcass using heparinized capillary tubes and aspirated into a cryotube containing freezing medium (Ham's F10 medium with 18% fetal calf serum and 10% glycerin). Each cryotube was rotated and frozen in liquid nitrogen.

The liver was removed from nestling house wren and tree swallow carcasses and weighed ($\pm$0.1 g). In tree swallows collected from 1998 about 0.3 g of liver from one chick per brood were placed into a cryotube for measurement of MFO activity. A few drops of glycerin were added to the cryotube and it was snap frozen in liquid nitrogen. The cryotubes were later transferred from the liquid nitrogen to an ultracold freezer (-80^{o}C) for storage until processing. The remaining livers were pooled by nest, placed in chemically clean jars and frozen at -80^{o}C until trace element analysis.

The upper gastrointestinal (GI) tract was removed from each of the nestling carcass. Contents (diet) were pooled by species and location, placed in chemically clean jars, and frozen at -80^{o}C until analysis. Samples from 1997 were analyzed for trace elements; whereas, samples from 1998 were analyzed for aliphatic hydrocarbons (AHs) and polycyclic aromatic hydrocarbons (PAHs). The nestling carcasses (including the heads, wings, feathers, beaks, and feet) were also pooled by nest and location, placed in chemically clean jars, frozen, and stored at -80^{o}C until analysis. Tree swallow nestlings from 1997 and 1998 and house wren nestlings from 1998 were analyzed for AHs, PAHs, and trace elements. House wren nestlings from 1997 were analyzed only for trace elements.

Additionally, we collected adult and fledgling cliff swallows (*Hirundo pyrrhonota*) from beneath three bridges across the River near the former Texaco Refinery (n=5), Bryan Stocktrail Bridge (n=5), and Patterson-Zonta Park (n=3). One barn swallow adult was also collected from the bridge at Patterson-Zonta Park. Mist nets were hung along side the bridges and swallows were collected alive. Within one hour of collection swallows were weighed ($\pm$0.1 g) and decapitated with a sharp pair of scissors. The liver, diet (GI tract contents), and carcasses were processed and analyzed identically to the house wren and tree swallow samples collected in 1998.

Sediment and Benthic Aquatic Insect Larvae

We collected composite sediment samples from the top six inches of sediment from each site, except EKW State Park, using a stainless steel spoon rinsed in de-ionized water and hexane. For AH and PAH analyses, one sediment sample and a duplicate were placed in chemically-cleaned amber glass jars and frozen. For trace element analyses, a sediment sample and a duplicate were placed in Whirl-Pak® bags and frozen.

We began our collection of benthic stage aquatic insects using benthic plate samplers, which are small round plates (10 cm. diameter) bolted together with 0.5 cm space between each plate. The samplers are attached to rocks, bank vegetation, or other substrate with rope or heavy gauge fishing line and submerged into the water. The plates provide an artificial habitat for the aquatic insect larvae. Because the river flow was high, we lost several samplers and decided to use kick nets as described in the U.S. Fish and Wildlife Service QA/QC protocols (U.S. Fish and Wildlife Service 1996) to collect insect larvae. Insect larvae collected included Plecoptera (stonefly), Odonata (damselfly), and Diptera (cranefly). Also, because of the difficulty in acquiring enough larval insects for analysis, stonefly and damselfly larvae were composited. Four samples of stonefly and damselfly larvae were placed in chemically clean 40 ml amber glass vials, frozen, and submitted for AH and PAH analyses. Three additional composite samples of stonefly and damselfly larvae were placed in chemically clean 40 ml clear glass vials, frozen, and submitted for trace element analysis. One sample of cranefly larvae from Amoco Park and one from Crossroads Park were collected, placed in chemically clean 40 ml clear glass vials, frozen, and submitted for trace element analysis.

Bioindicators Analysis

Tree swallow liver samples prepared for mixed function oxidase (MFO) activity in 1998 were shipped to Dr. Mark Melancon at Patuxent Wildlife Research Center, Laurel, Maryland. Hepatic microsomes were prepared from homogenates of thawed liver samples by differential centrifugation. The 11,000 g supernatant was centrifuged at 40,000 rpm for 60 minutes to obtain the microsomal pellet. Each 100,000 g pellet was resuspended in 2.0 ml/g of tissue weight of 0.05 M Na/K PO_4, 0.001 M disodium ethylenediamine tetraacetate, pH 7.6. Benzyloxyresorufin-O-dealkylase (BROD) and ethoxyresorufin-O-dealkylase (EROD) were assayed by the method of Burke and Mayer (1974) as adapted to a fluorescence microwell plate scanner (Melancon 1996). The 260 µl total assay volume contained microsomes equivalent to 0.65 mg liver, 2.5 µM substrate and 0.125 mM NADPH in 0.066 M Tris buffer, pH 7.4. Protein concentrations were determined by a 50% reduced volume Lowry assay (Lowry et al. 1951). BROD and EROD activities were calculated as pmol product/min/mg microsomal protein.

Blood of tree swallows collected for DNA CV analysis in 1998 were shipped to Dr. John Bickham at Texas A&M University, College Station, Texas. Frozen samples were thawed and aliquots of blood (50 µl) were removed for analysis. Suspensions of cell nuclei were prepared by the method of Vindelov et al. (1983). These samples were treated with RNase for at least 30 minutes and stained with propidium iodide for 15 minutes. Propidium iodide intercalates between the bases (Deitch et al 1982; Waring 1971) and stains both RNA and DNA. Nuclear DNA content was analyzed on a Coulter Profile II flow cytometer by quantification of nuclear fluorescence. This instrument utilizes a 488 nm Argon laser and is equipped with a computer program that determines half-peak coefficient of variation (CV) and mean, standard deviation, and number of cells for any particular region designated by the operator. Cells are simultaneously analyzed for nuclear fluorescence and side scatter, the latter of which is an indication of the amount of cytoplasm still attached to the nucleus. Therefore, cells with high levels of side scatter were excluded (gated) from the analysis in order to minimize variation resulting from sample preparation. We counted 10,000 cells in the G1 peak and recorded mean and standard deviation for each individual. The half peak CV of the gated G1 cell population was compared for each individual. Samples were analyzed as separate experiments, and all samples for a given experiment were analyzed consecutively on the same day to minimize variation. The machine operator was unaware of the identity of any samples and all samples were analyzed in random order. Chicken red blood cells and fluorescent microspheres were used as standards to align the flow cytometer.

Chemical Analysis

Aliquots of avian carcasses, avian GI contents, sediment, and invertebrates were analyzed for AHs and PAHs by Mississippi State Chemical Laboratory, Mississippi State University, Mississippi. Samples were digested in 6N aqueous potassium hydroxide for 24 h at 35^{o} C. Digestate was cooled and then neutralized with glacial acetic acid. The mixture was then extracted three times with methylene chloride and the extracts combined and concentrated to near dryness before reconstituting in petroleum ether for transfer to a 20 g 1% deactivated silica gel column topped with 5 g neutral alumina. AHs and PAHs were separated by eluting AHs from the column with 100 ml of petroleum ether; PAHs were eluted using 100 ml 40% methylene chloride/60% petroleum ether followed by 50 ml methylene chloride. The AH eluate was then concentrated to an appropriate volume for quantification by capillary column flame ionization gas chromatography (GC). The silica gel eluate containing the PAHs was concentrated and reconstituted in methylene chloride to be subjected to gel permeation chromatography cleanup prior to quantification by GC and fluorescence high-performance liquid chromatography. Minimum detection limits for AHs and PAHs were 0.01 µg/g wet weight (ww). The number of spikes, duplicates, and blanks was 9% of the total number of samples analyzed. Concentrations were not adjusted for recovery which averaged 71% and 78%, respectively, for the various AHs and PAHs. Concentrations of AHs and PAHs are reported on a wet weight basis.

Eggs, carcasses, and avian livers collected in 1997 and 1998, as well as the GI contents from birds collected at EKW in 1997 were analyzed for trace elements by Research Triangle Institute, Research Triangle Park, North Carolina. Trace element analysis for sediment and invertebrate samples was performed by Midwest Research Institute, Kansas City, Missouri. Samples were freeze-dried, weighed, and then homogenized in a blender. Subsamples of freeze-dried livers, sediments, and invertebrates were digested by nitric acid reflux and analyzed for total mercury by cold vapor atomic absorption spectrophotometry. Separate subsamples of the dried livers, sediments, and invertebrates were digested in stages with heat and nitric-perchloric acid and then analyzed for selenium and arsenic by graphite furnace atomic absorption spectrophotometry, and for the remaining trace elements by inductively coupled plasma - atomic emission spectrophotometry. The nominal lower limit of detection was 0.1, 0.2, 0.5 and 0.5 µg/g dry mass for cadmium, mercury, lead, and selenium. The number of spikes, duplicates, and blanks was 10% of the total number of samples analyzed. Concentrations were not adjusted for recovery, which averaged 91% overall for the various trace elements. Concentrations of trace elements are reported on a dry weight (dw) basis.

Statistical Analysis

Analytical results are presented individually in the appendices for each sediment sample and the duplicate taken at each site. However, for statistical purposes, the average concentration of a detected contaminant in a sediment sample and its duplicate is reported in the text because the samples cannot be considered independent.

We used one-half of the detection limits for those constituents reported as below the detection limit for statistical analyses. For measures of trace elements, AHs, PAHs, and monooxygenase activity, we log transformed (using base 10 logarithms) values to satisfy the homogeneity of variance assumption of analysis of variance (ANOVA). The Bonferroni multiple comparison method was used to determine differences among means. Unless otherwise stated, the probability level determining significance was $P \leq 0.05$. Linear correlation, using Pearson correlation coefficients, was used to identify associations among variables.

RESULTS AND DISCUSSION

Petroleum Hydrocarbons

Aliphatics

Several aliphatic hydrocarbons (AHs) were detected in sediment samples (Appendix 1). AHs were also detected in benthic aquatic insect larvae (Appendix 2) . Concentrations of total aliphatic hydrocarbons (TAHs) in insect larvae were highest at the upstream Game & Fish site, decreased slightly at Amoco Park, further decreased at Crossroads Park, and then increased at the Texaco Refinery site. Differences in TAHs in larvae samples were not significant among sites (Table 1).

Several AHs were detected in carcasses of nestling tree swallows and house wrens (Appendix 3, Appendix 4), and in the gastrointestinal contents of pooled diet samples of nestling tree swallows and house wrens (Appendix 5). Concentrations of TAHs were highest in nestling carcasses of both tree swallows and house wrens at the Game & Fish site and decreased slightly at the Texaco Refinery site (Table 1). TAH concentrations decreased further in tree swallow nestlings from EKW State Park site but differences in concentrations among sites were not significant. When only the Game & Fish and Texaco Refinery sites were considered, TAHs were not significantly different between species (wrens or swallows) or sites (two-way ANOVA, overall P=0.17) (Table 2). Concentrations of TAHs in the pooled diet sample from tree swallows nestlings tended to be higher at the Texaco Refinery site than the Game & Fish site; but, the concentration of TAHs in the pooled diet sample from house wrens was highest at the Game and Fish site and decreased at the Texaco Refinery site (Table 1).

Concentrations of TAHs from cliff swallows and the barn swallow collected under the various bridges along the River were detected in all carcasses. TAH concentrations were similar at all three sites (Table 3, Appendix 4) in the cliff swallows. Concentrations of TAHs in gastrointestinal samples from cliff swallows were highest at the Bryan Stocktrail Bridge followed by the Texaco Bridge. The upstream site (Patterson-Zonta Bridge) had the lowest concentration (Table 3, Appendix 5). However, these samples (carcasses and diet) were from adult birds that were no longer nesting or feeding young. Therefore, their tissue concentrations may reflect contaminant exposure outside the sampling area.

Table 1. Geometric means and ranges of total aliphatic hydrocarbon concentrations (µg/g wet weight) in sediment, benthic aquatic insect larvae, nestling carcasses, and pooled diet samples of nestlings from sites along the North Platte River.

Matrix / Species	Game & Fish	Patterson-Zonta Park	Amoco Park	Crossroads Park	Texaco Refinery	EKW State Park	ANOVA P values
Sediment	NC[a] (0.83 - 1.12) (n=2)		NC (0.82 - 1.2) (n=2)	NC (0.89 - 1.36) (n=2)	NC (1.47-1.48) (n=2)		
Invertebrates	6.2 (4.8 - 8.4) (n=4)		4.4 (0.7 - 11.9) (n=4)	2.6 (1.4 - 5.3) (n=4)	4.0 (2.8 - 8.6) (n=4)		0.48
Tree Swallow Nestling	NC (8.1 - 9.5) (n=2)	NC (7.30) (n=1)			6.4 (5.0 - 8.1) (n=4)	5.4 (5.1 - 7.1) (n=3)	0.10
House Wren Nestling	8.0 (6.8 - 9.3) (n=3)				6.4 (5.6 - 8.1) (n=3)		0.21
Tree Swallow Diet	5.6 (n=1)				75.6 (n=1)		----[b]
House Wren Diet	35.2 (n=1)				18.7 (n=1)		----

[a] NC = Geometric mean not calculable (n<3).
[b] Dashed lines indicate no ANOVA could be performed.

Table 2. Geometric means and ranges of total aliphatic hydrocarbon concentrations (µg/g wet weight) in carcasses of nestling tree swallows and house wrens from the Game & Fish site and the Texaco Refinery site along the North Platte River.

Species	Game & Fish	Texaco Refinery	2-way ANOVA P values / Mean Separation			
			Overall	Location	Species	Interaction
Tree Swallow Nestling	NC* (8.1 - 9.5) (n=2)	6.4 (5.0 - 8.1) (n=4)	0.17	0.03 Game & Fish > Texaco Refinery	0.69	0.67
House Wren Nestling	8.0 (6.8 - 9.3) (n=3)	6.4 (5.6 - 8.1) (n=3)				

* NC = Geometric mean not calculable (n<3).

Table 3. Geometric means and ranges of total aliphatic hydrocarbon concentrations (µg/g wet weight) in carcasses and pooled diet of adult swallows from sites along the North Platte River.

Matrix / Species	Patterson-Zonta Bridge	Bryan Stocktrail Bridge	Texaco Bridge	ANOVA P value
Adult Barn Swallow Carcass	8.73 (n=1)			----*
Adult Cliff Swallow Carcass	13.3 (9.8 - 17.3) (n=3)	15.3 (9.5 - 37.1) (n=5)	15.0 (8.1 - 70.0) (n=6)	0.89
Adult Cliff Swallow Diet	74.0 (n=1)	131 (n=1)	87.0 (n=1)	----

* Dashed lines indicate no ANOVA could be performed.

Ratios of certain hydrocarbons [pristane to n-heptadecane (n-C_{17}) and phytane to n-octadecane (n-C_{18})] can be used to indicate recent or chronic exposure to petroleum compounds (e.g. high ratios of pristane and phytane to n-C_{17} and n-C_{18}, respectively). Pristane and phytane are less abundant than n-C_{17} and n-C_{18} but they are frequently found in pollutant oils. Pristane and phytane are branched-chain rather than straight-chained hydrocarbons and consequently are less readily metabolized by organisms. Therefore, these compounds will accumulate in tissues when exposure to pollutant hydrocarbons is chronic such as the case when waterfowl ingest oil from contaminated food items or from preening oil-tainted feathers. (Hall and Coon 1988). Conversely, in acute incidences, it is expected that animals would have less time to accumulate pristane and phytane because acute exposures are often fatal. Consequently the ratios of pristane and phytane to n-C_{17} and n-C_{18}, ,respectively, are lower ratios than chronic ratios (Hall and Coon 1988).

Ratios of pristane and phytane to n-C_{17} and n-C_{18}, respectively, that could be calculated in sediment and benthic aquatic insect larvae samples are listed in Table 4. Ratios of phytane to n-C_{18} indicate that sediment from Amoco Park may have recently or may be chronically exposed to pollutant oil. Similarly, ratios of pristane to n-C_{17} by three of the four aquatic insect larvae and ratios of phytane to n-C_{18} by two of the four aquatic insect larvae at the Texaco Refinery site indicate possible recent or chronic exposure to petroleum hydrocarbons.

Pristane to n-C_{17} ratios were low for avian gastrointestinal contents and carcasses; and, phytane to n-C_{18} ratios were low in avian carcasses, which suggests that swallow and wren nestlings were not being chronically exposed to petroleum (Table 5). However, the phytane to n-C_{18} ratios were high in gastrointestinal contents of the cliff swallows and house wrens; and, the phytane to n-C_{18} ratios of the gastrointestinal contents of tree swallows were extremely high. Tree and cliff swallows consume emergent aquatic insects; whereas, house wrens consume terrestrial insects. The high phytane to n-C_{18} ratios of the gastrointestinal contents may indicate that some of the dietary items consumed by the birds were recently or chronically exposed to petroleum products.

Table 4. Concentrations of n-heptadecane (n-C_{17}), pristane, n-octadecane (n-C_{18}), and phytane (µg/g wet weight) in sediment and benthic aquatic insect larvae from the North Platte River. Samples where both pristane and phytane were below detection limits are not listed in this table.

Matrix / Species	Site	n-C_{17}	Pristane	Pristane/ n-C_{17} Ratio	n-C_{18}	Phytane	Phytane/ n-C_{18} Ratio
Sediments	Amoco Park	0.040	0.020	0.50	0.016	0.036	2.25
	Game & Fish	0.041	0.013	0.32	0.014	BDL*	—
	Texaco Refinery	0.066	BDL	<1.0	0.016	0.014	0.875
		0.062	BDL	<1.0	0.015	0.015	1.00
Stoneflies/Odonates	Amoco Park	2.6	0.013	0.0050	0.10	0.013	0.130
	Crossroads Park	3.3	0.081	0.025	0.075	0.011	0.147
		0.31	BDL	<1.0	0.024	0.012	0.500
	Texaco Refinery	1.1	1.2	1.1	0.029	BDL	—
		4.5	0.54	0.12	0.15	0.029	0.193
		0.17	0.90	5.3	0.020	0.023	1.15
		0.28	0.79	2.8	0.013	0.032	2.46

*BDL = Below Detection Limit

Table 5. Concentrations of n-heptadecane (n-C_{17}), pristane, n-octadecane (n-C_{18}), and phytane (µg/g wet weight) in avian gastrointestinal contents and carcasses collected from sites along the North Platte River. Samples where both pristane and phytane were below detection limits are not listed in this table.

Species	Matrix	Site	n-C_{17}	Pristane	Pristane / n-C_{17} ratio	n-C_{18}	Phytane	Phytane / n-C_{18} Ratio
Adult Cliff Swallow	Diet	Bryan Stocktrail Bridge	0.065	0.013	0.20	0.017	0.065	3.8
		Patterson-Zonta Park Bridge	0.12	0.041	0.34	0.061	0.12	2.0
		Texaco Bridge	0.36	0.010	0.028	0.060	0.36	6.0
Nestling House Wren	Diet	Texaco Bridge	0.14	0.023	0.16	0.041	0.14	3.4
		Game & Fish	0.10	0.020	0.20	0.039	0.10	2.6
Nestling Tree Swallow	Diet	Amoco Park	24	0.076	0.0030	0.29	24	83
		Patterson-Zonta Park	4.6	0.052	0.011	0.12	4.6	38
		Texaco Bridge	2.2	BDL*	<1.0	0.064	2.2	34
		Game & Fish	1.8	0.018	0.010	0.038	1.8	47
Adult Cliff Swallow	Carcass	Patterson-Zonta Bridge	0.23	BDL	<1.0	0.17	0.019	0.11
		Texaco Bridge	0.23	BDL	<1.0	0.18	0.022	0.12
			0.26	BDL	<1.0	0.23	0.013	0.057
			0.25	BDL	<1.0	0.27	0.043	0.16
			0.24	BDL	<1.0	0.24	0.039	0.16
			0.20	BDL	<1.0	0.19	0.093	0.49
Nestling Tree Swallow	Carcass	Patterson-Zonta Park	1.3	0.028	0.022	0.10	BDL	<1.0
		Texaco Refinery	0.44	BDL	<1.0	0.047	0.010	0.21
			1.1	0.023	0.021	0.084	BDL	<1.0
			0.64	BDL	<1.0	0.059	0.012	0.20
		Game & Fish	1.2	0.017	0.014	0.082	BDL	<1.0
Nestling House Wren	Carcass	Game & Fish	0.88	0.013	0.015	0.066	BDL	<1.0

*BDL - Below detection limit

Aromatics

Polycyclic aromatic hydrocarbons (PAHs) were detected in three out of four sediment samples (Table 6, Appendix 6). Although concentrations were low, benzo[a]pyrene (strongly carcinogenic), benzo[b]fluoranthene (moderately carcinogenic), and chrysene (weakly carcinogenic) (Eisler 1987a), were detected at the upstream Game and Fish site whereas, only chrysene was detected at the Texaco Refinery site (Table 7).

