U.S. Fish and Wildlife Service
Region 2
Contaminants Program

Playa Lakes of the Texas High Plains: A Contaminants Survey & Assessment of Biological Integrity

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EXECUTIVE SUMMARY/ABSTRACT

In response to increased interest in the quality of playa lakes and their recognition as valuable wildlife habitat, the Arlington Field Office of the U.S. Fish and Wildlife Service initiated a multi-year contaminants survey of playa lakes of the high plains of Texas in 1989. The study concluded in 1992 with additional laboratory analyses of remaining plant and invertebrate samples. Highlights include the following:

- Playa lakes serve as critical resting, wintering, and breeding habitat for several species of waterfowl, wading birds, shorebirds and other aquatic birds.

- Very high concentrations of arsenic were found in some playa lake sediment samples downstream of various land uses; only salt playas showed markedly lower concentrations. Potential sources of the arsenic include natural soil and rock erosion as well as arsenical pesticides. Zinc and copper were also elevated in some playa sediments.

- Potentially harmful concentrations of polycyclic aromatic hydrocarbons and other oil compounds were found in sediments near a brine discharge facility at Cedar Lake. This poses a potential problem for sandhill cranes and other waterbirds which sometimes make extensive use of Cedar Lake.

- A rapid bioassessment method to measure the degree of impairment at playa lakes surrounded by eight different land uses was developed and compared with accompanying contaminants data. The method used data on macroinvertebrates, zooplankton, plants, aquatic vertebrates, and birds.

- The rapid bioassessment method involved development of an Index of Biotic Integrity (IBI). The IBI demonstrated that there are trenchant differences among the various types of playa lakes surveyed. Aquatic communities in playas were clearly impaired by cattle feedlot wastes. The aquatic communities in playas receiving municipal effluents or brine disposal were also impaired, but to a lesser degree than those receiving feedlot wastes. There was a profound decrease in species richness at playas receiving feedlot wastes compared to other playas studied.

- Although playas receiving runoff from feedlots may be more similar to oil brine ponds than normal playas, they get very heavy bird use. Birds seem to be attracted to them because they provide a source of open water that does not freeze readily as well as food in the form of cattle feed and pollution tolerant invertebrates such as certain dipteran larvae.

- The potential bird hazards at feedlots are neither as immediate nor obvious as they are in oil pits. It will be difficult (and may require complex research) to fully determine the degree of hazards to birds.

- Playas fed by irrigation return flow from corn crops had a fairly diverse assemblage of invertebrates and plants. However, increasingly these "relatively clean" corn playas are drying up as farmers are changing over to more efficient irrigation methods that produce less runoff.

- The following potential playa lake hazards to migratory birds require more study: (1) concentrations and impacts of currently used pesticides which are not yet on routine Fish and Wildlife Service scans (includes synthetic pyrethroids, pass-through pesticides, "non-routine" feed additives, and breakdown products of all of the above); (2) exposure to the disease vector for avian cholera, and combinations of factors conducive to avian cholera; and, (3) effects of unbalanced, un-natural diet at feedlot and human sewage playas.

Keywords - playa lakes, wetlands, IBI, cattle, feedlots, strontium, copper, zinc, arsenic, nutrients, eutrophication, birds, sediments, metals, shorebirds, waterfowl, nitrogen, phosphates, water pollution, sewage, land use, agriculture, grazing, pesticides.

Project Numbers: 89-2-050, 90-2-050, 1992 2F05.

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United States Department of the Interior

FISH AND WILDLIFE SERVICE
P.O. Box 1306
Albuquerque, New Mexico 87103

In Reply Refer To:
Region 2/ES-EC

SEP 16 1996

Memorandum

To: Director, Fish and Wildlife Service, Washington, D.C. (AES/EC)

From: Acting Regional Director, Region 2

Subject: Contaminants Investigation Reports

91-2F2, E-mail Correction By R2 9/96

Attached are four contaminants reports. The report, *Playa Lakes of the Texas High Plains: A Contaminants Survey & Assessment of Biological Integrity,* was recently completed at the Ecological Services Field Office in Arlington, Texas. This report finalizes the investigation funded under 89-2-050, 90-2-050, and ~~1992 2F05~~. The other three reports are from the Ecological Services Field Office in Phoenix, Arizona. The *Contaminants in Fish and Wildlife Collected from the Lower Colorado River and Irrigation Drains of the Yuma Valley, Arizona* report completes the National Irrigation Water Quality Program project ID 2W30. The report titled *Contaminants in Sonoran Mud Turtles from Quitobaquito Springs, Organ Pipe Cactus National Monument, Arizona* and a report on lead shot contamination in proposed critical habitat were locally funded. These studies capitalized on ephemeral opportunities to further the Region's knowledge of contaminants issues in the Southwest.

If you have any questions or need more information, contact Stephen Robertson at (505) 248-6669.

Lynn B. Starnes

Attachments

cc: Geographic Managers, Region 2 (G/L)(T/L/E/E)

This report may be cited as follows:

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INTRODUCTION

More than 20,000 playa lakes occur in the Southern High Plains of New Mexico and Texas (Gustavson et al. 1994). Playa lakes are typically small (< 1.6 km in diameter), shallow (< 20 m deep), and often circular to oval wetland depressions. A few are as big as 40.5 hectares. Playa lakes should not be confused with the 30 or so much larger, irregular-shaped, saline lake basins in the Southern High Plains.

Nearly all of the Southern High Plains surface is internally drained into playa lakes. In the absence of man's activities, they are typically fed by thunderstorms and other precipitation events but are usually dry part of the year.

From a hydrological standpoint, playa lakes serve mostly as shallow evaporation ponds. Biologically, they serve as wetlands which are very important to birds and other wildlife in this relatively arid region. Playa lakes represent a source of aquatic habitat for resident and migratory avian species. In wet winters, they may provide from 93,150 to 101,250 surface ha of open water for 20 migratory game and 63 migratory nongame species (Nelson et al. 1983*a*). Additionally, eight migratory game species breed in the area. In some relatively wet years, playas may also provide significant habitat for summer nesting birds. Nationwide losses of wetlands resulting from land use changes and drought have made the remaining playas more critical as both migratory and breeding bird habitat.

A large majority of the playa lakes in the Southern High Plains are located in areas of intense agriculture. Several playas receive irrigation runoff from fields used for row crops or surface runoff from cattle feedlots. The aquatic biota of playas may be affected by the transport of herbicides and insecticides into the playas via: direct spraying of playas, transport via runoff, wind/spray drift, and water and wind transport of soil particles to which chemicals are attached.

Outbreaks of waterfowl diseases are not unusual in playas of the Southern High Plains of Texas. Bacteriological concerns involving wildlife include outbreaks of avian botulism (*Clostridium botulinum*) type C and avian cholera (*Pasteurella multocida*), which annually kill thousands of migratory waterfowl on the high plains. It is possible that the increased bacteria and nutrient content of playas affected by cattle feedlots also respresents an increased health risk to migratory waterfowl.

Playas that receive municipal effluent or cattle feedlot runoff have also been a concern from a contaminants standpoint for wintering birds that spend significant time feeding at these playas. The occurrence of toxic chemicals in significant amounts in the sludges and sediments of these playas is a possible concern in that birds may be accumulating unhealthy body burdens of toxic chemicals through water, food and sediment ingestion.

Agriculture, oil production, and municipalities generate a variety of effluents containing chemicals that have changed over time. For example, some agricultural chemicals such as DDT that were very harmful to fish and wildlife are no longer used, and changes in irrigation methods may subsquently change the amount of water available to playas for wildlife use. Some of the currently-used insecticides do not tend to bioaccumulate or persist as long as many of the banned insecticides, but some still are acutely toxic to birds and to the invertebrates birds eat (e.g. organophosphates). Invertebrates may be even more sensitive than fish to many of the currently-used insecticides.

Historical practices of waste oilfield brine disposal and discharges into Rich, Mound, and Cedar Lakes are a concern for fish and wildlife health. The lakes included in this study have historically been affected by oilfield pollution, and Cedar Lake NE was receiving oil brine waste with oil from a direct discharge at the time of sample collections. The smaller salt playas were also suspected of receiving oilfield brine pollution from groundwater sources.

A number of previous documents have characterized the playa lakes of the Southern High Plains and their importance to migratory birds; however, little information on contaminant issues has been available. Since some of man's current activities in the playa lakes region have the potential to create benefits for fish and wildlife, and other activities (i.e., agricultural, industrial, and urban) have the potential to reduce habitat and benefits for fish and wildlife resources, there has been a need to address the basic biology and current chemical regime of the playas. Therefore, a multi-year contaminants study of playa lakes in the Southern High Plains was initiated in 1989 by the Arlington Field Office of the Fish and Wildlife Service (Service).

Objectives of this study were to: 1) complete an inorganic, organic, and nutrient contaminants survey of sediments collected from several different playa categories in the Southern High Plains of Texas, 2) complete an inorganic and organic survey of invertebrates and plants collected from playas, 3) determine seasonal bird use of the playas during a one-year period, and 4) determine an Index of Biological Integrity (IBI) for the playas investigated in this study.

STUDY AREA

The specific study area within the Southern High Plains encompassed Bailey, Briscoe, Castro, Dawson, Deaf Smith, Floyd, Gaines, Hale, Hockley, Lamb, Lubbock, Lynn, Parmer, Swisher, and Terry Counties in the Panhandle of Texas (Figure 1). The study area for the bird surveys consisted of 29 playas within an area bounded on the north by Hereford in Deaf Smith County; on the east by Floydada in Floyd County; on the south to 9.6 km southwest of O'Donnel in Lynn/Dawson Counties; and on the west to Bovina in Parmer County.

Precipitation in the study area falls mainly from convective storms from May to August. Less than 18 percent of the annual precipitation falls from November to March and playas tend to be dry during this period (Orton 1969, Gustavson 1994). The mean annual precipitation generally decreases from northeast to southwest; the low level is about 15 inches (38 cm) in Dawson County and the high is about 21 inches (54 cm) in Gray County. West winds prevail during the winter months and south and southeast winds prevail during the summer months. Evaporation rates are high in the semiarid climate. The mean annual evaporation is about 96 inches (246 cm) within the study area (Nelson et al. 1983*a*).

Land use in the rural Southern High Plains is primarily cropland, irrigated cropland, grazing land, and oil production (Nelson et al. 1983*a*). Cropland and irrigated cropland are predominant in Castro, Deaf Smith, Floyd, Hale, Lamb, Lubbock, Parmer, and Swisher Counties in Texas. The distribution of crops in the study area is significant in evaluating wildlife habitat values. Corn, a heavy water user grown in highly irrigated areas, is mainly concentrated in Castro, Deaf Smith, Hale, Lamb, and Parmer Counties. Oil production within the study area occurs in Dawson, Gaines, and Terry Counties.

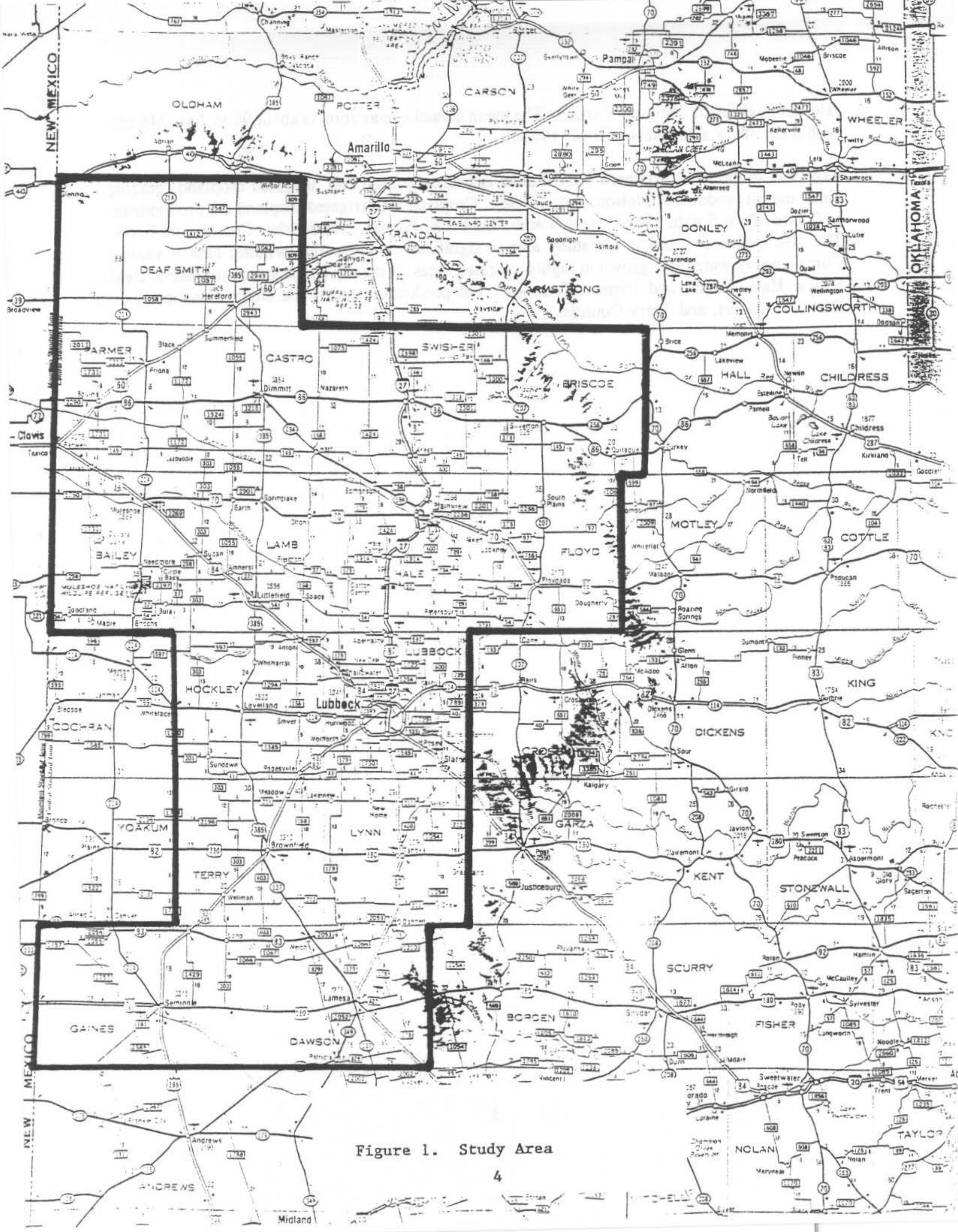


Figure 1. Study Area

MATERIALS AND METHODS

Eight land use categories were selected within the Southern High Plains. For each of the eight categories, four playa lakes were selected for the collection of sediment, invertebrates, and/or aquatic vegetation samples (Figures 2 & 3). Refer to Appendix 1 for details on playa lake locations. The eight land use categories and associated playa lake sample sites are as follows:

1. Irrigated cornfield playas - perennial drainwater from the corn fields is the primary water source for adjacent playas. Playas investigated for this study occurred in Parmer County and are identified in Figure 2 with letter code X.

2. Ephemeral row crop playas - agricultural activity includes plowing toward or through adjacent playas. Several types of crops are grown. Water runoff from this category is sporadic. Playas investigated for this study occurred in Hale and Parmer Counties and are identified in Figure 2 with letter code R.

3. Municipal effluent playas - effluent discharge from municipalities of Dimmit, Castro County; Olton and Sudan, Lamb County; and Bovina, Parmer County occurs year round into adjacent playas. Playas investigated for this study are identified in Figure 2 with letter code P.

4. Cattle feedlot playas - perennial runoff from feedlots in Deaf Smith and Parmer Counties drain into adjacent playas. Playas investigated for this study are identified in Figure 2 with letter code F.

5. Pasture/rangeland playas - runoff into playas is primarily after precipitation events. Playas investigated for this study occurred in Briscoe, Floyd, and Swisher Counties and are identified in Figure 2 with letter code E.

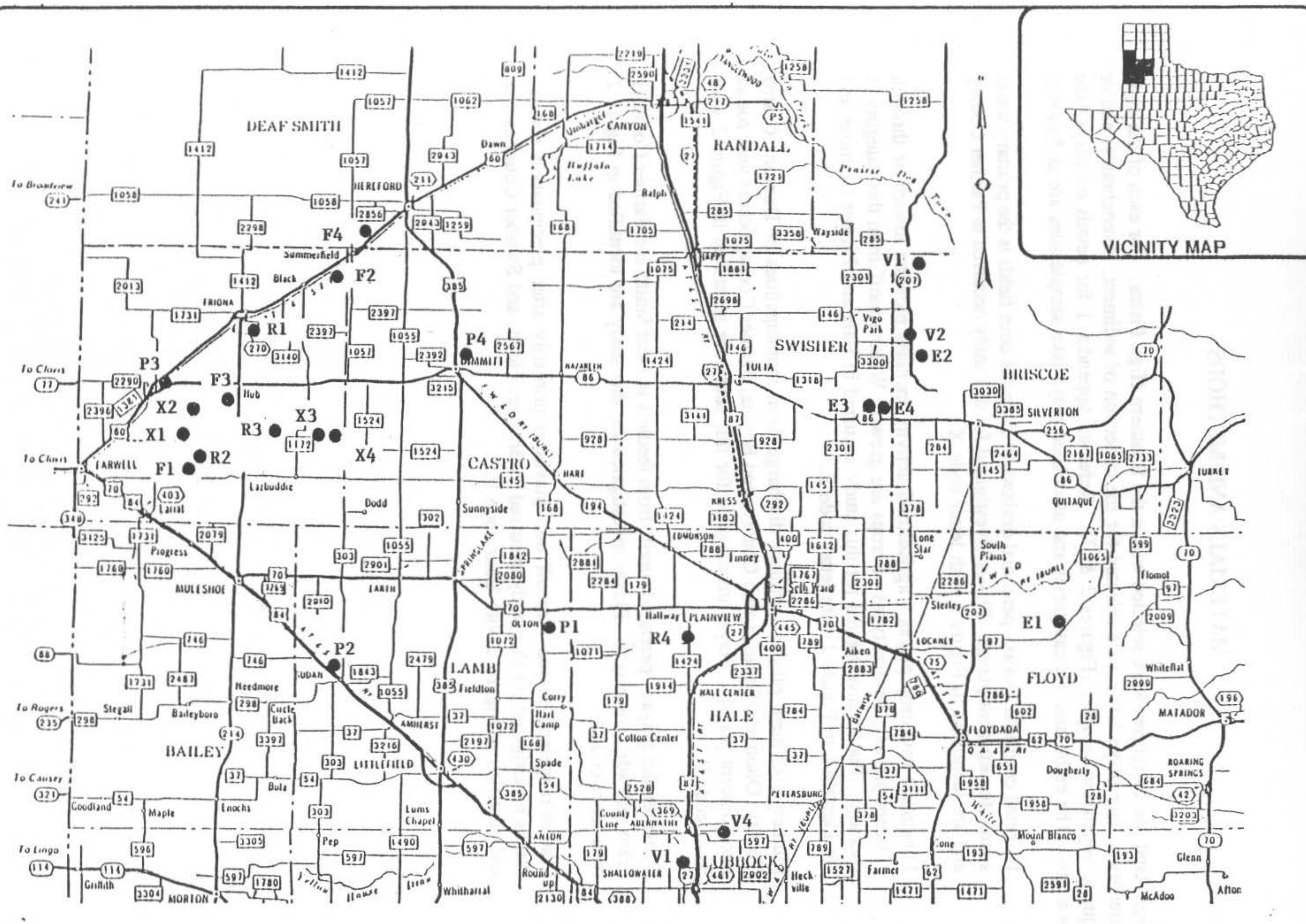


Figure 2. Study Site Locations North of Lubbock

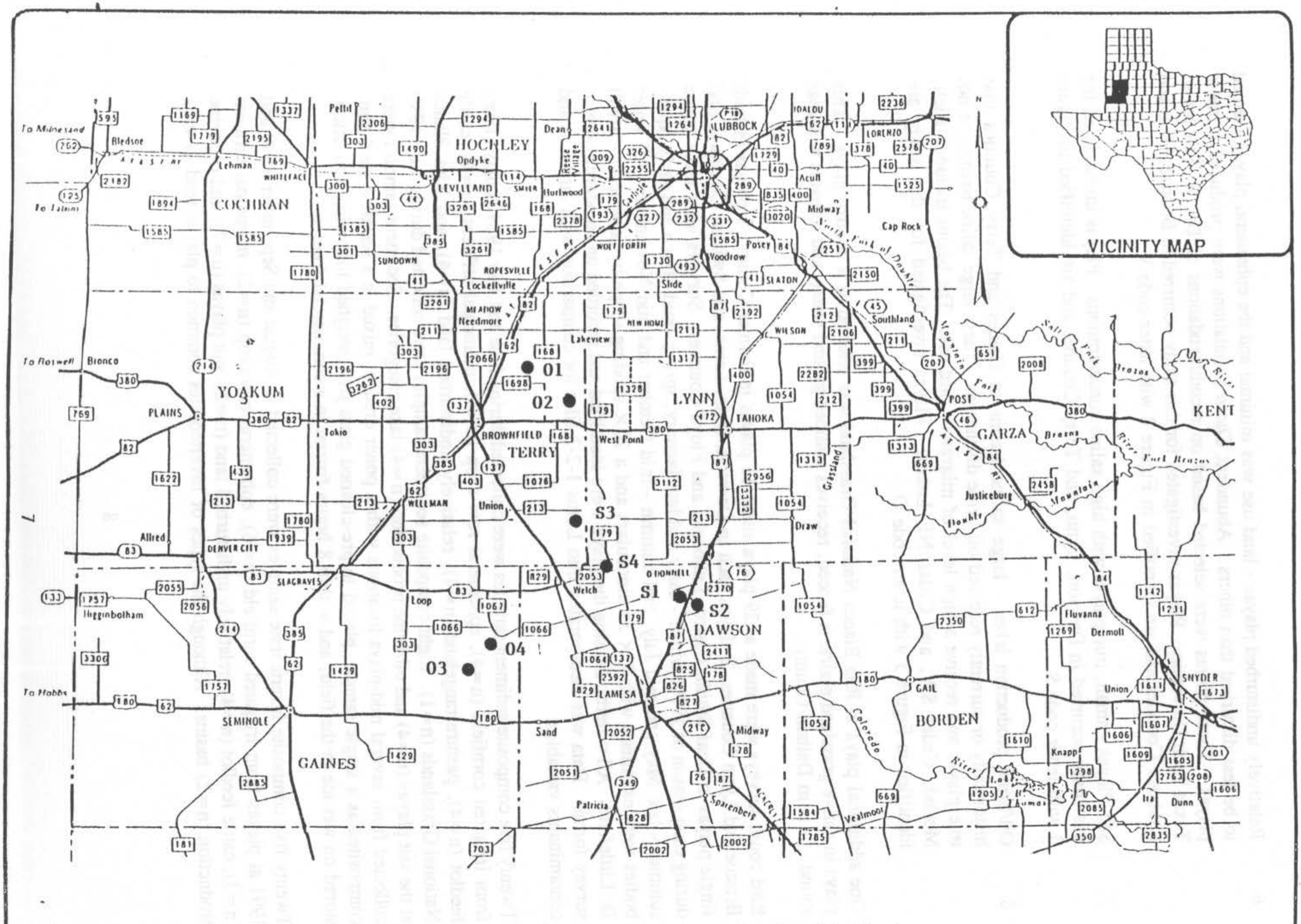


Figure 3. Study Site Locations South of Lubbock

6. Relatively undisturbed playas - land use was minimal and the ephemeral playas seemed to be less disturbed than others. Abundent *Chara* populations were produced in these playas. These playas were selected based on recommendations of Dr. V. Proctor of Texas Tech University. Playas investigated for this study occurred in Briscoe, Hale and Lubbock Counties and are identified in Figure 2 with letter code V.

7. Salt Playas - small, true playas with high saline concentrations. Playas investigated for this study occurred in Dawson, Lynn, and Terry Counties and are identified in Figure 3 with letter code S.

8. Oil/brine production lakes - large saline basins in Gaines and Terry Counties that historically or currently received oil brine discharges. These large saline basins are not true playas and receive a high level of migratory bird use. The basins included Rich, Mound, Cedar SW, and Cedar NE Lakes. Playas investigated for this study are identified in Figure 3 with letter code O.

One additional playa in Rita Blanca National Grassland was selected as a control playa. This playa in native grassland prairie is fenced, receives pumped ground water, and remains wet year round. It is in Dallam County.

Bird count surveys were made at 29 playa sites: 11 playas in Parmer County, 3 playas in both Briscoe and Lynn Counties, 2 playas each in Dawson, Hale, Lamb, and Swisher Counties, and single playas in Deaf Smith, Castro, Lubbock, and Floyd Counties. Surveys were made twice during each season of 1990: winter - early and late January, spring - mid March and early April, summer - late May and mid July, and autumn - mid October and mid November. All water bodies were examined with 7 × 35 binoculars and a 20× spotting scope by contractor Carroll D. Littlefield. All waterbirds using the playa were identified and recorded on standardized bird survey forms. Data was incorporated into Lotus 1-2-3 files for comparison with land use and contaminants variables.

