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MAXWELL NATIONAL WILDLIFE REFUGE
COLFAX COUNTY, NEW MEXICO

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CONTAMINANTS INVESTIGATION OF THE MAXWELL NATIONAL WILDLIFE REFUGE, NEW MEXICO, 1989

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Executive Summary

This investigation was conducted to determine the nature and extent of contaminants at Maxwell National Wildlife Refuge (Refuge) and how they may affect fish and wildlife resources, especially migratory birds. The 3,699-acre Refuge, located in northeastern New Mexico, includes several playas used for storing pre-use irrigation water.

Ten sediment and 42 biota samples collected from the Refuge were analyzed for 23 inorganic constituents, 6 chlorophenoxy acid herbicides, and 22 organchlorine compounds. In addition, mallard (Anas platyrhynchos) brains were collected and analyzed for cholinesterase activity.

Organochlorine compounds and chlorophenoxy acid herbicides were below detection or were below 1 ug/g (ppm) wet weight (WW) in sediment. At these levels, these compounds were considered to present little or no biological risk to biota on the Refuge. Diagnosis of brain tissue showed levels of cholinesterase activity inhibition that correlate to exposure of organophosphate or carbamate pesticides. Three out of five adult mallard brains had 28 to 52 percent inhibition. However, controls were unavailable to conclusively determine if exposure occurred within the study area.

Of the 23 elements analyzed in sediment, the mean concentrations of nine exceeded geochemical baseline values for soils in the western United States These elements were beryllium, boron, chromium, iron, lead, nickel, selenium, vanadium, and zinc. Of these, selenium was also elevated in biological samples. The highest selenium concentrations in migratory birds were in killdeer (Charadrius vociferus) liver and kidney samples (21.6 ug/g dry weight). This concentration may present biological risk (teratogenesis) to migratory birds that breed at the Refuge. The highest mercury concentration detected in fish from the Refuge was 0.21 ug/g WW in a rainbow trout

(Oncorhynchus mykiss) sample. This concentration is above the National

Contaminant Biomonitoring Program (NCBP) 85th percentile mercury concentration for fish nationwide.

Arsenic, beryllium, molybdenum, nickel, silver, and vanadium were detected in biological samples at such low levels, or in such a limited number of specimens, that concentrations of these elements were considered to present little or no risk to biota that inhabit the refuge. No determinations of biological risk to biota inhabiting the Refuge could be determined for lead because the detection limits were too insensitive. Any future studies should incorporate lead analysis in tissues; however, the detection limits must be considerably lower.

Introduction

The U.S. Fish and Wildlife Service (Service) is concerned with inorganic and organic contaminants present in national wildlife refuge ecosystems because of documented harmful effects to migratory birds and other biota (USFWS 1986). Conclusive evidence of mortality and birth defects in birds caused by contaminants introduced through irrigation drain water was demonstrated by the Service in 1983 at the Kesterson National Wildlife Refuge in the western San Joaquin Valley (Ohlendorf et al. 1986, 1987; Saiki and Lowe 1987; and Schuler 1987). Since that time, studies have been initiated in the western United States to identify the nature and extent of contamination from irrigation or drainage facilities on national wildlife refuges and other migratory bird or endangered species management areas (Knapton et al. 1988, Lambing et al. 1988, Peterson et al. 1988). This preliminary contaminants investigation was designed to determine the extent of organic and inorganic contaminants in sediment and biota at Maxwell National Wildlife Refuge (Refuge) in Colfax County, New Mexico.

Based on geology and land use in the study area, the potential exists for contaminant accumulation in water, sediment, and biota found on the Refuge.

Contaminants could originate from a variety of non-point sources within the watershed. These sources include agricultural practices, soil and riverbank erosion exacerbated by overgrazing, coal and other mining activities, and atmospheric deposition.

Refuge and Study Area

The Refuge, which includes 3,699 acres, was established by the Migratory Bird Conservation Commission on August 24, 1965. The Service owns 2,792 acres and the balance of 907 acres is owned by the Bureau of Reclamation and the Vermejo Conservancy District. The primary objective of the Refuge is to provide feeding and resting areas for a variety of wintering migratory birds.

The Refuge is located in Colfax County, in northeastern New Mexico, approximately 40 miles south of the New Mexico-Colorado border and 2.5 miles northwest of the Canadian River and the Village of Maxwell (Sections 9-11, 14-16, and 21-23, T27N, R22E). The Refuge is within the Canadian River Basin, bordered by the Sangre de Cristo Mountains to the west, the Raton Coal Field to the north, and a series of hills, plugs, and mesas of the Eagle Tail and Capulin volcanic mountain ranges to the east (Figure 1). The Canadian River and its tributaries, the Vermejo, Cimarron, and Mora rivers, originate in the Sangre de Cristo Mountains and flow easterly across open grasslands and irrigated farms. The 10-year average (1979-1989) of annual precipitation at the Refuge is 15.07 inches, whereas the evaporation rate is high, about 52 inches per year (French 1989, 1990).