Most PAHs were not detected in benthic aquatic insect larvae (Appendix 7). However, one sample of benthic aquatic invertebrate larvae from Amoco Park had a concentration of 0.049 μg/g wet weight (ww) of perylene and one sample from the Texaco Refinery site had a concentration of 0.051 μg/g ww of perylene, but perylene is a naturally occurring PAH (Table 6).

Concentrations of total PAHs (TPAHs) were detected in carcasses of tree swallow and house wren nestlings at all sites (Appendix 8) except in tree swallows collected at EKW State Park (Appendix 9). Concentrations of TPAHs in tree swallow nestling carcasses did not differ significantly among sites (Table 6); but when only the Game & Fish and Texaco Refinery sites were considered, TPAHs in swallows were significantly higher at the Texaco Refinery than at the Game & Fish site. Similarly, concentrations of TPAHs in wren nestling carcasses were significantly higher at the Texaco Refinery site than at the Game & Fish site (Table 6). Wren nestling carcasses also had significantly higher concentrations of TPAHs than the swallow carcasses (Table 8).

The higher PAH concentrations in swallows and wrens near the Texaco Refinery site compared to those at the Game & Fish site suggest higher exposure to PAHs because PAHs are not commonly found in clean tissues and, when they are, tend to be present in very small amounts (Hall and Coon 1988). Once ingested by animals, petroleum hydrocarbons are rapidly metabolized. For example, 94% of PAHs injected into chicken eggs on day 4 of incubation were metabolized within 14 days (Naf et al. 1992). Additionally, the higher concentrations of PAHs in wren carcasses than in tree swallow carcasses suggests that because wrens are terrestrial feeders, these birds were probably accumulating contaminants from the surrounding land rather than the River.

Concentrations of TPAHs were not detected in samples of pooled GI contents from tree swallows or house wrens at the Game & Fish site or in the tree swallow collected from Patterson-Zonta Park. TPAHs were detected in pooled GI contents samples from tree swallows and house wrens at the Texaco Refinery site and in the one sample from Amoco Park (Table 6, Appendix 10). Concentrations of TPAHs indicate that both swallows and wrens are ingesting some contaminated food items. At the Texaco Refinery site, the carcinogenic compounds of benzo[a]pyrene, benzo[b]-fluoranthene, and chrysene were detected in the house wren GI contents sample; whereas in the tree swallow GI contents benzo[a]pyrene was not detected (Table 7). The GI content sample from the tree swallow at Amoco Park contained only chrysene. The non-carcinogenic PAH's detected in GI content samples of house wrens and tree swallows from the Texaco Refinery included 1,2-benzanthracene, benzo(e)pyrene, phenanthrene, benzo(g,h,i)perylene, fluoranthene, naphthalene, and pyrene. The GI content sample from the tree swallow at the Amoco Park site contained the same non-carcinogenic PAHs except benzo(g,h,i)perylene. Such non-carcinogenic compounds can potentially cause acute toxicity in some organisms (Eisler 1987a) but currently no information exists on critical levels of PAHs in bird tissue. The predominance of unsubstituted PAHs and the general lack of alkyl-PAHs in all samples suggests that most of the PAHs were combustion-derived rather than from oil pollution (Voudrias and Smith 1986). The only alkyl-PAHs in our samples were 0.018

µg/g C1-phenanthrenes in the pooled wren diet and 0.02 µg/g 2-methylnapthalene in the pooled tree swallow diet.

Concentrations of PAHs in gastrointestinal contents of adult cliff swallows were below detection limits at all sites (Appendix 10). Some concentrations of PAHs were detected in the one barn swallow carcass from Patterson-Zonta Park and in the cliff swallow carcasses from all three sites. Differences in mean PAHs among sites in cliff swallow carcasses were significant (Table 9, Appendix 8). The TPAH concentrations in the cliff swallow carcasses were much higher at the Texaco Bridge and Patterson-Zonta Bridge sites compared to those carcasses collected at the Bryan Stocktrail Bridge. Chrysene, a mild carcinogen, was detected in one carcass from the Bryan Stocktrail Bridge site and in two carcasses from the Texaco Bridge site (Table 7). Because these birds were adults and not juveniles, they may have accumulated the PAHs prior to their arrival at these sites. Therefore, results of PAHs in cliff swallow carcasses are inconclusive.

Table 6. Geometric means and ranges of total polycyclic aromatic hydrocarbon concentrations (µg/g wet weight) in sediment, nestling carcasses, and pooled diet samples of nestlings from sites along the North Platte River.

Matrix / Species	Game & Fish	Patterson-Zonta Park	Amoco Park	Crossroads Park	Texaco Refinery	EKW State Park	ANOVA P values
Sediment	NC[a] (0.135) (n=1)		NC (BDL) (n=1)	NC (0.06) (n=1)	NC (0.11) (n=1)		----[b]
Invertebrates	NC (BDL) (n=4)		NC (BDL - 0.049) (n=4)	NC (BDL) (n=4)	NC (BDL - 0.051) (n=4)		
Tree Swallow Nestling	NC BDL[c] (n=2)	NC (0.23) (n=1)	NC (0.02) (n=1)		0.011 (BDL - 0.03) (n=4)	0.0050 BDL (n=3)	0.29
House Wren Nestling	0.0080 (BDL - 0.02) (n=3)				0.049 (0.036 - 0.06) (n=3)	0.0050 BDL (n=3)	0.02
Tree Swallow Diet	NC (BDL) (n=1)	NC (BDL) (n=1)	NC (0.82) (n=1)		NC 0.026 (n=1)		----
House Wren Diet	NC (BDL) (n=1)				NC 0.76 (n=1)		----

[a] NC = Not calculable.

[b] Dashed lines indicate no ANOVA could be performed.

[c] BDL = below detection limit.

Table 7. Concentrations of carcinogenic polycyclic aromatic hydrocarbons (µg/g wet weight) detected in samples from sites along the North Platte River.

Matrix	Species	Site	benzo[a] pyrene	benzo[b] fluoranthene	chrysene
Sediment		Game & Fish	—	—	0.014
			0.013	0.021	0.020
		Texaco Refinery	—	—	0.019
			—	—	0.019
Diet	House Wren Nestling	Texaco Refinery	0.055	0.036	0.18
	Tree Swallow Nestling	Amoco Park	—	—	0.11
		Texaco Refinery	—	0.010	0.12
Carcass	Tree Swallow Nestling	Amoco Park	—	—	0.010
	Adult Cliff Swallow	Bryan Stocktrail Bridge	—	—	0.020
		Texaco Bridge	—	—	0.014
		Texaco Bridge	—	—	0.014
	Tree Swallow Nestling	Texaco Refinery	—	—	0.017
	House Wren Nestling	Texaco Refinery	—	—	0.013

Table 8. Geometric means and ranges of total polycyclic aromatic hydrocarbon concentrations (µg/g wet weight) in carcasses of nestling tree swallows and house wrens from the Game & Fish site and the Texaco Refinery site along the North Platte River.

Species	Game & Fish	Texaco Refinery	2-way ANOVA P values / Mean Separation			
			Overall	Location	Species	Interaction
Tree Swallow Nestling	NC[a] BDL[b] (n=2)	0.011 (BDL - 0.03) (n=4)	0.02	0.01 Texaco Refinery > Game & Fish	0.04 Wren > Swallow	0.24
House Wren Nestling	0.0080 (BDL - 0.02) (n=3)	0.049 (0.036 - 0.06) (n=3)				

[a] NC = Not calculable.

[b] BDL = below detection limit.

Table 9. Geometric means and ranges of total polycyclic aromatic hydrocarbon concentrations (µg/g wet weight) in carcasses of adult swallows from sites along the North Platte River.

Species	Patterson-Zonta Bridge	Bryan Stocktrail Bridge	Texaco Bridge	ANOVA P value
Adult Barn Swallow	NC[a] 0.02 (n=1)			
Adult Cliff Swallow	0.07 (0.04 - 0.11) (n=3)	0.01 (BDL [b] - 0.04) (n=5)	0.08 (0.03 - 0.14) (n=6)	0.004 Texaco, Patterson-Zonta > Bryan Stocktrail

[a] NC = Not calculable.

[b] BDL = below detection limit

Biomarkers

MFO Activity

Hepatic EROD and BROD activities in tree swallow livers were nine times higher at the Texaco Refinery site than at the Game & Fish site but the difference between the two sites is not significant based on ANOVA results (Table 10). These results suggest that the nestlings at the Texaco Refinery site were exposed most probably to PAHs and that the livers were attempting to detoxify the chemical.

Table 10. Geometric means of ethoxyresorufin-O-dealkylase (EROD) and benzyloxyresorufin-O-dealkylase (BROD) activities in livers of nestling tree swallows at two sites along the North Platte River.

Mean activity*/range			
	Game & Fish (n=2)	Texaco Refinery (n=4)	ANOVA P value
EROD	16.7 8.9 - 31.4)	151 (30.1 - 325)	0.07
BROD	5.70 (2.8 - 11.5)	54.1 (8.2 - 171)	0.099

* EROD and BROD activity measured as pmol product/min/mg microsomal protein.

DNA CV

Half peak and full peak analysis of the blood samples taken from nestling tree swallows and the PAH concentrations in the corresponding carcass tissue are shown in Table 11. Measurement at half peak and full peak show that the DNA CV in the blood samples is not correlated with the corresponding total PAH concentration in carcasses of nestling tree swallows among sites (Table 12). These data suggest that the exposure of the birds to PAHs is not sufficient to break chromosomes; however, our sample size was very small. Custer et al. (2000) found that in lesser scaup (*Aythya affinis*), collected from the Indiana Harbor Canal, the coefficient of variation of DNA content in the blood was correlated with PAH concentrations in the carcasses.

Table 11. Results of flow cytometry for DNA content from blood samples and corresponding PAH concentrations in carcasses of nestling tree swallows collected at three sites along the North Platte River.

Site	Half Peak Analysis	Full Peak Analysis	PAH (µg/g)
Texaco Refinery	3.50	5.05	0.030
	3.02	5.33	0.005
	2.45	4.30	0.005
	3.51	3.81	0.017
Amoco Park	3.82	4.08	0.120
Patterson-Zonta Park	3.37	4.38	0.023
Game & Fish	4.09	4.22	0.005
	3.97	4.37	0.005

Table 12. Pearson correlation coefficient / P value between coefficient of variation of DNA content from blood samples and the corresponding PAH concentration in carcasses of nestling tree swallows (n=8) collected from sites along the North Platte River.

	PAH in carcass of bird (µg/g)
Half Peak Analysis	0.27470 0.5103
Full Peak Analysis	-0.25603 0.5405

Trace Elements

Trace element concentrations were not elevated in sediment samples from any of the sites (Appendix 11) compared to the reference site and differences among sites were not significant. However, barium in all sediment samples from this study (154 - 226 μg/g dw, n=8) was higher than in sediment samples taken from the Sweetwater Arm Unit (26.27 - 133.6 μg/g dw, n=18) of Pathfinder National Wildlife Refuge, 50 miles southwest of Casper (Ramirez, Jr. et al. 1995). Similarly, selenium was higher in sediment samples from this study (0.93 - 1.31 μg/g dw, n=8) than in sediment samples (<0.497 - 0.880 μg/g dw, n=18) from the Pathfinder National Wildlife Refuge (Ramirez, Jr. et al. 1995). However, this refuge is upstream of the Kendrick Irrigation Project, which is suspected of contributing selenium through irrigation return flows to the North Platte River (See et al. 1992).

Chromium

Chromium was elevated in aquatic insect larvae samples from all sites (Table 13, Appendix12) including the upstream site but concentrations were not significantly different among sites. The cranefly larvae sample from Amoco Park had the highest chromium concentration of 281μg/g dry weight (dw). At Crossroads Park, a stonefly/damselfly sample had a concentration of 208 μg/g dw and the cranefly larval sample contained 95.9 μg/g dw. Stonefly/odonate samples from the Texaco Refinery site also contained high concentrations of chromium with one sample containing 166 μg/g dw and another 61.6 μg/g dw. Aquatic invertebrates were not collected from the River during the Kendrick Irrigation Project. However, damselfly larvae from Rasmus Lee Lake, Goose Pond, and Ilco Pond within the Kendrick Project area had <1.90 μg/g dw (See et al. 1992). Additionally, damselfly larvae sampled in 1997 from ponds located on the Texaco Refinery property had chromium concentrations ranging from 0.503 to 1.57 μg/g dw (Dickerson and Ramirez 1998).

The concentrations of chromium in these aquatic insect larvae samples indicate that chromium from the surrounding environment (water/sediment) is being incorporated into the tissue of these organisms. These elevated chromium samples may be indicative of areas where chromium concentrations are high. These concentrations of chromium also exceed the guideline of 4.0 μg/g. This guideline is the concentration indicative of contamination in biological tissue (Eisler 1986) but the biological significance of total chromium concentrations over 4.0 μg/g to organisms, including birds that consume this dietary intake, is unclear (Eisler 1986).

Additionally, in Table 13, the geometric means for both the Amoco and Crossroads Park sites are shown with and without cranefly larvae included in the calculations with the odonate/stonefly samples. There were only two cranefly larvae samples and these samples tended to have slightly higher trace element concentrations than the stonefly/odonate samples (Appendix 12). The difference may be due to the cranefly larvae inhabiting stream areas where water flow was slower.

Chromium was not detected in the bank swallow egg from the Texaco Refinery or any of the tree swallow or wren eggs collected (Appendix 13, Appendix 14). Chromium was detected in one nestling tree swallow liver from the Texaco Refinery site (1.02 μg/g dw) (Appendix 15) and in one nestling tree swallow liver from EKW State Park (0.507 µg/g) (Appendix 14). Chromium was detected in all samples of nestling tree swallow and house wren carcasses (Table 14, Appendix 14, Appendix 16). Bird carcass samples from EKW State Park in 1997 had significantly higher concentrations of chromium than carcasses collected from all the other sites in 1998 (Table 14). Because the chromium concentrations in the bird carcasses from EKW State Park are at levels that could adversely affect the birds health and/or reproduction, we asked the laboratory to verify the initial results by doing another analysis of the samples. The laboratory analyzed the samples on November 8, 1999. The verification results were identical; however, we believe that the extremely elevated chromium concentrations in the tree swallow carcasses are an anomaly since this element was not elevated in the livers of these same birds or eggs from the same nest. Chromium was detected in most cliff swallow carcass samples and the one barn swallow carcass but none exceeded background concentrations (Table 15, Appendix 16) and differences were not significant among sites.

Table 13. Geometric means and ranges of chromium concentrations (µg/g dry weight) in benthic aquatic insect larvae from sites along the North Platte River.

Site	Range	Geometric Mean[a]	P value	Range	Geometric Mean[b]
Game & Fish	10.6 - 43.3	27.8	0.86		
Amoco Park	7.89 - 281	21.2		7.89 - 10.5	8.97
Crossroads Park	5.16 - 208	32.2		5.16 - 208	22.4
Texaco Refinery	15.2 - 166	23.8			

[a] n = 4 for Amoco Park and Crossroads Park where three samples at each site were composited stonefly/damselfly larvae plus one cranefly larvae sample; n = 3 for the Texaco Refinery and Game & Fish sites where only stonefly/damselfly larvae were collected.
[b]n=3 where geometric mean where cranefly larvae samples from Amoco Park and Crossroads Park were excluded from analyses.

Table 14. Geometric means and ranges of chromium concentrations (µg/g dry weight) in carcasses of nestling tree swallows and house wrens from sites along the North Platte River.

Species	Site	Range	Geometric Mean	2 way ANOVA P values/Mean Separation			
				Overall	Location	Species	Interaction
Tree Swallow Nestling	Game & Fish	1.83 - 7.69 (n=2)	*NC	0.0001	0.0001 EKW State Park > Texaco Refinery, Game & Fish	0.25	0.58
	Patterson-Zonta Park	9.32 (n=1)	NC				
	Texaco Refinery	2.47 - 6.20 (n=4)	3.6				
	EKW State Park	155 - 328 (n=3)	205.6				
House wren Nestling	Game & Fish	0.758 - 3.54 (n=3)	1.8				
	Texaco Refinery	2.07 - 5.79 (n=3)	3.5				
	EKW State Park	97.1 - 244 (n=3)	159.1				

*NC = Geometric mean not calculable (n<3).

Table 15. Geometric means and ranges of chromium concentrations (µg/g dry weight) in adult swallow carcasses from sites along the North Platte River.

Species	Site	Range	Geometric Mean	ANOVA P value
Adult Barn Swallow	Patterson-Zonta Park Bridge	7.10 (n=1)	NC[a]	
Adult Cliff Swallow	Patterson-Zonta Park Bridge	2.27 - 8.12 (n=3)	4.8	0.76
	Bryan Stocktrail Bridge	2.25 - 7.94 (n=5)	3.7	
	Texaco Bridge	2.65 - 6.75 (n=6)	3.8	

[a] NC=Not Calculable (n<3).

Mercury

Mercury was below detection limits for all aquatic insect larvae samples except one cranefly larvae sample from Crossroads Park, which contained a concentration of 1.31 µg/g dw. Mercury was also elevated slightly in the two aquatic insect larvae samples from the Texaco Refinery site (Table 16, Appendix 12); but mercury was below detection limits (<0.103 µg/g dw) in damselfly larvae collected in 1997 from ponds located on the Texaco Refinery property (Dickerson and Ramirez 1998). Recommendations indicate that fish and other aquatic food items consumed by avian predators should not exceed 0.1 µg/g ww or 0.4 µg/g dw assuming 75% moisture (Eisler 1987b). This recommended maximum food item concentration is based on the ability of mercury to bioaccumulate and biomagnify in the food chain (Jernelov and Lann 1971); although, the toxicity of mercury to avian species varies with form, dose, route of administration, species, sex, age, and physiological condition of the bird.

Table 16. Geometric means and ranges of mercury concentrations (µg/g dry weight) in benthic aquatic insect larvae from sites along the North Platte River.

Site	Range	Geometric Mean[a]	P value	Range	Geometric Mean[b]
Game & Fish	BDL[c]	BDL	----[d]		
Amoco Park	BDL	BDL		BDL	BDL
Crossroad Park	BDL - 1.31	0.109		BDL	BDL
Texaco Refinery	0.407 - 0.848	0.693			

[a] n = 4 for Amoco Park and Crossroads Park where three samples at each site were composited stonefly/damselfly larvae plus one cranefly larvae sample; n = 3 for the Texaco Refinery and Game & Fish sites where only stonefly/damselfly larvae were collected.
[b]n=3 where geometric mean where cranefly larvae samples from Amoco Park and Crossroads Park were excluded from analyses.
[c] BDL = Below Detection Limit.
[d] Dashed lines indicate no ANOVA could be performed.

Mercury was detected in tree swallow eggs from the Game & Fish site, the Texaco Refinery, and EKW State Park sites (Table 17, Appendix 13, Appendix 14). Mercury was significantly higher in eggs from EKW State Park when compared to the upstream Game & Fish site. Mercury was also detected in the one bank swallow egg (0.198 µg/g) from the Texaco Refinery site, the one tree swallow egg (0.22 µg/g dw) from Amoco Park, and the one tree

Table 17. Geometric means and ranges of mercury concentrations (µg/g dry weight) in eggs of tree and bank swallows and house wrens from sites along the North Platte River.