Twenty five composite sediment samples were collected during June and July 1989 at playa lakes from irrigated cornfield (n=4), ephemeral row crop (n=4), municipal effluent (n=4), cattle feedlot (n=4), pasture/rangeland (n=4), relatively undisturbed land (n=4), and Rita Blanca National Grasslands (n=1). Eight composite sediment samples were collected during July 1990 at the salt playas (n=4) and oil/brine production (n=4) lake categories. Sediment samples were collected from several mid-playa locations with a ponar dredge, mixed in a stainless steel pan, composited as a single sample, placed in pre-cleaned glass jars, weighed following collection, stored on wet ice in the field, and within 8 hours frozen in a commercial freezer.

Twenty five composite invertebrate samples were collected in August and September 1990 and 1991 at playas from irrigated cornfield (n=6), ephemeral row crop (n=2), municipal effluent (n=3), cattle feedlot (n=4), relatively undisturbed land (n=2), salt playas (n=7), and oil/brine production (n=2) basins. Although the types of invertebrates common to playas tend to vary between land use categories, we assumed that a composite sample taken at each playa would be representative of the waterfowl and shorebirds diet.

Fifty composite aquatic vegetation samples were collected in August and September 1990 and 1991 at playas from irrigated cornfield (n=12), ephemeral row crop (n=3), cattle feedlot (n=8), municipal effluent (n=12), relatively undisturbed (n=3), salt playas (n=10), and oil/brine production basins (n=2). Vegetation samples consisted of seeds and tubers known to be eaten by waterfowl, including seeds of barnyard grass, smartweed, and other common emergent plants as well as tubers of arrowhead and, when present, pondweed. Invertebrate and plant samples were collected from several locations within each playa, composited into respective single samples, placed in pre-cleaned glass jars, weighed, stored on wet ice in the field and within 8 hours frozen in a commercial freezer.

Sediment samples were analyzed for metalloids, organochlorine pesticides including polychlorinated biphenyls (PCBs), chlorophenoxy acid herbicides, organophosphates, carbamates, aliphatic hydrocarbons, polycyclic aromatic hydrocarbons (PAHs), oil and grease, and nutrients. Invertebrate samples were analyzed for metalloids, organophosphates, carbamates, and PAHs. Aquatic vegetation samples were analyzed for metalloids, organophosphates, and carbamates. One sediment, ten invertebrate, and seven plant samples were analyzed for strontium 90 (^{90}Sr).

All samples were submitted through the U. S. Fish & Wildlife Service's Patuxent Analytical Control Facility to its designated contract laboratories. Metalloid analyses for sediments collected in 1989 were conducted by Hazleton Laboratories America, Incorporated, Madison, Wisconsin. Sediment samples collected in 1990 were analyzed for metalloids by Environmental Trace Substances Research Center, Columbia, Missouri. Metalloid analyses for invertebrates and plants and strontium-90 for sediment, invertebrates, and plants were conducted by Research Triangle Institute, South Carolina. Organochlorine pesticides, chlorophenoxy acid herbicides, aliphatic hydrocarbons, PAHs, oil and grease analyses for sediments were conducted by Mississippi State Chemical Laboratory, Mississippi State University, Mississippi. Organophosphate and carbamate analyses for sediments, invertebrates, and plants were conducted by Patuxent Analytical Control Facility, Patuxent, Maryland. PAHs were analyzed for six invertebrate and one sediment samples by Geochemical and Environmental Research Group, Texas A&M University, Texas. Nutrient analyses were conducted by Versar Laboratories, Inc. of Springfield, Virginia. Patuxent was responsible for assessing quality assurance and control (QA/QC) procedures for all contract labs; all analyses met Patuxent standards for QA/QC. A thorough description of analytical methods is available from Patuxent. These methods are summarized below.

Arsenic and selenium concentrations in sediments were determined by hydride generation, and mercury was determined by cold vapor atomic absorption. The graphite furnace technique was used for aluminum, cadmium, lead, nickel, and chromium. Arsenic and selenium concentrations in invertebrates and plants were determined by graphite furnace atomic absorption spectrometry and mercury was determined by cold vapor atomic absorption. All other elements in sediments, invertebrates, and plants were determined by inductively coupled plasma atomic emission spectrophotometer. Organochlorine, PCBs, aliphatic and aromatic hydrocarbons, oil and grease, organophosphate and carbamate concentrations in sediments and invertebrate were determined by gas chromatography. Chlorophenoxy acid herbicides were determined by acid fraction. Strontium 90 for sediments, invertebrates, plants was determined by the yttrium-90 (daughter of strontium 90) beta activity.

The lower level of detection for organochlorines, chlorophenoxy acid herbicides, aliphatic and aromatic hydrocarbons was 0.01 ppm wet weight for sediment, invertebrate, and plant samples. In sediment, invertebrate, and plant samples the lowest detection limit for toxaphene and PCBs was 0.05 ppm wet weight and for oil and grease was 10 ppm wet weight. The lower limit of detection was 0.5 ppm wet weight for organophosphates and 1.0 ppm wet weight for carbamates in sediment, invertebrate, and plant samples. Percent moisture was determined for sediment, invertebrate, and plant samples.

Results are reported in mg/kg dry weight for sediment, invertebrate, and plant samples.

Rapid bioassessment data was assembled by characterizing invertebrates and aquatic vegetation that typify each playa category. Vegetation, hydrological factors, and other standardized observations were recorded on a "fill-in-the-blank" field form. Macroinvertebrates were collected using four standardized sweeps with a "D" net; two 15-foot long sweeps along shoreline vegetation, and two 15-foot long sweeps along the bottom in mid-playa. Smaller invertebrates in the water column (vegetation, daphnids, clam shrimp) were observed with a dissecting scope after collecting 500 ml of water next to aquatic vegetation. In the playas where there was no emergent aquatic vegetation, the water samples were collected about 3 meters from shore.

Karr et al. (1986) designed an Index of Biotic Integrity using 12 attributes of the fish assemblage involving species composition, trophic composition, fish abundance and fish condition. Plafkin et al. (1989) developed and described various bioassessment methods, some of which included benthic invertebrates. We developed an index tied primarily to taxa richness in two groups: aquatic macrophytes and aquatic macroinvertebrates considered to be characteristic of playa lakes.

Data from the physical and biological survey were compared with results of contaminant analyses (primarily sediment and tissue) and with information on the surrounding land use. Field observations included simple measurements of possible importance to the overall value of the playa as fish and wildlife habitat. Due to a lack of resources (and lack of specific taxonomic knowledge), our inventory of playa macrophytes and macroinvertebrates was a coarse one (i.e., identification of aquatic insects to order or family). However, this level of detail did result in a relatively quick and simple method.

Observations recorded at each playa during 1989 included: the area covered by emergent vegetation greater than 0.5 m tall, the area covered by each plant species of special importance to waterfowl or shorebirds (smartweed, barnyard grass, pigweed, sedge, spikerush, spikesedge, cattail, bulrush, pondweed), three classes for relative abundance of various invertebrate groups, and the number of *Chara* species present. Data sheets used in previous Service studies (Curtis and Beierman 1980) were consulted in preparation of the field form used in this study. As anecdotal or duplicative variables were thrown out and additional important parameters were identified, revised checklists of field observations were developed for use during the 1990 and 1991 observation and data collection (Appendix 2).

Some initial literature work was done to determine which "pollution tolerant species" metrics should be used in statistical analyses. The pollution tolerant metrics used were those variables retained for the data collected and observed in 1990 and 1991 and multi-variate analyses passing the statistical criteria and biologically judged to be potentially significant in describing the basic biology of the playas and/or the potential impacts associated with various land uses or toxic chemical impacts. The remaining variables were intensively analyzed in comparison with chemical data and habitat needs of the birds which use the playas.

Lotus 1-2-3 spreadsheets were used for data entry and simple analyses. Statgraphics software (Manugistics) was used for most statistical analyses, including correlation coefficient calculations and discriminant function analyses. All references to significantly lower or significantly higher in this report refer to the accepted level of statistical significance ($P < 0.05$). The differences between independent samples were tested with the Mann-Whitney nonparametric statistical test (see the copper, strontium, and zinc sections).

RESULTS AND DISCUSSION

Organochlorine Pesticides and PCBs and Chlorophenoxy Acid Herbicides

Sediment - DDE, a breakdown product of DDT and the only organochlorine compound detected, was recovered (0.01 and 0.02 mg/kg) in playa sediments associated with irrigated cornfield, ephemeral row crop, municipal effluent, and cattle feedlots. Sediment samples did not have detectible levels of PCBs and chlorophenoxy acid herbicide compounds.

Organophosphate and Carbamate Pesticides

Sediment, invertebrate, aquatic vegetation - These samples did not have detectable levels of organophosphate and carbamate compounds.

Aliphatic and Aromatic Hydrocarbons - Hydrocarbons include a wide variety of naturally-occurring and biologically synthesized substances. Petroleum hydrocarbons can be generally subdivided into two groups: aliphatic and aromatic. Aliphatic compounds are carbon-based straight chain and branched chain (e.g., pristane and phytane) structures, whereas aromatic compounds are carbon-based rings (e.g., benzene). Aliphatic hydrocarbons are comprised of three subgroups: 1) paraffins (alkanes), all of which are saturated and comparatively unreactive; 2) olefins (alkenes or alkadienes) which are unsaturated and quite reactive; and 3) acetylenes (alkynes) which contain a triple bond and are highly reactive (Sax and Lewis 1987). Most paraffins are insoluble in water, so their toxicity to aquatic life is low. Hydrocarbons of recent biological origin tend to have aliphatic compounds with odd-numbers of carbons dominant, whereas petroleum compounds have nearly equal concentrations of odd- and even-numbered aliphatics (Hall and Coon 1988). The ratio of pristane to phytane serves as a useful indicator of the presence of petrogenic hydrocarbons. If the ratio is near one, then the oil is of petroleum derived hydrocarbons (Broman et al. 1987). Interpretation of hydrocarbon residues in fishes is more complicated than for sediments because fish metabolize aromatic compounds (Eisler 1987b).

Hydrocarbon analyses did not include an extended scan for n-alkanes containing the 21 to 34 carbon atoms ($n\text{-}C_{21}$ to $n\text{-}C_{34}$), which are essential for proper interpretation of hydrocarbon data to determine if samples have been oiled (Robinson-Wilson, Everett. 1991. Memorandum to Region 6, 8 May). Because of insufficient hydrocarbon analyses, interpretation of hydrocarbon data is limited and sound conclusions of the effects on wildlife resources can not be made. However, the data will be presented for information purposes.

Sediment - Total aliphatic concentrations ranged from 0.49 to 6,040.7 mg/kg (Appendix 3). Consistently elevated hydrocarbons were found at Cedar Lake NE (56-765 mg/kg). Hydrocarbons were not detected in sediments from corn-irrigated, relatively undisturbed, Rita Blanca, and salt playas. Very low concentrations (< 0.02) of PAHs were recorded from ephemeral row crop, municipal effluent, cattle feedlots, and pasture/rangeland playas. However, high concentrations of several PAH compounds were recovered in playa sediments from Cedar Lake NE. The following were confirmed by GC/Mass spectrometry: napthalene (0.39 mg/kg), fluorene (1.9 mg/kg), and phenanthrene (16.5 mg/kg). Several other PAH compounds were also detected at Cedar Lake NE, but could not be confirmed by GC/MS due to strong interferences. The high concentrations of aliphatic and aromatic compounds in sediments from Cedar Lake reflect oilfield pollution. The practice of allowing waste disposal containing these contaminants into Cedar Lake may well have a negative impact on waterbirds which use the lake, and alternate disposal methods should be considered.

Invertebrate - Total PAH concentrations ranged from 0.027 to 0.208 mg/kg. Concentrations reported for this study were below the PAH concentrations detected in Trinity River fish (0.02 - 60.79 mg/kg) as reported by Irwin (1988).

Since sandhill cranes and other migratory birds feed at Cedar Lake NE, the PAH pollution is a cause for concern. Some aromatic compounds, i.e. long chain aromatics, are documented carcinogens in fish and have been associated with fish tumors (Baumann et al. 1982, Baumann 1984). Several PAHs and their by-products are documented to be tumorigenic, teratogenic, and mutagenic to a variety of fish and wildlife, including fish, birds, amphibians, and mammals (Eisler 1987).

Sediment standards are not available for most individual PAHs, but the interim sediment criteria value adopted by EPA for phenanthrene, a non-carcinogenic PAH, is 6.2 micrograms per gram carbon (μg/gC), equivalent to about 18.9 parts per million (USEPA 1988). A scientist working on the interagency task force developing these standards has informed us that interim standards for many other PAHs will be in the 1-20 parts per million range, and indications are that final criteria values may be much lower (Chris Ingersoll, U.S. Fish and Wildlife Service, pers. comm).

Oil and Grease

Oil and grease concentrations in sediments ranged from none detected to 126,000 mg/kg (Appendix 4). The Texas statewide 85th percentile for oil and grease in lake sediments was 2,353 mg/kg (Kubala 1990). Concentrations in cattle feedlot sediments exceeded the 85th percentile. The type of oil and grease components are not specified by the analysis. However, the oilfield wastes at Cedar Lake NE were presumably from petrochemical sources, as elevated levels of aliphatic hydrocarbons and PAHs were detected. The oil and grease detected at Cedar Lake NE, therefore, may pose additional environmental hazards to fish and wildlife.

Metalloids

Sediment - Twenty of the 23 metalloids analyzed for were detected in sediment samples from most of the playas (Appendix 5). Antimony (< 0.5 mg/kg wet weight), thallium (< 0.5-10 mg/kg wet weight), and tin (< 2.5 mg/kg wet weight) were not recovered above laboratory detection levels. Aluminum, cadmium, and magnesium were detected, but generally not at concentrations above concern levels.

Arsenic - Arsenic was recovered at concentrations of 3.3 to 71.5 mg/kg (Appendix 5). The International Joint Commission (IJC 1988) considered 1.1 mg/kg dry weight to be the background level in sediments. Sediments from the Great Lakes with arsenic concentrations below 3.0 mg/kg were classified as non-polluted by Beyer (1990). Concentrations greater than 7.0 and 11 mg/kg dry weight have been considered heavily polluted and elevated by Ingersol and Nelson (1989), Beyer (1990), and Crayton and Jackson (1991). The arsenic concentration proposed by EPA Region 6 as a guideline for determining acceptability of dredged sediment disposal is 5.0 mg/kg dry weight (USEPA 1973). The Texas statewide 90th percentile value for arsenic in freshwater sediments is 15.7 mg/kg dry weight (Davis 1987). Sixty six percent of the sediment samples had concentrations greater than 11 mg/kg and may be considered heavily polluted.

Many arsenic-containing herbicides have been used in the area, especially on cotton crops, and arsenic attached to small soil particles is presumably transported widely around the Texas Panhandle by the high and frequent winds. The high use of arsenicals in the study area, particularly in the southern portion of the study area where cotton continues to be intensively grown and there is potential for wind transport of small arsenic-contaminated soil particles, may constitute one source of the arsenic in sediment samples. Wind transport mechanisms are complex, and relative humidity, wind speed, and presence or absence of tall boundary vegetation may influence the effects of wind transport of arsenic and other contaminants into playa lakes (Dr. James Gregory and Clifford Fedler, Agriculture Engineering Department, Texas Tech University, pers. comm.). In the playa lake region, cultivated fields where little or no effort is made to control erosion will typically lose 4-6 tons of topsoil per acre per year from wind erosion, with some areas losing as much as 10 tons of topsoil per acre per year (Dr. J. Gregory, Texas Tech University, pers. comm.).

During 1987-1989, organic arsenicals were abundantly used within the study area (R. Holloway, Texas A&M, pers. comm. see also Table 11).

Playas may also serve as a natural sink for trace metals in soils washed off fields by precipitation events, and the lack of drainage from playas can increase heavy metal concentrations to extraordinarily elevated levels.

There are natural sources of arsenic in Texas soils; however, sediment concentrations found in this study are quite high in comparison with Texas soil concentrations found in the literature. A recent survey (TSSWCB 1991) revealed that 28 Texas counties had average soil arsenic concentrations of less than 1 ppm. Fifty-five counties had average arsenic concentrations between 1 ppm and 2 ppm. This concentration would be considered low, but the source of arsenic (natural or anthropogenic) is not established. In the Texas survey, eight counties' soil had average arsenic concentrations greater than 2 ppm, but no arsenic concentrations above 3 ppm were found in any sample (TSSWCB 1991).

Arsenic concentrations in soil samples from site E-3 and Buffalo Lake National Wildlife Refuge, pastures that have never been plowed, were recovered at 3.9 to 9.56 ppm. Concentrations in these soil samples may lead to the conclusion that the high arsenic concentrations recovered in the study area are coming from arsenical pesticides versus a natural source in soils.

Arsenic levels above 7 ppm in soils will begin to affect some sensitive plants and levels above 17 ppm will eventually kill some species of newly established vegetation (TSSWCB 1991). However, other (non-sensitive) aquatic plants can bioaccumulate arsenic to levels several thousand times higher than surrounding levels (Camardese et al. 1990).

Aquatic vegetation concentrations of arsenic as low as 30 ppm wet weight have been found to sublethally affect and potentially alter the growth, physiology, and development of ducklings (Camardese et al. 1990). Ducks and waterfowl ingest sediments when feeding, and 14 of the 33 sediment samples in the current study had arsenic levels above 30 ppm.

Barium - Barium was recovered at concentrations of 30 to 289 mg/kg (Appendix 5). Barium metal does not occur free in nature; it is found in zinc and iron ores and forms salts with sulfate, carbonate, chloride, nitrate, and hydroxide anions (National Library of Medicine 1988). Sediments with barium concentrations greater than 60 mg/kg dry weight were classified as heavily polluted in the Great Lakes Harbors (Beyer 1990). A majority (94%) of the sediment concentrations exceeded the 60 mg/kg polluted category. However, given the wide range of concentrations and the lack of definitive information on barium effects on fish and wildlife, it is difficult to ascertain the importance of elevated barium in the study area.

Beryllium - Concentrations of beryllium in sediment ranged from ND to 1.87 mg/kg (Appendix 5). Concentrations from 2-6 mg/kg are not considered elevated by EPA (1988); however, the 1987 soil clean up criteria for beryllium given by the New Jersey Department of Environmental Protection is 1 mg/kg dry weight (Beyer 1990).

Boron - Recovered concentrations of boron in sediments were 4 to 104 mg/kg (Appendix 5). EPA (1986) does not consider 10 mg/kg dry weight as elevated in soils. Nearly 85% of the levels found in this study exceeded 10 mg/kg.

Chromium - Chromium was recovered in sediment at concentrations of 4.2 to 157 mg/kg (Appendix 5). Chromium in sediments tends to be elevated in the vicinity of industrial operations and municipal waste treatment facilities where chromium is a significant component of wastes discharged into the environment (Eisler 1986). Sediments with chromium concentrations of 25 to 75 mg/kg dry weight were classified as moderately polluted and greater than 75 mg/kg as heavily polluted in the Great Lakes harbor by Beyer (1990). Background concentrations of chromium in freshwater sediments have been reported at 140 mg/kg (Eisler 1986). Sediments from Cedar Lake NE (157 mg/kg) were highly elevated. When compared to the Great Lakes, about 70% of the sediments in this study would be considered as moderately polluted. It is generally agreed that most chromium in sediment is unavailable to living organisms; adsorption and bioaccumulation are relatively minor (Eisler 1986).

Copper - Recovered concentrations of copper in sediment were at 2.6 to 54.4 mg/kg (Appendix 5). The highest copper concentrations were recovered in sediments from playas associated with cattle feedlots. The 90th percentile for copper in freshwater sediments in Texas was 40.0 mg/kg (Davis 1987). The IJC (1988) suggested 20.8 mg/kg dry weight to be a background concentration in sediments. About 50% of the playa sediments had concentrations of copper exceeding the IJC background level.

Elevated concentrations of copper are often recovered in the vicinity of municipal and industrial outfalls (US EPA 1983). Copper compounds are known to be used as feed additives for feedlot operations. In an earlier study of nearby Buffalo Lake National Wildlife Refuge, copper concentrations from the six upstream samples in Tierra Blanca Creek were significantly lower than the six samples in the study area known or suspected of being influenced by feedlot wastes (Irwin and Dodson 1991).

Iron - Concentrations of iron recovered in sediments ranged from 2720 to 32,500 mg/kg (Appendix 5). Sediments with iron concentrations from 17,000 - 25,000 mg/kg or > 25,000 mg/kg are classified as moderately to heavily polluted, respectively, in the Great Lakes harbor (Beyer 1990, Crayton and Jackson 1991). Greater than half of the sediment samples in the irrigated cornfield, ephemeral row crop, pasture/rangeland, and Rita Blanca Grassland playas fall within the range Beyer classified as moderately to heavily polluted.

Lead - Lead concentrations recovered in sediment were 3.1 to 58.2 mg/kg (Appendix 5). Sediments with lead concentrations < 40 mg/kg dry weight were classified as non-polluted in the Great Lakes harbor by Beyer (1990). With the exception of one cattle feedlot playa and Cedar Lake NE, sediment concentrations were below the level we considered non-polluted.

Manganese - Concentrations of manganese in sediments were recovered at 34 to 934 mg/kg (Appendix 5). Sediments with manganese concentrations at 300 - 500 mg/kg dry weight were classified as moderately polluted in the Great Lakes harbor by Beyer (1990). About half the sediment samples in this study fall within the above range. Weak trends suggested municipal effluent playas had relatively low levels and ephemeral row crop playas had higher levels.

Mercury - Mercury concentrations in sediments were below the detection limit in 18 of the 33 samples (Appendix 5). Recovered concentrations ranged from 0.03 to 0.25 mg/kg. Mercury has a propensity to bioaccumulate, so sediments with less than 1 ppm mercury may be a cause of concern to fish and wildlife. Mercury concentrations of 0.1 mg/kg fed to ducks reduced fertility and inhibited food conversion (USEPA 1980a). Many waterfowl species feed on sediment associated organisms and may indirectly ingest sediments.

Molybdenum - Molybdenum was recovered in sediments at concentrations of 1 to 20 mg/kg (Appendix 5). These concentrations were within background concentrations (5 to 57 mg/kg dry weight) from U.S. river sediments reported by Eisler (1989).

Nickel - Concentrations of nickel in sediments were recovered at 4 to 60 mg/kg (Appendix 5). The Texas statewide 90th percentile value was 31.8 mg/kg dry weight (Davis 1987). Great Lake sediments with concentrations higher than 50 mg/kg dry weight were classified as heavily polluted by Ingersoll and Nelson (1989) and Beyer (1990). One sample from the corn irrigated playa exceeded the concentration considered to be heavily polluted. Eighteen percent of the sediment samples were equal to or exceeded the range considered to be moderately polluted (20 - 50 mg/kg dry weight) by Beyer (1990).

Selenium - Selenium was recovered in about 40% of the sediment samples collected at concentrations of 0.3 to 15 mg/kg (Appendix 5). Selenium concentrations were several times higher than those considered background (< 0.75 mg/kg dry weight) in the U.S. (Eisler 1985a). Selenium concentrations in the salt playas, Rich Lake and Mound Lake, exceeded the level of concern (≥4 mg/kg dry weight) in sediments for fish and wildlife (Lemly and Smith 1987). Similar concentrations were observed in Mound Lake by TPWD (Roxie Cantu, TPWD, pers. comm. 1995).

Selenium occurs naturally in the environment in trace amounts; soil concentrations rarely exceed 2 mg/kg dry weight. (Lemly and Smith 1987). Although selenium is an essential micronutrient for normal animal nutrition, concentrations not greatly exceeding those required may produce toxic effects to waterfowl and other species of fish and wildlife. However, data suggest that agricultural practices are not producing or contributing selenium-laden waters into playas within the study area. Irrigation return-flow waters in northern California have been associated with elevated levels of selenium and other contaminants (Schuler 1987).

Silver - Silver was recovered only in one saline playa sediment sample (4 mg/kg) and exceeded the Texas statewide 90th percentile (3.0 mg/kg dry weight) for sediments (Davis 1987). NOAA suggested that the potential for biological effects of this contaminant sorbed to sediments was highest in sediments where its concentration exceeded 2.2 mg/kg dry weight and was lowest in sediments where its concentration was less than 1.0 mg/kg dry weight (Long and Morgan 1990).

Strontium and Strontium 90 - Strontium was recovered in sediments at concentrations of 16 to 8,620 mg/kg (Appendix 5). Cedar Lake NE sediments had the highest concentration of strontium (8,620 mg/kg). Strontium is a soft, silvery metal with physical and chemical properties similar to those of calcium. The health risks of elevated strontium in animal tissues are not well understood.

A Mann-Whitney statistical test showed that strontium concentrations from the four ephemeral row crop playa samples were significantly lower than concentrations in the four cattle feedlot playa samples (significant at 0.03). Similar results were reported by Irwin and Dodson (1991) at the Buffalo Lake National Wildlife Refuge in Randall County, Texas. Irwin and Dodson (1991) reported that strontium concentrations (< 56 mg/kg dry weight) in sediment samples from Tierra Blanca Creek and a playa north of Tierra Blanca Creek, both upstream from cattle feedlot sites, were significantly lower than the sediment concentrations from Tierra Blanca Creek samples suspected of being polluted by a large cattle feedlot (209-226 mg/kg dry weight) and a cattle feedlot waste water pond (300-310 mg/kg dry weight).

