U.S. FISH AND WILDLIFE SERVICE

ROCKY MOUNTAIN ARSENAL NATIONAL WILDLIFE REFUGE

FISCAL YEAR 1994 ANNUAL PROGRESS REPORT

Prepared in Partial Fulfillment of the Cooperative Agreement for Conservation and Management of Fish and Wildlife Resources at Rocky Mountain Arsenal, U.S. Fish and Wildlife Service and U.S. Army.

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by

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INTRODUCTION

History

The Rocky Mountain Arsenal (Arsenal) was created in 1942 by the U.S. Army (Army) for the sole mission of manufacturing chemical and incendiary munitions for the war effort. During World War II, mustard gas and chemical munitions were manufactured. Later GB nerve agent was produced.

All manufacturing plants and associated facilities were located in the center of the 17,000 acre Arsenal, for security reasons, and to protect nearby residents from the possibility of accidents. Production at the center of the Arsenal had little effect on the wildlife in the surrounding buffer zones. These outlying areas provided undisturbed habitat for many species of wildlife.

In 1946, the facilities used for manufacturing munitions were leased to Shell Chemical Company and modified for the production of insecticides and herbicides. Products produced during this time period included DDT, chlordane, aldrin, dieldrin, endrin, and parathion. Nematocides such as dibromochloropropane and DD soil fumigant were also produced at the Arsenal. Production of military and commercial chemical products before 1956 generated considerable chemical waste by-products (Trautmann and Kuznear 1980).

In 1968, the U.S. Army Matériel Command requested recommendations from the National Academy of Science on chemical agent disposal methods. Beginning in 1975, the primary mission of the Army at the Arsenal was to demilitarize and dispose of obsolete chemical munitions. Shell Chemical continued to lease production areas until 1982 when all production ceased.

In 1980, the mission of the Arsenal was further refined to direct the disposal of chemical agents and hazardous materials, and decontamination and cleanup of the installation (Sheely 1980). In 1988, the Secretary of the Army placed the Arsenal on inactive status and announced that the sole mission of the Arsenal was contamination cleanup.

The Arsenal was placed on the National Priorities List (NPL) in 1987 and is currently being cleaned up under the authority of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and the Superfund Amendments and Reauthorization Act of 1986 (SARA).

Physical attributes of the Arsenal

The Arsenal is 27 square miles, and is largely undeveloped, open grassland. The Arsenal was originally short-grass and sand prairie habitat, dominated by blue grama grass, western wheatgrass, sand bluestem grass, needle and thread grass, and sand sagebrush (Cooper 1988). Most native vegetation was lost through conversion of the lands to agricultural uses (Ebasco, et al. 1989). A variety of grasses and forbs can still be found on the Arsenal including four types of native grasslands. Approximately 20% of the Arsenal is presently native grasslands.

The Arsenal has relatively diverse habitats ranging from almost pure stands of native shortgrass prairie to extensive fields of brome cheatgrass, moist wetlands, intermittent streams, and permanent lakes. These habitats in turn support an abundant and varied animal life.

The area has a semi-arid climate. The climate is classified as moderate with a growing season of 135 days. The mean temperature is 64 degrees Fahrenheit. Average yearly precipitation is 15.51 inches.

The Arsenal lands are gently undulating to undulating and rolling. The elevation is approximately 5,300 feet mean sea level (MSL) at the southeastern corner and 5,100 feet MSL at the northwest corner. Average elevation is 5,250 feet MSL.

The Arsenal lies within the South Platte River drainage. The principle streams are intermittent and include First Creek, Irondale Gulch, and the Sand Creek lateral. First Creek drains the southeastern corner of the Arsenal, runs north, and eventually discharges in the O'Brien canal.

History of fish and wildlife management

Management of the wildlife has varied since the Arsenal's establishment. During the 1960's a Rod and Gun Club was established to provide recreation. Both federal civilian employees working at the Arsenal and military personnel were eligible for membership. This club stocked many species of wildlife on the Arsenal. Approximately 1,500 pheasants per season were released while quail were released only during certain years. Northern pike, bluegill, largemouth bass, and channel catfish were stocked in many of the Arsenal's lakes in the 1960's.

During this period the Army did some wildlife management, planting small food plots consisting of wheat, millet, corn, sorghum, and alfalfa. The acreage planted each year varied between 100 to 300 acres.

U.S. Fish and Wildlife Service involvement

The Arsenal was designed with substantial buffer zones surrounding chemical production facilities as a means to protect the public if a catastrophic event occurred. These lands have remained largely undeveloped. Vegetation succession, the removal of livestock, and limited human access since 1942 have resulted in wildlife habitat of considerable diversity. Surrounding urbanization and the expansion of agricultural practices have isolated the Arsenal, thereby magnifying its overall importance to local wildlife communities. The new Denver International Airport, the construction of the E-470 beltway, and associated development will continue to isolate wildlife habitat within the Arsenal.

U.S. Army Regulation 420-74, Natural Resources - Land, Forest, and Wildlife Management, establishes policies and procedures for the conservation, management, and restoration of lands and renewable resources on certain Army installations (U.S. Army 1986). Chapter 5 of Regulation 420-74 outlines fish and wildlife protection responsibilities, and provides for the coordination and implementation of fish and wildlife management plans with appropriate federal or state agencies.

On 23 March 1989, the Army and the U. S. Fish and Wildlife Service (Service) signed and implemented the Cooperative Agreement for Conservation and Management of Fish and Wildlife Resources at Rocky Mountain Arsenal (U.S. Government 1989). Under provisions of the Conservation Agreement, a Service field office was established on the Arsenal to provide centralized coordination of wildlife resource management. This Conservation Agreement was revised in the Spring of 1991 to reflect expansion and changes in the Service's role on the Arsenal. The revised Cooperative Agreement expanded the responsibilities of the Service and more accurately defined its role in activities by defining these activities within seven specific tasks (U.S. Government 1991).

On 9 October 1992 the President of the United States signed the Rocky Mountain Arsenal National Wildlife Refuge Act of 1992. This legislation gave management responsibilities for Arsenal natural resources to the Department of the Interior. The Service is mandated to manage the Arsenal "as if it were" a national wildlife refuge. After environmental cleanup is complete, the site will become one of the largest urban wildlife refuges in the country. Congress directed that use of the land as a refuge would not restrict or lessen the level of cleanup. Congress took an unprecedented step of pre-determining the final use of a superfund site as a refuge.

The purposes of the refuge, as set forth in the legislation are:

1. To conserve and enhance populations of fish, wildlife, and plants within the refuge, including populations of waterfowl, raptors, passerines, and marsh and waterbirds.

2. To conserve species listed as threatened and endangered under the endangered species act and species that are candidates for listing.

3. To provide maximum fish and wildlife oriented public use at levels compatible with the conservation and enhancement of wildlife and wildlife habitat.

4. To provide opportunities for compatible scientific research.

5. To provide opportunities for compatible environmental and land use education.

6. To conserve and enhance the lands and water of the refuge in a manner that will conserve and enhance the natural diversity of fish, wildlife, plants, and their habitats.

7. To conserve and enhance the quality of aquatic habitats within the refuge.

8. To fulfill international treaty obligations of the United States with respect to fish and wildlife and their habitats.

Fiscal year 1994 represents the second year of managing the Arsenal as if it were a part of the National Wildlife Refuge System. The following is an account of all Service activities conducted during FY94. Activities are reported based on their task number.

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TASK 1 - WILDLIFE HEALTH AND MANAGEMENT

TITLE: Biomonitoring Program

INTRODUCTION

In 1993, the Service initiated the Biomonitoring Program (BMP) for the Rocky Mountain Arsenal National Wildlife Refuge (Refuge). In April, 1994 the terrestrial portion of the BMP (TBM) (U.S. Fish and Wildlife Service 1994) was finalized and incorporated or addressed relevant comments from all reviewers. The goals of the BMP are: 1) To ensure that clean-up is successful at protecting wildlife populations that inhabit the Refuge, and 2) to ensure that Refuge habitats are restored. The BMP is designed to determine the ecological significance of environmental contaminants to wildlife populations that inhabit the Refuge. In order to adequately assess the effects of contaminants on wildlife, biomonitoring activities must integrate chemistry, toxicology, and ecology. Simply documenting the presence of a contaminant in the environment or in the tissues of an organism does not indicate biological effect. Unless specific data exists on the concentrations necessary to illicit biological effects, the presence of a contaminant in the environment only provides information that the potential exists for organisms to become exposed to that contaminant. The presence of a contaminant in tissues only confirms that the organism was exposed to that contaminant at some time prior to being collected.

The objectives of the TBM are:

a) To determine the influence of contaminants upon wildlife at the individual, population, and community levels using residue chemistry and health indices, and provide this supplemental data to the Parties and general public to assist in remedial action planning, risk management decisions, and wildlife management on the Refuge (i.e., establish the benchmark).

b) To document any damages to natural resources.

c) use the pre-remediation wildlife health status "benchmark" as a comparison against post-remediation conditions for long-term biomonitoring at the Refuge.

The BMP addresses the effects of contaminants on biological resources by considering impacts at different levels of organization (individual, population, and community) for both aquatic and terrestrial habitats. The TBM will assess individual, population, and community effects by studying six "sentinel" or indicator species. The sentinel species are deer mouse (Peromyscus maniculatus), plains pocket gopher (Geomys bursarius), European starling (Sturnus vulgaris), American kestrel (Falco sparverius), great horned owl (Bubo virginianus), and the American badger (Taxidea taxus). Each species represents a particular trophic level within the food chain which allows the Service to determine contaminant effects upon each trophic level and contaminant effects from food chain biomagnification.

A total of ten target analytes were selected (arsenic, mercury, *alpha*-chlordane, aldrin, dieldrin, endrin, *gamma*-chlordane, isodrin, ppDDE, and ppDDT) for investigation. These compounds and elements were selected based upon a selection process conducted by Army, Shell Oil Company, and the Environmental Protection Agency. A detailed discussion on the selection process was included in the BMP (U.S. Fish and Wildlife Service 1994). Organochlorine compounds (OCP's) were analyzed by Gas Chromatography/Electron Capture Detection, arsenic was analyzed by Graphite Furnace Atomic Absorption, and mercury was analyzed by Cold Vapor Atomic Absorption Spectroscopy. The certified reporting limit (CRL) for OCP's was 0.015 ppm, based on an 8 gram sample. Samples that were less than eight grams had a higher CRL. The CRLs for arsenic and mercury were 0.20 ppm and 0.050 ppm respectively, based on one gram samples. In 1994, the Service submitted over 600 biological samples for residue analyses. The results from over 500 have been received. Results from some submitted samples will be discussed in various reports included in this Annual Progress Report.

A draft aquatic biomonitoring plan (ABM) for the Refuge was completed in 1994 (U.S. Fish and Wildlife Service 1994). A final plan will be completed in 1995. The goals of ABM are: 1) to establish present conditions of aquatic resources on the Refuge, 2) to document any present or ongoing damage to resources, and 3) to develop methods that can be used in future monitoring, particularly to determine efficacy of remediation. Specific objectives of the ABM are: 1) to determine the extent of contaminant bioavailability in lake sediments, 2) to determine if contaminants are causing deleterious effects on aquatic biota, and 3) to determine if nonpoint source contamination is present and whether it may affect fish and wildlife resources. Results of the ABM will indicate whether further investigations on specific aspects of aquatic habitats on the Refuge are needed, will assist in determining solutions to correct detrimental effects, and will develop future monitoring methods.

The kestrel study, the Building 111 bird mortality study, Fortuitous Specimen Program, waterfowl study, fish health study, Section 36 prairie dog contaminant study, and the mourning dove contaminant study were conducted by the Service. Studies on starlings, deer mice, and badgers were conducted for the Service by the Institute of Wildlife and Environmental Toxicology (TIWET) of Clemson University. The pocket gopher investigation was conducted by the Department of Environmental Health-Center for Environmental Toxicology (CET), Colorado State University (CSU). The great horned owl investigation was conducted by the Department of Range and Wildlife, Texas Tech University. Aquatic studies are being conducted by the Department of Fishery and Wildlife Biology (DFWB), CSU, U.S. Fish and Wildlife Service Fish Disease Control Center (FDCC), and the Bozeman Fish Technology Center (BFTC). The TIWET, CET, DFWB, and Texas Tech projects are briefly described below, and detailed reports are included in Appendix A. Studies conducted by Service personnel (Refuge, FDCC, and BFTC) have detailed descriptions of this year's activities included in this report.

<u>American badger</u>

During the first two years of this project, efforts centered on two principal tasks: 1) conduct acute dosing studies on captive badgers using dieldrin, and 2) trap, sample, and transmitter wild badgers on the Refuge. Both phases have progressed well. In addition, sub-acute dieldrin dosing studies will be initiated in late 1994 or early 1995.

<u>Deer mouse</u>

During the first two years of this project, efforts have centered on three principal tasks: 1) Determination of seasonal small mammal diversity and abundance at a variety of locations on the Refuge, 2) analysis of enclosure study data collected during the fall of 1993; and 3) analysis of small mammal trapping data collected over the last year. All three tasks have progressed well and additional enclosure studies are planned for the future.

<u>European starling</u>

During the two years of this project, efforts focused on three principal tasks: 1) analysis of samples collected in a dieldrin dosing study which occurred in 1993, 2) establishment of starling nesting populations throughout the Refuge, and 3) collection of data on nest success, contaminant residues, and biomarkers.

Pocket gopher

During the first field season project, efforts focused on two major tasks: 1) preparation for laboratory and field investigations, and 2) selection of field sampling and monitoring locations on the Refuge.

Great horned owl

During the first field season project, efforts focused on three major tasks: 1) Monitor reproductive success of great horned owls on the Refuge; 2) Capture adult owls, attach radio transmitters and conduct telemetry to determine home range and; 3) capture juvenile owls, collect blood for residue analyses, and attach transmitters to determine mortality rates.

Sediment quality triad, fish communities, sublethal impacts

Researchers from DFWB will conduct studies on Lake Mary, Lake Ladora, and Lower Derby Lake on sediment quality by using benthic invertebrate communities; on the health of fish communities by determining reproductive success, survival, recruitment, and food habits; and on sublethal impacts to fish from contaminated sediments using biomarkers, laboratory studies, and computer models to integrate several study aspects. Preliminary work was conducted in 1994 and is reported in the appendices under the title "Effects of sediment contaminants on macroinvertebrate and fish assemblages in the lower lakes at Rocky Mountain Arsenal."

REFERENCES

U.S. Fish and Wildlife Service. 1994. Biomonitoring Program for Rocky Mountain Arsenal National Wildlife Area. Amendment 5 to the 1994 Fish and Wildlife Management Plan. U.S. Fish and Wildlife Service, Rocky Mountain Arsenal National Wildlife Refuge, Commerce City, Colorado. 159pp.

American kestrel

INTRODUCTION

Since 1982, productivity of American kestrel and contaminant concentrations in various kestrel tissues have been monitored at the Refuge. In 1993, the Service initiated an intensive two year investigation to determine what effects contaminants at the Refuge were having on kestrels. This annual report summarizes results from the Services study in 1993 and 1994. Much of the data in this report were presented by Service staff on November 3, 1994 at the 15th Annual Meeting of the Society of Environmental Toxicology and Chemistry held in Denver, Colorado. In addition, the Service is preparing a final report that summarizes the results of various aspects of the kestrel study that will include detailed analyses and discussion of the results of this investigation.

The objectives of this investigation were:

1) To quantify exposure of adult and nestling kestrels to dieldrin, endrin, aldrin, isodrin, *alpha*-chlordane, *gamma*-chlordane, DDE, DDT, mercury, and arsenic by analyzing for these chemicals in eggs, food items, and nestlings and conduct radio telemetry of adults.

2) To quantify responses (individual and population) to exposure by monitoring: 1) clutch size, hatching success, survival of adults, and nestlings, 2) growth and development of kestrel nestlings, and 3) biochemical and molecular responses.

3) Determine the "Effect Zone" (Henney at al. 1983; Henney 1987) for each target analyte in kestrel eggs, nestling blood, liver, brain, and prey items.

For more background information on the kestrel investigation, please refer to the BMP (U.S. Fish and Wildlife Service 1994).

METHODS

During the late winter of 1993, the Service removed 53 existing kestrel nest boxes on the Refuge and replaced them with 37 new nest boxes. The new boxes were placed in a systematic pattern to ensure coverage of highly, moderately, and lightly contaminated areas of the Refuge (Fig. 1-1). The Refuge was divided between the central core and peripheral areas. For the 1994 field season 15 nest boxes were placed at two nearby reference areas, Aurora Reservoir and Cherry Creek State Park (Fig. 1-2). Those sites were selected because the habitats are similar to the Refuge. The Service monitored kestrel activity near the boxes to detect possible nesting activity. After nesting was documented, the nests were intensively monitored to determine clutch sizes, hatching success, nestling survival, and contaminant exposure. In 1993, selected pairs of kestrels were captured and outfitted with radio transmitters to determine foraging areas. In 1994, only males were radio-tagged because they do most of the foraging and females spend considerable time incubating eggs and brooding young. Tissues (brain, liver, carcass, eggs, and prey items) were analyzed for the target analytes. In addition, a variety of biomarkers were measured (EROD, PROD, porphyrins, immune function, and biogenic amines) in liver, kidney, splenocytes, and brain. Detailed descriptions of the methods used will be included in subsequent reports.

RESULTS

American kestrel nesting activity increased on the Refuge from 1993 to 1994. In 1993, there were 25 nesting attempts on the Refuge, 18 (72%) of which were

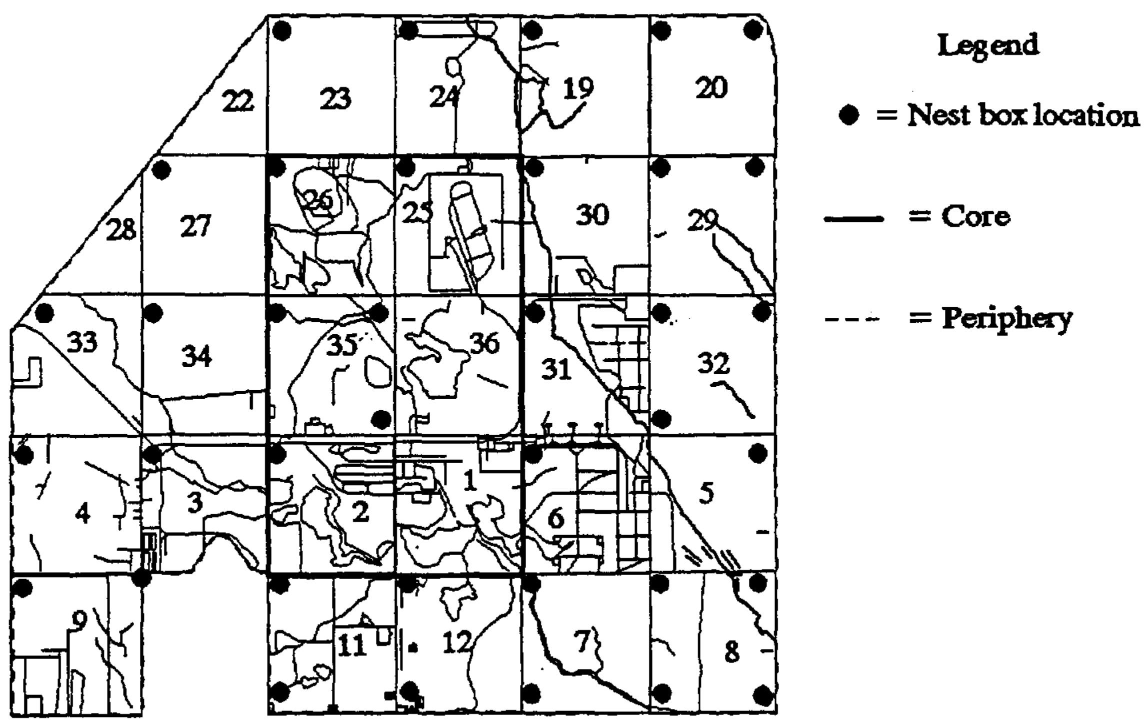


Fig. 1-1. Locations of kestrel nest boxes on Rocky Mountain Arsenal National Wildlife Refuge.

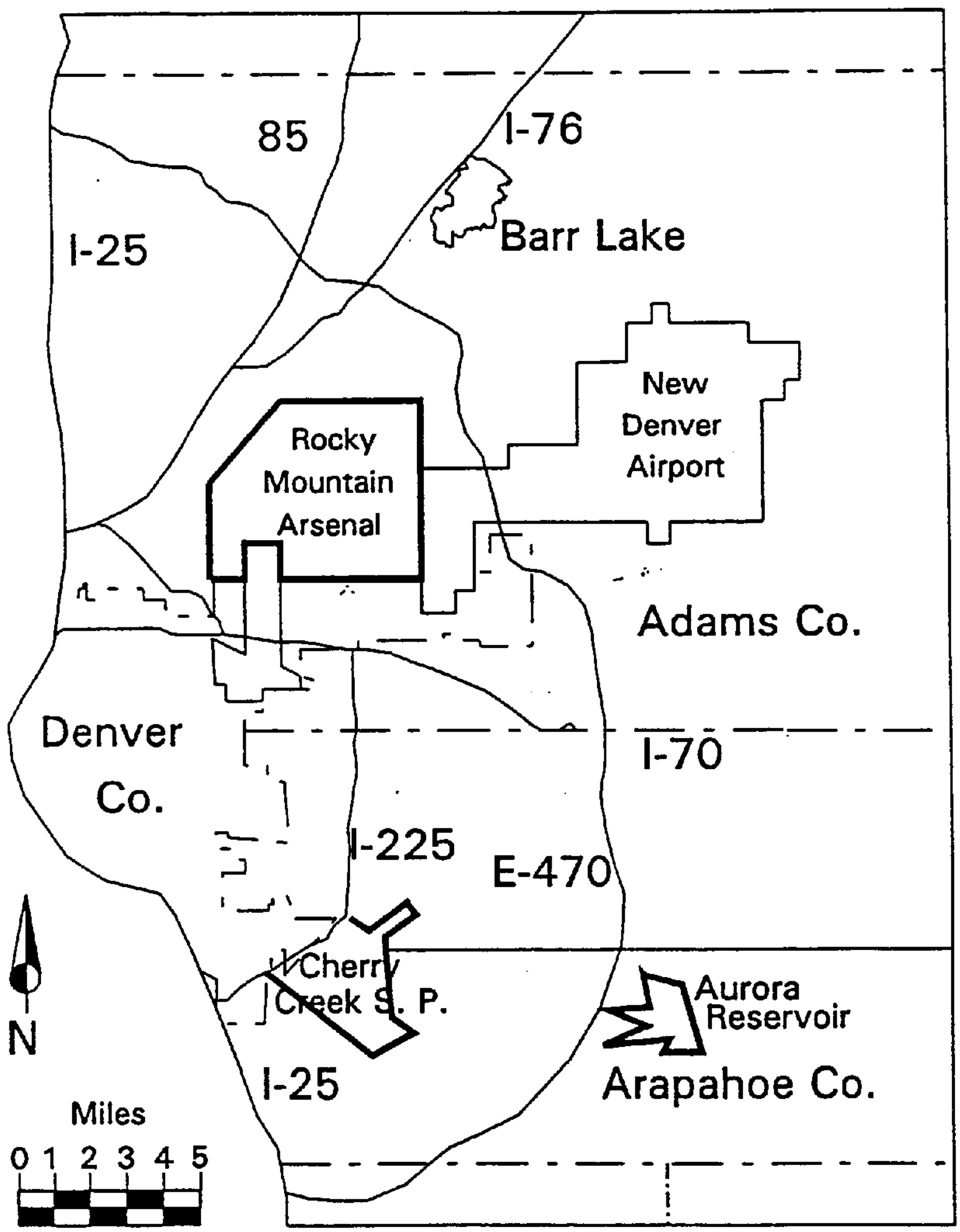


Fig. 1-2. Location of Cherry Creek State Park and Aurora Reservoir.

successful (at least 1 chick fledged). Fledging success Refuge-wide was 2.6 fledglings/nesting attempt. Seven nests failed to produce young. Five of the unsuccessful nests were located within or bordering the central core and the two others were located in peripheral areas of the Refuge (Figure 1-1). Refuge-wide, the average clutch-size (successful and unsuccessful nest attempts) was 4.5 eggs/nest. The average clutch size in the core was 4.5 eggs/nest and 4.6 eggs/nest in the periphery. Refuge-wide, the 18 successful nests produced 65 fledglings or 3.6 fledglings/successful nest (including one chick from each nest collected for chemical residue and biomarker analyses). The one egg collected from each nest box for residue determination was not used in the productivity determination. However, unhatched eggs were included in productivity determinations. When productivity data for 1993 are broken down between the central core and the periphery of the Refuge, kestrels that nested within the central core had significantly lower productivity (i.e., No. young fledged/nest) (Wilcoxon Rank-Sum, $z = -5.79$, $p < 0.05$) (Table 1-1). Nestling survival to fledging was 100% for all areas in 1993.

Table 1-1. Comparison of kestrel productivity (No. young fledged/nest attempt) between the Refuge central core and periphery, 1993.

	Central Core	Periphery
Nests	12	13
Mean young fledged/nest	2.08	3.15
SD	1.89	1.41

In 1994, 35 kestrel nesting attempts (37 nest boxes available) were recorded (11 in the central core, 24 in the periphery of the Refuge) of which 28 (80%) were successful. Fledging success Refuge-wide was 2.8 fledglings/nesting attempt. Seven nests failed to produce any young. Five of the unsuccessful nests were located within the peripheral areas of the Refuge and the two others were located in the central core. Refuge-wide, the average clutch-size (successful and unsuccessful nest attempts) was 4.7 eggs/nest. The average clutch size in the core was 5.0 eggs/nest and 4.45 eggs/nest in the periphery. Refuge-wide, the 28 successful nests produced 100 fledglings or 3.6 fledglings/successful nest (including one chick from each nest collected for chemical residue and biomarker analyses). When productivity data for 1994 are broken down between the central core and the periphery, kestrels that nested within the central core had significantly higher productivity than kestrels that nested in the periphery (Wilcoxon Rank-Sum, $z = -3.41$, $p < 0.05$) (Table 1-2). Nestling survival was 73% for the central core and 97% for the periphery. The Service suspected great horned owl predation at two kestrel nest boxes located in the core. Kestrel remains were found at the base of one box (35SE) and four nestlings disappeared from box 6NW. Peterson (pers. comm.) stated that great horned owl predation on kestrels nesting in boxes was not uncommon in South Dakota. Dead nestlings were found in one nest box in the central core (12NW) and one nest box in the periphery (12SW). The Service suspects that high temperatures were a possible cause of the mortality. Carcasses (2) from nest box 12SW were submitted for residue analyses. The carcass found in box number 12NW was too decayed to be submitted for residue analyses.

Table 1-2. Comparison of kestrel productivity (No. young fledged/nest attempt) between the Refuge central core and periphery, 1994.

	Central Core	Periphery
Nests	11	24
Mean young fledged/nest	3.0	2.8
SD	1.81	1.61

The reference sites used in 1994 had 6 nest attempts (15 nest boxes available), 5 (83%) of which were successful (four nest attempts at Cherry Creek, 2 attempts at Aurora Reservoir). Too few nesting attempts occurred for rigorous comparison to Refuge data. Nevertheless, it appears that kestrel productivity is quite similar to the Refuge. Fledging success at the reference sites was 3.0 fledglings/nesting attempt (SD ± 1.41). The one unsuccessful nest was attributed to great horned owl predation. The remains of the nestlings and the female were found at the base of the nest box. The average clutch-size for reference sites was 4.8 eggs/nest. The five successful nests produced 18 fledglings or 3.6 fledglings/successful nest (including one chick from each nest collected for chemical residue and biomarker analyses). Nestling survival was 82% for the reference sites. A comparison of kestrel nest success from 1982 through 1994 for the Refuge and various reference sites is provided in Fig. 1-3 and Tables 1-3 and 1-4.

The results of the productivity monitoring and egg residue data from 1993 and 1994 were pooled to determine the relationship of dieldrin concentrations in eggs and the number of young fledged per nest attempt. The results of this analysis indicated that there was no correlation ($r = -0.09$) (Fig. 1-4).

In 1994, 14 adult male kestrels were outfitted with transmitters because 1993 observations indicated that males did most of the foraging and females spend most of their time incubating and tending young. In addition, female home ranges and foraging areas were smaller than their mates and fell within those of the males. Kestrels were tracked for only 22 hours and 250 locations were recorded in 1994. In 1993, the Service tracked 23 adult kestrels (male and female) for 114 hours for a total of over 700 locations. The reasons for the reduced tracking time and locational data for 1994 is a result of two primary factors, transmitter failure and the large number of nests monitored ($n = 41$). Nevertheless, locational data for both years were analyzed and area estimates for male and female kestrel territories and foraging areas were calculated. Foraging areas were calculated only with individual kestrels with at least 10 foraging activity locations. Territories (foraging plus non-foraging locations) were calculated for individuals with ≥ 20 locations. In 1993, the average territory of a nesting pair of kestrels was 213 ha (SD ± 159.4 ha, $n = 7$). This area was made up almost entirely of the adult males combined hunting and non-hunting locations. The mean territory of a female kestrel was 29 ha (± 33 ha, $n = 8$). The mean foraging area of an adult male kestrel (1993 and 1994 combined) was 38 ha (± 36 ha, $n = 12$) and that of a female kestrel was 5.8 ha (± 5.4 ha, $n = 3$). Craighead and Craighead (1956) found that the mean territory size of adult kestrels in Wyoming during the breeding season was 202 ha ± 131. Balgooyen (1976) found that during egg laying, incubation, and brooding, female kestrels restricted their activities to a relatively small

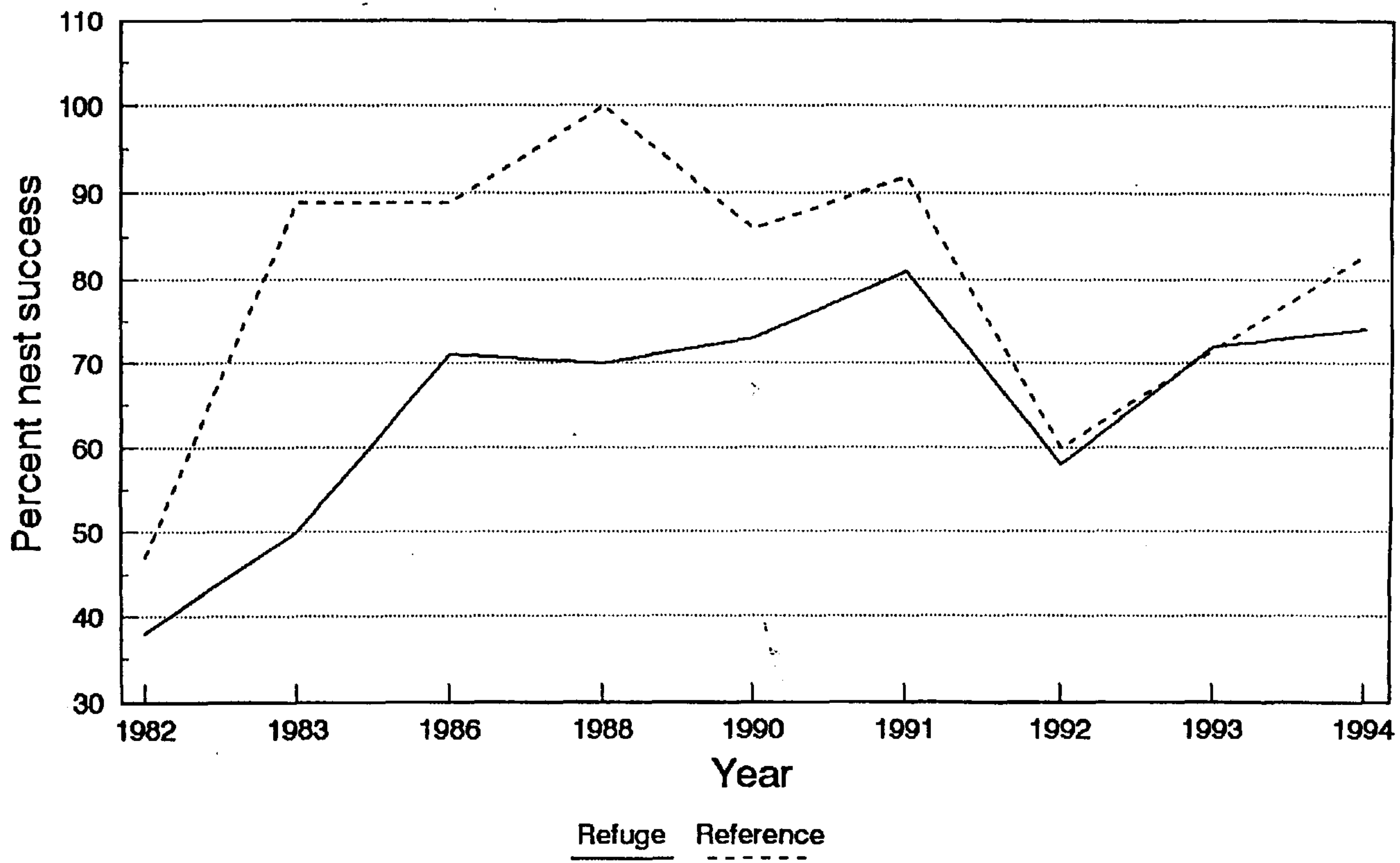


Fig. 1-3. Comparison of kestrel nest success between Rocky Mountain Arsenal NWR and reference sites, 1982-94.

Table 1-3. Summary of American kestrel productivity on Rocky Mountain Arsenal, 1982-94[1].

Year	1982	1983	1986	1988	1990	1991	1992	1993	1994
Nest Attempts	17	26	21	17	21	26	24	25	35
Clutch size	4.59	4.75	4.81	5.00	4.56	5.00	4.54	4.52	4.7
% of Nests Hatched	65	54	81	59	52	85	58	72	80
Hatchlings/Nest	3.09	2.85	3.65	3.14	4.18	3.58	3.86	3.6	3.5
% of Nests Fledged	38	50	71	70	73	81	58	72	74
# Fledged/Successful Nest	2.83	2.67	3.13	4.00	4.00	3.90	3.40	3.6	3.6
# Fledged/Nest Attempt	1.06	1.33	2.24	1.14	1.52	3.31	2.1	2.60	2.80

[1] 1982-1992 American kestrel summary data from Ebasco (written comm.) and DeWeese and McEwen (written comm.)

Table 1-4. Summary of American kestrel productivity from off-Refuge reference sites, 1982-94[1].

Year	1982	1983	1986	1988	1990	1991	1992	1994
Nest Attempts	19	10	9	5	9	12	5	6
Clutch size	4.74	4.80	4.78	5.00	4.89	4.91	5.0	4.8
% of Nest Hatched	58	90	89	60	78	100	80	100
Hatchlings/Nest	3.45	3.11	3.25	2.33	3.57	3.92	4.75	3.7
% of Nest Fledged	47	89	89	100	86	92	60	83
# Fledged/Successful Nest	3.33	3.12	3.12	2.00	3.17	3.90	3.33	3.6
# Fledged/Nest Attempt	1.70	2.78	2.78	1.20	2.11	3.58	2.0	3.0

[1] 1982-1992 American kestrel summary data from Ebasco (written comm.) and DeWeese and McEwen (written comm.)

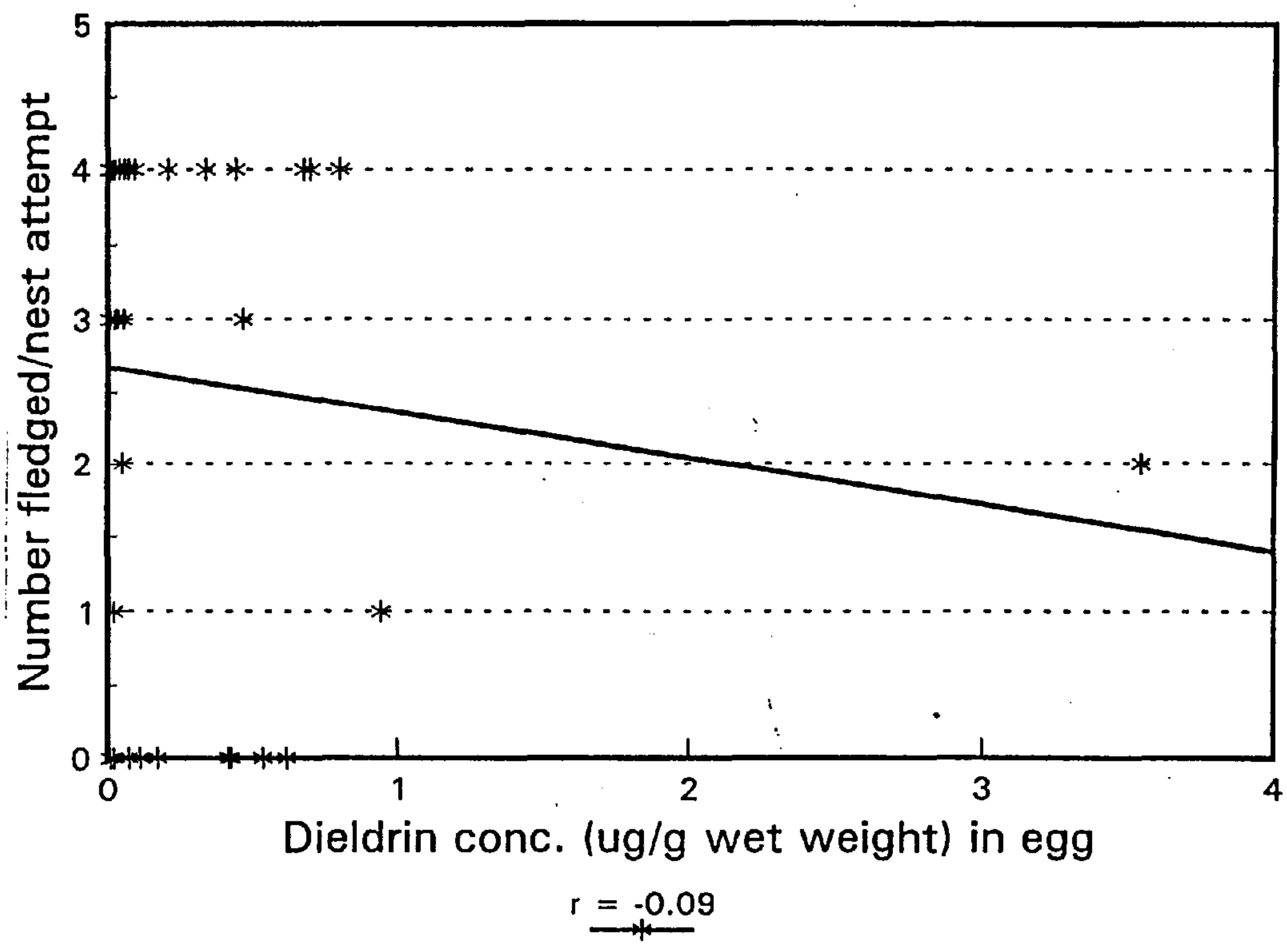


Fig. 1-4. Relation of dieldrin concentrations in kestrel eggs and the number of young fledged per nest attempt, 1993 and 1994.

area several acres in size near the nest and adult males foraged over a much wider area and conducted most of the hunting. The results of this study are consistent with Craighead and Craighead (1956) and Balgooyen (1976) findings. The Service will conduct additional telemetry on adult males and females in 1995 to validate the 1993 and 1994 observations. During the course of this two year investigation, only two transmittered kestrels were found dead. Unfortunately, both carcasses were too decayed for necropsy or residue analyses.

Results from over 200 hundred biological samples collected for the kestrel study during 1993 and 1994 have been received. A brief synopsis follows. The ten target analytes were analyzed in kestrel egg, carcass, liver, prey item, and brain. The most frequently reported analyte for 1993 and 1994 was dieldrin (119/251 = 47%) followed by ppDDE (106/251 = 41%). All other analytes were reported in less than 10% of the samples (Table 1-5). A further breakdown of the analytical data shows that dieldrin was reported in 82% (53/65) of the samples collected from the central core, 42% (55/130) in the periphery, and 0.05% (1/18) of the samples collected from the reference sites (Table 1-6.). Analytical results from the prey samples revealed that only eight of the 38 samples had reportable quantities of dieldrin (Table 1-5).

Table 1-5. Frequency of detections (No. detects/total samples) and maximum concentrations (ug/g wet weight) of target analytes in various kestrel tissues and prey items, 1993-94.

Tissue	As	Hg	Isodrn	Acldn	Aldrn	Dldrn	Endrin	Gcldn	ppDDE	ppDDT
Carcass	1/48 (1.4)	0/47	0/49	0/49	0/49	30/49 (2.84)	0/49 (0.015)	0/49	41/49 (1.18)	0/49
Egg	0/48	0/36	0/74	0/74	0/74	49/74 (6.24)	8/74	0/74	61/74 (4.08)	16/74 (0.055)
Liver	--	--	0/46	0/46	0/46	25/46 (2.8)	0/46	0/46	1/46 (0.1)	0/46
Prey Item	0/10	0/2	0/38	0/38	0/28	8/38 (3.29)	0/38	0/38	3/38 (.19)	0/38
Brain	--	--	0/46	0/46	0/46	7/46 (1.48)	0/46	0/46	0/46	0/46

Table 1-6. Frequency of detection (No. detects/total samples) of dieldrin and maximum concentration (ug/g wet weight) by treatment area, 1993 & 1994[1].

Tissue	Core Dldrn	Periph Dldrn	Ref. Site Dldrn	Sample size
Carcass	15/15 (2.84)	15/30 (0.18)	0/4	49
Egg	21/24 (6.21)	25/43 (0.62)	1/7 (0.016)	74
Liver	12/14 (2.8)	13/29 (0.59)	0/3	46
Brain	5/13 (1.48)	2/29 (0.09)	0/4	46

[1] No reference site was used in 1993.

Statistical analyses of residue data from eggs in 1993 show that concentrations of dieldrin were significantly higher (Wilcoxon Rank-Sum test, $z = -5.87$, $p < 0.05$) in the central core than the periphery. In 1994, there was also a significant difference (Wilcoxon Rank-sum test, $z = -2.32$, $p < 0.05$) in the concentrations of dieldrin in eggs from the central core and periphery. (Tables 1-7, 1-8, and 1-9). Dieldrin was detected in only one egg from the reference sites (Table 1-6).

Table 1-7. Comparison of dieldrin concentrations (ug/g wet weight) in kestrel eggs from the Refuge central core and periphery, 1993.

	Central Core	Periphery
n	13	12
Mean	0.99	0.06
SD	1.76	0.01

Table 1-8. Comparison of dieldrin concentration (ug/g wet weight) in kestrel eggs from the Refuge central core and periphery, 1994.

	Central Core	Periphery
n	12	29
Mean	0.24	0.042
SD	0.32	0.11

Table 1-9. Comparison of dieldrin concentrations (ug/g wet weight) in kestrel eggs from the Refuge central core, 1993 and 1994.

	Central Core 93	Central Core 94
n	13	12
Mean	0.99	0.24
SD	1.76	0.32

Concentrations of dieldrin in kestrel nestlings were highest in birds collected from the central core in both 1993 and 1994 (Tables 1-10 and 1-11). Too few nestlings were collected from the central core for rigorous statistical analysis. However, the mean concentration of dieldrin in kestrel carcasses from the core was >33 times higher than the mean concentration found in carcasses collected from the periphery in 1993 and 1994. Dieldrin was not reported in kestrel carcasses collected from reference sites in 1994.

Table 1-10. Comparison of dieldrin concentrations (ug/g wet weight) in kestrel carcasses from the Refuge central core and periphery, 1993.

	Central Core	Periphery
n	7	11
Mean	0.81	0.024
SD	0.64	0.019

Table 1-11. Comparison of dieldrin concentrations (ug/g wet weight) in kestrel carcasses from the Refuge central core and periphery, 1994.

	Central Core	Periphery
n	7	20
Mean	1.14	0.034
SD	1.2	0.009

A distribution analysis (box and whisker diagram) of the dieldrin residue data pooled for 1993 and 1994 revealed that the majority of the outlying dieldrin concentrations found in carcasses and eggs were typically collected from the same four or five nest boxes located in the central core (Figures 1-5 and 1-6). The median concentration of dieldrin in kestrel carcasses from the Refuge for 1993/1994 was 0.025 ug/g wet weight. The median concentration of dieldrin in kestrel eggs was 0.021 ug/g wet weight for that same period.

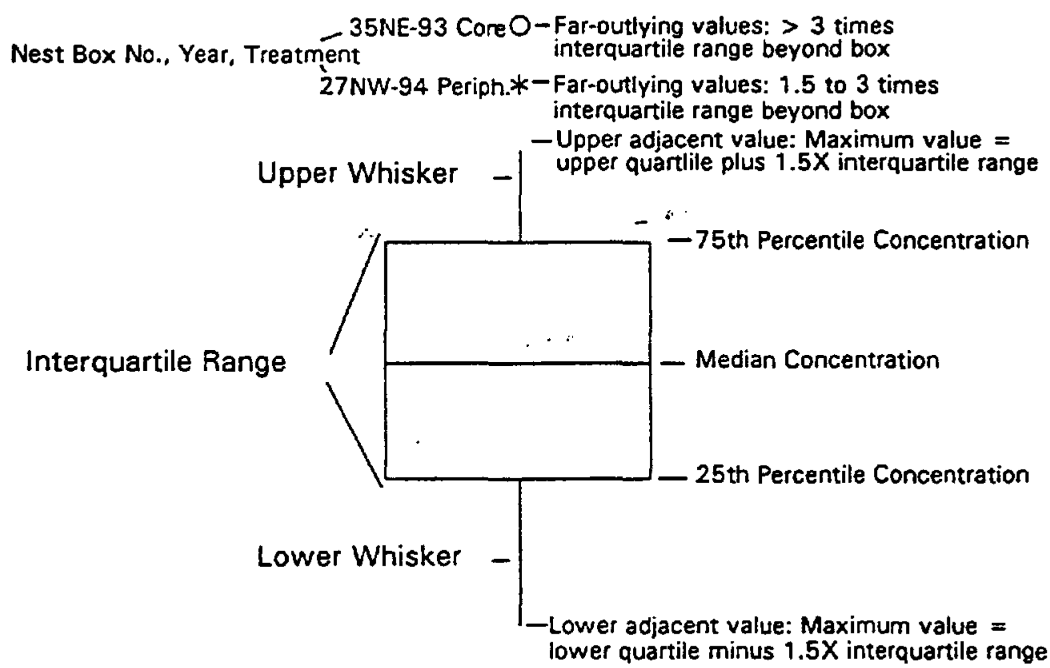
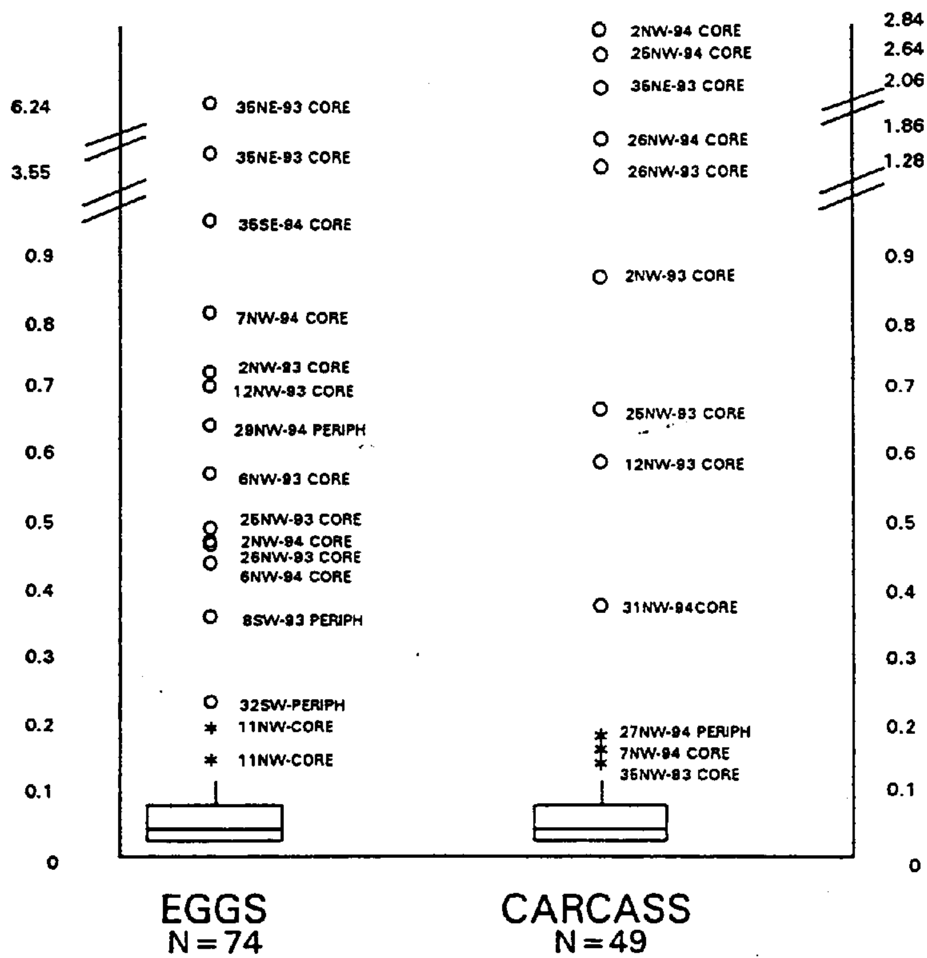


Fig. 1-5. Box and whisker diagram explanation.



* O Far outlying concentrations of dieldrin are typically reported in samples collected from the same group of nest boxes located in the central core of the Refuge

Fig. 1-6. Box and whisker diagram of the distribution of dieldrin concentrations in kestral carcasses and eggs, 1993 and 1994.

The Service analyzed various kestrel tissues for several biomarkers in hopes of determining if exposure to contaminants was causing toxicological responses in kestrel chicks. Unfortunately, not all data were received and reviewed in time for this report. A brief synopsis of some of the results of data received thus far are provided.

The mean hepatic Ethoxyresorufrin O-dealkylase (EROD) activity was higher in kestrel chicks from the central core in 1993 and 1994 (Tables 1-12 and 1-13). EROD is a P-450 enzyme involved in the biotransformation and metabolism of organic compounds. This enzyme is therefore useful in determining exposure to such chemicals. However, there was no strong correlation between liver dieldrin concentration and EROD (Fig. 1-7). This analysis was performed on 1994 data only because too few liver samples collected in 1993 had reportable concentrations of dieldrin. Interestingly, the highest EROD activities recorded for both years were in livers collected from kestrel nestlings from nest box 25NW. This nest box is located approximately 200 meters northeast of the Submerged Quench Incinerator.

Table 1-12. Comparison of Ethoxyresorufrin O-dealkylase (EROD) activity (nmol/mg protein/min.) in livers of kestrel nestlings from the Refuge central core and periphery, 1993.

	Central Core	Periphery
n	7	11
Mean	0.114	0.048
SD	0.144	0.022

Table 1-13. Comparison of Ethoxyresorufrin O-dealkylase (EROD) activity (nmol/mg protein/min.) in livers of kestrel nestlings from the Refuge central core, periphery, and reference sites, 1994.

	Central Core	Periphery	Reference
n	6	16	3
Mean	0.27	0.25	0.15
SD	0.345	0.167	0.043

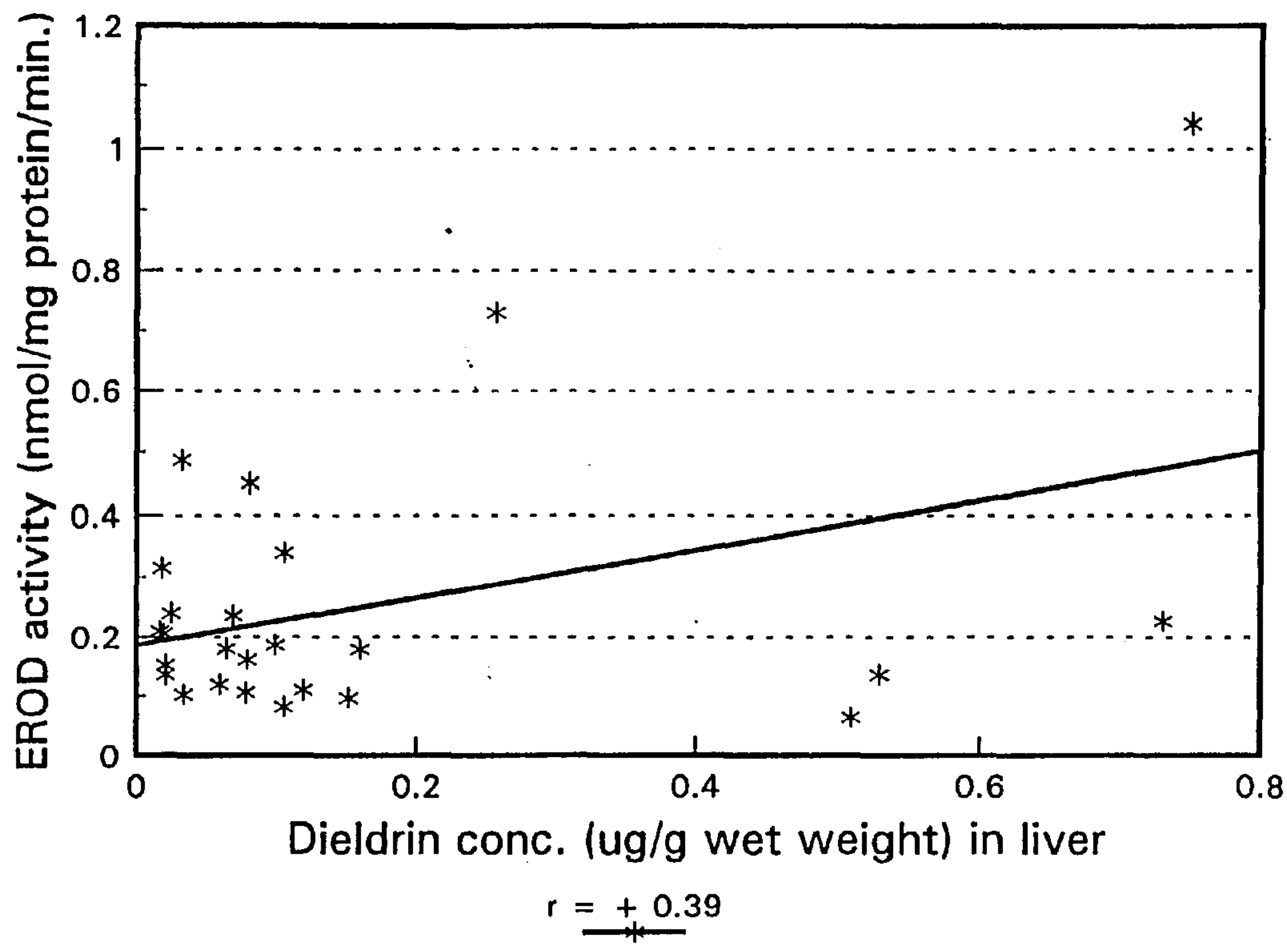


Fig. 1-7. Relation between Ethoxyresorufrin O-dealkylase (EROD) activity and dieldrin concentrations in kestrel livers, 1994.

The Service also evaluated the immune system effects (T and B-cell proliferation from splenocytes) of kestrel nestlings in 1994 and compared individuals from the central core, periphery, and reference sites. Several chemicals present at the Refuge, including dieldrin, have been shown to affect immune systems of a variety of animals under laboratory conditions. There was no significant difference between the three treatments (Table 1-14).

Table 1-14. Comparison of stimulation indices of T and B - cell populations from splenocytes of kestrels collected from the Refuge central core (C), periphery (P), and reference sites (R), 1994.

	Phytohaemagglutin-p (5ul)			Lipopolysaccaride-E.coli (5ul)			Phytohaemagglutin-m (5ul)		
	C	P	R	C	P	R	C	P	R
n	7	14	5	7	14	5	7	14	5
Mean	23.6	12.9	4.2	23.3	32.2	18.3	94.1	61.2	22.8
SD	35.3	19.2	4.1	34	31.96	22.8	128	83.7	25.8

A Kruskal-Wallis test indicated no significant difference in the means ($H = -12.7$ for PP5, -14.8 for LE5, and -3.6 for PM5, $P > 0.05$). However, sample sizes from the central core and reference sites may be too small to detect significant changes in T or B-cell stimulation indices.

DISCUSSION

As with previous programs, dieldrin was the most frequent Refuge-specific contaminant found in kestrels. It is infrequently found in kestrels collected from reference sites. DDE, which was also found frequently, is more ubiquitous in the environment, and as a result is commonly found in Refuge and reference site kestrels.

When compared qualitatively to previous years, overall kestrel productivity appears consistent with previous trends, i.e., generally stable nest success since 1986. DeWeese and McEwen (written comm.) found that kestrel nest success in 1982 was considerably lower than off-post reference sites (38% vs. 47%) and remained lower through 1986. However, current kestrel nest success on the Refuge is similar to reference sites and other enhanced populations in the western United States (Bloom and Hawks 1983; Toland and Elder 1987).

When current dieldrin concentrations found in kestrels collected from the Refuge are compared to concentrations reported to cause biological effects in kestrels and/or other avian species, it is apparent that kestrel populations are not likely to be directly affected by dieldrin. DeWeese and McEwen (written comm.) reported that the geometric mean concentration of dieldrin in eggs from 1982-83 to 1986 decreased (mean 1982/83 = 0.115, 1986 = 0.005 ug/g wet weight). The maximum concentration of dieldrin found in eggs in 1982/83 was 1.68 ug/g. The maximum concentration found in 1986 was 2.82 ug/g. In 1986, the arithmetic mean concentration of dieldrin was 0.504 ug/g wet weight. The raw analytical data from eggs collected from 1982/83 were not available to calculate geometric mean concentration in time for this report. DeWeese and

McEwen (written comm.) also found that there was no relationship between dieldrin concentrations in eggs and reproductive success. The arithmetic mean concentration of dieldrin reported in kestrel eggs collected from the Refuge in 1993/1994 was 0.246 ug/g wet weight (n = 74) (maximum concentration = 6.21 ug/g). The geometric mean concentration was 0.035 ug/g wet weight.

Lockie et al. (1969) and Lockie and Ratcliffe (1964) reported that when mean concentrations of dieldrin exceeded 1 ug/g wet weight in eggs of golden eagles (Aquila chrysaetos) in Scotland the population experienced poor reproductive success. However, Mendenhall et al. (1983) found that elevated dieldrin in eggs (x = 8.0 ug/g wet weight) did not significantly reduce reproductive success of captive barn owls (Tyto alba). Fowler et al. (1971) also found that dieldrin in eggs did not affect hatchability or chick survival in purple gallinules (Porphyrula martinica) and common gallinules (Gallinula chloropus) (mean dieldrin concentrations 6.51 and 9.37 ug/g wet weight, respectively). Potts (1968) found that shags (Phalacrocorax aristotelis) experienced reproductive failure when dieldrin concentrations in eggs exceeded 2 to 3 ug/g. Although the data on dieldrin effects on avian reproduction is somewhat contradictory, it is apparent that concentrations of dieldrin in kestrel eggs are significantly below levels where reproductive impacts at the population level are likely to occur.

The concentrations of dieldrin in nestling carcasses have not dropped since 1986. DeWeese and McEwen (written comm.) found that in 1986 the arithmetic mean concentration of dieldrin was 0.309 ug/g wet weight (maximum concentration 1.01 ug/g). In 1993-1994, the arithmetic mean concentration of dieldrin in nestling carcasses was 0.297 ug/g (n = 44)(maximum concentration 2.84 ug/g).

Stickel et al. (1969) concluded that dieldrin residues in brain tissue were superior to other tissues for determining the likelihood that birds were killed or seriously endangered by dieldrin. Stickel et al. (1969) reported on a range of dieldrin concentrations detected in brains of several species of raptors that were either found dead in the wild, or in convulsions, or experimentally poisoned. The dieldrin concentrations ranged from 4.4 to 12.0 ug/g wet weight (x = 8.1 ug/g). Wiemeyer et al. (1986) found that kestrels that were suspected of dying from dieldrin poisoning during a series of dieldrin + DDE + DDT dietary exposure studies had dieldrin concentrations in brain tissue ranging from 5.0 to 11.0 ug/g wet weight. Heinz and Johnson (1982) found similar concentrations of dieldrin in brains of brown-headed cowbirds (Molothrus ater) experimentally poisoned with dieldrin. However, the authors also studied sublethal responses (dieldrin-induced starvation) of cowbirds. The authors demonstrated that brain residues, perhaps as low as 1 ug/g in highly sensitive individuals, may be hazardous to birds by triggering irreversible starvation.

The maximum concentration of dieldrin reported in kestrel nestling brain tissue was 1.48 ug/g wet weight. Dieldrin was found in only 7 of the 46 brain samples collected from 1993 and 1994. Based on this information, it is unlikely that kestrel nestlings, Refuge-wide, would be seriously endangered by dieldrin.

CONCLUSION

Based on this preliminary analysis of data collected for this investigation, kestrel populations at the Refuge are not being affected by contamination. However, there is still the potential for contaminants, especially dieldrin, to affect individual kestrels. This situation would most likely occur in limited areas of the Refuge located near the disposal basins (Basins A or F) and the South Plants Complex (areas where the largest concentrations of dieldrin in kestrel tissues and soil are found). Concentrations of dieldrin in kestrel tissues have not changed substantially since 1986 even though numerous Interim Response Actions (IRA's) have been implemented. In fact, the highest concentrations of dieldrin reported in kestrel eggs and carcasses since the initiation of the kestrel monitoring program in 1982 were found in 1993 and 1994. It is apparent that the IRA's, with the exception of Basin F closure, have done little to reduce the risks of contaminant exposure and effect to kestrels on the Refuge. In addition, the potential exists for contaminant-induced effects to occur during remediation. Contaminants (organic and inorganic) currently located in the disposal basins could be liberated and mobilized during excavation of the basins. Other contaminants (organic and inorganic) could be formed and deposited on the Refuge during incineration operations. Therefore, monitoring of kestrel productivity, tissue residues, and biomarker activity should continue throughout clean-up.

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TITLE: Aquatic Biomonitoring Program

Urban runoff

Researches from Colorado State University will also be conducting toxicity tests on water from the Havana Interceptor, Havana Canal, and First Creek to assess potential impacts of contaminants entering the Refuge from industrial and residential areas south of the Refuge. Preliminary testing was conducted on Havana Interceptor and Havana Canal in 1994. Results are reported in the appendices under the title "Effects of sediment contaminants on macroinvertebrate and fish assemblages in the lower lakes at Rocky Mountain Arsenal."

Fish Health

Personnel from the U.S. Fish and Wildlife Service Fish Disease Control Center and the Bozeman Fish Technology Center prepared and examined histology slides from 10 bluegill collected from each of the three lakes on 7-8 June, 1994. The following results were provided by these cooperators.

Samples from Lake Ladora showed moderate basal hyperplasia of gill epithelium; glycogen vacuolation was varied from none to mild in liver samples, parasites were found in all fish livers and were moderately severe to severe; and one fish showed degenerative changes in the liver.

Samples from Lake Mary showed moderate hyperplasia in gill epithelium and moderately severe inflammation of gill tissue; a parasite was observed in one kidney sample; in the liver, glycogen vacuolation was none to mild and macrophage aggregates were mild to moderate, there was scattered degeneration of hepatocytes (parenchyma) in one sample, and moderate numbers of parasites were seen in five of seven fish.

Samples from Lower Derby Lake showed gill tissue to be mostly normal with some inflammation at the base of filaments and one fish showed an epitheliocystis infection; heart tissues had moderately severe infections of parasites; liver parasite infections ranged from moderate to severe, liver glycogen vacuolation ranged from none to mild, and degeneration and necrosis (cell death) of hepatocytes was moderate to moderately severe; kidney samples displayed severe parasite infections; spleens had abundant macrophage aggregates and severe parasite infection; a testis sample was normal, and stomachs were full of food.

Macrophage aggregates are localized centers of phagocytes that serve as indicators of diseased or damaged tissue. Hyperplasia is an abnormal increase in the number of cells composing a tissue or organ. Vacuolation is the formation or arrangement of vacuoles which are the fluid filled cavities in the cytoplasm of a cell, surrounded by a membrane that ususally encloses food, water, or air. Carbohydrates are stored in the liver as glycogen. Warmwater fish usually have considerable amounts of glycogen in the liver. The parasites observed were probably cestodes but could have been trematodes in many stages of degeneration. The tissue parasite load could probably be used as an indicator of stressed populations and could be evaluated grossly. This general survey of bluegill was only an initial investigation with a small sample size. In addition, some samples had poor fixation due to the preservative that was used. However, overall, Lower Derby fish appeared to be in the poorest condition. Additional species and greater numbers of fish will be collected in 1995.

Waterfowl

The objectives of waterfowl investigations under the ABM are to: 1) determine if waterfowl using Refuge lakes and wetlands contain significant concentrations of contaminants, 2) determine possible sources of contaminants to waterfowl, particularly through food items, 3) document and quantify waterfowl reproduction on the Refuge, and 4) determine which age, sex, and species of waterfowl may be the best indicators of contaminant impacts on the Refuge. The lakes and other aquatic habitats on the Refuge are used by pelicans, shorebirds, wading birds, and songbirds as well as waterfowl. However, many of these species are only on the Refuge for a short period of time (e.g. migration), occur in small numbers, or use both terrestrial and aquatic habitats making study of impacts from contaminated sediments difficult. Therefore, waterfowl (ducks, geese, coots) are being examined and are assumed to be representative of other birds that may use Refuge aquatic habitats. Shorebirds which use exposed sediment at the edge of water bodies, or possibly diving ducks, are the only species with potential direct exposure to sediments. Others would be exposed through food items or water.

The migratory habits of waterfowl make it difficult to determine where any detected contaminants have been accumulated from. This investigation focuses on the reproductive season because of concerns that contaminants could affect reproduction, and because waterfowl may be more susceptible to contaminant impacts during the reproductive season due to feeding habits. Ducks eat more animal foods during the breeding season because of protein demands for egg production (Martin et al. 1951, Krapu 1974, Johnsgard 1975, Swanson et al. 1985). In addition, ducks in the prenesting and nesting stage are less mobile (Derrickson 1978) and may spend more time on specific sites than at other times of the year. American coots (Fulica americana) feed mostly on aquatic vegetation, but will eat more animal foods during summer (Martin et al. 1951, Bent 1963, Ehrlich et al. 1988). Coots also have a relatively small home range during nesting (Sugden 1979). Thus, breeding birds may spend more time at specific sites on the lakes where contaminants could be accumulated.

Concentrations of contaminants in waterfowl tissues may also indicate potential hazards for human consumption of waterfowl using the Refuge lakes but that are shot by hunters off of the Refuge. Waterfowl were to be collected in the fall of 1994 to compare to other times of the year and to represent birds potentially taken by hunters. However, there were insufficient numbers of waterfowl, or birds could not be approached within shooting range, prior to closure of the Bald Eagle Management Area on 15 October.

Fifteen ducks or coots were collected by shotgun in 1994. All birds were weighed after collection and appeared to be in good condition and health. Two adult male coots, 1 female coot, one coot of undetermined sex, and 2 juvenile coots (1 female) were collected. Adult coot weights ranged from 0.45 to 0.80 kg. The juvenile coots weighed 0.019 kg and 0.35 kg. One female coot (94Aq02, Table 1-15) was collected with her newly hatched chick (94Aq01) and 2 eggs. Three male and 2 female redhead ducks (Aythya americana) were collected and weights ranged from 0.95 to 1.05 kg. Two male and two female mallards (Anas platyrhynchos) were collected ranging in weight from 0.90 to 1.25 kg.

Two juvenile Canada geese (Branta canadensis) were collected in Section 35 from the Building 111 lawn. These goslings had not yet developed breast muscle, therefore only brain and liver were collected. Juvenile Canada geese were collected because most geese on the Refuge are resident and may indicate whether contaminant accumulation occurs on the Refuge. Adult geese feed primarily on vegetation, but goslings may eat some animal matter.

Brain, liver, breast muscle, gastrointestinal tract and gizzard contents (GI contents), and eggs (if present) were dissected for chemical analyses.

Table 1-15. Contaminants detected (ppm wet weight) in waterfowl collected on the Refuge in 1994.

Sample Number	Species	Date Collected	Location	Tissue	Dieldrin[a]	DDE	Mercury
94Aq01	Coot	6/10/94	L. Ladora	carcass	0.080	0.025	bcrl
94Aq02	Coot	6/10/94	L. Ladora	liver	0.038	bcrl	
94Aq02	Coot	6/10/94	L. Ladora	brain	bcrl[b]	bcrl	0.086
94Aq02	Coot	6/10/94	L. Ladora	muscle	bcrl	bcrl	bcrl
94Aq02	Coot	6/10/94	L. Ladora	GI contents	bcrl	bcrl	
94Aq02	Coot	6/10/94	L. Ladora	egg #1	0.101	0.026	bcrl
94Aq02	Coot	6/10/94	L. Ladora	egg #2	0.116	0.029	bcrl
94Aq03	Coot	6/10/94	L. Ladora	liver	0.226	0.023	bcrl
94Aq03	Coot	6/10/94	L. Ladora	brain	bcrl	bcrl	
94Aq03	Coot	6/10/94	L. Ladora	muscle	0.065	0.051	
94Aq03	Coot	6/10/94	L. Ladora	GI contents	0.036	bcrl	bcrl
94Aq04	Coot	6/10/94	L. Ladora	liver	0.158	0.024	bcrl
94Aq04	Coot	6/10/94	L. Ladora	brain	0.052	bcrl	
94Aq04	Coot	6/10/94	L. Ladora	muscle	0.017	bcrl	bcrl
94Aq04	Coot	6/10/94	L. Ladora	GI contents	0.038	bcrl	bcrl
94Aq05	Coot	6/10/94	L. Ladora	liver	0.075	0.017	0.137
94Aq05	Coot	6/10/94	L. Ladora	brain	bcrl	bcrl	
94Aq05	Coot	6/10/94	L. Ladora	muscle	bcrl	bcrl	bcrl
94Aq05	Coot	6/10/94	L. Ladora	GI contents	0.018	bcrl	bcrl
94Aq06	redhead	6/10/94	L. Ladora	liver	0.117	0.017	bcrl
94Aq06	redhead	6/10/94	L. Ladora	brain	bcrl	bcrl	
94Aq06	redhead	6/10/94	L. Ladora	muscle	0.027	bcrl	bcrl
94Aq06	redhead	6/10/94	L. Ladora	GI contents	0.062	bcrl	

Table 1-15 (Continued).

Sample Number	Species	Date Collected	Location	Tissue	Dieldrin	DDE	Mercury
94Aq07	redhead	6/10/94	L. Ladora	liver	0.373	0.035	bcrl
94Aq07	redhead	6/10/94	L. Ladora	brain	0.071	bcrl	
94Aq07	redhead	6/10/94	L. Ladora	muscle	0.068	bcrl	bcrl
94Aq07	redhead	6/10/94	L. Ladora	GI contents	0.057	bcrl	bcrl
94Aq07	redhead	6/10/94	L. Ladora	eggs (4)	1.2	0.159	bcrl
94Aq08	redhead	6/10/94	wetland 1	liver	bcrl	bcrl	0.812
94Aq08	redhead	6/10/94	wetland 1	brain	bcrl	bcrl	
94Aq08	redhead	6/10/94	wetland 1	muscle	bcrl	bcrl	0.375
94Aq08	redhead	6/10/94	wetland 1	GI contents	bcrl	bcrl	
94Aq09	redhead	6/10/94	wetland 1	liver	bcrl	bcrl	1.58
94Aq09	redhead	6/10/94	wetland 1	brain	bcrl	bcrl	
94Aq09	redhead	6/10/94	wetland 1	muscle	bcrl	bcrl	0.338
94Aq09	redhead	6/10/94	wetland 1	GI contents	bcrl	bcrl	bcrl
94Aq10	C. goose	6/15/94	sec 35	liver	0.039	bcrl	bcrl
94Aq10	C. goose	6/15/94	sec 35	brain	bcrl	bcrl	
94Aq10	C. goose	6/15/94	sec 35	GI contents	bcrl	bcrl	bcrl
94Aq11	C. goose	6/15/94	sec 35	liver	0.029	bcrl	bcrl
94Aq11	C. goose	6/15/94	sec 35	brain	bcrl	bcrl	
94Aq11	C. goose	6/15/94	sec 35	GI contents	bcrl	bcrl	bcrl
94Aq12	redhead	6/17/94	L. derby	liver	0.090	bcrl	bcrl
94Aq12	redhead	6/17/94	L. derby	brain	0.027	bcrl	
94Aq12	redhead	6/17/94	L. derby	muscle	0.062	0.019	bcrl
94Aq12	redhead	6/17/94	L. derby	GI contents	0.046	bcrl	bcrl

Table 1-15 (Continued).

Sample Number	Species	Date Collected	Location	Tissue	Dieldrin	DDE	Mercury
94Aq13	mallard	6/17/94	L. derby	liver	0.053	bcrl	bcrl
94Aq13	mallard	6/17/94	L. derby	brain	bcrl	bcrl	
94Aq13	mallard	6/17/94	L. derby	GI contents	0.054	bcrl	bcrl
94Aq14	coot	6/17/94	L. Ladora	liver	bcrl	bcrl	0.115
94Aq14	coot	6/17/94	L. Ladora	brain	bcrl	bcrl	
94Aq14	coot	6/17/94	L. Ladora	muscle	bcrl	bcrl	bcrl
94Aq14	coot	6/17/94	L. Ladora	GI contents	bcrl	bcrl	bcrl
94Aq15	mallard	6/21/94	sec. 12	liver	0.025	0.017	0.256
94Aq15	mallard	6/21/94	sec. 12	brain	bcrl	bcrl	
94Aq15	mallard	6/21/94	sec. 12	muscle	bcrl	bcrl	0.082
94Aq15	mallard	6/21/94	sec. 12	GI contents	bcrl	bcrl	bcrl
94Aq16	mallard	6/21/94	sec. 12	liver	0.023	0.025	0.111
94Aq16	mallard	6/21/94	sec. 12	brain	bcrl	bcrl	
94Aq16	mallard	6/21/94	sec. 12	muscle	bcrl	bcrl	0.095
94Aq16	mallard	6/21/94	sec. 12	GI contents	bcrl	bcrl	bcrl
94Aq17	mallard	10/6/94	North Bog	liver			
94Aq17	mallard	10/6/94	North Bog	brain			
94Aq17	mallard	10/6/94	North Bog	muscle			
94Aq17	mallard	10/6/94	North Bog	GI contents	bcrl	bcrl	

[a]blank spaces indicate data not yet received.
[b]bcrl = below certified reporting limit.

Analytical results as well as collection dates and locations are given in Table 1-15. Complete analytical results have not yet been received. Specific collection locations are shown in Figure 1-8.

The range of dieldrin in brain tissue was 0.027 to 0.071 ppm, in liver 0.023 to 0.373 ppm, in muscle 0.017 to 0.068 ppm, and in GI contents 0.018 to 0.062 ppm. DDE ranged from 0.017 ppm in 3 liver samples to 0.159 ppm in a composite egg sample. Mercury was detected in 11 muscle, liver, and brain samples and ranged from 0.082 to 1.58 ppm. There were only two detections of arsenic at 0.496 ppm (94Aq02, GI contents) and 0.451 ppm (94Aq14, GI contents). There were no detections of aldrin, endrin, alpha-chlordane, gamma-chlordane, or isodrin.

The maximum concentration of dieldrin detected in Lake Ladora was 1.20 ppm in the eggs of a redhead duck (94Aq07). This same duck had the highest overall liver, brain, and muscle concentrations of dieldrin. The eggs also had the only detection of DDT at 0.02 ppm and the highest concentrations of DDE detected (0.159 ppm). The highest liver concentration of DDE (0.035 ppm) was also found in this redhead. A male redhead collected with the above redhead had the highest concentration of dieldrin in GI contents. The maximum dieldrin concentration in Lower Derby was 0.090 ppm in the liver of a redhead. Two redheads (94Aq08, 94Aq09) collected from the wetland in Section 8 had no detections of organochlorines, but did have the highest concentrations of mercury detected thus far.

White et al. (1981) found dieldrin in only one out of 41 migrant blue-winged teal carcasses. They found DDE in 4 carcasses from 0.11 to 1.20 ppm. White (1976) found DDE and/or DDT in 48 of 50 livers of waterfowl from Louisiana. DDE ranged from 0.02 to 38.69 ppm and DDT from 0.01 to 10.90 ppm. Four of their samples contained trace levels of dieldrin. In waterfowl collected in New York, Kim et al. (1984) found a mean liver DDE concentration of 0.09 ppm, mean brain concentrations of 0.017 ppm, and mean breast muscle concentration of 0.16 ppm. Mercury was detected from 0.02 to 10.0 ppm in livers and from 0.02 to 0.478 ppm in breast muscle of waterfowl in New York (Baker et al. 1976). DDE and mercury detections were similar to or lower than that found in some literature (Table 1-15). However, dieldrin was detected in 12 out of 15 liver samples and 7 out of 14 GI contents samples from the Refuge. Overall, most detections of organochlorines from data thus far received were in liver samples. Dieldrin and DDE concentrations in GI contents and liver samples suggest that the collected birds were recently exposed. In addition, coots collected from Lake Ladora with young probably had not ranged beyond Lake Ladora since initiating their nests. The incubation time of coots is 21 to 25 days. All coots had dieldrin concentrations in the liver, and 3 out of 4 had detections in GI contents, and detections in eggs laid by 94Aq02.

Cattails around Lake Ladora and upland areas around the wetlands in Section 7 were searched for waterfowl nests in May. However, search time was limited by personnel constraints. Two American coot (Fulica americana) nests were found on southern Lake Ladora and an incidental mallard (Anas platyrhynchos) nest was found in southern Section 12. The coot nests were successful. The mallard hen layed 9 eggs by 27 May, but the nest was found destroyed and the hen killed by a predator on June 11. An unidentified duck nest was also reported near wetland 2 but was also destroyed.

Eight waterfowl broods were reported by Service personnel on the Refuge. A mallard brood was observed on Highline Canal May 11, a brood of unknown species on First Creek on June 8, a brood of unknown species on wetland 4 on 20 June, 2 broods (one mallard) on North Bog 24 June and 3 August, 2 unknown broods on Havana Pond on 28 June, a pied-billed grebe (Podilymbus podiceps) brood on wetland 1 on 15 July, and 2 juvenile coots on Lake Ladora on 1 August. In addition, 2 juvenile coots were collected and 2 others were

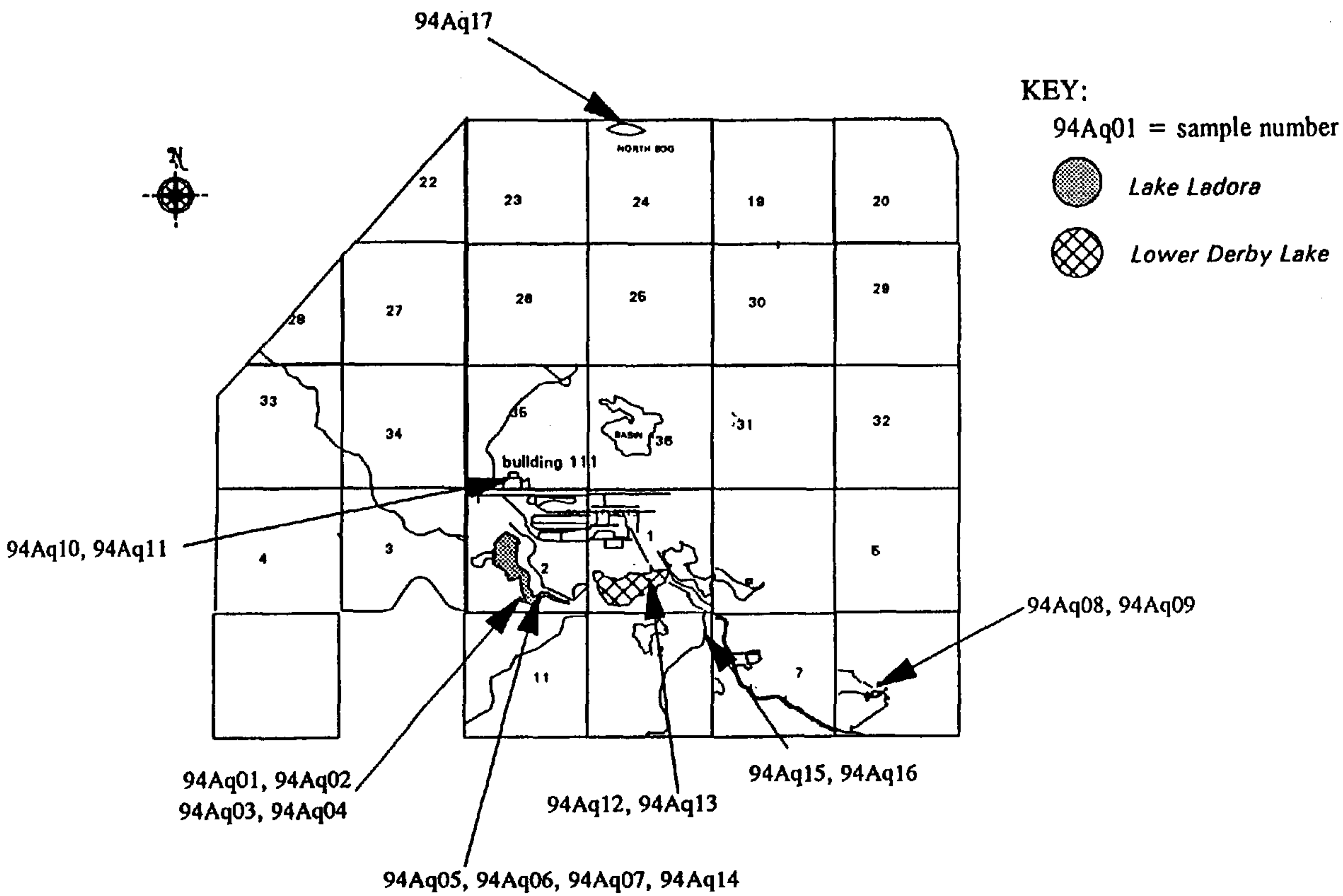

Fig. 1-8. Waterfowl collection locations on the RMANWR in 1994.

observed on Lake Làdora on 10 June. A redhead hen (94Aq07) that was collected on Lake Ladora contained eggs at the laying stage.

This initial investigation indicated that waterfowl may be accumulating contaminants from Refuge aquatic habitats. A more intensive reproduction survey and collections of waterfowl from a reference site, in addition to collections on the Refuge, will be conducted in 1995.

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TITLE: Fortuitous Specimen Program

INTRODUCTION

The objective of the Fish and Wildlife Service's Fortuitous Specimen Program is to determine the cause of death of wildlife incidentally found on the Refuge. Knowledge of mortality factors will help Service management efforts to reduce any detected significant impacts on wildlife. A fortuitous specimen collection and analytical protocol developed in 1993 was followed in 1994 (U.S. Fish and Wildlife Service 1994).

METHODS

Encountered dead/injured wildlife (fortuitous specimens) were reported by Service personnel, contractors, or other personnel working on the Refuge. If the cause of death was obvious (e.g. hit by car) or the specimen was badly decomposed, then it was disposed of on the Refuge, with the exception of a subset of these specimens which were saved for chemical analysis. Fresh specimens of known mortality (traffic mortality) were saved for possible taxidermy mounts. Appropriate specimens were sent to the National Wildlife Health Research Center (NWHRC) in Madison, Wisconsin for necropsy. Birds found at Building 111 (Section 35) were also included under the fortuitous specimen program (see following report herein on Building 111 Bird Mortalities). Four moribund specimens (mostly raptors) were sent to the Colorado State University Veterinary Teaching Hospital/Diagnostic Lab for clinical observation and necropsy. For necropsy results refer to Table 1-16 and Figure 1-10. Since necropsy reports were too extensive to include in this report, the primary diagnosis is reported in the table.

Tissues (brain, liver, kidney) and carcasses were returned to the Service by the NWHRC and then submitted to an Army contract lab, Environmental Science and Engineering Inc., for chemical analyses. Analytical priority was given to organochlorine pesticides, arsenic, then mercury (mercury then arsenic for aquatic samples). The analytical results reported in Table 1-17 were examined along with necropsy results in Table 1-16 to determine probable cause of death.

Guidelines for diagnosis of contaminant impacts to birds, particularly from dieldrin, were formulated with the literature cited at the end of this report, more specifically Stickel et al. (1969) and Heinz and Johnson (1982). In addition, scientists from the National Biological Survey, Patuxent Environmental Science Center, and the U.S. Fish and Wildlife Service who have conducted extensive work on dieldrin in birds were consulted. Laboratory dosing studies and other cited literature typically associate emaciation and/or loss of weight with dieldrin poisoning. The Service has developed a guideline of 9 ppm or greater dieldrin in the brain to indicate the cause of mortality or morbidity as dieldrin poisoning; 5 to 9 ppm of dieldrin in the brain, with supporting necropsy and/or clinical signs, to constitute suspected dieldrin poisoning; and brain dieldrin concentrations between 1 and 5 ppm are noted as levels of concern. Brain concentrations less than 1 ppm indicate undesirable exposure to dieldrin, but were not considered a factor in death. These guidelines may be adjusted slightly as new data are received.

Concentrations of 1 to 5 ppm in the brain of birds may indicate dangerous exposure to dieldrin, but the bird probably died of some other cause. Such animals may have been diseased or had some other problem leading to weight loss which initiated mobilization of dieldrin to the brain, thus resulting in the reported residues. Two examples are samples 93GH034 and 94B099. A red-tailed hawk, 94B099, not only displayed emaciation and seizures, but was found to be blind. This bird most likely lost weight due to blindness which resulted in the mobilization of 4.55 ppm dieldrin in the brain. The cause of blindness was not determined. This bird probably would have died regardless of dieldrin. The great horned owl, 93GH034, was a similar case with vision problems that had 1.10 ppm dieldrin in the brain.

Brain dieldrin concentrations greater than 1 ppm in live sentinel species collected for study indicate undesirable and dangerous exposure to dieldrin. Concentrations in the brain at this level could potenially cause the irreversible process of starvation (Heinz and Johnson 1982). Dieldrin in liver and other tissues may also indicate suspected mortality, but guidelines have not been formulated because data are limited and little information is available in the literature. Thus far, other organochlorines have been detected in fortuitous specimens, but have not been considered a factor in death. Further results may change this conclusion.

RESULTS

Analytical results obtained for all 1994 fortuitous specimens (including Building 111) are presented in Table 1-17. Many of the samples were consumed before all tests could be run. Also included in Tables 1-16 and 1-17 are results from 1992 and 1993 fortuitous samples not previously reported. The results for these samples were received after the 1993 annual report. Analytical results from 1993 Building 111 birds are in the following report on bird mortalities at Building 111.

One hundred and thirty-eight animals were collected under the Fortuitous Specimen Program in 1994 with nearly half of this number (46.2%, Figure 1-9) consisting of Building 111 birds. Raptors were the second largest group collected, almost 20% of the total.

For many specimens, cause of mortality could not be determined due to decomposition. For the 49 cases where Service personnel or a necropsy determined cause of death, trauma (usually vehicular collision) was the cause in almost 50% of the specimens (Figure 1-10). Deer were the species most affected by collisions. Collision (trauma) is the highest category of fortuitous samples collected because animals on roads, particularly deer, are more easily detected and more frequently reported to the Service. With the recent reduction of RMANWR speed limits, the number of collision mortalities may decline.

Dieldrin poisoning was the second highest diagnosed cause of death, affecting 22.4% (n=10) of the specimens, and the majority of Building 111 specimens. Samples displaying dieldrin poisoning or dieldrin levels of concern (n=7) were primarily from the core areas of the Refuge (Table 1-16). Electrocution, disease (avian pox) and emaciation were diagnosed in the remainder of the cases (6.1, 6.1 and 18.4% each). Cases indicated as emaciation on Figure 1-10 consist of birds in the range of dieldrin levels of concern or are animals for which analytical results have not yet been received. An ongoing database of all specimens has been developed and analytical results will be added as they are received.

More natural and other causes of mortality probably occur on the Refuge than what is reported here. However, organochlorine impacts to birds persists. Mammals do not appear to be impacted to the extent that birds are. Fortuitous specimen information has some value in determining various impacts to wildlife, but interpretation of necropsy and analytical results is difficult since no information on the history of individual specimens is available. The Service will continue to document mortality and the associated causes when possible.

Table 1-16. 1994 Fortuitous Specimens Found at Rocky Mountain Arsenal National Wildlife Refuge.

Sample Number	Species	Date Collected	Location (Section)	Fate	Necropsy result
94B001	Great Horned Owl	01/06/94	32	Archived	
94B002	Red-tailed Hawk	01/11/94	01	Disposed	
94B003	Ferruginous Hawk	01/13/94	19	Submitted	Emaciation, Dieldrin concern[a]
94B004	Ferruginous Hawk	01/19/94	09	Submitted	Avian pox
94M005	Jackrabbit	01/24/94	02	Disposed	*Trauma
94M006	Mule deer	01/19/91	25	Disposed	
94M007	Mule deer	01/20/94	34	Disposed	
94M008	Kangaroo rat	01/14/94	03	Archived	
94B009	Townsend solitaire	01/25/94	35	Disposed	
94M010	Cottontail	03/07/94	36	Disposed	
94B011	Golden Eagle	03/11/94	16	Submitted	*Electrocution
94B012	European starling	03/16/94	35	Archived	
94M013	Mule deer	03/19/94	35	Disposed	*Trauma
94M014	Kangaroo rat	03/25/94	36	Archived	
94M015	Coyote	03/30/94	36	Disposed	
94M016	Red fox	04/04/94	03	Disposed	
94M017	Cottontail rabbit	04/01/94	35	Disposed	
94M019	Mule deer	04/19/94	03	Disposed	*Trauma
94B020	B.B. Magpie	04/17/94	01	Submitted	Emaciation, Dieldrin poisoning
94B021	W. Meadowlark	04/18/94	35	Submitted	Emaciation, Dieldrin poisoning

* = Mortality cause determined by USFWS personnel.

Table 1-16 (Continued).

Sample Number	Species	Date Collected	Location (Section)	Fate	Necropsy result
94B022	European Starling	04/21/94	36	Submitted	convulsions, emaciation, Dieldrin concern
94M023	Mule deer	04/21/94	1	Disposed	*Trauma
94B025	G.C. Kinglet	04/22/94	35	Disposed	
94B026	European Starling	04/22/94	35	Disposed	
94B027	European Starling	04/22/94	35	Disposed	
94B028	Red-Tail Hawk	04/29/94	25	Submitted	Emaciation
94B029	unknown bird	05/02/94	35	Disposed	
94M030	Fox squirrel	05/05/94	35	Archived	
94B031	Rock Dove	05/09/94	4	Disposed	*Trauma
94H032	Bull snake	05/09/94	34	Disposed	*Trauma
94B033	Mourning Dove	05/11/94	31	Archived	
94B034	Say's Phoebe	05/15/94	35	Submitted	Emaciation
94B035	Red-Tail Hawk	05/16/94	23	Disposed	
94B036	American Robin	05/21/94	35	Submitted	Emaciation, Dieldrin poisoning
94B037	House Sparrow	05/22/94	35	Disposed	
94B038	House Finch	05/22/94	35	Disposed	
94B040	B.B. Magpie	05/25/94	3	Archived	
94B041	Mourning Doves	05/25/94	35	Disposed	
94B042	European Starling	05/26/94	35	Submitted	convulsions, TIWET[b]
94B043	American Robin	05/26/94	35	Submitted	Emaciation, Dieldrin poisoning

Table 1-16 (Continued).

Sample Number	Species	Date Collected	Location (Section)	Fate	Necropsy result
94B044	European Starling	05/26/94	35	Submitted	Emaciation, Dieldrin concern (167.297)[c]
94B045	European Starling	05/27/94	35	Submitted	Emaciation, Dieldrin poisoning
95B046	Northern Oriole	05/28/94	35	Submitted	Emaciation, trauma, Dieldrin poisoning
94B047	American Robin	05/28/94	35	Submitted	Emaciation, trauma, Dieldrin poisoning
94B048	American Robin	06/01/94	35	Submitted	emaciation, Dieldrin poisoning
94B049	Pocket Gopher	06/09/94	36	Archived	*Trauma
94B050	House Finch	06/08/94	35	Submitted	undetermined, Dieldrin concern
94B051	American Robin	06/10/94	35	Submitted	Trauma, Dieldrin concern (167.111)
94B052	European Starling	06/04/94	35	Submitted	convulsions, TIWET
94B053	European Starling	06/04/94	2	submitted	convulsions, TIWET
94B054	European Starling	06/06/94	35	Disposed	
94B055	Mallard Duck	06/11/94	12	Disposed	
94B056	American Robin	06/13/94	35	Archived	
94B057	House Finch	06/14/94	35	Archived	*Trauma
94B058	European Starling	06/14/94	35	Disposed	
94B059	European Starling	06/15/94	35	Archived	
94B060	American Robin	06/15/94	35	Archived	

Table 1-16 (Continued).

Sample Number	Species	Date Collected	Location (Section)	Fate	Necropsy result
94M061	Mule deer (fawn)	06/15/94	3	Disposed	*Trauma
94B062	House Finch	06/16/94	35	Disposed	
94B063	European Starling	06/16/94	35	Disposed	
94B064	American Kestrel	06/16/94	2	Archived	
94B065	Mourning Dove	06/19/94	02 & 11	Submitted	*Trauma
94B066	House Sparrow	06/20/94	35	Disposed	
94B067	nestling sp.	06/20/94	35	Disposed	
94B068	American Robin	06/22/94	3	Submitted	Emaciation, Dieldrin poisoning (167.248)
94B069	European Starling	06/22/94	35	Disposed	
94B070	W. Meadowlark	06/23/94	26	Archived	
94B071	European Starling	06/24/94	3	Submitted	Emaciation, Dieldrin poisoning (167.179A)
94B072	American Robin	06/21/94	35	Submitted	*Trauma, analytical only
94B073	American Robin	06/26/94	4	Archived	
94B074	House Finch	06/28/94	35	Archived	
94B075	House Sparrow	06/28/94	35	Disposed	
94B076	W. Meadowlark	06/28/94	35	Archived	
94B077	European Starling	06/28/94	35	Archived	
94B078	Western Kingbird	06/28/94	36	Submitted	Avian pox
94B079	European Starling	06/29/94	35	Disposed	
94B079A	House Sparrow	07/01/94	35	Archived	
94B080	Baltimore Oriole	07/01/94	35	Archived	
94B081	House Finch	07/05/94	35	Disposed	

Table 1-16 (Continued).

Sample Number	Species	Date Collected	Location (Section)	Fate	Necropsy result
94B082	American Robin	07/07/94	34	Archived	
94B083	American Robin	07/07/94	35	Submitted	*Trauma, analytical only
94B084	Western Kingbird	07/08/94	4	Archived	
94M085	Cottontail Rabbit	07/11/94	35	Disposed	
94B086	American Robin	07/11/94	35	Disposed	
94B087	House Sparrow	07/12/94	35	Disposed	
94B087A	American Robin	07/13/94	35	Disposed	
94B088	House Finch	07/14/94	35	Archived	
94M089	Jackrabbit	07/18/94	35	Disposed	Trauma
94M090	Cottontail Rabbit	07/18/94	35	Disposed	
94B091	American Robin	07/19/94	35	Disposed	
94B092	Mourning Dove	07/18/94	2	Archived	
94B093	Swain. Hawk egg	07/22/94	25	Submitted	Analytical Only
94M094	Coyote pup	07/22/94	23	Disposed	
94B095	Chipping Sparrow	07/25/94	35	Archived	
94B096	Mourning Dove	07/25/94	35	Submitted	undetermined
94B097	House Finch	07/28/94	35	Archived	
94B098	House Finch	07/29/94	35	Archived	
94B099	Red-Tailed Hawk	08/01/94	7	Submitted	Emaciation, Dieldrin concern
94B100	Canada Goose	07/29/94	2	Rehab.	

Table 1-16 (Continued).

Sample Number	Species	Date Collected	Location (Section)	Fate	Necropsy result
94B101	House Finch	08/02/94	35	Disposed	
94B102	House Finch	08/01/94	35	Disposed	
94B103	House Finch	08/04/94	35	Disposed	
94B104	House Finch	08/04/94	35	Disposed	
94B105	House Finch	08/05/94	35	Disposed	
94B106	Barn Owl	08/06/94	2	Submitted	Emaciation
94B107	House Finch	08/08/94	35	Submitted	Analytical only
94B108	Red-Tailed Hawk	08/12/94	35	Disposed	
94B109	Mourning Doves	08/17/94	35	Disposed	
94B110	American Kestrel	08/18/94	25	Submitted	Pending
94B111	Red-Tailed Hawk	08/24/94	6	Submitted	Emaciation, Dieldrin concern
94M112	Mule deer (fawn)	08/25/94	1	Disposed	
94B113	Great Horned Owl	08/27/94	25	Submitted	Pending
94B114	Swainson's Hawk	09/05/94	6	Submitted	*Trauma
94B115	Mourning Dove	09/06/94	35	Disposed	
94B116	Chipping Sparrow	09/07/94	35	Archived	
94B117	Ferruginous Hawk	09/09/94	36	Disposed	*Avian Pox
94M118	Mule deer	09/16/94	2	Disposed	
94M119	Silver haired bat	09/21/94	4	Submitted	Trauma
94M120	Mule deer	09/21/94	34	Disposed	*Trauma
94M121	Mule deer	09/17/94	2	Disposed	
94B122	Great Horned Owl	09/23/94	31	Submitted	Emaciation

Table 1-16. Continued.

Sample Number	Species	Date Collected	Location (Section)	Fate	Necropsy result
94B123	Red-Tailed Hawk	09/23/94	8	Disposed	
94B124	Barn Owl	09/25/94	25	Rehab.	
94B125	Barn Owl	09/25/94	25	Rehab.	
94B126	American Coot	10/09/94	1	Submitted	Trauma
94B127	Ferruginous Hawk	09/28/94	11	Rehab.	
94B128	Great Horned Owl	09/28/94	36	Disposed	
94M129	White-tailed deer	09/28/94	11	Disposed	*Trauma
94B130	Ferruginous Hawk	11/01/94	22	Submitted	Trauma
94B131	Great Horned Owl	10/03/94	1	Archived	*Electrocution
94B132	Killdeer	10/06/94	24	Archived	
94B133	Red-Tailed Hawk	10/12/94	25	Submitted	Electrocution
94B134	Red fox	10/24/94	4	Disposed	
94B135	Red-Tailed Hawk	10/25/94	25	Disposed	
94B136	Ferruginous Hawk	11/16/94	12	Submitted	Trauma
94M137	Coyote	11/18/94	1	Disposed	*Trauma
94M138	Coyote	11/18/94	1	Disposed	*Trauma
93GH034[d]	Great Horned Owl	11/17/93	1	Submitted	cataract, emaciated, Dieldrin concern
93GH035	Great Horned Owl	12/29/93	35	Submitted	leucocytozoon infection, emaciation, Dieldrin concern
93BO028	Barn Owl	10/21/93	36	Submitted	Emaciation
93SH015	Swainson's hawk egg	7/20/93	12	submitted	analytical only

Table 1-16. Continued.

Sample Number	Species	Date Collected	Location (Section)	Fate	Necropsy result
93RP027	Ring-necked pheasant	10/18/93	26	Submitted	trauma
93PD001	Prairie dog	1993	26	Submitted	analytical only
93PG005	Pocket gopher	1993	26	Submitted	analytical only
93GH032	Great horned owl	11/16/93	24	Submitted	electrocution
MA1	Badger	10/16/93	4	Submitted	distemper
92M001	Badger	8/91	28	Submitted	Trauma
923-5002	Badger	10/20/92	36	Submitted	undetermined
11088-1	Barn owl	10/15/92	25	Submitted	emaciation
11088-2	Barn owl	10/15/92	25	Submitted	emaciation
10943-1	Great horned owl	8/5/92		Submitted	emaciation, Dieldrin poisoning
11410-1	Bald Eagle	1/27/93	Buckley	Submitted	pulmonary congestion and hemorrhage
BOEG01	Barn owl eggs	5/14/93	25	Submitted	analytical only
11298-1	Great horned owl	5/18/93		Submitted	electrocution

[a] Dieldrin concern indicates dieldrin concentrations in the brain were at levels of concern (1-5ppm), and dieldrin poisoning indicates brain concentrations greater than 5ppm (Table 1-17).
[b] TIWET = The Institute of Wildlife and Environmental Toxicology.
[c] 167.000 denotes frequency of birds with transmitters as part of the Building 111 study.
[d] All samples following in table were collected prior to 1994.

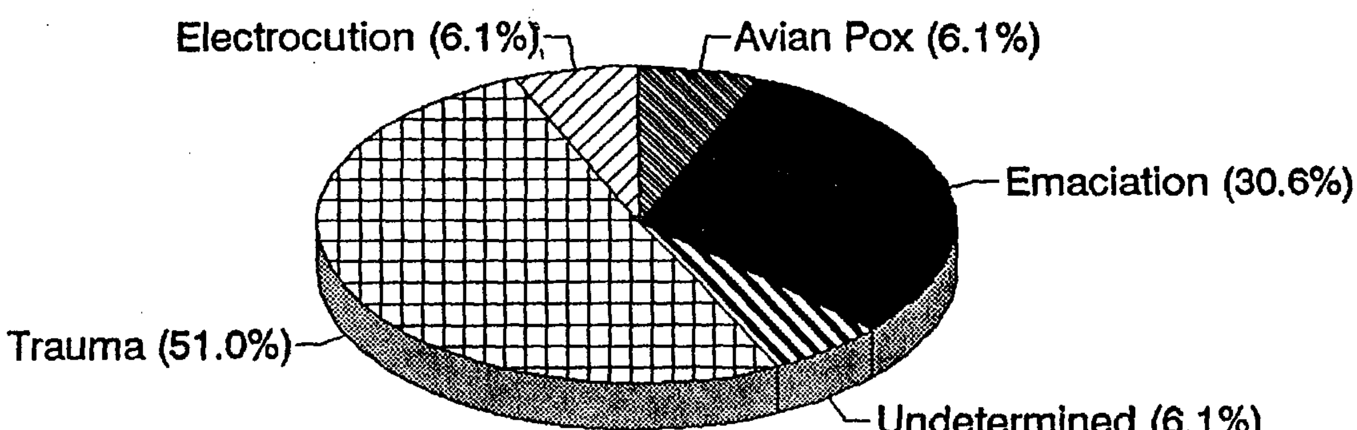

Fig. 1-9. Cause of death for 1994 fortuitous specimens (n=49) from RMANWR.

Table 1-17. Analytical results (ppm wet weight) of submitted 1994 Fortuitous Specimen tissues (reported thus far).

Sample Number	Species	Tissue	Dieldrin	Endrin	DDT	DDE	Mercury
94B003	Ferruginous Hawk	brain	1.49	bcrl[a]	bcrl	bcrl	sc[b]
94B003	Ferruginous Hawk	liver	0.02	bcrl	bcrl	bcrl	sc
94B004	Ferruginous Hawk	brain	[c]				
94B004	Ferruginous Hawk	liver					
94B011	Golden Eagle	brain	bcrl	bcrl	bcrl	0.015	bcrl
94B011	Golden Eagle	liver	bcrl	bcrl	bcrl	0.016	bcrl
94B020	B.B. Magpie	brain	12.72	0.47	bcrl	0.30	sc
94B020	B.B. Magpie	liver	5.05	0.22	bcrl	0.20	
94B021	W. Meadowlark	brain	10.40	0.28	bcrl	0.44	sc
94B021	W. Meadowlark	liver	15.69	0.38	bcrl	0.87	sc
94B022	European Starling	liver	9.66	bcrl	bcrl	0.87	sc
94B022	European Starling	brain	1.42	bcrl	bcrl	1.12	sc
94B028	Red-tailed Hawk	fat					
94B028	Red-tailed Hawk	brain	bcrl	bcrl	bcrl	0.05	sc
94B028	Red-tailed Hawk	liver	bcrl	bcrl	bcrl	0.13	0.341
94B033	Mourning Dove	brain	bcrl	bcrl	bcrl	bcrl	

Table 1-17 (Continued).

Sample Number	Species	Tissue	Dieldrin	Endrin	DDT	DDE	Mercury
94B033	Mourning Dove	muscle	bcrl	bcrl	bcrl	bcrl	
94B034	Say's Phoebe	brain					
94B034	Say's Phoebe	liver					
94B034	Say's Phoebe	carcass					
94B036	American Robin	carcass					
94B036	American Robin	brain	7.62	0.36	bcrl	0.72	sc
94B043	American Robin	liver	20.33	bcrl	bcrl	2.28	
94B043	American Robin	muscle	1.45	bcrl	bcrl	0.13	
94B043	American Robin	kidney	11.40	bcrl	bcrl	1.00	
94B043	American Robin	brain	18.33	bcrl	0.13	1.43	sc
94B044	European Starling	carcass					
94B044	European Starling	liver	3.36	bcrl	bcrl	0.71	
94B044	European Starling	muscle	1.40	bcrl	bcrl	0.33	
94B044	European Starling	kidney	2.55	bcrl	bcrl	0.58	
94B044	European Starling	brain	3.80	bcrl	bcrl	0.68	sc
94B045	European Starling	liver	6.57	bcrl	bcrl	bcrl	

Table 1-17 (Continued).

Sample Number	Species	Tissue	Dieldrin	Endrin	DDT	DDE	Mercury
94B045	European Starling	kidney	6	bcrl	bcrl	bcrl	
94B045	European Starling	muscle	1.02	bcrl	bcrl	bcrl	
94B045	European Starling	brain	7.95	bcrl	bcrl	bcrl	sc
95B046	Northern Oriole	carcass					
95B046	Northern Oriole	liver	13.26	bcrl	bcrl	bcrl	
95B046	Northern Oriole	kidney	13.51	bcrl	bcrl	bcrl	
95B046	Northern Oriole	muscle					
95B046	Northern Oriole	brain	20.74	bcrl	bcrl	bcrl	sc
94B047	American Robin	carcass					
94B047	American Robin	liver	10.28	0.20	0.08	7.53	
94B047	American Robin	kidney					
94B047	American Robin	muscle					
94B047	American Robin	brain	12.28	bcrl	1.20	8.72	sc
94B048	American Robin	liver	19.18	0.28	bcrl	2.33	
94B048	American Robin	kidney	bcrl	bcrl	bcrl	bcrl	
94B048	American Robin	muscle	2.53	bcrl	bcrl	0.26	

Table 1-17 (Continued).

Sample Number	Species	Tissue	Dieldrin	Endrin	DDT	DDE	Mercury
94B048	American Robin	brain	20.13	0.18	0.19	1.66	sc
94B050	House Finch	carcass	0.36	bcrl	bcrl	0.04	bcrl
94B050	House Finch	liver					
94B050	House Finch	kidney					
94B050	House Finch	muscle					
94B050	House Finch	brain	1.13	bcrl	0.08	4.35	
94B051	American Robin	liver	0.28	bcrl	bcrl	bcrl	
94B051	American Robin	kidney					
94B051	American Robin	muscle					
94B051	American Robin	brain	0.98	bcrl	1.04	6.12	sc
94B064	American Kestrel	carcass					
94B065	Mourning Dove	brain	0.13	bcrl	bcrl	bcrl	sc
94B065	Mourning Dove	muscle	0.05	bcrl	bcrl	bcrl	bcrl
94B068	American Robin	liver	9.88	0.24	bcrl	3.65	
94B068	American Robin	kidney	4.49	bcrl	bcrl	2.10	
94B068	American Robin	muscle	1.05	bcrl	bcrl	0.56	

Table 1-17 (Continued).

Sample Number	Species	Tissue	Dieldrin	Endrin	DDT	DDE	Mercury
94B068	American Robin	brain	11.23	0.26	0.17	5.00	sc
94B071	European Starling	liver	8.78	bcrl	bcrl	4.41	
94B071	European Starling	stomach	1.37	bcrl	bcrl	0.84	
94B071	European Starling	muscle	0.98	bcrl	bcrl	0.73	
94B071	European Starling	brain	10.40	bcrl	bcrl	5.33	sc
94B071	European Starling	kidney	4.46	bcrl	bcrl	2.81	
94B072	American Robin	carcass					
94B078	Western Kingbird	stomach	1.34	bcrl	bcrl	bcrl	
94B082	American Robin	brain					
94B082	American Robin	liver					
94B082	American Robin	carcass					
94B083	American Robin	carcass	2.12	0.05	3.12	15.7	bcr
94B092	Mourning Dove	brain	bcrl	bcrl	bcrl		
94B092	Mourning Dove	muscle	0.05	bcrl	bcrl	bcrl	
94B093	Swain. Hawk egg	egg	0.02	bcrl	bcrl	0.05	bcrl
94B096	Mourning Dove	brain					

Table 1-17 (Continued).

Sample Number	Species	Tissue	Dieldrin	Endrin	DDT	DDE	Mercury
94B096	Morning Dove	liver					
94B096	Mourning Dove	muscle					
94B096	Mourning Dove	carcass					
94B099	Red-Tailed Hawk	brain	4.55	0.12	bcrl	0.17	sc
94B099	Red-Tailed Hawk	liver	6.38	0.15	0.02	0.25	0.05
94B106	Barn Owl	brain					
94B106	Barn Owl	liver					
94B107	House Finch	brain					
94B107	House Finch	liver					
94B107	House Finch	carcass					
94B110	American Kestrel	brain					
94B110	American Kestrel	liver					
94B110	American Kestrel	brain					
94B111	Red-Tailed Hawk	brain	3.22	bcrl	bcrl	0.03	sc
94B111	Red-Tailed Hawk	liver	2.66	bcrl	bcrl	0.03	sc
94B113	Great Horned Owl	brain					

Table 1-17 (Continued).

Sample Number	Species	Tissue	Dieldrin	Endrin	DDT	DDE	Mercury
94B113	Great Horned Owl	liver					
94B113	Swainson's Hawk	brain					
94B114	Swainson's Hawk	liver					
94M119	Silver haired bat	liver	bcrl	bcrl	bcrl	bcrl	
94M119	Silver haired bat	viscera	bcrl	bcrl	bcrl	bcrl	
94B122	Great Horned Owl	brain					
94B122	Great Horned Owl	liver					
94B126	American Coot	brain					
94B126	American Coot	liver					
94B126	American Coot	muscle					
94B130	Ferruginous Hawk	brain					
94B130	Ferruginous Hawk	liver					
94B131	Great Horned Owl	brain					
94B131	Great Horned Owl	liver					
94B132	Killdeer	brain					
94B132	Killdeer	liver					

Table 1-17 (Continued).

Sample Number	Species	Tissue	Dieldrin	Endrin	DDT	DDE	Mercury
94B132	Killdeer	carcass					
94B133	Red-Tailed Hawk	brain					
94B133	Red-Tailed Hawk	liver					
94B136	Ferruginous Hawk	brain					
94B136	Ferruginous Hawk	liver					
94B137	Coyote	liver					
94B138	Coyote	liver					
11088-1[d]	Barn Owl	Brain	0.74	bcrl	bcrl	bcrl	sc
11088-2	Barn Owl	brain	0.46	bcrl	bcrl	bcrl	sc
93B0028	Barn Owl	liver	2.96				sc
923-5002	Badger	brain	2.46	bcrl	bcrl	bcrl	sc
923-5002	Badger	liver	9.65	bcrl	bcrl	bcrl	bcrl
MA1	Badger	brain	0.05	bcrl	bcrl	bcrl	bcrl
11298-1	Great Horned Owl	brain	0.1	bcrl	bcrl	bcrl	sc
11298-1	Great Horned Owl	liver	0.1	bcrl	bcrl	bcrl	0.06

Table 1-17 (Continued).

Sample Number	Species	Tissue	Dieldrin	Endrin	DDT	DDE	Mercury
10943-1	Great Horned Owl	brain	5.38				sc
93GH034	Great Horned Owl	brain	1.17	bcrl	bcrl		sc
93GH034	Great Horned Owl	liver	2.46	bcrl	0.13	1.72	bcrl
93GH035	Great Horned Owl	brain	4.31	bcrl	bcrl	bcrl	bcrl
93GH035	Great Horned Owl	liver	3.78	bcrl	bcrl		sc
11410-1	Bald Eagle	brain	bcrl	bcrl	bcrl	bcrl	0.35
11410-1	Bald Eagle	liver	bcrl	bcrl	bcrl	0.13	0.84
93SH015	Swainson's Hawk	egg	0.06	bcrl	bcrl	0.12	bcrl
93RP027	R.N. Pheasant	brain	0.29	bcrl	bcrl	bcrl	sc
93RP027	R.N. Pheasant	liver	2.44		bcrl	bcrl	sc
93PD001	Prairie Dog	carcass	bcrl	bcrl	bcrl	bcrl	bcrl
93PG005	Pocket Gopher	carcass	1.81	bcrl	bcrl	bcrl	bcrl
92M001	Badger	brain	bcrl	bcrl	bcrl	bcrl	bcrl
92M001	Badger	fat	0.13	bcrl	bcrl	bcrl	bcrl
93GH032	Great Horned Owl	brain	0.04	bcrl	bcrl	0.04	sc
BOEG01	Barn owl	eggs	0.26	bcrl	bcrl	0.03	bcrl

[a]bcrl = below certified reporting limit.
[b]sc = sample consumed; analytical priority was for organochlorine pesticides, arsenic, and mercury.
[c]Space indicates data not recieved yet.
[d]Following samples in the table were collected prior to 1994.

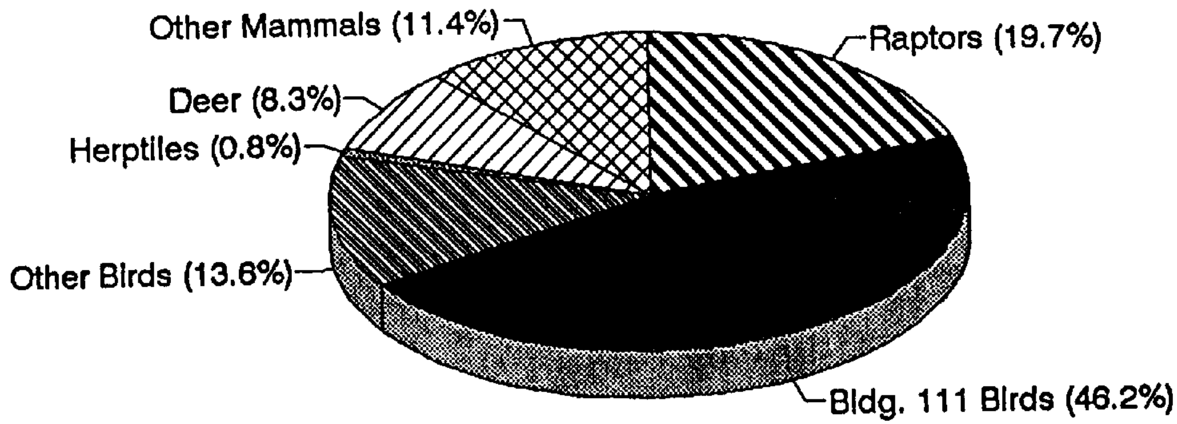

Fig. 1-10. Fortuitous specimens found at RMANWR, 1994 (n=138).

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TITLE: Bird Mortalities at the U.S Army Administration Complex (Building 111)

INTRODUCTION

The U.S. Army (Army) administration complex (Building 111) in Section 35 (Figure 1-11) on the Rocky Mountain Arsenal National Wildlife Refuge (Refuge) was built in 1942. This complex has a manicured, watered lawn and numerous coniferous trees and deciduous shrubs that provide a relatively unique habitat for passerine birds on the Refuge. The complex has been and is presently used by Army employees.

Bird mortalities at Building 111 have been recorded and investigated at least since 1982 (U.S. Fish and Wildlife Service 1983). Three European starlings (Sturnus vulgaris), a Northern oriole (Icterus galbula), and 2 Brewer's blackbirds (Euphagus cyanocephalus) found dead at building 111 in 1982 were reported by the U.S. Fish and Wildlife Service to have from 3.3 to 12 ppm dieldrin in brain tissues (U.S. Fish and Wildlife Service 1983). Two mourning doves (Zenaida macroura) found at Building 111 during the Biota Remedial Investigation (Environmental Science and Engineering 1989) were found to have dieldrin (up to 56.3 ppm), aldrin, and endrin in the carcasses. Fifteen fortuitous birds were reported from Building 111 in the Comprehensive Monitoring Program (CMP) (Stollar et al. 1992). Six of these birds were American robins (Turdus migratorius) and 4 were mourning doves. Analytical data from these birds are shown in Table 1-18. A report from 1976 (U.S. Army Environmental Hygiene Agency) investigated mortalities of starlings and stated that starling die-offs were a yearly occurrence, although the report did not state where on the Refuge the birds were found. No evidence of disease was found, and the authors indicated that dieldrin probably contributed to mortality.

In 1990, the Service assumed responsibility for the CMP to document and investigate the cause of death of animals found dead or dying at the refuge. A sizable number of specimens collected (n=63) between 1990 and 1992 came from birds in the vicinity of Building 111 (U.S. FWS, unpub. data). These birds were found at various locations encompassing the Building 111 complex from May through October. Fifty percent of the specimens were collected during July (Table 1-19). The three species of birds collected most frequently at Building 111 from 1990 - 1992 were starlings, robins, and doves. In 1991, a necropsy of a dying robin collected near Building 111 revealed an infestation of protozoan parasites in its brain blood vessels (U.S. Fish and Wildlife Service 1992). A live starling found with clenched talons and a loss of equilibrium in 1992 tested within the normal range for brain cholinesterase, a test measuring exposure to organophosphorus or carbamate compounds (U.S. Fish and Wildlife Service 1993). However, these birds were not analyzed for contaminants. Two other live starlings also found in 1992, one at Building 111 and one at Building 612, displayed convulsions but were only recently submitted for necropsy and contaminant analyses. The diagnoses on these starlings were undetermined, in part because of extended freezer storage time.

In 1993, daily carcass searches were conducted by the Service from April through October with ninety-eight bird specimens found (Table 1-19) (U.S. Fish and Wildlife Service 1994a). The majority of birds were found in June and were primarily house finches (Carpodacus mexicanus), robins, starlings, doves, and house sparrows (Passer domesticus). Necropsies were performed on 17 of these birds by the National Wildlife Health Research Center (NWHRC) in Madison, Wisconsin, the results of which showed undetermined causes of death and undetermined causes of emaciation. No viral or bacterial diseases were found. Trauma was determined to be the cause of death in one bird.

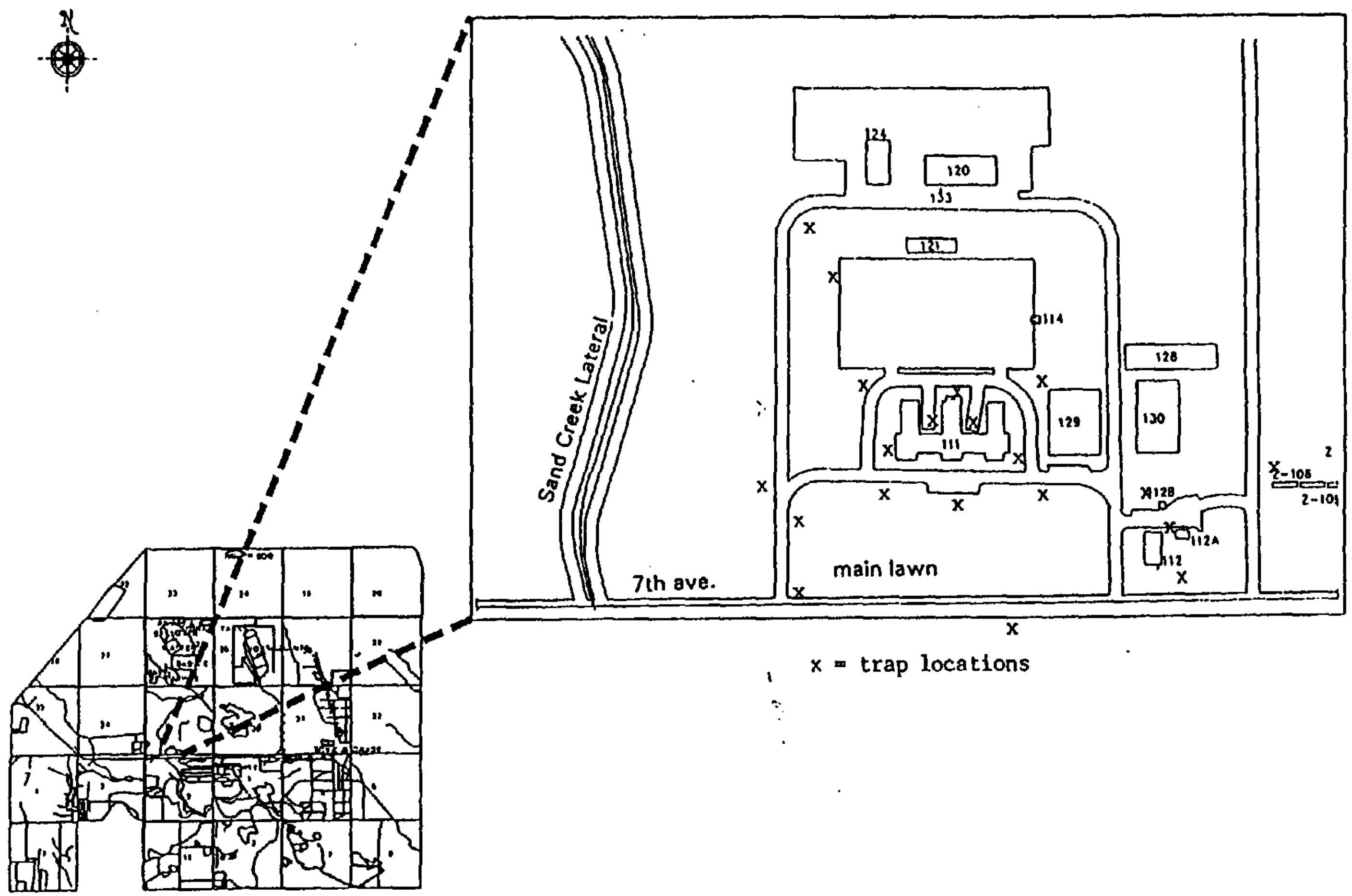

Fig. 1-11. U.S. Army administration area (Building 111) on the Rocky Mountain Arsenal National Wildlife Refuge.

Table 1-18. Ranges of analytical results (ppm wet weight) from fortuitous bird specimens (carcasses) found at the Building 111 complex on the Refuge under the Comprehensive Monitoring Program (Stollar et al. 1992).

Species	Number of samples	Dieldrin	Aldrin	Endrin	DDT	DDE	Mercury[b]
European starling	1	5.9	bcrl[a]	0.4	bcrl	4.3	0.05
American robin	6	1.2-19.0	bcrl	0.1-1.0	0.3-1.0	1.4-8.3	0.06-0.06
Mourning dove	4	7.8-32.0	1.30	0.3-1.3	0.3-0.3	0.5-0.5	0.4-0.4
black-billed magpie	1	5.1	bcrl	bcrl	0.2	2.2	bcrl
American kestrel	1	1.7	bcrl	bcrl	bcrl	0.122	bcrl
Red-tailed hawk	2	0.5-7.2	bcrl	0-0.1	bcrl	0-0.145	bcrl

[a] bcrl = below certified reporting limit.
[b] Arsenic was analyzed for but not detected.

Table 1-19. Species and fate of dead birds collected at Building 111.

Sample Number	Species	Date Collected	Age & Sex[a]	Fate
	Mourning dove	8/27/89	u/U	archived
	Western meadowlark	4/4/90	u/U	disposed
	Pine siskin	4/21/90	u/U	archived
	Mourning dove	5/1/90	u/U	archived, convulsions
	Mourning dove	5/13/90	u/U	archived
	Mourning dove	5/17/90	u/U	archived, convulsions
	Mourning dove	5/16/90	u/U	archived
	House finch	9/19/90	u/U	archived
	European starlings(3)	5/8/91	u/U	disposed
	House finch	5/10/91	u/F	disposed
	Common grackle	5/10/91	u/U	disposed
	American robin	5/28/91	u/M	disposed
	Common grackle	6/19/91	u/U	disposed
	European starlings(2)	6/25/91	u/U	disposed
	American robin	6/25/91	u/U	disposed
	American robin	7/12/91	hy/U	disposed
	European starlings(5)	7/12/91	u/U	disposed
	American robins (5)	7/12/91	u/U	disposed
	Common grackles (4)	7/12/91	u/U	disposed
	American robin	7/17/91	hy/U	disposed
	Unknowns (3)	7/17/91	u/U	disposed
	American robin	7/25/91	u/U	disposed
	European starlings(2)	7/25/91	u/U	disposed
	Unknowns (2)	7/25/91	hy/U	disposed
	European starling	8/14/91	u/U	archived
	Mourning doves (2)	8/21/91	u/U	disposed
	House sparrow	8/21/91	u/U	disposed

Table 1-19 (Continued).

Sample Number	Species	Date Collected	Age & Sex	Fate
	European starlings(2)	8/29/91	u/U	disposed
	Mourning dove	8/29/91	u/U	disposed
	House sparrow	8/29/91	u/U	disposed
	American robin	9/11/91	u/U	disposed
	European starling	9/11/91	u/U	disposed
	Black-billed magpie	9/18/91	u/U	archived
	Black-billed magpie	10/2/91	u/U	disposed
	House sparrow	4/2/92	u/U	disposed
	House finches (2)	7/10/92	u/U	disposed
	Mourning dove	7/15/92	u/U	disposed
	Black-billed magpie	7/15/92	u/U	disposed
	Northern oriole	7/15/92	u/U	disposed
	European starling	7/31/92	hy/U	disposed
	European starling	8/31/92	u/U	archived
	European starling	9/23/92	u/U	submitted, convulsions, undetermined
02	Sharp-shinned hawk	4/27/93	ahy/M	submitted, undetermined
ST-2	European starling	4/27/93	ahy/M	submitted, undetermined
ST-1	European starling	5/4/93	u/U	archived
07	European starling	5/18/93	ahy/F	submitted, undetermined
10	House finch	6/3/93	ahy/M	submitted, undetermined
	House finch	6/4/93	ahy/M	disposed
03	Western kingbird	6/7/93	ahy/M	submitted, undetermined
HF-3	House finch	6/7/93	ahy/F	submitted, not examined

Table 1-19 (Continued).

Sample Number	Species	Date Collected	Age & Sex	Fate
11	Common grackle	6/7/93	ahy/F	submitted, unsuitable for exam
	Unknown	6/7/93	hy/U	disposed
	Unknown	6/8/93	hy/U	disposed
	House finch	6/8/93	ahy/M	disposed
	Unknown (4)	6/8/93	hy/U	disposed
HF-27	House finch	6/9/93	ahy/F	archived
93MD008	Mourning dove	6/9/93	hy/U	archived
06	European starling	6/10/93	hy/F	submitted, undetermined
04	American robin	6/10/93	ahy/M	submitted, undetermined
08	House finch	6/10/93	hy/U	submitted, unsuitable for exam
	House finch	6/14/93	u/U	disposed
09	House finch	6/14/93	hy/F	submitted, unsuitable for exam
05	American robin	6/14/93	ahy/F	submitted, undetermined
HF-21	House finch	6/14/93	ahy/F	submitted, emaciation
AR-9	American robin	6/14/93	ahy/M	submitted, not examined
HF-4	House finch	6/15/93	u/U	submitted, not examined
	House finch	6/16/93	ahy/F	disposed
	Unknown	6/16/93	hy/U	disposed
HF-16	House finch	6/16/93	ahy/F	submitted, not examined
MD-12	mourning dove	6/16/93	hy/U	submitted for residue

Table 1-19 (Continued).

Sample Number	Species	Date Collected	Age & Sex	Fate
AR-19	American robin	6/17/93	ahy/F	submitted, convulsions, emaciation
HF-24	House finch	6/17/93	hy/U	submitted, emaciation
HF-15	House finch	6/17/93	u/U	submitted, not examined
-	House finch	6/17/93	ahy/F	disposed
	American robin	6/17/93	hy/U	disposed
MD-18	Mourning dove	6/17/93	hy/U	submitted for residue
	American robin	6/18/93	ahy/M	disposed
HF-17	House finch	6/18/93	u/U	submitted, not examined
	Unknown	6/18/93	ahy/U	disposed
	House sparrow	6/18/93	ahy/F	disposed
93HS009	House sparrow	6/20/93	hy/M	archived
AR-14	American robin	6/20/93	ahy/M	submitted, intestinal parasitism
HF-13	House finch	6/21/93	hy/U	submitted, not examined
	House sparrow	6/22/93	ahy/M	disposed
AR-8	American robin	6/22/93	ahy/M	submitted, intestinal parasitism
AR-25	American robin	6/22/93	u/U	submitted, not examined
HF-10	House finch	6/23/93	hy/U	submitted, not examined
	Mourning dove	6/23/93	u/U	disposed
	American robin	6/24/93	hy/U	disposed
	American robin	6/24/93	u/U	disposed
BO-11	Northern oriole	6/24/93	ahy/M	submitted, trauma

Table 1-19 (Continued).

Sample Number	Species	Date Collected	Age & Sex	Fate
	American robin	6/25/93	hy/U	disposed
	European starling	6/25/93	hy/U	disposed
	House finch	6/25/93	u/U	disposed
	Unknown	6/28/93	hy/U	disposed
93CG013	common grackle	6/28/93	hy/U	archived
93AR012	American robin	6/28/93	ahy/F	archived
	Common grackle	6/28/93	hy/U	disposed
	American robin	6/28/93	u/U	disposed
HF-23	House finch	6/28/93	hy/U	submitted, not examined
	House finch	6/30/93	ahy/F	disposed
HF-7	House finch	7/1/93	hy/F	submitted, emaciation
	American robin	7/2/93	hy/U	disposed
AR-22	American robin	7/2/93	ahy/M	submitted, not examined
	House finch	7/6/93	hy/U	disposed
	Unknown	7/6/93	hy/U	disposed
MD-6	Mourning dove	7/6/93	hy/U	submitted for residue
ST-5	European starling	7/7/93	hy/U	submitted, emaciation
	Mourning dove	7/9/93	hy/U	archived
1	American kestrel	7/11/93	ahy/M	submitted, poor condition
	House sparrow	7/13/93	hy/U	disposed
	American robin	7/14/93	hy/U	disposed
	House finch	7/14/93	ahy/M	disposed
	American robin	7/14/93	hy/U	archived
	Mourning dove	7/20/93	hy/U	disposed

Table 1-19 (Continued).

Sample Number	Species	Date Collected	Age & Sex	Fate
	Mourning dove	7/20/93	hy/U	disposed
	Mourning dove	7/22/93	hy/U	disposed
93HF019	House finch	7/23/93	hy/U	archived
93HF021	House finch	7/27/93	hy/U	archived
	House sparrow	8/2/93	hy/U	disposed
93MD022	Mourning dove	8/3/93	hy/U	archived
	European starling	8/3/93	hy/U	disposed
93BO023	Northern oriole	8/3/93	hy/U	archived
	Mourning dove	8/3/93	hy/U	disposed
	Mourning dove	8/5/93	hy/U	disposed
93ES024	European starling	8/10/93	hy/U	archived
	Mourning dove	8/10/93	hy/U	disposed
	House sparrow	8/12/93	hy/U	archived
	House finch (2)	8/20/93	u/U	disposed
	House sparrow	8/20/93	hy/U	disposed
93HS026	House sparrow	9/15/93	hy/F	archived
	House sparrow	9/21/93	ahy/F	disposed
	American robin	10/5/93	ahy/F	disposed
	House sparrow	10/27/93	ahy/M	disposed
	House sparrow (2)	11/17/93	u/U	disposed
94B009	Townsend's solitaire	01/25/94	ahy/U	disposed
94B021	Western meadowlark	04/18/94	ahy/M	submitted, emaciation
94B025	Golden-crowned kinglet	04/22/94	ahy/M	disposed
94B026	European starling	04/22/94	hy/U	disposed
94B027	European starling	04/22/94	u/U	disposed
94B029	Unknown	05/02/94	ahy/U	disposed

Table 1-19 (Continued).

Sample Number	Species	Date Collected	Age & Sex	Fate
94B034	Say's phoebe	05/15/94	ahy/M	submitted, emaciation, ChE[b]
94B036	American robin	05/21/94	ahy/M	submitted, emaciation, ChE
94B037	House sparrow	05/22/94	ahy/F	disposed
94B038	House finch	5/23/94	hy/U	disposed
94B041	Mourning dove (2)	05/25/94	hy/U	disposed
94B042	European starling	05/26/94	ahy/M	submitted to TIWET, convulsions
94B043	American robin	05/26/94	ahy/M	submitted, emaciation
167.297[c]	European starling	05/26/94	ahy/F	submitted, undetermined, ChE
94B045	European starling	05/27/94	hy/M	submitted, emaciation, ChE
95B046	Northern oriole	05/28/94	ahy/M	submitted, emaciation, trauma, ChE
94B047	American robin	05/28/94	ahy/M	submitted, trauma, emaciation, ChE
94B048	American robin	06/01/94	ahy/F	submitted, emaciation, ChE
94B052	European starling	06/04/94	hy/U	submitted to TIWET, convulsions
94B054	European starling	06/06/94	ahy/U	disposed
94B050	House finch	06/08/94	ahy/M	submitted, undetermined
167.11	American robin	06/10/94	ahy/M	submitted, trauma
94B056	American robin	6/13/94	ahy/F	archived
94B057	House finch	6/14/94	u/M	archived
94B058	European starling	06/14/94	hy/U	disposed
94B059	European starling	06/15/94	hy/U	archived

Table 1-19 (Continued).

Sample Number	Species	Date Collected	Age & Sex	Fate
94B060	American robin	06/15/94	ahy/F	archived
94B062	House finch	06/16/94	u/U	disposed
94B063	European starling	6/16/94	u/F	disposed
94B066 *	House Sparrow	06/20/94	ahy/F	Disposed
94B067	Unknown	06/20/94	hy/U	Disposed
94B072	American Robin	06/21/94	hy/U	submitted for residue only
94B069	European Starling	06/22/94	ahy/U	Disposed
94B070	Western meadowlark	06/23/94	hy/U	Archived
94B073	American Robin	06/26/94	hy/U	Archived
94B074	House Finch	06/28/94	hy/U	Archived
94B075	House Sparrow	06/28/94	u/U	Disposed
94B076	Western meadowlark	06/28/94	hy/U	Archived
94B077	European Starling	06/28/94	hy/U	Archived
94B079	European Starling	06/29/94	u/U	Disposed
94B079A	House Sparrow	07/01/94	hy/U	Archived
94B080	Northern oriole	7/4/94	ahy/U	Archived
94B081 *	House Finch	07/05/94	ahy/F	Disposed
94B083	American Robin	07/07/94	hy/U	submitted for residue only
94B086	American Robin	07/11/94	hy/U	Disposed
94B087 *	House sparrows (3)	07/12/94	ahy/M	Disposed
94B087A	American Robin	07/13/94	hy/U	Disposed
94B088	House Finch	07/14/94	u/U	Archived
94B091	American Robin	07/19/94	hy/U	Disposed
94B095	Chipping Sparrow	07/25/94	u/U	Archived
94B096	Mourning Dove	07/25/94	ahy/U	submitted, undetermined

Table 1-19 (Continued).

Sample Number	Species	Date Collected	Age & Sex	Fate
94B097	House Finch	07/28/94	u/U	Archived
94B098	House Finch	07/29/94	hy/U	Archived
94B101	House Finch	08/02/94	hy/U	Disposed
94B102	House Finch	08/01/94	hy/U	Disposed
94B103	House Finch	08/04/94	u/U	Disposed
94B104	House Finch	08/04/94	hy/U	Disposed
94B105	House Finch	08/05/94	u/U	Disposed
94B107	House Finch	08/08/94	ahy/F	submitted for residue only
94B109	Mourning dove (2)	08/17/94	hy/U	Disposed
94B115	Mourning Dove	09/06/94	ahy/F	Disposed
94B116	Chipping Sparrow	09/07/94	hy/U	Archived

[a] hy = hatch year, ahy = after hatch year, u = unknown, m = male, f = female.
[b] = ChE = cholinesterase inhibition.
[c] 167.111 denotes frequency of banded and transmittered birds, individuals marked with * were banded only.

To determine whether food and habitat availability affected avian mortality at Building 111, the relative abundance of passerine bird species was examined in 1993. Bird feeders were present at Building 111 but were removed in July of 1993. The five bird species most often observed, in descending order, were house finch, house sparrow, robin, starling, and dove. Collectively, an average 88 birds/day of these species were recorded over 21 count days (U.S. Fish and Wildlife Service 1994a). The most common species were also the most commonly found dead. To determine areas of use by the species commonly found dead at the Building 111 complex and determine causes of mortality, studies were expanded in 1994 to track a sample of individual birds.

METHODS

Daily carcass searches were conducted on the area surrounding Building 111 (Figure 1-11) from April through September. All carcasses or carcass parts were removed when found. Carcasses suitable for necropsy (not decomposed or scavenged) were submitted to the NWHRC. Necropsies included examination for gross lesions, histopathology, diagnostic testing for bacterial and viral disease, and tests for lead and brain cholinesterase inhibition. Brains and livers were dissected for chemical analyses. Whole body carcasses with feathers, feet, and GI tract removed were also analyzed. Quality assurance/quality control and sample handling followed the procedures in the biomonitoring program for the Refuge (U.S. Fish and Wildlife Service 1994b). Chemical analyses followed the U.S. Army chemical quality assurance plan for the target analytes (aldrin, dieldrin, endrin, isodrin, alpha-chlordane, gamma-chlordane, DDT, DDE, arsenic, and mercury) and were performed by Environmental Science and Engineering, Inc. in Denver.

Starlings and robins were chosen as species of focus for investigation because they were commonly found dead and were easily captured and fitted with radio transmitters. In addition, much information exists on the life history of these birds and on the effects of pesticides on starlings (Kendall et al. 1989). Mourning doves, house finches and house sparrows were also targeted for study.

Starlings, robins, and doves were captured with mist nets or funnel traps, and house finches, house sparrows, and incidental species were captured with funnel traps (Day et al. 1980). Trapping took place from 15 May to 28 July. Most trapping was done at the Building 111 complex (Figure 1-11). In addition, some traps were set in Sections 2, 3, and 34 to attempt recapture of transmittered birds. Any birds captured in these other areas were banded. Robins, starlings, finches, and sparrows were fitted with U.S. Fish and Wildlife Service leg bands and colored leg bands. A unique color combination was used for each individual bird. Other species captured received only U.S. Fish and Wildlife Service leg bands. Data recorded on each banded bird followed that recommended by Ralph et al. (1993) and included age, sex, weight, amount of fat, wing chord, molt, and breeding condition. Locations of incidental observations of color banded birds were recorded throughout the summer.

A harness design (Rappole and Tipton 1991) was used to attach 2 g radio transmitters to robins and starlings. Visual locations of each bird were attempted at least once per day to ensure they were alive and that transmitters were still attached. Individual birds were also observed for one to two hour periods to record locations and activities. Specific food items were recorded when possible. Attempts were made to observe each bird during morning, afternoon, and evening periods. Birds with transmitters were recaptured at the completion of study in funnel traps and euthanized in a carbon dioxide chamber or collected by pellet gun when possible. Necropsies and contaminant analyses were performed on these birds to correlate contaminant levels with use areas and for comparison with birds found dead.

Weekly nest searches were conducted at the Building 111 complex by visually inspecting trees and bushes and observing birds carrying nest material. The nest discovery, nest contents, location, and nest success were monitored.

Water samples were collected from 3 sites from puddles or lawn sprinklers at the Building 111 lawn and southeast Section 34 for analyses of metals, organophosphates/carbamates, and target analytes. Three soil samples were collected from the Building 111 lawn for analyses of metals and target analytes. Invertebrates were collected with sweep nets and pitfall traps, and earthworms were collected from the lawn by excavation. One composite invertebrate sample was analyzed for target analytes.

RESULTS

Sixty-six birds were found dead at the Building 111 complex. Specific locations of dead birds are shown in Figure 1-12. Thirteen (20%) were robins, 13 (20%) starlings, 15 (22%) house finches, 7 (10%) house sparrows, 6 (9%) mourning doves, and 12 (18%) other or unidentified species. Six robins, 6 house finches, 1 house sparrow, and 4 doves were nestlings or fledglings. Six starlings were fully fledged juveniles and none were nestlings. A list of all specimens found at Building 111 by the U.S. Fish and Wildlife Service since 1989, and their fate is provided in Table 1-19. Daily carcass searches were not conducted prior to 1993. Peak mortalities in 1994 were in June when 24 birds were found. Birds were found nearly every day from 15 May through June, and sometimes more than one bird was found per day.

Thirty-three specimens were unsuitable for necropsy or contaminant analysis due to decomposition or predation and were disposed, 12 were submitted to NWHRC, 2 starlings were submitted to The Institute of Wildlife and Environmental Toxicology to be analyzed as part of their ongoing starling study, 3 were submitted for contaminant analyses only, and 16 were archived for later analysis. Final diagnoses from necropsies performed at NWHRC indicated that bird deaths resulted from undetermined causes of emaciation, or were simply not determined. Six of the 10 birds exhibited brain cholinesterase inhibition (25% to 34%), and one was traumatized. Another of the 10 birds had signs of trauma along with cholinesterase inhibition. Gastrointestinal tracts of birds with cholinesterase inhibition were analyzed for organophosphate/carbamate compounds, but none were detected. In addition to the 66 birds found at Building 111, one starling was found at the fire department in Section 36 (sample number 94B022) and one at the Visitor Center in Section 2 (94B053). Both were found in convulsions and later died. A necropsy on 94B022 showed emaciation from undetermined causes. Contaminant results on this bird are given in Table 1-20. Results have not yet been received on all of the convulsing birds reported in Table 1-19.

Ninety-four birds were captured and banded. Only one dove was captured. Of these, 10 starlings and 7 robins were fitted with radio transmitters. Specific data on banded birds are presented in Table 1-21. Fifteen color banded birds (finches, sparrows, starlings) were resighted at Building 111, 16 at the visitor center (finches and sparrows), 3 starlings near south plants, and one finch in Section 26. Three house finches, 4 house sparrows, and 4 robins were recaptured at Building 111. Three banded sparrows and 1 banded finch were found dead at Building 111 near the areas where they were originally trapped, but were decomposed or scavenged and were unsuitable for necropsy. Two transmittered starlings were found dead. The death of one adult female (167.297) at Building 111 was undetermined, but exhibited cholinesterase inhibition, and had 3.80 ppm dieldrin in the brain. One juvenile male (167.179A), found in southeast Section 3 in a locust grove, died from an undetermined cause of emaciation and had 10.40 ppm dieldrin in the brain. Five starlings lost their transmitters after several days but were later sighted alive. One of these starlings (167.068) was recaptured and

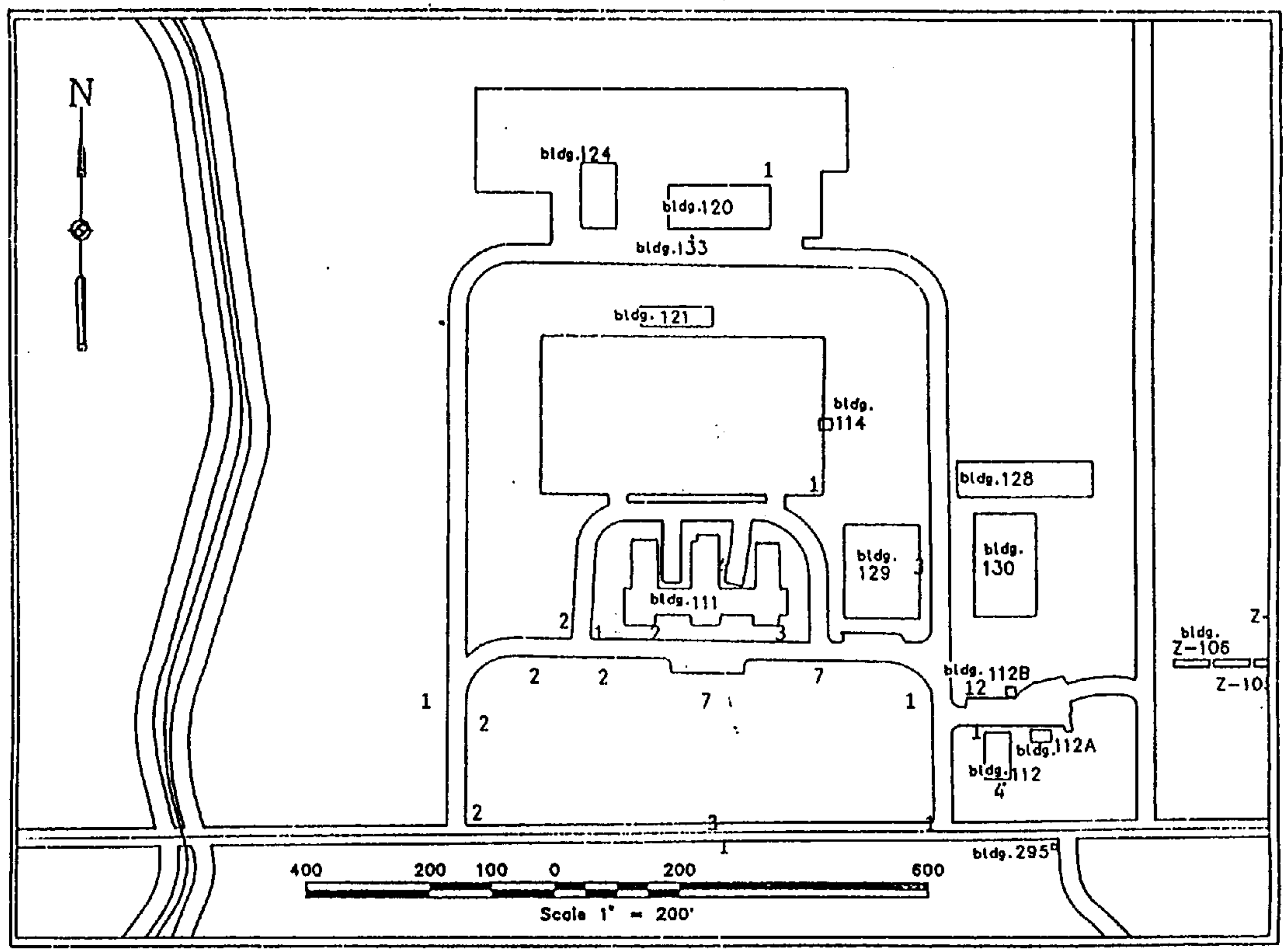

Fig. 1-12. Locations of dead birds (number found at each site) found at the Building 111 complex in 1994.

Table 1-20. Results of chemical analyses (ppm wet weight) for birds found dead at Building 111.

Sample Number	Species	Date	Tissue[a]	Percent Lipid	Dieldrin[b]	Endrin	DDT	DDE
ST-2	European starling	4/27/93	brain	5.0	6.38	bcrl[c]	bcrl	1.09
ST-2	European starling	4/27/93	liver	0.3	3.94	bcrl	bcrl	0.72
02 *	Sharp-shinned hawk	4/27/93	carcass, brain, liver	2.2	bcrl	bcrl	bcrl	1.37
ST-1	European starling	5/4/93	carcass	1.5	4.78	0.03	bcrl	0.67
07	European starling	5/18/93	brain	5.5	5.74	0.19	bcrl	0.26
07	European starling	5/18/93	liver		[d]			
10	House finch	6/3/93	liver					
03	Western kingbird	6/7/93	carcass, brain, liver	0.7	10.3	0.09	bcrl	0.67
04 *	American robin	6/10/93	carcass, brain, liver	1.5	3.2	0.04	bcrl	1.27
06	European starling	6/10/93	brain	2.9	6.90	bcrl	bcrl	0.44
06	European starling	6/10/93	liver					
05 *	American robin	6/14/93	carcass, brain, liver	0.7	0.20	bcrl	bcrl	0.21
09	house finch	6/14/93	carcass, brain, liver	0.7	bcrl	bcrl	bcrl	bcrl
HF-21	House finch	6/14/93	carcass	1.1	0.06	bcrl	bcrl	bcrl
HF-21	House finch	6/14/93	brain	5.0	bcrl	bcrl	bcrl	bcrl

Table 1-20 (Continued).

Sample Number	Species	Date	Tissue	Percent Lipid	Dieldrin	Endrin	DDT	DDE
HF-21	House finch	6/14/93	liver	1.3	bcrl	bcrl	bcrl	bcrl
AR-19	American robin	6/17/93	carcass	--	2.54	bcrl	bcrl	0.15
AR-19	American robin	6/17/93	brain	3	7.41	bcrl	bcrl	0.63
AR-19	American robin	6/17/93	liver	--	3.35	bcrl	bcrl	0.28
HF-24	House finch	6/17/93	carcass	0.9	bcrl	bcrl	bcrl	bcrl
HF-24	House finch	6/17/93	brain					
HF-24	House finch	6/17/93	liver					
AR-14	American robin	6/20/93	brain	3	7.9	0.27	2.03	12.5
AR-14	American robin	6/20/93	liver	--	10.9	0.19	bcrl	17.1
AR-25	American robin	6/22/93	brain	6.5	3.93	0.24	bcrl	1.11
AR-25	American robin	6/22/93	carcass					
AR-8	American robin	6/22/93	brain	5	8.07	0.17	2.38	12.7
AR-8	American robin	6/22/93	liver	0.3	5.9	0.15	bcrl	7.67
BO-11	Northern oriole	6/24/93	brain	6	0.34	bcrl	bcrl	0.16
BO-11	Northern oriole	6/24/93	liver	2	0.77	bcrl	bcrl	0.3
HF-7	House finch	7/1/93	carcass	1.5	0.02	bcrl	bcrl	bcrl

Table 1-20 (Continued).

Sample Number	Species	Date	Tissue	Percent Lipid	Dieldrin	Endrin	DDT	DDE
HF-7	House finch	7/1/93	brain	3	bcrl	bcrl	bcrl	bcrl
HF-7	House finch	7/1/93	liver					
HF-7	House finch	7/1/93	gizzard					
ST-5	European starling	7/7/93	brain	3	3.76	bcrl	bcrl	0.12
ST-5	European starling	7/7/93	liver	--	2.43	bcrl	bcrl	bcrl
MD-06	Mourning dove	7/6/93	carcass	0.5	0.39	bcrl	bcrl	bcrl
MD-12	Mourning dove	6/16/93	carcass	0.3	0.21	bcrl	bcrl	bcrl
MD-18	Mourning dove	6/17/93	carcass	2.8	0.043	bcrl	bcrl	bcrl
1	American kestrel	7/11/93	brain	--	1.34	bcrl	bcrl	bcrl
1	American kestrel	7/11/93	liver	--	1.55	bcrl	bcrl	bcrl
94BO21	Western meadowlark	4/18/94	brain	6.3	10.4	0.28	bcrl	0.44
94BO21	Western meadowlark	4/18/94	liver	1.1	15.69	0.38	bcrl	0.87
94BO22	European Starling	4/21/94	brain	6	1.42	bcrl	bcrl	1.12
94BO22	European Starling	4/21/94	liver	--	9.66	bcrl	bcrl	0.87
94BO36	American Robin	5/21/94	brain	9.5	7.62	0.36	bcrl	0.72
94BO36	American Robin	5/21/94	carcass					

Table 1-20 (Continued).

Sample Number	Species	Date	Tissue	Percent Lipid	Dieldrin	Endrin	DDT	DDE
94B043	American Robin	5/25/94	brain	4.4	18.33	bcrl	0.13	1.43
94B043	American Robin	5/25/94	liver	--	20.33	bcrl	bcrl	2.28
94B043	American Robin	5/25/94	muscle	0.1	1.45	bcrl	bcrl	0.13
94B043	American Robin	5/25/94	kidney	--	11.4	bcrl	bcrl	1
167.297 *	European Starling	5/26/94	brain	5.8	3.8	bcrl	bcrl	0.68
167.297	European Starling	5/26/94	liver	0.6	3.36	bcrl	bcrl	0.71
167.297	European Starling	5/26/94	muscle	0.1	1.4	bcrl	bcrl	0.33
167.297	European Starling	5/26/94	kidney	1	2.55	bcrl	bcrl	0.58
167.297	European Starling	5/26/94	carcass					
94B045	European Starling	5/27/94	brain	17	7.95	bcrl	bcrl	bcrl
94B045	European Starling	5/27/94	liver	--	6.57	bcrl	bcrl	bcrl
94B045	European Starling	5/27/94	kidney	0.8	6	bcrl	bcrl	bcrl
94B045	European Starling	5/27/94	muscle	0.1	1.02	bcrl	bcrl	bcrl
94B046	Northern Oriole	5/28/94	brain	8.3	20.74	bcrl	bcrl	bcrl
94B046	Northern Oriole	5/28/94	liver	0.6	13.26	bcrl	bcrl	bcrl
94B046	Northern Oriole	5/28/94	carcass					

Table 1-20 (Continued).

Sample Number	Species	Date	Tissue	Percent Lipid	Dieldrin	Endrin	DDT	DDE
94B046	Northern Oriole	5/28/94	kidney	1.7	13.51	bcrl	bcrl	bcrl
94B046	Northern Oriole	5/28/94	muscle					
94B047	American Robin	5/28/94	brain	4.9	12.28	bcrl	1.2	8.72
94B047	American Robin	5/28/94	liver	0.5	10.28	0.2	0.08	7.53
94B047	American Robin	5/28/94	kidney					
94B047	American Robin	5/28/94	muscle					
94B047	American Robin	5/28/94	carcass					
94B048	American Robin	6/1/94	brain	11	20.13	0.18	0.19	1.66
94B048	American Robin	6/1/94	liver	0.4	19.18	0.28	bcrl	2.33
94B048	American Robin	6/1/94	kidney	0.6	bcrl	bcrl	bcrl	bcrl
94B048	American Robin	6/1/94	muscle	0.1	2.53	bcrl	bcrl	0.26
111-01 [f]	American robin	6/11/94	carcass	0.5	1.04	bcrl	0.07	0.3
94B050	House Finch	6/15/94	carcass	2.5	0.36	bcrl	bcrl	0.04
94B050	House Finch	6/15/94	brain	0.5	1.13	bcrl	0.08	4.35
94B050	House Finch	6/15/94	liver					
94B050	House Finch	6/15/94	kidney					
94B050	House Finch	6/15/94	muscle					
167.111	American Robin	6/10/94	brain	3.5	0.98	bcrl	1.04	6.12

Table 1-20 (Continued).

Sample Number	Species	Date	Tissue	Percent Lipid	Dieldrin	Endrin	DDT	DDE
167.111	American Robin	6/10/94	liver	1.9	0.28	bcrl	bcrl	bcrl
167.111	American Robin	6/10/94	kidney					
167.111	American Robin	6/10/94	muscle					
94B072	American robin	6/21/94	carcass					
167.248	American robin	6/22/94	brain	4.8	11.23	0.26	0.17	5
167.248	American robin	6/22/94	liver	0.8	9.88	0.24	bcrl	3.65
167.248	American robin	6/22/94	carcass					
167.248	American robin	6/22/94	kidney	--	4.49	bcrl	bcrl	2.1
167.248	American robin	6/22/94	muscle	0.1	1.05	bcrl	bcrl	0.56
167.179A	European Starling	6/24/94	brain	9.2	10.40	bcrl	bcrl	5.33
167.179A	European Starling	6/24/94	liver	0.2	8.48	bcrl	bcrl	4.41
167.179A	European Starling	6/24/94	carcass					
167.179A	European Starling	6/24/94	kidney	--	4.46	bcrl	bcrl	2.81
167.179A	European Starling	6/24/94	muscle	--	0.98	bcrl	bcrl	0.73
167.179A	European Starling	6/24/94	stomach	0.4	1.37	bcrl	bcrl	0.84
94BO83	American Robin	7/7/94	carcass	3	2.12	0.05	3.12	15.7
167.264	American robin	7/8/94	brain	6.2	0.7	bcrl	0.87	4.8
167.264	American robin	7/8/94	liver	0.4	0.82	bcrl	0.22	3.68

Table 1-20 (Continued).

Sample Number	Species	Date	Tissue	Percent Lipid	Dieldrin	Endrin	DDT	DDE
167.068	European starling	7/8/94	brain	4.7	1.78	bcrl	bcrl	1.25
167.068	European starling	7/8/94	liver	1.1	2.5	bcrl	bcrl	1.29
167.068	European starling	7/8/94	carcass					
167.002	American robin	7/15/94	brain	--	1.5	bcrl	bcrl	2.42
167.002	American robin	7/15/94	liver	0.8	5.03	bcrl	bcrl	4.08
167.002	American robin	7/15/94	carcass					
94BO96	Mourning Dove	7/25/94	brain					
94BO96	Mourning Dove	7/25/94	liver					
94BO96	Mourning Dove	7/25/94	carcass					
94BO96	Mourning Dove	7/25/94	muscle					
167.278	American robin	8/5/94	brain	7.4	0.48	bcrl	0.7	4.83
167.278	American robin	8/5/94	liver	2	1.67	bcrl	bcrl	9.38
94B107	House Finch	8/8/94	brain					
94B107	House Finch	8/8/94	liver					
94B107	House Finch	8/8/94	carcass					

* Mercury was detected in these samples from 0.09 to 1.00 parts per million.
[a] See text for description of carcass analyses.
[b] Aldrin and arsenic were also analyzed for but not detected in any sample.
[c] bcrl = Below certified reporting limit.
[d] Blank spaces indicate data not yet received.
[e] 167.111 denotes frequency of transmittered birds corresponding to Figures 3 and 4.
[f] 111-01 was a live nestling purposely collected for contaminant analysis.

Table 1-21. Summary of status of birds captured at Building 111.

Species Banded	Number Banded	Sex			Age			Mean Weight and Range (g)		
		M	F	U	HY	AHY	U	M	F	U
House finch	25	13	7	5	4	12	8	22 (20-25)	22 (22-26)	17 (12-21)
House sparrow	26	12	14	0	4	11	12	26 (20-30)	27 (19-30)	
European starling	21	8	11	2	8	8	7	70 (61-85)	68 (44-79)	73 (65-15)
American robin	9	4	5	0	0	7	0	58 (49-82)	79 (76-88)	
Mourning dove	1	0	1	0	0	1	0		132	
Common grackle	10	2	6	2	8	0	2	92 (89-96)	80(78-82)	89 (89-90)

M = Male
F = Female
U = Unknown
HY = hatch year bird
AHY = after hatch year bird.

submitted for necropsy and chemical analyses. Two transmitter batteries stopped functioning after about 1 month, but these birds were last seen alive. One starling disappeared or the transmitter stopped functioning after one day.

Two transmittered robins were found dead. One adult male robin (167.111) exhibited trauma and, as it was found on the road, was probably hit by a car. Another adult male robin (167.248) displayed stomatitis and emaciation, and had 11.23 ppm dieldrin in the brain. One transmitter battery (167.264) stopped functioning shortly after attachment, but subsequent observations were made for a total of 21 locations on this bird. The bird was later recaptured. Two other robins (167.002 and 167.278) were recaptured before the transmitter batteries died. Necropsies on recaptured birds showed no significant lesions and apparently healthy birds with normal weight. The remaining robins were last seen alive after their transmitter batteries died.

The number of telemetry locations collected on robins ranged from 15 to 53 and for starlings from 3 to 38. Areas used by robins and starlings are shown in Figures 1-13 and 1-14. These figures show general areas of use only. Relocation samples were insufficient to statistically determine home ranges.

Detected brain residues of dieldrin in birds found dead ranged from 0.34 to 20.74 ppm. Of the 25 results on birds found dead, 60% (n=15) had dieldrin brain concentrations greater than 5 ppm, 28% (n=7) had between 1 and 5 ppm in the brain, 4% had less than 1 ppm, and 8% were below detection. All birds with detections less than 1 ppm were either recaptured live birds or trauma victims. Collected, transmittered birds had brain concentrations of dieldrin ranging from 0.14 ppm to 1.78 ppm. House finches had no detectable levels of dieldrin in brain tissue. Birds in convulsions for which results have been received (001, AR-19, 94B022) had brain concentrations of 1.3 ppm, 7.41 ppm, and 1.42 ppm, respectively. The mean dieldrin brain concentration in starlings found dead with undetermined cause of death was 5.79 ppm (n=8) and in robins was 10.77 ppm (n=9).

Liver concentrations of dieldrin in dead birds ranged from 0.28 to 20.33 ppm. Endrin was detected in the brains of 8 dead birds from 0.17 ppm to 0.36 ppm, DDT was found in 7 brains from 0.08 ppm to 2.38 ppm, and DDE in 19 brains from 0.12 to 12.65 ppm. Collected birds had no detections of endrin in the brain, 3 detections of DDT (0.15 ppm, 0.70 ppm, and 0.87 ppm), and all had DDE in the brain ranging from 0.87 ppm to 4.83 ppm. Kidney and muscle tissues also had dieldrin and DDE detections. One robin fledgling (94B083) from Building 111 had 0.019 ppm alphachlordane and 2.12 ppm dieldrin in the carcass. A robin nestling (111-01) collected from the Building 111 complex had 1.04 ppm dieldrin in the carcass. Mourning dove squab carcasses had dieldrin ranging from 0.04 to 0.389 ppm.

Generally, recaptured robins that stayed in the vicinity of Building 111 (167.002, 167.228, 167.111, 167.264) had lower concentrations of dieldrin, but similar concentrations of DDT and DDE as dead birds. Results have not yet been received on all tissues and carcasses.

Eleven robin nests, 7 dove nests, and 6 house finch nests were monitored. Starlings were observed taking food to nests and chicks could be heard, but because of the nest site locations in buildings, most starling nests could not be monitored. Four robin nests successfully fledged 2 or more young, one house finch nest fledged young, and one dove nest fledged 2 young. More fledglings were observed in the area than corresponded to the observed nests, indicating that all nests were not found. Nest success in starling nest boxes erected near Building 111 is reported in the appendix starling study annual progress report by The Institute of Wildlife and Environmental Toxicology.

Dieldrin (0.340 ppm), DDT (0.546 ppm), and DDE (1.585 ppm) were detected in a composite invertebrate sample collected from the Building 111 lawn. The bulk of this sample (approximately 8 g) was earthworms. Soil samples had dieldrin (0.356 ppm), DDT (0.766 ppm), DDE (0.629, 4.57 ppm), and DDD (0.626 ppm). In addition, 44.8 ppm lead was detected in one sample. No organochlorines, organophosphates, or carbamates were detected in water samples from puddles or sprinklers at Building 111. However, barium was detected in water from 2 sites (58 and 70 ppb). Zinc was detected at 1291 ppb in a sample collected from a puddle in a culvert where birds were observed bathing. The zinc may have been from the culvert material. The source of barium is unknown.

DISCUSSION

High nestling and fledgling mortality occurs in most birds (Welty 1982). In 1993, 57% of all mortalities were hatch year birds, and in 1994, 35% were hatch year birds. Once birds survive the postfledging period, the probability of death each year remains somewhat constant (Welty 1982, Ehrlich et al. 1988). The maximum life span for robins has been recorded as 13 years, 11 months and for the starling as 15 years, 3 months but the median life span is less (Klimkiewicz et al. 1983, Ehrlich et al. 1988). Farner (1945) used banding records to determine the average natural longevity of robins to be 1.7 to 1.9 years and cited longevity of starlings as 2 to 3 years. Farner (1945) calculated the annual survival rate of robins as 47% and 50% for starlings. Adult survival rates of starlings from banding records have been calculated as 43.3% and 48.1% (Fankhauser 1971, Stewart 1978). Welty (1982) cited the mean annual adult mortality rate of starlings as 53%.

The number of adult birds found dead with no indication of disease or injury at Building 111 may not be within the normal mortality range for songbirds, particularly since there is a history of these mortalities from the same location. Rosene and Lay (1963) studied the disappearance of quail (Colinus virginianus) remains and stated that finding even a small or moderate number of dead quail or their remains is reason to suspect heavier mortality. Since no evidence of disease or injury was found on most dead birds at Building 111 and because dieldrin concentrations were found in carcasses and brains of birds at Building 111 in the past, contaminant impacts were suspected. Brain residues, together with necropsy results, now indicate that many of the birds died from dieldrin poisoning.

Many studies have shown several ppm of dieldrin in the brain of birds to be associated with mortality (Linder et al. 1970, Clark 1975). Stickel et al. (1969) suggested 4 to 5 ppm in the brain as the lower limit to indicate cause of death from dieldrin poisoning. See the 'Fortuitous Specimen Program' report in this annual report for a discussion of interpretive guidelines for dieldrin residues. Dieldrin can cause loss of appetite (Linder et al. 1970, Flickinger and King 1972, Smith 1991) perhaps leading to weight loss. Nearly all dieldrin dosing studies cite loss of weight as an observed effect (see literature cited in 'Fortuitous Specimen Report' herein). Fergin and Schafer (1977) found that bobwhite quail lost weight shortly before death when dosed with dieldrin and Linder et al. (1970) found that pheasants (Phasianus colchicus) dosed with dieldrin typically stopped eating, lost weight, and were emaciated at death. Nusz et al. (1976) reported reduced weight gain in dosed versus control bobwhite quail and attributed it to the effects of dieldrin. Clark (1975) documented weight loss in redwinged blackbirds (Agelaius phoeniceus) dosed with aldrin. Heinz and Johnson (1982) studied cowbirds (Molothrus ater) and suggested that about 1 ppm or more of dieldrin in the brain could result in an irreversible process of starvation. In addition, there may be differences between species in the amount of dieldrin that can cause feeding to stop or cause mortality (Tucker and Haegele 1971, Heinz and Johnson 1982). Stickel et al. (1969) suggested that individuals that die with low brain residues are the ones that die first and may be over-represented among birds found dead. Ecobichon (1991) cites loss of weight and anorexia as chronic signs of DDT toxicity. Sixty percent of dead birds at Building 111 with emaciation and undetermined cause of mortality had lethal concentrations of dieldrin in their brains with the exception of house finches. Therefore, it is likely that the diagnoses of emaciation in Building 111 birds is indicative of organochlorine exposure. Although the diagnoses on house finches were also emaciation, these mortalities still are unexplained.