Species	Site	Range	Geometric Mean	2 way ANOVA P values/Mean Separation			
				Overall	Location	Species	Interaction
Tree Swallow	Game & Fish	0.26 -0.32 (n=3)	0.28	0.0001	0.01 EKW State Park> Game & Fish	0.0001 Swallow > Wren	0.85
	Patterson-Zonta Park	0.55 (n=1)	NC[a]				
	Amoco Park	0.22 (n=1)	NC				
	Texaco Refinery	0.19 - 0.48 (n=4)	0.39				
	EKW State Park	0.39 - 0.76 (n=3)	0.58				
Bank Swallow	Texaco Refinery	0.198 (n=1)	BDL[b]				
House Wren	Game & Fish	BDL (n=3)	BDL				
	Texaco Refinery	BDL - 0.20 (n=3)	0.10				
	EKW State Park	0.12-0.17 (n=3)	0.14				

[a] NC=Not Calculable.
[b] BDL = Below Detection Limit

swallow egg (0.549 μg/g dw) from Patterson-Zonta Park (Table 17). Concentrations of mercury >3.6 μg/g dw (assuming 75% moisture) in avian eggs are associated with adverse affects (Eisler 1987b). The concentrations in these egg samples do not exceed 3.6 μg/g dw but do indicate exposure to mercury. The geometric means give a preliminary indication that mercury is accumulated in a downstream pattern; but the concentrations of mercury in these samples are within background levels and do not appear to be bioaccumulating in birds to concentrations expected to cause adverse effects.

Mercury concentrations in house wren eggs were below detection limits for all samples except for the one at the Texaco Refinery site, which had a concentration of (0.198 μg/g dw), and the three collected at EKW State Park (0.12-0.17 μg/g) (Table 17). Because house wrens are terrestrial feeders and tree swallows are consuming emerging aquatic insects, this preliminary data may indicate that mercury is being obtained more from an aquatic source rather than a terrestrial source.

Mercury was detected and significantly higher in nestling tree swallow and house wren livers from Texaco and EKW State Park than from the Game& Fish site (Table 18, Appendix 14, Appendix 15). Mercury was also detected in one tree swallow liver from Amoco but not in the one liver sample from Patterson-Zonta Park. The mercury concentrations in the liver samples, like the egg samples, indicate exposure but concentrations were within background levels and indicate that bioaccumulation is not occurring. Mercury was detected in one of the three house wren liver samples from the Texaco Refinery site and one from EKW State Park; but mercury was not detected in house wren liver samples from the Game & Fish site. Mercury was also detected in tree swallow carcasses from the Texaco Refinery and the EKW State Park and in one house wren from EKW State Park (Table 19). Mercury was not detected in house wrens from either the Game & Fish or the Texaco Refinery site and mercury was not detected in bird carcasses from the Game & Fish site, Patterson-Zonta Park or Amoco Park (Table 19).

Similarly, mercury was also detected in the one barn swallow liver from Patterson-Zonta Park Bridge and in cliff swallow livers from all sites with the highest concentrations occurring in birds collected at the Texaco Bridge (Table 20, Appendix 15). Mercury was detected in most cliff swallow carcasses indicating some exposure to mercury but none exceeded background concentrations (Appendix 16) and differences were not significant among sites (Table 20). Mercury was highest in the one barn swallow carcass from Patterson-Zonta Bridge.

Table 18. Geometric means and ranges of mercury concentrations (µg/g dry weight) in livers of nestling tree swallows and house wrens from sites along the North Platte River.

Species	Site	Range	Geometric Mean	2 way ANOVA P values/Mean Separation			
				Overall	Location	Species	Interaction
Tree Swallow Nestling	Game & Fish	BDL[a] (n=2)	NC[b]	0.0003	0.002 Texaco Refinery, EKW State Park > Game & Fish	0.0008 Swallow > Wren	0.03
	Patterson-Zonta Park	BDL (n=1)	NC				
	Amoco Park	0.109 (n=1)	NC				
	Texaco Refinery	0.151 - 0.212 (n=4)	0.19				
	EKW State Park	0.158 - 0.266 (n=3)	0.19				
House Wren Nestling	Game & Fish	BDL (n=3)	BDL				
	Texaco Refinery	BDL - 0.151 (n=3)	0.07				
	EKW State Park	BDL - 0.119 (n=3)	0.07				

[a] BDL = Below Detection Limit.

[b] NC=Not Calculable.

Table 19. Geometric means and ranges of mercury concentrations (µg/g dry weight) in carcasses of nestling tree swallows and house wrens from sites along the North Platte River.

Species	Site	Range	Geometric Mean	2 way ANOVA P values/Mean Separation			
				Overall	Location	Species	Interaction
Tree Swallow Nestling	Game & Fish	BDL[a] (n=2)	NC[b]	0.001	0.0003 Texaco Refinery, EKW State Park > Game & Fish	0.0001 Swallow > Wren	0.0009
	Patterson-Zonta Park	BDL (n=1)	NC				
	Amoco Park	BDL (n=1)	NC				
	Texaco Refinery	0.155 - 0.216 (n=4)	0.19				
	EKW State Park	0.130 - 0.190 (n=3)	0.15				
House Wren Nestling	Game & Fish	BDL (n=3)	BDL				
	Texaco Refinery	BDL (n=3)	BDL				
	EKW State Park	BDL - 0.107 (n=3)	0.06				

[a] BDL = Below Detection Limit.

[b] NC=Not Calculable.

Table 20. Geometric means and ranges of mercury concentrations (µg/g dry weight) in adult swallow livers and carcasses from sites along the North Platte River.

Species	Matrix	Site	Range	Geometric Mean	ANOVA P value
Adult Barn Swallow	Liver	Patterson-Zonta Park Bridge	0.242 (n=1)	NC[a]	
Adult Cliff Swallow	Liver	Patterson-Zonta Park Bridge	BDL[b] - 0.218 (n=3)	0.12	0.03 Texaco Bridge > Patterson-Zonta Bridge
		Bryan Stocktrail Bridge	BDL - 0.356 (n=5)	0.14	
		Texaco Bridge	0.270 - 0.715 (n=6)	0.45	
Adult Barn Swallow	Carcass	Patterson-Zonta Park Bridge	0.769 (n=1)	NC	
Adult Cliff Swallow	Carcass	Patterson-Zonta Park Bridge	0.257 - 0.495 (n=3)	0.36	0.20
		Bryan Stocktrail Bridge	BDL -0.549 (n=5)	0.17	
		Texaco Bridge	0.232 - 0.588 (n=6)	0.42	

[a] NC=Not Calculable.
[b] BDL = Below Detection Limit.

Selenium

Selenium concentrations were elevated in all aquatic invertebrate samples (Appendix 12) and differences among sites were significant (Table 21). Selenium was highest at the upstream Game & Fish site and decreased in a downstream manner. Mean selenium concentrations were above the 3.0 µg/g dw threshold for all sites. Dietary selenium concentrations >3.0 µg/g dw can bioaccumulate through the food chain leading to adverse reproductive effects in aquatic birds (Lemly and Smith 1987; Ohlendorf et al. 1986). According to Lemly (1993), concentrations of 3.0 µg/g dw is the dietary toxicity threshold where the food organisms, although not directly affected themselves, could supply potentially toxic doses of selenium to species which are sensitive to selenium. The upstream Game & Fish site had the highest overall mean concentration for selenium. It is very likely the source of selenium is from the Kendrick Irrigation Project. Irrigation return flow runs into the River both above and below the reference site. Concentrations of selenium in odonate larvae collected from the Goose Lake and Rasmus Lee Lake wetlands on the Kendrick project area had geometric mean concentrations of 46.7 and 94.4 µg/g dw, respectively (See et al. 1992).

Table 21. Geometric means and ranges of selenium concentrations (µg/g dry weight) in benthic aquatic insect larvae from sites along the North Platte River.

<table>
<tr><th>Site</th><th>Range</th><th>Geometric Mean[a]</th><th>ANOVA P value</th><th>Range</th><th>Geometric Mean[b]</th></tr>
<tr><td>Game & Fish</td><td>8.82 - 11.0</td><td>10.2</td><td rowspan="4">0.04
Game & Fish >
Crossroads Park >
Amoco Park,
Texaco Refinery</td><td></td><td></td></tr>
<tr><td>Amoco Park</td><td>5.80 - 8.87</td><td>7.17</td><td>5.80 - 7.65</td><td>6.56</td></tr>
<tr><td>Crossroads Park</td><td>7.91 - 9.99</td><td>9.08</td><td>9.08 - 9.99</td><td>9.46</td></tr>
<tr><td>Texaco Refinery</td><td>5.68 - 8.64</td><td>7.27</td><td></td><td></td></tr>
</table>

[a] n = 4 for Amoco Park and Crossroads Park where three samples at each site were composited stonefly/damselfly larvae plus one cranefly larvae sample; n = 3 for the Texaco Refinery and the Game & Fish site where only stonefly/damselfly larvae were collected.

[b]n=3 where geometric mean where cranefly larvae samples from Amoco Park and Crossroads Park were excluded from analyses.

Selenium was detected in all egg samples from bank and tree swallows and house wrens (Appendix 13, Appendix14). There was no significant difference in selenium concentrations between the Game & Fish and the Texaco Refinery sites, although both of these sites showed higher selenium concentrations in eggs than EKW State Park (Table 22). Little information exists on the effects of selenium to small passerine birds. One study by King et al. (1994) indicated that concentrations of selenium greater than the background level of 3 μg/g dw in barn swallow eggs from a site in Texas near a selenium contaminated lake caused no reproductive problems (n = 20, range = below detection limit to 12 μg/g dw, geometric mean = 2.8 μg/g dw). However, a selenium concentration of 10 μg/g dw in sensitive aquatic bird eggs is the recommended embryotoxic threshold (USDOI 1998; Heinz 1996). Above this threshold, embryo viability and egg hatchability can be affected (Heinz 1996). According to Skorupa et al. (1996), the mean avian egg background concentration for selenium should be <3 μg/g dw with a concentration of <5 μg/g dw as a maximum background concentration. The onset of adverse effects to sensitive avian species occurs at a mean egg concentration of 8 - 10 μg/g dw with teratogenic effects occurring at 13 to 24 μg/g dw. Although some of the eggs samples we collected were elevated above the recommended background levels of between 3 and 5 μg/g dw, the selenium concentrations were below the concentrations shown to cause teratogenic effects.

Selenium was detected in livers from all bank and tree swallow and house wren nestlings (Appendix 14, Appendix 15). Concentrations tended to decrease in a downstream manner with significant differences among sites (Table 23). The Game & Fish and the Texaco Refinery sites had higher concentrations than EKW State Park. Additionally, livers from the tree swallow nestlings tended to have significantly higher selenium concentrations than the livers from the house wren nestlings. This may further support the idea that selenium concentrations are a result of the irrigation return flows into the River because the tree swallows gather most of their dietary items in aquatic systems as opposed to the more terrestrial feeding house wrens. Hepatic selenium concentrations >30 mg /kg are likely to cause reproductive impairments in aquatic birds; but it is thought that concentration <10 mg/kg indicate normal selenium exposure (USDOI 1998).

In swallow and house wren nestlings, selenium was detected in all carcasses (Appendix 14, Appendix 16). Differences were significant among sites with selenium concentrations tending to decrease downstream (Table 24). However, the tree swallow carcass from the Patterson-Zonta Park had a comparatively low selenium concentration of 1.26 μg/g dw. Tree swallow carcasses also had significantly higher concentrations of selenium than the house wren carcasses. Little reliable field information exists on selenium in avian muscle or carcasses (USDOI 1998).

Selenium was detected in adult cliff swallow liver samples but differences were not significant among sites (Table 25, Appendix 15). Selenium was also detected in the barn swallow liver sample from Patterson-Zonta Park, upstream of the refineries indicating the source of selenium is likely from irrigation return flows. Similarly, adult cliff swallow carcasses had selenium detected in all samples but differences were not significant among sites (Table 25, Appendix 16).

Table 22. Geometric means and ranges of elevated selenium concentrations (µg/g dry weight) in eggs of tree and bank swallows and house wrens from sites along the North Platte River.

Species	Site	Range	Geometric Mean	2 way ANOVA P values/Mean Separation			
				Overall	Location	Species	Interaction
Tree Swallow Nestling	Game & Fish	6.20 - 7.56 (n=3)	7.0	0.007	0.002 Game & Fish, Texaco Refinery > EKW State Park	0.55	0.20
	Patterson-Zonta Park	6.29 (n=1)	NC[a]				
	Amoco Park	5.98 (n=1)	NC				
	Texaco Refinery	5.41 - 8.86 (n=4)	7.3				
	EKW State Park	3.56 - 4.85 (n=3)	4.3				
Bank Swallow Nestling	Texaco Refinery	6.84 (n=1)	NC				
House Wren Nestling	Game & Fish	6.04 - 7.21 (n=3)	6.6				
	Texaco Refinery	5.58 - 6.35 (n=3)	5.9				
	EKW State Park	4.25 - 6.34 (n=3)	4.9				

[a] NC = Not Calculable.

Table 23. Geometric means and ranges of elevated selenium concentrations (µg/g dry weight) in livers of nestling tree swallows and house wrens from sites along the North Platte River.

Species	Site	Range	Geometric Mean	2 way ANOVA P values/Mean Separation			
				Overall	Location	Species	Interaction
Tree Swallow Nestling	Game & Fish	22.5 - 27.8 (n=3)	25.0	0.002	0.001 Game & Fish, Texaco Refinery > EKW State Park	0.02 Swallow > Wren	0.19
	Patterson-Zonta Park	26.6 (n=1)	NC*				
	Amoco Park	17.8 (n=1)	NC				
	Texaco Refinery	15.3 - 22.0 (n=4)	18.5				
	EKW State Park	12.9 - 17.6 (n=3)	15.6				
House Wren Nestling	Game & Fish	17.4 - 22.8 (n=3)	20.4				
	Texaco Refinery	15.4 - 19.5 (n=3)	17.1				
	EKW State Park	7.02 - 11.5 (n=3)	9.7				

* NC = Not Calculable.

Table 24. Geometric means and ranges of elevated selenium concentrations (µg/g dry weight) in carcasses of nestling tree swallows and house wrens from sites along the North Platte River.

Species (number collected)	Site	Range	Geometric Mean	2 way ANOVA P values/Mean Separation			
				Overall	Location	Species	Interaction
Tree Swallow Nestling	Game & Fish	10.6 - 13.5 (n=3)	11.9	0.0002	0.0005 Game & Fish, Texaco Refinery > State Park	0.0001 Swallows> Wrens	0.48
	Patterson-Zonta Park	1.25 (n=1)	NC*				
	Amoco Park	8.99 (n=1)	NC				
	Texaco Refinery	8.82 - 11.6 (n=4)	9.6				
	EKW State Park	6.78 - 8.09 (n=3)	7.6				
House Wren Nestling	Game & Fish	6.89 - 7.87 (n=3)	7.4				
	Texaco Refinery	5.95 - 8.21 (n=3)	7.0				
	EKW State Park	3.59 - 5.44 (n=3)	4.6				

* NC = Not Calculable.

Table 25. Geometric means and ranges of selenium concentrations (µg/g dry weight) in adult swallow livers and carcasses from sites along the North Platte River.

Species	Matrix	Site	Range	Geometric Mean	ANOVA P value
Adult Barn Swallow	Liver	Patterson-Zonta Park Bridge	16.3 (n=1)	NC*	
Adult Cliff Swallow	Liver	Patterson-Zonta Park Bridge	8.59 - 12.6 (n=3)	10.0	0.61
		Bryan Stocktrail Bridge	8.33 - 12.2 (n=5)	10.9	
		Texaco Bridge	7.76 - 11.8 (n=6)	9.9	
Adult Barn Swallow	Carcass	Patterson-Zonta Park Bridge	6.96 (n=1)	NC	
Adult Cliff Swallow	Carcass	Patterson-Zonta Park Bridge	4.91 - 5.80 (n=3)	5.4	0.37
		Bryan Stocktrail Bridge	4.29 - 11.6 (n=5)	6.8	
		Texaco Bridge	4.47 - 7.21 (n=6)	5.6	

* NC=Not Calculable.

SUMMARY

Our results suggest that for the study period, oil seeps into the North Platte River were not contributing significant PAH contamination into the aquatic food chain. In general, sample sizes were small and no conclusions can be made regarding those sites that had only one sample of a particular matrix. Additionally, we do not know the influence of yearly variation on the results of the AH and PAH analyses or trace elements analysis from 1997 to 1998, but the 1997 data from the EKW State Park were not critical to the overall conclusions of the study.

At those sites with larger sample sizes, we can make some general statements. PAHs were detected in sediment samples and in nestling tree swallow and house wren tissue indicating that these birds were exposed to PAHs. Additionally, total PAH concentrations in tree swallow and wren carcasses were significantly higher at the Texaco Refinery site than at the upstream reference site. However, the lack of methylated PAHs in carcasses, diet, and sediment samples suggests that the source of PAHs on the North Platte River was from combustion and not from petroleum. Also, the low pristane to n-C_{17} ratios in avian diet and tissue samples indicate a lack of chronic exposure in birds to petroleum at any of the sampling locations. Hepatic monooxygenase activities in tree swallows were induced nine-fold near the Texaco Refinery; but, this is probably a result of exposure to PAHs, which originated from combustion based on the lack of methylated PAHs found. The dynamic river system, with annual flushing flows, may not retain contaminants in concentrations that would adversely affect wildlife as could be the case in a lentic system.

Most trace elements were not elevated in any of the samples. Chromium was elevated in aquatic insect larvae from all sites but was either not detected or not accumulating in the avian samples above background concentrations. The exception was in nestling tree swallow and house wren carcass samples from EKW State Park, which had significantly higher concentrations of chromium than all the other sites. These very high chromium concentrations, could adversely affect the birds health and/or reproduction, but may indicate possible laboratory contamination. Mercury was significantly higher in tree swallow eggs from EKW State Park than the reference site but mercury concentrations in wren eggs were not detected. Mercury was significantly higher in bird livers at the Texaco Refinery site and EKW State Park when compared to the reference site. The source of the mercury is unknown but concentrations are within background levels. Selenium was elevated in aquatic insect larvae samples and detected in avian eggs, livers, and carcasses. Selenium tended to decrease downstream, although differences among sites were not significant and are most likely the result of irrigation return flows.

The North Platte River is complex with many contaminant sources influencing the system. Our study only begins to determine the bioavailability of some of the contaminants to birds. Contaminants such as pesticides or other organic compounds (e.g. PCBs, dioxins) and sewage outfall were not considered in this study but may be present.

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Appendix 1. Aliphatic hydrocarbon concentrations (µg/g wet weight) in sediment from the North Platte River, 1998.

Sediment Sample #	Site	n-decane	n-docosane	n-dodecane	n-dotriacontane	n-eicosane	n-heneicosane	n-hentriacontane
NPAPSD03	Amoco Park	0.021	<0.0100	0.033	<0.010	0.048	0.031	0.11
NPAPSD04	Amoco Park	0.013	<0.0100	0.025	0.012	0.020	0.021	0.11
NPCRSD03	Crossroads Park	0.014	<0.0100	0.025	<0.010	0.019	0.021	0.095
NPCRSD04	Crossroads Park	0.015	<0.0100	0.027	<0.010	0.017	0.021	0.12
NPGFSD05	Game & Fish	0.056	<0.0100	<0.010	<0.010	0.017	0.024	0.11
NPGFSD06	Game & Fish	0.014	<0.0100	0.024	<0.010	0.015	0.022	0.083
NPTXSD03	Texaco Refinery	0.015	<0.0100	0.027	0.016	0.022	0.031	0.30
NPTXSD04	Texaco Refinery	0.017	<0.0100	0.030	0.011	0.020	0.026	0.31

Sediment Sample #	Site	n-heptacosane	n-heptadecane	n-hexacosane	n-hexadecane	n-nonacosane	n-nonadecane	n-octacosane
NPAPSD03	Amoco Park	0.12	0.040	<0.0100	0.020	0.24	0.013	0.19
NPAPSD04	Amoco Park	0.083	0.057	<0.0100	0.017	0.17	0.021	0.060
NPCRSD03	Crossroads Park	0.078	0.62	<0.0100	0.018	0.21	0.023	0.054
NPCRSD04	Crossroads Park	0.083	0.062	<0.0100	0.014	0.23	0.024	0.062
NPGFSD05	Game & Fish	0.18	0.041	0.0360	0.016	0.33	<0.010	0.092
NPGFSD06	Game & Fish	0.12	0.047	<0.0100	0.012	0.28	<0.010	0.048
NPTXSD03	Texaco Refinery	0.15	0.066	0.0180	0.016	0.38	0.023	0.11
NPTXSD04	Texaco Refinery	0.14	0.062	<0.0100	0.016	0.39	0.022	0.090

Appendix 1 cont.