The strontium 90 concentration for sediment was below the detection limit of 1.22 pCi/g. Strontium 90, with a half-life of 29 years, is formed in nuclear explosions, is absorbed by growing plants, and when ingested, accumulates in bones (Sax and Lewis 1987). Strontium 90 is assimilated by cattle as they consume plants containing it, thus the source of strontium 90 in milk (Minnesota Department of Health 1962). Strontium 90 does not appear to pose a health risk to wildlife of the Southern High Plains.

Zinc - Zinc concentrations in sediments were recovered at 9.3 to 226 mg/kg (Appendix 5). The highest sediment concentrations were recovered in cattle feedlot playas. Background concentrations of zinc in sediments seldom exceed 200 mg/kg (Eisler 1993). A Mann-Whitney statistical test showed zinc concentrations from the four ephemeral rowcrop playa samples to be significantly lower than concentrations in the four cattle feedlot playa samples (significant at 0.03).

Similar results were reported by Irwin and Dodson (1991) at the Buffalo Lake National Wildlife Refuge in Randall County, Texas. Irwin and Dodson reported that zinc concentrations (< 29 mg/kg dry weight) in sediment samples from Tierra Blanca Creek and a playa north of Tierra Blanca Creek, both upstream from cattle feedlot sites, were significantly lower than in sediment samples from Tierra Blanca Creek suspected of being polluted by a large cattle feedlot (128-139 mg/kg dry weight) and a cattle feedlot waste water pond (491-538 mg/kg dry weight).

Invertebrates and aquatic vegetation - All nineteen metalloids tested for were detected in the invertebrate and aquatic vegetation samples from most of the playas. Beryllium was detected in a few samples, but not at concentrations above concern levels for invertebrates and plants (Appendices 6 and 7).

Arsenic - Arsenic was recovered in invertebrates at concentrations of non-detected to 122.6 mg/kg and in aquatic vegetation from non-detected to 199.4 mg/kg (Appendices 6 and 7).

Concentrations of arsenic in aquatic vegetation low as 30 ppm have been found to sublethally affect and potentially alter the growth, physiology, and development of ducklings (Camardese et al. 1990). Eight of 51 plant samples had arsenic levels above 30 ppm.

Barium - Barium was recovered at concentrations of 2.9 to 121 mg/kg for invertebrates and 1.2 to 454 mg/kg for aquatic vegetation (Appendices 6 and 7). No comparable data are available to assess whether barium concentrations reported in this study were elevated or within normal background range.

Boron - Recovered concentrations of boron in invertebrates were at non-detected to 379 mg/kg (Appendix 6). Concentrations recovered in aquatic vegetation were at 8.9 to 751 mg/kg (Appendix 7). Preliminary data suggests the potential for bioaccumulation or bioconcentration of boron is moderate for mollusks, crustacea, lower animals, and higher plants (Jenkins 1981). Plants take up boron from soil, groundwater, biocides, and air pollution (Jenkins 1981). Plant species vary in their sensitivity to boron, but many plants have problems with concentrations exceeding 1.0 mg/l (Hem 1985). The Service considers plant tissue levels to be elevated in boron if above 120 mg/kg dry weight. Vegetation samples from saline playas and Rich Lake have elevated concentrations of boron.

Cadmium - Cadmium was recovered at non-detected to 1.2 mg/kg for invertebrates and non-detected to 1.9 mg/kg for aquatic vegetation samples (Appendices 6 and 7). Anthropogenic sources of cadmium include fertilizer and municipal wastewater and sludge discharges (Eisler 1985b). Until other data become available, Eisler (1985) reports concentrations exceeding 0.1 mg/kg wet weight may be considered as a secondary hazard of cadmium poisoning to avian predators. Invertebrate and aquatic vegetation samples from irrigated cornfield, relatively undisturbed, and salt playas as well as Rich Lake contained such cadmium levels.

Chromium - Chromium was recovered at concentrations of non-detected to 7.5 mg/kg for invertebrates and non-detected to 10.2 mg/kg for aquatic vegetation tissue samples (Appendices 6 and 7). Chromium concentrations for invertebrate and aquatic vegetation samples from irrigated cornfield, ephemeral row crop, cattle feedlot, relatively undisturbed, and salt playas exceeded the 4.0 mg/kg dry weight level considered as evidence of chromium contamination (Eisler 1986). We recognize the possibility, however, of sediment contamination contributing to the elevated chromium in the samples.

Copper - Concentrations of copper for invertebrates was recovered at 3.2 to 45.8 mg/kg and for aquatic vegetation samples at 2.5 to 263.5 mg/kg. (Appendices 6 and 7). The National Research Council (1980) has indicated a threshold concentration of 300 μg/g wet weight as a health risk for avian species.

Mercury - Mercury concentrations for invertebrates were below the detection limit in 14 of the 25 samples (Appendix 6). Recovered concentrations for invertebrates ranged from 0.03 to 0.92 mg/kg. Seventeen of the 50 aquatic vegetation samples had recovered concentrations of mercury at 0.05 to 0.17 mg/kg (Appendix 7). The predator protection limit for mercury is 0.1 mg/kg wet weight for fish-eating waterfowl (NAS/NAE 1973). Only three invertebrate samples from irrigated cornfield and ephemeral row crop playas exceeded the 0.1 mg/kg concentration that may cause adverse effects on fish-eating birds (Eisler 1987a, NAS/NAE 1973).

Molybdenum - Molybdenum concentrations for invertebrates were below the detection limit in 21 of the 25 samples and for aquatic vegetation below the detection limit in 43 of 50 samples (Appendices 6 and 7). Data are lacking on the effects of molybdenum on avian wildlife under controlled conditions. All studies conducted with birds have been restricted to domestic poultry.

Nickel - Nickel was recovered in invertebrates at concentrations of non-detected to 7.8 mg/kg and in aquatic vegetation from non-detected to 27 mg/kg (Appendices 6 and 7). Little information is available on the effects of nickel body burdens on fish and wildlife.

Selenium - Selenium was recovered in invertebrates at concentrations of non-detected to 110 mg/kg and recovered in aquatic vegetation at non-detected to 39.3 mg/kg (Appendices 6 and 7). As a dietary source for waterfowl, invertebrate and aquatic vegetation samples from one ephemeral row crop and salt playa, and Rich and Mound Lakes, exceeded the concentration (≥ 3 mg/kg dry weight) that could cause reproductive failure or mortality in waterfowl due to food-chain bioconcentration (Lemly and Smith 1987). Similar concentrations were observed for invertebrates at Mound Lake by TPWD (Roxie Cantu, TPWD, pers. comm. 1995).

Strontium - Strontium was recovered at concentrations of 14.2 to 2,179.2 mg/kg for invertebrates and 7.7 to 1,174.2 mg/kg for aquatic vegetation tissue samples (Appendices 6 and 7). Salt playas had the highest concentrations of strontium in both invertebrates and vegetation. Body burden issues are not well understood.

Strontium 90 - Strontium 90 (^{90}Sr) was recovered in one of 11 invertebrate samples and in 3 of 8 aquatic vegetation samples. Strontium 90 behaves much like calcium in the biological environment, it is absorbed into the bone (Eisler 1994). For example, a positive relationship was demonstrated between reactor releases of ^{90}Sr to the Columbia River, Washington and ^{90}Sr concentrations in reed canary grass and eggshells of the Canada goose. Radionuclide concentrations in representative field collections of biota tend to be elevated in the vicinity of nuclear fuel reprocessing, nuclear power production, and nuclear waste facilities; in locations that receive radioactive fallout from nuclear accidents and atmospheric nuclear tests; and near sites of repeated nuclear detonations. Strontium concentrations in benthic invertebrates ranged from 1135 to 213,513 pCi/g in a South Carolina reactor cooling impoundment that was accidentally contaminated. No radiological criteria now exist for the protection of fishes, wildlife or other sensitive natural resources.

Vanadium - Vanadium was recovered at concentrations of 0.3 to 37.3 mg/kg for invertebrates and non-detected to 24.8 mg/kg for aquatic vegetation (Appendices 6 and 7). Dietary vanadium at 25 mg/kg, fed either as ammonium vanadate or vanadium sulfate, significantly depressed growth and caused mortality in young chicks (Hatchcock et al. 1964). Dietary vanadium at levels as low as 0.5 mg/kg wet weight have been shown to alter metabolism in mallards (White et al. 1980).

Zinc - Zinc was recovered at concentrations of 11 to 140 mg/kg for invertebrates and 7.4 to 160 mg/kg for aquatic vegetation (Appendices 6 and 7). The recommended maximum zinc limit in bird diets is 178 mg/kg dry weight to prevent marginal sub lethal effects (Eisler 1993). Concentrations recovered during this study did not exceed that dietary limit.

Nutrients

<u>Ammonia Nitrogen (NH_3-N)</u> - Ammonia is a biologically active nutrient normally present in most waters at low concentrations resulting from the degradation of nitrogenous organic matter (Flora et al. 1984). It may also enter playas through discharges of industrial wastes (e.g., as sewage effluent), or from agricultural runoff. Ammonia can contribute to stress on organisms,

including synergistic toxicity with metals (i.e., copper and zinc), and stress associated with low oxygen conditions (Ankley et al. 1990). The toxicity of ammonia can increase with increasing pH and temperature. Warm, alkaline waters prevail throughout the study area.

Nutrient cycling in prairie marshes and playa lakes includes a significant amount of nitrogen removal via denitrification processes. Especially under anaerobic conditions (such as are present at feedlots), nitrogen compounds are reduced to ammonia, and subsequently can be volatilized to the atmosphere. Nitrate is removed by these processes in playa wetlands to a greater extent than is ammonia, and ammonia can build up in anoxic sediments. Frequent or periodic drying/inundation of playas can result in large nitrogen losses during sequential processes of nitrification and denitrification.

Ammonium concentrations recovered in sediments ranged from 1.88 to 914 mg/kg (Appendix 8). Ammonium concentrations were highest in municipal effluent and cattle feedlot playas. Ammonium in sediments can contribute to the acute toxicity of freshwater fish and invertebrates (Ankley et al. 1990). Ammonium could be a contributing factor of reduced aquatic diversity in cattle feedlot playas. Invertebrate diversity was lowest at cattle feedlot playas.

Chemical Oxygen Demand (COD) - To determine the organic pollution load of sediments, chemical oxygen demand (COD) was determined using strong oxidizing agents. The higher the COD, the greater the organic pollution (Hem 1992). COD concentrations in sediments ranged from 7,560 to 794,000 mg/kg (Appendix 8). The highest COD was recovered in sediments from Cedar Lake NE at 794,000 mg/kg. The statewide 90th percentile for Texas sediment COD values was 78,093 mg/kg dry weight (Davis 1987). COD concentrations in the municipal effluent, cattle feedlot, relatively undisturbed and salt playas also exceeded the Texas 90th percentile.

Nitrate Nitrogen (NO_3-N) - Nitrate nitrogen concentrations in sediments ranged from 0.05 to 5.94 mg/kg (Appendix 8). Nitrate nitrogen concentrations above 20 mg/kg are considered very high for soils in Texas cotton fields (TSSWCB 1991). Nitrates in sediment from cattle feedlot playas were low even though they contained elevated total Kjeldahl nitrogen concentrations. Cattle feedlot playas had low dissolved oxygen concentrations in the water column and anoxic sediments. Lack of available oxygen is suspected as a suppressant of nitrate formation in cattle feedlot playas. Nitrates are soluble and can be transported to the groundwater; however, researchers at Texas A&M have suggested that the clay layers can effectively seal playa lakes (Sweeten, 1994). Under the anaerobic conditions found in feedlot playas, nitrates are reduced to nitrites, ammonium is fixed by nitrogen-fixing bacteria, and considerable amounts of ammonium are volatilized into the atmosphere. Excess nitrates contribute to the eutrofication of lakes (Hem 1992).

Total Kjeldahl Nitrogen (TKN) - TKN concentrations recovered in sediments range from 217 to 19,200 mg/kg (Appendix 8). Cattle feedlot playas had the highest TKN levels. Concentrations of TKN in feedlot sediments were up to ten times higher than concentrations in other playa sediment samples. An average TKN of 1,000 to 2,400 mg/kg would be expected in sediments supporting fertilized agriculture (Dr. Harold V. Eck, Soil Scientist, USDA, Bushland, TX, pers. comm.).

Organic Nitrogen - Concentrations of organic nitrogen in sediments paralleled TKN trends and ranged from 215 to 18,400 mg/kg (Appendix 8). Generally, organic nitrogen makes up better than 90% of the TKN. The highest concentrations were in sediments from cattle feedlot playas. The Texas statewide 85th percentile for organic nitrogen in lake sediments was 3,896 mg/kg dry weight (Kubala 1990). One municipal effluent playa and all cattle feedlot playas exceeded the 85th percentile value.

Total Phosphate - Total phosphate concentrations in sediment were recovered at 205 to 14,400 mg/kg (Appendix 8). As expected, total phosphate was recovered at greater concentrations than the soluble phosphate fraction. One municipal effluent playa and all cattle feedlot playas had the greatest concentration of total and soluble phosphate. The Texas statewide 85th percentile for total phosphate in lake sediments was 1,349 mg/kg dry weight (Kubala 1990). One municipal effluent playa and all cattle feedlot playas exceeded this concentration.

Total Soluble Phosphate - Concentrations of total soluble phosphate in sediments were recovered at 0.28 to 359 mg/kg (Appendix 8). All cattle feedlot playas had the greatest concentration of total soluble phosphate.

Soluble phosphate in sediments is readily available to rooted plants and other aquatic vegetation for growth. The soluble portion of the total phosphate in sediments would be the fraction most readily available for affecting phosphate concentration in the water column upon disturbance, resuspension, or as a part in the dynamic equilibrium at the sediment/water interface. High phosphate concentrations in lakes acts as a fertilizer, thus increasing productivity and eutrophication (Hem 1992). Dissolved oxygen, critical for fish and aquatic life, can be depleted as a result of the eutrophication process.

The percentage of total phosphate that is made up by the soluble phosphate fraction is also highest in cattle feedlot playas, where soluble phosphate ranges between 2% and 9.4% of the total phosphate. Playas of other uses generally had soluble phosphate less than 1% of total phosphate concentration. Municipal effluent playas and a pasture/rangeland playa had soluble phosphate ranging from 4.3 mg/kg to 18.4 mg/kg, and the ratio of soluble to total phosphate remained between 0.1% and 2.3%.

Conventional Limnological Water Quality Parameters

Conductivity and Temperature - Specific conductivity ranged from 100 to 80,000 μmhos (Appendix 8). Temperature ranged from 22.5 to 34.0°C. Conductivity is related to salinity and total dissolved solids because the ions in solution are what allow electrical current to be transmitted through water. Temperature of the solution alters the ion movement, and therefore the specific conductance increases with temperature for both salinity and conductivity. Conductivity increases about 2% per degree Celsius.

Greater conductivity would correspond with higher salinity and greater total dissolved solids. This is important to fish and other aquatic life because substances in solution exert osmotic pressure on aquatic organisms (McKee and Wolf 1963). When osmotic pressure becomes too high it can draw water out of vital body organs and cause cellular damage, dehydration, or death. Most aquatic life can adapt to minor or slow changes, but wide or sudden variations (i.e., sudden intrusion of oil field brine into a freshwater ecosystem) can be too severe for adaptation and result in elimination of species from affected areas (McKee and Wolf 1963, Weibe et al. 1934, Young 1923).

A depauperate fish community has often been found in waters with a specific conductance greater than 2,000 μmhos at 25°C (Nelson et al. 1983a). A specific conductance of 4,000 μmhos at 25°C is the approximate upper limit of ionizable salts tolerated by most fish (desert pupfish are notable exceptions). The specific conductivities at one cattle feedlot, the salt playas, and Rich, Mound and Cedar Lakes exceeded the 4,000 μmhos limit tolerated by most fish. Temperatures measured for these playas and lakes ranged from 24 to 34°C. The literature related to effects on fish and wildlife is usually expressed in related measures (salinity, total dissolved solids) rather than conductivity.

Dissolved Oxygen - Dissolved oxygen ranged from 0.2 to 20 mg/l (Appendix 8). The cattle feedlot playas had the most consistently depressed dissolved oxygen levels. Irwin and Dodson (1991) also observed similar depleted oxygen trends in Tierra Blanca Creek downstream from cattle feedlots. These data suggest the cattle feedlots create organic pollution that can depress dissolved oxygen. Organic pollution can place oxygen demands upon these playas that are greater than the influx of oxygen. Many species of fish and other aquatic organisms, which might otherwise inhabit these playas, would not have sufficient oxygen for their survival.

pH - The observed range of pH was 6.5 to 10 (Appendix 8). The EPA's water quality criteria for pH of freshwater for aquatic life is 6.5 - 9.0 (USEPA 1986). The relatively undisturbed and salt playas exceeded the EPA criteria.

Secchi Depth (water clarity) - Secchi depth ranged from 2 to 300 cm (Appendix 8). The data show a slight trend toward less clarity in playas influenced by cattle feedlots and toward more water clarity in relatively undisturbed and salt playas.

Substrate (bottom firmness) - Irrigated cornfield, ephemeral row crop, municipal effluent, cattle feedlot, and salt playas, and Rich and Cedar Lake had moderate to soft substrate. In contrast, the pasture/rangeland playas, Rita Blanca playa, and Cedar Lake SW had a harder substrate. Playas surrounded with land use practices that cause erosion and sedimentation would likely produce large amounts of silt, resulting in soft substrate. However, undisturbed playas typically have a hard substrate.

Bird Surveys

Winter bird surveys - During early January, the bird survey of all study playas identified 16 waterfowl, 3 marsh birds, and 1 shorebird species (Appendix 9). The late January survey identified 11 waterfowl, 6 marsh birds, and 1 shorebird species. Substantial winter use of municipal effluent and cattle feedlot playas was made by waterfowl (Tables 1 and 2).

Of the 13,656 ducks recorded in early January, the most abundant species was the northern pintail (44.4%). Other species included mallard (24.3%), American wigeon (20.1%), green-winged teal (8.4%), and northern shoveler (1.9%). Species composition had changed by late January when the green-winged teal (32.9%) was the most abundant species followed by the northern pintail (26.1%), American wigeon (25.5%), and mallard (11.2%). A majority of the ducks observed in early and late January, 99.1% and 99.3%, respectively, were dabblers and 0.9% and 0.7%, respectively, were divers.

Table 1. Waterfowl species and numbers observed on municipal effluent playas, January 1990.

Playa Number	P1		P2		P5		P8	
January Species	8	22	8	22	5	16	6	17
Lesser Canada Goose	125	502	-	-	-	-	1,250	833
Snow Goose	-	18	-	-	-	-	-	-
Mallard	270	220	-	43	11	71	1,550	160
N. Pintail	195	80	-	10	-	-	2,520	1,500
Green-winged Teal	640	1,723	-	140	-	42	225	415
Cinnamon Teal	1	2	-	-	-	-	-	-
A. Wigeon	80	45	-	-	9	82	400	1,025
N. Shoveler	-	1	-	7	47	56	1	1
TOTAL	1,311	2,591	0	200	67	251	5,751	3,934

Table 2. Waterfowl species and numbers observed on cattle feedlot playas, January 1990.

Playa Number	F1		F4		F7		F500	
January Species	5	16	6	17	5	16	6	17
Lesser Canada Goose	-	-	ice	10	1,250	9	-	371
Greater White-fronted Goose	-	-	-	-	1	-	-	-
Snow Goose	-	-	-	-	140	4	-	-
Ross'Goose	-	-	-	-	17	-	-	-
Mallard	12	-	-	101	95	125	60	79
N. Pintail	15	-	-	-	220	43	60	87
Green-winged Teal	210	283	-	166	1,564	-	9	178
A. Wigeon	30	21	-	6	260	627	16	40
N. Shoveler	-	-	-	-	2	-	-	22
Canvasback	-	-	-	-	54	-	-	-
Ruddy Duck	-	-	-	-	-	3	-	-
TOTAL	267	304	0	283	2,054	875	145	777

Among the geese recorded in early January, 94.3% were lesser Canada geese and 5.0% snow geese. In late January, lesser Canada geese were observed at a greater frequency (98.7%) than snow geese (1.3%).

Spring bird surveys - Waterfowl migration began in early February and was still in progress at the end of the spring study period. During the March survey, 15 species of waterfowl, 4 species of marsh birds, and 4 species of shorebirds were recorded (Appendix 9, Littlefield 1990). Similar results were observed during the April survey. Bird use of feedlot playas was mixed. Waterfowl use of municipal effluent playas is summarized in Table 3.

Total duck numbers in March were similar to those in January; however, species composition had shifted. The American wigeon (32.4%) was most abundant followed by green-winged teal (23.9%), mallard (12.8%), and northern pintail (10.3%). The majority of pintails had already migrated from the region. Northern shoveler made up 9.8% of the population in March, but increased to 35% by April. Green-winged teal made up 33.2% of the birds observed in April. Only 26 northern pintails were recorded and mallards declined to 8.3% in April. Diving duck percentages increased as migrants moved through the region. In March and April, divers made up 10.3% and 10.5%, respectively. This increase was a result of ruddy ducks migrating through the area in March.

A majority of lesser Canada geese migrated out of the study area by March and only two individuals were recorded in April. Snow geese were migrating through the region in March, and at one time as 2,132 geese were observed on a cattle feedlot playa. By April, snow goose numbers had dropped to a total of seven for all study sites.

Large numbers of shorebirds or marsh birds were not recorded. However, shorebird numbers and species diversity were increasing at the close of the spring observation period.

Summer bird surveys - The summer of 1990 was hot and dry throughout most of the study area, thus several playas were dry. In addition to study sites, a survey of playas was conducted throughout the Southern High Plains. The survey found duck pairs, primarily mallards, in substantial numbers. However, little evidence was seen of nesting attempts. It was not determined if this was a result of the excessive heat and drought conditions, which persisted through June. Pairs appeared to be highly mobile, not remaining on a particular playa for extended periods. Although heat and drought resulted in several study playas remaining dry throughout the study period, several waterfowl species took advantage of the constant water supply in municipal effluent and cattle feedlot playas.

Autumn bird surveys - During the October survey of the study playas, 13 waterfowl, 7 marsh birds, and 9 shorebird species were recorded (Appendix 9, Littlefield 1990). The November survey recorded 14 waterfowl, 3 marsh birds, and 6 shorebird species. Substantial autumn use of municipal effluent and cattle feedlot playas was made by waterfowl (Tables 4 and 5). Several playas were dry before the October and November surveys were initiated. These playas included one irrigated cornfield and saline playa, all ephemeral row crop, pasture/rangeland, and relatively undisturbed playas.

Of the 18,057 ducks recorded in October, the most abundant was American wigeon (33.1%). Other species included green-winged teal (27.1%), northern pintail (26%), and mallard (4.4%). Species composition shifted some by November, when the northern pintail (47.8%) was the most abundant species followed by the American wigeon (24.5%), green-winged teal (21.1%), and mallard (3.7%). A majority of the ducks observed in October and November were dabblers, 93% and 97.9%, respectively, and 7% and 2.1% were divers, respectively.

Table 3. Waterfowl species and numbers observed on municipal effluent playas, March and April, 1990.

Playa Number	P1		P2		P5		P8	
Date Species	3/15	4/11	3/15	4/11	3/12	4/10	3/13	4/10
Mallard	117	8	31	9	58	17	50	8
Gadwall	2	10	-	-	-	-	-	-
N. Pintail	118	-	-	3	-	-	47	2
Green-winged Teal	495	147	177	68	144	58	256	169
Blue-winged Teal	1	10	-	2	-	1	-	-
Cinnamon Teal	12	45	9	7	-	-	10	2
A. Wigeon	109	11	-	-	120	9	187	36
N. Shoveler	30	233	2	89	109	90	143	342
Redhead	-	1	-	2	-	-	-	-
Ring-necked Duck	-	-	-	-	-	-	-	-
Lesser Scaup	-	4	-	-	-	1	41	-
Bufflehead	-	-	-	-	2	-	-	1
Ruddy Duck	1	45	-	-	-	-	13	23
TOTAL	884	514	219	180	433	176	747	583

Table 4. Waterfowl species and numbers observed on municipal effluent playas, Autumn 1990.

Playa Number	P1		P2		P5		P8	
Species	Oct	Nov	Oct	Nov	Oct	Nov	Oct	Nov
Green-winged Teal	1,320	1,608	45	6	110	64	250	167
Mallard	69	133	6	2	27	18	-	-
N. Pintail	1,603	1,678	22	-	131	29	228	142
N. Shoveler	3	-	2	9	20	33	-	9
A. Wigeon	297	613	-	-	142	-	12	18
Redhead	19	-	-	-	14	2	-	-
Ring-necked Duck	9	1	-	-	1	3	-	-
Lesser Scaup	-	-	-	25	-	5	-	-
Ruddy Duck	45	8	-	-	-	-	-	-
TOTAL	3,365	4,041	75	42	445	154	490	336

Table 5. Waterfowl species and numbers observed on cattle feedlot playas, Autumn 1990.

Playa Number	F1		F4		F7		F500	
Species	Oct	Nov	Oct	Nov	Oct	Nov	Oct	Nov
Green-winged Teal	647	1,250	-	122	246	477	17	69
Mallard	70	65	8	-	23	72	3	20
N. Pintail	165	400	-	-	387	480	-	4
N. Shoveler	1	15	-	2	9	1	301	6
A. Wigeon	41	55	-	-	2,020	4,660	11	2
TOTAL	924	1,785	8	124	2,685	5,690	332	101

Overall Summary of Four-Season Bird Use of the Study Playas

Heaviest bird use was by ducks; geese were much less common while marsh and shorebirds were the least common. Only winter ducks and spring marsh birds showed correlations with playa size. Some correlations were present between presence of tall emergent vegetation and use by summer marsh birds, spring shorebirds, and summer ducks. Comparisons of overall bird use versus playa type and other variables showed heaviest bird use in the irrigated cornfield, municipal effluent, cattle feedlot, and salt playa categories.