Convulsions can also be a sign of organochlorine poisoning (Hudson et al. 1984, Ecobichon 1991). In addition to the two starlings undergoing convulsions at Building 111 (numbers 94B042 and 94B052, Table 1-19), one starling was collected at the fire station in Section 36 (number 94B022, Table 1-20) that was observed in suspected convulsions. Still another (94B053) was collected at the Visitor Center in Section 2 while undergoing convulsions. All four of these birds died following convulsions. The convulsive episodes were typical of organochlorine poisoning, particularly dieldrin poisoning with wing-beat convulsions, head bowed, and outstretched legs (Hudson et al. 1984). Starlings dosed with dieldrin by The Institute of Wildlife and Environmental Toxicology exhibited the same convulsive symptoms (Mike Hooper, pers. comm.). Dahlen and Haugen (1954) dosed quail with dieldrin and often found dead birds on their backs with heads drawn back, wings partially expanded, and legs extended. Several birds (starlings and mourning doves) were also seen in convulsive behavior at Building 111 in years past (Table 1-19). A robin (AR-19) and kestrel (001) were found at Building 111 while undergoing convulsions in 1993. In addition, U.S. Fish and Wildlife Service records (unpub. data) show a meadowlark (Sturnella neglecta) and starling were found in the past at the south plants and the Visitor Center undergoing convulsions.

As was apparently the case in past years, peak mortalities in 1993 and 1994 occurred during the breeding season. This is a stressful time for birds that have just completed migration and are beginning to nest. Weights of most birds will vary depending on the time of year. The weight of house finches has been reported as 21.4 g with a range of 19 to 25.5 g and as 18.9 g (Palmer and Fowler 1975, Dunning 1993). The average weight of house sparrows is 28.4 g with an average of 28 g for males (range 20.0 to 34.0 g) and 27.4 g for females (range 20.1 to 34.5 g)(Palmer and Fowler 1975, Dunning 1993). Starling males average 84.7 g and females 79.9 g (Dunning 1993). Robin weights can vary from 30 to 100 g according to Graber and Wunderle (1966). A range of 63.5 to 103 g with a mean of 77.3 g was found for robins in Pennsylvania (Dunning 1993). The weights of trapped finches and sparrows at Building 111 fell within the ranges found in the literature. Mean weights of starlings trapped were less than means given above (Table 1-21). The time of year of the starling weights taken were not given in the literature. Robin weights were lower than the mean but fall within ranges given in the literature. Male robin average weight was less than female average weight in this study.

Many studies were done on DDT effects on robins in the 1950's and 1960's when eggshell thinning was discovered and Rachel Carson's Silent Spring (1962) was published. Hunt (1969) noticed a seasonal pattern of mortality in robins and examined the physiological susceptibility of robins to DDT poisoning. He found that changes in body weight in the spring breeding season increased susceptibility to poisoning. The majority of dead robins were males and Hunt (1969) felt their susceptibility to poisoning was increased because of fat reserve loss and the physiological differences in reproductive roles. Males also arrive earlier on the breeding grounds, thus having more exposure time to contaminants. Hunt's (1969) data indicated that male robins undergoing normal weight losses reached their lowest weight during the same period that peak deaths were associated with DDT poisoning. In addition, the frequency of dying males increased as weight representing stored fat decreased, and mortality decreased as robin weights increased (Hunt 1969). He stated that even seemingly insignificant changes in tissue fat content may influence the immediate fate of contaminants. Five of eight robins were male in this study and in 1993, 6 of 8 adult robins found dead from June 10 - 28 were male. Studies indicate that organochlorines affect lighter birds before heavy birds (Stickel et al. 1969, Heinz and Johnson 1982). Environmental stresses such as migration, weather, and food availability can contribute to increased mobilization of organochlorines or increased susceptibility to contaminants (Scott et al. 1975, Geluso and Altenbach 1976, Maguire and Williams 1987, Keith and Mitchell 1993).

Soil concentrations of dieldrin range up to 100 ppm near Building 111 in Sections 1, 2, and 35. Past collections of ground beetles, grasshoppers, and earthworms from Basin A, Basin C and the south plants (all less than 1 mile flying distance from Building 111) have shown up to 3.8 ppm dieldrin and 0.561 ppm endrin (Stollar et al. 1992). However, the highest concentrations of DDT (1.49 ppm) and DDE (1.4 ppm) were found in earthworms at Building 111 (Stollar et al. 1992). These were whole body composite samples generally of at least 25 grams. In addition to potential increased susceptibility due to poor condition, peak mortalities may occur in spring because birds are eating more insects. Omnivorous robins and starlings are known to eat more insects in spring and switch to fruits in fall (Martin et al. 1951, Bent 1964, Wheelwright 1986, Wheelwright 1988). Consumption rates may increase with different phases of the breeding season and as adults begin to feed nestlings. Jefferies and Davis (1968) examined the dynamics of dieldrin among soil, earthworms, and song thrushes (Turdus ericetorum, the same genus as robins). The highest dosed bird died after 8 days with 16.88 ppm dieldrin in the brain after consuming a dose rate of 5.33 ppm per day and 12.38 ppm in the total diet for 8 days. In reviewing past data on dieldrin concentrations in invertebrates one may determine how a robin may accumulate lethal concentrations over the course of the breeding season.

Insects may also become available at peak times as hatches occur and attract birds. Bent (1964) cites an account of robins feeding extensively on 17-year locusts upon their emergence from the ground. Schultz (1983) documented Western kingbirds (Tyrannus verticalis) exploiting unusually high densities of tiger beetles. During one telemetry session on June 15, flocks of several species of insect eating birds including kingbirds, meadowlarks, orioles, starlings, and robins, were seen feeding in Basin C in Section 26. Robins were observed chasing and catching insects. One transmittered robin (167.248 on Figure 1-13) used the Basin C area for two days and was found dead four days later. Birds did not use Basin C in such numbers a few days later. Another transmittered robin (167.257) was seen with a flock of robins feeding on the berries of Rhus trilobata in Section 3 from July 7 through 11. Mixed flocks of bird species may serve as information centers as to sources of food (Welty 1982).

Most species found dead at Building 111 are insectivorous or omnivorous, including orioles and meadowlarks. However, doves, finches, and sparrows are seed eaters. Sampling of sunflowers, cheatgrass, kochia, and wild lettuce in the Comprehensive Monitoring Program (Stollar et al. 1992) showed arsenic ranging from 0.33 to 2.26 ppm; dieldrin from 0.03 to 0.63 ppm and detections of other contaminants. Finches were observed eating thistle (Carduus nutans) and mullein (Verbascum thapus) in the south plants and Section 26 in this study. These species could also be exposed to contaminants through dust bathing, picking up grit, or water from ephemeral puddles. However, finches have not shown lethal dieldrin levels in brains, and in fact, most have not displayed any detections of organochlorines in tissues (Table 1-20).

Although birds that forage on the Building 111 lawn are exposed to organochlorines, dieldrin poisoning does not appear to be specific to Building 111. Transmittered birds, particularly robins, that were constantly observed within a few hundred yards of the same location at Building 111 remained alive and healthy throughout the study period. Recaptured robins gained from 7.0 to 33.3 g after nesting. The 3 radioed birds (167.297, 167.248, 167.179A) with an undetermined cause of death ranged farther than Building 111 to Basin C and areas near the south plants (Figures 1-13 and 1-14). Two of these birds were found dead away from Building 111. In addition, species found dead such as meadowlarks and orioles have not been observed feeding on the lawn or using water at Building 111. Under the CMP (Stollar et al. 1992), 2 dead meadowlarks and a Brewer's blackbird were found near the lower lakes, the basins in Section 26, and the north plants. These birds had dieldrin concentrations ranging from 4.4 to 8.0 ppm in carcasses. The U.S. Fish and Wildlife Service (unpub. data) has records of songbirds found dead on areas of the Refuge other than Building 111.

Feeding on the Building 111 lawn may contribute to already accumulated contaminants. Soil and invertebrate samples taken from the Building 111 lawn in 1994 had dieldrin, DDT, DDE, and DDD. Past sampling under the CMP (Stollar et al. 1992) also showed low concentrations of endrin, DDT, and DDE in soil and earthworms from the Building 111 lawn. Robins are well known for feeding on mowed lawns and starlings have shown a preference for foraging for insects in short grass (Eiserer 1980, Ehrlich et al. 1988). These species may be attracted to the mowed lawn at Building 111. In addition, earthworms are near the surface and are easily available because of lawn watering. The highest brain dieldrin concentration of birds that foraged primarily at Building 111 was 1.50 ppm. This concentration indicates a potentially dangerous accumulation of dieldrin. Nestlings and fledglings (111-01, 94B083, MD-06, MD-12, and MD-18) from Building 111 also had dieldrin accumulations that indicate potential for local exposure.

The Building 111 complex is heavily used by birds for nesting, cover, water, and foraging. The Building 111 habitat is unique on the Refuge although the southern tier of the refuge also has trees and shrubs close to water that support nesting birds. Birds nesting at Building 111 would not be expected to range very far. However, nonbreeding birds or birds between nests may range farther than nesting birds and return to Building 111 to roost or initiate a second nest, and may subsequently die there. Juvenile starlings would also be expected to range farther, but may return to roost or get water and then die at Building 111. Moribund animals may also seek cover that is available at Building 111 and die there.

Characteristics of the carcass and habitats may inhibit searcher ability to find bird carcasses (Rosene and Lay 1963, Balcomb 1986, Linz et al. 1991). Dead birds are easily observed on the mowed lawn and many people use the area, thus making the chances of dead bird detection higher. Other areas of the Refuge with trees and shrubs, such as the locust thicket in Section 3 (Figures 1-13 and 1-14) where 2 dead transmittered birds were found, are much more difficult to search because of the vegetation. In addition, scavenger activity may be higher in these areas than at Building 111. Several studies have documented rapid scavenging of bird carcasses. The majority of dead birds at Building 111 were probably found during daily carcass searches.

In summary, lethal brain concentrations of dieldrin combined with the emaciation diagnoses and birds displaying convulsions, as well as the history of mortality, indicate that dieldrin is a principal cause of mortality of birds found at the Building 111 complex. Some natural mortality also occurs. It appears that birds with small home ranges around Building 111 are not dying, but that birds ranging into other areas are. However, birds may still be exposed to contaminants from the Building 111 lawn. A combination of low weights from breeding or competition for food resources at Building 111 may affect susceptibility to dieldrin. Peak mortality in the spring and summer could be related to additional stresses from migration and breeding, and increased feeding on insects. Observations of mortality at Building 111 are most likely high because many birds are attracted to the area, the mowed lawn and larger number of people make detection of dead birds more likely, and there may be less scavenger activity here. Bird mortality may be occurring in similar habitats on the Refuge, but it has not been reported because few people use these areas, and more dense vegetation and greater scavenging may reduce the possibility of finding carcasses. Efforts in 1995 will focus on documenting where on the Refuge birds are accumulating dieldrin.

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TITLE: Contaminant Residues in Mourning Dove Tissues

High concentrations of organochlorines were found in dead mourning doves (Zenaida macroura) collected on the Rocky Mountain Arsenal National Wildlife Refuge (Refuge) under the Remedial Investigation and Comprehensive Monitoring Program (Environmental Science and Engineering 1989, Stollar et al. 1992). Doves were also found dead at Building 111 in Section 35 in 1993 and 1994 (U.S. Fish and Wildlife Service 1994).

Game species such as the mourning dove use the Refuge but may be hunted and consumed off of the Refuge. Mourning doves are therefore included in a human health risk assessment being conducted for the Refuge. Doves were collected for a general assessment of current contaminant concentrations in their tissues. The Agency for Toxic Substances and Disease Registry may use these analytical data to determine whether further analyses of game species, such as doves, is needed for human health risk assessment.

Doves were collected with a pellet gun in July of 1994. Collection locations are shown in Figure 1-15. Three adult males, 2 adult females, 5 adult undetermined sex, and 2 juveniles were collected. One juvenile (94MD12) was collected from a nest before fledging. Brain, liver, and breast muscle were dissected for analyses. There were no detections of aldrin, endrin, isodrin, alpha-chlordane, gamma-chlordane, or arsenic. All other results are shown in Table 1-22. Other analytical results on tissues from doves found dead on the Refuge in 1994 are reported in the fortuitous specimen program report. Not all analytical results have been received. Thus far, dieldrin was detected from 0.021 to 0.533 ppm in muscle and liver samples and a whole nestling carcass. There was only one detection of DDE in a muscle sample and no mercury detections.

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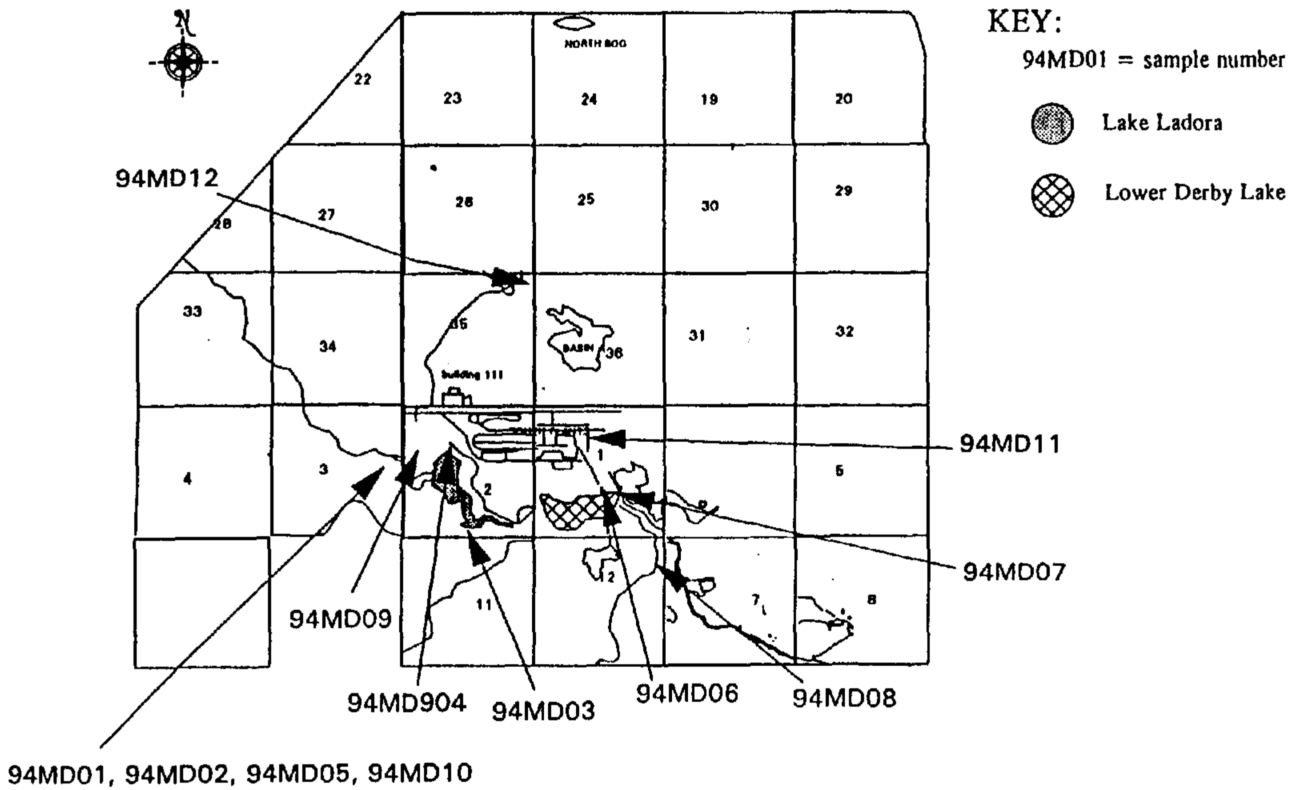

Fig. 1-15. Mourning dove collection locations on the RMANWR in 1994.

Table 1-22. Analytical results (ppm wet weight) from mourning doves collected on the Refuge in 1994.

Sample Number	Date Collected	Location	Tissue	Dieldrin[a]	DDE	Mercury
94MD01	7/6/94	sec 3	liver	bcrl[b]	bcrl	
94MD01	7/6/94	sec 3	brain	bcrl	bcrl	
94MD01	7/6/94	sec 3	muscle	bcrl	bcrl	bcrl
94MD02	7/6/94	sec 3	liver	bcrl	bcrl	
94MD02	7/6/94	sec 3	brain	bcrl	bcrl	
94MD02	7/6/94	sec 3	muscle	bcrl	bcrl	bcrl
94MD03	7/6/94	sec 2	liver	0.106	bcrl	
94MD03	7/6/94	sec 2	brain	bcrl	bcrl	
94MD03	7/6/94	sec 2	muscle	bcrl	bcrl	
94MD04	7/6/94	sec 2	liver	bcrl	bcrl	
94MD04	7/6/94	sec 2	brain	bcrl	bcrl	
94MD04	7/6/94	sec 2	muscle	bcrl	bcrl	bcrl
94MD05	7/6/94	sec 3	liver	0.533	bcrl	
94MD05	7/6/94	sec 3	brain	bcrl	bcrl	
94MD05	7/6/94	sec 3	muscle	bcrl	0.018	bcrl
94MD06	7/6/94	sec 1	liver	bcrl	bcrl	
94MD06	7/6/94	sec 1	brain	bcrl	bcrl	
94MD06	7/6/94	sec 1	muscle	bcrl	bcrl	bcrl
94MD07	7/6/94	sec 1	liver	0.104	bcrl	
94MD07	7/6/94	sec 1	brain	bcrl	bcrl	
94MD07	7/6/94	sec 1	muscle	bcrl	bcrl	bcrl
94MD08	7/6/94	sec 12	liver	bcrl	bcrl	
94MD08	7/6/94	sec 12	brain	bcrl	bcrl	
94MD08	7/6/94	sec 12	muscle	bcrl	bcrl	
94MD09	7/7/94	sec 2	liver			
94MD09	7/7/94	sec 2	brain	bcrl	bcrl	
94MD09	7/7/94	sec 2	muscle	0.021	bcrl	
94MD10	7/7/94	sec 3	liver			

Table 1-22 (Continued).

Sample Number	Date Collected	Location	Tissue	Dieldrin	DDE	Mercury
94MD10	7/7/94	sec 3	brain	bcrl	bcrl	
94MD10	7/7/94	sec 3	muscle	0.026	bcrl	
94MD11	7/7/94	sec 1	liver			
94MD11	7/7/94	sec 1	brain	bcrl	bcrl	
94MD11	7/7/94	sec 1	muscle	bcrl	bcrl	
94MD12	7/14/94	sec 35	whole	0.048	bcrl	bcrl

[a] blank spaces indicate data not yet received.
[b] bcrl = below certified reporting limit.

TITLE: ...ie Dog Management: Distribution and Abundance of the Black-tailed ...ie Dog.

INTRODUCTION

...tailed prairie dogs (*Cynomys ludovicianus*) provide a prey base for a B...ety of predators on the Refuge, including the ferruginous hawk (*Buteo ...alis*), badger (*Taxidea taxus*), coyote (*Canis latrans*) and threatened bald ...gle (*Haliaetus leucocephalus*). Prairie dogs also provide habitat for many wildlife species on the Refuge including burrowing owls (*Speotyto cunicularia*), desert cottontails (*Sylvilagus audubonii*) and prairie rattlesnakes (*Crotalus viridis viridis*). One study found that over 100 vertebrate species use prairie dog colonies as habitat (Clark et al. 1989). After a plague epizootic during 1988 and 1989 reduced the distribution by 95% (Ebasco 1989, U.S. Fish and Wildlife Service 1989, 1990), the Service deemed it crucial that their population levels be restored as close to pre-plague levels as possible. The focal point of this effort has been through prairie dog relocations into areas of former occupation with the assistance of several private organizations. From 1989 through 1993, the Service relocated 5800 prairie dogs to the Refuge from off-post sources (U.S. Fish and Wildlife Service 1994). A monitoring program to gauge the effectiveness of the relocation program was enacted in 1991, and included examining changes in distribution and abundance, as well as other demographic characteristics of the population. In 1993, prairie dog distribution was found to total 737.05 hectares (up from 99 ha in 1989), with a minimum estimated mean density of 22.57 prairie dogs per hectare (U.S. Fish and Wildlife Service 1994). The purpose of this continuing study has been to determine changes in the distribution and abundance of prairie dogs on the Refuge, and to assess future prairie dog management objectives.

METHODS

Distribution

Prairie dog town distribution was mapped in 1994 using a Global Positioning System (GPS) and software (Pathfinder) from Trimble Navigation Limited (Sunnyvale, CA). This is a new methodology from previous years which relied on aerial photographs and mylar overlays. The use of different methods between 1993 and 1994 may increase the error factor in area determination, but these errors are believed to be minimal. Prairie dog town mapping was conducted from 4 April to 23 May, 1994. Data was collected in the field using a TDC1 datalogger (or rover unit). GPS positions were collected by walking the perimeters of active prairie dog towns and recording positions at 10-15 second intervals. The rover unit files were then downloaded to a computer with pathfinder software. Differential correction (to increase accuracy to 2-5 meters) was completed using community base station files downloaded from the U.S. Forest Service in Fort Collins, CO. Area features (i.e. prairie dogs towns) were then read with the pathfinder software and the size of each area determined. Final maps were developed with the assistance of the Army's contractor DP Associates, Inc.

Abundance

Methods used to estimate population parameters were the same as those used in the 1993 survey, (U.S. Fish and Wildlife Service 1994) and are based on the methodology developed at the National Ecology Research Center (NERC, now with the National Biological Survey) in Fort Collins to evaluate black-footed ferret habitat (Biggins et al. 1989). Visual counts are a reliable and rapid method of censusing colonial, diurnal ground squirrels (Fagerstone 1983, Fagerstone and Biggins 1986, Powell et al. 1994) with the highest count representing an estimate of minimum population density. Study plots were selected on a representative, rather than a random basis, due to certain site characteristics needed to conduct visual counts. Site characteristics included being able to see the entire study plot from a single location, vegetation height, size of prairie dog town, and topographic relief. Size of plot depended on site specific characteristics and varied from 4 to 9 hectares. The plots were established using a surveyors transit and geodimeter, and corners marked with six foot lengths of 1/2 inch PVC tubing. Pin flags were set out at regular intervals along the sides of the plots to further assist in determining whether prairie dogs were in or out of the plot during counts.

Visual counts were conducted on each study plot (n=10) from 31 May to 7 July, 1994. Visual counts were performed for three consecutive days on each plot, starting approximately 1/2 hour after sunrise and continuing (with 15 minutes between counts) until prairie dog numbers began to decrease, usually mid-morning. The highest number of prairie dogs recorded during the three days of visual counts was then used to determine the density of each plot (highest count/area). All plots were summed and divided by the number of plots (n=10) to determine the raw mean density. Because plots were not randomly selected the usual confidence intervals cannot be used. Instead, the raw mean density is used as the lower density estimate. A visual correction factor (observability index) for black-tailed prairie dogs developed at NERC (raw mean density/.566) was used to estimate the upper population density. Density estimates obtained using this visual correction factor have compared favorably with estimates obtained from mark/recapture data using program CAPTURE (U.S. Fish and Wildlife Service 1993).

The observability index corrects for the number of prairie dogs not above ground during the counts and observer error. Both of these densities were multiplied by the total area occupied by prairie dogs to ascertain the prairie dog population estimate for 1994.

Litter surveys

Litter surveys are one method used to determine reproductive success in prairie dogs. Reproductive success is defined as the number of juveniles produced per mature female. Other methods for calculating reproductive success include counts of corpora lutea, placental scars, as well as counts of actual embryos (King 1955, Koford 1958, Tileston and Lechleitner 1966, Knowles 1987, Stockrahm and Seabloom 1988). However, these methods may not yield accurate indicators of reproductive success because embryo absorption and/or infant mortality can significantly reduce litter size before emergence from the natal burrow. For prairie dogs, average observed litter size is the most accurate determination of reproductive success (King 1955, Kerwin 1972, Stockrahm and Seabloom 1988). This can be determined either from counts of juveniles at the burrow openings, or inferred from trapping data.

Litter surveys were continued during 1994 in an effort to determine reproductive success of prairie dogs on the Refuge, and to compare these values with those found at other locations. All litter locations were flagged and litter size determined within 2 or 3 days post-emergence. Beyond this time frame the litters may begin to coalesce and form 'nursery' groups which confound litter size determination. Litter counts were conducted from 12 April to 9 May, 1994.

RESULTS AND DISCUSSION

Distribution

A total of 982.75 hectares (2428 acres) of active prairie dog towns were mapped from 4 April to 23 May, 1994 (Fig. 1-16, Table 1-23). This represents an increase of 33.3% over the 1993 distribution, and a 77% increase in area since 1991. Mapping of prairie dog distribution will again be conducted in the spring of 1995.

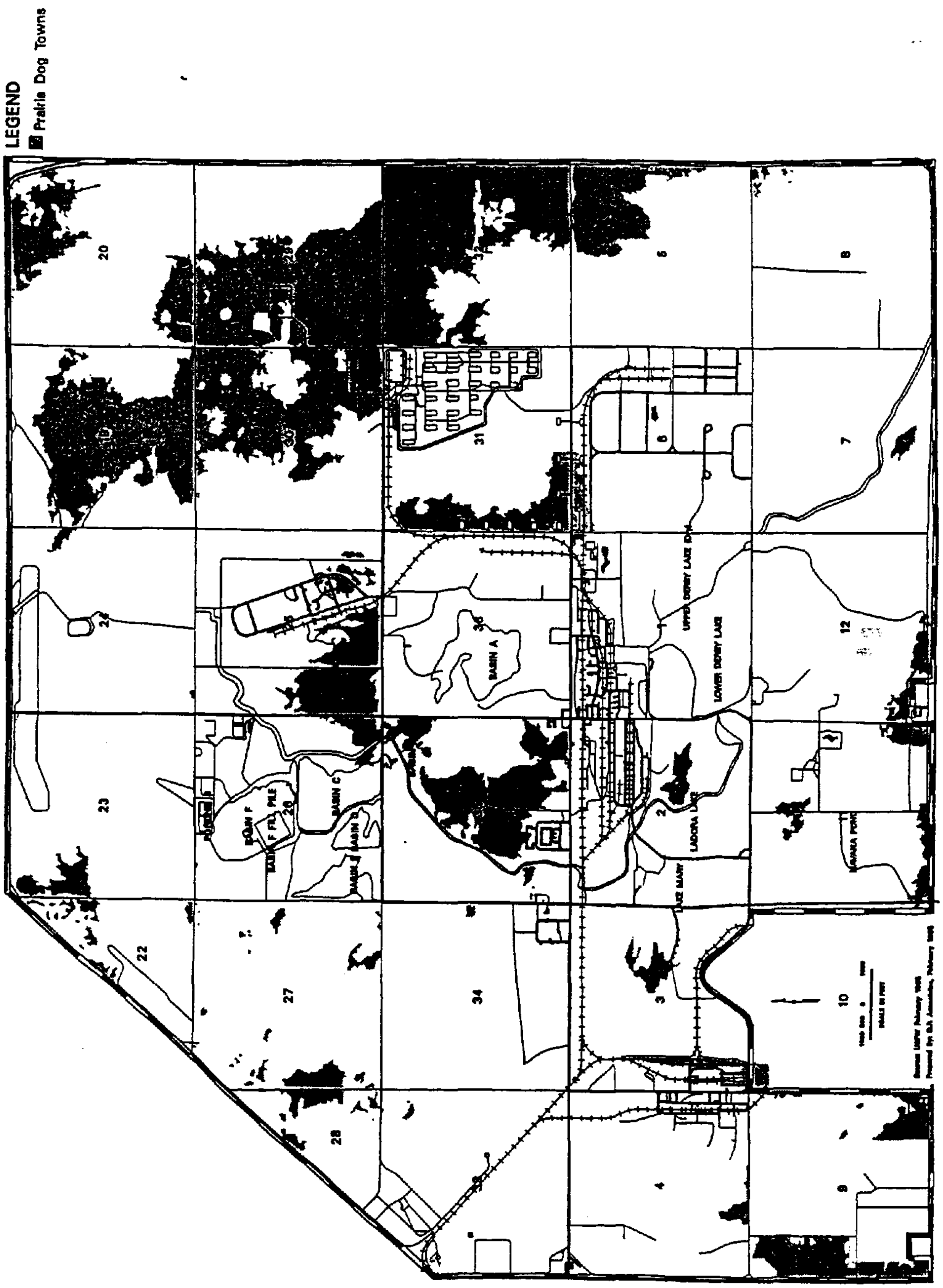

Fig. 1-17. Prairie dog town distribution at Rocky Mountain Arsenal NWR in May, 1994 (982.75 ha).

Table 1-23. Comparison of prairie dog town areas at Rocky Mountain Arsenal NWR, between 1993 and 1994, by section (in hectares).

Section	1993	1994	Percent Change
22	1.46	7.0	+379.4
23	2.59	11.51	+330.5
19	117.7	117.85	+.13
20	37.54	53.97	+43.7
28	5.69	10.33	+81.5
27	16.13	14.95	-7.3
26	7.1	8.59	+21.0
25	27.02	50.37	+86.4
30	52.92	115.25	+117.8
29	101.36	142.45	+40.5
33	5.96	1.42	-76.2
34	0.06	0.88	+1366.7
35	55.94	75.38	+34.7
36	0.6	----	----
31	26.01	35.2	+35.3
32	132.1	158.6	+20.1
4	3.33	4.25	+27.6
3	11.28	9.16	-18.8
2	10.71	7.89	-26.3
1	0.46	2.12	+360.8
6	4.29	6.54	+52.4
5	44.59	52.56	+17.9
9	41.22	52.04	+26.2
10	3.81	5.33	+39.9
11	15.56	21.93	+41.0
12	10.01	10.31	+2.9
7	1.04	3.2	+20.7
8	1.29	1.76	+36.4
24	----	1.91	----
Totals	737.05	982.75	+33.3

Abundance

Visual counts conducted on 10 study plots (Fig. 1-17) from 31 May to 7 July yielded a raw mean density of 23.47 prairie dogs per hectare (SE 1.31) (Table 1-24), with a range from 16.7 pd/ha to 29.0 pd/ha. After applying the observability index (from NERC) to the raw data, an upper density estimate of 41.46 (SE 2.31) prairie dogs/ha was obtained. These densities compare to 1993's reported densities of 22.57 and 39.88 pd/ha, respectively (U.S. Fish and Wildlife Service 1994), an increase of 4%. This is the lowest increase in density found since 1991, and may be partly influenced by the plague epizootic which was active during the visual counts.

Population Estimate

Combining the results of distribution and abundance yields a low population estimate of 23,065 and a high estimate of 40,745. Black-tailed prairie dog densities on the Refuge are comparable to, and in some cases exceed, densities found in other studies (Biggins 1989, Garret et al. 1982, King 1955, Koford 1958, Lewis et al. 1979, Tileston and Lechleitner 1966). In examining per capita growth rates ($r = \ln[N(t+1)/N(t)]$) for 1989 through 1994 (Table 1-25, Fig. 1-18) it can be seen that although the population of prairie dogs was increasing, the rate of population growth decreased from 1992 ($r = 0.371$), 1993 ($r = 0.344$) to 1994 ($r = 0.327$). The per capita growth rates seen in the post-plague prairie dog population at the Refuge (.343 , 1.05, .371, .344, and .327 for 1989-90, 1990-91, 1991-92, 1992-93, and 1993-94 respectively) compare favorably with the rates found by Knowles (1986) in a prairie dog population that had been controlled with zinc phosphide. Merriam (1966) demonstrated that under the most favorable conditions the maximum intrinsic rate of increase (r_m) could barely exceed 1.0 for black-tailed prairie dogs.

Litter Survey

A total of 61 litters were sampled between 12 April and 9 May, with a mean of 5.41 (SE .154) pups per litter and a range from 3 to 8. This represents a significant increase over the 1993 mean litter size of 4.44 (SE .284), using a Kruskal-Wallis (chi-square approximation) test ($H = 8.44$, 1 d.f., $p > .004$). These values compare favorably with, and in some cases exceed, litter sizes reported from other studies, ranging from 2.3 to 4.9 pups/litter (Garret et al. 1982; Knowles 1987; King 1955; Kerwin 1972; Tileston and Lechleitner 1966; Stockrahm and Seabloom 1988). Prairie dog litter sizes average 4 or 5 across their range and are believed to vary proportionally in relation to the previous years precipitation. Litter size was also examined by area/soil contamination (Table 1-26, Fig. 1-19) to determine if differences in means could be detected between areas of differing surficial soil contamination. No significant difference could be detected between white, pink or blue areas using a Kruskal-Wallis rank sum test ($H = -183.07$, 2 d.f., $p > .05$). These results may be influenced by the low level of resolution on the pink/blue/white map.

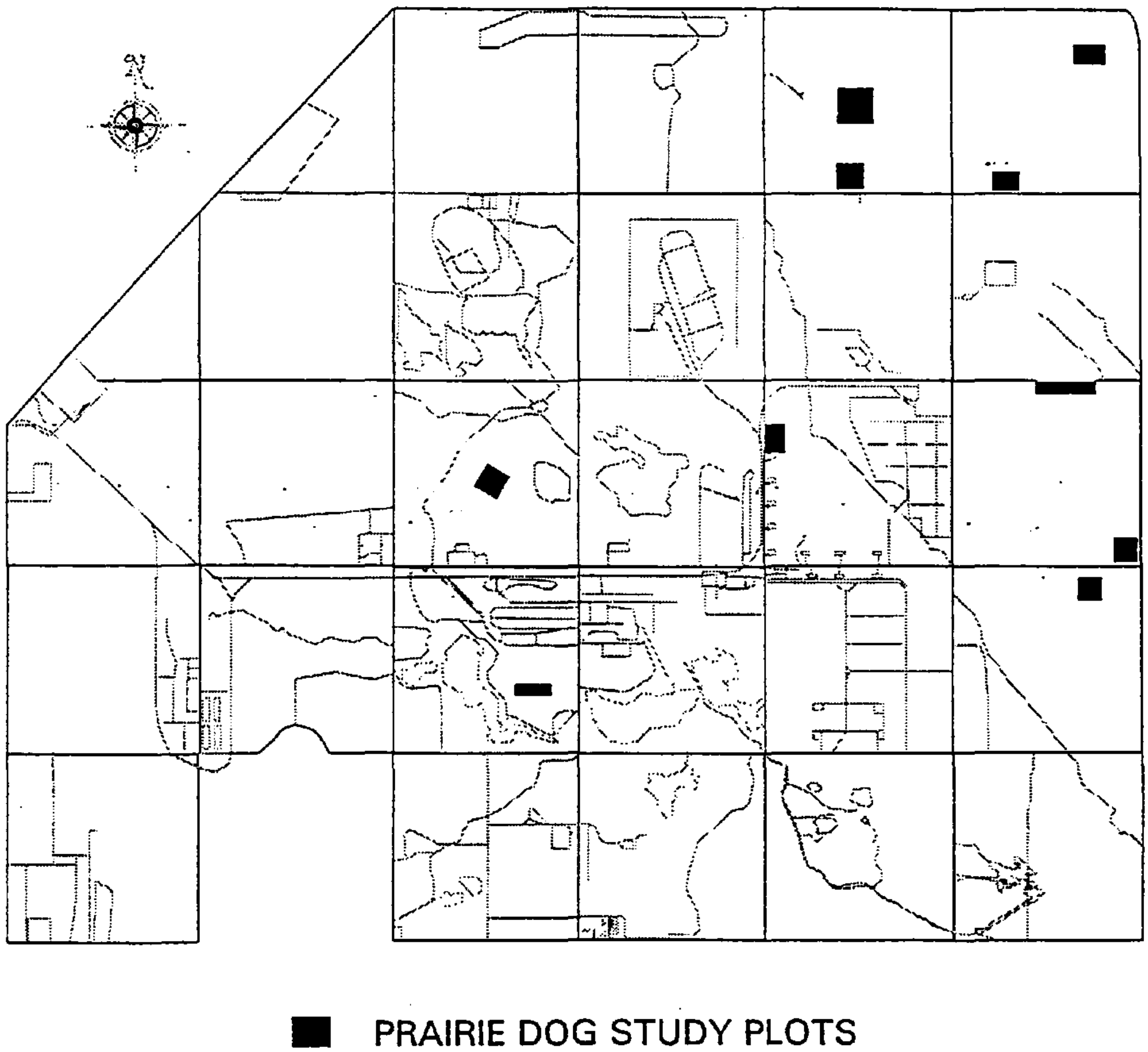

Fig. 1-17. Locations of prairie dog study plots used to conduct visual counts from 31 May to 7 July, 1994 at Rocky Mountain Arsenal NWR.

Table 1-24. Comparisons of mean prairie dog densities (per hectare) obtained from visual count data at Rocky Mountain Arsenal NWR, 1991-1994.

Plot	1991	1992	1993	1994
19N	18.0	21.55	26.33	16.67
20S	15.25	26.25	33.5	21.25
19S	---	11.25	26.25	29.0
20N	---	10.2	13.8	18.4
29	20.44	19.89	20.44	---
5	11.5	20.5	24.5	23.5
32N	12.25	24.5	24.0	18.5
32S	12.5	17.25	26.5	27.0
30	17.25	22.75	26.25	---
35	16.5	20.5	20.5	27.17
2	9.5	12.75	17.25	24.0
27N	---	6.5	12.0	---
22	13.25	---	---	---
31	---	---	---	27.0
Summary (SE,n)	14.64 (1.07,10)	17.78 (1.79,12)	22.57 (1.77,12)	23.47 (1.31,10)

Table 1-25. Prairie dog population fluctuations pre- and post plague at Rocky Mountain Arsenal NWR, 1988-1993.

Year	Mean Density	Area (ha)	Min. Pop. Est.	r[b]
1988[a]	20.2 (SE 1.6, n=24)	1850.8	37406	----
1989[a]	20.2 [c]	99.8	2017	-2.92
1990[a]	12.2 (SE 2.0, n=6)	232.9	2842	0.343
1991	14.6 (SE 1.08, n=10)	555.56	8134	1.05
1992	17.8 (SE 1.79, n=12)	663.27	11793	0.371
1993	22.57 (SE 1.77, n=12)	737.05	16636	0.344
1994	23.47 (SE 1.31, n=10)	982.75	23065	0.327

[a] 1988-1990 data from Stollar et al. 1992
[b] $r = \ln[N(t+1)/N(t)]$
[c] no visual count data available during plague epizootic; density approximated

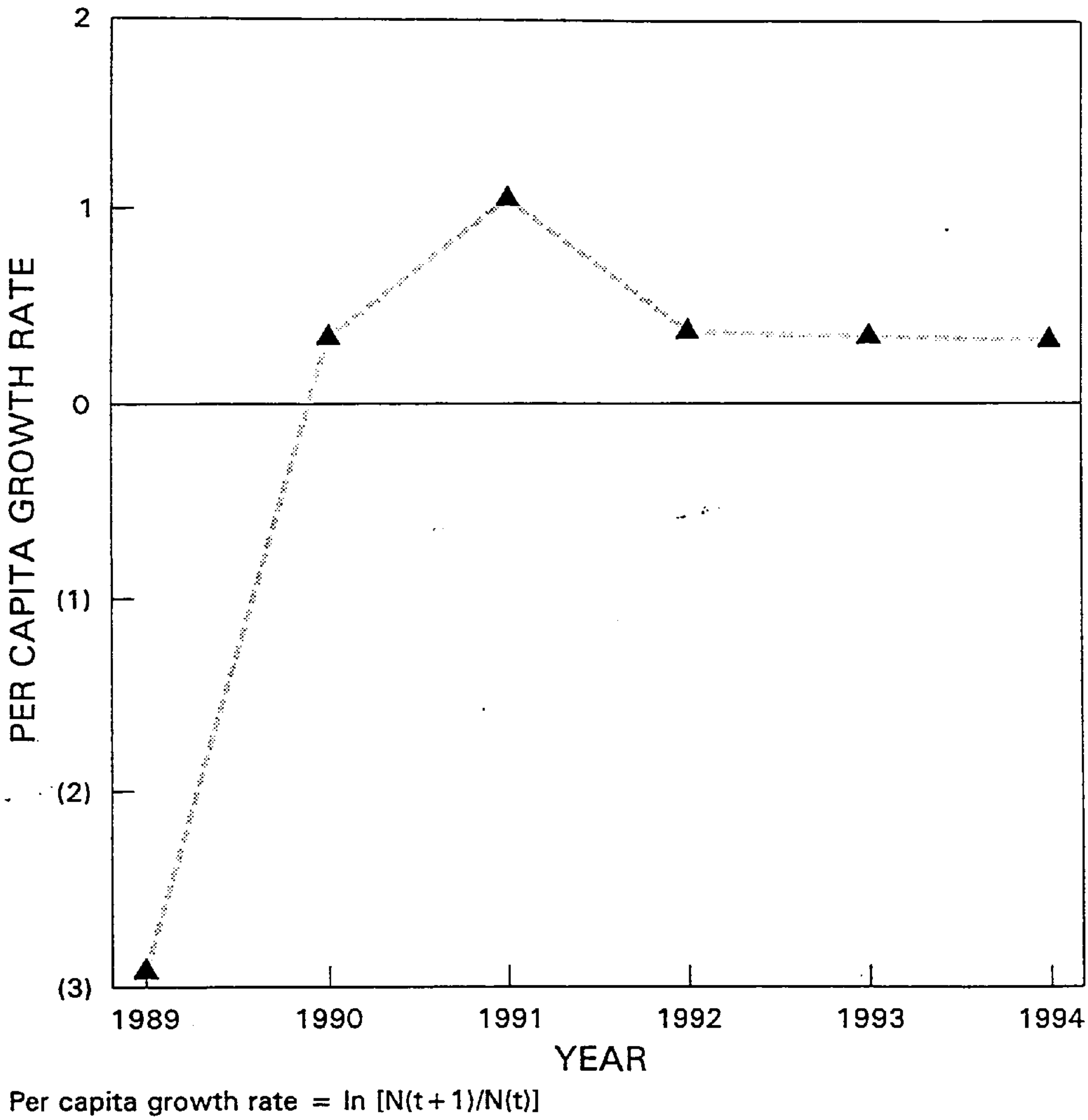

Fig. 1-18. Fluctuations in per capita growth rate in a post-plague event (1988-89) population of prairie dogs at Rocky Mountain Arsenal NWR.

Table 1-26. Comparison of prairie dog litter sizes from three different soil contaminant-level areas at Rocky Mountain Arsenal NWR in 1994. Pink areas are defined as being the most contaminated, blue areas have surficial soils contamination and white areas are free of contamination above background levels.

Area	$\bar{x}$	SE	n
White	5.229	.188	35
Pink	5.167	.366	12
Blue	5.929	.355	14

A Kruskal-Wallis test indicated no significant differences in the means (H = -183.07, 2 d.f., p >.05).

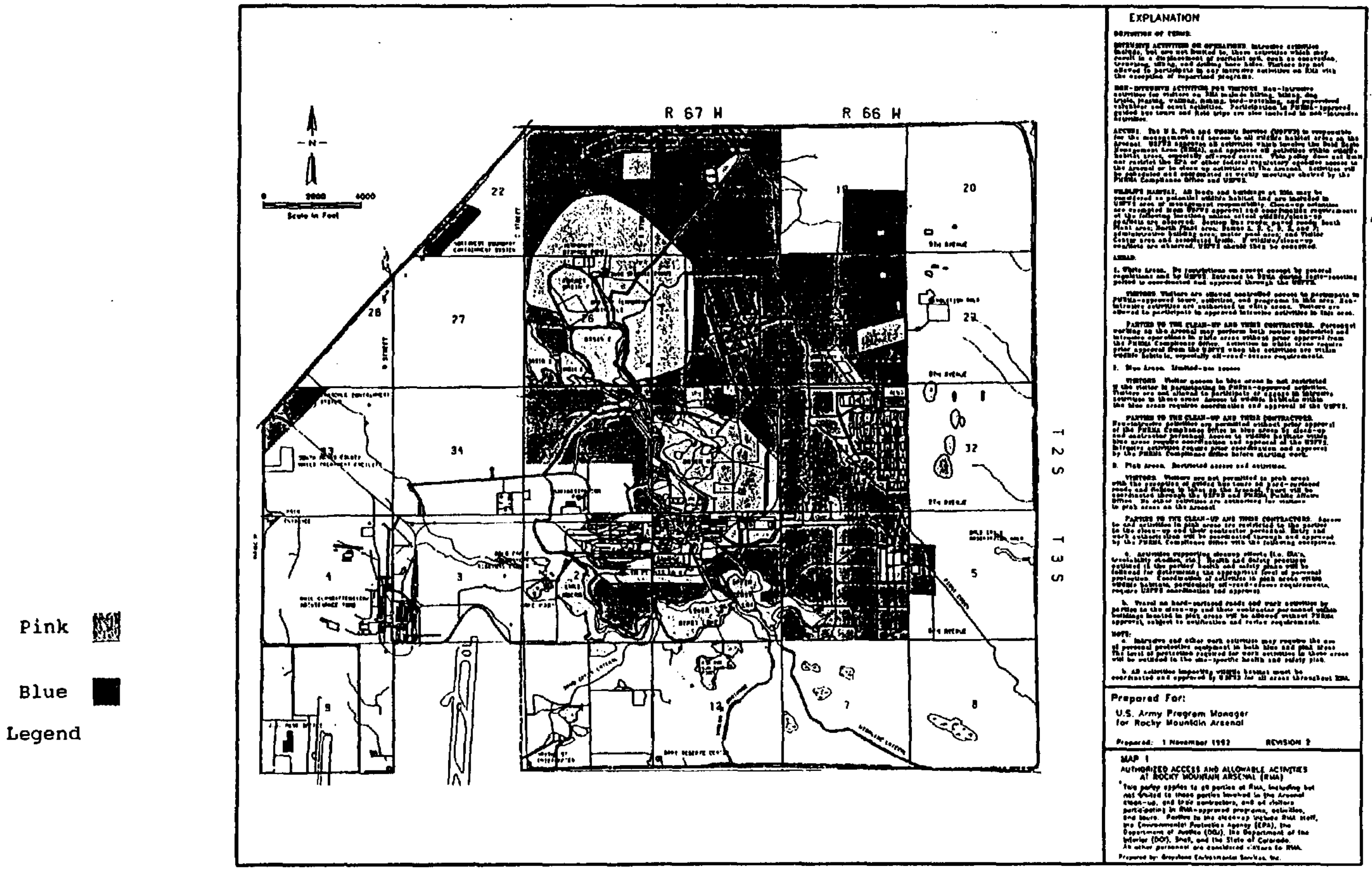

Fig. 1-19. Map of Rocky Mountain Arsenal NWR showing delineations of differing levels of surficial soils contamination.

Plague Epizootic

While conducting visual counts in the northeast corner of Section 30 on 15 June, it was found that numbers of prairie dogs were much lower than expected. Follow-up investigations confirmed the presence of plague (Yersinia pestis) on 17 June from carcasses collected at the site. In addition, fleas were collected from several suspected sites and sent to the Centers for Disease Control (CDC) in Fort Collins for analysis. Approximately 70 ha. of prairie dog towns in Section's 19, 20, 30, 29 and 32 were initially affected by the epizootic (Table 1-27, Fig. 1-20). The plague spread rapidly in these sections and by 8 July had affected 205 ha. (Fig. 1-21). This occurred in spite of preventative dusting (with a synthetic pyrethrin) in the perimeter of the plague affected area to control the plague flea vector (Oropsylla sp.). The epizootic continued throughout the summer (Table 1-27, Figs. 1-22 through 1-26) until by 27 September a total of 674 ha., or 68% of the active prairie dogs were decimated by plague. Additional, more widespread areas were dusted on 15-16 July and 3-4 August in an effort to control the epizootic. The dusting effort had mixed results, in some cases providing complete and continuing (through October) protection from the plague, as in Sections 25 (west of North Plants), 26 and the south boundary. In other instances it was as though no dusting had occurred at all, as in Sections 32, 35 and 5, where prairie dogs succumbed to plague 2 to 4 weeks or more after completion of dusting.

Table 1-27. Prairie dog town areas affected by plague epizootic of 1994 on Rocky Mountain Arsenal NWR.

Date	Area (ha)	% Affected
6/15	70	7%
7/8	205	21%
7/14	261	26%
7/20	398	40%
8/15	593	60%
9/15	631	64%
9/27	674	68%

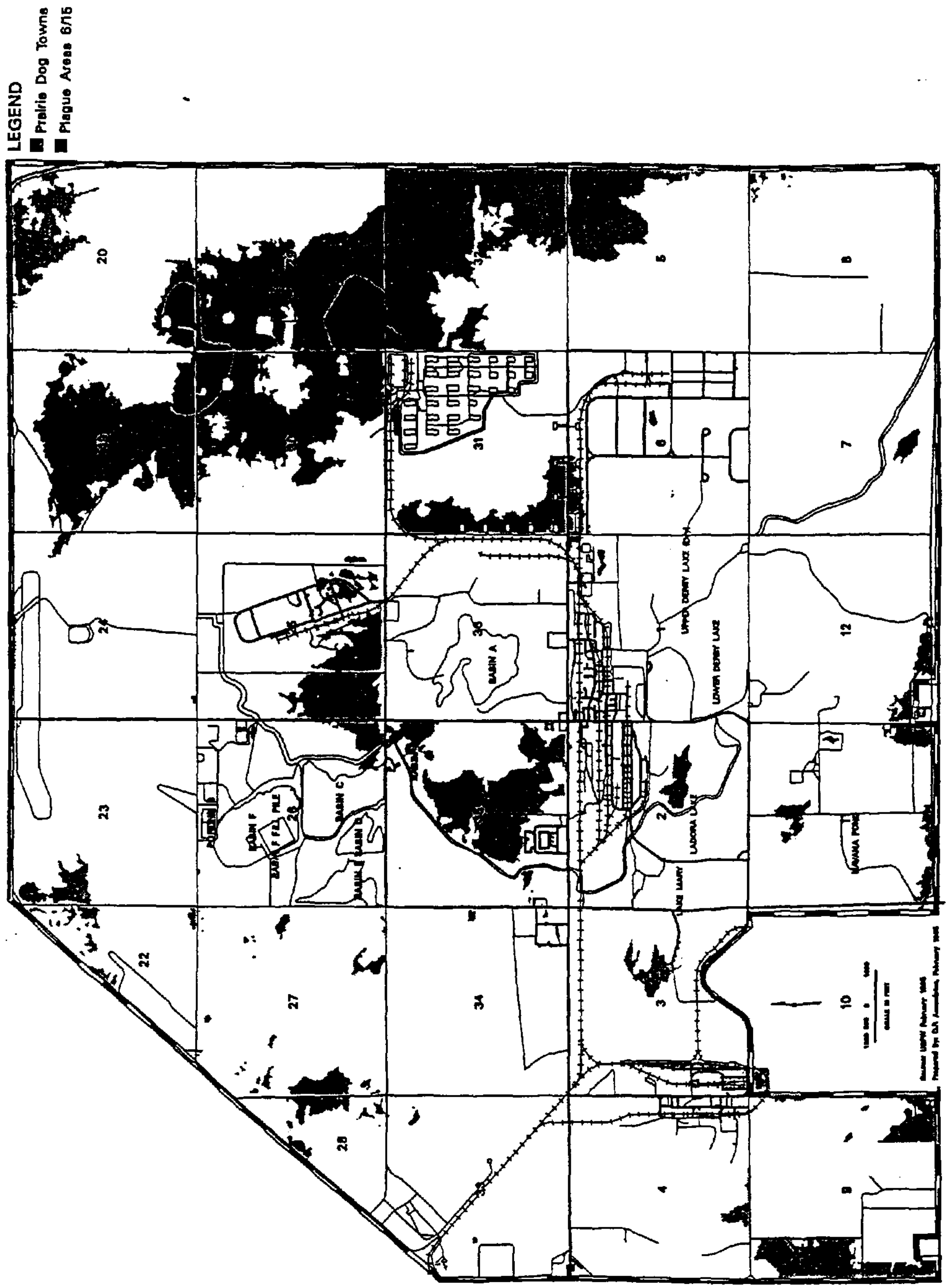

Fig. 1-20. Prairie dog towns affected by plague epizootic as of 15 June, 1994 (70 ha).

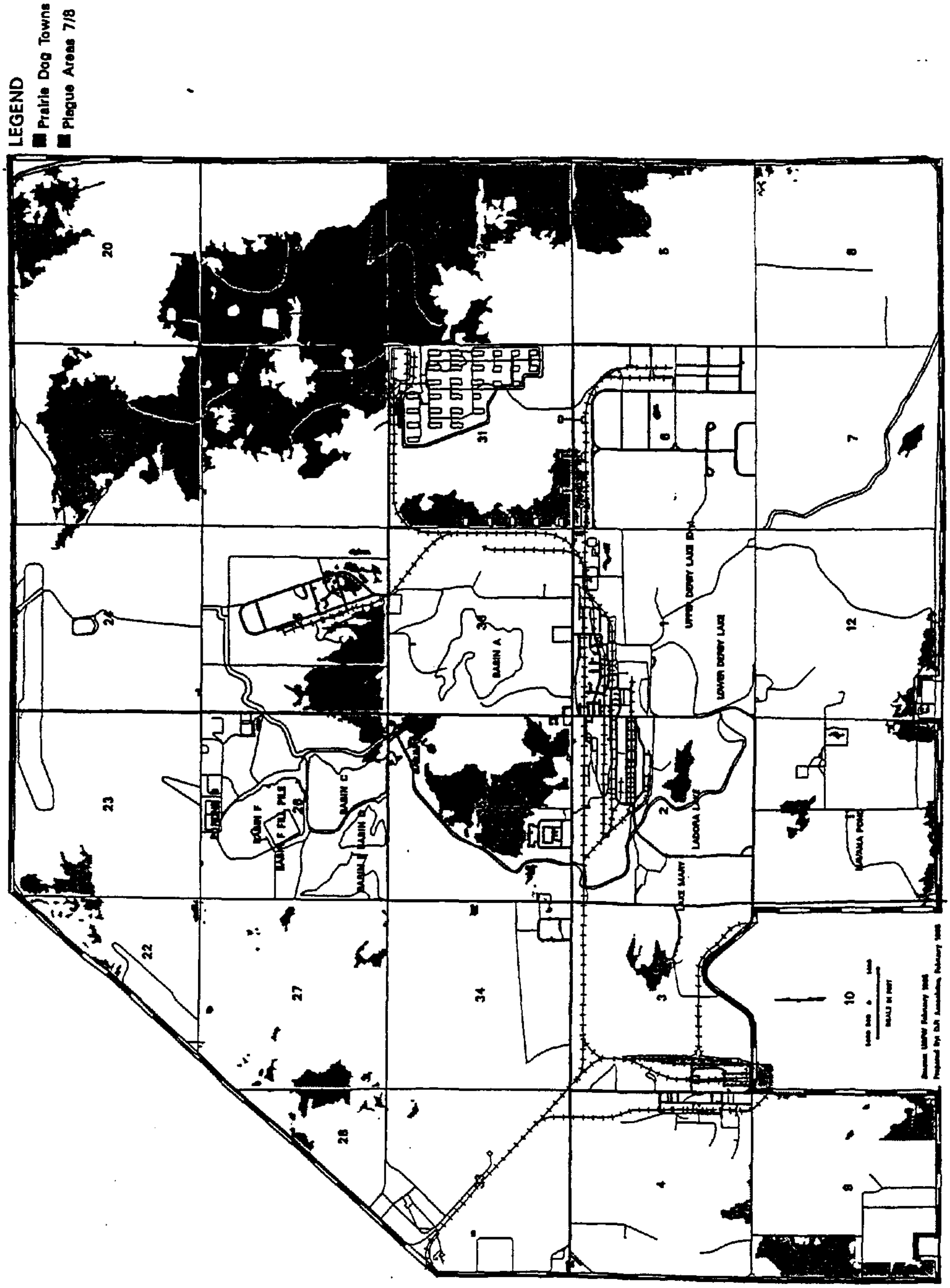

Fig. 1-21. Prairie dog towns affected by plague epizootic as of 8 July, 1994 (205 ha).

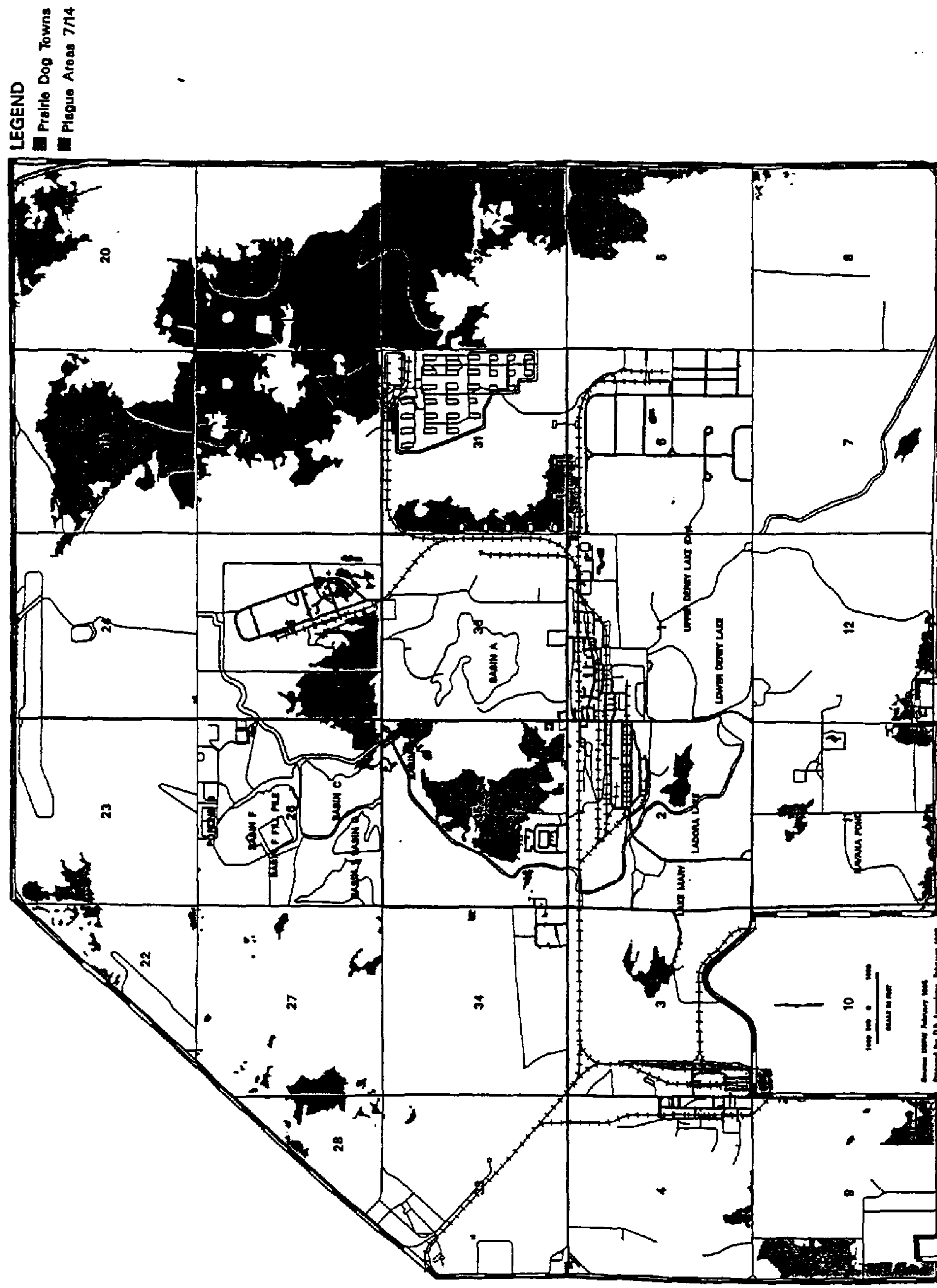

Fig. 1-22. Prairie dog towns affected by plague epizootic as of 14 July, 1994 (261 ha).

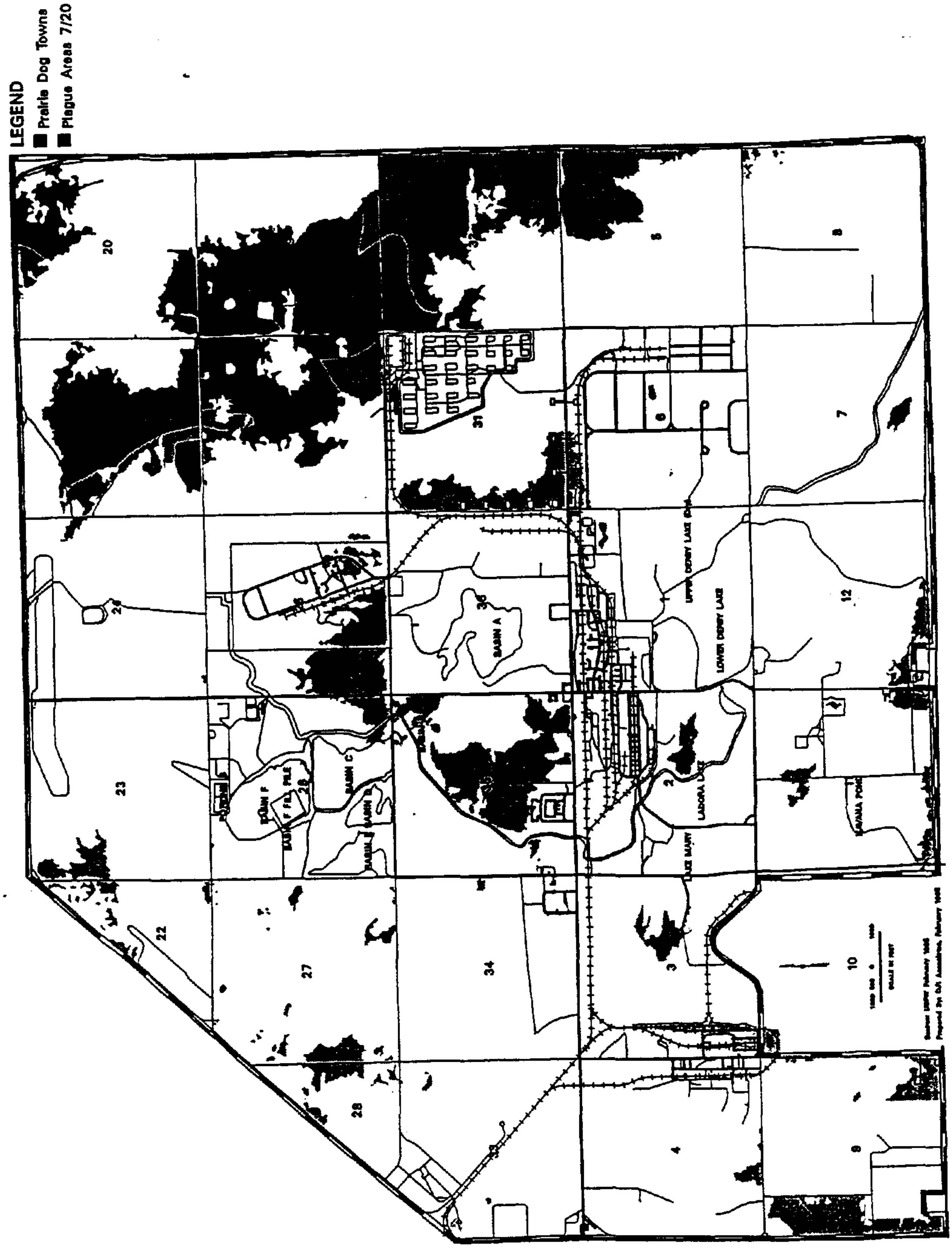

Fig. 1-23. Prairie dog towns affected by plague epizootic as of 20 July, 1994 (398 ha).

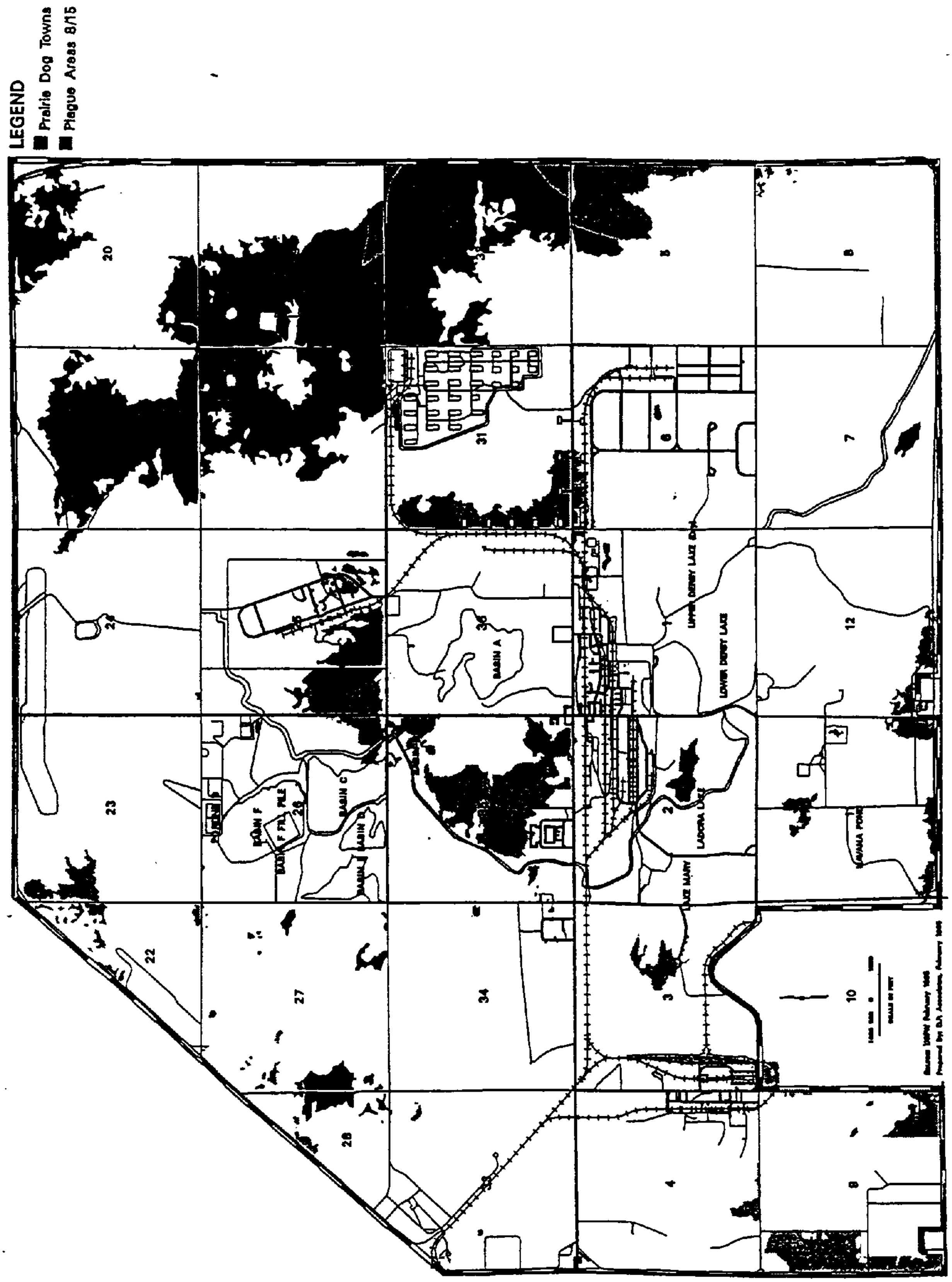

Fig. 1-24. Prairie dog towns affected by plague epizootic as of 15 August, 1994 (593 ha).

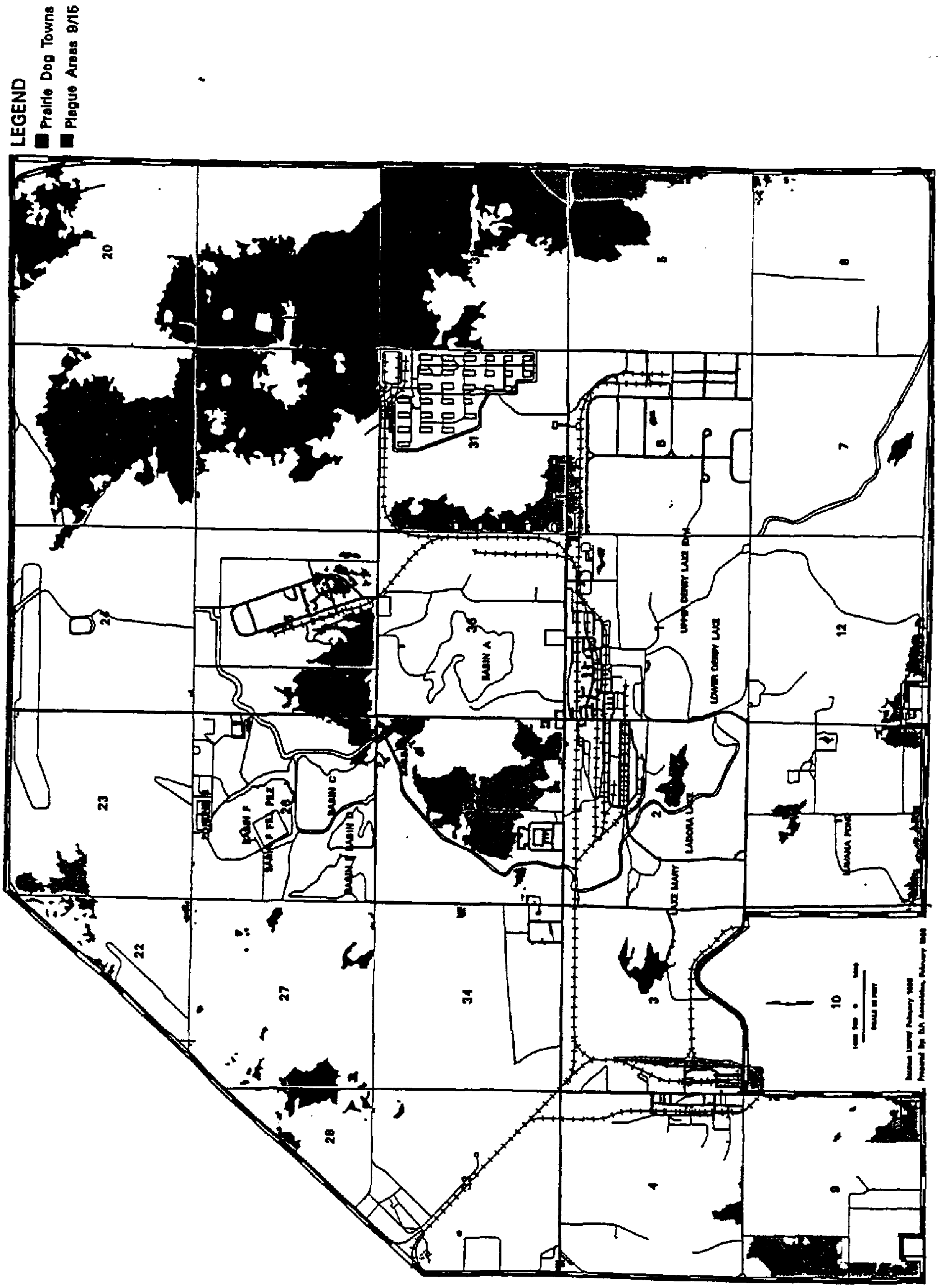

Fig. 1-25. Prairie dog towns affected by plague epizootic as of 15 September, 1994 (631 ha).

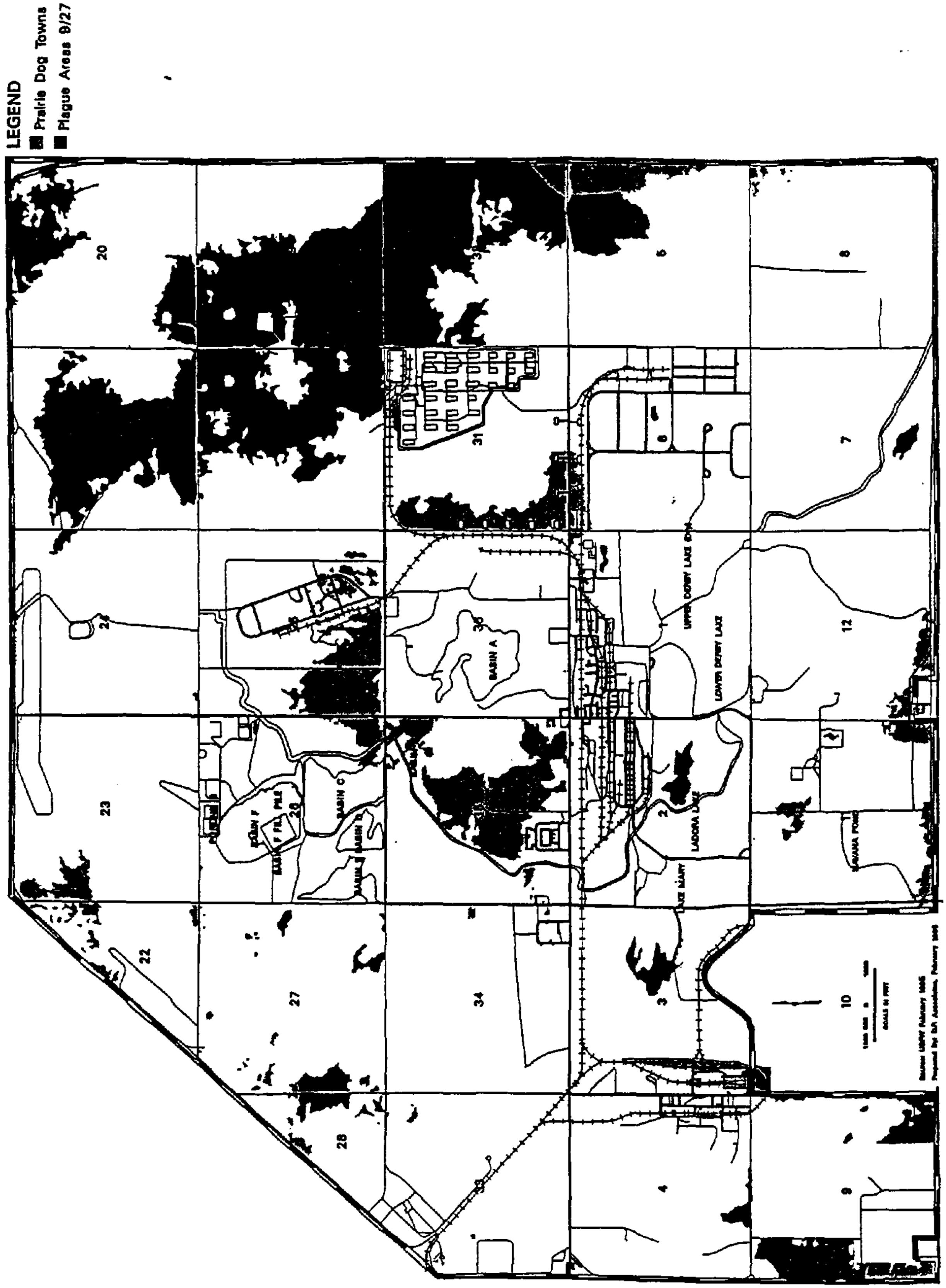

Fig. 1-26. Prairie dog towns affected by plague epizootic as of 27 September, 1994 (674 ha).

TITLE: Prairie Dog Management: Black-tailed Prairie Dog Relocations, 1994.

INTRODUCTION

Beginning in the fall of 1988 and extending throughout the summer of 1989, sylvatic plague systematically eliminated 95% of the black-tailed prairie dog population on the Refuge. From an estimated distribution of 1850 hectares in 1988 (Stollar and Assoc. 1992), prairie dog towns only occurred on 100 hectares by September, 1989. Prairie dogs distribution rebounded to an early 1994 distribution of 982.75 hectares, prior to the latest plague epizootic. Much of this recovery has been aided by the relocation program initiated by the Service in 1989, which relocated 6861 prairie dogs through the end of FY93. This program received invaluable support and assistance from a host of private relocation organizations (contributing 87.5% of the total released). This relocation program (from off-refuge sources) was discontinued in FY92 with the last prairie dogs to be accepted from off-refuge sources on 19 October 1992. Due to recent wide-spread plague epizootic, the Service is once again evaluating a potential prairie dog relocation program using off-refuge resources. In this report, prairie dog relocations during FY94 are summarized and future management objectives discussed.

METHODS

The methods used to relocate prairie dogs in FY94 were the same methods used in previous years and included: 1) spraying or dusting all prairie dogs before relocating them on the Refuge, and 2) recording the sex, age, weight and attaching ear tags to every prairie dog released. The relocation sites used in FY94 were areas affected by the plague epizootics of 1993 (Sections 27S, 27N and 27NE) and 1994 (Sections 20SW, 19SW and 30/29)(Fig. 1-27).

RESULTS AND DISCUSSION

During FY94, 175 prairie dogs were trapped and relocated on the Refuge by Service personnel (Table 1-28). The Service trapped nuisance prairie dogs from a number of locations where their presence may have interfered or conflicted with clean-up related activities. As of this writing, prairie dogs have been re-established in some areas decimated by plague earlier this year.

Management Objectives

Black-tailed prairie dogs at the Refuge play a vital role in maintaining diverse wildlife populations, including a large number of resident (coyotes, badgers and red-tailed hawks), breeding (Swainson's hawks) and wintering (bald eagles and ferruginous hawks) predators. Their manipulations of shortgrass prairie through selective feeding and burrowing behavior provides habitat for a wide range of wildlife species, from burrowing owls (*Speotyto cunicularia*) to prairie rattlesnakes (*Crotalus viridis viridis*). However, these same attributes that provide for such a complex wildlife habitat, can also lead to conflicts with human related activities. This is especially evident at the Refuge where the level of cleanup and related construction projects has increased dramatically in the last few years. This increase in human activity coincides with a future expanding prairie dog population, which necessitates aggressive management efforts. Re-establishment of a healthy prairie dog population, trapping nuisance prairie dogs from areas of conflict and installing barriers (vegetative, man-made, or a combination) to prevent re-colonization will be the primary concern of future prairie dog management. Efforts are underway to locate potential conflict areas, areas where re-vegetation will enhance future prairie dog expansion and sites where installation of barriers may be necessary to prevent further conflicts.

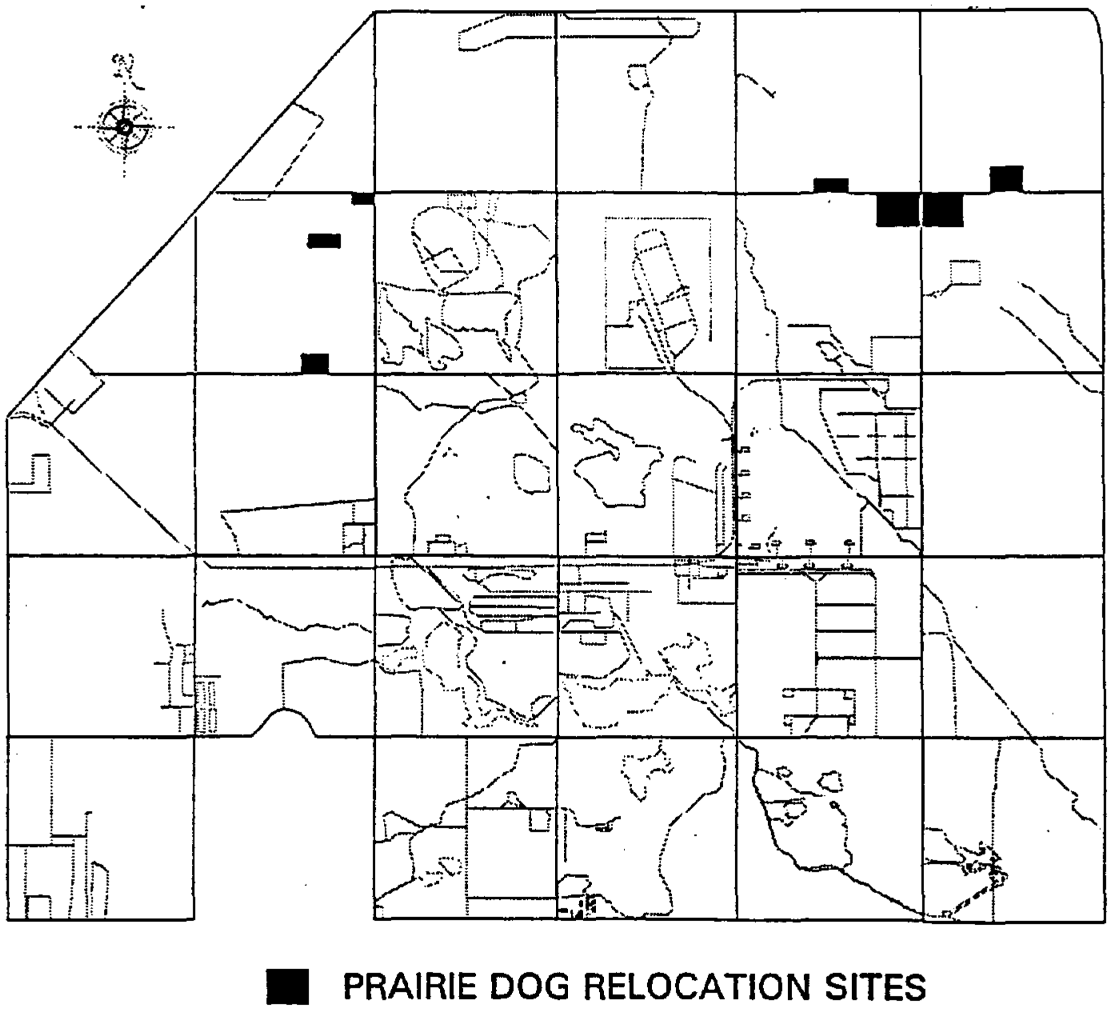

Fig. 1-27. Prairie dog relocation sites used during FY94 at Rocky Mountain Arsenal NWR.

Table 1-28. Prairie dog relocations at Rocky Mountain Arsenal NWR during fiscal year 1994.

CAPTURE SITE	NUMBER	RELEASE SITE	NUMBER
Building 111/112	62	Section 27 S	13
Army Reserve Center	57	Section 27 N	7
N. Boundary System	25	Section 27 NE	7
NW Boundary System	9	Section 20 SW	22
SQI	4	Section 19 SW	17
Eaglewatch	1	Section 30/29	109
Klein Water Treatment Facility	17		
TOTAL	175	TOTAL	175

TITLE: Prairie Dog Management: Section 36 Prairie Dog Study.

INTRODUCTION

Management of black-tailed prairie dogs (Cynomys ludovicianus) on the Refuge receives a high priority due to their importance as a prey base for wintering and nesting raptors, resident mammalian predators and other species of special concern, such as the burrowing owl (Speotyto cunicularia). Part of this management effort includes excluding prairie dogs from known or suspected areas of contamination, to preclude the transmission of contaminants up the food chain. Prairie dogs have been observed moving into formerly occupied areas in Section 36 from surrounding areas (Fig. 1-28) during the past year. By September 1994 the total area occupied in Section 36 was 34.16 hectares (84.38 acres). Prior to initiation of control efforts a sample of prairie dogs was collected to ascertain levels of contamination from different areas of Section 36.

METHODS

Active prairie dog burrows were flagged in all occupied areas of Section 36 (Fig. 1-28) and traps pre-baited on 8 and 9 September. Trapping/collecting occurred from 12 to 16 September, with trapped prairie dogs euthanized by pellet gun shot to the head. Prairie dogs were prepared for residue analysis by removing the stomach and intestinal tract. Each prairie dog was given a unique sample number, weighed, sexed, and aged (pup, yearling, or adult). The exact location of capture was marked with a pin flag and the coordinates (Universal Transverse Mercator (UTM)) were then determined using a Global Positioning System (GPS)(Table 1-29, Fig. 1-28).

RESULTS

A total of 25 prairie dogs were captured/collected from 12 to 16 September. All individuals had reportable concentrations of dieldrin in their tissues (Table 1-29). The concentrations ranged from 0.042 ug/g wet weight to 2.3 ug/g wet weight ($\bar{x}$ = 0.43 ug/g wet weight, SE = 0.15). The four highest concentrations of dieldrin found were in prairie dogs collected from the southcentral portion of Section 36 (Fig. 1-28).

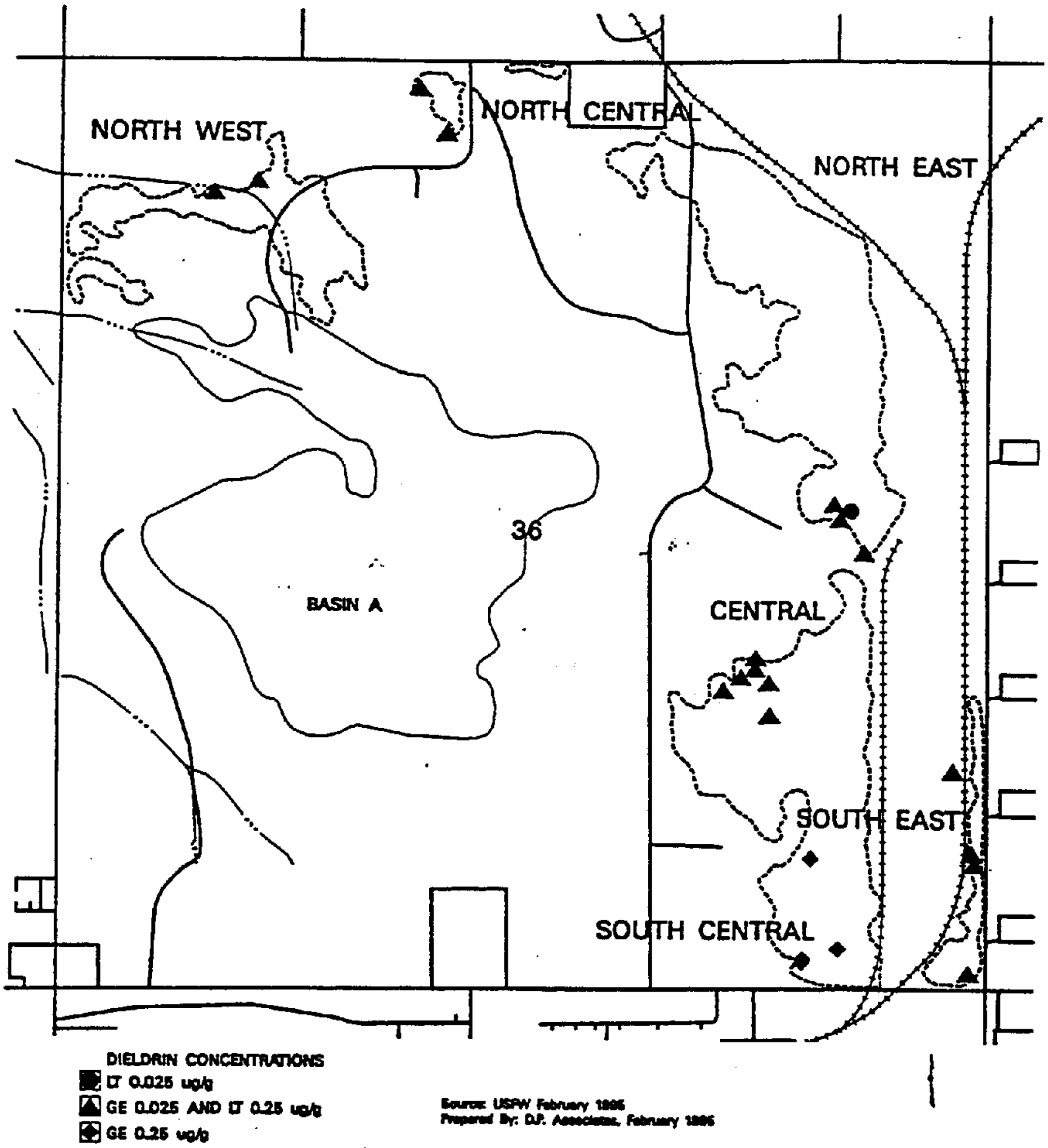

Fig. 1-28. Locations of prairie dog trapping/collecting areas within Section 36, Rocky Mountain Arsenal National Wildlife Refuge, 1994.

Table 1-29. Dieldrin concentrations (ug/g) in prairie dogs (whole carcass, sans GI tract) collected from different areas of Section 36 (T.2S, R.36W) at Rocky Mountain Arsenal NWR between 12 and 16 September, 1994.

Area	ID#,Sex/Age,Weight (g)	UTM coordinates	Dldrn.(ug/g)
Northwest	9424, M/A, 1050	4409556, 513457	0.183
	9425, M/A, 1160	4409577, 513535	0.208
N. Central	9415, F/A, 710	4409740, 513811	0.146
	9421, M/A, 1150	4409660, 513858	0.118
Northeast	9401, F/A, 770	4408994, 514548	0.069
	9416, M/A, 1000	4409008, 514567	0.094
	9422, F/P, 670	4408938, 514591	0.043
	9423, M/A, 1450	4409020, 514536	0.070
Central	9402, F/A, 920	4408719, 514373	0.123
	9403, F/A, 780	4408719, 514373	0.121
	9404, F/A, 700	4408709, 514422	0.088
	9405, M/A, 810	4408696, 514342	0.147
	9406, F/A, 880	4408652, 514423	0.168
	9407, F/A, 810	4408652, 514423	0.210
	9417, F/A, 950	4408753, 514399	0.075
	9418, F/A, 1090	4408734, 514397	0.076
S. Central	9408, M/P, 610	4408404, 514496	1.98
	9413, F/P, 680	4408229, 514482	2.30
	9414, F/A, 710	4408247, 514545	1.75
	9420, M/P, 690	4408223, 514480	2.29
Southeast	9409, F/P, 660	4408555, 514748	0.086
	9410, F/P, 650	4408555, 514748	0.095
	9411, M/A, 1260	4408414, 514780	0.042
	9412, F/P, 600	4408395, 514785	0.111
	9419, F/P, 530	4408206, 514775	0.110

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TITLE: Deer Health Study

INTRODUCTION

The Army installed a 2.5 m-high perimeter fence in late 1989 early 1990 which effectively prevented movement on or off of the Refuge by the mule and white-tailed deer populations. Mule and white-tailed deer are high profile species on the Refuge which can be found literally anywhere on the site. Both species of deer were collected on the Refuge during the Remedial Investigation and the Comprehensive Monitoring Program. Results from these studies indicated that deer were not accumulating elevated concentrations of any of the seven contaminants of concern (COCs).

In 1991 the Service conducted a herd health study to evaluate the overall physical health of both mule and white-tailed deer on the Refuge. No chemical analyses were performed for any of the 7 COCs during this study. Results of the 1991 deer health study indicated that both species were in good to excellent health. Several abnormalities were observed such as testicular atrophy, malformation of antlers, and overgrown hooves.

A graduate research project was initiated through the University of Wyoming in May 1990 to determine the interspecific relationships between sympatric mule and white-tailed deer on the Refuge. Additionally, the study was designed to determine recruitment and adult mortality for both species. Specific management recommendations and protocols will be made in the final report.

A total of 39 adult deer (mule and white-tailed) were outfitted with radio collars and were tracked through December 1992. Initial one year home ranges estimates were calculated for all transmittered deer. Home range sizes varied from 11.72 to 537.80 ha for mule deer and 36.85 to 3591.63 ha for white-tailed deer with summer home ranges being smaller than fall, winter and spring home ranges for both female mule and white-tailed deer (D. Whittaker, pers. commun.).

More than 3000 locations were recorded for the 39 adult deer. Many of these deer spent much of their time in areas of known contamination while others spent the majority of their time in "clean" areas. Because of the extensive locational and reproductive data collected during the previous 3 years, these adult deer could provide a unique insight into potential contamination of Refuge deer.

At the time of the study 25 adult deer still had functioning radio collars. It was believed that by collecting these deer it would be possible to gain insight on contaminant accumulation, overall animal health, and any reproductive affects contaminants may have.

Specific objectives of this study were to:

1) Determine accumulation of contaminants in collected deer.

2) Compare accumulated contaminants in deer using more contaminated sites with deer using "clean" areas.

3) To determine the overall health of the deer population at the Refuge.

METHODS

Deer were collected when they were considered to be the most stressed. At the Refuge this is usually late winter prior to green-up when food resources are scarce. Deer were located through radio telemetry and collected using a small caliber rifle shot dislocating the cervical vertebrae between C3-C6.

All collections were closely supervised and coordinated to avoid potential conflicts with on-going activities and bald eagle use. Necropsies and histopathological evaluations were conducted by board certified veterinarians from the Service's National Wildlife Health Center and the Colorado Division of Wildlife (CDOW).

Gross necropsies were preformed on all deer collected. Blood serum was collected and analyzed for a variety of viral and bacterial pathogens which indicate overall herd health. Blood serum was checked for Bovine Virus Diarrhea (BVD), Bluetongue/Epizootic Hemorrhagic Disease (EHD), Brucellosis, and Leptospirosis.

The left incisor was removed from all deer for aging purposes. Age was determined by sectioning the root of the incisor and counting annual rings in the cementum. Cementum analysis has been proven to be more accurate for aging than analysis of wear on the cheek teeth (Erickson and Seliger 1969).

Reproductive status was determined for all females. Reproductive tracts were removed and fetuses measured in an effort to determine approximate conception dates.

Tissues from the brain, liver, kidney, muscle and fat were collected and preserved for contaminant analysis. Tissues collected for chemical analysis were removed immediately during the necropsy (usually less than 30 minutes after death). Tissues were rinsed in DI water, placed in EPA approved jars suitable for OCP analysis, then frozen. Each sample was given a unique identification number. All sample collections and preservation methods conformed with the Army's Chemical Quality Assurance Plan (CQAP) (U.S. Army 1993). Chemical Assurance and Quality Control of contract laboratory analytical results was performed by PMRMA Laboratory Support Division.

Tissues collected during this study were analyzed for 10 target analytes. All tissues were submitted to Eureka laboratories for analysis. All tissue concentrations were based on wet weight with a detection limit of 0.015 ug/g for OCPs. Arsenic and mercury reporting limits were 0.20 ug/g and 0.05 ug/g respectively.

RESULTS AND DISCUSSION

On 6 and 7 March, 1993, the Service, assisted by veterinarians from the Service's National Wildlife Health Center and the Colorado Division of Wildlife, collected 5 white-tailed deer and 13 mule deer. Of these, 14 were females and 4 were males.

All deer were found to be in good to excellent health based on gross necropsies. Results of serologic, hematologic, and histologic evaluations can be found in the Service's FY93 Annual Progress Report.

Deer ranged in age from 4 to 17 years with the mean age being 8 years (Table 1-30). The overall mean is somewhat biased by the fact that only deer with radio collars were collected, and collars were attached to these animals for approximately 3 years.

Of the 14 females collected all but two were bred. Number of fetuses ranges from 1 to 3. Eight does were pregnant with twins, two with triplets, and two with a single fawn (Table 1-30). Of special note is the fact that the 17 year old white-tailed doe was bred with twins.

Table 1-30. Information collected for 18 mule and white-tailed deer collected at the Rocky Mountain Arsenal National Wildlife Refuge, 5-6 March 1993.

DEER ID	MD-43	MD-02	MD-20	MD-13	MD-03	MD-09	MD-18	MD-41	MD-14
SPECIES	MD	MD	MD	MD	MD	MD	MD	MD	MD
SEX	F	F	F	F	F	F	F	F	F
AGE	8	12	5	8	9	12	9	4	5
BODY WEIGHT (KG)	63.8	62.6	61.4	68.4	61.8	66.4	74.7	60	76.8
PREGNANT	Y	N	Y	Y	N	Y	Y	Y	Y
FETUS 1									
SEX	M		F	F		M	M	F	F
WEIGHT (G)	266.7		362.4	268		414	346	218	400
FR LENGTH	206		227	208		231	228	193	238
HF LENGTH	72		88	74		86	84	66	88
AGE (DAYS)	101		108	103		111	110	99	113
FETUS 2									
SEX	F		M	M			F	M	M
WT (G)	253.3		387.2	290			276	220	426
FR LENGTH	207		235	200			210	192	239
HF LENGTH	71		85	74			78	66	88
AGE (DAYS)	102		112	101			104	98	11
FETUS 3									
SEX							F	M	
WT (G)							262	206	
FR LENGTH							210	197	
HF LENGTH							78	67	
AGE (DAYS)							104	100	
CONCEPTION DATE	NOV 24	-----	NOV 15	NOV 23	-----	NOV 14	NOV 19	NOV 26	NOV 12

Table 1-30 (Continued).

DEER ID	WT-01	WT-15	WT-12	WT-16	WT-05	MD-56	MD-52	MD-60	MD-55
SPECIES	WT	WT	WT	WT	WT	MD	MD	MD	MD
SEX	F	F	F	F	F	M	M	M	M
AGE	9	8	5	14	17	7	5	4	4
BODY WEIGHT (KG)	66	57	67.4	61.4	64.6	92	85.6	94.8	93.8
PREGNANT	Y	Y	Y	Y	Y				
FETUS 1									
SEX	F	F	M	M	F				
WEIGHT (G)	288	358	580	546	334				
FR LENGTH	213	213	260	249	221				
HF LENGTH	78	81	103	116	92				
AGE (DAYS)	101	101	115	112	104				
FETUS 2									
SEX	M	M	F	M	F				
WT (G)	344.3	382	536	290	336				
FR LENGTH	218	219	258	200	222				
HF LENGTH	83	83	111	74	93				
AGE (DAYS)	103	103	114	101	104				
FETUS 3									
SEX									
WT (G)									
FR LENGTH									
HF LENGTH									
AGE (DAYS)									
CONCEPTION DATE	NOV 23	NOV 23	NOV 11	NOV 13	NOV 21				

FR is forehead-rump measurement.
HF is the measurement of hindfoot from the tip of hoof to the angle of hock (Larson and Tabor 1980).

Based on fetal measurements, conception dates for white-tailed deer ranged from 11 November to 23 November, with the $\bar{x}$ being 18 November (Table 1-30). Mule deer conception dates did not vary significantly from the white-tailed deer. Mule deer conception dates ranged from 12 November to 25 November with the $\bar{x}$ conception date being 19 November.

Brain, liver, kidney, fat, and muscle tissues were submitted to the Army's contract laboratory in California for contaminant analysis. Because of quality assurance problems at the lab the Service retrieved all samples and resubmitted to a new lab during 1994. The majority of tissue concentrations were below the detection limit of 0.015 ug/g wet weight for all compounds except dieldrin (n=9), mercury (n=8) and DDE (n=1).

Results of the analysis indicated that arsenic, aldrin, endrin, DDT, alphachlordane, gamachlordane, and isodrin were not detected in any tissues sampled. Only one deer had DDE in its muscle tissues. Dieldrin was the most commonly detected analyte (Table 1-31). Nine mule deer had reportable concentrations of dieldrin in fat tissue. Of the nine deer, four had dieldrin in liver tissue, and only one deer had reportable concentrations of dieldrin in the brain tissue. Dieldrin was not reported in any white-tailed deer sampled.

In a controlled dosing study Murphy and Korschgen (1970) found that white-tailed deer can tolerate relatively large amounts of dieldrin. Adult females ingested an average of 0.72 mg/kg/day of dieldrin for three years and survived the stresses of pregnancy, lactation, and captivity. Additional findings indicated that adult deer would conceive normally and in utero mortality would not occur, but excessive early post-partum mortality of undersized fawns and slower development of immature deer might be expected (at the levels of dieldrin provided in this study). The breeding potential of male deer was not impaired by dieldrin ingestion.

Murphy and Korschgen (1970) reported that deer fed the control diet had no detectable concentration of dieldrin in brain, liver, or muscle tissues. However deer fed the 5 ppm dieldrin treatment had mean concentrations of 0.35, 0.98, and 0.11 ug/g in brain, liver, and muscle respectively. Deer fed the 25 ppm diet had mean dieldrin concentrations of 4.41, 9.13, 1.19 ug/g in brain, liver, and muscle respectively. The results of this investigation clearly demonstrate a relationship between dieldrin exposure and tissue residue concentrations. The low number of dieldrin concentrations found in deer tissue or low concentration indicates that deer are not exposed to high concentrations of dieldrin in their diet.

Mercury was detected in 13 deer (Table 1-32). Only kidney tissues had mercury levels above the reporting level. Mercury concentrations in Refuge deer were lower than background mercury levels identified from free-ranging deer in Oklahoma (Kocan et. al. 1980).

The maximum concentrations of dieldrin in liver and brain from deer collected at the Refuge during 1993 was 0.12 ug/g, and 0.018 ug/g. No dieldrin was reported in muscle tissues.

The results of this study indicate that deer populations at the Refuge are not being adversely affected by contaminants present in the environment. This is supported by the results of the necropsies, population monitoring, and the results of the chemical analysis.

Table 1-31. Dieldrin concentrations (wet weight, ug/g) recorded for deer collected at Rocky Mountain Arsenal National Wildlife Refuge, March 1993.

ANIMAL NUMBER	LIVER	KIDNEY	FAT	BRAIN	MUSCLE
MD 2 93	----	----	----	----	----
MD 3 93	----	----	0.04100	----	----
MD 9 93	0.02500	----	0.12700	----	----
MD 13 93	----	----	0.02400	----	----
MD 14 93	0.11900	----	0.08600	----	----
MD 18 93	----	----	0.04710	----	----
MD 20 93	----	----	0.0200	----	----
MD 41 93	0.03700	----	0.18800	----	----
MD 43 93	----	----	----	----	----
MD 52 93	0.01700	----	0.03531	----	----
MD 55 93	0.05800	----	0.72400	0.01800	----
MD 56 93	----	----	----	----	----
MD 60 93	----	----	----	----	----
WT 1 93	----	----	----	----	----
WT 5 93	----	----	----	----	----
WT 12 93	----	----	----	----	----
WT 15 93	----	----	----	----	----
WT 16 93	----	----	----	----	----

* No data available.

---- Below ceritified reporting limits.

Table 1-32. Mercury concentrations (wet weight ug/g) recorded for deer collected at Rocky Mountain Arsenal National Wildlife Refuge, March 1993.

ANIMAL NUMBER	LIVER	KIDNEY	FAT
MD 2 93	----	----	*
MD 3 93	----	----	----
MD 9 93	----	0.05900	----
MD 13 93	----	----	----
MD 14 93	----	0.05500	----
MD 18 93	----	0.09600	*
MD 20 93	----	0.05600	----
MD 41 93	----	0.06800	----
MD 43 93	----	0.06100	*
MD 52 93	----	----	----
MD 55 93	----	----	*
MD 56 93	----	0.06700	----
MD 60 93	----	0.07000	----
WT 1 93	----	0.11700	----
WT 5 93	----	0.13400	----
WT 12 93	----	0.06200	----
WT 15 93	----	0.10500	----
WT 16 93	----	0.13800	----

* No data available.

---- Below certified reporting limit.

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TITLE: Population Status and Management of Mule and White-tailed Deer.

INTRODUCTION

The Refuge supports a large population of deer, estimated by the Service in 1990 at 350 mule deer and 150 white-tailed deer. After the perimeter fence was erected in March 1990, the deer population was considered a closed population. Management of a closed, non-harvested population, requires substantial information on demographics, especially recruitment and mortality. Additional information on inter- and intraspecific relationships of the sympatric mule and white-tailed deer populations is crucial in developing long-range monitoring and management techniques. A study was initiated in May 1990 to determine patterns of coexistence between mule deer (*Odocoileus hemionus*) and white-tailed deer (*O. virginianus*) on the Arsenal. This work was developed under a Cooperative Agreement between the Service and the Cooperative Fish and Wildlife Research Unit at the University of Wyoming.

With the increase in the mule deer population from 1990 to 1993, it has become necessary to address the problem of overpopulation. Since hunting and relocation are not viable techniques for population control on the Arsenal, other methods of regulation are needed. A study to investigate fertility control was initiated through a Cooperative Agreement between the Service and the Colorado Division of Wildlife (CDOW). This project is a 6-7 year project with the first 4 years being conducted at the CDOW deer pens in Fort Collins. Completion of the third year of study occurred in FY94.

METHODS

Deer ground counts

Deer ground counts were conducted to obtain population estimates during the winter of 1993/94. Counts were conducted along a standardized route beginning at sunrise. Counts were initiated in the southern portion of the Refuge and progressed north. Each deer seen was classified and recorded by species, age, and sex. Biologists used binoculars when deer were too far away to distinguish. Each group of deer was numbered and plotted on an aerial photo of the Refuge.

Herd health

Deer were collected during FY94 in an effort to obtain as much information on deer health as possible, and to attempt to reduce the growing deer herd. Based on a population model developed by the CDOW specifically for the Refuge deer herd, the Service's goal was to remove 75 adult female mule deer.

Mule deer were collected using a 22-250 rifle. Blood, teeth, reproductive tracts, pituitaries, hypothalamus, fecal, and livers were collected. Feces, blood, pituitary, hypothalamus, and reproductive tract were collected with the assistance of the CDOW for use in the fertility control study presently under way (Appendix B). Livers were collected for contaminant testing of the 7 contaminants of concern, and teeth for aging purposes.

RESULTS AND DISCUSSION

Ground counts

Deer ground counts were conducted on 17 February 1994, 11 March 1994, and 12 April 1994. As expected, mule deer were seen more frequently during these road counts than white-tailed deer. The highest number of mule deer was seen during the February count when 393 mule deer were counted. Mule deer numbers ranged from 305 up to 393. White-tailed deer numbers ranged from a low of 33 to a high of 121. Total numbers of deer seen included 347 on 11 March 1994, 409 on 12 April 1994, and 514 on 17 February 1994.

Herd Health

Between October 1993 and April 1994 the Service collected a total of 80 mule deer does. All deer collected were found to be in fair to excellent health based on gross observation. Liver samples were removed from each animal and submitted to the Army contract laboratory for contaminant analysis. Results have not been received for these samples, therefore results of analysis will be reported at a later date. Information on age and reproductive status of these deer can be found in Appendix B.

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TITLE: The Status of Reptiles and Amphibians on the Refuge

INTRODUCTION

The Service's management objectives for reptiles and amphibians include maintaining current population diversity and abundance, and establishing annual surveys for reptiles and amphibians on the Refuge. This two-year study fulfilled the need for a baseline inventory of herptiles (term used to denote the combination of reptiles and amphibians). Changes in terrestrial reptile abundance and diversity may indicate changes in the composition of microhabitats (Jones 1986). Aquatic system health may be reflected by those species sensitive to pollution and loss of permanent water such as aquatic amphibians, turtles, and snakes (Hall 1980). Studies done on the Refuge in the late 1970's (Thorne et al. 1979) showed several contaminants at detectable levels of potential harm, but samples were from four herptile species taken almost exclusively from known contaminated sites.

METHODS

During FY94 the Service continued data collection documenting reptile and amphibian species that inhabited the Refuge. Sampling techniques used included trapping triads and seining for amphibian larvae (Heyer et al. 1994). Captured individuals were measured, weighed, sexed and aged if possible. Specimens were not marked, but were released away from the trap site in the same habitat type.

Trapping triads

The twelve collection sites were the same as 1993 (U.S. Fish and Wildlife Service 1994a) located in habitats that had no restrictions on intrusive activities (Fig. 1-29). A trapping triad was installed at each site. Trapping triad design and placement were based on techniques outlined by Corn and Bury (1990). A triad consisted of three 16-foot metal drift fences radiating an equal distance from a central point. At both ends of each fence were pitfall five-gallon buckets buried to ground level. Funnel traps were positioned at the center of each fence on both sides. Habitats with triads were: upland trees, weedy forb (prairie dog town or cheatgrass), shrubland/succulent (sand sagebrush or yucca stands), wetland (bottomland meadows or cattail ribbons), and native perennial grasses (sand dropseed or needle and thread). Table 1-33 lists descriptions of vegetation characteristics (Morrison-Knudsen 1994), prominent features and locations of the sites.

Trapping triads were opened on 11 May, 1994. Traps were checked every other day beginning 13 May through 10 June when all traps were closed. Local climatological data was obtained from a weather station on Stapleton International Airport, but was not taken daily at each trap location.

Seining and shallow water searches

Throughout the 1994 season, bodies of water were checked for singing male frogs, egg cases, and amphibian larvae. This was done by walking shallow mudflats with a dip net, or pulling a seine along the shoreline. Sites sampled in this manner included all water bodies that were not considered contaminated. Artificial sites that were examined for herptiles were water control structures, livestock tanks, and wildlife guzzlers.

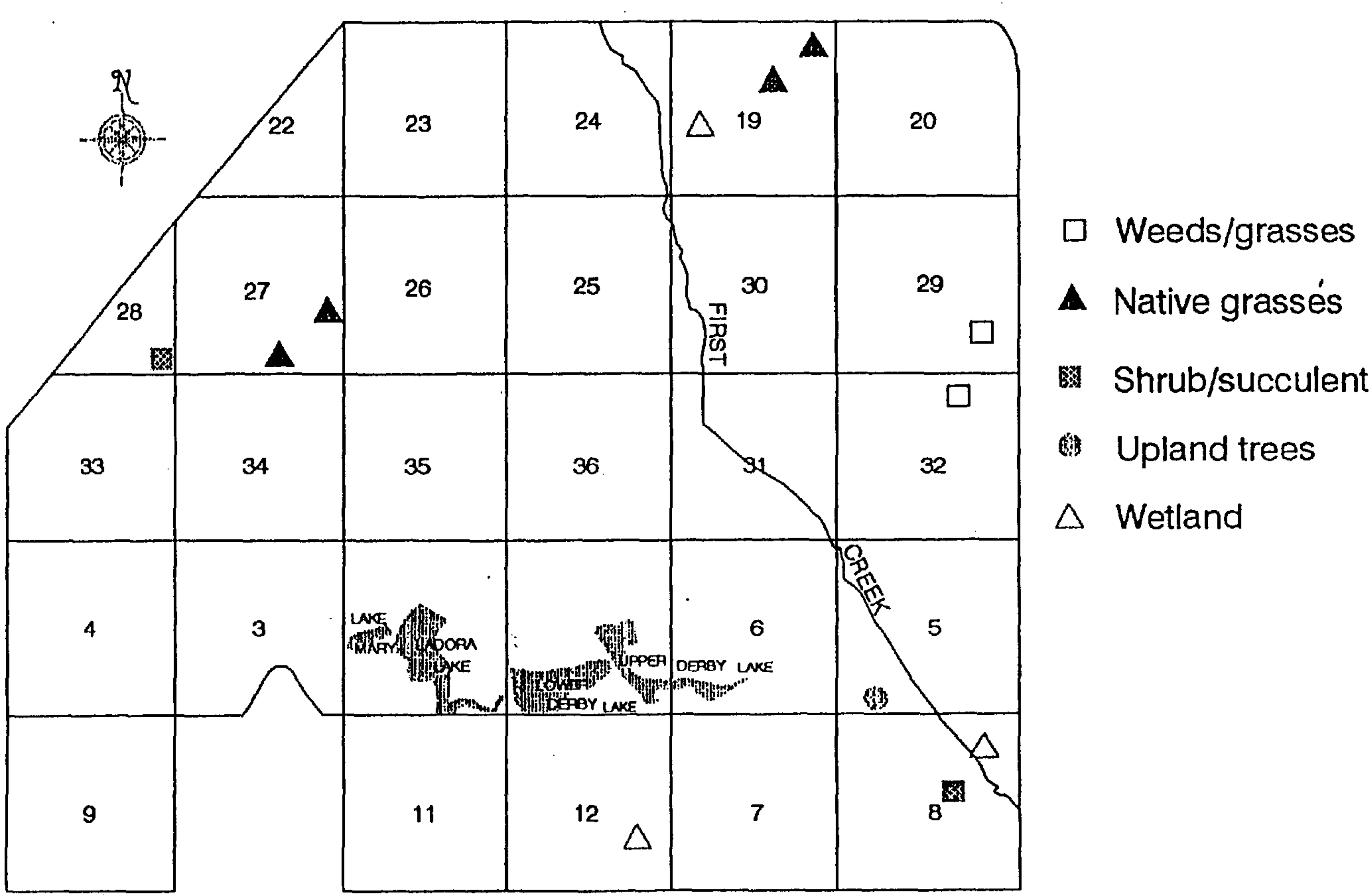

Fig. 1-29. Location and vegetation types of herptile traps on Rocky Mountain Arsenal National Wildlife Refuge, 1993-94.

Table 1-33. Locations and vegetation types at herptile trapping sites on the Rocky Mountain Arsenal National Wildlife Refuge 1993-94.

SITE	SECTION	VEGETATION TYPE	OTHER FEATURES
1	28	Yucca Stand	Upland area with coarse shallow soil dominated by *Yucca glauca*. No permanent water.
2	27	Needle and Thread Grasslands	Upland area with coarse soil dominated by *Stipa comata*. No permanent water.
3	27	Needle and Thread Grasslands	Upland area with coarse soil dominated by *Stipa comata*. No permanent water.
4	19	Bottomland Meadows	Bottomland area adjacent to historic channel of First Creek dominated by nonweedy perennials and forbs. Water was present in 1993, but lacking in 1994.
5	19	Sand Dropseed Grasslands	Upland area with coarse loamy soils dominated by *Sporobolus cryptandrus*. No permanent water.
6	19	Sand Dropseed Grasslands	Upland area with coarse loamy soils dominated by *Sporobolus cryptandrus*. No permanent water.
7	20	Weedy Forbs	Severely disturbed area with bare ground and few cheatgrass or perennial grass components in an active prairie dog town. Dominant species included bindweed, tansy mustard and tumble mustard. No permanent water.
8	29	Cheatgrass/weedy forbs	Severely disturbed area dominated by *Bromus tectorum* with no prairie dog activity. Dominant weeds included those at site 7 and wild lettuce, musk thistle, and Canada thistle.
9	8	Bottomland meadow	Bottomland area adjacent to First Creek with nonweedy perennials close to a cottonwood/willow gallery. Permanent water.
10	8	Sand Sagebrush Shrubland	Upland area dominated by *Artemisia filifolia*. Permanent water in the quarter section.

Table 1-33 (Continued).

SITE	SECTION	VEGETATION TYPE	OTHER FEATURES
11	5	Tree Grove	Remnant plantings of homestead with pine, red cedar, Chinese elm, and cottonwood. Permanent water is present in the next quarter section.
12	12	Cattail Ribbon	A narrow band of *Typha latifolia* and *T. angustifolia* surrounding a permanent shallow pond encircled by sand dropseed grasslands.

Incidental Collections

Many specimens were reported by Service or Army staff. Herptiles were reported inside buildings, crossing roads or incidental to other studies such as fish sampling and raptor monitoring.

RESULTS AND DISCUSSION

Table 1-34 lists an updated version of herptiles on the Refuge. The list is a compilation of current sightings, trap captures and recent historical documentation (Morrison-Knudsen 1989, U.S. Fish and Wildlife Service 1994a). Species from field guide range maps for Colorado (Hammerson 1986) were included if specimens were validated in the vicinity of the Refuge. Herptiles found in 1993 and 1994 represent 50% of the total list compared to 61% documented by Morrison-Knudsen in 1986 (Morrison-Knudsen Environmental Inc. 1989). The amphibians not detected by the U.S. Fish and Wildlife Service in the present study were the Great Plains toad (Bufo cognatus) and the northern leopard frog (Rana pipiens). Both of these amphibians could have a restricted occurrence on the Refuge, particularly the leopard frog whose populations are diminishing throughout the state (Hammerson 1986). The undetected reptiles were the short-horned lizard (Phrynosoma douglassii), wandering garter snake (Thamnophis elegans vagrans), and common garter snake (T. sirtalis). These reptiles may have been present, but not in the vicinity of the traps.

Trapping Triads

The five habitat categories are used for comparison between 1993 and 1994, but separated into nine more specific habitats for summary analysis and management recommendations. Six species totalling 148 captures were trapped in four habitats during the 1994 trapping session (Fig. 1-30) compared to 44 captures of five species in 1993. The most successful trap sites were in wetland habitats with 73 captures of three species including tiger salamander (Ambystoma trigrinum), Woodhouse's toad (Bufo woodhousii), and striped chorus frog (Pseudacris triseriata). In 1993, the wetland habitat sites also had the most captures and an additional species, the yellow-bellied racer (Coluber constrictor). The upland tree habitat traps caught 43 Woodhouse's toads, the second highest number of a single species, identical to 1993 results. The shrubland/succulent habitat sites caught 23 individuals, including Plains spadefoot toad (Scaphiopus bombifrons) and three species previously not caught in this habitat; Woodhouse's toad, many-lined skink (Eumeces multivirgatus), and Western bullsnake (Pituophis melanoleucus). In 1993, only four Plains spadefoot toads were caught in this habitat type. No herptiles were captured in weedy forb habitat in either year.

The most frequently captured species in 1994 was Woodhouse's toads (126), followed by Plains spadefoot toads (16) and tiger salamanders (3). Single captures included a striped chorus frog, a many-lined skink and a bullsnake. The latter two represented new species. No yellow-bellied racers were captured in 1994. This was similar to 1993 results for the top three ranked species. Two chorus frogs and two yellow-bellied racers were caught in 1993.

Temperature and precipitation appeared to have affected capture success. With many amphibians, temperature changes can initiate migration and significantly influence development and growth (Heyer et al 1994). Spadefoot toads in Colorado, for instance, will not respond to precipitation events, the normal breeding stimulus, if minimum daily temperatures are below 50°F (Hammerson 1986). Captures peaked on 4 June when six traps representing all four habitats caught 22 Woodhouse's toads, one tiger salamander and one Spadefoot toad. All trap nights one week prior to 4 June except one had high capture rates (20, 13, 4, 17, 18). Weather data showed thunderstorms on 24 and 25 May with a minimum temperature of 48° F that may have resulted in the subsequent 20 and 13 captures. On 1-3 June thunderstorms and an average minimum of 56° F

Table 1-34. Species list of reptiles and amphibians on Rocky Mountain Arsenal National Wildlife Refuge based on literature search and 1993-94 sightings.

COMMON NAME	SCIENTIFIC NAME	HAM[1]	MK[2]	USFWS[3]
Tiger Salamander	Ambystoma trigrinum	X	X	X
Plains Spadefoot	Scaphiopus bombifrons	X	X	X
Great Plains Toad	Bufo cognatus	X	X	
Woodhouse's Toad	B. woodhousii	X	X	X
Striped Chorus Frog	Pseudacris triseriata	X	X	X
Bullfrog	Rana catesbeiana	X	X	X
Northern Leopard Frog	R. pipiens	X	X	
Common Snapping Turtle	Chelydra s. serpentina	X		
Western Painted Turtle	Chrysemys picta bellii	X		X
Western Box Turtle	Terrapene o. ornata	X		
Spiny Softshell	Trionyx spiniferus	X		X
Lesser Earless Lizard	Holbrookia maculata	X	X	X
Short-horned Lizard	Phrynosoma douglassii	X	X	
Prairie Lizard	Sceloporus undulatus	X		
Many-lined Skink	Eumeces multivirgatus	X	X	X
Six-lined Racerunner	Cnemidophorus sexlineatus	X		
Western Hognose Snake	Heterodon nasicus	X	X	X
Eastern Yellow-bellied Racer	Coluber constrictor	X	X	X
Central Plains Milk Snake	Lampropeltis triangulum	X		
Northern Water Snake	Nerodia sipedon	X		
Smooth Green Snake	Opheodrys vernalis	X		
Western Bullsnake	Pituophis melanoleucus sayi	X	X	X
Plains Black-headed Snake	Tantilla nigriceps	X		
Wandering Garter Snake	Thamnophis elegans vagrans	X	X	

Table 1-34 (Continued).

COMMON NAME	SCIENTIFIC NAME	HAM[1]	MK[2]	USFWS[3]
Plains Garter Snake	T. radix	X	X	X
Common Garter Snake	T. sirtalis	X	X	
Lined Snake	Tropidoclonion lineatum	X		
Prairie Rattlesnake	Crotalis viridis viridis	X	X	X

[1] Hammerson 1986
[2] Morrison-Knudsen Environmental Services, Inc. 1989
[3] U. S. Fish and Wildlife Service 1993, 1994

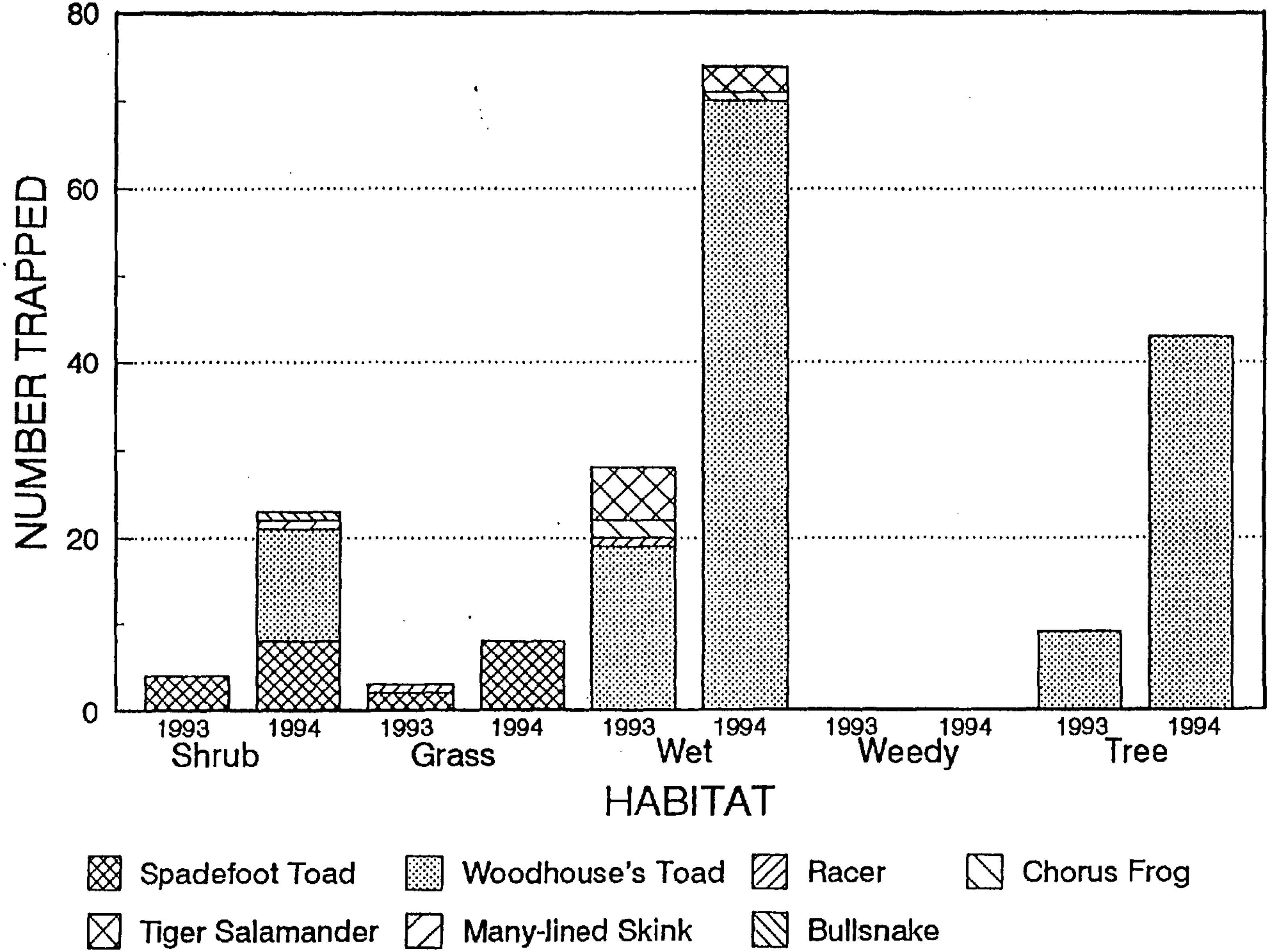

Fig. 1-30. Trapped reptiles and amphibians and associate habitats at Rocky Mountain Arsenal National Wildlife Refuge, 1993-94.

appeared to correlate with peak captures of 17, 18 and 24 individuals. In 1993, an early peak (11 captures) occurred 16 May following a rain event on 15 May and a minimum temperature of 50° F. A similar late peak (10) on 2-3 June corresponded to daily rain on those days and minimum temperatures of 60° F and 52° F respectively.

The importance of breeding sites and microhabitats to herptiles was indicated in this study but not statistically compared due to the nonrandom selection of study sites and placement of triads. Breeding sites such as the small pond in Section 12 attracted aquatic (entire life cycle occurs in water), semi-aquatic (life cycle includes aquatic and terrestrial stages) and terrestrial (entire life cycle occurs on land) amphibious species. The bottomland meadows along First Creek had two semi-aquatic amphibians and one terrestrial reptile. Tiger salamanders and Woodhouse's toads caught at these water sites were in breeding condition with enhanced sexual characteristics in males and egg excretion in females.

Microhabitats conducive to reptile occupancy, such as loose soil and shade providing structures, appeared to be present in the shrub/succulent sites. Many-lined skink and bullsnake juveniles found in Section 27 attested to breeding in the yucca stand habitat. The yucca stand site also had the highest number (10) of spadefoot toads who burrow readily in coarse soil. The presence of Woodhouse's toads in the sandsage brush site in 1994 was unusual. However, Hammerson (1986) reports these toads, normally associated with flood plains, have extended their range into semi-arid areas where irrigation is used. Wetland 1, south of the site, is supplementally filled with off-post water by an irrigation ditch. At site 11 in Section 5, the upland tree grove had intense structural diversity but only a single species (Woodhouse's toad) was captured. The area was a past homesite with both deciduous and coniferous trees, fallen logs, and a variety of herbaceous growth. Its isolation, unique habitat components and distance from water may have jeopardized its suitability for species richness.

The two native grass communities were not species rich trapping only spadefoot toads in both years and a yellow-bellied racer in 1993. None of the four traps (2, 3, 5, 6) had fallen trees or rocks to provide sunning areas or shade. Water availability was limited to temporary pools created by rainfall. The last two sites (7 and 8) also were devoid of structural diversity and readily available water. No herptiles were caught at these sites in either 1993 or 1994.

Seining and pond searches

Seining and visual searches of water bodies provided verification of the importance of Refuge water bodies to herptiles, both breeding and aquatic individuals.

Seining was conducted in Havana ponds, the Toxic Storage Yard pond and Bald Eagle Shallows during August. Larval forms of tiger salamanders were found at Havana ponds and Bald Eagle Shallows. Two spiny softshell turtles (Trionyx spiniferus) were seen in Bald Eagle shallows throughout the summer. In September the water completely dried up. Eastern Upper Derby Lake and the pond in Section 26 were dry this year. No herptiles were seen or heard using North Bog in 1994.

The water control structure in Section 8 located in sand sagebrush habitat caught a Plains spadefoot toad and Woodhouse's toads. In 1993, a small number of adult Woodhouse's toads were removed from the structure compared to numerous juvenile toads in 1994. The structure in Section 7, located in sand dropseed habitat caught hundreds of Woodhouse's toads of all ages, Plains spadefoot toads, and a bullfrog (Rana catesbeiana). Again, the presence of the irrigation ditches in these semi-arid habitats appeared to be the disseminating factor for Woodhouse's toads.

Wildlife guzzlers, one of which harbored approximately 15 Plains spadefoot toad tadpoles in 1993 were dry this year.

Incidental Specimens

Snakes were the most frequently reported herptiles observed incidental to other activities. A Plains garter snake (Thamnophis radix) was found dead in the B-111 lawn. Newborn prairie rattlesnakes (Crotalis viridis) were reported frequently entering buildings in September. A red-tailed hawk (Buteo jamaicensis) was seen grappling with a yellow-bellied racer in Section 12, which was in the hawk's talons but continued to wrap its body around the bird's legs.

A lesser earless lizard (Holbrookia masculata) was fed to an American kestrel (Falco sparverius) nestling in Section 12. The chick had an esophageal ligature to prevent it from swallowing food items brought to it by the parents as part of the contaminant investigations. Contaminant analysis of the lizard revealed no detectable contaminant levels (Rick Roy unpubl. data).

A Western painted turtle (Chrysemys picta) was seen during fish tracking in the upper arm of Ladora Lake. In 1993, a single small painted turtle was found in wetland 1.

Future studies and management recommendation

Future investigation of amphibians and reptiles on the Refuge should not be overlooked. Presently, reptiles and amphibians are not identified as sentinel specie in the biomonitoring program (U.S. Fish and Wildlife Service 1994b). However at the very least, breeding sites should be monitored throughout the cleanup effort to insure the vitality of all existing species. Further efforts should be made to determine whether species seen in 1986 still exist on the Refuge. Consideration should be given to creating or maintaining microhabitats to enhance reptilian populations. Water bodies should be protected from extensive erosion that could cause siltation in breeding ponds. Specifically, fill dirt borrow pits should not be located near breeding areas. Flood control efforts should be addressed by returning the creek to its natural course rather than by the installation of structures, such as riprap and cement, which will destroy existing shallow water habitat. Pollution from off-post, such as irrigation water, should be monitored for chemical content and excessive debris. Refuge personnel should remain active in decisions made regarding the fate of water entering the Refuge. The value of herptiles in the ecosystem, both as predators and prey, should not be ignored when deciding the future coarse of action for this Refuge.

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TITLE: The Distribution and Abundance of Passerine Birds

INTRODUCTION

The diversity of Refuge habitats ranges from wetland/riparian to shortgrass prairie. These habitats support numerous passerine bird species (Morrison-Knudsen 1989, U.S. Fish and Wildlife Service 1994). Service studies were designed to monitor the population status and habitat associations of passerine birds on the Refuge and to provide information for appropriate mitigation for habitats impacted during cleanup. Mitigation, habitat enhancement, and habitat management efforts may help ensure that species diversity and richness remain stable during cleanup. Monitoring efforts have included annual breeding bird surveys and Christmas bird counts. Habitat specific studies include a grassland songbird study conducted by Denver Museum of Natural History (1991-1993) and a riparian bird study using point counts during the breeding season on First Creek and Lower Derby initiated in 1994 (U.S. Fish and Wildlife Service 1993).

Western riparian areas have been targeted as a habitat of concern due to their high species count and diminishing land base (Johnson and Carothers 1981). On the Refuge, First Creek redesign for flood control events and the attraction of this area for future public use exemplify the need for documentation of its present importance to breeding and neotropical migrant songbirds.

METHODS

Christmas bird counts (CBC)

Christmas bird counts have been conducted on the Refuge by Denver Field Ornithologists and the Denver Audubon Society since the 1988-89 season. They traditionally are conducted on 1 January. The CBC's objective is to identify as many bird species and numbers as possible on the Refuge from sunrise to sunset. The route and method of surveying is random. Bird attraction devices, such as bird callers, taped songs and feeders are permissible.

Breeding bird survey (BBS)

The Breeding Bird Survey is a nationally standardized survey to compare avian population trends across the country. The fourth Refuge BBS was conducted on 9 June, 1994. This route was established in 1991 through the U.S. Fish and Wildlife Service Office of Migratory Bird Management. An observer traveled an established 25 mile route through representative habitats of the Refuge. The route consisted of 50 stops, lasting 3 minutes each, where all birds seen and heard were recorded (Fig. 1-31).

Point counts

The point count method has been adopted as the recommended standard censusing method for monitoring landbirds (Ralph et. al 1993). The riparian point count study was conducted on the entire length of First Creek and the perimeter of Lower Derby Lake. The lake was chosen because of its more expansive wetland vegetation but with the realization that the water characteristics would not mimic First Creek. The starting point for the First Creek sites was the Refuge's eastern perimeter fence along Buckley Road. To establish a random component to the count, subsequent point locations were placed a minimum of 250 meters apart plus an extra 0-50 meters generated from a random number table for a total of 35 points before the creek exits the Refuge at 92nd Street on the north boundary. Ten sites were placed on Lower Derby Lake using the same distance formula. Counts were made monthly during June, July and August beginning at sunrise and ending no later than 0930. Each count

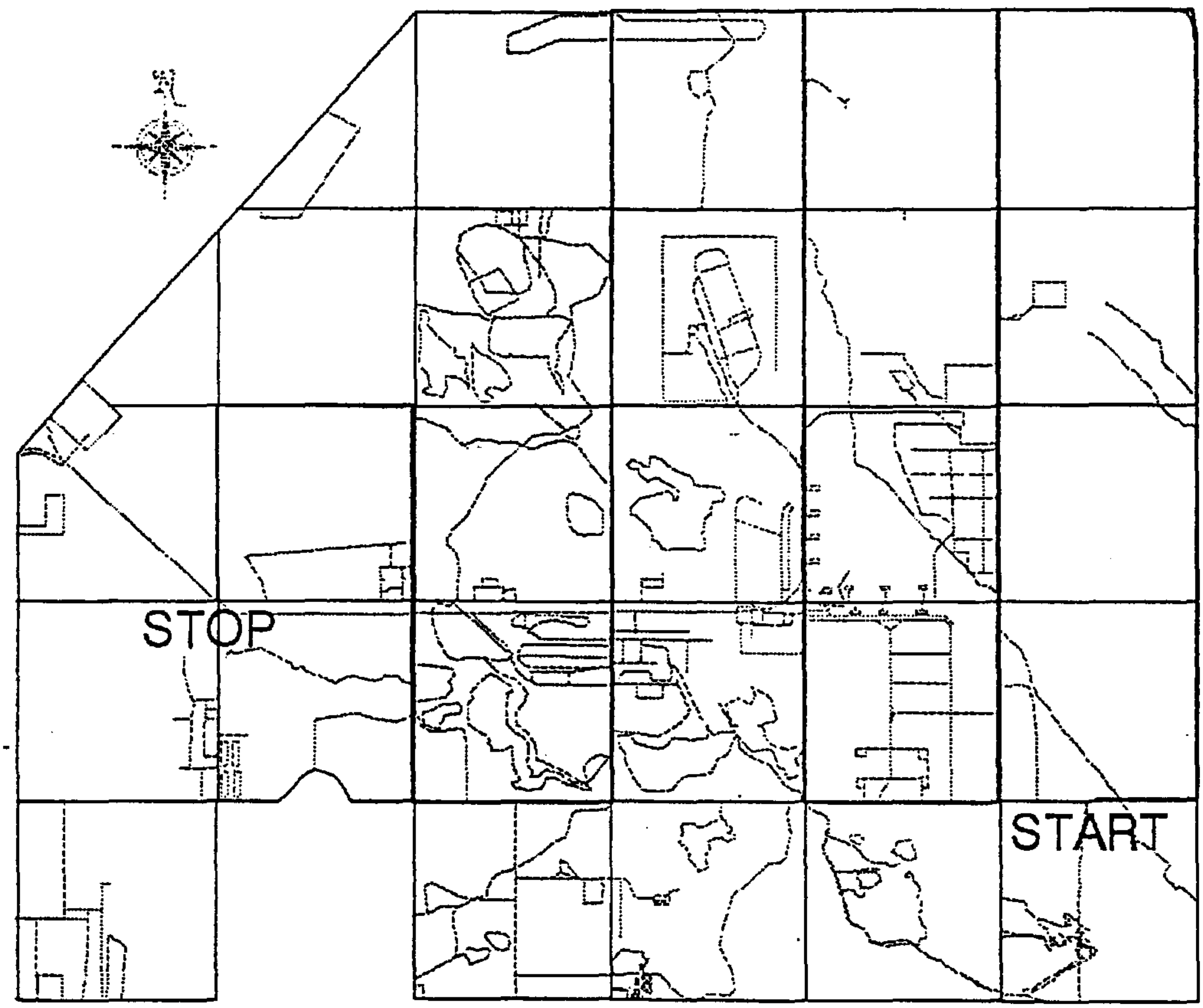

Fig. 1-31. Breeding Bird Survey route on Rocky Mountain Arsenal National Wildlife Refuge.

lasted five minutes with birds noted after the three minute mark tallied separately. Detection distances were noted as in or outside a 50 meter radius. Birds behavior and perch strata also were noted when possible. Nest searching and mistnetting were postponed until preliminary data gave an indication of sentinel species and locations on which to concentrate.

RESULTS AND DISCUSSION

Christmas bird count

Thirty-six bird species were recorded on the 1994 Christmas bird count (Table 1-35). Single sightings of a common merganser (Mergus merganser) and a pine siskin (Cardulis pinus) placed these species on the list for the first time. Large numbers of European starlings (Sturnus vulgaris), black-billed magpies (Pica pica) and house finches (Carpodacus mexicanus) were seen on the count. Comparison of Christmas bird counts from 1989 - 1994 revealed similar results in number of species observed (X = 36) but variation in total number of individuals seen (range: 746 to 2433) (Table 1-35). Twenty species were seen all six years.

Breeding bird survey

Forty bird species were recorded on the BBS in 1994 (Table 1-36). Western meadowlarks (Sturnella neglecta) were the most numerous species (149) and most widely distributed (49 stops). Red-winged blackbirds (Agelaius phoeniceus) were a distant second in numbers (47) with black-billed magpies a close third (45). Mourning doves (Zenaida macroura) were seen on almost half the stops (24) followed by black-billed magpies and ring-necked pheasants (Phasianus colchicus) at 22 stops each. A comparison of all four years reveals the Western meadowlark has been the most numerous and widely distributed bird on the Refuge followed by the mourning dove and Western kingbird (Tyrannus verticalus). Lark bunting (Calamospiza melanocorys) numbers remained low, but Eastern kingbird (Tyrannus tyrannus), Bullock's oriole (Icterus galbula bullockii) and ring-necked pheasant numbers increased. Twenty six species were detected on all four counts.

Point counts

During the 1994 breeding season, 53 bird species were detected on either the First Creek or Lower Derby Lake point counts (Table 1-37). It took two days to complete all the points on First Creek. Of the 47 species seen on First Creek, 20 were detected on all three counts and 14 were observed displaying reproductive behavior. On Lower Derby, 11 of the 35 species recorded were detected on all three counts and three species were involved in breeding activities. The most frequently seen species on First Creek were red-winged blackbirds, song sparrows (Melospiza melodia), Western meadowlarks, and common yellowthroats (Geothlpis trichas). On Lower Derby, the common species were red-winged blackbirds, Bullock's orioles, house wrens (Troglodytes aedon), and yellow warblers (Dendroica petechia). No unusual species were sighted in 1994, but the presence of grassland species such as the Western meadowlark, lark bunting, and grasshopper sparrow (Ammodramus savanarrum) on the counts alluded to the narrowness of the riparian area. Additionally, the frequent detection of brown-headed cowbirds (Molothrus ater) was alarming and may require future investigation regarding the extent of nest parasitism on the Refuge and its correlation to riparian area fragmentation.

Future work

Both the Christmas bird count and the breeding bird survey will be conducted annually ad infinitum as standard methods for determining species presence or absence, distribution and seasonal status (Fig. 1-32).

The riparian point count will be continued at least through 1996 with a probable extension. GIS mapping of the points will be obtained in 1995 at which time vegetative analysis will be conducted. Expansion of the study area may include Ladora Lake and Uvalda Ditch.

Table 1-35. Christmas bird count data collected on the Rocky Mountain Arsenal National Wildlife Refuge 1989-94. Species seen every count are highlighted.

SPECIES	1989	1990	1991	1992	1993	1994
Blk-crowned Night Heron	1	-	-	-	-	-
Canada Goose	162	90	330	375	160	600
Green-winged Teal	-	3	2	2	-	-
Mallard	6	29	66	4	6	4
Northern Shoveler	-	-	-	-	1	-
Gadwall	-	-	-	2	-	-
Ring-necked Duck	-	-	-	3	2	3
Common Goldeneye	-	1	-	2	-	1
Common Merganser	-	-	-	-	-	1
Bald Eagle	30	29	23	33	15	7
Northern Harrier	9	2	5	-	-	-
Red-tailed Hawk	15	9	12	5	5	13
Ferruginous Hawk	51	3	8	10	8	10
Rough-legged Hawk	18	20	7	7	7	4
Buteo species	2	-	-	4	-	-
Golden Eagle	12	1	1	-	-	5
American Kestrel	1	-	2	2	3	2
Merlin	-	2	1	-	-	-
Prairie Falcon	1	-	-	1	-	1
Chukar	-	-	-	8	2	1
Ring-necked Pheasant	101	9	1	27	21	28
Wild Turkey	-	-	-	-	1	-
Northern Bobwhite	17	-	-	28	-	-
Virginia Rail	2	-	-	-	-	-
American Coot	6	6	4	2	4	3
Ring-billed Gull	313	70	565	500	33	3
Herring Gull	2	-	-	-	-	-

Table 1-35 (Continued).

SPECIES	1989	1990	1991	1992	1993	1994
Rock Dove	-	4	41	49	39	70
Eastern Screech Owl	1	-	-	-	-	-
Great Horned Owl	14	4	4	2	4	3
Long-eared Owl	-	-	-	-	6	13
Burrowing Owl	-	-	1	-	-	-
Downy Woodpecker	8	7	7	2	3	3
Hairy Woodpecker	1	-	-	-	-	-
Northern Flicker	28	15	17	14	2	11
Horned Lark	113	15	37	425	250	-
Blue Jay	-	-	2	-	-	-
Black-billed Magpie	187	81	188	48	60	120
American Crow	-	-	1	4	-	-
Black-capped Chickadee	17	18	11	22	1	17
Mountain Chickadee	-	4	-	-	-	-
Red-breasted Nuthatch	-	1	-	-	-	-
Brown Creeper	2	-	-	1	1	-
Marsh Wren	1	-	-	-	-	-
Golden-crowned Kinglet	-	-	-	-	2	3
Townsend's Solitaire	-	-	2	3	-	1
American Robin	10	-	1-	2	1	4
Northern Shrike	2	1	-	-	1	-
European Starling	126	13	256	50	11	190
American Tree Sparrow	138	185	83	160	13	45
Song Sparrow	14	-	5	7	3	8
Swamp Sparrow	1	-	-	-	-	-
White-crowned Sparrow	3	-	15	-	6	-
Harris Sparrow	-	-	-	-	2	-

Table 1-35 (Continued).

SPECIES	1989	1990	1991	1992	1993	1994
Dark-eyed Junco (all)	196	70	123	136	112	72
Red-winged Blackbird	108	1	413	25	1	11
Western Meadowlark	78	37	6	15	20	3
House Finch	210	15	150	125	70	200
Pine Siskin	-	-	-	-	-	1
American Goldfinch	18	-	2	-	-	4
House Sparrow	2	-	32	235	85	90
TOTAL SPECIES	41	31	36	37	36	36
TOTAL INDIVIDUALS	2027	746	2433	2339	961	1555

Table 1-36. Breeding bird survey data collected on the Rocky Mountain Arsenal National Wildlife Refuge 1991-94. Species seen all survey years are highlighted.

SPECIES	TOTAL				STOPS OBSERVED			
	1991	1992	1993	1994	1991	1992	1993	1994
Pied-billed Grebe	1	-	-	-	1	-	-	-
Western Grebe	7	-	-	-	1	-	-	-
American White Pelican	-	-	11	5	-	-	2	1
Double-crested Cormorant	13	12	11	8	8	7	2	5
Great Blue Heron	13	6	4	1	11	6	2	1
Black-crowned Night Heron	-	-	1	-	-	-	1	-
Canada Goose	27	19	-	6	3	2	-	1
Mallard	4	5	-	3	3	1	-	2
Blue-winged Teal	1	-	4	1	1	-	2	1
Gadwall	1	-	-	-	1	-	-	-
Swainson's Hawk	10	2	6	5	9	2	5	5
Red-tailed Hawk	6	1	3	2	4	1	3	2
Ferruginous Hawk	-	1	1	-	-	1	1	-
American Kestrel	18	2	7	10	14	2	5	9
Ring-necked Pheasant	41	14	19	27	25	10	15	22
Northern Bobwhite	3	-	-	-	1	-	-	-
American Coot	5	2	-	-	3	2	-	-
Killdeer	3	9	9	7	1	7	4	5
Ring-billed Gull	-	7	-	-	-	1	-	-
Rock Dove	90	27	33	14	8	3	3	2
Mourning Dove	96	24	44	36	33	15	24	24
Great Horned Owl	4	4	-	2	2	1	-	2
Burrowing Owl	5	5	4	5	3	3	1	3
Short-eared Owl	-	-	2	-	-	-	2	-
Belted Kingfisher	-	1	-	-	-	1	-	-
Downy Woodpecker	2	-	-	1	2	-	-	1

Table 1-36 (Continued).

SPECIES	TOTAL 1991	1992	1993	1994	STOPS OBSERVED 1991	1992	1993	1994
Red-shafted Flicker	2	-	2	-	2	-	2	-
Western Wood-pewee	-	1	3	5	-	1	3	2
Western Kingbird	45	69	44	24	22	24	25	14
Eastern Kingbird	17	5	1	10	7	3	1	7
Horned Lark	28	7	22	17	11	5	13	9
N. Rough-winged Swallow	-	1	-	-	-	1	-	-
Barn Swallow	5	-	8	4	5	-	4	3
Black-billed Magpie	84	38	34	45	35	14	17	22
Black-capped Chickadee	-	-	7	-	-	-	2	-
Rock Wren	1	-	-	-	1	-	-	-
Bewick's Wren	-	1	-	-	-	1	-	-
House Wren	10	14	6	21	7	9	5	10
Marsh Wren	1	-	-	-	1	-	-	-
American Robin	26	19	12	17	9	12	10	10
Northern Mockingbird	-	-	1	-	-	-	1	-
European Starling	173	35	37	35	21	9	20	16
Warbling Vireo	1	-	-	-	1	-	-	-
Yellow Warbler	14	10	10	7	7	7	8	5
Yellow-rumped Warbler	-	-	1	-	-	-	1	-
Common Yellowthroat	8	7	7	7	7	6	5	6
Black-headed Grosbeak	1	-	-	1	1	-	-	1
Rufous-sided Towhee	1	-	-	-	1	-	-	-
Cassin's Sparrow	1	2	1	-	1	1	1	-
Lark Sparrow	2	-	-	-	2	-	-	-
Lark Bunting	92	293	1	4	14	30	1	3
Song Sparrow	5	-	1	4	2	-	1	4

Table 1-36 (Continued).

SPECIES	TOTAL				STOPS OBSERVED			
	1991	1992	1993	1994	1991	1992	1993	1994
Grasshopper Sparrow	25	12	12	5	13	8	9	4
Red-winged Blackbird	86	100	33	47	8	18	14	17
Western Meadowlark	349	526	149	158	46	48	49	49
Yellow-headed Blackbird	6	-	-	-	1	-	-	-
Brewer's Blackbird	2	278	10	3	1	23	5	1
Common Grackle	45	2	-	8	17	2	-	5
Brown-headed Cowbird	2	6	-	1	2	5	-	1
Orchard Oriole	1	-	1	-	1	-	1	-
Bullock's Oriole	49	13	11	23	21	7	9	18
House Finch	6	-	4	13	2	-	2	3
American Goldfinch	7	-	3	6	2	-	3	5
House Sparrow	37	39	3	9	10	7	1	3
TOTAL SPECIES	52	39	42	40				

Table 1-37. Bird species detected on point counts on First Creek and Lower Derby Lake, Rocky Mountain Arsenal National Wildlife Refuge during June, July and August 1994. Highlighted species were documented nesters.

SPECIES	FIRST CREEK			LOWER DERBY		
	Jun	Jul	Aug	Jun	Jul	Aug
Double-crested Cormorant		*				
Great Blue Heron	*					*
Black-crowned Night Heron						(*)
Canada Goose			(*)			*
Green-winged Teal	*					
Mallard	*			*		
Blue-winged Teal				*		
Cinnamon Teal	*					
Redhead				*		
Swainson's Hawk	*	*	*			
Red-tailed Hawk	*		*			
American Kestrel	*	*	*			
Ring-necked Pheasant	*	*		*		
Killdeer	*		*	*		*
Greater Yellowlegs			*		*	*
Spotted Sandpiper			*			
Rock Dove	*	*	*			*
Mourning Dove	*	*	*	*	*	
Great Horned Owl	*	*	(*)			
Belted Kingfisher			*			*
Downy Woodpecker	*	*	*		*	*
Northern Flicker	*		*	*	*	*
Western Wood-pewee	*		*		*	
Western Flycatcher			*			
Western Kingbird	*	*	*			*
Eastern Kingbird	*	*	*	*	*	*

Table 1-37 (Continued).

SPECIES	FIRST CREEK			LOWER DERBY		
	Jun	Jul	Aug	Jun	Jul	Aug
Horned Lark	*					
N. Rough-winged Swallow	*					
Cliff Swallow	*	*				
Barn Swallow	*	*	*	*	*	*
Black-billed Magpie	*	*	*	*	*	*
Black-capped Chickadee		*	*		*	*
House Wren	*	*	*	*	*	*
American Robin	*	*	*	*	*	*
European Starling	*	*	*	*	*	*
Yellow Warbler	*	*	*	*	*	*
Common Yellowthroat	*	*	*	*	*	*
Blue Grosbeak	*		*			*
Chipping Sparrow			*			
Lark Bunting			*	*		
Grasshopper Sparrow	*					
Song Sparrow	*	*	*	*	*	
Red-winged Blackbird	*	*	*	*	*	*
Western Meadowlark	*	*	*	*		
Yellow-headed Blackbird						*
Brewer's Blackbird	*					
Common Grackle	*	*	*		*	*
Brown-headed Cowbird	*	*		*	*	
Orchard Oriole	*					
Bullock's Oriole	*	*	*	*	*	(*)
House Finch			*			*
American Goldfinch	*	*	*	*	*	*

* detected at one or more point counts within 50 meters
(*) detected at one point count outside 50 meters

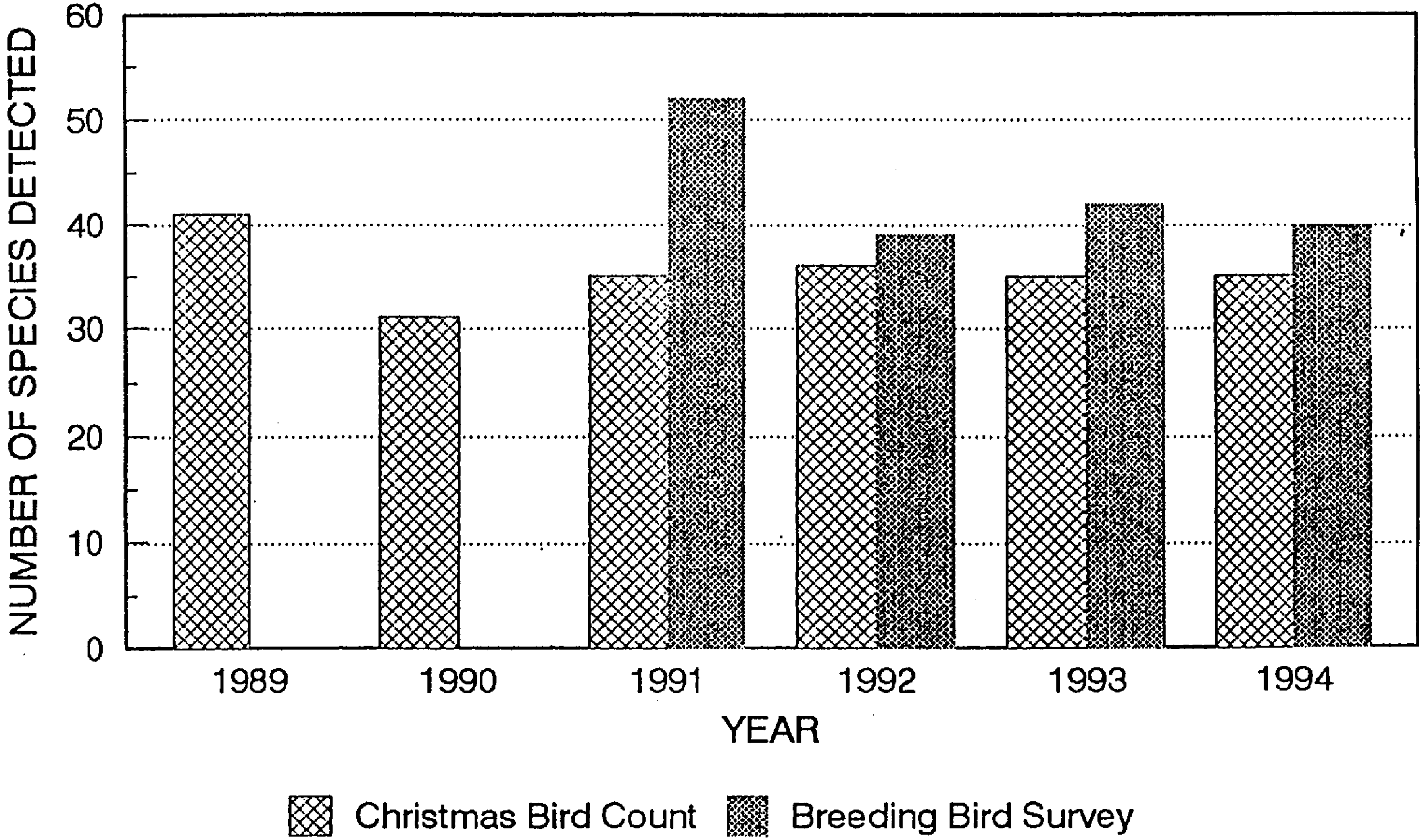

Fig. 1-32. Total number of bird species detected on Christmas bird counts and breeding bird surveys conducted at Rocky Mountain Arsenal National Wildlife Refuge, 1989-94.

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TITLE: Bald Eagle Investigations

INTRODUCTION

In 1986 a wintering bald eagle communal roost, classified as essential habitat under the Northern States Bald Eagle Recovery plan (U.S. Fish and Wildlife Service 1983), was discovered on the east side of the Arsenal (Environmental Sciences and engineering, Inc. 1988). As a result the Service initiated an intensive three year study to ascertain the impacts of Arsenal cleanup, construction of the new Denver International Airport, and highway development in the northeast metropolitan area on the wintering eagle population. This study was completed in 1990 and a final report summarizing results and stating recommendation for management and continued monitoring was finalized in July 1992 (U.S. Fish and Wildlife Service 1992a). The Service has continued to monitor the wintering bald eagle population since the completion of the study to keep advised of changes in activity, contaminant levels, and population levels with dynamic changes in available habitat associated with increased human development and activity. This report summarizes Service monitoring activities conducted during the winter of 1993-1994.

METHODS

Population trends

Population trends on the Refuge were evaluated by recording the number of bald eagles observed along a raptor road survey conducted from August 1993 through April 1994 (see methods Raptor Population Trends and Habitat Use section).

Habitat use and telemetry

Four eagles were radio-tagged and tracked during half-day periods. Exact locations were recorded only when the bird perched. Program Calhome (Kie et al. 1994) was used to calculate use areas using a 100 percent minimum convex polygon method (Mohr 1947). Overlay maps showing primary roads, rivers, and other key landmarks were also produced using this program.

Habitat use by bald eagles was classified by two methods. First, use was evaluated on the Refuge by comparing distributional peaks of bald eagles along the road survey route with existing vegetation maps (Morrison-Knudsen Environmental Services, Inc. 1992). Second, eagle habitat use was evaluated both on and off the Refuge by recording one of six habitat types (riparian-lake, riparian-stream, riparian-lake-stream, riparian-wetland, upland-tree, and grassland) for perched radio-tagged eagles. Duration of time spent perched in each habitat type and the presence or absence of prairie dogs was also recorded. Only perched locations were recorded, as perching reflects definite use of the habitat. Flying over a habitat does not necessarily imply use. Consequently, perched locations probably provide a better indication of habitat use than perched and flying locations combined.

Roost counts trends

Evening counts of bald eagles using the Refuge communal roost were initiated on 15 October 1993 and discontinued on 26 March 1994 after no eagles were recorded during three consecutive surveys. Counts were conducted every other night through the survey period following methods described by the U.S. Fish and Wildlife Service (1992a).

RESULTS AND DISCUSSION

Population trends

The mean number of eagles observed along the road survey during 1993-94 was slightly less than mean numbers observed during the last four winters (U.S. Fish and Wildlife Service 1991, 1992, 1993, 1994) (Table 1-38).

Habitat use and telemetry

Mean bald eagle use area size calculated using the 100 percent minimum convex polygon method was 128.8 km^2 (SD = 78.95, 62.1-239.3 km^2, n = 4). Bald eagle No. 930 was primarily observed on the southern part of the Refuge around Lower Derby Lake, Lake Ladora, and the Havana Ponds, and occasionally along the South Platte River near 112th Av. (Fig. 1-33). Bald eagle No. 850 also used the southern part of the Refuge but the majority of observations were recorded along the South Platte River between 128th Av. and 160th Av. (Table 1-39) (Fig. 1-34). Eagle No. 880 was infrequently observed on the Refuge, as it was almost exclusively observed along the South Platte River between 128th Av. and an area just north of 160th Av. (Table 1-39) (Fig. 1-35). Eagle No. 550 had the largest use area extending from the southern lakes area of the Refuge northeast to Barr Lake State Park and west to an area near 128th Av. and Federal Blvd. (Table 1-39) (Fig. 1-36). The use area observed for all eagles combined was very similar to the area observed for eagle No. 550 except for an extension to the north along the South Platte River (Table 1-39) (Fig. 1-37).

Bald eagles monitored on the Refuge during 1993-94 continued to exhibit distribution and use patterns similar to that observed during the previous four winters based on road survey data collected from 1988 through 1993 and 1992-1993 radio telemetry data (U.S. Fish and Wildlife Service 1992, 1993, 1994) (Fig. 1-38). Bald eagle occurrence along the Refuge road survey during 1993-1994 was greatest along survey legs 8, 14 through 16, and 20 through 23 (Fig. 1-39). Legs 8 and 14 through 16 are chiefly comprised of wetland habitats and associated riparian woodlands along Lakes Ladora, Lower Derby, and First Creek. This reflects the wetland habitats commonly occupied by bald eagles (Stalmaster 1987, Johnsgard 1990). The substantial numbers of eagles observed along leg 21 through 23 is probably due to the availability of prairie dogs in this area, and the high number of ferruginous hawks which eagles kleptoparasitize.

Radio-tagged eagles spent the greatest duration of time in riparian-stream habitats followed by riparian-lake, riparian-lake-stream, and upland trees habitats. (Table 1-40). Prairie dogs were present a minimum of 75 percent of the time perched radio-tagged eagles were monitored for five of the six habitats types (Table 1-40). The riparian-lake habitat was the only habitat where prairie dogs were not present the majority of the time radio-tagged eagles were monitored (Table 1-40).

Both methods of evaluating habitat use indicate the expected importance of riparian habitats to bald eagles, especially areas of mature cottonwood trees. Both methods also revealed the significance of prairie dogs to eagles wintering in the Denver metropolitan area. Prairie dogs are an important component of riparian areas adjacent to the South Platte River. Bald eagles may be selecting areas of highest prey availability by selecting sites along the river which provide prairie dogs, waterfowl, and fish as potential food items. Availability of habitats wasn't measured but observations indicate

Table 1-38. Bald eagles and other raptors observed along the Rocky Mountain Arsenal National Wildlife Area road survey during 31 surveys conducted from August 1993 through April 1994.

Species	Number Observed	Mean	Percent	RANGE
Red-tailed hawk	366	11.8	31.4	(3-43)
Rough-legged hawk	61	2.0	5.2	(0-6)
Ferruginous hawk	331	10.7	28.4	(1-19)
Bald eagle	104	3.5	8.9	(0-20)
Golden eagle	22	0.7	1.8	(0-3)
Swainson's hawk	68	2.2	5.8	(0-15)
American kestrel	24	0.8	2.1	(0-5)
Unknown buteo	30	1.0	2.6	(0-7)
Northern harrier	34	1.1	2.9	(0-5)
Prairie falcon	13	0.4	1.1	(0-3)
Burrowing owl	111	3.6	9.5	(0-28)
Total raptors	1166	37.6		(14-84)

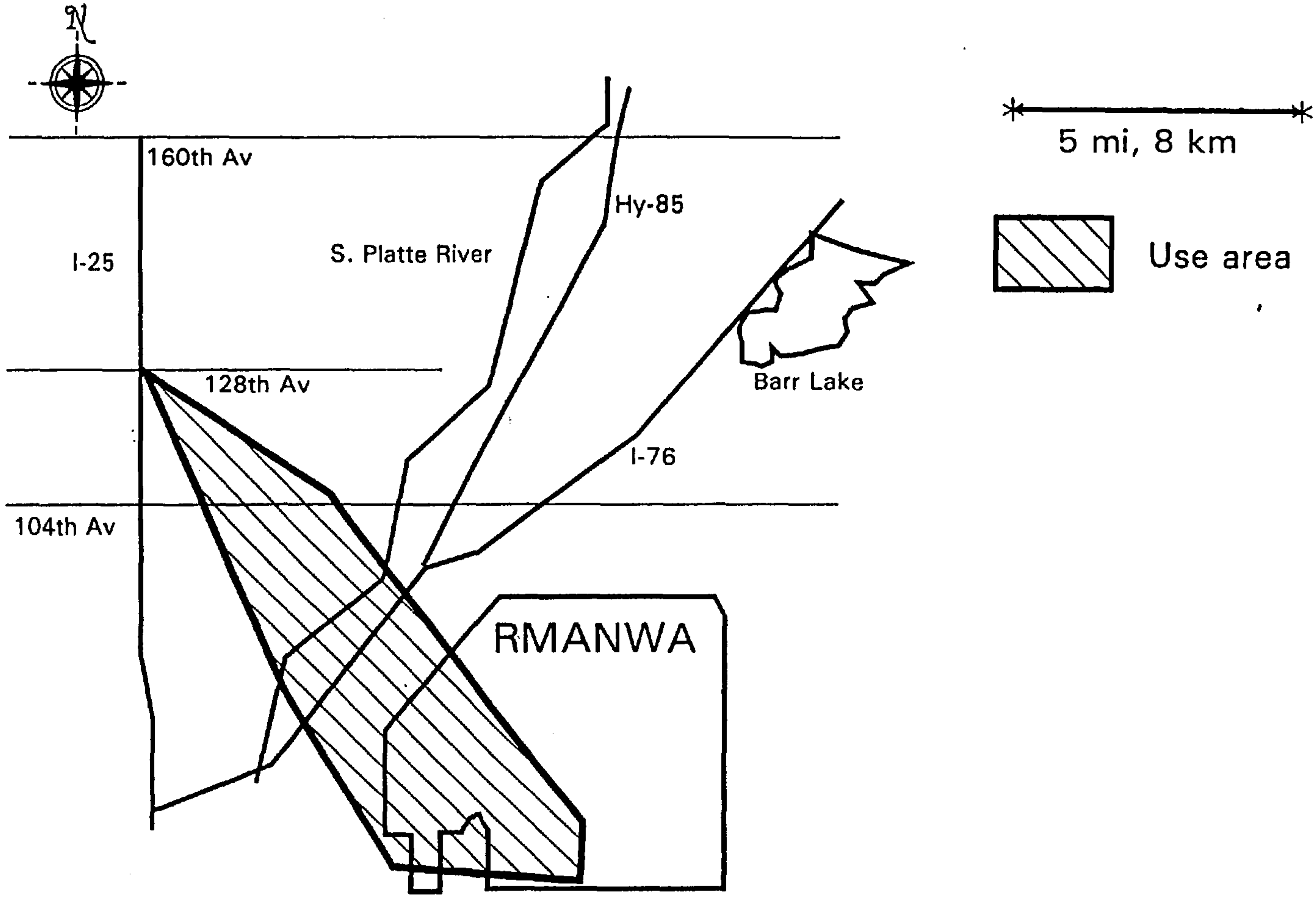

Fig. 1-33. Minimum convex polygon use area for eagle No. 930 captured on the Rocky Mountain Arsenal NWR, 1994.

Table 1-39. Estimates of use area size for four bald eagles captured on the Rocky Mountain Arsenal NWR, 1993 - 1994.

Eagle	Total # Locations	Minimum Convex Polygon (km^2)
Eagle 930	38	62.1
Eagle 850	63	104.1
Eagle 880	63	89.7
Eagle 550	47	239.3
Total	211	351.8

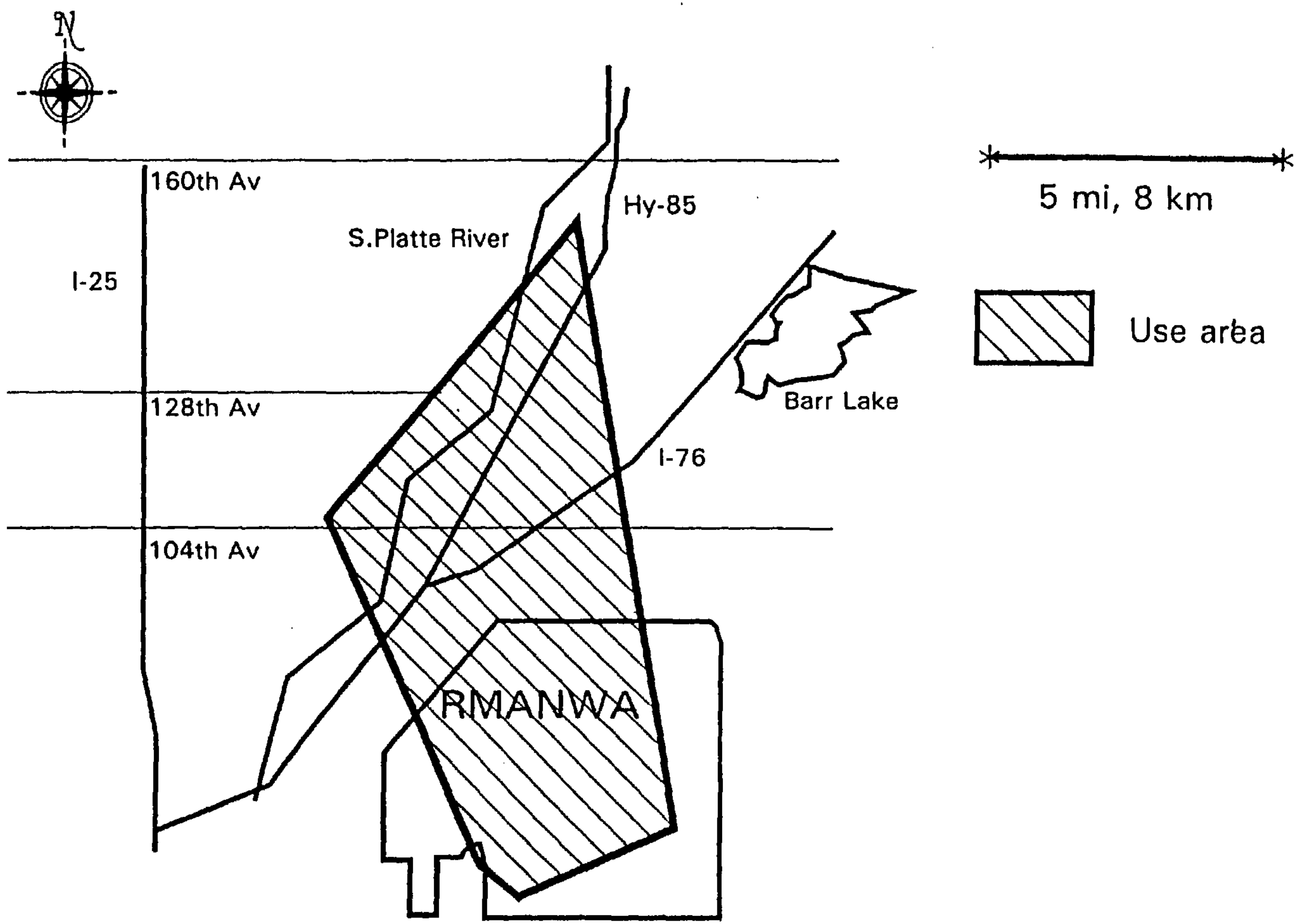

Fig. 1-34. Minimum convex polygon use area for eagle No. 850 captured on the Rocky Mountain Arsenal NWR, 1994.