Sediment Sample #	Site	n-octadecane	n-pentacosane	n-pentadecane	n-tetracosane	n-tetradecane	n-tetratriacontane	n-triacontane
NPAPSD03	Amoco Park	0.016	0.040	0.021	0.0130	0.034	0.0150	0.0100
NPAPSD04	Amoco Park	0.013	0.031	0.012	<0.0100	0.022	<0.0100	0.0120
NPCRSD03	Crossroads Park	0.013	0.015	0.014	<0.0100	0.020	<0.0100	0.0120
NPCRSD04	Crossroads Park	0.011	0.021	0.014	<0.0100	0.019	0.0120	0.0160
NPGFSD05	Game & Fish	0.014	0.069	0.011	0.0210	0.016	<0.0100	0.0180
NPGFSD06	Game & Fish	0.011	0.028	0.010	<0.0100	0.018	<0.0100	<0.0100
NPTXSD03	Texaco Refinery	0.016	0.060	0.016	<0.0100	0.022	0.0130	0.0320
NPTXSD04	Texaco Refinery	0.015	0.048	0.015	<0.0100	0.023	0.0110	0.0250

Sediment Sample #	Site	n-tricosane	n-tridecane	n-tritriacontane	n-undecane	phytane	pristane
NPAPSD03	Amoco Park	<0.010	0.018	0.065	0.0460	0.0360	0.0200
NPAPSD04	Amoco Park	0.013	0.014	0.053	0.0370	<0.0100	<0.0100
NPCRSD03	Crossroads Park	<0.010	0.016	0.052	0.0360	<0.0100	<0.0100
NPCRSD04	Crossroads Park	<0.010	0.018	0.062	0.0390	<0.0100	<0.0100
NPGFSD05	Game & Fish	0.024	<0.010	0.033	<0.0100	<0.0100	0.0130
NPGFSD06	Game & Fish	0.015	0.016	0.028	0.0370	<0.0100	<0.0100
NPTXSD03	Texaco Refinery	0.023	0.019	0.11	0.0390	0.0140	<0.0100
NPTXSD04	Texaco Refinery	0.018	0.019	0.11	0.0420	0.0150	<0.0100

Appendix 2. Aliphatic hydrocarbon concentrations (μg/g wet weight) in benthic aquatic insect larvae from the North Platte River, 1998.

Invertebrate Sample #	Common Name	Site	n-decane	n-docosane	n-dodecane	n-dotriacontane	n-eicosane	n-heneicosane
NPAPAI04	Stoneflies/Odonates	Amoco Park	0.024	0.025	0.0180	<0.0100	0.046	0.44
NPAPAI06	Cranefly larvae	Amoco Park	<0.010	0.019	<0.0100	<0.0100	0.017	0.17
NPAPAI09	Stoneflies/Odonates	Amoco Park	0.022	0.030	0.0220	<0.0100	0.044	0.39
NPAPAI10	Stoneflies/Odonates	Amoco Park	0.020	0.067	0.0230	<0.0100	0.067	0.73
NPCRAI02	Cranefly larvae	Crossroads Park	0.021	0.016	0.0200	<0.0100	0.016	0.19
NPCRAI06	Stoneflies/Odonates	Crossroads Park	0.027	0.019	0.0280	<0.0100	0.024	0.24
NPCRAI09	Stoneflies/Odonates	Crossroads Park	<0.010	<0.010	<0.0100	<0.0100	0.021	0.23
NPCRAI10	Stoneflies/Odonates	Crossroads Park	0.026	0.036	0.0220	0.0150	0.026	0.37
NPGFAI04	Stoneflies/Odonates	Game & Fish	0.014	0.019	0.0150	0.0140	0.028	0.30
NPGFAI07	Stoneflies/Odonates	Game & Fish	0.023	0.032	0.0200	<0.0100	0.035	0.38
NPGFAI09	Stoneflies/Odonates	Game & Fish	0.023	0.025	0.0230	0.0250	0.055	0.56
NPGFAI10	Stoneflies/Odonates	Game & Fish	0.022	0.021	0.0220	<0.0100	0.064	0.81
NPTXAI04	Stoneflies/Odonates	Texaco Refinery	0.018	0.047	0.0180	0.0380	0.022	0.17
NPTXAI05	Stoneflies/Odonates	Texaco Refinery	0.022	0.034	0.0220	0.0240	0.046	0.36
NPTXAI09	Stoneflies/Odonates	Texaco Refinery	0.019	0.038	0.0180	0.0160	0.014	0.096
NPTXAI10	Stoneflies/Odonates	Texaco Refinery	0.023	0.037	0.0210	<0.0100	0.025	0.19

Appendix 2 cont.

Invertebrate Sample #	Common Name	Site	n-hentriacontane	n-heptacosane	n-heptadecane	n-hexacosane	n-hexadecane	n-nonacosane
NPAPAI04	Stoneflies/Odonates	Amoco Park	0.011	0.048	0.900	<0.010	0.019	0.015
NPAPAI06	Cranefly larvae	Amoco Park	0.029	0.046	0.0990	<0.010	0.017	<0.010
NPAPAI09	Stoneflies/Odonates	Amoco Park	<0.010	0.077	2.57	<0.010	0.051	0.023
NPAPAI10	Stoneflies/Odonates	Amoco Park	<0.010	0.098	2.39	<0.010	0.046	0.024
NPCRAI02	Cranefly larvae	Crossroads Park	0.13	0.10	0.130	0.015	0.013	0.17
NPCRAI06	Stoneflies/Odonates	Crossroads Park	0.031	0.061	3.28	<0.010	0.063	0.048
NPCRAI09	Stoneflies/Odonates	Crossroads Park	0.017	0.077	0.300	<0.010	0.013	0.059
NPCRAI10	Stoneflies/Odonates	Crossroads Park	0.026	0.11	0.310	<0.010	0.013	0.044
NPGFAI04	Stoneflies/Odonates	Game & Fish	<0.010	0.035	0.740	<0.010	0.016	0.013
NPGFAI07	Stoneflies/Odonates	Game & Fish	0.010	0.059	0.390	<0.010	0.010	0.035
NPGFAI09	Stoneflies/Odonates	Game & Fish	<0.010	0.051	1.19	<0.010	0.024	0.011
NPGFAI10	Stoneflies/Odonates	Game & Fish	<0.010	0.063	1.06	<0.010	0.021	0.012
NPTXAI04	Stoneflies/Odonates	Texaco Refinery	0.24	0.18	1.09	0.14	0.027	0.35
NPTXAI05	Stoneflies/Odonates	Texaco Refinery	0.036	0.13	4.53	<0.010	0.077	0.16
NPTXAI09	Stoneflies/Odonates	Texaco Refinery	0.034	0.085	0.170	0.033	0.013	0.46
NPTXAI10	Stoneflies/Odonates	Texaco Refinery	0.039	0.11	0.280	0.038	0.015	0.32

Appendix 2 cont.

Invertebrate Sample #	Common Name	Site	n-nonadecane	n-octacosane	n-octadecane	n-pentacosane	n-pentadecane	n-tetracosane
NPAPAI04	Stoneflies/Odonates	Amoco Park	1.24	<0.010	0.071	0.740	0.029	<0.0100
NPAPAI06	Cranefly larvae	Amoco Park	0.0170	0.071	0.026	0.0540	0.023	0.0190
NPAPAI09	Stoneflies/Odonates	Amoco Park	0.690	<0.010	0.10	0.830	0.16	<0.0100
NPAPAI10	Stoneflies/Odonates	Amoco Park	1.39	<0.010	0.12	1.69	0.12	<0.0100
NPCRAI02	Cranefly larvae	Crossroads Park	0.0280	0.069	0.028	0.0670	0.026	0.0440
NPCRAI06	Stoneflies/Odonates	Crossroads Park	0.190	<0.010	0.075	0.240	0.28	<0.0100
NPCRAI09	Stoneflies/Odonates	Crossroads Park	0.210	<0.010	0.025	0.410	0.027	<0.0100
NPCRAI10	Stoneflies/Odonates	Crossroads Park	0.140	<0.010	0.024	0.300	0.044	<0.0100
NPGFAI04	Stoneflies/Odonates	Game & Fish	0.630	<0.010	0.042	0.540	0.043	<0.0100
NPGFAI07	Stoneflies/Odonates	Game & Fish	0.420	<0.010	0.034	0.660	0.046	<0.0100
NPGFAI09	Stoneflies/Odonates	Game & Fish	1.07	<0.010	0.072	1.13	0.063	<0.0100
NPGFAI10	Stoneflies/Odonates	Game & Fish	1.37	<0.010	0.082	1.25	0.039	<0.0100
NPTXAI04	Stoneflies/Odonates	Texaco Refinery	0.0320	0.140	0.029	0.230	0.052	0.0130
NPTXAI05	Stoneflies/Odonates	Texaco Refinery	0.940	<0.010	0.15	0.520	0.16	<0.0100
NPTXAI09	Stoneflies/Odonates	Texaco Refinery	0.0250	0.090	0.020	0.110	0.023	<0.0100
NPTXAI10	Stoneflies/Odonates	Texaco Refinery	0.0240	0.11	0.013	0.150	0.028	<0.0100

Appendix 2 cont.

Invertebrate Sample #	Common Name	Site	n-tetradecane	n-tetratriacontane	n-triacontane	n-tricosane	n-tridecane	n-tritriacontane
NPAPAI04	Stoneflies/Odonates	Amoco Park	0.013	<0.0100	<0.010	1.71	0.015	<0.010
NPAPAI06	Cranefly larvae	Amoco Park	<0.010	<0.0100	<0.010	0.120	<0.010	0.014
NPAPAI09	Stoneflies/Odonates	Amoco Park	0.017	<0.0100	<0.010	2.47	0.027	<0.010
NPAPAI10	Stoneflies/Odonates	Amoco Park	0.015	<0.0100	<0.010	5.00	0.026	<0.010
NPCRAI02	Cranefly larvae	Crossroads Park	0.014	<0.0100	0.030	0.130	0.023	0.040
NPCRAI06	Stoneflies/Odonates	Crossroads Park	0.017	<0.0100	<0.010	0.510	0.063	<0.010
NPCRAI09	Stoneflies/Odonates	Crossroads Park	0.013	0.0140	<0.010	0.990	0.011	<0.010
NPCRAI10	Stoneflies/Odonates	Crossroads Park	0.015	0.0240	0.046	1.03	0.032	<0.010
NPGFAI04	Stoneflies/Odonates	Game & Fish	0.012	<0.0100	<0.010	2.04	0.016	<0.010
NPGFAI07	Stoneflies/Odonates	Game & Fish	0.014	0.0140	0.021	2.80	0.011	0.014
NPGFAI09	Stoneflies/Odonates	Game & Fish	0.016	0.0110	0.014	3.10	0.041	<0.010
NPGFAI10	Stoneflies/Odonates	Game & Fish	0.016	0.0116	0.014	3.43	0.035	<0.010
NPTXAI04	Stoneflies/Odonates	Texaco Refinery	0.015	0.0330	0.038	0.240	<0.010	0.17
NPTXAI05	Stoneflies/Odonates	Texaco Refinery	0.017	0.0180	0.034	0.740	0.026	0.016
NPTXAI09	Stoneflies/Odonates	Texaco Refinery	0.013	0.0120	0.032	0.190	<0.010	<0.010
NPTXAI10	Stoneflies/Odonates	Texaco Refinery	0.014	0.0120	0.046	0.410	<0.010	<0.010

Appendix 2 cont.

Invertebrate Sample #	Common Name	Site	n-undecane	phytane
NPAPAI04	Stoneflies/Odonates	Amoco Park	0.030	<0.010
NPAPAI06	Cranefly larvae	Amoco Park	<0.010	<0.010
NPAPAI09	Stoneflies/Odonates	Amoco Park	0.029	0.013
NPAPAI10	Stoneflies/Odonates	Amoco Park	0.029	<0.010
NPCRAI02	Cranefly larvae	Crossroads Park	0.056	<0.010
NPCRAI06	Stoneflies/Odonates	Crossroads Park	0.045	0.011
NPCRAI09	Stoneflies/Odonates	Crossroads Park	<0.010	<0.010
NPCRAI10	Stoneflies/Odonates	Crossroads Park	0.025	0.012
NPGFAI04	Stoneflies/Odonates	Game & Fish	<0.010	<0.010
NPGFAI07	Stoneflies/Odonates	Game & Fish	0.023	<0.010
NPGFAI09	Stoneflies/Odonates	Game & Fish	0.032	<0.010
NPGFAI10	Stoneflies/Odonates	Game & Fish	0.024	<0.010
NPTXAI04	Stoneflies/Odonates	Texaco Refinery	0.021	<0.010
NPTXAI05	Stoneflies/Odonates	Texaco Refinery	0.030	0.029
NPTXAI09	Stoneflies/Odonates	Texaco Refinery	0.023	0.023
NPTXAI10	Stoneflies/Odonates	Texaco Refinery	0.046	0.032

Appendix 3. Aliphatic hydrocarbon concentrations (μg/g wet weight) in bird carcasses collected at sites along the North Platte River, 1998.

Sample #	Species*	Site	n-decane	n-docosane	n-dodecane	n-dotriacontane	n-eicosane	n-heneicosane
WA388-N	Tree Swallow	Amoco Park	0.054	0.035	0.032	<0.010	0.017	0.14
WCS10-A	Cliff Swallow	Bryan Stocktrail Bridge	0.019	0.042	0.068	0.062	0.022	0.10
WCS11-A	Cliff Swallow	Bryan Stocktrail Bridge	0.18	0.059	0.50	0.072	0.03	0.21
WCS12-A	Cliff Swallow	Patterson-Zonta Bridge	0.031	0.068	0.074	0.081	0.033	0.19
WCS13-A	Barn Swallow	Patterson-Zonta Bridge	0.010	0.054	0.037	0.064	0.027	0.17
WCS14-A	Cliff Swallow	Patterson-Zonta Bridge	0.047	0.036	0.049	0.034	0.025	0.20
WCS15-A	Cliff Swallow	Patterson-Zonta Bridge	0.075	0.052	0.062	0.065	0.033	0.16
WCS1-A	Cliff Swallow	Texaco Bridge	0.25	0.045	0.082	0.097	0.028	0.11
WCS2-A	Cliff Swallow	Texaco Bridge	0.022	0.081	0.064	0.099	0.044	0.31
WCS3-A	Cliff Swallow	Texaco Bridge	0.024	0.066	0.029	0.072	0.041	0.24
WCS4-A	Cliff Swallow	Texaco Bridge	0.036	0.043	0.082	0.064	0.026	0.12
WCS5-A	Cliff Swallow	Texaco Bridge	0.22	0.052	0.084	0.081	0.031	0.18
WCS6-A	Cliff Swallow	Texaco Bridge	0.18	0.074	0.10	0.066	0.041	0.23
WCS7-A	Cliff Swallow	Bryan Stocktrail Bridge	<0.010	0.093	0.027	0.061	0.064	0.13
WCS8-A	Cliff Swallow	Bryan Stocktrail Bridge	<0.010	0.054	0.069	0.14	0.026	0.21
WCS9-A	Cliff Swallow	Bryan Stocktrail Bridge	<0.010	0.035	0.13	0.072	0.025	0.21
WP400-N	Tree Swallow	Patterson-Zonta Park	0.040	0.045	0.039	0.013	0.021	0.15
WT350-N	Tree Swallow	Texaco Refinery	0.032	0.026	0.035	<0.010	<0.010	0.073
WT353-N	Tree Swallow	Texaco Refinery	0.023	0.037	0.020	0.031	0.012	0.086
WT358-N	Tree Swallow	Texaco Refinery	0.032	0.042	0.024	0.024	0.018	0.14
WT361-N	House Wren	Texaco Refinery	0.017	0.09	0.024	0.035	0.062	0.093
WT366-N	House Wren	Texaco Refinery	0.022	0.11	0.019	0.057	0.14	0.12
WT367-N	Tree Swallow	Texaco Refinery	0.027	0.037	0.017	0.050	0.017	0.16
WT368-N	House Wren	Texaco Refinery	<0.010	0.043	0.017	0.033	0.029	0.098
WW410-N	House Wren	Game & Fish	<0.010	0.036	0.024	0.044	0.041	0.11
WW411-N	Tree Swallow	Game & Fish	<0.010	0.25	0.020	0.043	0.042	0.27
WW414-N	House Wren	Game & Fish	<0.010	0.16	<0.010	0.083	0.027	0.33
WW417-N	Tree Swallow	Game & Fish	0.040	0.064	0.039	0.015	0.023	0.32
WW425-N	House Wren	Game & Fish	<0.010	0.051	0.028	0.021	0.049	0.059

* Tree swallows and house wrens are 12 day-old nestlings; cliff swallows and the barn swallow are adults.

Appendix 3 cont.

Sample #	Species*	Site	n-hentriacontane	n-heptacosane	n-heptadecane	n-hexacosane	n-hexadecane	n-nonacosane
WA388-N	Tree Swallow	Amoco Park	0.12	0.37	2.3	0.043	0.074	0.29
WCS10-A	Cliff Swallow	Bryan Stocktrail Bridge	0.31	1.2	0.082	0.20	0.14	1.1
WCS11-A	Cliff Swallow	Bryan Stocktrail Bridge	0.60	1.5	0.22	0.18	0.18	1.9
WCS12-A	Cliff Swallow	Patterson-Zonta Bridge	1.4	2.7	0.23	0.31	0.18	2.9
WCS13-A	Barn Swallow	Patterson-Zonta Bridge	0.61	1.8	0.22	0.19	0.18	1.8
WCS14-A	Cliff Swallow	Patterson-Zonta Bridge	0.38	1.3	0.23	0.12	0.16	1.1
WCS15-A	Cliff Swallow	Patterson-Zonta Bridge	1.0	1.4	0.26	0.14	0.23	2.2
WCS1-A	Cliff Swallow	Texaco Bridge	0.40	0.98	0.23	0.14	0.17	1.0
WCS2-A	Cliff Swallow	Texaco Bridge	0.52	1.9	0.26	0.42	0.20	1.4
WCS3-A	Cliff Swallow	Texaco Bridge	0.47	1.3	0.25	0.15	0.24	1.2
WCS4-A	Cliff Swallow	Texaco Bridge	0.50	1.1	0.16	0.14	0.17	1.5
WCS5-A	Cliff Swallow	Texaco Bridge	0.81	1.4	0.24	0.15	0.20	2.0
WCS6-A	Cliff Swallow	Texaco Bridge	0.45	1.2	0.20	<0.010	0.16	1.2
WCS7-A	Cliff Swallow	Bryan Stocktrail Bridge	0.66	1.4	0.071	0.17	0.18	2.4
WCS8-A	Cliff Swallow	Bryan Stocktrail Bridge	0.93	1.5	0.20	0.20	0.12	2.1
WCS9-A	Cliff Swallow	Bryan Stocktrail Bridge	1.1	1.7	0.20	0.14	0.17	2.3
WP400-N	Tree Swallow	Patterson-Zonta Park	0.15	1.1	1.3	0.067	0.084	0.61
WT350-N	Tree Swallow	Texaco Refinery	0.065	0.40	0.22	0.22	0.021	0.13
WT353-N	Tree Swallow	Texaco Refinery	0.16	1.2	0.44	0.55	0.033	0.42
WT358-N	Tree Swallow	Texaco Refinery	0.17	1.1	1.1	0.10	0.061	0.62
WT361-N	House Wren	Texaco Refinery	0.29	1.0	0.023	0.15	0.087	0.89
WT366-N	House Wren	Texaco Refinery	0.58	1.4	0.034	0.11	0.053	2.2
WT367-N	Tree Swallow	Texaco Refinery	0.16	1.4	0.64	0.11	0.042	0.48
WT368-N	House Wren	Texaco Refinery	0.59	0.99	0.025	0.085	0.041	1.6
WW410-N	House Wren	Game & Fish	1.2	0.97	0.027	0.096	0.080	1.4
WW411-N	Tree Swallow	Game & Fish	0.25	1.1	0.76	0.30	0.040	0.49
WW414-N	House Wren	Game & Fish	0.50	1.4	0.88	0.30	0.048	0.92
WW417-N	Tree Swallow	Game & Fish	0.25	0.84	1.2	0.071	0.060	0.49
WW425-N	House Wren	Game & Fish	0.54	0.94	0.034	0.086	0.12	1.7

* Tree swallows and house wrens are 12 day-old nestlings; cliff swallows and the barn swallow are adults.