Waterfowl use of playas in the Southern High Plains of Texas was not only dependent on factors within the lake basin itself, but also on land use practices in the vicinity of the playa. A number of duck species which associated with specific playas appeared to be dependent on surrounding agricultural areas for food. Mallard, green-winged teal, northern pintail, and American wigeon are well known for their field feeding behavior, and a playa's proximity to grain fields had an influence on the amount of use it received by these four species. Winter wheat near playa lakes is an important food source for geese and American wigeon. These species graze extensively on green vegetation. In addition, the American wigeon will often feed on waste grain given to cattle at feedlots, and wigeons were regularly seen feeding on the grain along with cattle in the corrals. Another important factor is the amount of exposed shoreline. In agricultural areas, usually the nearest water filled playa with a well developed shoreline was important as a loafing site for most dabbling ducks, particularly the green-winged teal and northern pintail. Without these shorelines, dabbling duck use was often limited.

Diving ducks usually preferred playas that contained abundant aquatic plants and invertebrates for food. This was clearly illustrated by the amount of diving duck and American coot use observed on one of the salt playas. Extensive muskgrass (*Chara* sp.) beds in this lake were probably responsible for attracting water bird species.

Water depth and invertebrate populations had an influence on shorebird use. Most shorebirds confine their activities to mud flats and shallow water; however, there are exceptions. Both the killdeer and Baird's sandpiper (*C. bairdii*) were observed feeding with cattle in feedlots, while killdeers, upland sandpipers (*Bartramia longicauda*), and long-billed curlews were seen feeding in recently plowed or mowed agricultural fields.

Rapid Bioassessment of the Biological Health of Playa Lakes

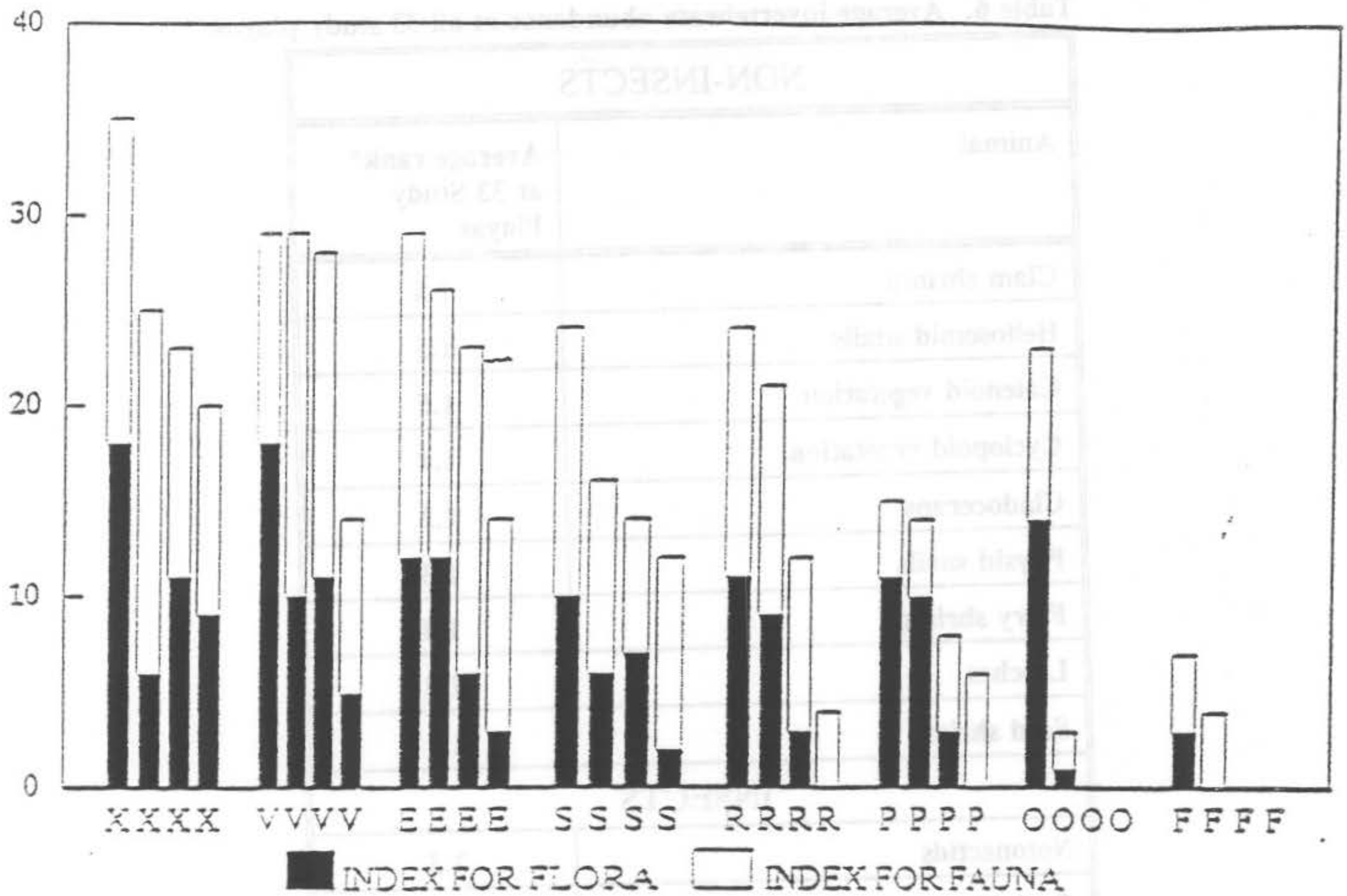
A rapid bioassessment method to measure the degree of impairment at playa lakes surrounded by eight different land uses was developed and used to compare with accompanying analytical data. This rapid bioassessment method encompassed data on macroinvertebrates (Table 6), zooplankton, plants (Table 7), aquatic vertebrates, and birds. Previously, the methods have used only fish or only invertebrate data.

After a lengthy period of preliminary data collection and statistical analysis, five indices of biological integrity (IBI) scoring metrics were developed (Table 8) and the mean IBI scores for playa classes were calculated (Table 9). The data showed some variability of playas within land uses, but several trends were also apparent regarding the lack of biological integrity of communities at feedlot playas and some oil brine production playas (Figure 4). This rapid bioassessment system demonstrated severe impacts from cattle feedlots on the ecology of playa lakes. Slightly less severe impacts at playa lakes receiving municipal effluent and oil brine were also apparent.

The populations of plants and animals typical of other playa lakes were absent from the playa lakes influenced by cattle feedlots. Total invertebrate taxa was negatively correlated to corixid scores and to percent pasture.

While the heaviest bird use occurred at irrigated cornfield, municipal effluent, cattle feedlot, and salt playas (Figure 5), the most abundant populations of invertebrates and diversity of plant species were found at the irrigated cornfield, relatively undisturbed, and pasture/rangeland playas (Figures 6 and 7). Total bird taxa correlated negatively with total invertebrate taxa and total plant taxa.

Since there are few salt playas and frequently-wet cornfield playas are decreasing in abundance, birds may be forced to rely on the municipal effluent and cattle feedlot playas more heavily. These two categories are the least healthy and have the lowest natural assemblages of invertebrates and aquatic vegetation (Figures 6 and 7).



X = Irrigated Cornfield
V = Relatively Undisturbed
E = Pasture/Rangeland
S = Salt Playas
R = Ephemeral Row Crop
P = Municipal Effluent
O = Oil Brine Production
F = Cattle Feedlots

Figure 4. Rapid Bioassessment Values By Playa Class arranged in descending order among and within class.

Table 6. Average invertebrate abundance at all 33 study playas.

NON-INSECTS	
Animal	**Average rank* at 33 Study Playas**
Clam shrimp	**1.8**
Heliosomid snails	**1.5**
Calenoid vegetation	**1.5**
Cyclopoid vegetation	**1.4**
Cladocerans	**1.3**
Physid snails	**1.3**
Fairy shrimp	**1.3**
Leeches	**1.2**
Seed shrimp	**1.1**
INSECTS	
Notonectids	**2.3**
Corixids	**2.2**
Damselfly larvae	**1.9**
Mayfly larvae	**1.5**
Dytiscid larvae	**1.5**
Dytiscid adults	**1.4**
Dragonfly larvae	**1.3**
Chironomids, red	**1.3**
Dipteran larvae	**1.2**
Water striders	**1.2**
Hydrophilids	**1.2**
Chironomids, not red	**1.1**

* See Appendix 2 for explanation of ranking codes.

Table 7. Average Percentage of Playa Coverage by Aquatic Plants.

AQUATIC VEGETATION	
Plants	**Average Percentage of Playa Coverage at 33 Study Playas**
pondweed	**6.8**
cat-tail	**5.7**
arrowhead	**3.8**
spikerush	**2.8**
smartweed	**2.7**
bulrush	**2.2**
Marsilea	**1.5**
burweed	**1.0**
barnyard grass	**0.9**
sedges	**0.4**

Note: In addition to the above listed plants, five playas had one species of *Chara* and two playas had two species of *Chara*. *Chara* presence is considered a clue that the playa is "relatively undisturbed."

Table 8. Indices of biological integrity scoring metrics, Playa Lakes, Texas 1989-91.

	Impaired 1	Fair 3	Good 5
Total plant taxa [8]	0 - 2	3 - 4	5 - 8
Total animal taxa [22]	0 - 6	7 - 11	12 - 21
Mayfly abundance [1]	1.0	1.1 - 1.9	2.0 - 3.0
Damselfly-dragonfly abundance [2]	2.0 - 2.1	2.2 - 3.9	4.0 - 6.0
Aquatic invertebrate abundance [10]	10.0 - 12.0	12.1 - 15.9	16.0 - 30.0

[n] = number of taxa considered in metric

Table 9. Mean index of biological ingegrity scores for playa class, Playa Lakes, Texas 1989-91.

	Average Percentage of Playa Coverage at 33 Study Playas
Feedlots	5.5
Oil/brine	6.5
Municipal Effluent	9.5
Rita Blanca Playa	10.5
Ephemeral row crop	13.5
Salt Playa	14.5
Pasture/rangeland	15.0
Corn irrigated	19.0
Relatively undisturbed	21.0

Land Use Summaries

Generally, playa draining watersheds of similar land use types showed similarity in many chemical and physical parameters. Discriminant analyses for land use tends to cluster playas according to land use.

The highest nutrient load, organic pollution, and elevated concentrations of copper, strontium, and zinc tended to occur in cattle feedlot playas and in municipal effluent playas. Salt playas and the large saline lake sediments contained elevated arsenic, chromium, molybdenum, strontium, COD, and oil and grease. Some contaminants (arsenic, barium, beryllium, nickel) may be slightly elevated in the ephemeral row crop, pasture/rangeland and relatively undisturbed playas, perhaps due to agricultural practices or other processes affecting these elements. A summary of findings for each playa land use associated with the playas studied follows.

<u>Irrigated Cornfield Playas</u>

In spite of concerns about pesticides in irrigation return flows and runoff from corn fields, the cornfield playas generally had diverse and abundant invertebrate populations and extensive use by waterbirds.

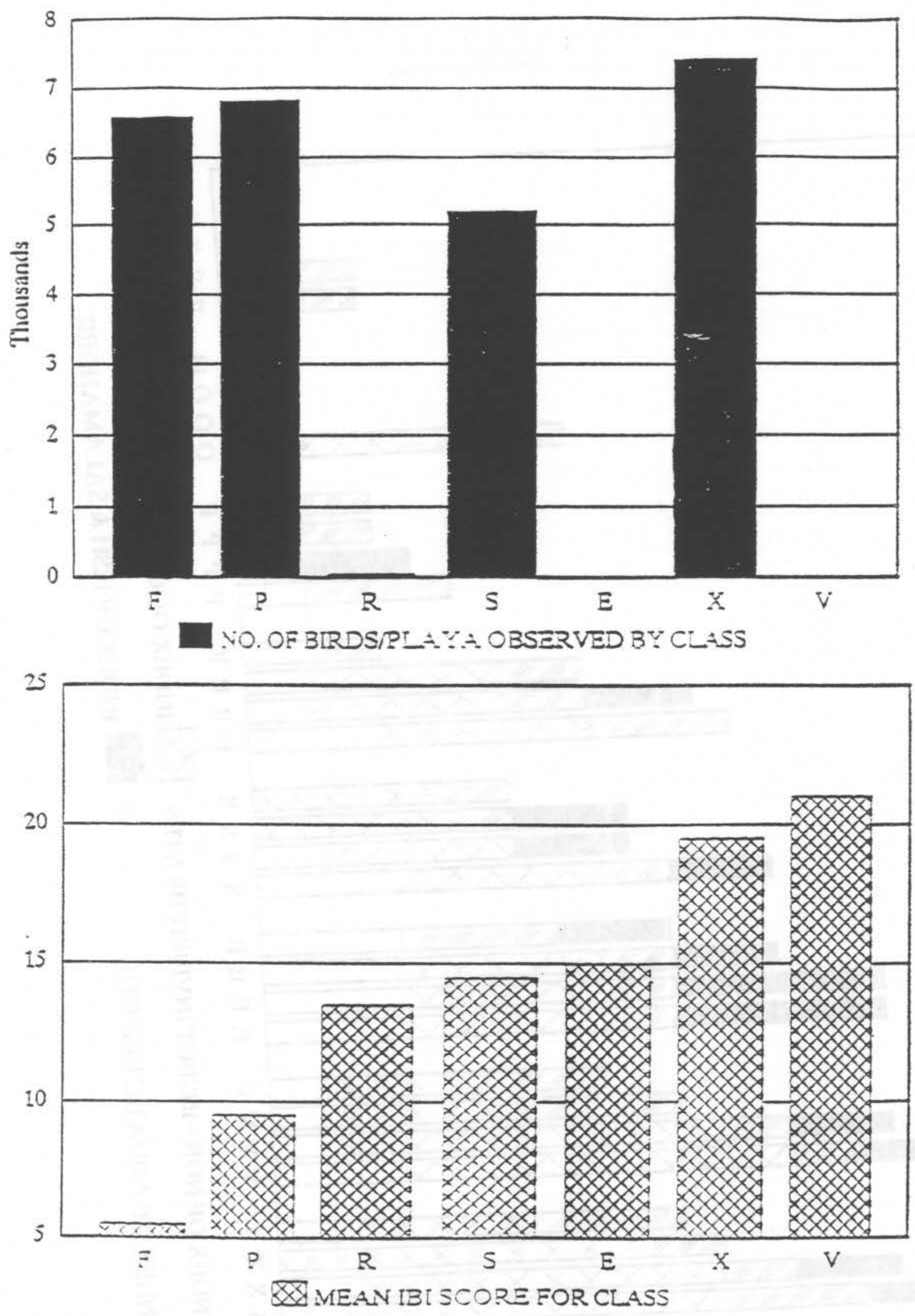


Figure 5. No. of Birds/Playa observed by Class and Mean IBI Score for Class

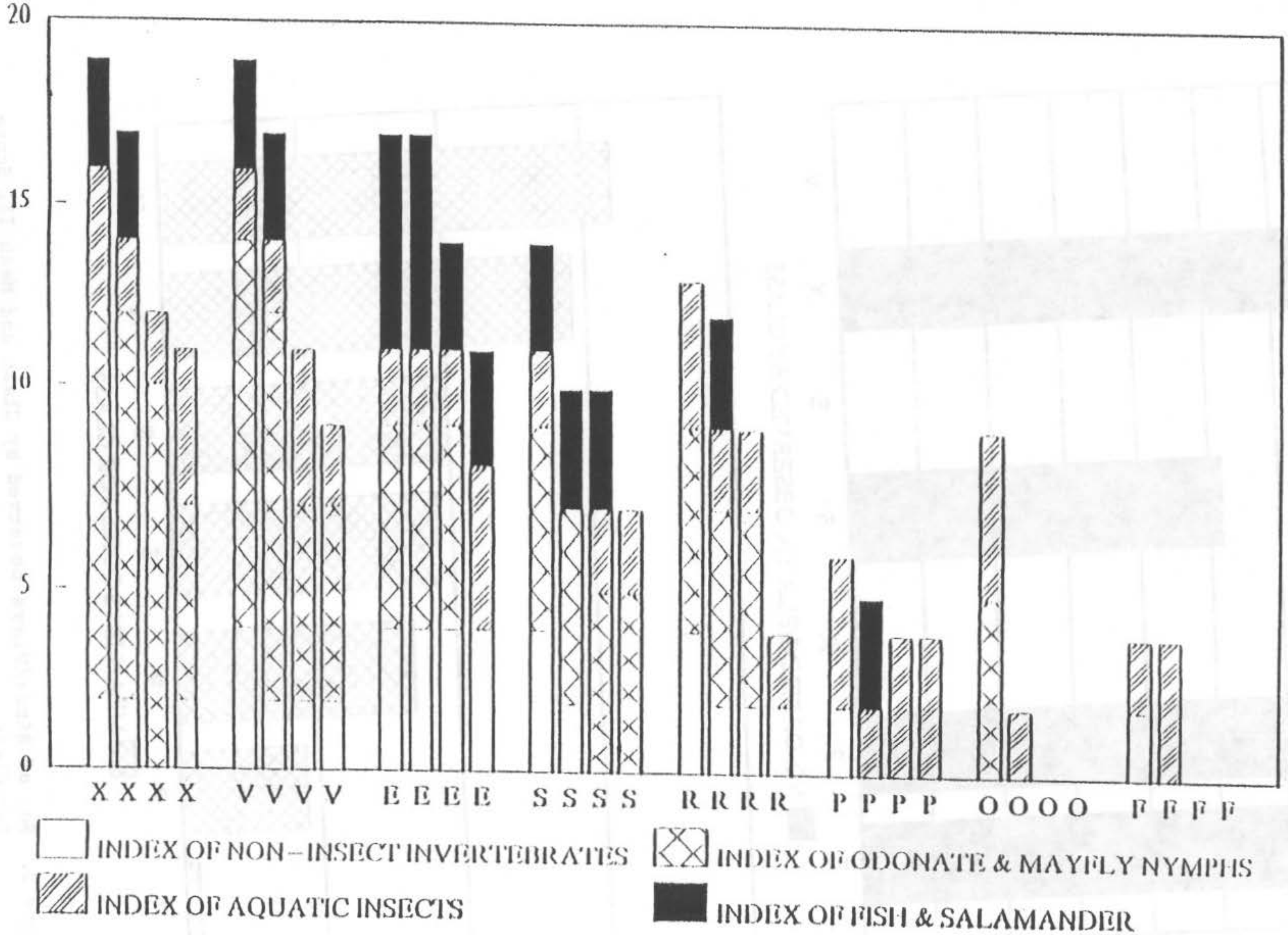


Figure 6. Fauna Index Values By Playa Class
arranged in descending order among and within class

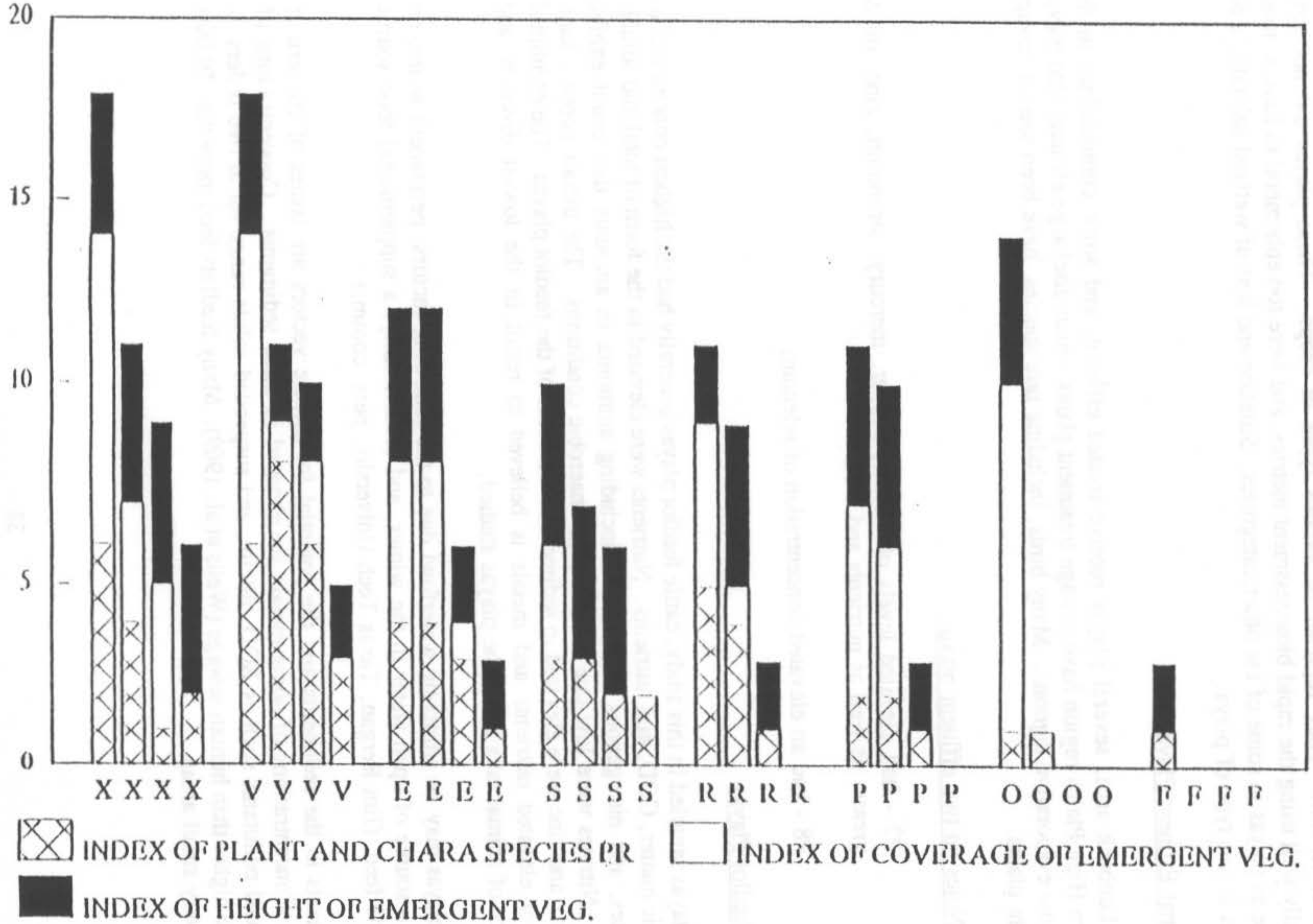


Figure 7. Flora Index Values By Playa Class
arranged in descending order among and within class

Row Crop Playas

This category was worst-case from the standpoint of siltation, often being plowed through straight down hill. They represented various types of crops. These playas did not score especially well using the rapid bioassessment metrics, and were too ephemeral to have as much bird use as playas in some of the other categories. Siltation and loss of wetland habitat is a big concern in this type of playa.

Municipal Effluent Playas

In the Lubbock area, several playas receive treated effluent, and some communities in the Southern High Plains region have sewage treatment plants which discharge effluent into playas or shallow evaporative lagoons. Many birds, including rare species, have been seen at sewage treatment plants.

Notes on two effluent playas

P2 - had elevated levels of arsenic, copper, mercury, strontium, zinc, oil & grease, as well as nutrients and COD

P8 - had an elevated concentration of selenium

Cattle Feedlot Playas

Of the playas sampled in this study, cattle feedlot playas generally had the highest concentrations of organic matter, COD, and nutrients. Nutrients were elevated in the form of total and soluble phosphates, and nitrogenous compounds, including ammonia in amounts that could exhibit toxicity. Nitrates were low due to reducing, anaerobic conditions. The metals copper, lead, strontium, and zinc were elevated in sediments from some of the feedlot playas. The combined stresses of elevated nutrients and metals is believed to result in the lowest diversity and abundance of animal taxa of all the playas studied.

Feedlot playas may be attracting waterfowl due to the following factors: permanent water, no hunting, a source of open water in the winter, and (occasionally) a supplemental food source from cattle feed (Jim Bergan, Texas Tech University, pers. comm.).

Contaminants in the sediments and the potential for disease vectors are issues of concern at feedlots. Concentrations of some metals are elevated in these sediments. Concentrations of conventional pollutants such as BOD, nitrate, and suspended solids range up to two orders of magnitude higher than human sewage (Wells et al. 1969). Many feedlots feed more than 50,000 cattle in very small areas.

Pasture/Rangeland Playas

Pastureland playas generally had reasonably high populations of invertebrates. However, bird use was low, presumably because many of the pastureland playas tend to dry up quickly. Most of the pasture playas were ringed by manure due to heavy cattle use and tended to show a milder version of some of the ecosystem responses displayed by feedlot-effected playas.

Relatively Undisturbed Playas

It was difficult to find any truly undisturbed "reference playas" that would represent conditions existing before anthropogenic alteration. It was thought that pasture playas would be relatively undisturbed. However, pasture playas would likely be affected by grazing practices. Certainly buffalo also had an affect on playas historically. However, buffalo were not confined such as cattle are today.