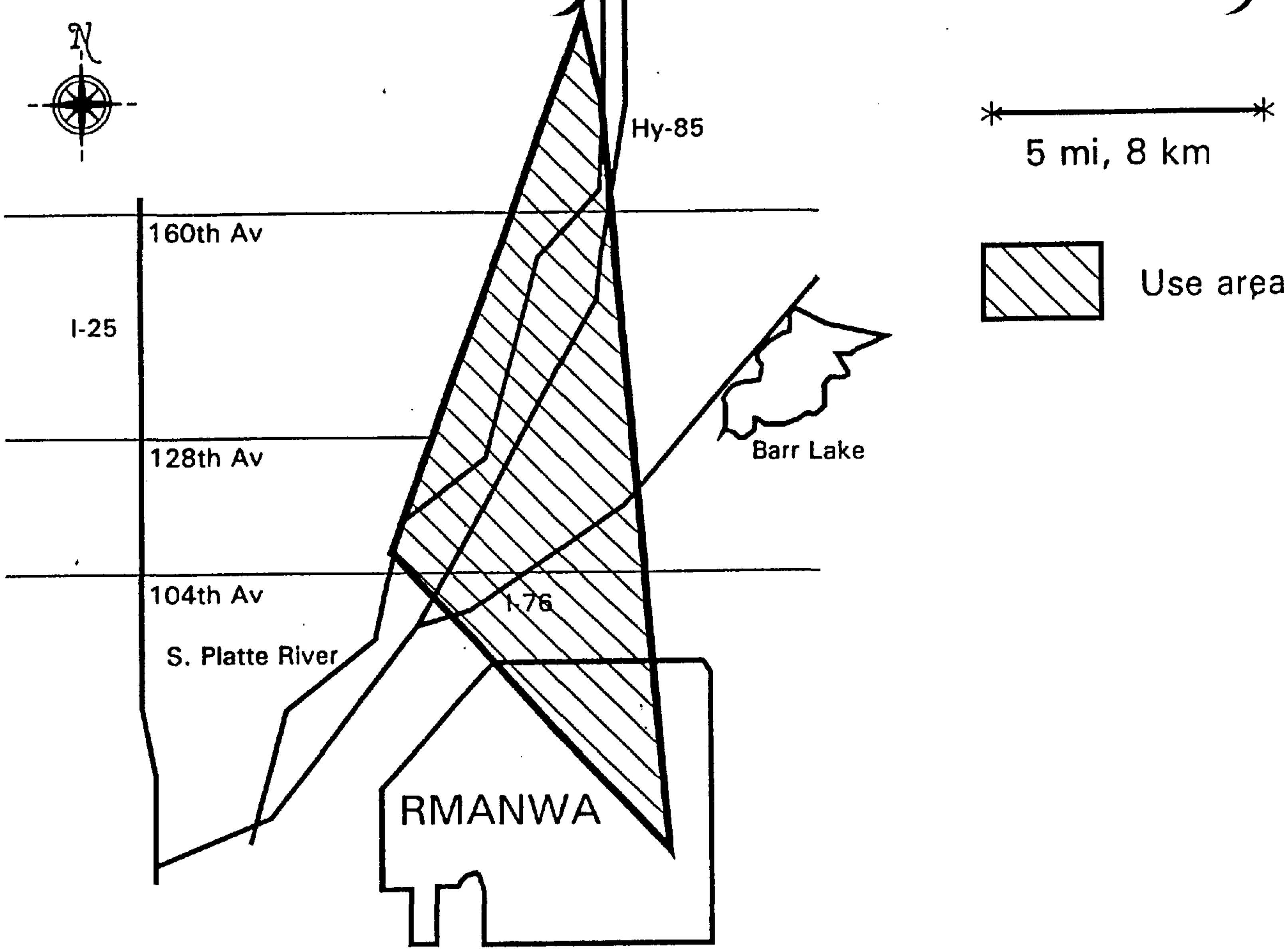

Fig. 1-35. Minimum convex polygon use area for eagle No. 880 captured on the Rocky Mountain Arsenal NWR, 1994.

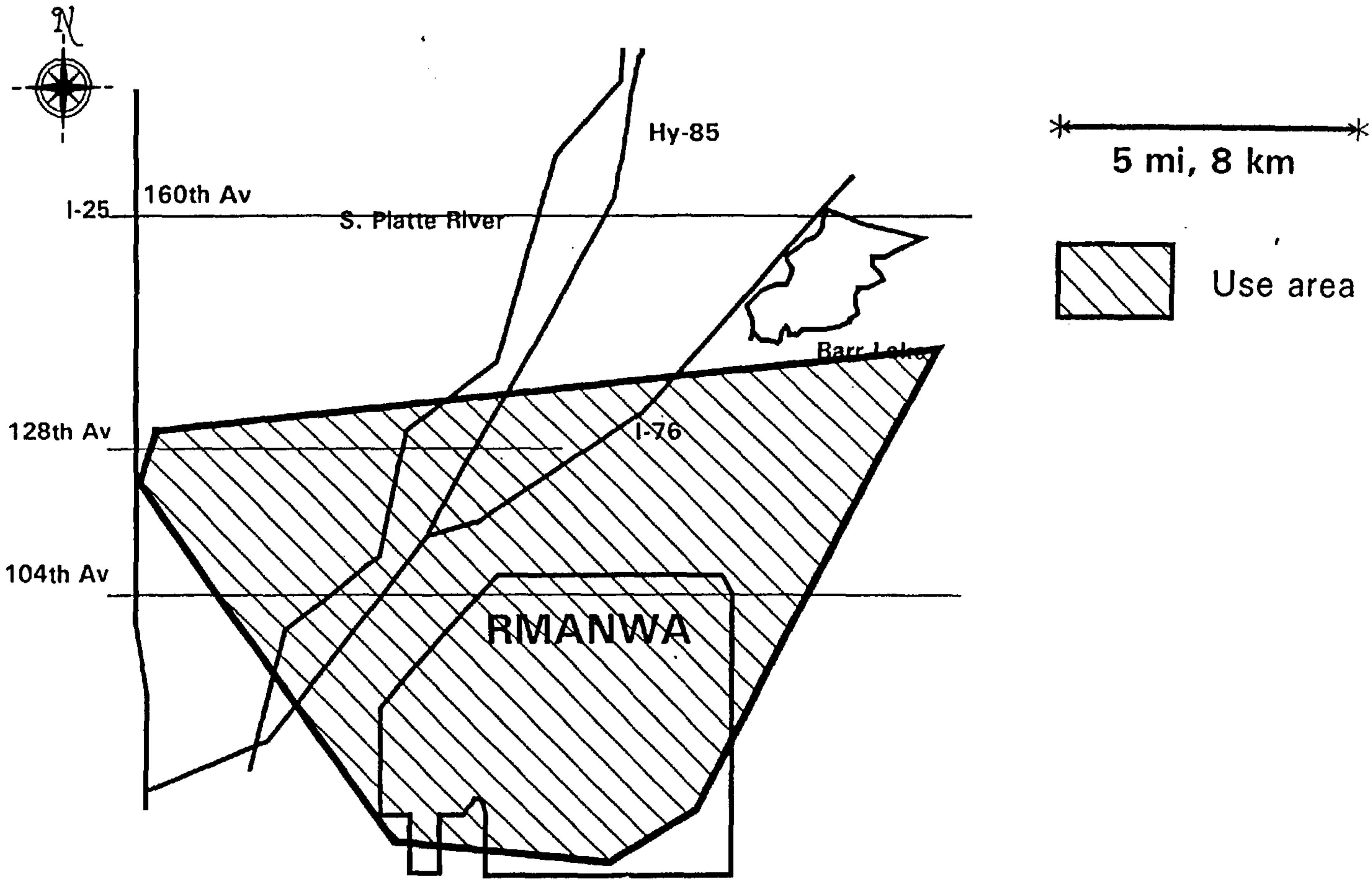

Fig. 1-36. Minimum convex polygon use area for eagle No. 550 captured on the Rocky Mountain Arsenal NWR, 1994.

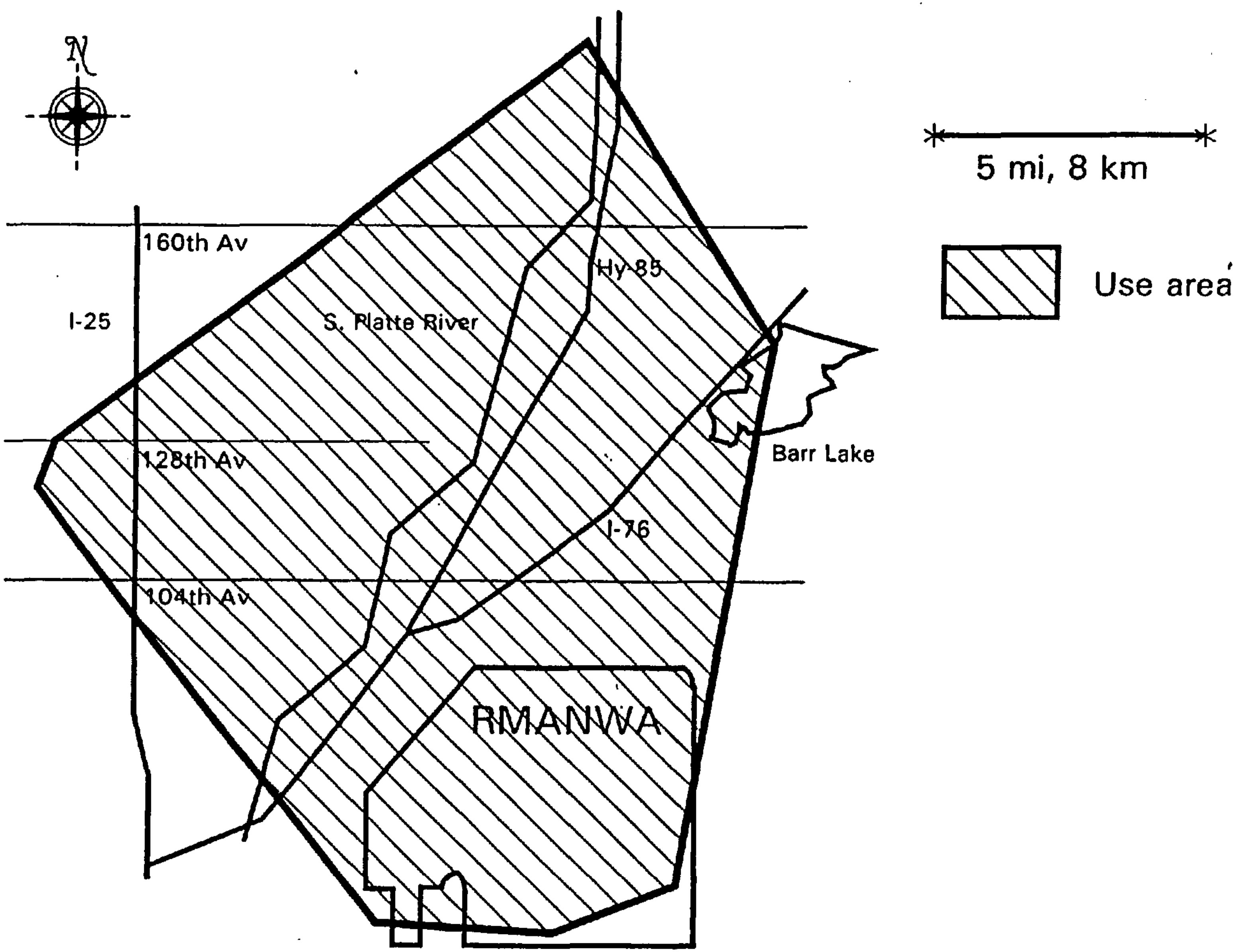

Fig. 1-37. Minimum convex polygon use area for eagles captured on the Rocky Mountain Arsenal NWR, 1994.

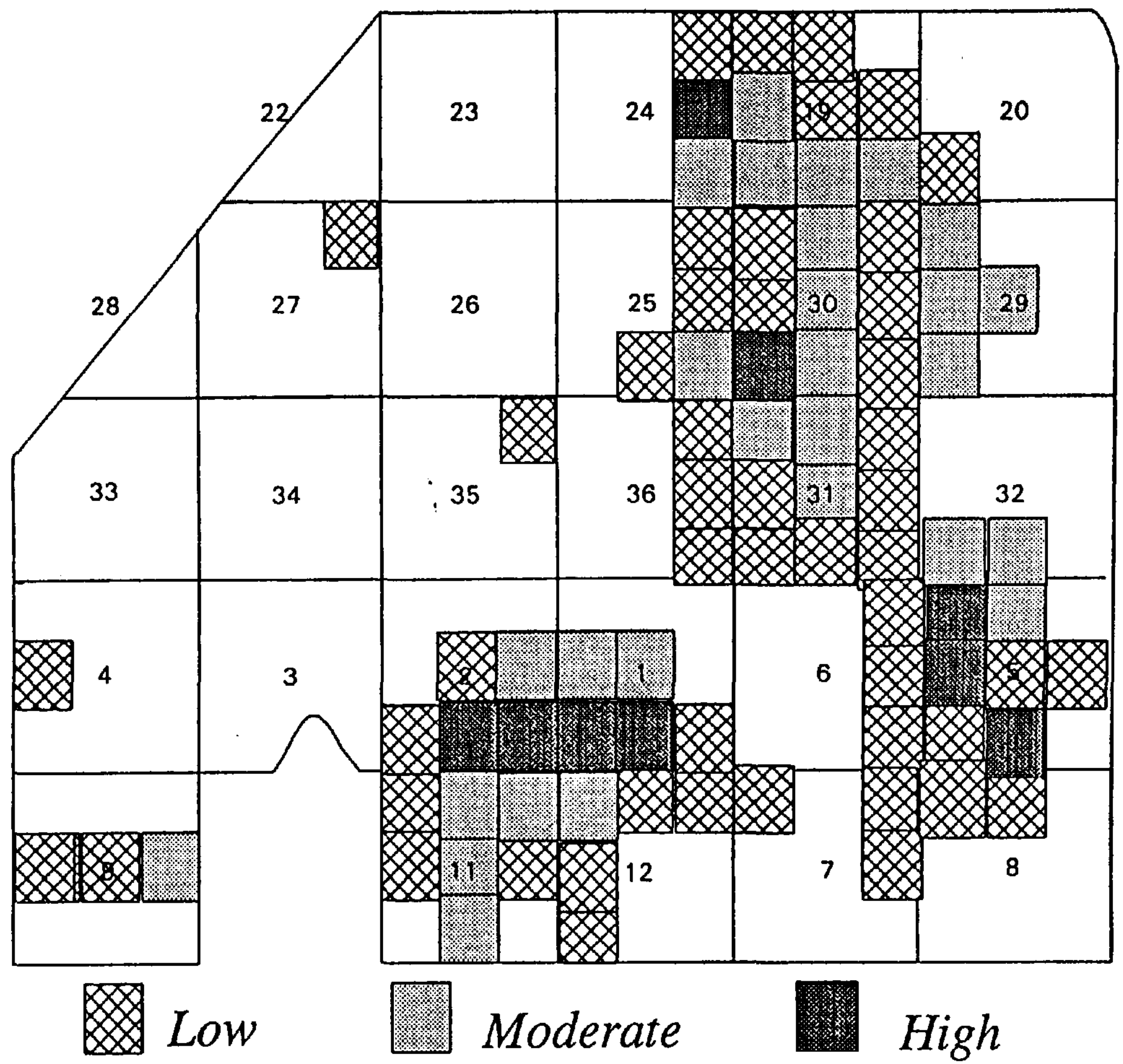

Fig. 1-38. Bald eagle use areas on the Rocky Mountain Arsenal NWR based on road survey data, 1989 - 1993, and radio telemetry data, 1993 - 1994.

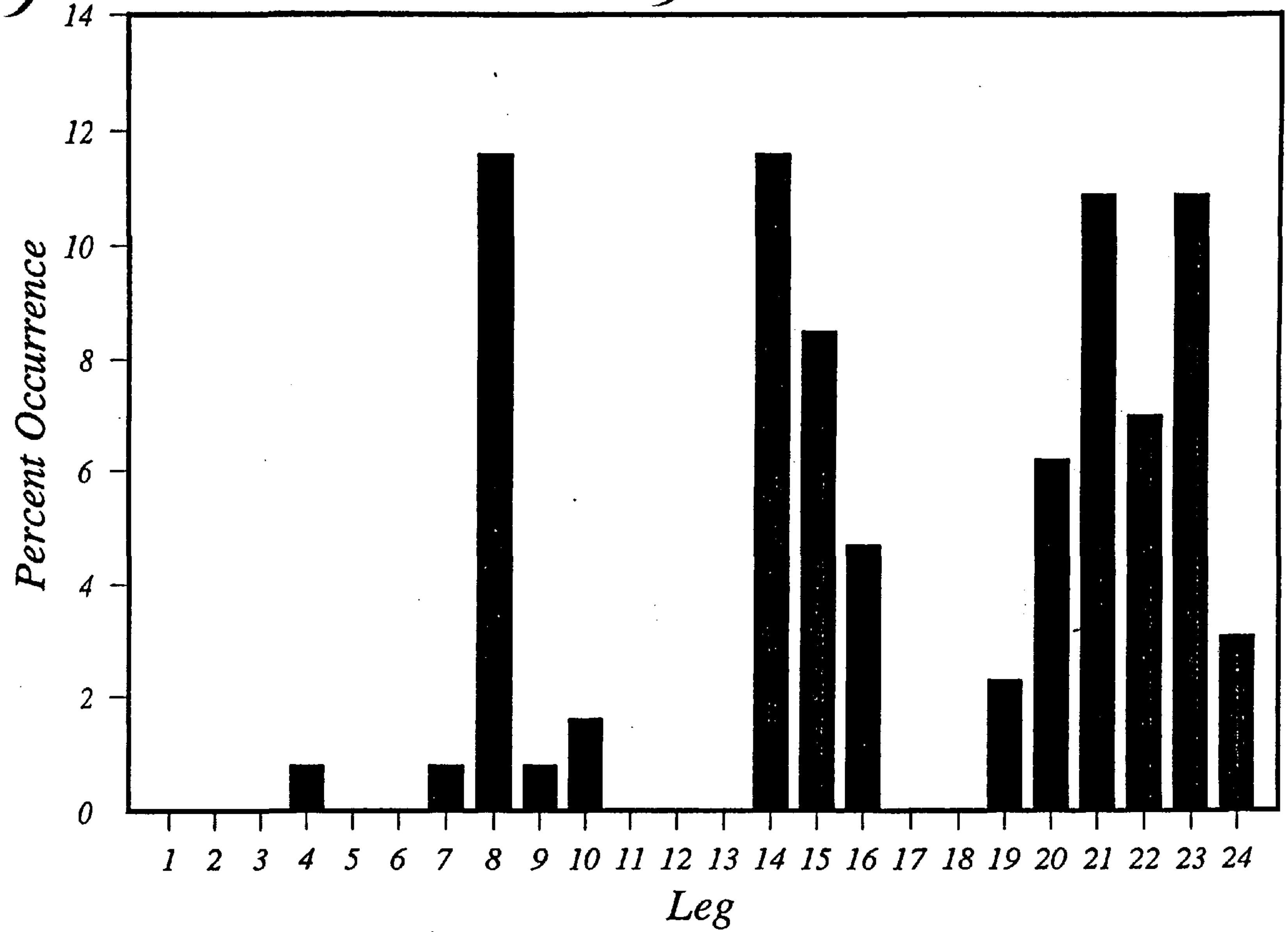

Fig. 1-39. Mean number of bald eagles observed per month on the Rocky Mountain Arsenal NWR road survey, August 1993 - April 1994.

Table 1-40. Habitat use by four radio-tagged bald eagles captured on the Rocky Mountain Arsenal NWR, 1993 - 1994.

Habitat	Time (min)	Mean (min)	Percent of Total	Percent P.dogs Present	Percent P.dogs Absent
Riparian - Lake	2307	576.8	25.8	23.7	76.3
Riparian - Stream	4287	1071.8	48.0	91.7	8.3
Riparian-Lake-Stream	1223	305.8	13.7	81.4	18.6
Riparian - Wetland	346	86.5	3.9	75.4	24.6
Upland - Tree	657	164.3	7.4	100.0	0.0
Grassland	106	26.5	1.2	100.0	0.0
Total	8820			72.8	27.2

that eagles may be selecting areas along the river occupied by prairie dogs greater than expected based on availability.

Roost counts

The peak number of bald eagles observed on the Refuge roost was 31 during 1993-94 with the mean two week high observed during early January (Fig. 1-40). This is down from a high of 38 observed during 1990-1991 (U.S. Fish and Wildlife Service 1992) but is a substantial increase from 20 observed in 1992-93 (U.S. Fish and Wildlife Service 1994). This increase in 1993-94 follows a decrease observed over the previous two winters (U.S. Fish and Wildlife Service 1993, 1994). The dynamic patterns of roost use observed during the last eight years may reflect periods (i.e. winters) of increased eagle disturbance followed by periods of decreased disturbance on the Refuge and surrounding areas due to changing human activity. However, the use patterns observed are most likely a result of natural fluctuations in bald eagle use of the roost due to weather patterns or other natural phenomena. The differences among winters may also be the result of changes in food availability at other Colorado Front Range locations. Eagles will often move to areas which provide easily available food sources (Southern 1963, Ingram 1965, Jonkel 1965, Keister et al. 1987). This behavior has been observed at fish kill sites along the South Platte River drainage basin in Colorado (U. S. Fish and Wildlife Service, unpublished data).

No substantial differences have been observed in the percentage of adult verses subadult bald eagle use of the Refuge roost over last five years (Fig. 1-41). This may reflect stability in population dynamics for the South Platte River Front Range bald eagle population (Stalmaster 1987, U.S. Fish and Wildlife Service 1993). However, long term data and monitoring of additional roost sites within the region would be necessary to accurately estimate regional wintering bald eagle population dynamics.

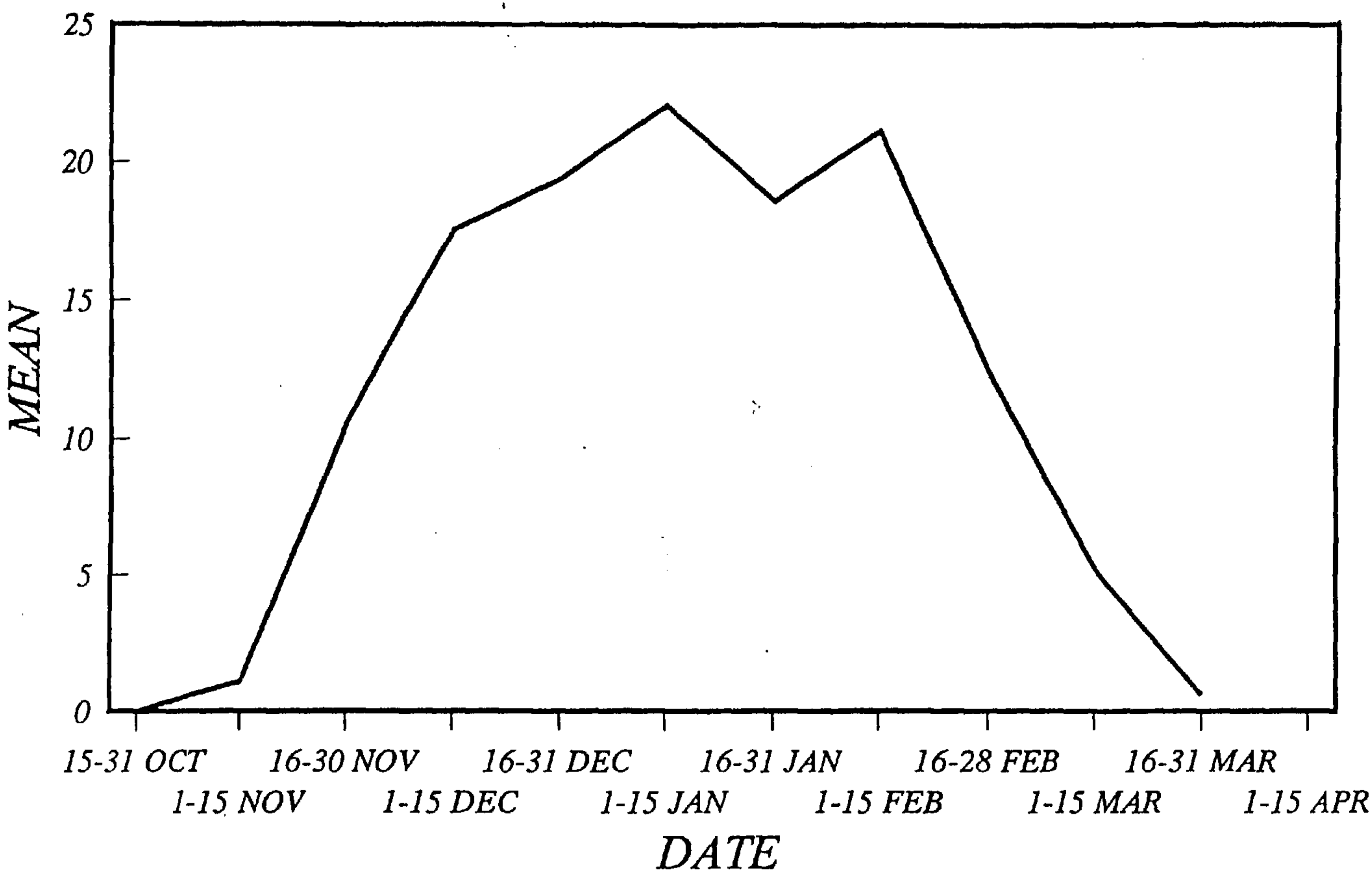

Fig. 1-40. Mean number of bald eagles observed during evening roost counts of the Rocky Mountain Arsenal NWR communal roost from 15 October 1993 through 26 March 1994.

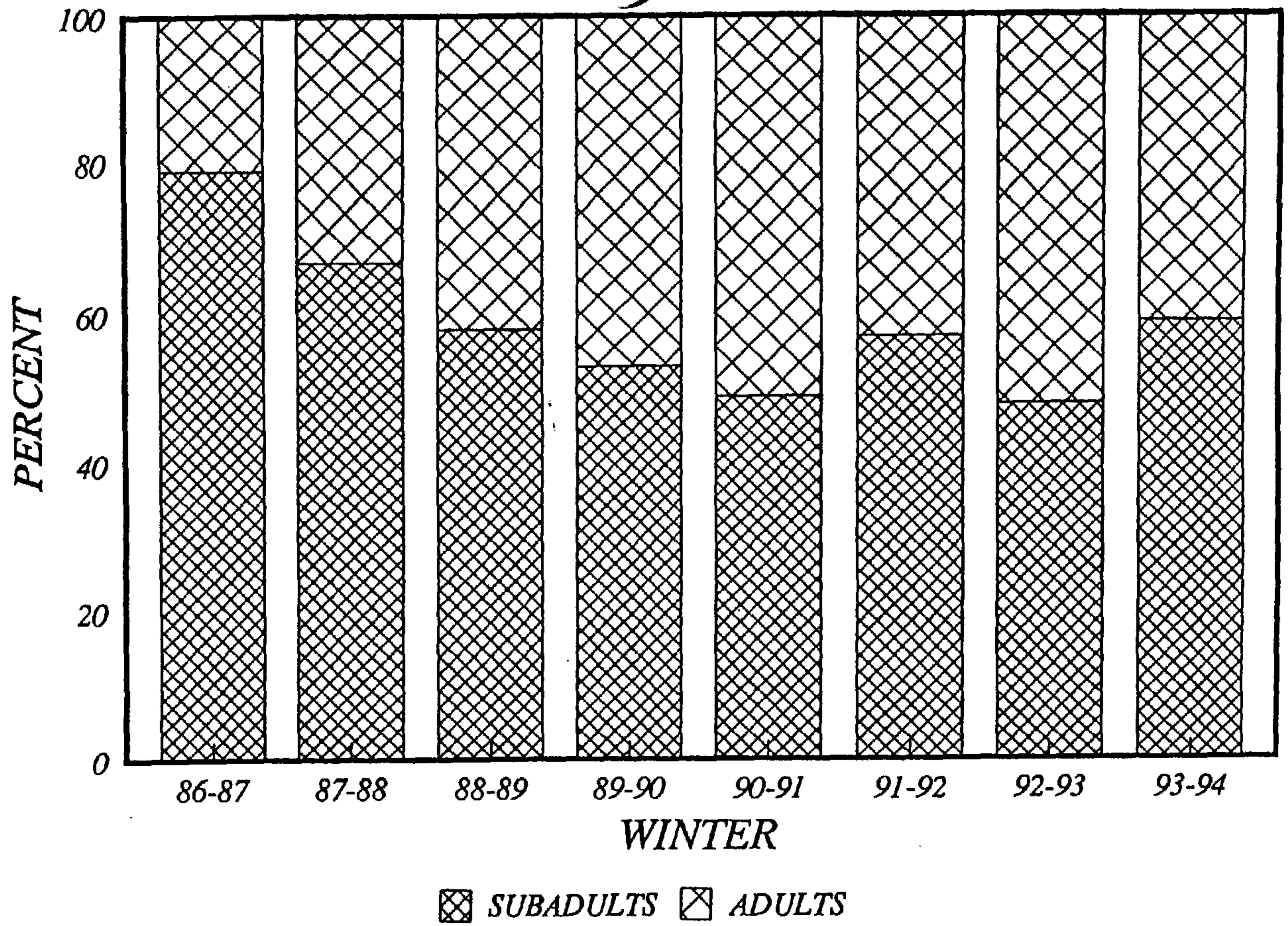

Fig 1-41. Percent adult versus subadult bald eagles observed during evening roost counts conducted during the winters of 1986-1987 through 1993-1994.

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TITLE: Raptor population trends and habitat use

INTRODUCTION

The Refuge supports a large and diverse raptor community (U.S. Fish and Wildlife Service 1993). The Refuge contains a mosaic of habitat types including wetland, riparian, and various types and successional stages of grasslands. Inventorying and monitoring raptor populations and habitat use enables the Service to protect these habitats and maintain population diversity and richness during Refuge cleanup. Baseline and long term data acquired will facilitate Service habitat management and habitat enhancement/mitigation projects for habitats impacted during Refuge cleanup. The surveys also provide information for eliminating or minimizing potential exposure of raptors to contaminated areas. This information will allow the Service to effectively place perch and nest structures over the Refuge to maintain wintering and resident raptor populations.

Roadside surveys were used to monitor bald eagle and other raptor abundance and distribution on the study area, and to provide an index of raptor habitat use. Road censusing is a cost efficient method to survey widely distributed raptors, and has been used extensively to monitor raptor population trends (Johnson and Enderson 1972, Bauer 1982) and habitat/perch use (Marion and Ryder 1975, Fischer et el. 1984).

Inventory and monitoring of nesting raptors was conducted during the spring and summer of 1994. Estimates of raptor reproductive success and productivity enable comparisons between years which can be used to make inferences about population status (Steenhof 1987). Changes in reproductive success/productivity may reflect changes in habitat composition and land use (Murphy 1989), contaminants exposure (Risebough and Monk 1989), human disturbance (Knight and Skagen 1988), or natural phenomena (i.e. weather, prey populations) (Garton et al. 1989, Johnsgard 1990). Information acquired will allow the Service to protect sensitive raptor nesting areas through the placement of "Sensitive Wildlife Area" signs.

METHODS

A road survey of raptors was conducted weekly from August 1993 through April 1994. A 24 mile road survey was driven 2 hours after sunrise on calm days with no precipitation (Fig. 1-42). Surveys were conducted by a single observer from an automobile cruising at 15-20 mph. Only birds observed with an unaided eye were recorded. If birds were not readily identifiable, the vehicle would be stopped and binoculars or a spotting scope would be used to make an identification. Species, age class when possible, activity, perching substrate, leg (mile) of transect, and a specific location were recorded for each raptor observed.

An index of abundance was calculated for each species during the survey period to enable comparisons to previous years data. This index was created by calculating the mean number of birds observed per survey for 31 surveys. An index was also calculated for all raptors combined, and the three most common wintering raptor species for each month. Habitat use by the three most common wintering species and all species combined was classified by comparing distributional peaks of raptors along the survey route with existing vegetation maps (Morrison-Knudsen Environmental Services, Inc., 1992).

Weekly surveys for breeding raptors were initiated in late March 1994. Breeding pairs/occupied territories of red-tailed hawks and Swainson's hawks were located by noting the behavior of adults during the breeding period (March-June), and systematically searching available nesting habitat. Once

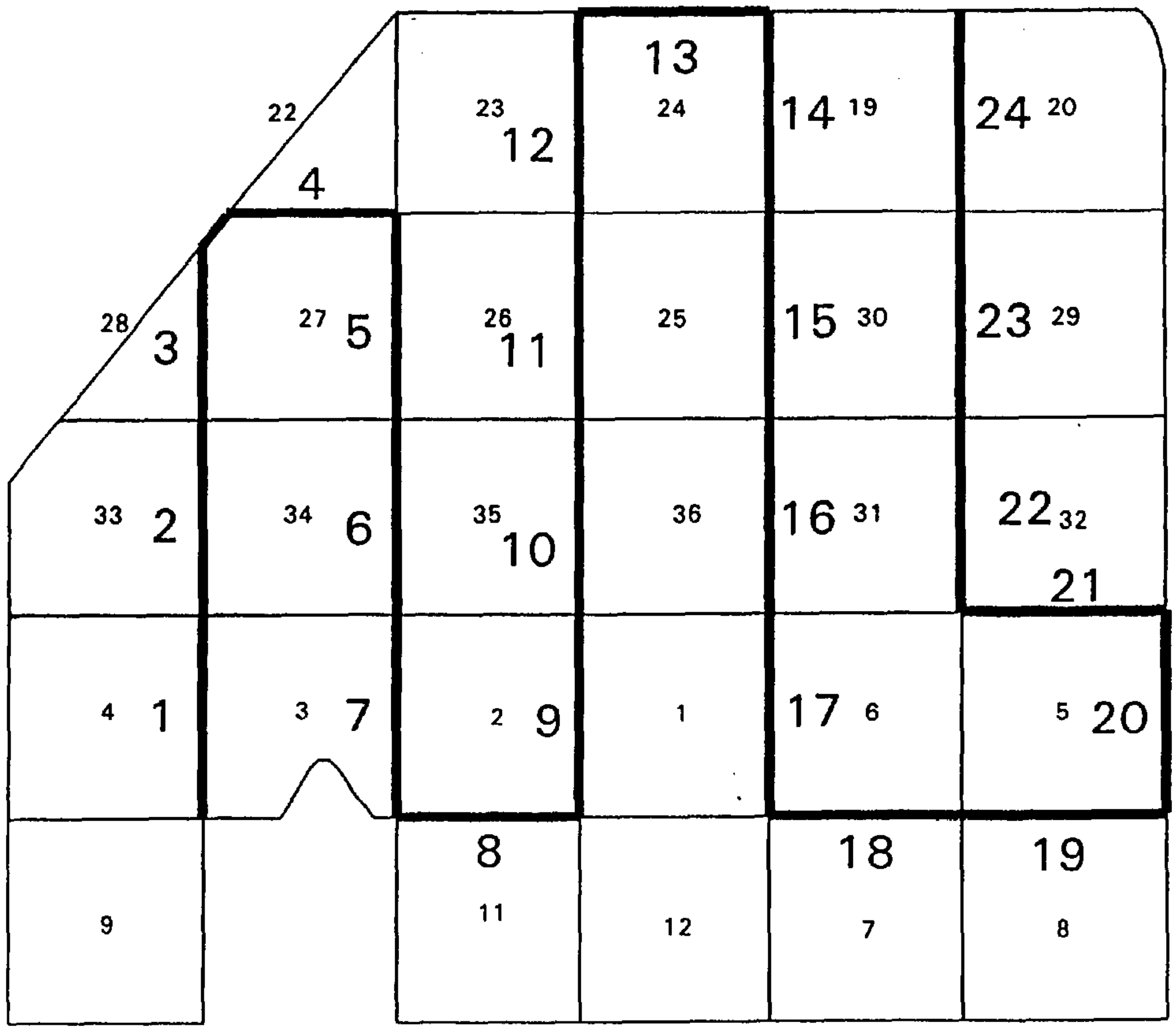

Fig. 1-42. Raptor road survey legs (each leg = 1 mile) used at the Rocky Mountain Arsenal NWR, August 1993 - April 1994.

occupied territories/breeding pairs were located, the areas were monitored weekly until the nest or territory was abandoned or young fledged. Past sampling has indicated that long-eared owls used locust thickets exclusively for nesting on the Refuge (U.S. Fish and Wildlife Service 1993). As a result, only locust thickets were searched during 1994. All locust thickets on the Refuge were searched twice during the nesting season. Surveys for breeding pairs of burrowing were conducted by systematically searching all prairie dog towns on the Refuge.

Terminology and definitions used in nest monitoring data analysis are similar to those proposed by Postupalsky (1974) and Steenhof (1987).

Other projects included:

A study by the Denver Museum of Natural History on ferruginous hawk habitat use, winter home range, food habits, and roosting and foraging habitats was completed (Beane and Preston 1995).

A study of ferruginous hawk winter ecology and migration at the Refuge was continued by the University of Minn. Cooperative Research Unit (Appendix A).

RESULTS

Raptor Population Trends and Habitat Use

Population Dynamics

A mean of 37.6 raptors was observed per survey (Table 1-41). Red-tailed hawks were the most frequently observed raptor followed by ferruginous hawks, burrowing owls, bald eagles and Swainson's hawks.

Red-tailed hawk numbers increased substantially from August through September and dropped from October through January followed by an increase through April (Fig. 1-43). Ferruginous hawk numbers were somewhat stable from August through February with a slight increase in September and decreased from March through April (Fig. 1-43). Relatively stable numbers of rough-legged hawks were observed from February through March (Fig. 1-43). Golden eagles were observed throughout the survey period with a slight increase in numbers observed during December (Fig. 1-44). Swainson's hawks and burrowing owl numbers peaked during August (Fig. 1-45). American kestrel were more common during August-September and March-April with occasional observations during the midwinter months (Fig. 1-45). Mean total raptors observed from August through April ranged from 24.0 to 66.3 (Fig. 1-46). Mean total raptors peaked during August (Fig. 1-46). Red-tailed hawks and ferruginous hawks combined comprised 59.8 percent of the observed raptor population during the survey period (Table 1-41).

Habitat use

Distributional peaks

Red-tailed hawks were most frequently observed along legs 14, 15 and 16 (Fig. 1-47). Habitat along these legs is mostly comprised of wetland habitats with associated riparian vegetation comprised of varying aged stands of cottonwoods along First Creek and Lakes Ladora, Mary, and Lower Derby, and grasslands dominated by crested wheatgrass and cheatgrass/weedy forbs.

Table 1-41. Raptors observed along the Rocky Mountain Arsenal National Wildlife Area road survey during 31 surveys conducted from August 1993 through April 1994.

Species	Number Observed	Mean	Percent	RANGE
Red-tailed hawk	366	11.8	31.4	(3-43)
Rough-legged hawk	61	2.0	5.2	(0-6)
Ferruginous hawk	331	10.7	28.4	(1-19)
Bald eagle	104	3.5	8.9	(0-20)
Golden eagle	22	0.7	1.8	(0-3)
Swainson's hawk	68	2.2	5.8	(0-15)
American kestrel	24	0.8	2.1	(0-5)
Unknown buteo	30	1.0	2.6	(0-7)
Northern harrier	34	1.1	2.9	(0-5)
Prairie falcon	13	0.4	1.1	(0-3)
Burrowing owl	111	3.6	9.5	(0-28)
Total raptors	1166	37.6		(14-84)

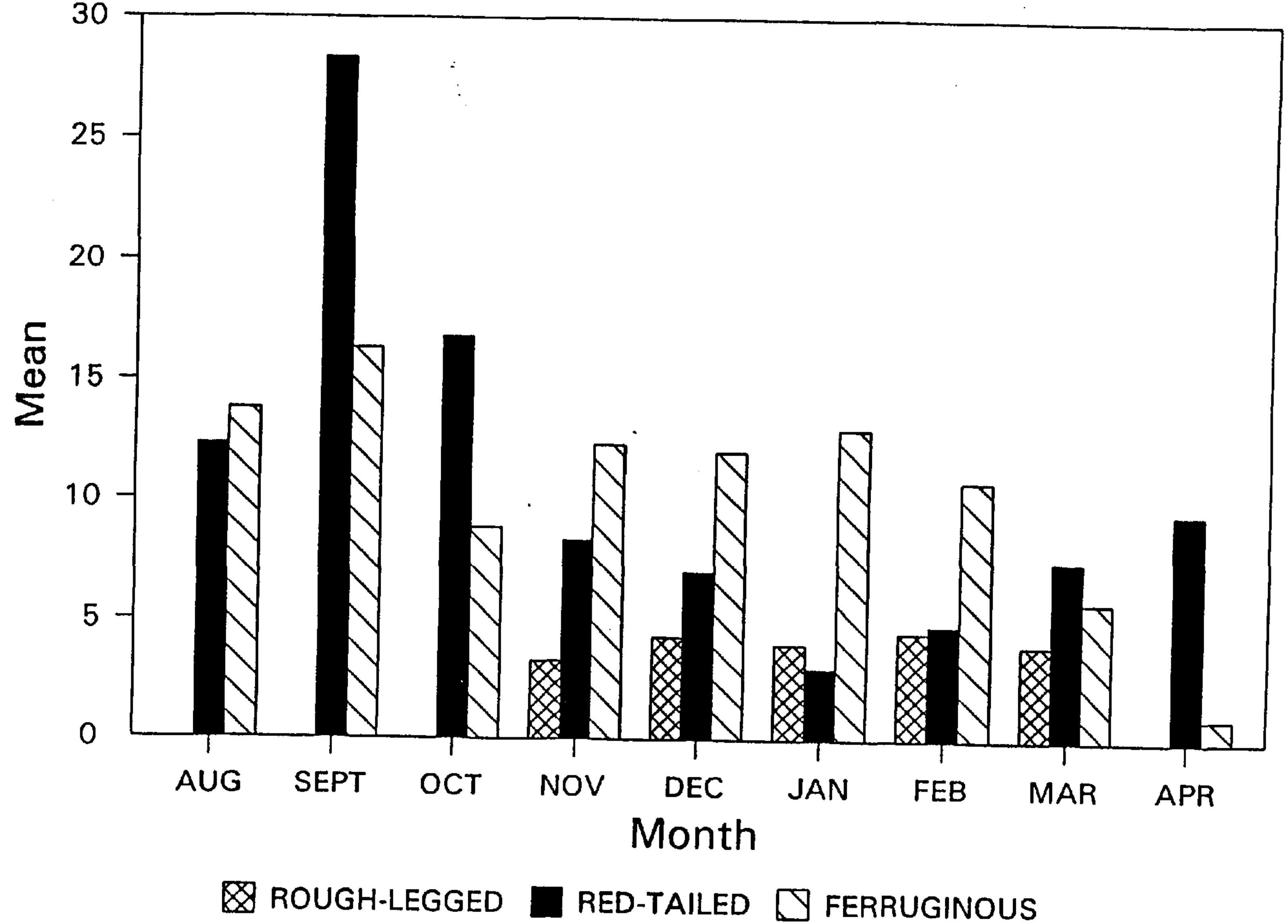

Fig. 1-43. Mean number of red-tailed hawks, ferruginous hawks, and rough-legged hawks observed on the Rocky Mountain Arsenal NWR road survey, August 1993 - May 1994.

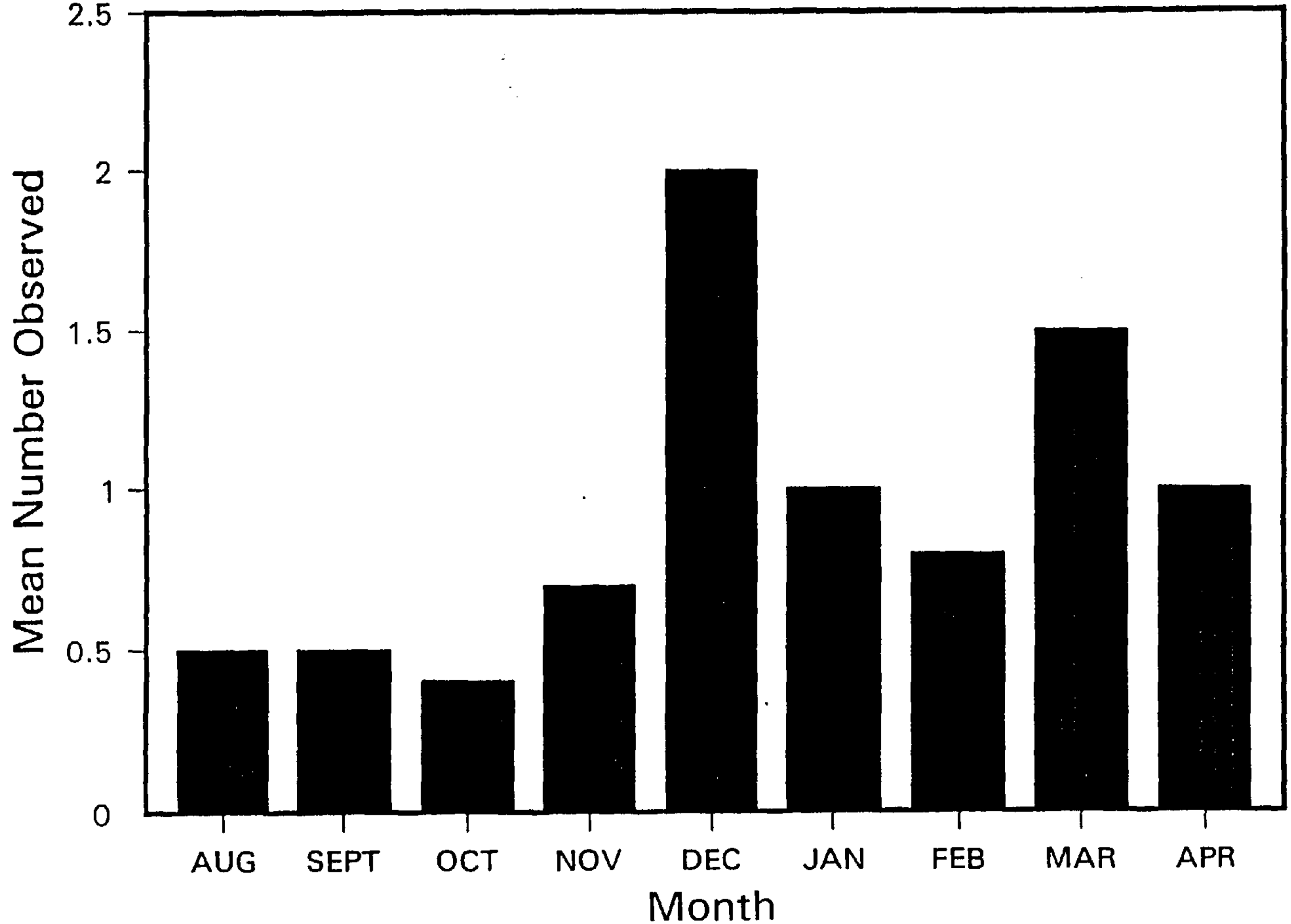

Fig. 1-44. Mean number of golden eagles observed per month on the Rocky Mountain Arsenal Road Survey, August 1993 - April 1994.

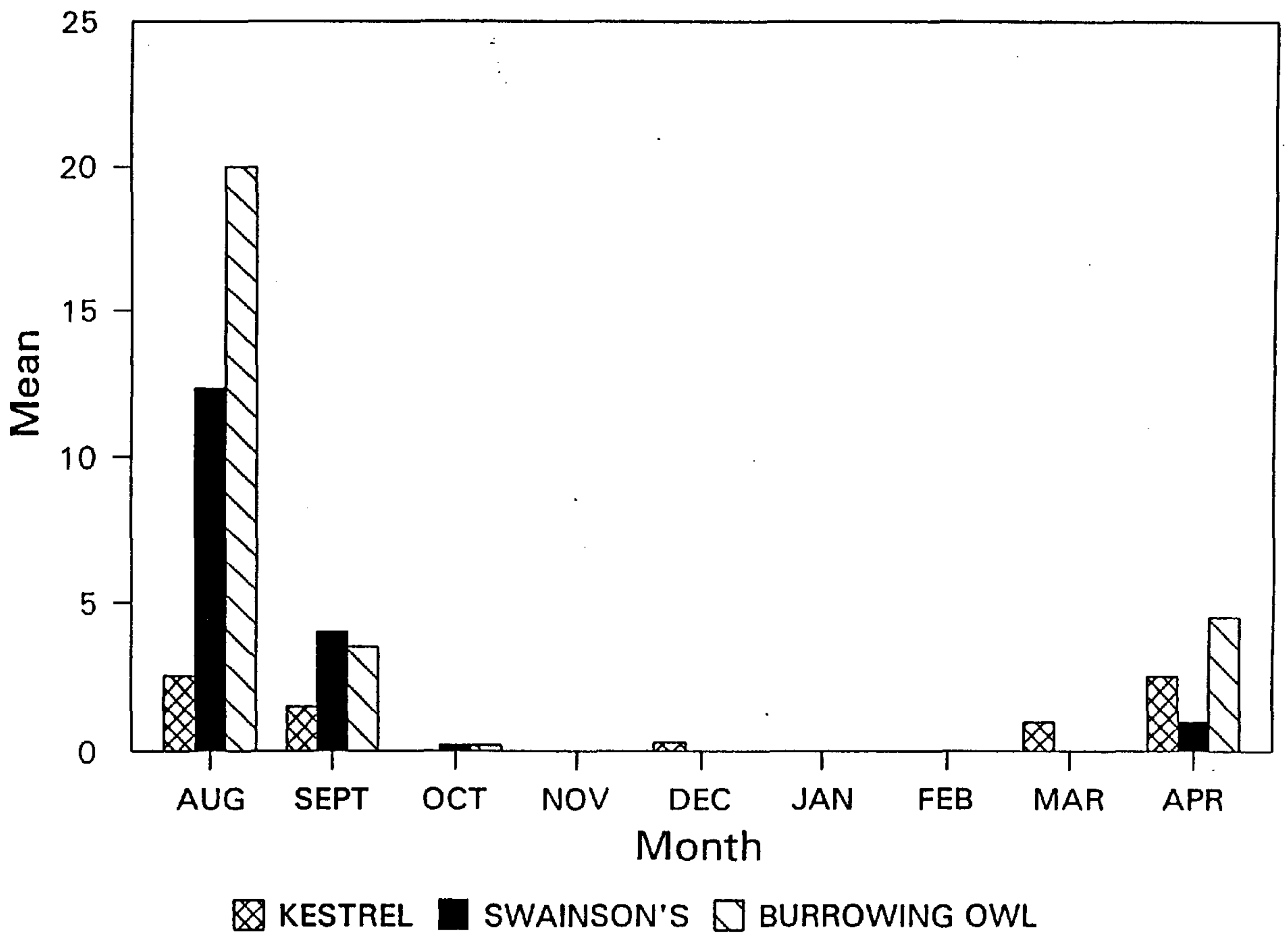

Fig. 1-45. Mean number of Swainson's hawks and American kestrels observed per month on the Rocky Mountain Arsenal road survey, August 1993 - April 1994.

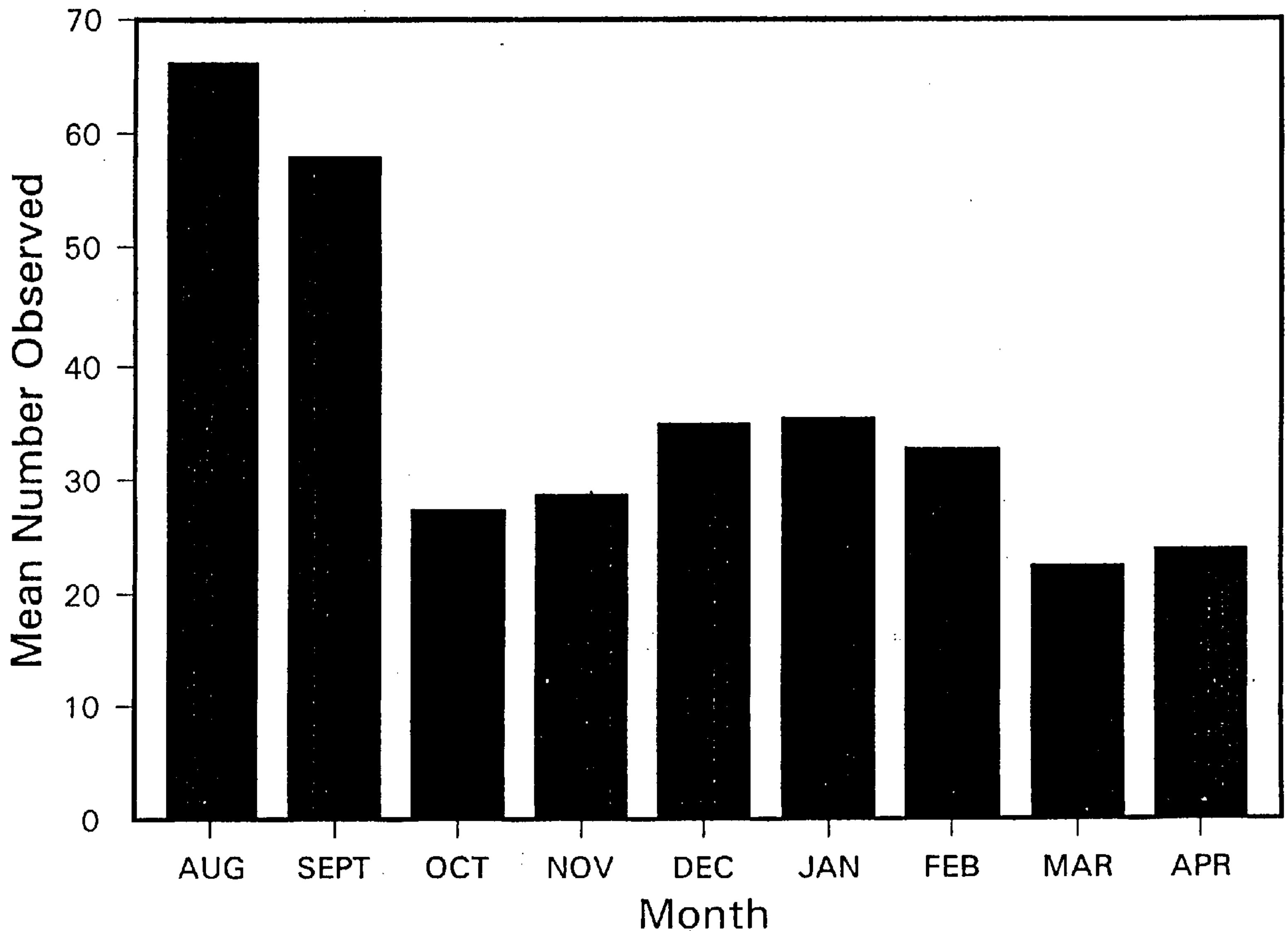

Fig. 1-46. Mean number of all raptors observed per month on the Rocky Mountain Arsenal NWR road survey, August 1993 - April 1994.

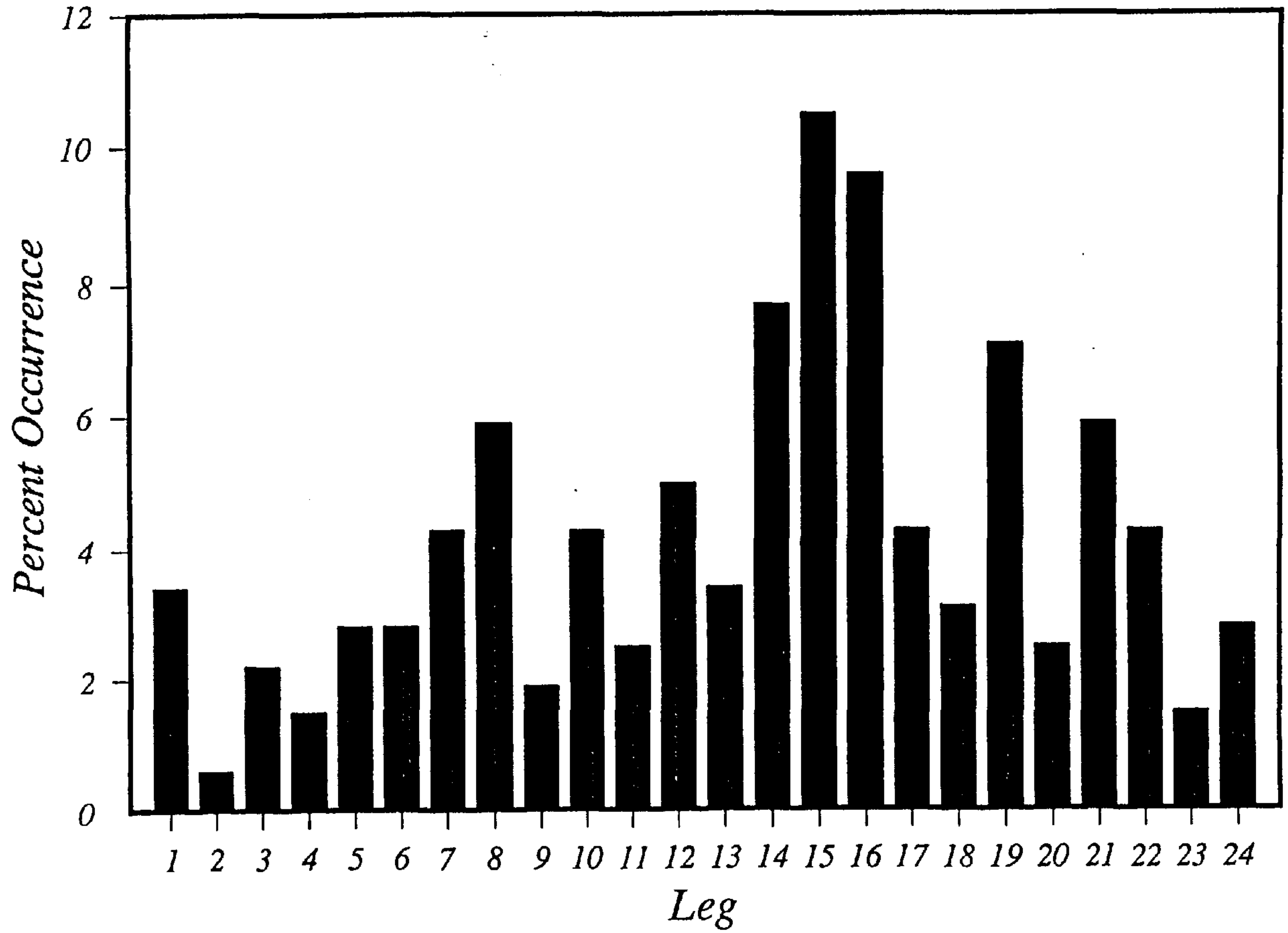

Fig. 1-47. Percent occurrence of red-tailed hawks on the Rocky Mountain Arsenal NWR road survey, August 1993 - April 1994.

The greatest number of ferruginous hawks were observed along legs 21 through 24 (Fig. 1-48). Habitat along these legs is chiefly comprised of grasslands dominated by weedy forbs with lesser amounts of cheatgrass/weedy forbs and native perennial grass. Rough-legged hawks were most commonly observed along legs 15, 17, and 19 (Fig. 1-49). Habitat along these legs is comprised of native perennial grass, cheatgrass/weedy forbs, wetlands, and seeded areas comprised of crested wheatgrass and a wheatgrass alfalfa mixture. Abundance along the road survey for all raptors combined was greatest along legs 14 through 16 and 20 through 24 (Fig. 1-50).

Perch Use

Sixty-nine percent of the red-tailed hawks observed along the road survey were flying and 31 percent were observed perched. Utility poles were the most frequently used perch substrate by red-tailed hawks followed by cottonwood trees (Table 1-42). Rough-legged hawks were observed flying 17 percent of the time and perched 83 percent of the time. Rough-legged hawks used cottonwood trees most often for perching followed by utility poles (Table 1-42). Ferruginous hawks were flying for 36 percent of the observations and perched for 64 percent. Utility poles were the primary perch used by ferruginous hawks (Table 1-42).

DISCUSSION

Raptor population trends and habitat use

Population Dynamics

The mean number of ferruginous hawks observed increased again during 1993-94. Numbers of ferruginous hawks have increased each winter from 1989-90 to 1993-94 (U.S. Fish and Wildlife Service 1992, 1993, 1994). This increase follows a substantial decrease after the 1988-89 winter (U.S. Fish and Wildlife Service 1992). The increase observed over the last four winters has been significantly correlated to an increase in prairie dog distribution and density on the Refuge (U.S. Fish and Wildlife Service, unpublished data). Prairie dog abundance and distribution on the Refuge has been slowly increasing after a considerable decline due to a sylvatic plague epizootic in 1988 and 1989 (Ebasco 1989). Prairie dog numbers have not reached the pre-plague population level, but distribution and abundance has increased notably when compared to post plague levels during 1989 to 1991 (U.S. Fish and Wildlife Service 1992, 1993). Red-tailed hawk numbers have increased in each of the last four winters (U.S. Fish and Wildlife Service 1993, 1994). This increase is also correlated to the observed increase in prairie dog distribution and abundance, however the relationship is not nearly as strong as the relationship observed between ferruginous hawks and prairie dogs (U.S. Fish and Wildlife Service, unpublished data). Rough-legged hawk numbers show no discernible trend during the last four years (U.S. Fish and Wildlife Service 1993, 1994). The absence of a substantial increase in red-tailed hawks and no increase in rough-legged hawks may indicate less specialization in the foraging behavior of these species. Ferruginous hawks may specialize on larger rodent species (e.g. prairie dogs) and lagomorphs (Blair and Schitoskey 1982, Gilmer and Stewart 1983, Johnsgard 1990).

Raptor use of the Refuge peaked during August and September due to a large influx of migrant red-tailed hawks and hatch year Swainson's hawks and burrowing owls recently fledged on the Refuge.

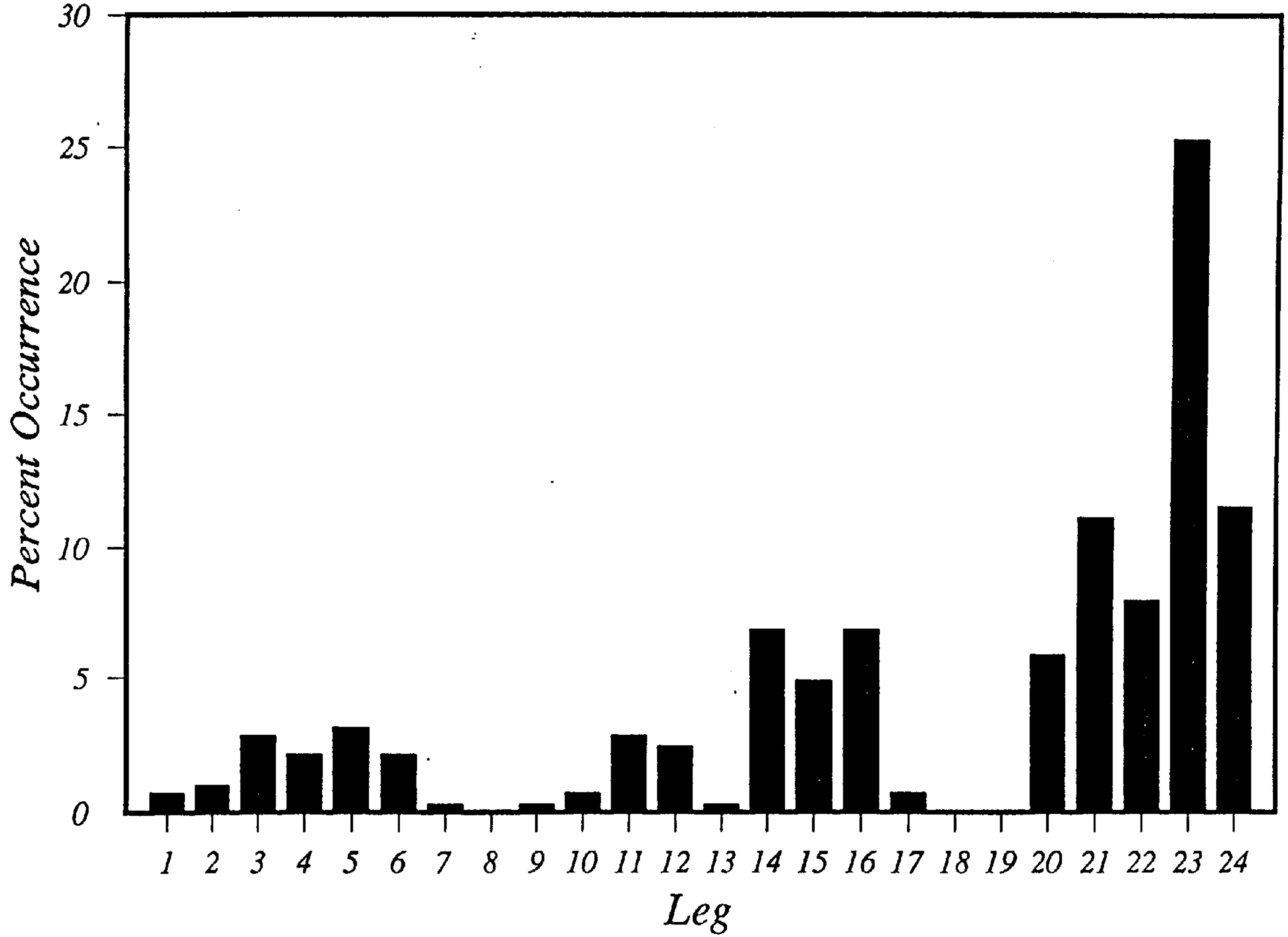

Fig. 1-48. Percent occurrence of ferruginous hawks on the Rocky Mountain Arsenal NWR road survey, August 1993 - April 1994.

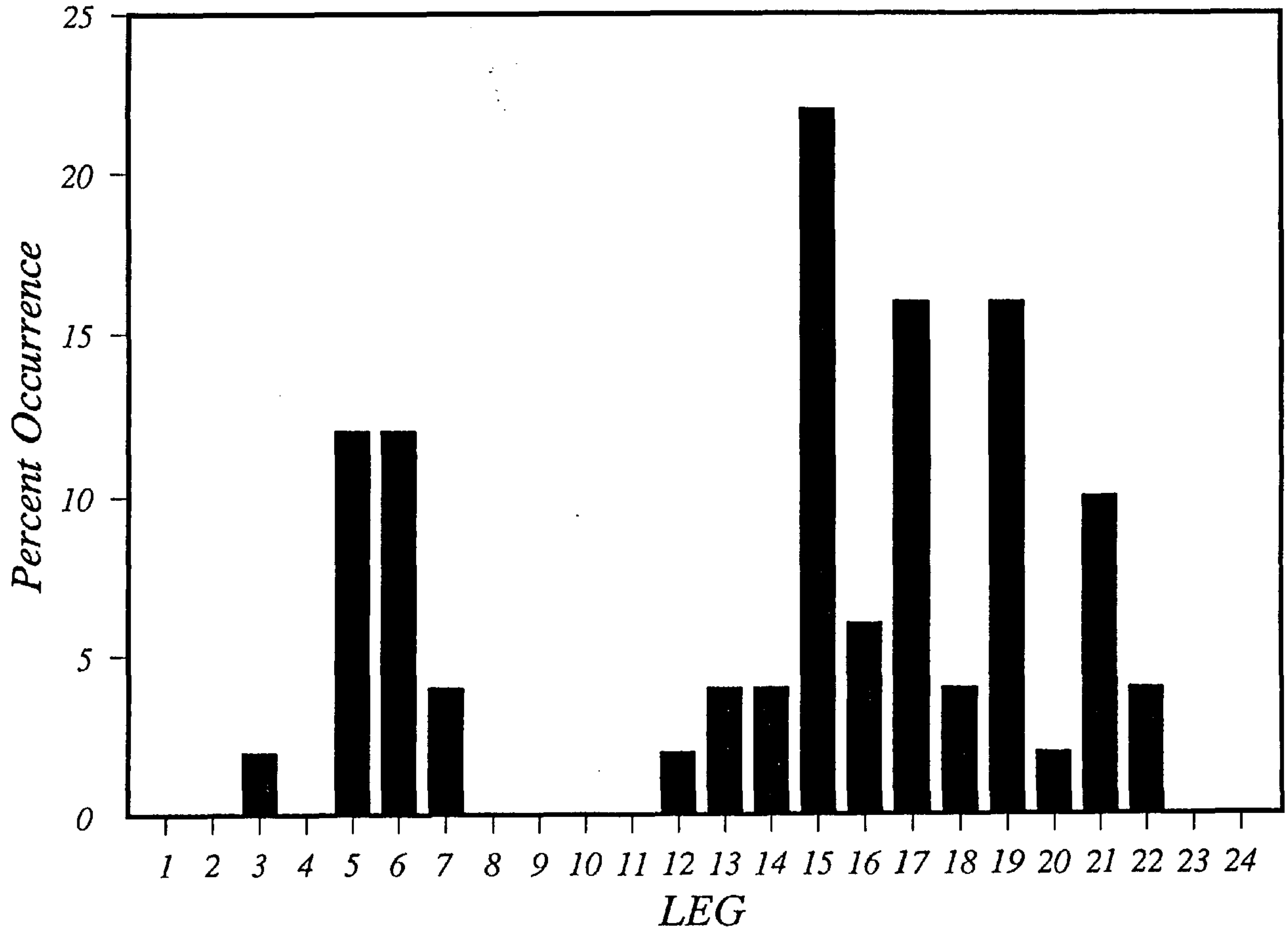

Fig. 1-49. Percent occurrence of rough-legged hawks on the Rocky Mountain Arsenal NWR road survey, August 1993 - April 1994.

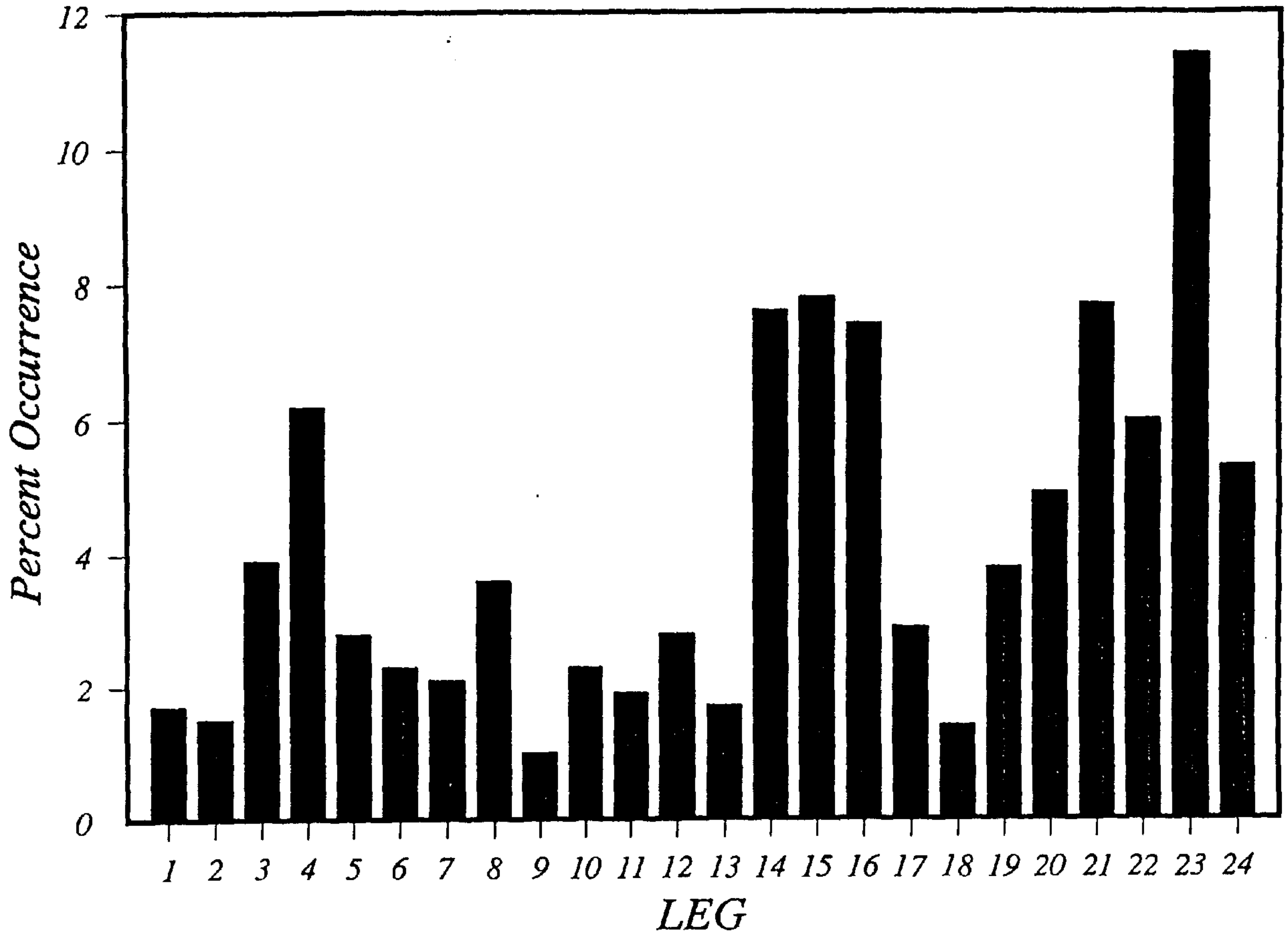

Fig. 1-50. Percent occurrence of all raptors on the Rocky Mountain Arsenal NWR road survey, August 1993 - April 1994.

Table 1-42. Percent perch use by raptors along the Rocky Mountain Arsenal NWR road survey during the winter of 1993-1994.

	Perch Type*							
Species	UP	CW	SE	GD	AS	OP	BL	RO
Red-tailed hawk	55	28	8	5	1	2	6	3
Ferruginous hawk	58	6	4	22	5	4	1	0
Rough-legged hawk	36	60	4	0	0	0	0	0

* UP = Utility Pole; CW = Cottonwood Tree; SE = Siberian Elm Tree; GD. = Ground; AS = Artificial Snag; OP = Other Post; BL = Building; RO = Russian Olive Tree.

<u>Habitat use</u>

As stated in the FY93 Annual Report significant differences existed between overall habitat usage and availability for the three most common wintering raptors (U.S. Fish and Wildlife Service 1994). As indicated by distribution along the road survey, habitat use during 1993-94 does not appear to be notably different than use observed during the past four winters (U.S. Fish and Wildlife service 1992, 1993, 1994). Red-tailed hawks and rough-legged hawks continue to occur along survey legs and in habitats comprised largely of wetlands habitat types. This may indicate selection of these habitats due to prey availability, or may be related to the availability of suitable perches. Perch availability per habitat type has not been measured. Greater numbers of ferruginous hawks continued to be observed in weedy forbs habitat types and along survey legs dominated by weedy forbs. This supports the conclusions of the FY93 Annual Report that distribution patterns observed for ferruginous hawks may be attributed to the availability of prairie dogs in this habitat type (U.S. Fish and Wildlife Service 1994).

RESULTS AND DISCUSSION

Raptor nest monitoring

Two breeding pairs of red-tailed hawks were monitored in 1994 (Fig. 1-48). Both pairs were using nests that were also used by red-tailed hawks in 1993. This is an increase from one breeding pair observed in 1992 (U.S. Fish and Wildlife Service 1993), but a decrease from three observed in 1993 (U.S. Fish and Wildlife Service 1994). Two young were observed in nest number 1 and three young were observed in nest number 2. All young fledged from both nests. One of the young from nest number 2 fledged prematurely and was cared for at the Birds of Prey Rehabilitation center for five days. This bird was returned to the nest tree and fledged with the remaining two young. A mean of 2.5 young fledged per breeding pair and a mean of 2.5 young fledged per successful nest. This is an increase in red-tailed hawk productivity when compared to 1993 (U.S. Fish and Wildlife Service 1994). These data also compare favorably with that of Millsap (1981) in Arizona, Peterson (1979) in Wisconsin, and Smith and Murphy (1973) in Utah. The adult female at nest number 2 had a green two rivet style VID legband on the left leg with an alpha/numeric code of 1 over 2 and a Service band on the right leg. The VID legband information indicated that it was most likely a bird banded on the Refuge in the southeastern portion of Section 11 on 2 February 1994 (D. Plumpton, pers. commun.).

Three breeding pairs of long-eared owls were observed in 1994 (Fig. 1-51). Nests numbers 1 and 2 were abandoned during the early incubation period. Three young successfully branched from nest number three. This results in 1.0 young branched per breeding pair and 3.0 young branched per successful nest (Table 1-43).

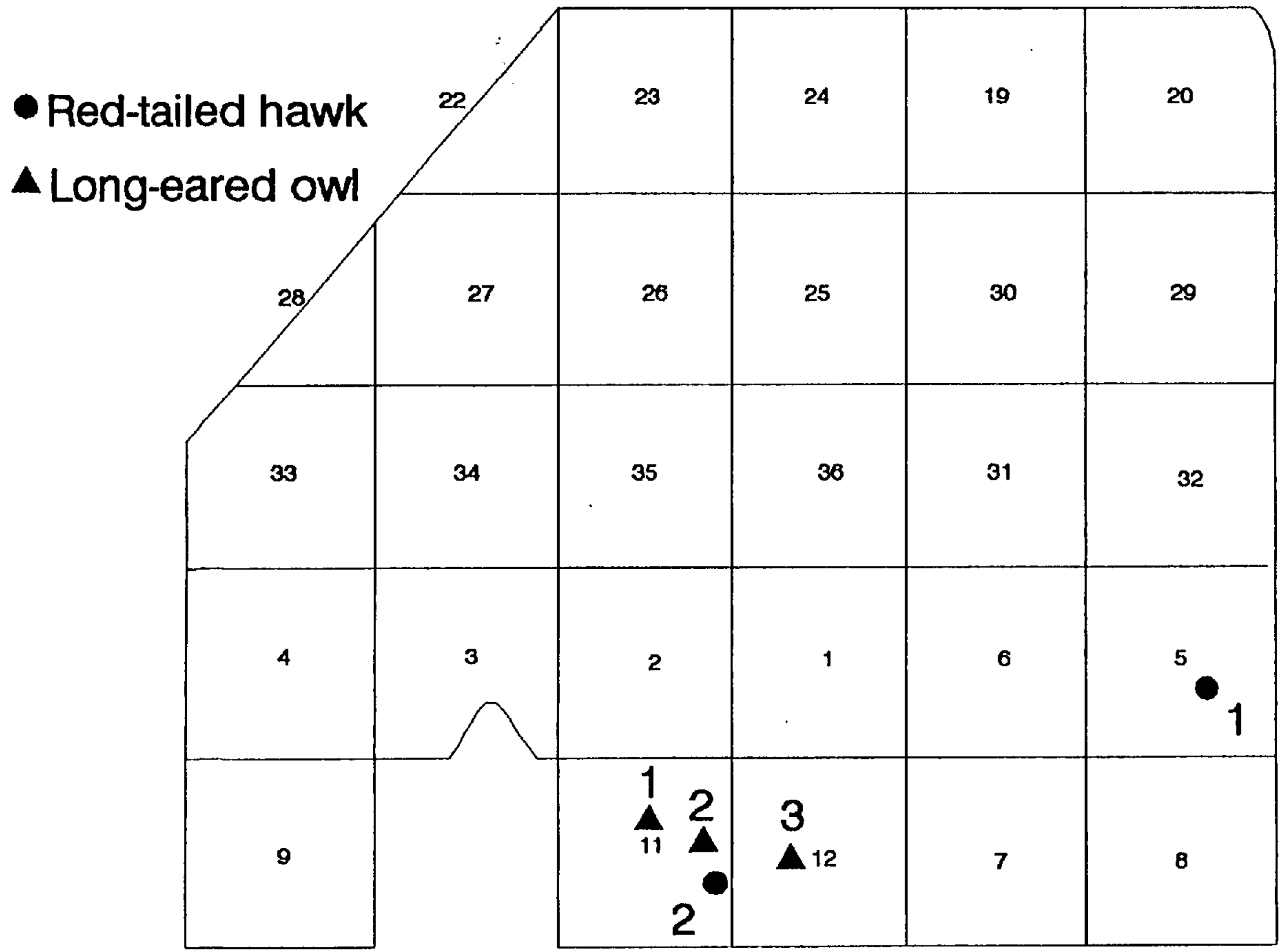

Fig. 1-51. Breeding pairs of red-tailed hawks and long-eared owls monitored on the Rocky Mountain Arsenal NWR, 1994.

Table 1-43. Burrowing owl reproductive success and productivity on the Rocky Mountain Arsenal NWR, 1990 - 1994.

	1990	1991	1992	1993	1994
Nesting attempts	23	33	34	41	
Number of successful Pairs (%)	20 (86)	33 (100)	25 (74)	36 (88)	
Minimum number young fledged	109	163	93	162	
Mean fledged per attempt	4.74	4.94	2.74	4.00	

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TITLE: Swainson's Hawk Nesting Ecology on the Refuge

INTRODUCTION

The Swainson's hawk is a prairie buteo that nests across western North America as far north as Alaska, and winters primarily in the Pampas region of Argentina (Johnsgard 1991). The Swainson's hawk is the second most common diurnal raptor breeding on the Refuge. Only the American Kestrel is more common (U.S. Fish and Wildlife Service 1993). The Swainson's hawk is a good candidate for study because: 1) there are suitable numbers of Swainson's hawks nesting on the Refuge (U.S. Fish and Wildlife Service 1993), 2) Swainson's hawks are moderately tolerant to disturbance (Bednarz 1989), 3) there is literature available regrading the effects of habitat alterations on this species (Bechard 1980, Bechard 1982, Woodbridge 1987), and 4) Swainson's hawks are a breeding top trophic level predator, as a result they are an appropriate species for monitoring long term trends in contaminant levels. These factors make the Swainson's hawk an opportune candidate to ascertain and monitor the potential effects of Refuge cleanup activities and habitat restoration projects. During the spring of 1994 the Service continued field investigations initiated in 1993 to describe the home range and habitat use of Swainson's hawks nesting on the Rocky Mountain Arsenal NWR. In addition, the diet of hawks during the nesting period is being evaluated through pellet analysis, and Swainson's hawk reproductive success and productivity continues to be monitored. Blood samples were collected from both adult and nestling Swainson's hawks for contaminant analysis. The Service also continued to band both nestlings and adults to ascertain nest site fidelity and philopatry. Changes in any of these parameters may indicate changes in habitat quality (Bechard 1980, Murphy 1989, Risebough and Monk 1989).

METHODS

Capture and handling

Attempts were made to capture the male and female of all breeding pairs. However, males were the focus of the majority of trapping effort, as they are primarily responsible for providing food for the young during the nesting period (Dunkle 1977, Fitzner 1978). Two methods were used to capture Swainson's hawks. A Dho-Gaza (Clark 1971) with a live bald eagle placed near the nest site was used. This technique was only used after young were observed in the nest to minimize the potential for nest abandonment by the adults. A variation of the Lockhart method (Bloom 1987) using weakened padded leghold traps baited with a mouse was also used. This technique was used throughout the nesting period by placing leghold traps beneath hawks perched along roads on the Refuge.

Two types of transmitters were used during 1994. A 15 gram transmitter was attached to the inner two rectrices of three hawks with waxed dental floss and Devcon 5 minute epoxy. Two gram transmitters were attached to a central rectrice of six hawks with waxed dental floss and Devcon 5 minute epoxy. All captured birds were winged-notched, banded with blue individual identifiable leg bands, and banded with U.S. Fish and Wildlife Service aluminum leg bands (Young and Kochert 1987). This aided in the identification of individual birds and will aid in the understanding of nest site fidelity.

Attempts were made to acquire blood samples from all captured adults. Blood was collected from the bracellis vein on the ventral side of the wing. After swabbing with alcohol, a 3 cc syringe with a 25 gauge needle was used to acquire blood samples. A small amount (1 cc) of sodium heparin was used to coat the needle and syringe before collecting blood.

Nests were visited once during the nesting period to band young. During this visit attempts were made to acquire blood samples from all nestlings using the same technique as described earlier for adults. This visit was made when the young were 1/2 to 3/4 of fledgling age to prevent premature fledgling (Grier and Fyfe 1987).

Telemetry and habitat use

Half-day, focal-animal observations (Altimann 1974) were obtained on habitat use for four radio-tagged male Swainson's hawks. Radio-tagged males were kept in sight with the aid of radio telemetry. The exact location, habitat type and activity (flying or perched) were recorded at 15 minute intervals. Habitats were divided into 10 general types (Table 1-44). Locations were recorded on aerial photographs and habitat types were determined using a modified version of an existing vegetation map (Morrison-Knudsen Environmental Services, Inc. 1992).

Program Calhome (Kie et al. 1994) was used to calculate home ranges using a 100 percent minimum convex polygon method (Mohr 1947). Amounts of each habitat type within home ranges of each transmittered bird were estimated using a Lietz Planix 8 electronic planimeter. Independence of data locations was assumed during habitat use analysis. Habitat use and availability tests were calculated for individual birds using methods of Neu et al. (1974) and Byers et al. (1984).

Nest Monitoring

Breeding pairs of Swainson's hawks on the Refuge were located by observing the behavior of adults during the breeding period and conducting systematic vehicle and foot searches of available habitat. All breeding pairs were monitored at least once a week until the young were fledged or the nest was abandoned. Observations of adult Swainson's hawks with blue colored leg bands were noted to ascertain nest site fidelity. Estimates of reproductive success and productivity were calculated using terminology adapted from Postupalsky (1974) and Steenhof (1987).

Food Habits

The diet of Swainson's hawks during the nesting period are being evaluated through pellet analysis. Pellet analysis follows procedures described by Marti (1987). Pellets were collected from beneath active nests weekly. Pellets are currently being dissected individually by hand. Feathers and hair are teased away from bony material using forceps, a dissecting needle, and a dissecting microscope. Identifiable bone remains are compared to reference collections housed at the Denver Museum of Natural History and skull keys (Glass 1973). Hair and feather remains are mounted on slides with a mounting medium and identified using techniques of Moore et al. (1974). The frequency of occurrence in pellets will be calculated by dividing the number of prey in each category by the total number in the sample.

Contaminants

Blood samples were collected as described earlier. The amount of blood collected from each hawk varied. However, a minimum sample of 3 cc's whole blood was necessary to acquire a 1 cc serum sample needed for analysis.

Table 1-44. Habitat types used for habitat use and availability estimates for male Swainson's hawks on the Rocky Mountain Arsenal NWR during 1994.

Category
Weedy Forbs--Disturbed areas dominated by weedy forbs with little or no component of cheatgrass or perennial grasses
Cheatgrass/Weedy Forbs--Disturbed areas with weedy forbs and a significant component of cheatgrass.
Crested Wheatgrass--Areas dominated by or seeded to crested wheatgrass.
Shrub/Succulents--Areas containing scattered rabbit brush, yucca, or pricklypear cactus with an understory usually comprised of cheatgrass/weedy forbs.
Wetlands--Areas dominated by water or wetland vegetation ranging from perennial grasses and forbs to cottonwood trees.
Locust Thickets--Areas dominated by dense stands of locusts.
Native Perennial Grasslands--Areas dominated by a mixture of cheatgrass and various native perennial grass species.
Cheatgrass--Areas dominated by cheatgrass without a significant component of weedy forbs.
Agricultural--Areas dominated by corn or wheat.
Buildings/roads--Areas comprised of paved roads and buildings.

Whole blood samples were centrifuged for 15 minutes at 2000 rpm's using a Jouan C-412 centrifuge. Serum was pipetted into 3 cc vacutainers and samples were placed in a -20° F freezer. All samples were stored on ice or in a refrigerator until centrifuged. Samples were then placed in a -20° F freezer. Samples were placed in the freezer within 3 hours of collection. Generally, blood samples will be evaluated for organochlorine contaminants of concern. However, depending on nest location individual samples may be analyzed for metal contaminants of concern. The methodology to analyze the small volume (1 cc) serum samples is currently being developed following U.S. EPA (1980).

RESULTS AND DISCUSSION

Capture and handling

Ten Swainson's hawks were captured and banded with blue individual identifiable leg bands, and U.S. Fish and Wildlife Service aluminum leg bands during 1994. Seven birds were captured using the modified Lockhart method and three with a dho-gaza. Twenty-one nestlings were banded with blue individual identifiable leg bands, and U.S. Fish and Wildlife Service aluminum leg bands during 1994. A minimum of one nestling blood sample was obtained from 11 of the 12 successful nests on the Refuge. A total of 17 blood samples were obtained from nestling Swainson's hawks.

Nest monitoring

Fourteen breeding pairs of Swainson's hawks were monitored on the Refuge in 1994 (Table 1-45) (Fig. 1-52). Nests numbers 1, 3, 4, 7, 12, and 13 were also used by Swainson's hawks in 1993 (Fig. 1-52). (U.S. Fish and Wildlife Service 1994).

The number of breeding pairs increased from nine in 1992 (U.S. Fish and Wildlife Service 1993) to eleven in 1993 (U.S. Fish and Wildlife Service 1994), to fourteen in 1994 (Table 1-46). The mean number fledged per breeding pair remained the same as the mean number observed in 1993 and higher than the mean number observed in 1992 (U.S. Fish and Wildlife Service 1993). The mean number fledged per successful nest decreased slightly when compared to 1993 (U.S. Fish and Wildlife Service 1994) (Table 1-46). These data compare favorably with that of Olendorff (1973) in northeastern Colorado, Dunkle (1977) in Wyoming, Fitzner (1978) in Washington, and Schmutz (1985) in Alberta. The slight increase in the number of breeding pairs over the last three years when surveys were conducted in a consistent fashion may indicate that no dramatic changes in habitat quality have occurred. However, raptors traditionally use and have a strong attachment to the same nest or nesting area year after year. As a result, negative changes in habitat quality or suitability may not be reflected in the number of breeding pairs when utilizing short term data. The current number of breeding pairs in an area may actually reflect past rather than present habitat conditions. Recent changes in habitat quality or suitability may be indicated by increases or decreases in reproductive success and productivity. No substantial changes in these parameters occurred between 1992 and 1994 (U.S. Fish and Wildlife Service 1993, 1994).

Food habits

Weekly collections of pellets from below Swainson's hawk nests were made throughout the nesting period in 1993 and 1994. These castings will be analyzed and a report summarizing results will be available in 1995. All hawks used certain habitats disproportionate to availability based on chi-square goodness-of-fit tests. The chi-squared goodness-of-fit test showed a significant difference between overall habitat usage and availability for the

Table 1-45. Nest specific Swainson's hawk productivity on the Rocky Mountain Arsenal National Wildlife Area during 1994.

Nest Number	Number of Nestlings Observed	Number Fledged
1	3	3
2	2	2
3	3	1
4	2	2
5	3	3
6	2	2
7	0	0
8	3	3
9	2	2
10	2	2
11	2	2
12	2	2
13	1	1
14	0	0
Total	27	25

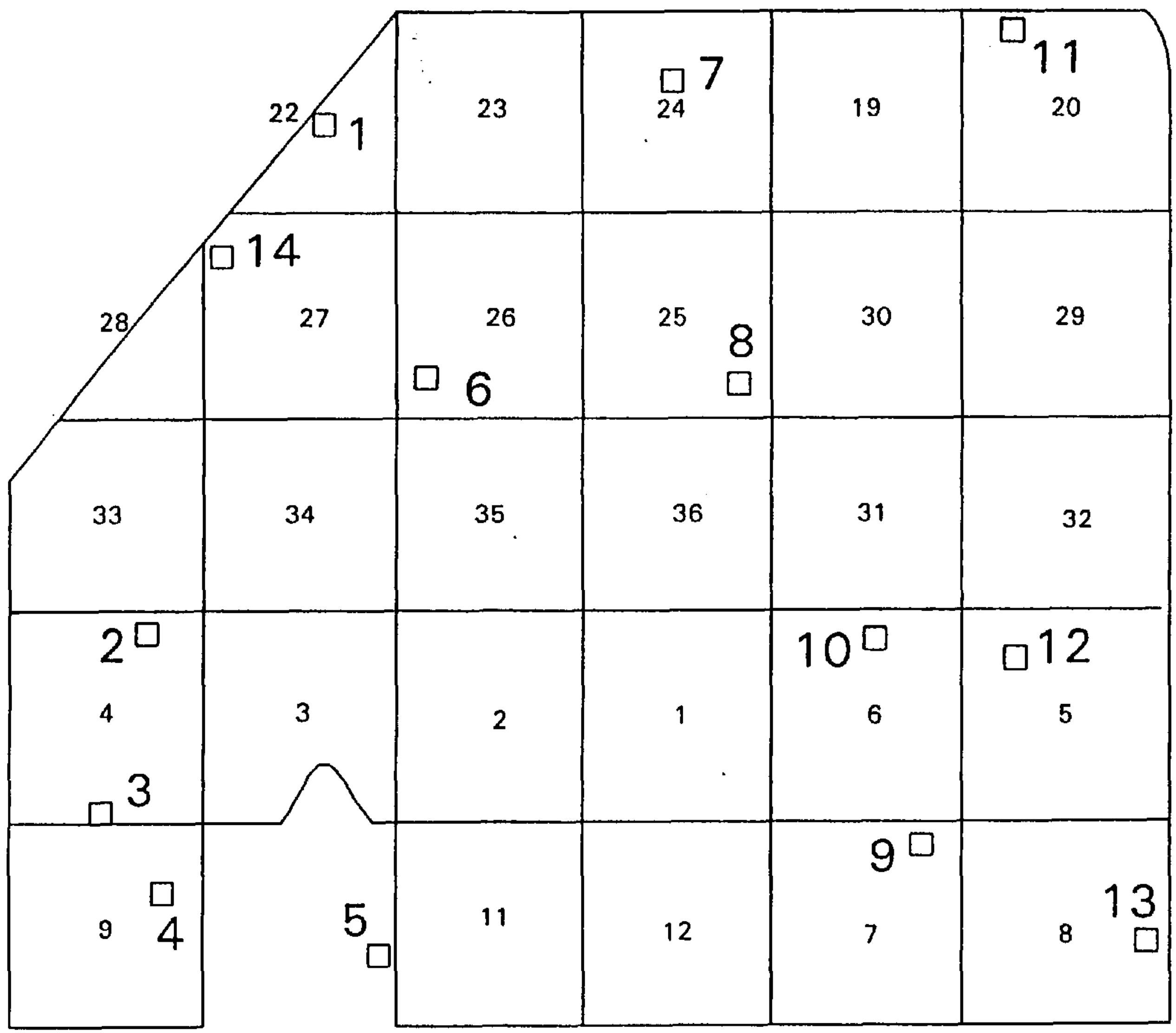

Fig. 1-52. Breeding pairs of Swainson's hawks monitored on the Rocky Mountain Arsenal NWR, 1994.

Table 1-46. Swainson's hawk productivity on the Rocky Mountain Arsenal National Wildlife Area during 1994.

Number of Breeding Pairs	14
Number of Nestlings Observed	27
Percent Successful Nests	86
Total Number Fledged	25
Mean Nestlings Per Breeding Pair	1.9 (0-3)
Mean Fledged Per Breeding Pair	1.8 (0-3)
Mean Fledged Per Successful Nest	2.1 (1-3)

Numbers in parentheses represent ranges

Telemetry and habitat use

The number of locations obtained per radio-tagged hawk ranged from 132 for the Section 4 bird to 192 for the Section 24 bird (Table 1-47). The Section 24 hawk spent a greater percentage of the time it was observed perched (Table 1-47). No substantial difference was observed between time spent flying and perched for the remaining three radio-tagged hawks (Table 1-47).

Mean home range size calculated using the 100 percent minimum convex polygon method was 2.05 km^2 (SD = 0.26, 1.80-2.40 km^2, n = 4) (Table 1-47).

Table 1-47. Estimates of home range size and activity of 4 male Swainson's hawks on the Rocky Mountain Arsenal NWR during 1994.

Hawk	Total # Locations	Time (%) Perched	Time (%)Flying	Minimum Convex Polygon (km)
Sect. 6	185	49.2	50.8	1.93
Sect. 22	133	65.4	34.6	1.80
Sect. 24	192	71.4	28.0	2.40
Sect. 4	132	57.6	42.4	2.05

Section 4 Swainson's hawk ($P < 0.05$, $X^2 = 24.134$, df = 3) (Table 1-48) (Fig. 1-53). Bonferroni confidence intervals (Table 1-49) indicated that native perennial grass was utilized less than would be expected by chance based on availability and weedy forbs were used greater than expected. The Section 6 Swainson's hawk habitat usage and availability differed significantly for habitats within its home range ($P < 0.05$, $X^2 = 110.528$, df = 3) (Table 1-50) (Fig. 1-54). Bonferroni intervals indicated that cheatgrass/weedy forb and crested wheatgrass were used less than expected based on availability and weedy forbs were used greater than expected (Table 1-51). A significant difference also existed between habitat usage and availability for the Section 22 hawk ($P = 0.05$, $X^2 = 163.186$, df = 5) (Table 1-52) (Fig. 1-55). Bonferroni confidence intervals indicated that cheatgrass and agricultural habitats were both used less than expected based on availability and cheatgrass/weedy forbs were used more than expected (Table 1-53). The Section 24 Swainson's hawk habitat usage and availability differed significantly ($P < 0.05$, $X^2 = 111.6$, df = 4) (Table 1-54) (Fig. 1-56). Bonferroni intervals indicated that shrub/succulents and wetland habitats were used less than expected and crested wheatgrass was used greater than expected (Table 1-55). There was an overall trend towards greater use of cheatgrass/weedy forbs and weedy forbs habitats. This may be due to a greater availability of prairie dogs in these habitat types (U.S. Fish and Wildlife Service 1994). Swainson's hawks are an opportunistic predator and may be utilizing young of the year prairie dogs as a important food item. Although, pellets collected from beneath active nests during 1993 and 1994 have not been analyzed, general observations during collections indicated that prairie dogs may be an important food item. Due to the lack of vegetative cover in these habitat types, other prey items may also be more available to Swainson's hawks. Other studies have suggested that a decrease in vegetative cover or density may increase prey availability to Swainson's hawks (Bechard 1982). A decrease in prey availability may occur as weedy areas are converted to native grasslands during habitat restoration due to an increase in vegetation density. As a result, remaining prairie dog towns may increase in importance as foraging areas for nesting Swainson's hawks.

Contaminants

The methodology to analyze serum samples is currently being developed. A report summarizing contaminant levels in Swainson's hawks should be available in 1995.

Table 1-48. Chi-squared test of habitat use/availability for the Section 4 Swainson's hawk at the Rocky Mountain Arsenal National Wildlife Refuge, 1994.

Habitat	Expected Use	Observed Use	$(O-E)^2/E$
Weedy forb	77.2	101	7.337
Native perennial grass	40.8	15	16.349
Crested wheatgrass	8.1	10	0.446
Other	5.9	6	0.002
Total	132.0	132	24.342

Table 1-49. Simultaneous Bonferroni confidence intervals for the Section 4 Swainson's hawk habitat use/availability data at the Rocky Mountain Arsenal National Wildlife Refuge, 1994.

Habitat	Exp. Prop Use	Act. Prop.Use	Bonf. Interval for P
Weedy forb	.6190	.7652	$+.6730 \leq P \leq .8574$ *
Native perennial grass	.3273	.1136	$-.0441 \leq P \leq .1826$ *
Crested wheatgrass	.0646	.0785	$.0182 \leq P \leq .1334$
Other	.0469	.0455	$.0002 \leq P \leq .0908$

* Significant at $\underline{P} < 0.05$

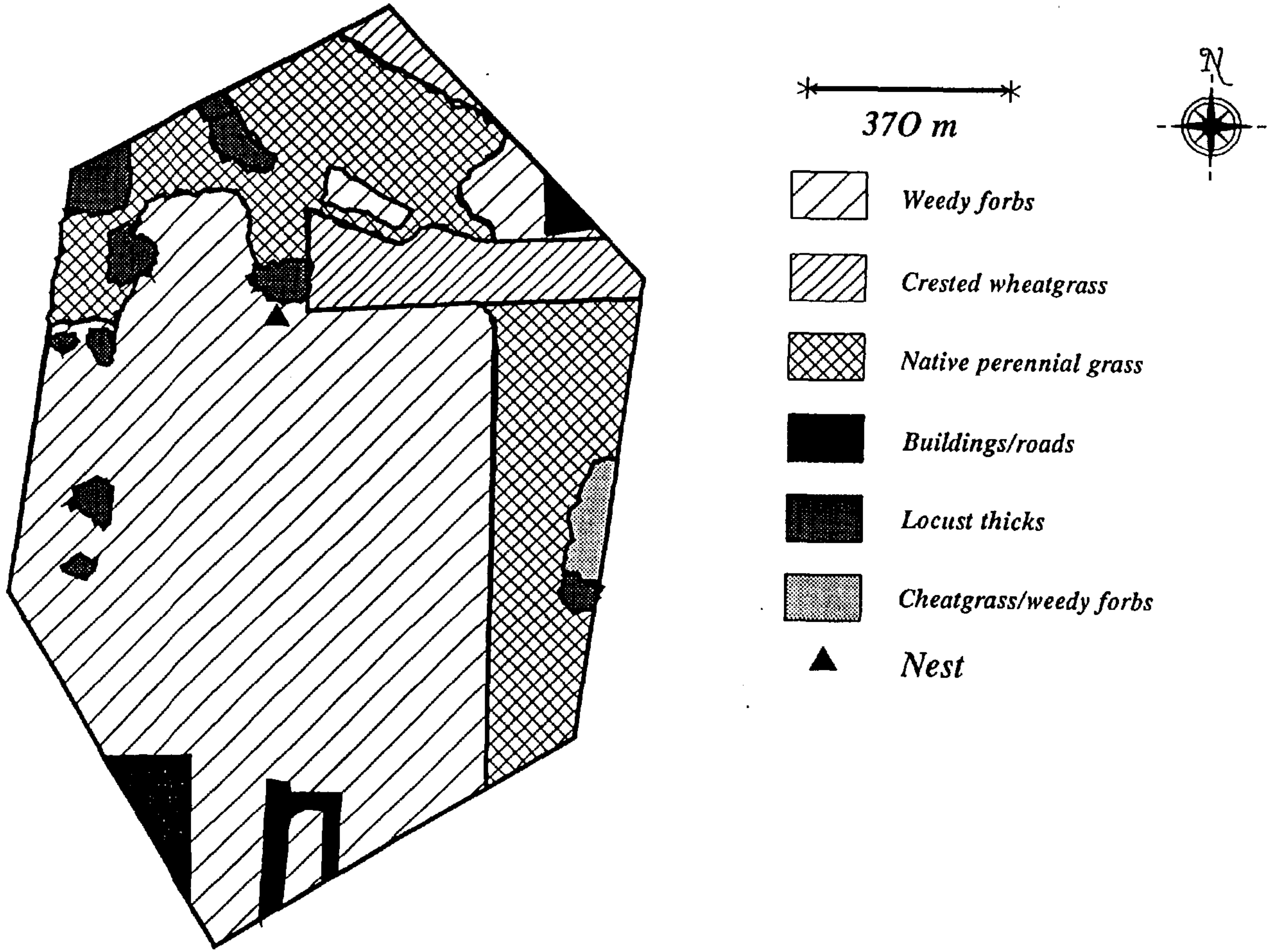

Fig. 1-53. Minimum convex polygon home range and habitats within the home range of the Section 4 Swainson's hawk on the Rocky Mountain Arsenal NWR, 1994.

Table 1-50. Chi-squared test of habitat use/availability for the Section 6 Swainson's hawk at the Rocky Mountain Arsenal National Wildlife Refuge, 1994.

Habitat	Expected Use	Observed Use	$(O-E)^2/E$
Cheatgrass/Weedy forb	59.6	40	117.781
Crested wheatgrass	76.4	43	2.042
Weedy forbs	32.3	86	2.402
Other	14.3	16	0.818
Total	179.9	185	110.528

Table 1-51. Simultaneous Bonferroni confidence intervals for the Section 6 Swainson's hawk habitat use/availability data at the Rocky Mountain Arsenal National Wildlife Refuge, 1994.

Habitat	Exp. Prop Use	Act. Prop.Use	Bonf. Interval for P
Cheatgrass/Weedy forb	.3223	.2162	$-.1405 \le P \le .2919$*
Weedy forbs	.1744	.4649	$+.3732 \le P \le .5566$*
Crested wheatgrass	.4113	.2324	$-.1548 \le P \le .3100$*
Other	.0865	.0775	$.0348 \le P \le .1382$

* Significant at $P < 0.05$

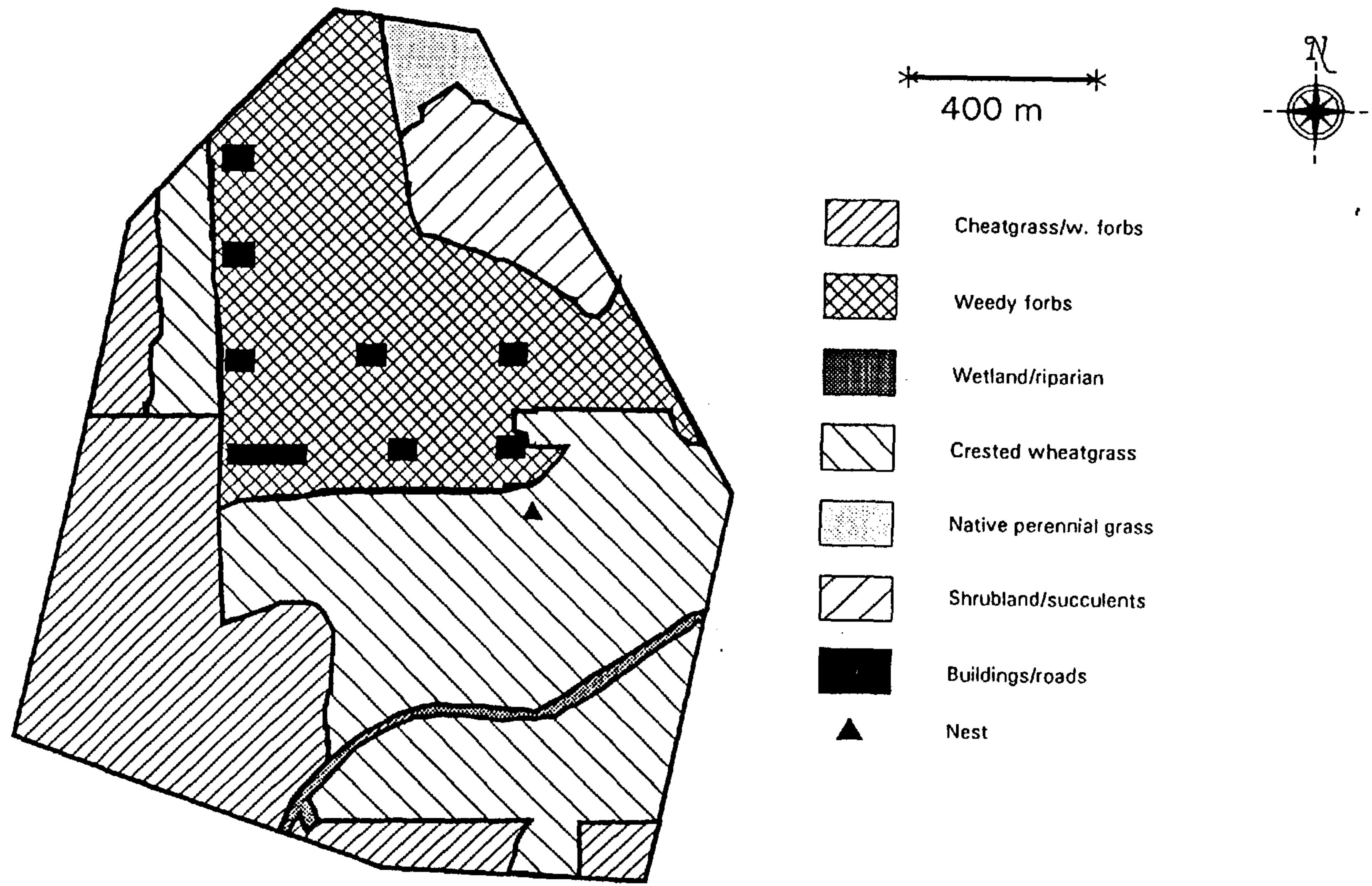

Fig. 1-54. Minimum convex polygon home range and habitats within the home range of the Section 6 Swainson's hawk on the Rocky Mountain Arsenal NWR, 1994.

Table 1-52. Chi-squared test of habitat use/availability for the Section 22 Swainson's hawk at the Rocky Mountain Arsenal National Wildlife Area, 1994.

Habitat	Expected Use	Observed Use	$(O-E)^2/E$
Cheatgrass/Weedy forb	31.8	93	117.781
Cheatgrass	21.3	5	12.474
Crested wheatgrass	29.8	22	2.042
Weedy forb	5.7	2	2.402
Agricultural	33.4	3	27.669
Other	11.0	8	0.818
Total	133.0	133	163.186

Table 1-53. Simultaneous Bonferroni confidence intervals for the Section 22 Swainson's hawk habitat use/availability data at the Rocky Mountain Arsenal National Wildlife Refuge, 1994.

Habitat	Exp. Prop. Use	Act. Prop. Use	Bonf. Interval for P
Cheatgrass/Weedy forb	.2394	.6992	+.5942≤P≤.8042*
Cheatgrass	.1603	.0376	-.0000≤P≤.0811*
Crested wheatgrass	.2240	.1654	.0803≤P≤.2505
Weedy forbs	.0426	.0150	.0000≤P≤.0428
Agricultural	.2509	.0226	-.0000≤P≤.0566*
Other	.0827	.0602	.0058≤P≤.1146

* Significant at $\underline{P} < 0.05$

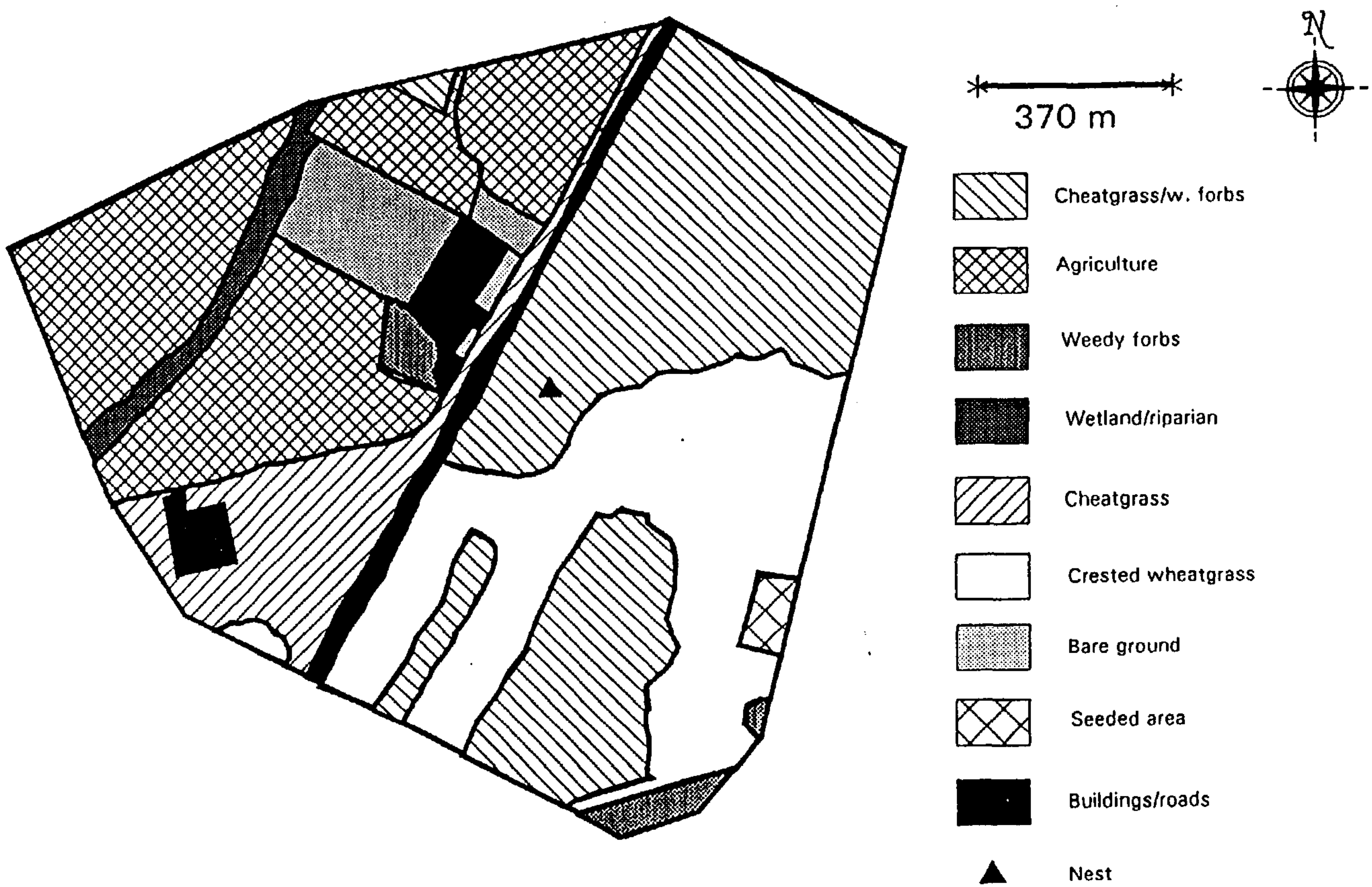

Fig. 1-55. Minimum convex polygon home range and habitats within the home range of the Section 22 Swainson's hawk on the Rocky Mountain Arsenal NWR, 1994.

Table 1-54. Chi-squared test of habitat use/availability for the Section 24 Swainson's hawk at the Rocky Mountain Arsenal National Wildlife Refuge, 1994.

Habitat	Expected Use	Observed Use	$(O-E)^2/E$
Cheatgrass/Weedy forb	107.6	103	0.197
Crested wheatgrass	26.4	72	78.764
Shrub/Succulent	32.2	3	26.480
Wetland	20.7	13	2.864
Other	5.1	1	3.296
Total	192.0	192	111.600

Table 1-55. Simultaneous Bonferroni confidence intervals for the Section 24 Swainson's hawk habitat use/availability data at the Rocky Mountain Arsenal National Wildlife Refuge, 1994.

Habitat	Exp. Prop. Use	Act. Prop. Use	Bonf. Interval for P
Cheatgrass/Weedy forb	.5605	.5365	$.4440 \leq P \leq .6290$
Crested wheatgrass	.1376	.3750	$+.2853 \leq P \leq .4648$
Shrub/Succulent	.1676	.0156	$-.0000 \leq P \leq .0386$
Wetland	.1079	.0677	$.0211 \leq P \leq .1143$
Other	.0264	.0052	$-.000 \leq P \leq .0104$ *

* Significant at $P < 0.05$

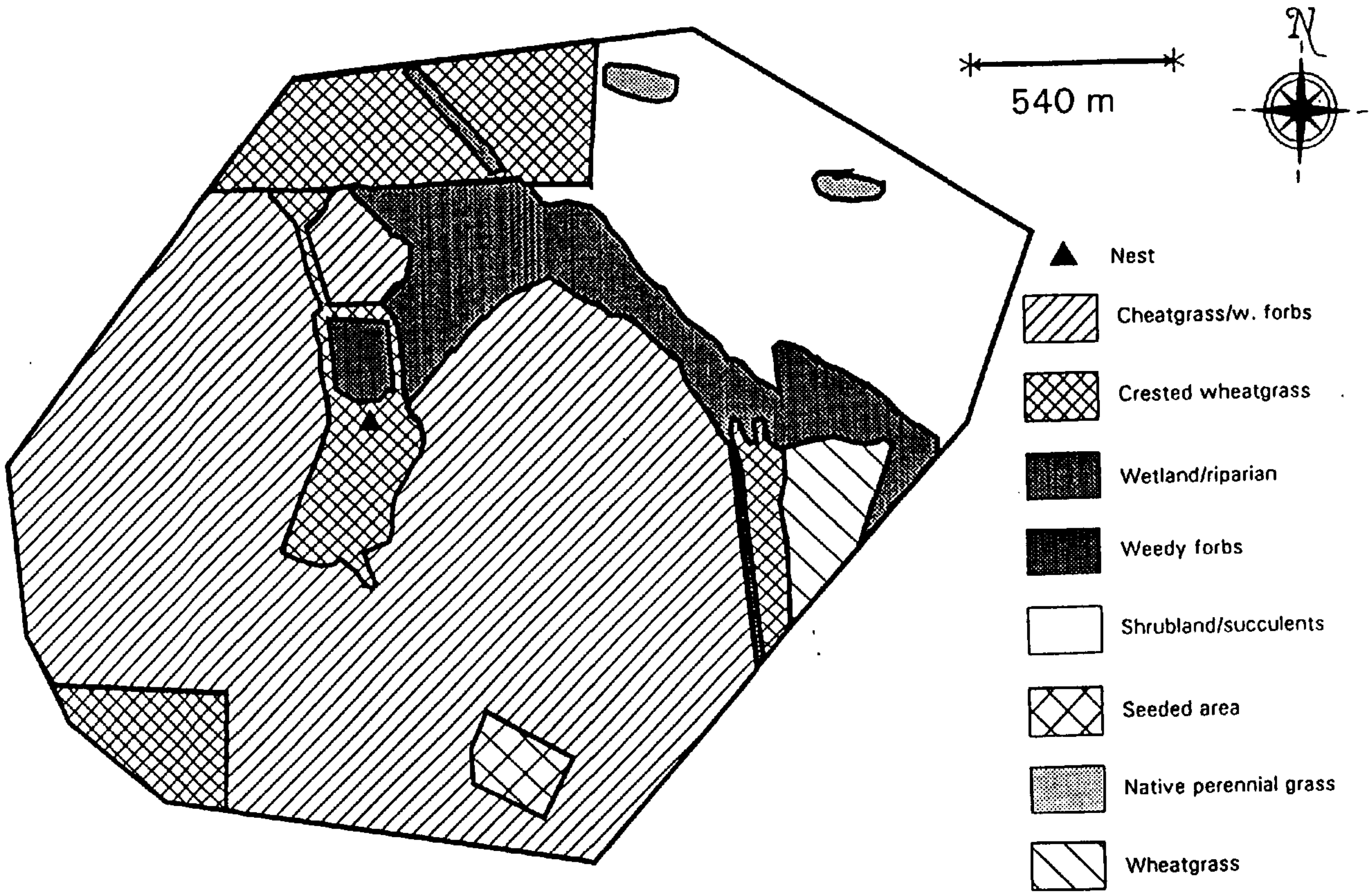

Fig. 1-56. Minimum convex polygon home range and habitats within the home range of the section 24 Swainson's hawk on the Rocky Mountain Arsenal NWR, 1994.

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TITLE: Waterfowl Population Trends and Habitat Use

INTRODUCTION

Surveys to monitor waterfowl population trends enable the Service to ascertain the importance of Refuge habitats to various species of waterfowl and determine periods of use by these species. The Refuge contains several wetland types that support a diverse waterfowl community (U.S. Fish and Wildlife Service 1992, 1993). Waterfowl are a secondary prey item of wintering eagles on the Refuge and proper waterfowl management will contribute to the quality of habitat for wintering eagles. The data acquired will also facilitate habitat management and mitigation for waterfowl habitats that may be impacted during Refuge cleanup. This information will assist with future plans to enhance public viewing potential of waterfowl and other waterbirds.

METHODS

Waterfowl were counted two hours after sunrise on calm days with no precipitation. Counts were conducted from twenty-one fixed observations points one to three times a month (Fig. 1-57). Waterfowl surveys were conducted from October 1993 through September 1994. An index of habitat use for all duck species combined, dabbling ducks, and diving ducks were computed by combining the data acquired from the 21 observation points into six areas representing similar habitats or the same wetland. An index of abundance over time was computed by calculating the mean number observed per month for Canada geese, American coots, all duck species combined, and separately for each duck species observed during a minimum of two months during the survey period.

RESULTS AND DISCUSSION

The mean number of ducks observed peaked in October through November during the Fall migratory period and in March during the Spring migratory period (Fig. 1-58). This generally follows the expected migratory chronology of most waterfowl species through northeastern Colorado (Rutherford 1966, Ringelman 1991) and follows the pattern observed on the Refuge for the last four years (U.S. Fish and Wildlife Service 1992, 1993, 1994). Canada goose numbers peaked during November during the Fall migratory period (Fig. 1-59). Canada goose numbers normally peak during November in northeastern Colorado (Rutherford 1966, Ringelman 1991). Canada goose numbers peaked in February during the Spring period in 1994 which is similar to the high use period observed during the previous four years (U.S. Fish and Wildlife service 1992, 1993, 1994) (Fig. 1-59). American coot seasonal population trends were similar to that observed for ducks during 1993-1994 (Fig. 1-60) and similar to American coot population trends observed during 1992-1993 (U.S. Fish and Wildlife Service 1994).

Dabblers comprised 29 percent and divers 71 percent of the observed duck population on the Refuge during 1993-1994. Dabblers comprised 66 percent and divers 34 percent of ducks observed during 1992-1993 (U.S. Fish and Wildlife Service 1994). This reversal in use of the Refuge by duck groups may reflect an increase in diver use of the Refuge during 1993-1994 or may be related to different migratory chronology between the groups and/or insufficient survey intensity. Surveys may have been conducted during the peak of dabbler migration in 1992-1993 and during the peak of diver migration during 1993-1994. During one survey conducted in late March 1994, 4134 redheads were observed, primarily on Lake Ladora. This was 57 percent of the ducks observed on the Refuge during surveys in 1993-1994. This suggests that survey timing/intensity may dramatically affect the number of waterfowl and species observed. The efficacy of the current survey intensity to monitor population trends is questionable. However, current methodology is probably sufficient to monitor broad seasonal use patterns. If population trends are to be

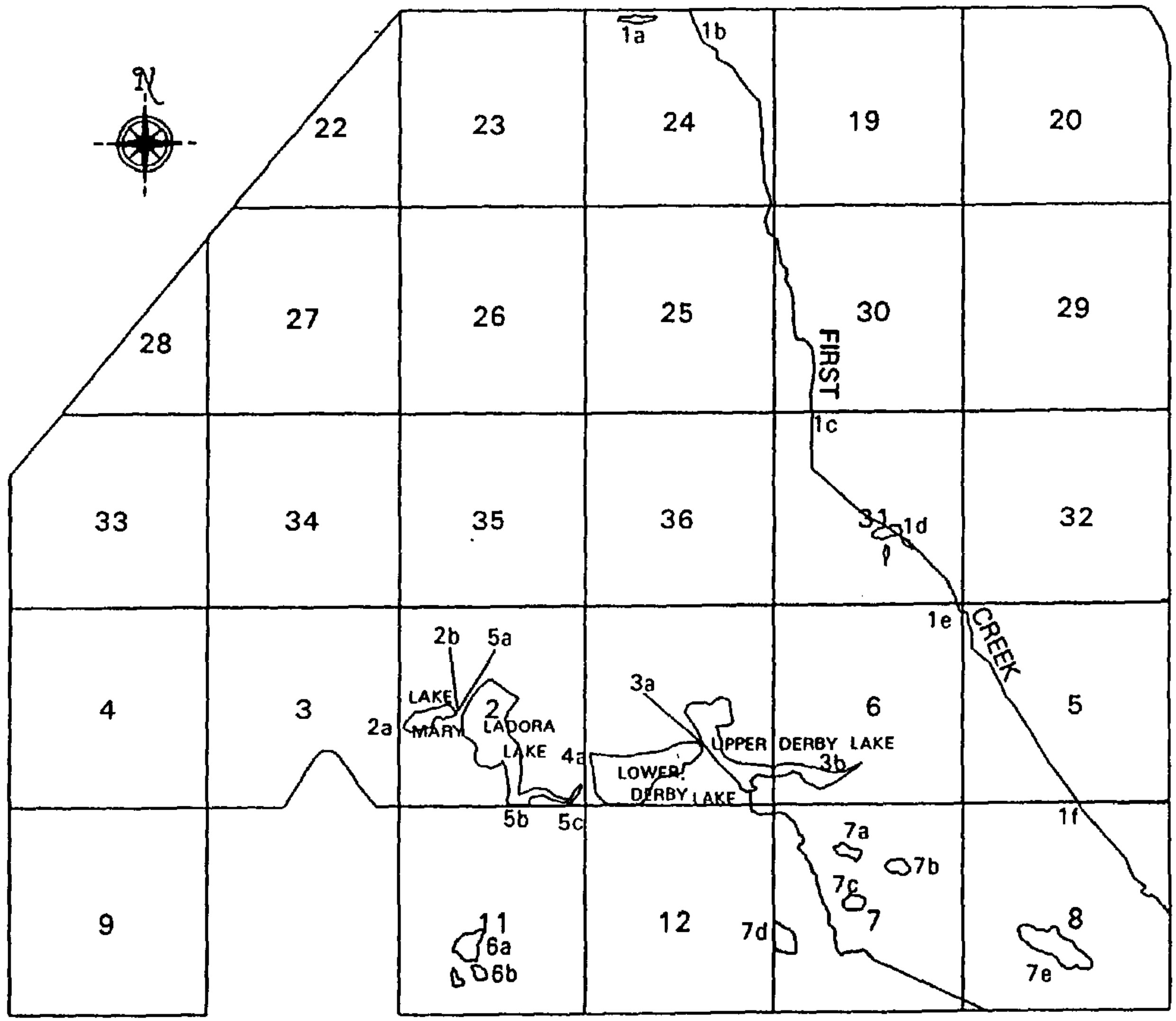

Fig. 1-57. Waterfowl survey locations used on the Rocky Mountain Arsenal NWR, October 1993 - September 1994.

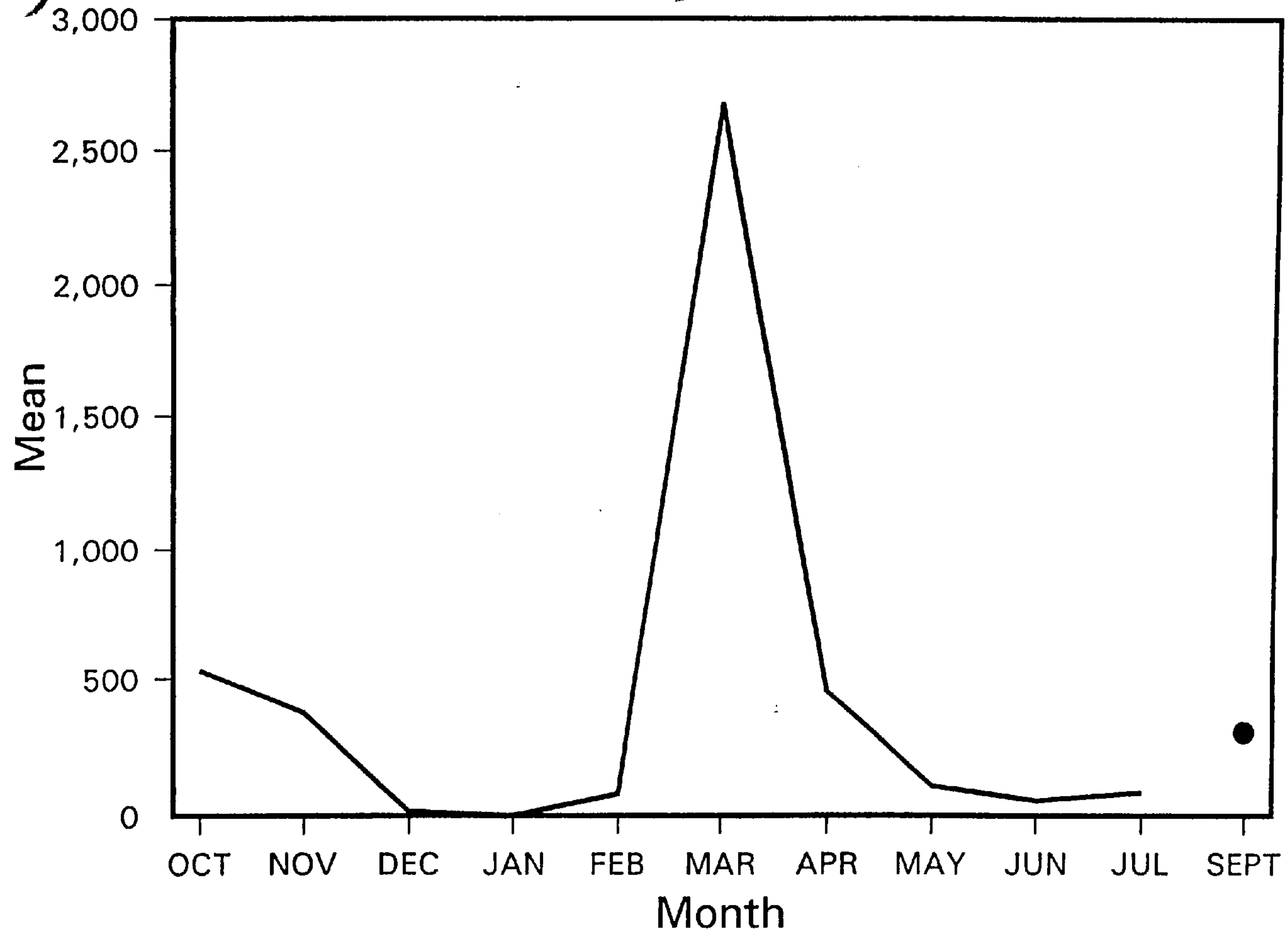

Fig. 1-58. Mean number of ducks observed per month on the Rocky Mountain Arsenal NWR, October 1993 - September 1994.

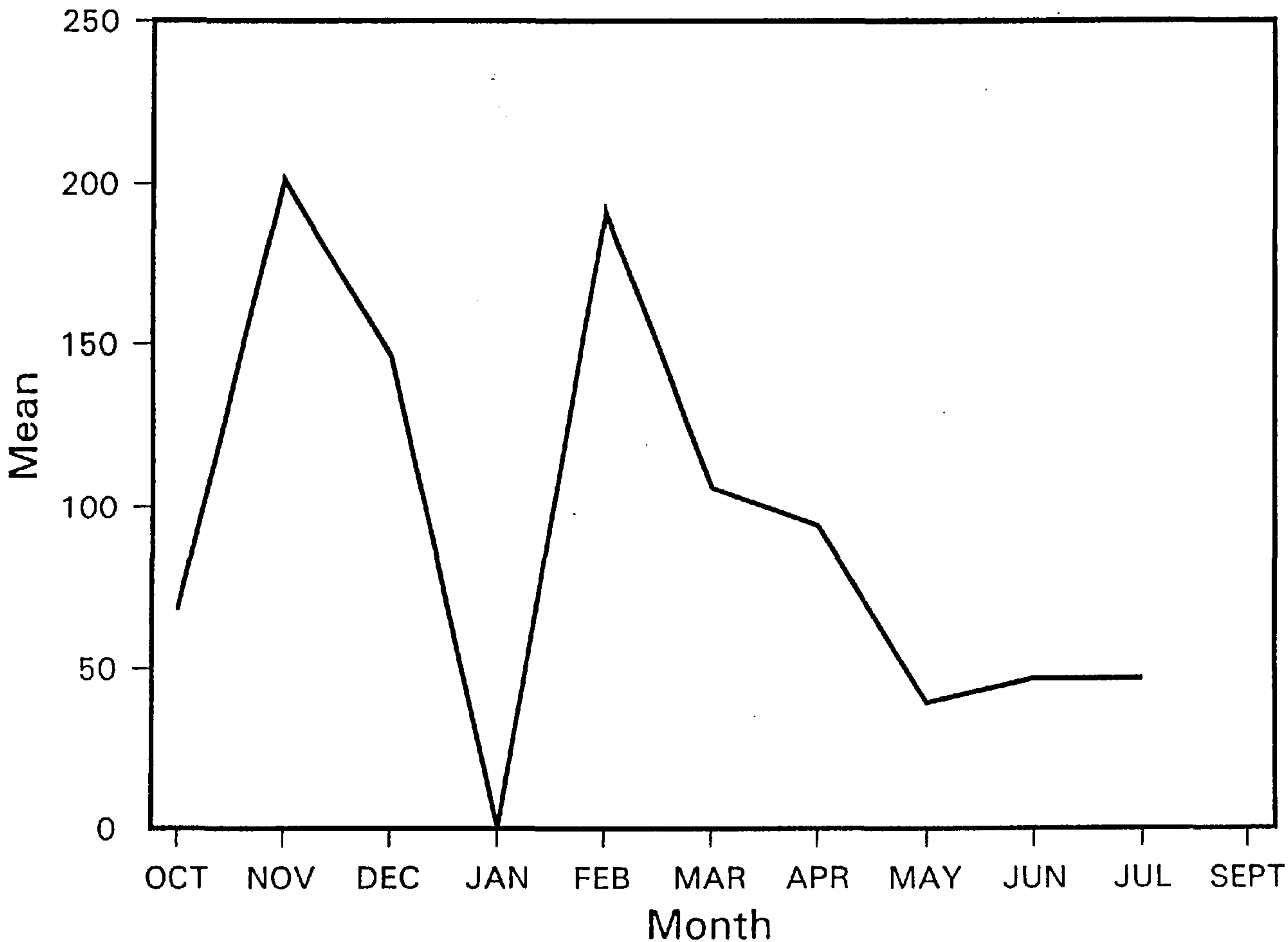

Fig. 1-59. Mean number of Canada geese observed per month on the Rocky Mountain Arsenal, October 1993 - September 1994.

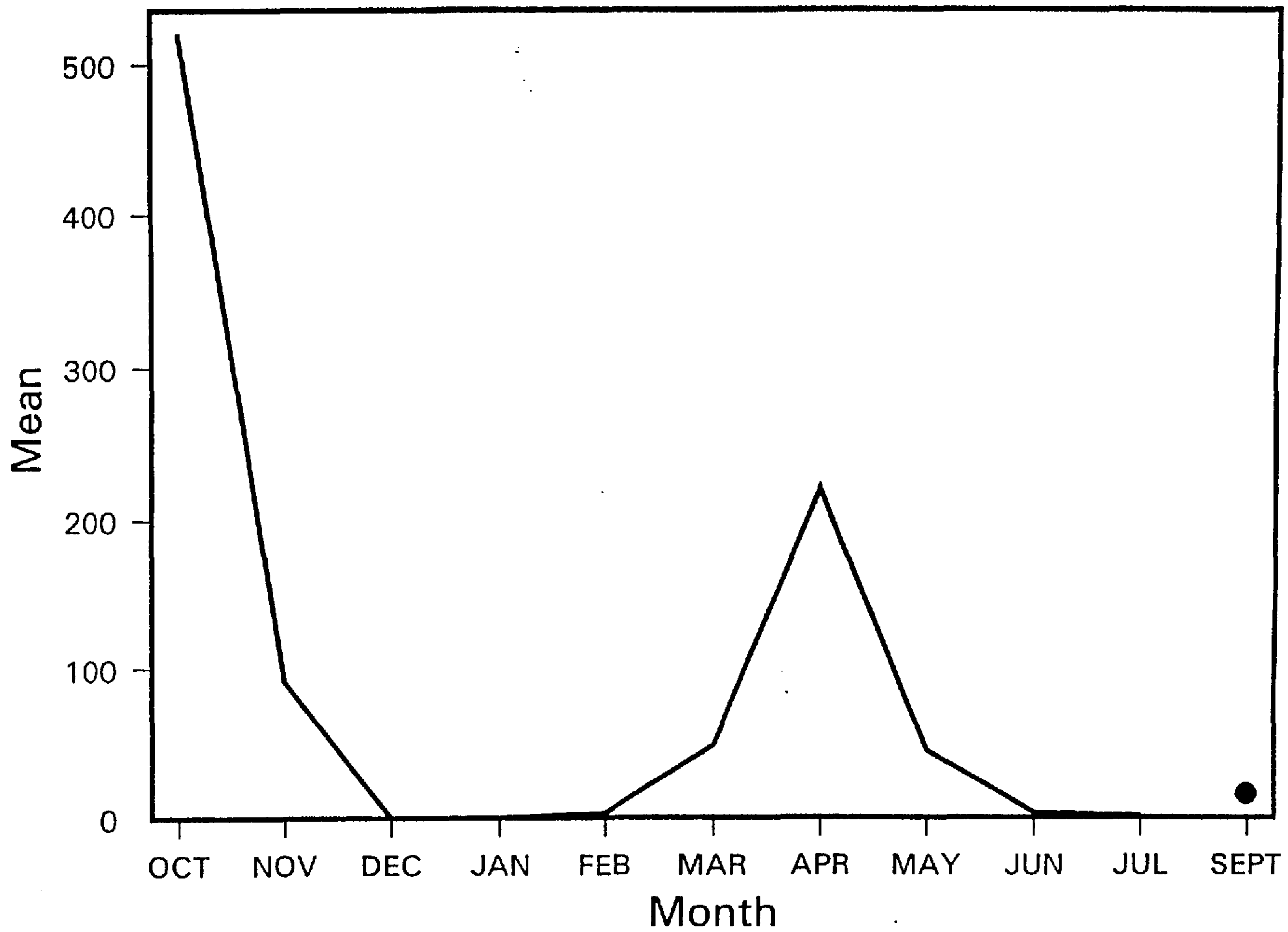

Fig. 1-60. Mean number of American coots observed per month on the Rocky Mountain Arsenal NWR, October 1993 - September 1994.

monitored an increase in survey intensity is required. Similar to 1992-1993, dabbler species comprised the majority of ducks on Havana Pond, Lake Mary, new wetland, and the First Creek corridor areas during 1993-1994 (U.S. Fish and Wildlife Service 1994) (Fig. 1-61). These sites contained shallow water areas or areas of water interspersed with vegetation. Dabbling ducks generally prefer shallow water areas with varying degrees of vegetation density (Bellrose 1976, Fredrickson and Reid 1988). Diving ducks usually select large open water bodies (Bellrose 1976, Fredrickson and Reid 1988) which are represented by Lower Derby Lake and Lake Ladora on the Refuge. Duck species observed on these lakes were primarily divers (Fig. 1-61). This is similar to use patterns observed during 1992-1993 (U.S. Fish and Wildlife Service 1994).

Population trends of most duck species were similar to that observed for all ducks combined (Fig. 1-62, 1-63, and 1-64). The most numerous duck species were redheads followed by mallards, gadwalls, and lesser scaup, and ring-necked ducks (Table 1-56). The surf scooter was the only new species observed during fiscal year 1994. It was observed at survey site 7e on 25 October 1993. This increases the Refuge waterfowl species list to 26 species (Table 1-57).

Lake Ladora received the highest duck use of the six areas again during 1993-1994 (Fig. 1-65). Lake Ladora provides some habitat for both dabblers and divers (U.S. Fish and Wildlife Service 1994). However, the percentage of the duck population observed on Lake Ladora comprised of divers increased from 66 percent to 99 percent from 1992-1993 to 1993-1994 (U.S.Fish and Wildlife Service 1994) (Fig. 1-61) and approximately 83 percent of the divers observed on the Refuge were observed on Lake Ladora (Fig. 1-66). This was a 15 percent increase from 1992-1993 (U.S. Fish and Wildlife Service 1994). The 1993-1994 data support the conclusions of the FY93 Annual Report, that Lake Ladora is probably the most important year round habitat for diving ducks on the Refuge (U.S. Fish and Wildlife Service 1994). The Havana Ponds and the new wetlands received the greatest dabbler use each comprising 30 percent of the dabblers observed on the Refuge (Fig. 1-67). Most waterfowl continued to be observed during migratory periods. As a result, these data do not indicate habitat quality for breeding or nesting waterfowl.

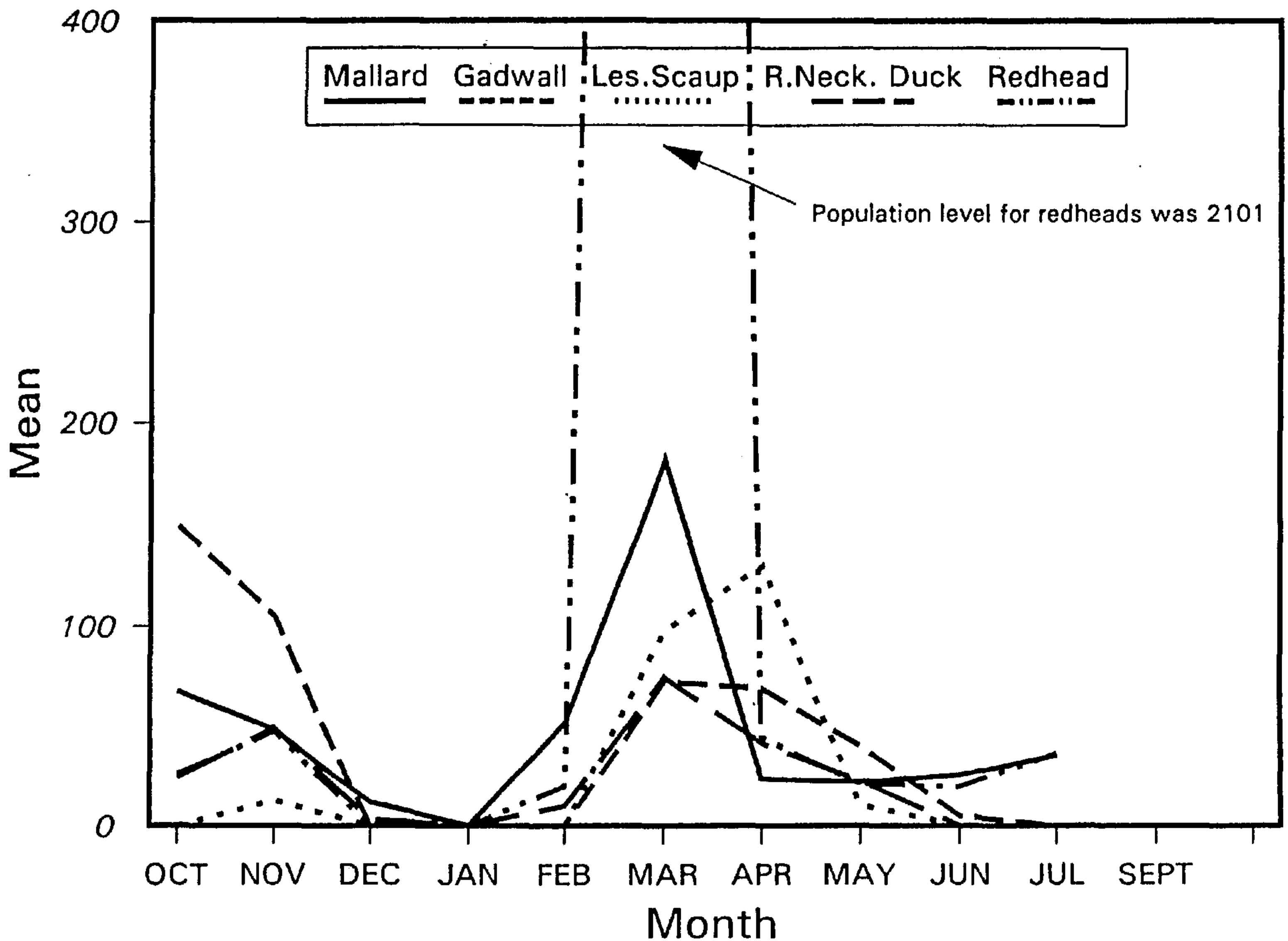

Fig. 1-62. Mean number of ducks observed for five species of ducks observed on the Rocky Mountain Arsenal NWR, October 1993 - September 1994.

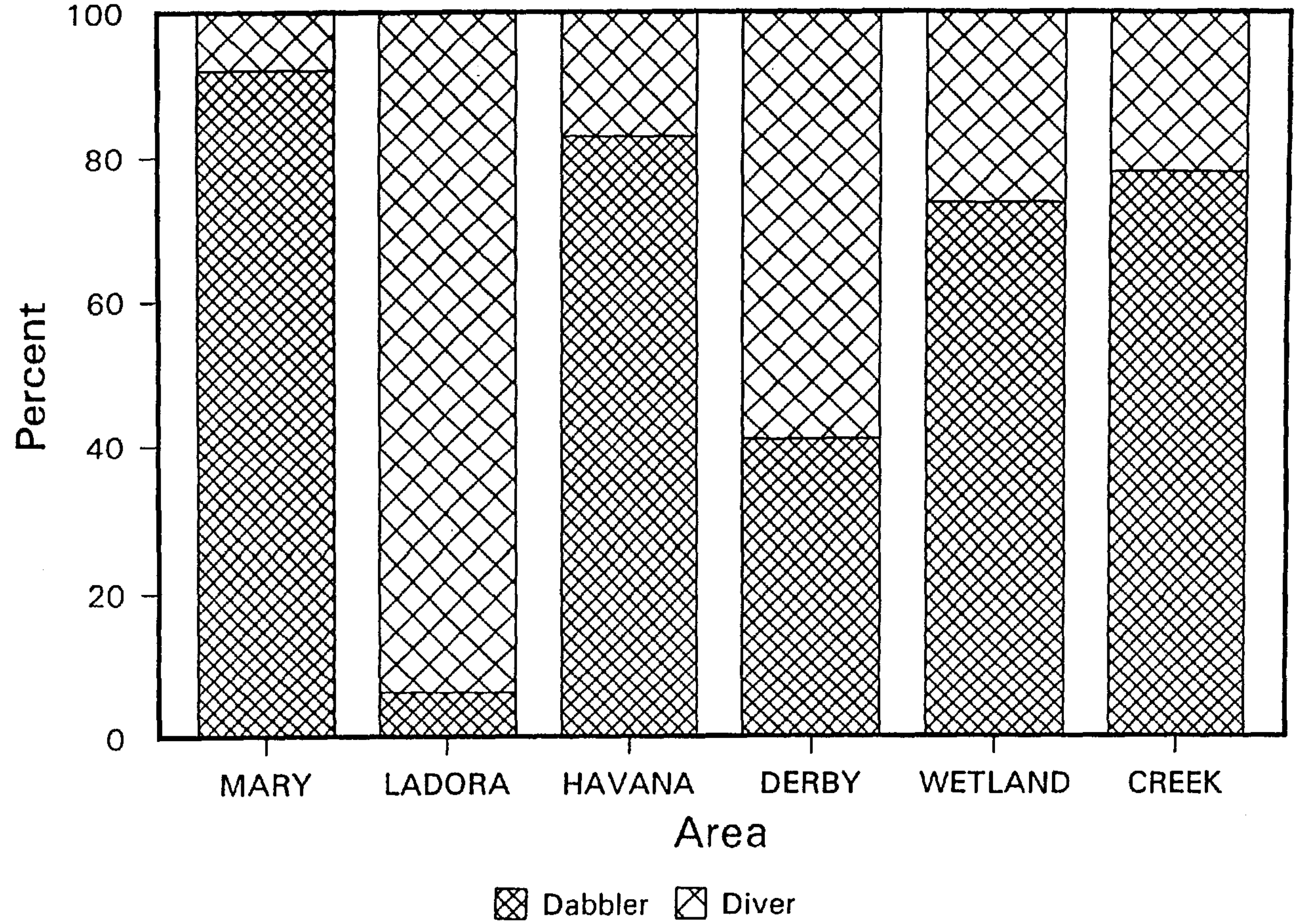

Fig. 1-61. Percent occurrence of dabblers versus divers for six areas during surveys on the Rocky Mountain Arsenal NWR, October 1993 - September 1994.

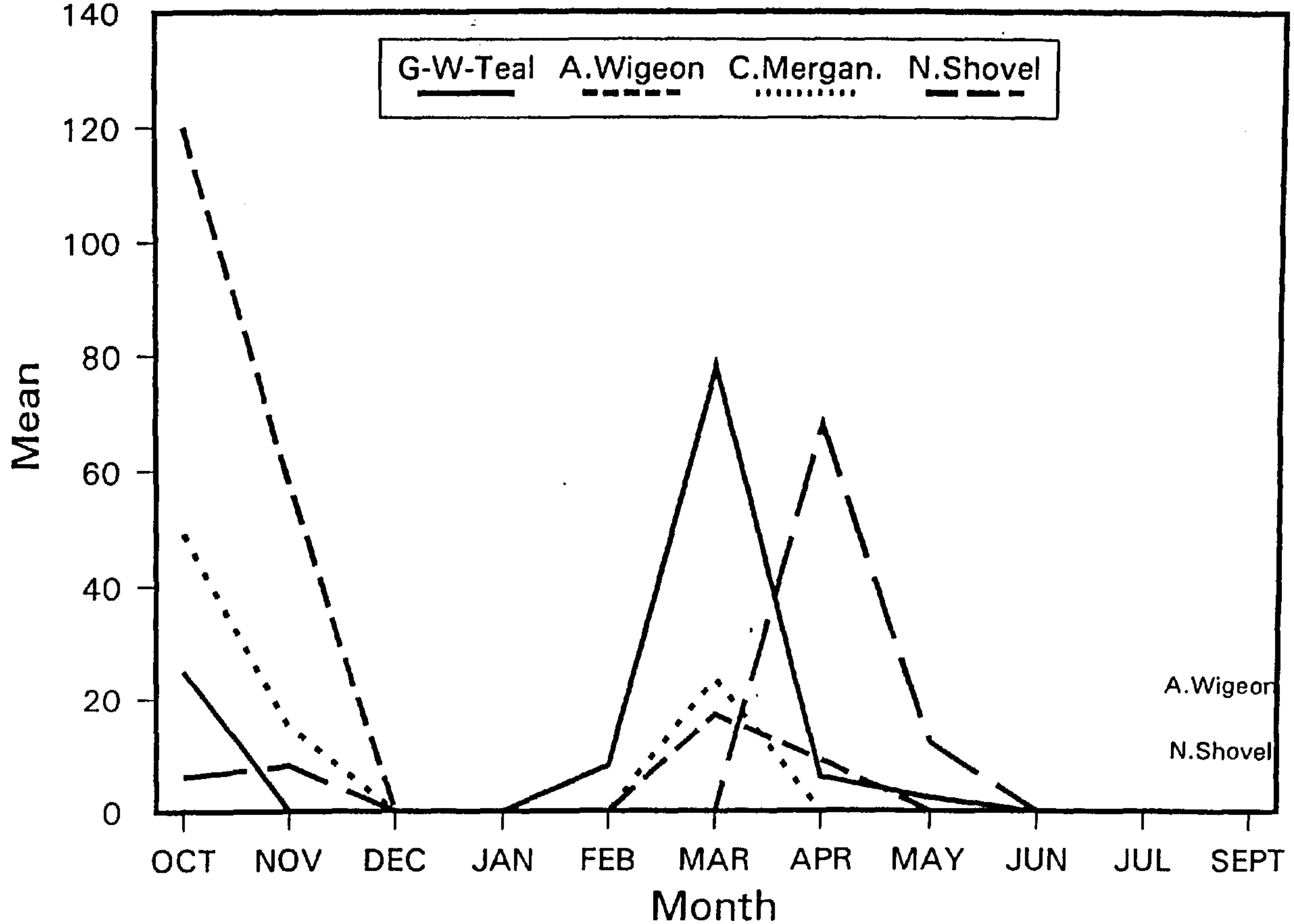

Fig. 1-63. Mean number observed per month for four species of ducks observed on the Rocky Mountain Arsenal NWR, October 1993 - September 1994.

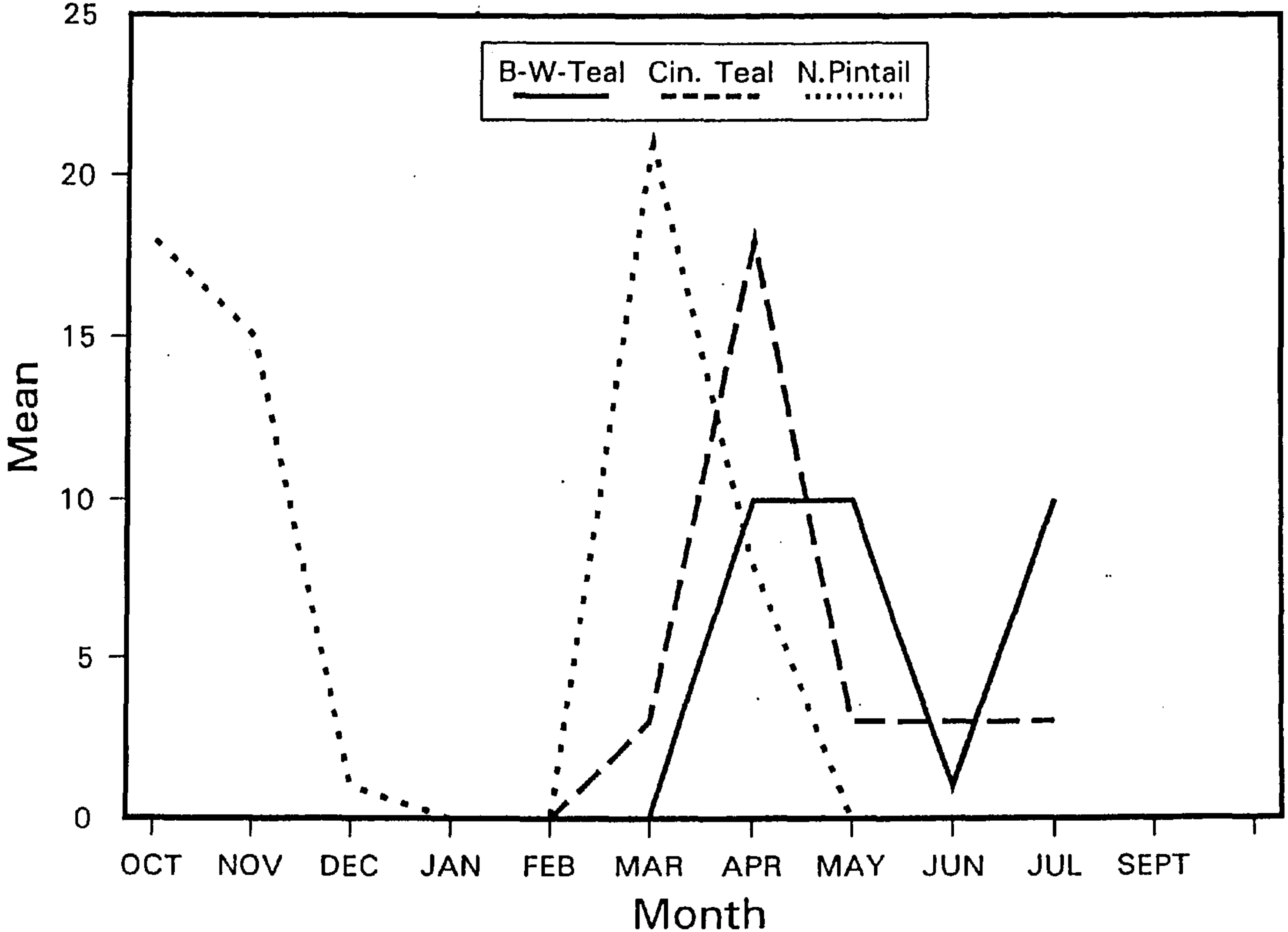

Fig. 1-64. Mean number observed per month for three species of ducks observed on the Rocky Mountain Arsenal NWR, October 1993 - September 1994.

Table 1-56. Waterfowl observed during Refuge surveys from October 1993 through September 1994.

Species	Number	Mean
Mallard	918	65.6
Gadwall	625	44.6
Green-winged teal	203	14.5
Redhead	4134	318.9
Ring-necked duck	277	19.8
Northern pintail	87	6.2
Norther shoveler	130	9.3
Lesser scaup	370	26.4
American wigeon	245	17.5
Blue-winged teal	54	3.9
Common merganser	111	7.9
Bufflehead	36	2.6
Common goldeneye	10	0.7
Canvasback	14	1.0
Cinnamon teal	41	2.9
Hooded merganser	3	0.2
Ruddy duck	5	0.4
Wood duck	2	0.1
Surf scooter	1	0.1
Total duck	7266	519.0
Canada goose	1124	80.3
American coot	1083	77.4

Table 1-57. Waterfowl species documented by the Service from 1987 through 1994 on the Rocky Mountain Arsenal NWR.

Species
Canada goose (Branta canadensis)
Greater white-fronted goose (Anser albifrons)
Snow goose (Chen caerulescens)
Mallard (Anas platyrhynchos)
Northern pintail (Anas acuta)
Gadwall (Anas strepera)
American wigeon (Anas americana)
Northern shoveler (Anas clypeata)
Blue-winged teal (Anas discors)
Cinnamon teal (Anas cyanoptera)
Green-winged teal (Anas crecca)
Wood duck (Aix sponsa)
Redhead (Aythya Americana)
Canvasback (Aythya valisineria)
Ringed-necked duck (Aythya collaris)
Lesser scaup (Aythya affinis)
Greater scaup (Aythya Marila)
Common goldeneye (Bucephala clangula)
Bufflehead (Bucephala albeola)
Red-breasted merganser (Mergus serator)
Common merganser (Mergus merganser)
Hooded merganser (Lophodytes cucullatus)
Ruddy duck (Oxyura jamaicensis)
Surf scooter (Melanitta perspicillata)
White-winged scooter (Melanitta deglandi)
Barrows's goldeneye (Bucephala islandica)

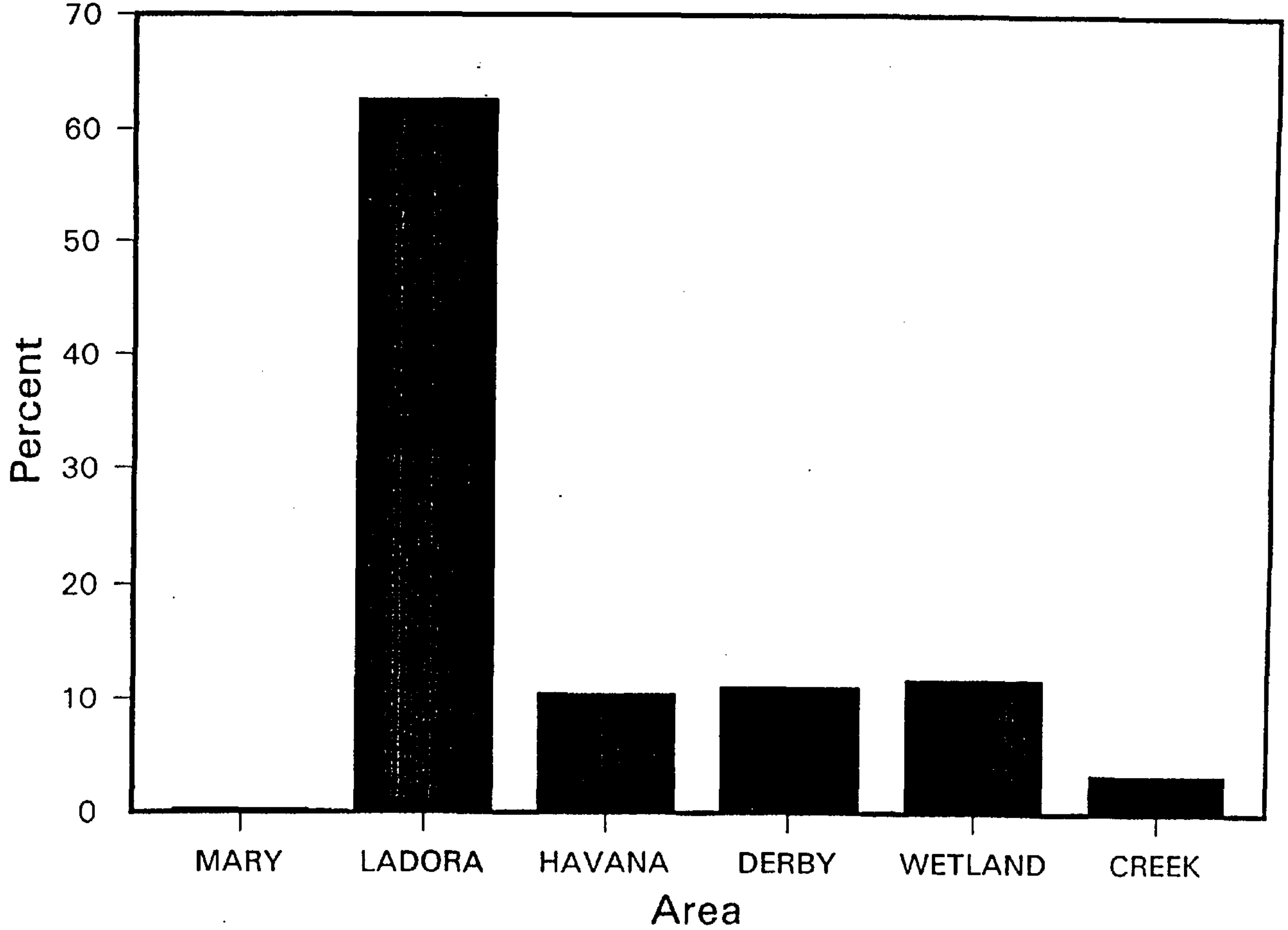

Fig. 1-65. Percent occurrence of all duck species combined for six areas during surveys on the Rocky Mountain Arsenal NWR, October 1993 - September 1994.

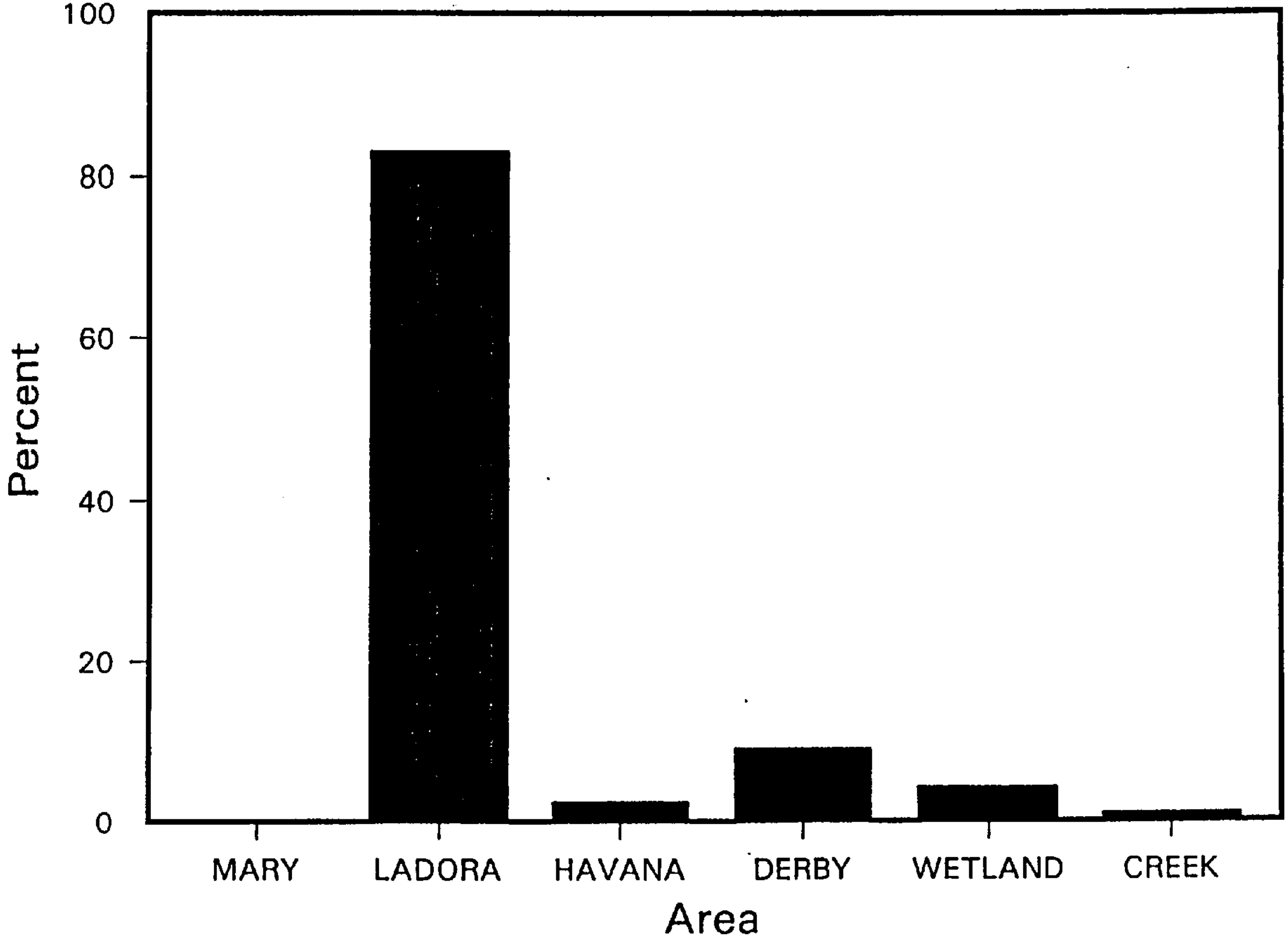

Fig. 1-66. Percent occurrence of divers for six areas during surveys on the Rocky Mountain Arsenal NWR, October 1993 - September 1994.