The majority of soils in the study area are formed from shales reported to have pockets of high selenium content ranging from 200 to 160,000 ug/kg (Anderson et al. 1982). The soil pH is neutral to strongly alkaline and slope is 0 to 7 percent. The elevation is 5,900 to 7,500 feet. Northwest of the Refuge in York Canyon and West York Canyon, an average of 600,000 tons of coal per year is mined from the Raton Coal Field. The coal is washed on site and the water is discharged, in accordance with U.S. Environmental Protection Agency (EPA) regulations, into the Vermejo River which provides water to the Refuge. North of the Refuge, the Town of Raton operates a small coal-fired power plant. These activities, as well as soil and riverbank erosion, may have an impact on water quality.

Water diverted by the Vermejo Conservancy District is stored in shallow lakes and conveyed through unlined canals to 7,379 acres of irrigable land. The majority of the irrigation water comes from the Vermejo River. The Vermejo Canal is provided with a maximum flow of 600 cubic feet per second and drains first through Stubblefield Lake, Laguna Madre, Lakes 12, 13, 14 on the Refuge, and finally to Lakes 11 and 20. Water available for irrigation of Refuge crops can only be delivered from Stubblefield and Laguna Madre Reservoirs.

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Figure 1 Location of Maxwell Wildlife Refuge

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These waters are delivered via Eagle Tail Canal. In 1988, the Refuge irrigated 440 acres of cropland with 950 shares of water leased from the Vermejo Conservancy District.

Lakes 12, 13, and 14, formerly natural playas, total 907 surface acres and comprise the majority of the wetlands on the Refuge (Figure 2). These lakes were originally modified in the early 1900's. The Vermejo Conservancy District now controls the water level of the lakes. Water levels fluctuate widely, preventing shoreline stabilization and Lakes 12 and 14 are often completely dry in the summer. In 1955 Lake 13's storage capacity was increased by raising and lengthening the existing dam. The dams of Lakes 12 and 14 were not changed at this time. Seepage below the dams creates small marshes. In the southwest corner of the Refuge, there is a natural playa that dries out in late summer but receives incidental irrigation runoff from a neighbor's field (French 1989). Some of the dissolved mineral levels in the lakes were higher than those of the Vermejo River (Table 1). Water quality data on Lakes 12, 13 and 14 were provided by the New Mexico Environment Department (Davis 1991).

In years past, Malathion was applied to Refuge croplands to control grasshopper infestations. Surrounding farm areas have a history of using aerially applied Malathion and Parathion to control insect pests. There were no malathion treatments from 1983 to 1986, however, 2-4-D may have been used. In October 1987, the Refuge applied Nolo bait, (Nosema locustae), a bacteriological treatment to the fields and Malathion to the ditch banks (French 1987). In 1988, there was a heavy infestation of grasshoppers and malathion was used on the Refuge on several occasions. Parathion was aerially applied to much of the private land adjacent to the Refuge.

See Table/Figure

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Figure 2 Maxwell National Wildlife Refuge Sample Site Locations

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TABLE 1. FIELD DETERMINATIONS OF WATER QUALITY FROM THE STUDY AREA INCLUDING THE VERMEJO RIVER, LAKE 12, 13, AND 14 ON MAXWELL NWR, AND THE CANADIAN RIVER. ALL values are averages where; cfs, is cubic feet per second instanteous discharge; pH is in standard units; ýý, indicate no available data; <, is less than. 1/2/ detection limit was used to calculate 3 and 5 year averages.

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SAMPLE COLLECTION AND ANALYTICAL METHODS

Sediment and biota samples were collected during June and July of 1989. Analytes, detection limits, and abbreviations used in this report are listed in Table 2. The species of biota collected depended upon their availability and their ability to bioconcentrate elements or compounds. The objective was to collect organisms that represent the various trophic levels; however, in some cases sample size and type were limited. Bird samples consisted of composite liver and kidney tissues and carcasses from blue-winged teal (Anas discors), cinnamon teal (A. cyanoptera), gadwall (A. strepera), coot (Fulica americana), and killdeer. Embryo samples were collected from cinnamon teal, gadwall, and killdeer. Brain samples were collected from adult mallards. Fish samples consisted of whole-body bullhead (Ameiurus spp.), channel catfish (Ictalurus punctatus), minnow species (Cyprinidae), rainbow trout, and white sucker (Catostomus commersoni). Plant samples consisted of composite seed and whole-plant tissue from bulrush (Scirpus subterminalis), spike rush (Eleocharis spp.), and pondweed (Potamogeton spp.). Different genera and species of macroinvertebrates were composited to make up adequate samples weights for analysis. Sample site locations are shown in Figure 2 and listed in Table 3.

Sediment samples were collected from all lakes on the Refuge and from one irrigation canal using a Wildco stainless steel hand corer. Each sediment sample was filtered through a 62 micron (0.062 mm) stainless steel mesh sieve and were composited for each site for a total of 10 samples. Four of these samples were analyzed for organochlorine compounds and one was analyzed for chlorophenoxy acid herbicides. The other six composite samples were submitted for inorganic analysis.