Dr. V. Proctor (Biology Department, Texas Tech University, pers. comm.) suggested that "relatively undisturbed" playas could be identified by their *Chara* populations. For this reason, four "relatively undisturbed" playas were chosen as reference sites (V playas) for this study. Chemical analyses and rapid bioassessment indexes confirmed that these playas were the most healthy and diverse compared to other playa categories studied.

Salt Playas

The salt playas observed in the current study had healthy populations of plants and invertebrates, semi-permanent water, and relatively high bird use. Hardstem bulrush invasions of playas south of Lubbock (such as those near Knott) mean they are getting saltier (B.L. Allen, Texas Tech University, pers. comm.). Although cadmium concentrations were not especially high (Ingersoll and Nelson 1989) in sediments and plant and invertebrate tissue, cadmium was detected more often in salt playas than in samples from other playas.

Oil/Brine Production

Whereas most intermittent row-crop agriculture playas are characterized by fresh, hard, alkaline, and carbonate waters, there are also some large sulfato-chloride lakes in the playa lakes region. Although not true playa lakes, these larger saline lakes were studied because of their high bird use and frequent bird die-offs. Cedar Lake was the site of an aflatoxin kill of sandhill cranes in February 1982, January 1985, and February 1985.

All of the large salt lakes surveyed in this study (Mound Lake, Cedar Lake, and Rich Lake) have been used to dispose of brine waters from oil production facilities. Cedar Lake was still receiving brine discharges from nearby oil processing facilities as of 1990. As a result of brine discharges, the saline lakes studied have increased chloride concentrations (Nelson et al. 1983b.) Oil brine also contains over 10,000 chemicals, many of which are harmful to wildlife (Nelson et al. 1983b). A recommendation would be to sample biota for non-routine as well as routine contaminants, including selected analyses for PAHs when suspected at saline lakes. One of the difficulties in identifying contamination by crude oil is that PAHs are not the only potentially harmful chemicals. More than 39,000 organic compounds have been identified in crude oil (Bud Burks, Oklahoma State University, pers. comm.).

Saline lakes are used by cranes and other migratory birds primarily for resting rather than for drinking and feeding (USFWS 1981). The high concentrations of sodium chloride, calcium sulfate, ferric sulfate, and other dissolved minerals are thought to discourage the establishment of most forms of aquatic vegetation and invertebrates of food value to waterfowl (USFWS 1981). Salinity of 400 parts per thousand has been attributed to Mound Lake in Terry County (Curtis and Beierman 1980).

<u>Notes on specific oil/brine playas</u>

O4 - contained the highest amounts of chromium, strontium, oil & grease, PAHs, aliphatics, and COD in sediments. It also contained elevated concentrations of copper, lead and zinc in sediments.

O1 & O2 - contained the highest selenium as well as elevated strontium, molybdenum, and nitrates.

Another observation of interest about bird use of the playas is that during the summer of 1990, abnormally dry conditions resulted in some playas becoming "death traps." Several playas received irrigation run-off in April, but by early June, many of these had dried. Young mallards, northern shovelers, killdeers, and American avocets died as a result. During the drought many adult duck pairs remained in the area, moved to feedlots and sewage plants, but did not attempt to nest.

Statistical analyses revealed that total bird taxa correlated highly with water regime. Total bird taxa also correlated with specific conductance, but that may be more a reflection of water regime since many of the playas which were consistently wet happened to be the saltier ones (feedlot and salt playa categories).

Various field data which characterize the study playas are recorded in Appendix 10.

SUMMARY

Factors which complicate contaminant problems in playas include the natural clay bottoms (which prevent contaminants from migrating downwards) and the fact that they are closed hydrological systems, which prevents export of contaminants into other waterways (Nelson et al. 1983 a and b). Thus metals and other long lasting contaminants from within the watershed (and airborne contamination) can accumulate in the playa making it a "sink".

In spite of potential impacts, some agricultural activities result in benefits to waterfowl (USFWS 1988). These include: 1) increased open-water availability in dry seasons as a result of irrigation return-flows and feedlot runoff/storage, and 2) availability of waste corn, wheat sprouts, and other food items related to agriculture. Although biologists hold varied opinions concerning the overall benefits derived from these activities, some benefits may be present, and some may be significant. Therefore, the adverse impacts of various human activities must be balanced against the benefits.

Feedlot contamination of playa lakes has clearly impaired the water quality and reduced the diversity and abundance of plant and invertebrate populations. Feedlot playas may also be impacting migratory bird movements in that birds are attracted to these playas because they provide a source of water that does not freeze readily as well as some food (cattle feed and a few very pollution tolerant worms).

Our initial data show that playas fed by irrigation return flow from corn crops had a fairly healthy assemblage of invertebrates and plants. However, increasingly these "relatively clean" corn irrigated playas are drying up as farmers are changing over to more efficient irrigation methods.

RECOMMENDATIONS

General Recommendations

Additional protective measures are necessary to protect the water quality and wildlife habitat values of playa lakes due to pollution from feedlots, municipal effluent, and (in the case of some large salt lakes) oil brine disposal. It may be possible to develop appropriate protective measures partially on a voluntary/cooperative basis. Through the Playa Lakes Joint Venture, the Service is working with landowners on a cooperative basis to protect or improve playa habitats. We also wish to address any potential problems through cooperation with the feedlot association and regulatory agencies.

Additional study needs we have identified are discussed below.

General Contaminant Effects on Birds

Mallards, pintails, coots, shovelers, and American avocets are among the species which should be studied in the future. Mallards from a known (clean) source may be used in caging studies. Avocets are common playa residents which have been seen frequenting degraded playas at both cattle feedlots and municipal effluent plants. Other bird species whose food habits are closely tied to the playas include the northern shoveler, diving ducks (like the ruddy duck and redhead), shorebirds, coots, rails, great blue herons, white-faced ibis, and pied-billed grebes (Jim Bergan, Texas Tech University, pers. comm).

Dietary Considerations Related to Waterbirds

Birds attracted to feedlot or municipal effluent playas could consume contaminated invertebrates and sediment. Wintering birds that spend significant time periods feeding at cattle feedlot or municipal effluent playas might also be eating undigested food found in manure (Dennis Jordy, FWS, pers. comm.). A study to determine the quality of available food and use of cattle operations may clarify the health risks to waterfowl.

Any occurrence of toxic chemicals in significant amounts in the sludges and sediments of these playas raises the possibility that birds may be slowly accumulating unhealthy body burdens of toxic chemicals which may affect their reproduction, behavior, or immune system. The benthic food and sediments (ingested by waterbirds while eating) at these sites may not be toxic enough to cause immediate death, but more research needs to be done to determine whether chronic toxicity is occurring.

The long-term well being of waterbird populations should be related to their dependence on corn, other cultilrated grains, or artificial food sources compared to natural wild foods. It is also possible that mallards utilizing a heavy diet of non-native foods may be surviving but not reproducing successfully (Lee Fredrickson, Gaylord Institute, MO, pers. comm.). For instance, pintails do much better with a normal assemblage of invertebrates than a diet heavy in agricultural products (Lauren Smith, Texas Tech University, pers. comm.). In years when there is not as much natural food, survival of mallards is down (Jim Bergan, Texas Tech University, pers. comm.). Ducks can die after 50 days if fed only corn (Mickey Heitmeier, pers. comm.). indicating that a diet based solely on grains is not good for birds. Although waste corn and other crop wastes may constitute a large percentage of waterfowl diets in some playa lake areas during the winter, invertebrates and other natural aquatic foods (including aquatic plants) are necessary to balance the diet. Aquatic insects, crustaceans, and molluscs comprise the bulk of animal food consumed by waterfowl (Sandra Borthwick, FWS, pers. comm.). Invertebrates are especially important components in the diets of very small ducklings and laying hens (Espey, Huston and Associates 1984). Due to this dietary importance, impacts on invertebrates from siltation or environmental pollution may result in indirect impacts on waterfowl and shorebirds.

Bird Disease

Future research related to bird disease should be designed to answer the following questions:

1. What environmental conditions of playas favor outbreaks of avian cholera and botulism? If avian cholera is partly a function of crowding, are water quality factors adding to the avian stress? Among the reasons this should be further investigated are:

   a. It has been discovered that unusually high cation/anion concentrations can influence toxicity, as can unusual ratios of various cations and anions (Ed Price, University of North Texas, pers. comm.). These same factors may also be significant in creating conditions favorable to culturing bird disease vectors. Various levels of calcium and magnesium may affect survivability of the avian cholera vector (*Pasteurella multocida*), as may the concentrations of other cations or anions (Ron Windingstad, FWS, National Wildlife Health Research Center, pers. comm.).

   b. Elevated levels of organic material, nitrogen compounds, and anaerobic bottom sediments may also favor proliferation of disease vectors such as *Clostridium botulinum*, the causative agent for botulism (USFWS 1981). High levels of nitrogenous and organic compounds may also favor salmonellosis and coccidiosis (USFWS 1981). At some locations in California water bodies having the worst water quality also have the highest incidences of bird disease (Lee Fredrickson, Gaylord Institute, pers. comm.).

   c. Researchers have found that the presence of cattle directly affects fecal coliform densities in adjacent streams and that feedlot runoff may contain pathogens which are harmful to humans and animals (USEPA 1982). Avian cholera occurring in the Texas High Plains has often been discovered in ponds or playa lakes located at or near animal feeding centers. The first case reported was at a chicken feeding operation (Harvey Miller, U.S. Fish and Wildlife Service, pers. comm.). In recent years, avian cholera outbreaks in the Texas High Plains have most frequently been found at cattle feedlot ponds.

2. Can feedlot cattle infected with *Pasteurella multocida* transmit this disease vector to birds and cause avian cholera? Other bacterial diseases can affect both birds and mammals, such as *Salmonella, Staphylococcus*, and *Streptococcus species*.

Pesticides

A large percentage of the playa lakes in Texas are located in areas of intense agriculture. Many of these playas receive runoff water from fields used for row crops or cattle feedlots. Waterfowl, shorebirds, and the invertebrates in their diet may be impacted by herbicides and insecticides via:

1) direct spraying of the playas
2) direct chemical transport via water (storm and general non-point source runoff)
3) air and water transport of soil particles with attached toxic chemicals
4) direct chemical transport via wind (spray drift)

In spite of these concerns, data generated in this study did not document direct impacts from pesticides on waterfowl, shorebirds, or the invertebrates eaten by birds. The playas fed by irrigation return flow from corn crops had relatively high populations of invertebrates. Nor were particular problems found in study playas related to the levels of organophosphate, carbamate, or chlorophenoxy compounds found on standard Fish and Wildlife Service scans. Most of the organochlorine pesticides are no longer used in the study area, and data from this study as well as past surveys (Flickinger and Krynitsky 1987) of organochlorine residues in playa lakes revealed little cause for concern. However, determation of specific direct and indirect impacts of all pesticides (and their breakdown products) on birds and other fish and wildlife resources was beyond the scope of the study. Additional, more focused studies are recommended to determine the extent of such problems.

Reasons to believe there may be problems related to pesticide use around playa lakes includes the following considerations:

1. Many newer pesticides which are very toxic to aquatic invertebrates eaten by water birds are still commonly used in the playa lakes area, and new compounds keep arriving on the scene (Tables 10 to 12).

2. Many currently used chemicals have not been studied as part of our standard scans, and some break down quickly into other compounds which are potentially harmful, so the absence of the parent compound does not mean that no toxicity to aquatic invertebrates and other biota has occurred. Thus, there are various ways these chemicals can cause problems for fish and wildlife, in spite of the fact that most of the newer compounds do not bioaccumulate to high levels in tissues, and many are not on the standard Fish and Wildlife Service scans.

3. Problems with drift from some of the commonly used farm pesticides have been documented for prairie potholes, a type of wetland similar to playa lakes (Grue et al. 1988). Aerial application of ethyl parathion at a rate of 1.1 kg/ha to sunflower fields surrounding wetland areas, but with no direct application to the wetlands, resulted in death of aquatic invertebrates and a 23% reduction of brain ChE activity in blue-winged teal ducklings collected two days post-spray (Grue et al. 1988). In other studies, 100 of 104 (96.2%) mallard ducklings died within three days after application of ethyl parathion (1.1 kg/ha) to adjacent sunflower fields. Data from related studies indicated that aerially applied pesticides are deposited into prairie potholes and cause impacts on aquatic invertebrates, even when meteorological conditions are excellent and when the applicator attempts to keep the spray out of the wetland (Tome et al. 1990).

Non-Routine Contaminants Other Than Pesticides:

This study (as well as a previous study conducted at nearby Buffalo Lake National Wildlife Refuge) identified some metals in high concentrations in feedlot playa and feedlot pond sediments. However, the sediments in feedlot ponds have not yet been analyzed for all the potential organic compounds (and breakdown products of these compounds) of possible concern.

Additional work recommended for the future includes: 1) determining which routine and non-routine contaminants are accumulating in selected waterfowl and shorebirds, and 2) conducting an intensive literature search on the meaning of residue concentrations identified in all three phases of the project to the well-being of North American waterfowl and shorebirds, and 3) possibly conducting detailed bird and food item bio-assessments (bioassays, caging studies, etc.). Since oil and grease levels were elevated at feedlots, it would also be appropriate to analyze feedlot sediments for PAHs in future studies.

Sedimentation/Siltation

The loss of habitat due to siltation/sedimentation may be a significant problem impacting playa lakes. (Harvey Miller, former Playa Lakes Joint Venture Coordinator, Lubbock, Texas, pers. comm.). In addition to potential impacts from toxic chemicals, many playa lakes appear to be filling up at a fairly rapid rate, due to siltation. Further study would be required to document the long-term impacts on playa lakes. During field work, we observed evidence of siltation impacts. Several anecdotal accounts concerning playas that were relatively deep 40 years ago, but are now shallow, were also expressed by local farmers. Normally playa lakes have relatively hard and flat bottoms, but in those receiving runoff from row crop agriculture or feedlots, the bottoms were quite soft. Some of the worst cases were fields where the farmer had plowed straight through the playa. In other locations, playas were totally surrounded by irrigated corn and were receiving high sediment loads with irrigation return-flow water. Even in areas with circle-pivot irrigation, the areas between the irrigated plots were often plowed straight downhill into the playa. In areas where inlet ditches were partially hidden by tall emergent vegetation, the area receiving input from plowed fields could often be found by following gradients of bottom softness. Although pasture land playas would ordinarily be receiving less silt than row crop playas, some pasture land playas were found to be nevertheless experiencing siltation problems due to overgrazing, very high (trampling) cattle concentrations adjacent to the playas, or connections to ditches from row crop areas.

The Conservation Reserve Program (CRP) should help retard the siltation problem in some areas, but a large percentage of the most valuable playas may not have long-term involvement in the program. Also, CRP lands can return to crop production after 10 years.

Table 10. A list of the "non-routine" compounds which are in the top 33rd percentile (by pounds of active ingredient applied in 1987-1989) of farm chemicals used in the study area hydro-units (R. Holloway, Texas A&M Agriculture Extension, personal communication). Non-routine compounds are those not included on standard Fish and Wildlife Service contract laboratory scans.

Compound		Total Pounds of Active Ingredient Applied
******INSECTICIDES******		
I	PROPARGITE	67835
I	SULPROFOS	10674
I	ESFENVALERATE	7778
I	PHOSPHAMIDON	6891
I	PERMETHRIN	6821
I	CYPERMETHRIN	6640
I	CYHALOTHRIN	4895
I	THIODICARB	4895
I	FENVALERATE	729
I	BIFENTHRIN	392
I	CYFLUTHRIN	276
******HERBICIDES******		
H	TRIFLURALIN	415941
H	ARSENIC ACID 75E	310770
H	ATRAZINE 4L	194443
H	PENDIMETHELIN	183938
H	PROMETRYN	178796
H	GLYPHOSPHATE	104364
H	METOLACHLOR	90488
H	PARAQUAT	32000
H	MSMA 4L	22584
H	AMETRYN	10059
H	FLUAZIFOP-P-BUTYL	9174
H	CYANAZINE	9102
H	NORFLURAZON	6923
H	ALACHLOR	3259
H	SETHOXYDIM	3196
H	DIURON	2431
H	ENDOTHALL	708
******GROWTH REGULATORS******		
G	ETHEPHON	36434
G	MEPIQUATE-CHLORIDE	213
******FUNGICIDES******		
F	CAPTAN 50W	5106

Table 11. Summary of total quantities of groups of compounds heavily used in the playa lakes study area in 1987-1989 but not included in in standard Fish and Wildlife Service contract laboratory scans (R. Holloway, Texas A&M, personal communication).

Families of Compounds Used	Total Pounds Active Ingredient Used
SYNTHETIC PYRETHROIDS	27531
TRIAZINES	392400
NITROANILINES	599879
ORGANOPHOSPHATES (NON-ROUTINE)	17565
ORGANIC ARSENICALS	333354

Table 12. Top 30% (by usage) of pesticides used on <u>corn and/or cotton</u> in the playa lakes study area in 1987-1989. Includes both routine and non-routine compounds. Percent use is based on total acres treated and/or total pounds of active ingredient used (R. Holloway, Texas A&M Agriculture Extension, personal communication).

INSECTICIDES	
ALDICARB*	PHORATE*
PROPARGITE	CYHALOTHRIN
DIMETHOATE 2.67E*	THIODICARB
CARBOFURAN*	METHYL PARATHION 4E*
TERBUFOS*	ACEPHATE*
CHLORPYRIFOS*	OXAMYL*
DICROTOPHOS*	AZINPHOS METHYL*
SULPROFOS	FENVALERATE
ESFENVALERATE	BIFENTHRIN
PHOSPHAMIDON	CYFLUTHRIN
PERMETHRIN	CYPERMETHRIN
HERBICIDES	
TRIFLURALIN	ENDOTHALL
ARSENIC ACID 75E	DICAMBA*
ATRAZINE 4L	DIURON
PENDIMETHELIN	SETHOXYDIM
PROMETRYN	ALACHLOR
GLYPHOSPHATE	NORFLURAZON
METOLACHLOR	CYANAZINE
PARAQUAT	FLUAZIFOP-P-BUTYL
MSMA 4L	AMETRYN

* These compounds were included in standard Fish and Wildlife Service Contract Laboratory Scans.

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Appendices

Appendix 1

Study Site Locations, Texas 1989 - 1990.

Sampling Site	County	Location
Irrigated Cornfield:		
X1	Parmer	SH 3333 & 1731, 4 mi East, 0.7 mi South on East side
X2	Parmer	from Bovina 2 mi South, 4.5 mi East, on North side
X3	Parmer	SH 145 & 1172, 1 mi East, 4 mi North, 1 mi East, on North side
X4	Parmer	SH 145 & 1172, 3 mi East, 4 mi North, 0.5 mi East, on North side
Ephemeral Row Crop:		
R1	Parmer	SH 2397 & 214, 2 mi East, 1 mi South, leave 2397, 0.7 mi South on East side, southern half of playa
R2	Parmer	from Clays Corner, 3.8 mi West, 2 mi North, 1 mi West, south side
R3	Parmer	from Clays Corner, 4.2 mi North, west into field between pivot irrigation 1/4 mi
R4	Hale	Intersection of SH 1071 & 1424, 0.2 mi North, on East side, 4.5 mi N of Hale Center on 1424
Municipal Effluent:		
P1	Lamb	South edge of Olton, East side of Hwy 168
P2	Lamb	NE side of town near landfill
P3	Parmer	end of Avenue G, go into gate
P4	Castro	from 385 near airport, 7 mi E, 1/2 mi south, East side, 2 long N-S pits dug

Appendix 1 (continued)

Sampling Site	County	Location
Cattle Feedlots:		
F1	Parmer	from Clays Corner, 5 mi West, North side
F2	Parmer	from Friona go NE on 60 11 mi, on SE side
F3	Parmer	from Hub (86 and 214), 2 1/2 mi South, 3/4 mi West
F4	Deaf Smith	from 60 and 1057 north 3 miles, East 1 mi, turn South to feedlot
Pasture/Rangeland:		
E1	Floyd	on 97 from Cedar Hill 3 mi East, 1 3/4 mi NE, on NW side
E2	Briscoe	going No. on 207 from Mackenzie Reservoir 1st road to East out of canyon
E3	Swisher	from 2301 and 86 intersection, 2.9 mi East, through gate on North side pasture road North 1 mi turn East 0.5 mi
E4	Swisher	from E3, go 1 mi East
Relatively Undisturbed:		
V1	Lubbock	1.1 mi west of New Deal on 1729
V2	Briscoe	southwest quadrant of intersection of 3300 and 207
V3	Briscoe	5 mi North of 146/207 intersection East side behind barb wire fence/gate dug on West side of playa
V4	Hale	2.5 mi East of Abernathy on 2060, South side

Appendix 1 (continued)

Salt Playas:

S1	Dawson	6 miles SW of O'Donnell near intersection of Hwys 1210, 178, and 87, on West side of HWY 87
S2	Dawson	6 miles SW of O'Donnell near intersection of Hwys 1210, 178, and 87, on East side of HWY 87
S3	Terry	SE Terry Co., 3.5 mi North of Pride Cem., 2.5 miles West and 0.3 mi South of New Moore
S4	Lynn	Frost Lake, 5 mi South and Dawson, 1 mi East of New Moore, just SE on intersection of HWYs 2033 and 179

Oil Brine Production:

O1	Terry	Rich Lake
O2	Terry	Mound Lake
O3	Gaines	Cedar Lake SW sampling site
O4	Gaines	Cedar Lake NE sampling site intersection FM 1066 & 1067

Rita Blanca National Grassland:

C1	Dallam	From 296/1879 intersection 1 mi West on North side 11 miles East of Texline

Appendix 2

FIELD DATA SHEETS

SEPTEMBER 1990 FIELD FORM

PLAYA NUMBER ____________________ Date: ________________ , 1990

PLAYA CATEGORY __________________ Time: ________________________
PHOTOS: ROLL # __________, SHOTS # ______________________________

R = Row crop / ephemeral / worst case P = POTW
X = Corn w/irrigation return flow, more permanent water F = Feedlot
EC = Ephemeral pastureland S = Salt
OB = Oilfield - Brine Impacted Salt Lakes

Owner's Name: ____
Operators Name: ____
Owner/Operators Address: ____________________________________
____

Owner's Phone: ______________________________ **County:** ______________

Water Temp: ______________ ° C **ENZYTEC RESULTS:** NEGATIVE POSITIVE

Dissolved Oxygen @ 1' _____._____ mg/l **MSL elevation** __________ ft.