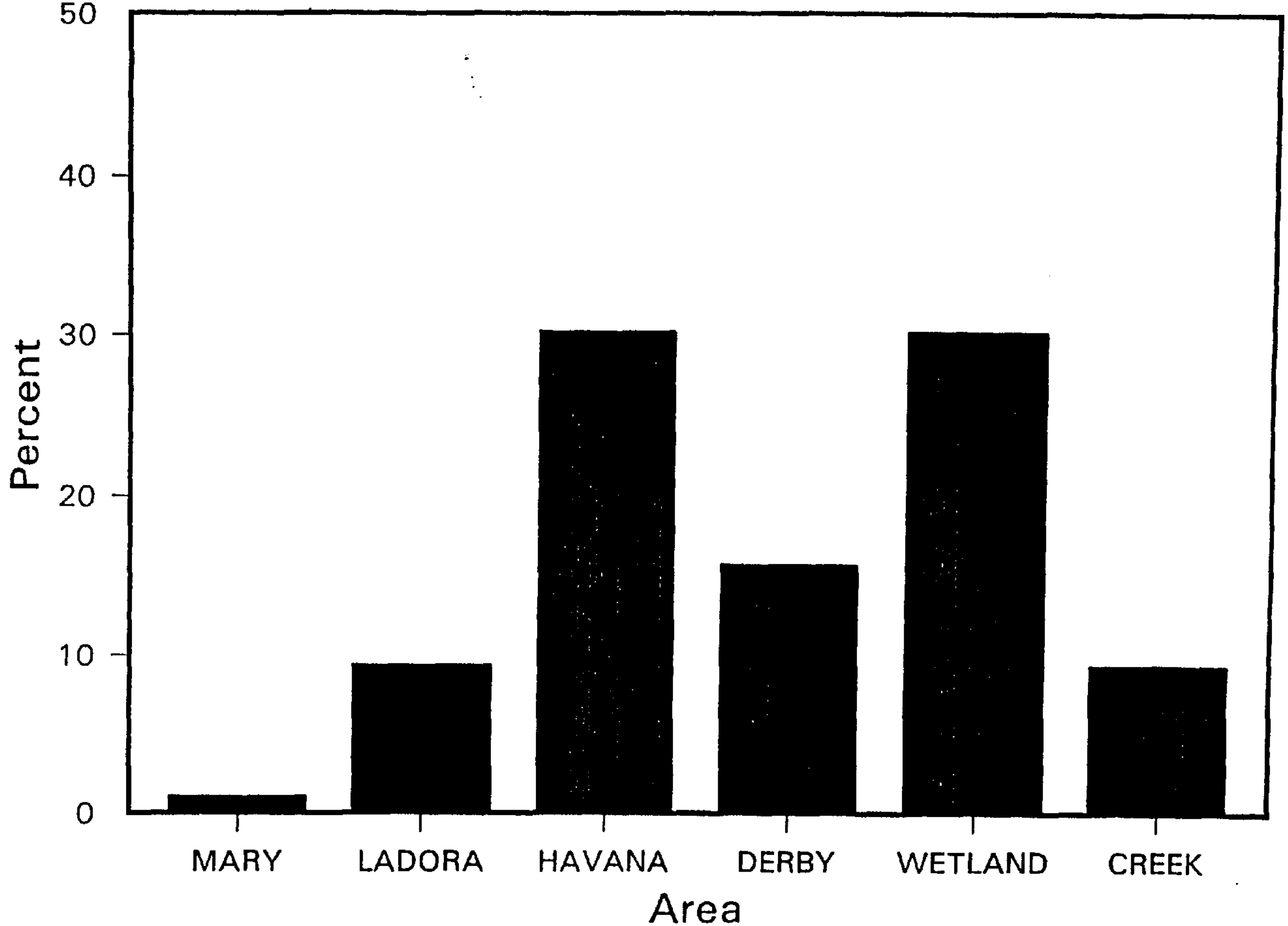

Fig. 1-67. Percent occurrence of dabblers for six areas during surveys on the Rocky Mountain Arsenal NWR, October 1993 - September 1994.

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TITLE: Water Resources and Sport Fishery Management.

INTRODUCTION

Fishery management objectives for the Refuge were to support the fishing pressure of 650 permitted anglers that catch an average of 0.5 to 1.0 fish per hour of effort. Lakes Mary, Ladora and Lower Derby management objectives were to provide a high quality sport fishery, and allow the most public use while minimizing wildlife and fishery habitat destruction. Objectives for other aquatic habitats on the Refuge are to maintain or enhance the existing quantity and quality of water resources. Lakes Mary, Ladora and Lower Derby were sampled during the 1994 season. Additionally, North Bog, Havana Pond, Bald Eagle Shallows, and the Storage Yard Pond were sampled.

The Refuge fishery is evaluated annually by monitoring fish population characteristics, and angler success, to ensure the fishery resource is not degraded and ensure the maintenance of a quality angling experience. Upper Derby Lake will be managed to minimize wildlife use of the area, and provide maximum flood protection by keeping the lake dry as called for in the Refuge Water Management plan. History of the lakes has been described in detail in a previous report (U.S. Fish and Wildlife Service 1991).

METHODS

Angler Data

Angler Survey

The roving clerk creel survey method (Malvestuto 1983) was used to estimate angler hours, and the distribution of angler use on Lakes Mary, Ladora and Lower Derby. Anglers were interviewed using the Colorado Fish and Wildlife Assistance Office creel census format modified for the Refuge.

Angler Success

Angler success includes fish catch rates, percent of the catch each species contributes, and size of fish caught. The modified Colorado Fish and Wildlife Assistance Office creel survey form was used during 1994.

Angler Satisfaction and Expertise

Satisfaction and expertise were evaluated during creel survey by asking the completed-day anglers' if they were "satisfied" with the number and length of fish caught, and if they were satisfied with their overall fishing experience at the Refuge. The anglers were also asked if they consider themselves as, inexperienced (value = 1), experienced (value = 2) or expert anglers (value = 3). Refuge creel data was analyzed using a D-base program written by the Service Fisheries Assistance office.

Fish Population Assessments

Gill net

Experimental mesh, monofilament gill nets were set on 7-9 June in standardized locations for four hours in Lakes Mary, Ladora and Lower Derby. Gill nets measured 45.7 m in length and consisted of six equal sized panels of bar mesh sizes 19, 25, 38, 50, 64, and 76 mm. All sizes and species of fish captured were weighed, measured, then released back into the lake. Gill net population assessment was used to compare 1994 data to previous years trends, and to evaluate angling impacts on the fishery. Gill net sites established in 1977 were repeated in 1994. Additionally, two gill nets were set at standardized locations for four hours in Lake Mary on 19 October to evaluate the effects of the increased angling pressure the lake experienced during 1994. Fish displaying hook wounds were categorized as 0 = no hook wounds, 1 = one hook wound, 2 = multiple hook wounds and 3 = torn mouth parts.

Electrofishing

Night electrofishing was conducted using a boat mounted Coffelt Mark XX electrofisher and 5,000 watt generator with a single boom 30 cm spherical anode. Three standardized 15-minute electrofishing stations were sampled in Lakes Mary, Ladora, and Lower Derby. All species and sizes of fish stunned were netted by Service personnel, weighed and measured, then released back into the lake. Sites established in 1991 were repeated in 1994. During 1994, all captured northern pike (*Esox lucius*), largemouth bass (*Micropterus salmoides*), and channel catfish (*Ictalurus punctatus*) larger than 250 mm were implanted with a Portable Integrated Transponder Tag (PIT) on the left side of the abdomen, just behind the pelvic fin. One 15-minute electrofishing station was conducted on Lake Mary on 19 October to help evaluate the effects of increased angling pressure during 1994. Fish hook wounds were analyzed similar to gillnet sampled fish.

Relative weight was calculated for all electrofishing samples. Relative weight is a condition index calculated by dividing the weight of the fish by the standard weight of a fish times 100 (Anderson 1980). For example, a 600 gram pike whose standard weight is 600 grams would have a condition factor of 100% and is an appropriate weight. Weights above 100% represent plump fish, weights below 100% represent lean fish.

Proportional Stock Densities (PSD) and Relative Stock Densities (RSD) were calculated for all electrofishing sampling occasions. Proportional Stock Density is defined as the number of quality sized fish divided by the number of stock sized fish multiplied by 100 (Gablehouse et al. 1982). Relative Stock Density is defined as the number of fish in a given size category divided by the number of stock sized fish (Gablehouse et al. 1982).

Aquatic Resources Sampling

North Bog, Havana Pond, Bald Eagle Shallows, and the Storage Yard Pond were sampled on 12, 23, and 24 August. Water temperature, water elevation, general site conditions, and fish composition were recorded. Fish were collected using a 1.52 m by 15 m seine with 6.3 mm bar mesh. Generally one pass of the seine was sufficient to collect a fish sample. First Creek did not flow frequently enough to allow sampling to occur.

Surface water temperatures, pH, conductivity and secchi depth measurements were collected from May of 1992 to May of 1993 in Lakes Mary, Ladora and Lower Derby. The water chemistry data was not presented in the 1993 annual report, therefore it will be presented in the 1994 report. Data was collected at two sampling stations within each impoundment; one near the inlet or upstream end (Site #1) and one near the outlet or downstream end (Site #2) of each impoundment. Surface water temperatures were collected using a direct-read mercury thermometer. Conductivity and pH were collected using a Yellow Springs Instruments Model 33 S-C-T meter. Secchi depths were collected using a standard black and white, eight inch secchi disc lowered into the water until it disappears, then retrieved until it becomes visible.

RESULTS

Angler Data

Angler Hours

Fishing permits were issued to 612 individuals in 1994 (601 public permits, 11 Arsenal employees and military personnel) on a lottery system. More detailed information regarding permit sales is available in the Task 4, Planning and Public Participation fishing program section. During the 1994 fishing season, the creel survey clerk made a total of 429 individual contacts; 206 (49%) anglers on Lake Mary, 130 (31%) on Lake Ladora and 83 (20%) on Lower Derby Lake. The average length of an angler day was 2.18 hours on Lake Mary, 3.55 hours on Lake Ladora and 2.32 hours on Lower Derby Lake. Manfredo (1991) determined that Arsenal anglers average 12.5 days of fishing each year. Based upon the sale of 612 permits and a average of 2.68 hours per angler day, it was estimated that Refuge anglers expended a minimum of 20,502 hours fishing at the Refuge in 1994. For comparison purposes, the 1982 annual report (Rosenlund 1982) estimated angler use at 11,000 hours of fishing pressure. Based on these estimatesm distribution of angler use on the Refuge lakes was 10,045 hours on Lake Mary, 6,356 hours on Lake Ladora and 4,101 hours on Lower Derby. Assuming 150 fishable surface acres of water, the Refuge supports approximately 137 hours of fishing pressure per acre. Lake Mary experienced significantly more fishing pressure in 1994 (10,045 hours) than in 1993 (2,854 hours). Distribution of angler use during an average day indicates peak use between 1800 hours and dark (Fig. 1-68) and averages 5.62 anglers. Anglers utilize the Refuge most heavily during the month of June and least during the month of October (Fig. 1-69).

Angler Success

Lake Mary anglers caught an average of 0.94 fish per hour. Bluegills (Lepomis macrochirus) represented 57% of the catch, largemouth bass 20% of the catch, and channel catfish provided 21% of the angler catch in 1994. Lake Ladora anglers caught an average of 1.16 fish per hour in 1994. Bluegill represented 71% of the fish caught, largemouth bass represented 17% and northern pike represented 8% of the catch during 1994. Additionally, yellow perch (Perca flavescens) made up 4% of the fish caught in Lake Ladora. Lower Derby Lake anglers caught .57 fish per hour in 1994, with bluegill representing 21%, largemouth bass represented 57% and northern pike represented 36% of the fish caught. Additionally, tiger muskie (Esox lucius x Esox masquinongy) represented 6% of the catch. Many anglers may not be capable of distinguishing tiger muskie from northern pike, therefore, survey results of these species may not be accurate. The childrens and handicap fishing programs at Lake Mary reported significantly higher bass catch rates during the 1994 summer and fewer bluegill catches (K. Batha pers. comm.).

Angler Satisfaction and Expertise

A satisfactory overall fishing experience of anglers polled on Lakes Mary, Ladora, and Lower Derby, was reported as 99.2%, 94.9%, and 86.4%, respectively. When asked to rate themselves, completed day Refuge anglers on Lake Mary reported an average of 1.23 or "inexperienced". Lake Ladora anglers ratings averaged 1.98 and Lake Lower Derby averaged 2.00 or "experienced". Historically Lake Ladora anglers have rated themselves well above experienced (average 2.6).

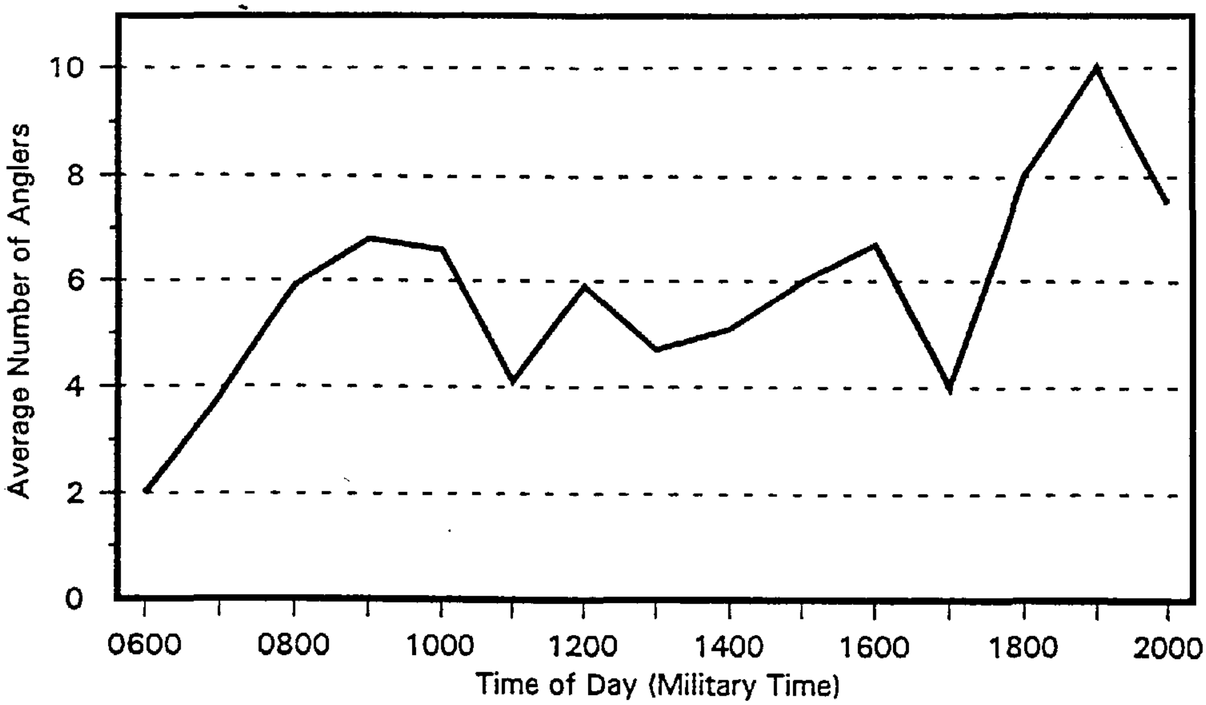


Fig. 1-68. Average number of anglers utilizing Refuge Lakes Mary, Ladora and Lower Derby during the 1994 fishing season.

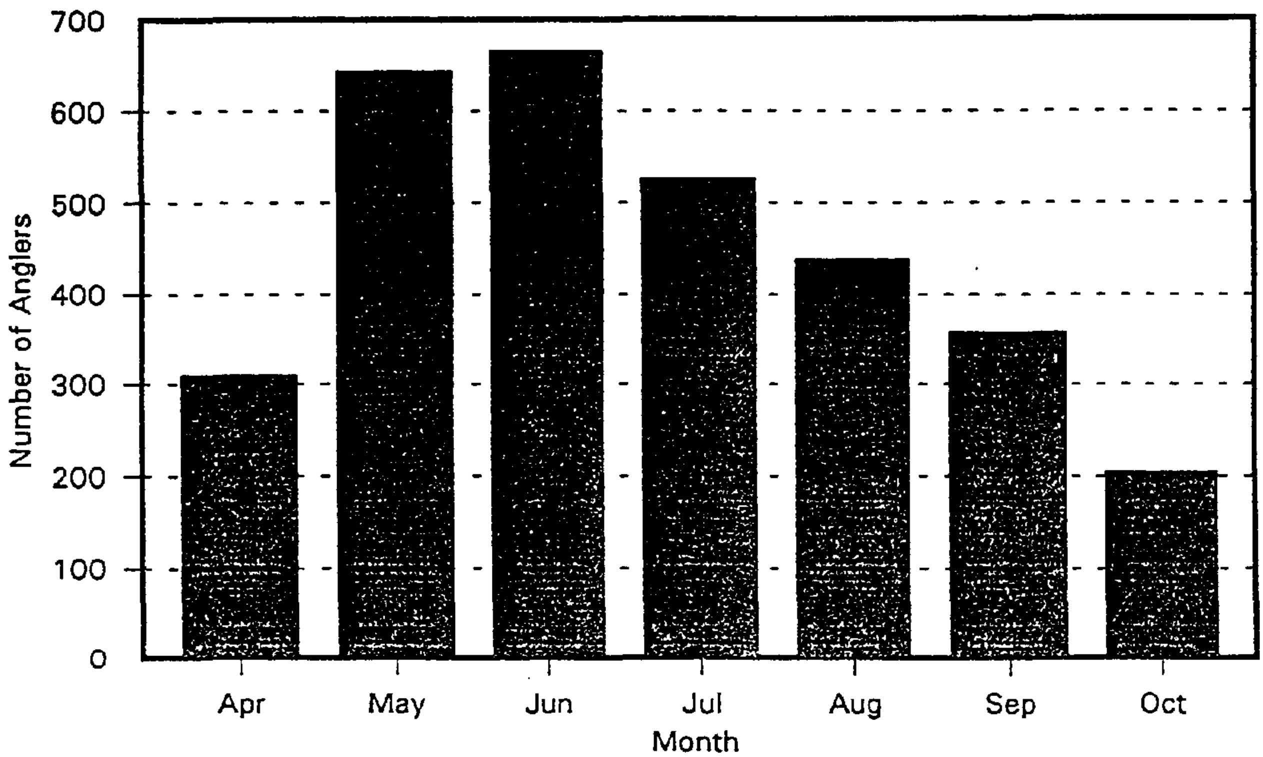


Fig. 1-69. Number of anglers by month fishing Refuge Lakes Mary, Ladora, and Lower Derby during the 1994 fishing season.

Fish Population Assessments

Gillnet

Two standardized Lake Mary gillnets were set for approximately 4 hours and 20 minutes each and captured ten largemouth bass, 40 bluegills, and two channel catfish (Table 1-58). No grass carp (Ctenopharyngodon idellus) were captured however their influence was evident by the reduction of aquatic plants in Lake Mary. Largemouth bass and bluegill kilograms per-net-hour were highest since the first standardized sample in 1979 (Table 1-58). Trout stocking was discontinued in 1993. Trout were not represented in the gillnets and are assumed not to exist in Lake Mary.

Lake Ladora gillnets were set for approximately 4 hours and 10 minutes each and captured ten northern pike, 13 largemouth bass, three yellow perch, 22 bluegill, and one green sunfish (Lepomis cyanellus). Gillnets captured more kilograms per-net-hour of northern pike (2.32) and largemouth bass (1.13) than captured since the first standardized sample in 1979 (Table 1-58). Black bullheads (Ictalurus melas) were not represented in the gillnets and were assumed to be eliminated by northern pike predation.

Lower Derby Lake gillnets were set for approximately four hours and ten minutes each and captured four northern pike, five carp and one tiger muskie which was 547 mm in total length.

Electrofishing

Two standardized fifteen minute electrofishing stations were conducted on Lake Mary which yielded 51 largemouth bass, 244 bluegill, one common carp (Cyprinus carpio), one black crappie (Pomoxis nigromaculatus) and two channel catfish. Largemouth bass catch per unit effort (30 largemouth bass > stock size per hour) continues to be low in Lake Mary. The largemouth bass PSD was 60 and bluegill PSD was 52 which fall into the desirable range described by Gablehouse et al. (1982). Two largemouth bass, initially captured and tagged on 22 June 1992, were recaptured. Largemouth bass PIT tag number 7F7D1D7020 was 408 mm total length (TL) and 1219 g weight, was initially tagged at 390 mm TL and 964 g. Largemouth bass PIT tag number 7F7D1D486D was 341 mm TL and 454 g was tagged at 320 mm TL and 498 g.

Three standardized electrofishing stations conducted on Lake Ladora captured 28 largemouth bass, 370 bluegill (not all bluegill were netted), three northern pike, ten yellow perch and one green sunfish (Lepomis cyanellus) (Table 1-59). Largemouth bass catch per unit effort (28 > stock size) was low. Largemouth PSD was 100% which may partially explain the low catch rates. Bluegill PSD is low (18%), therefore Gablehouse (1982) would categorize the Lake Ladora fishery as a "big bass option". The big bass option is a lake management strategy which provides fewer, but larger bass to the angler.

Three standardized electrofishing stations conducted on Lake Lower Derby captured 17 largemouth bass, one tiger muskie, seven northern pike, eight common carp, eight bluegill, two yellow perch, and one fathead minnow (Pimephales promelas). Largemouth bass catch per unit effort was low and PSD was 100% for both bluegills and largemouth bass. One captured largemouth bass was carrying a non-functional sonic transmitter implanted as part of the ongoing habitat use study (Appendix A). The transmitter was not removed and the largemouth bass was tagged with a PIT tag number 7F7D127A02. During the hook wound study, two gillnets set in Lake Mary in October yielded seven bluegill and two largemouth bass. Electrofishing collected 25 largemouth bass, one common carp, and 109 bluegill (not all bluegill were netted). Four largemouth bass (15%) showed evidence of hook wounds, two of which had torn mouth parts. Bluegill hook wounds were difficult to identify, and only two bluegills were noted as having hook wounds.

Table 1-58. Gill net sampling results on Lakes Mary, Ladora, and Lower Derby, RMANWR, 1979-1994.

LAKE MARY

Year	Trout Avg Ln	Kg/Net (Hr)	Bass Avg Ln	Kg/Net (Hr)	Bluegill Avg Ln	Kg/Net (Hr)
1979	279	0.22	170	0.02	0	0.00
1982	0	0.00	219	0.13	0	0.00
1985	0	0.00	268	0.14	178	0.04
1990	0	0.00	321	0.07	115	0.03
1991	620	1.63	263	0.34	119	0.15
1992	0	0.00	205	0.04	124	0.01
1993	0	0.00	388	0.39	115	0.02
1994	0	0.00	280	0.56	123	0.19

LAKE LADORA

Year	Pike Avg Ln	Kg/Net (Hr)	Bass Avg Ln	Kg/Net (Hr)	Bullhead Avg Ln	Kg/Net (Hr)
1979	615	0.29	323	0.11	260	0.80
1982	793	1.77	383	0.20	273	0.31
1985	754	0.42	284	0.10	283	0.25
1990	705	1.60	361	0.54	144	<.01
1991	657	2.20	318	0.81	-----	-----
1992	671	1.01	304	0.22	-----	-----
1993	657	0.84	386	0.19	-----	-----
1994	668	2.32	318	1.13	-----	-----

Table 1-58 (Continued).

LOWER DERBY

Year	Pike Avg Ln	Kg/Net (Hr)	Bass Avg Ln	Kg/Net (Hr)	Carp Avg Ln	Kg/Net (Hr)
1979	541	0.35	347	0.27	459	2.45
1982	568	1.35	401	0.05	513	0.93
1985	703	0.97	399	0.09	378	0.66
1990	691	3.60	0	0.00	497	-----
1991	567	0.26	331	0.22	530	1.69
1992	760	0.18	379	0.18	540	0.89
1993	509	0.56	350	0.37	-----	-----
1994	565	0.36	0	0.00	522	0.67

Table 1-59. Summary of 1993-94 electrofish sampling of Lakes Mary, Ladora, and Lower Derby at RMANWR.

LAKE MARY[1]

	Mean TL (mm)	N	CPUE >(S)	Average Relative Weight (%)	PSD (%)	RSD S-Q (%)	RSD Q-P (%)	RSD P-M (%)	RSD M-T (%)
1993 LMB	187	45	21	123	38	62	25	12	0
1994 LMB	214	51	30	115	60	40	13	47	0
1993 BLG [2]	122	53	69	152	10	90	10	0	0
1994 BLG [2]	118	91	117	136	52	48	52	0	0

LADORA LAKE[1]

	Mean TL (mm)	N	CPUE >(S)	Average Relative Weight (%)	PSD (%)	RSD S-Q (%)	RSD Q-P (%)	RSD P-M (%)	RSD M-T (%)
1993 LMB	244	27	13	116	100	0	20	70	10
1994 LMB	321	28	28	85	100	0	30	70	0
1993 NOP	346	4	2.6	98	100	0	50	50	0
1994 NOP	553	3	2.6	94	100	0	50	50	0
1993 BLG [2]	114	489	47	187	6	94	6	0	0
1994 BLG [2]	125	370	97	148	18	82	18	0	0

LOWER DERBY LAKE[1]

	Mean TL (mm)	N	CPUE >(S)	Average Relative Weight (%)	PSD (%)	RSD S-Q (%)	RSD Q-P (%)	RSD P-M (%)	RSD M-T (%)
1993 LMB	238	23	29	82	82	18	68	14	0
1994 LMB	355	17	23	92	100	0	76	24	0
1993 NOP	522	3	4	77	33	67	0	33	0
1994 NOP	502	7	9.3	78	14	86	0	14	0
1993 BLG	---	0	---	---	---	---	---	---	---
1994 BLG	94	8	4	130	0	100	0	0	0

[1] Faulty measuring board may have caused total fish length to be underestimated by 6 mm.
[2] Not all bluegill were netted.
TL = Total length.
LMP = Largemouth bass; BLG = Bluegill; NOP = Northern pike.
CPUE = Catch per unit effort; PSD = Proportional stock desnity; RSD = Relative stock density.
S = Stock size; Q = Quantity; P = Preferred; M = Memorable; T = Trophy.

Aquatic Resources Sampling

Havana pond maximum depth was approximately 1 m, and surface water temperature was 25° C. Trash carried on the Refuge from neighboring storm sewer drains continues to be a problem. The Havana pond gillnet sample yielded no fish. The seine was used to sample approximately 170 m of near shore habitat in the NE corner. The seine yielded 16 tiger salamanders, fathead minnows were abundant, backswimmers (Corixidae) were common, leeches (Annelida) were common, and Molluscs were common including clams (Sphaeriidae) and snails (Gyraulus sp.).

North Bog maximum depth was approximately 7 cm, water temperature was 23° C, and no live fish were noted. Common carp skeletal remains littered the shoreline. Snails (Gyraulus sp.) were noted as abundant throughout the impoundment.

Bald Eagle Shallows maximum depth was approximately 50 cm and water temperature was 26° C. The seine was pulled approximately 12 m beginning at the North end of the pond and sampled 189 crayfish (Decapoda), three tiger salamanders, and two fathead minnows.

Storage Yard Pond maximum depth was estimated at approximately 3.0 m, water temperature was 22° C and two complete seine hauls were completed through the entire impoundment. Twenty-four common carp (mean total length, 425 mm) were sampled and eliminated from the fishery. One Black bullhead, three fathead minnows, eighteen crayfish were also sampled.

Aquatic Habitat Management

Lake Mary pH levels ranged from 9.0 to 10.0 during the 1992-1993 sampling period (Fig. 1-70). The high pH levels, and high summer water temperatures (>24° C) are historically thought to be responsible for poor trout survival in Lake Mary. Lake Mary water clarity (Secchi depth) averages 155 cm and water conductivity averaged 705 umhos. Mean Lake Ladora water conductivity was 642 umhos and mean secchi depth is 166 cm (Fig. 1-71). Lake Ladora pH was moderately high and ranged from 8.1 to 9.1. Lower Derby mean water conductivity was 560 umhos and pH ranged from 8.1 to 9.2 (Fig. 1-72). Lower Derby Lake secchi depths averaged 86 cm.

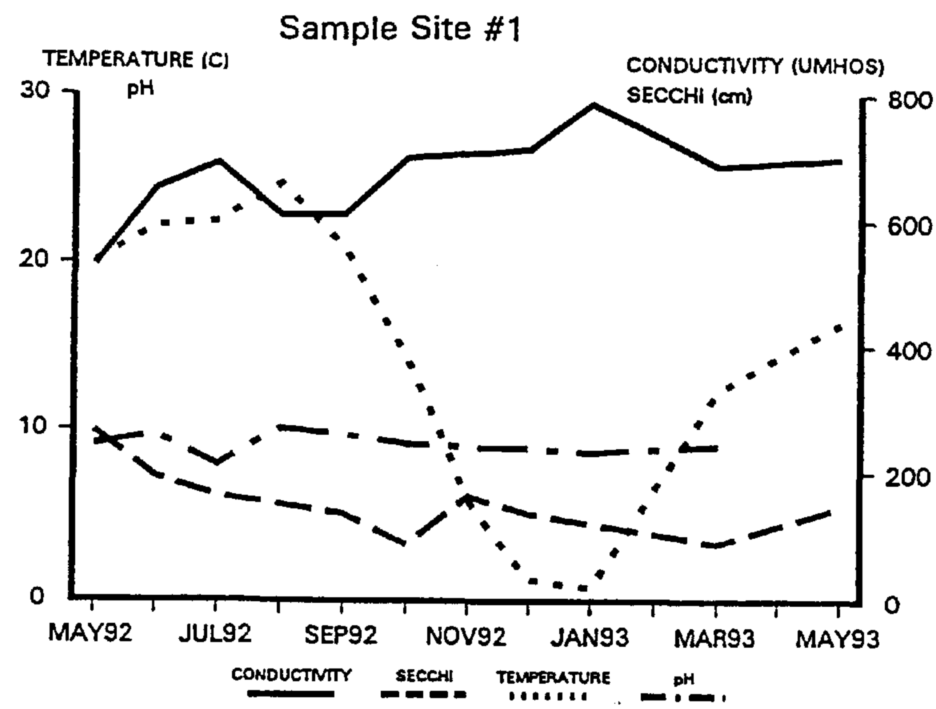
DISCUSSION

Most warmwater fisheries in Kansas support >50 largemouth bass (>stock size) per hour of electrofishing (Gablehouse et al. 1982). Refuge lower lakes display reasonable sizes and year classes of largemouth bass, however the number of fish captured in all three lakes appears to be low. Perhaps elevation limits carrying capacity and comparing Refuge lakes to Kansas lakes (Gablehouse et al. 1982) is unjustified.

The 1994 summer was warm and dryer than normal. Stormwater events and irrigation water inflow were much reduced. The low water prevented some sampling, therefore the 1995 sampling season will include the wetlands in Sections 7 and 8, First Creek, and the Rod and Gun Club Pond.

In general, fishing quality, satisfaction, and fish caught per hour was down during 1994. Extremely low water levels and high water temperatures probably account for the reduced performance of the Refuge fishery. Refuge anglers still rate themselves as some of the most experienced anglers found around the United States.

The grass carp in Lake Mary appear to be controlling aquatic vegetation growth sufficiently to allow fishing and provide good habitat. Manual weed removal to facilitate handicap angling was not necessary during 1994. Therefore, additional grass carp will not be stocked, however aquatic vegetation levels will continue to be monitored each year.



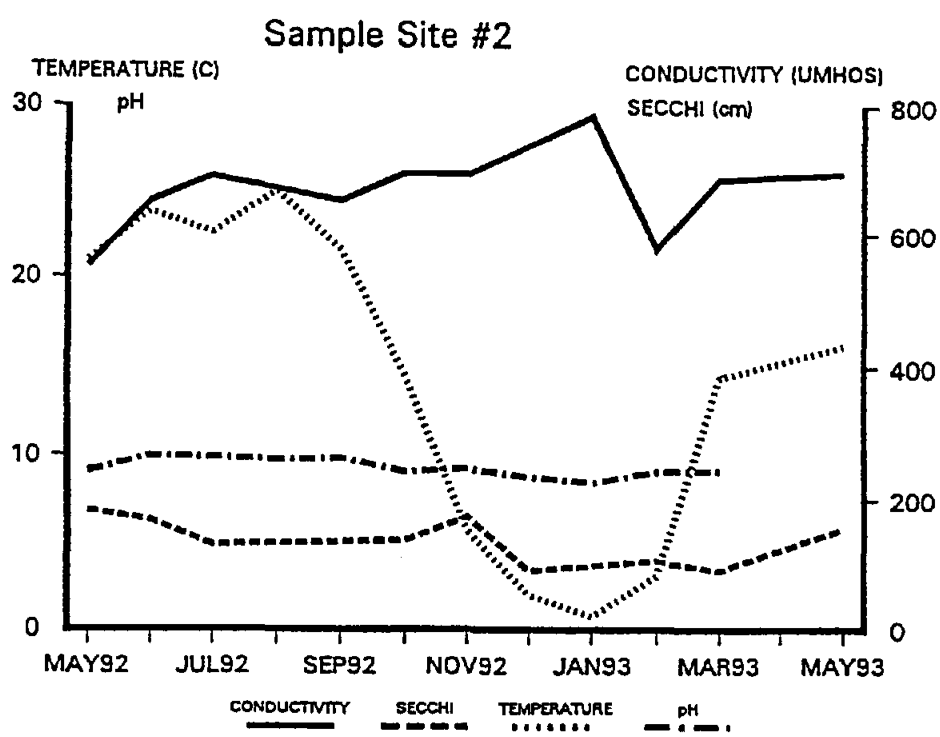
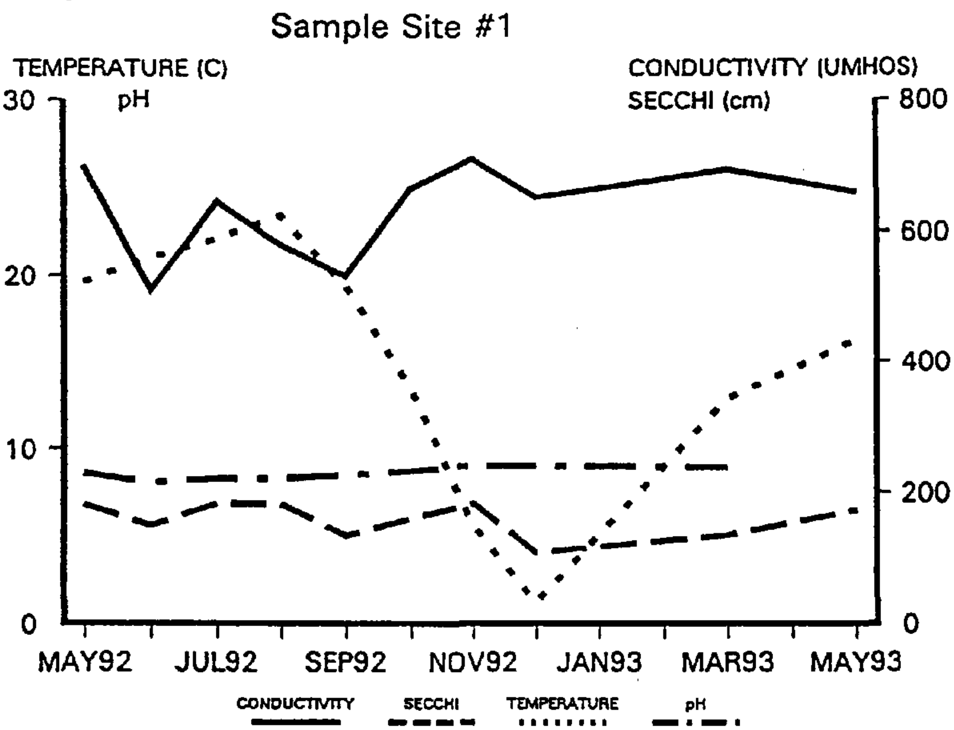


Fig. 1-70. Lake Mary water quality measurements from Sample sites #1 and #2 collected between May 1992 and May 1993, RMANWR.



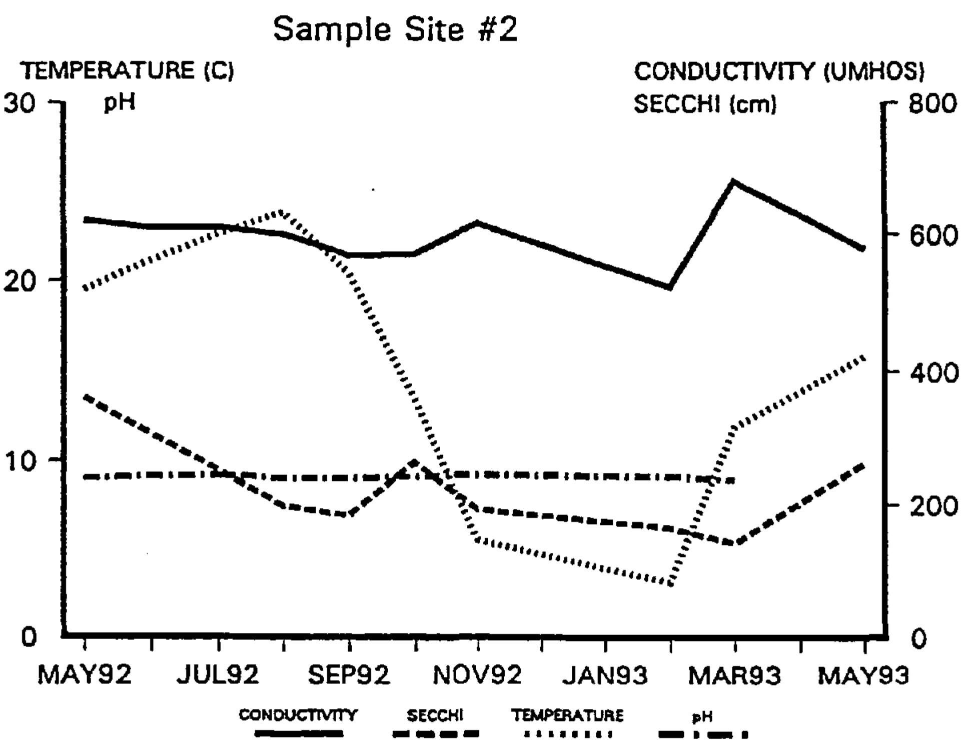
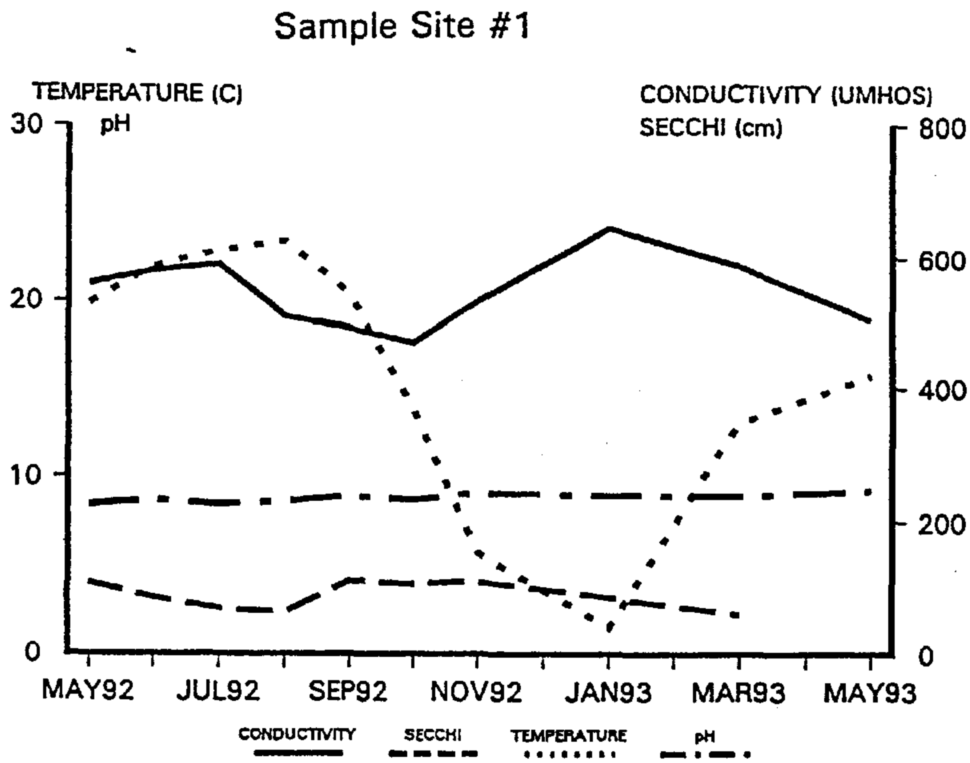


Fig. 1-71. Lake Ladora water quality measurements from Sample sites #1 and #2 collected between May 1992 and May 1993, RMANWR.



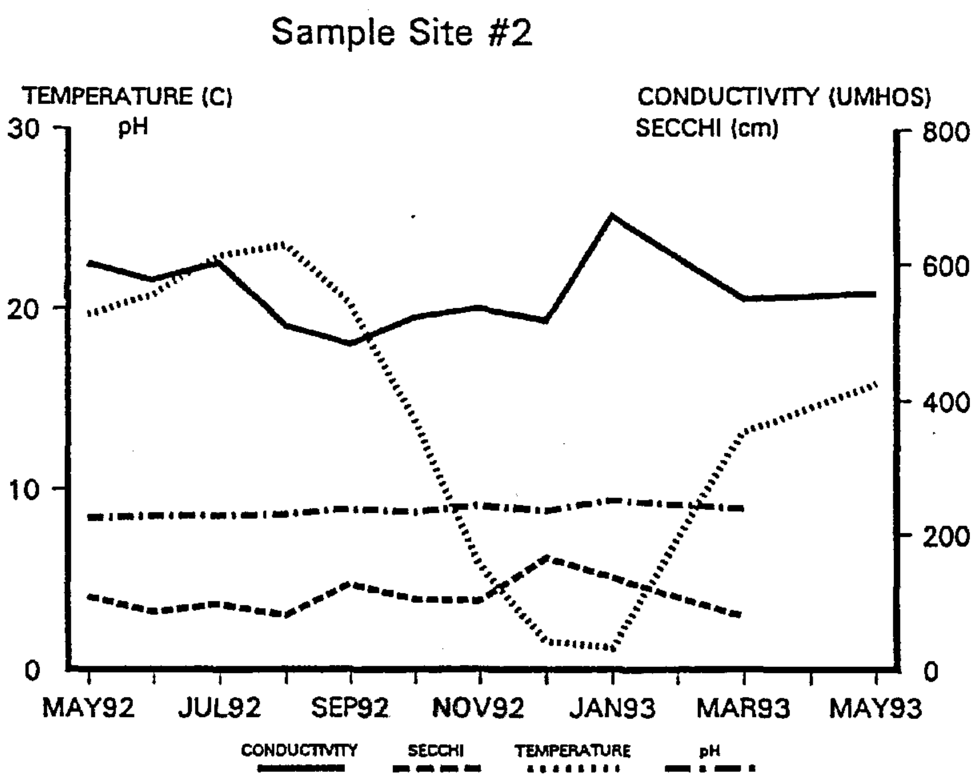


Fig. 1-72. Lake Lower Derby water quality measurements from Sample sites #1 and #2 collected between May 1992 and May 1993, RMANWR.

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TASK 2 - HABITAT ENHANCEMENT

TITLE: Mitigation on Rocky Mountain Arsenal National Wildlife Refuge

INTRODUCTION

The Cooperative Agreement for Conservation and Management of Fish and Wildlife Resources at Rocky Mountain Arsenal (U.S. Government 1989) defined a variety of Service responsibilities related to land use at Rocky Mountain Arsenal, later renamed Rocky Mountain Arsenal National Wildlife Refuge (Refuge). This agreement, revised in 1991 and 1993, includes Service responsibilities to: a) propose habitat mitigation efforts to offset potential adverse effects of remedial activities on fish and wildlife resources, b) coordinate with the Refuge staff to integrate fish and wildlife resource mitigation plans with other Refuge activities, c) maintain a complete record, including a photographic record of impacts to fish and wildlife resources and habitats and of mitigation responses to the same and d) incorporate results of fish and wildlife resource mitigation plan implementation into the annual reports (U.S. Government 1991 and 1993). The Service strived to meet the obligations of these agreements during FY 1994.

Project Plan Approval

The Service continued efforts to mitigate impacts on fish and wildlife habitat caused by cleanup-related activities. The Service worked closely with Army to avoid unnecessary damage to habitat and minimize unavoidable habitat losses. However, when adverse impacts to habitat occurred, the Service developed and implemented habitat restoration measures under the Mitigation Program to replace all habitat value lost.

The Service also worked closely with Army officials to refine a functional method for approving and implementing technical plans for habitat restoration projects. The complex 38-step process was revised to involve approximately 21 reviewers per plan. Each plan was subjected to a rigorous review by Service personnel at the Refuge, Army operational and legal staff and environmental consultants, Service and State archaeologists, Service contracting officials, and private contractors. Each plan required additional approval by Service and Army officials following any modifications pursuant to negotiations with the contractor's representative. A site-specific health and safety plan developed by the contractor was reviewed and approved by both Service and Army Health and Safety Officers before field work commenced.

Habitat Funding Alterations

In June, Army's Legal Office determined that the Service could no longer contract habitat restoration projects to independent contractors. Army believed that this contracting activity constituted "contract off-loading" whereby the contracting responsibility of one federal agency (i.e., the Army) is avoided or "off-loaded" onto another agency (i.e., the Service), with the additional overhead cost of the second agency. This decision prevented the Service from awarding new delivery orders to Total Terrain, a landscaping contractor, before most habitat restoration project plans could be processed.

Therefore, the Service and Army changed their strategy to implement habitat restoration projects at the Refuge. In the future, the Service will conduct most projects with its own employees and equipment. To accommodate this change, in FY 1994 the Service purchased equipment and materials needed for future projects with funds that otherwise would have been spent to contract for habitat restoration projects.

Jacobs Engineering

Jacobs Engineering (Jacobs) was awarded a five-year base operations contract by the Army to conduct engineering work at the Refuge. The Service was able to work with Jacobs in a similar manner as it had with United Engineers and Constructors (UE&C), the previous base operations contractor, to provide water to the five constructed wetlands in Sections 7 and 8 of the Refuge. Jacobs worked closely with the Service and the Service's contract research biologists to ensure that water level adjustment and other activities did not impact upon wildlife use of the wetlands, such as nesting American avocets (*Recurvirostra americana*), or wetland research efforts. Jacobs strived to maintain a maximum depth of 3.5 feet in Wetlands 1, 3, 4, and 5 (not including the conservation pool in Wetland 1), and a maximum depth of 2.5 feet in Wetland 2. The U.S. Geological Survey assisted Jacobs in monitoring the wetlands, using staff gages, Parshall flumes, and gaging stations.

Jacobs also was responsible for irrigating Habitat Restoration Project 19C (Enhancement of Wildlife Habitat in Northwest Corner of Section 2: Irrigation and Fencing). This task entailed expanding an existing irrigation system to serve two new trees planted in the area, then initiating and monitoring the system.

Total Terrain

The Service renewed the fourth year of a five-year contract with Total Terrain to conduct landscaping and revegetation on the Refuge, prior to the Army's decision to curtail this activity for future habitat restoration projects. Total Terrain continued to implement portions of numerous projects contracted prior to Army's off-loading determination (Table 2-1, Fig. 2-1). During FY 1994, Total Terrain continued to conduct four projects which had been funded, but not completed, prior to FY 1994:

Project 3B -- Revegetation in Northwestern Section 2
Project 4B, Phase 4 -- Shrub Planting at the Eagle Watch
Project 11 -- Restoration of Disturbed Areas at the Constructed Wetlands
Project 40A-- Closure and Revegetation of Roads in Sections 11 and 19

The Service also initiated six mitigation projects which had been funded prior to FY 1994, but were not initiated until FY 1994:

Project 29 -- Revegetation of Crested Wheatgrass Area in Section 29
Project 33 -- Cottonwood Planting
Project 34 -- Shrub Planting in Eastern Rocky Mountain Arsenal NWA
Project 42 -- Revegetation in Denver Museum of Natural History Study Plots
Project 45 -- Shrub Plantings within Vegetative Barriers
Project 50 -- Mitigation Assistance

Project 50 was developed to perform additional maintenance on seven previously funded projects:

Project 1 -- Wetland Construction
Project 3B -- Revegetation in Northwestern Section 2
Project 5 -- Enhancement of Wildlife Habitat in Section 34
Project 19C-- Restoration and Diversification of Wildlife Habitat in Northwestern Corner of Section 2: Irrigation and Fencing of Shrubs and Trees
Project 26 -- Construction and Installation of Wildlife Guzzlers
Project 27B-- Habitat Restoration for the Bald Eagle Management Area
Project 40 -- Road Closure and Revegetation

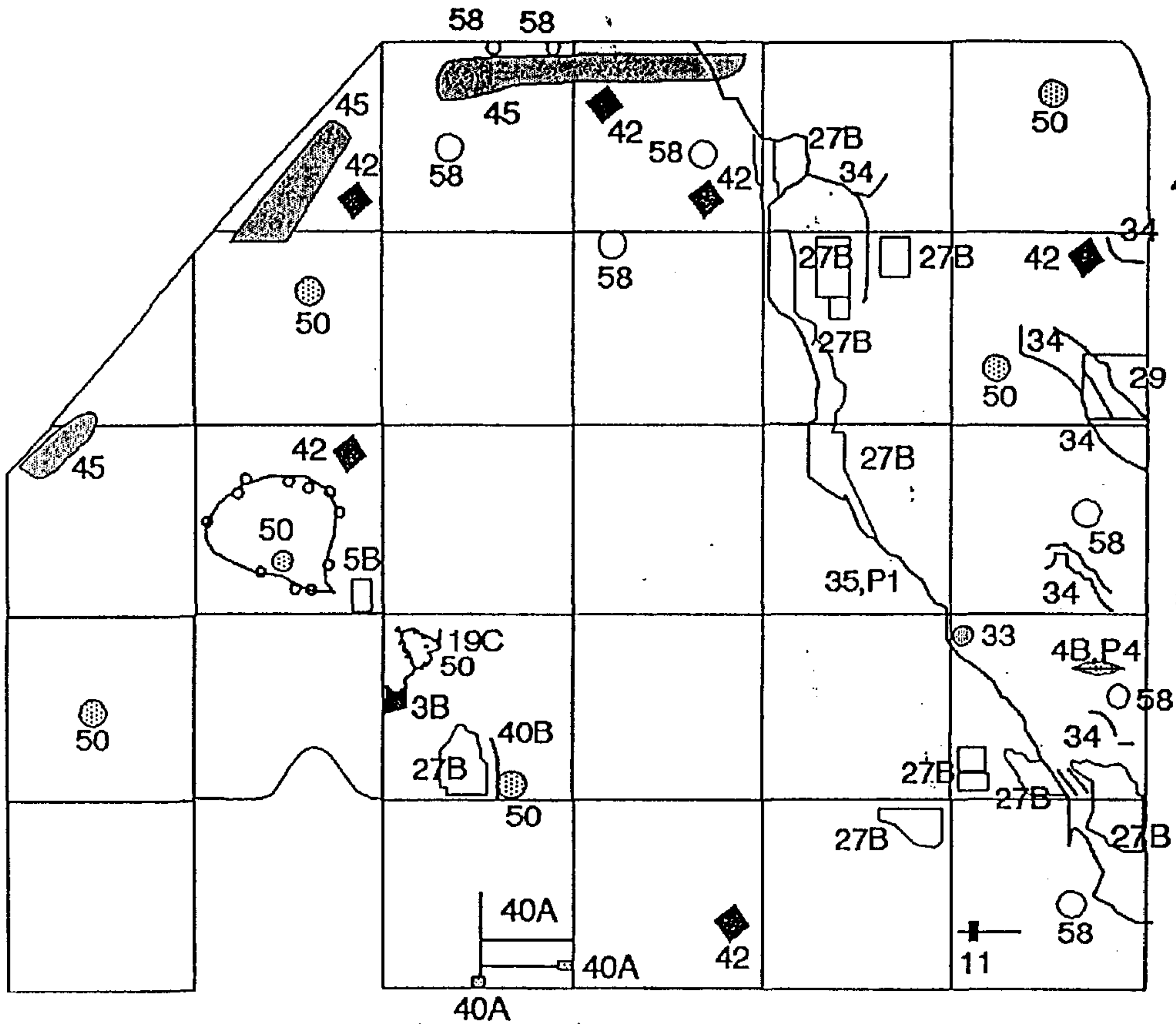
Table 2-1. Status of mitigation projects, Rocky Mountain Arsenal National Wildlife Refuge, FY 1994.

Project Number	Project Description	Contractor	Continued in FY 1994	Initiated in FY 1994 or will be initiated in FY 1995	Completed FY 1994*
3B	Revegetation in Northwestern Section 2	Total Terrain	X		X
4B, P4	Shrub Planting at the Eagle Watch	Total Terrain	X		X
5B	Revegetation of Barracks Area, Section 34	Total Terrain	X		
11	Revegetation of Wetland Roads	Total Terrain	X		X
19C	Fencing/Irrigation of Shrubs and Trees	Jacobs	X		
27B	BEMA Habitat Restoration	MK/Phillips	X		
29	Reveg. of Crested Wheatgrass, Section 29	Total Terrain		X	X
33	Cottonwood Planting	Total Terrain		X	X
34	Shrub Plantings in Eastern RMANWA	Total Terrain		X	X
35,P1	Redesign of First Creek	Roybal/McLaughlin	X		X
35,P1 Mod	Redesign of First Creek	Roybal/McLaughlin		X	X

Table 2-1 (Continued).

Project Number	Project Description	Contractor	Continued in FY 1994	Initiated in FY 1994 or will be initiated in FY 1995	Completed FY 1994*
40A	Closure/Revegetation of Abandoned Roads	Total Terrain	X		X
40B	Closure/Revegetation of Abandoned Roads	Morrison Knudsen		X	X
42	Revegetation of DMNH Plots	Total Terrain	X		
45	Shrub Plantings within Vegetative Barriers	Total Terrain		X	X
50	Mitigation Assistance	Total Terrain		X	X
58	Russian Knapweed Control	Total Terrain		X	

* Does not include guaranteed replacement of dead shrubs and trees.



PROJECT:

3B - Revegetation at Visitor Center
4B,P4 - Shrub Planting at Eagle Watch
5B - Revegetation at Barracks Area
11 - Wetland Road Revegetation
19C - Fencing and Irrigation
27B - BEMA Habitat Manipulation
29 - Revegetation in Section 34
33 - Cottonwood Plantings
34 - Shrubs in Eastern RMANWR
35,P1 - Redesign of First Creek (all of creek - including Mod.)
40A - Revegetation and Closure of Abandoned Roads
40B - Revegetation and Closure of Abandoned Roads
42 - Revegetation of DMNH Plots
45 - Shrub Plantings in BC Systems
50 - Mitigation Assistance
58 - Russian Knapweed Control

Figure 2-1. Map of mitigation projects partially or completely conducted during FY 1994, Rocky Mountain Arsenal National Wildlife Refuge.

One delivery order (Project 5B -- Revegetation of Barracks Area in Section 34) was awarded to Total Terrain prior to FY 1994, but will not be initiated until FY 1995, due to conflicts with Army projects on the same site. The Service awarded only one new habitat-related delivery order to Total Terrain during FY 1994 (Project 58 -- Restoration of Russian Knapweed Areas in Rocky Mountain Arsenal National Wildlife Area), for which the Contractor mowed eight sites containing knapweed (Centauria repens), a noxious exotic plant, and disced and seeded one site with western wheatgrass (Agropyron smithii).

Facilities Maintenance

Army's Facilities Maintenance (FM) division was responsible for maintaining several previous projects. Most of these projects involved watering plants (by hand or with irrigation systems), weeding, planting shrubs, applying wildlife repellent, and installing seedling protectors.

Roybal/McLaughlin

The Roybal Corporation subcontracted the conceptual design (i.e., Title I Services) for the Redesign of First Creek (Project 35, Phase 1) to McLaughlin Water Engineers (McLaughlin). McLaughlin subcontracted the vegetation aspects of their study to Aquatic Wetland Consultants. These two contractors were to provide an initial project design to construct and/or restore wetlands, stream meanders, riparian vegetation, etc., along most of the First Creek corridor on the Refuge. In FY 1994, the Service modified the delivery order for Title I Services to include the First Creek corridor in Section 8. This modification concentrated on an alternative design for a storm water detention basin, which may be required to detain flood water at this point in the future. The two studies were combined for the purposes of the final report and drawings.

National Park Service/Southwest Cultural Associates

As a federal agency, the Service is mandated by the Antiquities Act of 1906, the National Historic Preservation Act of 1966, Executive Order 11593 of 1971, and the Archaeological and Historic Preservation Act of 1974 to identify, preserve, and protect important cultural resources. Thus the Service and Army initiated a program during FY 1993 to meet these archaeological requirements. The Service accepted responsibility for contracting this work because habitat restoration projects would likely disturb areas not previously surveyed for cultural resources. The National Park Service (NPS) provided a Contracting Officer Representative and the Service provided an on-site daily point of contact to track the project.

The original survey was designed to cover 6,025 acres. The Service awarded an additional delivery order to the contractor during FY 1994 after discovering that approximately 5,700 additional acres would need to be surveyed to meet the requirements of the State Historic Preservation Office.

Morrison Knudsen

BEMA Habitat Manipulations - Project 27B

Morrison Knudsen (MK) continued Project 27B (Habitat Restoration for the Bald Eagle Management Area) mostly by evaluating vegetation health. This habitat restoration project, involving 9 separate tasks with an aggregate of 20 sites (Fig. 2-2), was initiated in 1989 to produce sand prairie, tallgrass prairie, mixed-grass prairie, western wheatgrass, a source of native grass seed mulch, and two sets of experimental plots. The individual tasks were designed to offset the loss of wildlife habitat from portions of Section 9 leased to Stapleton International Airport and from habitat disturbances on-post, diversify wildlife habitat and the raptor prey base, and identify the

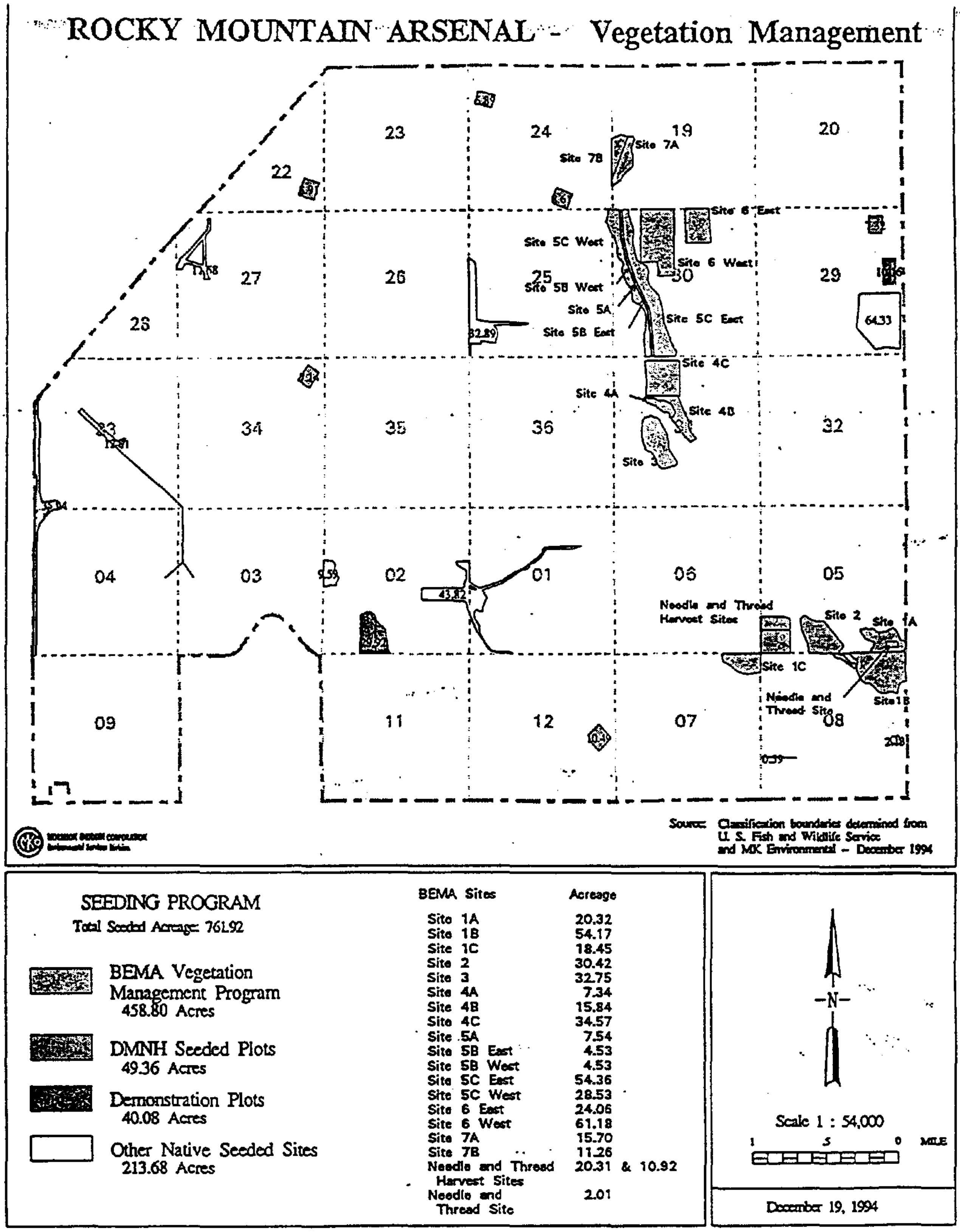


Fig. 2-2. Locations of habitat restoration projects conducted by Morrison Knudsen at Rocky Mountain Arsenal National Wildlife Refuge, 1989-1994.

most appropriate methods for establishing prairie communities during future mitigation projects at the Refuge. Prairie dogs (Cynomys ludovicianus) and lagomorphs (rabbits and hares) were used to define the raptor prey base.

MK monitored all BEMA sites using permanent line-point transects and Revegetation Information Monitoring and Analysis, Version 2.00 to measure and analyze vegetation (see Technical Plan 27B, U.S. Government 1994). Although MK did not conduct much of the revegetation field work (e.g., seeding) in FY 1994, their 1993 methods are described below to explain the FY 1994 results.

Agricultural methods used to improve BEMA sites included weed control (e.g., moldboard plowing, discing, applying herbicides, and mowing), soil preparation (e.g., moldboard plowing, chiseling, discing, harrowing), fertilizing, seeding (e.g., drilling, broadcasting), mulching (e.g., spreading, crimping), and transplanting shrubs with a transplanter attachment for a tractor. See Habitat Restoration Plan 27B for details.

Specifically, within BEMA Sites 1A, 1B, 1C, 2, 4A, 5A, 5B, 5C, 6E, 6W, 7A, and 7B, one opening per acre was seeded with forbs and shrubs (Tables 2-2 to 2-4) on 1 April 1993. The openings, which average five feet in diameter, were created with a tiller tractor attachment.

Four test plots in Section 29 were the only sites entirely seeded in FY 1993. Plots 1-4 were seeded with four separate seed mixes (Table 2-5) and mulched on 10 March 1993 to compare with the same seed mixes planted in Section 29 and the sandy soils of the Ladora Test Plots during previous fall periods and in Ladora during a previous spring.

On 6 July 1993, BEMA Site 1B was spot-sprayed with a herbicide mixture of Telar/2,4-D/Banvel/Surfactant to control Canada thistle (Cirsium arvense).

The lowest portion of BEMA Site 1C was sprayed with a Diquat/Surfactant mixture on 25 May to control cheatgrass (Bromus tectorum), and the same site was spot-treated with a 2,4-D/Banvel/Surfactant mixture on 5 July to control Canada thistle. On 30 September, BEMA Sites 4A, 4B, and N&T-North were treated with Telar/2,4-D amine/Surfactant, and the N&T-South site was spot-treated with the same mixture to control Canada and musk thistle (Carduus nutans). A Telar/2,4-D/Surfactant mixture was applied to Canada thistle and musk thistle within BEMA Site 5C, N&T-South, and Ladora Test Plots on 7 July, 21 May, and 21 May, respectively. Portions of N&T-South and Ladora Test Plots were also treated with the Diquat/Surfactant on 21 May to control cheatgrass.

The western side of BEMA Site 1B was mowed to control annual weeds on 16 July. The entire areas of sites 4A, 4B, and N&T-North were mowed for weed control on 29 July, 16 July and 15 July, respectively.

Table 2-2. Seed Mixes/Seeding Rates for Sites 1A, 1B, 1C, 2, 5A, 5B, and 5C, Bald Eagle Management Area, Rocky Mountain Arsenal National Wildlife Refuge, 1993.

Species	Common Name	Pounds PLS[1]/acre
Cleome serrulata	Rocky Mountain bee plant	0.25
Liatris punctata	Blazing-star	0.25
Gaillardia aristata	Blanket flower	0.25
Penstemon angustifolia	Narrow-leaf penstemon	0.25
Linum lewisii	Blue flax	0.25
Achillea lanulosa	Yarrow	0.25
Artemisia ludoviciana	Louisiana sagewort	0.025
Coreopsis tinctoria	Plains coreopsis	0.25
Sphaeralcea coccinea	Scarlet globemallow	0.25
Artemisia frigida	Fringed sage	0.025
Abronia fragrans	Sand verbena	0.25
Artemisia filifolia	Sand sagebrush	1.25
Chrysothamnus nauseosus	Rubber rabbitbrush	0.1
	TOTAL	3.65

[1] Pure live seed

Table 2-3. Seed Mixes/Seeding Rates for Site 4A, 7A and 7B, Bald Eagle Management Area, Rocky Mountain Arsenal National Wildlife Refuge, 1993.

Species	Common Name	Pounds PLS/acre
Asclepias tuberosa	Butterfly weed	0.25
Echinacea angustifolia	Purple coneflower	0.5
Helianthus annuus	Annual sunflower	0.1
Petalostemum purpureum	Purple prairie clover	0.1
Ratibida columnifera	Coneflower	0.1
Rudbeckia hirta	Black-eyed Susan	0.1
Prunus virginiana	Chokecherry	0.1
Atriplex canescens	Four-wing saltbush	0.2
Rhus trilobata	Skunkbrush sumac	0.1
Rosa woodsii	Wood's rose	0.1
Ribes aureum	Golden current	0.1
Shepherdia argentea	Silver buffaloberry	0.1
	TOTAL	1.85

Table 2-4. Seed Mixes/Seeding Rates for Site 6E and 6W, Bald Eagle Management Area, Rocky Mountain Arsenal National Wildlife Refuge, 1993.

Species	Common Name	Pounds PLS/acre
Gaillardia aristata	Blanket flower	0.1
Penstemon angustifolia	Narrow-leaf penstemon	0.1
Linum lewisii	Blue flax	0.1
Helianthus annuus	Annual sunflower	0.1
Achillea lanulosa	Yarrow	0.1
Artemisia ludoviciana	Louisiana sagewort	0.01
Sphaeralcea coccinea	Scarlet globemallow	0.1
Artemisia frigida	Fringed sage	0.01
	TOTAL	0.62

Table 2-5. Seed Mixes/Seeding Rates for Ladora and Section 29 Test Plots, Bald Eagle Management Area, Rocky Mountain Arsenal National Wildlife Refuge, 1993.

Species	Common Name	Variety	Pounds PLS/acre
	PLOT 1		
Andropogon hallii	Sand Bluestem	Woodward	3.8
Stipa comata	Needle-and-thread	Native	3.6
Oryzopsis hymenoides	Indian Ricegrass	Nespar	3.4
Calomovilfa longifolia	Prairie Sandreed	Goshen	1.4
Sporobolus cryptandra	Sand Dropseed	Native	0.7
Bouteloua gracilis	Blue Grama	Hachita	0.6
		TOTAL	13.5
	PLOT 2		
Buchloe dactyloides	Buffalograss	Sharp's Imp	8.0
Agropyron smithii	Western Wheatgrass	Arriba	4.9
Bouteloua gracilis	Blue Grama	Hachita	0.7
		TOTAL	13.6
	PLOT 3		
Stipa viridula	Green Needlegrass	Lodorm	3.5
Andropogon gerardii	Big Bluestem	Pawnee	3.6
Elytriga dasystachya	Thickspike Wheat	Critana	2.6
Sorghastrum avenaceum	Indiangrass	Holt	2.3
Panicum virgatum	Switchgrass	Neb 28	1.2
		TOTAL	13.2
	PLOT 4		
Agropyron smithii	Western Wheatgrass	Arriba	4.9
Elymus trachycaulus	Slender Wheatgrass	Revenue	2.9
Bouteloua curtipendula	Side-oats Grama	Vaughn	2.8
Schizachyrium scoparium	Little Bluestem	Pastura	2.1
Poa canbyii	Canby Bluegrass	Canbar	0.6
		TOTAL	13.3

Ladora and Section 29 Demonstration Areas

These plots were designed to demonstrate prairie restoration techniques and compare differences between spring and fall planting of varied seed mixes in Bresser sandy loam soil, characteristic of southern portions of the Refuge, and Weld loam, characteristic of northern portions of the Refuge.

Test plots were established west of Lake Ladora in Section 3 in conjunction with a planned visitor trail and recreation system. Approximately 30 acres of Bresser sandy loam were designated for this purpose. In late September 1991, eight one-acre plots were staked within the test area. The four plots on the northern end of the area were designated for seeding in fall 1991 and the four plots on the southern end were designated for seeding in spring 1992. Each of four fall plots received a different seed mix; spring plots received the same four seed mixes as fall plots. All eight plots were mowed in early June and early July 1992 and sprayed with herbicides at the end of July. During 1993, herbicides were applied again to control persistent Canada thistle and a dense infestation of musk thistle that were adversely affecting the seeded species.

A similar plot design was employed in Section 29 during fall 1992 and spring 1993. These plots were designed to compare the revegetation potential of Weld loam soils in Section 29 with the Bresser sandy loam soils in Section 3, using the same seed mixes as the Ladora plots. Weld loam soils have a higher clay content than the Bresser sandy loam soils. The entire site was mowed and turned with a moldboard plow in May 1992. It was left fallow for the summer, after which the soil was prepared and fall plots were seeded in October 1992. Spring plots were seeded in the spring of 1993. No weed control activity was required for this area.

Lower Derby Dam Spillway

Cover data have been collected on the area disturbed and re-seeded during the construction of the Lower Derby Lake spillway. Unique among the seeded sites at the Refuge, this area was dominated by sand sagebrush (*Artemisia filifolia*) prior to disturbance, and topsoil was salvaged from the site and spread over the area following disturbance. The area was seeded with a native seed mix, and barley straw was applied as a mulch over the area. Work was conducted in fall 1990.

Roads in Section 2

Phillips Seeding Company (Phillips) mowed, chiseled, and broadcast seed on 475 feet of a two-track road closed to vehicular traffic (Project 40B, Closure and Revegetation of Road in Southwestern Section 2). Phillips conducted this work for MK in conjunction with a portion of Project 50, for which Total Terrain planted 16 shrubs at one end of this road.

Service

Service personnel were active throughout FY 1994 to prevent unnecessary damage to wildlife habitat. Service personnel designed habitat restoration plans to compensate for habitat destroyed or degraded by Interim Response Actions and other cleanup-related activities, infrastructure construction and maintenance, and other disturbances. Service personnel also worked closely with mitigation contractors and inspected all mitigation projects both in-progress and after completion to maximize habitat value gained from these projects. The Service conducted 117 formal inspections of Total Terrain's work during FY 1994.

The Service continued a Habitat Assessment Program at the Refuge to evaluate fish and wildlife habitat, identify sensitive and essential habitats, quantify habitat losses due to disturbance and monitor habitat gains due to mitigation. Beginning in 1992 the Service differentiated the Refuge into eight Habitat

Types: 1) lacustrine, 2) wetland, 3) riverine/riparian, 4) upland trees, 5) shrubland/succulents, 6) native perennial grasses, 7) weedy forbs/grasses, and 8) disturbed. Each of these habitats was further classified according to the Service's Mitigation Policy (1981) into one of four "Resource Categories" based on its relative value to wildlife and regional scarcity. Designation of Resource Categories not only identifies which habitats are valuable and require protection, but prescribes the type(s) of mitigation acceptable for each classification. Resource Category 1 habitats are so valuable and/or scarce that no loss of existing habitat value is acceptable. No habitats at the Refuge have been classified as Resource Category 1. The mitigation planning goal for Resource Category 2 habitats, which are valuable for wildlife and relatively scarce, is no net loss of in-kind habitat value. This category includes Habitat Types 1-6 above. No net loss of habitat value (in-kind or out-of-kind) is preferred for Resource Category 3 habitats, which may be valuable for wildlife but are relatively abundant, including Habitat Type 7. Resource Category 4, for which the mitigation planning goal is to minimize the loss of habitat value, is assigned to habitats with relatively little value for wildlife, including Habitat Type 8.

The Service initiated field data collection for Habitat Evaluation Procedures (HEP) in FY 1994. HEP is a computer-based habitat modeling protocol which integrates structural, spatial, and temporal habitat variables to quantify habitat value for wildlife. Personnel from Argonne National Lab conducted the HEP with oversight by the Service and the National Biological Survey. This Habitat Assessment Program will continue throughout the remediation process.

To assist the Army in planning to mitigate the adverse impacts of both past and future contaminant remediation activities and other disturbances, the Service continued to update and refine its mitigation "balance sheet" which balances fish and wildlife habitat losses due to cleanup activities and other disturbances against habitat gains from mitigation projects. The balance sheet identifies specific habitat disturbances on the Refuge and their corresponding mitigation projects, and tabulates additional information such as the size of the areas, habitat types and Resource Categories affected by the disturbance, and habitat value units gained due to mitigation.

The Service also expanded its photography program to document implementation of mitigation projects and the impacts to fish and wildlife habitat caused by cleanup and other activities. Service personnel used 35mm single lens reflex cameras and interchangeable lenses to photograph impacted areas, document site conditions prior to implementation of mitigation projects, contractor work-in-progress, and success of revegetated sites. Photographs were recorded on 35mm color positive transparency (slide) film. Each slide was processed, mounted, labeled with a unique identifying number and description, and entered into a computer database system for future reference and presentations.

The Service worked on a variety of other significant habitat-related programs during FY 1994. The Service 1) initiated a fire management program through discussions with Service Regional Office personnel; 2) submitted Pesticide Use Proposals to the Regional Office for approval to apply several herbicides in revegetation plots; 3) developed long-range cost estimates by extrapolating contractor habitat restoration costs per acre of grassland and per plant for shrubs and trees; 4) assisted Army to identify acceptable borrow sites, select appropriate seed mixes, and evaluate past habitat damages; 5) evaluated future water needs; 6) evaluated lands at Stapleton International Airport and Denver International Airport for potential acquisition, conservation easement, or management agreement; 7) reviewed the Detailed Analysis of Alternatives for Contaminant Remediation to evaluate the relative impacts of each alternative on fish and wildlife habitats; and 8) participated in interagency planning for storm water management in Irondale Gulch and reviewed a draft Irondale Gulch Interagency Agreement.

RESULTS AND DISCUSSION

Jacobs Engineering

The Service worked with Jacobs to supply water to five artificial wetlands in Sections 7 and 8 in the southeastern portion of the Refuge during FY 1994. Water was available for the wetlands earlier than in the past; however, later in the summer, less water than normal was available because of the unusually hot, dry weather.

Water was delivered to the wetlands beginning on the following dates: 12 May, 25 May, and 22 August. Jacobs attempted to maintain water at levels optimal for wetland research projects (Appendix A), although filling Wetland 1 was delayed for several weeks to protect nesting avocets. Each of the wetlands was refilled from the Highline Canal as water became available during summer.

Jacobs Engineering was unable to irrigate the trees and shrubs in Section 2 (Tasks 19C). Twelve cottonwoods died, more than half of which were due to the lack of water. Most other plants appeared heat stressed but survived.

Total Terrain

Total Terrain worked on 11 of 12 projects awarded prior to FY 1994. One of the most intensive efforts was a revegetation project adjacent to the Visitor Center (Project 3B), for which Total Terrain fertilized, interseeded, and controlled weeds on four different prairie demonstration plots. They also planted 133 shrubs and 6 trees, mulched 287 shrubs and trees, and periodically sprayed wildlife repellent on all woody plants. Unfortunately, completion of the irrigation system for this project was delayed due to problems installing an appropriate backflow preventor. Inadequate early moisture probably was responsible for low germination of many native species. Certain species did well, particularly in the tallgrass area, despite the lack of water. These species are switchgrass, witchgrass (Panicum capillare), big bluestem, little bluestem, foxtail barley (Hordeum jubatum), yellow Indiangrass, sideoats grama, and blanket flower. Other areas exhibited excellent germination of blue flax, prairie coneflower, and fringed sage seed. After protective fences were removed to improve aesthetics, most species of shrubs were heavily browsed by deer despite the application of wildlife repellent.

Total Terrain completed its responsibilities for Project 4B, Phase 4, by drip irrigating 400 shrubs (rubber rabbitbrush and sand sagebrush) adjacent to the Eagle Watch throughout the summer. Most shrubs responded dramatically to irrigation by growing very tall. Even plants that had been chewed to the ground by prairie dogs recovered well with the addition of water and the absence of further depredation by prairie dogs. Measures specifically taken to exclude prairie dogs from the site were partly responsible for the absence of depredation, but the prairie dog population also declined dramatically due to an outbreak of the sylvatic plague epizootic.

Total Terrain tilled and seeded a 64-acre crested wheatgrass (Agropyron cristatum) stand in southeastern Section 29 using a native grass/forb/shrub seed mix (Table 2-6) in early FY 1994.

Table 2-6. Seed mix in southeastern corner of Section 29, Rocky Mountain Arsenal National Wildlife Refuge, FY 1994.

Species	Common Name	Variety	Pounds PLS/acre
Bouteloua gracilis	Blue grama	Hachita	0.9
Agropyron smithii	Western wheatgrass	Arriba	6.5
Buchloe dactyloides	Buffalo grass	Sharp's	12.9
Erysimum asperum	Western wallflower		0.1
Gaillardia aristata	Blanket flower		0.1
Penstemon angustifolius	Narrow-leaf penstemon		0.1
Linum pratense lewisii	Blue flax		0.1
Helianthus annuus	Annual sunflower		0.1
Achillea millefolium	Yarrow		0.1
Sphaeralcea coccinea	Scarlet globemallow		0.1
Artemisia ludoviciana	Louisiana sagewort		0.1
Artemisia frigida	Fringed sage		0.01
Dalea purpurea	Purple prairie-clover		0.1
Oenothera caespitosa	White tufted evening primrose		0.1
		TOTAL	21.31

Visual inspections of the site revealed that western wheatgrass and several native forbs were relatively successful. Native grass hay mulch was spread over the majority of this area; however, Kiwi Green, a less expensive soil moisture retention product, was applied instead of mulch to five acres to evaluate this product as a cost effective alternative to enhance germination and growth of native species, especially warm season species. It would be premature to base conclusions on these preliminary data after only one growing season and without an adequate control site for comparison. However, MK's preliminary data indicate that such a product may be useful in establishing native species. Data after one year show that cover by cool season species was greater (7% vs. 2%) in the Kiwi Green treated area than in the mulched area. However, cover by cheatgrass was also greater (5% vs. trace) in the Kiwi Green area than in the mulched area. And a greater cheatgrass component initially may result in a less desirable plant community in future years. It also must be stressed that there was not a control area with neither grass mulch nor Kiwi Green for comparison. Future comparisons of these two treatments may provide additional insight for prairie restoration at the refuge.

Total Terrain planted 7090 seedling and bareroot shrubs in numerous pre-selected sites in the eastern portion of the Refuge (Project 34 -- Shrub Planting in Eastern Rocky Mountain Arsenal National Wildlife Area). Of these, 570 were planted adjacent to the Eagle Watch and protected from depredation with seedling protectors. The remainder were planted in meandering strips using weed barrier to retain soil moisture. Approximately one-third of the latter shrubs were protected with seedling protectors, and the rest were sprayed with wildlife repellent. Visual inspections revealed that rubber rabbitbrush, winterfat, and three-leaf sumac did relatively well; the rabbitbrush and winterfat did not require seedling protectors to survive. Woods' rose (Rosa woodsii) and sand sagebrush also did relatively well, while Prunus and Symphoricarpus species did not.

Total Terrain also completed revegetating the road into Wetland 1 by planting 326 additional shrub seedlings. Visual inspections indicated that most of these shrubs survived despite the hot, dry summer.

Total Terrain planted 20 cottonwoods in northwestern Section 5 along First Creek. The trees were also fenced, mulched, and watered. However, unusually hot, dry weather appeared to kill half of the trees. Dead trees will be replaced by Total Terrain during FY 1995.

Total Terrain planted 128 five-gallon rubber rabbitbrush shrubs in clusters of 16 to discourage people from driving on unnecessary two-track roads (Project 40A -- Closure and Revegetation of Roads in Sections 11 and 19). Prairie dogs subsequently destroyed 12 of these shrubs. Total Terrain installed snowdrift fencing around two of the shrub clusters and the Service attached polyweave material to the fences to protect the shrubs from prairie dogs. Total Terrain guaranteed 70% survival of the shrubs. They also seeded 3.5 acres of the closed roads with native grasses and forbs (Table 2-7); however, most seed did not germinate due to harsh, dry weather conditions. Additional precipitation during 1995 could cause dormant seed to germinate without further Service action.

Total Terrain controlled weeds in six inactive study plots (Project 42, Revegetation of the Denver Museum of Natural History Study Plots) and interseeded three of them (Tables 2-8 and 2-9, Fig. 2-1). Weed control was limited to mowing and spot-spraying with 2,4-D. Response to seeding will be evaluated during FY 1995.

Total Terrain planted 5387 seedling and bareroot shrubs (including 316 replacement shrubs) in numerous lanes in the North Boundary, Northwest Boundary, and Irondale Containment Systems (Project 45 -- Shrub Planting in Vegetative Barriers). Most shrubs did not survive, with the lowest survival in the North Boundary Containment System. The likely causes of poor survival are that the shrubs were planted too late in the spring, weed barrier was not installed immediately after planting, and natural moisture was inadequate due to drought conditions. Seventy percent survival of the shrubs is guaranteed.

The Service awarded Total Terrain one delivery order (Project 50 -- Mitigation Assistance) that involved mostly maintenance of previous projects. Under this plan, Total Terrain watered trees and shrubs for Project 3B, mowed weeds for Project 19C, cleaned guzzlers for Project 26, and planted shrubs for Project 40 in FY 1994. During FY 1995, Total Terrain will complete responsibilities for planting shrubs for Projects 1 and 27B and watering shrubs for Project 5.

Table 2-7. Seed mix for road closures in Sections 11 and 19, Rocky Mountain Arsenal National Wildlife Refuge, 1994.

Species	Common Name	Variety	Pounds PLS/acre
Bouteloua gracilis	Blue Grama	Hachita	2.2
Agropyron smithii	Western Wheatgrass	Arriba	13.0
Sporobolus cryptandrus	Sand Dropseed		0.2
Calamovilfa longifolia	Prairie Sandreed	Goshen	0.8
Bouteloua curtipendula	Side-oats Grama	Vaughn	1.2
Stipa comata	Needle-and-thread		3.8
Andropogon hallii	Sand Bluestem	Woodward	2.0
Oryzopsis hymenoides	Indian Ricegrass	Nezpar	1.6
		SUBTOTAL	24.8
Linum pratense lewisii	Blue Flax		0.2
Helianthus annuus	Annual Sunflower		0.2
Achillea lanulosa	Yarrow		0.2
Sphaeralcea coccinea	Scarlet Globemallow		0.2
Artemisia ludoviciana	Louisiana Sagewort		0.2
Artemisia frigida	Fringed Sage		0.02
Delphinium virescens	Larkspur		0.2
Cleome serrulata	Rocky Mountain Bee Plant		0.2
Gaillardia aristata	Blanket Flower		0.2
Penstemon angustifolia	Narrow leaf Penstemon		0.2
Yucca glauca	Yucca		0.02
Atriplex canescens	Fourwing Saltbush		0.2
Coreopsis tinctoria	Plains Coreopsis		0.2
Artemisia filifolia	Sand Sagebrush		0.2
		TOTAL	27.24
Buchloe dactyloides*	Buffalo Grass	Sharp's	23.4

* Track 3, east of the locust thicket only

Table 2-8. Seed mix for habitat restoration Site CW-C, Section 22, Rocky Mountain Arsenal National Wildlife Refuge, 1994.

Species	Common Name	Variety	Pounds PLS/acre
Calamovilfa longifolia	Prairie sandreed	Goshen	2.5
Andropogon hallii	Sand bluestem	Woodward	5.5
Bouteloua gracilis	Blue grama	Hachita	1.0
Cleome serrulata	Rocky Mountain Bee Plant		0.1
Delphinium virescens	Larkspur		0.1
Liatris punctata	Blazing-star		0.1
Ipomoea leptophylla	Bush morning glory		0.1
Penstemon angustifolius	Narrow-leaf penstemon		0.1
Achillea millefolium	Yarrow		0.1
Abronia fragrans	Sand verbena		0.1
		TOTAL	9.7

Table 2-9. Seed mix for restoration Sites CW-D and WF-A, Sections 29 and 24, Rocky Mountain Arsenal National Wildlife Refuge, 1994.

Species	Common Name	Variety	Pounds PLS/acre
Bouteloua gracilis	Blue grama	Hachita	1.0
Buchloe dactyloides	Buffalo grass	Sharp's Impr.	13.0
Cleome serrulata	Rocky Mountain Bee Plant		0.1
Delphinium virescens	Larkspur		0.1
Liatris punctata	Blazing-star		0.1
Oenothera caespitosa	Stemless evening primrose		0.1
Penstemon angustifolius	Narrow-leaf penstemon		0.1
Linum pratense lewisii	Blue flax		0.1
Achillea millefolium	Yarrow		0.1
Artemisia ludoviciana	Louisiana sagewort		0.1
Coreopsis tinctoria	Plains coreopsis		0.1
Sphaeralcea coccinea	Scarlet globemallow		0.1
Artemisia frigida	Fringed sage		0.1
Astragalus missouriensis	Missouri milkvetch		0.1
Antennaria rosia	Pussytoes		0.1
Erysimum asperum	Western wallflower		0.1
Vicia americana	American vetch		0.1
Ratibida columnaris	Prairie coneflower		0.1
		TOTAL	9.7

Facilities Maintenance

FM weeded all shrub sites adjacent to BEMA gates, helped install the backflow preventor at the Visitor Center, and watered the cottonwoods at Building 611, seedlings at Building 613, and wildflowers along a trail in southwestern Section 2. However, reductions in staff limited FM's ability to assist the Service, and several planned projects were not conducted.

Roybal/McLaughlin

McLaughlin Water Engineers, along with Aquatic Wetland Consultants, had completed the conceptual design to construct and/or restore wetlands, stream meanders, riparian vegetation, etc. within most of the First Creek corridor within the Refuge when the Service modified the delivery order to include Title I Services for the First Creek corridor in Section 8. The two studies were combined and the final report was submitted to the Service in June (McLaughlin 1994). The report identified numerous opportunities for restoring meanders, wetlands, and riparian vegetation, and removing some anthropogenic structures (e.g., earthen dams), and provided an acceptable design for the Bald Eagle Shallows storm water detention basin. Title II Services for the final design should be conducted during FY 1995.

National Park Service/Southwest Cultural Associates

Southwest Cultural Associates (SWCA) was awarded the archaeological services contract. SWCA had surveyed approximately 6025 acres before the Service expanded the project to include an additional 5700 acres. SWCA completed most of the survey during FY 1994. Of 175 cultural resources recorded, 27 were determined to be prehistoric, 70 were historic sites, 8 were multi-component sites that contained both prehistoric and historic components, 26 were prehistoric isolated finds, and 44 were historic isolated finds. Three of the prehistoric sites had been previously recorded.

To date, seven sites have been recommended for formal testing. Testing was completed on three of these sites. SWCA initiated two test units at another site before weather forced them to abandon the work until spring.

Numerous historic sites (e.g., homesteads) were identified during the survey. Aerial photo surveys revealed that only 6 of 52 known historic sites in the southern tier (Sections 7, 8, 11, and 12) had been described by a cultural resources contractor who surveyed this area in 1984. SWCA and the Service are negotiating to include these sites in the SWCA project.

Morrison Knudsen

BEMA Habitat Manipulations (Project 27B)

Although low rainfall during the growing season of 1994 was very poor for vegetation growth, most habitat manipulation projects in the BEMA continued to be successful. Seeded species have become well established at most of the 20 BEMA sites, and vegetative cover is adequate to prevent erosion and provide a stable forage base. Total vegetation cover and species diversity was somewhat lower at many sites in 1994 because rainfall was inadequate during the growing season; however, cover provided by perennial species was essentially the same as in previous years. Establishing shrub species from seed continues to be problematic, although a few fringed sage plants have successfully germinated at most seeded sites.

After five growing seasons, cover provided by cool and warm season grasses and perennial forbs apparently is stable. The area covered by grasses and forbs adapted to site conditions has not fluctuated significantly after their initial establishment. Growth during both wet and dry growing seasons has produced about the same level of cover by these species. Although biomass was not measured, we would expect biomass production to vary considerably more with moisture. Needle-and-thread grass is the most important cool season species at this site. It occurs as a volunteer from seed both in the soil seed bank and from harvested needle-and-thread mulch spread specifically for this purpose. A variety of warm season grass species has been established at this site, providing considerable cover. Sand dropseed, blue grama, sand bluestem and switchgrass are important grass species, while western ragweed (Ambrosia psilostachya) has become the most common perennial forb at this location.

Annual grasses and forbs have not exhibited the same stability as perennial species. During 1994, the driest year of data collection, annual grasses, dominated by cheatgrass, achieved the highest cover value, and annual forbs provided the lowest amount. This outcome perhaps can be explained by the phenology of the dominant species in these groups. Cheatgrass germinates in the fall and is able to grow in very cool to freezing soil conditions. It is very efficient at using soil moisture from winter precipitation. On the other hand, annual forbs generally develop later in the spring and are more susceptible to dry soil conditions, especially if cheatgrass consumes most of the available soil moisture early in the growing season. Perennial species that occur in sandy soils may be less susceptible to soil moisture depletion by cheatgrass, because they are deeply rooted and may utilize a source of water not available to cheatgrass. However, seedlings of perennial species, for which surface soil moisture is critical to become established, may be more susceptible.

After three growing seasons, seeded species are not as well established at Site 1B as they are at Site 1A. Although a diversity of cool and warm season grasses has become established, vegetation cover at the site is dominated by only three species: sand dropseed, cheatgrass, and kochia (Kochia scoparia). Many other species are represented, but they represent a small percentage of total cover. Site 1B was seeded in fall 1991. Two very dry years followed, especially during the growing season for warm season grasses. These conditions likely contributed to the relatively poor growth of seeded species.

Site 1C is composed of three distinct topographic aspects: a generally north-facing slope, a dry bottom area, and a mesic bottom area. The slope and dry bottom were dominated by weedy annual species, while the mesic bottom site was dominated by Canada thistle. In spring 1993, cheatgrass dominated the entire bottom portion of the site, severely depleting soil moisture. Species seeded in fall 1992 were not evident. An attempt was made to control cheatgrass while not critically injuring seeded species. Diquat was broadcast over the area dominated by cheatgrass. This herbicide kills aboveground growth, but is not translocated, so below ground tissue survives. Thus, annual species are generally killed, while established perennial species are able to re-grow from underground reserves. In July, the mesic bottom area at this location was sprayed with Diquat to control persistent Canada thistle.

Under natural conditions, each of these three landscapes would likely support a unique plant community. Therefore, a different seed mix was selected for each location in an attempt to match vegetation to the different landscape characteristics. Green needlegrass (Stipa viridula) was added to the mix for the north-facing slope, switchgrass was the dominant species in the seed mix for the mesic bottom area, and the standard sand prairie mix was used for the dry bottom site. Each of the seed mixes was drill seeded and mulched in October 1993.

After two growing seasons, no seeded species had become established at Site 1C, and cheatgrass represented nearly 100 percent of vegetative cover. Revegetation efforts to date have been unsuccessful, and in fall 1994 the site was mowed and plowed to a depth of approximately 12 inches to bury cheatgrass seed and prevent its germination. A plan is being developed to conduct further prairie restoration efforts at this site; such a plan likely would involve preparing a shallow seed bed and seeding a sorghum (Sorghum vulgare) cover crop in spring 1995, sweeping the seeded area several times to control developing weed species (primarily cheatgrass) during the growing season, and finally reseeding with appropriate native seed mixes into existing stubble without further tilling in the Spring of 1996.

One successful outcome of habitat management at Site 1C has been to control Canada thistle. When management efforts began in 1992, this noxious weed dominated low areas of this site, where moisture accumulated. A combination of chemical and mechanical control has nearly eliminated this species from the site. Because of its persistent nature, this exotic species will likely require further treatment; however, the amount of effort required to maintain control will be much reduced.

Several factors likely contributed to the failure of restoration efforts at Site 1C. Both 1993 and 1994 were very dry, especially during the growing season for warm season species. This site initially was seeded in October 1992 followed by precipitation adequate to allow cheatgrass seed in the soil seed bank to germinate in the fall. Cheatgrass then depleted soil moisture available for other species in early spring 1993. Application of Diquat did not achieve the intended result. Although cheatgrass was immediately killed, it apparently had developed sufficiently to produce viable seed. Application of Diquat also may have affected seedlings of seeded species, even though none were evident at the time of application. However, seeded species also failed to become established on the north-facing slope, where this herbicide was not applied. The combination of low soil moisture, competition from cheatgrass and poor timing of herbicide application may have resulted in seeded species failing to become established at this site.

Site 4A, like Site 1A, is a tribute to the resilience of adapted native species. After four growing seasons, including the last two dry years, data collected at this site indicate that seeded warm season tallgrass prairie species comprise the greatest percentage of total cover by any vegetation class measured at this site, although total vegetative cover has decreased somewhat (MK-Environmental Services 1995). Cover by side-oats grama, switch-grass and yellow Indiangrass increased over previous years. In addition, a tall prairie dropseed, not recorded at the site in previous years, tentatively has been identified as Sporobolus asper. Two wildflowers uncommon on the Refuge, prairie coneflower and tall evening primrose (Oenothera villosa), also occur at this site, even though they were not included in the seed mix. The source of these species is unknown. Plants may have volunteered from seed in the soil seed bank or in the mulch that was applied. These species add to the uniqueness of this site.

The diversity of Site 4A declined somewhat due to low precipitation and Canada thistle control efforts prior to establishment of seeded species. Dry soil conditions appeared to affect annual forbs most severely, which declined from 1993 measurements at each of the major BEMA sites, contributing to an overall decline in diversity noted in 1994. At Site 4A, herbicides applied in fall 1993 likely affected a variety of perennial forbs, including the target species, Canada thistle. Control efforts were highly successful; average cover by Canada thistle declined from nearly 8% in 1993 to less than 1% in 1994.

Site 4B was mowed at the end of June 1994. Although efforts to control Canada thistle in this area have been mostly successful, seeded species still had not become established at Site 4B after three growing seasons. Cover by annual weed species was extensive, while cover by native perennial grasses and forbs was minimal at the end of the 1994 growing season. Seeding at this site was considered a failure, and the area will be plowed in early FY 1995. Further restoration efforts should involve planting a cover crop in spring 1995, conducting a series of sweep treatments to control weedy vegetation during the 1995 growing season, and seeding with a native seed mix in spring 1996.

Although precipitation was excellent to establish seeded warm season species during 1992, the year following fall seeding at this site, seeded species did not become established. Extensive growth of unexpected annual forbs and a delay in mowing the site to protect deer fawns may explain this. Early in spring 1992, the site became dominated by spear orach (Atriplex hastata) and tall marsh-elder (Cyclachaena xanthifolia), species which previously were not common at the site. These species quickly grew tall and dense, shading the ground surface and inhibiting germination and growth of seeded species. Deer delivered their fawns in this area in the spring; to protect the fawns, the area could not be mowed until early July. By that date, a copious amount of biomass had been produced, and mowing covered the ground with a thick layer of "green" mulch, further inhibiting seedling emergence. These conditions were followed by two consecutive dry years and total failure of the seeded species to become established.

Site 4C encompasses 35 acres north of sites 4A and 4B, and is separated from those areas by a drainage ditch apparently constructed by Army to divert what may be the only seep along First Creek. This area was characterized by a mix of native grasses and forbs and Canada thistle. The objective for this area was to control the spread of Canada thistle while enhancing native species. All management activity was conducted in 1992; the area was mowed in May and patches of Canada thistle were sprayed with herbicide in September. In 1993, management had effectively controlled Canada thistle and enhanced cover by native species; therefore, no further management activity was recommended for this site. However, productivity and species composition at the site could be improved by controlled burning. The large amount of biomass in both standing vegetation and litter would be adequate for a spring burn.

Through five years of management activity, a diverse grassland has been established at Site 5A. There has been a change in dominance from slender wheatgrass after the initial spring seeding to western wheatgrass and kochia after the 1994 growing season. Numerous other grasses and forbs occur at the site. The diversity of the area continues to increase, evidenced by the observation of several species for the first time during 1994. These include Russian olive (Elaeagnus angustifolia), alkali sacaton (Sporobolus airoides), tansy aster (Macaeranthera canescens) and heath aster (Virgulus ericoides). Total vegetation cover, even after two dry years, appears to be is at its highest level since the first year after seeding, when the site was covered by weedy forbs and short-lived slender wheatgrass. The change to dominance by western wheatgrass, which nearly doubled in cover from 13% in 1993 to 25% in 1994, indicates that a more stable plant community has developed, because western wheatgrass is native to the site, long-lived, and a common component of undisturbed areas of the Refuge and the region.

Results at Site 5B were similar to that of 5A. Cover by cool season perennial grasses has increased due to increases in both western wheatgrass and slender wheatgrass, while cover by warm season grasses generally decreased over five growing seasons. Cheatgrass provided considerably more cover in 1994 than it had in 1993 (14.9% versus 4.3%). Cover by kochia also increased in 1994, although cover by all annual forbs decreased compared to 1993. In general, a diverse grassland has developed through five growing seasons at this site.

Site 5C is in its third growing season and is not as mature or well-developed as the other seeded sites at this location. Warm season species are a small component of the total vegetation. Western and slender wheatgrasses, are well established, but at lower cover values than at the other locations. As at the other Site 5 subsites, cheatgrass increased while annual forb cover decreased in 1994.

It is interesting to note that 1992 and 1993 were good production years for sweetclover (Melilotus sp.) in Sites 5B and 5C. In 1992, distribution and quantity of precipitation may have been appropriate to germinate sweetclover seed in the soil seed bank. Since sweetclover is a biennial species, only the vegetative portion was produced in 1992; therefore, identification to species was not possible. Although 1993 was a dry year, the plants had enough stored energy reserves to produce abundant biomass and flowers, permitting identification of the species. Nineteen ninety-four was again a dry year and sweetclover did not appear in the data. At this location, the presence or absence of this species can be anticipated, based on climatic fluctuations. Although sweetclover receives extensive use by wildlife, it will not provide dependable forage or cover, as do some native species.

It was also interesting to combine the data for 1994 from all three areas at Site 5. Combining the data in this way increases the sample size considerably and characterizes the area on a landscape basis rather than as individual locations. The combined data indicate that the area is dominated by cool season native grasses, especially western wheatgrass, and annual forbs which together account for 60% of the total vegetative cover. Ranking of species dominance in the combined data is an indication of the successful restoration of this site. Although kochia is the most dominant species, and cheatgrass and bindweed are third and fourth respectively, six of the ten most dominant species are native perennial grasses. Western wheatgrass is ranked second, while slender wheatgrass, blue grama, Canada wildrye (Elymus canadensis), sand dropseed, and foxtail barley are ranked fifth through ninth, respectively. Numerous other species also occur at the site.

Substantial effort has been expended to control Canada thistle at Sites 5A, 5B and 5C. Canada thistle is a very aggressive perennial species with less value to wildlife than some other thistle species. It has proven extremely difficult to eradicate in all areas, but especially at Site 5A, where control efforts have been ongoing for five years. Mowing and applying a variety of herbicides have greatly reduced the prevalence of this species. The combined cover data for these three sites indicate that cover by Canada thistle was less than 1% in 1994. However, Canada thistle remains a potential invader throughout the sites. No management activities to control this species were conducted during 1994. Although further intensive management practices are not warranted for these sites at this time, treatment of isolated patches of Canada thistle should be considered to avoid major infestations. Since its occurrence is minimal at this time, Canada thistle may be controlled by manual removal using volunteer labor.

Site 6 includes two areas located in north-central Section 30. Locations 6W and 6E consist of approximately 61 and 24 acres, respectively. Both sites are characterized by Weld loam, Satanta loam, and Ascalon sandy loam soils on rolling uplands intermittently occupied by prairie dog towns. Although these sites included a component of native perennial grasses prior to initiation of this project, the dominant species were characteristic of highly disturbed land and considered undesirable for many wildlife species including prairie dogs. The goal for both areas was to establish shortgrass prairie dominated by western wheatgrass to develop resilient prairie dog habitat. Western wheatgrass appears to tolerate grazing pressure by prairie dogs better than other grasses. It is one of the few perennial species that emerged after prairie dog colonies were eliminated from this area by plague in 1988-89.

The upper two to three inches of soil in Site 6E was tilled in Spring 1989 and drill seeded with western wheatgrass only. Subsequently, herbicide was applied to control the abundant field bindweed at the site. An excellent stand of western wheatgrass was established, and cover by this species rose to 40% after the third growing season. After prairie dogs recolonized the site, the combination of prairie dog use and dry climatic conditions resulted in a decline in vegetation cover at the site. However, Site 6E continued to support a healthy stand of western wheatgrass in 1994, which contributes about 70% of the total vegetative cover of 31%. Plant species diversity, although low with a mean of 3.4 species per transect, increased slightly at this site, probably because prairie dog activity allowed adventive species to invade disturbed soils.

Site 6W also was established in spring 1989, when the area was treated with herbicides to control abundant annual weeds and was interseeded with western wheatgrass by drill seeding directly amid existing standing vegetation and litter without soil tilling. Little of the seeded western wheatgrass became established the first year, but existing clones of this species did grow in response to weed control and absence of prairie dog grazing. In the second year, the area was fertilized and ripped to a depth of two to three inches to stimulate growth of existing western wheatgrass. These treatments stimulated abundant seed production by western wheatgrass. It appeared that seedlings also germinated at that time from seed planted the previous year. Cover by western wheatgrass increased to 14% by the third growing season, and remains high at more than 12% in 1994. This area supports a more diverse and dynamic community than Site 6E. Total vegetation cover has remained somewhat stable through four seasons. In 1994, total vegetation cover was 54%, roughly equal to the four-year average of data collected. Cover by annual species has been especially variable at this site. Kochia and Russian thistle (Salsola australis) combined provided more than 70% of the total vegetative cover in the first year, but less than 1% in 1994 after four growing seasons. Cheatgrass increased from less than 1% of the total vegetation cover the first year to over 70% in 1994. Dramatic changes in annual species composition can be expected in early phases of plant community development.

Site 7 includes two subsites (7A and 7B) located adjacent to one another in western Section 19. These sites are characterized by Nunn clay loam, aquic haplustoll, and Ascalon sandy loam soils, and were dominated by thistles and other weedy species before revegetation efforts were initiated in 1989. After initial weed control activities, Site 7A was seeded with a cool season native grass seed mix in spring 1989, and Site 7B was seeded with a sorghum cover crop. The same native mix was interseeded at Site 7B in the spring of 1990. Seeded species initially established at these two sites were dramatically different and have remained quite different through five growing seasons. Seeded cool season species have predominated at Site 7A, while warm season species, particularly sand dropseed, have become established at Site 7B.

At Site 7A, seeded species initially were dominated by slender wheatgrass which composed 30% cover and nearly 35% of the total cover by all vegetation. Cover by slender wheatgrass has declined every year since its establishment to zero in 1994. However, as slender wheatgrass declined, western wheatgrass increased from an initial cover value of 3% to the current value of 33%, or 55% of the cover by all vegetation at this site. Cover by cool season perennial grasses has been stable, averaging approximately 33%. Two annual grass species have exhibited a similar dynamic at this site. Initial cover values for cheatgrass was high but subsequently declined to a minor amount. Japanese brome (Bromus japonicus) has reacted in the opposite manner, gaining cover value each year. Kochia also provided a significant amount of cover in the initial two growing seasons at this site, but has declined to become only a minor component. In general, growth of annual forbs has been characterized by a similar pattern, comprising an important component of the vegetation in initial years and declining in dominance each year thereafter. Although total vegetative cover has declined slightly, it remains high at 61%. Site 7A exhibits characteristics of a stable grassland, including dominance by native species and a low percentage of annual species. As with other seeded and native grassland locations at the Refuge, shrubs are lacking from this site.

Site 7B continues to progress, but it can be characterized as a less mature grassland than the adjacent Site 7A. Cover by warm season grasses, especially sand dropseed, has declined during the past two dry summers. Cover by this species (35%) was very high during the wet summer of 1992. Cover by cool season grasses, especially slender and western wheatgrasses, has increased to more than 6% during the same time period. This is the highest cover value measured for this vegetation class during the five years of data collection. Cool and warm season grasses together comprised 42% of the vegetation cover in 1994. Another important vegetation component at this site are annual forbs, especially kochia and musk thistle (Carduus nutans). Annual species cover 16% or nearly 30% of the total vegetative cover. As at other seeded sites, total vegetative cover has remained fairly consistent, averaging 59% (±5%).

Needle-and-Thread Grass (N&T) Harvest Area

This area consists of two subsites (N&T-S and N&T-N), both located in the southwestern corner of Section 5 and characterized by Bresser sandy loam soil. The management goal for this site has been to promote needle-and-thread grass seed production while controlling weedy species to provide a seed source for prairie restoration projects at other location on the Refuge.

Subsite N&T-S encompasses 20 acres originally dominated by needle-and-thread grass, sand dropseed, and weedy species, especially cheatgrass and Canada thistle. It was necessary to control weed species, especially cheatgrass, to prevent harvested seed from becoming contaminated with weed seed. Application of the herbicide Atrazine initially eliminated cheatgrass from the site, and needle-and-thread and sand dropseed became sole dominants. Harvesting weed-free hay from this location and spreading it as mulch on a tilled area in Site 1A succeeded in establishing needle-and-thread grass and demonstrated the effectiveness of this technique for potential use at other locations at the Refuge. Weed control efforts have resulted in a decline in broadleaf weedy species and virtual elimination of Canada thistle from the site.

The condition of the site in 1994 had deteriorated to the extent that it was no longer a viable seed source for needle-and-thread grass. Initial treatment of the site essentially eliminated cheatgrass and provided a harvest of clean needle-and-thread seed. However, since the initial year, cheatgrass has re-invaded the site and now covers 38% of the surface area, or 57% of the total vegetation cover. Because cheatgrass seed becomes viable at the same time as needle-and-thread, harvesting seed from this site is not prudent at this time. Methods of controlling cheatgrass which do not affect needle-and-thread grass need to be devised and implemented before the site can be used again as a source of desirable seed.

Atrazine, though a very effective herbicide, is not appropriate for use at a Refuge. However, glyphosate could be used an alternative to Atrazine. This herbicide should be applied while cheatgrass is growing and susceptible to the chemical, and while needle-and-thread is still dormant. Trials of this type have not been documented, but are may be worthy of further investigation.

Another potential method of inhibiting cheatgrass in established stands of native grasses involves applying a source of readily available carbon, such as sucrose (table sugar), to the soil. Carbon stimulates microbial activity in the soil, which consumes soil nitrogen and limits its availability to plants. The Service and MK are evaluating a proposal by Colorado State University to study the effectiveness of this technique at the Refuge. If proven effective, it could be incorporated into management plans in the future.

Subsite N&T-N consists of almost 11 acres adjacent to the northern border of Subsite N&T-S. Prior to tilling, this area was dominated by weedy species. The objectives for this area include expanding the area suitable to harvest seed and testing moldboard plowing as a tillage technique to limit growth of annual weeds, primarily cheatgrass, by burying the seed to a depth sufficient to preclude germination. Needle-and-thread grass hay harvested from 20 acres adjacent to this site was spread over this site after soil preparation in fall 1992. The site was mowed in July 1993 and herbicides were applied in September 1993 to control Canada thistle.

Although needle-and-thread grass initially became established at this site (4% cover), this species has declined during the past two dry years while cover by cheatgrass has increased considerably to 40% in 1994. Cover by sand dropseed also has increased. Sand dropseed will likely continue to increase at this location. Needle-and-thread grass should increase, as well; however, its rate of development may vary inversely with the success of cheatgrass. If cheatgrass continues to dominate, progress of needle-and-thread grass will be slow. However, if management efforts or natural processes result in a decline in cheatgrass, development of native grass species will be comparably advanced, and the area will become more characteristic of the management objective.

Ladora and Section 29 Demonstration Areas

Although the Ladora plots were designed as a demonstration area rather than a research area with replicated treatments and controls, some inferences may be drawn from data collected at the site. After three growing seasons, there were no other fall-seeded plots with better established warm season species. However, two of the four spring-seeded plots had considerably more cover by warm season species. This result may indicate that for the sandy soil type, spring seeding of warm season species would be more successful than fall seeding. Another interesting observation relates to invasion of cheatgrass into seeded areas. Although cheatgrass has increased in all plots since they were seeded with native species, the only large increase has been in one fall-seeded plot (4 fall). When compared to its spring-seeded counterpart, this plot exhibited a large difference in cover by warm season species (2% fall vs. 44% spring) for the same seed mix, and total vegetation cover also was greater in the spring-seeded plot (60% vs. 51%). It has been discussed elsewhere in this report how cheatgrass may inhibit establishment of warm season species. This example may indicate the obverse, i.e. when warm season species already are established, cheatgrass may have greater difficulty invading the site.

More time is needed for the Section 29 plots to develop before any rational inferences can be drawn. Preliminary data indicate warm season species were very poorly established regardless of planting date. However, cool season species were adequately established in all but one plot. These preliminary data indicate that cool season species may be appropriate for Weld loam soils.

Lower Derby Dam Spillway

Topsoil was salvaged from this site prior to excavation of the spillway and re-spread following excavation in an attempt to exploit the soil seed bank and propagate volunteer shrubs and other locally established species. However, the plant community has developed slowly and remains in the early stages of development after four years of growth. Nevertheless, a diversity of seeded native species has become established, and seeded shrubs (especially fringed sagebrush and sand sagebrush) are now evident at the site. Sand sagebrush has not been established at any other Refuge site by seeding. Although the plant community has been slow to develop, topsoil salvage and re-use may be valuable as a means to increase plant community diversity.

Closure and Revegetation of Roads in Southwestern Section 2 (Project 40B)

MK/Phillips applied 2.5 pounds of native seed mix (Table 2-10) to less than one acre in the two-track road in south-central Section 2. Where seed received sufficient moisture (mostly drainage from shrub watering), propagation was successful. Generally, soil conditions were too dry during the 1994 growing season to sustain any significant growth from the native seed.

Table 2-10. Seed mix for road closures in Southwestern Section 2, Rocky Mountain Arsenal National Wildlife Refuge, 1994.

Species	Common Name	Variety	Pounds PLS/acre
Bouteloua gracilis	Blue grama	Hachita	2.2
Agropyron smithii	Western Wheatgrass	Arriba	13.0
Sporobolus cryptandrus	Sand Dropseed		0.2
Calamovilfa longifolia	Prairie Sandreed	Goshen	0.8
Bouteloua curtipendula	Side-oats Grama	Vaughn	1.2
Stipa comata	Needle-and-thread		3.8
Andropogon hallii	Sand Bluestem	Woodward	2.0
Oryzopsis hymenoides	Indian Ricegrass	Nezpar	1.6
Cleome serrulata	Rocky Mountain Bee Plant		0.2
Delphinium virescens	Larkspur		0.2
Liatris punctata	Blazing-star		0.2
Oenothera caespitosa	Stemless evening primrose		0.2
Oenothera villosa	Tall Evening-primrose		0.2
Ipomoea leptophylla	Bush Morning Glory		0.2
Gaillardia aristata	Blanket Flower		0.2
Penstemon angustifolius	Narrow-leaf penstemon		0.2
Linum pratense lewisii	Blue flax		0.2
Helianthus annuus	Annual Sunflower		0.2
Achillea millefolium	Yarrow		0.2
Sphaeralcea coccinea	Scarlet globemallow		0.2
Coreopsis tinctoria	Plains coreopsis		0.2
Artemisia ludoviciana	Louisiana sagewort		0.2
Artemisia frigida	Fringed sage		0.02
Abronia fragrans	Sand Verbena		0.2
Yucca glauca	Yucca		0.02
Atriplex canescens	Fourwing Saltbush		0.2
Artemisia filifolia	Sand Sagebrush		0.2
Prunus besseyi	Sand Cherry		0.02
		TOTAL	28.26

Maps

MK worked with the Service throughout FY 1994 to develop or update the following maps: 1) Rocky Mountain Arsenal Vegetation Classification (with prairie dog colonies), 2) Rocky Mountain Arsenal Vegetation Classification (without prairie dog colonies), 3) Rocky Mountain Arsenal Habitat Classification, 4) Rocky Mountain Arsenal Resource Categories, 5) Rocky Mountain Arsenal 1937 Features Composite Map, and 6) Rocky Mountain Arsenal Depth to Groundwater.

Service

Eleven mitigation projects which had been approved and funded prior to FY 1994 were completed during FY 1994 (Project No. 3B, 4B-Phase 4, 11, 29, 33, 34, 35-Phase 1, 35-Phase 1 Modification, 40A, 45, and 58; Fig. 2-1). One additional mitigation project (40B) was funded and completed during FY 1994. The remaining mitigation projects that were funded during FY 1994 (5B, 50, and 58) will continue into at least FY 1995.

To date, 33 mitigation projects totaling about 800 acres have been implemented to partially offset impacts of 30 disturbance projects to about 1400 acres.

Currently, the Mitigation Balance Sheet compares only the areas of mitigation and operational assistance sites to the areas of impacted sites. These tables will be expanded during FY 1995. In the future, a quantitative estimate of habitat value based on Habitat Evaluation Procedures will be used to compare habitat value lost due to disturbances with habitat value gained due to mitigation and habitat restoration activities.

The Habitat Assessment Program was initiated to identify sensitive and/or essential habitat, to quantify the extent of unavoidable impacts to fish and wildlife habitat from contaminant remediation and a variety of other activities, determine suitable mitigation for those impacts, and monitor the effectiveness of mitigation post-implementation. The Service chose to use Habitat Evaluation Procedures (HEP) for this purpose (U.S. Fish and Wildlife Service 1976). In FY 1994, the Mid-Continent Ecological Sciences Center (MESC, formerly NERC) in Fort Collins, Colorado, developed habitat suitability indices for a suite of evaluation species selected to model each of the delineated habitat types at the Refuge. Initial HEP field data were collected beginning in July 1994 for all or portions of six sections (1, 2, 25, 26, 35, and 36) likely to be impacted directly by the cleanup, as well as three other sections (24, 31, and 34) identified as potential borrow sites for contaminant remediation activities. This work was carried out by personnel from Argonne National Laboratory under contract to the Army and with the guidance of MESC and Service personnel. Additional seasonal data will be collected as necessary in early spring 1995 to complete the data set for each species; data analysis and interpretation will continue throughout FY 1995.

Service personnel photographed 48 mitigation sites and 7 other habitat projects (i.e., operational assistance projects) involving 18 habitat restoration projects in various stages of completion. Twenty-nine rolls of color transparency film produced 854 slides documenting these efforts. In addition, aerial photographs of the Refuge taken during 1937 and 1948 were reviewed, particularly to identify historic wetlands.

Miscellaneous

The Service initiated efforts to develop a fire management program by investigating potential training in prescribed burning and fire ecology, entering pertinent data into the Refuge Fire Planning and Accounting System, and purchasing various fire-related equipment and supplies. A detailed fire management plan should be written and approved during FY 1995.

In January 1994, the Service submitted two pesticide use proposals for Projects 3B and 42 to spot-treat noxious weeds with herbicides. In response to concerns of Regional Office staff, the Refuge modified its proposals from tank mixes of three herbicides to 2,4-D alone.

The Service provided guidance and recommendations to Army and contractors on a variety of other projects such as seeding the Basin F Wastepile, borrow sites, and the fiber optics disturbed areas. Army and Service employees and relevant contractors also worked together to minimize impacts to habitats of high value to wildlife due to future borrow site development. For this purpose, Service personnel identified several potential borrow sites which have relatively little value for wildlife.

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TITLE: Operational Assistance Projects on Rocky Mountain Arsenal National Wildlife Refuge (Refuge)

INTRODUCTION

The Cooperative Agreement for Conservation and Management of Fish and Wildlife Resources at Rocky Mountain Arsenal (U.S. Government 1989) defined a variety of Service responsibilities related to land use at the Refuge. This agreement was revised in March 1991, and February 1993. These agreements included Service responsibilities to: a) propose habitat mitigation efforts to offset potential adverse effects of remedial activities on fish and wildlife resources, b) coordinate with the Refuge staff to integrate fish and wildlife resource mitigation plans with other Refuge activities, and c) incorporate results of fish and wildlife resource mitigation plan implementation into the annual reports (U.S. Government 1991 and 1993). The Service strived to meet the obligations of these agreements during FY 1994.

METHODS

Project Approval

The Service continued efforts to prevent impacts to wildlife and their habitat due to cleanup activities. When adverse impacts to habitat are unavoidable, the Service developed and implemented habitat restoration plans to replace all habitat value lost under the Mitigation Program. However, the Service also worked closely with Army to avoid unnecessary damage to habitat and minimize losses to the greatest practicable extent. These activities were carried out under the Operational Assistance Program. One Operational Assistance project (Plan 47) was approved and funded by Army in FY 1993. Total Terrain initiated this project in FY 1993 and completed it in FY 1994. Two additional projects (Plans 20D and 20E) were approved by Army, funded by Shell Oil Company (Shell), and completed by Phillips Seeding Company (Phillips) in FY 1994 (Table 2-11).

Table 2-11. Status of operational assistance projects, Rocky Mountain Arsenal National Wildlife Refuge, FY 1994.

Project Number	Project Description	Contractor	Started in FY 1994	Completed FY 1994*
20D	Fertilizing and Seeding Vegetative Barriers in Groundwater Containment Systems and portions of Section 36	MK/Phillips	X	X
20E	Vegetative Barrier Plantings in Basin A Neck	MK/Phillips	X	X
47	Shrub Plantings in the Bald Eagle Management Area	Total Terrain		X

* Does not include guaranteed replacement of dead shrubs.

Total Terrain

Total Terrain, Inc. of Pueblo, Colorado, has been the Service's principal landscape contractor at the Refuge since 1991. In FY 1994, Total Terrain completed work on Operational Assistance Plan 47 (Shrub Plantings in the Bald Eagle Management Area) which was funded and initiated in late FY 1993. Total Terrain was directed to plant a variety of native shrubs adjacent to steel gates at four entrances to the Bald Eagle Management Area (BEMA)(Fig. 2-3). These sites are: 1) the Havana Interceptor road at C Street, 2) Sixth Avenue at C Street, 3) E Street between Sixth and Seventh Avenues, and 4) E Street at the North Perimeter road. Proposed shrub plantings at a fifth BEMA gate at Sixth Avenue at the East Perimeter road, were originally included in this plan, but were later incorporated into Habitat Restoration Plan 34, Shrub Plantings in Eastern Rocky Mountain Arsenal National Wildlife Area. The BEMA gates are closed between 15 October and 15 April each year, during which access to BEMA is regulated by the Service to minimize disturbance to wintering bald eagles. Although the BEMA gates are not locked and access to BEMA may be authorized, personnel frequently drive off-road around the gates to avoid the inconvenience of opening them. This abuse has resulted in the destruction of vegetation and creation of ruts adjacent to some gates. This Plan provides assistance with management of the BEMA by discouraging motor vehicle operators from bypassing the steel gates at four commonly abused BEMA entrances and by underscoring the importance of BEMA to Arsenal employees and contractors. This plan also mitigates the damages of past abuses.

Morrison Knudsen

The Service worked with Morrison Knudsen Environmental Services (MK) to draft Operational Assistance Plan 20D (Fertilizing and Seeding Vegetative Barriers in Groundwater Containment Systems and portions of Section 36) approved in the first quarter of FY 1994 and Operational Assistance Plan 20E (Vegetative Barrier Plantings in Basin A Neck) approved in the second quarter of FY 1994.

During the 1980's and in 1990, areas of the Irondale Containment System, the North and Northwest Boundary Containment Systems, Basin A Neck Containment System and portions of Section 36 on the Refuge were seeded with a mixture of hycrest crested wheatgrass (Agropyron cristatum), and pubescent wheatgrass (Agropyron trichophorum) to deter black-tailed prairie dogs (Cynomys ludovicianus) from entering these areas. Prairie dogs may compromise the integrity of groundwater treatment facilities by burrowing into subsurface dams designed to contain contaminated groundwater and by damaging underground electrical systems. The height and unpalatability of these grasses discourage prairie dogs from colonizing these sites. However, these plant species also are unattractive to other wildlife, such as songbirds and large mammals, which do not interfere with the underground treatment facilities.

Plans 20D and 20E (Fig. 2-3) directed MK to enhance areas previously seeded with grasses by: a) fertilizing with ammonium sulfate, b) supplementing marginal plantings with additional wheatgrass seed, and c) by interseeding with fourwing saltbush (Atriplex canescens) seed, a woody shrub which is undesirable for prairie dogs but attractive to other wildlife species. Phillips, MK's contractor, conducted the fieldwork. Shell/MK provide funding.

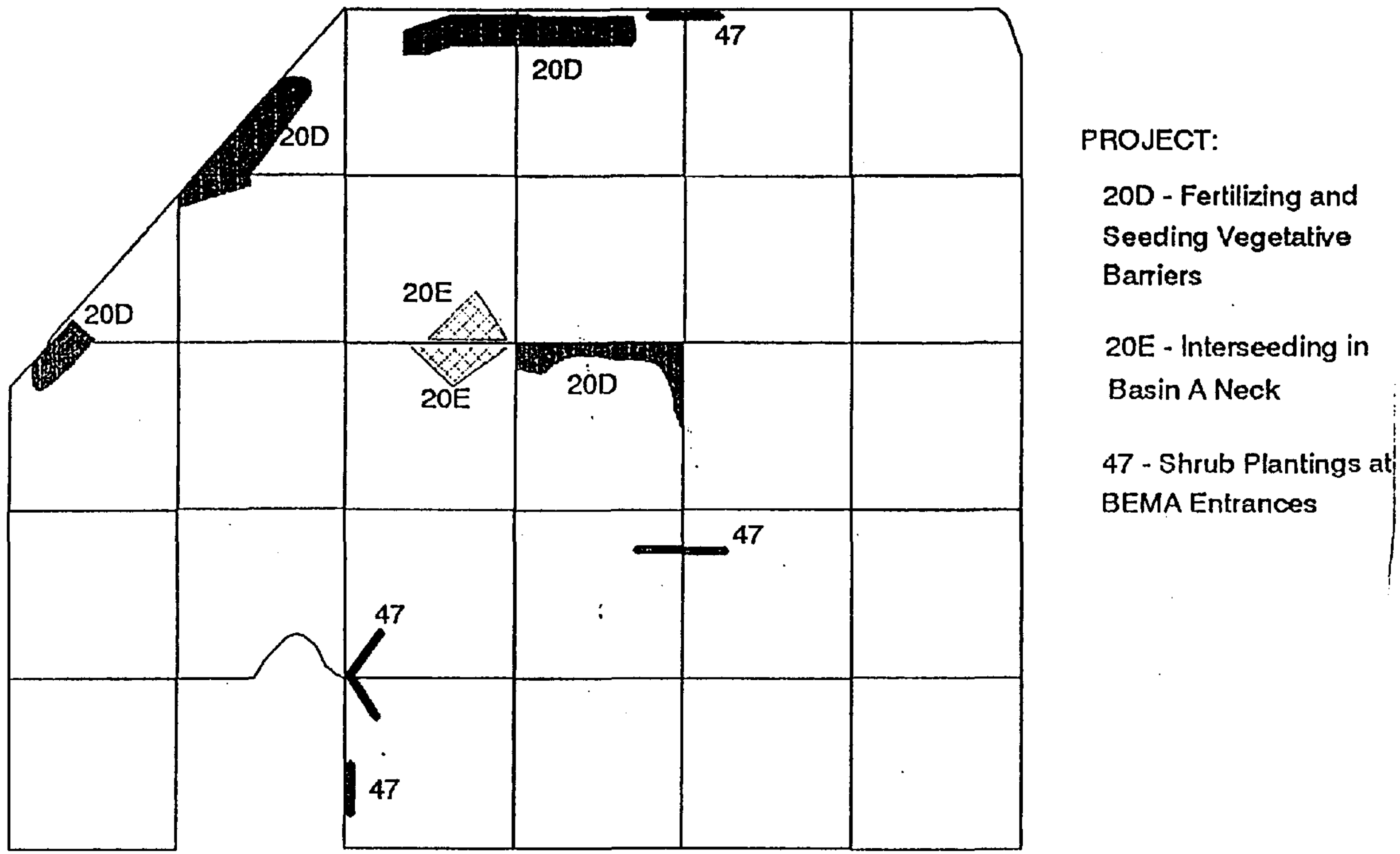

Fig. 2-3. Map of Operational Assistance projects completed in FY 1994, Rocky Mountain Arsenal National Wildlife Refuge.

RESULTS AND DISCUSSION

Total Terrain

Total Terrain planted a total of 896 shrubs at the four BEMA entrances during October 1993 as follows: 1) 56 sand sagebrush (Artemisia filifolia) north of the Havana Interceptor road at C Street, 2) 224 sand cherry (Prunus besseyi) on Sixth Avenue at C Street, 3) 392 skunkbrush sumac (Rhus trilobata) at E Street between Sixth and Seventh Avenues, and 4) 224 sand sagebrush on E Street at the North Perimeter Road. All shrubs were transplanted from 5-gallon containers. An inspection conducted during October 1994 revealed the following survival rates: 214 of 280 sand sagebrush, 205 of 224 sand cherry and 313 of 392 skunkbrush sumac. The overall survival rate was 82%. Plants that did not survive will be replaced by Total Terrain during spring of 1995.

Morrison Knudsen

During FY 1994, Phillips applied a total of 42,450 pounds of ammonium sulfate fertilizer to existing vegetative barriers encompassing a total of 430 acres in the North and Northwest Boundary Containment Systems, the Irondale and Basin A Neck Containment Systems, and portions of Section 36. Phillips seeded a total of 76 acres in the Northwest Boundary Containment System and Basin A Neck Containment System with 608 pounds of crested wheatgrass and 912 pounds of pubescent wheatgrass seed, and interseeded a total of 248 acres in the North and Northwest Boundary Containment Systems, Irondale and Basin A Neck Containment Systems with 67.2 pounds of fourwing saltbush seed. Due to unseasonably dry soil conditions throughout the 1994 growing season, these species did not show significant growth throughout the seeded sites. These areas will be monitored by MK during 1995. If there is sufficient natural moisture during the 1995 growing season, the areas seeded in 1994 can be expected to exhibit more vigorous growth.

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TITLE: Endangered Species Consultation

INTRODUCTION

The Cooperative Agreement for Conservation and Management of Fish and Wildlife Resources at Rocky Mountain Arsenal (U.S. Government 1989) defined a variety of Service responsibilities related to land use at the Rocky Mountain Arsenal National Wildlife Refuge (Refuge). This agreement, revised in March 1991 and February 1993, includes Service responsibilities to: a) fulfill Department of Interior responsibilities as specified in the Federal Facilities Agreement, b) coordinate negotiations, implement resolutions, and maintain related records of all activities necessary to address endangered species, and c) provide input for the responsibilities described above into Service Fish and Wildlife Resource Management Plans, Budgets, and Reports (U.S. Government 1991 and 1993). The Service strived to meet the obligations of these agreements during FY 1994.

Stapleton International Airport Section 9 Leasehold

In 1988, the City and County of Denver (Denver) entered into an agreement with the Army to lease a portion of Rocky Mountain Arsenal in Section 9, Township 3 South, Range 67 West, for the purpose of expanding commuter runway facilities at Stapleton International Airport. This leasehold area of approximately 293 acres had been an important winter feeding area for bald eagles. Section 7 of the Endangered Species Act requires each federal agency to review any action it authorizes, funds, or carries out to ensure the action does not jeopardize the continued existence of threatened and endangered species. If the agency determines that an action may affect such species, it is required to consult with the Service to determine the nature and extent of the effect and identify and implement appropriate measures to avoid or minimize the effect. As the federal agency responsible for the Stapleton expansion, the Federal Aviation Administration (FAA) entered into informal consultation with the Service. As a result Denver, the project proponent, agreed to fund habitat enhancement measures elsewhere on the Refuge to compensate for the loss of bald eagle habitat in Section 9. These measures are more specifically described under the title *BEMA Habitat Manipulations - Project 27B*, beginning on page 2-6.

Although the term of the 1988 lease is 50 years, ending in the year 2038, the agreement between the Service and Denver was in effect for only five years and expired May 31, 1993. Under the terms of this agreement, Denver was required to request an extension to the agreement or request that the FAA reinitiate endangered species consultations to consider the long-term effects of airport operations on bald eagles. This requirement would have been waived if Denver had abandoned the leasehold prior to May 31, 1993.

For each of the first four years of the agreement, the Service provided to Denver through the Army an annual progress report of its habitat enhancement efforts. In June 1993, the Service submitted its final report and notified Denver and the FAA of the need to reinitiate endangered species consultations or request an extension to the agreement. Denver asked the Service to defer further consultation pending an expected December 1993 closure of Stapleton Airport. The Service accepted the deferment and Denver agreed to begin restoration of Section 9 in the spring of 1994.

However, the closure of Stapleton Airport was contingent on opening Denver International Airport (DIA), which was first delayed from December 19, 1993 until March 9, 1994, then May 15, 1994, and subsequently delayed indefinitely pending the resolution of problems with the automated baggage handling system. These unforeseen delays have prompted the Service to reevaluate its position regarding the Section 9 leasehold and Endangered Species Act compliance.

Intra-Service Consultation and Species Status Surveys

The Service continued to monitor its programs and activities at the Refuge to ascertain if they were within the scope of the 1993 intra-Service consultation with the Colorado State Office. In its Biological Assessment, the Service also pledged to make every reasonable effort to determine the status of certain candidate species at the Refuge.

METHODS

Stapleton International Airport Section 9 Leasehold

Restoration of Section 9 in 1994 was to include removing the runway, taxiway, roads and other infrastructure, recontouring, and revegetating with a native seed mix. However, no site restoration has been done to date, because the airport facility continues in operation pending the opening of DIA. This violates the spirit if not the letter of the agreement between Denver and the Service. To realize a more immediate benefit to the winter population of bald eagles at the Refuge, in FY 1994 Denver and the Service considered mutually advantageous alternatives to restoring the Section 9 leasehold to its pre-1988 condition. One such alternative still under consideration would require Denver to grant a conservation easement or management agreement to the Service on DIA lands immediately east of the Refuge for the purpose of creating, enhancing, and managing wildlife habitat. In exchange, Denver would require the Army to relieve Denver of its responsibility to restore Section 9 to the pre-1988 condition following the eventual closure and abandonment of Stapleton Airport by Denver. This arrangement would benefit both the Refuge and Denver, since Section 9 is slated for disposal under the Refuge Act, DIA lands would provide a buffer for the Refuge from future airport development east of Peña Boulevard, and the Service would assume responsibility for operating and maintaining the DIA mitigation wetlands in Section 33, Township 2 South, Range 66 West, and an historic homestead in Section 4, Township 3 South, Range 66 West.

Intra-Service Consultation and Species Status Surveys

To meet its obligations under the 1993 Intra-Service consultation, in 1994 the Service completed status surveys for the Preble's meadow jumping mouse (*Zapus hudsonius preblei*) to determine if the subspecies occurs at the Refuge. The status survey involved more than 300 trap-nights sampling effort in suitable habitat, especially along the upland margins of streams, lakes, and wetlands.

There also was a reliable but unconfirmed sighting of another candidate species, the swift fox (*Vulpes velox*), by a graduate student mammologist and his assistant in the northern portion of the Refuge. Predator scent stations also were established throughout the Refuge, including the area in which the swift fox was sighted.

RESULTS AND DISCUSSION

Stapleton International Airport Section 9 Leasehold

The Service continued informal endangered species consultations with the FAA and Denver to assess the impacts of commuter runway operations at Stapleton International Airport on bald eagles at the Refuge. Stapleton will continue to use Section 9 until the new Denver International Airport (DIA) is operational, when Stapleton will cease all commercial and private aircraft operations. Pursuant to the 1988 agreement, Denver would be required to remove the commuter runway, restore the leasehold to its pre-1988 condition and return it to the Refuge to be managed for wildlife. However, the Rocky Mountain Arsenal National Wildlife Refuge Act of 1992 requires that the portion of Section 9 currently leased to Denver be sold at auction by the

General Services Administration (GSA). Efforts to restore the leasehold to pre-project conditions for the benefit of bald eagles could be wasted, if the land subsequently is developed for purposes incompatible with bald eagle use. Furthermore, under Section 7 of the ESA, the GSA would be required to consult with the Service to determine if the land disposal action may affect the bald eagle. Special conditions could be placed on the land to protect bald eagles which devalue the property to potential bidders. In view of this, the Service determined that it would be more prudent to pursue an agreement with Denver which allowed for the use of an alternative site or sites for the purpose of creating, enhancing, and managing bald eagle habitat. Denver has agreed in principal; however, the details still must be negotiated and there are numerous obstacles to be overcome. Negotiations will continue in FY 1995.

Intra-Service Consultation and Species Status Surveys

No Preble's meadow jumping mice were captured at the Refuge in spite of an intensive trapping effort. This result was not unexpected, as the only known populations of the subspecies along the Front Range have been found at higher elevations in Jefferson, Boulder, and Larimer Counties. To date, none have been found in Adams County. However, the Service will continue to be vigilant during all small mammal trapping efforts in Z. h. preblei habitat in the event a specimen is collected fortuitously. When more is known about this highly secretive subspecies and more effective collection techniques and equipment are available, additional trap nights may be devoted to it.

No further sightings or other evidence of the swift fox has been observed, including scent station data collected in the same vicinity. The Service will continue to be vigilant for this species at the Refuge. While its habitat is fairly secure here, coyotes at the Refuge could take a heavy toll on both kits and adults.

The results of studies of two other candidate species, the ferruginous hawk (Buteo regalis), and the western burrowing owl (Athene cunicularia hypugea), are described in detail elsewhere in this report.

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_____. 1993. Cooperative agreement for conservation and management of fish and wildlife resources at Rocky Mountain Arsenal. U.S. Fish and Wildl. Serv., Reg. 6. 14pp.

TASK 3 - ACTIVITIES COORDINATION

TITLE: Activities Management at the Refuge

INTRODUCTION

Activities Management at the Refuge consists of two separate projects, Activities Coordination and Bald Eagle Management Area (BEMA) management. The Activities Coordination Program, established in April of 1991, is supervised jointly by the U.S. Fish and Wildlife Service (Service) and the U.S. Army Rocky Mountain Arsenal (Arsenal) Safety, Health and Environment Office. The objectives of the program are to: (1) reduce activity conflicts between, and ensure the safety of, all Arsenal and Refuge employees, contractors, and other entities; and (2) minimize deleterious cleanup impacts on Refuge fish and wildlife resources. In this report, 1994 Arsenal and Refuge contractor activity will be provided.

A communal winter roost for bald eagles was discovered in the eastern portion of the Refuge in 1986. Two years later, the Service established a protective zone, the Bald Eagle Management Area (BEMA), which encompasses sensitive eagle roosting, feeding, and loafing areas. Between 15 October and approximately 15 April, all access into the BEMA for cleanup and maintenance activities is regulated by Service personnel to minimize disturbance to wintering bald eagles. This report presents BEMA access statistics for the 1993-1994 regulation period.

METHODS

Activities Coordination

For Activities Coordination, a Refuge map indicating locations of contractor activities was printed and reproduced weekly. Attached to the map was a schedule describing pertinent activity information such as type, location, and duration of activity, level of personal protective equipment (PPE) required, and designated point of contact. All Arsenal contractors and associated entities planning to conduct field activities were required to submit the aforementioned activity information on a standard activities coordination form one week prior to the onset of work. The one week notice period allowed time for activities management personnel to review the proposed field work for compliance conflicts and to prepare the map and schedule for the following week. A revision list was kept at the Activities Coordination Office for last minute changes. Maps and schedules were distributed at the weekly Army contractor's meeting. A more detailed description of the activities management process is presented in "Activities Policy and Procedures for Rocky Mountain Arsenal" dated 17 July 1991.

BEMA Access

The BEMA was closed from 15 October through 25 March, with the exception of the roost exclusion area, which remained closed until 15 April. All contractors, Army or Service staff needing access into the BEMA during the closure period were required to inform Activities Coordination personnel prior to each BEMA entry. Date, name of entity, activity, duration, and work location were recorded in a log book for each entry. Entities entering the BEMA displayed numbered vehicle hood cones which were provided by the Service. Periodic patrols were conducted through the BEMA to ensure contractor compliance with established BEMA protocol.

Information collected on BEMA entries throughout the regulation period was tallied and total numbers of entries per entity, sectional entries, monthly entries, and cumulative time spent in each section were calculated. For bus tours or other activities involving more than five sections, a sectional category entitled "Multiple Sections" or "MS" was used in the calculations of sectional entries and cumulative time.

RESULTS AND DISCUSSION

Activities Management

Fifty-two weekly activity maps and schedules representing the work of 34 different entities were produced and distributed in FY94. There were approximately 23,885 distinct activities performed during the year with an average weekly total of 459.3 projects. Monthly activities ranged from 392 for November to 556 activities during the month of May (Fig. 3-1). Contractor activities varied in duration, and all levels of PPE (A, B, C, and D) were represented.

Numbers of activities for FY94 increased by 118% when compared to FY93, 165% when compared to FY92, and 170% when compared to FY91 respectively (Fig. 3-2). The Service anticipates significant increases in contractor activity with the Record of Decision (ROD) in 1995.

There were approximately 485 revisions made to the activities schedules during the year, with an average of 40.4 modifications per month.

BEMA Access

Activities Management personnel recorded 1,875 entries into the BEMA by 23 Arsenal entities during the closure period (Table 3-1). Raytheon Engineers & Constructors logged 648 entries, or 34.56% of the total. The total entries of 4 entities - Raytheon Engineers & Constructors, U.S. Fish and Wildlife Service, Ebasco, and U.S. Geological Survey - comprised 80.16% of all BEMA entries during the closure period. Each of these entities logged more than 100 entries into BEMA.

The number of BEMA entries per month ranged from 152 in October to 427 in December (Table 3-2). Highest numbers of eagles were observed this winter in late January and early February. Activities recorded during these two months comprised 34% of the total.

Activity took place in all 14 sections of the BEMA (Table 3-3), with some activities, such as bus tours, involving more than 5 sections at a time. Entries into Sections 1 and 2 comprised 56% of the total entries. Lakes Mary, Ladora, Upper Derby, and Lower Derby are located in these sections, which provide some of the best diurnal eagle habitat on the Refuge.

Sectional entries for this year can be compared to those logged during the 1992-1993 regulation period (Table 3-3). Total number of entries dropped 19.18% from 2,320 in 1992-1993 to 1,875 in 1993-1994.

There were fewer entries into eight sections this year than last year. These declines ranged from 2.1% in Section 6 to 88.77% in Section 25. The drop in the entries into section 25 is due to Ebasco moving one of its air monitoring stations from this section to section 5. Therefore the regular checking that occurred during the 1992-93 season also moved.

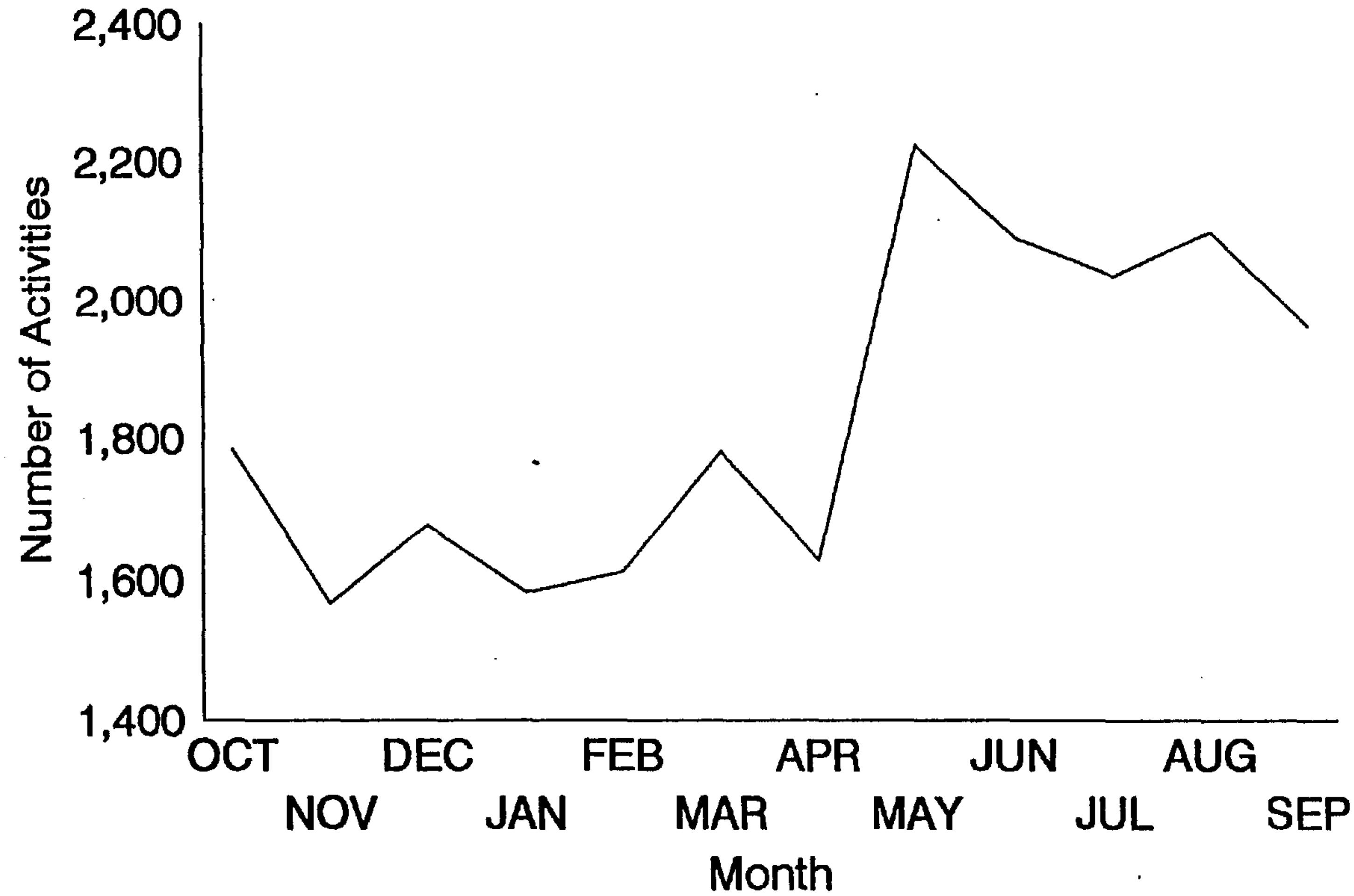

Fig. 3-1. Monthly Refuge field activities, 1993-1994.

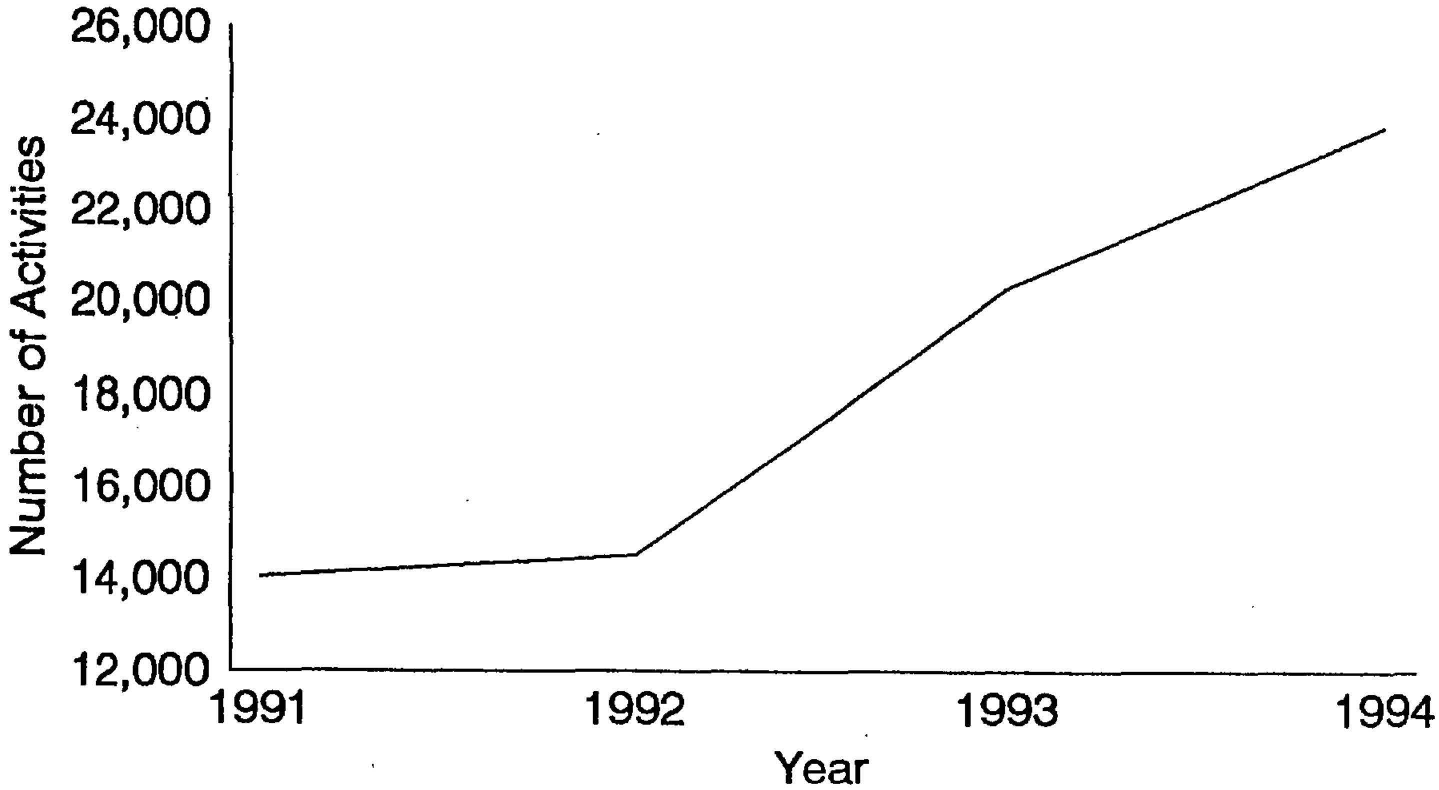

Fig. 3-2. Number of activities coordination entries at the Rocky Mountain Arsenal National Wildlife Refuge (1991-1994).

Table 3-1. Number of recorded BEMA entries for Arsenal entities requesting access during the 1993-1994 BEMA season, RMANWR.

Entity	Number of Entries
Raytheon Engineers & Constructors	648
U.S. Fish & Wildlife Service	397
Ebasco	321
U.S. Geological Survey	137
Enserch	103
Shattil/Rozinski	75
United Engineers	53
Harding Lawson Associates	38
PMR/RMA	17
Denver Museum of Natural History	16
Morrison/Knudson Environmental	15
Total Terrain	12
RMA/Facilities Maintenance	10
UNE	10
Clemson University	4
UNC Catalytic	4
Contractor Survey LTD.	3
Federal Aviation Administration	3
RMA/Public Affairs Office	3
Shell Oil Company	2
RMA/Fire Department	2
Tennessee Valley Authority	1
MGA	1
Total	1875

Table 3-2. Recorded number of BEMA entries per month during the 1993-1994 regulation period, October 15, 1993 - March 25, 1994, RMANWR.

Month/Year	Number of Entries
October 1993	152
November 1993	361
December 1993	427
January 1994	300
February 1994	335
March 1994	300
Total	1875

Table 3-3. Comparison of sectional entries between the 1992-1993 and 1993-1994 regulation periods, RMANWR.

Section #	1993-94 Entries	1992-93 Entries	Per Cent Change
1	610	681	-10%
2	410	631	-35%
MS[1]	221	334	-34%
11	205	145	+41%
5	101	110	-9%
25	11	98	-88%
6	93	95	-2%
8	31	65	-52%
7	33	54	-38%
12	28	27	-3%
31	48	23	+109%
30	35	19	+84%
19	24	14	+71%
24	14	13	+8%
32	11	11	0
Totals	1875	2320	-19%

[1]Multiple Sections: includes more than 5 sections.

Five sections showed a greater number of entries this year, ranging from a 8% increase in Section 24 to a 109% increase in Section 31 (Table 3-3). The increase in Section 31 activities is due to an increase in the number of activities by wildlife photographers Bob Rozinski and Wendy Shattil, and a water level monitoring program that was instituted by Harding Lawson & Associates. Additionally the Service conducted hawk and kestrel studies through this section during the BEMA season.

Cumulative time spent in each BEMA section is presented in Table 3-4. The amount of time spent in the BEMA increased by 60.8% between last year and this year (Table 3-4). The number of entries in BEMA decreased from last year, although it appears that contractors are spending more time in BEMA. This substantial difference could possibly be attributed to the placement of a research trailer by Enserch Environmental in Section 2. Enserch staff this facility between 8 to 16 hours per day. Additionally, Service tours increased in Sections 1 and 2 and USGS has increased water sampling activity in Section 11. Another contributing factor could be more stringent data entry in the BEMA log, and a more accurate examination of that data.

This year (FY 94), Service personnel continued to record requests for entry into BEMA which were denied. Many requests for BEMA access are allowed, but often times the day or time of day the contractor wants to do the work has to be altered. Of the seven recorded denials three contractors, HLA, the Army Reserve Center and Morrison/Knudson were denied access and had their work postponed until April 1994. Temporary postponements included the Army's aerial flight survey panels which were postponed until March of 1994. USFWS, USGS and Enserch Environmental were denied access on several occasions for a one day period because of eagles loafing near the intended worksites.

Table 3-4. Cumulative time (hours) spent within each BEMA section during the 1993-1994 regulation period, October 15, 1993 - March 25, 1994, RMANWR.

Section #	1993-94 Hours	1992-93 Hours
2	667.50	347.71
6	202.50	254.75
MS[1]	599.00	240.00
1	558.00	215.55
25	8.00	114.00
8	31.50	102.37
11	234.50	96.64
5	99.00	85.81
5	31.50	46.64
19	39.50	40.68
30	2.50	40.63
12	28.00	24.26
31	114.50	22.33
24	31.50	31.50
32	20.00	11.10
Totals	2667.00	1658.89

[1]MS - Multiple Sections. Includes more than 5 sections.

TITLE: Health and Safety

The Service Health and Safety (H&S) program at the Refuge Field Office continued to be high priority in FY94. The H&S officer presented safety information and tips at the beginning of each weekly staff meeting. Monthly health and safety committee meetings were conducted on the third Thursday of each month and later moved to Tuesday. The committee consisted of supervisors from each section, Project Leader, and the Health and Safety Officer. The health and safety information was summarized and a Health and Safety report submitted to the Region 6 Safety Office each month.

The H&S officer participated in all U.S. Army Rocky Mountain Arsenal safety meetings to ensure close coordination between U.S. Army and Service activities. The Service received quarterly fire inspections from the Rocky Mountain Arsenal Army Fire Department personnel. No major violations were noted, and all minor violations were corrected immediately. One H&S evacuation drill was conducted following the guidelines of the Service Emergency Response Plan.

The Service Refuge Health and Safety Plan was revised and implemented. All personnel continue to receive appropriate entrance and exit physicals. Annual physicals are offered to personnel conducting field activities that may involve contaminant exposure. Selected Service personnel received a baseline Lyme Disease test. No positive tests for Lyme Disease were documented in Service personnel.

Health and Safety related training continued in FY94 including basic First Aid, Cardio-Pulmonary Resuscitation (CPR), and Occupational Safety and Health Administration (OSHA) Hazardous Waste Operations and Emergency Response (HAZWOPER). Selected Service personnel attended the initial or refresher OSHA HAZWOPER training as required.

There were 46 Service personnel and contractors attending a four hour site specific Hazard Communication training course.

Health and Safety orientation and tour of the Refuge for Service personnel, volunteers, and contractors continued during FY94. There were approximately 52 people participating in the Health and Safety orientation and tours.

Three personal accidents or injuries were reported in FY94 (Table 3-5). Two Service personnel and one Service volunteer sustained injuries. A Service personnel sustained a hip injury from moving items. The second Service personnel sustained a minor job related stress injury. The Service volunteer sustained a broken hip from slipping on ice.

Seven motor vehicle accidents or incidents occurred in FY94 (Table 3-5). Two vehicles were involved in accidents with another vehicle. Two sustained minor damage of unknown cause. One vehicle struck a deer. One vehicle was struck by a wind blown gate. One vehicle had a broken windshield due from a thrown rock while parked at the Region 6 parking lot.

Since Plague is endemic to the Refuge, outbreaks were detected during the summer and continued into the fall and winter in various prairie dog towns on the Refuge. U.S. Army officials and Service personnel collected flea samples which were confirmed plague positive by the Centers for Disease Control in Fort Collins. The infected areas were dusted with Pyraperm 455 dust, in an effort to control the epizootics. Arsenal and Refuge personnel were advised of precautionary measures through informational fact sheets. No Arsenal or Refuge personnel were suspected of contracting plague.

Table 3-5 Accident Summary Table for FY 1994 at the RMANWR.

Quarter	Oct - Dec 1st Qtr	Jan - Mar 2nd Qtr	Apr - Jun 3rd Qtr	Jul - Sep 4th Qtr
Vehicle accidents		2	1	4
Personnel injuries	1	1		
Visitor/Volunteer Injuries		1		
Totals	1	4	1	4

TITLE: Law Enforcement

INTRODUCTION

In anticipation of future Refuge operations and law enforcement responsibilities, the Service continued to train personnel in law enforcement. Additionally, personnel were sent on training details to provide on the job training for specific functions such as refuge patrols, roadblocks, and Refuge fishing permit violations.

Specific objectives of the Service law enforcement program were to provide opportunities to acquire up to date law enforcement techniques; to provide opportunities to develop state and federal law enforcement contacts from different agencies; to expose law enforcement personnel to situations that may be encountered on a refuge; and to aid federal law enforcement in surveillance, monitoring, interrogation, apprehension of game violators, and enforcement of federal laws.

METHODS

Following Refuge Officer requirements and working cooperatively with the Army, Refuges Law Enforcement Coordinator, the Deputy Regional Director and, Assistant Regional Director of Law Enforcement for the Service, several training opportunities were provided during 1994.

Refuge Officers participated in annual law enforcement inservice training, annual physicals, and bi-annual firearms requalifications with .40 Caliber Smith and Wesson handguns and 870 Remington 12-gauge shotguns.

RESULTS AND DISCUSSION

Three credentialed officers maintained law enforcement authority at the Refuge. One Refuge Officer transferred to a Service position in North Dakota and allowed his Refuge Officer credentials to expire. Future plans may incorporate additional Refuge Officers in anticipation of Service sponsored public use activities on the Refuge.

Training

During FY94, one person from Activities Coordination was credentialed in Glynco, Georgia. Three people attended annual refresher training courses in Tucson, Arizona. Additionally, three Refuge Officers successfully requalified with their firearms in March and September 1994.

Routine angler and creel surveys were completed by a seasonal Co-op student throughout the summer. Additionally, angler and creel surveys were conducted by Refuge officers on a periodic basis.

Three Refuge Officers assisted state and federal wildlife officers in two trips to Scottsbluff Nebraska for patrolling the North Platte Refuge Complex and associated state owned lands during weekends of high public use. Several state citations were issued. No federal citations were issued during these training sessions.

Two Refuge Officers provided assistance to Service Special Agents on several occasions to enforce federal wildlife regulations. The training opportunities were useful and afforded all officers hands on experience in a variety of situations that are likely to be encountered at the Refuge.

TITLE: Pest Management - Mosquitos

INTRODUCTION

The Refuge contains a significant number of wetland areas suitable for mosquito production. Mosquito's in the southern four sections of the Refuge near the residential community of Montbello represent a potential public health problem, and a community relations concern. Historically, the Army pest control program used diesel fuel, malathion and other pesticides to control mosquito numbers. The Service policy is to explore alternative means of pest control and avoid the use of chemicals. Working cooperatively with the Army, the City and County of Denver and Tri-County Health Department, the Service began using mosquitofish (Gambusia affinis) and the bacterial larvicide Bacillus thuringiensis isrealiensis (BTI) to control mosquito populations on the Refuge in 1991.

Mosquitofish are a small carnivorous fish common in the Southeastern United States. Mosquitofish have upward facing mouth parts which allow them to feed on mosquito larvae suspended from the water surface. Refuge mosquitofish populations have been established annually in wetland sites #1, #2, the Rod and Gun Club Pond, Havana pond, and small wetlands along the southern border. BTI is a bacteria suspended on a substrate of ground corncob granules. When applied in water the endospores and delta-endotoxin crystals produced by BTI are dissolved from the corncob granules and are ingested by the mosquito larvae. The toxins attack the midgut of the larvae, resulting in death within 24 hours. BTI is highly specific to Nematocerous Dipteran larvae (mosquitos and blackflies) and is non-toxic to other forms of aquatic life.

METHODS

The Mosquito Management Program identified mosquito production areas by three methods: site tour, light traps, and historical information. Problem areas were defined as those which have standing water for at least two consecutive weeks, are protected from wind and wave action, and are within 1.61 km (1 mile) of a residential area. The primary problem areas identified included the wetland east of the Army Reserve Center in Section 12, and wetland sites #1 through #5 in Sections 7 and 8.

BTI was applied to problem areas prior to emergence of mosquito larvae in the spring. Each application was preceded by an inspection for mosquito larvae, and amounts of BTI applied were reported to the Army Pest controller. Approximately 250 pregnant mosquito fish were introduced into wetland sites #1 and #2 during the 1994 mosquito season.

RESULTS AND DISCUSSION

The granular form of BTI is easily applied, and can be concentrated in areas with high densities of mosquito larvae. Approximately 163.3 kg of the BTI mixture was applied to problem areas. Applications occurred two times, between June 2 and July 22, 1994 respectively.

Aggressive applications of BTI and drought appeared to minimize mosquito abundance. Tri-County Health didn't receive a complaint during 1994 season from communities around the Refuge. Future applications of BTI should focus on the Reserve Center and the wetlands with applications being made before mosquito larvae development. Cooperation is necessary for future success.

Mosquitofish provide a constant deterrent to mosquito larvae development, and minimize the dependence on routine field inspections. Attempts to locate mosquitofish in wetland sites #1 and 2 were unsuccessful. Wetland site #2 dried up shortly after mosquito fish introduction. Wetland site #1 experienced a gradual drawdown throughout the summer and it is thought that possible increased water temperatures or low oxygen levels may have killed the introduced mosquito fish.

TASK 4 - PLANNING AND PUBLIC PARTICIPATION

TITLE: Long Range Planning

INTRODUCTION

Passage of the Rocky Mountain Arsenal National Wildlife Refuge Act of 1992 necessitated development of a long-range plan for the U.S. Fish and Wildlife Service (Service) sponsored programs at the Rocky Mountain Arsenal National Wildlife Refuge (Refuge). Since 1987, the Service has developed annual fish and wildlife management plans for Army approval. These annual plans outline specific management objectives for the fiscal year.

A long-range plan which would provide the future vision of the Refuge and guide wildlife and habitat management decisions was needed. In late FY93, Shell Oil Company provided an initial grant to the National Fish and Wildlife Foundation to begin this long-range, comprehensive management or master plan.

The National Fish and Wildlife Foundation and the Service developed a cooperative agreement which identified the roles and responsibilities of each entity, developed schedules for master plan development, and galvanized a mutual commitment to planning the future Refuge. The Foundation conducted a search for firms interested in participating in plan development and developed a preliminary request for qualifications which was sent to 70 firms in January 1994.

METHODS

After a lengthy interview process, the Service and the National Fish and Wildlife Foundation selected Design Workshop, a Denver-based architecture and planning firm to assist the Service in developing the Master Plan. The National Fish and Wildlife Foundation and Design Workshop signed the contract 5 April 1994.

The Service hired two persons dedicated to coordinating the Master Planning effort. An Outdoor Recreation Planner entered on duty February 6th, 1994, and a Landscape Architect/Planner from Region 3 transferred to the Refuge at the beginning of April. The Landscape Architect brought substantial experience in Master Planning for Refuges and is the coordinator for this project.

The management planning process has been divided into a series of phases as follows:

- Project Initiation and Definition
- Resource Inventory and Analysis
- Program Definition and Feasibility
- Alternatives Analysis
- Environmental Documentation
- Master Plan Documentation
- Final Environmental Impact Statement
- Summary Brochure

As of the end of 1994, the planning process is on schedule and in the alternatives analysis phase of the project.

The following is a summary of the projects accomplished during each of the phases completed to date.

Project Initiation and Definition

Following the preparation of a project work plan, a contract with Design Workshop was executed with the fees and deliverables schedule outlined. Design Workshop submitted a list of all the consultant team members and detailed each member's involvement in the process.

The consultants attended a two-day orientation workshop held at the Refuge and wrote a brief memorandum of their understanding of the direction provided by the Service. From time to time, the consultants have conducted additional meetings with the Service to brief the staff on the planning progress.

Regional office and Refuge personnel, along with the consultants, attended a two-day workshop in Estes Park to create a vision for the Refuge. From this workshop, a preliminary concept plan was developed. Two major themes evolved out of this workshop, and the concept of management zones was also developed. The two themes are: 1) Wildlife is important because it enriches the quality of our lives, and 2) Each of us has inherited a piece of the Earth. The care and understanding we bring to our piece can affect the whole.

Resource Inventory and Analysis

The key aspects of this phase of the planning process included:

- Development of the public involvement program.
- Development of design project graphics, mapping format and standards.
- Identifying, collecting, mapping, and reviewing existing site and resource information and document.
- Development of goals and objectives.
- Interpretation of site features.

Public Involvement Program

The consultants and the Service outlined the objectives for engaging the public and public agencies into the planning process. A database was developed for both the public and public agencies. A letter was written to public agencies introducing the project and soliciting agency comment.

The Service and the consultants held a series of eight focus group workshops of varying interests to identify issues and concerns. These focus groups consisted of the following interest groups: tourism, business leaders, neighbors, environmental groups, environmental educators, recreational interests, public agencies, and the scientific community.

The Service held scoping meetings 12-14 September 1994 in Commerce City, Montbello, and a central location in Denver. Approximately 90 people participated in this process. The Service mailed 25,000 invitations to all the residents of Commerce City and Montbello, in addition to the Refuge's mailing list, part of the Army's, Denver Audubon's, and Colorado Wildlife Federation's mailing list. Volunteers distributed flyers at key locations in the community. Flyers were distributed to the Colorado Bird Observatory's monthly meeting. The Service released press notices of the meetings, and placed advertisements in the local newspapers. The notice of intent/notice of scoping meeting was printed in the Federal Register.

The Service received 23 written comments during the comment period following the scoping process in addition to the comments made orally at the meetings (stenographic record made). The consultants documented this process in a scoping report.

Project graphics

The graphics for the project were standardized and a logo for the project was developed. The consultants wrote a technical memorandum summarizing mapping standards.

Resource Inventory and Mapping

The consultants undertook an extensive resource inventory of the Refuge and summarized much of this information in a bound document. By the end of 1994, they developed the following maps using a geographic information system (GIS) program:

Regional Context
Local Zoning
Base Map
Natural Resources
Contours
Elevation
Slope
Soils Series
Vegetation
Habitat Types
Wildlife Habitats (Winter)
Wildlife Habitats (Spring, Summer, Fall)
Water Resources
Constraints
Utilities
Roads

Goals and Objectives

The Service held a goals and objectives workshop in mid-July and from this drafted goals to be refined during the planning process. The two broad, overall goals and six underlying goals are:

- To enhance and sustain fish and wildlife and their habitats.
- To provide the public with meaningful opportunities to experience nature in an urban setting.

Goal 1 Manage wildlife and habitat to contribute to ecosystem management using strategies that recognize the Refuge's different resource types and the varying purposes specified by the legislation.

Goal 2 Interact with communities and organizations through outreach, partnerships, and other cooperative efforts to create mutually beneficial relationships.

Goal 3 Create environmental education and outreach programs for urban populations to nurture an appreciation of nature and to help develop an environmental ethic.

Goal 4 Provide opportunities for enjoyable experiences through wildlife-oriented recreation.

Goal 5 Utilize the site's unique qualities to provide opportunities for research activities compatible with management of the Refuge.

Goal 6 Develop a program support system to provide facilities, funding, and resources necessary to accomplish Refuge purposes.

These goals will continue to evolve and will not be finalized until the final planning documents are completed.

Interpret Site Features

From the information collected to mid-August, the consultants developed a map of the important features of the Refuge. The northern and southern zone concept which arose out of the vision workshop was further refined. An additional zone, identified as the western zone, was also developed.

The western zone is composed of lands that will be developed as part of the redevelopment of Stapleton Airport and other lands that are part of the Arsenal that will be auctioned. The purpose of the western zone is to promote partnerships with the developers and future occupants of these lands to ensure that future land uses are compatible with the Refuge and to enter into partnerships that will help bring people and resources to the Refuge's support.

The northern zone contains most of the land which will be the focus of the restoration as a result of cleanup. The purpose of this zone will be to work towards developing a self-sustaining prairie ecosystem with a light-touch management philosophy.

The southern zone has a much greater diversity of wildlife and vegetation as a result of the introduction of water by farmers and ranchers. This diversity of wildlife and habitat will be maintained through active management practices. The main focus of this zone will be education and will be where most of the public use will be concentrated.

Program Definition and Feasibility

The key aspects of this phase of the planning process included:

- Identifying existing and potential biological communities needs and uses.
- Identifying existing and potential public uses and user groups and analyzing/assessing their needs and market demand.
- Compatibility analysis.
- Development of the preliminary program.

Existing and Potential Biological Communities

The planning staff held a one-day workshop to discuss the management requirements for existing and potential biological communities and the conflict resolution between management requirements and Refuge goals. The consultants documented the results of this workshop in a working paper.

Identifying and assessing public uses and user groups

The planning staff held several workshops in order to begin developing a framework for future public use at the Refuge. From this, the consultants compiled a document which identifies the users and potential users of the Refuge, their current and future needs, including environmental education programs--existing and potential. Also identified are potential education partnerships where the opportunity exists for programs in the Denver Metro area to complement the programs at the Refuge. The report includes a comprehensive list of all educational facilities within the Denver Metro Area.

A draft public use framework has been developed which outlines the mission of future public use and the underlying supportive messages. The overall message of all educational activities will be the need for each of us, whether as citizens or government employees, to take responsibility for both this Refuge and other places in our lives and to play a role in overcoming past environmental mistakes and making this and elsewhere better places. The supportive messages or themes are:

- The history of the Refuge--the historical interaction between land, people, and technology--offers many lessons for taking responsibility for this and other places. (History of land use, pollution).
- Wildlife benefits everyone's life, especially on this Refuge in the midst of the city. (Wildlife population dynamics).
- Nature consists of dynamic and interrelated systems. (Connections, ecosystem management).
- Understanding and working with natural processes is more responsible and efficient than ignoring such processes. (Inter-relatedness).
- People and nature depend on each other (Water management).
- The Service, in serving as the Refuge's stewards, must carefully manage the resource of this Refuge and its visitors if the resources are to be sustained. (Visitors/Users/staff).

These themes are continuing to evolve and will not be finalized until the public use plan is completed near the end of the project.

The market demand for the future Refuge is currently being assessed as of the beginning of December, 1994. This report will be forthcoming.