Appendix 3 cont.

Sample #	Species*	Site	n-nonadecane	n-octacosane	n-octadecane	n-pentacosane	n-pentadecane	n-tetracosane
WA388-N	Tree Swallow	Amoco Park	0.086	0.048	0.087	0.52	0.29	0.083
WCS10-A	Cliff Swallow	Bryan Stocktrail Bridge	0.023	0.20	0.13	1.1	0.15	0.12
WCS11-A	Cliff Swallow	Bryan Stocktrail Bridge	0.050	0.29	0.21	1.3	0.26	0.14
WCS12-A	Cliff Swallow	Patterson-Zonta Bridge	0.039	0.50	0.21	2.3	0.14	0.21
WCS13-A	Barn Swallow	Patterson-Zonta Bridge	0.048	0.32	0.27	0.76	0.13	0.13
WCS14-A	Cliff Swallow	Patterson-Zonta Bridge	0.046	0.23	0.17	0.96	0.18	0.098
WCS15-A	Cliff Swallow	Patterson-Zonta Bridge	0.050	0.27	0.26	1.0	0.20	0.11
WCS1-A	Cliff Swallow	Texaco Bridge	0.11	0.056	0.15	0.45	0.70	0.11
WCS2-A	Cliff Swallow	Texaco Bridge	0.059	0.48	0.23	1.8	0.42	0.18
WCS3-A	Cliff Swallow	Texaco Bridge	0.061	0.29	0.27	0.89	0.14	0.11
WCS4-A	Cliff Swallow	Texaco Bridge	0.029	0.23	0.18	0.96	0.14	0.12
WCS5-A	Cliff Swallow	Texaco Bridge	0.052	0.32	0.24	1.0	0.17	0.14
WCS6-A	Cliff Swallow	Texaco Bridge	0.070	0.84	0.19	1.4	0.18	0.16
WCS7-A	Cliff Swallow	Bryan Stocktrail Bridge	0.049	1.3	0.24	0.98	0.081	0.15
WCS8-A	Cliff Swallow	Bryan Stocktrail Bridge	0.038	0.41	0.15	1.0	0.13	0.12
WCS9-A	Cliff Swallow	Bryan Stocktrail Bridge	0.037	0.74	0.22	1.1	0.14	0.10
WP400-N	Tree Swallow	Patterson-Zonta Park	0.071	0.12	0.10	0.91	0.20	0.11
WT350-N	Tree Swallow	Texaco Refinery	0.032	0.15	0.020	0.63	0.087	0.074
WT353-N	Tree Swallow	Texaco Refinery	0.050	0.24	0.047	1.6	0.083	0.17
WT358-N	Tree Swallow	Texaco Refinery	0.047	0.14	0.084	0.83	0.13	0.088
WT361-N	House Wren	Texaco Refinery	0.039	0.97	0.16	0.89	0.042	0.18
WT366-N	House Wren	Texaco Refinery	0.055	1.2	0.13	1.0	0.045	0.15
WT367-N	Tree Swallow	Texaco Refinery	0.076	1.5	0.059	1.6	0.060	0.12
WT368-N	House Wren	Texaco Refinery	0.022	0.34	0.072	0.96	0.037	0.10
WW410-N	House Wren	Game & Fish	0.037	2.0	0.15	1.0	0.046	0.068
WW411-N	Tree Swallow	Game & Fish	<0.010	0.55	0.051	1.6	0.14	0.51
WW414-N	House Wren	Game & Fish	0.15	0.80	0.066	1.7	0.12	0.45
WW417-N	Tree Swallow	Game & Fish	0.20	0.80	0.082	1.3	0.19	0.17
WW425-N	House Wren	Game & Fish	0.017	1.7	0.21	0.59	0.051	0.12

* Tree swallows and house wrens are 12 day-old nestlings; cliff swallows and the barn swallow are adults.

Appendix 3 cont.

Sample #	Species*	Site	n-tetradecane	n-tetratriacontane	n-triacontane	n-tricosane	n-tridecane	n-tritriacontane
WA388-N	Tree Swallow	Amoco Park	0.055	<0.010	0.021	0.30	0.39	0.027
WCS10-A	Cliff Swallow	Bryan Stocktrail Bridge	0.14	0.052	0.085	0.60	3.9	0.088
WCS11-A	Cliff Swallow	Bryan Stocktrail Bridge	0.11	0.035	0.16	0.84	18	0.13
WCS12-A	Cliff Swallow	Patterson-Zonta Bridge	0.15	0.036	0.25	1.2	2.5	0.31
WCS13-A	Barn Swallow	Patterson-Zonta Bridge	0.11	0.022	0.14	0.43	0.91	0.23
WCS14-A	Cliff Swallow	Patterson-Zonta Bridge	0.16	0.023	0.12	0.72	1.7	0.098
WCS15-A	Cliff Swallow	Patterson-Zonta Bridge	0.18	0.029	0.17	0.61	1.1	0.21
WCS1-A	Cliff Swallow	Texaco Bridge	0.11	0.056	0.15	0.45	0.70	0.11
WCS2-A	Cliff Swallow	Texaco Bridge	0.16	0.041	0.21	1.1	3.8	0.15
WCS3-A	Cliff Swallow	Texaco Bridge	0.16	0.043	0.21	0.53	0.45	0.079
WCS4-A	Cliff Swallow	Texaco Bridge	0.097	0.033	0.16	0.48	4.6	0.11
WCS5-A	Cliff Swallow	Texaco Bridge	0.14	0.048	0.21	0.58	1.5	0.14
WCS6-A	Cliff Swallow	Texaco Bridge	0.10	0.047	<0.010	0.79	3.3	0.13
WCS7-A	Cliff Swallow	Bryan Stocktrail Bridge	0.22	0.052	0.14	0.53	0.29	0.13
WCS8-A	Cliff Swallow	Bryan Stocktrail Bridge	0.13	0.070	0.23	0.63	2.0	0.17
WCS9-A	Cliff Swallow	Bryan Stocktrail Bridge	0.21	0.034	0.20	0.82	3.8	0.27
WP400-N	Tree Swallow	Patterson-Zonta Park	0.12	<0.010	0.043	0.43	0.69	0.028
WT350-N	Tree Swallow	Texaco Refinery	0.048	<0.010	0.018	0.24	0.76	0.024
WT353-N	Tree Swallow	Texaco Refinery	0.053	0.044	0.054	0.43	0.076	0.053
WT358-N	Tree Swallow	Texaco Refinery	0.086	0.023	0.073	0.33	0.21	0.050
WT361-N	House Wren	Texaco Refinery	0.066	<0.010	0.092	0.27	0.015	0.061
WT366-N	House Wren	Texaco Refinery	0.045	0.013	0.16	0.34	0.010	0.11
WT367-N	Tree Swallow	Texaco Refinery	0.053	0.084	0.095	0.32	0.036	0.055
WT368-N	House Wren	Texaco Refinery	0.030	0.013	0.10	0.35	0.013	0.15
WW410-N	House Wren	Game & Fish	0.054	0.014	0.12	0.35	0.016	0.16
WW411-N	Tree Swallow	Game & Fish	0.062	0.031	0.14	0.72	0.073	0.082
WW414-N	House Wren	Game & Fish	0.051	0.034	0.21	0.85	0.095	0.12
WW417-N	Tree Swallow	Game & Fish	0.084	0.013	0.075	0.62	0.33	0.043
WW425-N	House Wren	Game & Fish	0.073	<0.010	0.093	0.20	0.012	0.12

* Tree swallows and house wrens are 12 day-old nestlings; cliff swallows and the barn swallow are adults.

Appendix 3 cont.

Sample #	Species*	Site	n-undecane	phytane	pristane
WA388-N	Tree Swallow	Amoco Park	2.5	<0.010	<0.010
WCS10-A	Cliff Swallow	Bryan Stocktrail Bridge	0.58	<0.010	<0.010
WCS11-A	Cliff Swallow	Bryan Stocktrail Bridge	9.9	<0.010	<0.010
WCS12-A	Cliff Swallow	Patterson-Zonta Bridge	1.3	<0.010	<0.010
WCS13-A	Barn Swallow	Patterson-Zonta Bridge	0.063	<0.010	<0.010
WCS14-A	Cliff Swallow	Patterson-Zonta Bridge	1.6	0.019	<0.010
WCS15-A	Cliff Swallow	Patterson-Zonta Bridge	4.0	<0.010	<0.010
WCS1-A	Cliff Swallow	Texaco Bridge	13	0.022	<0.010
WCS2-A	Cliff Swallow	Texaco Bridge	1.2	0.013	<0.010
WCS3-A	Cliff Swallow	Texaco Bridge	0.70	0.043	<0.010
WCS4-A	Cliff Swallow	Texaco Bridge	1.0	<0.010	<0.010
WCS5-A	Cliff Swallow	Texaco Bridge	10	0.039	<0.010
WCS6-A	Cliff Swallow	Texaco Bridge	8.3	0.093	<0.010
WCS7-A	Cliff Swallow	Bryan Stocktrail Bridge	0.10	<0.010	<0.010
WCS8-A	Cliff Swallow	Bryan Stocktrail Bridge	3.2	<0.010	<0.010
WCS9-A	Cliff Swallow	Bryan Stocktrail Bridge	2.8	<0.010	<0.010
WP400-N	Tree Swallow	Patterson-Zonta Park	1.4	<0.010	0.028
WT350-N	Tree Swallow	Texaco Refinery	1.7	<0.010	<0.010
WT353-N	Tree Swallow	Texaco Refinery	0.44	0.010	<0.010
WT358-N	Tree Swallow	Texaco Refinery	0.78	<0.010	0.023
WT361-N	House Wren	Texaco Refinery	0.017	<0.010	<0.010
WT366-N	House Wren	Texaco Refinery	0.014	<0.010	<0.010
WT367-N	Tree Swallow	Texaco Refinery	0.91	0.012	<0.010
WT368-N	House Wren	Texaco Refinery	0.015	<0.010	<0.010
WW410-N	House Wren	Game & Fish	0.018	<0.010	<0.010
WW411-N	Tree Swallow	Game & Fish	0.59	<0.010	<0.010
WW414-N	House Wren	Game & Fish	0.031	<0.010	0.013
WW417-N	Tree Swallow	Game & Fish	2.2	<0.010	0.017
WW425-N	House Wren	Game & Fish	0.018	<0.010	<0.010

* Tree swallows and house wrens are 12 day-old nestlings; cliff swallows and the barn swallow are adults.

Appendix 4. Aliphatic hydrocarbon concentrations (μg/g wet weight) in carcasses of tree swallow nestlings collected at Edness K. Wilkins State Park along the North Platte River, 1997.

Sample #	n-decane	n-docosane	n-dodecane	n-dotriacontane	n-eicosane	n-heneicosane	n-hentriacontane	n-heptacosane
WY800-N	0.025	0.090	0.040	0.022	0.049	0.140	0.200	0.600
WY805-N	0.073	0.084	0.043	0.031	0.071	0.260	0.250	1.20
WY811-N	0.020	0.069	0.030	0.031	0.045	0.140	0.180	0.670

Sample #	n-heptadecane	n-hexacosane	n-hexadecane	n-nonacosane	n-nonadecane	n-octacosane	n-octadecane
WY800-N	0.650	0.150	0.120	0.410	0.140	0.220	0.0980
WY805-N	0.570	0.120	0.180	0.490	0.220	0.220	0.150
WY811-N	0.350	0.120	0.110	0.370	0.130	0.230	0.0880

Sample #	n-pentacosane	n-pentadecane	n-tetracosane	n-tetradecane	n-tetratriacontane	n-triacontane	n-tricosane
WY800-N	0.560	0.190	0.170	0.160	0.0150	0.0700	0.310
WY805-N	0.950	0.150	0.230	0.170	0.0100	0.0650	0.510
WY811-N	0.490	0.200	0.120	0.120	<0.0100	0.0610	0.280

Sample #	n-tridecane	n-tritriacontane	n-undecane	phytane	pristane
WY800-N	0.110	0.060	0.460	0.260	<0.0100
WY805-N	0.150	0.087	0.660	0.038	<0.0770
WY811-N	0.190	0.047	0.300	0.017	0.0590

Appendix 5. Aliphatic hydrocarbon concentrations (µg/g wet weight) in gastrointestinal contents from birds collected at sites along the North Platte River, 1998.

Diet Sample #	Species*	Site	n-decane	n-docosane	n-dodecane	n-dotriacontane	n-eicosane	n-heneicosane
CSWADIET	Cliff Swallow	Bryan Stocktrail Bridge	0.069	0.17	0.34	0.44	0.032	0.69
CSWPDIET	Cliff Swallow	Patterson-Zonta Park Bridge	0.071	0.18	0.13	0.45	0.053	0.37
CSWTDIET	Cliff Swallow	Texaco Bridge	0.42	0.24	0.31	0.18	0.098	1.4
HWWTDIET	House Wren	Texaco Refinery	0.023	0.14	0.018	0.094	0.035	0.52
HWWWDIET	House Wren	Game & Fish	0.028	0.17	0.032	0.20	0.047	0.78
TSWADIET	Tree Swallow	Amoco Park	0.038	0.40	0.073	0.069	0.16	1.2
TSWPDIET	Tree Swallow	Patterson-Zonta Park	0.062	0.28	0.051	0.35	0.075	1.4
TSWTDIET	Tree Swallow	Texaco Refinery	0.028	0.26	0.021	<0.010	0.029	1.4
TSWWDIET	Tree Swallow	Game & Fish	<0.010	0.024	0.011	<0.010	0.011	0.11

Diet Sample #	Species	Site	n-hentriacontane	n-heptacosane	n-heptadecane	n-hexacosane	n-hexadecane	n-nonacosane
CSWADIET	Cliff Swallow	Bryan Stocktrail Bridge	12	22	0.065	1.7	0.016	35
CSWPDIET	Cliff Swallow	Patterson-Zonta Park Bridge	11	9.6	0.12	0.85	0.047	21
CSWTDIET	Cliff Swallow	Texaco Bridge	1.0	7.3	0.36	1.0	0.031	4.1
HWWTDIET	House Wren	Texaco Refinery	1.3	4.0	0.14	0.27	0.019	4.3
HWWWDIET	House Wren	Game & Fish	4.1	5.5	0.10	0.44	0.025	8.9
TSWADIET	Tree Swallow	Amoco Park	0.33	2.7	24	0.55	0.38	1.5
TSWPDIET	Tree Swallow	Patterson-Zonta Park	2.4	20	4.6	0.89	0.12	9.4
TSWTDIET	Tree Swallow	Texaco Refinery	0.65	25	2.2	<0.010	0.053	5.2
TSWWDIET	Tree Swallow	Game & Fish	0.14	0.69	1.8	0.051	0.036	0.38

* Tree swallows and house wrens are 12 day-old nestlings; cliff swallows are adults.

Appendix 5 cont.

Diet Sample #	Species*	Site	n-nonadecane	n-octacosane	n-octadecane	n-pentacosane	n-pentadecane	n-tetracosane
CSWADIET	Cliff Swallow	Bryan Stocktrail Bridge	0.030	2.6	0.017	16	0.34	1.1
CSWPDIET	Cliff Swallow	Patterson-Zonta Park Bridge	0.065	1.4	0.061	7.2	0.35	0.52
CSWTDIET	Cliff Swallow	Texaco Bridge	0.60	0.76	0.060	11	3.7	0.92
HWWTDIET	House Wren	Texaco Refinery	0.23	0.36	0.041	4.4	0.072	0.30
HWWWDIET	House Wren	Game & Fish	0.35	0.63	0.039	7.5	0.15	0.46
TSWADIET	Tree Swallow	Amoco Park	1.2	0.35	0.29	4.2	3.6	0.90
TSWPDIET	Tree Swallow	Patterson-Zonta Park	0.43	1.5	0.12	8.9	0.29	0.62
TSWTDIET	Tree Swallow	Texaco Refinery	0.21	<0.010	0.064	29	0.11	<0.010
TSWWDIET	Tree Swallow	Game & Fish	0.084	0.092	0.038	0.89	0.29	0.067

Diet Sample #	Species	Site	n-tetradecane	n-tetratriacontane	n-triacontane	n-tricosane	n-tridecane	n-tritriacontane
CSWADIET	Cliff Swallow	Bryan Stocktrail Bridge	0.091	0.15	2.1	6.4	25	2.1
CSWPDIET	Cliff Swallow	Patterson-Zonta Park Bridge	0.097	0.25	1.4	3.3	10	2.8
CSWTDIET	Cliff Swallow	Texaco Bridge	0.10	0.20	0.33	5.2	11	0.32
HWWTDIET	House Wren	Texaco Refinery	0.023	0.18	0.29	1.6	0.010	0.29
HWWWDIET	House Wren	Game & Fish	0.031	<0.010	1.6	3.0	0.17	0.93
TSWADIET	Tree Swallow	Amoco Park	0.083	<0.010	0.14	4.1	0.40	0.096
TSWPDIET	Tree Swallow	Patterson-Zonta Park	0.052	<0.010	0.72	4.4	0.45	0.70
TSWTDIET	Tree Swallow	Texaco Refinery	0.012	<0.010	<0.010	7.9	0.14	0.18
TSWWDIET	Tree Swallow	Game & Fish	0.013	<0.010	0.048	0.25	0.024	<0.010

* Tree swallows and house wrens are 12 day-old nestlings; cliff swallows are adults.

Appendix 5 cont.

Diet Sample #	Species*	Site	n-undecane	phytane	pristane
CSWADIET	Cliff Swallow	Bryan Stocktrail Bridge	2.5	0.054	0.013
CSWPDIET	Cliff Swallow	Patterson-Zonta Park Bridge	4.3	0.11	0.041
CSWTDIET	Cliff Swallow	Texaco Bridge	35	1.5	0.010
HWWTDIET	House Wren	Texaco Refinery	0.024	<0.010	0.023
HWWWDIET	House Wren	Game & Fish	0.047	<0.010	0.020
TSWADIET	Tree Swallow	Amoco Park	4.8	0.037	0.076
TSWPDIET	Tree Swallow	Patterson-Zonta Park	1.3	0.020	0.052
TSWTDIET	Tree Swallow	Texaco Refinery	2.1	<0.010	<0.010
TSWWDIET	Tree Swallow	Game & Fish	0.50	<0.010	0.018

* Tree swallows and house wrens are 12 day-old nestlings; cliff swallows are adults.

Appendix 6 . Polycyclic aromatic hydrocarbon concentrations* (µg/g wet weight) in sediment from the North Platte River, 1998.

Sediment Sample #	Site	benzo(a)pyrene	benzo(b)fluoranthene	benzo(e)pyrene	benzo(k)fluoranthene	chrysene
NPAPSD03	Amoco Park	<0.010	<0.010	<0.010	<0.010	<0.010
NPAPSD04	Amoco Park	<0.010	<0.010	<0.010	<0.010	<0.010
NPCRSD03	Crossroads Park	<0.010	<0.010	<0.010	<0.010	<0.010
NPCRSD04	Crossroads Park	<0.010	<0.010	<0.010	<0.010	<0.010
NPGFSD05	Game & Fish	<0.010	<0.010	0.016	0.022	0.014
NPGFSD06	Game & Fish	0.013	0.021	<0.010	<0.010	0.020
NPTXSD03	Texaco Refinery	<0.010	<0.010	<0.010	0.017	0.019
NPTXSD04	Texaco Refinery	<0.010	<0.010	<0.010	0.017	0.018

Sediment Sample #	Site	fluoranthene	perylene	phenanthrene	pyrene
NPAPSD03	Amoco Park	<0.010	<0.0100	<0.010	<0.010
NPAPSD04	Amoco Park	<0.010	<0.0100	<0.010	<0.010
NPCRSD03	Crossroads Park	0.015	<0.0100	<0.010	<0.010
NPCRSD04	Crossroads Park	<0.010	0.104	<0.010	<0.010
NPGFSD05	Game & Fish	0.022	0.103	<0.010	<0.010
NPGFSD06	Game & Fish	0.033	<0.0100	<0.010	0.023
NPTXSD03	Texaco Refinery	0.013	0.103	<0.010	0.017
NPTXSD04	Texaco Refinery	0.012	<0.0100	0.017	0.020

*Polycyclic aromatics below detection limits in all sediment samples include: 1,2,5,6-dibenzanthracene, 1,2-benzanthracene, acenaphthalene, acenaphthene, anthracene, benzo(g,h,i)perylene, biphenyl, C1-chrysenes, C1-dibenzothiophenes, C1-Fluoranthenes & Pyrenes, C1-fluorenes, C1-naphthalenes, C1-phenanthrenes, C2-chrysenes, C2-dibenzothiophenes, C2-fluorenes, C2-naphthalenes, C2-phenanthrenes, C3-chrysenes, C3-dibenzothiophenes, C3-fluorenes, C3-naphthalenes, C3-phenanthrenes, C4-chrysenes, C4-naphthalenes, C4-phenanthrenes, dibenzothiophene, fluorene, indeno(1,2,3-cd)pyrene, and naphthalene.