TABLE 2. ORGANIC AND INORGANIC CONTAMINANTS ANALYZED AT MAXWELL NATIONAL WILDLIFE REFUGE, 1989.

Abbreviations used in this report and detection level.

Organochlorine compounds

1 Hexachlorobenzene	(HCB)	12 o,p'-DDT	(o,p'-DDT)
2 alpha-Benzene Hexachloride	(a-BHC)	13 o,P'-DDE	(o,p'-DDE)
3 beta-BHC	(b-BHC)	14 o,p'-DDD	(o,p'-DDD)
4 delta-BHC	(d-BHC)	15 p,p'-DDT	(p,p'-DDT)
5 gamma-BHC	(g-BHC)	16 p,p'-DDE	(p,p'-DDE)
6 alpha-chlordane	(a-chlor)	17 p,p'-DDD	

(p,p'-DDD)

7	gamma-chlordane	(g-chlor)	18	Dieldrin	(Dield)
8	Oxychlordane	(oxchlor)	19	Endrin	(Endrin)
9	Heptachlor epoxide	(HCE)	20	Mirex	(Mirex)
10	cis-nonachlor	(c-nona)	21	Polychlorinated Biphenyls	(PCBs)
11	trans-nonachlor	(t-nona)	22	Toxaphene	(Toxaph)

Chlorophenoxy acid herbicides

1	Dicambra	(Dicam)	5	2,4,5-T	(2,4,5-T)
2	Dichloroprop	(Dichlor)	6	Silvex	(Silvex)
3	2,4-D	(2,4-D)			
4	2,4-DB	(2,4-DB)			

a) Level of Detection (LD) = 0.01 ug/g wet weight (WW) for tissue and sediment, except 0.05 ug/g WW for Toxaphene and PCBs.

Inorganic Compounds			Level of Detection in uq/g dry weight (DW)		
1	Aluminum	(Al)	A=50*	P=50*	S=100*
2	Antimony	(Sb)	A=50	P=50	S=60
3	Arsenic	(As)	A=0.3	P=0.3	S=0.3
4	Barium	(Ba)	A=2.0	P=3.0	S=4.0
5	Beryllium	(Be)	A=0.2	P=0.3	S=0.4
6	Boron	(B)	A=3.0	P=4.0	S=5.0
7	Cadmium	(Cd)	A=0.7	P=0.9	S=1.2
8	Chromium	(Cr)	A=3.0	P=4.5	S=6.0
9	Cobalt	(Co)	A=3.0	P=5.0	S=Not analyzed
10	Copper	(Cu)	A=4.0	P=4.0	S=5.0
11	Iron	(Fe)	A=5O	P=50	S=100
12	Lead	(Pb)	A=7.0	R=9.0	S=12
13	Magnesium	(Mg)	A=50	P=50	S=100
14	Manganese	(Mn)	A=2.0	P=2.0	S=4.0
15	Mercury	(Hg)	A=0.02	P=0.02	S=0.02
16	Molybedenum	(Mo)	A=3.5	P=5.0	S=6.0
17	Nickel	(Ni)	A=4.0	P=5.0	S=6.0
18	Selenium	(Se)	A=0.3	P=0.3	S=0.3
19	Silver	(Ag)	A=10	P=14	S=16
20	Strontium	(Sr)	A=2.0	P=3.0	S=4.0
21	Tin	(Sn)	A=50	P=50	S=60
22	Vanadium	(V)	A=2.0	P=2.5	S=5.0
23	Zinc	(Zn)	A=3.0	P=4.0	S=6.0

*; A = animal tissue, P = plant tissue, S = sediment

TABLE 3. - TABULATED CATALOG OF SAMPLES COLLECTED FROM MAXWELL NWR, 1989. [Analysis: I, inorganic; O, organochlorine; H, herbicide; C, cholinesterase; NO/COMP, composite amount].