Compatibility Analysis

As of 15 December, the Service and consultants are developing an opportunities and constraints map which will identify the best areas for recreational, interpretive, and environmental education activities to occur and areas where problems could exist in compatibility between programs identified in the Preliminary Program statement (see below). Additionally, the Service staff will be conducting a compatibility analysis of the preferred alternative in accordance with the standards set by the Service.

Development of the Preliminary Program

The Service held a two-day workshop in early November at Boettcher Mansion on Lookout Mountain to begin developing the program for the Refuge. From this workshop, a draft preliminary program was developed and is currently being reviewed and revised. This program identifies all the future programs and program elements for the Refuge. It includes management of the biological systems, public use, facilities, support facilities, infrastructure, and discussion of the Western Zone. It identifies the number of personnel that will be needed to manage the Refuge. This document will serve as the basis for outlining the management alternatives.

Alternatives Analysis

The key aspects of this phase of the planning are:

- Develop evaluation criteria.
- Develop alternative land use plans.
- Public review of alternative Plans.
- Development of a preferred alternative.
- Public review of preferred alternative.
- Draft preliminary master plan.

<u>Develop evaluation criteria</u>

As of 15 December 1994, the evaluation criteria for evaluating each of the alternative plans are currently being developed.

<u>Alternative land use plans</u>

As of 15 December 1994, the alternative land use plans are currently being developed.

<u>Public review of alternatives</u>

As of 15 December 1994, the next phase of public involvement is currently being scheduled and the logistics are being worked out. The Service is currently preparing copy for a newsletter which will be mailed out in January 1995 notifying the public of the next public meeting.

Additional Planning Effort

The Service has begun working with staff from the Stapleton Redevelopment Foundation and Commerce City to develop the partnerships and cooperation needed to make the Western Zone concept a reality in the future.

The Service has evaluated existing infrastructure including roads, utilities, and buildings to determine future Refuge needs.

The Service has evaluated current and future water requirements.

TITLE: Public Participation Program

INTRODUCTION

The Public Participation Program provides an opportunity for the public to learn about Refuge history, wildlife, and cleanup activities. Special emphasis is placed on helping the public develop an understanding and appreciation of wildlife and natural resources. Public Participation programs include wildlife bus tours; environmental education; open houses and other special events; the Eagle Watch viewing area; the Visitor Center; interpretive programs; interpretive signs and trails; fishing programs; a volunteer program; a scout program; and community outreach.

The Public Participation Program has reached more than 175,000 people since it began in late October 1989. During FY94, 46,904 people (27,113 children and 19,791 adults) learned about the Refuge through site visits or programs offered in the community. Thirty-eight percent of these programs were led by an active corps of volunteers. Volunteers contributed over 7,035 hours of service, equivalent to 3.21 full-time staff persons. FY94 program participation is presented on Table 4-1. Table 4-2 summarizes FY90 - FY94 program activity.

Wildlife Vehicle Tours

Bus tours provide opportunities for children and adults to learn about the history and natural resources of the Refuge and increase their awareness and appreciation of wildlife. During FY94, bus tours reached 10,057 people (5,475 adults and 4,582 children). Bus tours for school children (grades K-12) were offered Monday, and Wednesday-Friday between 8:00 a.m. and 4:00 p.m. The length of the tours varied from one to two hours depending on student grade levels. Public tours were offered Saturdays and Sundays at 9:00 a.m., 2:00 p.m., or 6:00 p.m. depending on the time of year. Special tours were offered for senior citizens, college students, daycares or summer camps, conservation organizations, community service clubs, scouts, and other groups as requested. All tours required advanced reservations. Most tours included a stop at the Visitor Center where participants were introduced to the Refuge with a video and displays in the exhibit room. Double-decker buses were used for groups of 50 or more. School buses were used for smaller groups.

Environmental Education Programs

Environmental education programs include school field trips, teacher training workshops, cooperative programs with conservation groups, and special programs for school children from communities near the Refuge (Montbello and Commerce City). The objective of the environmental education program is to provide urban children with positive outdoor learning experiences at the Refuge and increase their awareness of and interest in wildlife and natural resource conservation. Public Participation staff and Cooperative Education students have prepared curricula and are preparing a teacher's guide and education kit for the Refuge.

Field Programs

Field-based environmental education programs have reached just over 24,000 people since they began in August 1991. During FY94, new curricula were developed for grades K-8, and the curriculum for grades 9-12 was revised.

Two types of environmental education programs are offered at the Refuge: tour/walks and field programs. Both types were extended to two hours long in FY94 to provide a more comprehensive and less hurried learning experience. Field programs are available for grades 3-12, and tour/walks are provided for grades K-8.

Table 4-1. FY94 public participation programs and visitation.

PROGRAM	ADULTS	CHILDREN	TOTAL
Wildlife tours	5,475	4,582	10,057
Public	4,806	1,960	6,766
School	468	2,618	3,086
Other	201	4	205
Environmental Education	2,153	14,868	17,021
Tour/Walk	1,524	10,514	12,038
Field Program	629	4,354	4,983
Scout Programs	100	277	377
Girls	15	56	71
Boys	85	221	306
Interpretive Programs/Nature Walks	1,421	674	2,095
Public	1,360	550	1,910
Other	61	124	185
Presentations	843	2,642	3,485
Public	523	80	603
Schools	310	2,562	2,872
Other	10	0	10
Recreational Programs	2,754	1,155	3,909
Eagle Watch	2,523	865	3,388
Fishing Events	231	290	521
Special Events	7,045	2,915	9,960
On-site	1,825	1,079	2,904
Off-site	5,220	1,836	7,056
TOTALS	19,791	27,113	46,904

Table 4-2. Summary of FY90-FY94 public participation programs and visitation.

PROGRAM	FY90	FY91	FY92	FY93	FY94	TOTAL
Wildlife tours	10,000	21,000	32,754	18,876	10,057	92,687
Environmental Education		214	3,087	3,610	17,021	23,932
Presentations	1,500	3,000	1,399	1,189	3,485	10,573
Scout Programs					377	377
Interpretive Programs/Nature Walks		105	106	790	2,095	3,096
Eagle Watch	2,200	3,000	5,115	2,356	3,388	16,059
Special Events		7,000	11,381	2,688	9,960	31,029
Fishing Events		85	136	229	521	971
Field Dog Trials		890	686	216		1,792
TOTALS	13,700	35,294	54,664	29,954	46,904	180,516

Field programs consist of approximately 30 minutes in the Visitor Center (viewing the orientation video and exhibits), one hour in the field, and 30 minutes on tour to and from the field site. The upper elementary (grades 3-5) field program focuses on the prairie dog community and its importance. The middle school (grades 6-8) program takes place in a wetland and covers vegetation types and plant and animal adaptations to the wetland environment. The high school (grades 9-12) program involves techniques of estimating deer populations and methods of population control.

Tour/walk programs consist of an hour-long walk to Lake Mary, a 15-minute break in the Visitor Center (to view exhibits), and a 45-minute bus tour. The lower elementary (grades K-2) walk focuses on the senses and what one can learn about nature by using them. The upper elementary (grades 3-5) walk covers the importance of habitat and the habitat needs of specific Refuge wildlife discussed during the walk. The middle school (grades 6-8) walk will be developed in FY95.

During FY94, 17,021 people (14,868 students and 2,153 teacher/chaperons) participated in environmental education programs at the Refuge. Students came from Adams, Arapahoe, Denver, Jefferson, and Boulder counties.

<u>Educator Workshops and Curricula Projects</u>

A leader's guide for staff and volunteers was begun in FY94. The guide includes on-site curricula for grades K-12, background information, and leadership tips. It will be completed in early 1995.

In June 1993, the *Rocky Mountain Arsenal National Wildlife Area Teacher Resource Guide* was completed by the Denver Museum of Natural History (DMNH) education staff in cooperation with the Service and the Army. The guide contains classroom activities for grades 3-12. During FY94, 65 guides were distributed to Denver-area teachers upon request. These included 36 teachers who signed up at the Education Expo in March and seven to teachers at lunch-time trainings held at Rose Hill and Kemp elementary schools in Commerce City. Copies of the activities were also sent to each teacher in field trip confirmation packets.

The development of a curriculum guide for on-site, educator-led activities at the Refuge continued through FY94. From September through May, the education staff read and edited lessons submitted by educators under contract. Seven out of nine educators completed final lesson plans for inclusion in the curriculum guide. In September, Linda Lundgren, an educator, received the contract for completing the educator's guide; work will start in FY95. Based on the current timeline, this project will be completed in FY96.

A new curriculum project that began in FY94 is the *Rocky Mountain Arsenal National Wildlife Refuge Traveling Trunk*. This trunk will be available for educators to check out from Refuge staff and use in their classrooms. The trunk's curriculum guide will allow educators to teach their students about the land use history of the Refuge as well as how they can be responsible for protecting it and other places. The contents of the trunk will be designed during FY95.

<u>Special Projects</u>

Kemp Elementary School

Thirty-one 5th grade students from Kemp Elementary School in Commerce City participated in a series of special programs at the Refuge during FY94. The students completed a restoration project to learn about historic prairie habitat at the Refuge (fall); developed a mural with illustrations of wildlife seen from the Eagle Watch, part of a program on Threatened and

Endangered Species (winter); and completed a field study of wetland habitat along First Creek as part of a program on wetland function and water conservation (spring).

Kid's Care Conservation Club

In July 1994, a new program, the *Kid's Care Conservation Club,* was formed to provide an opportunity for children from Commerce City and Montbello to begin to develop a sense of ownership and concern about wildlife and natural resource issues at the Refuge. The Commerce City Recreation Center, Montbello Recreation Center, and Kinder College of Montbello worked with the Service staff to recruit participants. Fifty-nine children age 6-12 participated in five nature programs during the summer. Programs included *Snake Sayings and Toad Tales; Big Dipper, Little Dipper; Crawdad Crawl; Raptor Rap Session;* and *Buzzers, Hoppers, and Flutterers.* The Club continued to meet the second Wednesday of every month during Fall 1994.

Cooperative Education Students

Deanna Thompson, a Cooperative Education student from Texas Tech University, assisted the Public Participation staff with environmental education and public use programs during the spring of 1994. This was Deanna's second coop-ed assignment at the Refuge. She developed environmental education programs for the Wildlife Learning Lab, wrote the background section for the Refuge leader's guide, led environmental education programs, and assisted with planning Earth Day activities.

Jenna Dougherty, a biological technician with Texas Tech University, worked with Public Participation staff from May to December 1994. She led environmental education programs, developed the Refuge amphibian/reptile list, worked on the traveling trunk, and helped prepare for National Trails Day.

In June 1994, a cooperative education agreement between the Colorado Wildlife Federation, Shell Oil Company, National Fish and Wildlife Foundation, the Service, and the Army was extended. The agreement defined terms and conditions for the Federation to assist with the Service's public outreach to schools during FY94. The Federation provided wildlife presentations to 10,000 students.

Special Events

Special events held during FY94 included Bald Eagle Days (8-30 January), Federal Junior Duck Stamp Award Ceremony and Earth Day (23 April), and National Trails Day and National Fishing Week (4 June). The Service also hosted several fishing events for children, scouts, and disabled persons. A total of 2,904 people attended Service-sponsored special events on-site during FY94.

Bald Eagle Days

In its fifth year in 1994, the Bald Eagle Day celebration was changed to a month-long series of events. A variety of activities, geared toward audiences of varying ages and interests, took place from8 January through 30 January. The following list summarizes the Bald Eagle Days schedule:

Eyes On Eagles Open House, 1/8; 425 people
Scouting for Wildlife, 1/11; 15 people
Eagle Expo - Family Discovery Day Open House, 1/15; 830 people
Wildlife Viewing At Its Best, 1/16; 22 people
Scouting for Wildlife, 1/19; 29 people
Raptor Rap Session at MLK Middle School, 1/20; 364 people
Raptor Rap Session at John Amesse Elementary School, 1/21; 630 people

Wildlife Viewing At Its Best, 1/22; 38 people
America's Most Wanted, 1/23; 4 people
Scouting for Wildlife, 1/24; 12 people
Raptor Rap Session at Rose Hill Elementary, 1/25; 453 people
Raptor Rap Session at Kemp Elementary School, 1/27; 390 people
Winter Wildlife Film Festival, 1/29; 100 people
Where Eagles Soar Public Tours, 1/29; 400 people

The *Eyes On Eagles* and *Eagle Expo* open houses consisted of bus tours, conservation group booths, nature walks, and children's activities. During the *Eagle Expo* open house, children participated in a variety of bald eagle-related activities and received a stamp in an Eagle Expo Passport. Both events enjoyed sunny and warm weather.

Scouting for Wildlife programs were offered at the Eagle Watch for Girl and Boy Scouts. The program focused on endangered species. The Colorado Division of Wildlife's Watchable Wildlife staff led *Wildlife Viewing At Its Best*. Their presentation focused on ethical wildlife watching and places to watch wildlife in Colorado. *America's Most Wanted* was presented by the USFWS Law Enforcement division. Participants learned about wildlife laws and illegal wildlife products.

Raptor Rap Sessions were presentations with the captive birds of prey. These events were conducted in a school assembly setting. The *Winter Wildlife Film Festival* offered visitors an opportunity to view a variety of wildlife films. The *Where Eagles Soar Tours* consisted of a bus tour and presentation with the captive birds. January 29th was the only day of Bald Eagle Days that experienced bad weather. The month-long Bald Eagle Days worked well and gave visitors an opportunity to attend one or all of the activities.

Federal Junior Duck Stamp Program and Award Ceremony

The Refuge hosted Colorado's first annual Federal Junior Duck Stamp Art Contest in FY94; this contest is part of a kindergarten through twelfth grade conservation education program. Original duck stamp designs were received from 338 students. The artwork was judged on 13 April based on the following categories: K-3rd, 4th-6th, 7th-9th, and 10th-12th. A best-of-show design was chosen from all of the first place winners. Colorado's best-of-show design won 5th place in the national competition.

On 23 April, winning artists were honored during an award ceremony. Winners received a ribbon, certificate and prizes for their achievements; 125 people attended the ceremony. The winning artwork was on display in the Visitor Center for 3 months.

Earth Day Open House

In conjunction with the Federal Junior Duck Stamp Award Ceremony, the Service sponsored an Earth Day Open House. Three hundred and seventy-six people attended this combined event. In support of Earth Day, 140 Girl and Boy Scouts planted wildflowers and grasses and picked up trash. Other activities included nature walks, fishing, learning lab activities, and a display by the Metro Wastewater Reclamation District. Excellent weather contributed to a good turnout at the event.

National Trails Day/National Fishing Week

On 4 June, the Refuge began a week-long celebration of National Trails Day and National Fishing Week. A series of events was co-sponsored by the Commerce City Recreation Center and the Service. Commerce City celebrated the opening of a new trail system 11 June. Six hundred and fifty people (250 adults and 400 children) attended an open house on 4 June at the Refuge where activities included: bus tours, habitat booths with live animals, a kid's fish carnival, a kid's crawl-through prairie dog burrow, and kid's fishing at Lake Mary. One hundred scouts planted wildflowers and shrubs along the new Lake Ladora Trail. National Fishing Week was celebrated with scout fishing on 6 & 7 June and an evening of family fishing on 10 June.

Eagle Watch

The Eagle Watch is located on the eastern boundary of the Refuge and overlooks a winter bald eagle communal roost site along First Creek. The facility accommodates approximately 20 visitors at one time. Considerable improvements have been made to the Eagle Watch since it first opened in the winter of 1989/90. A closed circuit video camera with zoom and focus capabilities offers close up viewing of the eagles in the roost. The camera and audio systems send signals which are displayed on two video monitors. Although considerable effort was made in the winter of 1993/94 to keep the camera working, after numerous repairs, the camera continued to perform poorly, particularly when temperatures dropped below freezing. It was operational approximately 43 percent of the time. The audio system posed no problems other than occasional static through most of the 1993/94 season.

Camera repair work continued during the off-season in FY94. Work included camera repairs, locating and repairing the coaxial cable between the Watch and the roost, replacing conductor cables in the control box, and replacing the microwave audio system. During FY94 four directional signs were installed along 56th Avenue and Pena Boulevard. The signs included information about Eagle Watch hours and activities. During FY94, 3,834 people visited the Eagle Watch. The facility was open daily from 3:00 p.m. to dusk and Saturday mornings from 6:30 until 8:00 a.m. between 3 December 1994 and 13 March 1995. The facility was also opened on a limited basis for wildlife viewing during the summer of 1994. The Eagle Watch continued to be a popular program for volunteers to manage; volunteers staffed the facility 100% of the time.

In September 1993 the Denver Audubon Society formed a partnership with the Service to assist with volunteer recruitment and Eagle Watch management during the 1993\94 season. Denver Audubon Society volunteers contributed 22 percent of the volunteer hours during the 1993/94 season.

Visitor Center

The former Rocky Mountain Arsenal Army Officer's club was converted into a Visitor Center in January 1990. The Visitor Center is a multipurpose facility used as a staging area for tours, education programs, and special events. A conference room provides space for meetings, teacher training workshops, and fishing permit sales. The facility is open Monday through Friday between 8:00 a.m. and 4:00 p.m. It is open on a limited basis during weekends for interpretive programs and special events. Volunteers staff the facility almost 100% of the time. Their duties include answering the tour phone, taking tour and interpretive program reservations, keeping the facility clean, setting up meetings, assembling information packets, and greeting visitors.

Several improvements have been made to the Visitor Center since it opened in 1990. During FY94, construction work was completed to convert the kitchen area to an environmental education lab; tables, cabinets and work stations were installed in the lab; new lights were installed in the exhibit room; the hot water tank was replaced; and a carbon filter system was installed. Planning began to convert the small conference room into a bookstore to be managed by the Rocky Mountain Arsenal Wildlife Society and staffed by Service volunteers.

A variety of groups used the Visitor Center for meetings: U.S. Fish and Wildlife (Arsenal, Regional Office, Regional Directors, and others), U.S.

Army, Shell Oil Company, Colorado Wildlife Federation, National Wildlife Federation, National Fish and Wildlife Foundation, National Park Service, U.S. Geological Survey, and the Rocky Mountain Arsenal Wildlife Society. The special events held at the Visitor Center during FY94 were Bald Eagle Days, Earth Day/Federal Junior Duck Stamp program and award ceremony, and National Trails Day/National Fishing Week.

Interpretive Programs

During FY94, 2,095 people (1,421 adults and 674 children) participated in interpretive programs at the Refuge. In FY94, weekend guided nature walks continued to be offered on the Lake Mary trail, and, upon its completion, on the new Lake Ladora trail. These programs focused on wetland plants and animals. In addition, in the summer of 1994, the Eagle Watch was open to drop-in visitation, and, as part of this program, guided prairie nature walks were offered. The weekend interpretive program series begun in the summer of FY93 was continued in FY94. Program topics ranged from prairie mammals to birdwatching to wildlife photography to prairie restoration. Seasonal (fall, winter/spring, spring/summer) activity flyers were mailed to people on the Refuge mailing list informing them of upcoming program opportunities. Flyers were also taken to local teachers and community centers.

Four Refuge wildlife checklists - birds, amphibians/reptiles, mammals, and a kid's wildlife guide - were developed in FY94.

Interpretive Trails

During FY92, designs for trails linking the Visitor Center with lakes Mary and Ladora were developed by MK, a Shell contractor. In April 1993, Lake Mary trail construction was completed. During FY94, benches and trash cans were installed around the lake. Two handicapped fishing docks were built on the north side of Lake Mary, improving accessibility for disabled persons. A 35 by 35 foot hexagonal shelter was also installed for angler use. The Lake Mary trail was used for interpretive and environmental education programs and special events during FY94.

Lake Ladora trail plans were approved in FY93, and trail construction was completed during the spring of 1994. The Lake Ladora trail is 1.3 miles long and provides access for disabled persons to the Lake Ladora fishing dock.

Fishing Program

Public Participation staff are responsible for managing Refuge fishing programs including permit sales, coordinating fishing events and educational programs with the Arsenal Anglers fishing club, and responding to inquiries about fishing.

Permit Sales

A lottery system was developed to distribute fishing permits in FY93 to avoid problems in previous years. In prior years, anglers waited in line for 24 hours or longer at the west gate to ensure that they would be able to purchase a permit under the first-come-first-served, one-day-only permit sales system.

The lottery system was continued in FY94. A new policy in FY94 allowed anglers to bring pre-registered guests onto the Refuge to fish. Five hundred and seventy permits were made available to the public through the lottery system. Permits were twenty dollars each. Six hundred twelve fishing permits were sold during FY94, 601 to the general public and 11 to Arsenal personnel. A total of $12,240 was collected from permit sales and sent to the National Fish and Wildlife Foundation. The funds will be transferred to the Rocky

Mountain Arsenal Wildlife Society during FY95 and used to construct a handicapped-accessible boardwalk at Lake Mary.

Arsenal Anglers

Seventeen Arsenal Anglers, members of a fishing club which assists the Service with fisheries biology and public participation projects at the Refuge, contributed 457 hours of volunteer time in FY94. All Arsenal Anglers signed Service volunteer agreements. They participated in CPR, First Aid and other volunteer safety training and assisted with fishing and other special events.

Fishing Events

Five hundred and twenty-one people (290 children and 231 adults) participated in fishing events during FY94. Service staff and Arsenal Anglers organized and assisted with these events. One hundred and ninety-one participants were from the nearby communities of Montbello and Commerce City. Many of these participants were new to the sport of fishing. The Arsenal Anglers continued to work with patients from Craig Rehabilitation Hospital and Children's Hospital. They also purchased fishing lures and bait for these programs.

FY94 fishing events included:

- Craig Hospital - 4 May, 18 May, 8 June, 13 July, 27 July, 10 August, 7 Sept., 28 Sept. (Craig & Children's Hospital participants totaling 156).

- Children's Hospital - 13 July, 27 July, 10 August, 7 Sept.

- Family Fishing - 12 May, 10 June, 23 July, 26 August, 24 Sept. (109 participants).

- After School - 20 May, 26 May (44 participants).

- Scouts - June 6, June 7 (52 participants).

- Kids Care Conservation Club - July 30, Sept. 14 (82 participants).

- Kids Fish Carnival - August 13 (65 participants).

- Denver Parks & Rec (mentally disabled kids) - Sept. 17 (13 participants).

(Note: Approximately 100 children also fished at the 4 June National Trails Day/National Fishing Week celebration - see **Special Events** section of this report.)

Volunteers

Volunteers continue to be an integral part of the Public Participation program at the Refuge, leading 38% of the activities conducted in FY94. Volunteers contributed 7,035 hours, equivalent to 3.21 full time employees. Eighty volunteers assisted with bus tours, environmental education programs, fishing programs, presentations, special events, Eagle Watch, Visitor Center management, interpretive programs, and administrative duties at the Refuge. Volunteers continued to publish a monthly newsletter called the Talon and produce public use activity reports to track programs and participants throughout the fiscal year.

Volunteer Recruitment

Volunteers were recruited throughout the fiscal year through word of mouth, local newspapers, conservation group newsletters, Volunteers for Outdoor

Colorado, Mile High United Way clearinghouses and networks, and informational flyers, which were distributed to libraries, recreational centers, and universities. Personal contact during special events and programs was also very effective in recruiting volunteers.

Volunteer Training

Volunteer training continues to be a critical part of the recruitment and retention of qualified volunteers to lead and assist with public use programs. An annual comprehensive 32-hour training was continued in FY94. The training was conducted in October 1993 and included sessions on Refuge history, environmental cleanup, and wildlife health and management. Additional training was provided on safety, CPR, first aid, leading public and environmental education programs, and staffing the Eagle Watch and Visitor Center. Special training sessions were offered as needed throughout the year for new volunteers joining the program.

Volunteer Recognition

Volunteers are recognized and given awards after serving a specific number of hours or making a special contribution to the Service's programs. A minimum of 48 hours of service is expected each year from volunteers. Two volunteers, Bill Dowell and George Lewis, reached 1,000 hours of service in FY94; they deserve special recognition for their service. Harvey Cochran, Jo Platt, and Diane Buell completed more than 750 hours of service. One volunteer reached 500 hours and 8 volunteers reached 250 hours. A volunteer appreciation dinner was held during National Volunteer Week in April. One hundred ten volunteers, Service staff, and guests attended the event. Volunteers received certificates, pins, and Refuge mugs in appreciation of their contributions made throughout the year.

The variety and number of Public Participation programs offered at the Refuge would not be possible without the ongoing support of volunteers. Volunteers have a large impact on staff efficiency and help the Service reach new constituents each year.

Scout Program

During FY94, 377 scouts participated in merit badge programs and special events. In October 1993, Public Participation staff began leading scout programs for both girls and boys, grades 2-5. These programs were scheduled throughout FY94 on an individual basis. As part of an Eagle Scout project, thirty-seven scouts improved the Eagle Watch by cleaning, painting and installing shelves in the closet. Another Eagle Scout candidate earned his rank by organizing a seed gathering project. Appropriate scout reports were completed for the Regional Office.

In January, scouts participated in activities at the Eagle Watch as part of Bald Eagle Days. Scouts conducted service projects during the Earth Day Open House in April. One hundred and forty Girl and Boy Scouts planted wildflowers and grasses and picked up trash. Presentations were conducted at two scout round table meetings. Service staff sponsored an information booth at the annual Denver Area Scout Show.

In conjunction with National Trails Day, approximately 100 scouts participated in Service projects. They assembled picnic tables and did trail maintenance. Many scouts also enjoyed fishing and activities in the Visitor Center. Valley District Scout Leaders attended a wildlife tour which introduced them to the Refuge.

Community Outreach

During FY94, staff and one volunteer gave a total of 40 presentations in the community, reaching 3,485 people (843 adults and 2,642 children). Most programs were a slide show featuring Refuge wildlife, historical information, and visitor opportunities. The majority of the people were reached during the Bald Eagle Days' *Raptor Rap Sessions* which were held in local schools.

Special tours, meetings and presentations were arranged for Service employees from several offices, Congressional staff, Commerce City Parks and Recreation Department, Stapleton Redevelopment Foundation, Shell Oil Company, National Wildlife Federation, Colorado Wildlife Federation, National Fish and Wildlife Foundation, and other groups.

Service staff and volunteers participated in a variety of special events in the community during FY94 including the following: Denver Sportsmen's Show, Commerce City Derby Days, National Trails Day, Commerce City Parks and Recreation Center Halloween Party, News 4 Education Expo, Zoo Wildlights, the Scout Show, US West/United Way Connecting Colorado Fair, and the National Fish and Wildlife Foundation annual meeting.

The Rocky Mountain Arsenal Wildlife Society was established for the Refuge during FY94. This is a newly formed, nonprofit organizations of interested citizens dedicated to promoting public awareness and appreciation of nature and wildlife resources at the Refuge. The Society helps the U.S. Fish and Wildlife Service provide environmental education and wildlife-oriented recreation programs for Refuge visitors. Through volunteer and financial support of its members, the Society will produce interpretive and education materials for distribution to the public.

Planning for the 1995 Refuge calendar began in FY94 in cooperation with MGA, Denver Audubon Society, Mary Taylor Gray, Wendy Shattil and Bob Rozinski. A new introductory video was completed for use in the Visitor Center.

Media and Special Requests

Service staff assisted the print, video, radio and television media with numerous requests, interviews, press packets, and other information during FY94.

Newspaper coverage included:

- escorted a Brighton Blade photographer - January 1994
- Soar With the Eagles advertisement ran in The Denver Post, Rocky Mountain News, Commerce City Express and Brighton Blade - January 1994
- The Denver Post's Kid's Page focused on RMANWR - April 19, 1994
- The Rocky Mountain News published a story on the Russian Biologists who visited RMANWR - June 1994
- escorted a freelance writer for The Denver Post - July 1994
- press releases announcing nature programs were sent to *The Denver Post, The Rocky Mountain News, Commerce City Express, Commerce City Beacon, Boulder Daily Camera, Westword, and the Greeley Tribune*.

Magazine coverage included:

- Colorado Country Life, a publication of the Colorado Rural Electric Association, printed an article on bald eagles - October 1993
- escorted reporters from the *Refuge Reporter* - May 1994
- RMANWR visitor information was published in MarkAir Magazine - July/August 1994
- tour information was listed in the Denver Metro Convention and Visitor's Bureau 94/95 Official Visitor's Guide and Meeting Planners Guide.

- article on RMANWR was published in the *Refuge Reporter* -September 1994
- press releases announcing nature programs were sent to a variety of monthly magazines and newsletters.

Television/video coverage included:

- KWGN-TV in Denver and WPXI-TV in Pittsburgh aired a story on the Refuge produced by Ed Teachout, Impact Environmental Reports - October 1993
- Channel 2 aired a story on the bald eagle's status and eagle viewing opportunities at the Refuge - December 1993
- assisted CDOW in the field with acquiring white-tailed deer footage - December 1993
- News Four at Five aired a story on the increasing bald eagle population - January 1994
- Colorado Evening News aired a story on bald eagles - January 1994
- News Four Late Edition aired a story on bald eagles - January 1994
- News Four Today aired a story on the bald eagle's comeback - January 1994
- Newscenter Four at Noon aired a story on the bald eagle's success - January 1994
- Colorado Today (Channel 4) - RMANWR's Bald Eagle Days - January 1994
- News Four Weekend - Eyes on Eagles at RMA - January 1994
- Nine News - Bald Eagle Days at RMANWR - January 1994
- News Four Saturday - Annual Bald Eagle Days at RMANWR - January 1994
- Channel Two News - RMA open to raptor tour groups - January 1994
- News Four Today - tours of RMANWR to view eagles - January 1994
- Good Afternoon Colorado (Channel 9) - raptors at RMANWR and Bald Eagle Days - January 1994
- News Four Weekend - Eagle Expo at RMANWR - January 1994
- escorted writer/reporter from the PBS Nature Series - February 1994
- Colorado Getaways (Channel 4) filmed an environmental education program and toured the Refuge - March 1994
- Channel 2 aired a story on RMANWR and deer contraception - May 1994
- Channel 4 aired a story on the Russian Biologists who visited RMANWR - June 1994

Radio coverage included:

- KOA radio covered the fishing program - January 1994
- KID radio broadcasted Bald Eagle Days advertisements - January 1994

Miscellaneous

In the spring of FY94 a traveling exhibit was developed to inform neighboring communities of upcoming activities at the Arsenal. The exhibit was displayed in the lobbies of the Citywide Bank of Montbello, Montbello Library and in Commerce City's First Federal Bank and Omni Bank.

Service staff representatives regularly attended Public Affairs Subcommittee, Natural Resource Conservation Committee, Restoration Advisory Board, and Commerce City Small Business and Professional Association meetings.

Public Participation staff provided other special assistance as follows: Agency for Toxic Substances and Disease Registry - Arsenal Health Assessment; National Wildlife Federation - hosted a tour and breakfast for 240 members in December; participated in January Community Expo and other outreach programs, workshops, and meetings hosted by cleanup Parties to inform citizens of ongoing cleanup programs; participated in 1995 National Watchable Wildlife Conference steering committee/planning meetings; hosted a tour and meeting for Metro North Chamber of Commerce members; reviewed National Fish and Wildlife Foundation grant requests for education projects.

TASK 5 - ENGINEERING AND ADMINISTRATIVE SUPPORT

TITLE: Engineering Support

INTRODUCTION

The Service provides technical support to the Rocky Mountain Arsenal Program Manager (PMRMA) in the Environmental Engineering Division. There are four Service employees, one environmental scientist and three engineers, who work with the Environmental Engineering Division. The broad scope of support is engineering assistance in development of the Final Proposed Plan for cleanup under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) process to be put forth in the Record of Decision (ROD) for the Arsenal.

METHODS

The objective of engineering support is to provide technical assistance, project management, contract oversight, and interpretation for planning and investigation projects to support the development of the Proposed Plan for remediation of the Arsenal.

RESULTS

Offpost ROD Support

Project Title: Tri-County Health Department (TCHD) Domestic Well Sampling Program.

Objectives: The objectives of the TCHD Domestic Well Sampling Program are (1) to conduct an annual sampling of approximately 100 domestic wells (offpost of RMA) to evaluate drinking water quality and (2) to provide assistance to the Army for the submerged quench incinerator (SQI) hotline, which keeps residents updated on the operation of the SQI and allows them to ask questions of the Army.

Method: The wells are both shallow (unconfined alluvial aquifer) and deep (Denver or Arapahoe formation), although primarily shallow wells are sampled. A portion of the wells are sampled for diisopropylmethyl phosphonate (DIMP) only, because DIMP is the most widespread of the contaminants, and its extent defines the groundwater plume offpost.

Status: During the reporting period, six sampling events were conducted: four 25-well full-suite events, and two 100-well, DIMP-only events. TCHD is continuing to support the SQI hotline.

Project Title: Geophysical Investigation North of RMA (Woodward-Clyde Consultants).

Objectives: The objective of the Geophysical Investigation North of RMA is to evaluate subsurface geology and hydrogeology in the vicinity of the First Creek pathway and the northern pathway to support the final remedy for the Offpost Operable Unit.

Method: The contractor (contracted to the U.S. Army Corps of Engineers) is performing geophysical surveys in the First Creek and northern pathways and upgradient of the North Boundary Containment System to map the bedrock in order to give a more accurate picture of the hydrogeology of those pathways.

Status: During the reporting period, all onpost work was completed, access to private property offpost was completed, and a portion of the geophysical surveys were completed. Some work must wait until crops have been harvested in late autumn. Interpretation of the geophysical data will follow.

Project Title: Colorado School of Mines Geophysical Investigation.

Objectives: The objective of the CSM geophysical investigation is to evaluate the bedrock surface in the vicinity of the northern pathway.

Method: A combination of p-wave and s-wave seismic, electromagnetics, and microgravity is used to map the bedrock surface in a limited area on Shell property north of RMA.

Status: Field work was completed in 1992, and the contractor submitted a draft report in 1993. A revised draft report was submitted in spring 1994, and the contractor is finalizing the report, due in Spring 1995. Some additional field work had to be performed in summer 1994.

Western Tier Water Issues Support

Project Title: Western Tier Investigation (Jacobs Engineering Group).

Objectives: The objectives of the Western Tier Investigation are to evaluate contamination in the RMA Western Tier that may be originating from sources south or west of RMA, as well as contamination originating on RMA, and to evaluate whether that contamination is affecting South Adams County Water and Sanitation District.

Method: A combination of geophysical surveys, surface-water/sediment sampling, temporary drive-point well installation, and permanent monitoring well installation are being used to investigate the plumes of contamination in the Western Tier.

Status: During the reporting period, field work was conducted on the Arsenal and on property leased from the Arsenal by Stapleton International Airport (SIA) and the U.S. Postal Service. Additional field work on SIA property remains to be conducted.

Project Title: Western Tier Data Evaluation (Foothill Engineering Consultants).

Objective: The objective of the Western Tier Data Evaluation is to perform a literature review of all information relating to contamination originating on and off of RMA near the Western Tier and to evaluate whether a follow-up investigation is warranted.

Method: The contractor evaluated more than 60 reports and documents regarding contamination in or near the RMA Western Tier. The contractor will prepare a final report documenting the results of that evaluation.

Status: During the reporting period, the contractor continued to evaluate documents and reports regarding contamination in or near the RMA Western Tier. Sufficient evidence was found to warrant a follow-up investigation (see Western Tier Investigation project). Also, the contractor revised the civil litigation referral from the Army to the U.S. Department of Justice on the same subject. The contractor began preparing the final report.

FS/Detailed Analysis of Alternatives (DAA) Soil Support

Project Title: Soil Volume Refinement Program (Ensearch Environmental).

Objective: The purpose of this program is to gather additional soil data to support the Onpost Feasibility Study (FS). The data will be used to refine remediation volume estimates integral to the DAA.

Method: Implement a field program to collect surficial soil and deeper soil borings (to 40 ft.) at specific locations in the New Toxic Storage Yard. Surficial soil samples were analyzed for organochlorine pesticides (OCPs), arsenic, and mercury; soil samples from the deeper borings will be analyzed for soil physical characteristics.

Status: Field program was completed 27 August 1993. The Final report was distributed to the Organizations and State (OAS) in June 1994. A modification to the Task was completed in August 1994 in order to use remaining funds to do geotechnical work in the New Toxic Storage Yard and extend the period of performance (POP) through December 31, 1994.

FS/Soil Treatability Studies

Project Title: Soil Vapor Extraction Screening Program (Harding Lawson Associates).

Objective: To conduct field tests to measure in-situ soil permeability at multiple locations within Basin F and South Plants.

Method: Perform a two phased study to obtain in-situ soil permeability data and soil physical and chemical data for use in the model developed by Harding Lawson Associates to assess soil vapor extraction at Basin F and South Plants. Based on results of this screening program, pilot scale studies may be considered for these locations.

Phase I: Perform soil permeability tests at a total of sixteen locations: eight within Basin F, and eight within South Plants.

Phase II: Pilot-scale study in South Plants and Basin F. Vacuum extraction has been successfully applied for removal of volatiles from soils, but should be tested for site-specific chemical and geological conditions.

Status: Project was completed in May 1994. A Presentation of the final results was made to the OAS at the FS Subcommittee Meeting 17 May 1994. The Final Report was issued to the OAS in June 1994. There is no consideration being given to a Phase II program at this time.

Project Title: FS Soil Support Landfill Siting Study (Harding Lawson Associates).

Objective: To identify soils feasibility activities associated with the siting of an onsite landfill.

Method: The following subtasks will be performed to collect data for use in evaluating the siting of a landfill:

- Material Feasibility (Test Fill/Sealed Double Ring Infiltrometer Tests (SDRI) - Evaluate whether onsite materials are suitable for constructing landfill liner and cap.

- Area Feasibility - Identify areas suitable for landfill based on current regulatory and institutional criteria. Obtain data regarding the geology, hydrogeology, and geotechnical characteristics of the site to evaluate the feasibility of constructing a landfill in the existing foundation materials.

- Site Feasibility - Identify appropriate landfill site within one of the areas identified and evaluate the feasibility of constructing a landfill using onsite materials.

Status: The two test fills being constructed by HLA for the material feasibility portion of the Landfill Siting Study have been completed. Equipment for SDRI and two-stage borehole permeability tests has been installed and the SDRI tests are underway.

FS/Water Treatability Studies

Project Title: In-Situ Biotreatability Study (Ensearch Environmental).

Objective: To examine the feasibility of in-situ biodegradation of the benzene plume in the South Tank Farm area.

Method: In-situ biodegradation of benzene will be achieved by enhancing the natural microbial population in the aquifer. A three phase study will provide the information needed to understand the hydrogeology of the aquifer, problems that may exist with precipitation of iron and manganese, and nutrition requirements needed to enhance the microbial populations. The results of each phase will be analyzed to determine the feasibility of proceeding on to the next phase.

Status: The first phase of this study has been completed. The results of the first phase were presented at the FS Subcommittee meeting on 9 August 1994 to the Organizations and State (OAS). The information presented pertained mostly to the results from pumping tests and tracer tests. The results of the benzene and microbial analyses, are currently being reviewed. Results will be used to determine the technical approach for phase II, which involves the addition of oxygen to the groundwater to stimulate biodegradation of the benzene plume. Phase II is scheduled to begin the latter part of August.

A proposed modification to this task order to cover the additional level of effort required for phase I and II was submitted to contracting on 23 May 1994. Negotiations on this modification were completed on 15 August 1994.

Remedial Actions

Project Title: Above Ground Storage Tank Demolition (Roy F. Weston, Inc., and Gonzales Construction, Inc.).

Objective: The purpose of this program is the remediation of South Plants through removal of process and nonprocess above ground storage tanks (ASTs).

Method: Implement a field program to collect analytical data on contents of ASTs and possible contaminants both inside and outside identified tanks; take appropriate actions for tank demolition. Actions include: empty tanks of contents when necessary, decontaminate metal and ancillary equipment, cut tanks and piping into roll-off bin size, and send the metal to a recycler.

Status: Field program is ongoing. Projected completion dates are Summer 1995 for Weston and Summer 1995 for Gonzales. In addition to tank demolition, nonprocess utility pipeline are also being demolished under the Gonzales contract.

On & Offpost Settlement Discussion Support

Project Title: Preliminary Estimate of Natural Resources Damage Assessment and Restoration (NRDAR) for Rocky Mountain Arsenal.

Objectives: The objectives of the preliminary estimate for NRDAR are: (1) to quantify upper and lower bounds for potential NRDAR actions on the five classes of resources covered, (2) to identify potential resources trustees, and (3) to determine the best potential strategies for dealing with NRDAR at RMA.

Method: PMRMA's biota expert and a staff of nationally recognized natural resource economists evaluated the five classes of resources (air, geology/soil, surface water, ground water, and biota) considered under NRDAR for both On- and Offpost operable units. No original studies have been performed, but an evaluation of previously conducted studies was conducted. An in-depth analysis was developed for on-post biota with detailed cost estimates for both upper and lower bounds. Following this effort, a less rigorous evaluation of the remaining nine categories was conducted. The technical staff have also been available for consultations during settlement negotiations.

Status: This program was developed on short notice and tight schedule beginning in July 1994. Currently, the preliminary estimates are completed and the technical staff remains on call for support of settlement negotiations. Contracting issues are being completed at this time.

Historical Compliance

Project Title: Cultural Resources Coordination for Rocky Mountain Arsenal.

Objectives: The objectives of the Cultural Resources Coordination are: (1) to maintain compliance for the PMRMA and the Service with federal and state regulations concerning historical issues, (2) to identify potential conflicts and resolve prior to impact upon current PMRMA and Service operations and future planning, (3) maintain oversight of all historical surveys conducted at RMA, and (4) coordinate all historical activities at RMA.

Method: This task originally began as a "Section 106" compliance activity required for structural demolition, which led to a Memorandum of Agreement with the State Historical Preservation Office and the Advisory Council on Historic Preservation and an Interagency Agreement between the Service, PMRMA, and the National Park Service for an Historic American Engineering Recordation (HAER) of RMA. Additionally, a "Legacy" proposal has been developed and forwarded to interpret the various historical storylines at RMA. An interpretive prospectus has been developed by the National Park Service to assist in the development of the Comprehensive Refuge Management Plan for Rocky Mountain Arsenal National Wildlife Refuge. Coordination has been developed such that the various parties are aware of each other's actions and impacts to others involved.

Status: This program is ongoing. Currently, the HAER program is on schedule for completion in 1996. A complementary archeological survey program overseen by Task 2 is also underway and scheduled for completion in 1995. Modifications to the Interagency Agreement may be made to support oral/video history surveys of people involved in chemical manufacturing, wildlife, and site remediation. These oral histories would be used in future interpretive efforts as well as research.

PMRMA/Service Liaison

Project Title: PMRMA/Service Liaison.

Objectives: The objectives of this project are to further develop communications and understanding between PMRMA and Service staff personnel on a wide range of issues, with particular emphasis on integration of the Comprehensive Refuge Management Plan (Service) and the Post-Rod Implementation Plan (PMRMA).

Method: Information obtained at various Service and PMRMA meetings is analyzed and referred to the appropriate staff or management personnel for information or action. As a particular action or project develops, the respective staffs may have a project officer assigned to follow up.

Status: This program was developed to improve coordination between the staffs and continues at this time.

Chemical Weapons Treaty Support

Project Title: Chemical Weapons Treaty Technical Escort Support.

Objectives: The objective of this project is to support with a staff engineer (technically qualified on chemical production and holding appropriate security clearance) any inspections by foreign delegations concerning the chemical production at RMA and the removal/destruction of these facilities as proscribed under the Chemical Weapons Convention (CWC).

Method: Participate in and support all required training and preparation for potential inspections.

Status: This program continues at this time and will remain a requirement for PMRMA until RMA is removed by the treaty signatories from the CWC listed sites by a final inspection.

Integrated Endangerment Assessment/Risk Characterization (IEA/RC)

Project Title: IEA/RC Support.

Objectives: To assist the primary PMRMA staff engineer in completing and resolving disputes between the parties concerning the IEA/RC.

Method: Participate in and support all requested actions to bring the IEA/RC portion of the on-post RI/EA/FS process to closure.

Status: This program is concluded, excepting an ongoing dispute resolution study called the Supplemental Field Study concerning biomagnification factors for RMA biota. The Service engineer has transferred to other projects.

TITLE: Administrative Support

INTRODUCTION

Administrative support for all Service activities at the Arsenal was provided by the Administrative section. Administrative support included the Project Leader who has oversight responsibilities of all Service activities at the Arsenal. Support staff included, but was not limited to, a Budget Assistant, Office Assistant, and Office Automation Clerks. The cooperative agreement between the Army and the Service serves as the guideline for all work performed at the Arsenal.

METHODS

Administrative support assists staff with all functions that pertain to budget, procurement and purchasing, personnel, health and safety, property management, training, travel, change of station moves, payroll, and clerical needs. Other Administrative staff services included compliance with requirements defined in various Service, Army, EPA and Shell agreements and various administrative regulations required by the Service.

RESULTS

Budgetary and Fiscal Responsibilities

Budget and fiscal responsibilities were conducted by the Administrative Staff, including projection, justifications, management, accountability, monitoring and reconciliation of funds. Detailed records along with the computerized management system were maintained internally to serve as backup documentation. Development of required annual budget for upcoming fiscal year was submitted to the Army by 15 February for approval.

Procurement and Purchasing

The support staff assisted the Service staff with all procured items. Acquisitions were maintained with approving signatures and justification as to the necessity of the purchase. Expenditures were recorded and the procurement files were maintained internally for backup documentation. Equipment or non-expendable supplies that are procured or transferred to the Service at the Arsenal are maintained in a data base file and are identified by individual property numbers. All property items have been issued to Service personnel on hand-receipts to ensure tracking capabilities. Annual inventory audits were conducted internally to account for all property items. All purchases and property management controls are in accordance with the Federal Acquisition Regulations and Circulars, Department of Interior Acquisition Regulations, Federal Property Management Regulations, Interior Property Management Regulations, U.S. Fish and Wildlife Service Administrative Manual and the U.S. Fish and Wildlife Service Delegation of Authority Manual.

Personnel

Support staff assisted with all personnel issues including recruitment, termination, promotion, transfers, accretion, awards, tours of duty, position descriptions, performance plans and appraisals. Payroll is the responsibility of the support staff including submission of Time and Attendance sheets, monitoring annual, sick, compensatory time, leave without pay, Sunday premium and any other related issues. The support staff ensured that all necessary documentation and justifications were obtained and maintained for future use and ensured compliance with all regulations.

Vehicles

Service and General Services Administration (GSA) vehicles were monitored by the support staff to ensure that all vehicles follow the GSA Transportation and Motor Vehicle Regional Bulletins, and the Service Fleet Management System. Monthly, quarterly, and annual reports were completed. Quarterly inspections were completed to ensure that all vehicles are equipped with the required emergency equipment and supplies. The support staff ensured that the employees complied with Federal and State regulations regarding drivers licenses.

Training and Travel

All Service training and travel arrangements at the Arsenal were initiated by the support staff. The validity and justifications were monitored and maintained to ensure compliance with the scope of work for the site and that all costs were maintained and used in accordance with the Federal Travel Regulations and Service Policies.

Clerical Assistance

Clerical assistance was provided to the Service staff in all areas, including but not limited to word processing, copying, typing, filing, retrieving, and monitoring incoming and outgoing mail to ensure compliance of the various regulations.

U.S. FISH AND WILDLIFE SERVICE

ROCKY MOUNTAIN ARSENAL NATIONAL WILDLIFE REFUGE

FISCAL YEAR 1994 ANNUAL PROGRESS REPORT

APPENDIX A AND B

BIOMONITORING PLAN FOR THE EUROPEAN STARLING (*Sturnus vulgaris*) ON THE ROCKY MOUNTAIN ARSENAL:

1994 ANNUAL REPORT

Submitted to:

Project Leader
U.S. Fish and Wildlife Service
Building 111
Rocky Mountain Arsenal
Commerce City, Colorado 80022

Submitted by:

Dr. Michael Hooper and Sherry Skipper
The Department of Environmental Toxicology and
The Institute of Wildlife and Environmental Toxicology
Clemson University
P.O. Box 709, 1 Tiwet Dr.
Pendleton, South Carolina 29670

February 15, 1995

PROJECT TITLE	**BIOMONITORING PLAN FOR THE EUROPEAN STARLING (*Sturnus vulgaris*) ON THE ROCKY MOUNTAIN ARSENAL: 1994 ANNUAL REPORT**
SCCFWRU RESEARCH WORK ORDER NUMBER	**RWO - 18**
TIWET PROJECT NUMBER	**TIWET - 09339.2**
TESTING FACILITIES	The Institute of Wildlife and Environmental Toxicology P.O. Box 709, 1 TIWET Drive Pendleton, SC 29670 (803) 646-2200 U.S. Fish and Wildlife Service Rocky Mountain Arsenal Bldg 111 Commerce City, CO 80022 (803) 289-0232

STUDY DIRECTORS

Principal Investigator,
Biochemical Toxicology, TIWET

Michael J. Hooper, Ph.D. — Date: 02/15/95

OTHER INVESTIGATORS

Graduate Research Assistant
Biochemical Toxicology, TIWET

Sherry L. Skipper, B.S. — 02/15/95

QUALITY ASSURANCE AUDITS

Quality Assurance Officer, TIWET

James Osbey, B.S. — 02/15/95

MANAGEMENT

Institute Associate Director, TIWET

Raymond Nobler, Ph.D. — 02/15/95

GOOD LABORATORY PRACTICE COMPLIANCE STATEMENT

This study was conducted and audited in compliance with EPA Good Laboratory Practices as outlined in 40 CFR Part 160, August 17, 1989.

Michael J. Hooper
Study Director

02/15/95
Date

QUALITY ASSURANCE STATEMENT

This study was conduct under the auspices of The Institute of Wildlife and Environmental Toxicology Quality Assurance Program, and under full Good Laboratory Practices as outlined in 40 CFR Part 160, August 17, 1989. Any changes in the protocol or SOPs referenced in the protocol were documented in writing and signed by the Study Director.

The Quality Assurance Unit verbally notified the Study Director immediately of any problems encountered during audits. Written audit reports were also submitted to the Study Director and Management. Audits were performed on and written reports were generated for the following phases of the project:

Project 09339.2

Audit No.	Auditable Research Phase/Activity	Audit Dates	Dates Submitted to Study Director	Dates Submitted to Management
1	Data Records	05/15/94-05/17/94	07/22/94	07/25/94
2	Starling Nest Box Monitoring	05/15/94-05/17/94	07/22/94	07/25/94
3	Laboratory Assays/Animal Preparation	05/15/94-05/17/94	07/22/94	07/25/94

James E. Oakley (signature)
Date: 02/15/95

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INTRODUCTION

The goal of the European starling studies is to develop a biomonitoring program to assess survival, chemical bioaccumulation and biological response to chemical exposure in European starlings inhabiting the Rocky Mountain Arsenal based on rational techniques and endpoints which will withstand peer review and litigation challenges which frequently accompany focussed contaminant biomonitoring projects.

This report summarizes the activities of 1994 including the spring and summer field season as well as initial data evaluations. Updates on all stages of 1994 sample processing, reproductive success evaluations and plans for the upcoming 1995 field season are the primary focus.

Progress Toward Objectives

1. *Establish European starling nest box colonies in order to enhance the reproductive population of the species in proximity to sites of concern.*

   Nest boxes (306) were deployed on 17 sites during the winter of 1993 and monitored for nesting success and nestling chemical exposure and effects.

2. *Perform positive control dosing studies with dieldrin (and other pertinent COCs) in order to determine age-dependent toxicity and biomarker dose-response relationships.*

   Initial scoping studies run in the summer of 1993 have been analyzed and presented in the 1993 annual report. Additional studies attempted in 1994 were not completed due to high temperature effects on nestlings. These studies will be prioritized in the 1995 field season.

3. *Determine the role of food item transfer of contaminants to nestling starlings using esophageal constriction techniques.*

   Food Items were sampled from nestlings during the 1994 field season and have been identified to genus. Samples have been shipped to analytical lab for contaminant determinations. Similar collections will occur during the 1995 field season.

4. *Correlate the geographic distribution of chemical exposure and induced effects with known distribution of chemical contaminants as a means of determining bioavailability of contaminants and, eventually, remediation need and efficacy.*

   Contaminant distributions have been mapped on a GIS data base. Reproductive success endpoints are being entered for inclusion with these distributions. When available, biomarker, histological, and chemical residue will be added to complete the database and allow progression to analysis of exposure and effects distributions.

METHODS

Field Methods

Nest Box Monitoring

Nest Box monitoring was initiated on April 8, 1994 and proceeded through July 8, 1995.. Boxes were checked on a regular basis and activity recorded on nest Box monitoring sheets (TIWET Form No. 8, rev 4.4/91), one of which was used for each monitoring date. Nest condition was rated on a 1-4 scale. A rating of

1 - indicated no nesting material was present
2 - indicated some nesting material was present but no nest cup formed
3 - indicated that a partially formed nest cup was present and
4 - indicated a completely formed nest cup.

Other information recorded on the monitoring data sheet included number of eggs, number of live and dead nestlings and the presence of adult birds. Those nests with eggs close to the end of the incubation period or with nestlings, were monitored daily. Abnormalities found during monitoring were recorded on the comments section of the nest Box monitoring form.

Dead nestlings or adults found in or around the nest boxes were collected in glass containers and stored at -80C. Cracked eggs or eggs that remained unhatched after a reasonable incubation period were collected and stored similarly.

Nine day old birds, in select nest boxes, were used for food item collection (esophageal constriction) and were injected with sheep red blood cells (SRBC) to initiate an antibody response.

Reproductive Success Analysis

Data from nest Box monitoring forms were used for determination of reproductive success. Only nests considered fully tended were used in the analyses. A fully tended nest was considered a nest in which at least two eggs were laid within two monitoring periods. The following is a list of variables either measured or derived from information recorded on the nest Box monitoring forms. Variables A, B and D through G list the data taken from the nest Box monitoring sheets and variables C and H through K are derived from variables A through G.

A. *Nest Boxes Available* - The total number available on the site.
B. *Clutches Initiated* - The total number initiated on the site.
C. *Box Utilization* - The number of clutches initiated as a percent of nest boxes available (B / A).
D. *Clutch Size* - the total number of eggs laid.
E. *Eggs at Hatch* - The number of eggs present the last monitoring period before first egg hatched.

F. *Hatchlings* - The total number of nestlings that fully hatched.
G. *Nestlings at 15 Days* - The number of nestlings that survived until 15 days of age.
H. *Missing Eggs* - The number eggs that disappeared between clutch initiation and presence of first hatchling or, if no eggs hatched, the number of missing eggs within 12 days after the last egg of the clutch appeared. (D - E)
I. *Missing / Dead Nestlings* - The number of nestlings that died or disappeared between hatching and day 15 post-hatch. (F - G)
J. *Percent Eggs Hatched* - The number of eggs that hatched divided by the number of eggs in the clutch on the last monitoring period before hatching occurred. (F / E)
K. *Percent Nesting Efficiency* - The percentage of eggs which resulted in nestlings that survived until day 15. This was calculated as the number of 15 day nestlings divided by the clutch size. (G / D)
L. *Percent Fledging Efficiency* - calculated as percentage of hatchlings that lived to 15 days. This was calculated as the number of 15 day old nestlings divided by the total number of nestlings that hatched. (G / F)
M. *Percent Nesting Success* - The percentage of clutches initiated that produced at least one 15 day old nestling. [($G\geq1$) / B)]

Values for variables D through L were obtained for each clutch and the mean and standard deviation (s.d.) of clutch specific data were calculated for each site. Values for variables C and M were calculated on a site by site basis only.

Laboratory Analyses

Fifteen day old birds were brought into the laboratory for tissue collection and processing. Each bird was given a unique identification number according to the site and the nest Box from which it was taken. Body weights were taken for each bird. Nestlings were euthanized by asphyxiation in a chamber with a pre-charged saturated atmosphere of CO_2. If bird numbers (per nest) permitted, one bird, each, was designated for analysis of biomarkers, chemical residues, and histological analysis.* In nests with less than three nestlings, biomarkers was the first priority followed by chemical residue analysis. In clutches with more than three nestlings, all birds beyond the first three were designated for biomarker analysis. Unique individuals showing signs of intoxication were divided amongst all three sampling approaches, using conservative tissue collection techniques to try to obtain as much information as possible.

Biomarker Analysis

Immune Function. Blood was taken and serum isolated in order to measure antibody response to SRBC injection. A blood smear was made from whole blood for a white blood cell differential count. The spleen was removed, weighed and processed for lymphocyte blastogenesis studies. A single cell suspension in RPMI culture media was prepared from each spleen and adjusted to a final cell concentration of 1.67×10^7 cells/ml. Thirty μl aliquots of this suspension, which contained 500,000 lymphocytes, were pipetted into sterile 96-well tissue culture plates into wells that contained either RPMI culture media (unstimulated or control cells) or 5 μg/well mitogen along with RPMI culture media (stimulated cells). The mitogens used in this study were phytohemagglutinins PHA-M and PHA-P and lipopolysaccharides from Escherichia coli (LPS-E) and Salmonella typhimurium (LPS-S). Whenever possible, the sample was divided into triplicates for control and each mitogen. Plates were incubated for 48 hours in a 5% CO_2, humidified atmosphere at 41C. Eight hours prior to the end of the incubation, 0.5 μCi of ^{3}H-thymidine was added to each well. At the end of the 48 hour incubation, the plates were frozen at -20C, transferred to -80C freezers and transported back to Clemson University for further processing. The plates were brought to room temperature and the cells were harvested onto glass mats and placed into scintillation vials. Stimulation indices for each sample were calculated by dividing the mean of the disintegrations per minute (dpm) of the stimulated wells by the mean of the dpm of the unstimulated wells.

Tissue Collections. Liver and kidneys were removed, weighed and stored in liquid nitrogen. These tissues were transferred to a -80C freezer and will be stored there until P450 and porphyrin analysis can be performed at Clemson University. Heads were removed and shipped to Clemson for brain cholinesterase analysis. The remaining carcass was stored at -80C.

Chemical Residue Analysis

Blood was taken and plasma isolated for chemical residue analysis. Intact carcasses were placed in glass containers, stored at -80C and transferred to Clemson University where tissues were removed for chemical residue analysis. Liver, kidney, pectoralis muscle, brain and GI tract were isolated for COC analysis. Special emphasis was placed on metals in the kidney analysis. Samples were shipped to USFWS RMA for submission to analysis laboratories.

Histological Analysis

Blood was taken and plasma isolated. Tissues were removed, weighed and stored in a 10% buffered formalin solution. Tissues taken include eye (stored in Bouin's solution), GI tract, bursa, thymus, pancreas, liver, kidney, spleen, brain, heart and breast muscle, lung, bone, and nerve. These samples were transported to Colorado State University and prepared for histological evaluation using paraffin fixation and H and E staining. Histological readings are being performed in a blind sampling mode by Dr. David Getze of the Colorado State University Veterinary Diagnostic Laboratory.

Dieldrin Positive Control Dosing

LD50 dosing was performed in the field where nestlings were dosed at age day three post-hatch and at age day fifteen post-hatch. Nestlings in both experiments were administered oral doses of 50, 75, 100 and 200 mg/kg dieldrin and monitored for symptoms of intoxication.

RESULTS AND DISCUSSION

Field

The following section describes data associated with starling reproductive success evaluations. Two sets of summary data accompany this discussion. The first is a site by site listing of reproduction parameters (Table 1). The second is a summary sheet detailing the ranking of the different sites for each reproduction parameter (Table 2). Please refer to the two tables to help clarify this discussion.

Reproductive Success Parameter Analysis

Nest Boxes Available, Clutches Initiated and Box Utilization. Nest box utilization derived from the quotient of clutches initiated per nest boxes available, ranged from 33 % on the South Plants site to 200% on the eastern Toxic Storage Yard site. The D Street, Basin A and South Plants sites were conspicuously low with 33 to 50 percent use rates. Care should be taken in interpreting this parameter, however, as the sites with the two highest utilization rates had only moderate to low nesting success (Commerce City and the east side of the Toxic Storage Yards, respectively).

Clutch Size. Clutch size ranged from 5.33 eggs/clutch at the southwest facing Toxic Storage Yard to 2.83 eggs/clutch at the Basin A site. Most averages were from four to five eggs/nest, with the Basin C/F and Basin A sites conspicuously low at 3.6 and 2.83 eggs/nest. The high southwest Toxic Storage Yard value is also substantially above all other sites.

Eggs at Hatch. Interestingly, the southwest Toxic Storage Yard site with the largest clutch sizes also had the most eggs survive to hatch, with no egg losses in its 20 clutches. Alternately, the basin A and South Plants sites yielded no clutches which survived to hatch. there was a wide distribution of values within this endpoint. Note: This value is highly dependent on clutch size and should be evaluated in light of original number of eggs laid.

Hatchlings. The southwest Toxic Storage Yard site again had values in this variable which stood out above the other sites. 4.56 hatchlings were obtained from this site. Sites with small hatchling numbers were Basin A and South Plants with no hatchlings and Basin C/F and the southeast lawn of Building 111 having less than an average of one hatchling per nest. Note: This value is highly dependent on the number of eggs at hatch and can also be interpreted as it influences *Percent Eggs Hatched*, below.

Nestlings at 15 Days. With strong egg survival and hatchling production, the southwest Toxic Storage Yard site produced the greatest number of 15 day nestlings with an average of 2.67 per nest. Survival through the nestling phase showed wide variety of chick numbers. With no hatchlings, Basin A and South Plants had no 15 day nestlings. Note: This value is highly dependent on the number of hatchlings and can also be interpreted as it influences *Percent Fledging Efficiency*, below. Further, it provides influence on *Nesting Efficiency* (see below).

Missing Eggs. The difference between *Clutch Size* and *Eggs at Hatch*, values for this variable ranged from the southwest Toxic Storage Yard site with no missing eggs to the nests at South

Plants which lost all of their eggs prior to hatch. Basin A, the southeast lawn of Building 11 and Basins C/F each lost over 2.5 eggs/nest

Missing / Dead Nestlings. The difference between the number of *Hatchlings* and *Nestlings at 15 Days*, this value was lowest at the north end of the Toxic Storage Yards (0.89 missing or dead) closely followed by the southeast lawn of Building 111 (1.00). It should be noted however, that with an average of only 0.71 hatchlings/clutch on this site, the 1.00 missing or dead nestlings substantially depletes what little nestling generation occurred there. Care should thus be taken in the absolute interpretation of this endpoint.

The following four endpoints better interpret the collected data, giving insight to the importance of the previously observed data.

Percent Eggs Hatched. The average percentage of young hatching as a function of the number reaching the time to hatch, this value reflects egg fertility, development of the embryo and the bird's physical and physiological ability to escape the egg and begin an air breathing existence. Compared to the other three interpretive endpoints, success rates in this category were rather high ranging from 74 to 98 percent. The clutches on the southeast lawn of Building 111 had a conspicuously low hatch success of only 50% (five out of only ten hatch stage eggs).

Percent Nesting Efficiency. The average percent of 15 day nestlings as a function of eggs in the nest at the beginning of the clutch, this value is indicative of the return in ready to fledge nestlings for the investment of eggs in the clutch. Highest nest efficiency was at the southwest array of Toxic Storage Yard nest boxes where 50% was reached. All other "control" sites fell within 15% of this high value as did two other Toxic Storage Yard sites (west and north) and the North Plants. Nesting efficiency dropped off to 4.4% at the Basin C/F site while Basin A and The South Plants site had no 15 day young from either of their 6 and 10 clutches, respectively.

Percent Fledging Efficiency. The average percent of the hatchlings which survive to day 15 post hatch, this parameter had a high of 69% at the Northern Toxic Storage Yard site and a low of 24% for the D Street site. High values for this endpoint ranged from 57 to 63% followed by a fall off to values of 38 to 45%. The Basin A and South Plants sites had no nestlings hatch and therefore could not be evaluated.

Percent Nesting Success. The percentage of initiated clutches finishing with at least one 15 day old nestling, this parameter had a broad range of values from 88.9% on the Southwest Toxic Storage Yard to 0% on Basin A and the South Plants. After the particularly strong success of the southwest Toxic Storage Yard site, there was a progressive decrease in success when the other sites are compared. The more successful nests, in addition to the control sites (7, 9, 12 and 27), were the southwestern, western and northern Toxic Storage Yard sites and the North Plants.

Individual Site Assessments

Evaluation of the different reproductive parameters can shed light on potential causes associated with nesting failure when it occurs. To date, we have evaluated all sites for reproductive success and will be soon incorporating biomarker, histopathology and chemical residue into these evaluations to better fully assess potential cause and effect relationships. Please refer to Table 2 for the specific ranking of each site for each parameter.

Controls: These sites were chosen due to their distance from areas of high contamination and location near the periphery of the Refuge.

Site 7: High Line Canal. Overall nesting success was excellent for this control site with a 70% value making it the second most successful site. Though it had only a moderate percentage of hatched eggs (83%), it had large clutch sizes (4.68), few missing eggs (0.51) and a high fledging efficiency (60%) which led to high nesting efficiency (45%) and overall nesting success.

Site 9: Commerce City. Nesting Success was only moderate for this site (46.0%) and lowest of all of the four controls. This was due primarily to a loss of eggs (1.38) between nest initiation (4.52) and the time of hatch (3.14) and due to a relatively low hatch rate (80%). This site had the second highest box utilization rate at 167%.

Site 12: Shooting Range. Nesting success was relatively high on this site at 60%. Average clutch size was the second highest of all the sites (4.85) as was eggs at hatch (4.58) indicating relatively low egg losses during incubation (0.27). Hatching was also successful (90%). Fledging efficiency was low however (43%) due to large chick losses (2.55 dead or missing) which led to depressed numbers of 15 day chicks (1.73) compared to the average number of hatchlings (4.12). Though these chick losses led to decreased nesting efficiency (35%), sufficient nestlings remained in each nest to result in good nesting success.

Site 27: Treed Knoll. Third of the four controls, this site had 57.1% nesting success, similar to that at the shooting range. Most parameters had moderate to strong values resulting in a rather consistent results across all endpoints. There was no outright strengths or weaknesses on this site.

Moderate to Questionable Toxic Sites. Proximity to small sites of contamination, generally distant from the highly contaminated sites (Site 4) or historically high numbers of bird mortalities (Building 111 sites) led to the choice of these three sites.

Site 4: Railyard. There was relatively low nesting success (25.0%) on this site. Nests started out with one of the smallest average clutch sizes (3.94), though subsequent egg losses were not severe (1.25) and percent eggs hatched (84%) was moderate. Substantial chick losses, from what to appeared to be predation on the nestlings, led to lower nesting and fledging efficiencies (19% and 39%, respectively), the elimination of a large proportion of the nests resulted in the lower nesting success. A nestling showing strong signs of cyclodiene toxicity was recovered from this site.

Site 35A: West of Building 111. This site also had relatively low nesting success (33.3%), primarily due to large numbers of missing or dead chicks (3.0). Moderate clutch sizes and eggs at hatch (4.47 and 2.87, respectively) and the highest percentage of eggs hatched on the Arsenal

(98%) initially led to moderate numbers of hatchlings (2.80). Large numbers of dead or missing nestlings (3.00), however, led to lower nesting (23%) and fledging (44%) efficiencies. Loss of three of the eight nests with hatchlings led to the lowered nest success levels. A nestling showing strong signs of cyclodiene toxicity was recovered from this site.

Site 35C: Southeast Lawn, Building 111. This site was distinctive for its lack of nesting success (14.3%), having the second lowest level of the nests with surviving hatchlings. Ironically, clutch size was large at 4.71 eggs/nests but substantial losses of eggs (3.29) and an egg hatching rate which was lowest on the arsenal (50%) led to low hatchling (0.71) and 15 day nestling (0.43) numbers. The low number of missing or dead nestlings (1.0) is misleading, as the average nestling number at hatch (0.71) left little room for nestling loss. Low nesting success occurred as only one out of seven clutches produced a 15 day nestling.

High Toxicity Sites.
These sites were chosen in an attempt to place breeding birds in areas with maximum perceived hazard and assess their response, both as a measure of worst possible case exposures and as a way to establish a pre-remediation background for comparison to post-remediation conditions.

Site 1: South Plants. This site, along with Basin A, was one of two sites with no nesting success. Ten clutches were initiated, though the average clutch size was small (4.10). No eggs survived to hatch. Box utilization rates (33%), were lowest on the Refuge, probably reflecting extensive storage tank demolition which occurred shortly after the initiation of the nesting season. The impact of this disturbance may be responsible for the poor nesting success, a hypothesis to be tested in the 1995 field season.

Site 25: North Plants. Of all the toxic sites, the North Plants was one with some of the most consistently high success and efficiency ratings. With an overall nesting success rate of 59.4% (greater than two of the controls) this site was fifth of all sites and third of the toxic sites. Both box utilization (152%) and clutch sizes (4.81) were high. A moderate number of missing eggs (1.09) was made up for by high percentage hatching (92%), low nestling losses (1.62) and subsequent high nesting (45%) and fledging (62%) efficiencies.

Site 26: Basins F and C. Of the sites with surviving nestlings, this site had the lowest nesting efficiencies. Starting with one of the lowest clutch sizes (3.60), high egg losses (2.56) left clutches on this site little with which to proceed. Egg hatching efficiency was low (78%) leading to low (0.80) hatchling numbers. Nestling survival was moderate (40% fledging efficiency) though the low absolute numbers of 15 day nestlings (0.24) led to the very low nesting success (8.00%) and nesting efficiency (4.4%) values.

Site 31 - N: Toxic Storage Yard, North. Third in nesting success (50%) of the four Toxic Storage Yard nest Box sites, this site had lower clutch size(4.43), eggs at hatch (2.64) and hatchling (2.14) numbers than many sites. Missing egg numbers were also high (1.7). Once hatched, however, nestlings thrived on this site, with the lowest numbers of missing nestlings (0.89) and the highest fledging efficiency (69%) of all the sites on the refuge. The high nestling survival balanced the pre-hatch losses, resulting in the moderate nesting success and nesting efficiency (36%) values.

Site 31 - E: Toxic Storage Yard, East. The least successful (25.0%) of the Toxic Storage Yard sites, these nest boxes had the highest utilization rate on the Refuge (200%). Initial clutch size was moderate (4.35) as were egg losses (1.70). Hatching efficiency was high (94%) leading to moderate hatchling numbers (2.50), however chick losses were large (3.18) leading to low 15 day nestling numbers (0.75) and subsequently low fledging (31%) and nesting (16%) efficiencies and nesting success.

Site 31 - SW: Toxic Storage Yard, Southwest. This was the most successful site both of the Toxic Storage Yard sites and the refuge with an 88.9% nesting success and 50% nesting efficiency. An average of 5.33 eggs/clutch and 100% egg survival rate were also highs for the Refuge. Though the percentage hatching (86%), fledging efficiency (59%) and missing nestling (1.89) values weren't as strong as other sites , the resulting hatchling (4.56) and 15 day nestling (2.67) numbers were still the highest on the refuge. The contrast of this site with the northern and eastern sites deserves further attention.

Site 31 - W: Toxic Storage Yard, West. The second most successful of the four Toxic Storage Yard sites, this site had the third highest percent nesting success on the Refuge. Most statistics for this site are generally moderate to high (clutch size - 4.47, eggs at hatch - 3.73 and lost eggs - 0.73). Though nestling survival wasn't outstanding (2.00 missing or dead) nesting efficiency was good (37%) and fledging efficiency was strong (63%), leading to the site's overall success.

Site 35B: D Street. This site had the next to the lowest nesting success (13.3%) of the nests with nestlings. Clutch size wasn't extremely low (4.33), though substantial egg (1.87) and nestling (3.57) losses depleted most of the nestlings before they reached the 15 day nestling stage (0.27 / clutch). Subsequent egg hatch (74%), nesting efficiency (6.7%) and fledging efficiency (24%) values further reflected the low overall nesting success of this site.

Site 36: Basin A. Nest to the South Plants site, this site had the second lowest box utilization (40%) with only 6 clutches initiated. Clutch size was the lowest of all sites (2.83) with none of the eggs making it to hatch. Both nesting efficiency and nesting success values were 0%.

It can be seen that perceived toxicological threat based simply on location must be approached carefully in wildlife studies. Of the five most successful nesting sites, three are located on sites considered highly toxic. Actual interpretation of specific data based on detailed assessment of each site can provide insight on mechanisms of nesting failure. There were four primary causes for decreased nesting success in European starlings, small clutch size, high egg loss, decreased hatch efficiency and decreased fledging efficiency. When evaluated for each site's strengths and weaknesses, certain sites had particular weakness which led to decreased hatchng success. Other sites, however had low values for particular parameters that reflected preexisting small numbers of eggs or nestlings as the cause rather than actual decreased values. Omitting the latter provides the following tally.

Small Clutch		Egg Loss	
4	Railyard	1	South Plants
26	Basin F and C	9	Commerce City
31N	Toxic Storage Yard - North	26	Basins F&C
36	Basin A	31N	Toxic Storage Yard - North
		35B	D Street
		35C	SE Lawn, Bldg 111

Decreased Hatch Efficiency		Decreased Fledging Efficiency	
9	Commerce City	4	Railyard
35C	SE Lawn, Bldg 111	12	Shooting Range
26	Basins F&C	31E	Toxic Storage Yard
31N	Toxic Storage Yard - North	35A	West of Building 111
		35B	D Street

The 1995 spring field study will attempt to address these observations, based on laboratory results of biomarker and chemical residue analyses. Further analyses of this data will be performed once the primary, renesting and secondary breeding seasons have been separated.

European Starling Toxicity

During the Spring of 1994 four starlings were collected exhibiting signs of toxic exposures. The first occurred on May 21, 1994 in a nestling retrieved from Site 35B (D Street). All of the nestling's siblings had died within the previous three days. The bird was unable to stand, with it's neck tucked into its breast and leaning on its right side. There were intermittent full body tremors and jerking of the head and neck. Every five minutes, the bird exhibited full body seizure activities for approximately 20 seconds to one minute duration. Seizures consisted of rapid wing beating, hyperextension of the legs and feet, continued tucking of the head and neck and atypical vocalizations. After observing several repeated episodes and documenting their characteristics, the bird was bled and euthanized. Samples were collected for biomarkers, residue analysis and histopathology from this bird. A second nestling showing similar symptoms was collected from Site 25 on June 2, 1994. Two adult starlings were collected showing similar symptoms, one from the field South of Seventh Street from Building 111 and another from a treed area behind the visitor center.

The symptoms which these birds displayed are characteristic of those seen with cyclodiene poisoning. Chemical analysis and biomarker determinations will be necessary to test this hypothesis. Should it prove true, valuable data on brain cyclodiene concentrations associated with convulsive behavior will be obtained for correlation with samples collected from the rest of the nest box birds. A final interesting observation made of these apparently poisoned birds came following their death. Within a minute of death, each bird exhibited complete rigor mortis or a stiffening of the muscles which comes after death when ATP is no longer available to stimulate the relaxation of the muscles. None of the other 350 nestlings ever showed this quick of an onset of this condition. Even birds processed for histopathology, which often required 30 to 45 minutes processing time, did not show rigor mortis. It would appear that the extensive convulsive activity, with its concomitant depression in respiratory ventilation, leads to a severe ATP deficiency in the birds which is expressed by an extremely fast onset of rigor mortis.

Laboratory Analyses

Biomarker Analysis

Tissues are currently being processed for cholinesterase, cytochrome P-450s and porphyrin profiles. Lymphocyte blastogenesis assays have been read and data was grouped by site. Statistical analyses to date have showed no difference between reference sites (sites 7, 9, 12 and 27) as a group and all other sites. This data as with all biomarker data, will be reevaluated when chemical residue analysis and other biomarker studies are completed.

Interactions with USFWS Kestrel Project As their project developed in 1994, kestrel researchers felt there was much to be gained by combining efforts with our biomarker project and attempting to obtain immune function data from nestling American kestrels collected in this USFWS component of the biomonitoring project. Working closely with Richard Roy and his staff of Sharon Vaughn, Nick Mancha and Dennis Downing, SRBC inoculations, blood collections and smears, and spleen collections were performed on nestlings collected from kestrel nests. Mitogen-induced proliferation assays of kestrel spleenocytes were performed and are being analyzed currently.

Chemical Residue Analysis

Tissues have been submitted for analysis and we await their processing and reporting.

Histological Analysis

Tissues have been fixed, embedded, cut, mounted and stained. Dr. Getze has read the samples and is completing reports on each of the 101 birds submitted. Once complete, we will submit the key to the blind sample numbers which he was provided and he sill reread the slides for a further reevaluation in light of site by site grouping.

Dieldrin Positive Control Dosing

In three day nestlings, mortality occurred in all dose groups except 50 mg/kg at which both dosed nestlings lived. The LD50 appears to be between 50-75mg/kg for three day nestlings.
for the 15 day birds, two limited dosing studies were completed. The first, performed on June 22, 1994, resulted in all nestlings dying except control and 50 mg/kg. The second dosing occurred on June 25-26, 1995 and mortality occurred in all dose groups, possibly due to high temperatures at time of dosing. Temperature was reported to be 104F. These studies will be completed in the 1995 field season.

1995 Field Season

Planning and gear-up for the 1995 field season are under way. A second field season will be performed to assess the consistency of site specific findings and to further evaluate information pertinent to the 1994 field findings. Specifically, in addition to a similar reproductive success assessment tied to biomarkers, chemical residues and histopathology, radio transmitter studies will be performed on both adults and nestling starlings. Adults will be monitored to assess movement and feeding patterns associated with nest box location. Nestlings will be monitored to determine if post-fledging survival is affected by contaminant exposure. Specific targeted radio transmitter sites will be determined in late February with the availability of biomarker and residue data. Correlation of reproductive success, chemical exposure, biomarker and histopathological response data with chemical distributions on the Refuge is progressing and will be finalized in the 1995 study year. A final report for the work in 1993, 1994 and 1995 will be generated this year.

Table 1. Reproduction parameters for European starlings and their nestlings inhabiting nest boxes placed on sites at the Rocky Mountain Arsenal National Wildlife Refuge in the spring of 1994. Values are means of clutch specific data, listed above standard deviations (s.d.). NA indicates eggs or nestlings didn't survive to provide needed data. N values are below s.d. in parenthesis. Site designations of anticipated toxic potential based simply on proximity to known contaminated areas.

		A	B	C	D	E	F	G	H	I	J	K	L	M
		Data	Data	B / A	Data	Data	Data	Data	D - E	F - G	F / E	G / D	G / F	$(G \geq 1)^a$ / B
Site / Section	Site Description	Nest Boxes Available	Clutches Initiated	Box Utilization	Clutch Size	Eggs at Hatch	Hatchlings	Nestlings at 15 Days	Missing Eggs	Missing / Dead Nestlings	Percent Eggs Hatched	Percent Nesting Efficiency	Percent Fledging Efficiency	Percent Nesting Success
Control Sites														
7	High Line Canal	25	37	148%	4.68	4.16	3.49	2.16	0.51	1.48	83%	45%	60%	70.3%
					0.94	1.69	1.73	1.62	1.24	1.33	21%	34%	37%	
					(37)	(37)	(37)	(37)	(37)	(33)	(33)	(37)	(33)	(37)
9	Commerce City	30	50	167%	4.52	3.14	2.50	1.68	1.38	1.17	80%	35%	57%	46.0%
					1.05	2.20	2.02	1.94	2.12	1.25	27%	41%	44%	
					(50)	(50)	(50)	(50)	(50)	(35)	(35)	(50)	(35)	(50)
12	Shooting Range	25	33	132%	4.85	4.58	4.12	1.73	0.27	2.55	90%	35%	43%	60.6%
					1.18	1.50	1.63	1.61	0.84	1.84	17%	32%	36%	
					(33)	(33)	(33)	(33)	(33)	(31)	(31)	(33)	(31)	(33)
27	Treed Knoll	20	28	140%	4.79	4.11	3.61	2.11	0.68	1.75	88%	42%	52%	57.1%
					0.96	1.91	1.91	2.11	1.52	1.54	22%	41%	42%	
					(28)	(28)	(28)	(28)	(28)	(24)	(24)	(28)	(24)	(28)
Moderate to Questionable Toxic Sites														
4	Railyard	20	16	80%	3.94	2.69	2.25	0.88	1.25	2.44	84%	19%	39%	25.0%
					1.24	2.50	2.14	1.67	1.57	2.07	14%	35%	49%	
					(16)	(16)	(16)	(16)	(16)	(9)	(9)	(16)	(9)	(16)
35A	W of Building 111	12	15	125%	4.47	2.87	2.80	1.20	1.60	3.00	98%	23%	44%	33.3%
					1.13	2.80	2.73	1.93	1.80	2.39	6%	38%	44%	
					(15)	(15)	(15)	(15)	(15)	(8)	(8)	(15)	(8)	(15)
35C	SE Lawn, Bldg 111	8	7	88%	4.71	1.43	0.71	0.43	3.29	1.00	50%	9%	38%	14.3%
					0.95	2.44	1.50	1.13	2.43	0.00	42%	23%	53%	
					(7)	(7)	(7)	(7)	(7)	(2)	(2)	(7)	(2)	(7)

(Continued)

Table 1. Continued.

		A	B	C	D	E	F	G	H	I	J	K	L	M
		Data	Data	B / A	Data	Data	Data	Data	D - E	F - G	F / E	G / D	G / F	(G ≥ 1)[a] / B
Site / Section	Site Description	Nest Boxes Available	Clutches Initiated	Box Utilization	Clutch Size	Eggs at Hatch	Hatchlings	Nestlings at 15 Days	Missing Eggs	Missing / Dead Nestlings	Percent Eggs Hatched	Percent Nesting Efficiency	Percent Fledging Efficiency	Percent Nesting Success
High Toxicity Sites														
1	South Plants	30	10	33%	4.10	0.00	0.00	0.00	4.10	NA	NA	0%	NA	0.00%
					1.29	0.00	0.00	0.00	1.29	NA	NA	0%	NA	
					(10)	(10)	(10)	(10)	(10)	(0)	(0)	(10)	(0)	(10)
25	North Plants	21	32	152%	4.81	3.72	3.41	2.09	1.09	1.62	92%	45%	62%	59.4%
					0.93	2.04	1.98	1.96	2.08	1.81	15%	41%	42%	
					(32)	(32)	(32)	(32)	(32)	(26)	(26)	(32)	(26)	(32)
26	Basins F & C	30	25	83%	3.60	1.04	0.80	0.24	2.56	2.80	78%	4%	40%	8.0%
					1.35	2.15	1.71	0.83	1.56	2.68	23%	15%	55%	
					(25)	(25)	(25)	(25)	(25)	(5)	(5)	(25)	(5)	(25)
31-N	Toxic Storage Yard North	10	14	140%	4.43	2.64	2.14	1.57	1.79	0.89	79%	36%	69%	50.0%
					1.09	2.24	1.99	1.70	2.33	0.93	16%	39%	41%	
					(14)	(14)	(14)	(14)	(14)	(9)	(9)	(14)	(9)	(14)
31-E	Toxic Storage Yard East	10	20	200%	4.35	2.65	2.50	0.75	1.70	3.18	94%	16%	31%	25.0%
					1.09	2.50	2.42	1.37	2.00	1.89	11%	28%	36%	
					(20)	(20)	(20)	(20)	(20)	(11)	(11)	(20)	(11)	(20)
31-SW	Toxic Storage Yard Southwest	10	9	90%	5.33	5.33	4.56	2.67	0.00	1.89	86%	50%	59%	88.9%
					0.71	0.71	0.73	1.32	0.00	1.36	15%	25%	26%	
					(9)	(9)	(9)	(9)	(9)	(9)	(9)	(9)	(9)	(9)
31-W	Toxic Storage Yard West	10	15	150%	4.47	3.73	3.27	1.80	0.73	2.00	86%	37%	63%	66.7%
					1.51	2.52	2.37	1.66	1.33	2.10	20%	34%	36%	
					(15)	(15)	(15)	(15)	(15)	(11)	(11)	(15)	(11)	(15)
35B	D Street West of Basin A	30	15	50%	4.33	2.47	1.93	0.27	1.87	3.57	74%	7%	24%	13.3%
					1.11	2.47	2.28	0.70	1.85	2.15	34%	18%	42%	
					(15)	(15)	(15)	(15)	(15)	(7)	(7)	(15)	(7)	(15)
36	Basin A - North	15	6	40%	2.83	0.00	0.00	0.00	2.83	NA	NA	0%	NA	0.0%
					0.98	0.00	0.00	0.00	0.98	NA	NA	0%	NA	
					(6)	(6)	(6)	(6)	(6)	(0)	(0)	(6)	(0)	(6)

[a] (G ≥ 1) indicates the number of clutches with one or more-15 day nestlings in column G.

Table 2. Evaluation of reproduction endpoints in European starlings nesting on the Rocky Mountain National Wildlife Refuge. Sites were ranked by site from high to low success parameters.

Site / Section	Site Description	Nest Boxes Available	Clutches Initiated	Box Utilization	Site / Section	Site Description	Clutch Size	Site / Section	Site Description	Eggs at Hatch
31-E	Toxic Storage Yard	10	20	200%	31-SW	Toxic Storage Yard	5.33	31-SW	Toxic Storage Yard	5.33
9	Commerce City	30	50	167%	12	Shooting Range	4.85	12	Shooting Range	4.58
25	North Plants	21	32	152%	25	North Plants	4.81	7	High Line Canal	4.16
31-W	Toxic Storage Yard	10	15	150%	27	Treed Knoll	4.79	27	Treed Knoll	4.11
7	High Line Canal	25	37	148%	35C	SE Lawn, Bldg 111	4.71	31-W	Toxic Storage Yard	3.73
27	Treed Knoll	20	28	140%	7	High Line Canal	4.68	25	North Plants	3.72
31-N	Toxic Storage Yard	10	14	140%	9	Commerce City	4.52	9	Commerce City	3.14
12	Shooting Range	25	33	132%	31-W	Toxic Storage Yard	4.47	35A	West of Building 111	2.87
35A	West of Bldg. 111	12	15	125%	35A	West of Bldg 111	4.47	4	Railyard	2.69
31-SW	Toxic Storage Yard	10	9	90%	31-N	Toxic Storage Yard	4.43	31-E	Toxic Storage Yard	2.65
35C	SE Lawn, Bldg. 111	8	7	88%	31-E	Toxic Storage Yard	4.35	31-N	Toxic Storage Yard	2.64
26	Basins F & C	30	25	83%	35B	D Street	4.33	35B	D Street	2.47
4	Railyard	20	16	80%	1	South Plants	4.10	35C	SE Lawn, Bldg 111	1.43
35B	D Street	30	15	50%	4	Railyard	3.94	26	Basins F & C	1.04
36	Basin A - North	15	6	40%	26	Basins F & C	3.60	36	Basin A - North	0.00
1	South Plants	30	10	33%	36	Basin A - North	2.83	1	South Plants	0.00

(Continued)

Table 2. Continued.

Site / Section	Site Description	Hatchlings	Site / Section	Site Description	Nestlings at 15 Days	Site / Section	Site Description	Missing Eggs	Site / Section	Site Description	Missing / Dead Nestlings
31-SW	Toxic Storage Yard	4.56	31-SW	Toxic Storage Yard	2.67	31-SW	Toxic Storage Yard	0.00	31-N	Toxic Storage Yard	0.89
12	Shooting Range	4.12	7	High Line Canal	2.16	12	Shooting Range	0.27	35C	SE Lawn, Bldg. 111	1.00
27	Treed Knoll	3.61	27	Treed Knoll	2.11	7	High Line Canal	0.51	9	Commerce City	1.17
7	High Line Canal	3.49	25	North Plants	2.09	27	Treed Knoll	0.68	7	High Line Canal	1.48
25	North Plants	3.41	31-W	Toxic Storage Yard	1.80	31-W	Toxic Storage Yard	0.73	25	North Plants	1.62
31-W	Toxic Storage Yard	3.27	12	Shooting Range	1.73	25	North Plants	1.09	27	Treed Knoll	1.75
35A	West of Bldg 111	2.80	9	Commerce City	1.68	4	Railyard	1.25	31-SW	Toxic Storage Yard	1.89
31-E	Toxic Storage Yard	2.50	31-N	Toxic Storage Yard	1.57	9	Commerce City	1.38	31-W	Toxic Storage Yard	2.00
9	Commerce City	2.50	35A	West of Building 111	1.20	35A	West of Bldg 111	1.60	4	Railyard	2.44
4	Railyard	2.25	4	Railyard	0.88	31-E	Toxic Storage Yard	1.70	12	Shooting Range	2.55
31-N	Toxic Storage Yard	2.14	31-E	Toxic Storage Yard	0.75	31-N	Toxic Storage Yard	1.79	26	Basins F & C	2.80
35B	D Street	1.93	35C	SE Lawn, Bldg 111	0.43	35B	D Street	1.87	35A	West of Building 111	3.00
26	Basins F & C	0.80	35B	D Street	0.27	26	Basins F & C	2.56	31-E	Toxic Storage Yard	3.18
35C	SE Lawn, Bldg 111	0.71	26	Basins F & C	0.24	36	Basin A - North	2.83	35B	D Street	3.57
36	Basin A - North	0.00	36	Basin A - North	0.00	35C	SE Lawn, Bldg 111	3.29	36	Basin A - North	NA
1	South Plants	0.00	1	South Plants	0.00	1	South Plants	4.10	1	South Plants	NA

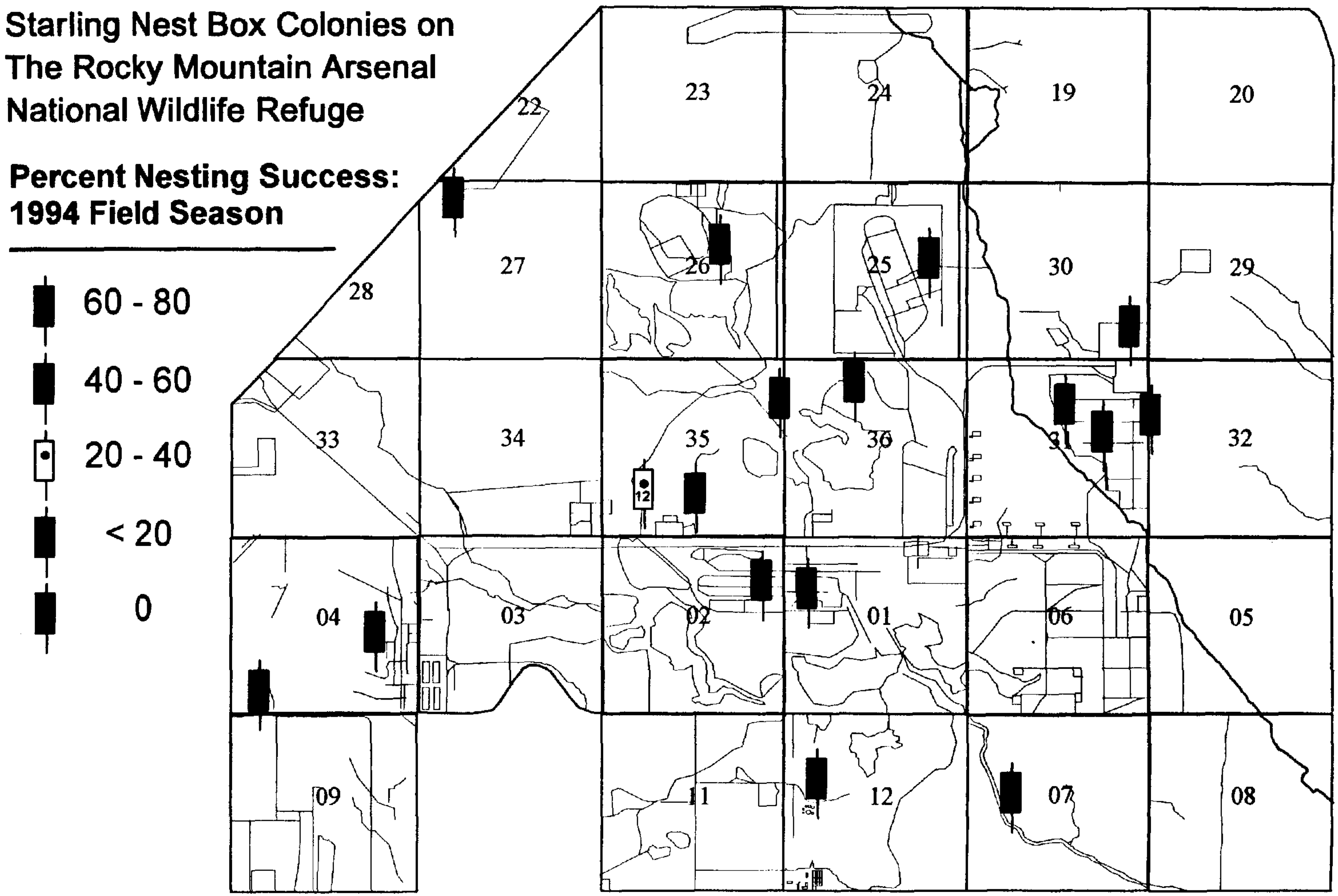
(Continued)

Table 2. Continued.

Site / Section	Site Description	Percent Eggs Hatched	Site / Section	Site Description	Percent Nesting Efficiency	Site / Section	Site Description	Percent Fledging Efficiency	Site / Section	Site Description	Percent Nesting Success
35A	West of Bldg 111	98%	31-SW	Toxic Storage Yard	50%	31-N	Toxic Storage Yard	69%	31-SW	Toxic Storage Yard	88.9%
31-E	Toxic Storage Yard	94%	7	High Line Canal	45%	31-W	Toxic Storage Yard	63%	7	High Line Canal	70.3%
25	North Plants	92%	25	North Plants	45%	25	North Plants	62%	31-W	Toxic Storage Yard	66.7%
12	Shooting Range	90%	27	Treed Knoll	42%	7	High Line Canal	60%	12	Shooting Range	60.6%
27	Treed Knoll	88%	31-W	Toxic Storage Yard	37%	31-SW	Toxic Storage Yard	59%	25	North Plants	59.4%
31-SW	Toxic Storage Yard	86%	31-N	Toxic Storage Yard	36%	9	Commerce City	57%	27	Treed Knoll	57.1%
31-W	Toxic Storage Yard	86%	12	Shooting Range	35%	27	Treed Knoll	52%	31-N	Toxic Storage Yard	50.0%
4	Railyard	84%	9	Commerce City	35%	35A	West of Bldg 111	44%	9	Commerce City	46.0%
7	High Line Canal	83%	35A	West of Bldg 111	23%	12	Shooting Range	43%	35A	West of Bldg 111	33.3%
9	Commerce City	80%	4	Railyard	19%	26	Basins F & C	40%	4	Railyard	25.0%
31-N	Toxic Storage Yard	79%	31-E	Toxic Storage Yard	16%	4	Railyard	39%	31-E	Toxic Storage Yard	25.0%
26	Basins F & C	78%	35C	SE Lawn, Bldg 111	8.6%	35C	SE Lawn, Bldg 111	38%	35C	SE Lawn, Bldg 111	14.3%
35B	D Street	74%	35B	D Street	6.7%	31-E	Toxic Storage Yard	31%	35B	D Street	13.3%
35C	SE Lawn, Bldg 111	50%	26	Basins F & C	4.4%	35B	D Street	24%	26	Basins F & C	8.00%
36	Basin A - North	NA	36	Basin A - North	0.0%	36	Basin A - North	NA	36	Basin A - North	0.00%
1	South Plants	NA	1	South Plants	0.0%	1	South Plants	NA	1	South Plants	0.00%

Starling Nest Box Colonies on The Rocky Mountain Arsenal National Wildlife Refuge

Percent Nesting Success: 1994 Field Season



DIELDRIN TOXICITY IN BADGERS (*Taxidea taxus*) INHABITING THE ROCKY MOUNTAIN ARSENAL: AN INTEGRATED FIELD AND LABORATORY INVESTIGATION

1994 ANNUAL REPORT

Submitted to:

Project Leader
U.S. Fish and Wildlife Service
Building 111
Rocky Mountain Arsenal
Commerce City, Colorado 80022

Submitted by:

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February 15, 1995

PROJECT TITLE - **DIELDRIN TOXICITY IN BADGERS (*Taxidea taxus*) INHABITING THE ROCKY MOUNTAIN ARSENAL: AN INTEGRATED FIELD AND LABORATORY INVESTIGATION. 1994 ANNUAL REPORT**

SCCFWRU RESEARCH WORK ORDER NUMBER RWO - 17

TIWET PROJECT NUMBER TIWET - 09339.1

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Raymond Noblet, Ph.D. — 02/15/95

GOOD LABORATORY PRACTICE COMPLIANCE STATEMENT

This study was conducted and audited in compliance with EPA Good Laboratory Practices as outlined in 40 CFR Part 160, August 17, 1989.

Michael J. Hooper
Study Director

02/15/95
Date

QUALITY ASSURANCE STATEMENT

This study was conduct under the auspices of The Institute of Wildlife and Environmental Toxicology Quality Assurance Program, and under full Good Laboratory Practices as outlined in 40 CFR Part 160, August 17, 1989. Any changes in the protocol or SOPs referenced in the protocol were documented in writing and signed by the Study Director.

The Quality Assurance Unit verbally notified the Study Director immediately of any problems encountered during audits. Written audit reports were also submitted to the Study Director and Management. Audits were performed on and written reports were generated for the following phases of the project:

Project 09339.1

Audit No.	Auditable Research Phase/Activity	Audit Dates	Dates Submitted to Study Director	Dates Submitted to Management
1	Badger Trapping	09/19/93-09/20/93	11/08/93	11/22/93
2	Badger Blood Sampling/Measurements	09/20/93	11/08/93	11/22/93
3	Acute Dosing - Badger	10/20/93-10/22/93	11/08/93	11/22/93
4	Shipping and Receiving of Acute Dosing Samples	02/02/94-02/03/94	02/15/94	02/15/94
5	Preparation of Microsomes-Acute Dosing Samples	02/17/94	02/22/94	02/22/94
6	Data Records	05/16/94-05/17/94	07/22/94	07/25/94
7	Badger Trapping/Telemetry	05/16/94-05/17/94	07/22/94	07/25/94
8	Blood Smear and Call Counting	05/16/94-05/17/94	07/22/94	07/25/94
9	Validation-Urine Extraction	07/27/94-08/04/94	10/28/94	12/12/94
10	Validation-HPLC Analysis	07/27/94-08/04/94	10/28/94	12/12/94
11	Badger Urine Analysis-Extraction	08/24/94-08/29/94	10/28/94	12/12/94
12	Badger Urine Analysis-HPLC	08/24/94-08/29/94	10/28/94	12/12/94
13	Creatinine Kinetic Test-Urine	09/23/94	10/28/94	12/12/94

James E. Osbey   Date: 02/15/95

James E. Osbey
Quality Assurance
The Institute of Wildlife and Environmental Toxicology

INTRODUCTION

The Rocky Mountain Arsenal National Wildlife Area (RMA, or the Refuge), located in southwest Adams County near Denver, Colorado, has, in the past, been a production and storage area for a multitude of weapons produced by the United States Army. Since the Second World War, chemical pesticides have been produced on this same property which was leased by private corporations. As a result of past waste storage and disposal practices, a number of areas within the Arsenal have been contaminated with a variety of chemicals. Seven chemicals of concern (COCs) have been identified. These are dieldrin, aldrin, endrin, DDT, DDE, mercury and arsenic. The Arsenal was placed on the Superfund National Priorities List in 1982. Since 1989, the Arsenal has been managed jointly by the U.S. Army and The U.S. Fish and Wildlife Service (USFWS) to protect wildlife resources.

Limited data are available on the impacts of dieldrin on tertiary predators. High residue levels, however, have been found in American badgers associated with the Arsenal site. Fortuitous discoveries of two badgers on the site have yielded residues of 29 and 75 ppm dieldrin in fat tissue. The latter animal contained 13 ppm dieldrin in the liver. These are the highest concentrations of dieldrin found in any species on the Arsenal. These findings initiated this research program which utilizes the badger as a biomonitoring species.

An integrated laboratory and field study is currently underway on the Rocky Mountain Arsenal National wildlife Refuge (Refuge) to assess the risk to American Badgers (*Taxidea taxus*) of dieldrin (1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4α,5,6,7,8,8α-octahydro-1,4-endo,exo-5,8-dimethanonaphthalene; HEOD). From a number of lethal and non-lethal biomarkers of exposure and effect, the health of the animals is the ultimate endpoint. To assess the health of the animal, we are using standard clinical pathology endpoints of serum chemistry profiles, serology, hematology and urology. Biomarker assays are also being studied, for ultimate comparison to samples collected in the field. Clinical pathology and biomarker endpoints are to be compared to lesions described from histopathology and residue tissue burdens.

An intense Radio telemetry study was initiated on the Arsenal from the start of the first capture on 04/02/94. The purpose of this portion of the study is to identify area use for individuals, define parameters within this range and categorize badgers into treatment groups. A Geographical Information System (GIS) is being utilized to model point locations into a core area of use. Once the core area has been described, it may be overlaid on a number of different coverages illustrating: Soil concentrations of COCs; COC concentration in prey items; habitat type; Soil type; and prey density (prairie dog towns). By utilizing this information we will be accomplishing two goals: 1) Correlation of health parameters with COC concentration in soil and prey items; 2) Provide USFWS information for management decisions on badgers in reference to contaminant effects as well as preferred habitat and soil type.

PROGRESS TOWARD OBJECTIVES

Objective 1. Determine an approximate acute toxic dose of dieldrin in badgers.

Acute dieldrin dosing was performed in 1993, with the initial results described in our 1993 Annual Report. Dose-response data indicate the badger is more resistant to dieldrin's acute toxic effects than many species. In this report, we describe dieldrin residue, clinical chemistry, biomarker and histopathological findings from the 1993 acute dosing study.

Objective 2. Establish a profile of dieldrin's toxicological effects occurring in badgers, encompassing low-level, environmental level and worst case scenario-levels in badgers maintained under clean, colony conditions. These positive control tests will establish pertinence of field findings.

Sub-chronic dosing studies are under way with one control and two dosing levels.

Objective 3. Establish residue excretion patterns in positive control individuals for correlation with data obtained from the field.

Chemical analysis data from acute dosing study tissues are reported herein. Samples of blood, feces and urine have been archived and await contract laboratory certification for these materials.

Objective 4. Establish a field collection program with primarily non-lethal and limited lethal collections of badgers inhabiting the Arsenal. Develop techniques for non-lethal collection of tissues and biological fluids.

We report here the first season's results from the Refuge badger trapping program. The non-lethal sampling and radio transmitter programs have been fully implemented. Lethal collections will not occur until the 1995 field season.

Objective 5. Create a Geographical Information System (GIS) which can integrate chemical distribution patterns, badger home ranges and exposure and effects oriented endpoints.

Initial GIS mapping results are reported. Badger home ranges have been overlaid on chemical distribution patterns and prey locations. Mapping techniques for exposure and effects oriented endpoints are under development.

Objective 6. Establish a geographical estimation of contaminant severity in terms of location and impact on badger populations.

Predictions from soil contaminant and home range information are discussed, though badger residue, health effects and demographic data have not been incorporated.

METHODS

Rocky Mountain Arsenal Badger Studies

Trapping. Trapping techniques used were the same as those described for badgers collected in the wild in WY for the acute dosing study.

Soil Samples from Badger Diggings. Near the end of the sampling period it was decided to collect soil from the trap site to have co-location of soil contaminant levels and badger locations. Only 3 samples were obtained this season, but this type of sampling will be a permanent part of the protocol for next year. Additionally, next season we may be sampling areas that individuals are using by collecting soil from fresh digging in areas of known use of transmittered badgers.

Biological Sample Collection. Samples collected from trapped individuals included blood, blood smears, urine, adipose tissue and fecal material.

Blood: Animals were anesthetized by IM injection of ketamine:xylazine (10:1). Blood was then drawn by venipuncture from the front leg. Seven mls were drawn without heparin for serology and serum enzyme analysis. An additional 10 mls were then drawn (40 units non-preservative heparin/ml blood) for hematology, lymphocyte blastogenesis assays and plasma residue concentration.

Urine. Urine was collected by two different methods. Two samples were collected after a modification to transport barrels were made. The bottom of the barrel was cut off and a stainless steel grate attached to it. A stainless steel pan was then hinged under the grate to collect a sample during a urination event. Twelve samples were collected at the Denver Zoo by cystocentesis. Badgers captured before "sampling barrel" was designed and Denver Zoo visits were not able to be sampled. The sample was then separated into 3 portions: 1) 1 ml was put into a plastic collection tube for urinalysis; 2) 3 - 5 mls was put into a plastic collection tube containing 50 mg Na_2HCO and 4 mg EDTA for urinary porphyrin quantification; 3) the remaining volume was placed in an I-Chem ® container for residue analysis.

Adipose. Adipose samples were obtained at the Denver Zoo during the surgical procedure of implanting peritoneal transmitters. If the badger had enough subcutaneous fat, the sample was taken from that area (n=8). However, individuals captured early in the spring did not have enough subcutaneous fat to obtain an adequate sample. For these animals, a portion of the omentum fat was biopsied (n=10). Animals captured before visits to the Denver Zoo were not sampled.

Fecal. No good method for obtaining fecal samples was found this season. The two samples that were collected were obtained by using the sampling barrel. Many methods described by veterinarians to collect fecal samples from other species were attempted. In the future, collection will be done manually by lubricating latex gloves worn by the observer and penetrating the anus with one finger to retrieve an adequate sample.

Transmitter Attachment and Implantation. Two different transmitter types were used this season. Collar and a peritoneal implant designs were used (Advanced Telemetry Systems INC, Isanti MN). Collars were initially employed in the spring when female badgers were pregnant or nursing young. The first implant was done on FA9 on 06/10/94. All collared badgers were attempted to be recaptured and implanted with new peritoneal transmitters.

Collar Attachment. Collars were attached at the site of capture. The adjustable strap was appropriately adjusted and excess length cut off. It was then placed around the neck and bolted on. The strapping was groomed into the fur of badger. Special care was taken not to make the excessively tight causing irritation, or too loose so that it fall off.

Peritoneal Implantation. All implantation procedures were done by Dr. Dave Kenny at the Denver Zoo. Badgers were initially anaesthetized with Ketamine/rompum (10:1 IM injection), and supplemented isoflurane gas during procedure as needed via intubation tube. The abdomen was shaved from the xiphoid process to anal. The area of the incision was thoroughly scrubbed 3 times with betadine and alcohol. A sterile drape with a hole exposing the area of incision was attached with towel clamps. An incision was made 1.5 inches long approximately 2-3 inches (depending on size, age, and sex) posterior to the xiphoid. A subcutaneous fat biopsy of approximately 2 g was taken near the point of incision. The linea alba was lifted (to avoid creating lesions on intestinal walls) with a forceps and cut through exposing the peritoneal cavity. The sterilized (gas sterilization) transmitter was then inserted into the cavity. Chromic cat gut (5.0 metric, 70 cm, taper ct-2 needle) was used to suture the linea alba. For each suture, two surgeons knot(double) and two singles were used. The epidermis was sutured (3.5 metric absorbable beige braided polyglycolic Acid, 67 cm, ODEXON "S", CE-10 30mm needle) using 4 double knots on each suture. The suture area then sealed using physiological compatible glue. An X-ray was taken to insure proper placement of the transmitter. The badger was then removed from intubating anesthesia and placed in a barrel for quite, undisturbed recovery from surgery and intramuscular injections of ketamine\rompum. After the animal had completely recovered from the anaesthetic, it was released at the site of capture.

Relocation of Radio transmitter-Equipped Badgers. Searches for radio-tagged individuals were conducted 5 nights/week at times varied from dusk to dawn. In the original study design we had planned on staggering the order of which we look for badgers to avoid temporal bias in area use estimates. However, it soon learned that badgers in burrows were extremely hard to locate and therefore we needed to obtain locations whenever it was possible. Since individuals are habitual, the result was obtaining relocations during similar time intervals in either the evenings or mornings for each badger. Relocations were estimated by triangulation which used a stacked, null telemetry antenna system mounted on a truck cab roof. The antenna was rotated from within the vehicle, allowing the operator to read "nulled" signal bearings from a compass rose affixed to the inner roof of the cab. The antenna system was calibrated daily prior to locational data collection and again immediately after data collection ended. After signal bearings from permanent stops were determined by the truck-mount system they were plotted on a photocopy of a topographic map (U.S. Geological Survey, Denver, CO) laminated onto a masonite map board to obtain the estimate of the location. Mapped locations were assigned Universal Transverse Mercator (UTM) grid coordinates based on proximity to grid line intersections and recorded to the nearest 10 m. If the locations came within 100 m of the site boundaries, they were recorded as an "on-site" location. Locations were recorded as "off-site" locations if found greater than 100 m from the boundary of the site. If only one or two bearings were able to be determined, the location was recorded as the UTM coordinates in the southwest corner of the square kilometer the observer could estimate the badger was found.

Accuracy Estimates of Relocation Data. Transmitters were placed by water sampling wells on the arsenal which have accurate UTM locations. Observed values from known distances were then compared to actual coordinates.

GIS Mapping and Data Analysis. All GIS mapping and area use estimates were done by Bill Henriques with TIWET and the Department of Environmental Toxicology at Clemson University using ARC/INFO (version 6.1.2 and 7.0.2 pre-release), the Unix-based GIS software which serves as the industry standard for spatial analysis tools.

Import of Badger Data into GIS. Data collected in the field were entered into QuattroPro at the Arsenal, reviewed for accuracy, then exported to an ASCII file for input into ARC/INFO. Point coverages of the relocation data for each badger were then created, which were projected to a coverage of the Arsenal boundary to account for spatial distortions due to the earth's curvature.

Other Data Sources. During the Summer of 1994, a month was spent on-site to determine the availability of GIS coverages on parameters of interest to this project. Coverages on land use, vegetation, and made-made structures were made available to Clemson University by DO Associates, a contractor to the Army responsible for the management of the Installation Restoration Data Management Information System (IRDMIS) database. All coverages provided by the Army (and their contractors) were in State Plane coordinates (NAD27); these were converted over to the UTM coordinate system prior to use with this project. Location data on prairie dog towns was collected by David Seery with the USFWS using a Pathfinder Global Positioning System (GPS) and converted over to an ARC/INFO coverage. Prairie dog data for sections south of road "C" and east of the lakes has recently been completed by the USFWS and will be used in future reports. In addition, the data dictionary for the IRDMIS database was reviewed and the extensive library of information was queried to determine the extent of information on concentrations of the 7 COCs in soil, and any information on residues in biota collected on site. These data sources were also used to create coverages for contaminant levels in surface soils and biota.

Home Range Analysis of Badger Relocations. Ten badgers currently have enough locations to do harmonic mean home range analysis (approximately 30 relocations). The harmonic mean home range analysis procedure (called the Home Range Interface or HRI) has been programmed into ARC/INFO by Sam Anderson of Clemson University, which provides a spatial analysis tool that can be run in a GIS environment. The HRI program analyzes the point coverage of badger relocation data to determine if a sufficient number of points are available for home range analysis, and constructs polygons which represent the desired percentage of harmonic mean area use estimates. In addition, the center of activity (core area) is calculated for each animal.

For badgers that lacked sufficient number of relocations for harmonic mean home range calculations, an estimate of the area use was made by creating polygons enclosing the majority of relocation points.

Generation of Polygon Coverages from Dieldrin Sampling Data. Concentrations of dieldrin in surface soil (0 - 1.5 feet in depth) were derived from sampling data queried from the Army's environmental database (IRDMIS). Over 4300 discreet sampling locations were imported into ARC/INFO and theissen polygons were created using the sampling points as the center of the polygon that defines a particular concentration of dieldrin, based upon the distance to the next sampling location. Clemson is also investigating other techniques for data analysis that may provide a more realistic concentration estimate of soil contamination and exposure. Kriging of the point data will provide a gradient of concentrations that are raster based; i.e., individual cells are assigned a concentration estimate as opposed to larger areas generalized in the theissen polygon approach.

Similar data exist for concentrations of DDT, DDE, arsenic, mercury, endrin and aldrin in surface soil. In addition, IRDMIS also contains concentrations of the COC's at different soil depths. It is anticipated that these data sources will also be used in future exposure scenarios.

Positive Control Studies with Badgers

The status and results of two dieldrin dosing studies are reported, a single dose acute exposure and a 90-day Sub Chronic exposure.

Acute Toxicity Study. The acute dosing study occurred in the fall of 1993. The 1993 annual report presents survival and behavioral data from that study. Clinical and histopathology and biomarker determinations from the acute study are described in this report.

90-Day Sub Chronic Toxicity Study. The Sub Chronic study is underway with pre-dose sample collection occurring in preparation for dose initiation in January, 1995.

Sample Analysis Techniques

Sample Analyses: Multiple analyses were performed, or are currently underway on all badger samples collected to date. Most analyses (with the exception of plasma dieldrin quantification) on blood samples have been executed, these include: clinical chemistry on serum, serology on serum, lymphocyte blastogenesis, and hematology. Urinalysis has been completed on all urine samples collected and we are now underway to complete urinary porphyrin analysis. ESE is currently developing methodology for determining dieldrin concentrations in urine. All adipose and fecal samples have been sent to ESE for residue analysis and we are now waiting for the results.

Serum Chemistry. Levels of Albumin (ALB), Total Protein (TPROT), Globulin (GLOB), Blood Urea Nitrogen (BUN), Creatinine (CREA), Cholesterol (CHOL), Glucose (GLUC), Total Bilirubin (TBIL); and activities of Alkaline Phosphatase (ALK P), Alanine Aminotransferase (ALT), Aspartate Aminotransferase (AST), γ-Glutamyl Transferase (GGT), Amylase (AMYL), Total Creatine Kinase (CK) and Lactic dehydrogenase (LDH) were determined on a VET TEST

8008 (IDEXX Laboratories, Westbrook, ME) at Wyoming State Veterinary Laboratory in Laramie, WY.

Serology. Serology to determine antibody titers to Canine distemper and plague (*Yersinia pestis*) were completed at the Wyoming State Veterinary Laboratory in Laramie, WY.

Hematology. Complete blood counts, hemoglobin, hematocrit, and WBC differentials were quantified for each sample at the time of capture on the RMA by using the a cell counter.

Urology. The presence of and quantification of relative levels of leukocytes, nitrites, urobilinogen, protein, blood, ketones, bilirubin, glucose, WBCs, RBCs, epithelial cells, bacteria, casts and crystals were determined using Ames Multi-Stixs (Miles Inc., Diagnostic Div., Elkhart IN) at the Wyoming State Veterinary Laboratory in Laramie, WY.

Lymphocyte Blastogenesis. Whole blood was diluted 2X with HBSS and layered over Ficol (D=1.078). The mixture was then centrifuged (30 min at 1000 g) and the lymphocytes harvested. Platelets were then selectively removed by a series of centrifugation. The number of lymphocytes/ml was normalized to 4×10^6. Ninety six well plates were prepared with 3 replications per treatment and 4 treatments/sample:

1. Control, RPMI 1640 (FBS+GLU+PEN/STREP);
2. Concanavalin-A, final concentration of 2.5 ug/ml);
3. Phytohemaglutinin-p, final concentration = 0.5 ug/ml;
4. Lipopolysaccharide, final concentration = 1 mg/ml.

All mitogens were diluted with RPMI 1640 (FBS+GLU+PEN/STREP).

One Hundred uls of the cell mixture was then added to the plates to attain a final volume/well of 200 uls. The plate was then incubated (5% CO_2, 38 C) 48 hrs before adding 50 uls of 3H-Thymidine (5 uCi/well). The plate was then incubated an additional 16 hrs before cells were harvested and samples quantified by scintillation counter.

Porphyrin Profile Quantitation. Urinary porphyrins were extracted and analyzed according to the HPLC method of Bowers et al., (1992). Briefly, Sep Pak C-18 columns extract porphyrins from acidified urine samples. The porphyrins bound to the Sep Pak are then washed and eluted with 35% and 100% methanol solutions, respectively. The methanol containing the porphyrins are then brought to dryness with nitrogen, reconstituted with 500 ul 1 N HCL, and filtered in preparation for HPLC analysis. HPLC analysis of the porphyrin solution is a reverse-phase, gradient-controlled, procedure using 250 x 4.6 mm, Altima 5 um C-18 HPLC analytical column from Altech. The HPLC system consisted of two pumps (Waters 520b) a SIM (Waters), a fluorescence detector (Schimadzu), and with a NEC model computer with Baseline 810 software program. Standards were purchased from Porphyrin Products. Final values were normalized for creatinine by purchasing a Creatinine test kit from StanBio Laboratory, Inc. This method is a rapid kinetic spectrophotometer assay.

Microsome preparation and Cytochrome P450 Activity Determination. Microsomal preparation of liver and kidney was performed. EROD/PROD activity was determined using a 96-well plate reader modification of the method described by Prough et al., 1972. Briefly, tissues were homogenized and microsome preparations isolated from tissue by centrifugation. Microsomal preparations were then diluted with protein- containing tris buffer and EROD/PROD activities were determined using a Perkin-Elmer LS50 Fluorometer equipped with a 96-well plate reader. Protein concentration (mg/ml) of the microsomal preparation was determined calorimetrically using a purchased kit (Sigma Chemical Company, St.Louis, MO). EROD/PROD activities are reported as pmoles substrate hydrolyzed/min/mg protein..

Histopathology. A number of tissues were taken at necropsy to microscopically observe lesions potentially induced by the dieldrin. These tissues include: brain, liver, kidney, inguinal skin, head skin, testes, ovaries, uterus, urinary bladder, mandibular lymph node, mesenteric lymph node, axillary lymph node, inguinal lymph node, thymus, rib bone, tongue, salivary gland, lung, thymus, thyroid gland, left ventricle, left atrium, AV valve, adrenal gland, spleen, duodenum, jejunum, ileum, stomach, colon, pancreas, medial thigh skeletal muscle, sciatic nerve, bone marrow smear, right eye, and spinal cord. As tissues were removed they were placed in a 10% formalin solution where they were stored for 1 week to "fix" the tissues. After a 1 week, the tissues were removed from the formalin, sliced, and portions the sliced portion placed in cartridges.

Analytical Chemistry. All analytical chemistry was performed by laboratories contracted through the U.S. Army. Data from these analyses were first archived by another contractor, DP Associates, who provided the values to the researchers.

RESULTS and DISCUSSION

Rocky Mountain Arsenal Badger Studies

Badger Trapping and Sampling

Badger Trapping. Thirty one captures of 600 trap nights were recorded from 03/19/94 to 09/01/94. Of those 31 captures, there were 21 different individuals with 10 recaptures. The demographic distribution of these badgers were: 6 adult females (FA1, FA4, FA8, FA9, FA10, FA22); 7 adult males (MA2, MA3, MA5, MA7, MA14, MA18, MA19); 4 juvenile females (FA11, FA12, FA13, FA15); and 4 juvenile males (MA16, MA17, MA20, MA21). Three of the Juveniles trapped are of known prodgeny: FA11 and FA12 are juveniles born to FA4; FA13 is a juvenile born to FA8. These were badgers that were captured in the same burrow the transmittered adult was simultaneously located. Therefore it was assumed these juveniles were born to those adults.

Transmitter Attachment and Implantation. Six radio telemetry collars were originally placed on badgers (3 Ad F, 3 Ad M). Four (3 Ad F, 1 Ad M) of these 6 were recaptured and replaced with peritoneal implants. A total of 17 peritoneal implants were placed into badgers and released in the field (6 Ad F, 3 ad. M., 4 Juv F, 4 Juv M). A total of 822 relocations were estimated from 165 sampling nights from dates of 04/03/94 to 12/08/94. The number of relocations/badger and respective notes are illustrated in Table 1.

Badger Radiotransmitters: Collars vs. Implants. Collars and peritoneal implants were both used in the study and each has disadvantages and advantages. Collars have a much better range (4-7 km) and attachment is obviously much less complicated and involves less risk than the implants especially during periods of pregnancy and nursing. However, the success of the transmitters was not very good. A total of 7 collars were attached to badgers and only 1 of these had no problems. Of the remaining 6 collars: 2 fell off the badgers; the antennas fell off of 2 more, significantly reducing its range; 1 transmitter nearly inflicted a fatal wound while losing its antenna; and 1 is suspected to have failed completely. Although implants have considerably shorter ranges (0-3 km), other problems such as potentially wounding the badger and antennas falling are not present. The implants also have the capacity to carry larger batteries and subsequently have a longer life span than do collar transmitters. Although the surgical procedure may be considered intrusive, we are fortunate to the professional assistance of the Denver Zoo which has appropriate facilities and personal to carry out the task with very little risk to the animal. From the experience gained this season, the use of collar transmitters will be limited to pregnant and nursing females captured in the months of March and April. Other researchers have successfully implanted females in May with few complications.

Laboratory Analyses

Serum Chemistry. Thirty blood samples were collected on the Refuge this year. The test tube containing the serum sample from badger MA20 was broken while it was being thawed at the Wyoming State Veterinary laboratory awaiting serology analysis (Serology had already been done). All analyses have been completed and are currently being tabulated for presentation and statistical evaluation.

Serology. Thirty blood samples were analyzed for serology. The current protocol described by the Centers of disease control and used by all state and federal agencies to quantify antibody titers to plague only provides for values from <1:4 to >1:512. Almost all samples demonstrated antibody titers >1:512. Therefore, with upcoming samplings, samples will be reanalyzed to better describe the titer. All analyses have been completed and are currently being tabulated for presentation and statistical evaluation.

Hematology. Thirty blood samples were analyzed for hematology this year. Problems with the cell counter prevented hemoglobin analysis of 5 samples before a technician from the company visited to fixthe machine. All analyses have been completed and are currently being tabulated for presentation and statistical evaluation.

Urology. Twelve urine samples were collected on the Refuge this year. Two samples from MA20 and MA21 were not analyzed because of inadequate sample volume. When a sample of small volume was obtained, aliquotes for residue analysis and porphyrin quantification were prioritized. All analyses have been completed and are currently being tabulated for presentation and statistical evaluation.

Lymphocyte Blastogenesis. Ten samples collected from Refuge badgers this year were successfully analyzed for lymphocyte blastogenesis. All analyses have been completed and are currently being tabulated for presentation and statistical evaluation.

Badger Relocation Activities

Accuracy Estimates of Relocation Data. Accuracy tests demonstrated mean errors of 58 m (n=5) in the easting coordinates, and 72 m (n=5) from the northing coordinates. Each relocation estimate will have an excepted potential error of <100 meters.

GIS Mapping and Home Range Analysis. Ten badgers currently have sufficient locations to do harmonic mean home range analysis (i.e. $\geq$ 30 relocations). Geometric mean soil concentrations of dieldrin were calculated for each of these badgers within the 95% harmonic means home range areas. Area use utilization (95% harmonic mean area use estimates) are described in Table 2. Data for badgers not having sufficient numbers of relocations for home range analysis were not presented in tabular form; as additional relocation points are determined the mean soil concentration and area use estimates using the harmonic mean method will be provided for these badgers as well.

Figures 1 through 6 provide preliminary results of the badger tracking study. Figure 1 is an overview of the study area, showing all relevant landmarks, roads, and buildings. This map also provides locations for radio transmitter reference locations. Figure 2 shows badger home range data for animals with greater than the minimum points needed (approximately 30) to conduct the harmonic mean method of home range analysis. Figure 3 shows area use data for badgers estimated from all relocation points (for badgers with less than 30 relocations). Figure 4 shows the location of prairie dog towns in relation to the badger home ranges calculated by the harmonic mean method. Figure 5 shows dieldrin concentrations overlaid on badger and prairie dog locations. Figure 6 is a close up of the harmonic mean home range (95% area use estimate and core area) for badgers FA1 and MA2, overlaid on dieldrin concentrations and prairie dog towns. Figure 6 approaches the level of detail we wish to use with each badger. The designation of exposure levels and correlations among badgers will be completed when all residue analysis from adipose samples are done. Also, some badgers have considerably less number of relocations because they were captured much later in the season. Therefore future reports will be able to define treatment groups much better and ultimately make better comparisons.

There appears to be a significant decrease in area use as winter approaches. Therefore, to avoid bias on seasonal use data it may be necessary to track badgers for up to 6 months and across multiple seasons to obtain accurate estimates of area use. For example the home range size for badger FA22 tracked from 09/01/94 to 12/08/94 is 0.983 km^2. Compare this to FA1 whose home range area is 3.83 km^2 and has been tracked since 04/02/94 and it is obvious that seasonal variations exist within area use and home range analyses. Age of badgers will also have an influence on home range size. All juvenile home range sizes are smaller than adult sizes and reflect the fact that they are shared with the adult female to which it was born. Dispersing juveniles will have to be tracked through the following years reproductive timepoint to accurately characterize its adult range.

Positive Control Badger Dosing Studies

Acute Dose Administration.

Of the eight captive badgers, three males and one female were used for acute toxicity testing. The other four animals were euthanized to provide control values and tissues for clinical and histopathology, hematology, serology and biomarker evaluations. Data on these dosed animals can be found in the 1993 Annual Report.

Badger M18 (dose = 50 mg/kg dieldrin)
Badger M19 (dose = 100 mg/kg dieldrin)
Badger M15 (dose = attempted 200 mg/kg dieldrin)
Badger F20 (dose = 100 mg/kg dieldrin)

Chemical Residues. Tissue organochlorine data have recently been received and are being tabulated. Blood, fecal and urine concentrations await method development by the analytical laboratory.

Clinical Pathology. Early indications show that clinical pathology was consistent with other findings that suggest that dieldrin has little effect on these endpoints. There are however a number of trends in these data and we are currently evaluating them for statistical significance.

Immune Function. Lymphocyte mitogen stimulation indexes (SI) appeared to decrease suggesting evidence of immunosuppression. Suppression of mitogen stimulation is a documented effect of dieldrin. However, small sample sizes inhibit proper statistical analyses across treatment groups, and large variances in SIs made diagnostic threshold analyses difficult. In spite of this difficulty, SI values for dosed individuals were observed to be considerably lower. Although SIs were lower, absolute response is not different. These results are due to the fact that background counts for dosed animals are significantly higher than those animals not dosed. High background counts indicate that the lymphocyte population was in stimulated state before the assay began. The validity of this finding is supported by Hematology results. Dosed animals demonstrated a state of leukocytosis due to a high lymphocyte population. Immune data are undergoing final statistical evaluation prior to their presentation.

Urinary Porphyrins. Neither individual porphyrin profiles ratios nor concentrations were altered by the administration of dieldrin. The low concentrations of baseline urinary porphyrins as well the low %RSE in the reference badgers may indicate the badger to be a good species for further porphyrin biomarker study. However, the two badgers who were orally dosed with dieldrin showed no signs of increased excretion of porphyrins. These results may be explained simply by dieldrin being only weakly porphyrinogenic or by limitations in sample size and length of exposure.

Cytochrome P450 Induction. All dosed and non-dosed badgers were pooled in their respective group regardless of sex or dose because of small sample size. Means were compared by students t-test and no significant difference between means was found ($P<0.5$).

Histopathology. Gross necropsy showed no significant lesions. Tissue weights between dosed and non-dosed animals were not found to be significantly different. The only microscopic lesion possibly attributed to the acute exposure of dieldrin was moderate swelling and vacuolation of hepatocytes without apparent necrosis or inflammation in the male given a dose of 50 mg/kg.

In summary, initial findings from acutely dosed badgers suggest that few critical systemic or tissue specific effects occur. The probability of the occurrence of acute exposures such as those described above is, however extremely likely. More probable is a chronic exposure scenario with long-term exposure allowing constant accumulation at target sites. This type of exposure will be addressed in this year's sub-chronic study.

90-Day Sub Chronic Study.

Wild badgers have been collected and are now awaiting the start of the sub-chronic study which will begin in January.

Collecting Activities. Twelve badgers were trapped from the wild in the same area and with the same methods used in the acute study. Trapping commenced the first week of August, 1994 and was finished September 8, 1994. Upon capture, measures were taken to avoid last years problem with distemper. For three weeks after capture, two rooms were used to isolate 6 badgers from the other 6 so that if an infected individual was captured and introduced to the captive colony, not all of badgers would have been exposed. All badgers were vaccinated with a modified live virus for distemper to help protect captive individuals if an infected badger was introduced to the colony. Only juveniles were taken into captivity with a sex ratio of 3 females and 9 males.

Preparation of Badgers for Dosing. Three pre-dosing samples of blood, feces and urine were collected from all individuals to quantify baseline measurements. Physiological implants which monitor ECG, body temperature and activity were placed subcutaneously in 8 badgers. Of those 8 implants, 5 transmitters have been sloughed or removed. Two transmitters were sloughed as they were placed in the abdomen and pressure necrosis from the animal laying down in the cage weakened the skin and the sutures. The remaining six transmitters were placed on the dorsal region of the animal. Three of those animals had severe problems with infection in the area of the suture line and the transmitters either failed or the leads separated from the main body of the unit. These transmitters were removed. Three badgers (all males) remain with transmitters and will be used in the experiment. Predosing data on these badgers will be collected.

Study Design. Eleven badgers (3 females, 8 males) remain in captivity. These badgers will be divided into 3 treatment groups utilizing doses of 0.0, 0.05, 0.5 mg/kg/day. Badgers will be dosed in food items with dieldrin dissolved in non-denatured ethanol (approximately 100 to 200 ul per dose). There will be 4 control badgers (3 M, 1 F); 3 badgers (2 M, 1 F) at the low dose; and 4 badgers (3 M, 1 F) at the high dose. One transmittered badger will be placed in each group. The exposure will last for 90 days. Urine and fecal will be collected at weekly intervals, while blood will be drawn at the end of the exposure period. Radiotelemetry data of heart rate, ECG, body temperature and activity will be collected weekly.

Dieldrin Purification.. Purification of dieldrin has been completed. A 90% stock obtained from Sigma Chemical Company (St. Louis, MO.) was vacuum sublimated with heat followed by recrystalization of the sublimation product in hot ethanol to yield a 99% high quality product. Shell chemists assisted with suggestions for this procedure.

UPCOMING ACTIVITIES

The 90 day sub-chronic study will be performed starting in mid February, a described above. substantial clinical, chemical and physiological data will be generated in this study for correlation with data from field collections. With most clinical and biochemical data from the field and acute studies now in hand, we will begin to build a data base of control and treatment values to assess the utility of the different endpoints.

Chemical residue data are now beginning to be available and we sill begin to examine not only the levels from the individuals in the acute dosing study but also those individuals from the 90 day study and from the field. From these data we hope to develop data on the toxicokinetic characteristics of dieldrin in badgers.

The field monitoring program will continue into its second complete year. We anticipate collecting at least one RMA badger for full health effects analysis. Previously radiotransmittered badgers will continue to be tracked as will new badgers captured for the first time. Improved data on seasonal, sex dependent and age dependent home range characteristics will be collected. We know from the acute dosing study that behavioral manifestations are dose-dependent and perhaps influenced by the sex of the individual. Behavioral characteristics which can be determined and long term survival will be important endpoints in the field monitoring program.

With the conclusion of the controlled dosing segments of the study, we will begin to try to build a monitoring strategy which can be implemented on the Refuge as part of the management program of the USFWS.

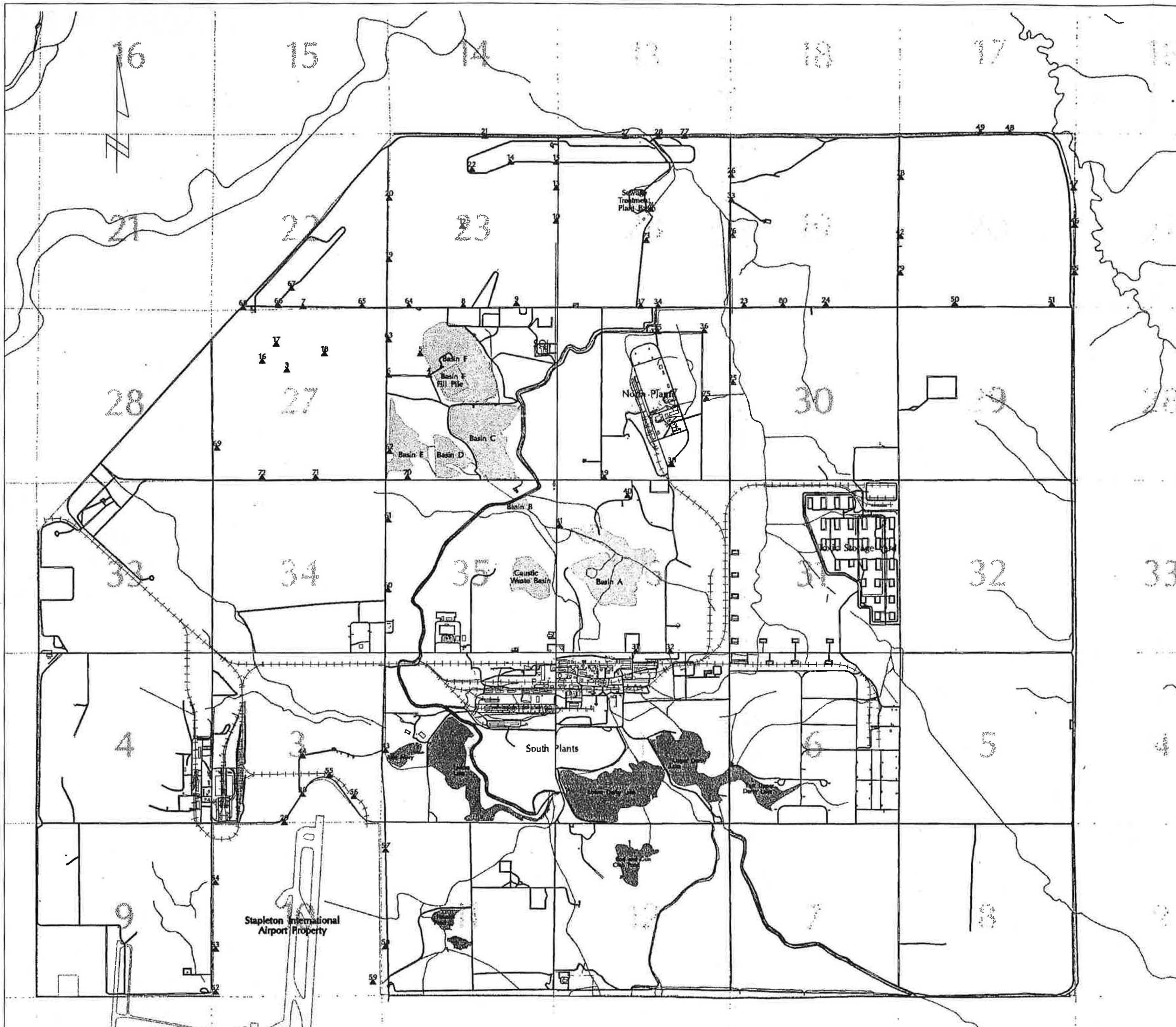
Table 1. Summary of Badger Relocations on the Rocky Mountain Arsenal from 04/03/94 to 12/08/94.

Badger Id #	Currently Active (Y/N)	Sex/Age	Relocations	Comments
Actively Tracked				
MA2	Y	M/AD	102	
MA18	Y	M/AD	29	
MA20	Y	M/JUV	35	
FA1	Y	F/AD	112	
FA4	Y	F/AD	106	Two 1994 offspring, FA11 and FA12
FA8	Y	F/AD	58	
FA9	Y	F/AD	53	Has moved offsite north of section 20.
FA11	Y	F/JUV	73	Dispersed juvenile, born to FA4
FA12	Y	F/JUV	72	Juvenile sharing a portion of FA4's territory.
FA13	Y	F/JUV	55	Was born to FA8 and has moved to the south end of the airport
FA22	Y	F/AD	39	
Totals	11		734	
No Longer Actively Tracked				
MA3	N	M/AD	21	Collared badger who was not recaptured before transmitter died
MA5	N	M/AD	17	Collared badger;suspect transmitter prematurely expired and was not recaptured
MA16	N	M/JUV	3	Found dead from coyote/badger attack
MA17	N	M/JUV	4	Suspect juvenile has dispersed offsite
MA19	N	M/AD	4	Suspect adult moved offsite
MA21	N	M/JUV	26	Suspect transmitter failure
FA10	N	F/AD	1	Suspect that either the transmitter died or the badger died deep in a burrow where it cannot be heard
FA15	N	F/JUV	12	Suspect juvenile has dispersed offsite
Totals	8		88	
Grand Total	19 Badgers		822 Relocations	

Table 2. 95% Harmonic Mean Home Range Size for Badgers Radio-tagged on the Rocky Mountain Arsenal National Wildlife Refuge. Home range maps with individual relocation points can be found in Figure 3.

Badger ID	Date Tracking Started	Home Range Size (Km^2)
MA2	04/05/94	5.63
MA20	08/17/94	2.80
FA1	04/03/94	3.83
FA4	04/17/94	9.47
FA8	05/18/94	3.55
FA9	06/11/94	3.47
FA11	06/28/94	2.56
FA12	06/28/94	1.77
FA13	07/06/94	5.07
FA22	09/01/94	0.984

Note: See table 1 for the number of relocations/badger used for home range estimates.



Land Form/Land Use & Radiotelemetry Reference Locations
Badger Biomonitoring Program
Rocky Mountain Arsenal
National Wildlife Refuge

Legend

- Waste Storage/Disposal Basins
- Freshwater Lakes & Ponds
- Paved Roads
- Unpaved Roads/Trails
- On-Post Rail System
- Radiotelemetry Stops

Scale = 1:36089

meters

0 500 1000 1500 2000

TIWET GIS Lab 1994

Figure 1.
In: Dieldrin Toxicity in Badgers Inhabiting the Rocky Mountain Arsenal: An Integrated Field and Laboratory Investigation. 1994 Annual Report

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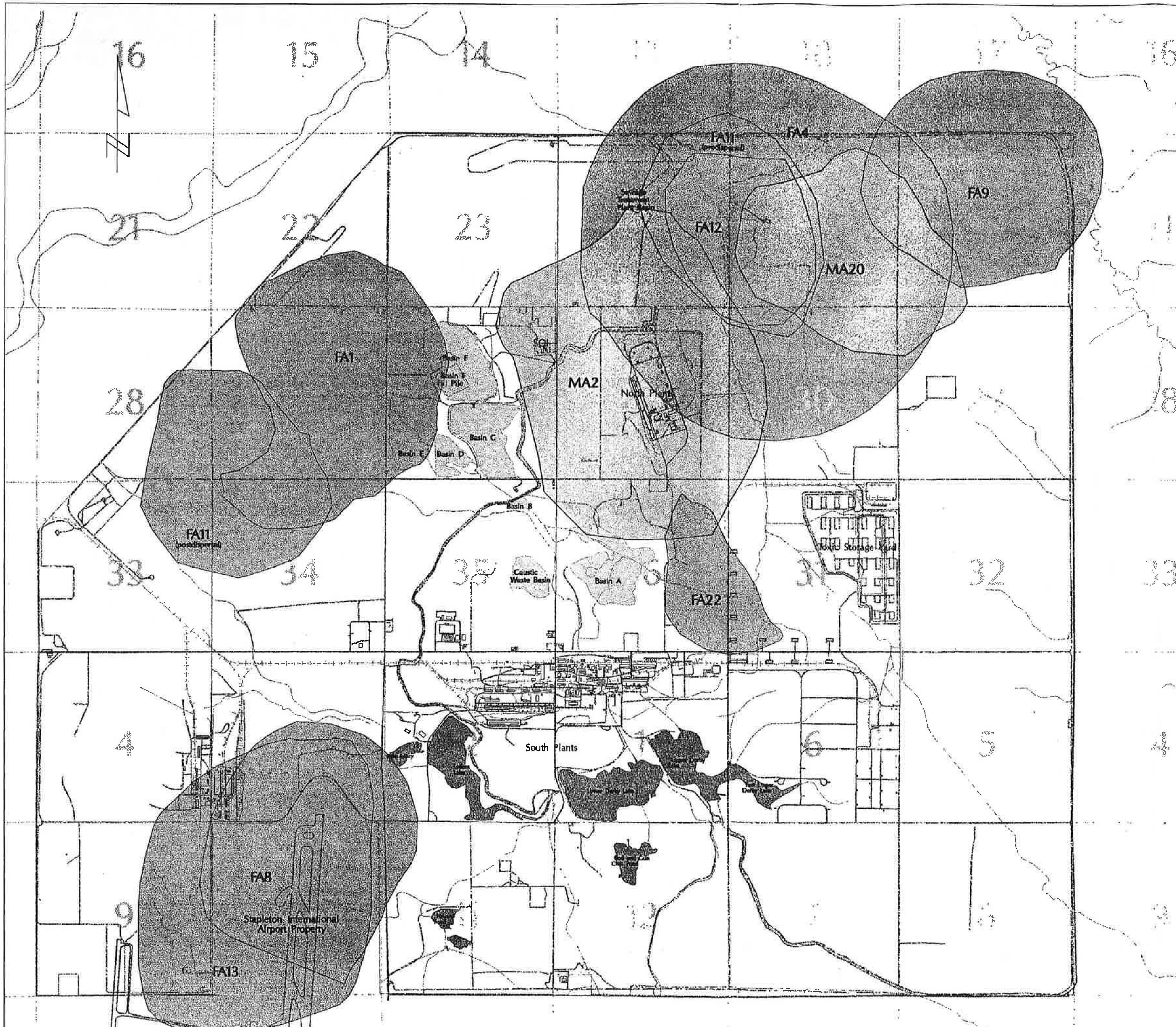
South Carolina Cooperative Fish and Wildlife Research Unit
Research Work Order #17; TIWET Project Number 09339.1
with the
U. S. Fish and Wildlife Service, Rocky Mountain Arsenal



Area Use Estimates Based on 95% Harmonic Mean Activity Contours for Badgers Inhabiting The Rocky Mountain Arsenal National Wildlife Refuge

Legend

- Female Badger Home Ranges
- Male Badger Home Ranges
- Waste Storage/Disposal Basins
- Freshwater Lakes & Ponds

Scale = 1:36089

meters

0 500 1000 1500 2000

TIWET GIS Lab 1994

Figure 2.
In: Dieldrin Toxicity in Badgers Inhabiting the Rocky Mountain Arsenal: An Integrated Field and Laboratory Investigation. 1994 Annual Report

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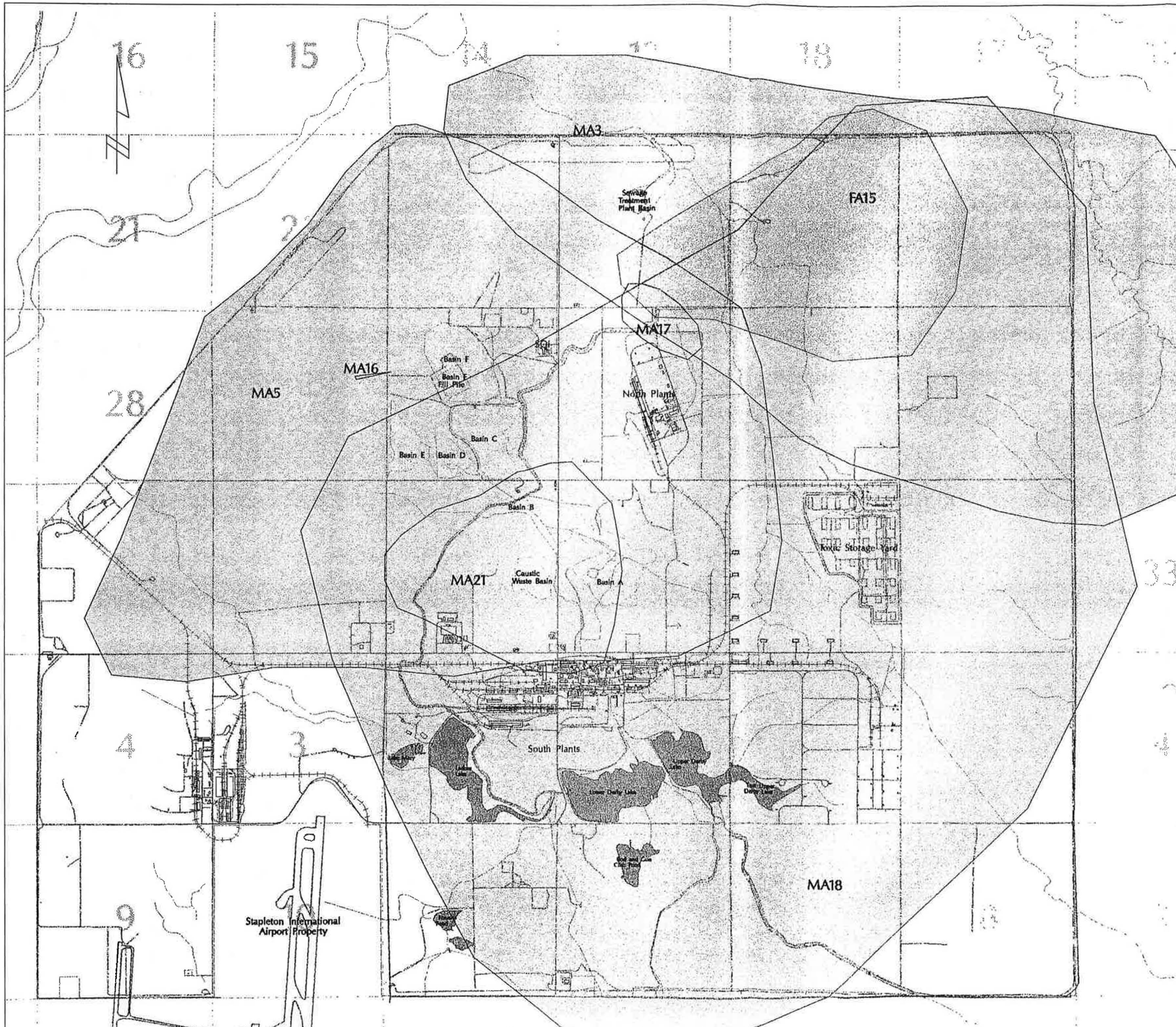

Estimated Home Range Areas Based on Point Locations for Badgers Inhabiting The Rocky Mountain Arsenal National Wildlife Refuge

Legend

- Female Badger Home Ranges
- Male Badger Home Ranges
- Waste Storage/Disposal Basins
- Freshwater Lakes & Ponds
- On-Post Rail System

Scale – 1:36089

meters

0 500 1000 1500 2000

TIWET GIS Lab 1994

Figure 3.
In: Dieldrin Toxicity in Badgers Inhabiting the Rocky Mountain Arsenal: An Integrated Field and Laboratory Investigation. 1994 Annual Report

Department of Environmental Toxicology and TIWET
The Institute of Wildlife and Environmental Toxicology
Clemson University, P.O. Box 708, 1 TIWET Drive
Pendleton, South Carolina, 29670 USA

South Carolina Cooperative Fish and Wildlife Research Unit
Research Work Order #17; TIWET Project Number 09339.1
with the
U. S. Fish and Wildlife Service, Rocky Mountain Arsenal

Prairie Dog Town Locations by GPS & Home Range and Point Relocations for Badgers Inhabiting The Rocky Mountain Arsenal National Wildlife Refuge

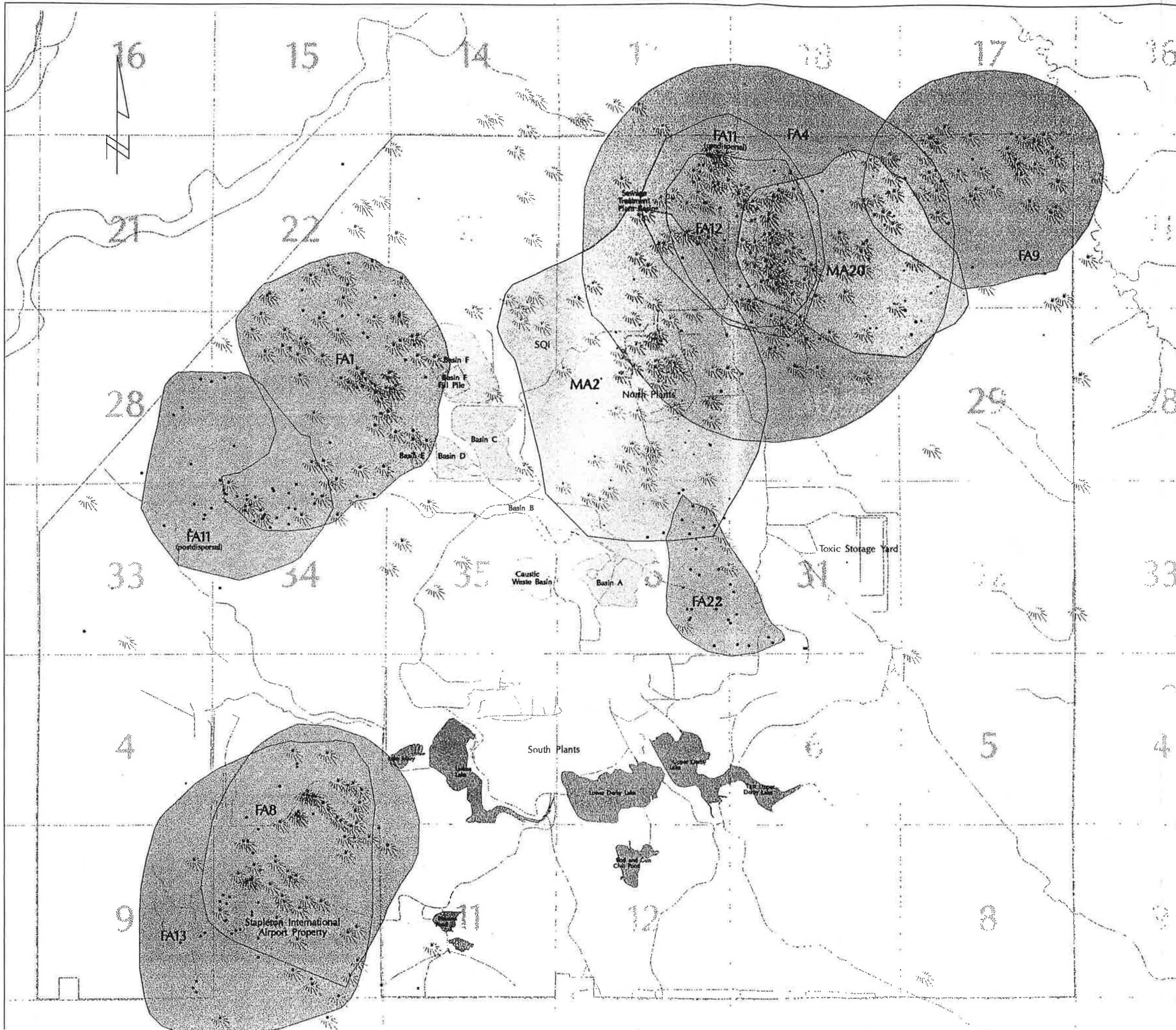

Figure 4.
In: Dieldrin Toxicity in Badgers Inhabiting the Rocky Mountain Arsenal: An Integrated Field and Laboratory Investigation. 1994 Annual Report

Department of Environmental Toxicology and TIWET
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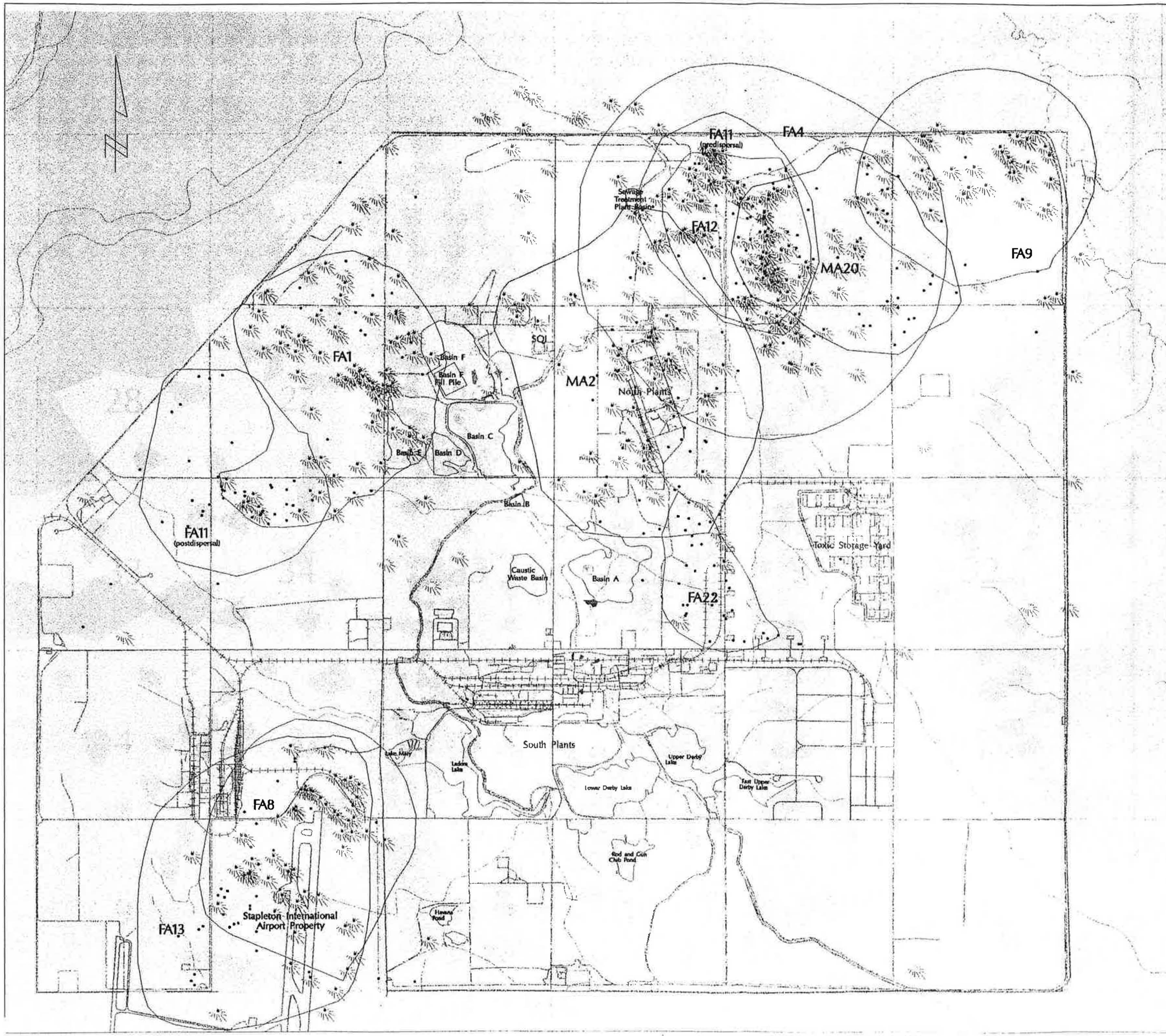
South Carolina Cooperative Fish and Wildlife Research Unit
Research Work Order #17; TIWET Project Number 09339.1
with the
U. S. Fish and Wildlife Service Rocky Mountain Arsenal



Harmonic Mean Home Range Areas of Badgers Inhabiting The Rocky Mountain Arsenal National Wildlife Refuge Overlaid on Dieldrin Surface Soil Concentrations & Prairie Dog Town Locations

Legend

- less than 0.3 ug/g dieldrin in soil
- 0.3 - 2.0 ug/g
- >2.0 - 10.0 ug/g
- >10.0 - 75.0 ug/g
- >75.0 - 250.0 ug/g
- >250.0 - 500.0 ug/g
- >500.0 - 750.0 ug/g
- >750.0 - 1000.0 ug/g
- >1000.0 ug/g - 1500.0 ug/g
- >1500.0 ug/g
- Female Badger Home Ranges
- Male Badger Home Ranges
- Badger Relocations by Triangulation
- Prairie Dog Town Locations by Pathfinder GPS

Scale - 1:36089

meters

0 500 1000 1500 2000

TIWET GIS Lab 1994

Figure 5.
In: Dieldrin Toxicity in Badgers Inhabiting the Rocky Mountain Arsenal: An Integrated Field and Laboratory Investigation. 1994 Annual Report

Department of Environmental Toxicology and TIWET
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South Carolina Cooperative Fish and Wildlife Research Unit
Research Work Order #17; TIWET Project Number 09339.1
with the
U. S. Fish and Wildlife Service, Rocky Mountain Arsenal

Home Range Polygons of Badgers FA1 and MA2 Overlaid on Prairie Dog Town Locations and Dieldrin Surface Soil Concentrations Rocky Mountain Arsenal National Wildlife Refuge

Legend

- less than 0.3 ug/g dieldrin in soil
- 0.3 - 2.0 ug/g
- >2.0 - 10.0 ug/g
- >10.0 - 75.0 ug/g
- >75.0 - 250.0 ug/g
- >250.0 - 500.0 ug/g
- >500.0 - 750.0 ug/g
- >750.0 - 1000.0 ug/g
- >1000.0 ug/g - 1500.0 ug/g
- >1500.0 ug/g
- Badger Home Range Core Area
- Badger Home Range 95% Harmonic Mean Activity Area
- Badger Relocations by Triangulation
- Prairie Dog Town Locations by Pathfinder GPS

Scale - 1:19685

meters

0 200 400 600 800 1000

TIWET GIS Lab 1994

Figure 6.
In: Dieldrin Toxicity in Badgers Inhabiting the Rocky Mountain Arsenal: An Integrated Field and Laboratory Investigation. 1994 Annual Report

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South Carolina Cooperative Fish and Wildlife Research Unit
Research Work Order #17; TIWET Project Number 09339.1
with the
U. S. Fish and Wildlife Service, Rocky Mountain Arsenal

BIOMONITORING PLAN FOR THE DEER MOUSE (*Peromyscus maniculatus*) ON THE ROCKY MOUNTAIN ARSENAL

1994 ANNUAL REPORT

Submitted to:

Project Leader
U.S. Fish and Wildlife Service
Building 111
Rocky Mountain Arsenal
Commerce City, Colorado 80022

Submitted by:

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February 15, 1995

PROJECT TITLE	**BIOMONITORING PLAN FOR THE DEER MOUSE (*Peromyscus maniculatus*) ON THE ROCKY MOUNTAIN ARSENAL: ANNUAL REPORT**
SCCFWRU RESEARCH WORK ORDER NUMBER	RWO - 16
TIWET PROJECT NUMBER	TIWET - 09339.3
TESTING FACILITIES	The Institute of Wildlife and Environmental Toxicology P.O. Box 709, 1 TIWET Drive Pendleton, SC 29670 (803) 646-2200 U.S. Fish and Wildlife Service Rocky Mountain Arsenal Bldg 111 Commerce City, CO 80022 (803) 289-0232

STUDY DIRECTORS

		Date
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Principal Investigator, Unit Leader, SCCFWRU	David L. Otis, Ph.D.	2/14/95

QUALITY ASSURANCE AUDITS

Quality Assurance Officer, TIWET	James Osbey, B.S.	02/14/95

MANAGEMENT

Institute Associate Director, TIWET	Raymond Noblet, Ph.D.	02/14/94

GOOD LABORATORY PRACTICE COMPLIANCE STATEMENT

This study was conducted in compliance with EPA Good Laboratory Practices as outlined in 40 CFR Part 160, August 17, 1989 with the following exceptions: Chemical contaminant concentrations in RMA soils. Identity and maintenance of original records on those samples are the responsibility of the test sponsor.

Michael J. Hooper
Study Director

02/14/95
Date

David L. Otis
Study Director

2/14/95
Date

QUALITY ASSURANCE STATEMENT

This study was conduct under the auspices of The Institute of Wildlife and Environmental Toxicology Quality Assurance Program, and under full Good Laboratory Practices as outlined in 40 CFR Part 160, August 17, 1989. Any changes in the protocol or SOPs referenced in the protocol were documented in writing and signed by the Study Director.

The Quality Assurance Unit verbally notified the Study Director immediately of any problems encountered during audits. Written audit reports were also submitted to the Study Director and Management. Audits were performed on and written reports were generated for the following phases of the project:

Project 09339.3

Audit No.	Auditable Research Phase/Activity	Audit Dates	Dates Submitted to Study Director	Dates Submitted to Management
1	Placement of Mice in Enclosures Injection of Sheep Red Blood Cell Monitoring of Enclosures	10/19/93-10/24/93	11/08/93	11/22/93
2	Small Mammal Trapping	10/19/93-10/24/93	11/08/93	11/22/93
3	Jerne Plaque Forming Cell Assay	10/22/93-10/24/93	11/08/93	11/22/93
4	T-Cell & B-Cell Blastogenesis Assay	10/23/93-10/24/93	11/08/93	11/22/93
5	Positive Control Dosing	03/22/94	04/05/94	04/06/94
6	EROD Analysis-Mice	04/15/94	04/19/94	12/12/94

James E. Osbey
James E. Osbey
Quality Assurance
The Institute of Wildlife and Environmental Toxicology

Date: 02/14/95

INTRODUCTION

The Rocky Mountain Arsenal National Wildlife Refuge (RMA, or the Arsenal), located in southwest Adams County near Denver, Colorado, has, in the past, been a production and storage area for a multitude of weapons produced by the United States Army. Since the Second World War, chemical pesticides have been produced on this same property which was leased by private corporations. As a result of past waste storage and disposal practices, a number of areas within the Arsenal have been contaminated with a variety of chemicals. Seven chemicals of concern (COCs) have been identified. These are dieldrin, aldrin, endrin, DDT, DDE, mercury and arsenic.

The deer mouse, in particular, and rodents, in general, are effective as environmental indicators. They are distributed over sites of interest, easily captured, found in both polluted and non-polluted environments, and their responses often correlate with the level of contamination to which they are exposed (McBee and Bickham 1990, Talmage and Watson 1991). The use of mammals with small home ranges ensures that the mammal is exposed to the contaminants on-site. In this way, observed individual or population responses can be more readily attributed to contaminants from a particular site. Because of their relatively large population size, confined home ranges and ease of capture, the current project focuses on the deer mouse, *Peromyscus maniculatus*. It has been the intent of this study to utilize a combination of enclosure studies with deer mice and trap-recapture studies with the Arsenal's small mammal communities to assess the bioavailability and effects of chemicals of concern (COCs) on rodents inhabiting the Rocky Mountain Arsenal.

<u>Previous Year's Activities Leading to this Year's Report</u>

Site Selection and Enclosure Deployment In choosing enclosure sites, habitat type was normalized as much as possible to allow for more sensitive assessment of contaminant effects with a minimum of site-associated interference. The focus was made on the chlorinated cyclodiene contaminants, and dieldrin in particular. Efforts were made to represent a broad range of contaminant concentrations in order to investigate the extent of exposure and effects potentially occurring on the RMA. Sites with potential for diverse contaminant profiles were chosen and evaluated analytically to assess contaminant concentrations. Analyses were performed for the following chemicals: dieldrin, aldrin, endrin, endrin aldehyde, endrin ketone, isodrin, HCCPD, DDE and DDT. Dieldrin, aldrin and endrin (total cyclodienes) were calculated and used to group enclosures such that a broad range of contaminant concentrations was represented.

Contaminant Concentrations. Dieldrin was by far the most abundant contaminant on all sites, found in all but one sample and ranging from not detectable in one of the reference site locations to 18 ppm on section 26 (Table 1). In general, aldrin levels were one quarter to one tenth those of dieldrin on each site. Endrin followed similar patterns as those seen in aldrin contamination. Endrin ketone concentrations ranging from not detected to 0.4 ppm in Section 26. Endrin aldehyde, DDT, DDE and HCCPD were not found in any of the samples analyzed.

Study Sites. Based on total cyclodienes concentrations, five sites were selected and three enclosures were situated on each site:

1) Two reference sites (sections 27 and 33) where total cyclodienes ranged from undetectable to 0.006 ppm.
2) Section 1 site where total cyclodienes averaged 0.06 ppm (0.056-0.068).
3) Section 26 site where total cyclodienes averaged 0.6 ppm (0.59-0.64).
4) Section 36 and Section 26 site where total cyclodienes averaged 1.8 ppm (1.60-1.91).
5) Section 26 site where total cyclodienes averaged 20.4 ppm (19.7-21.5).

Studies were conducted between 29 September and 22 October, 1993. Due to inclement weather on 17-18 October, about one-third of the mice were lost, as the rain washed out their burrows, exposing them to cold wet conditions which led to hypothermia. When possible, replacement mice were added to the enclosures, but almost all mice in the 0.06 ppm group were lost, eliminating this group from the study.

Stainless steel enclosures (perforated 18 gauge, 40 cm high, 55 cm diameter) were used. Chemically clean laboratory-raised deer mice were placed in enclosures for exposure durations of 6, 12 and 24 days. Following the exposure period, mice were processed at the US Army laboratory at RMA on the day they were removed from the field. Blood and spleens were assessed immediately for immune function. Livers for cytochrome P-450 determination, and the remaining carcass for residue analysis were snap frozen in liquid nitrogen and stored at -80°C, until subsequent analysis at TIWET.

Progress toward objectives

Objective 1. Evaluate functional relationships between contaminant levels and demographic parameters (i.e., survival rates, population size) of populations of deer mice that inhabit the Rocky Mountain Arsenal.
and
Objective 2. Collect a representative sample of wild mice from study sites for determination of concentration of chemicals of concern and biomarker levels.

A full year of trapping effort has been completed to date. Trapping will continue through 1995. The collection of wild rodent samples will not occur until late spring, 1995.

Objective 3. Establish deer mouse containment enclosures on sites of concern in order to assess bioavailability of and biological responses to site contaminants in clean mice placed on the sites.

Enclosures were established and deer mice deployed on sites in late 1993. Immune and cytochrome P-450 biomarker determinations were completed in 1994. Porphyrin and COC analyses will be performed early in 1995.

Objective 4. Perform positive control dosing studies with dieldrin (and other pertinent COCs as necessary) in order to determine toxicity and biomarker dose-response relationships.

Dosing studies with dieldrin and arsenic have been performed and the results are reported here-in.

Objective 5. Correlate the occurrence and geographic distribution of chemical exposure and induced effects, in wild and enclosed deer mice, to known distribution of chemical contaminants as a means of determining bioavailability of contaminants and, eventually, remediation efficacy.

Biomarker data from enclosure mice and demographic data from trapping studies are now available. Collections of wild rodents, residue analysis of both wild and enclosed rodents and biomarker evaluations of wild rodents will be obtained in the spring of 1995 for inclusion in this evaluation. When all data is available, correlations will be assessed.

SUMMARY OF ACTIVITIES

This annual report is a description of the work which has occurred from October 1, 1993 through December 31, 1995. It is divided into reports on small mammal demographic studies and enclosure and laboratory studies. These two approaches will form the foundation for wild small mammal sampling to occur during the 1995 field season and subsequent interpretation of chemical residue and health effects data emerging from those animals.