Appendix 7. Polycyclic aromatic hydrocarbon concentrations* (µg/g wet weight) in benthic aquatic insect larvae from the North Platte River, 1998.

Invertebrate Sample #	Common Name	Site	acenaphthene	perylene	phenanthrene
NPAPAI06	Cranefly larvae	Amoco Park	<0.010	<0.0100	<0.010
NPAPAI04	Stoneflies/Odonates	Amoco Park	<0.010	0.0490	<0.010
NPAPAI09	Stoneflies/Odonates	Amoco Park	0.010	<0.0100	<0.010
NPAPAI10	Stoneflies/Odonates	Amoco Park	<0.010	<0.0100	<0.010
NPCRAI02	Cranefly larvae	Crossroads Park	<0.010	<0.0100	<0.010
NPCRAI06	Stoneflies/Odonates	Crossroads Park	<0.010	<0.0100	<0.010
NPCRAI09	Stoneflies/Odonates	Crossroads Park	<0.010	<0.0100	<0.010
NPCRAI10	Stoneflies/Odonates	Crossroads Park	<0.010	<0.0100	<0.010
NPGFAI04	Stoneflies/Odonates	Game & Fish	<0.010	<0.0100	<0.010
NPGFAI07	Stoneflies/Odonates	Game & Fish	<0.010	<0.0100	<0.010
NPGFAI09	Stoneflies/Odonates	Game & Fish	<0.010	<0.0100	<0.010
NPGFAI10	Stoneflies/Odonates	Game & Fish	<0.010	<0.0100	<0.010
NPTXAI04	Stoneflies/Odonates	Texaco Refinery	<0.010	<0.0100	<0.010
NPTXAI05	Stoneflies/Odonates	Texaco Refinery	<0.010	<0.0100	<0.010
NPTXAI09	Stoneflies/Odonates	Texaco Refinery	<0.010	0.0510	0.010
NPTXAI10	Stoneflies/Odonates	Texaco Refinery	<0.010	<0.0100	<0.010

*Polycyclic aromatics below detection limits in all invertebrate samples include: 1,2,5,6-dibenzanthracene, 1,2-benzanthracene, acenaphthalene, anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(e)pyrene, benzo(g,h,i)perylene, benzo(k)fluoranthene, biphenyl, C1-chrysenes, C1-dibenzothiophenes, C1-Fluoranthenes & Pyrenes, C1-fluorenes, C1-naphthalenes, C1-phenanthrenes, C2-chrysenes, C2-dibenzothiophenes, C2-fluorenes, C2-naphthalenes, C2-phenanthrenes, C3-chrysenes, C3-dibenzothiophenes, C3-fluorenes, C3-naphthalenes, C3-phenanthrenes, C4-chrysenes, C4-naphthalenes, C4-phenanthrenes, chrysene, dibenzothiophene, fluoranthene, fluorene, indeno(1,2,3-cd)pyrene, naphthalene, perylene, phenanthrene, and pyrene.

Appendix 8. Polycyclic aromatic hydrocarbon concentrations[a] (µg/g wet weight) in carcasses of birds collected at sites along the North Platte River, 1998.

Sample #	Species[b]	Site	1,2-benzanthracene	C1-phenanthrenes	acenaphthene	benzo(e)pyrene
WA388-N	Tree Swallow	Amoco Park	<0.010	<0.010	0.012	<0.010
WCS10-A	Cliff Swallow	Bryan Stocktrail Bridge	<0.010	<0.010	<0.010	<0.010
WCS11-A	Cliff Swallow	Bryan Stocktrail Bridge	<0.010	<0.010	<0.010	<0.010
WCS12-A	Cliff Swallow	Patterson-Zonta Bridge	0.043	<0.010	<0.010	<0.010
WCS13-A	Barn Swallow	Patterson-Zonta Bridge	0.017	<0.010	<0.010	<0.010
WCS14-A	Cliff Swallow	Patterson-Zonta Bridge	0.018	0.019	<0.010	0.037
WCS15-A	Cliff Swallow	Patterson-Zonta Bridge	0.021	0.024	<0.010	0.036
WCS1-A	Cliff Swallow	Texaco Bridge	<0.010	0.014	<0.010	<0.010
WCS2-A	Cliff Swallow	Texaco Bridge	0.040	0.031	<0.010	<0.010
WCS3-A	Cliff Swallow	Texaco Bridge	0.014	<0.010	<0.010	<0.010
WCS4-A	Cliff Swallow	Texaco Bridge	0.018	0.018	<0.010	<0.010
WCS5-A	Cliff Swallow	Texaco Bridge	0.027	0.024	<0.010	<0.010
WCS6-A	Cliff Swallow	Texaco Bridge	0.020	<0.010	<0.010	0.043
WCS7-A	Cliff Swallow	Bryan Stocktrail Bridge	0.017	0.011	<0.010	<0.010
WCS8-A	Cliff Swallow	Bryan Stocktrail Bridge	<0.010	<0.010	<0.010	<0.010
WCS9-A	Cliff Swallow	Bryan Stocktrail Bridge	<0.010	0.012	<0.010	<0.010
WP400-N	Tree Swallow	Patterson-Zonta Park	0.023	<0.010	<0.010	<0.010
WT350-N	Tree Swallow	Texaco Refinery	0.030	<0.010	<0.010	<0.010
WT353-N	Tree Swallow	Texaco Refinery	<0.010	<0.010	<0.010	<0.010
WT358-N	Tree Swallow	Texaco Refinery	<0.010	<0.010	<0.010	<0.010
WT367-N	Tree Swallow	Texaco Refinery	<0.010	<0.010	<0.010	<0.010
WT361-N	House Wren	Texaco Refinery	<0.010	<0.010	<0.010	0.040
WT366-N	House Wren	Texaco Refinery	0.025	<0.010	<0.010	<0.010
WT368-N	House Wren	Texaco Refinery	0.036	<0.010	<0.010	<0.010
WW411-N	Tree Swallow	Game & Fish	<0.010	<0.010	<0.010	<0.010
WW417-N	Tree Swallow	Game & Fish	<0.010	<0.010	<0.010	<0.010
WW410-N	House Wren	Game & Fish	<0.010	<0.010	<0.010	<0.010
WW414-N	House Wren	Game & Fish	0.020	<0.010	<0.010	<0.010
WW425-N	House Wren	Game & Fish	<0.010	<0.010	<0.010	<0.010

Appendix 8 cont.

Sample #	Species	Site	C1-phenanthrenes	chrysene	fluoranthene	phenanthrene	pyrene
WA388-N	Tree Swallow	Amoco Park	<0.010	0.010	<0.010	<0.010	<0.010
WCS10-A	Cliff Swallow	Bryan Stocktrail Bridge	<0.010	0.020	<0.010	<0.010	<0.010
WCS11-A	Cliff Swallow	Bryan Stocktrail Bridge	<0.010	<0.010	<0.010	<0.010	<0.010
WCS12-A	Cliff Swallow	Patterson-Zonta Bridge	<0.010	<0.010	<0.010	<0.010	<0.010
WCS13-A	Barn Swallow	Patterson-Zonta Bridge	<0.010	<0.010	<0.010	<0.010	<0.010
WCS14-A	Cliff Swallow	Patterson-Zonta Bridge	0.019	<0.010	<0.010	<0.010	<0.010
WCS15-A	Cliff Swallow	Patterson-Zonta Bridge	0.024	<0.010	<0.010	<0.010	<0.010
WCS1-A	Cliff Swallow	Texaco Bridge	<0.010	0.014	<0.010	<0.010	<0.010
WCS2-A	Cliff Swallow	Texaco Bridge	0.031	<0.010	0.015	0.024	<0.010
WCS3-A	Cliff Swallow	Texaco Bridge	<0.010	<0.010	<0.010	0.013	<0.010
WCS4-A	Cliff Swallow	Texaco Bridge	0.018	<0.010	0.010	0.015	<0.010
WCS5-A	Cliff Swallow	Texaco Bridge	0.024	0.014	<0.010	0.013	<0.010
WCS6-A	Cliff Swallow	Texaco Bridge	<0.010	<0.010	0.014	<0.010	<0.010
WCS7-A	Cliff Swallow	Bryan Stocktrail Bridge	0.011	<0.010	<0.010	<0.010	<0.010
WCS8-A	Cliff Swallow	Bryan Stocktrail Bridge	<0.010	<0.010	<0.010	<0.010	<0.010
WCS9-A	Cliff Swallow	Bryan Stocktrail Bridge	0.012	<0.010	<0.010	<0.010	<0.010
WP400-N	Tree Swallow	Patterson-Zonta Park	<0.010	<0.010	<0.010	<0.010	<0.010
WT350-N	Tree Swallow	Texaco Refinery	<0.010	<0.010	<0.010	<0.010	<0.010
WT353-N	Tree Swallow	Texaco Refinery	<0.010	<0.010	<0.010	<0.010	<0.010
WT358-N	Tree Swallow	Texaco Refinery	<0.010	0.017	<0.010	<0.010	<0.010
WT367-N	Tree Swallow	Texaco Refinery	<0.010	<0.010	<0.010	<0.010	<0.010
WT361-N	House Wren	Texaco Refinery	<0.010	0.013	<0.010	<0.010	<0.010
WT366-N	House Wren	Texaco Refinery	<0.010	<0.010	<0.010	0.024	0.011
WT368-N	House Wren	Texaco Refinery	<0.010	<0.010	<0.010	<0.010	<0.010
WW411-N	Tree Swallow	Game & Fish	<0.010	<0.010	<0.010	<0.010	<0.010
WW417-N	Tree Swallow	Game & Fish	<0.010	<0.010	<0.010	<0.010	<0.010
WW410-N	House Wren	Game & Fish	<0.010	<0.010	<0.010	<0.010	<0.010
WW414-N	House Wren	Game & Fish	<0.010	<0.010	<0.010	<0.010	<0.010
WW425-N	House Wren	Game & Fish	<0.010	<0.010	<0.010	<0.010	<0.010

Appendix 8 cont.

[a] Polycyclic aromatics below detection limits for all avian carcass samples include: 1,2,5,6-dibenzanthracene, acenaphthalene, anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, biphenyl, C1-chrysenes, C1-dibenzothiophenes, C1-Fluoranthenes & Pyrenes, C1-fluorenes, C1-naphthalenes, C2-chrysenes, C2-dibenzothiophenes, C2-fluorenes, C2-naphthalenes, C2-phenanthrenes, C3-chrysenes, C3-dibenzothiophenes, C3-fluorenes, C3-naphthalenes, C3-phenanthrenes, C4-chrysenes, C4-naphthalenes, C4-phenanthrenes, dibenzothiophene, fluorene, indeno(1,2,3-cd)pyrene, naphthalene, and perylene.

[b] Tree swallows and house wrens are 12 day-old nestlings; cliff swallows and the barn swallow are adults.

Appendix 9. Polycyclic aromatic hydrocarbon concentrations (μg/g wet weight) in carcasses of tree swallow nestlings collected at Edness K. Wilkins State Park along the North Platte River, 1997.*

*All polycyclic aromatics were below detection limits for all carcass samples. The aromatic scanned included: 1,2,5,6-dibenzanthracene, 1,2-dibenzanthracene, 1-methylnaphthalene, 1-methylphenanthrene, 2,3,5-trimethylnaphthalene, 2,6-dimethylnaphthalene, 2-methylnaphthalene, C1-Fluoranthenes & Pyrenes, C1-chrysenes, C1-dibenzothiophenes C1-fluorenes, C1-naphthalenes, C1-phenanthrenes, C2-chrysenes, C2-dibenzothiophenes, C2-fluorenes, C2-naphthalenes, C2-phenanthrenes, C3-chrysenes, C3-dibenzothiophenes, C3-fluorenes, C3-naphthalenes, C3-phenanthrenes, C4-chrysenes, C4-naphthalenes, C4-phenanthrenes, acenaphthalene, acenaphthene, anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(e)pyrene, benzo(g,h,i)perylene, benzo(k)fluoranthene, biphenyl, chrysene, fluoranthene, fluorene, indeno(1,2,3-cd)pyrene, naphthalene, perylene, phenanthrene, and pyrene.

Appendix 10. Polycyclic aromatic hydrocarbon concentrations[a] (µg/g wet weight) in gastrointestinal contents from birds collected at sites along the North Platte River, 1998.

Sample #	Species[b]	Site	1,2-benzanthracene	benzo(a)pyrene	benzo(b)fluoranthene	benzo(e)pyrene
CSWADIET	Cliff swallow	Bryan Stocktrail Bridge	<0.020	<0.020	<0.020	<0.020
CSWPDIET	Cliff swallow	Patterson-Zonta Park	<0.050	<0.050	<0.050	<0.050
CSWTDIET	Cliff swallow	Texaco Bridge	<0.030	<0.030	<0.030	<0.030
HWWTDIET	House wren	Texaco Refinery	0.061	0.055	0.036	0.14
HWWWDIET	House wren	Game & Fish	<0.030	<0.030	<0.030	<0.030
TSWADIET	Tree swallow	Amoco Park	0.19	<0.030	<0.030	0.15
TSWPDIET	Tree swallow	Patterson-Zonta Park	<0.050	<0.050	<0.050	<0.050
TSWTDIET	Tree swallow	Texaco Refinery	<0.010	<0.010	0.010	0.071
TSWWDIET	Tree swallow	Game & Fish	<0.030	<0.030	<0.030	<0.030

Sample #	Species	Site	benzo(g,h,i)perylene	chrysene	fluoranthene	naphthalene	phenanthrene	pyrene
CSWADIET	Cliff swallow	Bryan Stocktrail Bridge	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
CSWPDIET	Cliff swallow	Patterson-Zonta Park	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
CSWTDIET	Cliff swallow	Texaco Bridge	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
HWWTDIET	House wren	Texaco Refinery	0.023	0.18	0.018	<0.015	0.16	0.073
HWWWDIET	House wren	Game & Fish	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
TSWADIET	Tree swallow	Amoco Park	<0.030	0.11	0.140	<0.030	0.17	0.058
TSWPDIET	Tree swallow	Patterson-Zonta Park	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
TSWTDIET	Tree swallow	Texaco Refinery	<0.010	0.12	<0.010	0.012	0.023	0.038
TSWWDIET	Tree swallow	Game & Fish	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030

[a]Polycyclic aromatics below detection limits in all gastrointestinal contect samples include: 1,2,5,6-dibenzanthracene, acenaphthalene, acenaphthene, anthracene, benzo(k)fluoranthene, biphenyl, C1-chrysenes, C1-dibenzothiophenes, C1-Fluoranthenes & Pyrenes, C1-fluorenes, C1-naphthalenes, C1-phenanthrenes, C2-chrysenes, C2-dibenzothiophenes, C2-fluorenes, C2-naphthalenes, C2-phenanthrenes, C3-chrysenes, C3-dibenzothiophenes, C3-fluorenes, C3-naphthalenes, C3-phenanthrenes, C4-chrysenes, C4-naphthalenes, C4-phenanthrenes, dibenzothiophene, fluorene, indeno(1,2,3-cd)pyrene, and perylene.

[b]Tree swallows and house wrens are 12 day-old nestlings; cliff swallows are adults.

Appendix 11. Trace element concentrations (µg/g dry weight) in sediment from the North Platte River, 1998.

Sediment Sample #	Site	Percent Moisture	Al	As	B	Ba	Be	Cd	Cr	Cu	Fe
NPAPSD01	Amoco Park	22.3	5720	4.74	4.17	166	0.386	0.815	8.39	8.11	9788.0
NPAPSD02	Amoco Park	24.6	4633	4.09	3.71	154	0.321	0.705	7.07	6.96	8535.0
NPCRSD01	Crossroads Park	35.9	9623	5.83	7.41	211	0.565	1.21	12.6	11.8	13389
NPCRSD02	Crossroads Park	36.7	9280	5.95	5.32	214	0.573	1.27	12.4	12.8	13618
NPGFSD01	Game & Fish	32.2	8086	4.74	5.87	195	0.498	1.11	10.4	9.97	11843
NPGFSD02	Game & Fish	32.8	7645	4.51	4.23	226	0.481	1.04	9.94	9.18	11210
NPTXSD01	Texaco Refinery	36.9	8713	5.51	5.87	175	0.515	1.03	13.0	11.6	12636
NPTXSD02	Texaco Refinery	34.2	8174	4.98	5.85	170	0.500	1.07	12.5	11.4	12219

Sediment Sample #	Site	Hg	Mg	Mn	Mo	Ni	Pb	Se	Sr	V	Zn
NPAPSD01	Amoco Park	<.0255	4443	182	0.488	10.6	8.17	0.985	46.9	17.6	37.1
NPAPSD02	Amoco Park	<.0555	3484	167	0.391	8.52	6.62	0.394	41.3	14.5	29.9
NPCRSD01	Crossroads Park	<.0347	7200	240	0.472	15.4	10.4	1.14	68.9	27.0	52.2
NPCRSD02	Crossroads Park	<.0638	7501	252	0.446	15.8	10.5	1.31	72.5	25.8	55.3
NPGFSD01	Game & Fish	<.0252	6451	209	<0.269	12.7	8.12	0.960	62.8	21.3	44.4
NPGFSD02	Game & Fish	<.0639	5989	208	0.424	12.1	8.42	0.942	63.5	19.9	41.8
NPTXSD01	Texaco Refinery	<.0444	6781	244	<0.269	14.0	17.6	0.930	84.5	23.8	51.3
NPTXSD02	Texaco Refinery	<.0505	6625	233	0.730	13.9	14.2	1.05	82.6	22.4	50.0

Appendix 12. Trace element concentrations (µg/g dry weight) in benthic aquatic insect larvae from the North Platte River, 1998.