SAMPLE #	LOCATION	SITE #	SAMPLE TYPE	NO/	WEIGHT	% MOISTURE

				COMP	INGRAMS	CONTENT	ANALYSIS TYPE
MXSM01	LAKE 13 & DRAIN	3	SEDIMENT	2	603.4	36.80	I
MXSM02	MAIN CANAL	5	SEDIMENT	3	309.4	34.20	I
MXSM03	NATURAL PLAYA	1	SEDIMENT	3	272.0	37.40	I
MXSM04	LAKE 14	4	SEDIMENT	3	255.8	31.10	I
MXSM05	LAKE 12 DRAIN	2	SEDIMENT	3	365.5	38.40	I
MXSM06	LAKE 13 & DRAIN	3	SEDIMENT	2	616.0	28.60	H
MSX007	MAIN CANAL	5	SEDIMENT	1	360.0	28.80	0
MXS008	NATURAL PLAYA	1	SEDIMENT	1	219.0	36.60	0
MXS009	LAKE 14	4	SEDIMENT	1	258.0	25.40	0
MXS010	LAKE 12 DRAIN	2	SEDIMENT	1	367.0	38.40	0
MXPM06	NATURAL PLAYA	1	BULRUSH (seed)	>100	27.9	64.60	I
MXPM12	LAKE 14 DRAIN	4	SPIKE RUSH (seed)	>100	99.0	65.80	I
MXPM13	LAKE 13	3	SPIKE RUSH (seed)	>100	51.3	67.00	I
MXPM14	LAKE 13 DRAIN	3	SPIKE RUSH (seed)	>100	37.4	61.10	I
MXPM15	LAKE 12 DRAIN	2	PONDWEED (plant)	>10	77.4	89.00	I
MXIM16	INFLOW TO 12, 13, 14	2,3,4	CRAYFISH	22	227.3	71.60	I
MXIM17	LAKE 13 DRAIN	3	CRAYFISH	25	277.1	76.90	I
MXIM18	LAKE 12 DRAIN	2	CRAYFISH	5	78.6	74.70	I
MXIM19	LAKE 14	4	AQUATIC INVERTEBRATES	>100	128.8	90.50	I
MXIM20	NATURAL PLAYA	1	AQUATIC INVERTEBRATES	>50	64.9	90.00	I
MXFM21	LAKE 13 INFLOW & DRAIN	3	BULLHEAD,CH. CATFISH	25	2076.4	80.40	I
MXFM22	LAKE 14	4	BULLHEAD	3	976.3	80.70	I
MXFM23	MAIN CANAL	5	MINNOWS	50	350.6	75.50	I
MXFM24	LAKE 12 DRAIN	2	MINNOWS	50	257.0	78.80	I
MXFM25	LAKE 13 INFLOW	3	WHITE SUCKER	2	168.8	68.40	I
MXFM26	LAKE 13	3	RAINBOW TROUT	2	1154.5	69.80	I
MXF027	13, 14 & INFLOW & DRAIN	3,4	BULLHEAD,CH. CATFISH	50	1650.0	80.00	0
NXF028	13, 12 & INFLOW & DRAIN	2,3	MINNOWS	>100	744.0	75.50	0

MXF0290	LAKE 13	3	RAINBOW TROUT	2	1630.0	69.00
MXFM53I	CONCHAS LAKE	7	CARP	3	4120.0	76.20
MXFM54I	CONCHAS LAKE	7	SHAD	5	1732.0	70.40
MXFM55I	CONCHAS LAKE	7	WHITE CRAPPIE	3	1055.8	74.00
MXF0560	CONCHAS LAKE	7	SHAD	5	1640.0	73.00
MXF0570	CONCHAS LAKE	7	WHITE CRAPPIE	3	903.0	71.00
MXAM30I	LAKE 12	2	GADWALL (liver/kidney)	3	13.0	69.60
MXAM31I	LAKE 12 & DRAIN	2	GADWALL (liver/kidney)	3	10.1	67.60
MXAM34I	LAKE 12 & DRAIN	2	COOT (liver/kidney)	3	39.8	69.90
MXAM35I	LAKE 14, 12 & DRAIN	2,4	KILLDEER (liver/kidney)	4	37.3	70.40
MXAM38I	LAKE 14 & DRAIN	4	KILLDEER (liver/kidney)	3	65.0	71.10
MXAM39I	12 DRAIN, 14 INFLOW	2,4	CINN TEAL (liver/kidney)	3	74.5	66.80
MXAM42I	LAKES 13 & 14	3,4	BW TEAL (liver/kidney)	3	59.9	72.00
MXA0320	LAKE 12	2	KILLDEER (carcass)	4	200.0	72.00
MXA0330	LAKE 12 & DRAIN	2	KILLDEER (carcass)	3	161.0	71.50
MXA0360	LAKE 12 & DRAIN	2	CINN TEAL (carcass)	3	545.0	70.50
MXA0370	LAKE 14, 12 & DRAIN	2,4	BW TEAL (carcass)	3	653.0	74.00
MXA0400	LAKE 14 & DRAIN	4	GADWALL (carcass)	3	1190.0	70.50
MXA0410	12 DRAIN, 14 INFLOW	2,4	GADWALL (carcass)	3	1210.0	71.50
NXA0430	LAKES 13 & 14	3,4	COOT (carcass)	3	720.0	71.00
MXEM44I	MAIN ROAD	6	KILLDEER (1 nest)	2	24.1	71.20
MXEM45I	LAKE 12 DRAIN	2	CINN TEAL (internal eggs)	3	20.0	63.20
MXEM46I	LAKE 14	4	GADWALL (internal eggs)	5	14.9	52.50
MXE0470	LAKE 14	4	GADWALL (1 nest)	2	37.3	69.00
MXAC48C	LAKE 13	3	MALLARD (brain)	1	61.0	NA
MXAC49C	LAKE 13	3	MALLARD (brain)	1	49.0	NA
MXAC50C	LAKE 13	3	MALLARD (brain)	1	38.0	NA
MXAC51C	LAKE 12	2	MALLARD (brain)	1	48.0	NA
MXAC52C	LAKE 14	4	MALLARD (brain)	1	38.0	NA

Fish were collected from the Refuge using seines or gill nets. Whole body samples were combined into composites of like genus and species. Birds were shot with steel shot, carcasses were analyzed for organochlorine compounds and liver and kidney samples were analyzed for inorganic constituents (Table 2). Bird embryos were either hand gathered from nests or removed from the oviduct of a collected specimen. Five mallards were shot and their brains submitted for analysis of cholinesterase enzyme (ChE) activity. Aquatic plant samples were gathered by hand. Aquatic invertebrates were collected with underwater light traps or seines, and were combined into composite samples. Collection and dissection equipment were decontaminated after each sample.