Small Mammal Demographic Studies

Capture-Recapture

Six small mammal trap grids, established in 1993, were trapped during sessions in October, 1993, and March, June, August, and October 1994. Plots 27 and 33 are control sites, Plots 1 and 23 have medium levels of dieldrin contamination, and Plots 26 and 36 have the highest levels of dieldrin contamination. All grids are located in cheatgrass/weedy forb cover types. Each 1.2 ha grid was trapped for five to seven days depending on the number of new animals captured during the last days of trapping. *Peromyscus maniculatus* population estimates were calculated using the heterogeneity model M_h in Program CAPTURE (Table 1). Thus far, the model selection procedure in CAPTURE has indicated that the model which assumes that individuals have different capture probabilities is the best single choice for an estimation model. Although populations are relatively small, average capture probabilities have been large (p=0.49) resulting in fairly precise population estimates. Populations on Plots 27 and 33 often have not been large enough to permit population estimation. No *P. maniculatus* were captured on Plot 27 in August. The number of individual *P. maniculatus* recaptured between sessions is summarized in Table 2. Estimates of survival between successive trapping sessions were calculated using the standard Jolly-Seber model and are presented in Table 3. The large standard errors of these estimates prohibit any reliable inferences about differential survival among plots. We do not anticipate that additional trapping will improve precision. In 1995, the more statistically efficient Cormack-Jolly-Seber models will be used to estimate survival using Program SURGE.

The October, 1993 trapping session produced the highest number of species while the highest populations of small mammals were captured in March, 1994 (Tables 4-8). *Reithrodontomys megalotis* and *Microtus ochrogaster* were captured in October, 1993 and March 1994, but have not been captured in August or October, 1994. The number of small mammals and the number of species declined during the summer and fall of 1994. Shannon-Wiener diversity indices and species richness are presented in Table 9.

Several complications have arisen during the year. On several occasions coyotes have disturbed the trap grids and removed animals from the traps. Several traps were found 1-50+ meters from their original location, and many had traces of blood, or small mammal parts in the trap. Thermal exposure has been a minor source of mortality, occurring only 2% of 3000 captures. Another potential problem is the encroachment of prairie dog towns on the southeastern section of Plot 26 and southern section of Plot 27. This encroachment could possibly be a factor in the drastic decrease of small mammals on Plot 26 in August and October, 1994.

Soil Sampling

In September, 1993 surficial soil samples were collected and analyzed for chlorinated pesticides, arsenic, and mercury (Table 10). In order to improve the precision of the soil contaminant estimates, we requested that additional soil samples be collected from Plots 23, 26, and 36. In October, 1994, six sampling locations were randomly selected within each plot and ENSEARCH scientists removed the top few centimeters of soil at cardinal points around the selected site. The soil was placed in sample jars and analyzed for chlorinated pesticides, mercury, arsenic, and several other compounds by Foster Wheeler Environmental Corp. an Army approved labs. The soil sample results allowed us to divide the six plots into three categories based on the levels of dieldrin contamination. The additional samples collected in October improved the precision of the estimates of average contamination. Variation in contamination definitely increases, however, with the average level of contamination, which indicates that spatial heterogeneity in dieldrin levels within one ha contaminated sites can be large.

Vegetation Sampling

Vegetative cover and density was sampled in August, 1994 in order to describe plant community parameters in the study sites. We hope to use these data to adjust for any potential confounding effects of vegetation on the small mammal population and community parameters. Each plot was divided into microhabitats, if applicable, and six sampling quadrats were randomly located in each microhabitat. Vegetative cover was estimated using a 1/2 m^2 Daubenmire quadrat (Daubenmire, 1959). Six vegetation coverage classes (0-5%, 5-25%, 25-50%, 50-75%, 75-95%, and 95-100%) were used to categorize cover estimates for all species found in each quadrat. *Bromus tectorum* was the predominate species found on the trap grids. Cover estimates for *Bromus* spp., litter and total live vegetation are listed in Table 11.

Statistical Analyses

Correlation statistics were used to examine preliminary relationships between population and community level parameters and amount of dieldrin contamination. Nonparametric Spearman rank correlations between *P. maniculatus* population size and dieldrin levels for each trapping session revealed no significant ($p < 0.05$) correlations in June (0.07), August (p=0.07) or October (p=0.32), 1994, but significant (p <0.05) positive correlations in October, 1993, and March, 1994

(Fig. 1). Average population size was marginally correlated with dieldrin contamination levels ($p=0.07$). With respect to total small mammal population numbers, a significant correlation was found only in March, 1994. However, the correlation of the average small mammal population numbers, pooled over all trap sessions was marginally significant with dieldrin contamination levels ($p=0.07$, Fig.2).

Total species richness for all trap sessions combined was not correlated with dieldrin ($r=-0.70$, $p=0.12$, Fig 3). Similarly, average Shannon-Wiener diversity rank was not related to soil contamination ($r=-0.49$, $p=0.33$, Fig. 4)

Discussion

Even though *P. maniculatus* population size and dieldrin were found not to be significantly correlated in three of the five sessions, the June and August sessions and the overall average produced positive correlations that were marginally significant. Thus far, we have found no evidence to support a hypothesis that *P. maniculatus* population levels and dieldrin are negatively correlated. Although indices of community biodiversity and structure have not been significantly correlated with contamination to date, one emerging hypothesis might be that small mammal communities on less contaminated sites are more complex. The most potentially confounding effect on the relationship between population and community parameters and dieldrin is due to differences in habitat among plots. We tried to minimize habitat differences by selecting sites that were classified into the same cover type by existing land cover maps, but there could be other unknown habitat factors influencing parameters. Further vegetation and habitat sampling will compensate for some of this inherent variation and we plan to further identify any history of disturbance in the sites that may be important. It is expected that small mammal populations will fluctuate during the year, and that certain species will be captured in some seasons and not others. However, if environmental conditions are the same and a high numbers of a species have been captured in a season one year, its presence should be expected the next. This was not the case with *Reithrodontomys megalotis*. It is thought that precipitation is a major factor in small mammal population parameters, affecting food sources such as seeds and insects. Because 1994 was a extremely hot and dry summer, the lack of precipitation could have negatively affected *R. megalotis* and *Microtus ochrogaster* populations.

Enclosure and Laboratory Studies

Methods

Immune function. The Cunningham modification of the Jerne plaque-forming cell assay was used. Briefly, six days prior to euthanasia, mice were injected with 10^8 sheep red blood cells, intraperitoneally. At euthanasia, spleens were removed from the mice and placed in RPMI-1640 media. Spleens were then homogenized to form a single cell suspension. The number of viable cells in the resulting suspension was counted using trypan blue and a hemocytometer. The number of plaque forming cells was determined using the Cunningham modification of the Jerne plaque assay (Jerne and Nordin 1963, Cunningham and Szenberg 1968). An aliquot of the single cell suspension was mixed with sheep red blood cells and guinea pig complement, placed in a chamber, and incubated for one hour at 37C and 5% CO_2. After incubation, the number of plaques was counted using a phase contrast microscope and results reported as plaques per 10^6 spleen cells.

Microsomal Enzyme Determinations. Hepatic enzyme activity, microsomes were prepared from livers by homogenizing the tissues in ice-cold sucrose buffer with a power-driven, Teflon glass homogenizer. The homogenate was centrifuged for 20 minutes at 15,000 x g. The supernatant was then centrifuged at 105,000 x g (4°C) for one hour. The resulting pellet was washed and resuspended in a 20% glycerol resuspension buffer and stored at -80°C until analyzed. EROD (ethoxyresorufin-O-deethylase) and PROD (pentoxyresorufin-O-dealkylase) activities were determined using the method of Prough et al. (1978) modified for use on a 96-well equipped Perkin-Elmer luminescence spectrometer set to read each well five times during the assay so that a kinetic determination of the reaction rate could be determined. The excitation wavelength was 550 nm and the emission wavelength was 585 nm. Protein was determined using the bicinchoninic acid technique of Smith et al. (1985).

Laboratory Studies. Concurrent laboratory studies were undertaken at TIWET to assess responses of deer mice exposed to dieldrin and arsenic separately under controlled conditions. Male mice, 7-8 weeks old, were placed 6 to a cage in a randomized fashion and allowed to acclimatize to the conditions of the treatment room (12 hour light/dark cycle, 22°C, 65% relative humidity, food/water *ad libitum*) for one week before dosing was initiated. Both food and water were analyzed for the presence of contaminants. Chemical was dissolved in chemically pure corn oil and administered intraperitoneally at a volume of 10 ml/kg. Mice received dieldrin or Arsenic on days 1,3,5,7 and 9; 4 x 10^8 sheep red blood cells on day 6, and were euthanized on day 11. Dosages administered were dieldrin; 0, 0.08, 0.25, 0.80, and 2.5 mg/kg body weight/day and Arsenic; 0, 0.005, 0.05, 0.5 and 5.0 mg/kg body weight/day. Immune and enzymatic responses were determined following procedures outlined above.

Statistical Analysis. Differences in number of plaque-forming cells per 10^6 splenocytes as a function of field exposure site and exposure duration were tested in a 2-way analysis with interaction using a multivariate general linear model for analyzing unbalanced data (SYSTAT). Immunological responses and hepatic enzyme activities for RMA enclosure studies did not differ significantly among exposure durations within any exposure concentration, therefore values were pooled by cyclodiene concentration. Subsequent one-way analysis of variance tested for differences between enclosure associated cyclodiene concentrations in the soil. Data from laboratory dosing studies were tested by a one-way analysis of variance. In all analyses where significant differences were detected, pairwise comparisons were performed using the Bonferroni means separation method with an overall error rate, α, of 0.05.

Results

RMA Enclosure Studies. Numbers of plaque-forming cells were quantified as a measurement of immune function integrity which addresses multiple immune system interactions including antigen recognition, processing and presentation, production of discrete antibody synthesizing lymphocyte populations, antigen antibody coupling, and complement fixation. Total plaque-forming cells per

10^6 splenocytes (Figure 1) showed significant ($p \leq 0.05$) variation among treatment concentrations but not among exposure times. Deer mice in the 0.6 ppm cyclodiene group had fewer plaques per 10^6 splenocytes than mice in the reference (0.006 ppm) group ($p \leq 0.01$). In contrast, mice exposed to 1.8 ppm cyclodienes showed elevated numbers of plaques per 10^6 splenocytes compared to the 0.6 and 20.0 ppm groups ($p \leq 0.005$) but not the 0.006 ppm reference group ($p = 0.05$).

Hepatic enzyme activity displayed a more consistent relationship with soil dieldrin concentration. Mice in the 20 ppm cyclodiene group showed significant elevations ($p \leq 0.05$) in EROD activity relative to all other groups (Figure 2). EROD activity in these mice was 1.4-fold higher than for mice in the reference group. There was no correlation between EROD induction and exposure duration among treatment concentrations. PROD activity showed no significant variation among exposure groups or exposure durations (Figure 3).

Laboratory Studies. Total plaque-forming cells per 10^6 splenocytes in dieldrin dosed laboratory mice (Figure 4) showed significant ($p \leq 0.05$) variation among treatment concentrations in a dose dependent manner, with values significantly ($p \leq 0.005$) higher in the 0 and 0.08 mg/kg/day groups than in the other three dose groups. Although there was also an indication of enhancement of the immune response in the 0.08 mg/kg/day group, this was not significant. EROD activity displayed a significant 2.2-fold elevation in the 0.80 and 2.5 mg/kg/day groups relative to other groups (Figure 4). The dose required to elicit enzyme induction was 3.2-fold greater than the dose that elicited immunosuppression. There was no significant variation in PROD activity among groups.

Arsenic dosed mice, at the highest, 5.0 mg/kg/day dose, showed suppressed numbers of plaque-forming cells per 10^6 splenocytes when compared to controls (Figure 5). No other arsenic dose groups were significantly suppressed below control levels. EROD and PROD data have not yet been generated for the arsenic dosing study mice.

Discussion

Controlled laboratory dosing studies indicate that dieldrin and arsenic suppress normal immunological responses to antigenic challenge. Dieldrin also induces hepatic enzyme activity in deer mice in a dose-dependent manner. Immunosuppression is a more sensitive endpoint, occurring at approximately one-third the dieldrin dose required for P450 (EROD) induction. Enclosured mice at RMA displayed increased EROD activity at the 20 ppm sites, though immune function responses showed no consistent relationship to total soil cyclodiene concentrations. The lack of immune suppression in the presence of EROD induction is contrary to the effects predicted in laboratory studies. The differing patterns of P450 induction and immune suppression between studies indicate causative factors at the RMA which may be beyond total cyclodiene levels. We are currently quantifying the complete contaminant profiles at the enclosure sites to determine which contaminants might be responsible for the observed results. Enclosure studies suggest that ecological risk assessments at RMA based solely on soil cyclodiene concentrations may not adequately reflect the bioavailability and bioaccumulation of chemicals of concern for wildlife inhabiting these sites.

Other Activities

Danny Allen has assisted several other RMA research projects on badgers, starlings, kestrels, and great horned owls. On March 19, 1994, Mr. Allen gave a presentation on the rodents of the Rocky Mountain Arsenal Wildlife Refuge to a USFWS tour group. After a slide presentation, the tour moved out to observe his trapping procedures. On October 15, 1994, Danny Allen had a committee meeting and his graduation requirements were discussed and approved. On November 3, 1994, we presented two posters, one on the small mammal trapping study and one on the enclosure and laboratory studies, at a special symposium dedicated to the RMA at the SETAC annual meeting in Denver, CO.

PLANNED ACTIVITIES FOR NEXT YEAR

Small Mammal Study

Small mammals will be trapped on three more occasions in March, late May or early June, and August, 1995. Vegetation and litter depth will be sampled in each plot during the May trap session to further characterize any differences in habitat between the plots. Danny Allen will take full course loads at Clemson University during the spring and fall semesters and plans to graduate in December, 1995.

Laboratory and Enclosure Studies

Though there does not appear to be substantial immunostimulation by arsenic in deer mice, the potential for a protective effect when given concommitantly with dieldrin will be explored with a combined dieldrin/arsenic exposure study followed by Jerne PFC response assessments. Immune suppression's significance at the levels observed in dieldrin dosing studies will be evaluated as part of an immune challenge study. Deer mice dosed with dieldrin at concentrations leading to Jerne PFC suppression will be challenged with the parasite, *Trichenella spiralis*, to determine if the Jerne PFC test is a good predictor of the functional capability of the immune system. If so, the occurrence of Jerne PFC suppression in study mice is solid evidence for a potentially lethal effect due to decreased immune capacity in the wild.

Culmination of Laboratory, Enclosure and Trapping Studies

Ongoing research will correlate biomarker responses and residue levels in enclosured deer mice with population demographics, health and residue levels in wild rodent species found at RMA. Selective collections will be made from previously trapped areas to examine health effects endpoints and residue patterns of wild rodents occupying study sites. Matrices of study endpoints will be examined to determine the endpoints or combination of endpoints which are sensitive and those which correlate best to on-site wildlife demographics and population health. A final report of this phase of the research will be submitted at the end of the calander year, 1995.

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Table 1. Total number of individual *Peromyscus maniculatus* captured (M), population estimate (N) using heterogeneity model in Program CAPTURE, and standard error (S.E.) of the population estimate.

		Date of Trap Session				
Plot		10/93	3/94	6/94	8/94	10/94
27	M	5	13	3[a]	0[a]	2[a]
	N	5 (0.13)	13 (0.11)	-	-	-
33	M	8	11	5[a]	5	4[a]
	N	8 (2.38)	12 (1.76)	-	5 (1.26)	-
1	M	20	32	14	13	19
	N	30 (6.71)	34 (3.03)	16 (3.15)	14 (1.76)	21 (3.08)
23	M	13	56	39	32	47
	N	15 (2.27)	57 (3.01)	40 (1.37)	36 (3.88)	57 (5.65)
26	M	28	56	15	16	5[a]
	N	32 (3.71)	67 (5.95)	36 (8.77)	32 (7.39)	-
36	M	41	52	37	16	19
	N	56 (6.85)	62 (5.78)	45 (5.58)	17 (1.75)	21 (2.14)

[a] No population estimates available from Program CAPTURE.

Table 2. Number (M) of *P. maniculatus* released and recaptured in subsequent trapping sessions for all plots combined.

		Date of recapture			
Date of release	M	3/94	6/94	8/94	10/94
10/93	125	23	4	2	2
3/94	219		40	16	7
6/94	111			32	17
8/94	82				24

Table 3. Survival estimates (ϕ) and standard errors for each trap grid using the Jolly-Seber model.

Plot	10/93 - 3/94		3/94 - 6/94		6/94 - 8/94	
	ϕ	SE	ϕ	SE	ϕ	SE
27	.4000	.2191	.5385	-	-	-
33	.5000	.1768	.4545	.4257	.2000	.1673
1	.2105	.0935	.1828	.2028	.1978	.1347
23	.3846	.1349	.3828	.0724	.5791	.1051
26	.6667	.4850	.1067	.0648	.2667	.1128
36	.0488	.0336	.2600	.0620	.3426	.2062

Table 4. Number of individuals for each species captured in October, 1993.

	Plot					
Species	27	33	1	23	26	36
Peromyscus maniculatus	6	9	21	13	31	45
Dipodomys ordii	-	9	-	-	9	10
Spermophilus tridecemlineatus	*	*	*	*	*	*
Onychomys leucogaster	-	3	-	-	-	-
Reithrodontomys megalotis	19	17	20	5	1	1
Perognathus hispidus	*	-	*	-	-	-
Spermophilus spilosoma	-	*	-	-	-	-
Microtus ochrogaster	*	*	*	-	-	*
Mus musculus	3	2	1	1	3	4

* indicates a species not individually marked until June, 1994

Table 5. Number of individuals for each species captured in March, 1994.

	Plot					
Species	27	33	1	23	26	36
Peromyscus maniculatus	13	11	33	55	55	52
Dipodomys ordii	-	22	-	-	6	7
Spermophilus tridecemlineatus	*	*	*	*	*	*
Reithrodontomys megalotis	6	11	16	4	1	8
Perognathus hispidus	*	-	-	-	-	-
Perognathus flavescens	-	1	-	-	-	-
Microtus ochrogaster	*	*	-	-	-	*

* indicates a species not individually marked until June, 1994)

Table 6. Number of individuals for each species captured in June, 1994.

	Plot					
Species	27	33	1	23	26	36
Peromyscus maniculatus	3	5	13	38	15	37
Dipodomys ordii	-	9	-	1	2	7
Spermophilus tridecemlineatus	7	2	11	3	13	2
Onychomys leucogaster	-	1	-	-	-	-
Reithrodontomys megalotis	-	2	2	-	-	2
Perognathus hispidus	3	-	2	-	-	-
Perognathus flavescens	-	16	-	-	-	-
Microtus ochrogaster	1	-	-	-	-	1

Table 7. Number of individuals for each species captured in August, 1994.

	Plot					
Species	27	33	1	23	26	36
Peromyscus maniculatus	-	5	13	32	16	16
Dipodomys ordii	-	7	-	-	4	5
Spermophilus tridecemlineatus	2	-	5	1	1	1
Reithrodontomys megalotis	1	-	-	-	-	-
Perognathus hispidus	4	-	7	-	-	-
Perognathus flavescens	1	12	-	-	-	-
Mus musculus	1	-	-	-	-	-

Table 8. Number of individuals for each species captured in October, 1994.

	Plot					
Species	27	33	1	23	26	36
Peromyscus maniculatus	2	4	19	47	5	19
Dipodomys ordii	-	7	-	-	3	8
Spermophilus tridecemlineatus	1	-	-	1	3	2
Onychomys leucogaster	-	1	-	-	-	-
Perognathus hispidus	-	-	1	-	-	-
Mus musculus	1	1	-	-	-	-

Table 9. Species diversity (D) using Shannon-Wiener index and species richness (R).

	Date									
	10/93		3/94		6/94		8/94		10/94	
Plot	D	R	D	R	D	R	D	R	D	R
27	0.81	6	0.63	5	1.19	4	1.42	5	1.04	3
33	1.39	8	1.11	6	1.43	6	1.03	3	1.10	4
1	0.78	6	0.63	3	1.09	4	1.02	3	0.20	2
23	0.76	4	0.25	3	0.35	3	0.13	2	0.10	2
26	0.84	5	0.41	4	0.90	3	0.67	3	1.07	3
36	0.78	6	0.68	5	0.82	5	0.72	3	0.82	3

Table 10. Estimated dieldrin concentrations (ppm) and associated standard error (SE) from surficial soil samples taken from trapping grids. These data are presented here for comparison's purposes, as they are as yet unvalidated by the Army's contract laboratory (see text).

	Date of collection		
	9/93 (n=6)	10/94 (n=6)	Combined Samples
Plot 27	0.0049 (0.0024)	-[a]	0.0049 (0.0024)
Plot 33	0.0046 (0.0018)	-[a]	0.0046 (0.0018)
Plot 1	0.0728 (0.0288)	-[a]	0.0728 (0.0288)
Plot 23	0.2433 (0.1176)	0.1883 (0.0214)	0.2158 (0.0855)
Plot 26	0.6700 (0.3940)	0.5883 (0.1930)	0.6292 (0.2988)
Plot 36	0.7017 (0.6599)	0.2450 (0.0826)	0.4733 (0.5078)

[a] No surficial soil samples were taken.

Table 11. Percent cover of *Bromus* spp., litter, and total live vegetation estimated from n 1/2 m^2 quadrats in each trap grid.

Plot	n	Bromus spp.	Litter	Total Live Vegetative Cover
27	15	12.33	55.67	17.50
33	15	13.83	23.67	30.14
1	20	12.00	18.50	20.63
23	10	16.75	37.50	19.50
26	10	21.25	27.00	22.75
36	20	23.38	29.25	29.38

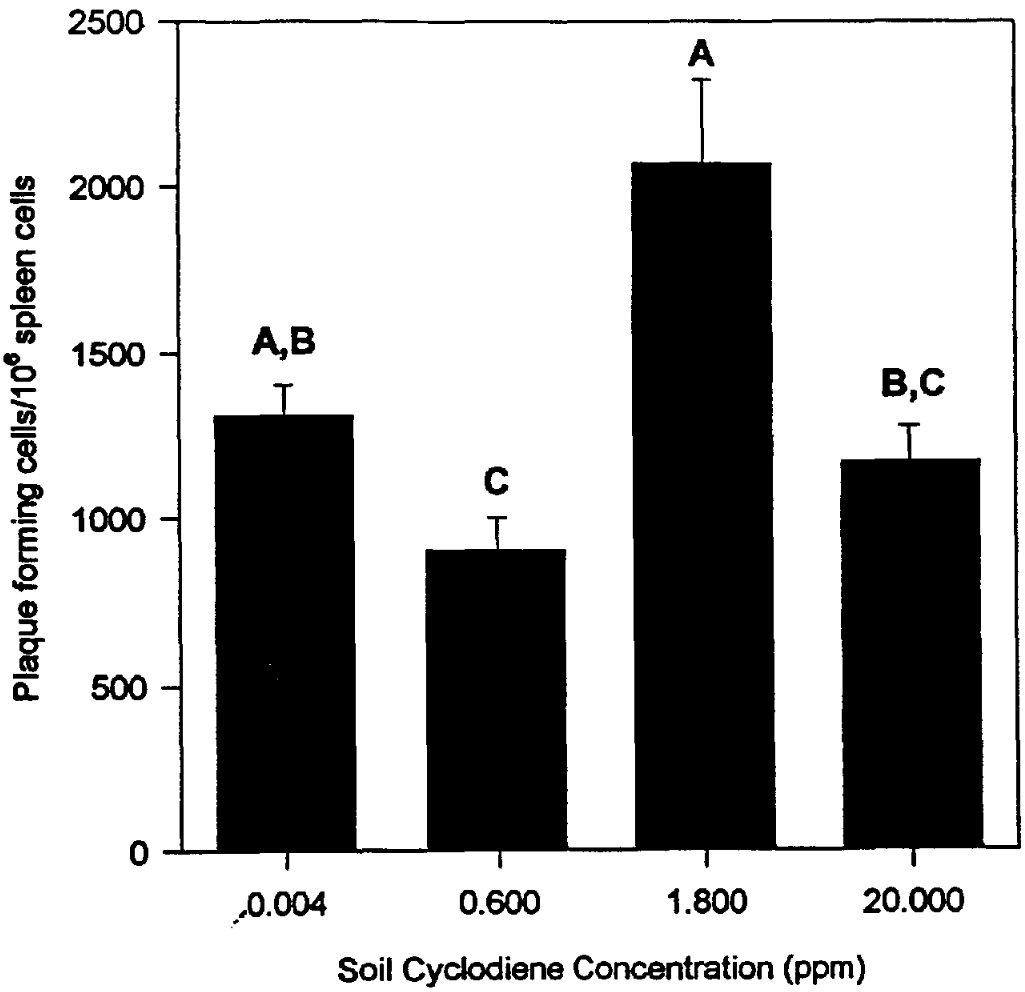

Figure 1. Jerne plaque forming cell response in deer mice maintained in enclosures on the Rocky Mountain Arsenal National Wildlife Refuge. Doses with similar letters are not significantly different.

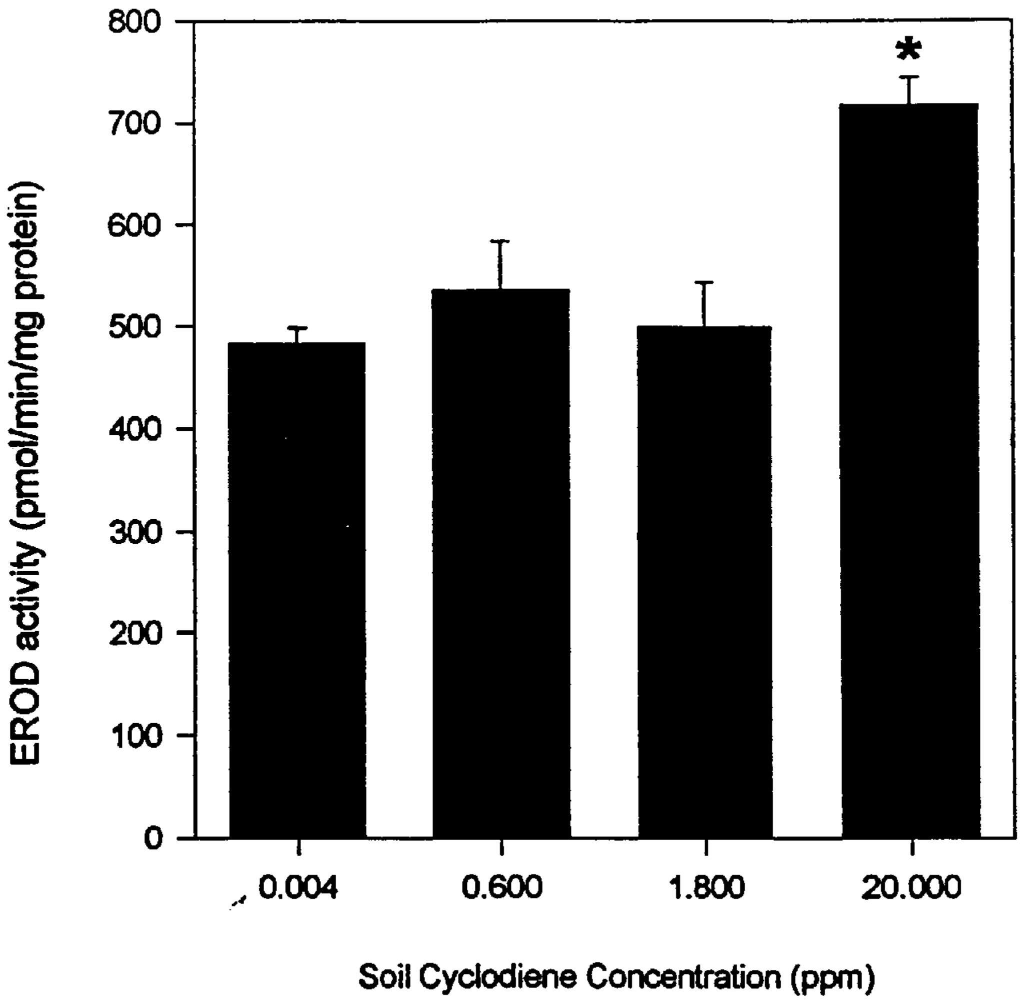

Figure 2. Ethoxyresorufin-O-dealkylase (EROD) activity in deer mice maintained in enclosures on the Rocky Mountain Arsenal National Wildlife Refuge. * Indicates values significantly greater than controls.

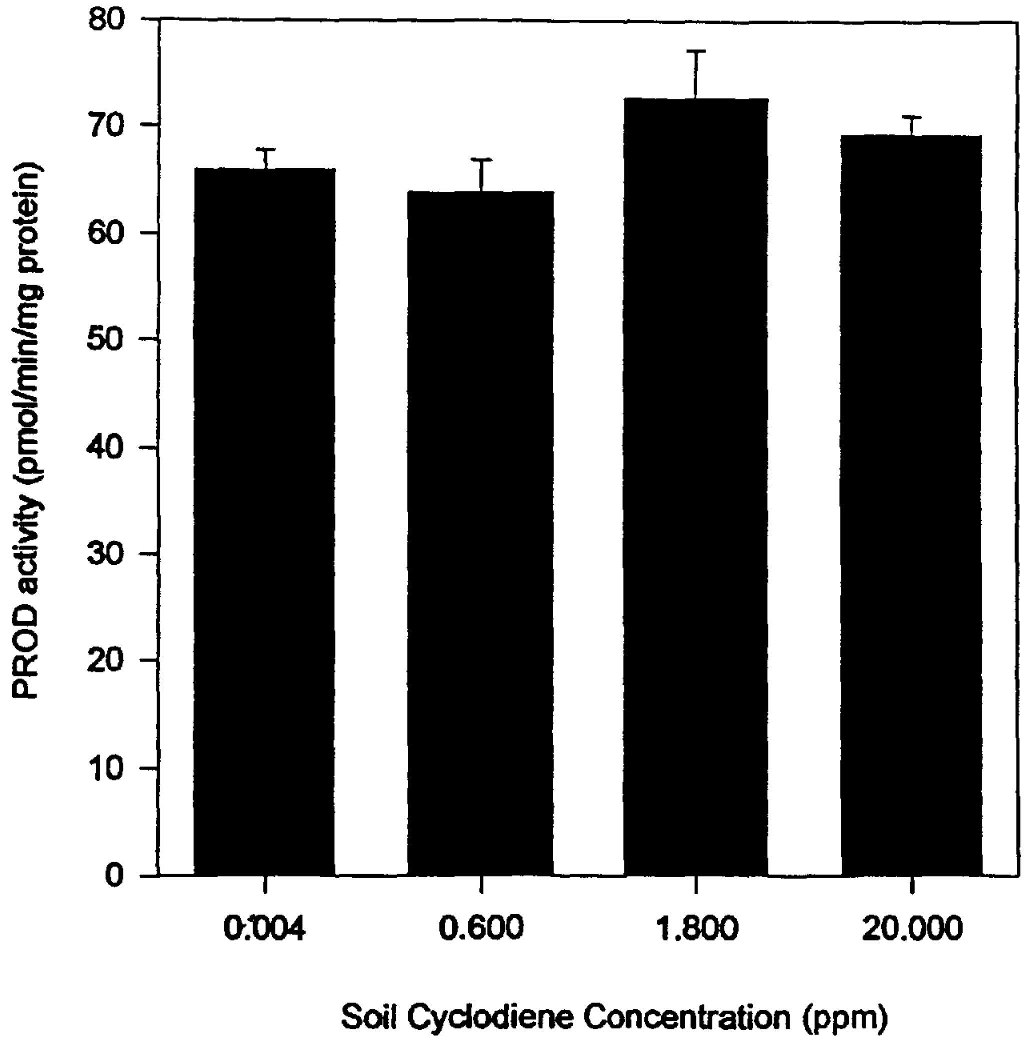

Figure 3. Pentoxyresorufin-O-dealkylase (PROD) activity in deer mice maintained in enclosures on the Rocky Mountain Arsenal National Wildlife Refuge.

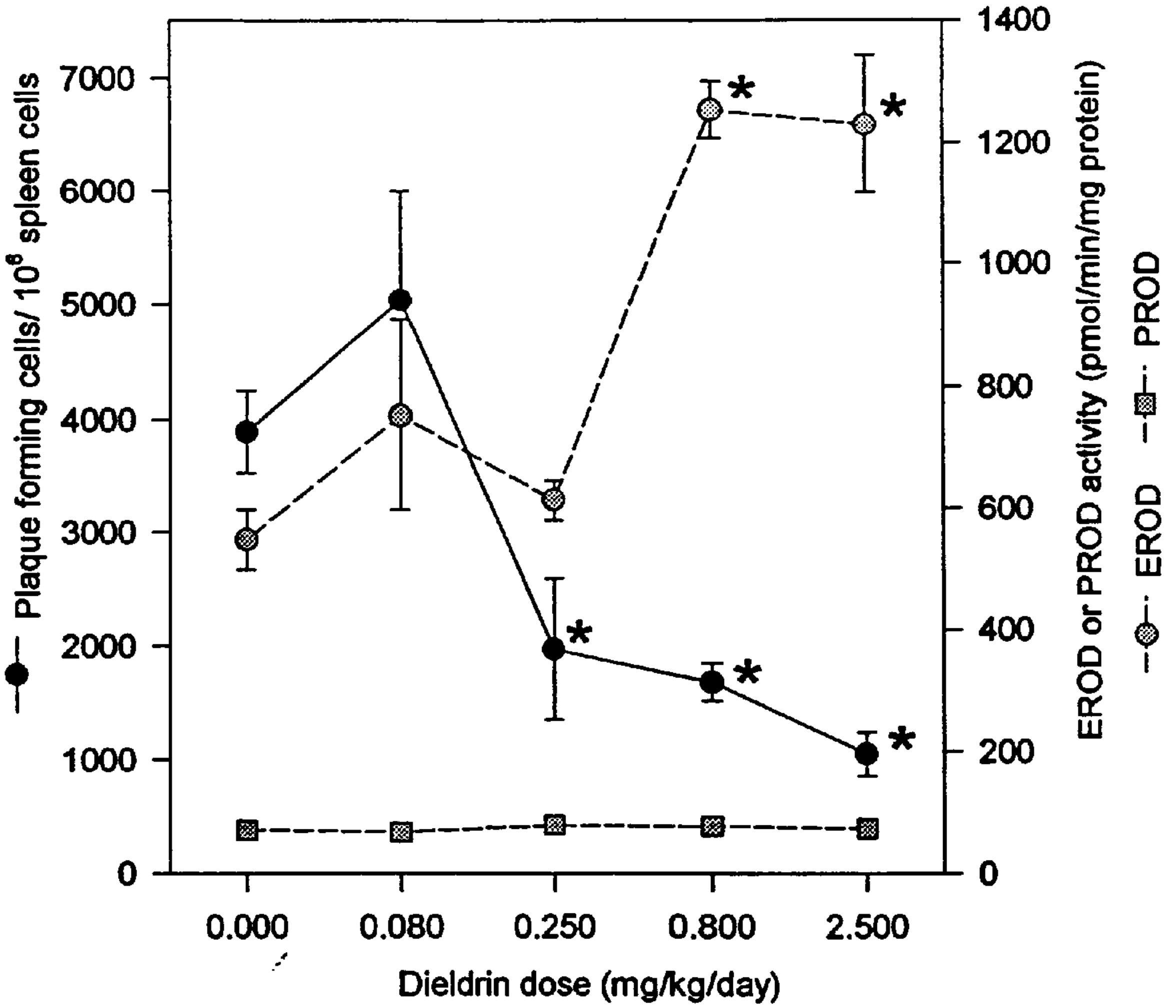

Figure 4. EROD, PROD and Jerne PFC response to dieldrin exposure in deer mice dosed and maintained under laboratory conditions. * Indicates responses significantly different from control.

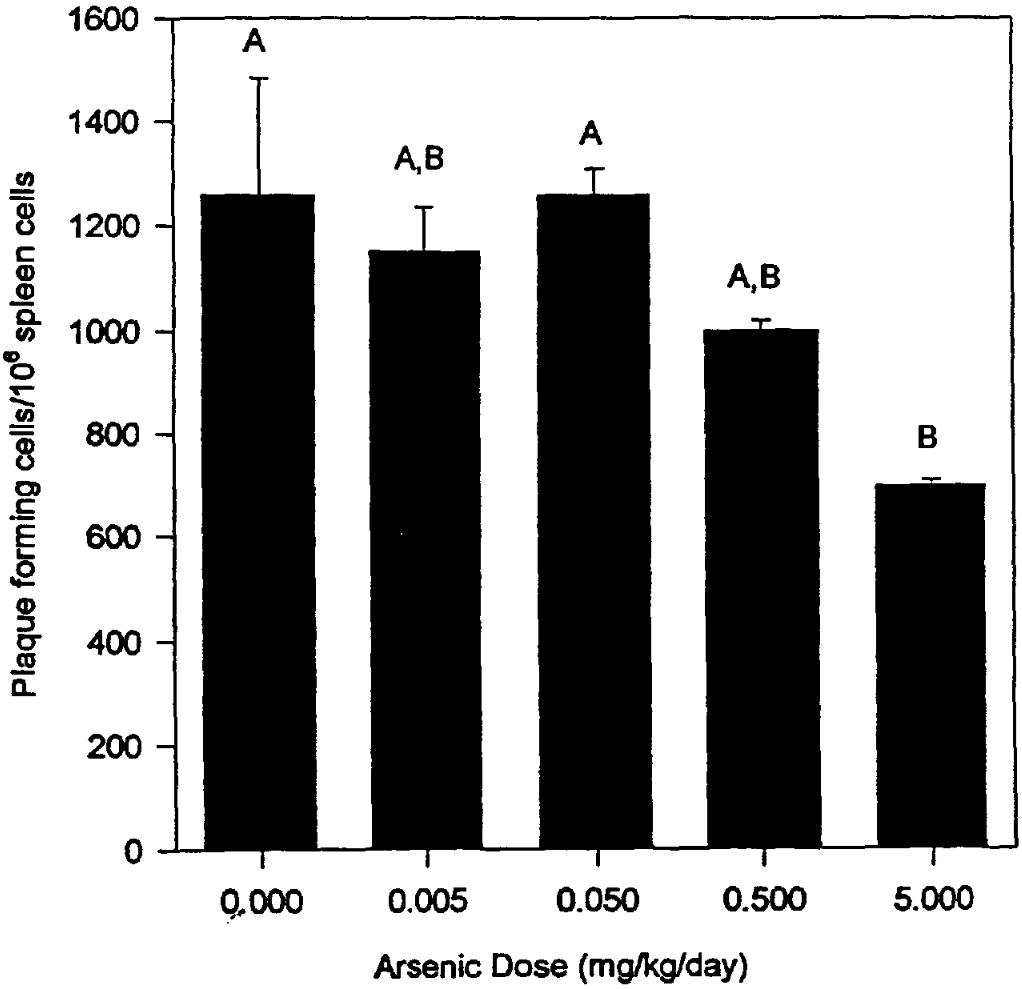

Figure 5. Jerne PFC response to arsenic exposure in deer mice dosed and maintained under laboratory conditions. Doses with similar letters are not significantly different.

Progress Report

for

Effects of Environmental Contaminants on Great Horned Owls at the Rocky Mountain Arsenal

Submitted by:

Rosemary A. Frank
December 1994

Introduction

The first field season of the study examining the effects of contaminants on Great Horned Owls (GHO) (Bubo virginianus) began January 1994. The following report summarizes information gathered February through November 1994. Two additional field seasons will take place in 1995 and 1996.

Two primary objectives of the study were:

1. Correlate contaminant exposure levels (core area vs. non-core area) with GHO productivity parameters and adult mortality.

2. Relate contaminant levels of juvenile owls in relation to exposure (core vs. non-core) to juvenile survival rates.

Each objective will be addresses in terms of data collected and completed analysis to date.

Objective 1.

Sixteen pairs of great horned owls were located on the arsenal during the 1994 breeding season. Twelve pairs established nests, and 11 nests produced young. Of the 11 successful nests, three were established in the core area and the other eight were non-core area nests.

Table 1. GHO nest site productivity in core and non-core areas at the Rocky Mountain Arsenal, Colorado recorded Jan.- May 1994.

Reproductive Activity	Location	
	Core	Non-core
Pairs	4	12
Pairs nesting (%)	0.75	0.75
Nest success (%)	0.66	1.00

In 1994 four adult owls were trapped and equipped with radio transmitters. Two birds were captured in the core area of the arsenal and 2 from non-core areas. One of the radio equipped birds (core area) was found dead and the cause of death is still undetermined. Another adult owl (unmarked), found dead in the core area on the arsenal showed signs of electrocution.

Objective 2.

In 1994 the eleven GHO nests produced 24 nestlings. Twenty-three owls survived to fledge. All 23 fledglings were captured, body measurements and blood samples were collected. Seventeen fledgling owls were equipped with radiotransmitters.

Transmittered birds were monitored daily for survival and dispersal. Transmitter signals were used to visually locate the owls. Owl locations were recorded on U.S. Geological Survey (U.S.G.S.) 7.5 minute quadrangles and the field locations translated into Universal Transverse Mercator (UTM) systems coordinates (Lancia 1974).

In September, a non-core area juvenile owl was found dead. organochlorine analysis of tissues are still pending. In November, a core area juvenile owl died of electrocution after becoming entangled in powerlines.

Table 2. Monthly survival rate (Heisey and Fuller 1985) of HY great horned owls captured in core and non-core areas at the Rocky Mountain Arsenal, Colorado, and radio-tracked from May - November 1994.

	Core		Non-Core	
Month	Radioed	Surv.	Radioed	Surv.
May	4	1.00	13	1.00
June	4	1.00	13	1.00
July	4	1.00	13	1.00
August	4	1.00	13	1.00
September	4	1.00	12	0.91[a]
October	4	1.00	12	1.00
November	3	0.56[b]	12	1.00

[a] variance equals 0.07
[b] variance equals 0.01

Future project goals.

In the upcoming 1995 field season, I will trap adult owls, take tissue samples for contaminant analysis, and equip them with radio transmitters. I will monitor night foraging activities to determine habitat usage and foraging areas. I will collect small mammals within GHO foraging areas for contaminant analysis.

I will monitor nests to determine numbers of nesting pairs, nestlings, and fledglings. I capture fledglings, take tissue samples for contaminant analysis and equip them with radio transmitters. Juvenile owls will be monitored for survival through July. 1994 data indicates that dispersal activity does not occur until late November.

LITERATURE CITED

Heisey, D. M. and T.K. Fuller. 1985. Evaluation of survival and cause-specific mortality rates using telemetry data. J. Wild. Manage. 49:668-674

Lancia, R. A. 1974. A universal grid system for map locations. Wild. Soc. Bull. 2:72

PATTERNS OF COEXISTENCE FOR SYMPATRIC MULE AND WHITE-TAILED DEER ON THE ROCKY MOUNTAIN ARSENAL, COLORADO

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December, 1994

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CHAPTER I

INTRODUCTION AND STUDY AREA

Interactions between 2 or more species or individuals can be grouped into 3 broad categories, predation, competition, and mutualism (Keddy 1989). Although predation is rare or non-existent between herbivores, predation from an additional species may have profound effects on the population dynamics and interactions between sympatric herbivores. Competition occurs when individuals utilize common resources that are of limited supply, or if individuals harm one another in the process of obtaining resources (Birch 1957, Krebs 1985). Mutualism occurs when both interacting species benefit and 1 species cannot live without the other. Mutualism may be possible between herbivorous species but is not likely between sympatric deer species and will not be discussed further.

Characteristics of wildlife populations are ultimately governed by the births and deaths of individuals. Local population dynamics are affected by many factors including species-habitat interactions, interactions with closely related species, and interactions with predators. Patterns of habitat use in relation to quantity and quality of habitats may effect recruitment of new individuals, and survival of adult individuals. These interactions may be disrupted or altered when a species is faced with competition with a closely related species. Effects of any changes will ultimately be noticed in recruitment and survival rates for the population. Similary, predation may strongly influence dynamics of local populations. In situations where closely related species are sympatric, predation may serve to mediate the effects of competition allow coexistence of the species (Hastings 1978).

Mule deer (Odocoileus hemionus) and white-tailed deer (O. virginianus) have been extensively studied throughout their respective North American ranges. Volumes of literature are available concerning these 2 important big game species (Wallmo 1981, Halls 1984). Mule deer distributions include the majority of the Rocky Mountain west and deer can be found in the entire range of habitat types found in this region (Wallmo 1981b). White-tailed deer can be found in most of the continental United states and occur in environments ranging from north temperate to sub tropical (Baker 1984).

Mule deer occur sympatrically in parts of their distribution with at least 8 species of native ungulates, 7 species of domestic ungulates, and numerous exotic species (Mackie 1981). Similarly, white-tailed deer share most of their range with other domestic and wild ungulates (Baker 1984). White-tailed deer appear to be expanding their range westward and are encroaching on mule deer habitats (Baker 1984). Similarly, mule deer may be expanding their range to include areas historically dominated by white-tailed deer (Wallmo 1981b). Sympatric ranges of these closely related species occur from Canada to Mexico and from Washington to North Dakota (Mackie 1981, Baker 1984). Habitats in these sympatric areas range from riparian, grassland, and agricultural areas on the plains to coniferous forests in the intermountain west (Mackie 1981).

Although variable reproductive and survival rates for both species are a function of ecological factors in a particular region, it is largely believed that white-tailed deer have inherently higher rates of productivity (Beasom and Wiggers 1984). It also is well documented that white-tailed deer have a higher proportion of fawns reproducing, and a higher incidence of triplets (Bartmann et al. 1992). Interspecific differences in natality and mortality, as expressed at the local level, will dictate management of mule and white-tailed deer in those areas where they occur sympatrically.

Relatively little is known about interactions of mule and white-tailed deer on sympatric ranges. Existing studies of sympatric mule and white-tailed deer interactions have been conducted either in the northern (Martinka 1968, Kramer 1973, Swenson et al. 1983, Wood et al. 1989) or southern (Anthony and Smith 1977, Krausman 1978, Beasom and Krysl 1984, Beasom and Wiggers 1984, Wiggers and Beasom 1986) portions of species overlap. No studies have been found documenting interactions between these species in the middle latitudes of their North American ranges.

Mule and white-tailed deer are sympatric on the Rocky Mountain Arsenal (RMA) northeast of Denver, Colorado. The deer population is free-ranging over 6,900 ha contained within a 2.5 m-high perimeter fence. Animals have been subject to numerus developmental and industrial activities. Management objectives for deer on RMA called for maintenance of 1990 species and sex ratios (U.S. Department of Interior, Fish and Wildlife Service, 1990). Current activity on RMA involves the clean up of chemical industry waste and removal of manufacturing plants. This activity can potentially effect deer populations on RMA through habitat loss and change.

A study was designed to document demographic, spatial, and habitat use patterns of sympatric mule and white-tailed deer on Rocky Mountain Arsenal. Results and protocols from this study may be directly applied toward management of both species of deer on RMA. Knowledge gained from this study may be applied to future research and management of sympatric mule and white-tailed deer populations in similar situations elsewhere.

Five overall objectives were originally proposed for this study:

1) To determine interspecific relationships between sympatric mule and white-tailed deer on Rocky Mountain Arsenal.

2) To determine intraspecific relationships of mule deer and white-tailed deer on Rocky Mountain Arsenal.

3) To quantify population characteristics of sympatric mule and white-tailed deer on Rocky Mountain Arsenal.

4) To compare sympatric deer population statistics from Rocky Mountain Arsenal to sympatric and allopatric deer population statistics not on Rocky Mountain Arsenal.

5) To provide management recommendations and data collection protocols to U.S. Fish and Wildlife Service and U.S. Army personnel concerning deer populations and habitats on Rocky Mountain Arsenal.

STUDY AREA

History

The study was conducted on the Rocky Mountain Arsenal (RMA) about 16 km northeast of Denver in southern Adams County, Colorado (Figure 1.1). Elevation ranged from 1564 to 1625 m with gently rolling topography. Temperatures ranged from -9° to 31° C with a mean precipitation of 38 cm/yr. Historic habitat on RMA was typical of the central great plains. Grasslands, predominantly shortgrass prairie, were interspersed with small groves of trees and riparian areas.

RMA was established in 1942 by the U.S. Army for the production of chemical and incendiary weapons. Production of weapons ceased in 1969. Additionally, many of the same weapons that were manufactured at RMA were demilitarized at RMA. Three private companies (CF&I Fuel and Iron, Julius Hyman and Company, and Shell Chemical Company) have held leases on manufacturing facilities at RMA for the manufacture of chemical products after production of weapons ceased. No leases were held during the course of this study. Primary military and civilian activity since 1970 has been detoxification of chemicals and contaminated areas, and removal of industrial facilities.

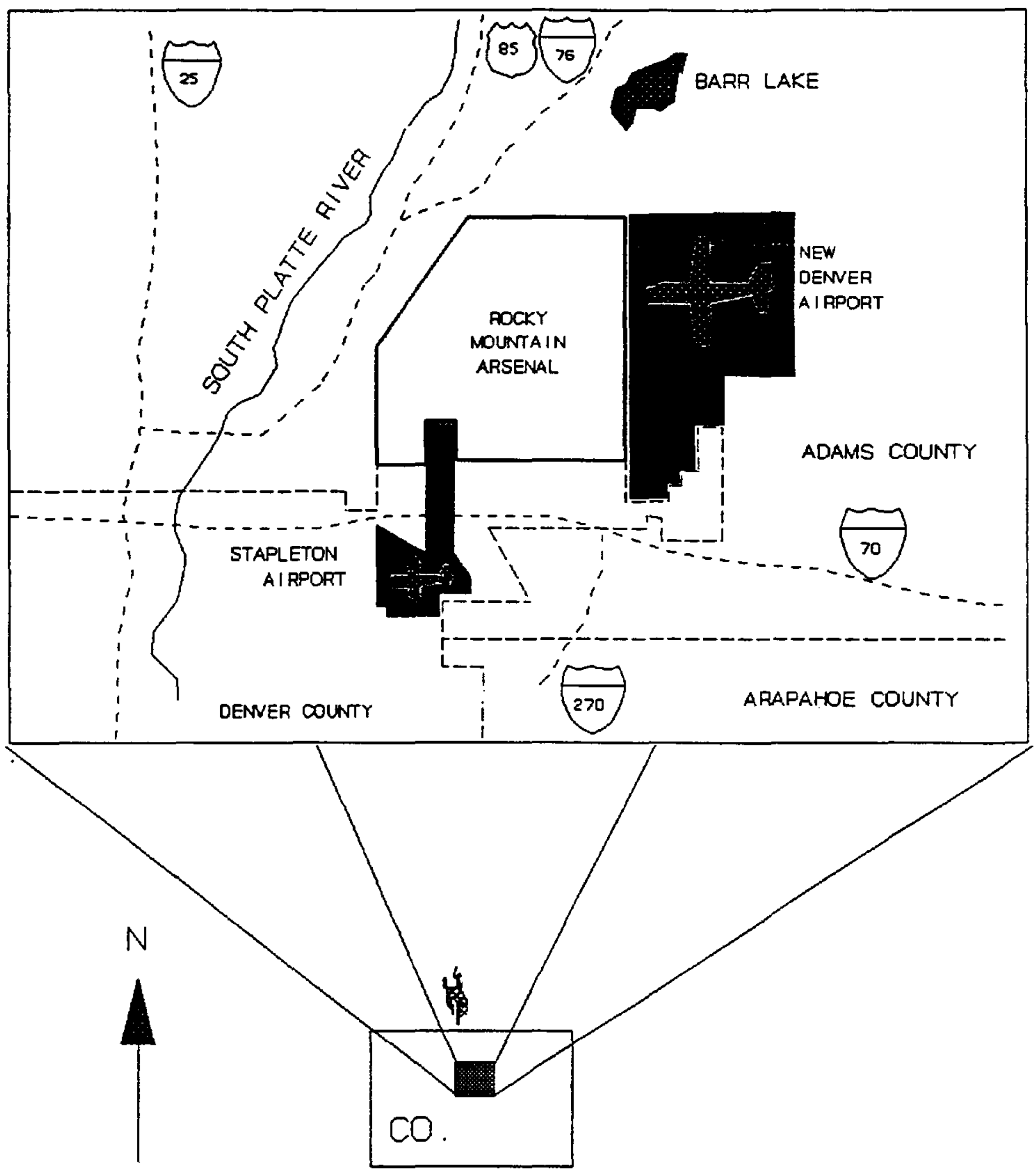

Figure 1.1. Location and description of Rocky Mountain Arsenal study area, Colorado.

Military and civilian activity has had profound affects on habitats at RMA. The size of RMA is a result of these activities. Manufacturing facilities were centrally located with ≥ 2 km of buffer area surrounding the facilities. This resulted in a total area of 6,900 ha being protected from urban development typical of the area. Many areas were used to store chemical and industrial waste products, thus modifying biotic and abiotic structure of the habitats. The facilities themselves have replaced or modified historic habitats. Additionally, although not a topic of this research, potential existed for direct contamination of biota as a result of activities at RMA.

In 1987, RMA was designated as an Environmental Protection Agency (EPA) superfund cleanup site as per the 1980 Comprehensive Environmental Response, Compensation and Liability Act (CERCLA). Primary activity since achieving superfund status has been directed toward compliance with CERCLA regulations.

The U.S. Fish and Wildlife Service (USFWS) has been involved with resource management on RMA since the discovery of a communal bald eagle roost in 1986. In 1989, the USFWS entered into a cooperative agreement with the U.S. Army. This agreement allows the USFWS to maintain an active role in preserving and managing natural resources at RMA.

Current Environment

With respect to deer populations, RMA can be considered an island of habitat in a predominantly urban environment. The south, and west boundaries were adjacent to urban housing and warehouse areas. The north, and east boundaries were predominantly agricultural areas. The entire perimeter was surrounded by a 2.4 m-high chain link fence that was completed 31 March 1990. Denver's Stapleton International Airport runways extended about 2 km into RMA on the south side. Construction of the new Denver International Airport east of RMA began in 1990. Future development associated with the new airport could potentially displace most of the remaining agricultural areas on the north and east sides of RMA, increasing the isolation or island affect of biota on RMA.

Current vegetation characteristics on RMA are primarily governed by past and present military and industrial activities. Industrial activities have altered habitat to include extensive areas of non-native herbaceous vegetation interspersed with remnant areas of native vegetation, shrubs and trees, and wetland/riparian areas.

Currently 8 major vegetation types are defined for RMA: weedy forbs, cheatgrass (Bromus tectorum) and weedy forbs, perennial grasses, crested wheatgrass (Agropyron cristatum, Ag. desertorum), shrublands/succulents, locust (Robinia spp.) thickets, wetlands, and tree groves (Morrison-Knudson Environmental Services, Inc. 1989). Weedy forb and cheatgrass/weedy forb are characteristic of severely disturbed sites. Dominant species for weedy forb sites include field bindweed (Convolvulus arvensis), summer-cypress (Kochia iranica), russian thistle (Salsola iberica), tall tumble-mustard

(Sisymbrium altissimum), and tansy-mustards (Descurania spp.). Cheatgrass/weedy forb sites are dominated by cheatgrass, blue lettuce (Lactuca serriola), summer-cypress, field bindweed, canada thistle (Cirsium arvense), bristle thistle (Carduus nutans), tall tumble-mustard, and tansy-mustards.

Native perennial grassland is further divided according to dominant species. Major native species include blue grama (Bouteloua gracilis), needle-and-thread (Stipa comata), sand dropseed (Sporobolus cryptandrus), western wheatgrass (Pascopyron smithii), red three-awn (Aristida longiseta), foxtail barley (Hordeum jubatum), and inland saltgrass (Distichlis spicata).

Groves of shrubs and trees are scattered throughout RMA. Shrub species include rubber rabbitbrush (Chrysothamnus nauseosus), sand sagebrush (Artemisia filifolia), yucca (Yucca glauca), and New Mexico locust (Robinia neomexicana). Tree species include plains cottonwood (Populus sargentii), white poplar (P. alba), and Siberian elm (Ulmus pumila). Wetland areas are dominated by cattails (Typha latifolia, T. angustifolia), Canada thistle, and stands of cottonwood and willow (Salix amygdaloides).

Early records of deer populations on RMA are limited. Ground counts conducted in 1976 resulted in 47 and 50 deer being counted during spring and fall, respectively (Colorado Division of Wildlife, unpubl. data). A spring count in 1977 produced a count of 53 deer. None of these counts distinguished between mule and white-tailed deer. An aerial count conducted in

December 1986 resulted in a total 156 deer (129 mule deer, 22 white-tailed deer, 5 unclassified) (Colorado Division of Wildlife, unpubl. data). Buck:doe:fawn ratios for this count were 50:100:53 and 0:100:45 for mule and white-tailed deer respectively. Early winter 1989-1990 deer populations were estimated at 270 mule deer and 70 white-tailed deer (Hanna and Lindzey 1990). Buck:doe:fawn ratios for winter of 1989-90 were estimated to be 59:100:57 and 20:100:35 for mule and white-tailed deer, respectively (Hanna and Lindzey 1990).

Similar to those of deer, records of predator numbers on RMA were limited. Ten coyotes (Canus latrans) were observed on RMA during the 1986 aerial count (Colorado Division of Wildlife, unpubl. data). Hein (1992) estimated average daily and total coyote populations of 50 and 73, respectively, for the winter of 1991-1992. Although population estimates were not available, badgers (Taxidea taxus) were common and red fox (Vulpes vulpes) were periodically sighted on RMA.

No public hunting had been allowed since about 1976, and livestock grazing had not occurred since establishment as a military installation. Management objectives call for maintenance of deer populations at approximately 1990 mule:white-tailed deer and buck:doe:fawn ratios (U. S. Department of Interior, Fish & Wildlife Service, 1990).

CHAPTER II

POPULATION CHARACTERISTICS FOR SYMPATRIC MULE AND WHITE-TAILED DEER ON ROCKY MOUNTAIN ARSENAL, COLORADO

INTRODUCTION

Characteristics of wildlife populations are ultimately governed by the births (natality) and deaths (mortality) of individuals. Local population dynamics may be affected by many factors including habitat quantity and quality, available space, and interaction with other individuals of the same or different species. Interactions between 2 or more individuals or species can be grouped into 3 broad categories, competition, predation, and mutualism (Keddy 1989). Competition occurs when individuals utilize common resources that are in short supply, or when the individuals seeking a resource harm one another in the process (Birch 1957, Krebs 1985). Competition may occur within a species (intraspecific) or between species (interspecific). Although competition itself is difficult to measure, the effects of competition on 2 species will ultimately be noticed in the demographics of both species. Most notable are increases in mortality (Birch 1957, Schoener 1983) or changes in reproductive ability of one or both species (Birch 1957, DeBach 1966, Schoener 1983). Predation affects mortality rates of prey species and may or may not limit ungulate populations (Connolly 1978). In systems containing 1 predator species and 2 competing prey species, predation may serve to mediate populations and allow coexistence of competing prey species (Hastings 1978).

A great deal of knowledge is available concerning natality rates for mule deer (Odocoileus hemionus) (MD) and for white-tailed deer (O. virginianus) (WTD). Although few actual comparisons have been reported, white-tailed deer are generally thought to have higher potential reproductive rates than mule deer (Kramer 1971, Beasom and Wiggers 1984). Differences in reproductive ability have been attributed to nutrition, predation, population genetics, (Beasom and Wiggers 1984) and local environmental factors (Kramer 1971, Beasom and Wiggers 1984). Where environmental factors influence reproductive ability, white-tail populations appear to be most affected (Kramer 1971). Date of parturition may affect survival of offspring (Rutberg 1987). For sympatric species, an earlier or later parturition date may provide an advantage to 1 species over another. Although information is available for survival and parturition dates for mule and white-tailed deer on allopatric ranges (Weber 1966, Swenson 1972, McGinnes and Downing 1977, Baker 1984, Halls 1984, Bowyer 1991), we found no information documenting parturition dates, and predation rates for neonatal fawns where mule and white-tailed deer occur sympatrically.

Mule and white-tailed deer occur sympatrically on Rocky Mountain Arsenal (RMA) near Denver, Colorado. A 3-year study was conducted documenting population characteristics of sympatric mule and white-tailed deer on RMA. Relative differences in rate of population growth, recruitment, and survival are discussed.

METHODS

Animal Capture and Telemetry

Adult deer were captured during winters of 1989-1990 and 1990-1991 using Clover traps (Clover 1956), a Coda-Netgun (Coda Enterprises, Mesa, Ariz.), or a Cap-Chur gun (Palmer Chemical and Equipment Co., Douglasville, Ga.). Deer were outfitted with activity sensing radio-transmitters (Telonics, Mesa, Ariz.). Expandable collars were used on all adult males. No physical measurements were collected on animals captured during winter 1989-1990. Data collected on individuals captured during winter 1990-1991 included weight (kg), ear, tail, and metatarsal gland length (cm). Ear, tail, and metatarsal gland length were averaged for each species and used as a reference for identifying possible hybrid individuals. Adults were aged according to tooth wear and replacement. Estimated species and sex ratios (Hanna and Lindzey 1990) for the population were approximated in the telemetered sample. Attempts also were made to trap animals in areas representative of species' distributions.

Fawns were captured during springs of 1991 and 1992 by observing does emphasizing radio-collared animals. We also systematically searched areas where fawns were thought to be. Fawns were measured and tagged with 28 gm solar-powered ear-tag transmitters with a battery back up mortality sensor (Advanced Telemetry Systems, Inc., Isanti, Minn.). A mortality signal began if the fawn was immobile for > 4 hours. Measurements taken on fawns included weight (kg), left hind foot, new growth of left hind hoof, metatarsal gland length, and length of the body, left ear, and tail (cm).

Exact parturition dates were recorded when a doe was observed in labor, or when fawns were captured while on the birthing site. Birth sites were identified when afterbirth or discharge was observed on the doe, fawn, or at the site, and when does were observed in labor before the fawns were captured. Behavior of the doe and fawn(s) also was used to indicate birth sites. Birth sites were identified when does were observed cleaning themselves, the site, or the fawns (Marchinton and Hirth 1984).

New hoof growth, measured with calipers, was used to estimate age and birth date of fawns not captured on the birth site (Haugen and Speake 1958, Robinette et al. 1973). Parturition dates also were determined through close observation of radio-collared does. Does were located and observed daily during fawning seasons for signs of having fawns. Signs included obvious weight loss, swollen udders, and behavioral cues. Parturition dates were not used however, unless fawns belonging to collared does were captured.

All transmittered deer were monitored for mortality. We attempted to visually observed each deer every 2-3 days. Adults not seen in $\geq$2 days were located on foot. Pulse rate change of fawn transmitters indicated death of the individual. We conducted field necropsies on all dead deer as quickly as possible to determine time and cause of death (CITE).

Population Characteristics

Demographics of both species were monitored seasonally. Natality was estimated by intensely monitoring radio-collared does throughout the fawning seasons of 1990-1992. The number of neonates per doe and number of does with at least 1 fawn were estimated for each fawning season. Information on fetal rates was collected opportunistically from studies conducted by USFWS personnel on RMA, or from dead does found on RMA during periods of gestation. Total number of animals collected during a given year was small enough ($\leq$ 5.0% of the population) to have insignificant effects on population estimates.

Population composition was monitored with monthly ground composition surveys conducted from an established route (Figure 2.1) between September and April of each winter. An extensive road system and high visibility during this time period allowed nearly complete coverage of RMA. All individuals seen were classified to species, age (fawn, adult) and sex.

Two aerial population counts were conducted each winter during December or January, dependent on snow conditions (LeResche and Rausch 1974, Samuel et al. 1983). A helicopter was used to fly transects 1/4 mile apart in an east-west direction starting on the south perimeter and moving north (Figure 2.2). Air safety regulations prohibited flight north of airport runways (due to the Emergency Landing Corridor) except for very short time periods. Therefore, the area immediately north of Stapleton Airport runways was flown only as Stapleton Air Traffic Control

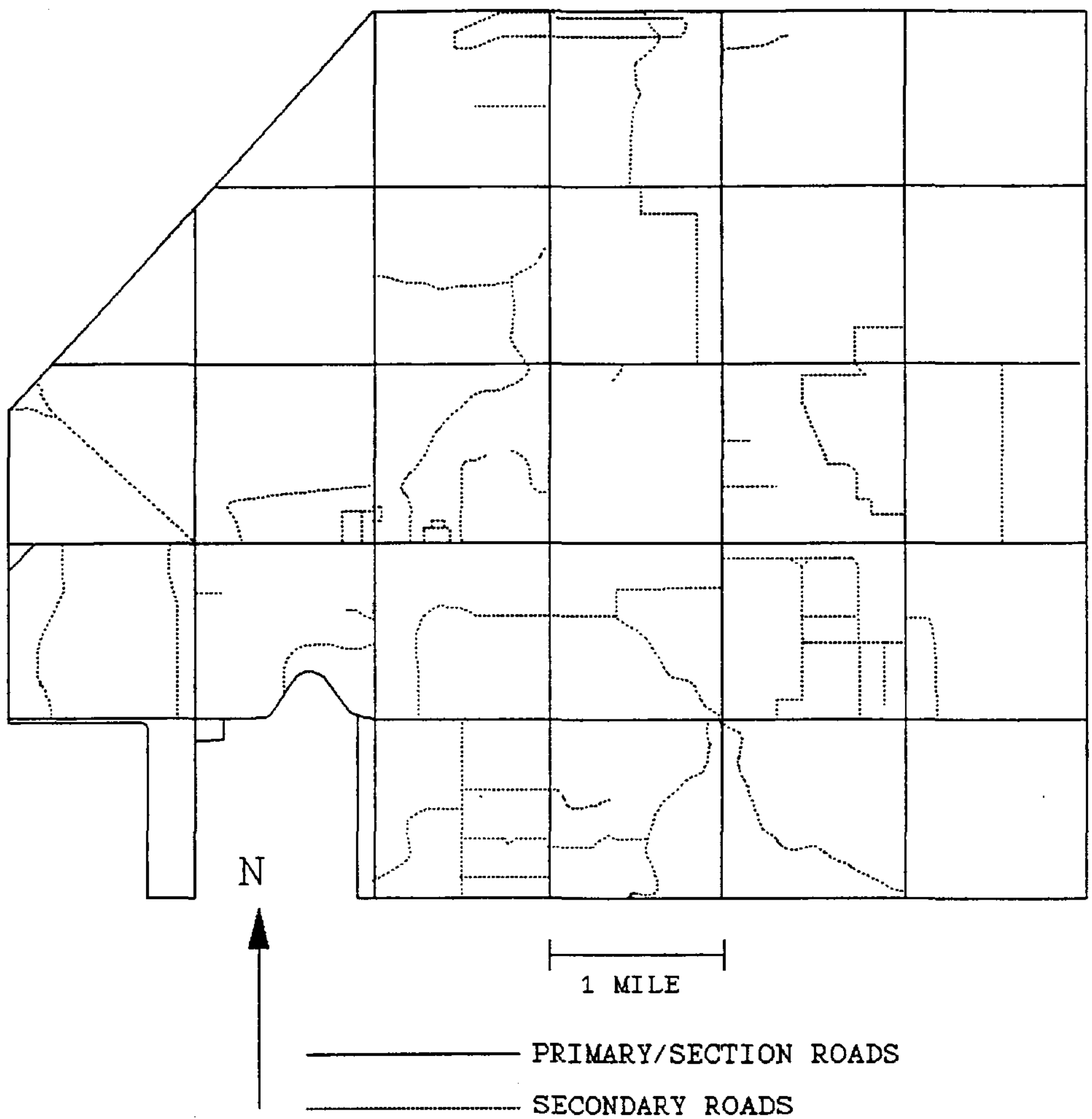

Figure 2.1. Roads used for ground deer composition surveys on Rocky Mountain Arsenal, Colorado, 1989-1993.

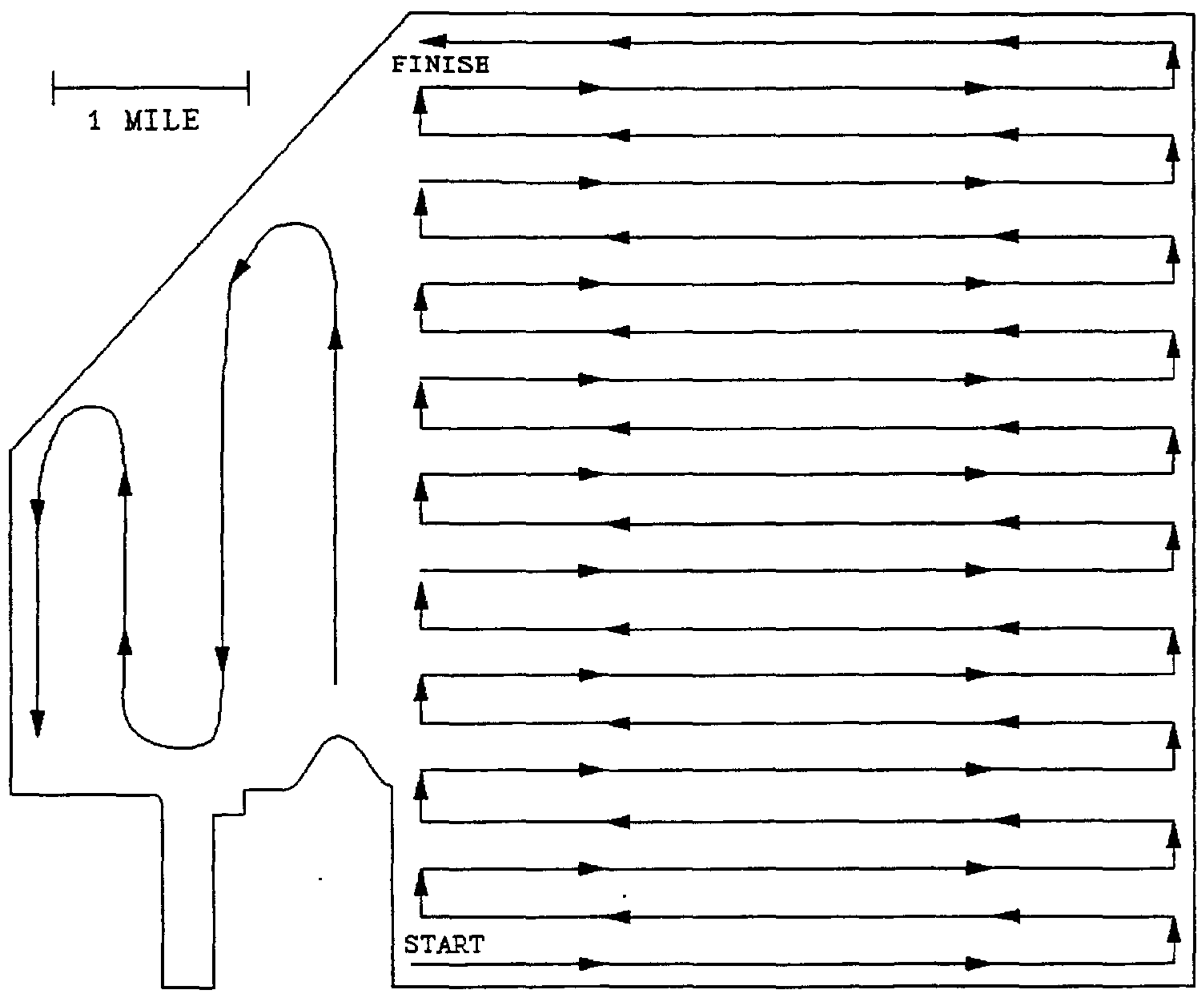

Figure 2.2. Aerial deer survey route for Rocky Mountain Arsenal, Colorado, 1989-1993.

tower allowed. Deer were tallied by species but were not classified by age or sex. A ground observer followed behind the helicopter to determine the number and location of all radio-collared deer on RMA.

All marked individuals sighted during ground and aerial were recorded. Population size was estimated using the hyper-geometric, closed population, mark-resight model (Bartmann et al. 1987, White 1993, pers. Comm.). Ground and air counts conducted through the winter were pooled to obtain annual winter population estimates. Only counts where $\geq$ 20% of marked individuals for a species were seen were used to obtain population estimates. Mark-resight population estimates were used to estimate overall mean density of each species per year.

Statistical Analyses

The Kaplan-Meier product limit estimator (Kaplan and Meier 1958, White and Garrott 1990) was used to estimate probability of neonate survival (S(t)) from birth to 30 days, and for adults throughout the study. Differences between species' survival probability functions were tested using the procedures of Cox and Oakes (1984) (White and Garrott 1990). Maximum likelihood analysis of variance using PROC CATMOD (SAS Institute Inc., Cary, North Carolina) (White and Garrott 1990) was used to test species, parturition date, weight (kg), body length (cm), sex, and capture site (birth or non-birth site) as predictors of fawn survival. Species, sex, and age at capture were tested as predictors of adult survival. All parturition date calculations used Julian calendar values. Differences in fall and spring buck:doe:fawn ratios, mortality, and recruitment of both species were compared using the z- and t-test (Johnson 1980, Iman and Conover 1989, respectively). Parameters of population growth were estimated using the Ricker (CITE) version of the logistic growth equation. Differences between capture statistics were analyzed using T-tests.

RESULTS

Deer Capture, Measurements, and Telemetry

A total of 159 animals were instrumented with radio transmitters during the course of this study (Table 2.1). Thirteen mule and 7 white-tailed adult ($\geq$ 1.5 yr. old), female deer were transmittered during winter 1989-1990. Thirteen mule deer (9 adult males, 4 adult females), and 7 white-tailed deer (4 adult males, 3 adult females) were collared during winter 1990-1991. The total adult telemetered sample was 9 male and 17 female mule deer, and 4 male and 10 female white-tailed deer. Mean age at capture (yr) for transmittered adults was 4.16 $\pm$ 1.56, 3.02 $\pm$ 0.92, 3.0 $\pm$ 0.5, and 3.14 $\pm$ 1.37 for male mule deer, female mule deer, male white-tails, and female white-tails, respectively.

Adult and fawn mule deer were heavier ($\underline{P} < 0.01$) than white-tailed deer on RMA (Table 2.2) during winter 1990-91. Sex specific weight differences between species were not observed in female fawns ($P = 0.80$) or adult males ($P = 0.27$). However, male, mule deer fawns and adult, female mule deer were heavier (P

Table 2.1. Number of deer radio-collared during each trapping session, by species, age, and sex.

CAPTURE PERIOD	MULE DEER			WHITE-TAILED DEER			
	MALE	FEMALE	FAWN	MALE	FEMALE	FAWN	TOTAL
Winter 1989-90	--	13	--	--	7	--	20
Winter 1990-91	9	4	--	4	3	--	20
Spring 1991 ♂♂	--	--	20	--	--	4	24
♀♀	--	--	15	--	--	4	19
Spring 1992 ♂♂	--	--	20	--	--	19	39
♀♀	--	--	28	--	--	10	38
Total	9	17	83	4	10	37	160

Table 2.2. Interspecific comparisons of weight, ear, tail and metatarsal gland length for mule and white-tailed deer captured during winter 1990-1991 on Rocky Mountain Arsenal, Colorado.

AGE GROUP	SEX	VARIABLE	MULE DEER MEAN	MULE DEER SE	WT DEER MEAN	WT DEER SE	P>T
FAWN	MALE	WEIGHT (kg)	47.02	1.03	38.98	2.01	<0.01
		MT GLAND (cm)	11.67	0.79	2.52	0.30	<0.01
		TAIL (cm)	24.38	0.87	29.96	1.33	<0.01
		EAR (cm)	21.36	0.24	14.96	0.41	<0.01
	FEMALE	WEIGHT	38.00	1.08	37.43	1.48	0.80
		MT GLAND	12.15	0.72	2.87	0.18	<0.01
		TAIL	22.33	0.72	30.48	0.46	<0.01
		EAR	20.85	0.22	14.48	0.26	<0.01
	BOTH	WEIGHT	43.41	1.64	38.08	1.17	0.01
		MT GLAND	11.86	0.53	2.71	0.17	<0.01
		TAIL	23.69	0.67	30.25	0.62	<0.01
		EAR	21.19	0.19	14.70	0.24	<0.01
ADULT	MALE	WEIGHT	78.12	3.32	71.40	3.63	0.27
		MT GLAND	12.81	0.42	3.72	0.93	<0.01
		TAIL	26.61	0.98	31.50	2.81	0.05
		EAR	22.26	0.32	16.27	0.33	<0.01
	FEMALE	WEIGHT	70.20	2.17	58.33	1.51	<0.01
		MT GLAND	12.58	0.26	2.61	0.17	<0.01
		TAIL	25.17	0.86	31.88	0.71	<0.01
		EAR	21.92	0.32	15.45	0.33	<0.01
	BOTH	WEIGHT	75.62	2.49	62.18	2.07	<0.01
		MT GLAND	12.75	0.31	3.04	0.38	<0.01
		TAIL	26.20	0.74	31.71	1.21	<0.01
		EAR	22.16	0.24	15.80	0.25	<0.01

< 0.01) than male white-tail fawns and adult female white-tailed deer, respectively. Metatarsal gland length (cm), and ear length (cm) was greater ($P < 0.01$) in mule deer than white-tailed deer in all interspecific comparisons. Tail length (cm) was greater for white-tailed deer ($P < 0.01$).

Only 1 captured deer, a yearling, male white-tailed deer, was possibly a hybrid based on these criteria. Metatarsal gland length for this individual (7.3 cm) fell almost exactly 1/2 way between the species means of 12.75 and 3.04 for mule and white-tailed deer, respectively (Table 2.3). Additionally, this deer had white spotting on the bottom portion of each leg just above the hoof.

During spring of 1991, 43 fawns (20 MD ♂, 15 MD ♀, 4 WTD ♂, and 4 WTD ♀) were captured and fitted with radio transmitters (Table 2.1). During spring 1992, 77 fawns (29 MD ♂, 28 MD ♀, 19 WTD ♂, and 10 WTD ♀) were transmittered. Because weight (Kg), body length, foot length, and chest girth (cm), and date of parturition did not differ ($P > 0.05$) between years within species, data was pooled across years for interspecific comparisons. Average age at capture of fawns was 2.74 ± 0.39 and 4.55 ± 0.85 ($\bar{x} \pm SD$) days for mule and white-tailed deer, respectively (Table 2.3). Mean parturition date differed ($P < 0.01$) between species in all analyses with white-tailed deer fawns born 8 to 10 days earlier than mule deer fawns. Newborn ($\leq$ 1 day old) mule and white-tailed deer fawns did not differ ($P >$ 0.05) in weight, body length, or hind foot length. Female mule

Table 2.3. Interspecific comparisons of birth date (JULIAN DAY), weight, body length, and hind foot length for mule and white-tailed deer fawns captured during spring 1991 and 1992 on Rocky Mountain Arsenal, Colorado.

AGE GROUP	SEX	VARIABLE	MULE DEER MEAN	MULE DEER SE	WT DEER MEAN	WT DEER SE	P>T
ALL AGES	CMBND	CPTR. AGE	2.74	0.39	4.55	0.85	0.06
		BIRTH DATE	158	0.65	149	1.07	<0.01
		WEIGHT (KG)	4.17	0.10	3.90	0.18	0.18
		BODY LGTH. (CM)	73.76	0.57	72.69	1.16	0.42
		FOOT LGTH. (CM)	26.53	0.15	26.03	0.37	0.21
≤ 1 DAY	FEMALE	BIRTH DATE	160	1.18	150	3.30	<0.01
		WEIGHT	3.71	0.13	3.30	0.37	0.22
		BODY LGTH.	71.85	1.02	72.48	4.18	0.89
		FOOT LGTH.	25.95	0.22	24.97	1.13	0.43
	MALE	BIRTH DATE	159	1.11	150	1.40	<0.01
		WEIGHT	3.71	0.15	3.53	0.20	0.44
		BODY LGTH.	71.58	0.69	71.15	1.70	0.82
		FOOT LGTH.	26.03	0.25	26.08	0.72	0.94
	CMBND	BIRTH DATE	159	0.81	150	1.38	<0.01
		WEIGHT	3.71	0.10	3.45	0.18	0.17
		BODY LGTH.	71.73	0.65	71.59	1.73	0.94
		FOOT LGTH.	25.98	0.16	25.71	0.60	0.67
> 1 DAY	FEMALE	BIRTH DATE	157	1.62	149	1.86	<0.01
		WEIGHT	4.66	0.23	3.67	0.33	0.03
		BODY LGTH.	76.16	1.39	70.66	2.08	0.04
		FOOT LGTH.	27.29	0.32	25.81	0.78	0.05
	MALE	BIRTH DATE	156	1.24	148	2.52	<0.01
		WEIGHT	4.75	0.21	4.80	0.38	0.91
		BODY LGTH.	76.42	1.00	76.30	2.00	0.95
		FOOT LGTH.	27.17	0.30	26.78	0.46	0.46
	CMBND	BIRTH DATE	157	0.99	148	1.63	<0.01
		WEIGHT	4.71	0.15	4.33	0.29	0.20
		BODY LGTH.	76.30	0.82	73.79	1.56	0.12
		FOOT LGTH.	27.23	0.22	26.35	0.43	0.04

deer fawns greater than 1 day old, however, were heavier (P = 0.03), longer bodied (P = 0.04), and had longer hind feet (P = 0.05) than did white-tailed deer fawns of comparable age. Male mule and white-tailed deer fawns did not differ ($P > 0.05$) in these measurements.

Production

Pre-natal reproductive status was assessed using 26 female deer. Six female mule deer (4 $\geq$ 1.0 yr, 2 < 1.0 yr) and 6 female white-tailed deer (4 $\geq$ 1.0 yr, 2 < 1.0 yr) were collected during March and April of 1991 (U. S. Fish & Wildl. Serv. 1991, Unpubl. Data). All female deer > 1 year old were carrying twin fetuses (Table 2.4). Neither mule deer fawn had fetuses but 1 of the white-tail fawns had a single fetus (Table 2.4). Sex ratios of fetuses in this sample were 0.6:1 and 3.5:1 males:females for mule and white-tailed deer, respectively.

Fourteen female deer ($\geq$ 1.5 yr) were collected during March 1993 (U. S. Fish & Wildl. Serv. 1993, Unpubl. Data). Mule deer (n = 9) had 1.67 fetuses per doe and white-tailed deer (n = 5) had 1.80 fetuses per doe (Table 2.4). Male:female ratios of fetuses in the second sample were 1.14:1 and 0.8:1 for mule and white-tailed deer respectively. Combined, mule deer had 1.77 and white-tailed deer had 1.89 fetuses per adult female. combined male:female ratios were 0.92:1 and 1.57:1 for mule deer and white-tailed deer, respectively.

Although insufficient for statistical evaluation, data from late spring early summer fawns:collared doe ratios suggest an

Table 2.4. reproductive statistics for female mule and white-tailed deer on Rocky Mountain Arsenal, Colorado.

SOURCE	YEAR	VARIABLE	MD	WTD
U.S. Fish and Wildlife Service. 1991, 1993. Unpubl. Data.				
	1991	Fetuses:Doe	2.00:1	2.00:1
		Males:Female	0.60:1	3.50:1
	1993	Fetuses:Doe	1.67:1	1.80:1
		Males:Female	1.14:1	0.80:1
Pooled 1991, 1993		Fetuses:Doe	1.77:1	1.89:1
		Males:Female	0.92:1	1.57:1
This Study				
	1990	Fawns:Doe	1.00:1	0.71:1
	1991	Fawns:Doe	1.23:1	0.80:1
		Males:Female	1.33:1	1.00:1
	1992	Fawns:Doe	1.70:1	1.60:1
		Males:Female	0.71:1	1.90:1

increase for both species between 1990 and 1992. Mule deer fawn:doe ratios were 1.0:1, 1.23:1, and 1.7:1 and white-tailed deer fawn:doe ratios were 0.71:1, 0.8:1, and 1.6:1 for 1990, 1991, and 1992, respectively. Fawns:collared doe did not differ ($\underline{P}$=0.48) between species.

Mortality

Twelve (10 mule deer, 2 white-tailed deer) of the 39 collared adult deer died during the study (Table 2.5). Three mule deer females died, probably from vehicle accidents, after leaving the study area. Two mule deer (1 female, 1 male) were killed by coyotes, 1 mule deer female was killed by a vehicle, and 4 mule deer (2 females, 2 males) died from unknown causes on RMA. Both white-tailed deer that died were males. One was killed by a vehicle and 1 was collected by USFWS personnel. Transmitters on 2 white-tailed deer (1 buck, 1 doe) failed. Because fawn mortality patterns were similar ($\underline{P} > 0.05$), analyses were conducted on pooled data across years. Seventy-nine percent (46 of 58) of mule and white-tailed deer fawn deaths were caused by coyotes. Two mule deer fawns were killed by vehicles and 6 fawns (5 mule deer, 1 white-tailed deer) died of unknown causes.

Survival

Adult mule deer survival remained high during the first 18 months of the study then declined from spring of 1991 through mid-winter 1992-1993 (Figure 2.4). Adult white-tailed deer survival remained high through mid-winter 1991-1992 before showing a decline through the last winter of the study.

Table 2.5. Cause of death for mule and white-tailed deer mortalities on Rocky Mountain Arsenal, Colorado, 1990-1992.

AGE CLASS	CAUSE	n		%[1]	
		MD	WTD	MD	WTD
Adults	Coyote	2	0	20.0	0.0
	Vehicle	1	1	10.0	50.0
	Unknown	7	0	70.0	0.0
	Other	0	1	0.0	50.0
	Adult Total	10	2	100.0	100.0
Fawns	Coyote	27	19	79.4	79.2
	Vehicle	2	0	5.9	0.0
	Unknown	5	1	14.7	4.2
	Other	0	4	0.0	16.7
	Fawn Total	34	24	41.0[2]	64.9[2]
	Lost transmitter	45	11	----	----

[1] Calculated as (n for cause)/(total for age class). Does not include lost transmitters.

[2] Represents percent of transmittered fawns that died.

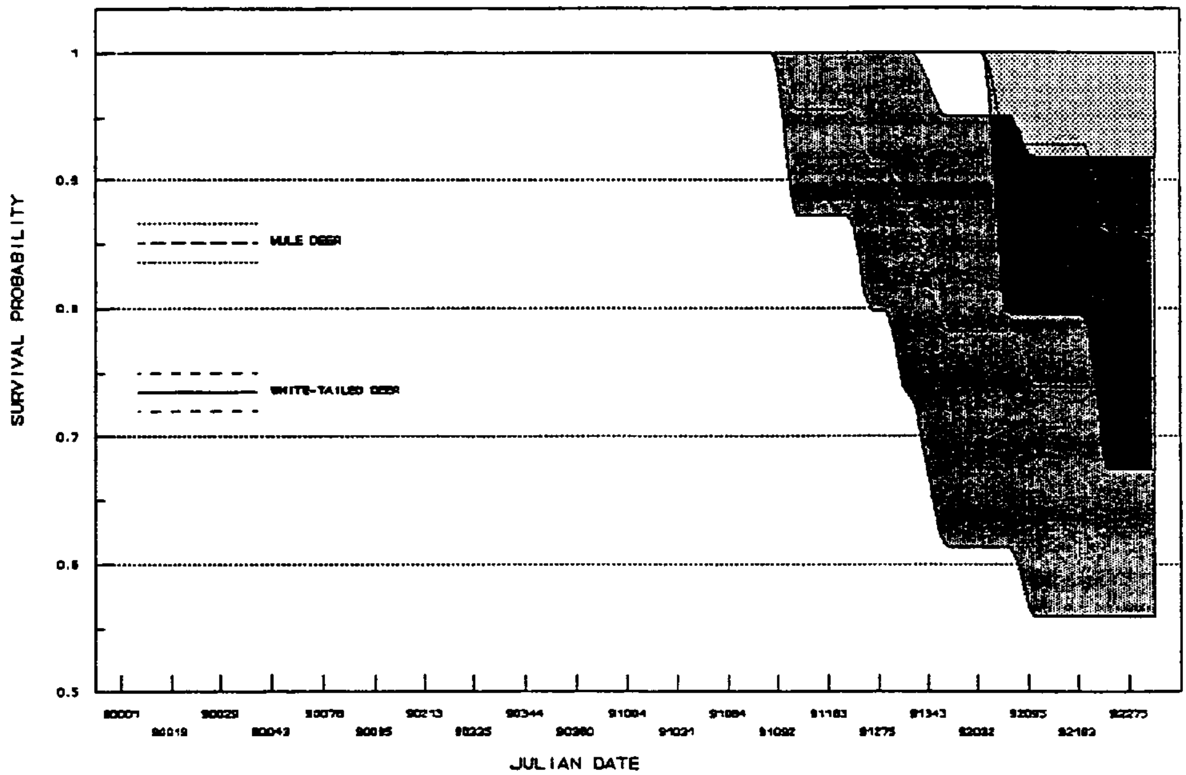

Figure 2.4. Kaplan-Meier probability of survival ($S_{(t)}$) for adult mule and white-tailed deer on Rocky Mountain Arsenal, Colorado, 1990-1992.

Probability of survival S(t) for adults was greater (P<0.01) for white-tail deer ($s_{(t)}$ = 0.786) than for mule deer ($s_{(t)}$ = 0.693). Logistic regression analyses indicated, however, that sex was the best (P=0.09) predictor of survival in adult deer (Table 2.6).

Fifty-six of 120 fawns transmittered during 1991 and 1992 lost their transmitters. Most transmitter loss (50 of 56 or 89.3%) occurred after 30 days. For this reason, survival analysis for fawns was conducted only through 30 days post-partum. Probability of survival from birth to 30 days (Figure 2.5) was greater (P<0.001) for mule deer fawns than for white-tailed deer fawns. Whether fawns were captured on or off of birth sites was not a significant predictor of survival (P=0.09), therefore birth-site and nonbirth-site data were pooled for maximum likelihood analyses of fawn survival. Logistic regression indicated that birth date was a significant (P=0.01) predictor of survival to 30 days of age (Table 2.7). Weight (P=0.06) and total body length (P=0.09) also contributed to predictability of the model.

Population Composition

Forty-five ground and air surveys were conducted between December 1989 and April 1993 (Table 2.8). All aerial surveys (total n = 7) were conducted within 2 days of snowfall to increase sightability of animals (LeResche and Rausch 1974, Samuel et al. 1983). Mean total number of mule deer counted from the air increased from 154.0 in winter 1989-90 to 397.5 in winter 1992-93. Mean total number of white-tailed deer counted from the

Table 2.6. Maximum likelihood analysis of variance for adult mule and white-tailed deer survival on Rocky Mountain Arsenal, Colorado, 1990-1992.

SOURCE	DF	χ^2	PROBABILITY
Intercept	1	0.22	0.64
Species	1	0.73	0.39
Sex	1	2.89	0.09
Capture age	1	0.04	0.84

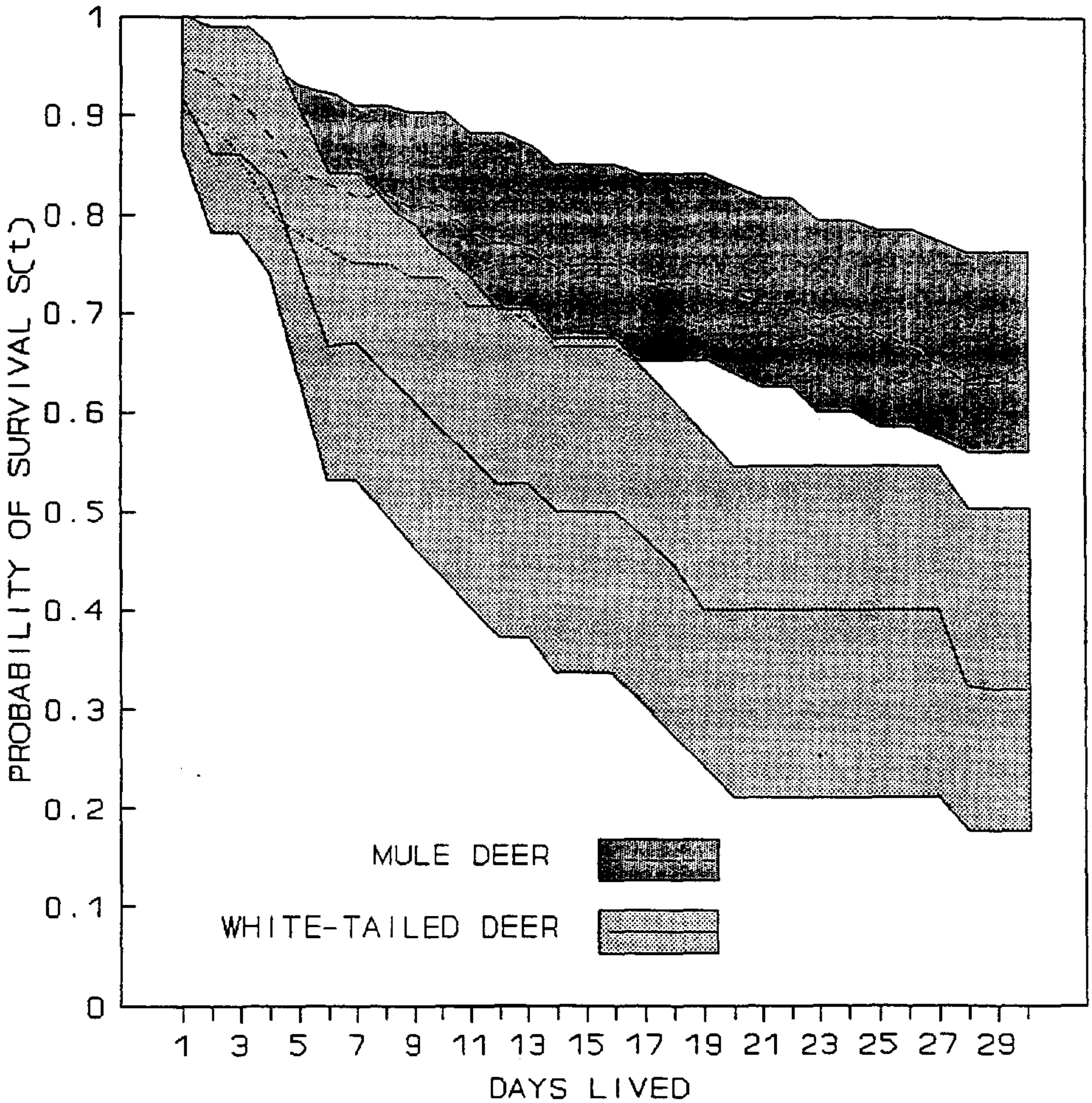

Figure 2.5. Kaplan-Meier probability of survival ($S_{(t)}$) to 30 days of age for mule and white-tailed deer fawns on Rocky Mountain Arsenal, Colorado, springs 1991 and 1992.

Table 2.7. Maximum likelihood analysis of variance for mule and white-tailed deer fawn survival to 30 days on Rocky Mountain Arsenal, Colorado, 1990-1992.

SOURCE	DF	χ^2	PROBABILITY
Intercept	1	5.94	0.05
Site	1	0.47	0.50
Species	1	1.71	0.19
Sex	1	1.39	0.24
Foot (cm)	1	0.68	0.41
Weight (kg)	1	3.49	0.06
Body (cm)	1	2.88	0.09
Birth Date	1	5.98	0.01

Table 2.8. Summary statistics for ground and aerial deer composition surveys conducted on Rocky Mountain Arsenal, Colorado, 1989-1993.

COUNT TYPE	VARIABLE MEAN	MULE DEER				WHITE-TAILED DEER			
		89-90	90-91	91-92	92-93	89-90	90-91	91-92	92-93
Aerial									
	n	1	2	2	2	1	2	2	2
	# Deer	154.0	200.5	286.0	397.5	73.0	72.0	35.5	84.0
	# Collars	3.0	11.0	9.0	9.0	3.0	6.5	2.5	6.0
	% Collars	33.3	56.8	50.0	58.1	60.0	56.8	17.9	54.5
Ground									
	n	5	7	9	17	5	7	9	17
	# Males	54.0	42.9	46.3	46.7	16.6	10.6	12.3	10.9
	# Females	75.8	69.1	71.7	80.9	25.0	21.7	23.2	22.4
	# Fawns	48.0	44.6	55.3	68.0	9.8	10.6	13.4	14.5
	# Unclassified	35.6	18.1	7.6	8.6	9.8	2.9	4.2	3.6
	Total Deer	213.4	174.7	180.9	204.3	61.2	45.7	53.2	51.2
	Males:100 Female	60.0	60.6	62.2	60.5	69.5	50.0	56.0	52.5
	Fawns:100 Female	57.8	63.9	78.0	81.6	34.5	44.7	55.4	68.5
	# Collars	7.5	7.7	5.9	4.8	3.0	3.6	5.4	3.7
	% Collars	72.2	44.6	31.8	30.8	45.7	36.3	39.9	33.1
Combined Air/Ground									
	n	6	9	11	19	6	9	11	19
	Total Deer	203.5	180.4	200.0	224.6	63.2	50.0	49.6	54.7
	# Collars	6.0	8.4	6.5	5.3	3.0	4.2	4.9	4.0
	% Collars	59.3	47.3	35.1	34.0	50.5	40.9	35.9	35.7

air ranged from a low of 35.5 in winter 1991-92 to a high of 84.0 during winter 1992-93. Ground composition surveys (total n = 38) were conducted under snow cover conditions ranging from 0 - 100%. Mean annual number of mule deer counted from the ground ranged from 174.7 to 213.4 and white-tailed deer from 45.7 to 61.2.

The ratio of males:100 females appeared stable for mule deer from year to year but fluctuated for white-tailed deer. The number of bucks per 100 does did not differ (P=0.21) between mule and white-tailed deer. Winter mean fawn to doe ratios (fawns:100 adult ($\geq$1.5 yr old) does) generally increased throughout the study period. Mule deer had greater (P=0.004) fawn to doe ratios than did white-tailed deer.

Number of marked mule deer seen was affected (P=0.02) by type of survey (ground vs air). A greater (P=0.03) percentage of marked mule deer were seen from the air (51.9% $\pm$ 0.1) than the ground (36.5% $\pm$ 0.2). Type of survey, however, did not affect (P=0.31) number of marked white-tailed deer seen. Number of marked individuals seen from the air ranged from 33.3 to 58.1% for mule deer and 17.9 to 60.0% for white-tailed deer. Percentage of marked deer seen from the air did not differ (P=0.50) between mule and white-tailed deer. Percent of marked deer seen during ground composition surveys generally decreased between winter 1989-90 and winter 1992-93 for both species. During winter 1989-90, 72.2 and 45.7 % of marked mule and white-tailed deer respectively, were seen from the ground. During winter 1992-93, only 30.8 and 33.1% of mule and white-tailed deer respectively, were seen. Percent of marked deer seen on ground composition surveys did not differ (P=0.98) between species.

Population Trends

Mule deer populations on RMA increased throughout the study

(Figure 2.6). Spring 1990 mule deer numbers were estimated to be 306 (251-426). Between winters 1990 and 1993, mule deer numbers increased by 111% to approximately 646 (560-764). Mean per capita growth rate (r_0) for mule deer for the period 1990-1993 was 0.25 (Table 2.9).Density more than doubled between 1986 (18.7 deer/km^2) and 1990 (44.3 deer/km^2), then doubled again between 1990 and 1993 (93.6 deer/km$^{2)}$.

White-tailed deer numbers on RMA also increased throughout the study. White-tailed deer population growth between 1990 and 1993 was not as dramatic as that for mule deer, increasing 32% from 114 (87-191) in 1990 to 151 (130-181) in 1993. Mean per capita growth rate (r_0) for white-tailed deer was 0.08. Trends in white-tailed deer gross density were similar to those for mule deer, increasing between 1990 (16.5 deer/km^2) and 1993 (21.9 deer/km^2).

During the 1986 aerial deer survey (Colorado Division of Wildlife, 1986, unpubl. data), 151 total deer were counted. By 1990, total deer populations on RMA had nearly tripled to an estimated number of 420 animals. Deer numbers nearly doubled again between 1990 and 1993 (797 animals). Mean per-capita growth rate (r_0) for all deer combined was 0.18.

Corresponding gross deer density, without regard to species, showed similar patterns. Density nearly tripled between 1986 (21.9 deer/km^2) and 1990 (60.9 deer/km^2), and nearly doubled between 1990 (60.9 deer/km^2) and 1993 (115.5 deer/km^2). Most of the combined deer population and density increases can be attributed to the changes in the mule deer population.

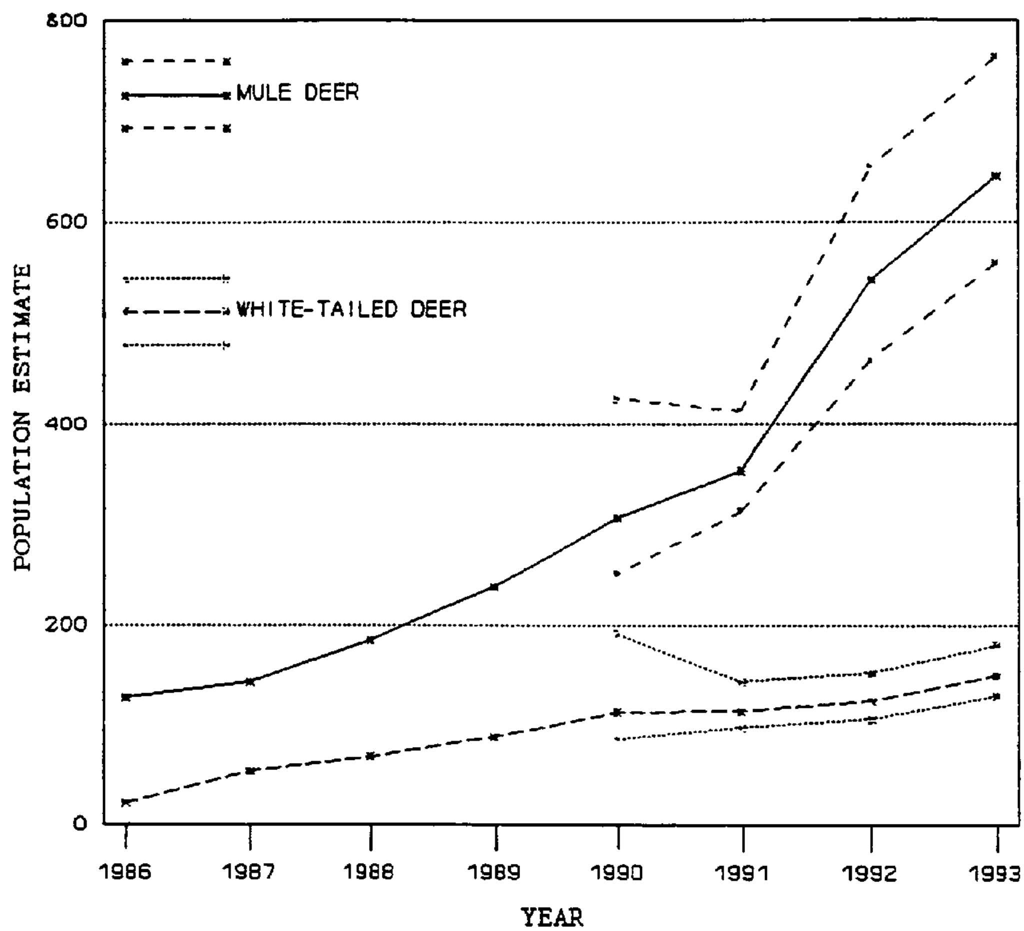

Figure 2.6. Population trends for mule and white-tailed deer on Rocky Mountain Arsenal, Colorado, 1986-1993.

Table 2.9. Population parameters for mule and white-tailed deer on Rocky Mountain Arsenal, Colorado, 1986-1993.

SPECIES	YEAR	$\hat{N}$[1]	% CHANGE	$\hat{D}$[2]	% CHANGE
Mule Deer					
	1986[3]	129	----	18.7	----
	1990	306	+137.2	44.3	+136.9
	1991	353	+ 15.4	51.2	+ 15.6
	1992	543	+ 53.8	78.7	+ 53.7
	1993	646	+ 20.0	93.6	+ 18.9
White-tailed Deer					
	1986[3]	22	----	3.1	----
	1990	114	+418.2	16.5	+432.3
	1991	115	+ 0.8	16.7	+ 0.6
	1992	125	+ 8.7	18.1	+ 8.4
	1993	151	+ 20.8	21.9	+ 21.0
All Deer					
	1986	151	----	21.9	----
	1990	420	+178.1	60.9	+178.1
	1991	468	+ 11.4	67.8	+ 11.3
	1992	668	+ 42.7	96.8	+ 42.8
	1993	797	+ 19.3	115.5	+ 19.3

[1] Population estimate for year.

[2] Deer/Km^2.

[3] Colorado Division of Wildlife, Unpublished Data.

DISCUSSION

Pre- and post-partum fawns per mule deer doe on RMA are similar to those reported for allopatric mule deer elsewhere in Colorado (Robinette et al 1973), Washington (Steigers and Flinders 1980), and Montana (Nellis 1968, Hamlin et al. 1984). Similarly, white-tailed deer on RMA performed similarly to white-tails on allopatric ranges (Verme 1969, Dapson et al. 1979, Mundinger 1981, Dusek et al 1989, Nixon et al. 1991). While evidence of white-tailed fawns breeding on RMA (U. S. Fish & Wildl. Serv. 1991, Unpubl. Data) provides general support for the belief that white-tailed deer have slightly higher potential reproductive rates than mule deer (Kramer 1971, Beasom and Wiggers 1984), the 2 species did not differ ($\underline{P}$ = 0.48) in fawns produced per collared doe (Table 2.4) indicating that initial fawn production is similar for both species of deer on RMA. Fawn production also was similar for sympatric mule and white-tailed deer populations in Montana (Wood et al. 1989).

Given that fawn production is similar between species, and that both species are exposed to relatively similar environmental conditions, it is reasonable to believe that 2 closely related sympatric species would exhibit similar patterns of mortality and population growth. Although fawn production was similar, marked differences in adult and fawn survival were observed between deer species on RMA. Additionally, mean per capita growth rate for mule deer (r_0 = 0.25) was more than 3 times that for white-tailed deer (r_0 = 0.08). This suggests that population regulation factors affect mule deer differently than they affect white-tailed deer when the species are sympatric.

Mule and white-tailed deer on RMA exhibited differing patterns of habitat use (Chapter IV). Mule deer readily used open areas with little woody vegetation whereas white-tails were generally found in areas on RMA with greater woody vegetation. Swenson et al. (1983) reported that white-tailed deer wintered in more productive habitats than mule deer. Additionally, Wiggers and Beasom (1986) found that white-tailed deer used areas with greater canopy cover of woody vegetation. In areas with extremely low temperatures, it also is believed that white-tails commonly select wooded areas for thermal protection over open areas with abundant winter forage (Matchke et al. 1984). Physiological body temperature regulation is energetically costly (Vaughan 1978). Additionally, subtle differences in the ability to withstand temperature extremes exist between closely related mammalian species (Vaughan 1978). Therefore, selection should favor species with behavioral mechanisms for controlling thermoregulation (Vaughan 1978). Most adult mortality on RMA, principally mule deer, occurred during periods of nutritional stress and temperature extremes (winter and early spring). Observed interspecific differences in adult deer survival may be associated with habitat selection patterns on RMA. White-tailed deer using wooded areas would have lower energy requirements than mule deer in open, sparsely wooded areas of RMA. Therefore, different adult survival rates may be partially explained by differing habitat use patterns during winter and early spring.

Wood et al. (1989) suggested that interspecific differences in adult mortality were responsible for observed differences in population fluctuations between mule and white-tailed deer. Although adult survival was lower for mule deer compared to white-tailed deer on RMA, several additional factors must be addressed prior to making a conclusion. First, deer on RMA were not subject to hunting pressure commonly found in most populations. The lack of annual hunting allowed deer populations on RMA to attain a relatively old age distribution (Colo. Div. Wildl. 1993, unpubl. data). Second, mean buck to doe ratios of 60.8 and 57.0 for mule and white-tailed deer, respectively, are much higher than reported for hunted populations elsewhere (Gavin et al. 1984, Menzel 1984, Kufeld 1989, Nebr, Game Parks Comm. 1990). It is generally believed that bucks have higher mortality rates than does, even in unhunted populations (Connolly 1981). Third, because new animals were not telemetered during the final year of study, adult mortality patterns may not be representative of the populations during the last winter. Most adult deer that died on RMA were males and occurred during the final winter of study. The relatively old age of the telemetered mule deer males and high buck to doe ratios in the population may have predisposed the telemetered sample to high mortality during the final winter of the study. Therefore, I do not believe that differences between adult survival are entirely responsible for observed differences in deer population trends on RMA.

Patterns of mule and white-tailed deer fawn mortality during the first 30 days of life on RMA are similar to those reported for allopatric populations elsewhere. Salwasser et al. (1978) reported fawn mortality rates of 50-70% during the first 4 weeks post-partum in California and attributed losses to poor nutrition. Hamlin et al. (1984) observed summer fawn mortality rates of 4-56% (mean = 32%) over 5 years in Montana with mortality greater in late summer than early summer. Fawn mortality rates of 50% during the first month, and 54% during the first 7 months were found by Steigers and Flinders (1980) in Washington. Hamlin et al. (1984) and Steigers and Flinders (1980) implicated coyote predation as the main factor influencing early survival of fawns. Additionally, Steigers and Flinders (1980) believed that alternate prey species (leporids and microtine rodents) were influential on fawn survival in Washington. Cook et al. (1971) found that 93% of white-tailed deer fawn mortality in Texas occurred during the first 30 days of life with 53% of all deaths caused by coyote predation. Schwede et al. (1991) observed 5 of 6 (83.3%) fawn mortalities, all due to predation, during the first 2 weeks. Estimates of total summer fawn mortality range from 59% in Montana (Mundinger 1981) to near 80% Washington (Gavin et al. 1984) and Minnesota (Fuller 1990). Fawn mortality patterns on RMA also are similar to those found for sympatric mule and white-tailed deer in Montana (Wood et al. 1989).

Probability of survival from birth to 30 days was greater for mule deer ($s_{(30d)}$ = 0.661) than for white-tailed deer ($s_{(30d)}$ = 0.340) fawns (Figure 2.5). Date of parturition was the best ($\underline{P}$ = 0.01) predictor of survival for fawns. Estes (1976) and Rutberg (1987) have shown that synchrony of birth, or lack thereof, can effect survival of neonatal ungulates. Young born outside the peak of parturition when densities of young are low have lower survival than those born during the peak density of young. Because mule deer outnumbered white-tailed deer about 4:1, peak density of fawns, regardless of species, was primarily governed by timing of parturition by mule deer. Assuming that parturition dates of mule and white-tailed deer fawns captured during 1991 and 1992 represent their respective populations on RMA, about 75% of all white-tailed deer fawns were born prior to peak fawn densities. Over half (58.3%) of known white-tailed deer fawn mortality, most due to coyote predation, occurred during the period preceding peak fawn density.

Interspecific differences in neonate survival are only partially explained by the observed differences in date of parturition. Many authors have attributed early neonate mortality to poor nutrition prior to and during parturition (Verme 1969, Salwasser et al. 1978, Dapson et al. 1979, Mundinger 1981) or to predation (Steigers and Flinders 1980, Gavin et al. 1984, Hamlin et al. 1984, Fuller 1990, Schwede et al. 1991).

Recent studies, however, have indicated that high neonatal mortality in white-tailed deer may be a density dependent response to high population levels (Ozoga et al. 1982, Dusek et al. 1989, Nixon et al. 1991). Availability of suitable fawn rearing areas is reduced (Ozoga et al. 1982, Nixon et al. 1991) and social interactions between does increase (Ozoga et al. 1982, Dusek et al. 1989) with increasing deer densities. High density dependent neonate mortality in reindeer (Rangifer tarandus) was attributed to food limitation for the cows during late gestation (Skogland 1985). However, Clutton-Brock et al. (1987) found no effect of density on neonate survival in red deer (Cervus elaphus). No studies were found documenting density dependent mortality of neonatal mule deer fawns. Overall gross density of deer (both species combined) for RMA was 96.8 and 115.5 deer/km^2 during 1991 and 1992, respectively (Table 2.9). These are much higher than those reported for studies documenting density dependent white-tailed deer fawn mortality (Ozoga et al. 1982, Nixon et al. 1991, Dusek et al. 1989). Higher neonate survival of mule deer suggests that this density dependent response may not occur for mule deer, at least at the deer densities observed during this study.

Two additional mechanisms may be affecting fawn survival on RMA. First, mule and white-tailed deer exhibit different behavioral responses in the presence of predators (Geist 1990). Mule deer quite readily attack or aggressively defend themselves against predators. In contrast, white-tailed deer generally vacate an area when predators approach. Anecdotal observations on RMA support the observations of Geist (1990). Mule deer were commonly seen chasing coyotes out of an area whereas aggressive interactions between white-tailed deer and coyotes were never observed.

Second, Coyotes on RMA may be "experienced" at preying on fawns. In areas with high ungulate densities, coyote populations have been shown to have delayed dispersal and maintain higher pack sizes (Bowen 1981, Moehlman 1989). Delayed dispersal may serve to increase observational and trial and error experience levels (Bekoff and Wells 1986) of the coyote population on RMA. The net result would be highly efficient predators of deer. Additionally, predators are known to synchronize predatory activity with the activities of prey and temporal variation in prey preference may not be a chance result of prey encountered, but rather predators may be intent on specific prey at the onset of the hunt (Curio 1976). White et al. (1987) observed a bimodal distribution of winter predation on migratory mule deer fawns in Colorado. Coyote predation was higher during those periods when deer used a specific portion of the study area (White et al. 1987). Deer on RMA were non-migratory. Additionally, 12 of 17 (70.6%) radio-transmittered coyotes were regularly found on RMA (Hein 1992). The sedentary nature of predator and prey populations on RMA would allow for development of efficient predatory techniques by coyotes. Efficient search patterns by coyotes in the absence of defense by adults may expose newborn white-tail fawns to a higher probability of predation than mule deer fawns.

Few wildlife populations exist without fluctuation in response to environmental changes. Drastic population increases in ungulates are characteristic of favorable changes in resources, or are typical of newly established populations (Caughley 1970). A review of the literature (Caughley 1970) revealed that eruptions in ungulate populations typically follow 4 stages: 1) initial increase, 2) initial stabilization, 3) population decline, and 4) post decline. Mule deer on RMA showed a dramatic increase during the 4 years of this study. White-tailed deer, although not as dramatic, also increased in population. This suggest that mule and white-tailed deer on RMA were observed in the initial increase stage. Although data is incomplete, high adult mortality during the last year also suggests that mule deer may be approaching the initial stabilization stage.

Many authors believe that deer populations are limited by recruitment of fawns into the population (Ozoga et al. 1982, White et al. 1987, Dusek et al. 1989). Mechanisms of regulation are diverse. Density dependent fawn mortality is regulated in mule deer by over-winter mortality (White et al. 1987, Bartmann et al. 1992). Predation and starvation during winter may act independently in a compensatory manner (Bartmann et al. 1992). Conversely, density dependent mortality in white-tailed deer is more apt to occur for neonates (Ozoga et al. 1982, Dusek et al.

1989) with relatively high over-winter fawn survival (Mundinger 1981, Gavin et al. 1984, Nixon and Hansen 1992).

Low survival of neonates and high adult survival indicates that white-tailed deer population growth on RMA is indeed limited, to some extent, by recruitment of fawns into the population. Coyote predation is the principle mechanism determining neonate survival and may be influenced by high deer densities on RMA. Higher neonate survival, and higher winter fawn:adult doe ratios suggests that mule deer are less affected by fawn recruitment than are white-tailed deer. Conversely, this data suggests that adult survival may be a more important limiting factor for mule deer. Habitat selection patterns as they effect energy requirements during winter and early spring are the primary mechanisms governing adult deer survival on RMA.

Although limited movement on and off the study area was observed, commercial development and management practices surrounding RMA will potentially restrict immigration and dispersal routes available to deer on RMA even further. At the same time, deer populations on RMA continued to increase. A typical pattern for wildlife populations increasing within a confined area is for the population to overshoot the ecological carrying capacity for the area. When this occurs, habitat can become severely damaged, and general health of the population usually decreases. Habitat degradation and declining health of the deer herd are real possibilities for RMA. Several deer management alternatives are available for personnel on RMA.

First, no management is a possibility. The situation at RMA would allow for long term, controlled observation of the demographic consequences of population interaction and density dependent population control of native ungulates. Additionally, the high level of public use and proximity to a major population center provides an excellent opportunity for public education concerning the natural factors, and problems affecting wildlife populations. The second alternative is artificial population regulation. Dapson et al. (1979) showed that by reducing density, one could reduce mortality rates of neonates in white-tailed deer. It also is commonly accepted that, given adequate habitat, animals at intermediate densities are generally healthier than those at extremely high densities. A third alternative already being pursued (Griess 1993, pers. comm.), is artificial sterilization. Feasibility of this alternative is dependent on results of ongoing research (Colorado Division of Wildlife 1993, unpubl. data). The history and current nature of RMA excludes public hunting as an alternative for deer management at this time.

CHAPTER III

SPATIAL CHARACTERISTICS AND HABITAT SELECTION PATTERNS OF SYMPATRIC DEER IN COLORADO

INTRODUCTION

Habitat selection is a hierarchical process (Johnson 1980). First-order selection is selection of the physical or geographic range of a species. At this level of selection, white-tailed deer appear to be expanding their range westward and are encroaching into mule deer habitats (Baker 1984), and mule deer may be expanding their range to include areas historically dominated by white-tailed deer (Wallmo 1981b). However, mule and white-tailed deer still exhibit distinct areas of allopatry and sympatry within their respective geographic distributions. Second-order selection is the determination of specific home ranges for individuals or social groups within the range determined by first-order selection. Within this level, third-order selection relates to the way individuals or groups utilize specific habitat types found within a home range. Third-order selection is usually associated with habitat preference patterns. Fourth-order selection equates to selection of specific components of the habitat types used within a home range.

Two aspects of animal movement must be considered when discussing the home range of an animal (White and Garrott 1990). The first component is the basic map of location estimates obtained from tracking an animal. Graphically displayed, maps of the distribution of location estimates contain a great deal of information about movements of individuals, and in many cases this information should be emphasized (White and Garrott 1990). Second, as defined by Burt (1943), the home range of an animal or species has an areal component (White and Garrott 1990). A variety of methods have been developed which produce estimates of the area (acres, ha, m^2) used by individuals or populations.

Sympatric distributions of closely related species may lead to competition between those species involved. However, competitive exclusion may produce segregation at second-order and higher levels of selection (Kramer 1971) which allows continued coexistence of the 2 species. Additionally, differing time-space use patterns at higher selection levels also may allow coexistence (Kramer 1973). Therefore, knowledge of second-order distribution patterns and third- and fourth-order habitat selection patterns is necessary for management of sympatric species.

The current geographic distribution of the genus Odocoileus encompasses most of the North American continent and parts of Central and South America (Wallmo 1981, Baker 1984). In North America, mule deer (Odocoileus hemionus) are primarily distributed in the west, and white-tailed deer (O. virginianus) are primarily distributed in the east. However, these 2 important species of deer rarely occur in the absence of other ungulate species and occur sympatrically in an area from Canada to Mexico and from Washington to North Dakota (Mackie 1981, Baker

1984). Habitats in these sympatric areas range from riparian and agricultural areas on the plains to coniferous forests in the intermountain west (Mackie 1981). Many studies have been conducted that describe mule and white-tailed deer habitat characteristics and interactions with livestock (Mackie 1970, Dusek 1975, Rost and Bailey 1979, Brown 1984, Loft et al. 1987), and with native ungulates such as elk (*Cervus elaphus*) and moose (*Alces alces*) (Telfer 1967, Irwin 1975, Singer 1979, Jenkins and Wright 1987, 1988).

Although much is known of mule and white-tailed deer studied in allopatry, relatively little is known of deer distributions at second-order and higher selection levels where the 2 species occur sympatrically. Several authors report second-order, allopatric distributions within the first-order sympatric ranges of mule and white-tailed deer (Kramer 1973, Anthony and Smith 1977, Swenson et al. 1983, Smith 1987, Wood et al. 1989). However, these studies may be inadequate due to weaknesses in data collection and analysis techniques, or are not applicable to specific situations due to variations in habitats and local environmental conditions (Anthony and Smith 1977).

A study was conducted to document the spatial relationships and habitat use patterns of sympatric mule and white-tailed deer on Rocky Mountain Arsenal (RMA) in northeast Colorado. Comparative aspects of seasonal home ranges and distributions of sympatric mule and white-tailed deer are discussed in relation to first- and second-order selection. Within-home range habitat use patterns of both species are presented to address patterns of third-order selection. Fourth-order selection patterns are presented as diet composition for the 2 species.

METHODS

Animal Capture and Telemetry

Adult deer were captured during winters of 1989-1990 and 1990-1991 using Clover traps (Clover 1956), a Coda-Netgun (Coda Enterprises, Mesa, Ariz.), or a Cap-Chur gun (Palmer Chemical and Equipment Co., Douglasville, Ga.). Deer were outfitted with activity sensoring radio-transmitters (Telonics, Mesa, Ariz.). Expandable collars were used on adult males. No physical measurements were collected on animals captured during winter 1989-1990. Data collected on individuals captured during winter 1990-1991 included weight (kg), ear, tail, and metatarsal gland length (cm). Ear, tail, and metatarsal gland length were averaged for each species and used as a reference for identifying possible hybrid individuals. Adults were aged according to tooth wear and replacement. Estimated species and sex ratios (Hanna and Lindzey 1990) for the population were approximated in the telemetered sample. Attempts also were made to trap animals in areas representative of species' distributions.

Radio-tracking was conducted to include all 24 hr in a day at least once every week. Animals were located between 2400 hr (midnight) and 1200 hr (noon) on Monday and Tuesday, and between 1200 and 2400 hr on Thursday and Friday of each week. Attempts were made to locate all telemetered individuals once during each radio-tracking session. A random numbers table was used to determine the order in which animals were located. This randomly determined order was strictly adhered to when locating animals. Each individual was searched for until found before searching for another individual. No individual was located more than once during any 24 hr period to insure independence of observations. Radio-tracking was conducted from a 4x4 pickup truck utilizing existing roads on RMA. Deer were located using homing techniques (White and Garrott, 1990). A 2-element yagi antenna (Telonics, Mesa, Ariz.) was used to direct the observer to each animal. An extensive road system allowed visual identification of most individuals using a truck mounted spotting scope or hand-held binocular. Radio-tracking at night was conducted with the aid of a hand-held spotlight. Triangulation techniques were used only when deer were in areas that prohibited sighting the individual or in areas where entry was prohibited.

Information recorded at the time of visually sighting each individual included: Julian date, 24-hr time, habitat type, activity, approximate inter- and intra-specific distance from other deer, and group composition. Distances were categorized in 10 m increments. Location estimates were plotted on 1:24,000 USGS topographic maps and Universal Transverse Mercator (UTM) coordinates were recorded for each location estimate. Location estimates were visually compared to locations of all deer observed during winter ground and aerial surveys conducted to determine if utilization distributions obtained from radio-telemetry represented the actual distribution of deer on RMA.

Habitat Availability and Use, and Diet Composition

Dominant vegetation was used to define habitat types on RMA. Eleven habitat types were used in analyses: weedy forb (WF), cheatgrass / weedy forb (CWF), native perennial grassland (PNG), crested wheatgrass (CW), shrublands/succulents (SS), locust thickets (LT), wetlands (WR), cultivated species (CS), dryland trees (TS), wetland trees (WTS), and buildings (BLD). All habitat types were entered into a data base using a 60 m x 60 m grid cell system. Each grid cell was coded for dominant habitat type found in that cell.

Study area availability of habitat types was determined by counting the number of cells containing each habitat type within study area boundaries. Individual home range availability was determined by counting the number of cells containing each habitat type found within the convex polygon home range of each individual. Habitat use was determined by the frequency of observations in each habitat type by each individual. All values for habitat availability and use were determined seasonally.

Diet composition was determined monthly for each species. Fecal samples of known origin were collected when individual deer were observed defecating. Samples were collected, marked by species, and air dried in paper bags. Monthly composite samples were prepared by taking 2 random pellets from each individual sample and combining those into 1 sample for each species and season (Hansen and Lucich 1978). Personnel at the Colorado State

University Composition Analysis Laboratory identified forage species in samples down to the lowest taxon possible using the micro-histological techniques outlined by Hansen et al. (1974). Results were converted to percent dry weight for statistical analyses using the procedures of Holechek and Gross (1982).

Statistical Analyses

White and Garrott (1990) identified 2 important considerations when discussing home ranges: 1) The purpose for estimating home ranges, and 2) Do data collection procedures satisfy that purpose. The major purpose for determining home ranges in this study is for seasonal comparison between mule and white-tailed deer on RMA, and comparing between sexes within a species. For purposes of this discussion, a home range, or utilization distribution, is that portion of RMA that is utilized by a species or species-sex class during a specified time period. Although the aerial extent is calculated, reported, and compared, it is primarily the location of the home ranges and location estimates in relation to the other species-sex classes that is of interest. The random, independent nature and timing of data collection procedures are more than sufficient for these purposes. Aerial estimates (ha) of seasonal home ranges for individuals were calculated using the 95% adaptive kernel estimator. This technique makes no assumptions about the shape of underlying utilization distributions, has well understood statistical properties, and is statistically robust (Silverman 1986, Worton 1989, Powell 1993). Preliminary analyses also indicated that adaptive kernel estimators included less area outside fenced boundaries (not available to deer) and better illustrated the shape of the home range than did other probabilistic estimators. Individual sample sizes were similar enough to allow analysis of variance between species-sex classes.

Comparison between mule and white-tailed deer utilization distributions were conducted at 2 levels within the selection hierarchy identified by Johnson (1980). A X^2 contingency table analysis was used to determine if each species' annual utilization distribution suggested uniform use throughout the Arsenal, and whether mule and white-tailed deer had similar annual utilization distributions (First-order selection). Multi-Response Permutation Procedures (MRPP) (Mielke and Berry 1982, Zimmerman 1985, Biondinni et al. 1988) were used to test whether mule deer and white-tailed deer had similar seasonal utilization distributions between species, whether utilization distributions of males and females were similar between species, and whether the sexes were similar within species (Second order selection).

The X^2 test admittedly suffers from an arbitrary judgment on size of grid cells to be used. However, at the temporal (annual) and spatial scale (1 km^2 for RMA) being looked at for first-order hypotheses, I feel the test addresses the question of discerning differences in geographic area of use for mule and white-tailed deer on RMA. MRPP tests the null hypothesis that 2 species-sex classes' utilization distributions are from the same parent distribution. Permutations are used to estimate the probability of the same parent distribution. If the null hypothesis is rejected, it is inferred that the 2 species or species-sex classes are utilizing different areas. The test is nonparametric, makes no assumptions about the shape of the underlying distribution, and sample sizes may be quite dissimilar in the data sets being compared.

Year x habitat contingency table analyses indicated that individuals used habitats similarly across years during specific seasons. Therefore, all observations within a season were pooled across years for each individual. A Chi-Square test of homogeneity was used to test whether habitats found within individual seasonal home ranges for a species were in similar proportions to those found within the entire study area (Second-order selection).

Two tests were conducted to address patterns of habitat use within home ranges (Third-order selection). Friedman's T test was used to determine the preference patterns for each habitat type. Selection for or against habitats was determined using Wilcoxon's Signed Ranks test. Both tests compared proportions of habitat types found within individual seasonal home ranges (expected) against observed proportions of habitat types used. Assuming that the telemetered samples represent the respective mule and white-tailed deer populations, both Friedman's and Wilcoxon's tests represent respective mean population habitat preference and selection, respectively, patterns for each species. Fourth-order selection was addressed by comparing diet composition between forage classes. Percent similarity (P) (Renkonen 1938, cited in Krebs 1989) was calculated to assess similarity of seasonal diets between species.

Inter-specific differences in home range selection patterns and within home range habitat use patterns were analyzed using analysis of variance conducted by habitat type. Second-order selection tests compared mean relative percent of home ranges for each habitat type. Third-order selection compared mean relative percent use for each habitat type between species/sex groups. Percent similarity was used to address inter-specific differences in diet composition.

RESULTS

Animal Capture and Telemetry

Forty adult deer were captured and marked with radio-transmitters during this study. Twenty deer (13 mule deer females, 7 white-tailed deer females) were marked during winter 1989-1990, and 20 (9 mule deer males, 4 mule deer females, 4 white-tailed deer males, 3 white-tailed deer females) were marked during winter 1990-1991 (Table 2.1). Mean age at capture (yr) for transmittered adults was 4.16 ± 1.56, 3.02 ± 0.92, 3.0 ± 0.5, and 3.14 ± 1.37 for male mule deer, female mule deer, male white-tails, and female white-tails, respectively.

One marked deer left the study area prior to completion of the fence and 12 marked deer died from various causes during the study (Table 2.5). Radio-tracking was conducted on 17 - 35 deer from 1 March 1990 through 29 February 1992. Seasons were defined as SPRING (1 March to 31 May), SUMMER (1 June to 31 August), FALL (1 September to 30 November), and WINTER (1 December to 28/29 February). Mortalities combined with staggered entry of marked individuals resulted in varying seasonal sample sizes. Visual comparison of location estimates obtained through radio-telemetry with locations of deer seen during winter ground and aerial surveys suggested that utilization distributions obtained from radio-collared deer adequately represented the distributions of the respective species' populations (Figure 3.1).

Home Range Size

Mean seasonal 95% adaptive kernel home range area ranged from 1796 - 3133 ha for mule deer and 1319 - 2061 for white-tails (Table 3.1). Female seasonal home range area ranged from 1673 - 2788 and 1243 - 2341 ha for mule and white-tailed deer, respectively. Home ranges varied from 1920 - 3676 and 1395 - 2402 ha for mule and white-tailed deer males, respectively. Analysis of variance suggested that home ranges did not differ ($\underline{P}$ = 0.58) between seasons (Table 3.2). Male and females of both species used areas that were similar ($\underline{P}$ = 0.90) in aerial extent across seasons. Analysis of variance also indicated that mule deer used larger ($\underline{P}$ = 0.003) areas than did white-tailed deer.

Utilization Distribution Comparisons

First-order selection tests were conducted annually for each species resulting in 3 comparisons per species. Mule deer and white-tailed deer exhibited nonuniform ($\underline{P}$ < 0.001) utilization distributions during all 3 years of comparisons (Table 3.3).

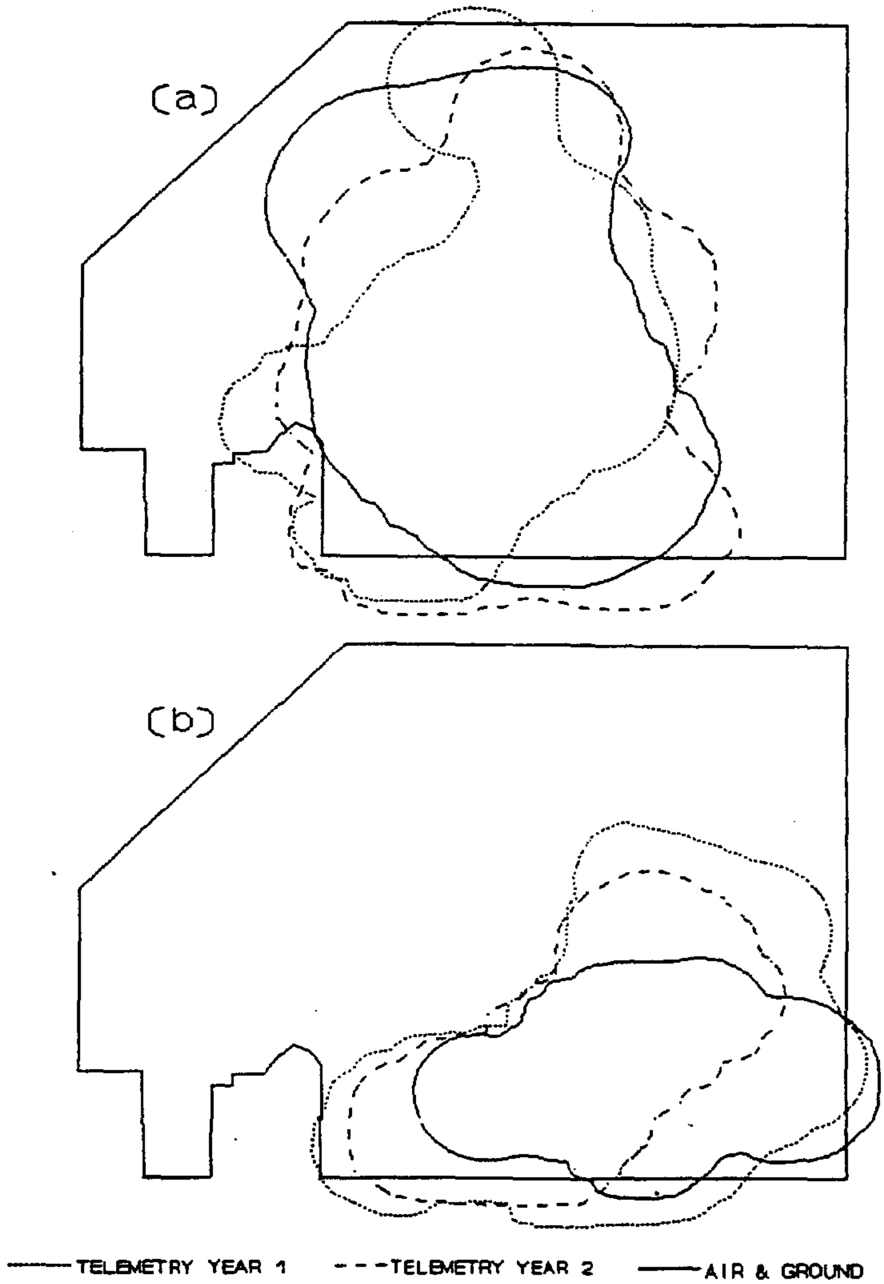

Figure 3.1. Visual comparison of radio-telemetry location estimates with locations of deer observed during winter ground and aerial surveys for mule deer (a) and white-tailed deer (b).

Table 3.1. Mean seasonal 95% Adaptive Kernel home range estimates (ha) for male and female deer on Rocky Mountain Arsenal, Colorado, 1990-1992.

	Mule Deer			White-Tailed Deer		
Season	Female	Male	Mean	Female	Male	Mean
Spring	2771	3676	3133	1562	2402	1898
Summer	2788	2501	2673	2341	1640	2061
Fall	2518	2452	2491	2011	1225	1696
Winter	1673	1920	1796	1243	1395	1319
Mean	2507	2637	2562	1839	1666	1766

Table 3.2. Analysis of variance for size (ha) of seasonal 95% adaptive kernel home range area for mule and white-tailed deer on Rocky Mountain Arsenal, Colorado, 1990-1992.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Species	1	6019352.00	6019352.00	10.76	0.003
Season	3	4639270.60	1546423.53	2.76	0.579
Sex	1	8779.31	8779.31	0.02	0.901
Error	32	17903081.99	559471.31		

Table 3.3. X^2 contingency table results testing for uniform utilization distributions by mule and white-tailed deer on RMA.

Species	Year	N	X^2	Pr > X^2
Mule Deer	1	956	5303	< 0.001
	2	1355	3659	< 0.001
	3	875	2282	< 0.001
White-tailed Deer	1	567	4089	< 0.001
	2	899	4904	< 0.001
	3	612	3429	< 0.001

Typically, large areas of RMA were not utilized by either mule deer or white-tailed deer (Figure 3.2). Three inter-specific comparisons of utilization distributions were conducted between mule and white-tailed deer. At an annual time scale, mule and white-tailed deer utilization distributions did not differ (P = 1.0) between species on RMA (Table 3.4).

All between species comparisons conducted at the seasonal level (Second order selection) demonstrated that mule deer and white-tailed deer utilized different ($P < 0.001$) areas within RMA (Table 3.5). Although mule and white-tailed deer utilization distributions typically had overlapping areas, a significant number of location estimates for each species were observed in areas unique to each species during a particular season (Figure 3.3). A similar trend was observed when species were compared by sex (Table 3.6). Mule deer males used different areas than did white-tail males and mule deer females used different areas than did white-tail females.

Eight within species seasonal comparisons between males and females were conducted using MRPP for each species of deer. Mule deer males utilized different areas ($P < 0.001$) than mule deer females in 100% of the seasons compared (Table 3.7). White-tail males utilized different ($P \leq 0.05$) areas than white-tail females in only 75% of the seasons compared. Data indicated that white-tail males and females utilized the same geographic areas during winter 1990-1991 ($P = 0.78$) and during spring 1991 ($P = 0.09$).

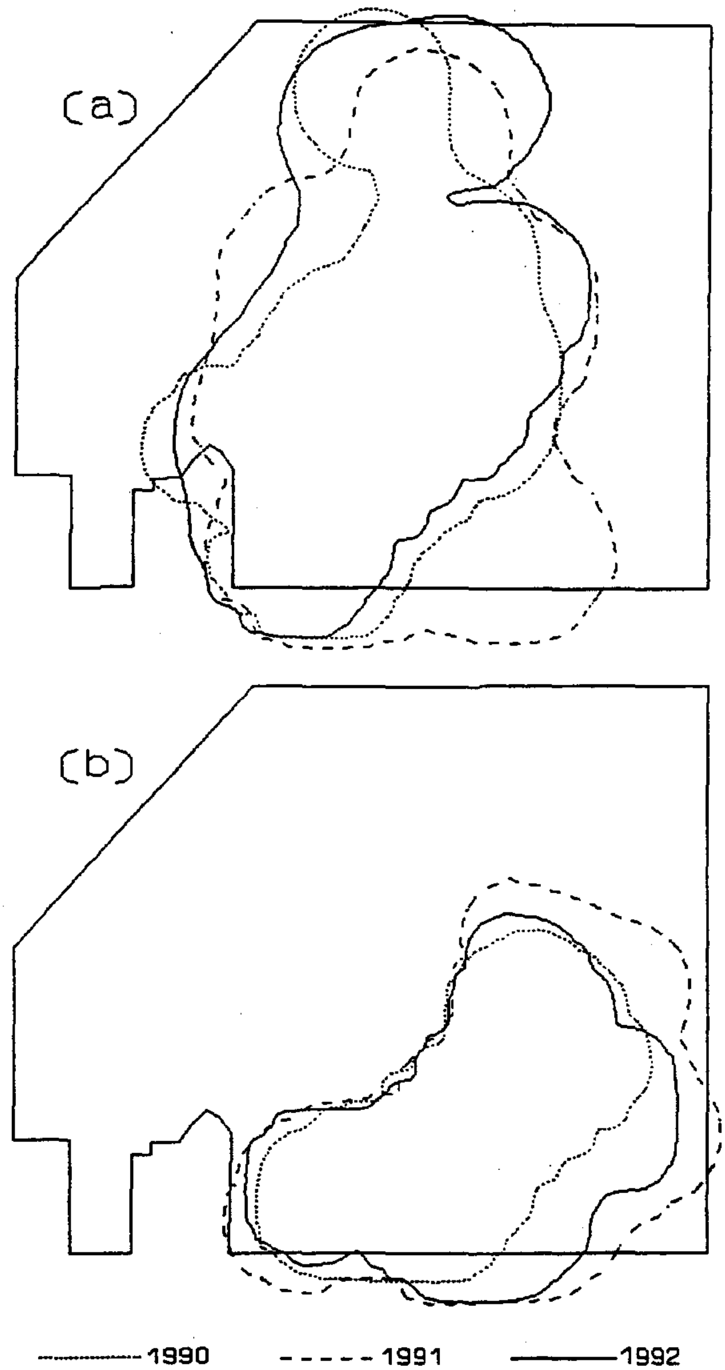

Figure 3.2. Annual utilization distributions for mule deer (a) and white-tailed deer (b) on Rocky Mountain Arsenal, Colorado 1990-1992.

Table 3.4. X^2 contingency table results testing for inter-specific differences in annual utilization distributions between mule and white-tailed deer on RMA.

	Number of Locations (N)			
Year	Mule Deer	White-tails	X^2	Pr > P
1	956	567	8.195	1.0
2	1355	899	3.961	1.0
3	875	612	3.627	1.0

Table 3.5. Probability (MRPP) of mule and white-tailed deer having the same seasonal utilization distributions on RMA.

		Number of Locations (N)		
Year	Season	Mule Deer	White-tails	Pr > P
1	Spring	169	112	< 0.001
	Summer	236	139	< 0.001
	Fall	305	189	< 0.001
	Winter	213	107	< 0.001
2	Spring	365	227	< 0.001
	Summer	373	233	< 0.001
	Fall	321	228	< 0.001
	Winter	292	222	< 0.001
3	Spring	283	207	< 0.001
	Summer	301	213	< 0.001
	Fall	287	199	< 0.001

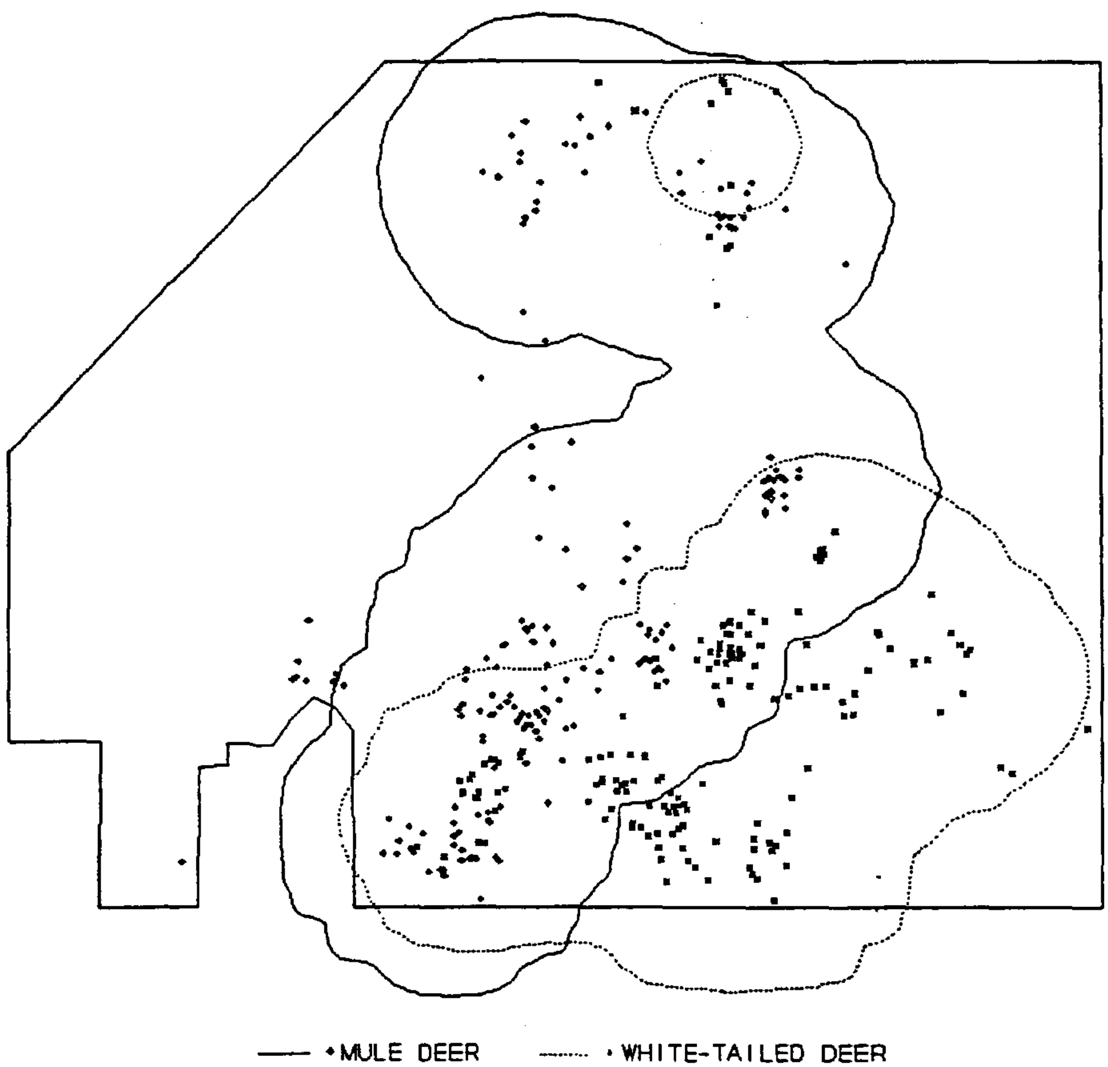

Figure 3.3. Mule and white-tailed deer utilization distributions during summer 1992 on Rocky Mountain Arsenal, Colorado.

Table 3.6. Probability (MRPP) of mule and white-tailed deer males, and mule and white-tailed deer females having the same seasonal utilization distributions on RMA.

			Number of Locations (N)		
Year	Season	Sex	Mule Deer	White-tails	Pr > P
1	Spring	Female	169	112	< 0.001
	Summer	Female	236	139	< 0.001
	Fall	Female	305	189	< 0.001
	Winter	Female	171	96	< 0.001
		Male	42	11	< 0.001
2	Spring	Female	221	175	< 0.001
		Male	144	52	< 0.001
	Summer	Female	244	173	< 0.001
		Male	129	60	< 0.001
	Fall	Female	194	161	< 0.001
		Male	127	67	< 0.001
	Winter	Female	191	158	< 0.001
		Male	101	64	< 0.001
3	Spring	Female	175	156	< 0.001
		Male	108	51	< 0.001
	Summer	Female	191	166	< 0.001
		Male	110	47	< 0.001
	Fall	Female	174	154	< 0.001
		Male	113	45	< 0.001

Table 3.7. Probability (MRPP) of males and females having the same seasonal utilization distributions within a species on RMA.

			Number of Locations (N)		
Year	Season	Species	Female	Male	Pr > P
1	Winter	Mule Deer	171	42	< 0.001
		White-Tail	96	11	0.78
2	Spring	Mule Deer	221	144	< 0.09
		White-Tail	175	52	< 0.001
	Summer	Mule Deer	244	129	< 0.001
		White-Tail	173	60	< 0.001
	Fall	Mule Deer	194	127	< 0.001
		White-Tail	161	67	0.004
	Winter	Mule Deer	191	101	< 0.001
		White-Tail	158	64	< 0.001
3	Spring	Mule Deer	175	108	< 0.001
		White-Tail	166	51	< 0.001
	Summer	Mule Deer	191	110	< 0.001
		White-Tail	166	47	< 0.001
	Fall	Mule Deer	174	113	< 0.001
		White-Tail	154	45	0.05

Mule Deer Habitat Use and Diets

Proportions of habitat types within individual mule deer seasonal home ranges were different ($P < 0.01$) than proportions of habitat types found throughout the study area (Second order selection). Mule deer females consistently selected home ranges with greater than expected proportions of cheatgrass/weedy forbs and less than expected proportions of weedy forb and perennial grasslands (Table 3.8). Mule deer bucks tended to have seasonal home ranges with lower than expected proportions of the perennial grassland and crested wheatgrass types.

Habitat preference patterns within home ranges (Third order selection) varied by season and sex for mule deer (Table 3.9). Locust thickets (LT) received high preference rankings by does during all 4 seasons. Three habitat types (dryland trees, perennial native grasses, and cheatgrass/ weedy forbs) received high preference rankings by mule deer does in 3 of 4 seasons. Crested wheatgrass received low preference rankings in all 4 seasons as did shrublands during spring summer and fall by mule deer females. Mule deer males showed strong preferences only during spring, summer, and winter with perennial grasslands, dryland and wetland trees, and cheatgrass/weedy forb areas being consistently preferred habitat types.

Selection of habitat types relative to within home range availability appeared to be stronger in mule deer females than males. Females consistently selected for locust thickets, perennial grasslands, weedy forbs, and cheatgrass/weedy forbs.

Table 3.8. Second-order habitat preference patterns for mule deer on Rocky Mountain Arsenal, Colorado, 1990-1992.

			HABITAT TYPE										
SEX	+/-/=	SEASON	WF	CWF	BLD	PNG	CW	CS	WR	SS	LT	TS	WTS
FEMALE	+	SPRING	0.0[1]	46.7	40.0	13.3	6.7	6.7	20.0	20.0	0.0	13.3	26.7
		SUMMER	0.0	40.0	20.0	6.7	20.0	20.0	26.7	26.7	0.0	20.0	6.7
		FALL	0.0	33.3	40.0	6.7	13.3	13.3	20.2	33.3	0.0	6.7	6.7
		WINTER	0.0	60.0	33.3	13.3	0.0	20.0	20.0	13.3	0.0	20.0	13.3
	-	SPRING	73.3	33.3	13.3	66.7	33.3	13.3	0.0	20.0	0.0	0.0	0.0
		SUMMER	66.7	40.0	13.3	53.3	20.0	0.0	0.0	0.0	0.0	0.0	0.0
		FALL	60.0	33.3	0.0	60.0	26.7	0.0	0.0	13.3	0.0	0.0	0.0
		WINTER	86.7	26.7	0.0	73.3	46.7	0.0	0.0	6.7	0.0	0.0	0.0
	=	SPRING	26.7	20.0	46.7	20.0	60.0	80.0	80.0	60.0	100	86.7	73.3
		SUMMER	33.3	20.0	66.7	40.0	60.0	80.0	73.3	73.3	100	80.0	93.3
		FALL	33.3	33.3	60.0	33.3	60.0	86.7	80.0	53.3	100	93.3	93.3
		WINTER	13.3	13.3	66.7	13.3	53.3	80.0	80.0	80.0	100	80.0	86.7
MALE	+	SPRING	62.5	75.0	12.5	12.5	12.5	12.5	12.5	0.0	0.0	0.0	12.5
		SUMMER	75.0	12.5	0.0	12.5	12.5	0.0	12.5	0.0	0.0	0.0	12.5
		FALL	12.5	25.0	12.5	25.0	37.5	25.0	12.5	0.0	0.0	0.0	37.5
		WINTER	0.0	100	25.0	0.0	0.0	25.0	0.0	0.0	0.0	0.0	12.5
	-	SPRING	12.5	12.5	0.0	75.0	50.0	0.0	0.0	25.0	0.0	0.0	0.0
		SUMMER	12.5	37.5	37.5	50.0	75.0	25.0	12.5	0.0	0.0	0.0	0.0
		FALL	37.5	12.5	0.0	50.0	25.0	0.0	0.0	25.0	0.0	0.0	0.0
		WINTER	37.5	0.0	0.0	100	100	0.0	0.0	25.0	0.0	0.0	0.0
	=	SPRING	25.0	12.5	87.5	12.5	37.5	87.5	87.5	75.0	100	100	87.5
		SUMMER	12.5	50.0	62.5	37.5	12.5	100	87.5	75.0	100	100	87.5
		FALL	50.0	62.5	87.5	25.0	37.5	75.0	87.5	75.0	100	100	62.5
		WINTER	62.5	0.0	75.0	0.0	0.0	75.0	100	75.0	100	100	87.5

[1] Percent of individuals selecting for (+), against (-), or exhibiting no selection (=) for habitats comprising a home range.

Table 3.9. Third-order habitat selection patterns for mule deer on Rocky Mountain Arsenal, Colorado, 1990-1992.

SEX	PREFERENCE RANK	HABITAT TYPE / PREFERENCE / SELECTION SPRING			SUMMER			FALL			WINTER		
FEMALE	1	LT[1]	a[2]	+[3]	CWF	a	+	CWF	a	+	BLD	a	+
	2	WF	a	+	WF	a	+	LT	a	+	WTS	a	+
	3	TS	a	=	PNG	a	+	WR	a	+	LT	a	=
	4	PNG	ab	+	LT	a	+	PNG	ab	+	TS	a	=
	5	CWF	b	+	TS	ab	+	WTS	b	+	CWF	a	=
	6	CS	b	=	WTS	b	=	TS	b	=	SS	ab	=
	7	WR	b	=	BLD	b	=	WF	bc	=	PNG	b	=
	8	WTS	bc	=	WR	b	=	CS	c	=	CS	b	=
	9	BLD	cd	=	CS	b	=	CW	c	=	WF	b	=
	10	SS	cd	-	SS	bc	=	BLD	c	=	WR	b	=
	11	CW	d	-	CW	c	=	SS	c	=	CW	b	-
MALE	1	PNG	a	+	CWF	a	+	PNG	a	=	CWF	a	+
	2	LT	a	+	PNG	a	+	BLD	a	=	TS	a	+
	3	TS	a	+	WTS	ab	=	CWF	a	=	PNG	ab	+
	4	WTS	ab	+	LT	b	=	TS	a	=	LT	b	=
	5	SS	bc	=	WR	b	=	WF	a	=	WTS	bc	=
	6	CS	c	=	BLD	b	+	LT	a	=	CW	c	=
	7	BLD	cd	=	TS	bc	=	CS	ab	=	SS	c	=
	8	WR	d	=	WF	c	=	SS	ab	=	WR	cd	=
	9	CWF	de	=	SS	c	=	WR	ab	=	WF	d	=
	10	CW	ef	-	CS	c	-	WTS	ab	=	BLD	d	-
	11	WF	f	-	CW	c	-	CW	b	=	CS	d	=

Mule deer male selection patterns were more variable and only consistently selected for perennial grasslands and either dryland tree or wetland tree areas.

Twenty-one monthly composite fecal samples were analyzed for mule deer diet composition (Fourth-Order selection). Samples were sufficient to conduct seasonal diet composition analyses on 4 seasons for 2 years. Although 10 grasses, 27 forbs, and 12 browse species were identified, a relative high percentage of deer diets were only identifiable to grass forb or browse. Therefore, most analyses were limited to 3 forage classes: % grass, % forb, and % browse.

Percent composition of grasses and forbs did not differ ($\underline{P}$ > 0.05) between seasons for mule deer (Table 3.10). Percent composition of browse species was greater ($\underline{P}$ = 0.03) in summer ($\bar{x}$ = 36.63%) than spring ($\bar{x}$ = 10.55%), fall ($\bar{x}$ = 9.13), and winter ($\bar{x}$ = 7.20). Percent similarity of mule deer seasonal diets varied (Table 3.11). Winter an spring diets were most similar (52.90%) while fall and winter diets were least similar (37.72%) with respect to those forage species that were identified.

White-Tailed Deer Habitat Use and Diets

Similar to mule deer, proportions of habitat types within individual white-tailed deer seasonal home ranges were different ($\underline{P}$ < 0.01) than proportions of habitat types found throughout the study area (Table 3.12). Female seasonal home ranges consistently had higher proportions of the locust thicket, dryland tree, wetland tree, and wetland/riparian habitat types.

Table 3.10. Analysis of Variance test of seasonal effects within a species for percent grass, percent forb, and percent browse composition of diets.

Species	Variable	Source	df	SS	MS	F	P
Mule Deer	% Grass	Season	3	478.44	159.48	1.56	0.23
		Error	17	1742.57	102.50		
	% Forb	Season	3	267.38	89.13	0.28	0.83
		Error	17	5386.63	316.86		
	% Browse	Season	3	2927.56	975.85	3.57	0.03
		Error	17	4645.07	273.24		
Whitetails	% Grass	Season	3	1109.90	369.97	1.62	0.22
		Error	14	3187.83	227.70		
	% Forb	Season	3	4318.89	1439.63	1.79	0.19
		Error	14	11254.99	803.93		
	% Browse	Season	3	812.56	270.85	0.41	0.75
		Error	14	9361.44	668.67		

Table 3.11. Percent similarity of seasonal diets for mule deer and for white-tailed deer.

		Season			
Species	Season	Spring	Summer	Fall	Winter
Mule Deer	Spring	100.00	40.32	48.41	52.90
	Summer		100.00	44.40	41.04
	Fall			100.00	37.72
	Winter				100.00
Whitetails	Spring	100.00	51.71	27.44	32.28
	Summer		100.00	44.40	41.04
	Fall			100.00	23.52
	Winter				100.00

Table 3.12. Second-order habitat preference patterns for white-tailed deer on Rocky Mountain Arsenal, Colorado, 1990-1992.

			HABITAT TYPE										
SEX	+/-/=	SEASON	WF	CWF	BLD	PNG	CW	CS	WR	SS	LT	TS	WTS
FEMALE	+	SPRING	30.0[1]	40.0	0.0	20.0	50.0	0.0	70.0	40.0	50.0	50.0	80.0
		SUMMER	10.0	40.0	0.0	40.0	30.0	20.0	70.0	30.0	40.0	60.0	70.0
		FALL	0.0	30.0	0.0	50.0	50.0	10.0	70.0	50.0	60.0	60.0	70.0
		WINTER	0.0	50.0	0.0	50.0	20.0	0.0	100	40.0	80.0	100	100
	-	SPRING	70.0	40.0	100	70.0	30.0	80.0	0.0	50.0	40.0	30.0	0.0
		SUMMER	80.0	50.0	80.0	40.0	30.0	50.0	0.0	50.0	30.0	20.0	0.0
		FALL	90.0	60.0	100	40.0	30.0	90.0	0.0	50.0	10.0	0.0	10.0
		WINTER	100	50.0	100	40.0	50.0	100	0.0	30.0	0.0	0.0	0.0
	=	SPRING	0.0	20.0	0.0	10.0	10.0	20.0	30.0	10.0	10.0	20.0	20.0
		SUMMER	10.0	10.0	20.0	20.0	40.0	30.0	30.0	20.0	30.0	20.0	30.0
		FALL	10.0	10.0	0.0	10.0	20.0	0.0	30.0	0.0	30.0	40.0	20.0
		WINTER	0.0	0.0	0.0	10.0	30.0	0.0	0.0	30.0	20.0	0.0	0.0
MALE	+	SPRING	50.0	25.0	0.0	25.0	25.0	25.0	75.0	50.0	50.0	50.0	100
		SUMMER	50.0	0.0	0.0	25.0	0.0	0.0	75.0	25.0	25.0	50.0	75.0
		FALL	25.0	25.0	0.0	75.0	25.0	0.0	50.0	50.0	50.0	50.0	100
		WINTER	0.0	50.0	0.0	50.0	50.0	0.0	0.0	75.0	25.0	50.0	75.0
	-	SPRING	50.0	50.0	100	50.0	50.0	75.0	25.0	50.0	50.0	50.0	0.0
		SUMMER	50.0	25.0	100	50.0	50.0	50.0	0.0	75.0	50.0	50.0	0.0
		FALL	75.0	75.0	100	25.0	25.0	75.0	25.0	25.0	50.0	0.0	0.0
		WINTER	100	50.0	100	25.0	0.0	75.0	25.0	25.0	25.0	0.0	0.0
	=	SPRING	0.0	25.0	0.0	25.0	25.0	0.0	0.0	0.0	0.0	0.0	0.0
		SUMMER	0.0	75.0	0.0	25.0	50.0	50.0	25.0	0.0	0.0	0.0	25.0
		FALL	0.0	0.0	0.0	0.0	50.0	25.0	25.0	25.0	0.0	50.0	0.0
		WINTER	0.0	0.0	0.0	25.0	50.0	25.0	75.0	0.0	50.0	25.0	25.0

[1] Percent of individuals selecting for (+), against (-), or exhibiting no selection (=) for habitats comprising a home range.

Males consistently used areas with greater proportions of dryland and wetland trees. The weedy forb, cultivated species, and building habitat types occurred in less than expected proportions for both male and female whitetail seasonal home ranges.

Habitat preference patterns within home ranges also varied across season and sex for white-tailed deer (Table 3.13). The locust thicket, dryland tree, and perennial grassland habitat types were preferred by females during all 4 seasons. The wetland trees, weedy forbs, and wetland/riparian types were preferred during 2 of 4 seasons by females. Only 1 habitat type, locust thickets, was preferred during all for seasons by whitetail males. However, the perennial grassland, wetland and dryland trees, wetland/riparian, and weedy forb types were preferred during 3 seasons by males.

Within home range habitat selection appeared stronger in whitetail females than in males (Table 3.13). Females selected for locust thickets in all 4 seasons, and selected for dryland trees, perennial grassland, wetland/riparian, and weedy forb habitat types during 3 of 4 seasons. Whitetail males showed consistent selection only for locust thickets (2 of 4 seasons). Most other habitat types were selected against or used as expected across seasons.

Eighteen monthly composite fecal samples were analyzed for white-tailed deer diet composition. Again, analyses were limited to the 3 main forage classes: % grass, % forb, and % browse. No seasonal differences ($\underline{P} > 0.05$) were noted in percentages of

Table 3.13. Third-order habitat selection patterns for white-tailed deer on Rocky Mountain Arsenal, Colorado, 1990-1992.

	PREFERENCE ORDER / SELECTION											
SEX	SPRING			SUMMER			FALL			WINTER		
FEMALE	PNG[1]	a[2]	+[3]	LT	a	+	TS	a	+	PNG	a	+
	LT	a	+	TS	a	=	LT	a	+	TS	a	+
	TS	a	+	WR	a	+	WR	a	+	LT	a	+
	WR	b	+	WF	a	+	WF	a	+	WTS	ab	+
	WTS	b	=	WTS	a	=	PNG	ab	=	WF	bc	=
	WF	b	+	PNG	a	+	CS	b	=	CS	bc	-
	CS	bc	=	CWF	ab	=	WTS	b	=	WR	cd	=
	CWF	c	=	CS	bc	=	CWF	b	=	SS	d	=
	SS	cd	-	SS	c	-	CW	c	-	CWF	d	=
	CW	d	-	CW	c	=	SS	c	-	CW	d	=
MALE	LT	a	+	WTS	a	+	TS	a	+	TS	a	+
	PNG	a	=	LT	a	=	WTS	a	=	PNG	a	=
	WTS	a	=	WR	a	=	WR	a	=	LT	a	+
	CS	ab	=	WF	ab	=	LT	a	=	WR	ab	=
	SS	b	=	TS	ab	=	WF	a	=	WTS	b	=
	TS	b	=	CWF	b	=	PNG	a	=	WF	b	=
	WF	b	=	SS	b	=	CS	ab	-	CS	b	=
	WR	b	-	CS	b	-	CWF	b	=	CWF	bc	=
	CW	b	=	PNG	bc	=	SS	b	-	SS	c	-
	CWF	b	=	CW	c	-	CW	b	-	CW	c	-

grass, forb, and browse species in the diets of white-tailed deer (Table 3.10). Spring and summer diets were the most similar (51.71%) while fall and winter were the least similar with respect to composition of those forage species that were identifiable (Table 3.11).

Inter-Specific Habitat and Dietary Comparisons

Seasonal home ranges (Second-order selection) of mule and white-tailed populations contained different relative proportions of several habitat types (Table 3.14). Whitetail seasonal home ranges had a higher ($P < 0.05$) proportion of wetland area trees during all 4 seasons. Mule deer seasonal home ranges contained greater ($P < 0.05$) proportions of buildings during all seasons. Second-order differences were most dramatic during winter when 7 of 11 habitat types occurred in different proportions in mule and whitetail home ranges, respectively.

Differences between mule and whitetail male, and mule and whitetail female seasonal home ranges were not as consistent as those for the population (Table 3.14). No differences ($P > 0.05$) were noted during summer for females, or during fall for males. Whitetail female home ranges contained a higher ($P = 0.03$) proportion of wetland trees during spring, fall, and winter, higher ($P <= 0.01$) proportions of perennial grasses during fall and winter, and a higher ($P = 0.01$) proportion of crested wheatgrass during winter. Mule deer female home ranges contained a greater proportion of cheatgrass/weedy forbs during winter. Mule deer male home ranges contained greater ($P <= 0.05$)

Table 3.14. Comparison of Second-Order seasonal habitat selection patterns between mule and white-tailed deer.

HABITAT	SPRING			SUMMER			FALL			WINTER		
	MD	WT	P	MD	WT	P	MD	WT	P	MD	WT	P
POPULATION												
Weedy Forb (WF)	11.95	12.61	0.88	16.39	7.09	0.05	8.00	3.30	0.13	8.59	3.71	0.04
Cheatgrass/WF	23.53	18.92	0.33	17.16	17.06	0.98	22.56	13.83	0.08	37.85	15.05	<0.01
Perennial Grasses	11.28	17.79	0.13	13.81	20.43	0.15	11.68	24.94	<0.01	7.80	26.30	<0.01
Crested Wheatgrass	12.13	15.24	0.23	11.93	15.50	0.23	14.15	16.64	0.36	5.53	13.87	<0.01
Shrublands	7.67	8.21	0.77	9.06	8.61	0.85	9.03	10.31	0.64	5.66	10.88	0.08
Locust Thicket	2.49	1.77	0.53	2.38	2.81	0.73	2.39	3.35	0.46	1.74	2.62	0.39
Wetland Trees	6.47	10.58	0.01	5.27	9.44	0.01	6.55	11.28	0.01	6.50	11.16	0.02
Dryland Trees	6.12	6.53	0.80	5.84	8.52	0.16	5.91	9.05	0.06	5.14	8.80	0.07
Cultivated Species	3.93	1.97	0.08	3.42	3.08	0.82	3.89	1.43	0.10	5.41	1.47	<0.01
Wetland/Riparian	5.59	6.38	0.21	8.11	7.46	0.57	6.52	5.86	0.49	5.14	6.13	0.47
Buildings	8.83	0.00	<0.01	6.63	0.00	0.04	9.31	0.00	0.02	10.62	0.00	<0.01
MALES												
Weedy Forb (WF)	23.41	18.01	0.54	36.28	11.01	0.03	13.56	6.13	0.37	14.90	3.56	0.03
Cheatgrass/WF	26.77	13.81	0.05	11.57	15.59	0.45	23.54	14.71	0.25	48.72	8.34	<0.01
Perennial Grasses	8.92	21.26	0.14	15.74	22.11	0.47	12.64	24.35	0.15	3.97	31.90	0.06
Crested Wheatgrass	11.36	12.00	0.89	9.10	13.48	0.49	18.35	18.02	0.96	3.71	14.91	<0.01
Shrublands	4.07	9.30	0.02	5.82	7.19	0.52	5.95	10.89	0.07	1.97	17.05	0.03
Locust Thicket	0.28	2.28	0.29	0.20	2.29	0.32	0.28	1.44	0.23	0.14	1.40	0.24
Wetland Trees	5.33	7.93	0.21	3.90	10.66	0.01	7.76	11.96	0.22	6.36	8.95	0.53
Dryland Trees	2.65	6.87	0.23	2.83	7.01	0.28	3.64	6.23	0.06	1.86	8.50	0.08
Cultivated Species	6.94	2.45	0.04	3.79	2.84	0.59	4.79	1.79	0.31	7.92	1.96	0.03
Wetland/Riparian	5.15	6.09	0.32	8.95	7.83	0.67	6.07	4.46	0.31	2.33	5.41	0.07
Buildings	5.12	0.00	0.01	1.82	0.00	0.31	3.39	0.00	0.10	8.13	0.00	0.05
FEMALES												
Weedy Forb (WF)	5.84	10.46	0.26	5.78	5.52	0.94	5.03	2.17	0.22	5.23	3.77	0.48
Cheatgrass/WF	21.81	20.96	0.89	20.15	17.65	0.70	22.03	13.47	0.20	32.06	17.73	0.05
Perennial Grasses	12.53	16.40	0.45	12.77	19.76	0.21	11.17	25.18	0.01	9.85	24.06	<0.01
Crested Wheatgrass	12.54	16.54	0.21	13.44	16.30	0.49	11.91	16.09	0.21	6.49	13.47	0.01
Shrublands	9.59	7.77	0.39	10.79	9.18	0.68	10.68	10.09	0.87	7.64	8.41	0.73
Locust Thicket	3.67	1.57	0.11	3.55	3.02	0.75	3.51	4.11	0.73	2.59	3.11	0.71
Wetland Trees	7.08	11.64	0.03	6.01	8.95	0.18	5.91	11.01	0.03	6.57	12.05	0.03
Dryland Trees	7.96	6.40	0.44	7.45	9.13	0.49	7.12	10.18	0.16	6.88	9.72	0.29
Cultivated Species	2.32	1.77	0.70	3.22	3.19	0.98	3.40	1.28	0.29	4.08	1.28	0.07
Wetland/Riparian	5.83	6.50	0.44	7.65	7.31	0.82	6.76	6.42	0.79	6.65	6.42	0.90
Buildings	10.81	0.00	0.01	9.20	0.00	0.04	12.46	0.00	0.02	11.96	0.00	<0.01

proportions of weedy forbs during summer and winter, and the cheatgrass/weedy forbs and cultivated species habitat types during spring and winter. Whitetail female home ranges had less ($P < 0.05$) of the building habitat type during all seasons but males differed ($P <= 0.05$) only during winter and spring.