Bottom anaerobic No Yes

pH @ 1' __________.________ **Specific Conductivity @ 1':** ______________ μmhos

Secchi depth: ___.___ m **Color** ______________________

Turbidity: ____

Air Temp: _____° Wind speed ________ Wind Dir. ________

Cloud cover: ____
Recent weather notes ______________________________________
____

WATER REGIME

1 = Intermittent [< 4 mths] 2 = Ephemeral [> 4 & < 9 mths] 3 = Perennial [> 9 & < 12 mths] 4 = Permanent [year-rnd]

	[1]	[2]
Stream/creek fed: - - -	No	Yes
Spring fed: - - - - - -	No	Yes
Ditch/Canal fed: - - -	No	Yes
Groundwater/Pump fed: -	No	Yes
Terraces: - - - - - - - -	No	Yes
Road bisection: - - - -	No	Yes
Powerline bisection: -	No	Yes
Hunting: - Unknown	No	Yes
Natural pipes: - - - -	No	Yes
Salt crust: - - - - - - -	No	Yes
Irrigation return flow:	No	Yes

Is water pumped from playa to irrigate: No Yes -> crop type ______________
Pits excavated: No Yes -> Max Depth of Pit ________ Avg pit depth ________

DAYS SINCE PLAYA BECAME WET (i.e. WAS DRY) ____________________ DAYS

DATE OF LAST RAIN

____

Appendix 2 (continued)

FIELD DATA SHEETS

SIZE OF PLAYA ___________ ACRES

AVERAGE WATER DEPTH CENTIMETERS ___________

Leeward (typically Northwest) wave deposits No Yes
Windward (typically Southeast) soil deposits No Yes

BOTTOM HARDNESS: 1 = HARD 2 = MODERATE 3 = SOFT

DEPTH OF SOFT LAYER ABOVE RANDALL CLAY ___________ CENTIMETERS

DENSITY OF CORE : 1 = VERY DENSE 2 = MEDIUM 3 = VERY LOOSE

LANDUSE IN THE PLAYA WATERSHED

FIELD/ROW CROPS

___________ % AREA IN CORN

___________ % AREA IN COTTON

___________ % AREA PLOWED OR EXPOSED SOIL

___________ % AREA OTHER CROP - name ___________

___________ % AREA OTHER CROP - name ___________

___________ % AREA ALL CROPS AND PLOWED SUM OF ABOVE

___________ % AREA IN CRP OR UNGRAZED PRAIRIE

DITCHES DIVERTING CROP IRRIGATION RETURN-FLOW TO PLAYA PRESENT
1 = NO 2 = YES

SODDED / GRASSLINED DITCHES DIVERTING IRRIGATION RETURN-FLOW TO PLAYA
1 = NO 2 = YES

RANGELAND

___________ % AREA PASTURE

	[1]	[2]
DOMINANCE OF RANGELAND VEGETATION - -	No	Yes
MARGIN OF PLAYA TRAMPLED BY CATTLE - -	No	Yes
PLAYA RINGED BY MANURE - - - - - - - - -	No	Yes
CATTLE FENCED FROM PLAYA - - - - - - - -	No	Yes

CONCENTRATION OF CATTLE 1 = LOW 2 = MEDIUM 3 = HIGH

FEEDLOT

___________ % AREA CATTLE FEEDLOTS TOTAL # HEAD OF CATTLE ___________

	[1]	[2]
FEEDLOTS PRESENT IN ANY PORTION OF WATERSHED	No	Yes

OILFIELD EXPLORATION/PRODUCTION

_________ % DRAINAGE AREA OILFIELD   TOTAL # WELLS VISIBLE FROM PLAYA

SEWAGE

______ % VOLUME FROM POTW / WWTP _____ ______MGD   NPDES # TX ____________

TWC PERMIT # ____________

++

DIAGRAM PLAYA, AQUATIC VEGETATION AND LAND USE BELOW

PLANTS

_________ % OF WET AREA IN EMERGENT VEGETATION

_________ % OF SHORELINE IN EMERGENT VEGETATION

_________ % SMARTWEED COVERAGE

_________ % BARNYARD GRASS COVERAGE

_________ % CATTAIL COVERAGE

_________ % BULRUSH COVERAGE

_________ % SPIKERUSH COVERAGE

_________ % ARROWHEAD COVERAGE

_________ % PONDWEED COVERAGE type ____________________

_________ % BURHEAD (ECHINODORUS)

_________ % WATER CLOVER (MARSILEA)

_________ % COVERAGE OTHER MACROPHYTE name ________________________

HEIGHT OF TALLEST EMERGENT VEGETATION ______METERS NAME _______________

EMERGENT VEGETATION   1 = TALL   2 = SHORT

FLOATING ALGAL MATS   [1] light   [2] medium   [3] heavy

++

PLAYA CHARACEAE

________ NUMBER OF *Chara* SPECIES PRESENT ______________________________

Chara braunii   CLEAR STEMMED, MORE CLOSED, CLUMPED_____________

Chara haitensis   OPEN, ROUGH, OOGONIUM/ANTHERIDIUM CONJOINED_______

Chara foliolosa   MALE ORANGE, OOGONIUM/ANTHERIDIUM SEJOINED

++

Appendix 2 (continued)

FIELD DATA SHEETS

UPLAND	[1]	[2]					
Shrub or tree shelter belt present:	No	Yes -> direction from Playa ______					
Locoweed (Astragalus sp.) present:	No	Yes					
Cocklebur present:	No	Yes	also	1	-	2	- 3
Wooly leaf bursedge present:	No	Yes	also	1	-	2	- 3

ANOMALIES / GENERAL NOTES

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____

Appendix 2 (continued)

FIELD DATA SHEETS
ABUNDANCE / PRESENCE CODES

1.0=ABSENT 1.1=RARE 2=NORMAL OR PRESENT BUT NOT VERY HIGH OR LOW 3=ABUNDANT

VOLVOX	1.0	1.1	2.0	3.0	MAYFLY LARVAE LATERAL ABDOMINAL GILLS	1.0	1.1	2.0	3.0
NEMATODES	1.0	1.1	2.0	3.0	DAMSELFLY LV THIN, 3 FLAT TAIL GILLS	1.0	1.1	2.0	3.0
LEECHES	1.0	1.1	2.0	3.0	DRAGONFLY LV STOUT, NO EXTERNAL GILLS	1.0	1.1	2.0	3.0
TUBIFICID WORMS	1.0	1.1	2.0	3.0	STONEFLY LV WING PADS	1.0	1.1	2.0	3.0
PHYSID SNAILS CONICAL	1.0	1.1	2.0	3.0	CORIXIDS WATER BOATMEN	1.0	1.1	2.0	3.0
HELIOSOMA PLANORBID SNAILS	1.0	1.1	2.0	3.0	NOTONECTIDS BACKSWIMMERS	1.0	1.1	2.0	3.0
CYCLOPOID COPEPODS 2 EGG SACS SHORTER ANTENNAE	1.0	1.1	2.0	3.0	WATER STRIDER	1.0	1.1	2.0	3.0
CALANOID COPEPODS 1 EGG SAC LONGER ANTENNAE	1.0	1.1	2.0	3.0	HYDROPHILIDS WATER SCAVENGERS	1.0	1.1	2.0	3.0
CLAM SHRIMP CONCHOSTRACHANS 10-28 APPEND.	1.0	1.1	2.0	3.0	DYTISCID LARVAE	1.0	1.1	2.0	3.0
SEED SHRIMP OSTRACODS NO GROWTH LINES 2-3 APPEND.	1.0	1.1	2.0	3.0	DYTISCID ADULT DIVING BEETLES	1.0	1.1	2.0	3.0
FAIRY SHRIMP ANOSTRACANS NO CARAPACE	1.0	1.1	2.0	3.0	SEP. HEADED BEETLES	1.0	1.1	2.0	3.0
TADPOLE SHRIMP NOTOSTRACANS CARAPACE OVER HEAD	1.0	1.1	2.0	3.0	HORSE/DEER FLY LARVAE	1.0	1.1	2.0	3.0
DAPHNIDS	1.0	1.1	2.0	3.0	CRANEFLY LV	1.0	1.1	2.0	3.0
CRAYFISH	1.0	1.1	2.0	3.0	CHIRONOMID RED	1.0	1.1	2.0	3.0
SALAMANDERS	1.0	1.1	2.0	3.0	CHIRONOMID NOT RED	1.0	1.1	2.0	3.0
______________	1.0	1.1	2.0	3.0	SHORE FLIES EPHYDRIDS	1.0	1.1	2.0	3.0
______________	1.0	1.1	2.0	3.0	DIPTERAN LARVAE	1.0	1.1	2.0	3.0
______________	1.0	1.1	2.0	3.0	______________	1.0	1.1	2.0	3.0

Appendix 2 (continued)

FIELD DATA SHEETS

BIRDS

LIST SPECIES ______________________________

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____

____

Past history of bird kill due to cholera No Yes ______________

Past history of bird kill due to other cause No Yes ______________

specify 1) BOTULISM 2) MYCOTOXINS 3) OP PESTICIDE 4) OTHER name__________

Appendix 3

Aliphatic hydrocarbon concentrations in sediments (mg/kg dry weight) from Playa Lakes, Texas, 1990.

Aliphatic Hydrocarbons	S1	S2	S3	S4	Site Rich Lake 01	Mound Lake 02	Cedar Lake SW 03	Cedar Lake NE 04
N-dodecane	*	*	*	0.03	*	*	0.01	204.1
N-tridecane	*	0.02	*	0.05	0.02	0.02	0.03	238.1
N-tetradecane	*	0.07	*	0.08	0.05	0.2	0.05	272.1
Octylcyclohexane	*	*	*	*	*	*	*	56.1
N-pentadecane	0.18	0.05	0.12	0.08	0.15	0.18	0.08	476.2
Noncycyclohexane	*	*	*	*	*	*	*	100.3
N-hexadecane	0.05	0.05	0.06	0.05	0.02	0.04	0.03	612.2
N-heptadecane	0.87	0.31	0.41	0.23	0.10	0.12	0.13	714.3
Pristane	0.10	*	*	*	*	*	0.04	527.2
N-octadecane	0.10	0.02	0.06	0.08	0.03	0.04	0.03	748.3
Phytane	0.34	0.09	0.35	0.35	0.14	0.16	0.03	612.2
N-nonadecane	0.16	0.05	0.18	0.15	0.03	0.04	0.03	714.3
N-eicosane	0.10	0.02	0.12	0.08	0.02	0.02	0.03	765.3
Total Residue	1.9	0.68	1.3	1.34	0.56	0.82	0.49	6040.7

* - None detected

Appendix 4

Oil and grease concentrations in sediments (mg/kg dry weight).

Playa Site[1]	Oil & Grease
X1	110
X2	50
X3	ND
X4	90
R1	70
R2	ND
R3	90
R4	70
P1	480
P2	1660
P3	95
P4	250
F1	3210
F2	4360
F3	340
F4	4220
E1	80
E2	160
E3	90
E4	170
V1	490
V2	450
V3	330
V4	290
O1	512
O2	904
O3	170
O4	126000
S1	653
S2	600
S3	608
S4	745
C1	ND

[1] - X = corn irrigated, R = Ephemeral row crop, P = Muncipal effluent, F = Cattle feedlot, E = Pasture/Rangeland, V = Relatively undisturbed playa, O = Oil Brine, S = Salt Playa, C = Rita Blanca National Grassland.

ND - None detected

Appendix 5

Metalloid concentrations in sediments, (mg/kg dry weight).

Playa Site[1]	Arsenic	Mercury	Selenium	Aluminum
X1	38.60	0.056	*0.45	36300
X2	36.60	0.044	*0.42	35500
X3	22.40	0.040	*0.40	25000
X4	39.40	0.130	*0.49	45900
R1	31.10	0.057	*0.46	18800
R2	69.80	0.071	*0.55	40100
R3	38.20	0.058	*0.50	29100
R4	20.90	*0.020	*0.38	21800
P1	15.30	0.069	0.49	22800
P2	71.50	0.254	0.52	18100
P3	3.30	*0.019	*0.075	3040
P4	10.40	*0.020	2.60	17400
F1	11.10	*0.048	0.77	8260
F2	24.10	*0.057	*1.15	17200
F3	6.60	*0.022	*0.085	7050
F4	50.00	0.108	1.30	30900
E1	44.20	*0.026	*0.50	36400
E2	29.90	*0.020	*0.395	23200
E3	37.40	*0.023	*0.455	22100
E4	33.20	*0.021	*0.415	24000
V1	37.30	*0.028	*0.55	36000
V2	35.30	*0.022	*0.44	29900
V3	10.50	*0.022	*0.085	15000
V4	58.90	*0.023	*0.465	37700
O1	6.20	*0.005	7.00	11000
O2	10.40	0.020	15.00	17800
O3	5.10	*0.010	1.10	3350
O4	4.70	0.054	1.60	5570
S1	7.60	0.030	0.30	28000
S2	8.30	0.030	0.53	27900
S3	7.00	0.030	4.50	15900
S4	5.00	*0.005	6.30	18500
C1	52.70	*0.022	*0.43	39500

[1] - X = corn irrigated, R = Ephemeral row crop, P = Muncipal effluent, F = Cattle feedlot, E = Pasture/Rangeland, V = Relatively undisturbed playa, O = Oil Brine, S = Salt Playa, C = Rita Blanca National Grassland.

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Appendix 5 (continued)

Metalloid concentrations in sediments, (mg/kg dry weight).

Playa Site[1]	Barium	Beryllium	Boron	Cadmium	Chromium
X1	221	1.71	11.90	0.72	29.00
X2	201	1.45	14.10	0.51	29.10
X3	143	1.04	8.73	*0.20	20.50
X4	213	1.87	22.60	*0.25	36.80
R1	148	1.01	6.78	*0.23	17.60
R2	231	1.72	12.60	*0.23	40.00
R3	173	1.34	8.26	*0.26	25.50
R4	107	0.93	104.00	*0.39	18.80
P1	158	0.99	19.80	*0.31	19.50
P2	143	0.65	42.00	*0.65	18.10
P3	30	0.19	6.61	*0.19	4.23
P4	122	0.73	14.10	*0.21	35.00
F1	105	*0.48	15.30	*0.48	8.62
F2	151	*0.57	56.80	*0.57	16.60
F3	161	*0.22	22.60	*0.22	7.43
F4	183	1.08	43.80	*0.54	27.60
E1	187	1.56	16.10	*0.26	31.40
E2	133	1.11	15.30	*0.20	21.70
E3	142	1.19	48.20	0.46	21.00
E4	142	1.08	10.50	*0.21	21.90
V1	215	1.55	15.50	*0.28	29.60
V2	208	1.41	75.10	*0.22	25.70
V3	134	0.70	10.10	*0.22	13.50
V4	211	1.76	11.30	*0.23	30.60
O1	112	0.49	85.00	*0.20	8.60
O2	78	0.78	63.00	*0.20	12.00
O3	50	0.10	54.00	*0.20	6.70
O4	76	0.42	25.00	*0.20	157.00
S1	180	1.40	4.00	*0.20	19.00
S2	185	1.10	25.00	0.30	20.00
S3	152	0.80	60.00	0.40	12.00
S4	167	0.87	30.00	0.40	14.00
C1	289	1.55	22.00	*0.22	35.40

[1] - X = corn irrigated, R = Ephemeral row crop, P = Muncipal effluent, F = Cattle feedlot, E = Pasture/Rangeland, V = Relatively undisturbed playa, O = Oil Brine, S = Salt Playa, C = Rita Blanca National Grassland.

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Appendix 5 (continued)

Metalloid concentrations in sediments, (mg/kg dry weight).

Playa Site[1]	Copper	Iron	Lead	Magnesium	Manganese
X1	22.30	27200	14.20	5700	479
X2	18.60	25800	15.80	5300	430
X3	13.10	18100	2.96	4680	290
X4	22.20	32500	20.10	7050	520
R1	15.90	15900	9.16	4000	330
R2	24.00	28500	20.30	6000	449
R3	19.10	22500	11.30	4130	397
R4	11.90	16300	8.05	3040	296
P1	21.10	17000	19.90	4490	224
P2	54.40	12100	18.70	5230	171
P3	3.94	2980	3.20	929	45
P4	11.70	12600	7.34	3600	215
F1	18.60	6260	*2.88	3240	164
F2	42.30	13700	8.86	6390	366
F3	14.60	5380	3.15	3300	114
F4	35.10	21700	58.20	7740	436
E1	21.40	26200	19.60	5260	377
E2	14.60	18500	15.90	4660	246
E3	18.00	17800	22.80	3800	356
E4	15.60	18600	17.50	4200	330
V1	20.30	25200	27.20	5930	416
V2	18.70	22200	21.30	5490	363
V3	11.50	11500	10.10	3280	124
V4	20.90	27400	25.20	5660	429
O1	4.20	6530	6.00	26100	122
O2	6.70	10100	10.00	18300	126
O3	2.60	2720	4.00	15100	34
O4	29.30	10400	57.00	7190	96
S1	15.00	18300	21.00	53100	248
S2	12.00	15800	17.00	9030	934
S3	8.40	10400	10.00	15900	272
S4	9.60	12200	13.00	12700	381
C1	24.30	31800	21.80	11200	525

[1] - X = corn irrigated, R = Ephemeral row crop, P = Muncipal effluent, F = Cattle feedlot, E = Pasture/Rangeland, V = Relatively undisturbed playa, O = Oil Brine, S = Salt Playa, C = Rita Blanca National Grassland.

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Appendix 5 (continued)

Metalloid concentrations in sediments, (mg/kg dry weight).

Playa Site[1]	Molybdenum	Nickel	Strontium	Vanadium	Zinc
X1	*2.25	20.90	63.90	55.20	75.60
X2	*2.13	20.40	81.30	52.00	76.70
X3	*2.01	15.50	78.00	38.50	55.40
X4	*2.46	60.00	102.00	68.30	94.90
R1	*2.29	16.50	68.60	34.10	47.30
R2	*2.86	24.90	62.00	58.70	98.90
R3	*2.59	19.70	49.90	48.00	69.80
R4	*1.94	13.20	34.90	35.90	49.80
P1	*3.09	14.90	143.00	40.40	75.60
P2	*6.50	13.20	677.00	31.30	144.00
P3	*1.86	*1.49	33.10	6.39	15.20
P4	*2.04	5.63	76.10	22.90	56.50
F1	*4.79	9.77	149.00	16.70	136.00
F2	*5.70	15.00	168.00	31.10	226.00
F3	*2.19	6.12	164.00	14.90	75.30
F4	*5.40	18.80	189.00	47.00	206.00
E1	*2.60	19.60	32.00	53.90	76.20
E2	*1.99	13.80	44.70	35.10	61.70
E3	*2.28	15.40	41.40	33.70	64.60
E4	*2.08	14.90	50.40	38.10	62.40
V1	*2.77	22.50	62.10	52.80	86.80
V2	*2.21	17.90	108.00	43.10	76.20
V3	*2.19	10.10	73.20	23.40	40.90
V4	*2.32	24.60	83.00	55.80	81.90
O1	6.20	5.00	1560.00	31.00	16.00
O2	19.00	8.10	1970.00	59.50	27.00
O3	16.00	4.00	456.00	12.00	9.30
O4	3.00	8.90	8620.00	14.00	129.00
S1	1.00	17.00	164.00	23.00	53.70
S2	4.30	15.00	551.00	31.00	46.70
S3	20.00	9.80	4070.00	68.00	30.00
S4	5.80	12.00	16.00	47.00	40.00
C1	*2.16	28.80	179.00	65.50	95.00

[1] - X = corn irrigated, R = Ephemeral row crop, P = Muncipal effluent, F = Cattle feedlot, E = Pasture/Rangeland, V = Relatively undisturbed playa, O = Oil Brine, S = Salt Playa, C = Rita Blanca National Grassland.

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Appendix 6

Metalloid concentrations in invertebrates (mg/kg dry weight).

Playa Site[1]	% moisture	Aluminum	Arsenic	Barium	Beryllium
X1-1	72.7	2630.0	1.6	66.6	* 0.1
X1-8	68.6	4044.6	1.7	54.5	0.2
X2-1	88.4	1020.0	* 0.5	15.2	* 0.1
X3-8	71.9	8540.9	12.9	121.4	0.4
X4-1	75.6	2870.0	2.6	66.0	* 0.1
X4-8	83.3	2413.2	3.0	52.3	0.2
R1-1	90.0	1020.0	3.7	44.1	* 0.1
R1-8	84.0	325.6	2.1	11.8	* 0.1
P1-1	93.6	5080.0	2.3	83.1	* 0.1
P2-1	79.5	1120.0	* 0.5	24.4	* 0.1
P3-1	80.9	4770.0	2.6	71.5	0.2
F1-8	83.2	1610.0	* 0.5	30.0	* 0.1
F2-1	75.0	5190.0	2.1	68.6	* 0.1
F3-1	0.0	210.0	0.4	10.7	* 0.0
F3-8	75.8	2710.0	2.1	74.8	* 0.1
V1-1	79.7	1600.0	3.4	65.1	* 0.1
01-1	86.8	1430.0	26.0	13.0	* 0.1
02-1	87.3	1190.0	44.7	7.3	* 0.1
S1-8	0.0	98.9	1.4	7.7	* 0.0
S2-1	79.4	2840.0	18.0	18.2	* 0.1
S2-8	80.5	2569.2	48.3	17.5	0.1
S3	85.4	214.4	61.6	4.1	* 0.1
S3-1	87.1	130.0	10.0	2.9	* 0.1
S4-1	89.4	703.8	99.1	26.7	* 0.1
S4-8	86.7	1451.1	122.6	26.7	* 0.1

[1] - X = corn irrigated, R = Ephemeral row crop, P = Muncipal effluent, F = Cattle feedlot, EC = Pasture/Rangeland, V = Relatively undisturbed playa, S = Salt Playa, C = Rita Blanca National Grassland.

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Appendix 6 (continued)

Metalloid concentrations in invertebrates (mg/kg dry weight).

Playa Site[1]	Boron	Cadmium	Chromium	Copper	Iron
X1-1	6.2	0.3	1.9	13.3	1760.0
X1-8	3.8	0.5	3.4	12.5	2474.5
X2-1	2.5	0.4	* 0.5	17.6	651.0
X3-8	9.9	0.4	7.5	10.4	6939.5
X4-1	5.0	0.2	2.4	19.5	2090.0
X4-8	6.5	0.6	3.3	26.8	2467.1
R1-1	5.7	0.7	2.2	45.8	928.0
R1-8	3.2	0.6	1.3	21.2	360.0
P1-1	21.7	* 0.1	3.8	11.4	3190.0
P2-1	* 0.6	* 0.1	1.2	10.4	770.0
P3-1	12.8	0.4	3.9	16.1	3450.0
F1-8	2.8	* 0.1	1.5	15.4	1120.0
F2-1	8.6	* 0.1	5.2	22.3	3730.0
F3-1	0.9	0.1	0.4	4.0	200.0
F3-8	* 0.6	* 0.1	2.5	26.0	1810.0
V1-1	5.6	0.3	1.7	19.1	1710.0
O1-1	358.0	0.6	1.5	9.6	832.0
O2-1	57.5	0.3	1.2	8.2	980.0
S1-8	1.3	* 0.1	0.3	3.2	147.0
S2-1	27.6	* 0.1	2.0	8.5	1890.0
S2-8	31.7	0.5	2.6	23.2	1923.1
S3	91.8	* 0.2	1.0	12.7	251.4
S3-1	78.9	* 0.1	* 0.6	12.1	157.0
S4-1	377.4	1.0	1.8	8.6	502.8
S4-8	379.7	1.2	2.2	6.5	887.2

[1] - X = corn irrigated, R = Ephemeral row crop, P = Muncipal effluent, F = Cattle feedlot, EC = Pasture/Rangeland, V = Relatively undisturbed playa, S = Salt Playa, C = Rita Blanca National Grassland.

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Appendix 6 (continued)

Metalloid concentrations in invertebrates (mg/kg dry weight).

Playa Site[1]	Lead	Mercury	Magnesium	Manganese	Molybdenum
X1-1	5.8	* 0.10	1930.0	285.0	* 0.6
X1-8	* 0.8	0.09	1480.9	183.1	* 0.6
X2-1	0.5	* 0.10	1480.0	61.6	* 0.5
X3-8	6.3	0.14	3124.6	268.3	1.6
X4-1	3.8	0.23	1870.0	335.0	* 0.5
X4-8	* 1.5	0.40	2353.3	247.9	* 1.2
R1-1	* 2.5	0.92	1870.0	206.0	* 2.0
R1-8	* 1.6	0.53	1125.0	113.8	* 1.2
P1-1	4.2	* 0.11	2510.0	1090.0	* 0.5
P2-1	1.7	* 0.11	1460.0	19.4	* 0.6
P3-1	6.9	* 0.11	2510.0	191.0	* 0.5
F1-8	1.5	* 0.10	2190.0	151.0	1.6
F2-1	2.1	* 0.10	3670.0	179.0	* 0.5
F3-1	* 0.3	0.06	394.0	8.2	* 0.2
F3-8	* 0.5	* 0.11	1490.0	55.8	* 0.5
V1-1	1.8	* 0.10	1690.0	272.0	* 0.5
O1-1	1.3	* 0.11	24900.0	452.0	3.8
O2-1	2.3	* 0.11	5400.0	38.3	2.6
S1-8	* 0.5	0.03	409.0	176.0	* 0.4
S2-1	* 0.5	* 0.11	8030.0	1510.0	* 0.5
S2-8	* 1.3	0.15	8512.8	1733.3	* 1.0
S3	* 1.7	0.10	9657.5	746.6	* 1.4
S3-1	* 0.6	* 0.11	7170.0	592.0	* 0.6
S4-1	* 2.3	* 0.05	30943.4	334.0	* 1.8
S4-8	3.8	0.09	30300.8	357.9	* 1.5

[1] - X = corn irrigated, R = Ephemeral row crop, P = Muncipal effluent, F = Cattle feedlot, EC = Pasture/Rangeland, V = Relatively undisturbed playa, S = Salt Playa, C = Rita Blanca National Grassland.

* = value below detection limit (DL) is represented as (0.5 x DL)

Appendix 6 (continued)

Metalloid concentrations in invertebrates (mg/kg dry weight).

Playa Site[1]	Nickel	Selenium	Strontium	Vanadium	Zinc
X1-1	3.4	2.4	811.0	7.0	70.5
X1-8	3.3	1.5	563.7	9.0	39.2
X2-1	* 0.5	2.0	74.1	1.9	109.0
X3-8	7.8	1.2	132.7	18.6	43.8
X4-1	2.6	3.8	287.0	6.9	82.3
X4-8	3.5	2.6	213.8	11.8	88.6
R1-1	1.6	6.1	38.4	3.5	140.0
R1-8	1.3	2.9	34.3	1.4	83.8
P1-1	3.4	2.8	485.0	6.3	68.3
P2-1	* 0.6	3.8	67.8	1.2	109.0
P3-1	5.0	2.0	189.0	9.2	71.1
F1-8	1.5	* 0.5	47.5	2.7	121.0
F2-1	7.5	* 0.5	97.0	9.2	124.0
F3-1	0.4	0.7	14.2	1.0	25.7
F3-8	1.8	2.2	341.0	6.6	68.6
V1-1	3.4	1.3	139.0	6.2	82.3
O1-1	5.6	72.2	501.0	37.3	50.7
O2-1	2.7	110.0	599.0	6.3	65.1
S1-8	0.4	* 0.4	16.6	0.3	11.0
S2-1	2.2	3.9	646.0	3.8	90.4
S2-8	3.0	4.4	533.3	4.7	99.5
S3	1.8	20.9	374.7	2.2	107.5
S3-1	2.5	15.4	319.0	1.3	103.0
S4-1	1.7	4.0	2179.2	5.5	42.0
S4-8	2.4	3.1	2030.1	5.8	40.4

[1] - X = corn irrigated, R = Ephemeral row crop, P = Muncipal effluent, F = Cattle feedlot, EC = Pasture/Rangeland, V = Relatively undisturbed playa, S = Salt Playa, C = Rita Blanca National Grassland.

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Appendix 7

Metalloid concentrations in aquatic vegetation (mg/kg dry weight).