The frozen samples were shipped to U.S. Fish and Wildlife Service, Patuxent Wildlife Research Center, Analytical Control Facility, certified contract labs. Processing and preservation of samples were in accordance with procedures outlined by the Patuxent Wildlife Research Center (USFWS 1985a, 1985b).

Analyses for organic compound residues were performed at the Mississippi State Chemical Laboratory. Tissue samples were extracted with hexane, dried, and the lipid content determined. The samples were then partitioned into fractions using chromatographic columns (Florisil, silica gel, or silicic acid). Organochlorine residues were quantified using packed or megabore column, electron capture, gas chromatography. The results of these analyses are provided in Appendix A. Sediment samples were extracted and partitioned into fractions using either a separatory funnel or column chromatography; analysis continued in the same manner as for tissue samples. Results of the chlorophenoxy acid herbicide analysis are shown in Table 4.

Table 4. Results of Chlorophenoxy Acid Herbicide Analysis on sediment sample composited from Lake 13 and drain. Values are in ug/g, wet weight.

ND, none detected; MSTR, moisture content in percent; weight is in grams; see table 2 for analyte abbreviations.

SAMPLE #	WEIGHT	MSTR	ANALYTE					
			DICAM	DICHLOR	SILVEX	2,4-D	2,4,5-T	2,4-DB
MXSH06	616.0	26.8	ND	ND	ND	ND	ND	ND

Analysis and diagnosis of ChE activity in mallard brains was performed by Dr. Elwood Hill, U.S. Fish and Wildlife Service, Patuxent Wildlife Research Center, according to methods detailed in Hill and Fleming (1982) and Hill (1988). The results are shown in Table 5.

Analyses for inorganic contaminants were performed at the Research Triangle Institute, North Carolina. Samples were homogenized, freeze dried, digested with nitric acid, and filtered. Separate digestions were conducted for selenium, arsenic, and mercury. Selenium and arsenic were analyzed using Graphite Furnace Atomic Adsorption (GFAA). Mercury analysis was performed using Cold Vapor Atomic Absorption (CVAA). Analysis of other elements was by Inductively Coupled Plasma Emission Spectroscopy (ICP). The results of inorganic analysis in dry weight are shown in Appendix B with wet weight results in Appendix C.

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Table 5. Results of Cholinesterase Enzyme Activity Assays of Mallards collected from Maxwell National Wildlife Refuge-1989.

SAMPLE #	SITE LOCATION	ChE ACTIVITY[sup]a	ChE INHIBITION[sup]b
MXAC48	Lake 13	9.3	0
MXAC49	Lake 13	5.7	52%
MXAC50	Lake 13	12.6	0
MXAC51	Lake 12	8.7	28%
MXAC52	Lake 14	6.0	50%

[sup]a Micromoles of acetylthiocholine iodide hydrolyzed per minute per gram of tissue (wet weight) at 25°C.

[sup]b Percent of ChE inhibition is calculated from published values for apparently normal free-living adult mallards (n=11, mean ChE activity = 12 umoles/min/g, diagnostic threshold = 9; Hill 1988).

DISCUSSION OF RESULTS

Determining what a specific concentration of a particular compound means to a biological system is difficult. There is inadequate information on "normal" contaminant levels in fish and wildlife or their food items to adequately assess risk. Action and alert levels proposed by various agencies and experts are often only for specific applications (Irwin 1988). In this study, comparative levels of contaminants reported in fish and wildlife tissues were used to determine if residue levels of certain compounds in our samples were elevated. Contaminant levels of concern reported in scientific literature from other investigations were used, where appropriate, to determine whether or not an environmental risk may exist.

Organic Contaminants

Analysis for chlorophenoxy acid herbicides included tests for Dicamba, Dichlorprop, Silvex, 2,4-D, 2,4-DB, and 2,4,5-T. These herbicides are used to control herbaceous terrestrial and aquatic plant growth. Analytical results indicate these herbicides were not detectable in sediments collected from Lake 13 and drain (Table 4).

No organochlorine compounds were detected in sediment samples. Levels of the p'p-DDE averaged 0.01 ug/g WW in fish samples collected from the Refuge. This is below the NCBP geometric mean level of 0.19 ug/g WW p'p-DDE (Schmitt et al. 1990). The maximum concentration in birds (0.85 ug/g WW) was found in killdeer along with residues of hepatochlor epoxide, lindane, and total PCB's. Organochlorine contaminant levels of all biotic samples were below the predator protection level of 1.0 ug/g WW for combined DDT, DDE, and DDD (Nat'l Acad of Sci 1973). A summary of concentrations of organochlorine compounds is presented in Appendix A.