Within home range habitat selection patterns also differed between mule and white-tailed deer populations (Table 3.15). Mule deer consistently used the cheatgrass/weedy forb habitat type more ($P <= 0.01$) than did whitetails. Whitetails used more ($P < 0.05$) dryland trees during summer, fall, and winter, more ($P < 0.05$) wetland trees during summer and fall, and more ($P <= 0.01$) perennial grasses during winter and spring than did mule deer. Trends comparing males verses males and females verses females inter-specifically were similar.

Analysis of Variance indicated that there were no differences between deer species, or for the species X season interaction of percent diet composition of grasses ($P = 0.73$), forbs ($P = 0.45$), and browse ($P = 0.86$) (Table 3.16). A seasonal effect was observed only for percent composition of grasses with grass use higher ($P = 0.05$) in winter and spring (12.11 and 21.87%, respectively) than in summer (6.98%) and fall (8.40%). However, this effect was for pooled deer species as apposed to within deer species. No inter-specific seasonal differences ($P > 0.05$) were noted for individual forage species that were identified in the samples. Mule and white-tailed deer diets were most similar, with respect to identified forage species, during

Table 3.15. Comparison of Second-Order seasonal habitat use patterns between mule and white-tailed deer.

HABITAT	SPRING MD	SPRING WT	SPRING P	SUMMER MD	SUMMER WT	SUMMER P	FALL MD	FALL WT	FALL P	WINTER MD	WINTER WT	WINTER P
POPULATION												
Weedy Forb (WF)	13.99	10.86	0.28	19.40	12.91	0.08	11.94	8.33	0.16	6.34	6.75	0.96
Cheatgrass/WF	23.31	7.88	<0.01	26.94	14.90	0.01	31.74	11.12	0.01	51.26	12.43	<0.01
Perennial Grasses	18.02	29.74	<0.01	17.70	20.92	0.34	20.99	24.44	0.42	13.56	32.82	<0.01
Crested Wheatgrass	5.74	6.30	0.71	5.76	5.66	0.94	8.30	8.26	0.99	5.67	8.69	0.35
Shrublands	6.81	5.83	0.55	6.27	4.69	0.45	6.14	3.73	0.07	8.31	9.57	0.76
Locust Thicket	15.64	19.78	0.45	13.48	13.97	0.92	13.70	16.54	0.56	21.52	12.95	0.20
Wetland Trees	9.80	10.91	0.66	9.73	18.06	0.04	7.67	16.26	0.01	12.35	14.22	0.61
Dryland Trees	8.15	16.14	0.22	8.16	13.42	0.04	7.91	15.41	<0.01	12.13	18.28	0.03
Cultivated Species	6.35	5.45	0.80	3.13	1.64	--	9.56	2.62	0.13	4.73	5.56	--
Wetland/Riparian	8.90	7.68	0.58	10.87	11.85	0.67	10.89	10.23	0.81	6.29	7.28	0.56
MALES												
Weedy Forb (WF)	12.13	7.23	0.12	23.98	19.16	0.60	16.15	11.56	0.39	6.35	16.67	0.07
Cheatgrass/WF	20.58	9.00	0.12	27.34	10.29	0.02	23.85	6.46	0.04	62.46	8.92	0.01
Perennial Grasses	21.89	31.14	0.01	21.14	21.38	0.97	24.87	20.45	0.65	9.11	36.85	<0.01
Crested Wheatgrass	5.82	5.38	0.79	7.50	6.67	--	11.02	11.94	0.91	--	--	--
Shrublands	6.57	7.77	0.62	4.58	6.67	--	5.70	4.98	0.75	3.57	14.54	0.61
Locust Thicket	9.64	23.83	0.25	12.50	9.57	--	8.24	8.34	0.99	--	--	--
Wetland Trees	15.03	11.82	0.57	8.66	28.11	0.03	9.42	20.39	0.04	16.65	12.40	0.71
Dryland Trees	9.35	4.89	0.09	4.98	9.80	0.28	6.27	13.37	0.18	10.71	21.79	0.03
Cultivated Species	7.28	6.25	--	--	--	--	--	--	--	3.57	5.56	--
Wetland/Riparian	3.57	4.28	--	15.54	11.24	0.33	6.89	10.08	0.51	9.09	10.32	0.83
FEMALES												
Weedy Forb (WF)	14.86	12.31	0.51	16.79	10.40	0.04	9.14	6.89	0.35	6.75	4.77	0.36
Cheatgrass/WF	24.89	7.63	<0.01	26.72	15.92	0.07	36.59	13.78	0.01	44.86	13.74	<0.01
Perennial Grasses	15.81	29.17	<0.01	15.58	20.79	0.20	18.59	26.04	0.18	17.02	31.20	0.04
Crested Wheatgrass	5.67	6.69	0.67	5.23	5.49	0.86	6.94	7.03	0.98	3.03	8.69	--
Shrublands	6.97	3.88	0.20	6.98	4.30	0.31	6.53	3.37	0.09	9.10	7.58	0.73
Locust Thicket	19.33	17.76	0.83	13.57	15.62	0.74	15.06	20.64	0.34	21.52	13.70	0.29
Wetland Trees	6.95	10.54	0.19	10.44	13.04	0.49	6.66	13.91	0.01	9.96	14.77	0.12
Dryland Trees	7.46	20.24	0.15	9.08	15.03	0.06	8.96	16.23	0.01	12.88	16.88	0.24
Cultivated Species	4.95	4.65	--	--	--	--	6.52	2.62	0.20	--	--	--
Wetland/Riparian	9.31	8.81	0.84	8.92	12.09	0.23	11.96	10.29	0.62	5.98	5.97	0.99

Table 3.16. Analysis of Variance test of species, season, and interaction effects for percent grass, percent forb, and percent browse in diets of sympatric mule and white-tailed deer.

Variable	Source	df	SS	MS	F	P
% Grass	Species	1	19.78	19.78	0.12	0.726
	Season	3	1435.16	478.39	3.01	0.045
	Species X Season	3	153.18	51.06	0.32	0.810
	Error	31	6538.51	210.92		
% Forb	Species	1	316.52	316.52	0.59	0.448
	Season	3	3080.38	1026.79	1.91	0.148
	Species X Season	3	1505.89	501.96	0.94	0.435
	Error	31	16641.61	536.83		
% Browse	Species	1	13.92	13.92	0.03	0.861
	Season	3	3410.75	1136.92	2.52	0.076
	Species X Season	3	329.38	109.79	0.24	0.865
	Error	31	14006.51			

winter (70.41%) and least similar during spring (39.41%). Inter-specific similarity of diets was intermediate to the extremes during summer (65.21%) and fall (42.48%).

DISCUSSION

Mule Deer Distribution & Habitat Use

Mule deer habitat and diet selection patterns found in this study are similar to those reported elsewhere for mule deer in similar habitats (Severson 1981, Bodurtha et al. 1989, Wood 1987, Wood et al. 1989, Loft et al 1991). At the finest level of comparison (Fourth-order selection), forbs composed the majority of mule deer diets in all seasons (60.4-79.1%). Third order selection patterns indicated that mule deer preferred and selected the cheatgrass/weedy forb and weedy forb habitat types, both containing high proportions of perennial and annual forbs. Habitats containing high structural components (BLD, WTS, TS, and LT) received high use only during winter. This suggests that emergent properties of diet selection and thermo-regulation within habitat components may be the primary mechanisms operating at this level of selection.

Habitat composition of mule deer home ranges varied. Mule deer home ranges typically had less than expected proportions of perennial grasses (PNG), weedy forbs (WF), and crested wheatgrass (CW), whereas the cheatgrass/weedy forb type consistently occurred in higher proportions. The PNG, WF, and CW habitat types generally provided little cover for mule deer. Areas of cheatgrass/weedy forb had a large russian thistle component that provided additional thermal and security cover The fact that habitat types containing structural attributes (LT, TS, WTS, LT, and SS) were rarely found in less than expected proportions suggests that cover as well as forage may govern second-order distributions of mule deer.

The fact that mule deer did not use RMA uniformly was not unexpected. Wildlife populations rarely exist in areas where all resource needs are not met. Additionally, 2 factors are present that limit the majority of deer to RMA in itself. First, and most important, RMA is an isolated island of habitat for deer. Activities and land use practices surrounding RMA severely limits the amount of available habitat to deer. Second, RMA was surrounded by a relatively deer-proof fence during this study. This may be perceived as a confounding factor. However, no single telemetered animal used RMA in its entirety. This leads me to believe that deer were free-ranging within the study area boundaries and subsequent habitat selection patterns were representative of deer populations in this type of environment.

Whitetail Distributions & Habitat Use

Whitetail patterns of habitat and diet selection also are similar to those reported for similar situations elsewhere (Gavin et al. 1984, Gladfelter 1984, Petersen 1984, O'Connor 1987, Dusek et al. 1989, Nixon and Hansen 1992). Forbs predominated whitetail diets in all seasons (44.3-89.4%). The trend for third-order selection patterns was for habitat types containing woody vegetation (LT, TS, WTS). This suggests that fourth-order diet selection of forbs may be independent of third order-selection for thermal and security cover.

Second-order selection patterns again suggest that habitats with a strong structural component are important. At this level, no individual whitetail home range contained the building habitat type. The building habitat type was the type with the most human activity. This indicates that whitetails select home ranges primarily on the bases of security cover.

First-order selection patterns were, again, not surprising. White-tailed deer cannot be expected to use and survive well in areas that do not provide necessary life requisites. Large areas of RMA apparently do not supply enough security cover that emerges as an important mechanism governing second-order habitat selection.

Inter-Specific Comparisons

Patterns of herbivory are constrained by the spatial distribution of the resources important to the specific herbivore (Coughenour 1991). Consequently, the spatial distribution of herbivores can be expected to closely mimic the distribution of available resources. Hierarchy theory states that it is only the emergent properties of finer scales that are observed at courser scales of analysis (Allen and Starr 1982, O'Neill et al. 1986, Coughenour 1991). Conversely, the large scale provides the context within which finer scales must operate.

At the large scale of habitat selection (First-order), neither species of deer on RMA exhibited spatial use patterns that included the entire study area. Additionally, mule deer and white-tailed deer distributions did not differ at this scale. No consistent trends are found in existing literature describing mule deer - white-tailed deer interactions at this level of selection, although many report substantial areas of spatial overlap (Anthony and Smith 1977, Kramer 1973, Wood et al. 1989). In those situations where the species distributions do overlap considerably, it is probable that different time-space use patterns (higher orders of selection) allow coexistence of the 2 species (Kramer 1973).

Mule and white-tailed deer on RMA had different patterns of spatial and habitat use at second and third-order levels of selection similar to those reported elsewhere (Martinka 1968, Anthony and Smith 1977, Swenson et al. 1983, Wiggers and Beasom 1986, Smith 1987, Wood et al. 1989). Of these, all but 1 (Smith 1987) report that topography is a primary driving mechanism. This is not the case for deer on RMA. I feel that mule deer select habitats primarily based on forage availability and whitetails select habitats based primarily on amounts of security cover available. Whitetail diet selection occurs within the restraints imposed by third order selection processes. Mule deer habitat selection (third-order) is an emergent property of diet selection mechanisms operating at the fourth-order level.

Conclusion

When looked at individually, the lack of inter-specific differences in first and fourth order selection patterns suggest that mule deer and white-tailed deer may be competing for space and forage on RMA. However, differing space and habitat use patterns at second and third order selection levels allow the 2 deer species to coexist. Because these levels ultimately govern the realm within which diet selection must operate for the 2 species, the threat of diet competition is elliminated for the time being. In the same light, emergent properties of second and third order selection currently produce differing time-space use patterns that allow mule and white-tailed deer to coexist at the largest scale analyzed.

Two additional important points must be considered, however. First, RMA is a relative closed population with respect to both deer species. Emigration and imigration opportunities are extremely limited. Long term increases in populations could force competitive interactions that alter and/or destroy the observed spatial segregation between the species. Second, The future of many habitat types on RMA is uncertain. Compliance with CERCLA regulations will alter both amounts and juxtaposition of most habitat types found within RMA boundaries. This too may alter the observed patterns of selection by mule and white-tailed deer on Rocky Mountain Arsenal.

CHAPTER IV

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HABITAT USE BY WINTERING FERRUGINOUS HAWKS IN COLORADO

SECOND ANNUAL PROGRESS REPORT

for the period 1 October 1992 to 1 August 1994

submitted by:

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to

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Rocky Mountain Arsenal National Wildlife Area

1 August 1994

HABITAT USE BY WINTERING FERRUGINOUS HAWKS IN COLORADO

Abstract: Characteristics of ferruginous hawk (*Buteo regalis*) habitat use and home range were studied during the winters of 1992-1993 (FY 93) and 1993-1994 (FY 94). Radio-telemetry equipped hawks (*n* = 26) were tracked for 104 full days to determine home range area and aspects of habitat use and time budgeting. Data were collected from hawks within areas altered to varying degrees by human development, to allow examination of hawk behavioral response to habitat condition or availability. Future sex determinations will allow sex-specific analyses of home range size and habitat use.

No class of animal has the ability to exercise habitat selection to the degree that birds do (Cody 1985:5). Birds are well adapted to make use of newly created niches, and to occupy, avoid, or vacate newly altered ones (see review by Knopf 1986). In general, habitat loss to development or other alteration by humans results in lower species richness and an increase in dominance of a few species (Morrison et al. 1992:152). The quantity of habitat, or the size of the remaining patch, limits the size of the metapopulation that it can sustain (Morrison 1986:435). Extinction rate in habitat patches is a function of increasing isolation, such as that caused by fragmentation and decreasing area

(Morrison et al. 1992:70). Also, extinction rates within fragmented habitats are generally higher for species with specialized resource requirements than more generalist species (Morrison et al. 1992:70).

The ferruginous hawk (Buteo regalis) is one such specialist species, occupying a specific and narrow range of habitats, and having specialized prey requirements (Schmutz 1987, 1989). It is found year-round in Colorado, uncommonly in summer with greater numbers migrating through and wintering in the state (Andrews and Righter 1992:79).

Although it is nearly axiomatic that habitat loss to development by humans will negatively impact wildlife dependent on that habitat, little quantitative work exists documenting this relationship or the stages at which it progresses. Schmutz (1989) examined the relationship between degree of cultivation and nesting by ferruginous and Swainson's (B. swainsoni) hawks, and concluded that these species will persist only where grazing was the dominant land use by humans. Knopf (1986) reported on changes in avian communities resulting from landscape-level habitat changes, documenting species invasions accompanying human-induced plant community changes.

The goals of our study are to quantify aspects of winter habitat use and behavior by ferruginous hawks, and also investigate the differences exhibited by ferruginous hawks encountered in habitats altered to varying degrees by human development. Our aim is to quantify the behavioral response of wintering ferruginous hawks to deteriorating habitat availability or quality.

Herein, we describe our investigation of winter habitat use by ferruginous hawks, centered at Rocky Mountain Arsenal National Wildlife Area, and summarize data collected during the 1992/93 and 1993/94 field seasons.

The objectives of this study are to:

1) Describe quantitatively ferruginous hawk home range, habitat use, and time/activity budgeting in winter. Test for differences in home range, habitat use, behavior, and relative abundance among habitats altered to varying degrees by human development.

2) Test the Chi-squared analysis of habitat use at various sampling intensities, by contrasting real-time hawk habitat use data with simulated tracking intervals subsampled from real-time data.

3) Determine the age and sex structure of the ferruginous hawk population wintering in and migrating through northeastern Colorado. Test for differences in winter behavior based on sex and age class. Investigate causes and significance of differential habitat use from ecological, morphological, and behavioral perspectives.

4) Investigate the degree to which morphological characteristics may be used to distinguish sex in ferruginous hawks, and the extent to which ferruginous hawks exhibit reversed sexual size dimorphism. Describe and evaluate the effectiveness of available blood sexing technologies for the ferruginous hawk.

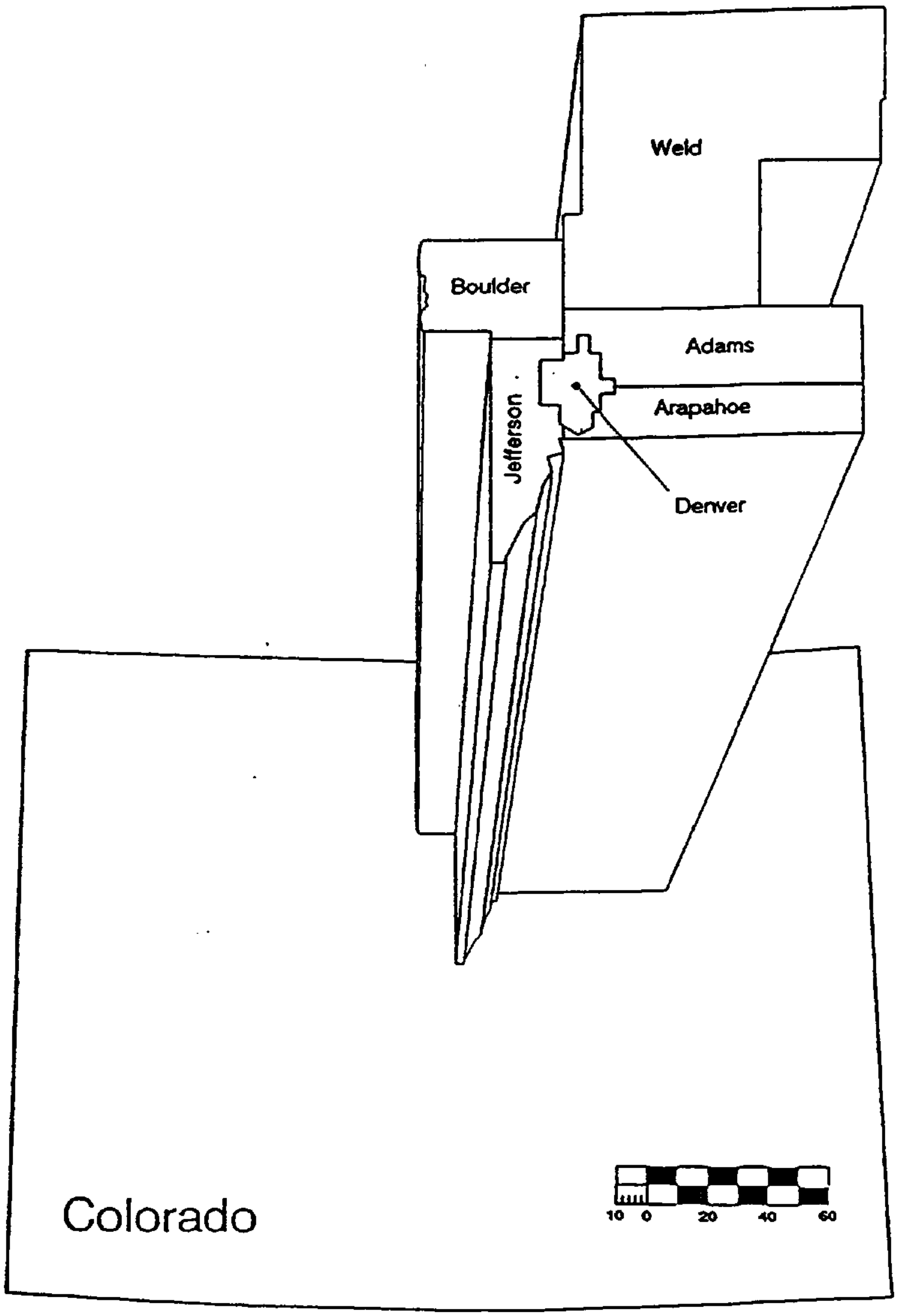
Study Area

No formal study area has been established. Our objective is to study the habits of ferruginous hawks in as large an area as possible, with a range in degree of human development. Size of the study area will be dictated by logistics, dispersal and winter residency of transmitter-equipped hawks, and manpower capabilities. It is expected that tracking activities will take place in portions of Adams, Arapahoe, Boulder, Denver, Jefferson, and Weld Counties, Colorado (Figure 1).

Methods

Wintering ferruginous hawks were captured using leg hold traps that had been padded and weakened (Bloom 1987) and baited with carrion, leg-hold traps baited with live mice used to capture perched hawks (Plumpton et al., in review), and lagomorph carcasses wrapped in noose carpets and tossed from a moving vehicle near perched hawks. Upon capture, hawks were weighed to the nearest 25 g using a spring scale, and a series of morphometric measurements was taken. A blood sample was taken from the brachialis vein for eventual sex determination by Polymerase Chain Reaction (PCR; Dr. Robert Baker, Department of Biological Sciences, Texas Tech University). Captured hawks were fitted with tail-mounted radio telemetry transmitters (Wildlife Materials, inc., Carbondale, Il., U.S.A.) weighing 18-20 g, and were banded with USFWS and Visual Identification legbands (Acraft Sign and Nameplate Co., Ltd, Edmonton, Alta, Can.).

Figure 1. Study area.



Telemetry tracking was subsequently conducted to determine the area and habitat types occupied by a given hawk throughout the course of an entire day. The order in which radio-instrumented hawks were tracked was randomized initially and with each additional capture. Tracking began before hawks left their nighttime roost. Hawks were visually monitored continuously throughout the daylight period, and data were collected on the size of the daily home range, perches used, duration of use by habitat type, and prey captures and attempts. Additionally, these data will be analyzed based on sex following sex determination.

Results and Discussion

Ninety-four raptors were captured, exclusive of burrowing owls (Speotyto cunicularia; Table 1), and not including 8 recaptures of ferruginous hawks and 2 recaptures of red-tailed hawks (Buteo jamaicensis). Ferruginous hawks trapped during the summer months were banded only, and were not radio equipped. Six of the hawks captured in the winter of 1993-1994 were banded the prior year during this study.

Twenty-six hawks were radio-tracked for 104 full days in the first 2 years of this study (Table 2). Hawks during midwinter spent little time flying, and much of the day perching. Habitat use was therefore defined to include only perched (ground or elevated) locations, as flying locations were not clear instances of habitat use. Daily home range

Table 1. Summary of raptor captures, 1 October 1992-1 August 1994.

	Number Captured FY 1993	FY 1994
Aquila chrysaetos	1**	
*Buteo regalis**	23	30
Buteo jamaicensis	4	14
Buteo lagopus	1	
Buteo swainsoni	3	
Falco mexicanus	1**	
Haliaeetus leucocephalus		5**

*sex to be determined by future DNA analyses.
**Banded under station permit by USFWS-RMA personnel.

Table 2. Summary of ferruginous hawk radio-telemetry tracking data collection, 1992-1993.

Year	No. full days tracked	No. Hawks
FY1993	49	10
FY1994	55	16
Total	104	26

was then defined to include all areas within which the hawk perched, between and including morning and evening roosts.

Future work

Blood sexing by C-, W-, and Z-linked DNA probes (Zoogen, Inc., Davis, CA U.S.A.) has proven unreliable for sexing ferruginous hawks. Additional blood samples from known-sex ferruginous hawks, and unknown-sex, wild-trapped hawks will be forwarded to Texas Tech University for analysis. These samples may be sent to University of Massachusetts for analysis, also by PCR, as a redundant check on analytical results. Once analyses prove to accurately classify unknown sex, wild hawk blood samples, habitat use analyses on a sex-specific basis will be conducted.

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Evaluating Largemouth Bass and Northern Pike Habitat Use on the Rocky Mountain Arsenal

ANNUAL REPORT

January 1995

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YEAR IN REVIEW

Increased understanding of habitat use by largemouth bass and northern pike on the Rocky Mountain Arsenal was facilitated with the introduction of artificial structures to the lake basins. A variety of structures popular in other Southwestern impoundments were donated to us by Jim Warnecke and the Arizona Game and Fish department. Fish use of these structures has been definitively evaluated with daily monitoring by David Dreeves, an instrumental summer assistant on the project. Effects on movement patterns during 24-h tracks will also be evaluated. Standardized angling and angler surveys were used to evaluate catch rates off different structure types as well.

Oral presentations describing our research at the Rocky Mountain Arsenal were given at the annual meeting of the Colorado-Wyoming chapter of the American Fisheries Society, the Colorado Division of Wildlife research summit, Tom Smith's radio talk show (KTLK), and an Arsenal Anglers meeting. In July, we were invited to Ohio State University to give a seminar on real time data acquisition for quantifying fish habitat diversity. The mapping system we developed for work on the Arsenal will be adopted for two Ohio projects. Strong interest in this area has stimulated the establishment of an annual workshop explore this research further.

Arsenal research results were also integrated into another manuscript, titled "Habitat use by northern pike and largemouth bass: Application of GIS in fisheries". This overview of GIS will be presented at the third Reservoir Fisheries Management conference to be held in Chattanooga, Tennessee in June 1995. The paper will appear in an edited book titled "Reservoir fisheries management: Strategies for the 90's" that cover the proceedings. This paper is currently under peer review.

QUARTER HIGHLIGHTS

Continued low water levels in both Ladora and Lower Derby prevented us from mapping the basins and artificial structures this quarter as we had hoped. Levels in Lower Derby have dropped to record lows, a full 6 feet below full pool. This drawdown has exposed many of the artificial structures resulting in a decrease in use by largemouth bass and northern pike. The lakes will be "topped off" this winter with well water, ensuring our ability to map the basins during ice off in the spring. This is actually an ideal time to do intensive mapping since all aquatic macrophytes will have died back under winter ice.

Fortunately, enough water was available in Ladora to investigate bias associated with determining fish location. In any telemetry project, finding the transmitter is only part of the problem. Once located, the researcher must determine position on a coordinate system. Using sonic transmitters has allowed us to determine where a transmitter is, with better than meter accuracy. Error introduced via this avenue is negligible. We presume that the bulk of our error is incurred while mapping positions onto an aerial photograph inscribed with a 20 meter grid. Since prominent landmarks on the photograph are used to determine the coordinates of the fish, we suspected that our results might be biased as a function of distance from shore. An investigation of this concern is discussed in the HABITAT MAPPING section.

ECHO INTEGRATOR / HABITAT MAPPING

Telemetry error was evaluated by locating 50 random coordinates around Ladora conventionally (using key landmarks), and with a differential global positioning system (DGPS). It was assumed that the DGPS provided an accurate representation of position. We assessed precision of the unit by taking repeated measurements at a known location

(Ladora dam tower). Although the owners manual suggests an acquisition time of 180 s, logistical reasons forced us to acquire data for just 60 s. This does not seem to be a concern, as all sampling intervals provided reasonably precise location estimates (Figure 1).

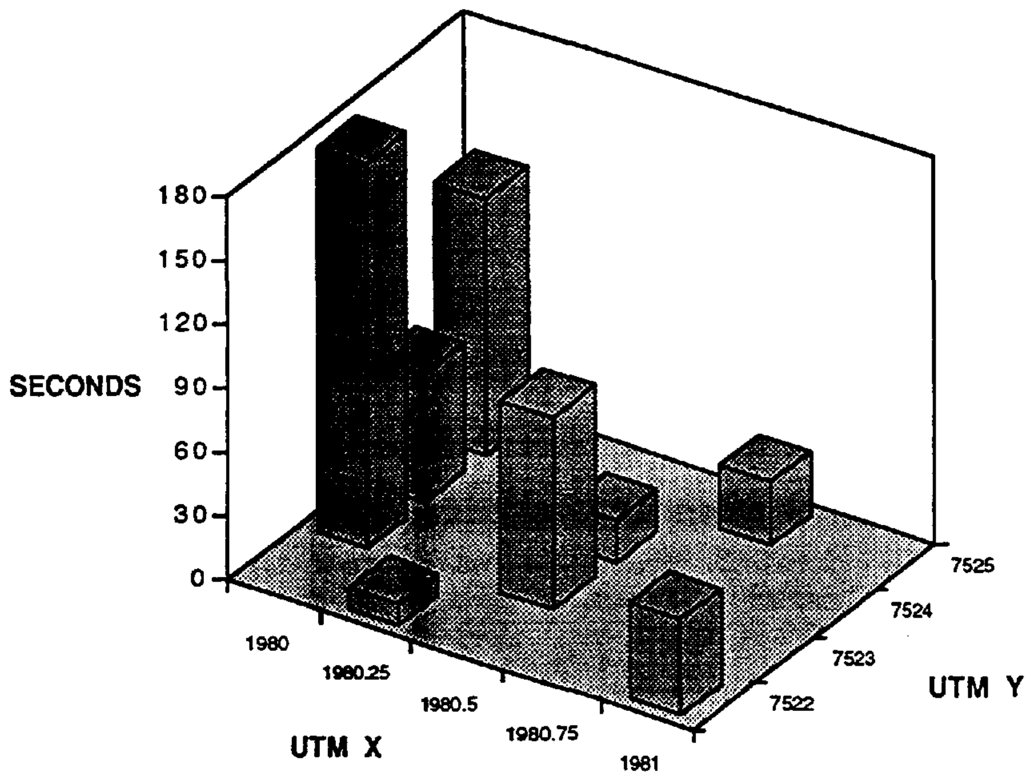

Figure 1: Location estimates were taken with a Trimble™ DGPS unit at the south-east corner of the dam tower on Ladora on October 13, 1994. The last 4 digits of the easting and northing are displayed on the x (51****) and y (440****) axis respectively. The vertical axis depicts the duration spent acquiring a location estimate.

The geometric distance between positions calculated by conventional means and that provided by the DGPS was determined, and assumed to be an estimate of error. As expected, error was less for points closer to shore (Figure 2). When these errors are interpolated over the entire lake, implications of this trend become more evident (Figure 3). It is apparent that our tracking records are biased towards more movement for fish located in the center of the basin. Fortunately, this bias works in our favor. We currently document the least movement of both northern pike and largemouth bass in winter when they congregate in this warmer, deeper water in the center of the lake. We have probably overestimated movement in winter as a result of this bias, making the differences in winter and ice-free month movement even more pronounced.

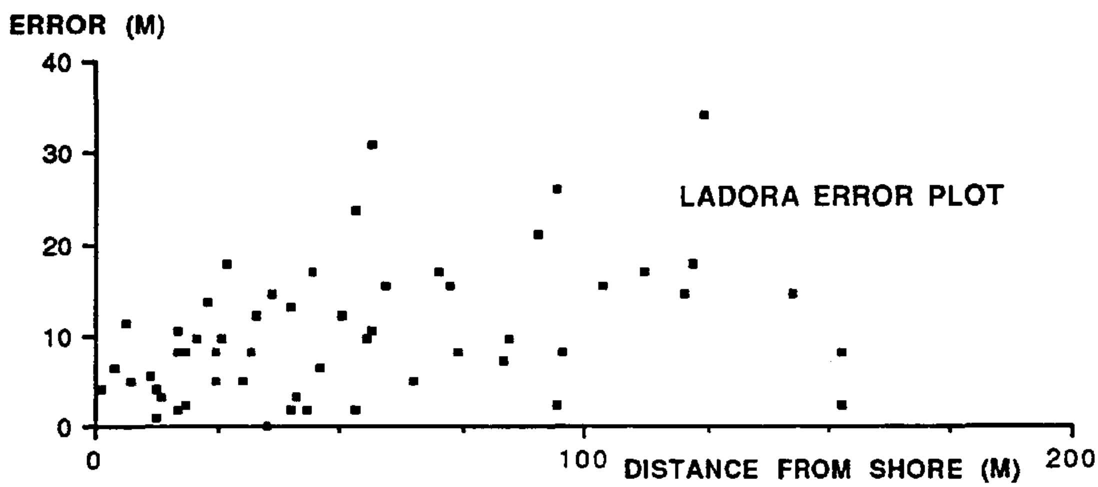

Figure 2: The distance between differentiated GPS and conventional location estimates on Ladora are plotted as error against the distance from shore.

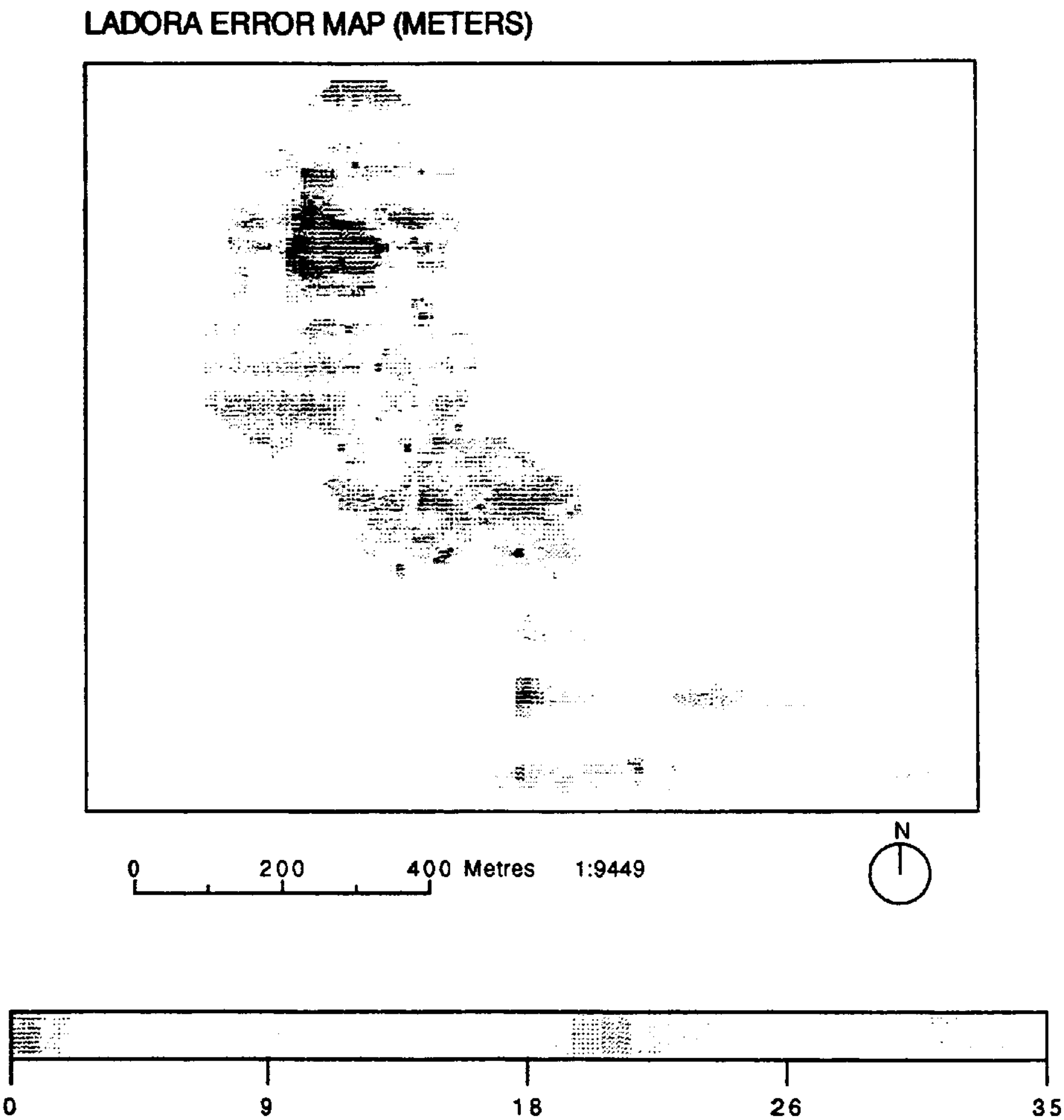

Figure 3: A matrix of error associated with location estimates on Ladora was generated in LabVIEW™ software. This file was then interpolated in MapII™ by octants with a mask of the lake perimeter.

A method for determining transect sample sizes for adequate characterization of a basin was also established this year. Bootstrap confidence intervals were used to determine when the variability among transects is reduced to an acceptable threshold beyond which further sampling is not necessary. In the example below, we ran 34 transects with random start points and bearings on a local pond. The sinuosity diversity index was calculated for the first 2, 3, 4, ..., 34 transects. A 95% bootstrap confidence interval robust to limitations of normal theory was calculated around each point, resampling each "population" of transects 1000 times with replacement. The graph (Figure 4) demonstrates that after about 25 transects, the confidence interval seems to stabilize at a reasonable breadth. We might therefore have been justified in ending our sampling efforts after the 25th transect.

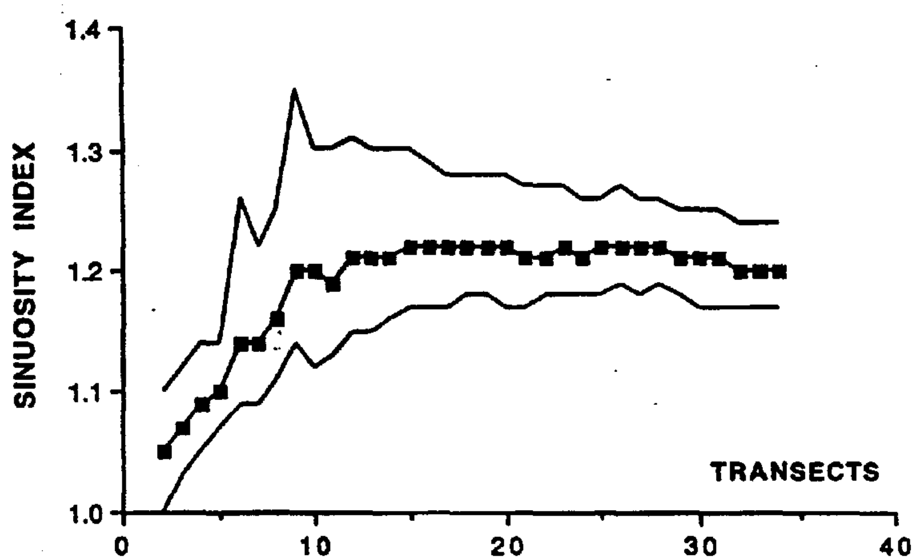

Figure 4. Mean transect sinuosity indices were calculated for increasing numbers of transects from a local pond. A 95% bootstrap confidence interval was constructed around each mean.

TELEMETRY

Three randomly selected Lower Derby largemouth bass, five Lower Derby northern pike, and one Ladora northern pike were implanted with coded sonic transmitters in May (Appendix 1). The implantation procedure was identical to that performed on previous occasions, with one exception. The Animal Care and Use Committee at Colorado State University demanded that we switch from chromic gut to vicryl sutures. They argued that gut dissolved too rapidly, preventing the incision from healing (this despite 98% retention of transmitters by fish sewn up with gut over the past three years). Respecting their opinion, we used vicryl which proved to be a huge mistake. Vicryl is supposed to last 6 weeks before dissolving in humans, yet it has been known to last up to a year. It is easy to conceive that it might last even longer in poikilotherms. Some fish were recovered during routine sampling six weeks after implantation. The incisions had healed up nicely, yet the suture insertion points were grossly infected. After consulting with some surgeons, we found that this was not surprising. Vicryl is a weave laced with interstices ideal for bacterial growth. Unfortunately, this problem did not come to our attention soon enough, and some fish were lost.

We recaptured all but 2 of the vicryl sutured fish after being told that the lesions would heal quickly upon suture removal. An additional 6 fish (also included in Appendix 1) were implanted with transmitters in July, to ensure adequate sample sizes. We generally do not like to operate on fish in warm summer water temperatures, but the unexpected mortalities caused by the vicryl suture left us no choice.

Despite this setback, substantial data was collected this year. David Dreeves greatly enhanced our tracking efforts. In addition to our monthly 24-h tracks, Dave monitored fish location 3-5 times a week over the course of the summer, allowing us to better evaluate habitat use (especially of our artificial structures). Fish use of these structures in Ladora was light as expected, presumably due to thick macrophyte beds that shrouded the habitat.

Early season flooding was probably responsible for the surprisingly light use in Lower Derby initially. The original basin is basically devoid of structure. When the lake was refilled in the spring however, flooded vegetation and emerging macrophytes provided substantial cover. This new habitat diversity allowed fish to move off their traditional haunts along the pipe, and provided competition for our artificial structures. Access to this new habitat was refuted as water levels began to fall over the course of the summer. Use of the artificial structures by largemouth bass increased dramatically at that point.

ARTIFICIAL STRUCTURES

Artificial structures were placed in both lakes Ladora and Lower Derby to develop further understanding of habitat influence on largemouth bass and northern pike behavior. One of each structure type (Figure 5) was placed randomly around the perimeter of a 10 m circle in the center of a 50x50 m block. Three blocks were established randomly in water 2-3 m deep adjacent to the dams in Ladora and Lower Derby.

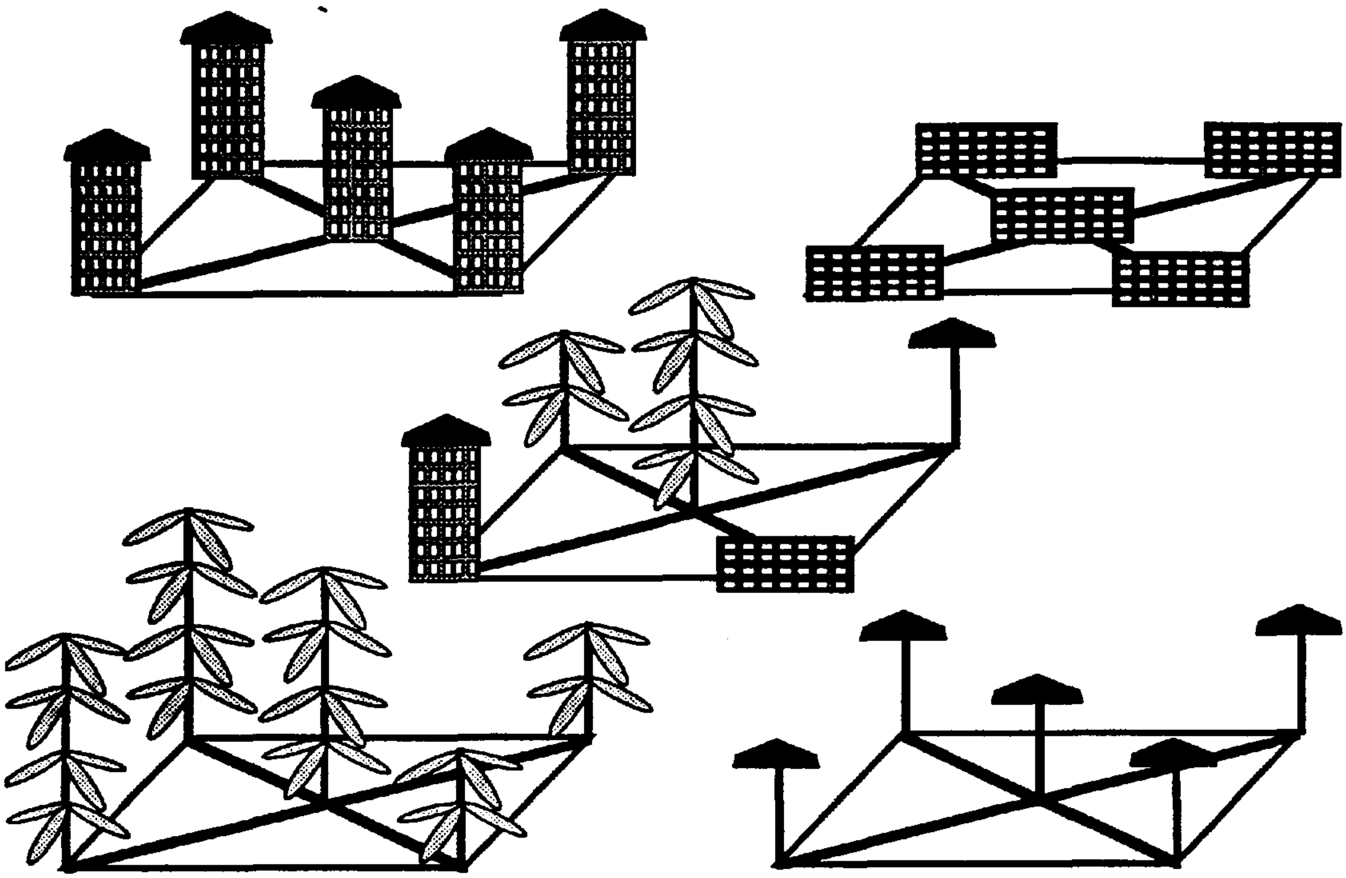

Figure 5: Crappie condos, bass bungalows, fish'n trees, and magic mushrooms are fastened to 3/4 inch rebar frames to generate the five structures distributed around a 10 m diameter circle within a 50x50 m block.

Northern pike and largemouth bass use of artificial structures was monitored over the summer by locating transmittered fish daily, standardized angling, and angler survey forms. Our preliminary results from the standardized angling (Figure 6) seem to indicate a preference by largemouth bass for the "Fish'n Trees" in both lakes. Artificial structures incorporating these trees accounted for 66% of the largemouth bass captured. Largemouth bass use of structure in Lower Derby was three times that in Ladora. This can probably be attributed to extensive macrophyte growth that covered much of the structures in Ladora, and the lack of structural diversity in Lower Derby. As expected, northern pike use of the structures was limited in both lakes, with eight times as many largemouth bass being caught off them than northern pike. Northern pike did not seem to display any preference for a particular structure type.

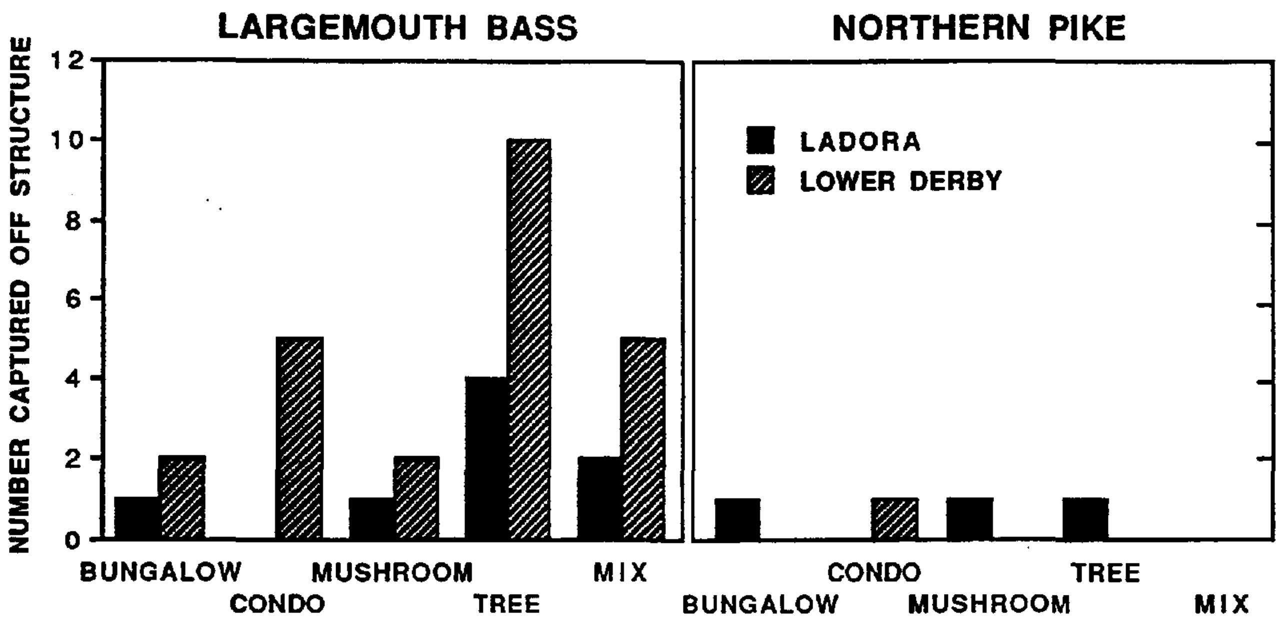

Figure 6: All artificial structures were fished on 8 separate occasions for a period of 5 minutes each from late July through August 1994 for a total of 22.5 rod hours. Gear type was consistent within trials.

Future Plans

We intend to terminate 24-h tracks after the March 1995 full moon. This will have given us an opportunity to monitor individual largemouth bass and northern pike for four years, the longest telemetry study in fisheries to date. Limited field work will proceed after that time to complete mapping lake bottoms with the added artificial structures, and to recover telemetered fish so that transmitter uptake by the intestinal wall can be evaluated.

ACKNOWLEDGMENTS

We wish to extend our gratitude to Fred Krampetz for running the DGPS unit in the field, and differentiating the position estimates for us. We also thank USFWS employees at the Rocky Mountain Arsenal who assisted in assembling the artificial structures. Bill Ringer, Corrie Callenbach, and Terry James are acknowledged for assisting on 24-h tracking sessions this quarter.

APPENDIX

A. Summary of vital statistics for northern pike and largemouth bass handled in Ladora and Lower Derby during 1994. All PIT tag numbers listed are recaptures, as no new transponders were available.

LADORA

Species	Length (mm)	Weight (kg)	Captured	Method	PIT tag	Transmitter
NOP	410	454	5/12/94	LINE	na	
NOP	562	1278	5/12/94	LINE	na	
NOP	540	1020	5/12/94	LINE	na	
NOP	341	255	5/12/94	LINE	na	
NOP	780	2835	5/12/94	LINE	na	
NOP	621	1503	5/12/94	LINE	na	
NOP	871	4309	5/12/94	LINE	na	11-4
NOP	620	1616	5/12/94	LINE	na	
LMB	360	567	5/12/94	LINE	na	
LMB	360	680	5/12/94	LINE	na	
LMB	511	1930	7/21/94	LINE	na	10-5
LMB	520	1700	7/21/94	LINE	na	13-2
LMB	470	1450	7/21/94	LINE	7F7D1E1C57	5-10
LMB	450	1360	7/21/94	LINE	na	
LMB	410	960	7/21/94	LINE	na	

LOWER DERBY

Species	Length (mm)	Weight (kg)	Captured	Method	PIT tag	Transmitter
NOP	624	1134	5/2/94	LINE	na	10-5
NOP	450	454	5/2/94	LINE	na	
NOP	635	1049	5/2/94	LINE	na	
NOP	473	454	5/9/94	LINE	na	
NOP	452	454	5/9/94	LINE	na	
NOP	460	510	5/9/94	LINE	na	
NOP	475	567	5/9/94	LINE	na	
NOP	765	2126	5/9/94	NET	na	13-2
NOP	780	2041	5/9/94	NET	na	12-3
NOP	756	2353	5/9/94	NET	na	11-5
NOP	775	2268	5/9/94	NET	na	10-6
NOP	682	1247	5/9/94	NET	na	
MSK	610	1247	5/2/94	LINE	na	
MSK	622	1361	5/9/94	LINE	na	
MSK	586	1021	5/9/94	LINE	na	
MSK	564	850	5/9/94	LINE	na	
MSK	605	1134	5/9/94	LINE	na	
LMB	331	595	5/2/94	LINE	na	
LMB	338	624	5/2/94	LINE	na	
LMB	338	595	5/2/94	LINE	na	
LMB	361	794	5/2/94	LINE	na	
LMB	364	822	5/2/94	LINE	na	
LMB	346	652	5/9/94	LINE	na	
LMB	413	1107	5/9/94	LINE	na	
LMB	342	624	5/9/94	LINE	na	
LMB	316	510	5/9/94	LINE	na	
LMB	365	737	5/9/94	LINE	na	
LMB	411	1134	5/9/94	LINE	7F7D1E463A	
LMB	364	794	5/9/94	LINE	7F7D1D300F	
LMB	332	567	5/9/94	LINE	na	
LMB	439	1361	5/9/94	LINE	na	
LMB	440	1446	5/9/94	LINE	na	13-3
LMB	470	1814	5/9/94	LINE	na	14-2
LMB	450	1588	5/9/94	LINE	7F7D1D0571	5-10
LMB	418	1219	5/9/94	LINE	7F7D13D6D	
LMB	430	1360	7/19/94	LINE	na	
LMB	445	1220	7/19/94	LINE	na	14-2
LMB	375	960	7/19/94	LINE	na	13-3
LMB	350	620	7/19/94	LINE	na	
LMB	416	1240	7/20/94	LINE	na	12-4

EFFECTS OF SEDIMENT CONTAMINANTS ON MACROINVERTEBRATE AND FISH ASSEMBLAGES IN LOWER LAKES AT ROCKY MOUNTAIN ARSENAL

Annual report Submitted to the U.S. Fish and Wildlife Service
Rocky Mountain Arsenal

15 December, 1994

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Objectives

To assess the effects of contaminated sediments at Rocky Mountain Arsenal National Wildlife Refuge (Refuge), research was begun in 1994 towards integrating laboratory experiments, computer models, and field sampling of macroinvertebrate and fish assemblages. In addition to assessing present conditions at the Refuge, this integrated approach will also be used to evaluate the success of future remediation activities.

The objectives of this research are:

1) to determine the effects of sediment contaminants (dieldrin, aldrin, endrin, DDT, DDE, Hg, As) on benthic macroinvertebrate assemblages in reservoirs at the Refuge;

2) to assess the effects of nonpoint source pollution on water quality in Havana Pond and First Creek

3) to measure demographics and community ecology of fishes in Lower Lakes on the Refuge;

4) to develop specific biomarkers to detect exposure of fish to dieldrin and other COC's in reservoirs at the Refuge.

5) to link physiological changes in fish exposed to sediment contaminants to population and community-level endpoints (e.g., bioenergetics, changes in fish community structure).

Materials and Methods

Nonpoint source pollution

To identify potential nonpoint sources of pollution at the Refuge, water samples (4 L) were collected by USF&WS personnel from Havana Pond and Havana Canal on 26 September 1994. Samples were concurrently taken by U.S. Geological Survey personnel on the Refuge to be analyzed for water quality and for contaminant residues. These data have not yet been received. These samples were stored on ice (4°C) and transported to Colorado State University (CSU) on the same day. Water samples were stored at 4°C for 24 h prior to use in toxicity tests.

To measure the toxicity of nonpoint source pollution at the Refuge, chronic toxicity tests were conducted with Ceriodaphnia dubia exposed to water collected from Havana Pond and Havana Canal. Neonates less than 24 h old were obtained from laboratory cultures and isolated in individual 30-ml polystyrene cups containing 15 ml of water. Experiments were conducted in an environmental growth chamber maintained at 25°C±1°C on a 16 h light and 8 h dark light cycle. Animals were fed 100 ul YTC and 50 ul algae suspension daily. Water was changed every other day and effects of exposure on reproduction (number of neonates per female) was monitored daily.

Field sampling- sediments and benthic invertebrates

Field sampling was conducted at Lower Derby Lake, Lake Ladora, and Lake Mary on 19 October 1994. Physical and chemical data, sediment, and benthic macroinvertebrates were collected from each lake (Lower Derby, n=12; Lake Ladora, n=10; Lake Mary, n=3). All sites were located along transects corresponding to known contaminated and uncontaminated areas.

Physicochemical parameters measured in the field included secchi depth, water and air temperature, dissolved oxygen and lake depth. Water samples collected from selected sites were transported to CSU and analyzed for water hardness, alkalinity, conductivity and pH.

Two sediment samples were collected using a Ponar (surface area=225 cm^2) sampler from each site. Sediments for chemical analysis and toxicity tests were removed from one sample and the second sample was used for invertebrate analysis. Sediments for chemical analysis and toxicity testing were placed in individual 250 ml certified clean glass containers. Sediment samples for chemical analyses were stored on ice during transport to the U.S. Army contract laboratory. Sediments for toxicity testing were stored on ice and transported to CSU.

Samples for invertebrate analysis were washed in a 500 µm mesh sieve and preserved in 70% EtOH. These samples were transported to CSU for analysis.

Field sampling- fish

Fish sampling was conducted by USFWS biologists on 19 October, 1994 at Lake Mary. A standardized experimental gillnet was set for 4 hours in late afternoon, and 15 minutes of shoreline electrofishing effort was conducted at 2030 h using DC power and a spherical electrode. All largemouth bass (*Micropterus salmoides*) observed were netted during the 15 minute transect. Bluegills (*Lepomis macrochirus*) were collected for 9 minutes of electrofishing.

A subsample of the catch was preserved for stomach analysis, aging, and contaminant analyses. We have removed stomach and scales from a subsample of 30 preserved bluegills and four largemouth bass. Remaining samples will be processed in the upcoming quarter. Scale radii were measured on a microfiche reader and backcalculations performed using the Fraser-Lee method. Fish condition was evaluated by computing length-weight regressions and relative weight (W_r) for bluegill and largemouth bass sampled at Lake Mary on October 19, 1994.

Scale samples from largemouth bass and northern pike sampled at Lower Derby and Ladora lakes and largemouth bass at Lake Mary in March and June 1992 were obtained from USFWS biologists. We will age these scales and attempt backcalculation in upcoming quarters to examine for annual variability in length at known ages.

Sediment and pore water toxicity tests

Sediment toxicity tests were conducted at CSU following standard protocols. Tests were conducted in 500 ml glass beakers, with water to sediment ratios of approximately 4:1 (400 ml water:100 ml sediment). Moderately-hard reconstituted water prepared according to standard protocols was used as overlying water for this test. Thirty second-instar *Chironomus tentans* obtained from laboratory cultures at CSU were placed into each beaker. Experiments were conducted in a Precision model 818 incubator at 20°C on a 16h:8h light:dark cycle. All beakers were aerated during the experiment. Physicochemical parameters (pH, D.O., conductivity and temperature) were measured daily in each beaker. After a 5-d exposure period, chironomids were recovered by washing the contents of each beaker through a 0.6-mm mesh sieve and percent mortality was recorded.

Pore water for *Ceriodaphnia dubia* toxicity tests was obtained from the remaining sediments using centrifugation (@ 2500 rpm for 7 minutes). Acute (48 h) toxicity tests were conducted with *C. dubia* exposed to pore water from each site following standard U.S. Environmental Protection Agency protocols. Because of the small volume of pore water obtained from these sediments, we used two replicates per site.

Fish tissue dissections

Thirty fish provided by USFWS biologists were dissected on 15 October 1994 at CSU. Species composition was as follows: five northern pike (NPK), four largemouth bass (LMB), and 21 bluegill sunfish (BGL). Weight of NPK ranged from 498 to 2438 grams; weight of LMB ranged from 73 to 121 grams; and BGL weight ranged from 36 to 105 grams.

Total length (TL) and standard length (SL) were measured for all 30 fish. Scales were removed from all three species and clirethra were removed from NPK for aging. Kidney, liver, viscera, and muscle (filet) were removed from NPK for contaminant analysis. Liver, viscera, and muscle were dissected from the LMB and BGL. Kidney tissue was not removed from LMB and BGL due to its small size. All tissues were placed in 125 ml certified-clean glass containers and placed in a freezer. The tissues were stored on ice and transported to USFWS for contaminant analysis.

Results

Nonpoint source pollution

Physicochemical characteristics of Havana Pond and Havana Canal are shown in Table 1. Hardness, alkalinity, pH, and conductivity were greater in Havana Canal.

Although controls from the Havana Pond toxicity tests failed (e.g., >20% mortality), the mean number of neonates per adult was similar in other treatments and ranged from 12.2 to 14.5. Test results from Havana Canal indicated significant acute and chronic toxicity (Fig. 1). Results of general linear models and least squares means tests indicated that the number of neonates per adult differed significantly from controls in the 12.5%, 25%, and 50% dilutions ($p=0.0001$). Acute mortality was measured in the 50% and 100% treatments.

Physicochemical data

The lower secchi depth in Lower Derby indicated significantly higher turbidity (Secchi range=0.3-0.55 m) in this lake compared to Mary and Ladora (Table 2). We also observed that sediment from Lake Mary had higher amounts of sand and lower amounts of clays, which may account for greater water clarity of these systems. Water temperature and dissolved oxygen were similar among sites, the only exception being Lake Ladora stations L1-L4 where dissolved oxygen was highly variable.

Results from sediment contaminant analysis showed aldrin was detected only at stations D11 and L1 (284 ppb, 408 ppb, respectively). Organochlorines were below detection at all other sites. Arsenic was detected in sediment samples from D8 and M1 (2300 ppb, 1500 ppb, respectively) and mercury was detected in sediment samples from L7 (950 ppb). The low number of samples with detectable levels of organochlorines is probably a result of the relatively high detection limits, especially at Lower Derby stations.

Sediment and pore water toxicity tests

Dissolved oxygen levels measured in the test beakers on day 5 ranged from 6.1 to 7.5 mg/L. Conductivity and pH ranged from 400-500 umho and pH ranged from 7.0-7.3 (respectively).

Chironomid (*Chironomus tentans*) mortality was variable among lakes and sites (Fig. 2). Percent mortality ranged from 0% at D2 to 93% at L1. In general Lake Ladora sediment had the greatest toxic effects, as chironomids exposed to six of the 10 sites exhibited >70% mortality. In Lower Derby Lake four of 12 sites had >50% mortality and no site at Lake Mary showed >40% mortality. Measured levels of organochlorines or Hg corresponded to high mortality of *C. tentans* at stations L1, D11 and L7 (93% 47%, and 77%).

Results of pore water acute toxicity tests generally agreed with the trends of the sediment toxicity tests (Figs. 2, 3). Pore water from Lake Ladora sediments showed toxicity to *C. dubia* at six of 12 sites. Mortality of *C. dubia* ranged from 0-50% when exposed to pore water from Lake Mary or Lower

Derby Lake.

Fish sampling

Bluegills comprised the majority of the fish sampled in both the gillnet and electrofishing samples. The gillnet captured seven bluegills with a mean length of 124 mm (TL), and 2 largemouth bass with a mean length of 342 mm. Electrofishing sampled 110 bluegills with a mean total length of 119 mm and 25 largemouth bass with a mean length of 250 mm. The distribution of bluegills caught during electrofishing was bimodal, with 75 mm and 125 mm modes (Table 4). A larger range of sizes of largemouth bass was sampled by electrofishing, with modes of 150 mm, and 250 mm, and a maximum of 450 mm (Table 5). One common carp (Cyprinus carpio) was collected during electrofishing (214 mm TL).

Changes in length-weight regressions over time can be used to track changes in fish condition. Length-weight regressions computed for bluegill and largemouth bass from Lake Mary in October 1994 were as follows:

Bluegill	Log_{10} (Weight (g))= -4.953 + 3.095*Log_{10}(Length (mm)) $R^2 = 0.96$, $N = 83$, $p < 0.001$
Largemouth bass	Log_{10} (Weight (g))= -5.627 + 3.316*Log_{10}(Length (mm)) $R^2 = 0.99$, $N = 26$, $p < 0.001$

Mean relative weight (W_r) of bluegill (90%) was lower than that for largemouth bass (101%) (Table 6). However, caution should be used in interpreting the absolute value of relative weights. Standard weights used to compute W_r are derived from fish populations across the country, and may not represent the condition of healthy populations in the vicinity of RMA. Changes in W_r through time and comparisons of W_r from RMA fish populations with those in uncontaminated systems in the area are more easily interpreted. Further, it may be more informative to compute relative weights for various size classes of fish to look for possible ontogenetic bottlenecks. The bluegill data from Lake Mary do not indicate such bottlenecks as there is no relationship between W_r and total length (Table 7). Relative weight of 200-300 mm largemouth bass appears to be lower than W_r for 300-500 mm bass, but all bass had relative weights in what is generally considered the acceptable range (>85%; Flickinger, pers. comm.). Virtually all bluegill and largemouth bass we dissected were heavily infested with an unidentified parasitic worm in the viscera.

Table 1. Physicochemical measurements for Havana Pond and Havana Canal at the Refuge.

SITE	pH	Hard. (mg/L $CaCO_3$)	Alk.	D.O. (mg/L)	Cond. (umho)
Havana Pond	7.5	66	48	6.8	244
Havana Canal	8.4	124	75	6.8	402

Table 2. Field physicochemical parameters taken 19 Oct. 1994 at the Refuge for Lakes Mary, Ladora and Lower Derby.

Site	Secchi Depth (m)	D.O. (mg/L)	Water °C	Air °C	Depth (m)
M1	1.4	6.1	8	10	1.4
M2	1.8	6.3	8	10	1.8
M3	1.35	6.4	8	10	1.35
L1	0.4	4.9	9	15	0.4
L2	0.9	10.0	8	15	0.9
L3	1.1	11.8	9	15	1.1
L4	0.7	12.2	9	14	0.7
L5	2.5	7.5	9	-	2.8
L6	2.0	7.2	9	-	2.7
L7	2.2	7.5	9	14	3.1
L8	2.2	7.9	8	-	2.2
L9	2.1	7.4	8	-	4.25
L10	2.5	7.2	7	-	2.8
D1	0.3	8.4	5	11	0.8
D2	0.4	8.8	5	-	0.5
D3	0.35	8.5	5	-	1
D4	0.4	7.5	7	14	1.3
D5	0.3	7.2	7	-	1.5
D6	0.4	7.5	7	13.5	1.1
D7	0.4	7.4	7	14	0.7
D8	0.45	7.4	7	14	1.2
D9	0.5	7.3	7	-	2.2
D10	0.4	7.4	7	13	2.2
D11	0.55	7.5	7	-	2.6
D12	0.55	7.7	8	-	1.25

Table 3. Hardness, Alkalinity, pH and Conductivity Parameters for Mary, Ladora and Lower Derby Lakes.

Site	Hard. (mg/L $CaCO_3$)	Alk.	pH	Cond. (umho)
M2	130	96	8.2	682
L1	232	215	8.1	734
L3	180	126	8.6	688
L6	148	93	5.6	665
L9	164	91	8.3	663
D1	144	88	8.0	489
D2	142	86	8.0	488
D3	144	85	7.9	490
D4	146	86	7.2	499
D8	148	86	7.3	498
D11	146	86	7.6	497

Table 4. Length-frequency histogram of bluegills sampled by USFWS during electrofishing on Lake Mary on October 19, 1994.

Total Length (mm) Midpoint		Freq	Cum. Freq	Percent	Cum. Percent
0		0	0	0.00	0.00
25	***	3	3	2.73	2.73
50	********	8	11	7.27	10.00
75	**************	14	25	12.73	22.73
100	******	6	31	5.45	28.18
125	**************************************	38	69	34.55	62.73
150	*************************************	37	106	33.64	96.36
175	****	4	110	3.64	100.00
200		0	110	0.00	100.00
225		0	110	0.00	100.00
250		0	110	0.00	100.00
275		0	110	0.00	100.00
300		0	110	0.00	100.00
325		0	110	0.00	100.00
350		0	110	0.00	100.00
375		0	110	0.00	100.00
400		0	110	0.00	100.00
425		0	110	0.00	100.00
450		0	110	0.00	100.00
475		0	110	0.00	100.00
500		0	110	0.00	100.00

5 10 15 20 25 30 35

Frequency

Table 5. Length-frequency histogram of largemouth bass sampled by USFWS during electrofishing on Lake Mary on October 19, 1994.

Total Length (mm) Midpoint		Freq	Cum. Freq	Percent	Cum. Percent
0		0	0	0.00	0.00
25		0	0	0.00	0.00
50		0	0	0.00	0.00
75		0	0	0.00	0.00
100		0	0	0.00	0.00
125	*****	1	1	4.00	4.00
150	********************	4	5	16.00	20.00
175	*****	1	6	4.00	24.00
200	**********	2	8	8.00	32.00
225	*****	1	9	4.00	36.00
250	**	8	17	32.00	68.00
275	***************	3	20	12.00	80.00
300	*****	1	21	4.00	84.00
325		0	21	0.00	84.00
350		0	21	0.00	84.00
375	**********	2	23	8.00	92.00
400		0	23	0.00	92.00
425	*****	1	24	4.00	96.00
450	*****	1	25	4.00	100.00
475		0	25	0.00	100.00
500		0	25	0.00	100.00

```
-----+----+----+----+----+----+----+----+
     1    2    3    4    5    6    7    8
               Frequency
```

Table 6. Relative weight (Wr) histograms of bluegills (upper panel) and largemouth bass (lower panel) sampled by USFWS using electrofishing and experimental gillnet on October 19, 1994.

Bluegill *Lepomis macrochirus*

```
    WR                                              Cum.             Cum.
Midpoint                                      Freq  Freq  Percent  Percent
         |
   70    |*                                      2     2     2.38     2.38
         |
   80    |**********                            20    22    23.81    26.19
         |
   90    |************************              48    70    57.14    83.33
         |
  100    |****                                   8    78     9.52    92.86
         |
  110    |**                                     3    81     3.57    96.43
         |
  120    |**                                     3    84     3.57   100.00
         |
  130    |                                       0    84     0.00   100.00
         |
         -----+----+----+----+----
             10   20   30   40
               Frequency
```

Largemouth bass *Micropterus salmoides*

```
    WR                                              Cum.             Cum.
Midpoint                                      Freq  Freq  Percent  Percent
         |
   70    |                                       0     0     0.00     0.00
         |
   80    |                                       0     0     0.00     0.00
         |
   90    |****************                       8     8    29.63    29.63
         |
  100    |**************************            13    21    48.15    77.78
         |
  110    |******                                 3    24    11.11    88.89
         |
  120    |****                                   2    26     7.41    96.30
         |
  130    |**                                     1    27     3.70   100.00
         |
         ----+---+---+---+---+---+--
             2   4   6   8  10  12
               Frequency
```

Table 7. Relative weight (Wr) as a function of fish total length of bluegills ('B') and largemouth bass ('L') sampled by USFWS using electrofishing and experimental gillnet on October 19, 1994.

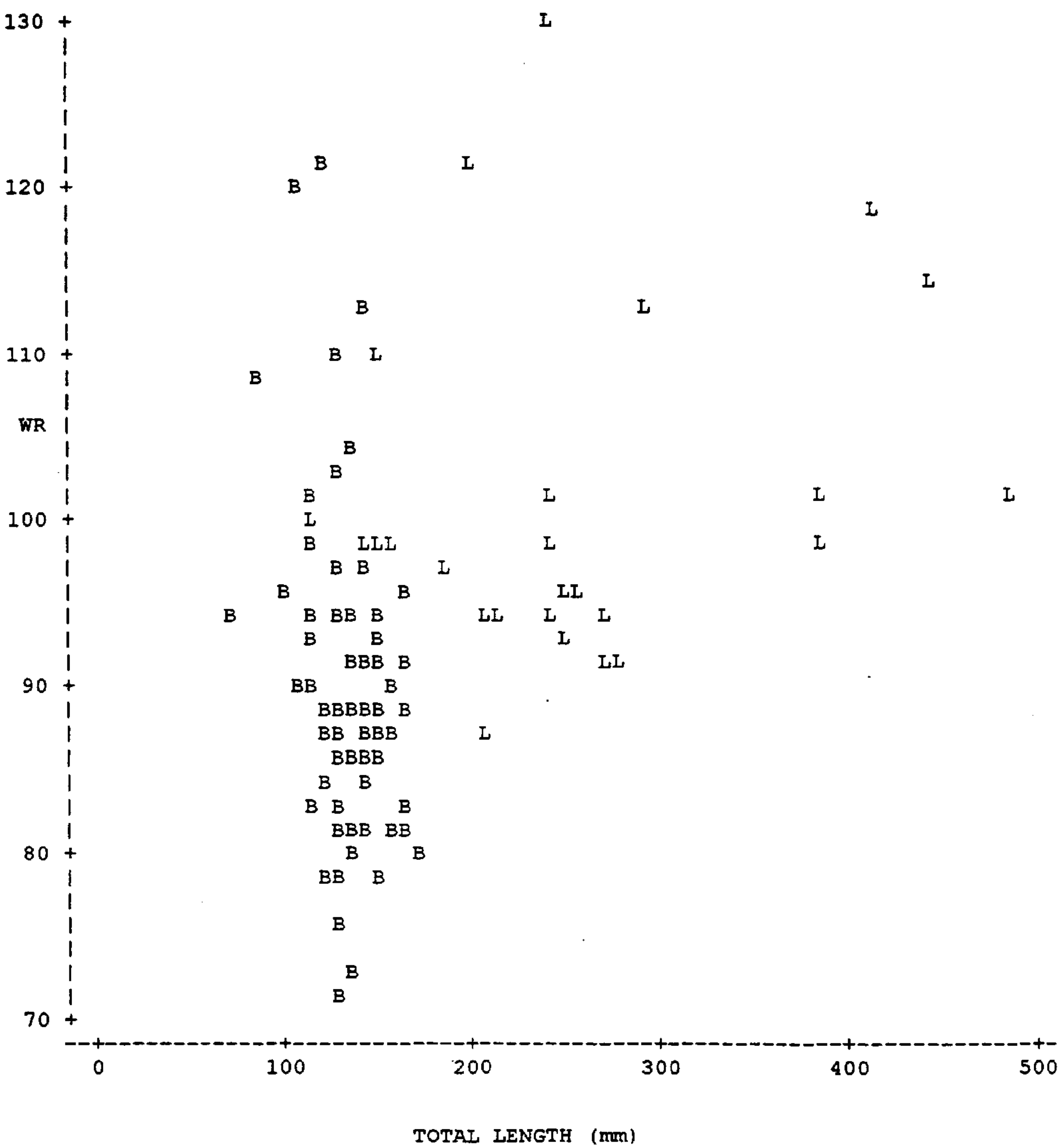


Fig. 1

Havana Canal Toxicity Test Results

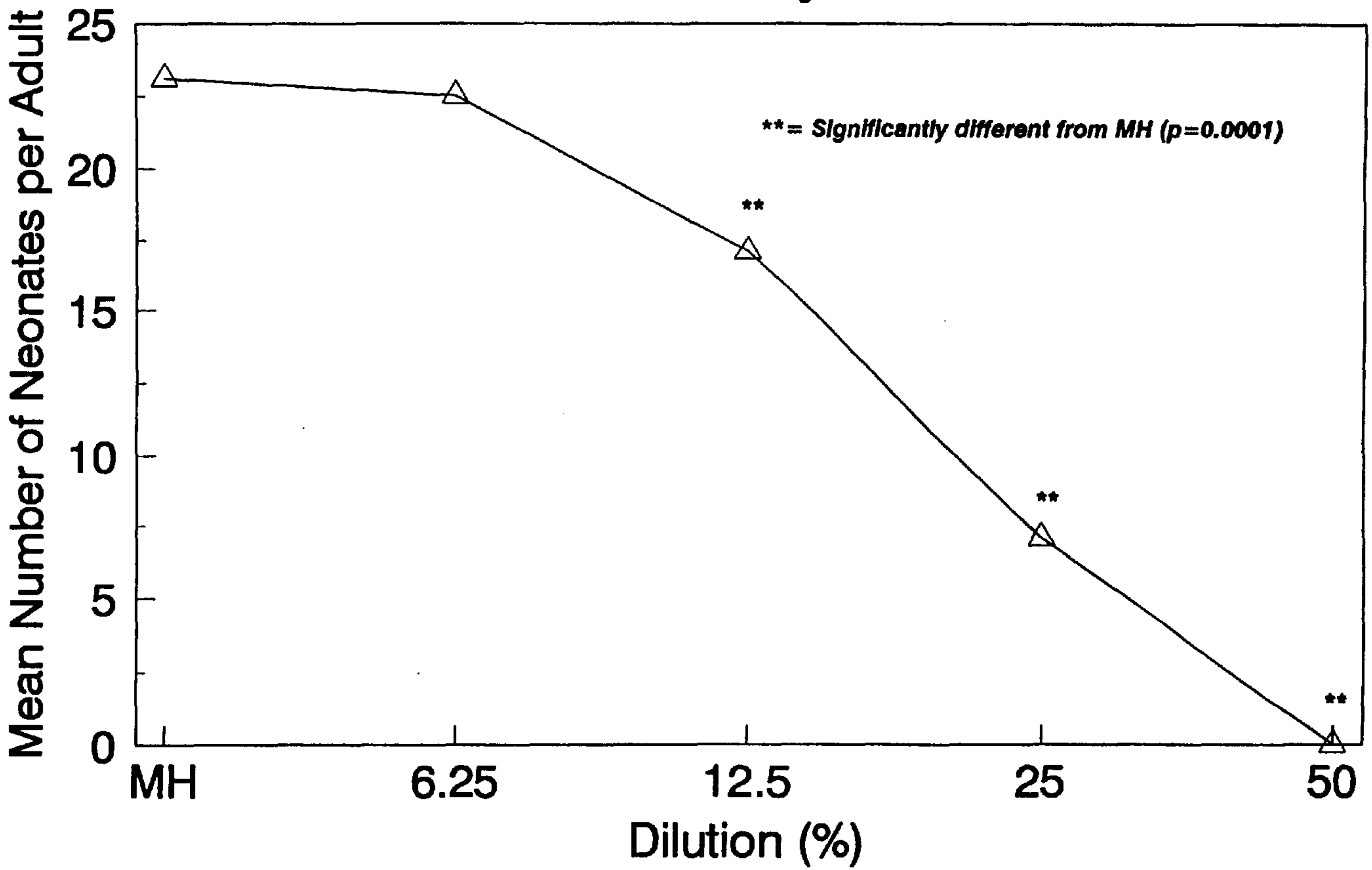


Figure 2

RMA SEDIMENT TOXICITY TEST RESULTS

For Lakes Mary, Ladora and Lower Derby

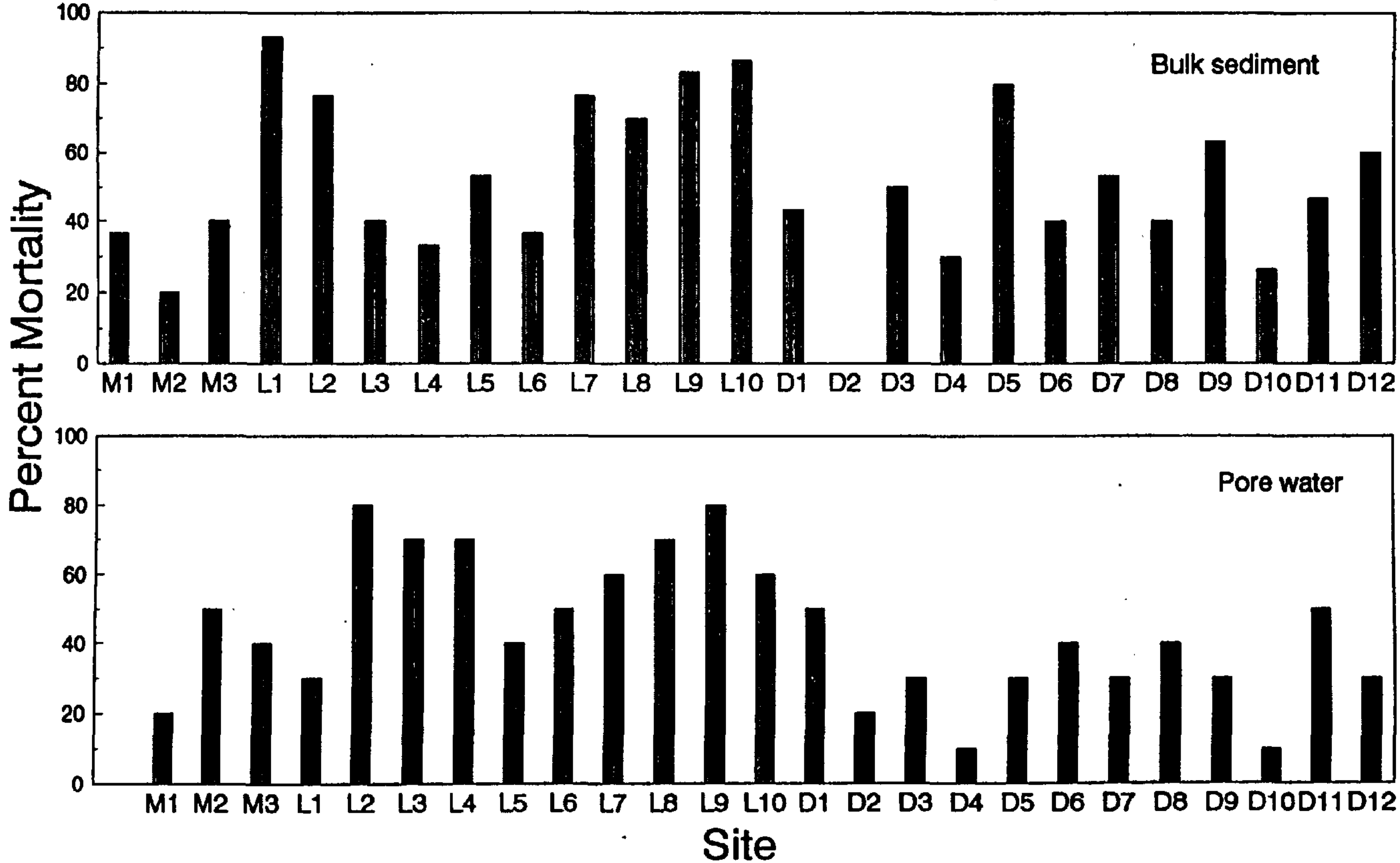
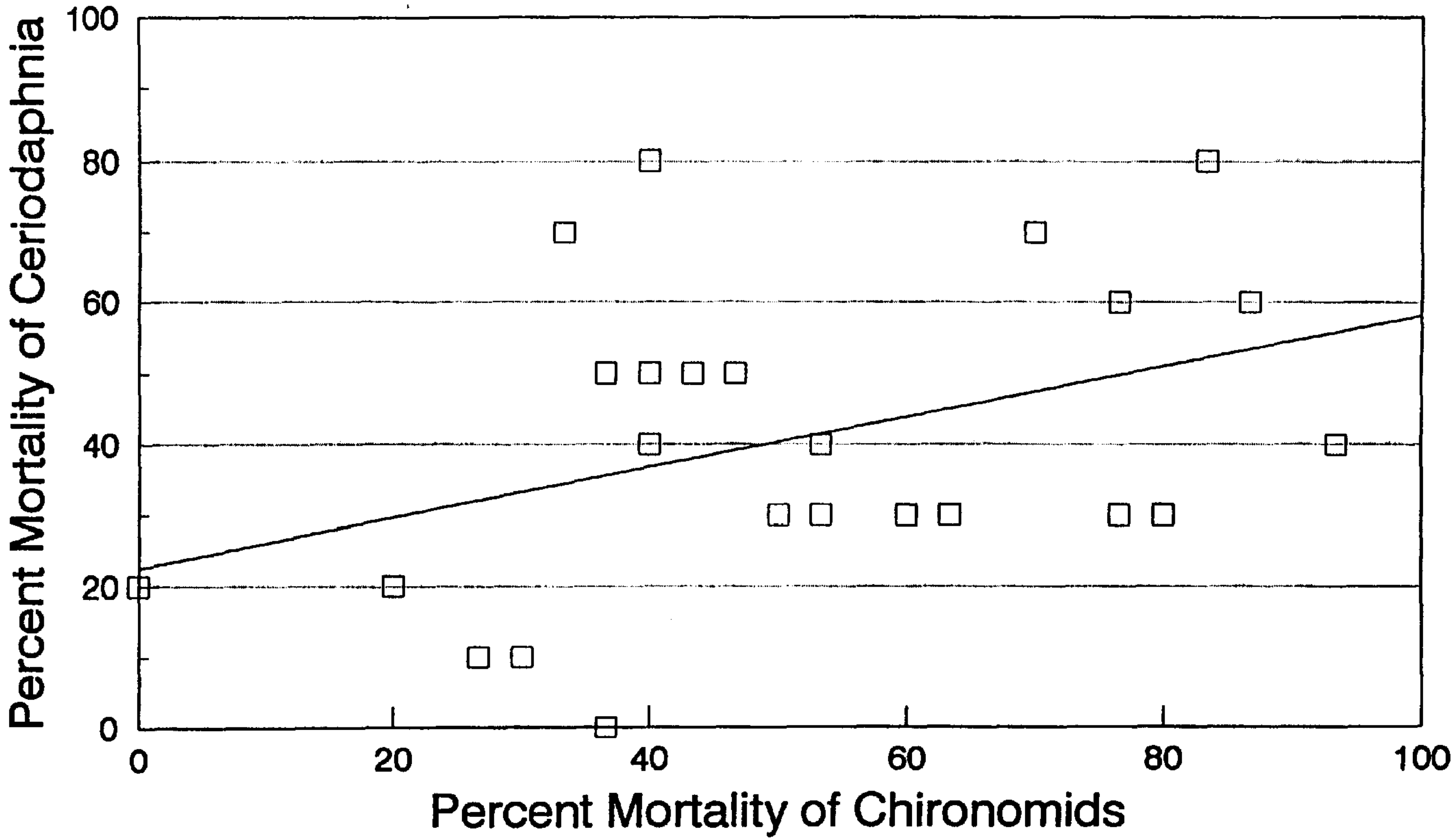


Fig. 3

Relationship Between Chironomid and Ceriodaphnia Mortality



CONTAMINANT ASSIMILATION, WATER QUALITY MONITORING, AND AQUATIC MACROINVERTEBRATE COLONIZATION IN WETLANDS AT THE ROCKY MOUNTAIN ARSENAL

Annual Report Submitted to the U.S. Fish and Wildlife Service
Rocky Mountain Arsenal, Adams County, CO

December 1994

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This report summarizes work performed throughout 1994. Activities accomplished throughout the past year include completion of macroinvertebrate processing in March, initial analysis of water quality and macroinvertebrate data, analysis and writing of contaminant assimilation data, and presentation of the latter at three professional meetings.

This report consists of two sections. The first presents water quality and macroinvertebrate work completed on the newly-created RMA wetlands, focusing on wetlands RMA3 and RMA4. The second presents work on contaminant assimilation within the water column of RMA3 and RMA4. Both sections are preliminary, although the latter section is nearing completion. There is some overlap between chapters, primarily in the introductory and methods sections. This allows each chapter to stand on its own. Page numbering and figures are separate between sections. Revisions in the upcoming final report will not include this redundancy.

WATER QUALITY AND MACROINVERTEBRATE COLONIZATION OF ROCKY MOUNTAIN ARSENAL WETLANDS

INTRODUCTION

During the summer of 1991, the U.S. Fish and Wildlife Service and the U.S. Army created five new wetlands on Rocky Mountain Arsenal (RMA). These wetlands were created for provision of habitat on what is soon to be a national wildlife refuge. Due to RMA's proximity to residential, industrial, and transportational land uses, nonpoint pollution of surface waters is of concern to the USFWS.

Creation of these wetlands provided the opportunity to study water quality and macroinvertebrate colonization of newly created wetlands on the eastern plains of Colorado, of which data is currently lacking. Because there is a concern for future nonpoint pollution, there is a need for background information on the water quality and macroinvertebrate communities in these wetlands.

SITE DESCRIPTION

RMA is located 7 km northeast of downtown Denver, Colorado, just north of Stapleton International Airport and 5 km west of Denver International Airport. RMA is surrounded by residential communities and industrial activities to the south and west. It is expected that there will be industrial and commercial development to the east due to eventual operation of the new airport.

The wetlands were created on the southeast corner of RMA during the summer of 1991. Wetlands RMA3, RMA4, and RMA5 were natural basins requiring only water for wetland creation. A road which serves as a dike on the west perimeter of RMA2 was heightened so as to elevate the water holding capacity of this basin. Machine scale landscaping was performed on RMA1. The main basin of this wetland was layered with bentonite to guarantee a permanent pool.

Ditches were dug connecting Highline Lateral Canal to all five wetlands. Highline Lateral branches off of Highline Canal, southeast of the RMA boundary. Water for Highline Canal is diverted from the South Platte River (prior to entry into Chatfield Reservoir). Filling of the basins is dependent upon water rights, natural precipitation, and snow melt.

RMA1 and RMA4 were hydrologically permanent wetlands, maintaining surface water throughout the study period (Table 1). RMA3 was semipermanent, running dry for three weeks during May 1992. RMA2 and RMA5 were temporary wetlands throughout the study, the latter maintaining surface water for approximately eight weeks following inundation. RMA2 maintained water throughout most of the study, but this often consisted of a 10 m diameter pool.

METHODS

Water Quality: Wetlands with measurable surface water (>0.05 m) were sampled weekly in 1991, from 16 August through 21 November. Sampling in 1992 and 1993 occurred from ice-off (early March) through the fall freeze (late November). Field measurements included water temperature, dissolved oxygen, and depth. Temperature and dissolved oxygen were measured with a Y.S.I. Model 51B dissolved oxygen meter. On each occasion, 1 L of water was collected from each wetland and transferred to the laboratory (Colorado State University, Fort Collins, CO). Conductivity and pH were measured with a VWR Scientific EC Meter (Model 1054) and a Chemacadet pH meter (Model 5984-50), respectively. Alkalinity and hardness were determined using sulfuric acid titration (pH 4.5) and EDTA titration, respectively (USEPA 1983).

Macroinvertebrates: Macroinvertebrates were collected from RMA3 and RMA4 biweekly from September 1991 through November 1993, excepting ice cover periods (December through February). Each sweep was conducted for thirty seconds, working from the middle of the wetland (defined as the greatest depth) towards the shore using a D-frame net (1 mm-mesh). Equal sampling effort was spent in three zones; the greatest depths, intermediate depths, and shoreline (including the open water, vegetation, and benthic habitats). The net was maneuvered through each zone for ten seconds. Samples were preserved in 70% ethanol and transferred to the laboratory where they were sorted, identified, and enumerated. Identification was taken to the lowest taxa possible using Merritt and Cummins (1988).

Statistical Analysis

Water Quality: All data was analyzed with SAS[R] statistical software (SAS 1989). Due to non-normal distribution and heterogeneity of variances in water quality data, results were analyzed with nonparametric methods. Data was pooled by season (within years) to allow comparisons between and within wetlands over time. Wilcoxon's sign rank method (PROC NPAR1WAY, SAS 1989) was used to determine statistical differences in measured parameters between and within wetlands. Unless stated otherwise, water quality and macroinvertebrate data was assessed with $\alpha=0.05$. To control experimentwise error rate, α-values were adjusted with the Bonferroni method.

Macroinvertebrates: Relative abundance was determined at the generic and functional group scale. Functional group designation was based on Merritt and Cummins (1988). Species diversity (Shannon-Wiener) and richness were plotted over time using monthly means. Comparisons of diversity, richness, and evenness were made between wetlands using seasonally pooled data from 1991 through 1993. Significant differences between wetlands were determined with t tests (SAS 1989).

RESULTS and DISCUSSION

WATER QUALITY

Within Wetlands, RMA3: Water quality data from all newly-created wetlands and Ladora Lake is listed in Appendix A. Depth was highly variable within RMA3, particularly in 1992 (Fig.1, Table 1). Generally, alkalinity and hardness were significantly lower during seasons in which depth was significantly greater than the previous year (i.e., fall 1992, spring 1993). Dissolved oxygen increased throughout the study. This was expected due to decreasing oxygen demand following initial inundation in August 1991. There was a general increase in pH throughout the study.

Within Wetlands, RMA4: Water hardness, conductivity, and pH increased significantly throughout the study (Fig.1, Table 2). Bottom depth of RMA4 was relatively stable, with the exception of significantly greater depths in the fall of 1992.

Comparisons Between Wetlands: There were no significant differences in water quality between wetlands the first summer following inundation (Fig.1, Table 3). Greater depths of RMA4 throughout the fall of 1991 and spring of 1992 resulted in significantly lower alkalinity, hardness, and conductivity relative to RMA3. The similar depths of the wetlands in the fall of 1992 resulted in similar water quality between the two. Although depth was typically greater in RMA4 throughout 1993, conductivity was consistently higher, as was alkalinity in the fall.

The differences in conductivity between wetlands in 1991 and 1992 was driven primarily by water depth. However, in 1993 conductivity increased within RMA4 regardless of depth, and was consistently higher than in RMA3. This was most likely a result of differences in surrounding landscapes of each wetland. RMA3 is surrounded by flat, sandy terrain. This results in little, if any interaction with groundwater. RMA4 is situated in a relatively well defined basin. Following precipitation events (i.e., snowmelt or rainfall), groundwater from the adjacent southern slope discharges into the wetland or at the wetland periphery. This results in a buildup of salts, which, following rainfall or during filling via overland flow, is washed into the wetland. Thus, differences in hydrology of these wetlands as a result of surrounding landscapes appear to be influencing their respective water quality characteristics.

MACROINVERTEBRATES

Fifty four taxa were identified from RMA wetlands (Appendix B). Plotting of relative abundance of individual taxa illustrated wetland development over time. For example, the mayfly *Callibaetis* dominated community abundance in the fall of 1992 and was consistently abundant throughout much of 1993 in both wetlands (Fig.2.a.). Relative abundance of *Enallagma* (a damselfly) peaked in the late summer-early fall of 1992 and 1993 within RMA3, whereas this peak was only evident during 1993 in RMA4.

Both of these organisms are primarily epiphytic but differ in feeding strategies. *Callibaetis* is a collector-gatherer whereas *Enallagma* is a stalking predator. The gradual establishment of both of these organisms is probably related not only to their colonization abilities (of which both are well adapted for) but also to development of food resources (i.e., algae, oligochaetes, Chironomid larvae). The notably low relative abundance of *Enallagma* in RMA4 during the summer/fall of 1992 may be a result of other factors such as higher densities of predaceous fathead minnows (*Pimephales promelas*). The dry period in RMA3 during the spring of 1992 killed fathead minnow populations which had become established over the previous six months. This did not occur in RMA4, thus, fish may have maintained relatively low abundance of *Enallagma* throughout 1992. Increasing community diversity throughout 1993 may have provided alternative food items for predaceous fish, allowing *Enallagma* to become increasingly abundant.

Planorbidae (an obligatory epiphytic snail) abundance within RMA4 increased gradually from the summer of 1992 through the fall of 1993 (Fig.2.b.). This trend was similar, but delayed in RMA3.

This most likely demonstrates a response to vegetative growth which was dependent on the hydrology. Vegetation became established in RMA4 early relative to RMA3. This is possibly a result of the 1992 dry period in RMA3, or may be due to a relatively superior seed bank in RMA4 (D. Cooper, personal comm.).

The predatory midge Tanypodinae (subfamily of Chironomidae) was present in relatively low abundance throughout 1992, followed by a peak in the spring of 1993 in both wetlands (Fig.2.b.). This may demonstrate both a need for this taxa to establish its population through a complete year, and/or an increase in prey base during the spring of 1993, which had not occurred by the spring of 1992.

Relative abundance at the functional group level in 1991 was dominated by collector-gatherer/filterers (primarily Chironominae) and piercer-predators (primarily Corixidae, order Hemiptera). These organisms are typical of early colonizers of temporary habitats (Wiggins 1980). There was high relative abundance of collector-gatherer/filterers in the spring and fall of 1992. This is a result of high relative numbers of Chironominae and *Callibaetis* (early and late, respectively, Fig.3). These trends were similar but more stable in 1993.

Predator abundance was dominated by damselflies (primarily *Enallagma*) whereas the piercer-predators consisted primarily of Corixids. Predators overall became well established in both wetlands during the summer of 1992 and were consistently abundant within RMA3 throughout 1993 (Fig.3). Predator relative abundance in RMA4 was high in the spring and moderate throughout the rest of the year, dominated by *Enallagma*. Scrapers (Gastropods) became well established during the summer of 1992 and maintained relatively high abundance in both wetlands throughout the summer and fall of 1993.

At the community level, species richness and diversity increased rapidly following inundation and also following the dry period in RMA3 (Fig.4). Trends in 1992 and 1993 suggest increasing richness and diversity during the summer in both wetlands during 1992. This trend is not as evident in 1993. Trends in evenness were similar to species diversity. Comparisons of data pooled by season over all years indicate similar species richness between wetlands in each season. Diversity and evenness were significantly greater in RMA4 during the summer ($p=0.004$ and 0.005, respectively).

Overall, trends at the functional group level were less variable than at the generic level. Plotting trends at the generic level highlighted the driving forces behind trends at both the functional group and community scale. Information from each scale adds to interpretation of development of communities in these wetlands. Further analysis will examine similarity between macroinvertebrate communities between wetlands and temporally within wetlands (i.e. spring 1992 vs. spring 1993).

LITERATURE CITED

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Wiggins, GB, RJ Mackay, and IM Smith. 1980. Evolutionary and ecological strategies of animals in annual temporary pools. Archive Hydrobiologie Supplement 58:97-206.

Table 1. Mean depth and surface area of newly-created wetlands at Rocky Mountain Arsenal. Depths were measured weekly (or biweekly) from August 1991 to November 1993, excluding ice-cover periods (late November-mid March).

wetland	depth (m)[1] mean±se (min-max)	surface area (ha)[2]
RMA1	1.28±0.07 (0.06-2.13)	2.62
RMA2	0.36±0.03 (0.00-0.84)	0.10
RMA3	0.58±0.04 (0.00-1.30)	1.60
RMA4	0.74±0.03 (0.31-1.26)	1.49
RMA5	0.50±0.04 (0.00-0.91)	1.08

[1] Mean depths are based on measurements when surface water was present. Zeros were included in range to indicate that wetlands were dry at least one time during this study.

[2] Surface areas were calculated from mean depths.

Table 2. Temporal trends in water quality of wetlands RMA3 and RMA4 from 1991 to 1992 and 1992 to 1993. The arrows indicate a significant increase (↑) or decrease (↓) over time in the measured parameter (α=0.05). 'ns' indicates no significant change over time.

parameter	1991 to 1992 summer	1991 to 1992 fall	1992 to 1993 spring	1992 to 1993 summer	1992 to 1993 fall
RMA3					
pH(SU)	ns	↑	ns	↑	ns
alkalinity(mg/L-CaCO3)	ns	↓	↓	ns	ns
hardness(mg/L-CaCO3)	↑	↓	↓	ns	↑
conductivity(uS)	↑	ns	ns	↑	↑
temperature(°C)	ns	ns	ns	ns	ns
dissolved oxygen(mg/L)	ns	↑	↑	↑	ns
depth(M)	ns	↑	↑	↓	↓
RMA4					
pH(SU)	↑	↑	↑	↑	ns
alkalinity(mg/L-CaCO3)	ns	ns	ns	ns	ns
hardness(mg/L-CaCO3)	↑	ns	↑	↑	↑
conductivity(uS)	↑	↑	↑	↑	↑
temperature(°C)	ns	ns	ns	↓	ns
dissolved oxygen(mg/L)	ns	ns	↑	ns	ns
depth(M)	ns	↑	ns	ns	↓

Table 3. Differences in water quality between wetlands RMA3 and RMA4 from 1991 to 1993. The number indicates a wetland was significantly greater than the other for the respective parameter (α=0.05) while 'ns' indicates no significant difference between wetlands (3=RMA3, 4=RMA4).

	1991		1992			1993		
Parameter	summer	fall	spring	summer	fall	spring	summer	fall
pH	ns	ns	3	ns	ns	ns	ns	ns
alkalinity	ns	3	3	ns	ns	ns	ns	4
hardness	ns	3	3	ns	ns	ns	ns	ns
conductivity	ns	3	3	ns	ns	4	ns	4
temperature	ns	ns	ns	ns	ns	ns	ns	ns
dissolved oxygen	ns	ns	ns	ns	ns	ns	ns	ns
depth	ns	4	4	ns	ns	ns	4	ns

Figure 1. Means of RMA3 and RMA4 water quality parameters measured weekly (or biweekly) from August 1991 through November 1993, excluding December through February. Data represents seasonal means (n=5 to 17), horizontal bars are standard deviation. SP=spring, SU=summer, and F=fall.

Figure 2. Trends in relative abundance of (a) *Callibaetis sp.*, *Enallagma sp.*, (b) Planorbidae, and Tanypodinae in wetlands RMA3 and RMA4 at Rocky Mountain Arsenal. Data represents monthly means collected from September 1991 through November 1993, excluding December through February.

Figure 3. Trends in relative abundance of macroinvertebrate functional groups in wetlands RMA3 and RMA4 at Rocky Mountain Arsenal. Data represents monthly means collected from September 1991 through November 1993, excluding December through February.

Figure 4. Trends in species richness and species diversity (H) of macroinvertebrate communities in wetlands RMA3 and RMA4 at Rocky Mountain Arsenal. Data represents monthly means collected from September 1991 through November 1993, excluding December through February.

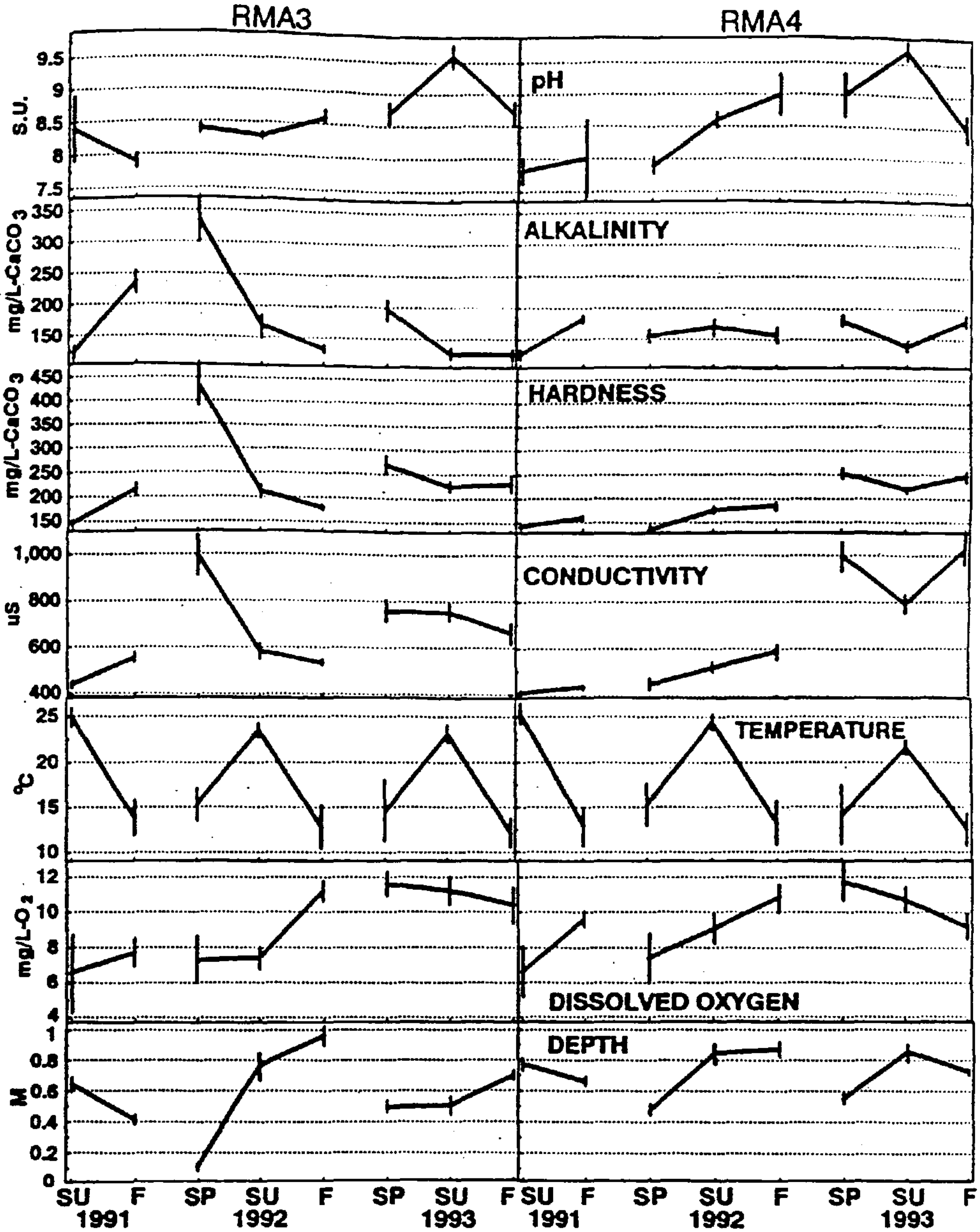
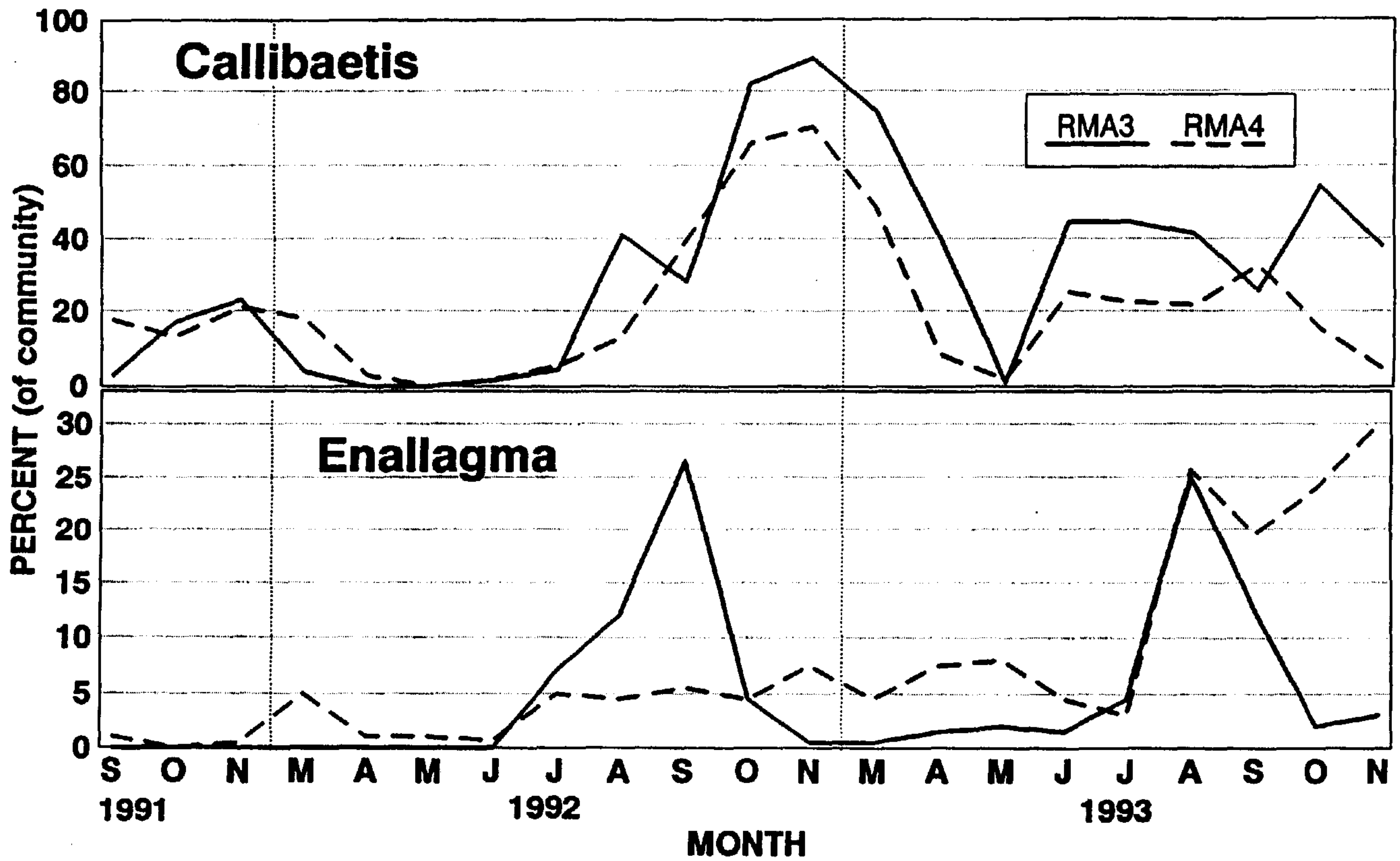

RMA3
RMA4
pH
S.U.
ALKALINITY
mg/L-CaCO3
HARDNESS
mg/L-CaCO3
CONDUCTIVITY
uS
TEMPERATURE
°C
DISSOLVED OXYGEN
mg/L-O2
DEPTH
M
SU F SP SU F SP SU F
1991 1992 1993
SU F SP SU F SP SU F
1991 1992 1993

Figure 1

Figure 2.a.



Callibaetis
Enallagma
RMA3
RMA4
PERCENT (of community)
100
80
60
40
20
0
30
25
20
15
10
5
0
S O N M A M J J A S O N M A M J J A S O N
1991
1992
1993
MONTH

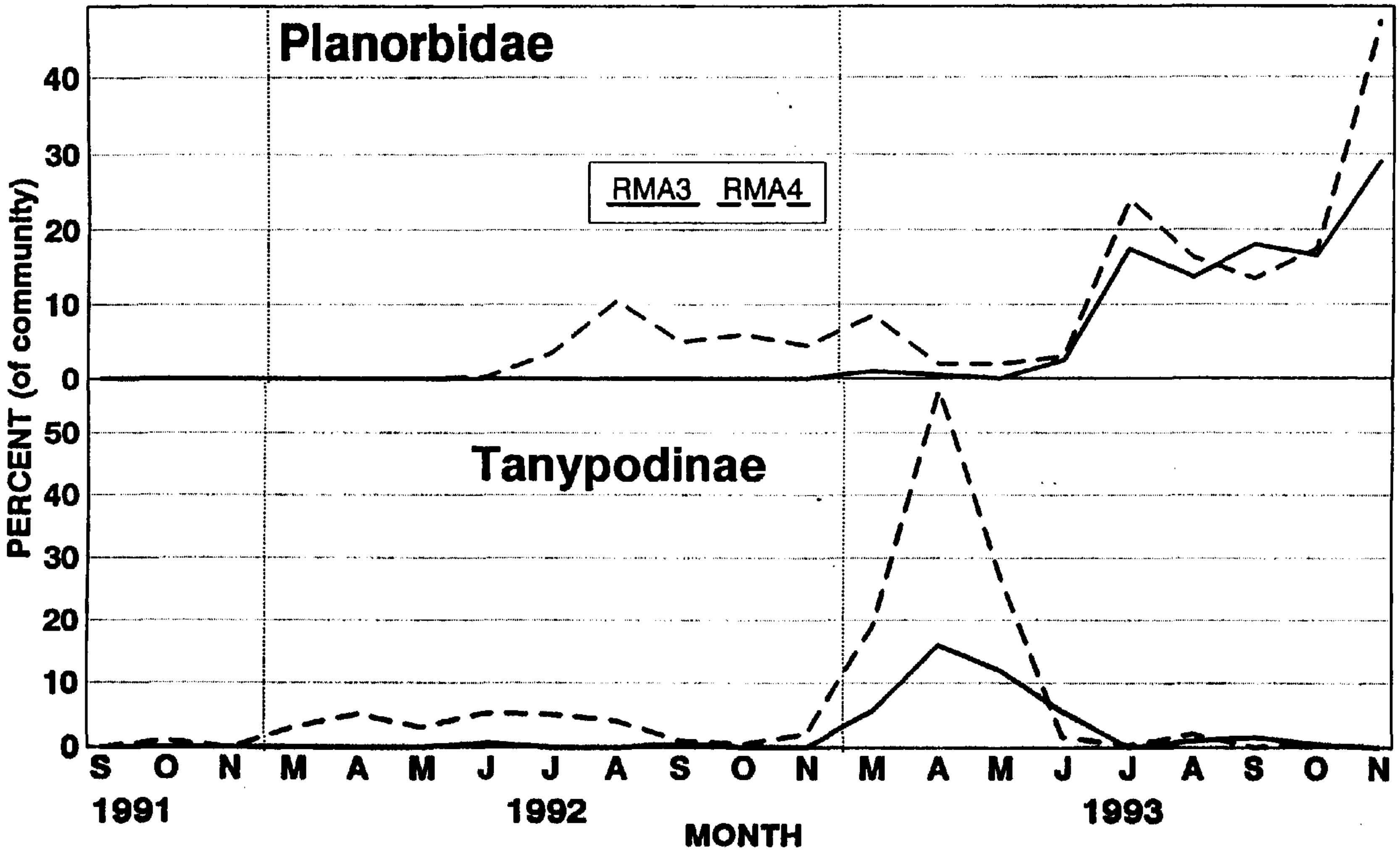
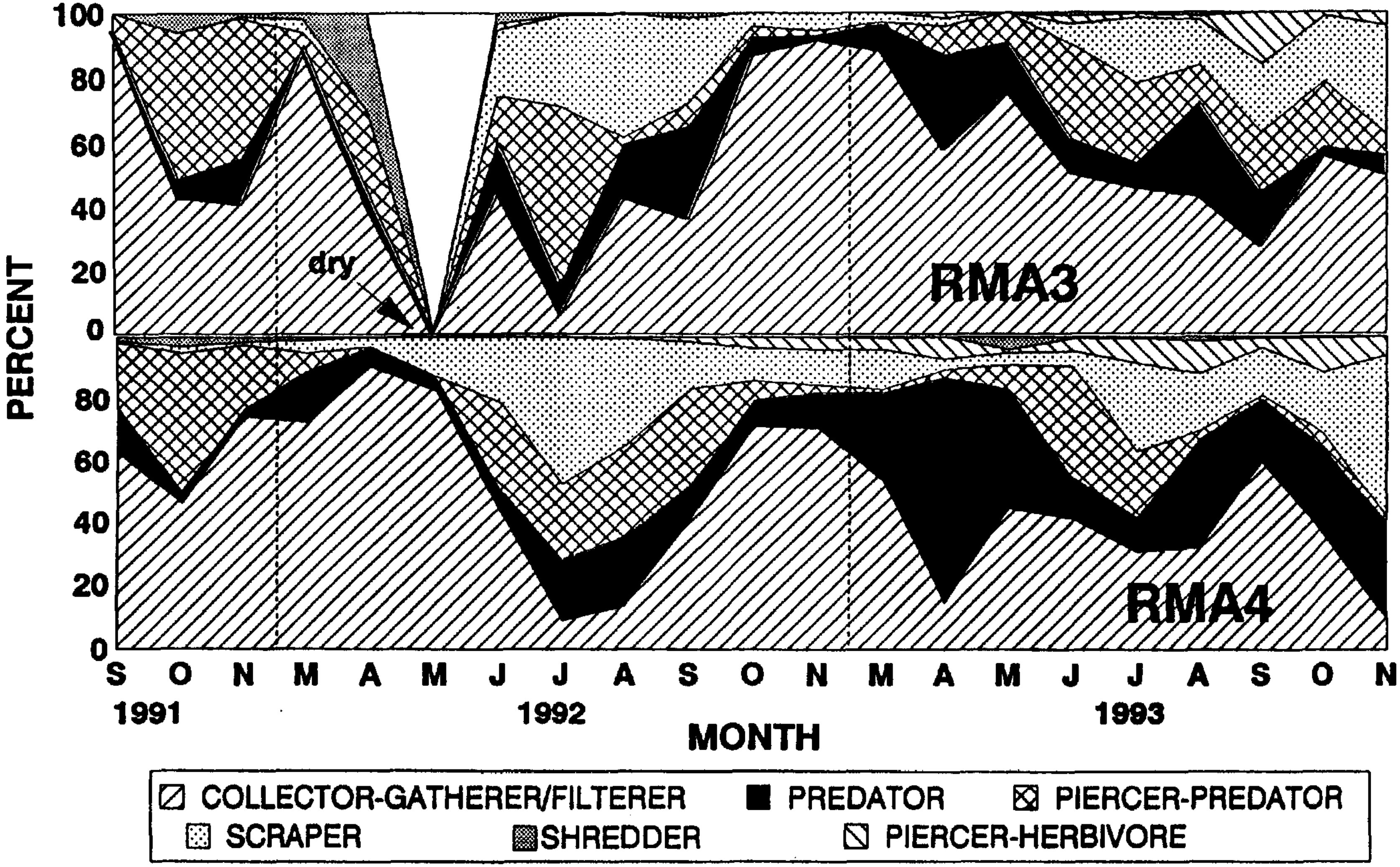
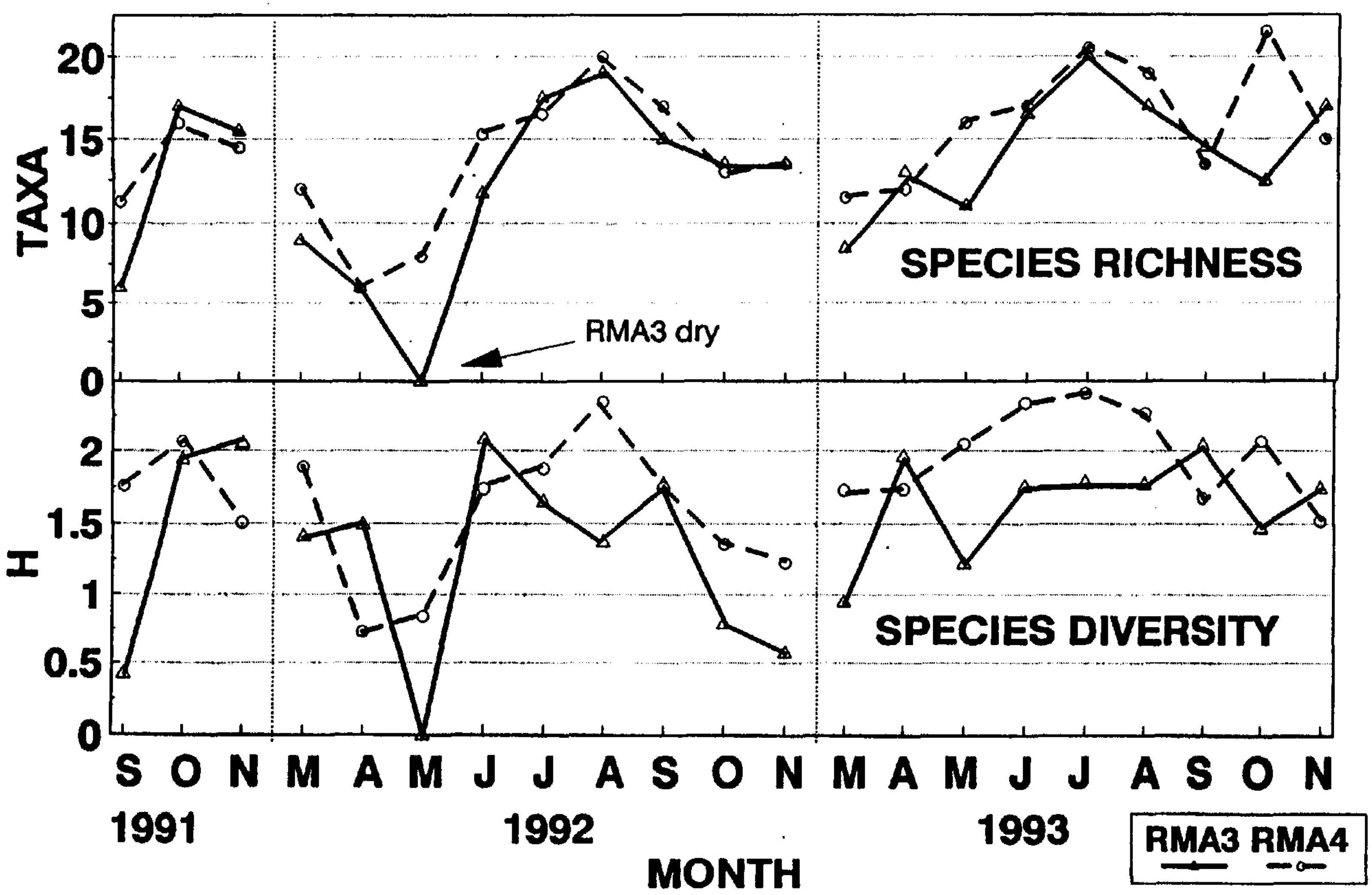

Planorbidae
Tanypodinae
RMA3
RMA4
PERCENT (of community)
40
30
20
10
0
50
40
30
20
10
0
S O N M A M J J A S O N M A M J J A S O N
1991
1992
1993
MONTH

Figure 2.b.

Figure 3



PERCENT
100
80
60
40
20
0
dry
RMA3
RMA4
S O N M A M J J A S O N M A M J J A S O N
1991
1992
1993
MONTH
COLLECTOR-GATHERER/FILTERER
PREDATOR
PIERCER-PREDATOR
SCRAPER
SHREDDER
PIERCER-HERBIVORE



TAXA
20
15
10
5
0
SPECIES RICHNESS
RMA3 dry
H
2
1.5
1
0.5
0
SPECIES DIVERSITY
S O N M A M J J A S O N M A M J J A S O N
1991
1992
1993
MONTH
RMA3 RMA4

Figure 4

Appendix A. Regularly monitored water quality parameters in newly-created Rocky Mountain Arsenal Wetlands and Ladora Lake (RMAL).

RMA1

year	season	date	pH (SU)	alk* (mg/L CaCO3)	hard (mg/L CaCO3)	cond (umho)	temp (°C)	diss. oxygen (mg/L)	total depth (m)
1991	summer	16 Aug	.	.	.	.	.	.	.
		29 Aug	.	.	.	.	.	.	.
		5 Sep	.	.	.	.	.	.	.
		12 Sep	.	.	.	.	.	.	.
	fall	19 Sep	.	.	.	.	.	.	.
		26 Sep	.	.	.	.	.	.	.
		30 Oct	.	.	.	.	.	.	.
		17 Oct	.	.	.	.	.	.	.
		24 Oct	8.9	220	62	890	11	9.5	.
		7 Nov	8.9	200	60	842	7	10.5	.
		21 Nov	.	.	.	.	.	.	.
1992	spring	17 Mar	9.2	119	88	364	10	8.7	0.55
		31 Mar	8.9	142	94	411	9.5	9.4	0.40
		14 Apr	8.8	196	127	520	19	7.9	0.06
		16 Apr	8.8	198	129	517	14	9.4	.
		21 Apr	.	.	.	.	.	.	.
		5 May	8.9	287	94	916	12	8.1	0.52
	summer	19 May	8.8	102	130	455	20	8	1.43
		3 Jun	7.8	96	123	415	19	7.5	1.83
		9 Jun	8	94	120	398	18.5	3.9	2.03
		16 Jun	8	92	124	389	23	3.7	2.12
		24 Jun	8	110	138	423	24.5	1.7	2.13
		30 Jun	8	115	142	441	23	4.5	2.04
		7 Jul	8.1	132	151	465	24.5	4	1.95
		14 Jul	8.2	142	151	484	24.5	5	1.87
		21 Jul	8.3	142	152	470	25	6.4	1.83
		28 Jul	7.9	151	156	490	25	5	1.75
		5 Aug	8.3	160	156	510	22	5.4	1.65
		11 Aug	8.8	163	155	509	25	9.1	1.57
		19 Aug	9.1	156	142	494	24	14.3	1.51
		25 Aug	9.2	92	104	386	19	10.2	1.83
		9 Sep	8.9	84	113	410	18.5	8.2	2.09
	fall	21 Sep	8.4	112	133	458	19	8.4	1.92
		5 Oct	8.8	105	130	474	17	9.9	1.77
		19 Oct	8.8	110	128	494	13.5	10.8	1.63
		2 Nov	8.9	111	124	498	8	10.8	1.52
		16 Nov	8.8	107	118	494	8	11.2	1.42
1993	spring	11 Mar	9.1	90	83	436	5	10.4	1.13
		30 Mar	9.2	109	92	481	8	10.4	1.04
		13 Apr	9.5	102	74	450	13	10.2	1.04
		27 Apr	9.8	100	62	468	17	11	0.99
		6 May	10.2	107	56	509	17	11	0.91
	summer	18 May	8.6	138	75	555	21	7.6	0.87
		2 Jun	8.5	116	127	465	19	5.6	1.4
		8 Jun	8.7	130	136	499	18	8.5	1.3
		15 Jun	8.9	126	130	509	22.5	7.6	1.19
		22 Jun	8.7	133	136	520	23	7.8	1.16
		29 Jun	8.7	114	129	485	23.5	7.6	1.23
		6 Jul	8.7	134	146	568	18	7.1	1.13
		13 Jul	8.6	146	151	606	20.5	6.2	1.07
		20 Jul	8.6	137	137	603	22.5	6.4	1.02
		26 Jul	8.8	136	134	628	22	8.3	0.98
		3 Aug	8.9	146	136	693	19	6.6	0.9
		10 Aug	9	124	112	679	20	6.8	0.85
		17 Aug	9.9	98	74	660	19	5.8	0.81
		26 Aug	10	98	62	722	19.5	14.2	0.75
		31 Aug	9.6	118	74	737	15.5	11.6	0.73
		8 Sep	9.4	134	68	767	15.5	4.8	0.7
		15 Sep	9.5	158	76	805	14	10.8	0.67
	fall	22 Sep	9.3	78	108	419	15	12	1.34
		29 Sep	9.5	72	108	386	15	11.2	1.34
		6 Oct	9.2	74	112	408	15.5	8.4	1.2
		13 Oct	9.1	82	112	421	13	10.8	1.13
		27 Oct	8.6	100	126	453	7.5	9.5	1.07
		1 Nov	.	.	.	.	.	.	.
		12 Nov	8.3	120	150	504	4.5	10.5	1.02

* alk=alkalinity, hard=hardness, cond=conductivity, temp=temperature

RMA2

year	season	date	pH (SU)	alk* (mg/L CaCO3)	hard (mg/L CaCO3)	cond (umho)	temp (°C)	diss. oxygen (mg/L)	total depth (m)
1991	summer	16 Aug	8	100	128	382	25	6.6	.
		29 Aug	8.8	75	122	267	31	8.1	.
		5 Sep	9.1	120	132	212	28.5	8.5	0.22
		12 Sep	9.8	115	134	407	26	15	0.17
	fall	19 Sep	9.1	140	172	505	22.5	15	0.07
		26 Sep	.	.	.	.	.	.	.
		30 Oct	.	.	.	.	.	.	.
		17 Oct	.	.	.	.	.	.	.
		24 Oct	.	.	.	.	.	.	.
		7 Nov	.	.	.	.	.	.	.
		21 Nov	.	.	.	.	.	.	.
1992	spring	17 Mar	7.5	15	15	81	13	9.9	0.16
		31 Mar	7.4	22	26	62	11	9.6	0.17
		14 Apr	.	.	.	.	.	.	.
		16 Apr	.	.	.	.	.	.	.
		21 Apr	.	.	.	.	.	.	.
		5 May	.	.	.	.	.	.	.
	summer	19 May	7.8	110	156	502	27	7.1	0.64
		3 Jun	7.8	93	127	415	21.5	5.2	0.73
		9 Jun	7.7	74	106	346	16	3.8	0.79
		16 Jun	8.1	86	123	384	22	2.9	0.72
		24 Jun	8	87	132	398	25	7.3	0.73
		30 Jun	8.1	102	147	432	22	5	0.58
		7 Jul	8	110	158	459	22.5	4.2	0.4
		14 Jul	8.2	108	156	478	23.5	7.6	0.3
		21 Jul	8	76	85	263	21.5	6	0.35
		28 Jul	7.8	95	107	318	24.5	10.2	0.24
		5 Aug	8.9	124	131	384	22	11.6	0.21
		11 Aug	8.8	147	158	444	20.5	9	0.15
		19 Aug	8.4	199	188	519	26	8.4	0.14
		25 Aug	7.8	68	114	351	15.5	6.1	0.79
		9 Sep	7.9	90	152	488	17	5.2	0.64
	fall	21 Sep	7.7	138	204	636	20.2	5.7	0.27
		5 Oct	8.1	82	170	654	16	13.6	0.17
		19 Oct	7.7	69	183	755	11	8.8	0.11
		2 Nov	8.7	135	246	887	8	11.6	0.08
		16 Nov	8	182	284	981	10.5	10.4	0.06
1993	spring	11 Mar	.	.	.	.	.	.	0.18
		30 Mar	.	.	.	.	7	10.7	0.12
		13 Apr	9.1	94	82	295	17	9.8	0.12
		27 Apr	.	.	.	.	.	.	.
		6 May	.	.	.	.	.	.	.
	summer	18 May	.	.	.	.	.	.	.
		2 Jun	7.7	109	143	445	20	3.4	0.76
		8 Jun	7.5	117	152	481	15	4.5	0.59
		15 Jun	7.9	97	142	426	22	8	0.55
		22 Jun	8	78	118	351	20.5	5.7	0.67
		29 Jun	8.2	73	118	359	23.5	6.4	0.76
		6 Jul	8.7	66	118	346	19	7.4	0.84
		13 Jul	8.2	72	120	383	21	13	0.59
		20 Jul	8.3	93	138	426	23	13.5	0.37
		26 Jul	8.1	96	156	474	19.5	8.6	0.24
		3 Aug	8.8	54	122	492	17	9.2	0.18
		10 Aug	8.1	68	144	561	21.5	14	0.15
		17 Aug	.	.	.	.	.	.	0.11
		26 Aug	8	82	142	425	20	6.2	0.55
		31 Aug	8	88	152	444	15	6.8	0.38
		8 Sep	8.6	108	172	495	14.5	6.6	0.17
		15 Sep	8.4	110	174	522	14	9.2	0.21
	fall	22 Sep	8	62	98	312	15.5	8.3	0.66
		29 Sep	7.9	70	112	349	13	5.4	0.47
		6 Oct	7.8	90	138	420	14.5	7.4	0.24
		13 Oct	8.2	94	142	428	15	10.4	0.21
		27 Oct	8	78	100	309	7	10.8	0.21
		1 Nov	.	.	.	.	.	.	.
		12 Nov	8	72	92	285	5	13.2	0.21

* alk=alkalinity, hard=hardness, cond=conductivity, temp=temperature

RMA3 year	season	date	pH (SU)	alk* (mg/L CaCO3)	hard	cond (umho)	temp (°C)	diss. oxygen (mg/L)	total depth (m)
1991	summer	16 Aug	7.4	100	132	399	25.5	2	.
		29 Aug	8.8	114	144	449	27	8.2	.
		5 Sep	9.6	130	146	431	25	12	0.7
		12 Sep	7.8	150	158	467	22	3.7	0.59
	fall	19 Sep	7.4	170	176	473	15.5	4.1	0.56
		26 Sep	7.9	185	182	505	21	6.7	0.37
		30 Oct	7.9	205	190	501	18	8.3	0.31
		17 Oct	8.2	250	222	596	16	8.2	0.46
		24 Oct	7.8	285	246	632	11	6.2	0.43
		7 Nov	8.1	290	252	610	7	9.7	0.37
		21 Nov	8.2	262	242	568	8	10.4	0.35
1992	spring	17 Mar	8.3	240	294	716	11.5	7	0.17
		31 Mar	8.3	264	380	873	11.5	8.6	0.18
		14 Apr	8.3	395	520	1139	20	8.8	0.12
		16 Apr	8.4	367	469	1065	14	9.9	0.12
		21 Apr	8.7	400	500	1180	19.5	2	0.09
		5 May	.	.	.	.	.	.	.
	summer	19 May	.	.	.	.	.	.	.
		3 Jun	8.3	81	194	530	23.5	8.4	0.34
		9 Jun	8	77	130	381	17.5	5.7	1.02
		16 Jun	7.9	109	155	452	22.5	0.3	1.08
		24 Jun	8	138	184	519	24.5	5.8	0.98
		30 Jun	8.2	156	204	563	23.5	8.8	0.91
		7 Jul	8.6	179	228	614	26	9	0.84
		14 Jul	8.3	200	238	650	27	8.5	0.78
		21 Jul	8.5	212	245	650	23.5	8.1	0.73
		28 Jul	8.3	222	244	660	27	9	0.67
		5 Aug	8.6	247	265	707	25.5	7.5	0.56
		11 Aug	8.5	268	283	760	25	7.2	0.49
		19 Aug	8.6	286	297	785	26.5	9.7	0.43
		25 Aug	8.1	86	130	392	18	6.3	1.26
		9 Sep	8.4	107	164	486	19	8.6	1.3
	fall	21 Sep	8.8	116	171	499	19.5	10.3	1.17
		5 Oct	8.5	127	176	523	17	10.4	1.05
		19 Oct	8.6	135	180	541	12.5	11.5	0.94
		2 Nov	8.5	141	181	556	7	10.2	0.85
		16 Nov	8.8	140	182	553	8	13.4	0.79
1993	spring	11 Mar	8.4	139	208	600	5.5	10.3	0.59
		30 Mar	8.4	189	258	729	8	10.2	0.52
		13 Apr	8.6	198	278	762	15	11	0.52
		27 Apr	9	229	301	828	22.5	12.6	0.46
		6 May	9.3	226	306	867	22	14	0.37
	summer	18 May	8.8	286	398	1049	26	10.4	0.29
		2 Jun	8.4	119	212	606	20	6.4	0.87
		8 Jun	8.4	130	225	642	19.5	8.6	0.88
		15 Jun	8.5	144	246	690	23.5	7.6	0.79
		22 Jun	9.1	139	235	656	26	15	0.76
		29 Jun	10.1	123	216	660	24.5	15	0.69
		6 Jul	10.5	108	205	697	22	12	0.58
		13 Jul	10.5	92	189	709	23.5	12.2	0.52
		20 Jul	10.2	93	183	715	26	14.1	0.46
		26 Jul	10.6	88	192	786	26	13.9	0.41
		3 Aug	9.8	98	216	896	19	9	0.32
		10 Aug	9.8	102	220	968	26	13.4	0.26
		17 Aug	10.6	94	218	1107	34	15	0.2
		26 Aug	9.3	110	204	603	19	7	0.44
		31 Aug	9.4	132	220	647	18	8.6	0.4
		8 Sep	9.2	150	230	686	19	6.8	0.32
		15 Sep	9.8	142	218	682	20	15	0.27
	fall	22 Sep	8.6	76	148	446	15	9.4	0.85
		29 Sep	8.3	96	186	557	15.5	6.6	0.79
		6 Oct	8	120	222	645	17	6.8	0.72
		13 Oct	8.6	132	240	681	14.5	13	0.67
		27 Oct	9.3	146	266	736	9	12.4	0.64
		1 Nov	9.2	152	274	780	8.2	12.7	0.62
		12 Nov	9.2	154	284	786	5.5	12.2	0.59

* alk=alkalinity, hard=hardness, cond=conductivity, temp=temperature

RMA4

year	season	date	pH (SU)	alk* (mg/L CaCO3)	hard	cond (umho)	temp (°C)	diss. oxygen (mg/L)	total depth (m)
1991	summer	16 Aug	7.2	115	128	374	26	2.5	.
		29 Aug	8.1	120	134	401	27	8.1	.
		5 Sep	7.9	120	146	431	26	8.8	0.81
		12 Sep	8	150	146	420	22	7.1	0.73
	fall	19 Sep	7.8	170	156	416	16.5	9	0.67
		26 Sep	8.1	175	160	437	20	10.6	0.63
		30 Oct	8	185	164	428	17	9.4	0.56
		17 Oct	8.2	188	166	470	15	8.2	0.73
		24 Oct	8	200	164	462	11	8.8	0.69
		7 Nov	7.8	190	160	452	5	9.8	0.67
		21 Nov	8.1	165	148	406	6	11.4	0.67
1992	spring	17 Mar	7.6	122	120	376	10	7	0.58
		31 Mar	7.8	131	122	392	11	8.6	0.56
		14 Apr	7.8	172	145	465	20	6.2	0.47
		16 Apr	7.6	167	138	435	14	3.3	0.48
		21 Apr	7.9	148	127	478	11.5	5.5	0.46
		5 May	8.4	194	161	540	25	13.6	0.34
	summer	19 May	8.8	238	212	677	26.5	15	0.31
		3 Jun	9.5	130	167	532	28	15	0.4
		9 Jun	8.2	88	125	380	18.5	6.3	1.17
		16 Jun	8	115	144	440	22.5	5.4	1.1
		24 Jun	8.1	142	157	476	24.5	5.8	1
		30 Jun	8.2	160	162	492	23	5.5	0.98
		7 Jul	8.1	175	171	510	25.5	6	0.91
		14 Jul	8.6	183	171	515	28	9.3	0.88
		21 Jul	8.6	186	176	520	27	8.5	0.85
		28 Jul	8.2	200	188	549	26.5	8.9	0.81
		5 Aug	8.6	224	206	595	25.5	8.6	0.73
		11 Aug	8.8	248	218	620	25.5	10.6	0.69
		19 Aug	8.7	232	200	607	27	10.5	0.64
		25 Aug	8.5	108	176	432	19	8.8	1.02
		9 Sep	9.7	107	151	474	19	12.8	1.14
	fall	21 Sep	9.8	122	159	499	19.5	13.8	1.04
		5 Oct	9.6	137	168	539	18	10.2	0.93
		19 Oct	8.9	157	184	596	13	10.2	0.84
		2 Nov	8.4	183	200	641	7	8.8	0.79
		16 Nov	8.2	188	205	663	8.5	11	0.73
1993	spring	11 Mar	8.3	162	221	794	5	9.8	0.64
		30 Mar	8.4	207	267	934	8	9.5	0.58
		13 Apr	8.6	195	280	1024	15.5	10.2	0.58
		27 Apr	9.5	170	248	1052	22	14	0.52
		6 May	10	168	250	1172	20	15	0.44
	summer	18 May	9.6	234	266	1281	25	12.8	0.37
		2 Jun	10.2	115	209	763	19.5	13.3	0.53
		8 Jun	10.3	106	184	676	18	11.8	0.72
		15 Jun	10.6	116	195	724	23.5	10.3	0.64
		22 Jun	8.8	93	173	553	24	7.4	1.26
		29 Jun	8.5	122	208	667	24	9	1.16
		6 Jul	9.2	136	220	692	22	10.3	1.11
		13 Jul	9.5	142	222	671	21.5	12.2	1.1
		20 Jul	9.8	147	226	696	23.5	14.1	1.01
		26 Jul	10.4	146	224	723	23	15	0.96
		3 Aug	10	136	214	794	19	10.6	0.88
		10 Aug	10.3	132	206	798	26.5	15	0.84
		17 Aug	10.1	140	216	864	26	10	0.79
		26 Aug	9.8	132	216	813	19.5	6.9	0.81
		31 Aug	9.6	144	276	867	17.5	7.4	0.78
		8 Sep	9.5	152	224	881	17	4.8	0.73
		15 Sep	9.3	160	228	959	18	11	0.7
	fall	22 Sep	9.1	124	198	788	15.5	8.4	0.81
		29 Sep	9.4	158	222	884	16.3	9.8	0.76
		6 Oct	8.8	174	232	927	17.5	7.2	0.72
		13 Oct	7.9	188	244	983	15	7	0.69
		27 Oct	8	208	264	1127	9	8.6	0.69
		1 Nov	8.2	206	278	1240	8.5	12.1	0.69
		12 Nov	8.3	200	282	1245	5.5	11.4	0.67

* alk=alkalinity, hard=hardness, cond=conductivity, temp=temperature

RMA5			pH	alk*	hard	cond	temp	diss. oxygen	total depth
year	season	date	(SU)	(mg/L CaCO3)		(umho)	(°C)	(mg/L)	(m)
1991	summer	16 Aug	.	.	.	.	.	.	.
		29 Aug	.	.	.	.	.	.	.
		5 Sep	7.4	110	140	433	25	1.4	0.8
		12 Sep	7.4	140	152	457	23	1	0.57
	fall	19 Sep	8.1	165	164	465	19	10.2	0.37
		26 Sep	7.6	175	174	510	25	7.3	0.18
		30 Oct	.	.	.	.	.	.	.
		17 Oct	.	.	.	.	.	.	.
		24 Oct	.	.	.	.	.	.	.
		7 Nov	.	.	.	.	.	.	.
		21 Nov	.	.	.	.	.	.	.
1992	spring	17 Mar	.	.	.	.	.	.	.
		31 Mar	.	.	.	.	.	.	.
		14 Apr	.	.	.	.	.	.	.
		16 Apr	.	.	.	.	.	.	.
		21 Apr	.	.	.	.	.	.	.
		5 May	.	.	.	.	.	.	.
	summer	19 May	.	.	.	.	.	.	.
		3 Jun	.	.	.	.	.	.	.
		9 Jun	8.1	76	98	301	17	7.5	0.52
		16 Jun	8	90	132	397	23.5	3.2	0.79
		24 Jun	8	86	122	370	25	1.1	0.91
		30 Jun	8	103	131	380	26	2.5	0.78
		7 Jul	8	121	140	402	27	4.9	0.64
		14 Jul	7.8	144	149	413	24	0.4	0.55
		21 Jul	8.2	144	146	406	29	5.6	0.44
		28 Jul	7.9	149	148	412	26	5	0.3
		5 Aug	8.8	150	138	405	28.5	13.5	0.25
		11 Aug	.	.	.	.	.	.	.
		19 Aug	.	.	.	.	.	.	.
		25 Aug	8.3	70	112	338	18.5	9.3	0.69
		9 Sep	7.5	92	135	418	18	6.9	0.88
	fall	21 Sep	7.9	138	146	449	19.5	5.1	0.64
		5 Oct	8	137	158	486	19	7.2	0.4
		19 Oct	7.9	148	170	539	13	7.6	0.15
		2 Nov	.	.	.	.	.	.	.
		16 Nov	.	.	.	.	.	.	.
1993	spring	11 Mar	.	.	.	.	.	.	.
		30 Mar	.	.	.	.	.	.	.
		13 Apr	.	.	.	.	.	.	.
		27 Apr	.	.	.	.	.	.	.
		6 May	.	.	.	.	.	.	.
	summer	18 May	.	.	.	.	.	.	.
		2 Jun	.	.	.	.	.	.	.
		8 Jun	.	.	.	.	.	.	.
		15 Jun	.	.	.	.	.	.	.
		22 Jun	7.4	77	128	388	19	2.1	0.78
		29 Jun	7.5	132	156	451	28	4	0.62
		6 Jul	8.2	74	124	381	24	11.8	0.81
		13 Jul	8	99	151	447	23.5	8.6	0.73
		20 Jul	8.1	122	162	479	25.5	13	0.62
		26 Jul	8.7	134	170	495	25	7.6	0.52
		3 Aug	8.8	154	180	518	19	8.6	0.34
		10 Aug	7.8	178	194	573	29	2.6	0.2
		17 Aug	8.3	180	190	580	24	9.8	0.15
		26 Aug	.	.	.	.	.	.	.
		31 Aug	.	.	.	.	.	.	.
		8 Sep	.	.	.	.	.	.	.
		15 Sep	.	.	.	.	.	.	.
	fall	22 Sep	7.9	68	130	382	16	8.2	0.22
		29 Sep	8.1	72	132	383	17.5	8.6	0.64
		6 Oct	8.1	76	134	397	18	11.2	0.49
		13 Oct	8.3	74	132	386	15.5	13	0.34
		27 Oct	8.1	66	112	343	12.5	4.4	0.15
		1 Nov	8	62	114	354	10	3.7	0.2
		12 Nov	.	.	.	.	.	.	.

* alk=alkalinity, hard=hardness, cond=conductivity, temp=temperature

RMAL

year	season	date	pH (SU)	alk* (mg/L CaCO3)	hard (mg/L CaCO3)	cond (umho)	temp (°C)	diss. oxygen (mg/L)	total depth (m)
1991	summer	16 Aug	.	.	.	.	.	.	.
		29 Aug	8	150	206	775	.	.	.
		5 Sep	8.3	180	202	729	24	8.6	.
		12 Sep	8.1	150	168	517	23	7.1	.
	fall	19 Sep	8	170	180	543	18.5	7.9	.
		26 Sep	8.5	165	186	595	19.5	12.2	.
		30 Oct	8.4	190	214	618	19	12	.
		17 Oct	8.6	182	210	705	15	9.2	.
		24 Oct	8.5	195	210	692	12	9.9	.
		7 Nov	8.8	135	162	599	4.5	10.7	.
		21 Nov	8.4	180	204	657	5	11.2	.
1992	spring	17 Mar	8.3	149	189	665	10.5	10.6	.
		31 Mar	8.4	158	198	689	11.5	9.4	.
		14 Apr	8.3	158	196	678	16.5	9.2	.
		16 Apr	8.3	163	203	685	15.5	9.2	.
		21 Apr	8.5	160	204	713	15	9.8	.
		5 May	8.5	168	212	734	21.5	12.3	.
	summer	19 May	8.6	160	208	719	24	12.9	.
		3 Jun	8.2	144	171	579	21.5	11	.
		9 Jun	8.1	145	174	568	22	6.1	.
		16 Jun	8.1	137	161	518	23.5	8.8	.
		24 Jun	8.3	148	182	602	24.5	7.4	.
		30 Jun	8.3	168	209	663	26	10.3	.
		7 Jul	8.5	158	197	658	25.5	10.6	.
		14 Jul	8.5	168	207	688	27	10.1	.
		21 Jul	8.4	112	138	465	26.5	7.2	.
		28 Jul	8.1	143	154	543	27	5.3	.
		5 Aug	7.9	167	204	657	25	4.8	.
		11 Aug	7.9	163	201	675	24	6.7	.
		19 Aug	8.1	154	194	679	25	8	.
		25 Aug	8	159	195	661	20.5	5.5	.
		9 Sep	8.1	126	168	549	20	7.5	.
	fall	21 Sep	8.3	152	193	638	19.5	8.4	.
		5 Oct	8.3	157	200	676	16	9.7	.
		19 Oct	8.4	167	210	707	12.5	11.4	.
		2 Nov	8.3	162	206	705	7.5	9.3	.
		16 Nov	8.4	153	196	693	7	13.2	.
1993	spring	11 Mar	.	.	.	.	.	.	.
		30 Mar	99	888	888	888	9	9.5	.
		13 Apr	8.4	146	190	663	13	10.4	.
		27 Apr	8.6	150	190	670	17.5	11.5	.
		6 May	8.9	142	190	673	16	12.5	.
	summer	18 May	8.4	165	194	690	19.5	8.2	.
		2 Jun	8.9	195	164	683	21.5	12.6	.
		8 Jun	9.1	189	189	668	20.5	15	.
		15 Jun	9.2	127	166	642	26.5	15	.
		22 Jun	8.8	148	185	663	.	.	.
		29 Jun	8.8	129	180	598	27.5	12	.
		6 Jul	9	128	181	645	23.5	14.7	.
		13 Jul	8.6	127	179	613	23.5	11.5	.
		20 Jul	8.5	151	192	655	25	10.2	.
		26 Jul	8.8	156	190	679	26	13.6	.
		3 Aug	8.7	128	172	598	21	10	.
		10 Aug	8.5	146	180	650	25	9.8	.
		17 Aug	8.3	164	202	675	26	8.8	.
		26 Aug	8.2	132	178	638	21.5	6.7	.
		31 Aug	8.3	6.6	10.7	665	17.5	7.1	.
		8 Sep	8.2	150	190	690	20	7.4	.
		15 Sep	8.8	106	152	610	18	8.5	.
	fall	22 Sep	8.5	124	172	651	16	8.6	.
		29 Sep	9.1	108	156	647	18	11.2	.
		6 Oct	8.9	122	166	661	18.5	14.2	.
		13 Oct	9	100	146	641	14.5	11.1	.
		27 Oct	9.1	114	158	653	11	14	.
		1 Nov	.	.	.	.	.	.	.
		12 Nov	.	.	.	.	.	.	.

* alk=alkalinity, hard=hardness, cond=conductivity, temp=temperature

Appendix B. Macroinvertebrates identified from wetlands RMA3, RMA4, and RMA5 at Rocky Mountain Arsenal from August 1991 through November 1993.

ORDER	FAMILY	GENUS/SUBFAMILY
Ephemeroptera	Caenidae	*Caenis*
"	Baetidae	*Callibaetis*
Zygoptera	Coenagrionidae	*Enallagma*
"	Lestidae	*Lestes*
Anisoptera	Aeshnidae	*Aeshna*
"	"	*Anax*
"	Libellulidae	*Libellula*
"	"	*Sympetrum*
Hemiptera	Corixidae	*Cenocorixa*
"	"	*Corisella*
"	"	*Hesperocorixa*
"	"	*Sigara*
"	"	*Trichocorixa*
"	Notonectidae	*Buenoa*
"	"	*Notonecta*
"	Gerridae	-
"	Saldidae	-
Trichoptera	Hydroptilidae	*Agraylea*
"	Leptoceridae	*Oecetis*
"	"	*Traienoides*
"	Limnephilidae	*Limnephilus*
Coleoptera	Dytiscidae	*Agabus*
"	"	*Copelatus*
"	"	*Coptotomus*
"	"	*Graphoderus*
"	"	*Hygrotus*
"	"	*Laccophilus*
"	"	*Rhantus gutticolis*
"	"	*Thermonectus*
"	"	*Uvarus*
"	Hydrophilidae	*Berosus*
"	"	*Enochrus*
"	"	*Helophorus*
"	"	*Tropisternus*
"	Haliplidae	*Haliplus*
"	"	*Peltodytes*
Diptera	Ceratopogonidae	*Bezzia*
"	"	*Dasyhelea*
"	Chaoboridae	*Chaoborus*
"	Chironomidae	*Chironominae*
"	"	*Orthocladiinae*
"	"	*Tanypodinae*
"	"	*Tanytarsini*
"	Culicidae	*Culex*
"	"	*Culiseta*
"	Stratiomyidae	*Odontomyia*
"	Sarcophagidae	-
"	Syrphidae	-
"	Tabanidae	*Hybomitra*
"	Tipulidae	-
Hydracarina	-	-
Amphipoda	-	-
Gastropoda	Physidae	-
"	Planorbidae	-

CONTAMINANT ASSIMILATION WITHIN THE WATER COLUMN OF TWO COLORADO PRAIRIE WETLANDS

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INTRODUCTION

Beneficial functions provided by wetlands have been well documented (Forbes 1880, Mitsch and Gosselink 1993, Richardson 1993). Understanding these benefits, combined with a need for sound management techniques has led to the use of wetlands in water quality mitigation. Wetlands have been used for treatment of urban runoff, mine tailings, and sewage effluents (Daukas et al 1989, Howard et al. 1989, Schiffer 1989, Silverman 1989). To improve the use of wetlands for water quality enhancement, a greater understanding of the processes which allow wetlands to function as the "kidney of the landscape" (Mitsch and Gosselink 1993) is necessary. This understanding includes the role of abiotic and biotic factors in modifying toxicity of contaminants to aquatic organisms.

Many researchers have demonstrated the influence of physiochemical variables on toxicity of metals to aquatic life (Babich and Stotzky 1985, Sprague 1985). Increased water hardness decreased toxicity of cadmium to *Oncorhynchus mykiss* (Pascoe et al. 1986) and copper to *Ceriodaphnia dubia* (Belanger et al. 1989) and macroinvertebrate communities in experimental streams (Clements et al. 1989). Everall et al. (1989) suggest that high alkalinity (as $CaCO_3$) may decrease toxicity of zinc to fish, whereas Nelson et al. (1994) report the opposite for *C. dubia*. Toxicity of a variety of contaminants is influenced by pH (Campbell and Stokes 1985, Belanger and Cherry 1990) and suspended solids (Sprague 1985, Hall et al. 1986). In addition, dissolved organic matter alters metal toxicity by complexing, adsorbing, and altering metal speciation (Aiken et al. 1985, Babich and Stotzky 1985, MacCarthy 1989). Stackhouse and Benson (1989) demonstrated a decrease in cadmium toxicity to *Daphnia magna* in presence of 5 mg/L humic acid, whereas effects on chromium toxicity were variable.

Other researchers have examined effects of multiple physiochemical factors on metal toxicity. Often these tests are performed using laboratory reconstituted waters (Paulaskis and Winner 1988, Everall et al. 1989, Meador 1991), which improves control of physiochemical parameters. Although the use of natural waters in toxicity testing (Hongve et al. 1980, Belanger and Cherry 1990, Winner and Owen 1991) decreases control of parameters, it allows for more realistic test conditions. Results acquired using site specific wetland water would increase potential for 'success' in the design of wetlands for contaminant assimilation.

We define contaminant assimilation as the ability of a wetland system to buffer aquatic organisms from negative impacts of contaminants. Assimilation of contaminants within a wetland system can occur through interactions with vegetation, sediments, micro-organisms, and within the water column (Sprague 1985, Hammer 1992, Catallo 1993). Because the water column is the first compartment in which contaminants typically encounter wetlands, events occurring here are critical towards the success of the system in treating contaminants. Contaminant assimilative events within the water column include adsorption (i.e., to suspended materials), absorption/uptake (i.e., by phytoplankton), binding (i.e., chelation), and consumption or transformation by zooplankton and bacteria (Babich and Stotzky 1985).

The goal of this research was to examine the influence of several physiochemical variables on contaminant assimilation within the water column of two newly created Colorado prairie wetlands. To achieve this goal, we conducted *Ceriodaphnia dubia* chronic toxicity tests using water collected from these wetlands which was spiked with zinc. Results from this work will be applicable towards the design of wetlands for treatment of nonpoint contaminants.

<u>Site Description</u>

This study was conducted at Rocky Mountain Arsenal National Wildlife Refuge (RMA), located approximately 7 km northeast of downtown Denver, CO (Fig.1). Wetlands RMA3 and RMA4 were created at RMA during the summer of 1991 and are located approximately 0.5 km apart in rolling sand prairie terrain. Both wetlands existed as natural basins, requiring only a consistent water source for wetland creation. Water for the wetlands was supplied by an irrigation supply canal from the South Platte River.

The wetlands were first inundated August 1991, and additional water was supplied to the wetlands (when available) throughout the spring, summer, and fall of each year. Revegetation patterns suggested that both sites had functioned as wetlands in the past (D. Cooper, personal comm.). The RMA3 basin is relatively flat, while RMA4 is bordered to the south and east by a slight rise in elevation, resulting in a well defined basin. Mean depths throughout the study were 0.52 M in RMA3 and 0.71 M in RMA4, covering approximately 1.21 and 1.42 ha, respectively.

METHODS

<u>Test Organisms</u>

Ceriodaphnia dubia used in tests were cultured in the laboratory (Colorado State University, Fort Collins, CO) in moderately hard reconstituted water (pH≈8.25, alkalinity≈65, hardness≈90). Cultures were fed a 1:1 mix of YCT and algae (*Selenastrum* *capricornutum*) and maintained at 25±1°C on a 16:8 h light:dark photoperiod. *C. dubia* used in tests were less than 24 hour old and all obtained within an 8 hour time frame (USEPA 1989).

Chronic Toxicity Tests

Water Quality Assessment: This study involved three sets of *C. dubia* chronic toxicity tests. We first assessed water quality of RMA3 and RMA4 with a standard EPA three brood chronic toxicity test (USEPA 1989). Three grab samples (12 L total) were collected from each wetland and transported on ice to the laboratory. Water was filtered through a plankton net (1 mm mesh) to remove large debris and indigenous organisms. Water from the three locations within each wetland was thoroughly mixed.

C. dubia were exposed to six dilutions (n = 10 per dilution) of water from each wetland (0, 6.25, 12.5, 25, 50, and 100%). Wetland water was diluted with moderately hard reconstituted water (culture water) which also served as the control. Tests were conducted in 30 ml polystyrene cups, each containing 20 ml of test water. Water temperature and light were maintained by a Precision Scientific Incubator (Model 818) at 25±1°C on a 16:8 h light:dark photoperiod. Conductivity, pH, dissolved oxygen, and temperature were measured daily. Water and food (200 μl of YCT:algae mix per day, USEPA 1989). The number of neonates produced per individual was monitored through production of the third brood by a minimum of 80% of the control organisms.

Zinc-Spiked Tests: To estimate zinc assimilation within the two wetlands (RMA3 and RMA4) we measured the change in zinc toxicity over time, and with varying physiochemical conditions. Eight chronic toxicity tests were performed using zinc spiked RMA3 and RMA4 water. Tests were conducted in February, May, July, and November in 1992 and 1993. The May 1992 test was not used in analysis due to improper measurement of suspended solids. Methods were similar to those described above, except that organisms were exposed to various zinc concentrations in 100% wetland water. Zinc was chosen because it occurs commonly in urban runoff (citations), particularly in the vicinity of RMA (Ellis et al. 1984, RMA citation).

Initial target concentrations were 0, 50, 100, 200, and 500 μg/L zinc. Due to 100% mortality in the 500 μg/L zinc treatments during the first three tests, target concentrations were changed to improve assessment of reproductive effects. The 500 μg/L zinc exposures were decreased to 350, 175, and 200 μg/L zinc for tests four, five, and six and seven, respectively. Correspondingly, the 200 μg/L zinc exposures (second highest) were decreased to 125, and 150 μg/L zinc during tests five, and six and seven, respectively. The 50 and 100 μg/L target zinc exposures remained the same throughout the study. Target concentrations were always the same between wetland treatments within tests.

Previous work has demonstrated that suspended solids modify metal toxicity (Babitch and Stotzky 1985, Sprague 1985, Hall et al. 1986). To discern the effects of suspended solids on zinc toxicity, a third set of chronic toxicity tests were performed using filtered and unfiltered water from RMA4. We selected RMA4 for these experiments due to consistently higher levels of suspended solids (pers. observation). Twelve liters of RMA4 water were filtered through a type A/E glass fiber filter (0.45 μm) to remove suspended solids. These tests were performed concurrently with the zinc spiked toxicity tests using RMA3 and RMA4 (unfiltered) water.

Physiochemical Factors: Physiochemical variables measured from the wetlands prior to toxicity tests included pH, alkalinity, hardness, conductivity, temperature, depth, dissolved oxygen, suspended solids, dissolved organic carbon, and total zinc concentration. Physiochemical measurements were made within 12 hours of collection and toxicity tests were started within 24 hours. Suspended solids were measured using gravimetric procedures (EPA 1983). Samples for dissolved organic carbon measurement were filtered (0.45 μm), acidified, and then analyzed using infrared absorption detection. Total zinc was measured on day 0 and at the end of each test with flame atomic absorption spectrophotometry. Temperature and dissolved oxygen were measured in the field with a Y.S.I. Model 51B dissolved oxygen meter. Water (one liter) was collected from each wetland and transferred to the laboratory. Conductivity and pH were measured in the laboratory with a VWR Scientific EC Meter (Model 1054) and a Chemacadet pH meter (Model 5984-50), respectively. Alkalinity and hardness were determined using sulfuric acid titration (pH 4.5) and EDTA titration, respectively (USEPA 1983).

Statistical Analysis

Water Quality Assessment: Data were analyzed with SAS^R statistical software (SAS 1989). The number of neonates (young *C. dubia*) produced per female from the water quality assessment test were analyzed with PROC GLM (SAS 1989). Significant differences (α=0.05) between dilutions within wetland treatments were determined with Ryan's-Q multiple range test (SAS 1989).

Zinc-Spiked Tests: We compared *C. dubia* reproduction and survival between RMA3 and RMA4, and between filtered and unfiltered RMA4 water using non-linear regression and pairwise comparisons. EC_{25} values (effective concentration at which there is a 25% decrease in a response relative to controls) and 95% confidence intervals were estimated to compare effects of zinc on *C. dubia* between wetland treatments. The number of neonates produced (productivity) was estimated as a function of measured zinc concentrations (log_{10}) using weighted non-linear regression (Bruce and Versteeg 1992). We interpreted higher EC_{25} values to be indicative of greater contaminant assimilative capacity of wetland water.

Comparisons of *C. dubia* reproduction and survival between wetland treatments were made with t tests and X^2 analysis, respectively (SAS 1989). Alpha values were 0.05 throughout, and were adjusted with the Bonferonni method when multiple pairwise comparisons were made (Scheider 1993).

Physiochemical Factors: Stepwise multiple regression (SAS 1989) was used to examine the influence of pH, alkalinity, hardness, conductivity, wetland depth, suspended solids, and dissolved organic carbon on zinc toxicity. Mean number of neonates from all zinc treatments was regressed as a function of these physiochemical variables. The significant level of entry (sle) into the stepwise regression model was $p \leq 0.15$. Analysis was performed on each wetland separately. T tests were used to compare physiochemical parameters between wetlands.

RESULTS

Water Quality Assessment: The number of neonates produced increased with percent wetland water in both wetlands (Fig.2). Production in culture water was above the minimum three brood mean (15 neonates/replicate) required by the EPA for satisfactory surface water quality designation (USEPA 1989). These results suggest that water from RMA3 and RMA4 was of sufficient quality for use in our zinc-spiked toxicity tests.

Physiochemical variables: The range in pH was similar between wetlands, and was predominantly between 8.0-9.5 (Table 1). However, pH during test six was 10.6 for RMA3, which resulted in 30% mortality of *C. dubia* exposed to RMA3 control water. Because USEPA (1989) guidelines require 80% survival within control treatments, this test was not used in the comparisons of RMA3 and RMA4. However, because survival in RMA4 and filtered RMA4 water controls was >80%, results from this test were included in comparisons of filtered and unfiltered water.

Dissolved organic carbon was the only physiochemical variable which was significantly different between wetlands ($p=0.01$). Suspended solids and conductivity were both typically higher in RMA4, although neither was significant overall ($p>0.10$). Alkalinity, hardness, and depth were similar between wetlands.

Zinc-Spiked Tests: Toxic effects of zinc on *C. dubia* in RMA3 treatments was greater than on those exposed to RMA4 water. The EC_{25} (95% CI) estimates for RMA3 and RMA4 were 71.3 (57.4-88.6) and 172.7 (168.2-177.2) μg/L zinc, respectively. Productivity and survival of *C. dubia* were similar between wetland controls (Fig.3). Productivity was significantly higher in RMA4 in the 100 and 125-200 μg/L zinc exposures ($p \leq 0.002$, Fig.3a). There was no mortality of organisms exposed to zinc-spiked RMA4 water in the four lowest zinc concentrations (Fig.3b). Survival was significantly greater in RMA4 treatments in the 125-200 and 200-500 μg/L zinc exposures ($p \leq 0.01$).

Six tests were included in the stepwise multiple regression. No physiochemical variables significantly (sle of $p \leq 0.15$) explained mean number of neonates produced by *C. dubia* exposed to zinc-spiked RMA3 water. Suspended solids was the only significant explanatory variable selected in regression of RMA4 results ($F=5.4$, $p=0.08$, $R^2=0.57$).

The EC_{25} estimates for filtered and unfiltered RMA4 water were 114.7 (101.5-129.7) and 97.4 (84.9-111.9), respectively. Although EC_{25} CI's overlapped, histograms display significantly greater productivity and survival of *C. dubia* in unfiltered water. Productivity was significantly higher in unfiltered water in controls and in all levels of zinc exposure ($p \leq 0.01$, Fig.4a). Survival was significantly higher in unfiltered treatments in the 100 and 200-350 μg/L target zinc levels ($p \leq 0.002$, Fig.4b).

DISCUSSION

C. dubia exposed to zinc in water from RMA4 had higher reproduction and survival than organisms in zinc-spiked RMA3 water. Both non-linear regression and pairwise comparisons indicated higher potential contaminant assimilation in RMA4 than in RMA3. Stepwise multiple regression suggested that suspended solids was the most important factor that modified zinc toxicity in RMA4. Suspended solids was positively associated with reproduction and survival of organisms exposed to zinc-spiked RMA4 water.

Suspended solids decrease metal bioavailability to aquatic organisms through sorption and through changes in water chemistry (Sprague 1985, Hall et al. 1986). The extent of metal sorption is primarily a function of organic carbon content, cation exchange capacity, and particle size distribution of suspended solids (Sprague 1985). Addition of suspended solids may also result in water chemistry changes (i.e., increase in alkalinity or hardness) which decrease metal bioavailability (Hall et al. 1986).

This study supports previous findings that show a positive influence of suspended solids on contaminant assimilation within the water column. The significant difference in reproduction between filtered and unfiltered controls suggests that suspended solids may have provided essential nutrients which enhanced *C. dubia* reproduction. Other physiochemical factors (i.e., hardness, DOC) may also contribute to both increased reproduction of test organisms and contaminant assimilative capacity of the water column.

It is generally accepted that DOC, particularly the humic acid (HA) portion, reduces toxicity of trace metals through precipitation, complexation, and adsorption (Hongve et al. 1980, McCarthy 1989, Paulaskis and Winner 1991). DOC was the only parameter which was significantly different between wetlands during toxicity tests (Table 1). Assuming HA constitutes 30 percent of DOC (citation), HA in RMA3 and RMA4 averaged approximately 4 and 6 mg/L, respectively. Paulaskis and Winner (1991) found 0.75 mg/L humic acid decreased zinc toxicity to *D. magna*. Stackhouse and Benson (1989) reported that 5 mg/L humic acid decreased toxicity of cadmium, but had little effect on chromium toxicity to *D. pulex* and *D. magna*. Addition of 2-6 mg/L DOC greatly reduced available Cu^{2+} and subsequent toxicity to *D. magna* (Meador 1991). Hongve et al. (1980) found a slight decrease in zinc toxicity to phytoplankton communities within water with 5.6 mg/L DOC. DOC values throughout our tests were > 9.0 mg/L in both wetlands (Table 1).

Although previous studies have demonstrated that DOC reduces toxicity at concentrations below those measured in RMA3 and RMA4, DOC was not a significant variable in the stepwise multiple regression models. It is possible that DOC was not contributing significantly towards assimilation of zinc, though previously discussed studies suggest this is unlikely. DOC may have been effective in binding zinc up to a certain limit, the limit being below typical values in RMA3 and RMA4, thus, additional DOC functioned little towards decreasing zinc toxicity (i.e., we lacked the lower DOC values necesarry to detect correlations with *C. dubia* responses to zinc stress). Or it is possible that beneficial input of essential nutrients in the *C. dubia* diet may outweigh benefits of complexation of zinc, and as previously suggested, this limit was surpassed in each test. Due to the relatively high concentrations of DOC combined with the significant differences between RMA3 and RMA4 in contaminant assimilative capabilities and DOC, we suggest that this was a significant factor in these wetlands.

Previous work (Bradley and Sprague 1985, Campbell and Stokes 1985) suggests that toxicity of zinc to aquatic biota decreases as pH increases above 7.0 (i.e., 8 < pH < 10) due to increasing Zn(OH) and $ZnCO_3$ precipitation. In river water with high hardness (168 mg/L as $CaCO_3$), zinc was less toxic to *C. dubia* at high pH (9.0) than low (6.0), although this was not statistically significant (Belanger and Cherry 1990). Meador (1991) attributed decreased toxicity of copper to *D. magna* at pH of 8 to particulate formation. Although increasing pH also decreases toxicity of many metals, high pH may also be toxic. Belanger and Cherry (1990) determined the LC_{50} for *C. dubia* with regards to alkaline pH (OH^- concentration) occurred at 10.3. We observed low reproduction and increased mortality in the one test in which pH was >10.3. These results highlight the significance of high pH as an additive stressor not only with regard to toxicity testing, but also ecologically, particularly in the presence of other stresses such as zinc. Little is known of the specific physiological impacts of alkaline conditions on *C. dubia* (Belanger and Cherry 1990).