Playa Site[1]	% moisture	Aluminum	Arsenic	Barium	Beryllium
X1-1	80.5	406.2	0.7	28.7	* 0.1
X1-3	85.0	969.0	* 0.5	57.0	* 0.1
X1-8	81.3	3096.3	3.7	61.5	* 0.1
X2-1	82.6	5977.0	2.4	136.8	0.2
X2-3	72.3	1020.0	* 0.5	65.5	* 0.1
X2-8	72.3	1671.5	1.8	155.6	* 0.1
X3-1	84.1	3717.0	2.1	115.7	0.1
X3-3	84.3	1414.0	1.0	65.0	* 0.1
X3-8	79.9	1089.6	1.1	49.2	* 0.1
X4-1	82.4	4994.3	8.9	89.8	0.2
X4-3	81.5	495.0	1.2	36.8	* 0.1
X4-8	84.4	1903.9	2.4	46.2	* 0.1
R1-1	92.4	3171.1	8.4	151.3	* 0.4
R1-3	89.2	5370.4	7.4	164.8	* 0.3
R1-8	84.6	1850.7	8.5	80.5	* 0.2
P1-1	66.0	178.0	* 0.5	10.9	* 0.1
P1-3	62.7	209.4	1.3	12.8	* 0.0
P1-8	64.8	120.5	3.3	14.5	* 0.0
P2-1	83.7	114.0	* 0.5	6.6	* 0.1
P2-3	67.8	232.3	1.7	10.6	* 0.0
P2-8	79.6	250.5	1.9	17.0	* 0.1
P3-1	81.4	768.8	3.5	19.8	* 0.1
P3-3	71.1	368.0	* 0.5	7.5	* 0.1
P3-8	76.1	431.0	1.6	13.7	* 0.0
P4-1	65.8	88.9	2.2	2.1	* 0.0
P4-3	57.7	63.8	0.7	1.2	* 0.0
P4-8	61.2	224.7	0.6	2.5	* 0.0
F1-3	79.1	1756.0	2.9	51.2	0.1
F2-3	78.7	202.4	2.0	4.8	* 0.0
F3-1	68.2	264.5	0.9	20.8	0.0
F3-3	86.7	9190.0	* 2.2	164.0	* 0.1
F3-8	63.4	169.4	0.8	16.9	0.0
F4-1	76.4	130.1	2.4	2.2	* 0.0
F4-3	66.9	125.7	1.8	2.2	* 0.0
F4-8	66.9	107.3	0.8	1.7	* 0.0
V1-1	83.6	9207.3	19.6	454.3	0.4
V1-3	82.3	2800.0	10.0	329.0	1.05
V1-8	81.2	3984.0	10.4	189.9	0.2
O1-3	83.3	1712.6	88.6	16.5	* 0.1
O2-3	25.6	159.0	* 0.5	3.9	* 0.1
S1-1	80.5	231.3	9.9	242.6	* 0.1
S1-8	85.9	374.5	52.3	386.5	* 0.1
S2-3	82.1	111.0	1.9	12.0	* 0.1
S2-8	82.2	1269.7	49.8	33.0	* 0.1
S3-1	77.7	222.4	26.5	3.6	* 0.0
S3-3	82.4	62.8	2.0	2.1	* 0.1
S3-8	79.4	5436.9	64.6	89.8	0.2
S4-1	82.2	498.9	199.4	11.1	* 0.1
S4-3	88.6	602.6	150.9	11.8	* 0.1
S4-8	83.8	510.5	187.0	11.1	* 0.1

[1] - X = corn irrigated, R = Ephemeral row crop, P = Muncipal effluent, F = Cattle feedlot, EC = Pasture/Rangeland, V = Relatively undisturbed playa, S = Salt Playa, C = Rita Blanca National Grassland.

* = value below detection limit (DL) is represented as (0.5 x DL)

Appendix 7 (continued)

Metalloid concentrations in aquatic vegetation (mg/kg dry weight).

Playa Site[1]	Boron	Cadmium	Chromium	Copper	Iron
X1-1	16.1	* 0.2	0.9	23.4	310.8
X1-3	15.8	0.1	1.8	3.7	510.0
X1-8	16.8	* 0.2	3.0	9.9	3369.0
X2-1	22.5	* 0.2	5.2	6.0	4701.2
X2-3	25.1	0.1	1.2	3.8	337.0
X2-8	19.5	* 0.1	1.9	9.9	1458.5
X3-1	41.6	0.5	3.4	7.7	2207.6
X3-3	31.3	* 0.2	1.7	7.0	898.1
X3-8	16.8	0.4	1.4	13.2	666.7
X4-1	20.0	0.4	4.4	9.0	6704.5
X4-3	15.2	0.1	* 0.5	5.2	266.0
X4-8	25.3	* 0.2	1.9	9.0	1884.6
R1-1	29.9	* 0.4	4.0	24.7	2736.8
R1-3	31.8	* 0.3	5.1	11.6	5509.3
R1-8	22.8	* 0.2	2.4	11.4	2246.8
P1-1	11.1	* 0.1	0.6	3.9	147.0
P1-3	39.4	0.1	0.6	3.2	189.5
P1-8	49.7	* 0.1	0.5	8.6	129.6
P2-1	24.6	0.1	* 0.5	2.5	120.0
P2-3	15.3	* 0.1	0.6	107.5	198.1
P2-8	21.6	* 0.1	0.8	4.5	212.8
P3-1	20.8	* 0.2	1.1	10.7	661.3
P3-3	13.4	0.1	* 0.6	3.3	299.0
P3-8	18.0	* 0.1	0.8	17.8	370.7
P4-1	18.1	* 0.1	0.5	50.9	118.4
P4-3	14.7	* 0.1	0.4	98.6	85.6
P4-8	16.0	* 0.1	0.8	211.3	304.1
F1-3	8.9	* 0.1	2.9	17.1	1846.9
F2-3	36.6	0.4	0.8	19.3	212.2
F3-1	18.2	* 0.1	0.7	3.8	251.3
F3-3	14.9	0.1	10.2	23.9	5420.0
F3-8	15.3	* 0.1	0.6	6.3	177.1
F4-1	17.4	* 0.1	0.8	53.4	166.1
F4-3	16.0	* 0.1	0.6	47.7	148.0
F4-8	11.2	* 0.1	0.5	16.1	127.8
V1-1	16.2	0.4	6.4	8.5	9939.0
V1-3	13.4	0.5	5.1	6.8	3050.0
V1-8	16.1	* 0.2	3.4	5.4	4797.9
O1-3	598.8	1.3	2.5	263.5	1209.6
O2-3	30.9	0.1	* 0.6	4.3	132.0
S1-1	12.9	* 0.2	1.1	9.1	350.3
S1-8	16.0	* 0.2	1.9	12.2	613.5
S2-3	20.4	0.1	1.2	11.8	76.0
S2-8	71.9	0.4	2.2	17.5	1202.3
S3-1	191.9	* 0.1	0.7	5.7	186.6
S3-3	59.5	0.1	* 0.6	9.3	66.9
S3-8	327.2	0.7	4.7	5.7	3349.5
S4-1	330.9	1.9	0.8	2.8	237.6
S4-3	394.7	1.5	1.5	9.2	371.1
S4-8	332.1	1.8	0.9	4.1	265.4

[1] - X = corn irrigated, R = Ephemeral row crop, P = Muncipal effluent, F = Cattle feedlot, EC = Pasture/Rangeland, V = Relatively undisturbed playa, S = Salt Playa, C = Rita Blanca National Grassland.

* = value below detection limit (DL) is represented as (0.5 x DL)

Appendix 7 (continued)

Metalloid concentrations in aquatic vegetation (mg/kg dry weight).

Playa Site[1]	Lead	Mercury	Magnesium	Manganese	Molybdenum
X1-1	* 1.3	* 0.02	3338.5	146.2	* 1.0
X1-3	* 0.6	* 0.10	3220.0	317.0	* 0.6
X1-8	4.5	0.06	3304.8	273.8	* 1.1
X2-1	5.2	0.06	5649.4	403.5	* 1.1
X2-3	* 0.6	* 0.11	4510.0	425.0	* 0.6
X2-8	1.8	* 0.02	7729.6	606.5	* 0.7
X3-1	5.4	* 0.03	3496.9	159.8	* 1.2
X3-3	5.6	0.06	2949.0	105.1	* 1.3
X3-8	5.6	* 0.02	2920.4	80.1	* 1.0
X4-1	3.6	* 0.03	3647.7	555.1	* 1.1
X4-3	* 0.5	* 0.11	2940.0	302.0	* 0.5
X4-8	* 1.6	0.08	2410.3	286.5	* 1.3
R1-1	* 3.3	0.17	5921.1	834.2	* 2.6
R1-3	5.8	0.11	4453.7	657.4	* 1.8
R1-8	* 1.6	0.11	3948.1	281.2	* 1.3
P1-1	1.2	* 0.09	2120.0	264.0	* 0.5
P1-3	* 0.7	* 0.01	1841.8	260.9	* 0.5
P1-8	* 0.7	* 0.01	2028.4	295.5	* 0.6
P2-1	* 0.5	* 0.10	2100.0	16.9	* 0.5
P2-3	5.1	* 0.01	1975.2	19.8	* 0.6
P2-8	* 1.2	* 0.02	2696.1	23.4	*0.9
P3-1	9.4	* 0.03	3263.4	160.2	* 1.1
P3-3	7.7	* 0.11	2180.0	165.0	* 0.5
P3-8	9.0	* 0.02	2786.6	110.0	* 0.8
P4-1	2.4	* 0.01	2207.6	184.5	* 0.6
P4-3	4.0	* 0.01	1794.3	164.3	* 0.5
P4-8	9.3	* 0.01	1966.5	91.2	* 0.5
F1-3	2.5	0.06	1354.1	110.1	* 1.0
F2-3	* 1.2	* 0.02	7323.9	67.1	2.4
F3-1	* 0.8	* 0.01	2235.9	150.9	* 0.6
F3-3	4.2	* 0.11	3760.0	140.0	1.9
F3-8	* 0.7	* 0.01	2041.0	109.8	* 0.5
F4-1	* 2.9	* 0.02	3288.1	68.2	* 0.8
F4-3	2.5	* 0.01	2549.9	53.8	* 0.6
F4-8	* 0.8	* 0.01	2353.5	67.4	* 0.6
V1-1	5.1	0.10	6524.4	1329.3	6.8
V1-3	2.3	* 0.11	5280.0	1040.0	4.2
V1-8	3.9	0.07	3856.4	443.1	3.4
O1-3	10.7	* 0.03	29580.8	760.5	4.8
O2-3	* 0.5	* 0.11	1420.0	37.5	* 0.5
S1-1	* 1.3	0.06	1687.2	5641.0	* 1.0
S1-8	* 1.8	0.09	2326.2	14113.5	* 1.4
S2-3	* 0.6	* 0.11	5390.0	386.0	* 0.5
S2-8	* 1.4	0.09	9438.2	12528.1	2.6
S3-1	* 1.1	0.05	7174.9	829.6	* 0.9
S3-3	* 0.5	* 0.11	6010.0	174.0	* 0.5
S3-8	2.8	0.10	16407.8	1898.1	* 0.9
S4-1	* 1.4	0.06	44606.7	343.8	* 1.1
S4-3	* 2.1	* 0.04	32982.5	513.2	* 1.7
S4-8	* 1.5	0.06	46851.9	311.7	* 1.2

[1] - X = corn irrigated, R = Ephemeral row crop, P = Muncipal effluent, F = Cattle feedlot, EC = Pasture/Rangeland, V = Relatively undisturbed playa, S = Salt Playa, C = Rita Blanca National Grassland.

* = value below detection limit (DL) is represented as (0.5 x DL)

Appendix 7 (continued)

Metalloid concentrations in aquatic vegetation (mg/kg dry weight).

Playa Site[1]	Nickel	Selenium	Strontium	Vanadium	Zinc
X1-1	3.6	0.8	83.1	1.7	40.4
X1-3	1.9	*0.5	123.0	5.5	44.9
X1-8	3.7	1.0	104.3	8.1	33.4
X2-1	5.1	1.6	193.7	16.2	19.1
X2-3	1.6	*0.5	179.0	1.9	21.1
X2-8	3.0	1.0	299.3	4.6	13.8
X3-1	3.3	2.0	232.7	15.5	35.7
X3-3	2.0	1.7	128.7	6.3	30.2
X3-8	1.9	1.0	99.0	1.7	30.5
X4-1	4.6	1.0	111.9	14.7	27.6
X4-3	2.0	*0.6	88.9	5.5	20.3
X4-8	2.5	1.2	81.4	6.4	22.2
R1-1	5.9	2.2	350.0	12.1	36.2
R1-3	5.6	1.3	260.2	19.6	38.7
R1-8	3.9	1.2	150.0	7.9	30.6
P1-1	*0.6	*0.5	46.1	*0.6	23.5
P1-3	0.3	1.1	40.8	0.6	13.9
P1-8	0.3	0.8	44.9	0.4	16.6
P2-1	*0.5	*0.5	46.5	*0.5	21.8
P2-3	0.9	0.6	64.9	0.5	76.7
P2-8	*0.3	0.8	106.4	0.4	21.4
P3-1	1.5	0.5	71.5	1.4	36.0
P3-3	0.6	*0.5	29.5	*0.6	41.9
P3-8	1.3	1.2	51.1	0.8	37.7
P4-1	1.5	0.3	40.1	0.2	44.2
P4-3	2.2	0.3	21.3	*0.1	69.1
P4-8	3.5	*0.4	20.4	0.9	131.7
F1-3	4.1	2.5	61.2	8.0	88.0
F2-3	1.7	1.4	41.0	*0.1	65.3
F3-1	0.8	0.9	48.4	0.8	13.8
F3-3	7.1	*0.5	159.0	21.3	141.0
F3-8	1.0	0.8	36.9	0.2	15.9
F4-1	2.7	1.2	7.7	*0.1	113.6
F4-3	2.5	0.9	10.4	0.2	87.6
F4-8	0.9	0.9	7.9	0.2	69.8
V1-1	5.7	1.0	607.3	24.8	36.2
V1-3	9.9	*0.5	550.0	10.8	33.2
V1-8	3.6	1.6	266.0	11.8	24.8
O1-3	27.0	39.3	559.3	12.7	128.1
O2-3	1.8	6.0	61.8	*0.6	17.0
S1-1	0.7	0.5	111.8	0.9	44.2
S1-8	*0.4	0.7	141.1	1.8	25.5
S2-3	1.3	*0.5	118.0	0.6	160.0
S2-8	1.2	2.5	382.6	5.0	25.8
S3-1	1.0	3.9	266.4	2.8	15.2
S3-3	1.9	1.3	190.0	*0.6	36.0
S3-8	5.6	6.9	1116.5	23.4	18.3
S4-1	1.4	1.9	1174.2	3.0	10.8
S4-3	2.1	2.3	1061.4	4.5	17.0
S4-8	0.8	1.4	1030.9	3.7	13.8

[1] - X = corn irrigated, R = Ephemeral row crop, P = Muncipal effluent, F = Cattle feedlot, EC = Pasture/Rangeland, V = Relatively undisturbed playa, S = Salt Playa, C = Rita Blanca National Grassland.

* = value below detection limit (DL) is represented as (0.5 x DL)

Appendix 8

Nutrient concentrations (mg/kg dry weight), chemical oxygen deman, percent moisture, and percent organic matter in sediment.

Playa Site[1]	Chemical Oxygen Demand	Percent Moisture	Ammonia	Nitrate	Percent Organic Matter
X1	48000	42.5	75.80	1.65	4.72
X2	39200	55.2	90.90	1.48	3.26
X3	29100	41.7	34.70	3.71	3.13
X4	40900	48.8	57.50	1.04	4.42
R1	28500	41.8	58.90	1.86	3.18
R2	50100	52.6	86.50	0.53	5.36
R3	56800	62.2	130.00	0.21	5.09
R4	24300	34.3	30.20	1.44	2.31
P1	106000	70.4	377.00	1.42	10.70
P2	160000	82.0	644.00	2.15	14.30
P3	17800	25.2	41.40	1.66	1.76
P4	32900	43.8	222.00	0.65	2.67
F1	557000	74.4	626.00	0.05	33.00
F2	514000	75.6	808.00	0.12	35.80
F3	112000	45.2	109.00	0.81	11.40
F4	407000	71.4	914.00	1.09	25.40
E1	41700	54.0	83.80	1.72	5.17
E2	33000	36.7	80.10	0.97	3.31
E3	47000	40.0	56.30	1.12	4.46
E4	34300	39.2	38.50	0.72	3.64
V1	109000	52.5	77.30	1.52	8.42
V2	61100	42.9	103.00	1.42	5.13
V3	43000	39.6	44.40	5.94	4.30
V4	64900	49.1	111.00	0.22	5.79
O1	20100	42.2	34.20	2.64	4.97
O2	57300	57.0	61.90	3.19	9.41
O3	7560	22.2	1.88	1.95	4.86
O4	794000	41.3	60.80	0.77	24.70
S1	83100	67.5	47.30	0.53	9.15
S2	88500	69.9	89.30	0.65	8.24
S3	128000	82.8	119.00	1.93	12.00
S4	98200	67.2	41.20	3.86	9.49
C1	20200	41.7	16.70	1.97	2.97

[1] - X = corn irrigated, R = Ephemeral row crop, P = Muncipal effluent, F = Cattle feedlot, EC = Pasture/Rangeland, V = Relatively undisturbed playa, S = Salt Playa, C = Rita Blanca National Grassland.

Appendix 8 (continued)

Nutrient concentrations (mg/kg dry weight), chemical oxygen deman, percent moisture, and percent organic matter in sediment.

Playa Site[1]	Organic Nitrogen	Total Phosphate Soluble	Total Kjeldahl Nitrogen	Total Phosphate
X1	1420	1.33	1500	623
X2	1280	2.61	1370	428
X3	975	3.99	1010	292
X4	1390	1.20	1450	481
R1	877	1.15	936	304
R2	1230	1.22	1320	686
R3	1460	1.31	1590	677
R4	744	1.04	774	273
P1	3220	11.50	3600	1310
P2	12000	18.40	12600	14400
P3	689	4.25	730	641
P4	1360	14.20	1580	634
F1	16700	314.00	17300	3320
F2	18400	359.00	19200	5910
F3	8010	62.30	8120	3010
F4	13800	306.00	14700	4390
E1	1020	1.70	1100	675
E2	980	11.40	1060	490
E3	1640	1.28	1700	660
E4	972	3.95	1010	481
V1	3410	3.51	3490	624
V2	1730	1.66	1830	676
V3	1290	1.45	1330	487
V4	2300	2.92	2410	490
O1	520	1.41	554	290
O2	2220	1.50	2280	375
O3	215	0.28	217	205
O4	837	4.07	898	1100
S1	2460	0.94	2510	459
S2	2710	1.90	2800	571
S3	1460	4.17	1580	595
S4	2800	1.97	2840	634
C1	658	0.82	675	692

[1] - X = corn irrigated, R = Ephemeral row crop, P = Muncipal effluent, F = Cattle feedlot, EC = Pasture/Rangeland, V = Relatively undisturbed playa, S = Salt Playa, C = Rita Blanca National Grassland.

Appendix 8 (continued)

Nutrient concentrations (mg/kg dry weight), chemical oxygen deman, percent moisture, and percent organic matter in sediment.

Playa Site[1]	Water Temperature °C	Dissolved Oxygen Mg/L	pH	Specific Conductivity μmhos	Secchi Depth cm
X1	26.0	5.0	8.5	440	16.0
X2	24.5	5.9	8.0	590	19.0
X3	23.5	6.9	8.0	500	57.0
X4	29.0	6.2	8.5	700	19.0
R1	29.5	10.0	9.0	400	19.0
R2	32.0	6.0	8.5	460	3.0
R3	20.0	6.6	8.0	360	11.0
R4	26.0	7.5	8.9	280	7.0
P1	30.0	15.8	9.0	1200	10.0
P2	29.0	20.0	9.0	1050	18.0
P3	25.5	1.9	9.0	780	11.0
P4	29.0	6.1	8.0	1800	13.0
F1	29.0	0.2	6.5	400	12.0
F2	29.5	0.5	*	21750	2.0
F3	25.5	1.2	8.0	750	70.0
F4	22.5	1.0	*	7600	3.0
E1	24.0	6.3	7.5	230	3.5
E2	25.0	5.1	8.0	100	5.0
E3	25.0	5.6	7.8	120	30.0
E4	28.4	5.4	7.5	175	3.4
V1	25.0	3.0	6.9	220	61.3
V2	25.0	7.2	7.8	140	42.0
V3	24.5	8.8	10.0	230	33.0
V4	29.0	8.0	8.5	380	47.5
O1	27.0	12.0	8.6	40000	26.0
O2	24.0	7.8	8.5	33000	*
O3	30.0	1.8	7.3	80000	*
O4	34.0	3.0	7.3	79000	*
S1	26.0	8.0	9.5	1700	88.0
S2	25.0	7.2	8.0	20400	37.0
S3	28.5	7.3	8.4	38000	37.0
S4	24.0	12.0	9.7	23000	300.0
C1	25.0	8.8	*	910	105.0

[1] - X = corn irrigated, R = Ephemeral row crop, P = Muncipal effluent, F = Cattle feedlot, EC = Pasture/Rangeland, V = Relatively undisturbed playa, S = Salt Playa, C = Rita Blanca National Grassland.

* = not measured.

Appendix 9

Bird species observed by season: Winter (January) 1990

Common name:	Scientific name:
red-winged blackbird	*Agelaius phoeniceus*
northern pintail	*Anas acuta*
American wigeon	*Anas americana*
northern shoveler	*Anas clypeata*
green-winged teal	*Anas crecca*
cinnamon teal	*Anas cyanoptera*
mallard	*Anas platyrhynchos*
gadwalls	*Anas strepera*
white-fronted goose	*Anser albifrons*
pipit	*Anthus spinoletta*
great blue heron	*Ardea herodias*
redhead	*Aythya americana*
ring-necked duck	*Aythya collaris*
canvasback	*Aythya valisineria*
Canada geese	*Branta canadensis parvipes*
bufflehead	*Bucephala albeola*
red-tailed hawk	*Buteo jamaicensis*
rough-legged hawk	*Buteo lagopus*
ferruginous hawk	*Buteo regalis*
chestnut-collared longspur	*Calcarius ornatus*
snow goose	*Chen caerulescens*
Ross' goose	*Chen rossii*
northern harrier	*Circus cyaneus*
killdeer	*Charadrius vociferus*
American crow	*Corvus brachyrhynchos*
horned larke	*Eremophila alpestris*
prairie falcon	*Falco mexicanus*
American coot	*Fulica americana*
sandhill crane	*Grus canadensis canadensi*
herring gull	*Larus argentatus*
ringed-billed gull	*Larus delawarensis*
Harris' hawk	*Parabuteo unicinctus*
eared grebe	*Poiceps nigricollis*
ruddy duck	*Oxyura jamaicensis*
white-crowned sparrow	*Zonotrichia leucophrys*

Appendix 9 (continued)

Bird species observed by season: Spring 1990

Common name:	Scientific name:
red-winged blackbird	*Agelaius phoeniceus*
northern pinail	*Anas acuta*
wiegon	*Anas americana*
northern shoveler	*Anas clyeata*
green-winged teal	*Anas crecca*
cinnamon teal	*Anas cyanoptera*
blue-winged teal	*Anas discors*
gadwalls	*Anas strepera*
mallard	*Anas platyrhynchos*
water pipit	*Anthus spinoletta*
great blue heron	*Ardea herodias*
lesser scaup	*Aythya affinis*
redhead	*Aythya americana*
lesser Canada goose	*Branta canadensis parvipes*
buffle head	*Bucephala albeola*
red-tailed hawk	*Buteo jamaicensis*
Swainson's hawk	*Buteo swainsoni*
chestnut-collared longspur	*Calcarius orantus*
least sandpiper	*Calidris minutilla*
killdeer	*Charadrius vociferus*
snow goose	*Chen caerulescene*
Ross' goose	*Chen rossii*
northern harrier	*Circus cyaneus*
American crow	*Corvus brachyrhynchos*
American coot	*Fulica americana*
barn swallow	*Hirundo rustica*
black-necked stilt	*Himantopus mexicanus*
ring-billed gull	*Larus delawarensis*
long-billed dowitcher	*Limnodromus scolopaceus*
long-billed curlew	*Numenius americanus*
rubby duck	*Oxyura jamaicensis*
double-crested cormorant	*Phalacrocorax auritus*
red-necked phalarope	*Phalaropus lobatus*
Wilson's phalarope	*Phalaropus tricolor*
eared grebe	*Podiceps nigricollis*
pied-billed grebe	*Podilymbus podiceps*
greater-tailed grackle	*Quiscalus mexicanus*
American avocet	*Recurvirostra americana*
bank swallow	*Riparia riparia*
Say's phoebe	*Sayornis sata*
chipping sparrow	*Spizella passerina*
tree swallow	*Tachycineta bicolor*
lesser yellowleg	*Tringa flavipes*
greater yellowleg	*Tringa melanoleuca*
scissor-tailed flycatcher	*Tyrannus forficatus*
yellow-headed blackbird	*Xanthocephalus xanthocephalus*
mourning dove	*Zenaida macroura*
white-crowned sparrow	*Zonotrichia leucophrys*

Appendix 9 (continued)