Cholinesterase Inhibition

Organophosphates such as Malathion and Parathion and carbamates such as Carbofuran inhibit the cholinesterase (ChE) enzyme, causing a build-up of acetylcholine along nerve synapses (Ramade 1987). Physical symptoms of ChE inhibition can include paralysis, and unusual or subdued behavior (Murphy 1986). Severe ChE inhibition may lead to death (Smith 1987).

Cholinesterase enzyme inhibition occurred in 3 of the 5 mallard brains tested (Table 5). Although the percentage of ChE inhibition was diagnostic of exposure to organophosphate or carbamate pesticides (Hill, pers. comm.), we were not able to determine if this exposure occurred within the study area.

Additionally, there were no observations of abnormal behavior prior to collection in any of the mallards collected for this study.

Inorganic Contaminants in Water. Sediment and Biota

Certain elements can have profound effects on aquatic species through the accumulation and biomagnification in the food chain (Lemly and Smith 1987). Arsenic, chromium, nickel, and vanadium are known to bioaccumulate in invertebrate and plant species more than in fish, bird, or mammal species (Ramade 1987). Mercury, lead, and selenium are known to bioaccumulate in aquatic species from small quantities in water or sediment (parts per billion) to adverse or lethal tissue levels (parts per million) (Eisler 1985b, 1987, 1988b). Elements that bioaccumulate, or are found at a level of concern, are discussed in this report.

Water quality data (circa 1987) from Lakes 12, 13, and 14 was provided by the New Mexico Environment Department (Davis 1991). Data from the Canadian River were available from the U.S. Geological Survey Water Resources Data Reports (USGS 1987-89) and water quality data from the Vermejo River were taken from Leftwich (1985)(Table 1). In water samples collected for these studies, most elements of concern were below the analytical level of detection. A summary of these results is included in Table 1.

The effect of sediment chemistry on the concentration of elements in water is dependent on chemical and physical factors such as pH, Eh, temperature, and the solubility of individual elements. Soil profile, and microbiological activity are also important factors. Aquatic sediments often have an increased capacity to bind metals because of greater amounts of organic matter (DOI Task Group 1985). We have used ranges of trace element concentration in soils of the western conterminous United States (Shacklette and Boerngen 1984) as a reference baseline for evaluating concentrations in sediment samples from

the Refuge. Any significant increase in concentration compared to these baseline levels could indicate that an element was elevated. (Table 6)

Arsenic

Arsenic in the environment accumulates in plants and invertebrates (Eisler 1988). Invertebrate samples from the Refuge had detectable levels of arsenic from 0.3 to 0.8 ug/g WW. Eisler (1988) reported that arsenic concentrations less than 1 mg/kg WW caused few, if any, chronic effects to birds, mammals, and aquatic species. Arsenic was not detected in the tissue samples taken from fish or birds at the Refuge. Therefore, arsenic does not seem to be present at toxic concentrations in Refuge biota.

Cadmium

Cadmium residues were below the limit of detection in sediment, plant, and fish samples taken from the Refuge, but the element was detected in one crayfish sample and in one composite aquatic invertebrate sample. In bird liver and kidney samples, cadmium residues ranged from less than 0.70 to 8.45 ug/g DW. Gadwall and cinnamon teal from Lake 12 had the highest cadmium concentrations but were below the 10 ug/g WW (14 ug/g DW) level used as an indicator of harmful cadmium concentrations in migratory birds (Eisler 1985a).

Mercury

Mercury is the most toxic heavy metal to fish and can readily bioaccumulate in aquatic systems (Eisler 1987). Mercury was detected in four of five invertebrate samples, in all fish samples (maximum concentration 0.21 ug/g WW), in all bird liver and kidney samples, and in two of three bird embryo samples. Mercury was not detected in any of the plant samples. The 85th

TABLE 6. COMPARISON OF DETECTED TRACE ELEMENT CONCENTRATIONS BETWEEN BASELINE SOIL OF THE WESTERN CONTERMINOUS UNITED STATES (as summarized from Shacklette and Boerngen 1984) AND SEDIMENT FROM MAXWELL NWR. ALL Values are ug/g dry weight. See Table 2 for abbreviations.

ELEMENT	BASELINE SOILS (RANGE)	GEOMETRIC MEAN	MAXWELL SOILS (RANGE)	GEOMETRIC MEAN
Al	15,000 - 230,000	58,000	16,200 - 53,200	29,000
As	1.2 - 22	5.5	2.8 - 6.5	4.5
Ba	200 - 1,700	580	339 - 553	428
Be	0.13 - 3.6	0.68	<0.40 - 1.3	0.8 b
B	5.8 - 91	23	56.3 - 100	68
Cr	8.5 - 200	41	34.5 - 63.3	46
Fe	5,500 - 80,000	21,000	24,400 - 30,700	25,950
Pb	5.2 - 55	17	22 - 38	27
Mg	1,500 - 36,000	7,400	4,420 - 10,800	5,005
Mn	97 - 1,500	380	222 - 772	312