Invertebrate Sample #	Common Name	Site	% Moisture	Al	As	B	Ba	Be	Cd
NPAPAI01	Stoneflies/Odonates	Amoco Park	75.0	308.0	1.36	4.39	17.5	<0.0262	0.446
NPAPAI02	Stoneflies/Odonates	Amoco Park	75.5	488.0	1.91	4.92	27.3	0.0321	0.611
NPAPAI03	Stoneflies/Odonates	Amoco Park	74.3	204.0	0.647	5.41	10.9	<0.0360	0.476
NPAPAI05	Cranefly Larvae	Amoco Park	88.1	2189	5.87	9.98	99.5	0.155	0.566
NPCRAI03	Stoneflies/Odonates	Crossroads Park	81.5	1474	4.98	20.3	46.4	0.0889	1.18
NPCRAI04	Stoneflies/Odonates	Crossroads Park	74.8	678.0	2.39	4.53	23.4	0.0547	0.557
NPCRAI05	Stoneflies/Odonates	Crossroads Park	74.4	694.0	2.89	6.80	26.8	0.0805	0.446
NPCRAI01	Cranefly Larvae	Crossroads Park	84.6	1737	2.64	8.43	47.8	0.121	0.462
NPGFAI01	Stoneflies/Odonates	Game & Fish	78.5	1384	4.26	8.46	28.0	0.101	1.64
NPGFAI02	Stoneflies/Odonates	Game & Fish	78.1	1364	5.25	7.50	35.4	0.0969	1.40
NPGFAI03	Stoneflies/Odonates	Game & Fish	77.1	1240	3.86	12.2	26.6	0.0807	1.27
NPTXAI01	Stoneflies/Odonates	Texaco Refinery	82.3	1260	3.19	11.1	31.5	0.0999	1.12
NPTXAI02	Stoneflies/Odonates	Texaco Refinery	84.2	235.0	1.56	10.3	18.1	0.0365	0.521
NPTXAI03	Stoneflies/Odonates	Texaco Refinery	85.0	552.0	1.96	11.7	20.4	0.0518	0.719

Invertebrate Sample #	Common Name	Site	Cr	Cu	Fe	Hg	Mg	Mn	Mo	Ni
NPAPAI01	Stoneflies/Odonates	Amoco Park	10.5	30.6	740.0	<0.0691	1741	74.3	<0.305	5.79
NPAPAI02	Stoneflies/Odonates	Amoco Park	8.72	30.6	879.0	<0.0981	1842	80.5	<0.268	5.41
NPAPAI03	Stoneflies/Odonates	Amoco Park	7.89	35.5	422.0	<0.0926	1909	63.1	1.62	9.70
NPAPAI05	Cranefly Larvae	Amoco Park	281	27.7	7211	<0.0972	2594	459	34.2	180
NPCRAI03	Stoneflies/Odonates	Crossroads Park	208	28.0	3160	<0.0973	2375	149	25.3	138
NPCRAI04	Stoneflies/Odonates	Crossroads Park	10.4	22.7	1422	<0.0949	1401	91.8	0.973	8.34
NPCRAI05	Stoneflies/Odonates	Crossroads Park	5.16	20.6	3614	<0.0944	1349	218	0.722	5.19
NPCRAI01	Cranefly Larvae	Crossroads Park	95.9	16.0	2937	1.31	2005	242	11.7	63.4
NPGFAI01	Stoneflies/Odonates	Game & Fish	43.3	33.1	2146	<0.0821	2354	109	5.04	29.7
NPGFAI02	Stoneflies/Odonates	Game & Fish	29.4	24.7	2372	<0.0939	2425	123	3.61	22.0
NPGFAI03	Stoneflies/Odonates	Game & Fish	10.6	28.5	1893	<0.0824	2038	88.7	0.939	8.32
NPTXAI01	Stoneflies/Odonates	Texaco Refinery	15.2	22.9	1690	0.407	2610	356	1.57	11.5
NPTXAI02	Stoneflies/Odonates	Texaco Refinery	61.6	19.9	947.0	0.966	1966	438	7.91	41.4
NPTXAI03	Stoneflies/Odonates	Texaco Refinery	166	28.2	1797	0.848	2137	518	20.5	110

Appendix 12 cont.

Invertebrate Sample #	Common Name	Site	Pb	Se	Sr	V	Zn
NPAPAI01	Stoneflies/Odonates	Amoco Park	<1.57	7.65	18.8	1.41	162
NPAPAI02	Stoneflies/Odonates	Amoco Park	<1.38	6.37	17.6	1.76	166
NPAPAI03	Stoneflies/Odonates	Amoco Park	<2.16	5.80	19.7	0.978	200
NPAPAI05	Cranefly Larvae	Amoco Park	5.18	8.87	27.8	11.4	107
NPCRAI03	Stoneflies/Odonates	Crossroads Park	1.78	9.99	22.3	6.21	112
NPCRAI04	Stoneflies/Odonates	Crossroads Park	<1.82	9.08	14.2	2.88	99.7
NPCRAI05	Stoneflies/Odonates	Crossroads Park	<1.83	9.34	12.2	3.82	105
NPCRAI01	Cranefly Larvae	Crossroads Park	4.32	7.91	21.2	6.97	88.2
NPGFAI01	Stoneflies/Odonates	Game & Fish	1.87	11.0	22.9	5.00	130
NPGFAI02	Stoneflies/Odonates	Game & Fish	<1.74	10.8	22.2	4.67	114
NPGFAI03	Stoneflies/Odonates	Game & Fish	<1.77	8.82	20.0	4.28	121
NPTXAI01	Stoneflies/Odonates	Texaco Refinery	2.33	8.64	98.3	4.54	94.9
NPTXAI02	Stoneflies/Odonates	Texaco Refinery	<1.77	5.68	143	2.15	60.3
NPTXAI03	Stoneflies/Odonates	Texaco Refinery	2.23	7.48	106	3.92	76.8

Appendix 13. Trace element concentrations (µg/g dry weight) in bird eggs collected at sites along the North Platte River, 1998.

Sample #	Species	Site	% Moisture	Al	As	B	Ba	Be	Cd	Cr	Cu	Fe
WA388-P	Tree Swallow	Amoco Park	83.4	<4.99	<0.499	24.0	4.30	<0.0998	<0.0998	<0.499	2.14	127
WP400-P	Tree Swallow	Patterson-Zonta Park	77.6	<5.03	<0.503	35.3	1.49	<0.101	<0.101	<0.503	2.47	94.2
WT350-P	Tree Swallow	Texaco Refinery	79.6	<10.8	<1.08	80.7	3.09	<0.216	<0.216	<1.08	2.29	171
WT353-P	Tree Swallow	Texaco Refinery	80.8	<5.05	<0.505	40.7	2.47	<0.101	<0.101	<0.505	2.46	158
WT358-P	Tree Swallow	Texaco Refinery	82.3	<9.29	<0.929	67.0	4.00	<0.186	<0.186	<0.929	2.21	120
WT367-P	Tree Swallow	Texaco Refinery	82.7	<4.99	<0.499	40.2	2.90	<0.0998	<0.0998	<0.499	1.77	102
WT361-P	House Wren	Texaco Refinery	82.2	<7.53	<0.753	105	5.10	<0.151	<0.151	<0.753	3.22	114
WT366-P	House Wren	Texaco Refinery	82.4	<7.06	<0.706	102	4.64	<0.141	<0.141	<0.706	3.57	194
WT368-P	House Wren	Texaco Refinery	81.7	<5.94	<0.594	40.8	5.13	<0.119	<0.119	<0.594	2.30	134
WT370-P	Bank Swallow	Texaco Refinery	71.2	14.5	<0.510	36.6	2.16	<0.102	<0.102	<0.510	1.94	158
WW411-P	Tree Swallow	Game & Fish	81.7	16.3	<1.03	74.9	3.87	<0.207	<0.207	<1.03	2.32	172
WW417-P	Tree Swallow	Game & Fish	82.2	<9.43	<0.943	43.5	5.29	<0.189	<0.189	<0.943	2.50	148
WW424-P	Tree Swallow	Game & Fish	82.4	<10.2	<1.02	79.5	7.80	<0.203	<0.203	<1.02	1.89	150
WW410-P	House Wren	Game & Fish	80.6	<11.1	<1.11	72.7	4.67	<0.222	<0.222	<1.11	3.45	176
WW414-P	House Wren	Game & Fish	82.7	<6.51	<0.651	36.2	22.6	<0.130	<0.130	<0.651	4.16	114
WW425-P	House Wren	Game & Fish	82.8	<5.35	<0.535	36.5	12.0	<0.107	<0.107	<0.535	2.79	115

Appendix 13 cont.

Sample #	Species	Site	Hg	Mg	Mn	Mo	Ni	Pb	Se	Sr	V	Zn
WA388-P	Tree Swallow	Amoco Park	0.220	329	2.46	<0.499	<0.499	<0.299	5.98	15.0	<0.499	65.7
WP400-P	Tree Swallow	Patterson-Zonta Park	0.549	208	1.60	<0.503	<0.503	<0.302	6.29	7.42	<0.503	44.5
WT350-P	Tree Swallow	Texaco Refinery	0.464	387	3.40	<1.08	<1.08	<0.647	8.73	12.1	<1.08	70.6
WT353-P	Tree Swallow	Texaco Refinery	0.430	328	2.91	<0.505	<0.505	<0.303	6.95	14.7	<0.505	49.2
WT358-P	Tree Swallow	Texaco Refinery	0.483	340	3.16	<0.929	<0.929	<0.558	8.86	11.6	<0.929	68.3
WT367-P	Tree Swallow	Texaco Refinery	0.191	284	1.47	<0.499	<0.499	<0.299	5.41	9.64	<0.499	51.0
WT361-P	House Wren	Texaco Refinery	<0.151	436	4.56	<0.753	<0.753	<0.452	6.35	18.8	<0.753	55.8
WT366-P	House Wren	Texaco Refinery	<0.141	338	2.56	<0.706	<0.706	<0.424	5.58	12.0	<0.706	52.3
WT368-P	House Wren	Texaco Refinery	0.198	399	2.13	<0.594	<0.594	<0.356	5.72	36.0	<0.594	52.0
WT370-P	Bank Swallow	Texaco Refinery	0.198	293	2.85	<0.510	<0.510	<0.306	6.84	11.4	<0.510	52.7
WW411-P	Tree Swallow	Game & Fish	0.261	331	3.22	<1.03	<1.03	<0.620	7.36	16.7	<1.03	53.8
WW417-P	Tree Swallow	Game & Fish	0.255	370	2.23	<0.943	<0.943	<0.566	6.20	19.8	<0.943	47.8
WW424-P	Tree Swallow	Game & Fish	0.319	414	2.66	<1.02	<1.02	<0.610	7.56	17.2	<1.02	64.4
WW410-P	House Wren	Game & Fish	<0.222	399	2.39	<1.11	<1.11	<0.667	7.21	9.90	<1.11	60.5
WW414-P	House Wren	Game & Fish	<0.130	843	3.73	<0.651	<0.651	<0.391	6.77	60.7	<0.651	76.0
WW425-P	House Wren	Game & Fish	<0.107	574	2.51	<0.535	<0.535	<0.321	6.04	33.2	<0.535	64.7

Appendix 14. Trace element concentrations (µg/g dry weight) in eggs, gastrointestinal tract contents, livers, and carcasses from tree swallows and house wren nestlings collected at Edness K. Wilkins State Park along the North Platte River, 1997.

Sample #	Species	Matrix	% Moisture	Al	As	B	Ba	Be	Cd	Cr	Cu
WY800-P	Tree Swallow	Egg	80.4	28.0	<0.899	26.9	4.37	<0.180	<0.180	<0.899	2.06
WY805-P	Tree Swallow	Egg	80.7	27.3	<0.947	14.1	2.57	<0.189	<0.189	<0.947	2.50
WY811-P	Tree Swallow	Egg	82.6	19.1	<0.526	19.3	3.89	<0.105	<0.105	<0.526	2.95
WY807-P	House Wren	Egg	80.5	13.5	<0.499	14.1	13.1	<0.0998	<0.0998	<0.499	3.02
WY808-P	House Wren	Egg	82.2	12.6	<0.505	14.8	11.1	<0.101	<0.101	<0.505	2.94
WY812-P	House Wren	Egg	82.6	22.5	<0.564	24.7	14.5	<0.113	<0.113	<0.564	6.13
WYTREE-D	Tree Swallow	GI Tract	69.0	104	0.750	42.6	6.25	<0.135	0.176	<0.676	68.0
WYWREN-D	House Wren	GI Tract	69.5	346	<1.58	81.8	19.9	<0.316	1.40	<1.58	38.6
WY800N-L	Tree Swallow	Liver	68.8	17.0	<0.499	14.9	<0.499	<0.998	<0.0998	0.507	25.4
WY805N-L	Tree Swallow	Liver	68.2	<5.04	<0.504	8.48	<0.504	<0.101	<0.101	<0.504	16.6
WY811N-L	Tree Swallow	Liver	69.5	<5.09	<0.509	9.90	<0.509	<0.102	<0.102	<0.509	52.5
WY801N-L	House Wren	Liver	66.0	7.47	<0.608	20.3	<0.608	<0.122	0.164	<0.608	22.2
WY807N-L	House Wren	Liver	69.2	<5.51	<0.551	17.5	<0.551	<0.110	<0.110	<0.551	24.2
WY812N-L	House Wren	Liver	67.5	<5.57	<0.557	21.7	<0.557	<0.111	0.124	<0.557	21.3
WY800-N	Tree Swallow	Whole body	66.1	12.4	<0.504	<2.02	3.11	<0.101	<0.101	328	8.93
WY805-N	Tree Swallow	Whole body	64.4	8.68	0.540	<2.04	3.00	<0.102	<0.102	155	8.90
WY811-N	Tree Swallow	Whole body	69.9	9.10	<0.509	<2.04	1.89	<0.102	<0.102	171	9.38
WY801-N	House Wren	Whole body	70.3	40.5	<0.502	<2.01	6.78	<0.100	<0.100	170	7.46
WY807-N	House Wren	Whole body	74.2	28.0	<0.501	<2.00	6.96	<0.100	0.223	97.1	7.00
WY812-N	House Wren	Whole body	70.8	46.1	<0.504	<2.02	10.7	<0.101	0.223	244	7.78

Appendix 14 cont.

Sample #	Species	Matrix	Fe	Hg	Mg	Mn	Mo	Ni	Pb	Se
WY800-P	Tree Swallow	Egg	136.0	0.391	415.0	3.36	<0.899	<0.899	<0.0899	4.55
WY805-P	Tree Swallow	Egg	87.6	0.654	360.0	1.79	<0.947	<0.947	<0.0947	3.56
WY811-P	Tree Swallow	Egg	112.0	0.757	386.0	3.94	<0.526	<0.526	0.0675	4.85
WY807-P	House Wren	Egg	110.0	0.173	300.0	5.55	<0.499	<0.499	<0.998	4.35
WY808-P	House Wren	Egg	121.0	0.122	293.0	4.60	<0.505	<0.505	1.24	4.25
WY812-P	House Wren	Egg	120.0	0.120	434.0	6.17	<0.564	<0.564	1.18	6.34
WYTREE-D	Tree Swallow	GI Tract	150.0	<0.135	533.0	6.66	1.51	<0.676	0.168	7.53
WYWREN-D	House Wren	GI Tract	342.0	<0.316	998.0	26.1	3.11	<1.58	<3.16	<1.58
WY800N-L	Tree Swallow	Liver	1316	0.266	631.0	4.32	2.44	<0.499	0.440	17.6
WY805N-L	Tree Swallow	Liver	886.0	0.167	638.0	2.98	2.32	<0.504	0.352	16.7
WY811N-L	Tree Swallow	Liver	806.0	0.158	661.0	3.72	2.16	<0.509	0.250	12.9
WY801N-L	House Wren	Liver	4184	<0.122	672.0	5.11	4.25	1.00	1.34	11.3
WY807N-L	House Wren	Liver	2020	<0.110	748.0	5.65	3.69	<0.551	<1.10	7.02
WY812N-L	House Wren	Liver	2263	0.119	750.0	5.25	3.36	<0.557	<1.11	11.5
WY800-N	Tree Swallow	Whole Body	2468	0.190	732.0	38.4	2.43	52.9	0.149	8.09
WY805-N	Tree Swallow	Whole Body	1427	0.141	791.0	22.0	1.46	4.96	0.204	7.93
WY811-N	Tree Swallow	Whole Body	1598	0.130	813.0	26.3	1.54	6.95	0.125	6.78
WY801-N	House Wren	Whole Body	1576	0.107	951.0	27.7	1.53	2.16	<1.00	5.44
WY807-N	House Wren	Whole Body	1019	<0.100	1053	18.8	1.22	6.60	<1.00	3.59
WY812-N	House Wren	Whole Body	1905	<0.101	1129	28.4	2.51	30.7	<1.01	5.00

Appendix 14 cont.

Sample #	Species	Matrix	Sr	V	Zn
WY800-P	Tree Swallow	Egg	29.3	<0.899	61.6
WY805-P	Tree Swallow	Egg	33.5	<0.947	56.1
WY811-P	Tree Swallow	Egg	17.8	<0.526	56.9
WY807-P	House Wren	Egg	14.4	<0.499	53.7
WY808-P	House Wren	Egg	13.2	<0.505	49.3
WY812-P	House Wren	Egg	20.8	<0.564	69.1
WYTREE-D	Tree Swallow	GI Tract	90.2	<0.676	23.4
WYWREN-D	House Wren	GI Tract	42.8	<1.58	238
WY800N-L	Tree Swallow	Liver	0.536	<0.499	72.0
WY805N-L	Tree Swallow	Liver	0.386	<0.504	63.3
WY811N-L	Tree Swallow	Liver	0.290	<0.509	79.4
WY801N-L	House Wren	Liver	0.246	<0.608	78.7
WY807N-L	House Wren	Liver	0.341	<0.551	94.9
WY812N-L	House Wren	Liver	0.236	<0.557	102
WY800-N	Tree Swallow	Whole Body	33.0	1.53	249
WY805-N	Tree Swallow	Whole Body	41.6	0.643	201
WY811-N	Tree Swallow	Whole Body	25.2	0.790	218
WY801-N	House Wren	Whole Body	23.2	0.830	271
WY807-N	House Wren	Whole Body	31.1	<0.501	365
WY812-N	House Wren	Whole Body	31.1	1.29	200

Appendix 15. Trace element concentrations (µg/g dry weight) in livers from birds collected at sites along the North Platte River, 1998.

Sample #	Species*	Site	% Moisture	Al	As	B	Ba	Be	Cd	Cr
WA388-L	Tree Swallow	Amoco Park	68.9	<5.02	<0.502	9.74	<0.502	<0.100	<0.100	<0.502
WCS10-L	Cliff Swallow	Bryan Stocktrail Bridge	67.2	<8.83	<0.883	23.2	<0.883	<0.177	<0.177	<0.883
WCS11-L	Cliff Swallow	Bryan Stocktrail Bridge	65.2	<7.86	<0.786	12.8	<0.786	<0.157	0.673	<0.786
WCS12-L	Cliff Swallow	Patterson-Zonta Bridge	64.3	<7.29	0.980	26.6	<0.729	<0.146	1.88	<0.729
WCS13-L	Barn Swallow	Patterson-Zonta Bridge	64.3	<10.5	<1.05	8.72	<1.05	<0.211	1.63	<1.05
WCS14-L	Cliff Swallow	Patterson-Zonta Bridge	64.5	<8.01	<0.801	24.6	<0.801	<0.160	0.856	<0.801
WCS15-L	Cliff Swallow	Patterson-Zonta Bridge	63.5	<9.84	<0.984	<3.94	<0.984	<0.197	1.24	<0.984
WCS1-L	Cliff Swallow	Texaco Bridge	66.7	<9.77	<0.977	22.6	<0.977	<0.195	0.756	<0.977
WCS2-L	Cliff Swallow	Texaco Bridge	66.2	<8.68	<0.868	24.2	<0.868	<0.174	1.12	<0.868
WCS3-L	Cliff Swallow	Texaco Bridge	70.9	<8.39	<0.839	32.7	<0.839	<0.168	0.654	<0.839
WCS4-L	Cliff Swallow	Texaco Bridge	66.4	<10.7	<1.07	21.0	<1.07	<0.214	1.32	<1.07
WCS5-L	Cliff Swallow	Texaco Bridge	67.1	<8.65	<0.865	10.1	<0.865	<0.173	0.737	<0.865
WCS6-L	Cliff Swallow	Texaco Bridge	63.1	<6.87	<0.687	12.8	<0.687	<0.137	0.862	<0.687
WCS7-L	Cliff Swallow	Bryan Stocktrail Bridge	68.9	<10.4	<1.04	43.5	<1.04	<0.208	<0.208	<1.04
WCS8-L	Cliff Swallow	Bryan Stocktrail Bridge	63.3	<7.89	<0.789	23.2	<0.789	<0.158	1.08	<0.789
WCS9-L	Cliff Swallow	Bryan Stocktrail Bridge	65.2	<6.96	<0.696	20.8	<0.696	<0.139	0.709	<0.696
WP400-L	Tree Swallow	Patterson-Zonta Park	67.8	<7.94	<0.794	17.8	<0.794	<0.159	0.186	<0.794
WT350-L	Tree Swallow	Texaco Refinery	68.8	<6.96	<0.696	14.9	<0.696	<0.139	<0.139	<0.696
WT353-L	Tree Swallow	Texaco Refinery	71.7	<7.74	<0.774	23.3	<0.774	<0.155	<0.155	<0.774
WT358-L	Tree Swallow	Texaco Refinery	70.0	<5.05	<0.505	17.5	<0.505	<0.101	<0.101	<0.505
WT367-L	Tree Swallow	Texaco Refinery	71.3	7.94	<0.506	9.06	<0.506	<0.101	0.242	1.02
WT361-L	House Wren	Texaco Refinery	69.4	<5.48	<0.548	32.3	<0.548	<0.110	<0.110	<0.548
WT366-L	House Wren	Texaco Refinery	72.4	<10.1	<1.01	29.0	<1.01	<0.202	<0.202	<1.01
WT368-L	House Wren	Texaco Refinery	73.3	<5.02	<0.502	27.7	<0.502	<0.100	<0.100	<0.502
WW411-L	Tree Swallow	Game & Fish	69.2	<6.78	<0.678	21.1	<0.678	<0.136	<0.136	<0.678
WW417-L	Tree Swallow	Game & Fish	69.0	<5.06	<0.506	15.3	<0.506	<0.101	<0.101	<0.506
WW410-L	House Wren	Game & Fish	71.9	<9.16	<0.916	70.5	<0.916	<0.183	<0.183	<0.916
WW414-L	House Wren	Game & Fish	70.3	7.83	<0.748	42.5	<0.748	<0.150	<0.150	<0.748
WW425-L	House Wren	Game & Fish	68.6	<6.93	<0.692	29.9	<0.692	<0.138	<0.138	<0.692

* Tree swallows and house wrens are 12 day-old nestlings; cliff swallows and the barn swallow are adults.