The difference in landscapes surrounding RMA3 and RMA4 may have influenced the abiotic characteristics of these wetlands. The RMA3 basin was relatively flat and sandy, resulting in little interaction with groundwater. RMA4 actually had groundwater discharging into the wetland periphery following precipitation events (i.e., rain, snowmelt) which resulted in a buildup of precipitated salts. These salts were then flushed into the wetland during filling events (rain, snow melt, overland filling). This process was most likely the source of increasing conductivity in RMA4 two years following creation of these wetlands (pers. observation). Elevated conductivity indicates higher concentrations of ions, such as Ca^{2+} and Mg^{2+} (Hem 1989), which may compete with metals for binding sites on external surfaces of aquatic organisms (i.e., gills). Increasing conductivity of RMA4 may eventually increase the assimilative capabilities of this wetland over time.

Management Implications: The overall goal of this study was to determine which physiochemical factors were most influential in contaminant assimilation within the water column of newly-created wetlands. Our results suggest that suspended solids, dissolved organic carbon, and pH were the most influential factors. We suggest that wetlands may be designed in ways which augment suspended solids and DOC so as to increase contaminant assimilation within the water column. For example, wetland location determines ground water interactions, which influence nutrient levels and the cation-anion composition of the water column. Nutrient levels and suspended solids may also be influenced by the type of water delivery to the wetland (i.e., overland flow, unlined ditch). Use of overland flow and unlined ditches may increase suspended solids and/or nutrient input. The difference in DOC between wetlands in our study may have been a result of the mode in which water was delivered. Water for RMA3 was delivered through unlined ditches, whereas RMA4 was supplied with overland flow.

In addition to wetland location and method of water delivery, other manipulations may enhance contaminant assimilation within the water column of freshwater prairie wetlands (Table 2). Allowing natural variations in depth will promote diversity in vegetation, and subsequently, diverse populations of bacteria and phytoplankton. Decreasing depths (controlling inflow and outflow) will result in increased concentrations of cations (conductivity), enhancing competition with nonorganic contaminants on biotic binding sites (i.e., gills).

In conclusion, contaminant assimilative capacity of wetland water is complex and most likely determined by several physiochemical factors. Information on the influence of combinations of two or three variables on metal toxicity are of great value; however, a connection must be made between these studies and natural field conditions in which a multitude of variables are involved. Site-specific information on water chemistry characteristics, hydrology, and geology are obligatory in the design of wetlands for contaminant assimilation.

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Table 1. Mean values of physiochemical variables of wetlands used in seven chronic toxicity tests. The asterisks indicates significantly different means between wetlands (α=0.05).

	RMA3	RMA4
measured variable	mean ± se (min - max)	mean ± se (min - max)
pH (SU)	8.8±0.4 (7.5-10.6)	8.6±0.4 (7.0-10.4)
alkalinity (mg/L-CaCO3)	165±20 (88-229)	187±22 (125-304)
hardness (mg/L-CaCO3)	223±24 (118-301)	233±32 (120-387)
conductivity (μS)	662±69 (312-828)	823±133 (368-1240)
temperature (oC)	15.1±3.8 (1.0-27.0)	14.1±3.7 (1.0-26.5)
depth (m)	0.51±0.10 (0.06-0.94)	0.69±0.07 (0.41-0.96)
suspended solids (mg/L)	7.0±2.7 (1.9-22.9)	23.7±13.1 (3.1-101.0)
DOC (mg/L)	14.0±1.2 (9-18)	20.7±1.7 (14-27)*

Table 2. Management activities which may enhance contaminant assimilative capacity within the water column of freshwater prairie wetlands.

activity	desired effect	references
<u>Wetland location</u>		
•↑ ground water interaction	•↑ suspended solids*, hardness, and conductivity	•1,2,3,4,5,6
•↑ wind exposure	•↑ suspended solids	•4,5,6
•substrate which promotes neutral pH	•maintain pH of 7-9.5 SU	•2,6,7
<u>Water delivery</u>		
•overland flow	•↑ nutrient input which results in higher DOC	•1,3,5,6,8,9
•unlined ditches	•↑ suspended solids, nutrients(DOC), hardness	•1,2,3,4,5,6,8,9
<u>Hydrology</u>		
•↓ depths during periods of potential contaminant impact	•↑ hardness, alkalinity	•1,2,3,6
•allow for temporal variation in depth	•improve variability in phytoplankton community (maintain and ↑ DOC)	•1,3,5,6,8,9
<u>Habitat</u>		
•promote diverse types of habitat	•maintains healthy, diverse micro-organism populations	•1,10,11

*All references to suspended solids refer to non-contaminated, incoming solids.

1-Marble 1992, 2-Belanger and Cherry 1990, 3-Paulaskis and Winner 1988, 4-Hall et al. 1986, 5-Hongve et al. 1980, 6-this study, 7-Campbell and Stokes 1985, 8-Stackhouse and Benson 1989, 9-Winner and Owen 1991, 10-Babitch and Stotsky 1985, 11-Hammer 1992.

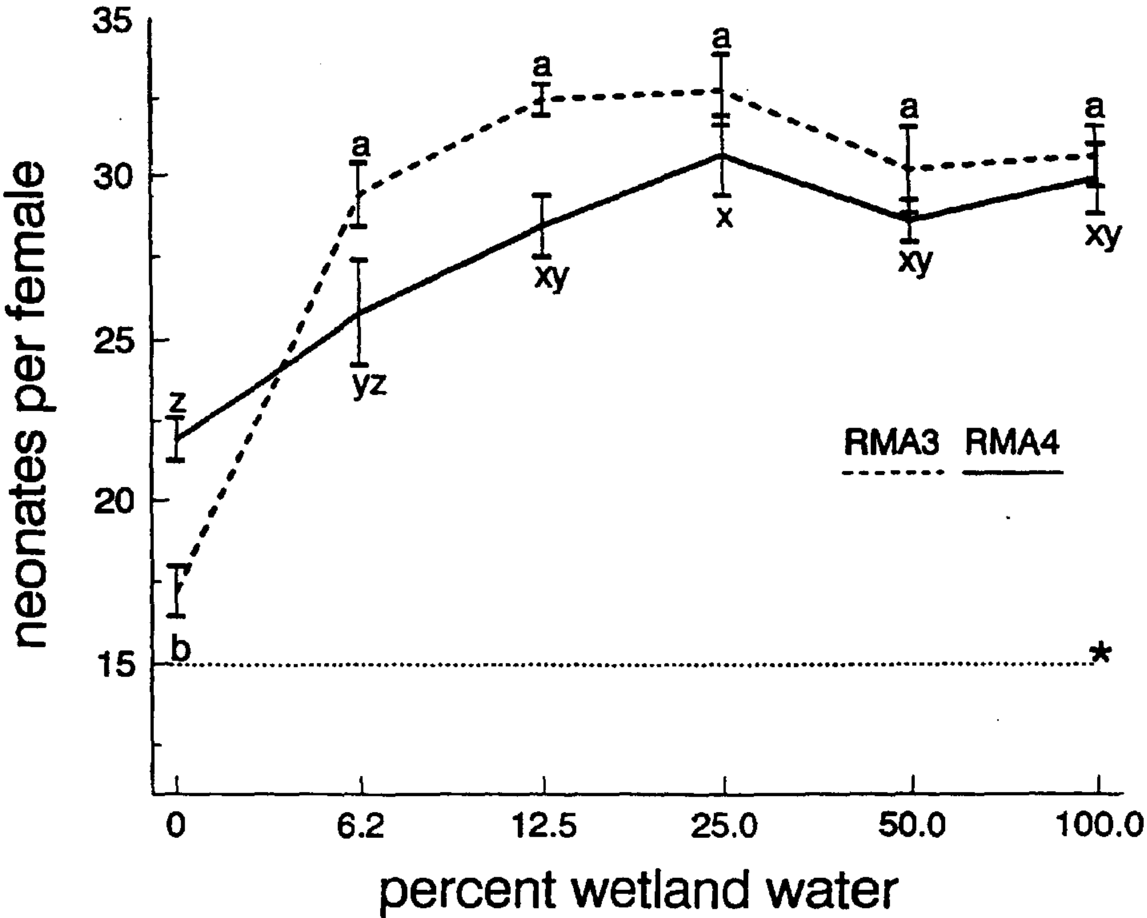
Figures

Figure 1. Wetlands RMA3 and RMA4 at Rocky Mountain Arsenal Wildlife Area, Adams County, CO. (***NOT INCLUDED IN THIS DRAFT***)

Figure 2. Mean number of neonates produced by *Ceriodaphnia dubia* from a standard three brood chronic toxicity tests using water from wetlands RMA3 and RMA4. Error bars represent standard error. Wetland water was diluted with moderately hard reconstituted water. Points with the same letters are not significantly different (α=0.05) and refer to within wetland comparisons.

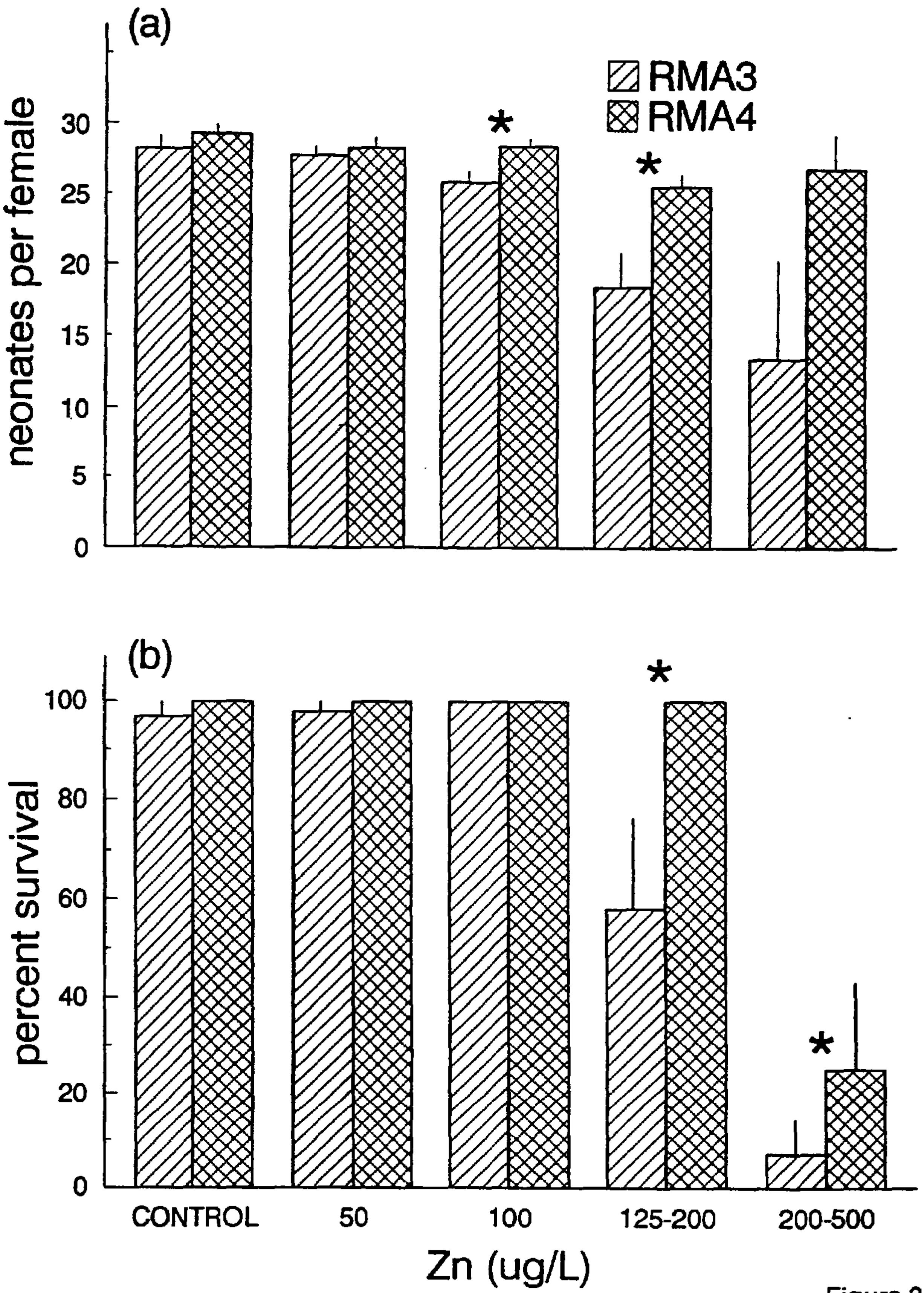
Figure 3. Mean number of neonates produced (a) and survival (b) of *Ceriodaphnia dubia* from six chronic toxicity tests using zinc-spiked RMA3 and RMA4 water. Error bars represent standard errors, asterisks refer to significant differences between wetland exposures (α=0.05).

Figure 4. Mean number of neonates produced (a) and survival (b) of *Ceriodaphnia dubia* from five chronic toxicity tests using zinc-spiked filtered and unfiltered RMA4 water. Error bars represent standard errors, asterisks refer to significant differences between wetland exposures (α=0.05).



* EPA level for satisfactory water quality designation (USEPA 1989)

Figure 2



(a)
RMA3
RMA4
neonates per female
0
5
10
15
20
25
30
*
*
(b)
percent survival
0
20
40
60
80
100
*
*
CONTROL
50
100
125-200
200-500
Zn (ug/L)

Figure 3

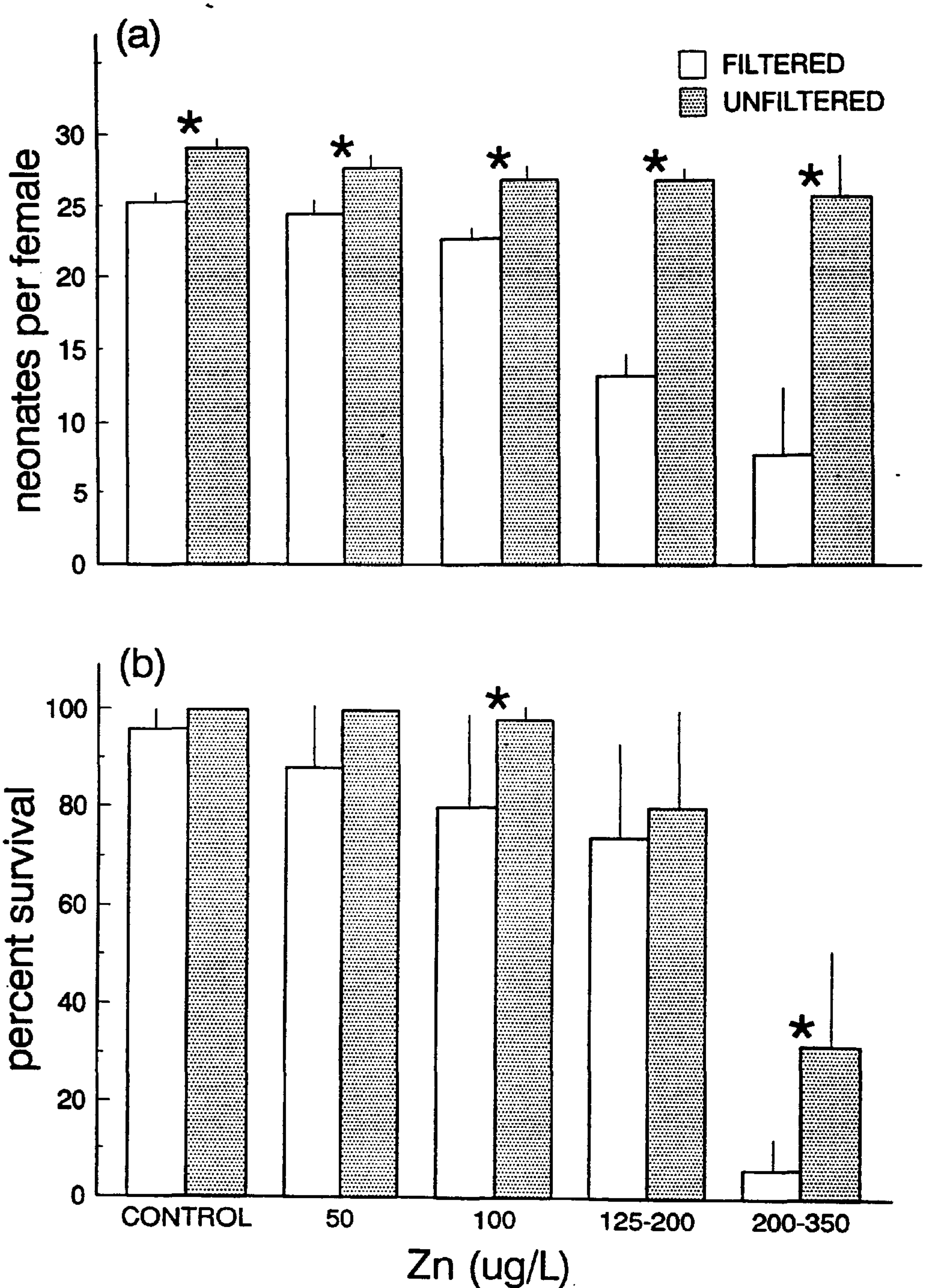

(a)
FILTERED
UNFILTERED
neonates per female
0
5
10
15
20
25
30
(b)
percent survival
0
20
40
60
80
100
CONTROL
50
100
125-200
200-350
Zn (ug/L)

Figure 4

THE CREATION OF WETLANDS AT THE ROCKY MOUNTAIN ARSENAL NATIONAL WILDLIFE AREA:

MONITORING THE TRENDS AND PROCESSES OF VEGETATION ESTABLISHMENT ON SHORT AND LONG TIME SCALES AND ALONG WATER TABLE GRADIENTS

FINAL REPORT

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SUMMARY

Five wetlands were created at the Rocky Mountain Arsenal National Wildlife Area in fall, 1991 by diverting water from the Highline Canal into naturally occurring dry basins. Project goals were to provide wildlife habitat and to perfect methods for creating wetlands that could be used for stormwater treatment. The present report discusses our findings on the hydrology, soils and vegetation of these wetlands from 1992-1994.

Our study established four transects in wetlands 1, 3 and 4, and three transects in wetlands 2 and 5. Along each transect from the center of the wetland to the upland margin, permanent plots, 6 m^2 in size were established every 20 cm of vertical rise. A total of 121 plots were established. Each plot was equipped with a ground water monitoring well or staff gauge to measure the duration of flooding and high water tables. Depth of standing water or to the water table was measured regularly through the entire three year period. Each summer all plant species present in each plot were listed and their canopy coverage estimated. Soil oxidation-reduction potential was measured at 5, 10 and 20 cm soil depths at selected plots in the first two years of this study to determine the relationship between soil oxygen relationships and the water table.

The five basins naturally supported dryland grass communities and had a water table far below the soil surface. The application of ditch water created ponded conditions. The rate of water infiltration was different for each wetland, being most rapid in wetland 5, an interdune sand basin, and least rapid in wetland 1, the central portion of which has a constructed bentonite liner. After filling with water, the wetlands begin to drawdown immediately. Ground water profiles across each basin indicate that immediately beyond the edge of the ponded water the water table is relatively deep, and drops off at a steep angle. Each wetland loses water into the ground and builds the water table beneath it into a ground water mound. Thus, sites are

either flooded, or have a relatively deep water table. This is not a desirable situation, since many wetland margin plant species and communities thrive in areas with either shallow standing water, or a water table close to the ground surface.

Although we introduced many tens of thousands of viable wetland plant seeds and hundreds of living rhizomes and whole plants into the wetlands, wetland vegetation was not well-developed at several of the wetlands after three years. During the first year of flooding, wetland basins 2 and 4 developed stands of pepperwort (Marsilea mucronata) and spikerush (Eleocharis palustris) indicating that these species had survived as dormant seeds within these basins' soils. Thus, basin 2 and 4 were natural wetland basins that had supported wetland vegetation in the past and retained viable soil seedbanks. Flooding restored an appropriate hydrologic regime for their growth. However, basins 1, 3, and 5 were newly created. In particular wetland 5 drained quickly and is very slow to develop wetland vegetation. Wetland basin 1 was filled in year 1, but in year 2, American avocets nested near the shore and their nest was protected by not filling the basin in year 2 until late in the summer. Thus, succession that had occurred in year one was set back.

Cluster analysis using Two Way INdicator SPecies ANalysis (TWINSPAN) for years 1, 2 and 3, indicated that all communities present in year 3 had developed during year 1. The restored basins developed communities in year one which persist today, and the created basins developed largely weed and cattail (Typha spp.) dominated communities in year one which persist today.

Multivariate direct gradient analysis, performed with the computer program CANOCO, was used to ordinate the stand data while constraining the axes to be linear combinations of measured environmental variables. The resulting analyses of deep water plots (aquatic vegetation) and shallow water plots (emergent vegetation) show that the duration of standing water was an important environmental variable for determining the composition of plots, but of nearly equal importance was whether the basin was an historical natural wetland. In addition, whether the basin was a natural wetland was more important than the year in successional time as a predictor of vegetation composition. The importance of these environmental variables to the ordination was tested using Monte Carlo permutation methods and all were found to explain a significant ($p<0.05$) proportion of the variation in the vegetation data set.

This project aimed to test 4 main hypotheses; (1) that the occurrence of past wetland vegetation in a basin does not influence its rate of succession, (2) that the maximum water depth reached in a basin does not affect the pathway of succession, (3) that the duration of flooding and high water tables does not affect the pathway of succession and (4) that the removal of _Typha_ which established from seed in year one does not affect the pathway of succession. All hypotheses were tested using multivariate direct gradient analysis, and Monte Carlo permutations. The importance of the basin having once supported wetland vegetation has already been discussed and is one of the most important factors driving successional processes. The maximum water depth is important in two ways. Because basins filled to a maximum depth would most likely hold water for a long time, it was a positive factor in driving succession. However, overfilling a basin, as happened in wetland 3 in year 1, resulted in the mortality of many emergent plant species. Maximum water level must be carefully managed to allow successional processes to proceed.

The duration of flooding is the most important hydrologic factor. Sites with more than 90 days of flooding each year supported submerged aquatic plants, while those with less than 90 days, but more than 7 days of flooding supported emergent wetland plants. Sites with less than 7 days of flooding supported few wetland plants. The removal of _Typha_ was statistically significant ($p<0.05$), but was the least important of all the factors tested in this study. However this may be because overfilling of basins resulted in mortality of *Typha* when this species should have become a major ecosystem component.

INTRODUCTION

Wetlands are among the most biologically diverse and productive ecosystems on earth (Mitsch and Gosselink 1993). In their natural state, they provide a variety of benefits including flood conveyance, shoreline stability, water quality improvement, food chain support, fish and wildlife habitat and recreational values (Adamus 1983).

Despite their many social, economic and ecological values, wetland losses due to human exploitation have been extensive. Many wetlands have been significantly degraded by activities such as filling, draining, stream dewatering and channelization. It has been estimated that in presettlement times, 81 million hectares of wetlands existed in the conterminous United States (Dahl 1990). By the mid 1970's, less than half remained. Despite government programs and policies designed to discourage or prevent wetland destruction, nearly one million hectares of the nations remaining wetlands were destroyed from the mid 1970's to the mid 1980's (Dahl and Johnson 1991).

Historically numerous wetlands occurred on land that is now the Rocky Mountain Arsenal. Aerial photographs of the Arsenal from 1937 show prairie marshes and wet meadows as well as riparian forests and sloughs scattered across the landscape. This includes a large emergent marsh and associated wet meadow complex in section 36, north of South Plants. After industrial development in the mid 1940's, section 36 became an area where much of the waste from chemical manufacturing was disposed of and the wetlands that existed were subsequently destroyed. This area is now the site of the most intensive Superfund cleanup efforts.

The creation and restoration of wetlands have become popular for compensating for the losses of natural wetlands and for reversing the trend of decreasing wetland resources. Although there have been many wetland creation and restoration projects undertaken in recent years, there is a paucity of scientific information on how to best create and restore these ecosystems, especially in the Rocky Mountain West (Cooper 1988, Ischinger and Schneller-McDonald 1988). In addition, once a wetland ecosystem has been created, little is known about the resultant hydrology, hydric soil development, and patterns of plant species colonization and establishment on short or long time scales (Mutz et al. 1989) or the success of various methods of plant propagation. An understanding of the successional patterns and processes in wetlands would be extremely valuable for building models of how wetland communities get established under certain environmental conditions and how they change with time. This understanding could be applied in situations where it is desirable to create new or restore existing wetlands such as for wildlife habitat and passive water treatment facilities. The creation of new wetlands or the restoration of degraded wetlands will also provide important new habitat for native flora and fauna and help restore the balance of dryland to wetland that once existed in Colorado.

Hypotheses

Data collection, analysis and interpretation have focused on the testing of four principal hypotheses. These hypotheses are:

1. The occurrence of past wetland vegetation in the basins does not influence the rate or direction of succession.

2. The maximum water depth in the basins does not affect the pathway of succession.

3. The duration of flooding does not affect the pathway of succession.

4. The removal of *Typha* spp. individuals which established from seed during year one does not affect the pathway of succession.

METHODS

Creating the Wetlands

Five landscape depressions were chosen to create wetlands in the southeast corner of the Rocky Mountain Arsenal in Fall, 1991 (Figure 1). The locations were chosen based on their proximity to their principle water source, the Highline Canal Lateral, and because they are natural depressions. Pre-construction ground water monitoring of the basins was not performed on the assumption that surface water from the canal would be adequate to support wetlands.

Water is supplied to the 5 wetlands from the Highline Canal. Wetlands 2, 3, 4 and 5 all receive water through a series of lateral ditches from the main canal. Because it is located over a hill from the canal, Wetland 1 is filled via a large pipe that syphons water from the canal and deposits it in the east side of the wetland.

The basin of wetland 1 was excavated and lined with bentonite to reduce infiltration. The upper edges on the east side were contoured to create 4 small islands and a large shallow flooded area. Wetland 2 is a natural, shallow basin that was dammed by a dirt road on its west side. Wetlands 3, 4 and 5 are natural inter-dune basins.

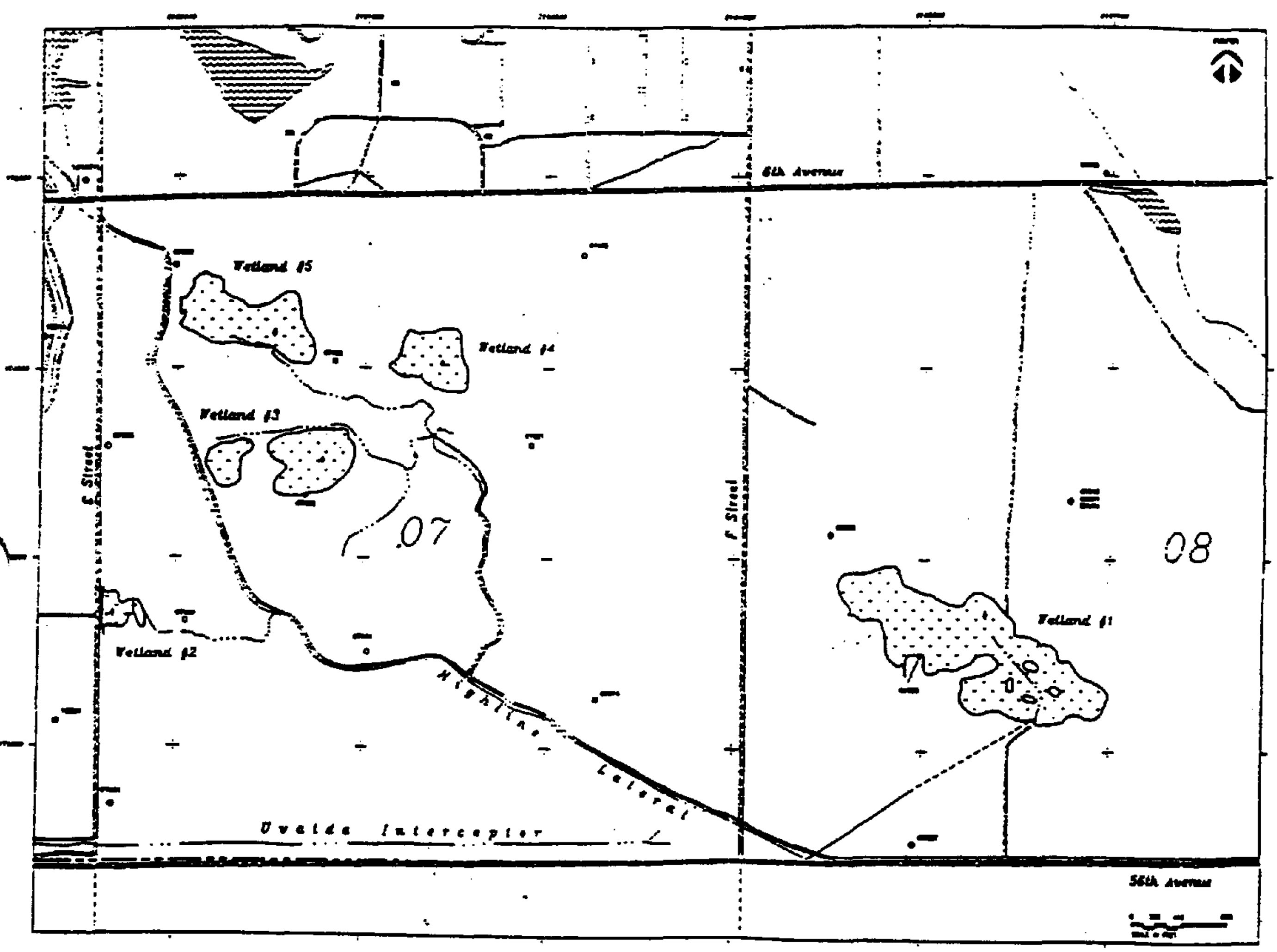

Figure 1. Location of Wetlands 1 - 5 at the Rocky Mountain Arsenal National Wildlife Area.

Vegetation Sampling

In order to investigate the vegetation dynamics of each wetland, 121 permanent sampling plots were established. At each wetland, transects were located along the most gentle and well defined gradients from the center of the basin to the uplands. Wetlands 1, 3, and 4 have four transects each while wetlands 2 and 5 have three transects each. Each transect contains between five and seven sampling plots where all hydrology, soil and vegetation measurements and observations were taken. Plots along the transects were chosen corresponding to an approximate 20 cm increase in elevation between each plot from the wetland basin to the uplands. Each plot is 6 m^2 and is marked with an orange-tipped metal rod at each corner. Most plots are 2m by 3m with the 3m side parallel to the slope. This plot size was chosen based on the drier stands which contained more plant species than the stands in the wetland basin. Preliminary sampling showed that increasing the plot size above 6m^2 did not result in additional species being sampled.

Vegetation was sampled in each plot late in the growing season in 1992, 1993 and 1994. All plant species occurring in a plot were recorded and the percent cover for each species was estimated. Plant nomenclature follows Weber (1990). Data were analyzed using cluster analysis in the computer program TWINSPAN (Hill 1979) as well as multivariate direst gradient analysis in CANOCO (ter Braak 1988).

Hydrology Sampling

A shallow groundwater monitoring well was installed at each of the non-flooded plots to measure the depth to the water table. For each well, a hole was hand augered 5 to 8 feet deep and cased with 2.54cm PVC pipe. The bottom half of the casing was machine slotted and coupled to a section of solid pipe on the top half. The casing was capped on the bottom and inserted in the hole where native soil was backfilled and packed around the well.

Metal staff gauges were installed at each plot where permanent standing water was anticipated to measure water depth. Wells and staff gauges were surveyed for position and elevation so that ground water elevations and water table profiles could be produced. Water levels were measured at each well or staff gauge with a metal measuring tape twice a month from mid-May through September of each year.

Soil Sampling

Oxidation - reduction (redox) potential of the soil was measured along three transects in wetlands 1, 3 and 4. Plots where redox potential was measured were chosen along the margins of the wetlands where soil saturation was expected to increase and decrease over the course of the growing season while the wetlands filled up and drew down.

Ten stations were chosen to examined redox potential in the wetlands. At each station, a replicate pair of redox electrodes was installed at 5, 10 and 20 cm soil depths. Redox electrodes were constructed by welding 16 gauge platinum wire onto 10 gauge insulated copper wire and sealing the junction with waterproof epoxy. Measurement were taken according to methods described by Faulkner et. al. (1989) with an Orion model 250A portable pH/mV meter every two weeks from May through September, 1992, and less frequently in subsequent years.

Plant Introductions

A combination of seeding, live planting and vegetation manipulation was undertaken at each wetland in an attempt to determine the influence of these treatments on rates of succession and community development. Seeds of various native wetland plants were collected in the fall of 1991 and broadcast along the east edges of wetlands 1, 3, 4 and 5 in June, 1992. The following tables list the weights and numbers of seeds of each species introduced.

Weight of seeds (grams)

Species	Wetland 1	3	4	5
Schoenoplectus lacustris ssp. *acutus*	75	75	75	75
Bolboschoenus maritimus ssp. *paludosus*	235	110	110	110
Sparganium eurycarpum	15	15	15	15

Number of seeds

Species	Wetland 1	3	4	5
S. lacustris ssp. *acutus*	100,000	100,000	100,000	100,000
B. maritimus ssp. *paludosus*	90,000	42,000	42,000	42,000
Sparganium eurycarpum	220	220	220	220

Plants were collected from nearby wetlands and transplanted into the created wetlands in June, 1992. All plants were placed in random locations along the wetland margins at approximately the same water depths from which they were harvested. Most plants were collected as individuals, i.e., as a single shoot and short section of rhizome. However, some were in clumps containing several to many shoots and rhizomes. The east halves of wetlands 1, 3 and 4 received transplants while the west halves were allowed to develop naturally. The following list gives the numbers and species planted at each wetland. Transplants were not introduced into wetlands 2 and 5.

Wetland			
1	3	4	Plant species
60	8	88	*Bolboschoenus maritimus* subsp. *paludosus*
-	17	-	*Carex nebraskensis*
-	14	-	*Hippuris vulgaris*
-	5	-	*Juncus compressus*
-	-	2	*Juncus torreyi*
30	-	90	*Persicaria amphibia*
-	37	-	*Sagittaria latifolia*
86	46	-	*Schoenoplectus lacustris* subsp. *acutus*
47	-	51	*Schoenoplectus lacustris* subsp. *creber*
75	-	124	*Schoenoplectus pungens*
-	21	-	*Sparganium eurycarpum*

Typha latifolia is an obligate wetland plant that quickly invades new or disturbed wetland sites. In many cases it forms dense, homogeneous stands often outcompeting all other plant species and reduces wildlife habitat quality in general (Paine 1994). In an attempt to determine how *Typha latifolia* influences the community composition of created wetlands, this species is being removed from the south halves of wetlands 2, 3 and 4 and allowed to remain in the north halves.

RESULTS

HYDROLOGY

Hydrologic studies were conducted to evaluate the effectiveness of the method used to create the five wetlands.

The first goal was to document the duration of flooding and soil saturation at the permanently marked plots. This information will provide a quantitative basis for evaluating plant community development and the success of vegetation establishment in different water regimes. A second goal was to examine the relationship between depth to water table (or depth of standing water) and soil anaerobiosis. Finally, hydrology was examined to determine the rate and direction of water loss from each wetland and the influence of the naturally occurring ground water table on the wetlands.

Water availability to the Rocky Mountain Arsenal wetlands is sporadic with no scheduled delivery times or predetermined quantities. When called for by owners of Highline Canal water rights, water is released from Chatfield Reservoir, west of Denver, into the Highline Canal. Any excess water not used by senior owners can then be used to fill the wetlands. High water demand during the growing season by agricultural users and lack of an adequate supply during dry years results in extended periods of low water and in some cases dry conditions in several of the wetlands. In addition, in some years water does not arrive on the Arsenal until June whereas natural prairie marshes are typically flooded in early spring. Hence, there is little hydrologic resemblence between the created wetlands and naturally occurring prairie marshes. Although seasonal drawdowns are common in prairie marshes, it is difficult to manipulate and manage vegetation in the wetlands without controlling the timing of water delivery.

Wetland 1

Wetland 1 was created in an interdune basin. A dike was constructed on its northern side to impound deep water. The upper edges on the eastern side were contoured to create four small islands and a large shallow flooded area. The basin of wetland 1 was excavated and lined with bentonite in 1991 to reduce water loss through infiltration.

Figure 2 is a profile from west to east of wetland 1. Wells 28 through 32 and 44 through 47 are in native soil while wells 33 through 43 and 48 through 51 are in the clay lined basin. On the west side (left side of Figure 2), areas that were not inundated with surface water had water tables that dropped off steeply. For example, on 28 July, plot 31 was flooded while plots 28, 29 and 30 had a water table 0.5 to 1.5 feet below the soil surface. This pattern persisted through the period of record indicating that the introduction of surface water to wetland 1 created a ground water mound. The mound had very steep sides on the west and less steep sides on the east side of the wetland.

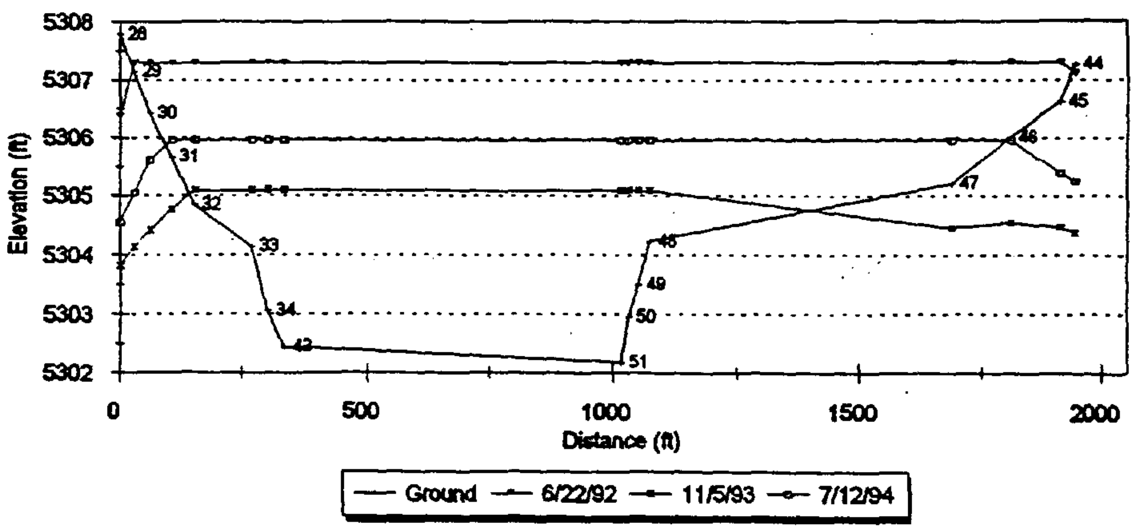

Figure 2. West to east profile of wetland 1. Numbers on ground surface line represent well numbers and locations.

Wetland 2

Wetland 2 is a natural wetland basin that periodically fills with rain or snowmelt water. Several factors contributed to this wetland drying out often during the summers. A high surface area to volume ratio allowed evaporation to occur quickly. Evapotranspiration of water by the extensive emergent plant cover was another factor. The natural water table was deep and contributed little if any to the hydrology of the wetland. All water that was introduced from the Highline Canal was perched atop unsaturated soil. Figure 3 is a north-south profile through wetland 2 showing that the surface water of this wetland is far above the ground water table.

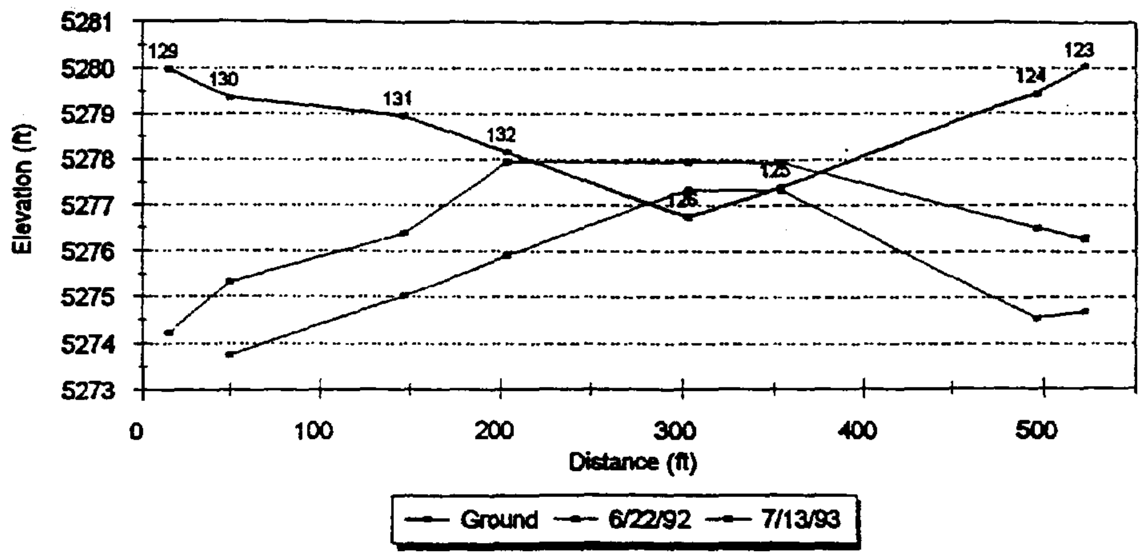

Figure 3. West to east profile of wetland 2.

Wetland 3

Wetland 3 is a naturally occurring interdune basin that historically did not appear to be a natural wetland. The topography surrounding this depression is such that diking and excavation were not needed to impound water.

Figure 4 is an east-west hydrologic profile showing that wetland 3 occurs as a ground water mound with steep sloping sides. It also shows that the naturally occurring ground water table east of wetland 3 is higher than the adjacent ground water. For example, on 8 May, 1992, ground water was more than 1.5 feet higher at well 36 than at well 40. Thus, it appears as if a natural ground water slope exists from east to west.

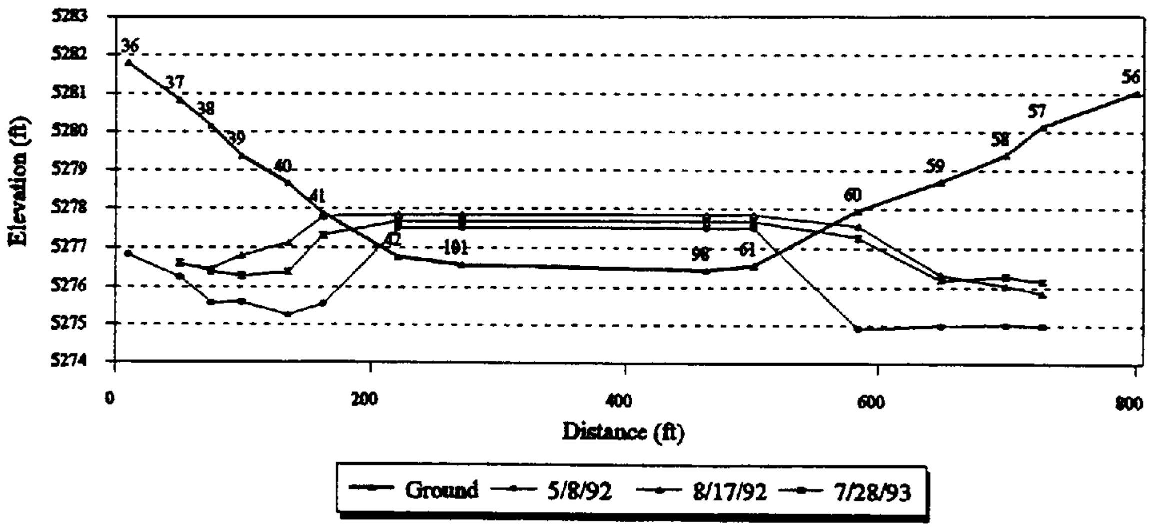

Figure 4. East to west profile of wetland 3.

Wetland 4

Wetland 4 is a natural wetland basin as evidenced by the rapid growth of native wetland plants soon after the basin was flooded in August, 1991.

Figure 5 is a south to north profile of Wetland 4 and illustrates clearly that there is a ground water source to the south of this wetland at all times of record. The water table drops quickly on the north side of the wetland.

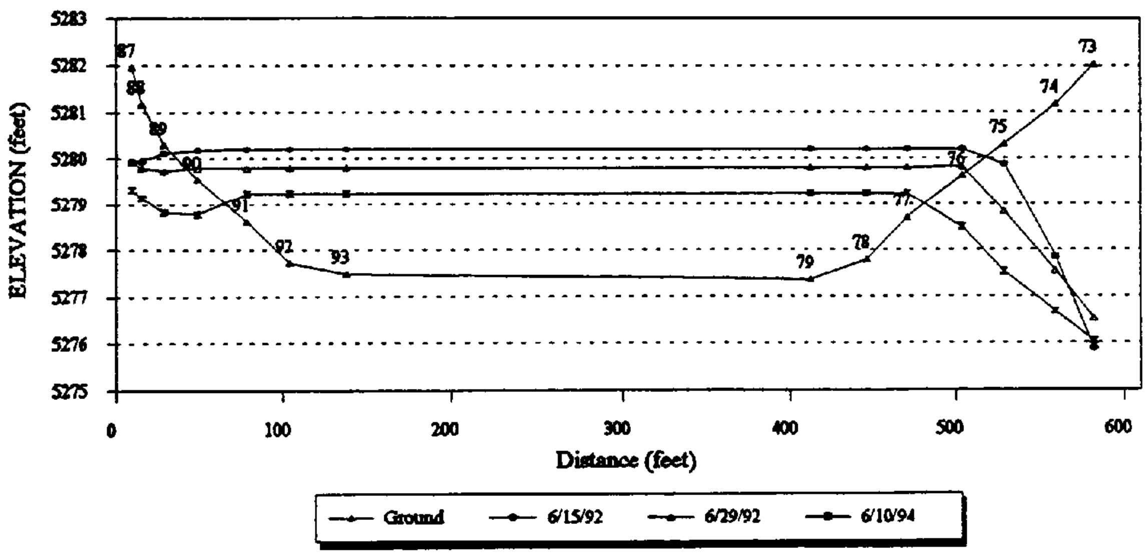

Figure 5. South to north profile of wetland 4. Note ground water source on the south side of the wetland.

When examined together, the south-north and west-east (Figure 6) profiles suggest wetland 4 loses water on the west, east and north sides and receives water from the groundwater table on the south at certain times of the year. For example, on 5 June, 1992, the surface water level in the wetland was much lower than the ground water on the south while on the west, east and north sides the water table dropped in a short distance. However, after the wetland received Highline Canal water later in the summer (i.e., on 15 June, 1992) the surface water levels were higher on all sides than the adjacent groundwater.

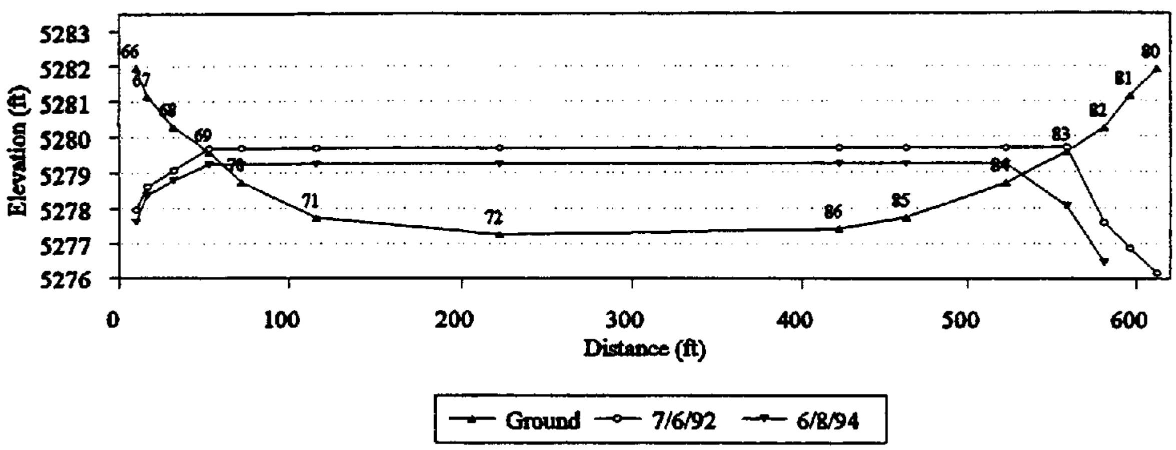

Figure 6. West to east profile of Wetland 4. Numbers on ground surface line represent wells or staff gauges.

Wetland 5

Wetland 5 is a natural interdune basin that is not an historic wetland. The water table profiles shown in Figure 7 indicate similar hydrologic processes occurring here as occur in the other four wetland basins with steep sloping mounds perched atop unsaturated soil.

Water seeped from wetland 5 more quickly and lacked surface water more often than any of the other 4 wetlands. The high surface to volume ratio led to high evaporation rates while a highly porous substrate allowed for much infiltration. Evapotranspiration probably played a negligible role due to the paucity of living vegetation in this wetland.

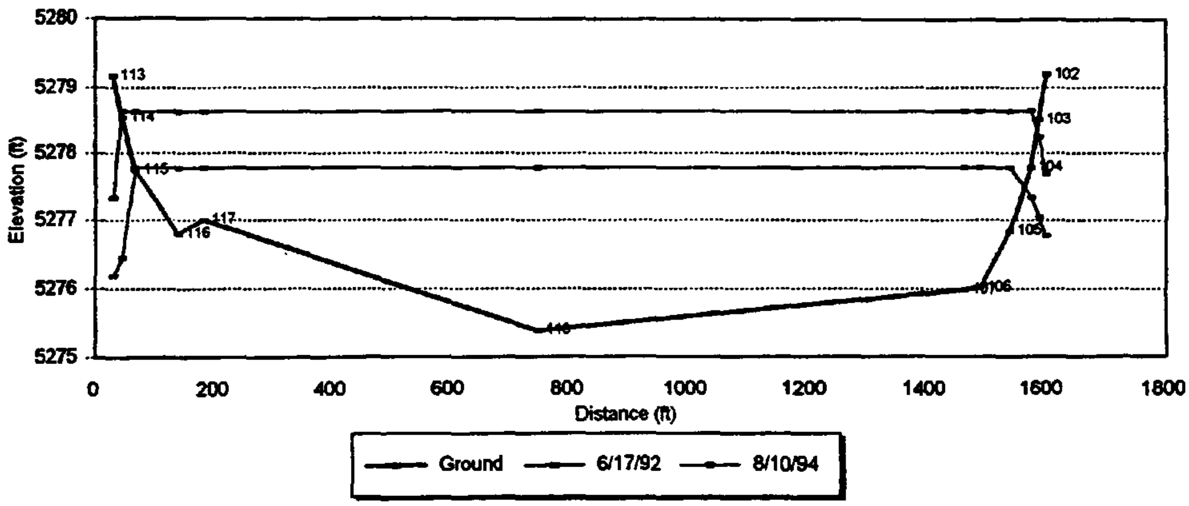

Figure 7. South to north profile of Wetland 5.

A general hydrologic feature common to all of the wetlands as evidenced by the above water table profiles is the lack of close connectivity between the naturally occurring ground water system and the surface water in the wetlands. The implications of this feature are twofold. First, water must be added to the basins at frequent intervals to maintain a high water table and wetland conditions. As mentioned previously, this is not always possible given the current water source. Second, the extent of soil saturation on the wetland margins is of limited extent resulting in flooded soils with standing water or dry soils separated by a narrow band of saturated soil.

Figures 8 through 12 show hydrographs for the wetlands from 1992 through 1994. Each of these figures shows a pattern of variable filling times and associated drawdowns from year to year. For example, in wetland 4 the water level was high early in the growing season of 1992 and the wetland was allowed to drawdown. In August, water was introduced again and the sites that were drying out were reflooded. In 1993, the wetland received water in late June and experienced a long and gradual drawdown for the remainder of the growing season. Water was introduced in late May and again in late August in 1994.

The unnatural timing of the filling and drawdown events in each wetland limits the long term development of wetland plant communities because the hydrologic regime at any one site is variable from year to year. Sites that are capable of supporting a particular suite of species one year may be too dry (or too wet) the following year to support the same species.

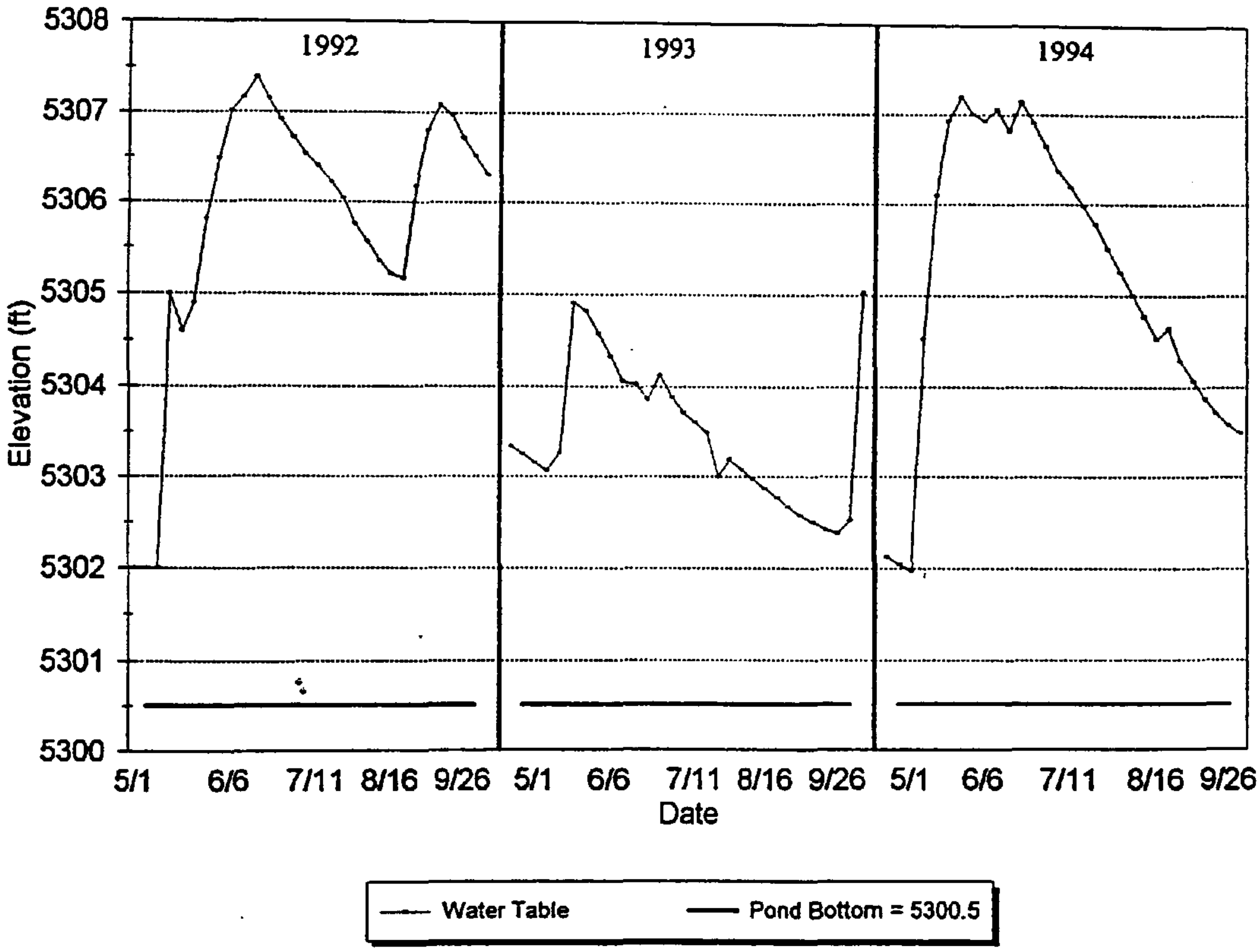

Figure 8. Hydrograph of Wetland 1, 1992-1994 showing variable filling times and water table elevations.

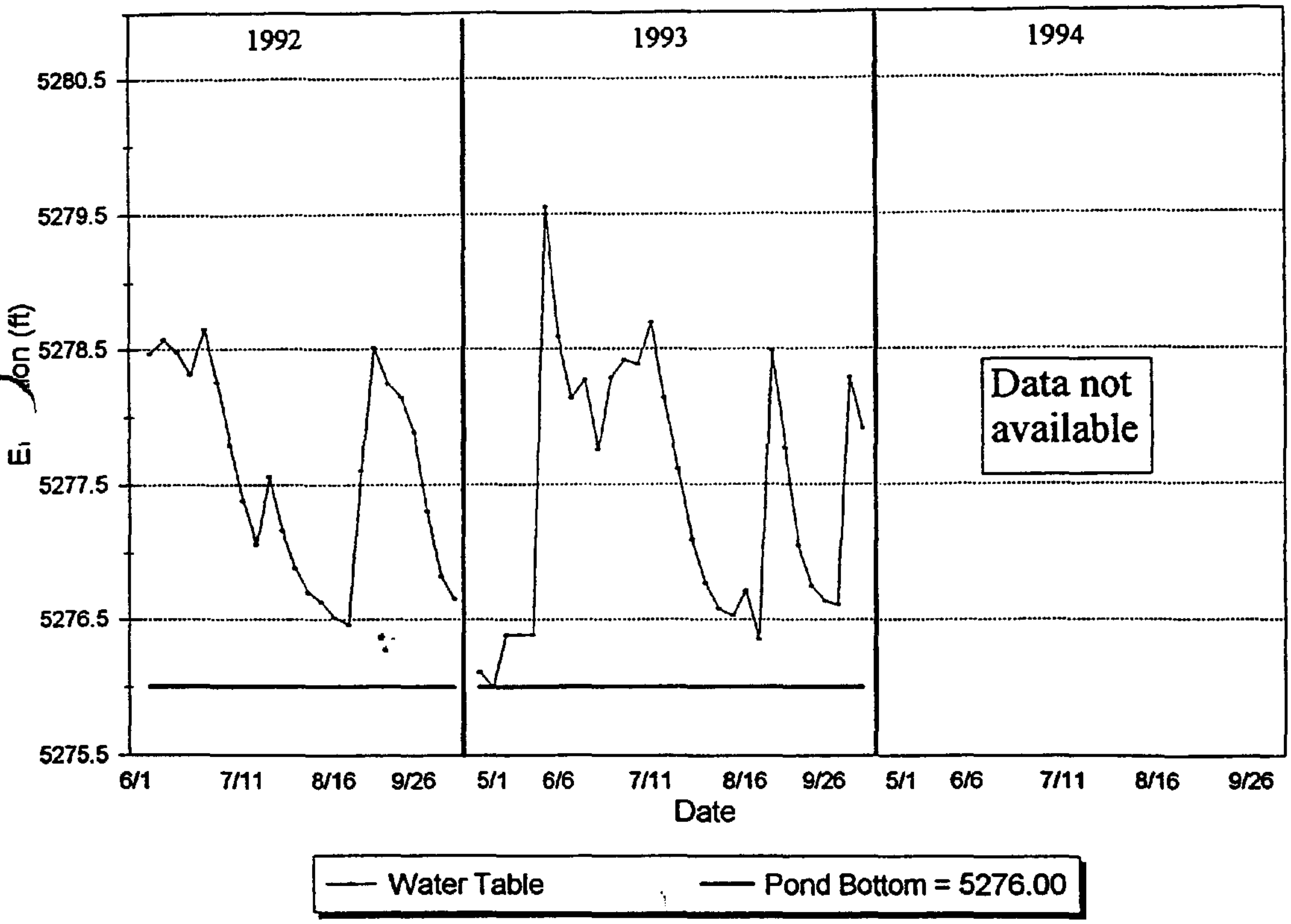

Figure 9. Hydrographs of Wetland 2, 1992, 1993.

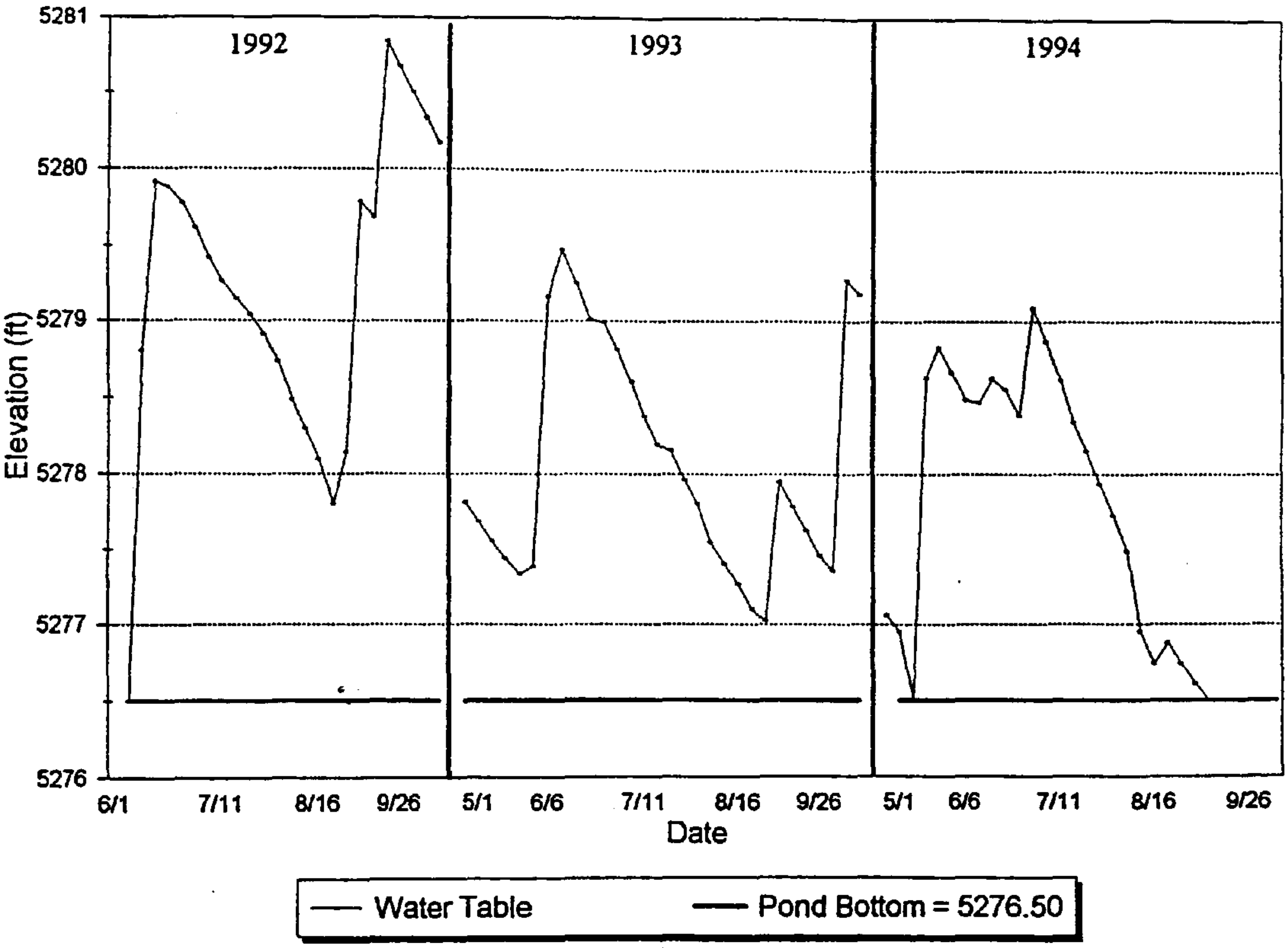

Figure 10. Hydrographs of Wetland 3, 1992-1994.

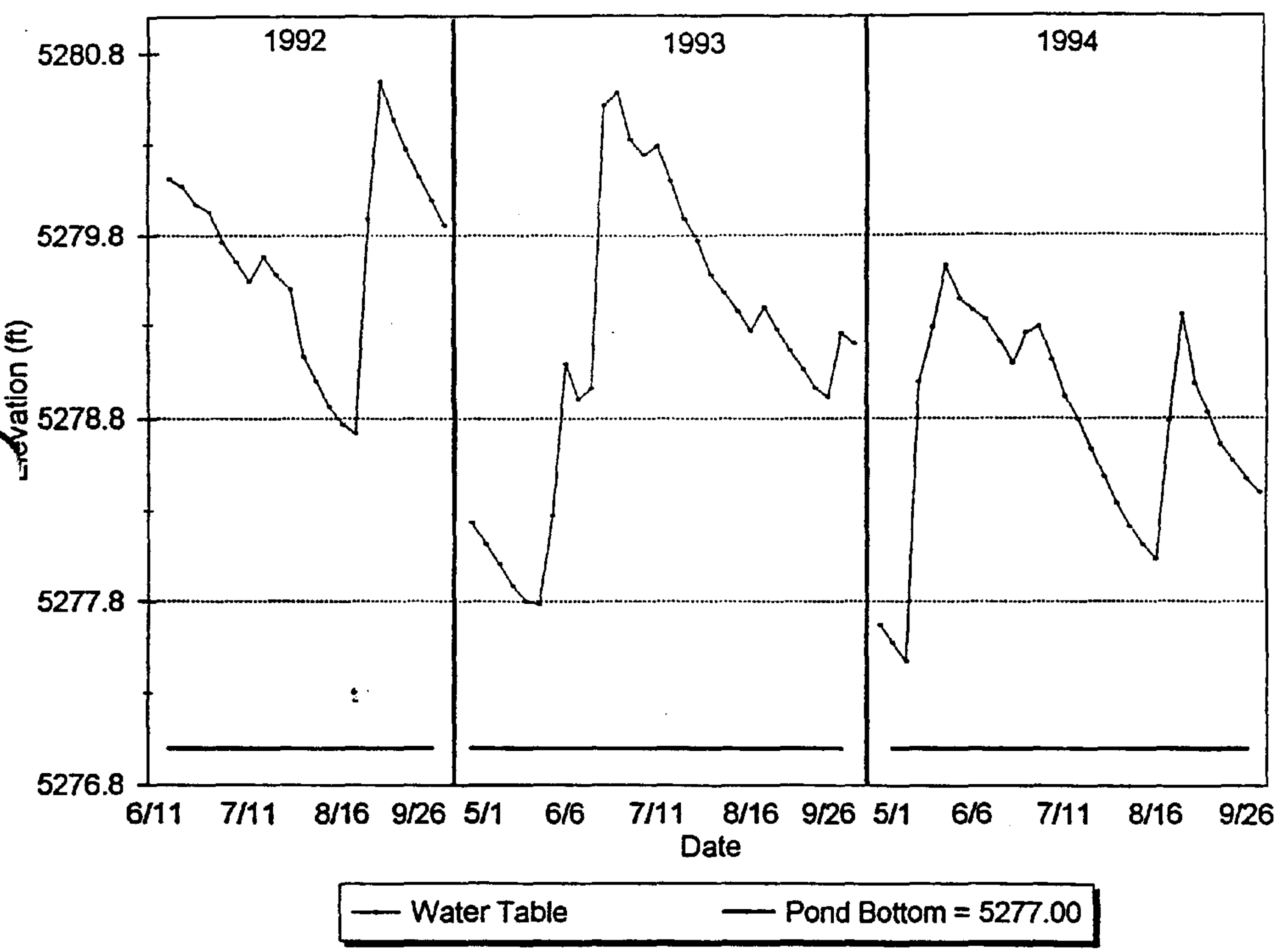

Figure 11. Hydrographs of Wetland 4, 1992-1994.

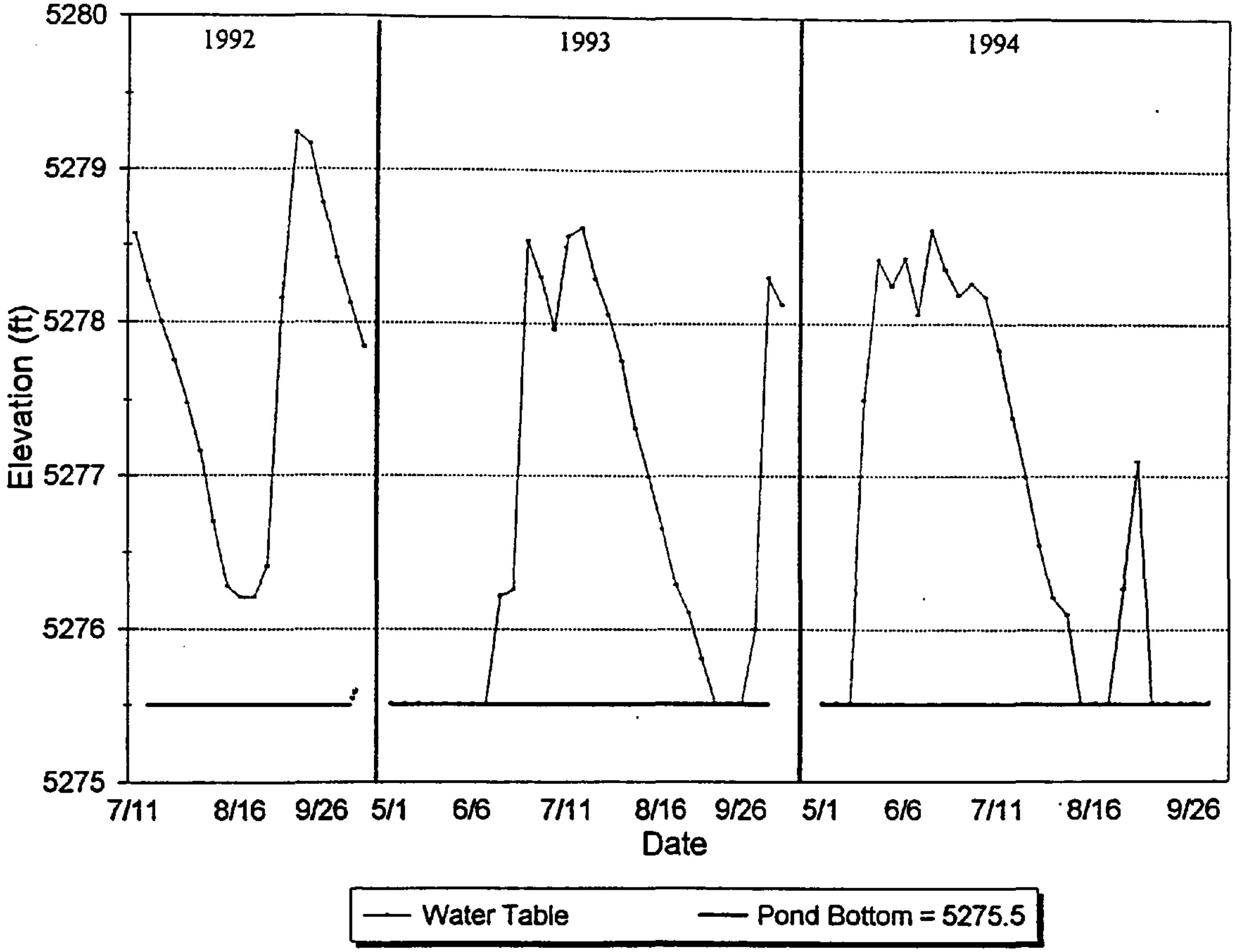

Figure 12. Hydrographs of Wetland 5, 1992-1994.

SOILS

Soil oxidation-reduction (redox) potential (Eh) was measured to help quantify the relationship between the hydrologic regime, the soil environment and plant distribution. This parameter helped us determine (a) how long during the growing season the soil must be saturated or flooded before becoming anaerobic and reduced, and (b) how long the soils remain anaerobic and reduced after the water table drops below a particular soil depth.

Redox potential is an important measure of the soil environment due to its effect on rooted plants and the biogeochemical cycle (Mausbach and Richardson 1994). Only plants that have developed physiological and morphological adaptations to deal with anaerobic conditions can survive for extended periods of time in such environments (Armstrong 1975, Kozlowski 1984). As a result, soils that are anaerobic and reduced for long duration during the growing season support predominantly wetland plant species.

Redox potential is measured in millivolts (mv) from +700 to -350 mv. Soils are considered aerobic when redox potential is +320 to +350 mv or greater. Below +320 mv, soil oxygen becomes undetectable and soils are anaerobic (Pearsall and Mortimer 1939, Sikora and Keeney 1983). Soils with redox potentials from +320 to +100 mv are moderately reduced. Between +100 and -100 mv soils are said to be reduced, while soils with redox potentials lower than -100 are considered highly reduced. Reproducible results are possible with the type of electrodes used in the present study only when Eh is less than +350 mv.

Biogeochemical changes that occur in soils once they are flooded and Eh drops from +350 to -300 mv are generally well-known. Nitrate is reduced at 200 mv, manganese at 200 mv, iron at 120 mv, sulfate at -75 to -150 mv, and carbon dioxide at -250 to -350 mv (Turner and Patrick 1968, Gambrell and Patrick 1978, Mitsch and Gosselink 1993). The eight stations in which redox potential was measured at the Rocky Mountain Arsenal wetlands indicated that wherever standing water occurred for more than a few days during May through September, or where the water table was within 20 cm of the soil surface, anaerobic and reducing conditions occurred in the top 20 cm of soil.

In general, soil Eh was extremely responsive to water table fluctuations. Figure 13 shows redox profiles during 1992 for three different stations, 35, 36, and 37 at wetland 1. Station 35 occurs in the highest landscape position, while 37 is the lowest. The water table never reached the soil surface at station 35, but when redox electrodes were installed in mid-June the water table was approximately 20 cm below the surface and over the next two months, dropped to more than 80 cm. Redox potential at 5 and 10 cm never dropped below +350 mv, thus it was aerobic during this entire time. However, at 20 cm, Eh dropped below +300 mv indicating that it was slightly reducing for a few weeks. Thus, important differences occurred in soils at 10 and 20 cm depth.

Standing water occurred at station 36 for several weeks in early June, as shown in Figure 15. When flooded, all soil depths monitored were reducing with Eh between 0 and -100 mv. Once the water table dropped below 20 cm in early July, eH at 5 cm rose to around 500 mv and persisted there for the remainder of the summer. At 10 cm soil depth, Eh increased but soils did not become aerobic, while at 20 cm depth, Eh never increased.

Station 37 was deeply flooded in the early summer and flooding occurred again in late summer. Soils in early summer were extremely reducing (to near -300mv), and at 20 cm depth never became aerobic while at 5 and 10 cm the soils became aerobic for several weeks in August. The rise in Eh was gradual at 5 cm, while it occurred over a 1 week period in late July at 10 cm. The rapid rise in Eh at 10 cm depth occurred once the water table dropped below 20 cm and soils became aerobic at this depth before they did at 5 cm. It indicates that more organic surface horizons can remain anaerobic longer than deeper horizons with less organic matter following a drawdown.

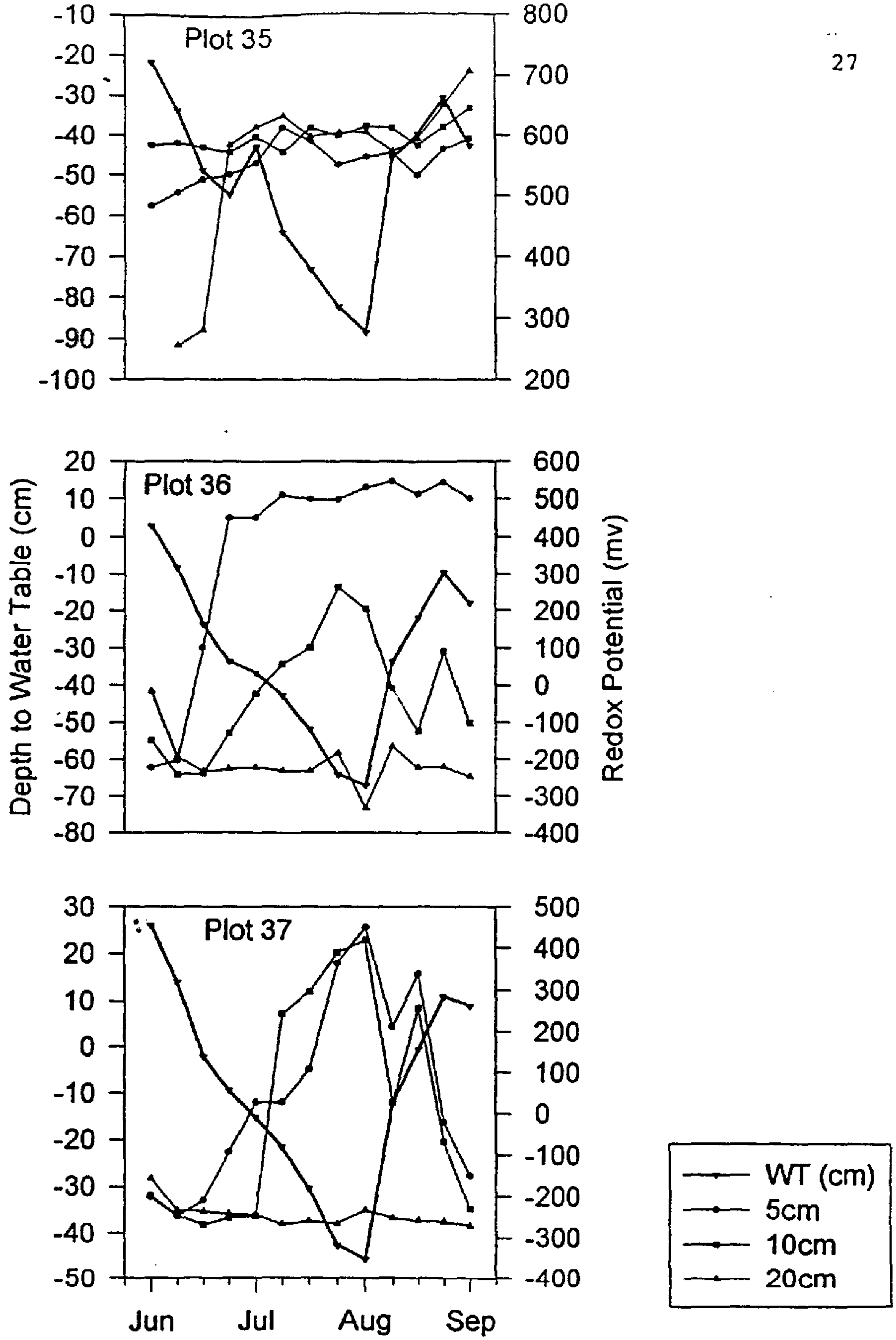

Figure 13. Redox potential measured at 5, 10 and 20 cm soil depths at Plots 35, 36 and 37, Wetland 1.

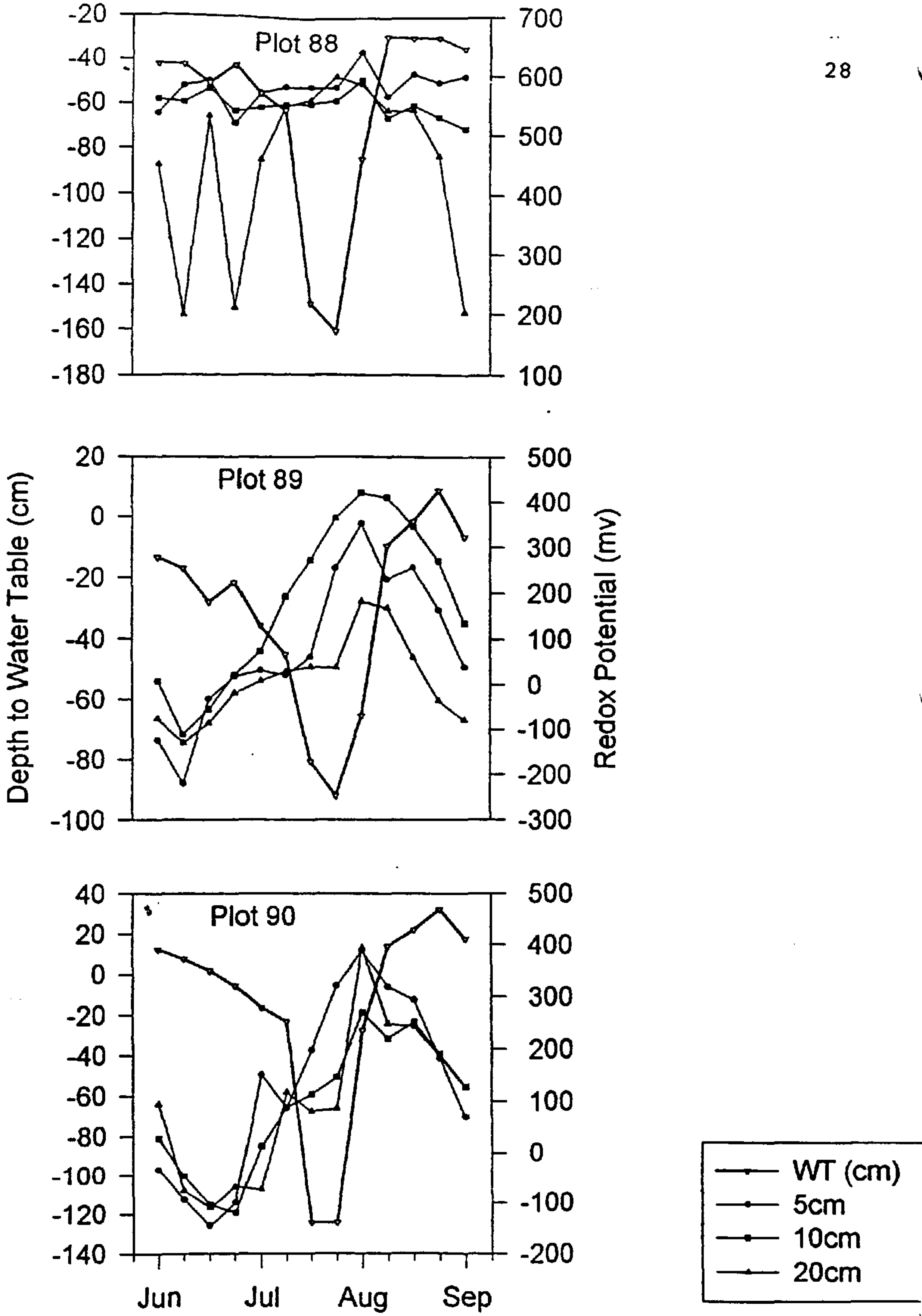

Figure 14. Redox potential measured at 5, 10 and 20 cm soil depths at Plots 88, 89 and 90, Wetland 4.

Similar patterns are seen in Figure 14, which shows redox profiles for stations 88, 89, and 90 at wetland 4. Station 88 is the highest site, while 90 is the lowest. Station 80 is never flooded and only soils at 20 cm depth become anaerobic. At station 89 and 90, the water table is near the soil surface for long duration early in the summer and soils at all depth are extremely reduced. Eh rises as the water tables drop, but it takes a long time for aerobic conditions to occur at any depth once the water table drops below that depth. For example, at station 90, the water table drops below 20 cm depth in late July, but Eh at 20 cm does not rise to greater than +350 mv until mid-August, more than 2 weeks later, while at 10 cm depth, the soils do not rise to +350 again. At station 89, the water table drops below 10 cm in late June and below 20 cm in early July, but Eh at 5 cm does not rise to +350 mv until mid-August, more than 1 month after the water table dropped to below 20 cm and nearly 2 months after the water table dropped below 10 cm. These data clearly indicate the important control of water table on the soil environment.

VEGETATION

The effect of hydrology on wetland plant establishment and community development over the three year study period is illustrated in Figure 15. Schoenoplectus lacustris subsp. creber, Typha latifolia and Eleocharis palustris are native emergent wetland plant species while Potemogeton pectinatus is a native aquatic plant.

Typha latifolia, Eleocharis palustris and Potemogeton pectinatus were all present in wetland 1 at the end of the growing season in 1992. Water was not introduced into wetland 1 early in the summer of 1993 to prevent the flooding of nesting avocets along the shoreline. By mid-summer when the young birds had fledged, water was not available from the highline canal. It was mid-September (towards the end of the growing season) before

wetland 1 received the next appreciable supply of water in 1993. The lack of water during the early and middle part of the growing season effectively eliminated these three species from the sampling plots in 1993. However, these plants recolonized the wetland in 1994 when water was brought in early in the summer.

Wetland 2 is a small basin impounded by a dirt road on the west side. When Highline Canal water first filled this wetland in August of 1991, it quickly developed a plant cover dominated by Marsilea mucronata, an aquatic fern native to playa wetlands on the Great Plains. The presence of this plant indicates that this basin is a natural wetland that periodically fills with rain or snowmelt water.

Marsilea mucronata and Eleocharis palustris are adapted to periodic and prolonged dry periods. The number of plots with Eleocharis palustris did not change over the three year study period while Typha latifolia was eliminated from the two plots where it occurred in 1992 and 1993. Schoenoplectus lacustris subsp. creber, and Potemogeton pectinatus did not occur in wetland 2 in any year.

Wetland 3 saw an increase in the number of plots with Schoenoplectus lacustris subsp. creber and a decrease in the number of plots with Typha latifolia. This was likely due to a flood event at the end of 1992 that drown most Typha latifolia plants recruited that year while allowing the more flood tolerant Schoenoplectus lacustris subsp. creber to survive. Potemogeton pectinatus frequency remained the same while Eleocharis palustris does not occur in wetland 3.

Wetland 4 is a natural seasonal wetland basin. When Highline Canal water was first introduced here in August of 1991, Marsilea mucronata, Potemogeton pectinatus and Eleocharis palustris germinated and grew from the soil seed bank. The number of plots where Schoenoplectus lacustris subsp. creber and Potemogeton pectinatus occurred in wetland 4 did not exhibit an upward or downward trend over the three year study period. However, the number of plots with Typha latifolia

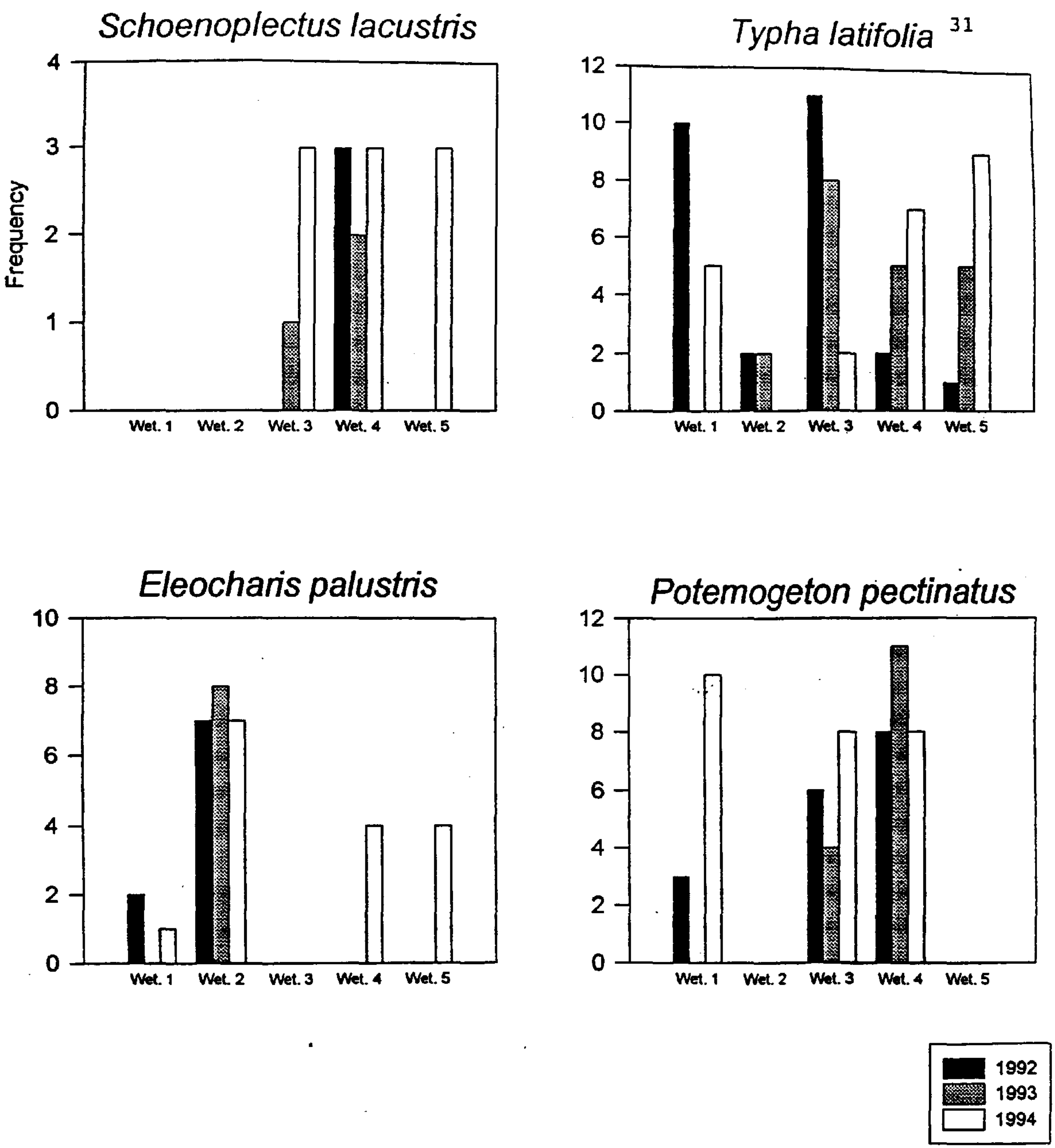

Figure 15. Number of plots with *Schoenoplectus lacustris, Typha latifolia, Eleocharis palustris and Potemogeton pectinatus* in each wetland.

increased from 2 to 7 as a result of drawdowns that exposed mudflats favorable to seed germination and the vegetative spread of adult plants. Eleocharis palustris, absent from wetland 4 in 1992 and 1993, colonized four plots in 1994.

Wetland 5 was devoid of all four species the first 2 years except for Typha latifolia which increased over the three year period. In 1994, Eleocharis palustris and Schoenoplectus lacustris subsp. creber colonized three and four plots, respectively, due to more favorable hydrologic conditions the last year. Potemogeton pectinatus does not occur in wetland 5 due to the lack of permanent and prolonged standing water.

Vegetation Classification (TWINSPAN)

Vegetation in the 121 permanent plots was classified using "two way indicator species analysis" (TWINSPAN), a divisive hierarchical classification technique (Hill 1979). The goal is to derive clusters of stands with similar vegetation composition which we can then use to determine which environmental factors may be causing the vegetation similarities and dissimilarities.

The analysis indicated that all communities present in year 3 had developed during year 1. The restored basins developed communities in year one which persist today, and the created basins developed largely weed and cattail (Typha spp.) dominated communities in year one which persist today.

The first level of division in the data is between aquatic and terrestrial stands. Aquatic stands are dominated by species of Potamogeton, Typha, Eleocharis and others, while the terrestrial stands have high coverage by Bromus tectorum, Conyza canadensis and other species. Also, in this terrestrial group are wetland margin stands which retain a high percent coverage of dryland plants, but have been invaded by wetland species such as the smartweed, Persicaria lapathifolia.

It is clear from this first division that site hydrologic regime, particularly the period of inundation and the development of anaerobic conditions in the soil is the most important local of anaerobic conditions in the soil is the most important local environmental factor determining the composition of stands along the study gradients. Within the gradient, the duration of inundation will determine the floristic composition.

The second level of division in the data splits the aquatic stands into the true aquatics dominated by Potamogeton pectinatus, and the emergent stands dominated by Typha and Eleocharis palustris. The terrestrial stands are divided into two groups, one dominated by Bromus tectorum and Conyza canadensis, and a second dominated by Persicaria spp. and other wetland margin species.

The final classification is presented below and includes 8 community types. This classification is illustrated in Figure 16.

1. Potamogeton pectinatus - Potamogeton pusillus. This community type is dominated by pondweeds and is most common in the wetlands 3 and 4 where wetland plant seeds were dormant in the soils. These sites were wetlands prior to wetland creation. These communities will spread through the study area to aquatic ecosystems in wetlands 1, 2 and perhaps 5 through bird feces. This is a very valuable community type for waterfowl and invertebrate habitat and food supplies.

2. Chara spp. This aquatic algae occurs on the bottoms of nearly unvegetated wetlands. Thus, it is most common in wetland 1 and other new wetlands. It is a valuable plant species and we hypothesize that this community will not retain its current character once the pondweeds become established in all wetlands.

3. Eleocharis palustris - Typha latifolia. Spikerush and cattail dominate the margins of wetlands 2 and 4, and will likely eventually dominate the margins of all wetlands. This community is best developed in the preexisting wetlands. Most likely it will become dense and extremely productive in subsequent growing

seasons.

4. Persicaria lapathifolia. This Eurasian annual plant species is widespread throughout the temperate zone of North America and often dominates wet and disturbed ponds and pond margins. It was robust at the Rocky Mountain Arsenal wetlands during 1992, but its abundance is decreasing as long-lived perennials, such as cattail and bulrush, come to dominate the wetland margins.

5. Sisymbrium altissimum - Typha latifolia. This community occurred during 1992 on pond margins that were wet during 1991 and dry in the early parts of 1992. These sites were wet enough during 1991 to kill most of the dryland plants, but a soil seed bank of Sisymbrium and Descurania spp. (two coarse annual mustards) germinated and these species were prolific during 1992. This community was abundant around wetland 3 in particular.

6. Agropyron smithii. Western wheatgrass dominates native prairie in relatively good condition throughout the study area. These areas are not heavily populated by prairie dogs. It represents a remnant condition and is relatively uncommon.

7. Bromus tectorum. Cheatgrass dominates the most disturbed dryland sites in the study area. Few other plants occur with it in many areas and we segregate this as a separate community type.

8. Bromus tectorum - Conyza canadensis. Cheatgrass along with horseweed dominate complex dryland communities that have been moderately disturbed but contain a large number of plant species. These are the most species rich communities in the study area and contain a combination of native perennial and annual species and annual weeds.

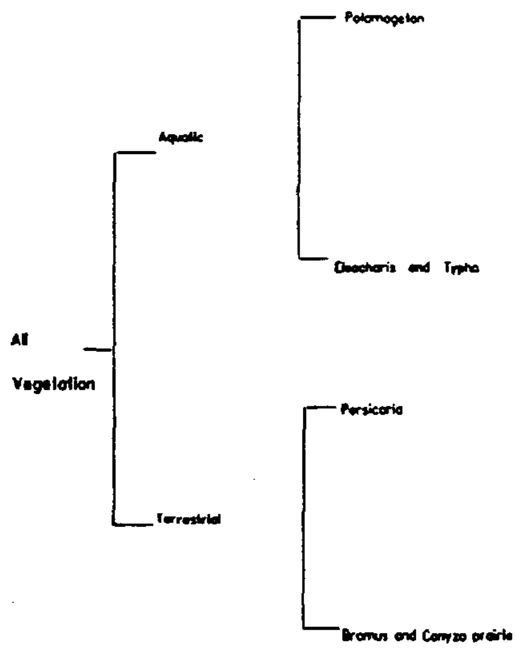

Figure 16. Twinspan classification output for Wetland Creation study area vegetation. Four major communities are distinguished on this diagram.

Community Ordination (CANOCO)

In many community ecology studies, direct gradient analysis methods are used to explore the large underlying patterns in plant species distribution (Barbour et al. 1987). These patterns indicate the main directions of variation within the data, and the environmental parameters which may be creating the patterns. For this study, plant species abundance data (species composition and percent cover) are used as input from each plot. Quantitative and nominal environmental data are also collected from each plot. Four quantitative environmental variables (1) maximum water depth, (2) average water depth, (3) number of days flooded, (4) year (1, 2, or 3), and two nominal variables, (5) whether the basin had supported wetland vegetation in the past, and (6) whether cattails were pulled from the plot area in 1992, were used for each plot for each year. Plot number was used as a covariable, and the variance due to the dependance of a plots vegetation on the past year's vegetation was reduced. CANOCO was run with the default settings.

Plot data was divided into three partial data sets based upon the number of days that a plot was flooded. Plots flooded for at least 90 days for 2 out of the 3 years studied were considered aquatic, plots flooded for 7 to 90 days were considered emergent, and plots flooded for less than 7 days were considered non-wetland plots. Plots in the aquatic and emergent data sets were analyzed using Canonical Correspondence Analysis (CCA), a form of multivariate direct gradient analysis using the computer program CANOCO (ter Braak 1988). CCA reveals pattern of association among plots, between species' abundances, and measured environmental variables. CCA escapes the assumption of linearity and is able to detect unimodal relationships between species and environmental variables (ter Braak 1986, ter Braak and Prentice 1988). CCA is not appropriate for species that show multimodal responses to an environmental variable (Jongman et al. 1987). Since our plots are organized along a very steep gradient from deep water to dry grassland, every species was assumed to have a unimodal response to this gradient. CCA uses a reciprocal averaging algorithm to identify linear combinations of weighted environmental variables that maximize dispersion of species abundance scores along one or more ordination axes. Plots and species are represented as point in the ordination space which show the approximate location of their weighted average with respect to the environmental variable. Environmental variables are shown as arrows indicating the direction of major variation.

To test which environmental variables contributed significantly to the ordination axes we performed Monte Carlo permutation tests on each variable. The Monte Carlo test in CANOCO reassigns the individual environmental measures at random to the plots, and tests its eigenvalue. This test is performed

99 times for each variable, and if the first and second eigenvalues from the original data set fall within the highest 5% of the 99 randomly generated data sets, than that environmental variable is considered to contribute significantly ($p<.05$) to the first or second canonical axes. Most of the variables use for CCA in the present analyses were significant at $p<0.01$. The importance of each environmental variable to the ordination axes is shown in a table of interset correlations.

Several other statistics also indicate the significance of the resulting ordination plot (ter Braak 1990). The eigenvalue measures the importance of an axis ranging from 0 (no importance) to 1 (very important). The species-environment correlation measures the strength of the relation between species and environment for a particular axis. The percentage of variance of the species data and of the species-environment relation explained by the axes is also given.

Aquatic Vegetation Analyses.

The final CCA triplot (plots, species and environmental axes) for the aquatic plots is shown in Figure 17. The figure shows plots for wetland 1, 3, and 4 for all three years and the most important species. Both axis 1 and 2 have high eigenvalues indicating that they are both important. A statistical summary of the CCA analysis is presented in Table 1. The interset correlations (Table 2) show that the environmental variables "Maximum water table" and "Average water table" are highly negatively correlated with axis 1, while "Year" and the nominal variable "Natural", are highly negatively correlated with axis 2. The arrows show the main direction of variation in the three quantitative variables, while the position of "Natural" shows its weighted average centroid. All four variables are significant ($p<.01$) as determined by Monte Carlo permutation tests, and all had similar F ratios of 7.43 to 8.42.

The large arrows in the graphs show the main direction of variation in the environmental variables. The three smaller arrows within the graph show the main direction of change for the vegetation plots in the three wetlands from year 1 to year 3. For example, the arrow for wetland 1 indicates that plots in this wetland generally occurred in the top right side of the ordination space in year 1, moved to the far right in year 2 and then moved toward the center in year 3. These plots had a sparse cover of Chara sp. in year 1 and were largely dry and supported weed communities dominated by Salsola australis and Chenopodium glaucum in year 2. The site was flooded again in 1994 and vegetation developed that supported Potamogeton pectinatus in many plots.

Plots in wetland 3 are shown moving from the top left of the ordination diagram toward the middle, while those of wetland 4 move from the middle toward the bottom. Wetland 4, a natural basin that we hypothesize historically supported wetland vegetation, developed an aquatic vegetation cover dominated by Potamogeton pectinatus and P. pusillus in year 1, and by year 3 supported several other aquatic species including Zanichellia palustris and Najas guadalupensis. Plots in wetlands 1 and 3 in year 3 are relatively similar to wetland 4 plots in years 1 and 2. This suggests that succession is leading to the development of Potamogeton communities at all wetlands. However, wetland 4, which had a dormant seed bank, is successionally several years ahead of the newly created wetlands 1 and 3.

The ordination diagram also illustrates that the environmental gradients "Year" and "Natural" both vary in the same direction. This indicates that year 1 plots in the natural wetland (number 4) are similar to the vegetation of plots in the other wetlands (1 and 3) in later years. Thus, basins with naturally occurring seed banks are vegetatively years ahead of basins without dormant wetland seed banks.

Table 1. Statistical summary of CCA for the aquatic plot data.

Axes	1	2	Total inertia
Eigenvalues	.540	.499	4.804
Species-environment correlations:	.861	.778	
Cumulative percentage variance			
of species data	12.1	23.3	
of species-environment relation:	40.1	77.3	
Sum of all unconstrained eigenvalues			2.115
Sum of all canonical eigenvalues			1.220

Decomposed variance:

28% of variance explained by measured environmental variables
4% of variance explained by covariable plot number
68% of variance unexplained

Table 2. Inter-set correlations of environmental variables with ordination axes for aquatic plots.

Variable	Axis 1	2
Year	-34	-522
Average Water Table	-549	112
Maximum Water Table	-659	64
Natural	-46	-538

Emergent Vegetation Analysis

CCA of the emergent vegetation produced a complex ordination diagram (Figure 18). This ordination has 5 statistically significant environmental variables, the same 4 as used in the aquatic plot analysis, plus "Number of days flooded" for each year. The main direction of variation in the hydrology variables is toward the upper right, while the main direction of variation of "Year" and "Natural" is toward the lower right. Again, "Natural" and "Year" are varying in the same direction indicating that the restored basins develop vegetation that is successionally advanced by one or more years over the other newly created basins.

Wetlands 2 and 4 are natural basins and supported *Eleocharis palustris*, *Marsilea mucronata* and *Schoenoplectus lacustris* subsp. *creber* from the first year they were reflooded. The arrow that shows their change from year 1 to year 3 is short. Wetland 5 plots are all on the left, dry side of the ordination space. This basin is an interdune area with very rapid infiltration rates that dries relatively soon after flooding. Its vegetation has changed from one dominated by typical dryland grasses and herbs, to one dominated by annuals, such as *Sisymbrium altissimum*, and *Bromus tectorum* which grow before the site is flooded. Wetland one plots were wet years 1 and 3, but largely dry in year 2. Hence, the arrow showing the main direction in variation in these plots extends from the top to the middle and back to the upper right. The emergent wetland vegetation at this site is poorly developed, and is composed of scattered individuals of *Typha latifolia*. Wetland 3 emergent plots have developed a significant cover of *T. latifolia* and other wetland plants.

The most unusual vegetation succession in the study area has occurred on the south side of wetland 4 where a naturally high water table has created a ground water discharge pattern that has brought appreciable salts to the soil surface. Here a halophyte community dominated by *Spergularia media*, *Glaux maritima*, *Hordeum jubatum*, *Bolboschoenus maritimus* ssp. *paludosus*, and *Schoenoplectus pungens* has developed. Salt incrustations are prominent on the soil surface in mid summer. Stands with this floristic composition occur in the lower right corner of the ordination diagram.

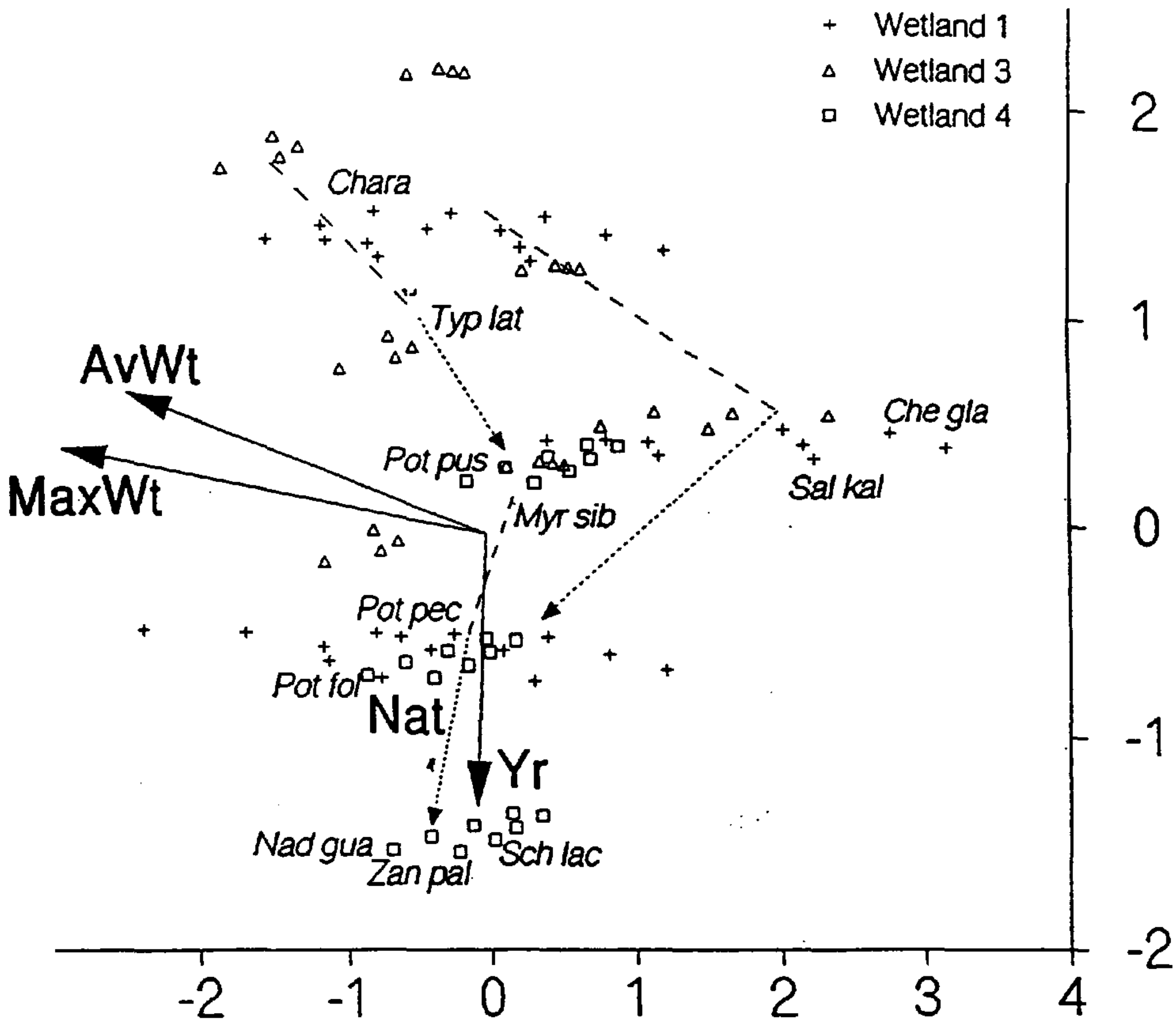

Figure 17. Triplot based on canonical correspondence analysis of aquatic vegetation plots, species and environmental variables for wetlands 1, 3 and 4. See text for discussion.

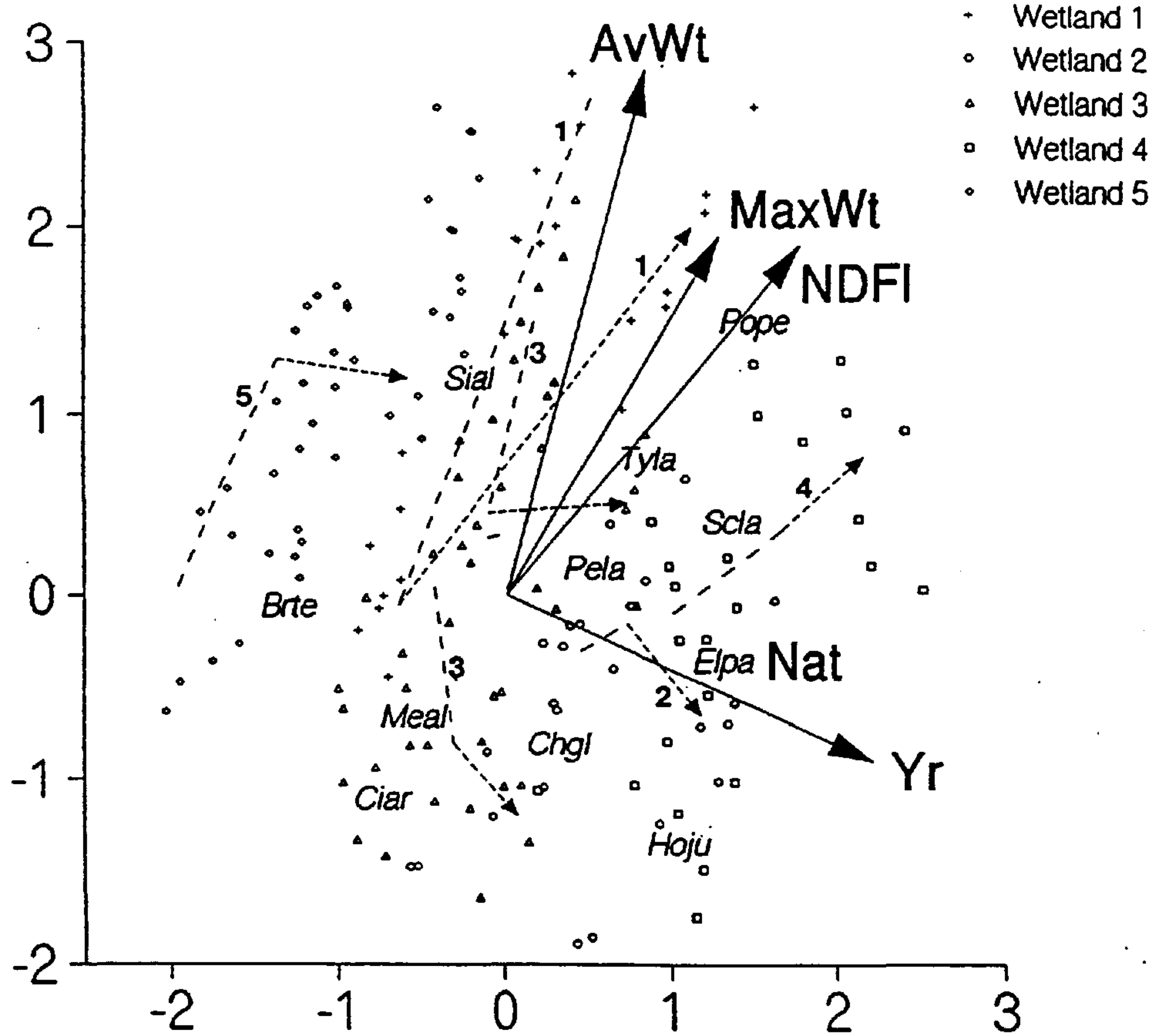

Figure 18. Triplot based on canonical correspondence analysis of emergent vegetation plots, species and environmental variables for wetlands 1 - 5. See text for discussion.

CONCLUSIONS AND MANAGEMENT RECOMMENDATIONS

HYPOTHESIS TESTING

Data collection and analyses have been focused on the testing of four principal hypotheses discussed earlier. Each has been posed as a null hypothesis, which must be falsified by statistical analyses before another hypothesis can be proposed and accepted. These hypotheses are discussed below.

Hypothesis 1: "Whether a basin supported wetland vegetation in the past or not makes no difference on the rate or direction of succession in that basin". A viable seedbank in wetlands 2 and 4 was nearly as important an environmental factor as the duration of flooding or any other hydrologic factor. Viable seeds of many wetland plants germinated and allowed during the first year, the development of plant communities that were surprising in their composition. Using Monte Carlo permutation methods this factor was significant to the ordinations produced with CCA at $p<0.01$. It clearly points to the importance of restoring formerly drained wetland basins, as opposed to creating wetlands in basins that have never supported wetland vegetation.

Hypothesis 2: "The maximum water depth reached in the basins does not affect the pathway of succession". The maximum water depth in basins affects successional patterns in two ways. First, because the duration of water in basins is in many ways a function of water depth and volume, maximum depth is highly correlated with duration of flooding. Duration of flooding is one of the most important factors in determining the colonization of basins by wetland plants. Secondly, when filled to the maximum recommended water depths, approximately 3.5 to 4 feet in depth, the basins are susceptible to accidental overfilling during a large rainstorm which produces runoff. Accidental overfilling occurred in 1992 and resulted in very high mortality of emergent plants, particularly in wetland 3. This event has had a very significant effect on the direction of succession in wetland 3.

Hypothesis 3: "The duration of flooding and high water tables does not affect the pathway of succession". The duration of flooding was the most significant environmental factor ($p<0.01$) in all the CCA analyses performed. It indicates that increasing the duration of flooding in all wetlands is the most important factor for driving the processes of succession and establishing the desired wetland plant communities. The most effective means of accomplishing this is to secure additional water sources that can be used to fill the basins early in the spring (April if possible), and to keep them full through at least mid-July.

Hypothesis 4: "The removal of *Typha* spp. individuals which established from seed during year 1 does not affect the pathway of succession". The removal of *Typha* from 1/2 of wetlands 2, 3, and 4 was statistically significant ($p<0.05$), but was the least important of the environmental variables tested. We suggest that it may have been a more significant factor if the accidental overfilling of wetland basin 3 in 1992 had not resulted in the mortality of large stands of *Typha*. Thus, our treatment was overshadowed by this hydrologic event. However, we do feel that removal of *Typha* on year 1 and 2 of a newly created wetland is an important step in allowing the establishment of more desirable bulrushes and other emergent plant species. The removal of *Typha* can be performed by pulling, or where water levels can be controlled, filling the basins to depths greater than 3 feet in the zones where *Typha* is established will result in their mortality. To assure their mortality stems can first be cut and then flooded.

MANAGEMENT RECOMMENDATIONS

The research we have conducted over the past three years has allowed us to evaluate the wetland creation project and consider the management of these wetlands and the creation of additional wetlands in the future. Our suggestions are listed below.

1. Restore wetlands where possible instead of creating new wetlands. Numerous wetlands occurred on the Rocky Mountain Arsenal in pre-settlement, and even in pre-Arsenal time. Most of these can be identified on the 1937 aerial photographs of the site. These basins contain viable seeds of wetland submergent and emergent plant species and can very quickly develop a complex and desirable plant cover. Wetland basins 2 and 4 in this study developed plant cover in aquatic zones and emergent zones during the first year. Many of these first year communities were similar to what have just started to develop in the created wetland basins, wetlands 1, 3 and 5, in year 3. We suggest that it takes created wetlands approximately 3 to 5 years longer to develop the same plant cover as restored basins and perhaps several more years to develop diverse plant communities.

2. Secure a reliable source of water. Many of these management recommendations are contingent upon a more reliable source of water than the current water right available. This may include negotiating for more senior Highline Canal water rights or locating a new source altogether. The wetlands discussed in this report require a great deal of water to sustain them. In addition, the timing of water delivery is crucial to developing diverse and valuable wetland plant communities and wildlife habitat. Future wetland creation or restoration projects at the Rocky Mountain Arsenal should include a water budget early in the planning stages to ensure that sufficient water is available.

3. Increase the duration of flooding. Increasing the duration of flooding increases the rate of plant succession. For

example, wetland 5, which did not sustain long-duration flooding due to rapid infiltration rates, lags well behind all other wetlands in the development of wetland vegetation.

4. Decrease the maximum depth of water. Water depth is a critical factor in the maintenance of plant zonation on wetland shorelines. In addition, many wetland plant species can occur in saturated soils, but are intolerant of deep flooding. Even broad-leaf cattail (*Typha latifolia*), one of the most ubiquitous wetland plant species, drowns if exposed to water more than 3 feet deep for more than a few days. During year 2 of this study, wetland 3 was filled to its recommended depth. Soon thereafter, a large rainstorm occurred increasing the depth of water by almost a foot. This water rise resulted in >90% mortality of the cattails in this wetland. Other more desirable species, such as *Sagittaria latifolia*, and *Hippuris vulgaris* also suffered. We suggest that wetland basins that could potentially be overfilled should have a drainage weir installed which could be used to lower water levels in case of accidental overfilling. We also suggest that should a wetland become dominated by cattails, this weir could be used to purposely overfill the wetland and kill cattails.

5. Fill wetlands early in the spring. Wetland plants begin to grow very early in spring, typically in late April or early May. Filling wetlands early will allow these plants to have a long growing season and maximize their ability to spread clonally. In addition, filling wetlands early will provide maximum habitat for migratory waterfowl. During 1993 a pair of American avocets nested on the shore of wetland 1. To protect this pair and their clutch of eggs, the wetland was not filled in summer when the other wetlands were filled. Thus, this wetland dried up to unprecedented levels and most of the established shoreline species died.

6. Utilize native soil as basin substrate whenever possible. The central portion of wetland 1 was lined with bentonite prior to its first filling. The goal was to create a conservation pool that would support perennial water and fish. Fish would die during the winter and provide food for overwintering bald eagles. However, the development of aquatic and emergent wetland plants has been very slow on the bentonite substrate and lags well behind wetlands 2, 3, and 4. Bentonite is an added expense that should be used only where the permeability of the soils is so great that a wetland could be created in no other way.

7. Select areas for restoration and creation that have a water table close to the soil surface. The depth to ground water in basins selected for possible wetland restoration and creation should be monitored for at least 12 months. Restoration and or creation should only be attempted in basins that have a water table within 1 to 2 meters during the early portion of the summer. If these sites are selected, it will take a relatively small amount of water to create saturated soils beneath the wetland and build a ground water mound which will greatly reduce further infiltration. This ground water mound will reduce the amount of water required for wetland maintenance, extend the duration of flooding, and reduce ground water recharge and potential impacts to the aquifer.

8. Adult plants should be introduced to establish the vegetation. Our efforts to establish vegetation included large amounts of seed, as well as the transplanting of adult plants. Most seeds either did not germinate or success was very slight. Newly germinating plants are targets for avian herbivores, such as geese and ducks. These herbivores can consume most of the young plants that emerge from seed, however, they have less of an impact on adult plants. Adult plants of most wetland species can spread rapidly clonally. They can also produce an abundance of

seed which is dispersed directly into the wetland where it overwinters underwater and has a much higher germination rate than the seeds we introduced. The density of planting depends upon many factors. However, in general, one plant per 3 to 4 square meters appears sufficient.

ACKNOWLEDGEMENTS

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ANNUAL PROGRESS REPORT

1993-1994

PART 1

TITLE: Regulation of Mule Deer Population Growth by Fertility Control: Laboratory, Field, and Simulation Experiments

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Controlling the growth of animal populations is fundamental to maintaining proper balance between wildlife and the habitats they use. Hunting has traditionally been used to maintain this balance, but there are an increasing number of circumstances where hunting animals to regulate their numbers is not feasible. In these cases, fertility control offers a promising alternative to hunting as means of limiting population growth.

One of the most promising new approaches to wildlife contraception involves linking a synthetic analog of gonadotropin releasing hormone (GnRH) to a cytotoxin. In order to provide an estimate of the dose of GnRH conjugate required for contraception, it is essential that the potency of GnRH analog be determined in the species of concern during different stages of the reproductive cycle.

We conducted two experiments with captive mule deer and elk to determine and compare the patterns of LH secretion following intravenous treatment with GnRH analog during the breeding season, anestrus, and pregnancy. In the first experiment, five adult female elk (average body mass = 277 kg) and three adult female mule deer (average body mass = 61 kg) were administered each of five doses of GnRH analog (.3, 1, 3, 10, and 30 μg/50kgBW) at weekly intervals during the breeding season and anestrus. In the second experiment, we measured LH response during the first trimester of pregnancy in six adult female elk and mule deer challenged with each of six doses of GnRH analog (.5, 1, 2, 4, 8, and 16 μg /50kgBW). Mule deer and elk were fitted non-surgically with indwelling jugular catheters and blood samples collected analyzed for LH at 0, 30, 60, 90, 120, 180, 240, 300, and 360 min post-treatment. Serum samples were analyzed for LH concentrations using radioimmunoassay. Pituitary response to treatments was assessed by determining maximum LH secretion (ng/ml) for each dose of GnRH analog.

Mule deer and elk differed in pituitary responsiveness to GnRH analog. During the breeding season and anestrus, elk required three times more GnRH analog than mule deer to achieve maximum LH secretion (Figs. 1 and 2). Both species were more responsive to GnRH stimulation during the breeding season than during anestrus. In contrast to other reproductive states, mule deer were less responsive than elk to all doses of GnRH analog during pregnancy (Fig. 3). Furthermore, maximum serum concentrations of LH in pregnant elk and mule deer showed a similar pattern of decline during gestation (Figs. 4 and 5).

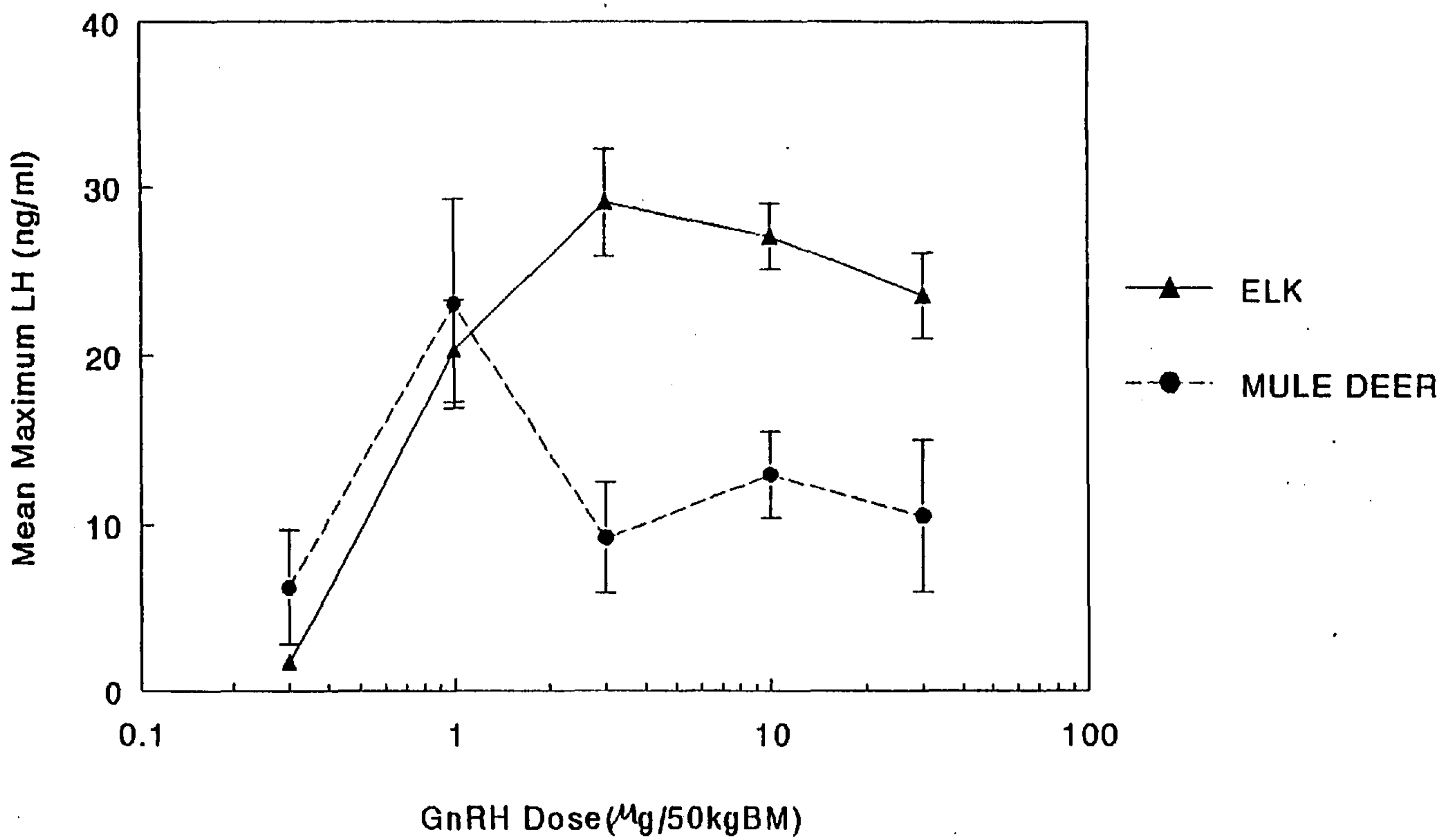

Figure 1. Maximum serum concentrations of LH for GnRH analog-induced release of LH in female elk and mule deer during the breeding season.

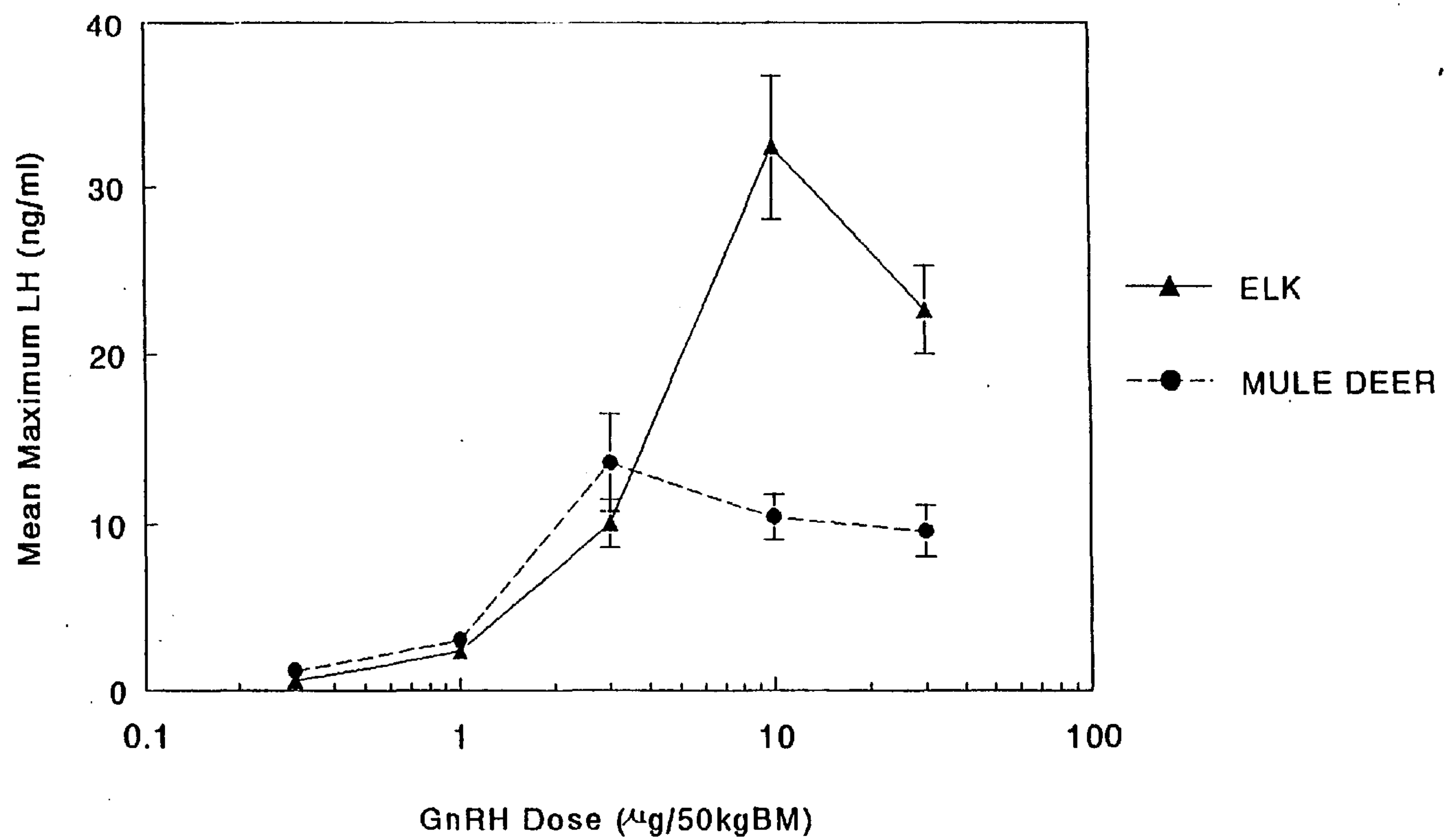

Figure 2. Maximim serum concentrations of LH for GnRH analog-induced release of LH in female elk and mule deer during anestrus.

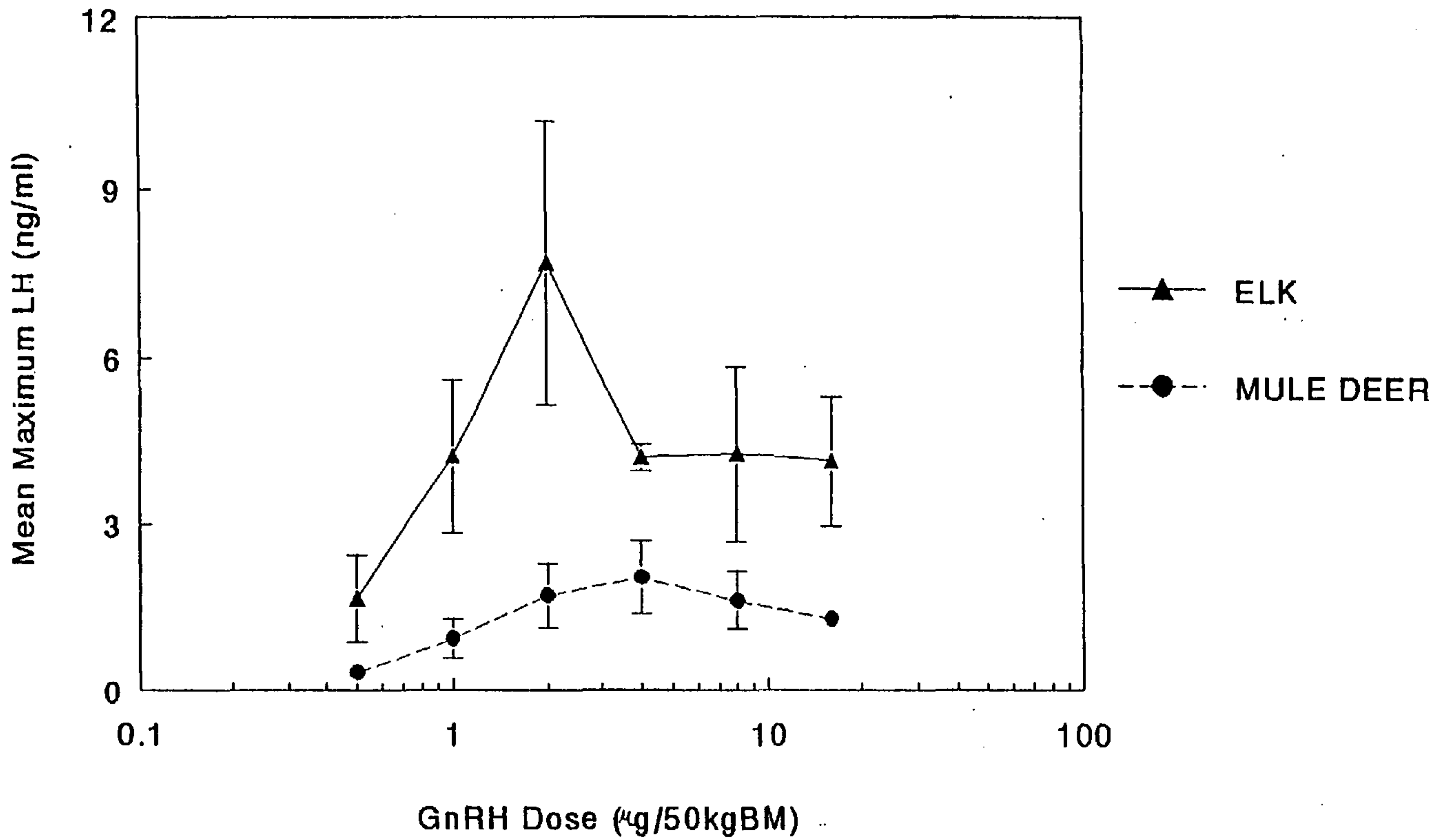

Figure 3. Maximum serum concentrations of LH for GnRH analog-induced release of LH in pregnant elk and mule deer.

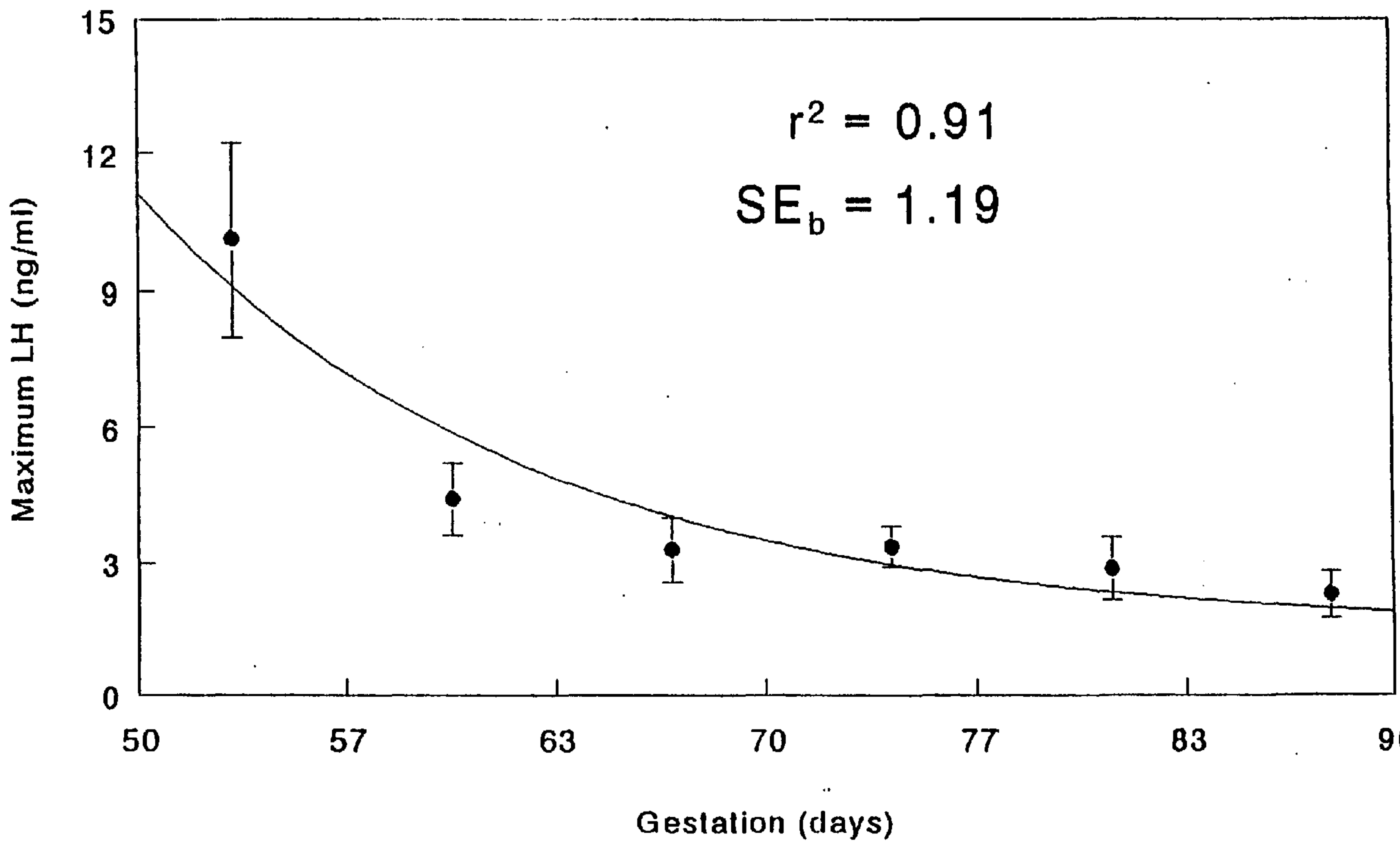

Figure 4. Maximum serum concentrations of LH in pregnant elk treated with GnRH analog at weekly intervals over a period of 6 weeks.

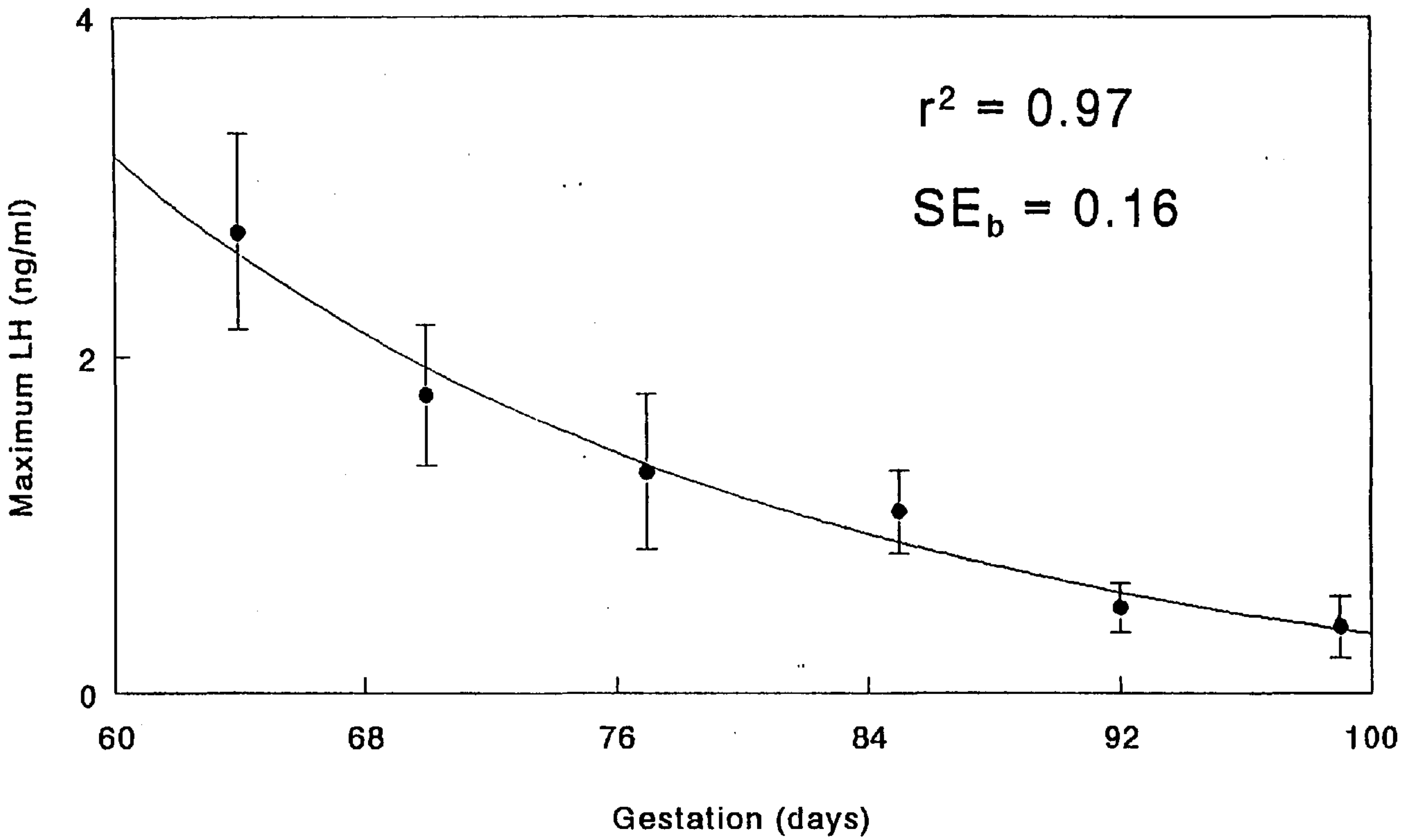

Figure 5. Maximum serum concentrations of LH in pregnant mule deer treated with GnRH analog at weekly intervals over a period of 6 weeks.

We conclude from these studies that the amount of GnRH analog required for maximum secretion of LH from the anterior pituitary is species specific and the effective dose for contraception is dependent on the reproductive status of the female. Although mule deer and elk were different in the magnitude of response to GnRH analog, the patterns of response were similar for both species. Each species showed a marked difference in pituitary sensitivity to exogenous GnRH between the breeding season and seasonal anestrus, but the amount of releasable LH is similar. In contrast, during pregnancy the amount of releasable LH declines with advancing gestation, but there is not a measurable change in pituitary sensitivity to GnRH analog.

PART 2

TITLE: FERTILITY STUDIES OF FEMALE MULE DEER AT THE ROCKY MOUNTAIN ARSENAL

INVESTIGATOR: Dan L. Baker

OBJECTIVES

The objectives of this project were to 1) estimate conception dates and breeding season of female mule deer at the Rocky Mountain Arsenal(RMA) in order to determine optimum time of delivery of contraceptives 2) estimate fetal rates of female mule deer at RMA in order to provide information for fertility control models 3) evaluate fecal progesterone levels in female mule deer as a potential non-invasive technique for determination of pregnancy following treatment of contraceptives 4) collect anterior pituitary glands and hypothalamus from pregnant mule deer in order to estimate dosage requirements for contraception.

METHODS

Collection of Deer

Approximately ten female mule deer were shot each month at 2-3 week intervals from November 2, 1993 to April 19, 1994. Collection dates were: November 10 (n = 11), November 16 (n = 10), December 8 (n = 10), December 29 (n = 11), January 25 (n = 10), February 16 (n = 10), March 9 (n = 9), April 19 (n = 9). A total of 80 females were collected and examined during this period. All deer were shot through the spine in the cervical region. Mean time of death was 1802 ± 0.14 (SE) hours.

Estimation of Age

The left incisor tooth was collected from each deer. Deer with deciduous dentition were assigned an age using the tooth replacement chronology of Robinette et al. (1957). Deer with permanent dentition were assigned an age from counts of dental cementum annuli in the first incisor (Erickson and Seliger 1969).

Pregnancy Rates

Reproductive tracts of 80 females were examined for pregnancy. Does lacking identifiable embryos or fetuses after December 29 were regarded as current breeding failures. If copra lutea were present we used only those does in which there was gross evidence, through presence of embryos or pigmented degenerating copra lutea, that the doe either had been or was currently pregnant. Reproductive data was summarized by the following age classes: yearling, 2-year old, prime, old and unclassified. Yearlings examined for pregnancy were 18-23 months of age; 2-year olds were 30-35 months of age; prime does were those estimated to be 3 to 7 years old, inclusive, and old does were 8 years and older. Unclassified does were those known only to have been older than fawns.

Breeding Season

The female reproductive tract including the ovaries were removed in the field and transported to the laboratory for examination. The primary purpose of measuring the embryos and fetuses was to estimate probable age at the time of death; hence conception dates and the breeding season for this population. Fetal forehead-rump measurements were made as described by Armstrong (1950). Measurements of twins and triplets were averaged to provide a single value. We estimated the age of each fetus by using the linear regression of forehead-rump length (mm) (Y) and age (days) (X) established from known-age mule deer fetuses between the ages of 48-174 days old (Hudson and Browman (1959). Fetal ages in this study were estimated to be within this age range, and Short (1970) indicated a linear relationship adequately reflected this period of fetal growth.

Pregnancy Determination Using Fecal Progesterone

Progesterone concentrations have been used to diagnose pregnancy in a variety of wildlife species. Monitoring fecal progesterone concentrations may provide a means to remotely diagnose pregnancy without risk, stress, or cost associated with capturing animals. If fecal progesterone were an accurate predictor of pregnancy then it would be a useful tool in evaluating contraceptive treatments for mule deer at the Rocky Mountain Arsenal. To evaluate this technique, we collected 5 ml of blood and 10 g of fresh feces from each female mule deer. Samples were then placed in a cooler and transported to the laboratory for later analysis. Serum and fecal progesterone concentrations were quantified using radioimmunoassay. We compared known reproductive status of females with measured levels of progesterone in serum and feces.

Anterior Pituitary/Hypothalamus

The brain was completely removed from the cranium by first making three-four cuts on the skinned skull with a bone saw or cleaver, two along the edge of the frontal and parietal bones, and one perpendicular to the longitudinal axis of the skull, and at or just above, the postorbital process of the frontal bone. Following removal of the brain, the anterior pituitary gland was removed from the sella turcica by cutting the diaphragm sellae at the rim of the sella turcica. The gland was wrapped in aluminum foal, labelled and placed on dry ice.

RESULTS AND DISCUSSION

Age Characteristics of the Sample

Age distribution of females collected during 1993-1994 is summarized in Figure 6. Approximately 53% of the females collected were of prime breeding age (3-7 years); 7% yearlings, 25% were 2-year old and 15% were 8 years or older. The oldest female collected was 14 years old. Most females examined were judged to be in good to excellent condition. It should be noted that these collections were not a random sample of the entire breeding population since larger females were intentionally selected over smaller animals. Thus, the proportion of yearling females is probably under-represented in these collections.

Pregnancy Rates

Reproductive data from 48 does collected after December 29 are shown in Table 1. Examinations of these does were made sufficiently long after conception or after the breeding season so that fetal counts could be made and breeding success or failure determined. Before this date, pregnancy could not be determined by gross examination of the reproductive tract, thus 32 females were excluded from this data set.

Table 1. Pregnancy records for female mule deer collected at the Rocky Mountain Arsenal,1993-1994.

Age Class	Total Does Examined	Percent Does Pregnant	Fetuses Per Pregnant Doe	Fetal Rate[a]
Yearlings	2	100.0	2.00	2.00
2-years	14	92.8	1.84	1.71
Prime	28	96.4	1.78	1.72
Old	4	75.0	2.00	1.50
Total	48	93.0	1.86	1.75

[a]Fetal Rate = $\frac{\text{total prenatal young}}{\text{total females of breeding age}}$

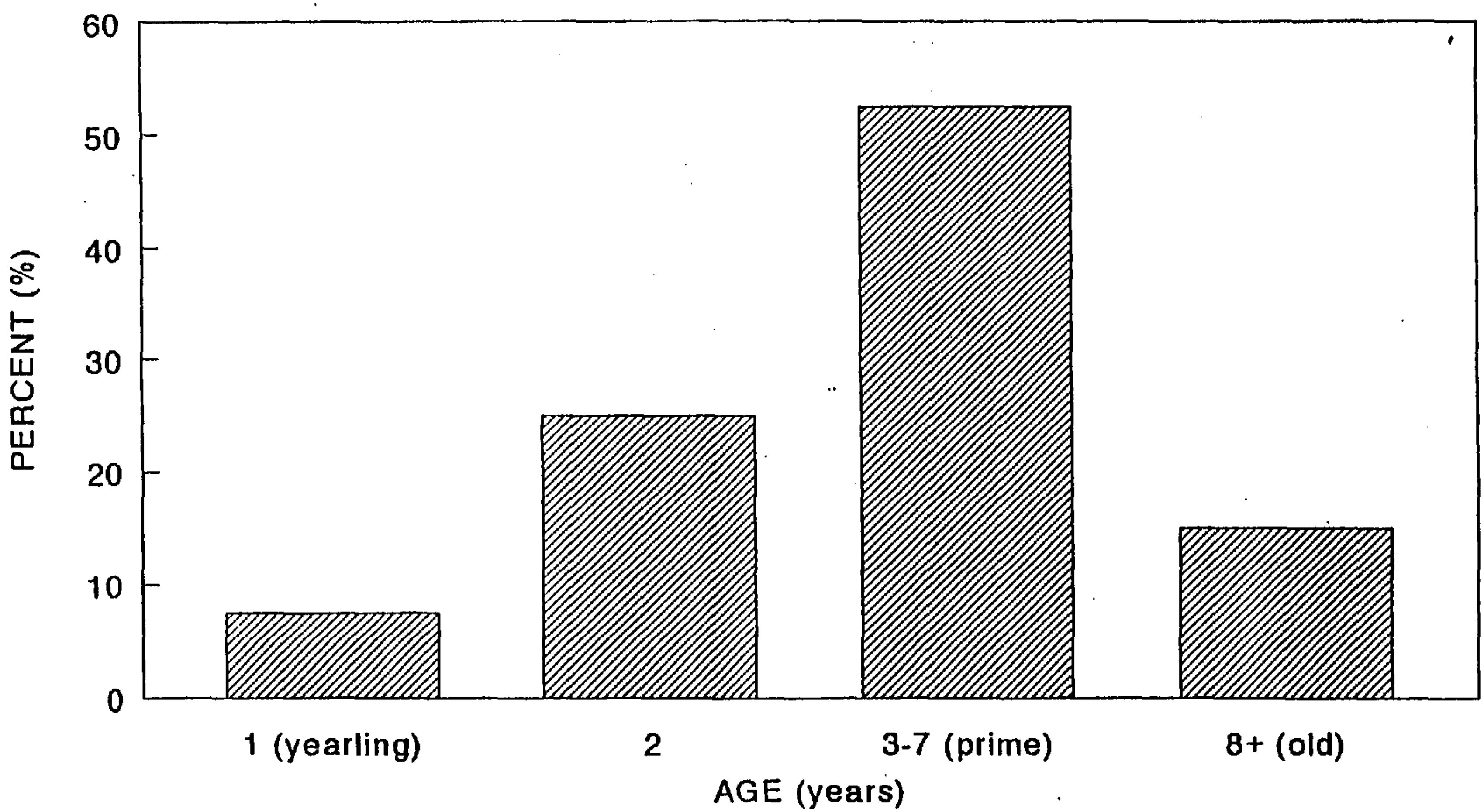

Figure 6. Age distribution of female mule deer collected at the Rocky Mountain Arsenal during 1993-1994.

Pregnancy rate across all age classes was 93%. The fetal rate for all does was 1.75. Yearlings: Only two yearling females were examined. Both were pregnant and both had two fetuses. Two-Year-Olds: The fetal rate for this age class was similar to that observed in both prime and old age groups. Twins outnumbered singles by about 5.5:1, with no triplets found. Prime (3-7-year olds): About 96% of these females were pregnant but the rate per pregnant animal was lower than that for 2-year-olds and old does. Two sets of triplets were found in this group. Old (8+ years:The pregnancy rate and fetal rate for this group was substantially lower than that for other age classes. On the basis of the meager information here (n = 4) it does not appear, however, that productivity of does at the RMA is significantly impaired by senescence. Two females, age 13 and 14 were pregnant with two fetuses each.

Breeding Season

We examined and measured 53 mule deer fetuses during the period January 25 to April 19, 1994. The sex ratio of fetuses was 1.5 males:1 female. The growth rate for mule deer fetuses derived from data of Hudson and Browman (1959) was applied to the 1993-1994 Rocky Mountain Arsenal data (Figure 7). This rate was similar to the rate for known-age fetuses and also similar to fetal growth rates for mule deer in the Piceance Basin in western Colorado (Bartmann 1986).

We used fetal growth rates to estimate breeding dates. Linear regressions of estimated breeding date on collection date were then calculated (Figure 8). The slope of this regression line was not significantly ($P = \geq 0.021$) different from 0. Thus, breeding date estimates were similar regardless of collection date. We estimate from these data that peak of conception for female mule deer occurs about November 23 and 95% of these females conceive between November 19 and November 27.

Pregnancy Determination Using Fecal Progesterone

Fecal and serum progesterone concentrations followed similar patterns during gestation (Figures 9 and 10). Concentrations of fecal progesterone gradually increased from conception to a peak of 175 ng/g at 64 days of pregnancy, then gradually declined until collections were terminated at day 156. Although there was substantial individual variation in fecal progesterone concentrations, levels in non-pregnant females were noticeably lower than those for pregnant females after 48 days of gestation.

Serum progesterone levels rose to a peak of 3.76 ng/ml at day 35 of gestation, then showed little change between day 35 and day 156. These levels were clearly lower than those measured for captive females (Figure 10). In summary, it appears from these data that both serum and fecal progesterone concentrations can be used to diagnose pregnancy in free-ranging mule deer.

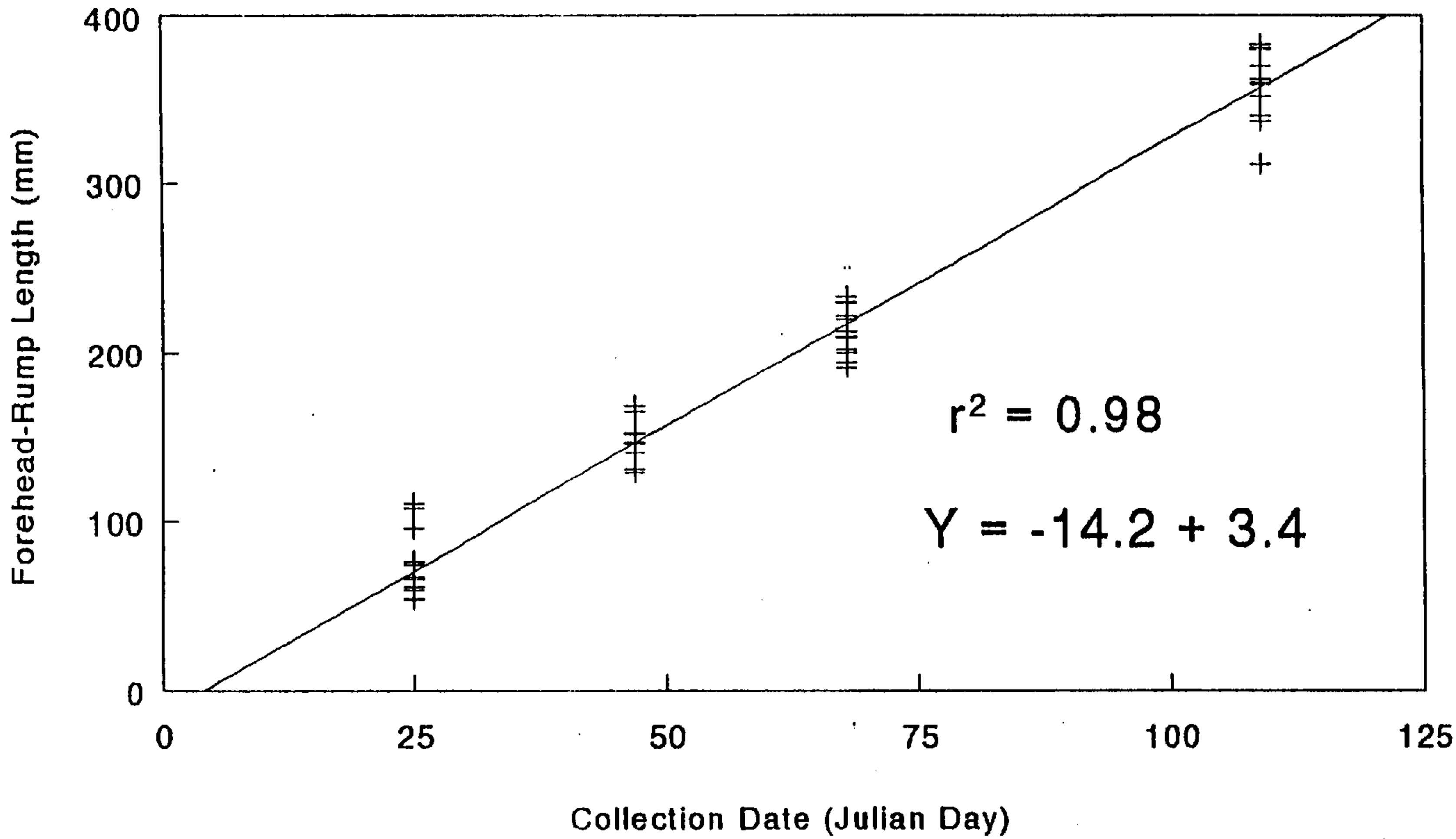

Figure 7. Forehead-rump length as a function of collection date for mule deer fetuses collected at the Rocky Mountain Arsenal during 1994.

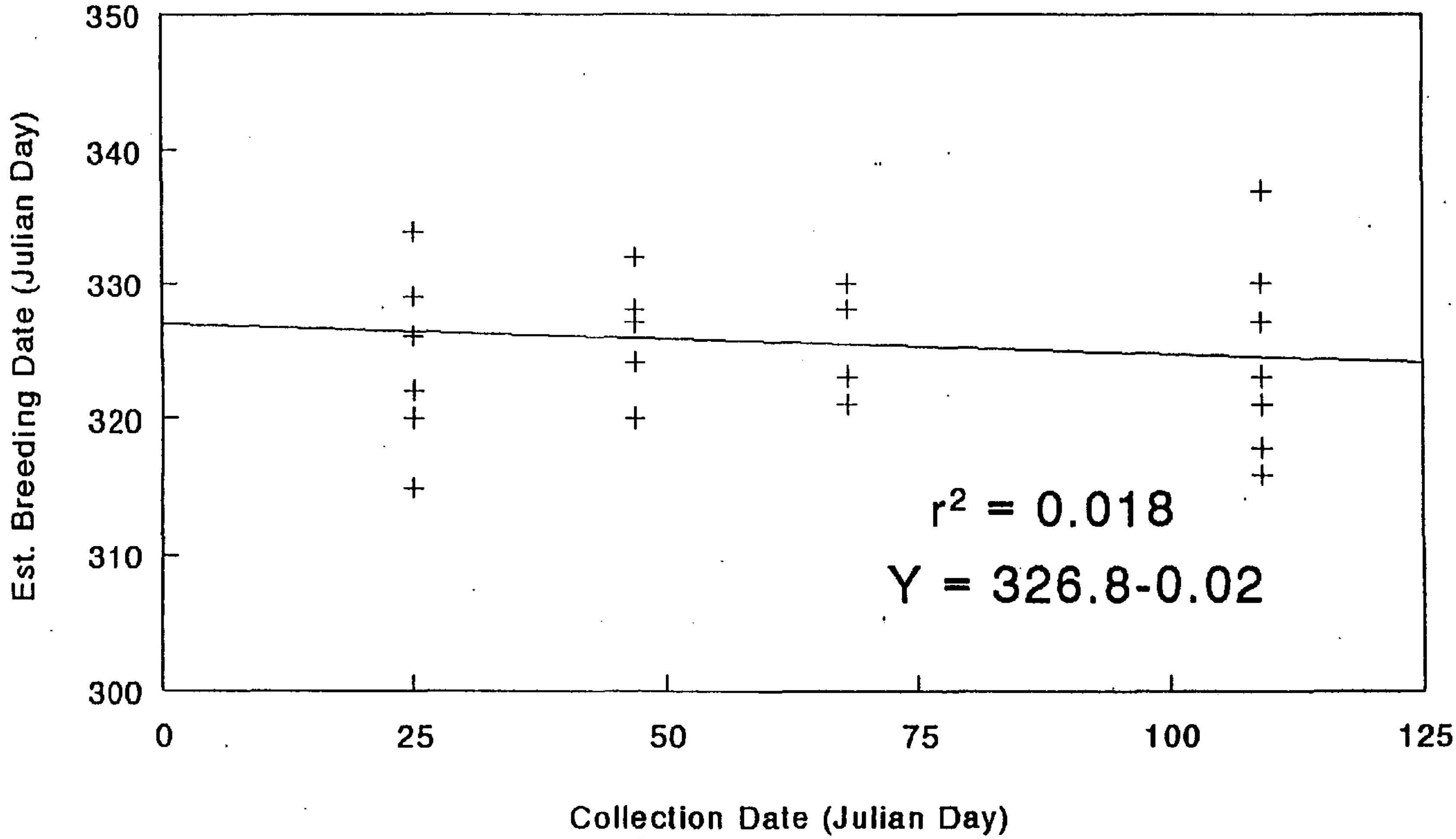

Figure 8. Estimated breeding date of female mule deer at the Rocky Mountain Arsenal using fetal growth rate calculated from data of Hudson and Browman (1959).

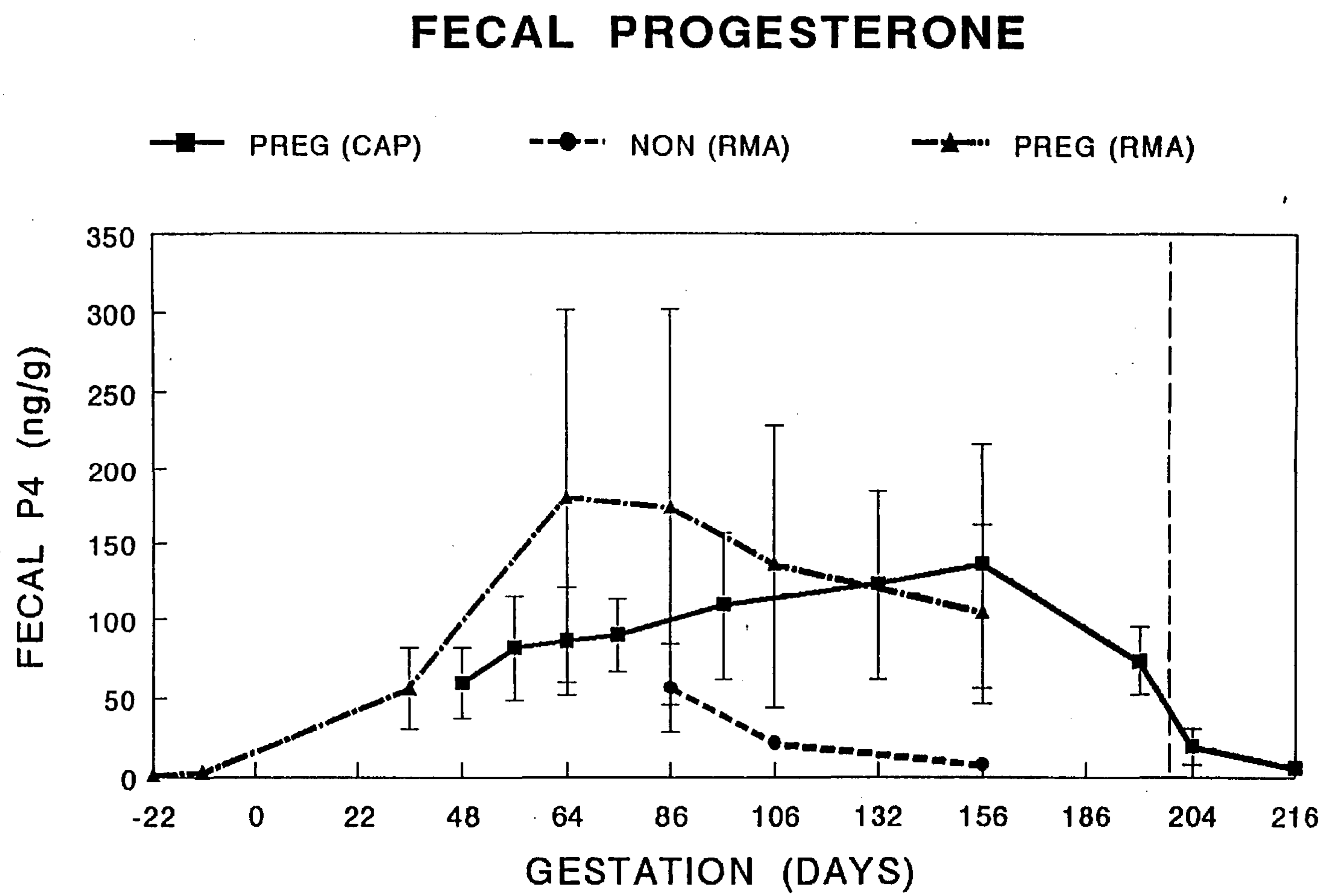

Figure 9. Fecal progesterone concentrations of pregnant mule deer collected at the Rocky Mountain Arsenal during 1993-1994, and from captive mule deer at the Foothills Wildlife Research Facility in Ft Collins, Colorado.

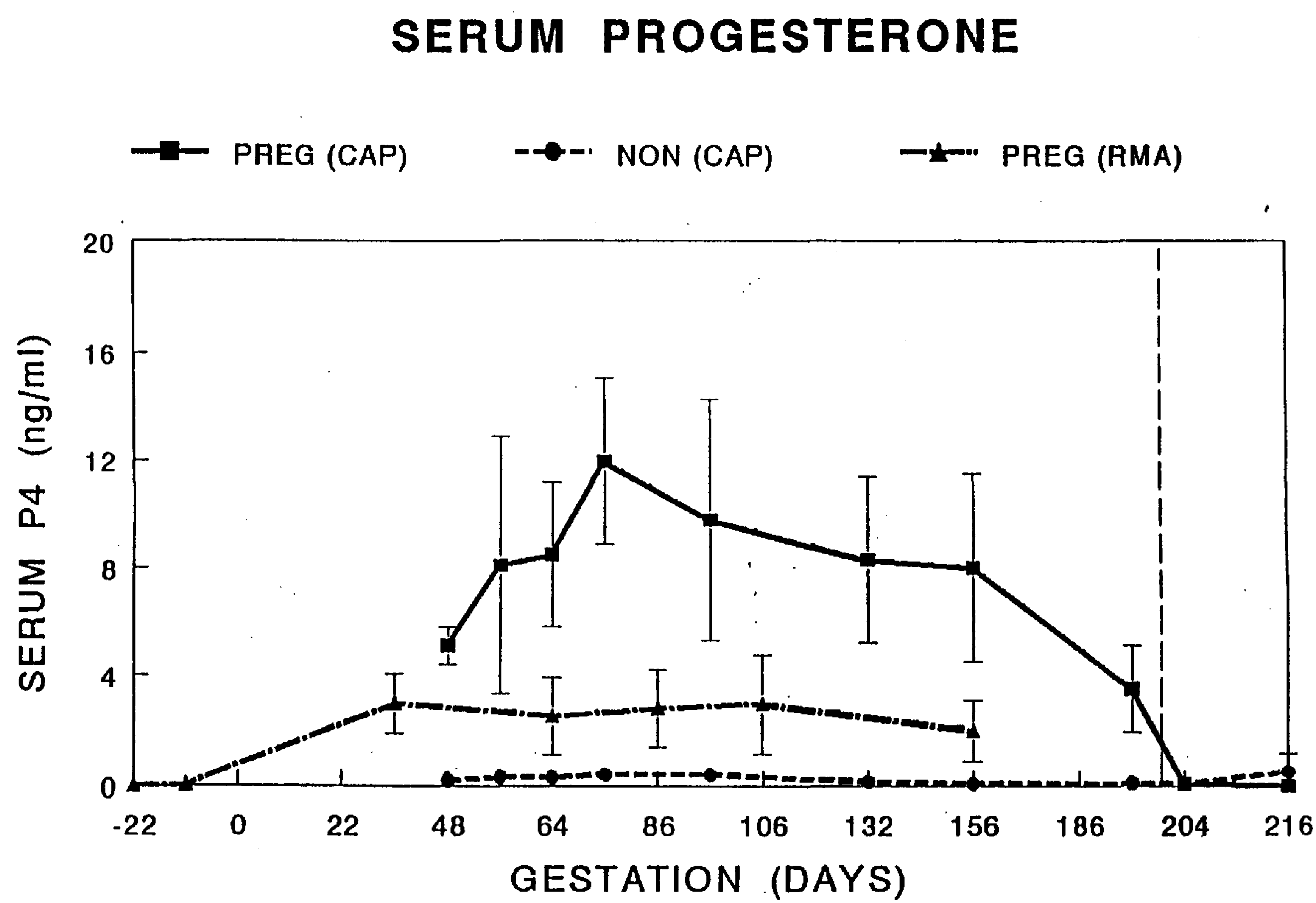

Figure 10. Serum progesterone concentrations of pregnant mule deer collected at the Rocky Mountain Arsenal during 1993-1994, and from captive mule deer at the Foothills Wildlife Research Facility in Ft Collins, Colorado.

Anterior Pituitary /Hypothalamus

Analysis of these samples are currently being conducted at the Dept. of Physiology, Colorado State University.

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