Hg	0.0085 - 0.25	0.046	<0.02 - 0.03	0.023 b
Ni	3.4 - 66	15	15.8 - 25	19
Se	0.039 - 1.4 (0.6 a)	0.23	<0.30 - 0.71	0.48 b
Sr	43.0 - 930	200	90 - 256	142
V	18 - 270	70	77 - 141	102
Zn	17 - 180	55	67 - 109	82

a For shale, Eben and Shacklette, 1982.
b Geometric mean calculated with 1/2 detection limit

percentile concentration of mercury in fish from the Refuge was 0.08 ug/g WW. The maximum concentration was 0.21 ug/g WW in a rainbow trout sample collected from Lake 13. The NCBP 85th percentile concentration of mercury in whole-body fish samples is 0.17 ug/g WW (Schmitt and Brumbaugh 1990), and the predator protection level is 0.10 ug/g ww (Eisler 1987). Results from this study indicate that mercury may be bioaccumulating in some fish species from the Refuge and additional studies should be conducted.

Selenium

Selenium (Se) was not detected in sediment from Lakes 12 and 13, but was highest (0.7 ug/g DW) in sediment taken from the main irrigation canal. Selenium was detected in all tissue samples collected at the Refuge, but not in aquatic plants. Concentrations in fish seemed to be dependent on location and trophic level. The concentrations of selenium in fish were highest in upper trophic level species (rainbow trout) or in fish from inflow canals. For example, the concentration of Se in minnows collected in the main canal (1.49 ug/g WW) was nearly twice the concentration found in minnows collected from Lake 12 (0.70 ug/g WW).

To protect predators from accumulating toxic levels of selenium, Eisler (1985b) suggested consumption levels less than 0.5 ug/g WW. Seventeen of the

20 tissue samples collected at the Refuge exceeded this level. Three of the six fish samples collected had selenium concentrations that exceeded the NCBP 85th percentile of 0.73 ug/g WW (Schmitt and Brumbaugh 1990). The geometric mean selenium concentration of fish from the Refuge (0.80 ug/g WW) exceeded the NCBP geometric mean of 0.42 ug/g WW (Schmitt and Brumbaugh 1990). For this survey, selenium concentrations above the 85th percentile are considered elevated and are interpreted as evidence of selenium contamination.

The highest concentrations of selenium in bird liver and kidney samples were from killdeer. Killdeer liver and kidney samples collected from the Refuge had selenium concentrations of 20.5 and 21.6 ug/g DW. Elevated concentrations of selenium (greater than 10 ug/g DW) were also detected in liver and kidney samples of blue-winged teal and gadwall (Appendix B). According to Skorupa et al. (1990) waterbird populations with mean liver selenium concentrations below 10 ug/g DW do not experience selenium-induced teratogenic effects; populations with mean concentrations above 30 ug/g DW usually do experience treatogenic effects and; populations with mean concentrations between 10 and 30 ug/g DW require individual studies of reproductive performance to assess risk with high confidence.

The highest selenium concentration in embryos collected from the Refuge was 5.2 ug/g DW in killdeer. Embryos of cinnamon teal and gadwall were below 3 ug/g DW. According to Skorupa et al. (1990) waterbird populations with mean egg selenium concentrations below 3 ug/g DW do not experience selenium-induced teratogenic effects; populations with mean concentrations greater than 20 ug/g DW usually do experience teratogenic effects and; populations with mean concentrations between 3 and 20 ug/g DW require individual studies of reproductive performance to assess risk with high confidence. Based on these comparisons, it appears that nesting birds, especially killdeer, at the Refuge are accumulating selenium to levels which may be adversely effecting reproduction. Additional study of nesting birds and their embryos from the

Refuge will be necessary to support this conclusion or identify specific effects, if any.

Other Elements

Elements such as barium, beryllium, boron, molybdenum, nickel, strontium and vanadium, were detected in Refuge biota and sediment samples. The levels that were detected were not sufficiently elevated to assess the potential for

impacts to fish and wildlife. With the exception of boron, the range of concentrations of elements in sediment from the Refuge are within the baseline range of values from soils in the western United States (Shacklette and Boerngen 1984). Boron, chromium, iron, manganese, nickel, vanadium, and zinc were more concentrated in sediment from the natural playa than at the other lakes probably because of evapoconcentration.

The highest concentrations of aluminum, mercury, lead, and strontium in sediment were detected at Lake 14. This lake also has smaller storage capacity compared to Lake 13 and is probably prone to element concentration through evaporation.

Summary

With regard to organochlorine contamination, DDE, a breakdown product of DDT, was the most frequently detected organic compound in Refuge biota. Killdeer had the highest levels of DDE as well as PCBs, BHC, oxychlordane, and heptachlor epoxide. This may reflect diet or metabolic differences between plover species and other bird species sampled.

Three of five mallards tested positive for ChE inhibition at a level diagnostic of exposure to organophosphorus insecticides, such as Malathion and Parathion, which are used in the study area.