Appendix 15 cont.

Sample #	Species*	Site	Cu	Fe	Hg	Mg	Mn	Mo	Ni	Pb	Se
WA388-L	Tree Swallow	Amoco Park	24.8	1151	0.109	622.0	3.89	1.89	<0.502	<0.301	17.8
WCS10-L	Cliff Swallow	Bryan Stocktrail Bridge	18.3	974.0	<0.177	754.0	6.36	3.23	<0.883	<0.530	11.0
WCS11-L	Cliff Swallow	Bryan Stocktrail Bridge	14.1	1236	0.179	640.0	6.46	2.49	<0.786	<0.472	8.33
WCS12-L	Cliff Swallow	Patterson-Zonta Bridge	15.5	982.0	0.218	681.0	6.33	2.36	<0.729	<0.437	8.59
WCS13-L	Barn Swallow	Patterson-Zonta Bridge	17.2	703.0	0.242	679.0	4.72	3.49	<1.05	<0.633	16.3
WCS14-L	Cliff Swallow	Patterson-Zonta Bridge	15.8	952.0	0.179	658.0	6.10	3.63	<0.801	<0.481	9.16
WCS15-L	Cliff Swallow	Patterson-Zonta Bridge	14.0	1040	<0.197	740.0	6.29	4.50	<0.984	<0.591	12.6
WCS1-L	Cliff Swallow	Texaco Bridge	19.2	661.0	0.650	842.0	6.60	3.37	<0.977	<0.586	9.10
WCS2-L	Cliff Swallow	Texaco Bridge	18.8	870.0	0.715	736.0	6.96	3.88	<0.868	<0.521	10.7
WCS3-L	Cliff Swallow	Texaco Bridge	14.3	2297	0.664	946.0	5.25	3.25	<0.839	0.740	11.8
WCS4-L	Cliff Swallow	Texaco Bridge	20.0	935.0	0.301	880.0	9.01	3.74	<1.07	<0.641	9.83
WCS5-L	Cliff Swallow	Texaco Bridge	18.1	558.0	0.327	892.0	7.10	2.68	<0.865	<0.519	10.7
WCS6-L	Cliff Swallow	Texaco Bridge	14.6	1027	0.270	639.0	6.43	2.43	<0.687	3.46	7.76
WCS7-L	Cliff Swallow	Bryan Stocktrail Bridge	15.3	3392	<0.208	862.0	5.91	3.67	<1.04	<0.625	12.2
WCS8-L	Cliff Swallow	Bryan Stocktrail Bridge	15.1	656.0	0.356	650.0	5.17	2.71	<0.789	<0.473	11.7
WCS9-L	Cliff Swallow	Bryan Stocktrail Bridge	15.4	746.0	0.286	659.0	5.51	2.86	<0.696	<0.418	11.6
WP400-L	Tree Swallow	Patterson-Zonta Park	30.6	1685	<0.159	816.0	6.36	2.61	<0.794	<0.476	26.6
WT350-L	Tree Swallow	Texaco Refinery	28.1	1232	0.209	870.0	5.18	2.32	<0.696	<0.418	21.6
WT353-L	Tree Swallow	Texaco Refinery	37.9	956.0	0.212	809.0	4.92	1.64	<0.774	<0.464	22.0
WT358-L	Tree Swallow	Texaco Refinery	19.9	1487	0.203	703.0	4.36	1.80	<0.505	<0.303	16.1
WT367-L	Tree Swallow	Texaco Refinery	30.6	498.0	0.151	1106	5.50	1.38	0.743	<0.304	15.3
WT361-L	House Wren	Texaco Refinery	14.3	1323	<0.110	811.0	5.89	1.51	<0.548	<0.329	19.5
WT366-L	House Wren	Texaco Refinery	28.0	3217	<0.202	1021	5.81	2.62	<1.01	<0.605	15.4
WT368-L	House Wren	Texaco Refinery	21.8	1699	0.122	901.0	5.54	1.90	<0.502	<0.301	16.7
WW411-L	Tree Swallow	Game & Fish	29.2	910.0	<0.136	763.0	3.71	2.10	<0.678	<0.406	22.5
WW417-L	Tree Swallow	Game & Fish	14.7	1176	<0.101	628.0	4.46	2.00	<0.506	<0.304	27.8
WW410-L	House Wren	Game & Fish	31.0	3607	<0.183	1003	7.20	3.41	<0.916	<0.550	21.4
WW414-L	House Wren	Game & Fish	28.3	3135	<0.150	915.0	6.10	3.03	<0.748	<0.449	17.4
WW425-L	House Wren	Game & Fish	17.3	1814	<0.138	670.0	5.17	2.80	<0.692	<0.416	22.8

* Tree swallows and house wrens are 12 day-old nestlings; cliff swallows and the barn swallow are adults.

Appendix 15 cont.

Sample #	Species*	Site	Sr	V	Zn
WA388-L	Tree Swallow	Amoco Park	0.238	<0.502	81.1
WCS10-L	Cliff Swallow	Bryan Stocktrail Bridge	0.358	<0.883	81.0
WCS11-L	Cliff Swallow	Bryan Stocktrail Bridge	<0.314	<0.786	68.9
WCS12-L	Cliff Swallow	Patterson-Zonta Bridge	0.359	<0.729	83.0
WCS13-L	Barn Swallow	Patterson-Zonta Bridge	<0.422	<1.050	72.0
WCS14-L	Cliff Swallow	Patterson-Zonta Bridge	<0.320	<0.801	80.3
WCS15-L	Cliff Swallow	Patterson-Zonta Bridge	<0.394	<0.984	83.0
WCS1-L	Cliff Swallow	Texaco Bridge	<0.391	<0.977	94.2
WCS2-L	Cliff Swallow	Texaco Bridge	<0.347	<0.868	92.7
WCS3-L	Cliff Swallow	Texaco Bridge	<0.336	<0.839	85.2
WCS4-L	Cliff Swallow	Texaco Bridge	<0.427	<1.07	108
WCS5-L	Cliff Swallow	Texaco Bridge	<0.346	<0.865	110
WCS6-L	Cliff Swallow	Texaco Bridge	0.297	<0.687	71.2
WCS7-L	Cliff Swallow	Bryan Stocktrail Bridge	<0.417	<1.04	86.8
WCS8-L	Cliff Swallow	Bryan Stocktrail Bridge	<0.316	<0.789	71.1
WCS9-L	Cliff Swallow	Bryan Stocktrail Bridge	<0.279	<0.696	74.3
WP400-L	Tree Swallow	Patterson-Zonta Park	<0.318	<0.794	86.0
WT350-L	Tree Swallow	Texaco Refinery	0.486	<0.696	82.6
WT353-L	Tree Swallow	Texaco Refinery	0.492	<0.774	91.1
WT358-L	Tree Swallow	Texaco Refinery	0.272	<0.505	81.3
WT367-L	Tree Swallow	Texaco Refinery	0.625	<0.506	133
WT361-L	House Wren	Texaco Refinery	0.488	<0.548	110
WT366-L	House Wren	Texaco Refinery	0.549	<1.01	114
WT368-L	House Wren	Texaco Refinery	0.378	<0.502	119
WW411-L	Tree Swallow	Game & Fish	<0.271	<0.678	75.5
WW417-L	Tree Swallow	Game & Fish	0.338	<0.506	70.3
WW410-L	House Wren	Game & Fish	0.779	<0.916	129
WW414-L	House Wren	Game & Fish	0.621	<0.748	96.1
WW425-L	House Wren	Game & Fish	0.348	<0.692	78.3

* Tree swallows and house wrens are 12 day-old nestlings; cliff swallows and the barn swallow are adults.

Appendix 16. Trace element concentrations (μg/g dry weight) in bird carcasses collected at sites along the North Platte River, 1998.

Sample #	Species*	Site	% Moisture	Al	As	B	Ba	Be	Cd	Cr
WA388-N	Tree Swallow	Amoco Park	69.3	12.7	<0.663	<2.65	2.99	<0.133	0.183	4.73
WCS10-A	Cliff Swallow	Bryan Stocktrail Bridge	61.7	69.8	<0.619	<2.48	8.37	<0.124	<0.124	4.15
WCS11-A	Cliff Swallow	Bryan Stocktrail Bridge	55.8	126	<0.727	<2.91	6.09	<0.145	0.251	2.25
WCS12-A	Cliff Swallow	Patterson-Zonta Bridge	61.9	65.3	<0.738	<2.95	7.55	<0.148	0.278	2.27
WCS13-A	Barn Swallow	Patterson-Zonta Bridge	62.0	44.2	<0.687	<2.75	4.80	<0.137	0.213	7.10
WCS14-A	Cliff Swallow	Patterson-Zonta Bridge	63.6	143	<0.751	<3.00	9.92	<0.150	0.331	8.12
WCS15-A	Cliff Swallow	Patterson-Zonta Bridge	59.8	88.5	0.780	<2.67	6.30	<0.133	0.609	5.82
WCS1-A	Cliff Swallow	Texaco Bridge	64.0	150	<0.762	<3.05	7.15	<0.152	0.188	3.10
WCS2-A	Cliff Swallow	Texaco Bridge	60.2	125	<0.681	<2.72	6.81	<0.136	0.392	6.75
WCS3-A	Cliff Swallow	Texaco Bridge	65.2	91.8	<0.733	<2.93	4.51	<0.147	0.359	2.65
WCS4-A	Cliff Swallow	Texaco Bridge	64.4	320	<0.667	<2.67	8.93	<0.133	0.193	4.30
WCS5-A	Cliff Swallow	Texaco Bridge	60.9	79.6	<0.628	<2.51	8.84	<0.126	0.144	3.19
WCS6-A	Cliff Swallow	Texaco Bridge	59.1	104	<0.667	<2.67	7.43	<0.133	0.149	4.02
WCS7-A	Cliff Swallow	Bryan Stocktrail Bridge	64.4	113	<0.691	<2.76	8.07	<0.138	0.172	7.94
WCS8-A	Cliff Swallow	Bryan Stocktrail Bridge	58.6	85.0	<0.672	<2.69	7.38	<0.134	0.351	4.16
WCS9-A	Cliff Swallow	Bryan Stocktrail Bridge	61.5	150	<0.672	<2.69	6.64	<0.134	0.200	2.38
WP400-N	Tree Swallow	Patterson-Zonta Park	66.2	12.3	<0.630	<2.52	2.42	<0.126	<0.126	9.32
WT350-N	Tree Swallow	Texaco Refinery	66.7	14.6	0.830	<2.76	4.08	<0.138	<0.138	6.20
WT353-N	Tree Swallow	Texaco Refinery	71.8	10.9	<0.643	<2.57	4.95	<0.128	<0.128	2.98
WT358-N	Tree Swallow	Texaco Refinery	71.0	13.7	<0.679	<2.72	3.13	<0.136	<0.136	3.53
WT367-N	Tree Swallow	Texaco Refinery	73.3	36.3	<0.665	<2.66	7.80	<0.133	<0.133	2.47
WT361-N	House Wren	Texaco Refinery	70.6	98.6	<0.639	<2.56	5.86	<0.128	0.143	2.07
WT366-N	House Wren	Texaco Refinery	74.6	119	<0.648	<2.59	4.99	<0.130	0.161	5.79
WT368-N	House Wren	Texaco Refinery	75.8	57.8	<0.641	<2.56	4.93	<0.128	<0.128	3.65
WW411-N	Tree Swallow	Game & Fish	69.3	13.2	<0.653	<2.61	2.57	<0.130	<0.130	1.83
WW417-N	Tree Swallow	Game & Fish	70.3	29.9	<0.611	<2.44	3.32	<0.122	<0.122	7.69
WW410-N	House Wren	Game & Fish	71.7	62.8	<0.646	<2.58	7.37	<0.129	0.132	3.54
WW414-N	House Wren	Game & Fish	70.1	59.8	<0.678	<2.71	9.40	<0.136	<0.136	2.09
WW425-N	House Wren	Game & Fish	71.0	45.5	<0.651	<2.60	9.07	<0.130	0.143	0.758

* Tree swallows and house wrens are 12 day-old nestlings; cliff swallows and the barn swallow are adults.

Appendix 16 cont.

Sample #	Species*	Site	Cu	Fe	Hg	Mg	Mn	Mo	Ni	Pb	Se
WA388-N	Tree Swallow	Amoco Park	5.17	129	<0.133	698.0	1.82	<0.663	<0.663	<0.398	8.99
WCS10-A	Cliff Swallow	Bryan Stocktrail Bridge	6.98	284	<0.124	809.0	3.96	<0.619	<0.619	0.680	8.37
WCS11-A	Cliff Swallow	Bryan Stocktrail Bridge	6.48	223	0.367	700.0	5.20	<0.727	<0.727	0.640	4.29
WCS12-A	Cliff Swallow	Patterson-Zonta Bridge	7.64	261	0.495	761.0	5.61	<0.738	<0.738	1.03	4.91
WCS13-A	Barn Swallow	Patterson-Zonta Bridge	9.00	234	0.769	834.0	4.16	<0.687	<0.687	6.23	6.96
WCS14-A	Cliff Swallow	Patterson-Zonta Bridge	8.91	383	0.257	976.0	7.34	<0.751	<0.751	1.63	5.65
WCS15-A	Cliff Swallow	Patterson-Zonta Bridge	6.90	351	0.373	679.0	5.59	<0.667	<0.667	1.97	5.80
WCS1-A	Cliff Swallow	Texaco Bridge	8.28	319	0.588	947.0	6.87	<0.762	<0.762	1.26	5.72
WCS2-A	Cliff Swallow	Texaco Bridge	8.22	326	0.597	775.0	7.22	<0.681	<0.681	3.49	5.66
WCS3-A	Cliff Swallow	Texaco Bridge	9.18	323	0.442	869.0	6.60	<0.733	<0.733	3.66	7.21
WCS4-A	Cliff Swallow	Texaco Bridge	9.59	562	0.345	1007	9.70	<0.667	0.683	1.66	5.84
WCS5-A	Cliff Swallow	Texaco Bridge	7.52	254	0.232	810.0	5.34	<0.628	<0.628	0.850	4.91
WCS6-A	Cliff Swallow	Texaco Bridge	7.33	307	0.426	743.0	6.92	<0.667	<0.667	15.0	4.47
WCS7-A	Cliff Swallow	Bryan Stocktrail Bridge	8.78	331	<0.138	1241	6.03	<0.691	<0.691	0.630	11.6
WCS8-A	Cliff Swallow	Bryan Stocktrail Bridge	7.54	238	0.549	746.0	6.54	<0.672	<0.672	0.900	5.51
WCS9-A	Cliff Swallow	Bryan Stocktrail Bridge	8.22	326	0.344	822.0	6.93	<0.672	<0.672	0.730	6.51
WP400-N	Tree Swallow	Patterson-Zonta Park	5.75	180	<0.126	688.0	2.72	<0.630	<0.630	<0.378	1.25
WT350-N	Tree Swallow	Texaco Refinery	6.98	134	0.216	905.0	3.48	<0.691	<0.691	<0.414	9.15
WT353-N	Tree Swallow	Texaco Refinery	6.09	120	0.216	842.0	3.32	<0.643	<0.643	<0.386	11.6
WT358-N	Tree Swallow	Texaco Refinery	5.63	138	0.170	778.0	2.46	<0.679	<0.679	<0.408	8.82
WT367-N	Tree Swallow	Texaco Refinery	7.68	165	0.155	1031	4.47	<0.665	<0.665	<0.399	9.00
WT361-N	House Wren	Texaco Refinery	6.30	321	<0.128	1099	5.93	<0.639	<0.639	0.860	7.11
WT366-N	House Wren	Texaco Refinery	7.35	374	<0.130	1208	6.72	<0.648	<0.648	1.08	5.95
WT368-N	House Wren	Texaco Refinery	7.72	314	<0.128	1085	6.42	<0.641	<0.641	<0.385	8.21
WW411-N	Tree Swallow	Game & Fish	4.68	111	<0.130	786.0	1.63	<0.653	<0.653	<0.392	10.6
WW417-N	Tree Swallow	Game & Fish	5.44	195	<0.122	795.0	3.85	<0.611	<0.611	<0.367	13.5
WW410-N	House Wren	Game & Fish	6.49	262	<0.129	977.0	4.92	<0.646	<0.646	<0.388	7.87
WW414-N	House Wren	Game & Fish	6.04	196	<0.136	978.0	3.67	<0.678	<0.678	<0.406	6.89
WW425-N	House Wren	Game & Fish	6.12	172	<0.130	1062	3.63	<0.651	<0.651	<0.391	7.62

* Tree swallows and house wrens are 12 day-old nestlings; cliff swallows and the barn swallow are adults.

Appendix 16 cont.

Sample #	Species*	Site	Sr	V	Zn
WA388-N	Tree Swallow	Amoco Park	24.0	<0.663	88.4
WCS10-A	Cliff Swallow	Bryan Stocktrail Bridge	44.3	<0.619	108
WCS11-A	Cliff Swallow	Bryan Stocktrail Bridge	15.1	<0.727	108
WCS12-A	Cliff Swallow	Patterson-Zonta Bridge	21.4	<0.738	121
WCS13-A	Barn Swallow	Patterson-Zonta Bridge	17.9	<0.687	124
WCS14-A	Cliff Swallow	Patterson-Zonta Bridge	21.2	<0.751	137
WCS15-A	Cliff Swallow	Patterson-Zonta Bridge	12.9	<0.667	133
WCS1-A	Cliff Swallow	Texaco Bridge	25.3	<0.762	161
WCS2-A	Cliff Swallow	Texaco Bridge	18.4	<0.681	146
WCS3-A	Cliff Swallow	Texaco Bridge	13.5	<0.733	180
WCS4-A	Cliff Swallow	Texaco Bridge	16.0	0.867	132
WCS5-A	Cliff Swallow	Texaco Bridge	16.7	<0.628	115
WCS6-A	Cliff Swallow	Texaco Bridge	16.0	<0.667	122
WCS7-A	Cliff Swallow	Bryan Stocktrail Bridge	46.3	<0.691	190
WCS8-A	Cliff Swallow	Bryan Stocktrail Bridge	19.2	<0.672	110
WCS9-A	Cliff Swallow	Bryan Stocktrail Bridge	19.2	<0.672	137
WP400-N	Tree Swallow	Patterson-Zonta Park	18.1	<0.630	86.0
WT350-N	Tree Swallow	Texaco Refinery	28.2	<0.691	99.4
WT353-N	Tree Swallow	Texaco Refinery	29.6	<0.643	90.6
WT358-N	Tree Swallow	Texaco Refinery	21.4	<0.679	96.1
WT367-N	Tree Swallow	Texaco Refinery	34.9	<0.665	119
WT361-N	House Wren	Texaco Refinery	33.1	<0.639	103
WT366-N	House Wren	Texaco Refinery	23.2	<0.648	111
WT368-N	House Wren	Texaco Refinery	30.5	<0.641	107
WW411-N	Tree Swallow	Game & Fish	24.9	<0.653	89.3
WW417-N	Tree Swallow	Game & Fish	26.9	<0.611	104
WW410-N	House Wren	Game & Fish	26.6	<0.646	95.1
WW414-N	House Wren	Game & Fish	27.4	<0.678	105
WW425-N	House Wren	Game & Fish	21.7	<0.651	99.2

* Tree swallows and house wrens are 12 day-old nestlings; cliff swallows and the barn swallow are adults.