Bird species observed by season: Summer 1990

Common name:	Scientific name:
spotted sandpiper	*Actitis macularia*
northern pintail	*Anas acuta*
red-winged blackbird	*Agelaius phoeniceus*
American wigeon	*Anas americana*
northern shoveler	*Anas clypeata*
green-winged teal	*Anas crecca*
cinnamon teal	*Anas cyanoptera*
mallard	*Anas platyrhynchos*
gadwell	*Anas strepera*
great blue heron	*Ardea herodias*
lesser scaup	*Aythya affinis*
redhead	*Aythya americana*
lesser Canada goose	*Branta candensis parvipes*
western sandpiper	*Calidris mauri*
least sandpiper	*Calidris minutilla*
snowey plover	*Charadrius alexandrinus*
killdeer	*Charadrius vociferus*
snow goose	*Chen caerulescens*
black tern	*Chidonias niger*
snowy egret	*Egretta thula*
American coot	*Fulica americana*
black-necked stilt	*Himantopus mexicanus*
cliff swallows	*Hirundo pyrrhonota*
Mississippi kite	*Ictinia mississippiensis*
scissor-tailed flycatcher	*Muscivora forficat*
long-billed curlew	*Numenius amer*
black-crowned night-heron	*Nycticorax nycticorax*
rubby duck	*Oxyura jamaicensis*
double-crested cormerant	*Phalacrocorax auritus*
Wilson's phalarope	*Phalaropus tricolor*
white-faced ibis	*Plegadis chihi*
eared grebe	*Podiceps nigricollis*
pied-billed grebe	Podilymbus podiceps
greater-tailed grackle	*Quiscalus mexicalus*
American avocet	*Recurvirostra americana*
greater yellowleg	*Tringa melanoleuca*
solitary sandpiper	*Tringa solitaria*
lesser yellowleg	*Trinoa flavipes*
Western kingbird	*Tyrannus vertical*
yellow-headed blackbird	*Xanthocephalus xanthocephalus*
Mourning dove	*Zenaida macroura*

Appendix 9 (continued)

Bird species observed by season: Autumn 1990

Common name:	Scientific name:
Cooper's hawk	*Accipter cooperi*
red-winged blackbird	*Agelaius phoeniceus*
northern pintail	*Anas acuta*
American wigeon	*Anas americana*
norther shoveler	*Anas clypeata*
Green-winged teal	*Anas crecca*
blue-winged teal	*Anas discors*
mallard	*Anas platyrhychos*
wood duck	*Anas sponsa*
gadwall	*Anas stepera*
water pipit	*Anthus spinoletta*
great blue heron	*Ardea herodias*
lesser scaup	*Aythya affins*
redhead	*Aythya americana*
ring-necked duck	*Aythya collaris*
canvasback	*Aythya valisineria*
upland sandpiper	*Bartramia longicauda*
lesser Canada geese	*Branta canadensis parvipes*
buffleheads	*Bucephala albedola*
red-tailed hawk	*Buteo jamaicensis*
ferruginous hawk	*Buteo regalis*
Baird's sandpiper	*Calidris bairdii*
stilt sandpiper	*Calidris himantopus*
western sandpiper	*Calidris mauri*
least sandpiper	*Calidris minutilla*
killdeer	*Charadrius vociferus*
snow goose	*Chen caerulescens*
northern harrier	*Circus cyaneus*
marsh wren	*Cistothorus palustris*
American crow	*Corvos brachyrhynchos*
snowy egret	*Egretta thula*
American coot	*Fulica americana*
common snipe	*Gallinago gallinago*
ring-billed gull	*Larus delawarensis*
long-billed dowitcher	*Limnodromus scolopaceus*
long-billed curlew	*Numenius amaericanus*
rubby duck	*Oxyura jamaicensis*
Harriss hawk	*Parabuteo unicinctus*
double-crested cormorant	*Phalacrocorax auritus*
white-faced ibis	*Plegadis chihi*
single black-bellied plover	*Pluvialis squatarola*
eared grebe	*Podiceps nigricollis*
pied-billed grebe	*Podilymbus podiceps*
great-tailed grackle	*Quiscalus mexicanus*
American avocet	*Recurvirostra americana*
lesser yellowleg	*Tringa flavipes*
greater yellowleg	*Tringa melanoleuca*
yellow-headed blackbird	*Xanthocephalus xanthocephalus*
white-crowned sparrow	*Zonotrichia leucophrys*

Appendix 10

Field data pertinent to study playas

Playa Site[1]	Water Regime *	Return Flow ◆	Playa Size acres	Max Playa Depth cm	Bottom Hardness ~	Percent Watershed Cropland	Percent Watershed Cornfield
X1	4	2	40	45.7	3.0	100	55
X2	4	2	32	81.0	2.5	99	98
X3	3	2	4	72.0	3.0	80	40
X4	4	2	5	120.0	1.0	100	40
R1	2	2	8	5.0	2.5	90	5
R2	1	2	3	7.0	3.0	100	60
R3	3	2	8	31.0	2.0	100	80
R4	2	2	10	70.0	3.0	100	20
P1	4	1	15	9.0	3.0	60	10
P2	4	1	5	50.0	3.0	60	0
P3	4	1	30	90.0	2.0	0	0
P4	4	1	55	100.0	3.0	50	0
F1	4	2	15	30.0	3.0	0	0
F2	4	2	15	18.0	3.0	50	0
F3	4	1	10	100.0	2.0	15	15
F4	4	2	12	9.0	3.0	25	25
E1	2	1	5	45.0	2.0	0	0
E2	2	1	3	48.0	2.5	0	0
E3	2	1	69	45.0	1.0	0	0
E4	3	1	68	2.5	1.0	0	0
V1	2	1	10	50.0	1.0	100	0
V2	2	1	15	90.0	1.0	0	0
V3	2	1	2	150.0	1.0	0	0
V4	1	1	15	67.0	2.5	80	0
O1	4	1	73	100.0	3.0	0	0
O2	3	1	5	2.0	2.0	5	0
O3	3	1	40	2.0	1.0	0	0
O4	3	1	15	2.0	3.0	0	0
S1	4	1	150	100.0	3.0	50	0
S2	4	2	40	75.0	2.0	80	0
S3	4	1	140	200.0	3.0	10	0
S4	4	1	35	160.0	2.0	30	0
C1	4	2	11	95.0	1.0	10	0

[1] - X = corn irrigated, R = Ephemeral row crop, P = Muncipal effluent, F = Cattle feedlot, EC = Pasture/Rangeland, V = Relatively undisturbed playa, S = Salt Playa, C = Rita Blanca National Grassland.

* - 1 = intermittent = wet < 4 months; 2 = ephemeral = wet 4-9 months;
3 = perennial = wet 9-12 months; 4 = permanent = wet year round;

◆ = 1 - no irrigation return flow to playa, 2 - yes irrigation return flow to playa

~ = 1 - hard, 2 - moderate, 3 - soft

Appendix 10 (continued)

Playa Site[1]	Percent Watershed Cotton	Percent Watershed Plowed	Percent Watershed CRP-like	Percent Watershed Pasture	Rangeland Vegetation ♦	Playa w/manure *
X1	10	30	0	5	1	1
X2	0	0	1	1	1	1
X3	0	0	20	0	1	1
X4	40	20	0	0	1	1
R1	0	80	0	10	1	1
R2	10	30	0	0	1	1
R3	10	10	0	0	1	1
R4	0	80	0	0	1	1
P1	0	50	0	0	1	1
P2	0	0	0	0	1	1
P3	0	0	0	10	2	1
P4	0	50	0	45	1	1
F1	0	0	0	0	1	2
F2	10	40	0	0	1	2
F3	0	0	0	25	1	1
F4	0	0	0	25	1	1
E1	0	0	0	100	2	2
E2	0	0	100	100	2	2
E3	0	0	0	100	2	2
E4	0	0	0	100	2	2
V1	80	0	0	0	1	1
V2	0	0	0	100	2	1
V3	0	0	0	100	2	1
V4	80	0	20	0	1	1
O1	0	0	0	100	2	1
O2	5	0	0	95	2	1
O3	0	0	0	100	2	1
O4	0	0	0	100	2	1
S1	50	0	0	50	2	1
S2	80	0	0	20	1	1
S3	0	0	90	0	2	1
S4	30	0	70	0	2	1
C1	0	10	0	90	2	1

[1] - X = corn irrigated, R = Ephemeral row crop, P = Muncipal effluent, F = Cattle feedlot, EC = Pasture/Rangeland, V = Relatively undisturbed playa, S = Salt Playa, C = Rita Blanca National Grassland.

♦ = Dominance of rangeland vegetation, 1-no, 2-yes

* = Playa ringed by manure, 1-no, 2-yes

Appendix 10 (continued)

Playa Site[1]	Concentration of Cattle ♦	Number Chara Species	Percent Coverage Cat-tails	Percent Coverage Bulrush	Percent Coverage Spikerush	Percent Coverage Sedges
X1	1.5	0	0	0	0	0
X2	1.0	0	0	0	0	0
X3	1.0	0	20	0	0	0
X4	1.0	0	60	2	3	3
R1	1.0	0	0	2	0	0
R2	1.0	0	0	0	0	0
R3	1.0	0	0	5	0	0
R4	1.0	0	0	0	0	0
P1	1.0	0	30	10	0	0
P2	1.0	0	45	0	0	0
P3	2.0	0	0	0	0	0
P4	1.0	0	0	0	0	0
F1	3.0	0	0	0	0	0
F2	3.0	0	0	0	0	0
F3	3.0	0	0	0	0	0
F4	3.0	0	0	0	0	0
E1	2.0	0	0	0	1	0
E2	2.5	1	0	0	14	0
E3	2.0	0	0	0	18	0
E4	2.0	0	0	0	0	0
V1	1.0	1	0	0	32	0
V2	1.0	2	0	0	10	0
V3	1.5	2	0	0	2	0
V4	1.0	1	0	0	2	0
O1	1.0	0	0	0	0	0
O2	1.0	0	0	48	0	0
O3	1.0	0	0	0	0	0
O4	1.0	0	0	0	0	0
S1	1.5	0	20	0	0	0
S2	1.0	0	2	1	0	0
S3	1.0	0	5	0	0	0
S4	1.0	1	0	0	0	0
C1	1.0	1	6	6	12	10

[1] - X = corn irrigated, R = Ephemeral row crop, P = Muncipal effluent, F = Cattle feedlot, EC = Pasture/Rangeland, V = Relatively undisturbed playa, S = Salt Playa, C = Rita Blanca National Grassland.

♦ = Concentration of cattle, 1-low, 2-medium, 3-high

Appendix 10 (continued)

Playa Site[1]	Percent Coverage Smartweed	Percent Coverage Arrowhead	Percent Coverage Barnyard Grass	Percent Coverage Pondweed	Percent Coverage Burweed	Percent Coverage Marsilea
X1	40	0	0	0	0	0
X2	1	0	4	0	0	0
X3	1	0	10	10	0	0
X4	10	0	3	0	0	0
R1	10	20	10	75	0	0
R2	0	0	0	0	0	0
R3	1	1	0	5	0	0
R4	2	0	0	0	0	0
P1	0	0	0	0	0	0
P2	4	0	0	0	0	0
P3	0	0	1	0	0	0
P4	0	0	0	0	0	0
F1	0	0	0	0	0	0
F2	0	0	0	0	0	0
F3	1	0	0	0	0	0
F4	0	0	0	0	0	0
E1	0	8	0	0	0	1
E2	0	26	0	0	0	8
E3	2	18	0	0	0	6
E4	0	0	0	0	0	1
V1	16	32	0	0	15	20
V2	0	10	0	0	15	15
V3	1	1	2	12	2	0
V4	0	2	0	0	0	0
O1	0	0	0	2	0	0
O2	0	0	0	0	0	0
O3	0	0	0	0	0	0
O4	0	0	0	0	0	0
S1	0	8	0	70	2	0
S2	0	0	0	1	0	0
S3	0	0	0	1	0	0
S4	0	0	0	2	0	0
C1	0	0	0	45	0	0

[1] - X = corn irrigated, R = Ephemeral row crop, P = Muncipal effluent, F = Cattle feedlot, EC = Pasture/Rangeland, V = Relatively undisturbed playa, S = Salt Playa, C = Rita Blanca National Grassland.

Appendix 10 (continued)

Playa Site[1]	Total Plant Taxa ♦	Percent Coverage Emergent Vegetation	Height Emergent Vegetation (meters)	Emergent Vegetation *	Presence Absence Cocklebur ~
X1	1	40	1.80	2	2
X2	2	5	1.00	2	2
X3	4	31	2.50	1	2
X4	6	81	2.50	1	2
R1	5	42	0.50	2	1
R2	0	0	0.00	2	2
R3	4	7	1.00	2	2
R4	1	2	0.20	2	2
P1	2	40	2.10	1	1
P2	2	49	2.10	1	1
P3	1	1	0.20	2	2
P4	0	0	0.00	2	1
F1	0	0	0.00	2	2
F2	0	0	0.00	2	1
F3	1	1	0.35	2	1
F4	0	0	0.00	2	1
E1	3	9	0.40	2	1
E2	4	40	0.60	2	1
E3	4	38	0.60	2	1
E4	1	0	0.40	2	1
V1	6	80	0.70	2	1
V2	6	20	0.30	2	1
V3	8	6	0.40	2	1
V4	3	4	0.30	2	1
O1	1	0	0.00	2	1
O2	1	95	1.00	2	1
O3	0	0	0.00	2	1
O4	0	0	0.00	2	1
S1	3	30	2.00	1	1
S2	3	3	2.00	1	1
S3	2	5	3.00	1	1
S4	2	0	0.00	2	1
C1	6	34	1.00	1	2

[1] - X = corn irrigated, R = Ephemeral row crop, P = Muncipal effluent, F = Cattle feedlot, EC = Pasture/Rangeland, V = Relatively undisturbed playa, S = Salt Playa, C = Rita Blanca National Grassland.

♦ = Number of plant taxa observed

* = Emergent vegetation, 1-tall, 2-short

~ = Presence/absence of cocklebur, 1-no, 2-yes

Appendix 10 (continued)

Playa Site[1]	Presence Absence Wooly Bursedge *	Abundance Leeches ♦	Abundance Physid Snails ♦	Abundance Planorbid Snails ♦	Abundance Cyclopoid Copepods ♦
X1	2	2.0	1.0	2.0	1.0
X2	2	1.0	3.0	1.0	1.0
X3	1	1.1	1.0	1.0	1.0
X4	1	1.0	1.0	1.0	1.0
R1	1	3.0	2.0	2.0	3.0
R2	2	2.0	1.0	1.0	1.0
R3	2	1.0	1.0	1.0	1.0
R4	2	1.0	1.0	1.0	1.0
P1	1	1.0	1.0	1.0	1.0
P2	1	1.0	1.0	1.0	1.0
P3	1	1.0	1.0	1.0	1.1
P4	1	1.0	1.0	1.0	1.0
F1	2	1.0	1.0	1.0	1.0
F2	1	1.0	1.0	1.0	1.0
F3	1	1.0	1.0	1.0	3.0
F4	1	1.0	1.0	1.0	1.0
E1	1	2.5	1.1	3.0	1.0
E2	1	1.1	1.0	3.0	1.0
E3	1	1.0	1.0	3.0	3.0
E4	1	1.0	1.5	2.0	2.0
V1	1	1.1	2.0	2.0	2.0
V2	1	1.1	1.0	3.0	3.0
V3	1	1.0	1.0	2.0	2.0
V4	1	2.0	1.0	1.5	1.0
O1	1	1.0	1.0	1.0	1.0
O2	1	1.0	1.0	1.0	1.0
O3	1	1.0	1.0	1.0	1.0
O4	1	1.0	1.0	1.0	1.0
S1	1	1.0	3.0	3.0	3.0
S2	1	1.0	1.0	1.0	1.0
S3	1	1.0	1.0	1.0	1.0
S4	1	1.0	1.0	1.0	2.0
C1	1	2.0	3.0	1.0	1.0

[1] - X = corn irrigated, R = Ephemeral row crop, P = Muncipal effluent, F = Cattle feedlot, EC = Pasture/Rangeland, V = Relatively undisturbed playa, S = Salt Playa, C = Rita Blanca National Grassland.

* = Presence/absence of wooly leaf bursedge, 1-no, 2-yes

♦ = Abundance = 1-absent, 1.1-rare, 2-uncommon to medium, 3-abundant

Appendix 10 (continued)

Playa Site[1]	Abundance Calenoid Copepods ◆	Abundance Clam Shrimp ◆	Abundance Seed Shrimp ◆	Abundance Fairy Shrimp ◆	Abundance Cladocerans ◆
X1	2.0	2.0	1.0	2.0	1.0
X2	3.0	2.0	1.0	1.0	1.0
X3	1.0	1.0	1.0	1.0	1.0
X4	3.0	2.0	1.1	1.0	1.1
R1	1.0	1.0	1.0	1.0	1.0
R2	3.0	1.0	1.0	1.0	1.0
R3	3.0	2.0	1.0	1.0	1.0
R4	3.0	2.0	1.0	2.0	1.0
P1	1.0	3.0	1.0	1.0	1.0
P2	1.0	2.0	1.0	1.0	1.0
P3	1.0	2.0	1.0	1.0	1.0
P4	1.0	3.0	1.0	1.0	3.0
F1	1.0	1.1	1.0	1.0	1.0
F2	1.0	1.0	1.0	1.0	1.0
F3	1.0	1.0	1.0	1.0	3.0
F4	1.0	1.1	1.0	1.0	1.0
E1	1.0	2.5	3.0	1.1	1.1
E2	1.0	3.0	2.0	3.0	1.1
E3	1.5	3.0	1.0	3.0	2.0
E4	1.0	3.0	1.0	3.0	2.0
V1	2.0	1.0	1.0	1.0	1.0
V2	2.0	2.0	2.0	2.0	2.0
V3	1.0	3.0	1.0	1.0	1.1
V4	1.0	2.0	1.1	2.0	1.0
O1	1.0	1.0	1.0	2.0	1.0
O2	1.0	2.0	1.0	1.0	1.0
O3	1.0	1.0	1.0	1.0	1.0
O4	1.0	1.0	1.0	1.0	1.0
S1	1.0	2.0	1.0	1.0	1.1
S2	1.0	1.0	1.0	1.0	1.0
S3	2.0	1.0	1.0	1.0	1.0
S4	3.0	3.0	1.0	1.0	1.0
C1	1.0	1.0	1.0	1.0	3.0

[1] - X = corn irrigated, R = Ephemeral row crop, P = Muncipal effluent, F = Cattle feedlot, EC = Pasture/Rangeland, V = Relatively undisturbed playa, S = Salt Playa, C = Rita Blanca National Grassland.

◆ = Abundance 1-absent, 1.1-rare, 2-uncommon to medium, 3-abundant

Appendix 10 (continued)

Playa Site[1]	Abundance Mayfly Nymphs ◆	Abundance Damselfly Nymphs ◆	Abundance Dragonfly Nymphs ◆	Abundance Water Boatmen ◆	Abundance Backswimmers ◆
X1	2.0	2.5	1.1	3.0	3.0
X2	3.0	3.0	2.0	2.0	3.0
X3	3.0	3.0	2.0	3.0	3.0
X4	3.0	2.0	3.0	3.0	3.0
R1	1.0	3.0	1.0	3.0	1.0
R2	1.0	1.0	1.0	3.0	3.0
R3	2.0	3.0	1.0	1.0	3.0
R4	1.0	2.0	1.0	2.0	2.0
P1	1.0	1.0	1.1	3.0	3.0
P2	1.0	1.1	1.0	3.0	3.0
P3	1.1	1.0	1.0	3.0	3.0
P4	1.1	1.0	1.0	2.0	3.0
F1	1.0	1.0	1.0	1.0	1.1
F2	1.0	1.0	1.0	1.1	1.0
F3	1.0	1.0	1.0	3.0	3.0
F4	1.0	1.0	1.0	1.0	1.1
E1	1.0	1.5	1.0	1.0	3.0
E2	1.1	2.0	2.0	2.0	3.0
E3	1.0	2.0	1.0	1.0	3.0
E4	1.0	1.0	1.0	2.0	3.0
V1	3.0	1.0	1.0	3.0	3.0
V2	3.0	3.0	2.0	1.0	3.0
V3	3.0	3.0	1.1	1.0	3.0
V4	1.5	2.0	1.0	3.0	3.0
O1	1.0	1.0	1.0	3.0	1.0
O2	1.0	3.0	1.0	2.0	1.0
O3	1.0	1.0	1.0	1.0	1.0
O4	1.0	1.0	1.0	1.0	1.0
S1	2.0	2.0	2.0	3.0	1.1
S2	1.0	3.0	1.0	3.0	1.0
S3	1.0	3.0	1.0	3.0	2.0
S4	1.0	3.0	1.0	2.0	1.0
C1	3.0	3.0	2.0	3.0	3.0

[1] - X = corn irrigated, R = Ephemeral row crop, P = Muncipal effluent, F = Cattle feedlot, EC = Pasture/Rangeland, V = Relatively undisturbed playa, S = Salt Playa, C = Rita Blanca National Grassland.

◆ = Abundance 1-absent, 1.1-rare, 2-uncommon to medium, 3-abundant

Appendix 10 (continued)

Playa Site[1]	Abundance Water Striders ◆	Abundance Water Scavengers ◆	Abundance Dytiscid Larvae ◆	Abundance Dytiscid Adults ◆	Abundance Dipteran Larvae ◆
X1	2.0	2.0	1.0	1.1	1.0
X2	1.0	1.0	3.0	1.1	1.5
X3	1.0	1.0	1.1	1.0	1.0
X4	1.1	1.0	1.1	1.1	1.0
R1	1.1	1.0	3.0	2.0	1.0
R2	1.0	1.0	1.0	1.0	1.0
R3	1.0	2.0	2.0	2.0	1.0
R4	1.0	1.0	1.1	2.0	1.0
P1	1.0	1.0	2.0	2.0	1.0
P2	1.0	1.0	3.0	1.0	1.0
P3	1.0	1.0	2.0	1.0	1.0
P4	1.1	1.0	2.0	2.0	1.0
F1	1.0	1.0	1.0	1.0	2.0
F2	1.0	1.0	1.0	1.0	1.0
F3	1.0	1.0	1.5	1.0	1.0
F4	1.0	1.0	1.0	1.0	1.0
E1	1.1	1.5	1.1	1.1	1.5
E2	2.0	1.0	1.0	1.0	1.1
E3	1.0	2.0	2.0	1.1	1.0
E4	1.0	1.1	3.0	2.0	1.0
V1	2.0	3.0	2.0	2.0	1.1
V2	2.0	1.0	1.0	1.0	1.0
V3	1.0	1.1	1.1	2.5	1.0
V4	1.0	1.0	2.0	1.0	1.0
O1	1.0	1.0	1.0	1.1	2.0
O2	2.0	1.0	1.0	3.0	3.0
O3	1.0	1.0	1.0	1.0	1.0
O4	1.0	1.0	1.0	1.0	1.0
S1	1.0	1.1	1.0	2.0	1.1
S2	1.0	1.0	1.0	1.0	1.0
S3	1.0	1.0	1.0	1.0	2.0
S4	1.0	1.0	1.0	2.0	1.0
C1	2.0	1.0	1.1	1.1	2.0

[1] - X = corn irrigated, R = Ephemeral row crop, P = Muncipal effluent, F = Cattle feedlot, EC = Pasture/Rangeland, V = Relatively undisturbed playa, S = Salt Playa, C = Rita Blanca National Grassland.

◆ = Abundance 1-absent, 1.1-rare, 2-uncommon to medium, 3-abundant

Appendix 10 (continued)

Playa Site[1]	Abundance Chironomids [reddish] ◆	Abundance Chironomids [not-red] ◆	Presence Absence Salamanders ◆	Presence Absence Fish ◆	Total Animal Taxa
X1	1.0	1.0	1	1	13
X2	1.5	1.0	1	2	12
X3	1.0	1.0	1	1	7
X4	1.0	1.0	2	1	12
R1	1.1	1.0	1	1	9
R2	1.1	1.0	1	1	5
R3	1.0	1.0	2	1	8
R4	1.0	1.0	1	1	7
P1	1.1	1.0	1	1	6
P2	3.0	1.0	1	1	6
P3	1.0	1.0	2	1	7
P4	1.0	1.0	1	1	7
F1	3.0	3.0	1	1	5
F2	1.0	1.0	1	1	1
F3	1.0	1.0	1	1	5
F4	1.0	1.0	1	1	2
E1	1.5	1.5	2	2	17
E2	1.0	1.1	2	2	16
E3	1.0	1.0	2	1	11
E4	1.0	1.0	2	1	11
V1	2.0	1.0	1	1	13
V2	1.0	1.1	2	1	15
V3	1.5	1.1	1	2	13
V4	1.0	1.0	1	1	10
O1	1.0	1.0	1	1	4
O2	1.1	1.0	1	1	7
O3	1.0	1.0	1	1	0
O4	1.0	1.0	1	1	0
S1	1.0	1.0	1	2	14
S2	2.0	1.0	1	1	3
S3	2.0	1.0	1	2	7
S4	1.0	1.0	1	2	7
C1	1.0	1.0	1	1	11

[1] - X = corn irrigated, R = Ephemeral row crop, P = Muncipal effluent, F = Cattle feedlot, EC = Pasture/Rangeland, V = Relatively undisturbed playa, S = Salt Playa, C = Rita Blanca National Grassland.

◆ = Abundance 1-absent, 1.1-rare, 2-uncommon to medium, 3-abundant