Evidence of selenium contamination was found in biota at the Refuge. Mercury concentrations in some fish tissue samples were above recommended levels for protection of predators (0.1 ug/g), and were highest in a rainbow trout sample. Selenium residues in biota were at levels that may be causing reproductive impairment to migratory birds. Bird samples from the Refuge had selenium residues comparable to birds from the San Joaquin Valley where

widespread selenium toxicity and embryonic mortality have been reported (Ohlendorf 1989, Skorupa et al. 1990).

A potential source of selenium in the watershed and Refuge lakes may be from weathered shales, which are a primary component of the soils and geology of the study area. Activities that contribute to soil and riverbank erosion may then have the greatest effect on water concentrations of selenium. Other possible sources could be from coal mining activities such as coal wash discharge into the Vermejo River or atmospheric fall-out from a coal-fired power plant to the north.

Recommendations

Selenium seems to be accumulating in the biota at the Refuge and could represent a threat to migrating and resident birds as well as other wildlife species. A comprehensive contaminant investigation should be developed that addresses, in detail, the effects and trends of selenium and other elements in water, sediment and biota at the Refuge. Physical water chemistry studies on a seasonal basis should be conducted in conjunction with other studies on the Refuge. Sediment from the Vermejo River, the High Line Canal, the Vermejo Ditch, the Eagle Tail Canal, Stubblefield Lake, Laguna Madre, and Lake 11 should be analyzed separately to determine the relative contaminant contribution of each area. Potential sources of contamination from coal mining activities should also be investigated. An analysis of Pierre shale and other shale and sandstone which make up the parent materials of the soil could establish background levels of selenium in the watershed.

Specific management recommendations cannot be made at this time because of a lack of site specific data. This study was designed to determine if migratory birds at the Refuge potentially could be exposed to and accumulating harmful levels of inorganic/organic contaminants. This study did not attempt to

isolate the source(s) of contamination. During the summer of 1991 another, more detailed, study was conducted at the Refuge. This study was designed to determine if the source(s) of selenium is on the Refuge or if selenium may be introduced into the Refuge from irrigation supply water. When the data from the 1991 study are available, it may then be possible to make specific management recommendations. Finally, it may be advisable that staff from the Refuge conduct some sampling of biota at the Refuge to develop a database whereby a selenium (and other inorganic) status and trends analysis can be conducted. Should this option be considered viable for inclusion in general Refuge monitoring, this office would be pleased to assist in training, the design and on-site implementation of such efforts.

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See Table/Figure

APPENDIX A.- ANALYTICAL RESULTS OF ORGANOCHLORINE CONTAMINANTS IN BI0TA MD SEDIMENT FROM MAXWELL NWR, 1989. [All values are in micrograms per gram, wet weight.
Species: CH catfish, channel catfish; BW Teal bluewinged teal;
CINN Teal, cinnamon teal; WEIGHT, sample weight in grams; MSTR, moisture content in percent; LIPID. % lipid content;
ND, none detected at detection limit; Compound abbreviations in Table 2].

(SEE ORIGINAL)

See Table/Figure

APPENDIX A (Concluded).- ANALYTICAL RESULTS OF ORGANOCHLORINE IN BIOTA AND SEDIMENT FROM MAXWELL NWR, 1989. [All values are in micrograms pr gram, wet weight. Species: CH Catfish, channel catfish; BW Teal, bluewinged teal; CINN Teal, cinnamon teal; WEIGHT, sample weight in grams; MSTR,

moisture content in percent; LIPID, % lipid content; ND, none detected
at detection limit; Compound abreviations in Table 2]

(SEE ORIGINAL)

See Table/Figure

APPENDIX B.- ANALYTICAL RESULTS OF INORGANICS IN BIOTA AND SEDIMENT FROM MAXWELL NWR, 1989.
[Values are in micrograms per gram, dry weight. Species: Wh Sucker, white sucker;
RB Trout; Aq. Invert., aquatic invertebrates; MSTR, moisture content in percent;
IE, internal egg; <, less than analytical detection limit; Compound abbreviations
in Table 2].

(SEE ORIGINAL)

See Table/Figure

APPENDIX B (Concluded). - ANALYTICAL RESULTS OF INORGANICS IN BIOTA AND SEDIMENT FROM MAXWELL NWR, 1989. [Values are in micrograms per gram, dry weight. Species: WH Sucker, white sucker; RB Trout, rainbow trout; Aq. Invert., aquatic invertebrates; MSTR, moisture content in percent; IE, internal egg; <, less than analytical detection limit; Compound abbreviations
in Table 2].

(SEE ORIGINAL)

See Table/Figure

APPENDIX C. - ANALYTICAL RESULTS OF INORGANICS IN BIOTA AND SEDIMENT FROM MAXWELL NWR, 1989.
[Values are in micrograms per gram, wet weight, MSTR, moisture content in
percent; IE, internal eggs; <, less than detection limit; Element abbreviations
in Table 2].

(SEE ORIGINAL)

See Table/Figure

APPENDIX C (Concluded). - ANALYTICAL RESULTS OF INORGANICS IN BIOTA AND SEDIMENT FROM MAXWELL
NWR, 1989. [Values are in micrograms per gram, wet weight. MSTR,
moisture content in percent; IE, internal eggs; <, less than
detection limit; Element abbreviations in Table 2].